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165 User Requirements and interests for Fully Focused SAR Altimetry and Innovative River Level Gauges for Coastal and River Monitoring.

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167 Towards high resolution volume variation from space remote sensing

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168 An efficient statistical method to correct large-scale precipitation products: Empirical Conditional Probability (ECP) method.

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169 TOWARDS THE PARTITIONING OF EVAPOTRANSPIRATION USING REMOTE SENSING CALIBRATION-FREE MODELS

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170 Toward a global long-term spatio-temporal variations of surface water storage anomaly from space from 1992 to 2015

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171 Amazon basin cal/val sites for satellite altimetry.

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172 Operational monitoring of French Guiana rivers using spatial hydrology

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173 Lake Desiccation Monitoring in Persian Plateau, Causes and Effects

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174 HiVE Mission: Revolutionizing Water Resource Management with Global Thermal Imagery

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175 Satellite observations of snow parameters in mountain regions in support of water management

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176 GEWEX and International Research Collaboration in Water Research

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177 Contribution of daily observations of water surface elevation from SWOT Nadir altimeter for near-real time monitoring and short-term discharge forecasting in the Maroni River basin, French Guiana.

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239 Advancing Hydrological Understanding in Environmental Hazard Risk Assessment.

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Towards a digital twin of the water cycle in the Mediterranean Basin

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Satellite Earth observations (EO) are an accurate and reliable data source for atmospheric and environmental science. Their increasing spatial and temporal resolutions, as well as the seamless availability over ungauged regions, make them particularly appealing for hydrological modeling. This work shows recent advances in the use of high resolution satellite-based EO data in hydrological modelling over the Mediterranean basin. The simulation framework is based on the distributed model Continuum, forced by various combinations of meteorological data, including atmospheric reanalysis, satellite products, ground-based weather radars and in situ observations. Discharge data from a centralized database were extracted for 53 locations across the basin, providing calibration and validation information for the model experiments. Meteorological input data, including precipitation, air temperature, humidity, wind speed, and solar radiation, were obtained from ERA5, a global atmospheric reanalysis dataset. Additionally, high-resolution satellite precipitation data were produced within the project to be used for comparison with the reanalysis data.

The Continuum model was calibrated in four river basins: the Ebro, Herault, Medjerda, and Po river basin, using observed discharge time series as benchmark. A multi-site calibration procedure was employed, iteratively searching for the optimal parameterization that best matched the observed discharge data. The model calibration covered a 2-year period, excluding the initial 6 months for warm-up. The Kling-Gupta Efficiency was used as a cost function to evaluate the match between simulated and observed discharges. The Continuum model was then run at 1km and 1 hour resolution for the years 2015-2021, covering the entire Mediterranean basin divided in 28 computational domains. Simulations were run in parallel on a High Permormance Computing (HPC) cloud infrastructure, enabling scalability for future domain expansions. In the Po river basin, further experiments were conducted, by forcing the hydrological model with satellite precipitation and evaporation, while satellite-derived soil moisture and snow depths were ingested through a data-assimilation scheme.

The evaluation of the hydrological simulations using EO data was conducted at 53 river gauges. The validation results showed varying skill levels, with the Herault and Po basins demonstrating the best performance. The Ebro and Medjerda basins exhibited poorer results, due to the presence of man-made reservoirs, challenges in precipitation estimates in dry areas, and issues with observed data quality. Despite the variability in performance across the basins, skillful correlations were observed in all four basins, with moderate underestimation of observed discharge values.

These findings highlight the applicability of the Continuum model for hydrological simulations in the Mediterranean basin, while also emphasizing the challenges and limitations associated with data quality and specific basin characteristics. Results contribute to the understanding of water dynamics in the Mediterranean region and show the feasibility of high resolution hydrological simulations over large regions, to support water management and disaster monitoring in the framework of the ongoing efforts to produce a Digital Twin of the Earth (DTE) water cycle.

Performance evaluation of multiple satellite rainfall products for Dhidhessa River Basin (DRB), Ethiopia

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Precipitation is a crucial driver of hydrological processes. Ironically, a reliable characterization of its spatiotemporal variability is challenging. Ground-based rainfall measurement using rain gauges is more accurate. However, installing a dense gauging network to capture rain-fall variability can be impractical. Satellite-based rainfall estimates (SREs) could be good alternatives, especially for data-scarce basins like in Ethiopia. However, SRE rainfall is plagued with uncertainties arising from many sources. The objective of this study was to evaluate the performance of the latest versions of several SRE products (i.e., CHIRPS2, IMERG6, TAMSAT3 and 3B42/3) for the Dhidhessa River Basin (DRB). Both statistical and hydrological modeling approaches were used for the performance evaluation. The Soil and Water Analysis Tool (SWAT) was used for hydrological simulations. The results showed that whereas all four SRE products are promising to estimate and detect rainfall for the DRB, the CHIRPS2 dataset performed the best at annual, seasonal and monthly timescales. The hydrological simulation-based evaluation showed that SWAT's calibration results are sensitive to the rainfall dataset. The hydrological response of the basin is found to be dominated by the subsurface processes, primarily by the groundwater flux. Overall, the study showed that both CHIRPS2 and IMERG6 products could be reliable rainfall data sources for the hydrological analysis of the DRB. Moreover, the climatic season in the DRB influences rainfall and streamflow estimation. Such information is important for rainfall estimation algorithm developers.

Satellite-based mapping of river discharge at very high spatio-temporal resolution: The Ebro and Po basins

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The new ESA project “4DMED-Hydrology” aims at developing a high-resolution and consistent reconstruction of the Mediterranean terrestrial water cycle by using the latest developments of Earth Observation (EO) data. 4DMED-Hydrology intends to exploit synergies among EO data to retrieve different water cycle components (i.e., precipitation, evaporation, water storage river discharge) in order to represent accurately our environment and to feed advanced decision support systems in a changing climate for a more resilient society. Among water component, the river discharge integrates many water-related processes over land, it is crucial for understanding inland water. Unfortunately, in situ measurements are very sparse at the global scale. This paper presents a totally new approach for the mapping (i.e. spatially continuous estimate) of the river discharge based on satellite observation of hydrological variables and the water budget balance. First continuous satellite estimate of three water components (precipitation, evapotranspiration, and total water storage change) are corrected at basin scale using river discharge from a few gauge measurements. Secondly, the water budget is balanced at the grid level using flow direction for horizontal water exchange. This approach is therefore based solely on satellite products and in situ measurements without the use of any dynamical model (except river map).

This methodology is used in two meditereanean basin : the Po and Ebro benefiting from the development of novel data products such as precipitation and evapotranspiration, at high spatio-temporal resolution in the context of ESA 4DMED project as well as a dedicated physical/statistical data-fusion for the dynamical downscaling of GRACE data at daily and 1km resolution. The mapping and harmonization are evaluated using leave-one-out experiment (mean KGE is 0.6 over the Ebro), to be compared to 0.5 for a river dynamic model such as Continuum. The spatially continuous river discharge shows a good agreement with the model while being closer to in situ measurment. Our new developments that constrain the terrestrial water budget using topography and the water mass conservation opens new doors for hydrology in general. It demonstates advance towards a high (hyper) resolution characterisation of the terrestrial hydrology at continental scale to help decision making in water resources management, agriculture, and natural hazards predictions and response.

Improved Soil Moisture Retrieval using Machine Learning

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Terrestrial land surfaces are characterised by strong heterogeneities of, among other variables, soil texture, orography, land cover, snow, or Soil Moisture (SM). SM is of broad scientific interest due to its role in the Earth system: It impacts the partitioning of the incoming water and energy over land and affects then the variability of the terrestrial water and energy cycle. SM is also of capital practical value for a wide range of applications from floods forecasting to agriculture and water management. The scientific community has made significant progress in estimating SM from satellite-based passive MicroWave (MW). For a decade, ESA CCI SM project has released a daily estimates at a 0.25° resolution, that relies on a physical-based inversion scheme to retrieve SM from passive MW. As an alternative to physical-based inversions, Neural Network (NN) retrieval algorithms have been successfully implemented for a number of sensors in recent years (Aires et al., 2005; Kolassa et al., 2016). For coarse resolution MW instruments such as SMOS, these algorithms are currently used at the pixel level. New Machine Learning (ML) architectures such as Convolutional Neural Networks (CNN), have been shown to be efficiently applied to coarse resolution observations to retrieve surface variables (e.g., LST, Boucher et al. 2023). Models are calibrated on a database of satellite observations (the inputs) and corresponding SM estimates (the target) to learn the statistical relationship between them. We proposed recently the concept of “location” as the way to help a statistical model to adjust its behaviour to local conditions. By specializing its behaviour to local conditions, it is possible to “simplify” the relation between passive MW and soil moisture variable on a particular pixel by erasing some of the missing parameters. We propose several NN and ML architectures to incorporate localization information into the networks, thus reducing local biases as much as possible. We compare NNs which require specific input variables to understand the localization of a specific pixel CNNs which incorporate the notion of spatial dependency directly within their architecture. We compare CNNs and Local CNNs which spatial filters are localized. We train our networks over CONUS using five years of data extracted on from SMOS BTL3 and ERA5 ECMWF model. The best strategy for a global-scale retrieval is yet to be found for such an image-processing scheme, but potential solutions and their respective advantages and disadvantages are discussed.

Enabling Climate Resilient Flood Management in South Sudan Using Earth Observation Data

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In 2022, South Sudan was ranked as the world's most vulnerable country to climate change and the one most lacking in coping capacity. Furthermore, it is also one of the world's most politically fragile nations. The country is facing challenges related to riverine flooding, including four consecutive years of floods (2019-2022) that have displaced hundreds of thousands of people and left many struggling to access food.

Working in collaboration with the World Bank, the European Space Agency (ESA) Global Development Assistance (GDA) Climate Resilience Consortium, through GMV, is using Sentinel-1 high-resolution Synthetic Aperture Radar (SAR) imagery for flood monitoring in South Sudan. More specifically, Sentinel-1 imagery is used to monitor flood extension and frequency to identify the most flood prone areas. Then, detailed flood hazard maps are generated based on factors such as flood frequency, flood extent, or a combined flood hazard index. The resulting Earth Observation (EO)-based maps provide key information on the extent, frequency, and persistence of recent flooding seasons (2017-2022). This detailed flood hazard information can raise awareness of flood risk among local institutions and communities. For such purpose, EO data is consolidating its role in helping reduce flood risk to citizens' lives and livelihoods, as ground data is very sparse across many countries. By combining EO-based flood hazard maps with exposure datasets such as for population, building or crops, we provide additional country-wide information on the potential impacts of recent floods. The service covers the entire country of South Sudan and enables the creation of a flood hazard and exposure index, allowing the World Bank team to detect flooding hotspots and prioritize investment accordingly. These efforts will help the government develop detailed flood risk management plans.

ESA's GDA Programme is a global partnership implemented with key International Financial Institutions (IFIs) – World Bank and Asian Development Bank - to mainstream the use of Earth Observation (EO) into development operations.

Fully Focused SAR Altimetry and Innovative River Level Gauges for Coastal Monitoring – the FFSAR-Coastal Project

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"Fully focused" processing of SAR altimeter data provides opportunities for exciting new applications, as it provides hitherto unachievable along-track resolution (potentially under 10m).

The objective of the FFSAR-Coastal Project is to evaluate the potential of FFSAR altimeter data to make a significant new contribution to coastal and estuarine monitoring systems.
Two different environments are being considered:

- The Severn Estuary and river: A highly dynamic mixed tidal estuary environment.
- The lower Rhone Delta and Camargue: A low lying, flat river delta and wetland environment

DTU Space have implemented the SMAP (Standalone Multi-Mission Altimetry Processor) and applied it to Sentinel 3A and 3B altimeter data for the two regions in the study) to generate time series of data for selected tracks, and these data validated against in-situ data. The in-situ data comprise data from existing tide gauges, but also from four newly installed innovative "micro-gauges" provided by vortex.io, two in each region. Drone campaigns with an embedded LiDAR altimeter have been carried out to provide high-resolution sea level measurements, to provide a water level profile between the micro-gauge location and the satellite ground track.

Subsequent analysis has investigated the capability of FFSAR altimeter data to capture small scale physical signals (surface gradients, currents, roughness signatures) in highly tidal regions and to detect and measure tidal asymmetry/gradients across estuaries not seen with conventional altimetry. For the Rhône delta the analysis has focussed on the ability of FFSAR data to accurately map different low-lying channels and filaments.

Remote monitoring of water storage in reservoirs behind dams using satellite imagery - a case study in the Algarve, Portugal

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Water is a most important natural resource on Earth and a scarce resource in much of it. Reservoirs behind dams are an effective solution to store water, which can be used to meet the needs of human consumption, agriculture, livestock, electricity production and ecological flow. Systematic monitoring of water volumes stored in these man-made lakes is of utmost importance to ensure proper management of water and all activities that depend on it.

Earth Observation or satellite-based remote sensing can provide a decisive contribution to the near-real-time and near-continuous assessment of available water reserves, both at a local and regional scales. To fulfil this goal, it is necessary, for each of the reservoirs, a mathematical model that relates the volume of the water body with the size of the superficial visible water plan. The validity of these mathematical models depends mainly on the accuracy of the topographic survey carried out before the start of filling the man-made lake, and also on low rates of soil erosion in the watershed minimising the deposition of sediments over time.

Numerical indices such as the Normalised Difference Water Index (NDWI), originally proposed by McFeeters in 1996, are also needed. NDWI enables the identification and mapping of open water features, distinguishing them from bare soil and terrestrial vegetation features. The index computation requires multispectral imagery, and uses visible green light and near-infrared radiation bands, which were chosen to maximize the high reflectance of the water features recorded in the Green band and to minimize the low reflectance recorded in the NIR band.

Landsat, Sentinel-2 and Pléiades Neo are three different satellite programs supplying multispectral imagery that can easily be used to compute the NDWI. One of the most significant differences between programs is the resolution of the images: 30 meters for Landsat, 10 meters for Sentinel-2 and 1.2 meters for Pléiades Neo. Among the most important similarities, it can be mentioned the amplitudes of the Green and NIR bands that are almost coincident, the availability of pre-processed and ready-to-use products, and the existence of structured libraries.

The Algarve region (5000 km^2) is located in the south of mainland Portugal and has been affected by climate change, with a reduction in precipitation and an increase in air temperature. It has six reservoirs behind dams which, when fully stored, represent around 400 million cubic meters of water. But there are years with low levels of storage, sometimes with critical values at the end of the summer period, and the environmental, social and economic conflicts related to water management are growing. This study demonstrates the effectiveness of using Landsat and Sentinel-2 imagery to estimate the volumes of water stored in these six man-made lakes. Sentinel-2 images provide excellent results ($r^2 = 0.99$), when comparing official values provided by SNIRH (National Water Resources Information System) with values estimated based on NWDI.

In the future, it is intended to study Pléiades Neo imagery, and it is also intended to remotely evaluate water volumes in ponds and also in seasonal water courses.

River Basin DREAMing

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The role of satellite altimetry in monitoring river heights is well-established, with measurements forming vital inputs to river models. Soil moisture retrieval has also been investigated, initially over arid terrain, by crafting DRy EArth Models (DREAMs). DREAMs model the response of a completely dry surface to nadir illumination at Ku band.
The first DREAM with significant hydrological content was created over the Kalahari desert, where altimeter soil moisture estimates were successfully derived. DREAMcrafting was then attempted over the Congo and Amazon basins. Comparing the Congo basin DREAM with independent data (Dargie et al, 2017) revealed a wealth of DREAM surface hydrological information. It was realised that these DREAMs could be used to investigate altimeter data retrieval over rivers and wetlands.

Data from Sentinel-3A/B, CryoSat-2, EnviSat, Jason1/2 and ERS1/2, together with a database of over 86000 graded River and Lake time series, were analysed to address the following questions:
1) How well did previous altimeter missions recover height and backscatter data over these river basins?
2) What proportion of the overflown river basin surfaces must be monitored to optimise retrieval of these data over rivers and wetlands?

The first step was to assess the proportion of river DREAMs that have a pixel classification as river or wetland. For the Amazon basin, the statistics are: 23% rivers and 36% wetland/seasonally inundated surfaces. For the Congo, 13% are river and 34% wetland/seasonally flooded areas. It is noted that many smaller tributaries are below the current 10" spatial resolution of the DREAMs, and are classified with their surrounding terrain as wetland pixels.
The DREAMs were then overflown with multi-mission altimeter data. In summary, the highest data retrieval rate is found over river and wetland pixels, with lower percentages over 'soil' pixels. This is an expected outcome, as excluding rivers and wetlands selects for rougher topography. ERS1/2 and EnviSat performed best, recovering data from a high proportion of both the Congo and Amazon river and wetland surfaces. Sentinel-3 OLTC masks are found to preclude monitoring of many tributaries and almost all wetlands in both the Congo and Amazon basins.

One conclusion is that, within the constraints of satellite orbit and repeat period, data can be successfully gathered over the majority of these river and wetland surfaces. It is also clear that very detailed DREAM models, at least 10" resolution, are required to capture the intricate structure in river basins.
The monitoring capabilities of the current generation of SAR altimeters are not being fully realised over inland water due to critical constraints on the OLTC masks. In this era of climate change, the observation strategy should be focussed towards global monitoring, as evolving climate patterns can alter priorities in unforeseen ways.

Dargie, GC; Lewis, SL; Lawson, IT; Mitchard, ET; Page, SE; Bocko, YE; Ifo, SA (2017). Age, extent and carbon storage of the central Congo basin peatland complex. Nature, 542 pp.86-90. 10.1038/nature21048.

Groundwater potential modeling of Ar Rub Al Khali using multi-sources of remote sensing in a GIS.

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In arid and semi-arid regions, there has been excessive consumption of groundwater and scarce rainfall due to climate change. The Changes in climate and rainfall patterns might affect groundwater recharge in the region and have led to sharp depletion in groundwater table and quality and represent a challenge to develop the Arabian Peninsula regions. This study aims to modify an approach, which calls a weight of hydrological evidence (WoHE) approach. The WoE combines different datasets, as controlling factors of the occurrence of a particular phenomenon by weighting each factor using a long linear from a Bayesian- based model. The approach is based on calculating the logarithmic ratio of the total areas of distribution good (event) and distribution bad (non-event) of features such as faults, palaeochannels and zones of flow accumulation. The approach starts by mapping fault zones, palaeochannels, drainage basins and flow accumulation zones from the Advanced Land Observing Satellite (ALOS) DEMs and validating their texture features extracted from the Sentinel-1 images. More specifically, the DEM was used to reveal surface and near-surface paleochannels using the D8 algorithm and drive zones of accumulation, transmission and dispersion by applying a 3×3 local window that fitted to the DEM and the change in gradient of a central pixel in relation to its 8 neighbours from a bivariate quadratic function. The results show that the ARAK mega-basin, which occupies an area of about 1,174,973 km2, is divided into four types. The first type is very longitudinal and narrow in shape, such as the Al Juf basin terminating Mondafan depression and Al Khabir and Khujaymah palaeolakes and end in the SGSB and occupy an area of 154,507 km2 (13.23%). The second type is wide and longitudinal in shape, such as the Tuwayq and Ad Dawasir basins terminating at the Yabrin and Wajid depressions, the Arabian Gulf, and occupying an area of 265553 km2 (22.74%) and 329931 km2 (28.25%). The third type is wide and short, such as Hadramout and Dhofar terminating at the SGSB and Mutaridah depressions occupying an area of 161,583 km2 (13.83%) and 177000 km2 (15.15%), respectively. The fourth type is short and small such as the Oman basin in the east, terminating at Mutaridah depression and occupying an area of 79,141 km2 (6.77%). The results also revealed new several
micro-depressions in terms of zones of flow accumulation and occupies an area of 309.25 km2 (26.48%). These zones are the hope of the Arabian Gulf Council Countries (AGCC), especially Saudi Arabia and the UAE. The proposed approach is an effective approach to improve the hydrological modelling and summarize large datasets over a very regional scale obtained using machine learning, which is used widely in the literature. The results exhibited that the basins of Dhofar have the highest values for the WoHE of 0.0432.

Keywords: Ar Rub Al Khali , WoHE , Palaeochannels , ALOS, DEM, Sentinel-1

OPPORTUNITIES FOR LAKE ICE REMOTE SENSING FROM CURRENT AND FUTURE GLOBAL NAVIGATION SATELLITE SYSTEM REFLECTOMETRY (GNSS-R) MISSIONS

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Being listed among Essential Climate Variables (ECVs), lake ice forms an important and prevalent landscape of northern regions. However, among the cryospheric targets foreseen for Global Navigation Satellite System Reflectometry (GNSS-R) missions, lake ice is not a major one such that only a few studies have so far employed Cyclone GNSS (CYNGSS), as the most-known space-based GNSS-R mission, as a tool for the remote sensing of lake ice physical properties. Considering these previous studies, we examined three CYGNSS limitations in lake ice monitoring that can be addressed by recent and upcoming GNSS-R missions, such as Spire, SMAP-R, and HydroGNSS. The first opportunity, which is provided by all modern missions, is polar coverage that allow researcher to monitor Arctic and sub-Arctic freshwater lakes. The second one is modern coherence detection techniques, which is planned to be used in the next generation of GNSS-R missions, such as HydroGNSS, that facilitate discriminating lake ice from open water. The third progress is the use of digital elevation models (DEMs) to track specular points more precisely. The latter advancement, which is among the features of HydorGNSS and Soil Moisture Active Passive Reflectometry (SMAP-R) missions, helps to evaluate the lake ice impact on reflected GNSS signals more precisely.

An inter-comparison of approaches and frameworks to quantify irrigation from satellite data

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This study provides the first inter-comparison of different state-of-the-art approaches and frameworks that share a commonality in their utilization of satellite remote sensing data to quantify irrigation at a regional scale. The compared approaches vary in their reliance on either soil moisture or evapotranspiration data, or their joint utilization of both. The two compared frameworks either combine satellite and rainfed hydrological models in a baseline framework or use soil water balance modeling in a soil moisture-based inversion framework. The inter-comparison is conducted over the lower Ebro catchment in Spain where observed irrigation amounts are available for benchmarking. Our results showed that within the baseline framework, the joint approach using both soil moisture and ET remote sensing data, only differed by +17 mm from the irrigation benchmark (922 mm) during the main irrigation season over two years, and by +41 mm and -228 mm for approaches relying solely on soil moisture and ET, respectively. A comparison of the different frameworks showed that the main advantage of the more complex baseline framework was the consistency between soil moisture and ET components within the hydrological model, which made it unlikely that either one ended up representing all irrigation water use. However, the simplicity of the soil moisture-based inversion framework, coupled with its direct conversion of soil moisture changes into actual water volumes, effectively addresses the key challenges inherent in the baseline framework, which are associated with uncertainties related to an unknown remote sensing observation depth and the static depth of the soil layers in a conceptual model. The performance of the baseline framework came closest to the irrigation benchmark and was able to account for the precipitation input, which resulted in more plausible temporal distributions of irrigation than what was expected from the benchmark observations.

SWOT expertise center : an full working environment for calibration and validation activities

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The Surface Water Ocean Topography (SWOT) satellite has been launched on December 16th, 2022. Onboard, the new instrument ‘KaRIn’, is a revolution for both oceanography and hydrology communities and gives access to small scale measurements over ocean, worldwide river heights and flows, and lake heights.

The SWOT expertise center provides tools and a full working environment for calibration and validation activities. The high resolution of karin instrument, hence the volumetry (16TB of products per day), was a driver to build optimized storage and methods to ease calval activities.
Experts have access to numerous data providers such as copernicus dias, ecmwf, and a dedicated database of in-situ data with colocated SWOT data to facilitate the validation processes.

It also allows to test new karin algorithms and fully reprocess karin products from L1 to L2 data to check and validate its scientific performance before ground segment implementation.

The expertise center is now operational and ensure SWOT calval activities. Prospects address but could be foreseen for wider activities such as hydrological research, multi-sensor comparison…

Assimilation of Sentinel-1 data to improve estimates of snow, soil moisture, irrigation and discharge in the Po river basin

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The Po river (Italy) network sustains the discharge of snow melt water from the Alps and Apennines, combined with surface and deep subsurface runoff from the hillslopes and valley. During the summer, the river network also supplies irrigation water to the large agricultural area in the Po river valley. The Po basin is thus a unique testbed to study various water budget components in an environment with pronounced seasonal water storage dynamics and human water management. In this study, we evaluate how Sentinel-1 data assimilation can help optimising estimates of the various water budget components in the Po basin.

More specifically, we assimilate 1-km Sentinel-1 data into the Noah-MP land surface model coupled to an irrigation module and the hydrological modeling and analysis platform (HyMAP) as runoff routing module. The Noah-MP simulations are forced with ERA5 meteorology for the years 2015-2023. Sentinel-1 snow depth retrievals are assimilated over the mountains in the winter, whereas Sentinel-1 backscatter are mainly assimilated in the summer, to update snow depth, snow water equivalent, and surface soil moisture. These updates subsequently trigger updates in estimates of irrigation, leaf area index, discharge and other variables, resulting in a self-consistent re-analysis of the entire water budget of the Po basin. The impact of the Sentinel-1 data assimilation is quantified using independent in situ and remotely sensed measurements of soil moisture, irrigation, snow depth and discharge.

New long-term analysis of meteorological droughts in Ukraine

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Drought is one of the high-impact natural phenomena observed in any climatic conditions and can bring damage to various sectors of the economy and cause noticeable environmental impacts. In Ukraine, the economic impacts of drought are most often seen in the agriculture and water sector, causing reduced or total crop damage, including through impacts on irrigation systems during hydrological drought. The existing studies show divergent results on the trends in the frequency and severity of droughts in the last decades, so, the purpose of this study is to identify changes in the spatiotemporal distribution and severity of meteorological droughts in Ukraine between 1946 and 2020. Two drought indices were applied for comparative analysis: the standardized precipitation index (SPI) and the standardized evaporation precipitation index (SPEI). Both indices were calculated on 3- and 12-months timescales. The gridded dataset of monthly air temperature and atmospheric precipitation for Ukraine with high spatial resolution ($0.1^{o} \times 0.1^{o}$), which developed in the Ukrainian Hydrometeorological Institute, was used. Results of time series analysis of drought indices showed at least 20 episodes, in which more than 25% of the territory of Ukraine was affected by drought of varying intensity. Trends show an increase of the drought severity determined mostly by the strong observed increase of the atmospheric evaporative demand. Comparison of two time scales shows that it is better to identify major drought episodes using long time scales (12 months), as in short periods (3 months) there are high variability of the indices that complicate spatiotemporal analysis but suitable for solving tasks in seasonal drought monitoring. At the same time, the analysis of the areas covered by drought clearly demonstrates on short time scale that a mild drought can very quickly cover more than 50% of the country, and its frequency is very high due to seasonality of precipitation.Tendencies towards an increase in the duration and intensity of droughts were observed mainly in the southwestern, central and northern regions of Ukraine. The main contribution to this increase belonged to droughts in spring and summer. The temporal analysis of the spatial distribution of areas affected by drought during the identified main drought episodes showed the existence of different patterns in drought propagation across the territory of Ukraine.

The unprecedented heat waves in Summer 2022 caused lake shrinkage in the middle and lower Yangtze River Basin

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The middle and lower Yangtze River Basin (MLY) encountered unprecedented heat waves in Summer 2022, but few studies have focused on lake change affected by these heat waves. Multi-source remote sensing data (Sentinel-1, Landsat, ICESat-2, etc) were used to obtain monthly lake area and water level of 73 lakes in the MLY from January 2019 to December 2022 to assess lake changes. Results showed that the total lake area of 73 lakes decreased by 3069 km2 in September 2022, compared with the same period from 2019 to 2021. Among 34 lakes with water level data from July to December 2022, 18 lakes (53%) decreased by more than 1 m in water level. The temperature was the most important climatic factor causing lake shrinkage in the MLY, as compared to the precipitation, evaporation, and runoff. This study can help understand the impact of climate change on lakes and provide references for decision making regarding water resource management strategy to adapt climate change.

The River Discharge Climate Change Initiative project

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The Global Climate Observing System (GCOS) identified river discharge as an Essential Climate Variable (ECV) (GCOS, 2022). However, there is currently no satellite instrument able to directly measure river discharge. In this ESA River Discharge precursor CCI project (more information https://climate.esa.int/en/projects/river-discharge/), three methodologies are explored: (1) the use of multiple satellite radar altimeters mission to provide long time series of water elevation and the estimation of discharge through a rating curve approach, (2) multispectral sensors, specifically in the near infrared (NIR) band, which are also able to detect river dynamic variability (i.e. the ratio between the reflectance of a dry pixel and a wet pixel is expected to represent river flow variation), and (3) the combination of these 2 approaches. The large advantage of the multispectral sensors, compared to radar altimeters, is the sub-daily temporal resolution, however they cannot penetrate clouds (contrarily to radar altimeters).
This RD_CCI+ is a proof-of-concept and is therefore not yet global. It aims at providing discharge estimation from 2002 to 2022, at different locations over 18 river basins. These selected targets cover different climatic zones (from the tropics to the Arctic), different drainage areas (from 50,000 km2 to the Amazon basin), and different levels of human activities and in situ observations. The first results of the project will be presented during the Hydrospace workshop.

Satellite Altimetry Data for Societal Benefit: Supporting Applications User Communities

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More than thirty years of satellite radar altimetry data from an enduring U.S. and European partnership has demonstrated the very high potential and value of remote sensing for operational and practical applications. The work of both the scientific research community and of the applied science user communities provides important assessment of value of the substantial investments made by international space agencies in developing satellite systems for Earth observation.

Global analyses of the satellite altimetry time series continue to provide critical scientific understanding for climate and research topics in the ocean, coastal zones and land surface waters. In addition, it contributes to applied uses of the data for operational agencies, private sector companies, and other practical applications as well as information about decadal changes in Earth's water systems.

Our focus is broadly on societal applications of data and information products derived from these missions, which includes coastal impacts assessments (i.e., storm surge, coastal currents, coastal discharge of large river systems), fisheries management, marine transport, and disaster risk management related to sea level change and flooding (both coastal and inland), water resources management, weather and climate forecasting and assessments, and biodiversity impacts in these areas, among others.

Here we illustrate some of the applications of satellite altimetry data from historic, current and future missions (TOPEX/Poseidon; Jason 1, 2, and 3; Sentinel 6 Michael Freilich, Sentinel 6B and 6C), with a focus on the newest mission, Surface Water and Ocean Topography (SWOT), launched in December 2022, which will provide high resolution data for research and applications, and on the SWOT Early Adopter (EA) program.

Estimation of Lake Water Levels from Sentinel-6 Fully-Focused SAR observations using numerical simulations

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Remote sensing techniques are crucial for sustaining a continuous and global climate monitoring of inland waters. In particular, recent progress in satellite radar altimetry has enabled the observation of an increasing number of small and medium size lakes and reservoirs, even in complex topography. The arrival of radar altimeters operating in Synthetic Aperture Radar (SAR) mode has considerably improved the resolution of the observations in the along-track direction, passing from several kilometers in conventional limited-pulse altimeters, to hundreds of meters in close-burst altimeters when applying unfocused SAR (UFSAR) processing and even to the theoretical limit of half the along track antenna length in open-burst altimeters that can totally exploit the Fully-Focused SAR (FFSAR) processing technique. Sentinel-6 with the Poseidon-4 radar altimeter is the first operational mission to operate in open-burst mode allowing this enhanced performance over inland waters [1].

The inversion methods to estimate geophysical parameters, such as Lake Water Level (LWL), from the backscattered altimetry signal are commonly called retrackers. These retrackers can be empirical, such as the widely used OCOG method or physically-based, that is to say, a background waveform model is derived from the theoretical knowledge of the microwave scattering process and then fitted to the real backscattered signal received on-board. Several retrackers of the second type have been developed for processing conventional pulse-limited radar observations, like the Brown-like models, and also for UFSAR observations in the case, for example, of the SAMOSA model. Nevertheless, no specific retracker for FFSAR observations has been developed yet. One of the limitations of analytical and numerical physical-based retrackers concerns the assumption that the radar footprint is completely covered by water. This assumption, that holds for large lakes, begins to degrade the accuracy on the retrieved geophysical parameters when monitoring smaller water bodies. For this reason, a retracker based on numerical simulations was proposed in 2021 adapted to UFSAR observations [2]. This latter model has the advantage of taking into account a prior knowledge of the lake contour and, in this way, only in-water areas of the radar footprint contributes to the simulated backscattered waveform. In this work, the derivation of a similar retracker based on numerical simulations and taking into account the FFSAR processing particularities is presented. This results in the first retracking model specifically developed for altimetry FFSAR observations. Examples of applications to Sentinel-6 data will be presented. Preliminary performances of the newly developed retracker will be provided for a variety of lakes for which in-situ observations of LWL are available.

[1] Donlon, C.J., et al, 2021. The Copernicus Sentinel-6 mission: Enhanced continuity of satellite sea level measurements from space. Remote Sensing of Environment, 258, p.112395.
[2] Boy, F. et al, 2021. Improving Sentinel-3 SAR mode processing over lake using numerical simulations. IEEE Transactions on Geoscience and Remote Sensing, 60, pp.1-18.

Measuring longitudinal river profiles from Sentinel-6MF Fully-Focused SAR mode

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The Garonne River in France drains an important part of the northern Pyrenees and its northern foreland. In this study, we particularly focused in Marmande location where Sentinel-6 MF satellite flies along the Garonne River over a transect of 20km. While satellite radar altimetry missions have been used uniquely when rivers are observed at nadir, here we developed a new technique that exploites cross-track radar signals and retrieves the longitudinal river profile (in certain conditions). This breakthrough in rivers observation using radar altimeters is possible with the emergence of the Fully Focused SAR processing (Egido et al, 2017, Fully Focused SAR Altimetry: Theory and Applications) that provides 50cm along track resolution measurements. FFSAR is particularly accurate on Sentinel-6 MF mission which embarks the first altimeter (POSEIDON-4) with an open-burst SAR mode.

We designed a new algorithm that uses a river centerline to estimate then the water surface elevation all along the river, accounting for the slant range effect in case the river is not observed at nadir. The longitudinal river profile is provided with a 10m spatial resolution and a vertical precision better than 10cm RMS.

Applied to Sentinel-6 MF data over 8 months, we will show how the Garonne river longitudinal profile evolves between low and high waters. In parallel, a validation campaign has been held to provide reference measurements using UAV, equipped with laser altimeters (VorteX-io). This validation shows an excellent agreement between UAV and Sentinel-6MF longitudinal profile within few centimeters over 20km transect.

This new technique, even applicable to few cases, opens new perspective in the observations and understanding of longitudinal river profile evolution in time and space. Other examples over France and the US will be presented and discussed.

Satellite products supporting the understanding of the interaction between inland waters and the coastal zone during extreme events: the case study of the Po River drought

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In the summer of 2022, the Po River experienced what is marked as the worst drought in 70 years. In fact, the lack of rainfall and reduced snowfall, together with rising temperatures, led to a drastic reduction in water levels, with significant consequences not only for agriculture but also for the local population. The rationalisation of drinking water for urban areas and the irrigation of crops in densely populated agricultural areas were just some of the consequences, along with dried up springs and trampled river beds. The situation was exacerbated by saltwater intrusion into the river, which destroyed crops and made irrigation almost impossible up to 40 km from the estuary, in the Adriatic Sea. The analysis aimed to assess two aspects: 1) whether satellites were able to monitor the drop in water levels along the river and whether this was also reflected in the Adriatic Sea; and 2) whether it was possible to monitor the salt wedge intrusion in the downstream sections of the Po River by satellite.

In order to answer these two questions, data were collected from ground stations (managed by the Agenzia Interregionale del Fiume Po, AIPo) and various satellite products: radar altimetry from Sentinel-3 and Cryosat-2 for the river and the sea, laser altimetry from Icesat-2 for the river, and optical imagery from Sentinel-2 for the river and the sea.

The results of the analysis confirm that the satellite observed the significant decrease in both water levels and river discharge in the summer of 2022. In addition, the analysis of the data at the virtual stations in the downstream part of the Po River, together with the data along the tracks crossing the plume closer to the mouth of the river, showed the interaction between the sea and the river. In particular, the temporal series of the river clearly show the influence of the sea for several kilometres along the river (more than 40 km as reported in the news), probably related to the salt wedge intrusion, which has caused significant damage to agriculture and drinking water aquifers for a long time after the event. The study qualitatively shows that extreme hydrological events can also be captured in the open sea in this region.

Nadir altimetry over land: achievements using the Open-Loop Tracking Command (OLTC) and benefits for inland waters users

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In times of ever decreasing amount of in-situ data for hydrology, satellite altimetry has become key to provide global and continuous datasets of water surface height. Indeed, studying lakes, reservoirs and rivers water level at global scale is of prime importance for the hydrology community to assess the Earth's global resources of fresh water.
Much progress has been made in the altimeters' capability to acquire quality measurements over inland waters. In particular, the Open-Loop Tracking Command (OLTC) now represents an essential feature of the tracking function. This tracking mode's efficiency has been proven on past missions and it is now stated as operational mode for current Copernicus Sentinel-3 and Sentinel-6 missions, as well as the nadir altimeter onboard the SWOT mission. Altimeters have benefited from iterative improvements brought to onboard tables contents, repeatedly since 2017.

In 2023, no less than five nadir altimetry missions hold up-to-date OLTC tables with a very satisfactory data acquisition success rate over inland waters (i.e. more than 90% for inland water targets at nadir). Each mission has its own specificities on how it handles the OLTC command and tracking mode switch, and its own database of targets (depending on the orbit).
The number of hydrological targets used to define the tracking command currently reaches almost 75,000 for each Sentinel-3 and about 30,000 for Sentinel-6A and Jason-3 on its interleaved orbit. The nadir altimeter of the SWOT Mission, also holds OLTC tables with about 60,000 targets.
These major improvements over the last few years have been made possible by the analysis and merging of the most up-to-date digital elevation models (SRTM, MERIT and ALOS/PalSAR) and water bodies databases (HydroLakes, GRaND v1.3, SWBD, GSW, SWORD). In addition, special effort is put into introducing the most recent reservoir databases. This methodology ensures coherency and consistent standards between all nadir altimetry missions and types of hydrological targets.
Finally, additional efforts have been carried out to define a relevant tracking command outside of hydrological areas, in order to keep track of the continental surface and enabling potential other land applications, while optimizing the OLTC onboard memory.
This year, a special experiment is also carried out over land ice margins in several areas such as Antarctica or Greenland, to improve the tracking of the surface by the altimeter and we expect to improve by at least a factor of 30% the number of relevant data compared to the Closed-Loop mode.

The OLTC function of nadir altimeters constitutes a great asset for building a valuable and continuous record of the water surface height of worldwide lakes, rivers, reservoirs, wetlands and even a few continental glaciers.
This work is essential at institutional and scientific levels, to make the most of current altimeters coverage over land and to be used for the validation of the Surface Water and Ocean Topography (SWOT) mission. In this context, we will present an overview of OLTC achievements and perspectives for future altimetry missions.

The ESA Scout HydroGNSS Small Satellite Mission

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HydroGNSS is a small satellite mission under the ESA Scout Programme tapping into NewSpace, as part of ESA's FutureEO Programme, within a budget of €30m and a schedule of three years from mission kick-off to launch. The mission comprises of two satellites using an innovative GNSS-Reflectometry instrument to measure parameters closely related to Essential Climate Variables (ECVs) and release them as products to users: soil moisture, inundation, freeze/thaw, biomass, ocean wind speed and sea ice extent.
Water is a natural resource vital to climate, weather, and life on Earth, and unforeseen global variability in hydrology poses one of the greatest threats to the world's population.

Scientists, meteorologists and others increasingly use global soil moisture measurements from space for accurate weather forecasting, flood warning services, agriculture, subsidence, permafrost sensing, and climate modelling. HydroGNSS will complement and potentially fill gaps from other missions sensing soil moisture, notably ESA's SMOS and NASA's SMAP missions, and complement ESA's Biomass mission for forest biomass sensing addressing coverage restrictions over northern regions.

GNSS-Reflectometry (GNSS-R) is a type of bistatic radar utilising abundant continuously-transmitted L-Band signals from GPS, Galileo and other navigation satellite as signals of opportunity. Forward reflections are used, and unlike with back-scatter, reflections off flat surfaces are stronger than off rough surfaces. This means that GNSS-R is particularly sensitive to sheltered inundated surfaces, such as rivers, lakes and wetlands, where reflected signals can remain coherent. The L-band frequency is lower than most radars, and is better able to penetrate vegetation, and can map out river tributaries even under jungle canopies to a resolution potentially better than 1 kilometre. Unlike other radar systems, no transmitter is required, enabling small satellites to provide measurement quality usually associated with large and costly satellites.

HydroGNSS follows previous TechDemoSat-1 and NASA CYGNSS missions that, while designed to collect GPS reflections over the ocean for wind speed sensing, uncovered significant potential applications over ice and land. The HydroGNSS instrument has been expanded to exploit Galileo signals, dual-polarization, complex 'coherent channel' (amplitude/phase) and second frequency (L5/E5a) acquisitions. These advances increase the coverage, resolution and help separate out different parameters from soil moisture effects, such as surface roughness and vegetation. HydroGNSS uses the SSTL-21 platform and at approximately 65 kg, is practical for a low-cost future constellation.

Following Kick Off in October 2021, the satellites and ground segment are being designed and assembled. The science team raised scientific readiness level by developing an End-to-End simulator that represents measurements and error sources and tests the Level 1 and Level 2 processors. The products will be shared publicly with registered users over the web based upon ESA's 'free and open' policy. The ride-share launch has provisionally been set for late 2024. Subsequently, a short campaign will be undertaken to calibrate and validate products before they are made available via a data-delivery service. Subsequently HydroGNSS will generate products that will contribute towards hydrological ECVs feeding into better knowledge of the Earth's climate.

Early exploration of the application of the SWOT River Database (SWORD) on pre-SWOT altimetry observations for river discharge estimation using an open-source framework

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River discharge is an Essential Climate Variable (ECV). It is an important variable to understand the climatic processes and climate extremes such as floods and droughts, as well as for the management of water applications, including drinking water, agriculture, industrial use, inland navigation, etc. Additionally, river discharge at the outlet of a river basin is an important parameter in understanding the closure of the water balance between the continents and the oceans. However, river discharge is not measured in many parts of the world. Further, many existing river discharge gauging stations have been discontinued over time, or their data is no longer publicly available. This hinders our understanding of the changing climate system and limits scientific and well-informed management of our water systems. In this context, remote observations of river discharge using altimetry technology have become a plausible alternative for river discharge estimation. Further, the newly launched Surface Water and Ocean Topography (SWOT) mission is expected to increase our capabilities of earth-observation-based river discharge estimation. In anticipation of the SWOT mission, a detailed geospatial dataset for rivers, including extensive attribute information, has been developed by Altenau et al. (2021) called the SWOT River Database (SWORD).

In our contribution, we explore the opportunities this new SWORD dataset provides in river discharge estimation, for now, using pre-SWOT altimetry observations such as the Sentinel-3 mission. Further, we explore the potential of building an open-source pipeline to compute river discharge using remote-sensing observations. As such, in addition to our scientific exploration, we also envisage a nudge towards a paradigm-shift towards open-source earth observation practices in our community.

What can we learn from numerical simulations of satellite altimetry signals over rivers?

Detailed study and comparison to a dataset of Sentinel-6MF individual echoes

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Radar altimeters are primarily designed for ocean surfaces. Over rivers, the water extent occupies a small area in the 30-km-wide antenna's main lobe. Consequently, radar echoes over inland waters have a particular shape, very different than the one commonly observed in altimetry over oceans. Resolving the radar equation for non-linear or complex river shapes is almost impossible and one must rely on numerical simulation. This makes water level measurement challenging over rivers. Recent developments in altimetry over inland water have allowed retrieving water levels of narrow rivers (less than 200 meters wide), but with a precision way under sea surface height measurements. The retracking process, which is the inversion of the waveform to retrieve the water level in the measured signal, also fails due to contaminations of the scene by the surrounding environment.

In this context, we investigate how a numerical simulation of the observed scene can help understanding the influence of several topographical and geophysical parameters on the shape of the measured waveforms. The goal of this study is to find out to what extent simulated signal can be used to improve retracking techniques and perform better in complex observation cases.
Using a representative dataset of rivers sampling varying widths (from 50 meters up to 1500 meters) and different geometries, we perform simulations of the altimeter signal. We use watermasks from different approaches and sources at different resolutions: from handmade masks based on satellite optical images to Pekel's mask. This approach ensures the representativeness of our simulations and allows identifying the influence of different properties of the observed scene on the simulated signal. We compare our numerical simulations to real measurements from the Sentinel-6 Michael Freilich mission, launched in November 2020, which holds the Poseidon-4 Ku-band altimeter. This altimeter provides over certain areas and time periods a highly valuable dataset of individual echoes at 9 kHz frequency. This dataset is key to understand the fundamentals of altimetry over inland waters.

We show comparisons of the simulated vs. measured signal over rivers with variable widths, roughness, slope and surrounding environment complexity. Learning from these comparisons, we develop a heuristic method to integrate simulations in the retracking process.

This work offers great potential in the use of numerical simulations to enhance retracking techniques of altimetry over inland waters. Future work will include the use of SWOT-derived water masks to describe the observed scene and an assessment of the performance of this new retracking method with respect to other remote sensing products or in-situ data.

Estimation of winter wheat water requirement in a semi-arid region using satellite remote Sensing

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Recent research has highlighted the potential of remote sensing techniques in determining crop water requirements in agricultural regions. This study specifically investigates the application of vegetation indices to estimate the water needs of winter wheat crops in the Setif region of Northeast Algeria. The research utilizes reference evapotranspiration values obtained from a mobile application and combines them with the crop coefficient (Kc). Sentinel 2 satellite data is employed to derive various vegetation indices, including NDVI, NDRE, MSAVI, ReCI, and NDMI. The study reveals a strong positive correlation between crop water requirement and all five vegetation indices. Notably, the highest correlation coefficients were observed during January-March, with R2 values of 0.95, 0.93, 0.92, and 0.91 for NDMI, NDVI, MSAVI, ReCI, and NDRE, respectively. The root mean square error (RMSE) values for the five vegetation indices ranged from 1.68 to 2 mm/decade. However, lower correlations were observed during the late season (Ripening stage), with R2 values ranging from 0.21 to 0.30 and RMSE varying between 7.4 and 14.65 mm/decade.

Estimation of Groundwater Storage: Can Storage Change Derived from the Gravity Recovery & Climate Experiment (GRACE) be a Substitute for a Calibrated Numerical Flow Model?

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In many parts of the world, information about the availability of groundwater and the change in storage is limited mainly due to the lack of periodical quantitative monitoring and the reluctance to data sharing. Therefore, the estimation of groundwater storage is a difficult challenge. The objective of this study is to present a comparative analysis of two approaches that can be used in groundwater storage estimation. More specifically, we question if groundwater storage change derived from the Gravity Recovery and Climate Experiment (GRACE) data can be a substitute for storage change estimates obtained from a calibrated numerical flow model.

A MODFLOW-based flow model is constructed for the Alasehir-Sarigol alluvial aquifer that is located in the east of the Gediz river basin, western Turkiye. Due to the over-exploitation of groundwater primarily used for irrigation of vineyards, the area suffers from significant land subsidence. The model is calibrated using 395 hydraulic head observations from twenty-two wells. The calibrated model RMSE value is 5.6 m. The groundwater recharge input of the model is obtained by a remote sensing-supported water balance method. Hydraulic parameters such as hydraulic conductivity and storage coefficient are determined as a result of the calibration of the groundwater flow model. Modeling results for the 2013-2021 simulation period show that groundwater storage in the aquifer decreases at a rate of 83.9 Mm^3/yr. The change in groundwater storage is alternatively determined for the same period from the terrestrial water storage (TWS) mass concentration (mascon) solution of the GRACE remote sensing product. TWS represents the total water content above ground and in the subsurface, therefore data normally needs to be adjusted to obtain an estimate of groundwater storage. However, streams in the region can be ignored as a contributor to the TWS as they are intermittent and have typically low discharges. The soil water content in the unconfined aquifer is determined using ERA-5 data. The discrepancy between both approaches of groundwater storage changes is analyzed in terms of model accuracy and resolution/scale issues of the GRACE data. Furthermore, the possibility of supporting the calibration process of the groundwater flow model through the conjunctive use of the GRACE-derived storage change data is discussed.

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Evaluation of Altimetry Data over Polish Rivers Using Water Gauge Stations and Hydrodynamical Model

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Satellite radar altimetry was developed to examine ocean elevation variability, but since had found applications in inland water observation. This study is aimed to evaluate the accuracy and utility of altimetry data in hydrological monitoring. Forty-six virtual stations made by Theia Hydroweb located on Polish rivers were selected for this assessment. The data consists of Sentinel-3A, Sentinel-3B, and Jason-3 missions. Altimetry data from 2019 to 2022 were analyzed. Twenty-seven of the selected stations were located in a radius of 5 km from water gauge stations for direct comparison. Another seven were compared with the hydrodynamical model but with a close neighborhood of water gauge stations for maximum model accuracy. Twelve were selected to be compared with the hydrodynamical model but with no upstream and downstream gauges located in the vicinity. Each station's location was thoroughly described to evaluate the source of occurring deviations between the compared data and to justify outlier measurements. The data was transformed to enable comparison, including field measurements for some virtual stations. The analysis showed that the majority of the selected virtual stations had a strong correlation with gauge or modeled data with varying accuracy. Out of all stations, thirty-five have a correlation coefficient higher than 0.7, three more between 0.5 to 0.7, and only six below 0.5 with no statistical significance. The best results from the comparison had a station on the Oder River with a mean difference of 7 cm between the altimetry data and the water gauge. There were a couple of stations with considerably excessive differences (more than 1 m) but maintained a very strong correlation (above 0.7). The study also observed that the angle between the riverbed and satellite track crossing might be an important factor in altimetry data accuracy.

Generation of high-resolution water surface slopes from multi-mission satellite altimetry

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Water surface slope (WSS) of rivers is a key parameter in hydrological modelling, which allows for estimation of the transport and erosion capacity of a river, its flow velocity and discharge. On a local scale, WSS can be measured with a GNSS receiver installed on a boat, using remote sensing techniques (e.g. airborne lidar) or from a Digital Elevation Model (DEM). The most accurate method to measure WSS avoiding high-cost field campaigns is based on Water Surface Elevations (WSE) measured at in-situ stations. However, in poorly gauged rivers the neighboring gauges can be up to hundreds of kilometers apart, which inhibits a proper river profile observation. The gap in decreasing number of gauge readings is partially filled with satellite altimetry over rivers. Altimetry based WSE can be used to estimate WSS between neighboring measurements. Here, we present an innovative approach for estimating high-resolution WSS derived from multi-mission satellite altimetry for the largest Polish rivers.

In this study, we used measurements from 12 altimetry missions: CryoSat-2, ERS-1/-2, Envisat, ICESat, ICESat-2, Jason-2/-3, SARAL, Sentinel-3A/-B, and Sentinel-6A. These observations cover the years from 1994 to 2022. We extracted the river centerlines from the global “SWOT Mission River Database” (SWORD). In order to validate the obtained results, we used WSE from 81 gauges, which are maintained by the Institute of Meteorology and Water Management – National Research Institute (Instytut Meteorologii i Gospodarki Wodnej – Państwowy Instytut Badawczy, IMGW-PIB). Additionally, we used the reach-scale “ICESat-2 River Surface Slope” (IRIS) and the DEM-derived WSS values from SWORD.

To obtain WSS, we first determined WSE at each satellite pass crossing the studied river. Next, we split rivers into sections without dams and reservoirs. The Support Vector Regression (SVR) has been applied to reject outliers. Then, water levels were assigned to a given river kilometer (bin). The approach for estimating WSE for each river kilometer is based on a section-wise weighted Least Square Adjustment with an additional Laplace condition and an a priori gradient condition. Finally, WSS are derived from WSE between each river kilometer.

To assess the accuracy of the proposed approach, we compared the obtained WSS with the slopes between IMGW-PIB gauges. For large rivers (Vistula, Odra, Warta), the multi-mission approach revealed high accuracy with preliminary Root Mean Squared Error (RMSE) below 30 mm/km. For smaller, mountain rivers (San, Dunajec) the preliminary errors were slightly larger (RMSE ~100 mm/km). We also compared our accuracies with those of the slopes based on DEM models, lidar data, ICESat-2 altimetry, and SWORD database. In general, the multi-mission approach revealed the highest accuracy.

Assessing the Utility of Multi-Mission High-resolution Satellite Signals for Hydrologic Model Calibration in a Tropical River Basin

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For sustainable water resources management at catchment scale, assessing the streamflow by accounting for different hydrological fluxes is indispensable. In the hydrologic literature, this assessment is generally carried out by setting up various hydrologic models; however, these models are highly dependent on the availability of the in-situ data. For instance, for calibrating a hydrologic model, there is a necessity of spatiotemporally distributed meteorological forcing of precipitation and temperature, and the at-station in situ streamflow time series datasets. However, with the decline in the number of gauging stations for these variables, hydrologic modelling studies are severely affected. These data scarcity issues in hydrological modelling could be solved at a greater extent by the use of surrogate public domain high resolution satellite datasets. Although several studies have already tested the satellite precipitation products (SPP) in hydrologic modelling, the calibration of hydrologic models using both remote sensing (RS)-derived streamflow and SPP has not been explored yet. In this context, the physically-based semi-distributed Soil and Water Assessment Tool (SWAT) hydrological model was selected for deployment in the Brahmani River Basin in eastern India for streamflow assessment. Here, for model calibration, the streamflow timeseries retrieved from the RS-based CFUS model which was developed by an integrated modelling framework of Frank copula and the 30m×1-day high resolution synthetic Landsat remote sensing images. For precipitation, the public domain SPP variants, APHRODITE, CHIRPS, GPM and SM2RAIN, were then used individually in SWAT as the meteorological forcing. The above combinations were tested for three gauging stations of the selected river basin which provided reasonable performance. Thus, this study demonstrates the potential utility of the high-resolution public domain satellites for catchment scale water management using the hydrological modelling studies and, subsequently, provides an insight for extending the methodology to several ungauged river sites across the globe.

Towards a pan-Mediterranean snow reanalysis: 4DMED-SNOW

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Snow plays a key role in the water budget of the Mediterranean Sea, but a clear characterization of the Mediterranean snow water resources is still missing. In the context of three projects funded by the European Space Agency within the Digital Twin Earth - Hydrology initiative, we are working toward a first-of-its-kind, coherent, high-resolution (1 km, daily granularity), and multi-decadal (2000-2022) reanalysis of the Mediterranean Snow Water Equivalent (SWE) that will provide such figures: 4DMED-SNOW. This reanalysis uses downscaled ERA5 meteorological data and satellite-based precipitation as input for S3M, an operational and spatially distributed snow model. Input precipitation fields are being corrected to consider orographic gradients and precipitation under-catch by using daily snapshots of snow depth from the C-SNOW Sentinel-1 product. Spatially explicit daily snapshots of snow depth and SWE are being validated with in-situ snow measurements across the Mediterranean-Sea region. These estimates demonstrate the added value of remote-sensing products to tackle societally relevant questions in the 21st century.

Developing a Bio-optical Model for Shallow Coastal Zones in the German Baltic.

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This research aims to develop a bio-optical model specifically adapted for shallow coastal zones of the German Baltic coast. The primary objective is to improve spatial coverage of ecological assessments and facilitate effective coastal management practices through the implementation of remote-sensing techniques. This study fills crucial gaps in understanding the complex and dynamic bio-optical characteristics of coastal waterbodies with high Chlorophyll-a and Coloured Dissolved Organic Matter (CDOM)-contents.

Thorough site selection is conducted to encompass a diverse range of coastal environments, accounting for variations in sediment types, vegetation cover, depths, and turbidity. Field measurements of principal bio-optical parameters (BOPs), such as Chlorophyll-a concentration (Chla), Total Suspended Matter (TSM), and Coloured Dissolved Organic Matter (CDOM), provide the necessary data for model development. Spectrally resolved absorption coefficients (a) of key constituents including CDOM (aCDOM), water (aW), non-algal-particles (aNAP), and chlorophyll (aChl) are also quantified. Remote sensing techniques are employed to acquire surface water remote sensing reflectance (Rrs) and underwater light attenuation (Kd) data.

A random forest machine learning algorithm is employed to identify robust correlations and important features within the datasets. During the analysis phase, the spectral signatures of Rrs and Kd in relation to measured BOPs and absorption coefficients were assessed. Analyses are conducted on individual variables, variable interactions, model prediction, and sensitivity to achieve a comprehensive understanding of the relationships between predictor variables (BOPs and absorption coefficients) and response variables (Kd and Rrs).

The validity of the model is ensured through extensive validation exercises using independent data and satellite-based estimations. Performance evaluation focuses on accuracy, precision, and reliability, with comparative analysis against existing approaches highlighting the distinct advantages and contributions of the developed model.

The results demonstrate the application of the developed bio-optical model in estimating and predicting BOPs in shallow coastal zones. Based on in-situ data collected in 2022 for Kd and Rrs, it is observed that BOPs and absorption coefficients account for 33% to 47% of the variabilities in Kd and Rrs values. The mean squared residuals range from 0.22 to 0.034, indicating a reasonably good fit of the model to the data, with predicted values being closely aligned with measured values. The model also identifies variables of higher importance, particularly CDOM and aW, which play influential roles in the prediction process.

The strengths and limitations of the model are thoroughly examined, providing comprehensive insights into its potential applications for coastal ecosystem assessment and management. The accurate estimation of parameters facilitated by this model holds significant potential for supporting effective management practices aimed at the conservation and sustainable utilization of coastal ecosystems. Future research endeavours can focus on refining the model, extending its applicability to larger-scale assessments, exploring its performance under diverse environmental conditions, as well as assessing other regression models to enhance our understanding of these complex patterns.

Improving SAR Altimeter processing over inland water - the ESA HYDROCOASTAL project

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The objectives of the HYDROCOASTAL project, funded by the European Space Agency under the EO Science for Society programme, are to enhance our understanding of interactions between the inland water and coastal zone, between the coastal zone and the open ocean, and the small scale processes that govern these interactions. The project also aims to improve our capability to characterize the variation at different time scales of inland water storage, exchanges with the ocean and the impact on regional sea-level changes

To achieve these aims, the HYDROCOASTAL project team has developed and implemented new SAR altimeter processing algorithms for the coastal zone and inland waters, and with these processed Sentinel 3A, 3B and Cryosat-2 data to generate to generate an initial 2-year Test Data Set for selected regions. The performance of these new algorithms has been evaluated, by statistical analyses and comparison against in situ data. From this analysis, the best performing algorithms have been identified and a processing scheme implemented to generate a global scale coastal zone and inland water altimeter data set.

A series of case studies were implemented to assess these products in terms of their scientific impact on inland waters. All the produced data sets are available on request to external researchers, and full descriptions of the processing algorithms available via the project web-site

We will provide a short introduction to the project, before presenting the results from the inland water impact assessment case studies, and key recommendations for future implementation in SAR altimeter processing.

hydroweb.next, a thematic hub for hydrology data centralizing free access to innovative hydrology data including SWOT

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In the frame of Theia (Data and Services centre for continental surfaces) and SWOT (Surface Water and Ocean Topography satellite) projects, CNES developed a hydrology production center and a distribution thematic hub, hydroweb.next, to promote a wide access to hydrology data derived from satellite observations. These solutions are focusing on the necessity to answer the needs of users from the hydrology community: water agencies, NGOs, startups, industry, research laboratories…etc.

The production center, Hespérides, routinely operates innovative algorithms for water detection, water quality and fractional snow cover retrieval based on Sentinel-1 and Sentinel-2 observations. Other algorithms will be added in the future such as water temperature and reservoir surface extent and volume.

hydroweb.next is a distribution platform focusing on hydrology users. It provides free access to services (advanced product search, vizualisation on a map or timeseries, download, analyses…etc) and products that may be useful for hydrology studies. The product catalog will not only include the products operated in the Hespérides production center but also the SWOT products, products from other Theia catalogs and other external catalogs such as Copernicus Services (Land, Emergency, Climate). These external products may come from any source as long as they are of interest for users and publicly available. They may be derived not only from satellite observations but also in situ, models, or airborn.

The LSA SAF data record on evapotranspiration and surface energy fluxes: sub-daily estimates across Europe, Africa and South America throughout the operational life of the MSG satellite

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The Satellite Application Facility on Land Surface Analysis (LSA-SAF, http://lsa-saf.eumetsat.int/) program by EUMETSAT pursues the objective of optimally exploit spaceborne information by meteorological satellites to characterize the Earth's continental surface. The LSA SAF has developed and set up an operational service to disseminate products related to solar radiation, vegetation, wild fires and evapotranspiration (ET) and surface latent (LE) and sensible (H) heat fluxes.

This contribution elaborates on the LSA SAF ET and surface heat fluxes (SF) products; in particular, a recently generated dataset that encompasses the operational life of the Meteosat Second Generation (MSG) satellite; i.e. starting in 2004. The dataset encompasses the period 2004-2022 and is intended to be coupled with the operational service that provides estimates in near-real time. The datasets consists of estimates of ET and SF at half-hourly time step. In addition, the ET estimates are aggregated every day into a daily ET product. The products are freely available to users after a simple registration step.

The estimates are greatly based on other biophysical products developed by the LSA SAF and derived from observations by the MSG satellite. The algorithm is also forced by meteorological data, soil moisture data obtained from H-SAF (http://hsaf.meteoam.it) and land cover related parameters.

The quality of the ET/SF products has been verified by validating the simulations against measurements at eddy covariance stations located in a variety of ecosystems and by comparisons to other products.

In this contribution, more details are given on the algorithm, the forcing datasets and the results of validation exercises. Useful information will be given on the access to data and possible applications.

An integrated approach for estimating river discharge by leveraging near-infrared sensors

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River discharge is a crucial parameter for understanding and managing water resources. Traditionally, river discharge has been measured using ground-based methods, which are often limited to the most developed countries due to their cost of installation and maintenance and can be challenging to implement in remote or inaccessible regions. However, with advancements in space technology, measuring river discharge from space has emerged as an alternative approach that provides global-scale observations and continuous monitoring capabilities.

Among the different available methodologies, the CM approach applied to Near Infrared (NIR) satellite imagery has distinguished itself for its wide applicability. However, the known compromise between spatial and temporal resolution of satellite sensors still represents a limitation for the application of this methodology to obtain accurate and timely flow information, since the sensors with higher revisit time lack in spatial resolution and, conversely, the ones with higher spatial resolution have lower temporal frequency.

To overcome this issue, here we investigate the potential of a multi-mission approach capable of combining the different characteristics of multiple optical sensors into a single time series of estimated river discharge. Specifically, the outcomes of the CM approach applied to MODIS (AQUA and TERRA), Landsat (5, 7 and 8), Sentinel 2, Sentinel 3 OLCI and MERIS were combined together through a statistical merging over 40+ sites in different rivers worldwide. The results indicates that this methodology has the potential to obtain river discharge estimates with higher frequency and accuracy than the single sensors, proving the usefulness of the multimission approach to improve the quality of river discharge estimates from NIR sensors.

Surfwater – Water Extent Dynamics for Resources Monitoring

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Climate change has significantly impacted the water cycle, emphasizing the need for enhanced monitoring of water resources. Recent advancements in altimetry missions have provided valuable insights into water dynamics. However, to obtain a comprehensive understanding, it is essential to integrate data from other satellite imagery sources.
This presentation introduces Surfwater, a water extent product developed by CNES (Centre National d'Études Spatiales). Surfwater utilizes the combined capabilities of Sentinel-1 and 2 satellites to provide systematic water extent information. Several time scales and products are foreseen : water extents by single or multiple observations and monthly and yearly occurrence products. CNES has commenced regular production in France in 2023, with plans to expand coverage to Europe and other continents in 2024. Products will be available at “hydroweb.next” portal.
Surfwater product has been used for a large scale validation campaign on SWOT water extent (on Calval phase) and the launch of Stockwater project in 2021/2022, which focused on monitoring reservoirs using a combination of digital elevation models and water extent data. This work has enabled a significant national government investment (France-2030: Fast-track on Hydrology) for new operational systems on reservoirs volume monitoring.
Current CNES research focuses on improving individual water bodies segmentation, notably by means of multitemporal, intrapixel, and Super-Resolution strategies. By integrating Surfwater with other altimetry inputs, such as the upcoming SWOT mission, we show an improvement in the precision and reliability of water volume estimations. This innovative approach holds great potential for facilitating informed decision-making and efficient management of water resources on a larger scale.

WADIT - Water Digital Twin

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Water Digital Twin (WADIT) is an ongoing project started in 2023 coordinated by Apulian Aerospace Technology District in partnership with Planetek Italia srl, Sitael SPA, National Research Council, and University of Bari Aldo Moro.

The project's main objective is to create a Digital Twin of the physical assets (land use, soil moisture, frequency and date of crops' irrigation, irrigation techniques, etc.) for water management at the basin level, aimed at supporting the water balance. WADIT focuses on analyzing water needs related to water use in agriculture to obtain a reliable estimate of actual water consumption in cultivated fields.

The models to be studied, designed, and experimentally implemented will be based on Artificial Intelligence techniques applied to process Big-Data, in terms of multi-platform remotely sensed data, data from agro-meteorological stations, Copernicus Services core data, commercial data, census data.

The outcome system will be able to provide, at district/basin level, the estimate of irrigation needs/consumption, periodically updated based on the data acquired and processed in near real-time on the area of interest. It will be able to create scenarios for short-term estimation (12 months to consider the herbaceous species' variability) or for the simulation of land transformations that entail radical changes in requirements over the long term (10/20 years as in the case of planting tree species).

Three study areas in Apulia region (in the south of Italy) are planned to address different characteristics of the territory (crops, farm structure, availability of irrigation sources, services, and quality of irrigation water). Each zone, covering approximately 25km2, will include farms that can provide all necessary data for calibration and validation of remote sensing data and their integration in the balance model to be developed within the project.

The aims of the WADIT are:

- produce dynamic land use maps and identify the location and extension of irrigated areas through the processing of time series of optical, radar and hyperspectral EO data based on artificial intelligence techniques;
- highlight irrigated areas with a high probability of unauthorized water use
- prepare the library of Crop Coefficients for different types of crops in different agro-ecological contexts
- use weather and climate data to feed the models for calculating irrigation requirements
- create a digital infrastructure, the Digital Twin, to automate the processing, analysis, and reporting, together with analytic indicators production.

WADIT will provide a Decision Support System:

1. For public and private entities in charge of water management that have to estimate and assess seasonal irrigation needs and consumption at basin/district/region level, and according to the water availability, plan its use
2. for irrigation water service management public and private entities as a tool for monitoring and controlling irrigation withdrawals at the farm level
3. for operators in the agricultural sector for planning investments in cultivations, both in the short term for annual crops and in the medium term for tree crops (20/50 year timeframe).

Using image processing techniques to detect inland water bodies in Sentinel-6MF Fully Focused SAR

radargrams and improve water surface height retrieval: A case study over Garonne River

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Satellite altimetry has emerged as a powerful system for monitoring and understanding Earth's water resources. This technology has revolutionized our ability to monitor not only the oceans but also inland water bodies, including rivers, lakes, and reservoirs worldwide. In recent years, there has been a growing need to retrieve river water levels using altimetry data. Water surface height (WSH) retrieval is usually done by performing waveform retracking algorithms that can be empirical or physically based. This process becomes very critical over inland waters due to complex surface characteristics with respect to the ocean. Indeed, multiple scattering can disturb the radar echoes as the signal interacts with surrounding land areas and water bodies of different sizes, relative altitudes and backscattering properties, making the river water level retrieval a real challenge and sometimes with low accuracy.

Recently, an important step forward has been made with the Sentinel-6MF mission and its on-board Poseidon-4 radar nadir altimeter. Its numerical radar architecture, operating in Open-Burst mode makes it now possible to exploit the full capabilities of the Fully Focused SAR (FFSAR) processing providing very high azimuth resolution (with very low grating lobes) in comparison to the conventional pulse-limited radar and delay/Doppler altimetry [1] which appears to be very useful in differentiating small targets along the satellite track. By combining neighboring waveforms and looking at 2D radar scenes it appears to be possible to see the river features emerging as bright curves from the darker surroundings and local ponds. Considering image processing techniques, this work aims to locate the river signal in the radargrams if the signal-to-noise ratio allows it, depending on the river's roughness and position from nadir. This useful information is then used in the 1D retracking step to improve water level accuracy. For this purpose, well-known edge operators (e.g., Sobel) are performed on FFSAR pseudo-image and compared. Moreover, a new physically based retracker algorithm, inspired from current studies overs lakes [2], is developed to account for this a priori information and to determine a more accurate water level. Preliminary results and performances analysis will be presented over the Garonne case study for which in-situ observations are also available.

This study shows innovative methods using nadir altimetry and how to exploit the full potential of this technique over hydrology. Our results will also be used in the frame of the SWOT mission Cal/Val and we believe it will be an added-value dataset to validate the river products from the swath altimeter KaRin.

[1] A. Egido and W. H. F. Smith, "Fully Focused SAR Altimetry: Theory and Applications," in IEEE Transactions on Geoscience and Remote Sensing, vol. 55, no. 1, pp. 392-406, Jan. 2017, doi: 10.1109/TGRS.2016.2607122.
[2] Boy, F. et al, 2021. Improving Sentinel-3 SAR mode processing over lake using numerical simulations. IEEE Transactions on Geoscience and Remote Sensing, 60, pp.1-18.

Fault tolerant approach to regenerate L1B SAR altimetry waveforms for enhancing L2 retrackers performance

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The main scope of this paper is to automatically determine anomalous waveforms generated in Level 1B processing chain of satellite altimetry and introducing methods to regenerate and refine waveforms in order to achieve better results for measuring water level in coastal areas and inland water bodies. Efficient identification and extraction of anomalous waveforms greatly improve retracking accuracy, leading to the generation of precise water level time series that serve as vital inputs for hydrological studies. In general, the abnormal behaviours in generated waveforms may be an indication of environmental changes, instrument malfunctions, or other critical factors affecting the accuracy of altimetry measurements. To find anomalous waveforms that deviate from the expected patterns as the primary objective of this paper, our framework leverages state-of-the-art unsupervised machine learning technique to analyse the waveforms without relying on prior knowledge or labelled data. To do this, firstly, we categorised different parameters of the satellite's altimeter and features related to shape of waveforms of the provided dataset, and then using a two-step density distribution probability analysis of these two categories, abnormal waveforms can be identified. The secondary purpose of this framework is proposing a robust strategy in order to retrieve abnormal waveforms in the level 1B SAR processing chain. This step of the framework is vital for narrow rivers and small inland water bodies, in which lack of enough measurements generated by satellite on related cycle cause missing hydrology data for that period of time. In contrast to previous studies focusing solely on investigating L2 waveforms to determine precise retracking gates for multipeak and noisy waveforms, we propose an additional step in the L1B processing chain, specifically tailored for coastal and inland waters, enabling the retrieval of abnormal waveforms. Owing to the fact that in both fully focused and unfocused synthetic aperture radar (SAR) processing, the final waveform is formed through the combination of various beam looks from the altimeter during fixed illumination time in stacks to the desired point on the surface, certain looks in the stack may exhibit undesirable patterns due to variations in environmental characterization, antenna footprint, and sidelobe gain. The proposed methods will mitigate the presence of undesirable waveforms in the stack prior to the generation of the final waveforms.
A comprehensive evaluation of the proposed methodology is conducted using Sentinel-3A datasets and in-situ measurements over three different inland waters, demonstrating the capability of our approach in accurately detecting and retrieving anomalous waveforms. The results demonstrate that the water level time series, obtained by regenerated waveforms and different retracking algorithms have significantly improved and indicate the potential of our framework for enhancing the reliability and robustness of satellite altimetry data, contributing to a better understanding of the Earth's dynamic processes.

Keywords: Anomaly detection and retrieving, SAR Altimetry, Level 1B waveforms

What are Benefits and Dangers when Using Artificial Intelligence for Monitoring of Soil Moisture from Earth Observation Data?

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Artificial Intelligence (AI) methods are widely used in the field of Earth observation and one sees an ever increasing number of publications that use deep learning or one of the many other AI methods to monitor geophysical variables from satellite measurements. As most publications predominantly highlight the positive aspects and usefulness of AI, we would like to discuss both, benefits and dangers when using AI in Earth observation. We base our work on a review of recent studies that trained AI models on satellite, model, and in situ data for either forward modelling of the satellite observations or for retrieving soil moisture. Our review shows that AI methods are very powerful, yielding accurate results for data close to their training distribution. They can beat physical and semi-empirical models that are confined by a more rigid model structure, thus being less flexible to handle unexplained behavior in the data. This makes AI methods very seductive, but the naive application of such methods can lead to unintended consequences. The most obvious case is when the data used for training the AI models are flawed, biased, or insufficient, leading to inaccurate results and wrong decision-making. Less obvious is the problem of overfitting, especially when training on high-dimensional raw data from different sources, or on data corrupted by non-stationary noise. Furthermore, labels are often at different scales, if available at all (sparse point-scale in situ observations vs. kilometer-scale model and satellite data), creating much more complex problems. Last but not least, it is notoriously difficult to understand how AI models came to their conclusions. Hence, great care must be taken in preprocessing the input data, and crafting the target loss function, to avoid noise induced local minima and unintended failure modes. In recent years, work has been done in other fields such as ML and Computer Vision to highlight, and address these problems, but the most recent developments have so far been underappreciated by the Earth observation community. In our work, we want to highlight some difficulties that arise from developing AI that is trustworthy, and applicable in the real world. For this we will show examples from using AI methods in combination with different semi-empirical models to retrieve soil moisture from Sentinel-1 and ASCAT.

New high-resolution precipitation and soil moisture Earth-Observation data for hydrological modelling in the Mediterranean region.

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Recent developments in Earth Observation (EO) systems offer new high-resolution (1 km, daily) datasets for various components of the water cycle. Our study focus on assessing the added value of new precipitation and soil-moiture data sets for hydrological modeling in the Mediterranean Region (MR). The study considers five rainfall dominated catchments around the MR (Spain, France, Italy, Tunisia, Morocco). Five lumped parameter hydrological models (HM) were compared to obtain an ensemble of simulated hydrographs accounting for both structural and parametric hydrological model uncertainties. The parameter estimation procedure is performed for any combination of precipitation and soil-moisture data sets. The simulated hydrographs obtained with new high resolution data sets are compared with the ones obtained with reference data (depending on available data for each test sites) as well as coarser satellite data sets. The main results highlight that (i) the hydrological predictions are more sensitive to precipitation data rather than the selected hydrological model, (ii) the multi-resolution analysis of hydrological predictions against observations show a better correlation across temporal scales with high-resolution precipitation data sets and (iii) the proposed methodology can be used for hydrological model selection with a better assessment of the hydrological model's parameters compensation effects related to the bias in satelite data sources.

Altimetry for the hydrology of Arctic rivers

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The Arctic continental environment is experiencing the most remarkable changes due to intense climate warming. In such remote regions characterized by harsh natural conditions, the observation of natural parameters has always been a challenge, and the detection and assessment of recent environmental changes is becoming more and more onerous due to declining ground observation networks.

Altimetry is one of the remote sensing techniques that has already proven its capacity to inform us about variability and changes in different components of the Arctic continental water cycle. As in other latitudes, we can observe the year-round water level regime of Arctic lakes, rivers and wetlands; evaluate river discharge; and investigate the interannual dynamic of surface wetness conditions (drying or expansion of lakes and wet zones). Our specific interest in Arctic water bodies and watercourses is the ice cover, which can occupy lakes and rivers up to eight months each year. Being sensitive to the water phase change, altimetric measurements allow for the monitoring of seasonal ice dynamics (freezing/melting) in lakes, rivers and bogs and also for the estimation of freshwater ice thickness. Based on results from the ESA Arctic+ Fresh Water Fluxes, ESA HYDROCOASTAL and ESA precursor CCI Discharge projects, we demonstrate how altimetry water level measurements in Arctic rivers have evolved over nearly two decades, starting from 2000s, and how they have been used for the retrieval of discharge in large and medium size rivers. The effect of river ice on satellite water level measurements and, consequently, the estimation of discharge will be shown for low resolution conventional and high resolution SAR altimetry instruments for several typical Arctic fluvio-geomorphological conditions. Finally, we will discuss how progress in understanding the interaction between freshwater ice and altimetry signals, achieved in the framework of ESA LIAM and ESA CCI Lakes+ projects, can help in interpreting the regional differences observed when a river hydrodynamic model is coupled with winter altimetry height measurements.

The studies were supported by ESA Arctic+ Fresh Water Fluxes (2016-2018), ESA LIAM (2021-2022), ESA CCI LAKES+ (2020-2022), ESA HYDROCOASTAL (2019-2023), ESA precursor CCI Discharge (2023-2024) and RNF N_22-27-00633 AltiMo (2022-2023) projects.

Towards a Digital Twin for the Water and Energy Cycle over Land

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Climate change profoundly affects the global water, energy, and carbon cycle, increasing the likelihood and severity of extreme events. Better decision-support systems are essential to accurately predict and monitor environmental disasters and optimally manage water and environmental resources. A Digital Twin (DT) of the water and energy cycle over land would offer ground-breaking solutions for monitoring and simulation. Yet, it requires high-resolution (1 km, 1 hour-day) satellite Earth Observation (EO) data, fully integrated with advanced and spatially distributed modeling systems. Building a high-resolution DT over land is challenging due to: (i) the impact of human interventions on land processes through, e.g., irrigation, reservoir management, water diversion, land use and land cover changes, (ii) the need for actual high-resolution (1 km, 1 hour-day) input (e.g., precipitation, evaporation) and ancillary (e.g., soil texture, vegetation) data for characterizing the complexity of the system (for several variables, e.g., soil moisture and evaporation, ground data are scarce), and (iii) the complexity of integrating EO and modeling in a seamless, parsimonious and consistent manner for large-scale applications at high-resolution.
A DT is a virtual replica of a real-world system composed of three main elements: observations, model simulations, and user interventions. On this basis, the overall objectives of a DT for the water and energy cycle are:
1. Developing high-resolution EO-based products over the whole of Europe and targeted regions in Africa, integrated with in situ observations, for the different components of the water and energy cycle. An error characterization of the EO-based products will also be carried out.
2. Integrating high-resolution EO-based products and advanced modelling for developing: (a) use cases in cooperation with dedicated stakeholders, and (b) science cases.
3. Developing an ad-hoc web platform to make the use and science cases available to the public, not only for data visualization and exploration but also for direct interaction with simulations and results.
The presentation will show first results toward the development of a DT for the water and energy cycle, as developed in the ESA DTE Hydrology project, with applications in the Mediterranean basin for flood and landslide risk mitigation, and for water resources management.

Mapping The Seasonal Variability Of Swedish Ramsar Wetlands By Combining Deep Learning, SAR And Optical Imagery

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Wetland ecosystems provide a multitude of provisioning, cultural and regulating ecosystem services which contribute to the livelihoods of their inhabitants. In Sweden, 68 wetlands have been designated as sites of international importance, meaning there is a national collective responsibility to conserve, protect and manage them. To sustainably manage these wetlands, precise monitoring with dense spatiotemporal coverage is required; however, most wetlands have either poor or no in-situ monitoring techniques. Remote sensing techniques such as optical and aerial imagery have been used to fill the gap, but due to the inability of the optical sensors to see the water below vegetation, the wetland area is poorly constrained and most likely underestimated. This project aims to close this knowledge gap by exploiting remote sensing techniques and deep learning to get accurate information about wetland water extent and estimate their hydrological regime. Our work provides a wholly unique and interesting insight into wetlands' seasonal and annual variability and explores them in the context of Swedish landscapes.

We exploit the double-bounce backscattering ability of synthetic aperture radar (SAR) data to penetrate water below vegetation to retrieve wetland water extent. Water extent is automatically delineated using a state-of-the-art deep learning algorithm which employs Normalised Difference Water Index (NDWI) maps from optical imagery. This method eliminates the cost of manual delineation so that a new database of wetland extent will be produced with minor human input. We use deep learning as a tool for data generation, yet we recognise that future work must involve validation with in-situ, hydrological or other remote sensing-derived data to publish a useful and robust dataset.

We hypothesise that optical imagery significantly underestimates the total water extent. This work will demonstrate how the combination of optical and SAR imagery can be exploited to greatly improve our hydrological understanding of wetlands.

The use of remote sensing and field data for water quality monitoring in the Iron Gate I reservoir on the Danube River

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Danube water stored in the Iron Gates I (IG I) reservoir is important for hydropower resources, tourism, freshwater supply, and landscape. The IG I reservoir was built in 1970 together with former Yugoslavia, for hydropower purposes and fluvial traffic improvements in the Gorges area. IG1 is the biggest reservoir along the Danube River that raised the water level by 30 meters and led to important environmental changes.

The uncontrolled development of tourism in the Danube Gorge area, which become the “Romanian Riviera '' with the increased number of accommodation facilities consisting of hotels and guest houses without adequate infrastructure for sewage water collection and treatment is a key factor in aquatic environment protection. Most wastewater is spilled stealthy into the Danube and a large amount of organic matter composed of nitrates, nitrites, phosphorus, and ammonium ends up in Cerna Bay, increasing the condition for aquatic vegetation blooming and the process of eutrophication.

For this reason, rapid water quality monitoring is an important issue for local communities and stakeholders. The use of water indexes derived from satellite images is an easy and efficient way if the data has enough spatial and temporal resolution to retrieve adequate information.

To estimate water quality were proposed many indices that capitalize the spectral response of water constituents stored in spectral bands.

Chlorophyll is present in phytoplankton and aquatic vegetation, evidenced by the absorption of the red channel of visible light with an edge between 680-800 µm. To estimate the chlorophyll-a pigment in coastal shallow and inland waters was developed a particular algorithm Case 2 Regional Processor (Doerffer and Schiller, 2007). Because water is an environment with many physical and chemical processes, the inversion of water leaving reflectance needs a proper atmospheric correction and used an algorithm based on neural network with multiple nonlinear regressions to improve the performance. This model was renamed into Case 2 Regional CoastColour and implemented in SNAP platform which can perform with Sentinel 2 MSI data (Brockmann et al., 2016).

The field campaign consisted of spectrometric investigation using visible and NIR sensors for reflectance caption in precise locations, these raw data were processed in Apogee SpectroVision for reflectance, energy, and photon flux density estimation. Using a multiparameter YSI sonde we managed to collect in the same locations till the depth of 20 meters the values of temperature, pH, nitrate, turbidity, and chlorophyll). Other devices like a single beam echosounder and the DGPS Leica GS18T helped us with in situ data collection.

The remote sensing approach started with Sentinel 2 MSI images processed in SNAP application with the implemented C2R and C2RCC algorithms and is based on values obtained from field investigation to establish new coefficients regarding water leaving reflectance and water physical parameters for model calibration.

The results consist of a spatial model for water parameters with 10 meters spatial resolution which reveal the hotspots of water pollution and confirm the availability of satellite remote sensing as an efficient tool for inland water monitoring.

Prediction of Fast Developing Hydrological Processes by Daily GRACE(-FO) Data Assimilation

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Data Assimilation (DA) of satellite Earth Observation data into water balance models is widely used for improving hydrological model estimates by increasing their accuracy and realism. Particularly, the Assimilation of Total Water Storage Change (TWSC) data derived from the Gravity Recovery and Climate Experiment (GRACE) mission and its Follow On (GRACE-FO) has shown promising results by introducing trends as well as improving the annual and interannual variability of water storage compartments. However, few studies have tested the performance and contributions of GRACE(-FO) DA for predicting fast evolving hydrological events such as (sub-monthly) floods. This is investigated in this study covering the Brahmaputra River Basin during three flooding events of years 2004, 2007, and 2012.

For our experiments, in addition to the widely used monthly GRACE observations, the assimilation of the daily GRACE data of the University of Graz is also implemented. Especially, (1) we address whether the relatively low spatial resolution of daily GRACE data (resolved up to order/degree 40), compared to the monthly solution that is resolved up to order/degree 60 and higher, is affecting the DA results; (2) we evaluate changes in intensity and timing of the flood peaks after introducing the daily observations. For this, first, the signal content of both monthly and daily GRACE data is analyzed in the context of different fast-evolving flood events. When averaging at the subbasin scale, the daily data has been shown to accurately follow the long-term variability and trends of monthly solutions, while at the same time representing the superimposed high frequency variability related to the short-term hydrological dynamics. Then, both daily and monthly observations are assimilated into the W3RA water balance model through a sequential Ensemble Kalman Filter-based DA approach. The results indicate that the daily DA correctly modifies the short-term dynamics, for example, reducing the Root Mean Squared Error (RMSE) of prediction from 36.2 mm to 12.4 mm in year 2004, 60.7 mm to 13.8 mm in 2007, and 66.4 mm to 10.6 mm in 2012 when comparing model predictions to the assimilated GRACE TWS data. The monthly DA has presented some technical challenges to catch the dynamics of the flood events, which is mainly due to the lack of having a temporal updating scheme that properly acknowledges the dynamics of water storage changes during these events. The DA results are validated against satellite derived surface soil moisture and in-situ groundwater level measurements.

Developing snow-drought indices using H-SAF operational products

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Droughts are intensifying in a warming climate, with implications ranging from urban water supply to agriculture, energy security, and ecosystem services. In this framework, droughts in mountain regions see the emerging feature of snow droughts, that is, a lack of snow water resources compared to historical conditions for the same time and location. Monitoring snow droughts is crucial to properly manage water resources from mountains to lowlands, especially in snow-dominated regions where snowmelt supports water security during the summer, dry season. Despite this importance, a coherent, European system to monitor snow droughts in real time is still missing. Here, we present a prototype for such a system developed within the Eumetsat H-SAF initiative using satellite data. The current prorotype includes semi-operational estimates of snow-covered-area anomalies for the 13 most extensive mountain massifs in Europe using SE-E-SEVIRI (H10) snow-mask data by VIS/IR radiometry and fractional-snow-cover anomalies for the whole European continent based on FSC-E (H12) effective snow cover by VIS/IR radiometry. Estimates by this observatory are now being compared with estimates of Snow Water Equivalent by operational, blended satellite-model approaches (S3M Italy) and with other drought metrics developed within the H-SAF initiative. Potential future steps of this project include the extension of this observatory to the whole northern hemisphere, using H-SAF products SE-D-SEVIRI (H34) and ESC-H (H35).

AlTiS : Generating Water Level Time-Series from Radar Altimetry

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Satellite radar altimetry can be used to determine water level height of continental water bodies, if used with appropriate processing that depends on the size and geometrical configuration of the targets. AlTiS (Altimetry Time Series) is software designed to visualize and process radar altimetry data with the goal of generating time series data of radar altimetry data over water bodies of different sizes such as river, lakes and wetlands. Even if its major goal is the creation of time-series of water levels derived from the altimetry range, it can also be used to generate time series of any other altimetry parameters (e.g., corrections applied to the range, backscattering coefficients, or brightness temperatures).

Through a Graphical User Interface (GUI), without any skills in data processing, the user can handle altimetry data in order to:

- Display several parameters of altimetry data like surface height, altimetric range, atmospheric corrections (ionosphere and wet and dry troposphere path delay corrections) and also to display some characteristic parameters of the waveform like the backscatter coefficient, and peakiness.
- Graphically select altimetric measurements to remove outliers and easily done owing to Landsat background image.
- Generate water height time series from the valid altimetry data previously selected
- Export the time series into various files format as CSV and HydroWeb

AlTiS accepts CTOH altimetry products (Level 2 GDR supplied by the CTOH). CTOH GDR data have been specifically conditioned to optimize the data size by making a geographical selection and includes the right altimetry parameters for hydrological studies.

AlTiS can process several altimetric data products from followed missions : Jason-1/2/3, ERS-2, ENVISAT, SARAL, Sentinel-3A/B, and soon, Sentinel-6/Jason-CS and the nadir altimeter onboard SWOT. They are supplied for free through a web request form on the CTOH website (http://ctoh.legos.obs-mip.fr/applications/land_surfaces/altimetric_data/altis).

AlTiS is mainly employed for hydrological applications and can be used for training courses on radar altimetry at bachelor or master levels. It is also a very convenient tool to analyse the radar altimetry data contained in the GDR over any type of land surfaces.

AlTiS is a software developed by CTOH as part of its activities as a National Observation Service. AlTiS is a free software, and it is released as an open source under the CeCill Licence. Altis is working under python3 environment and tested for GNU/Linux, Windows 10/11.

AlTiS is available on GitLab : https://gitlab.com/ctoh/altis

Multi-source data and modeling to understand climate and human compounding effects on flood risk in the Bay of Bengal

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Water resources in the Bay of Bengal, located mostly within Bangladesh, are gradually shrinking. The region has historically been rich in water resources. However, climate change, intensive rice irrigation, poor sanitation practices, and the presence of naturally occurring Arsenic contamination in groundwater have severely impacted both the water quality and usual abundant water availability in Bangladesh. Besides, current scientific literature defines sea level rise (SLR) as a major factor in increasing global coastal flood risk in recent and future decades, showing that coastal flood risk, particularly over mega deltas, is exacerbated by natural and human-induced subsidence. However, the impacts of climate-induced hydrological change (CHC) on flooding and synergy with human activities are often overlooked.

Here, we develop and evaluate a modeling system for the Bay of Bengal that accounts for climate and human impacts on hydrology. Based on “what-if” scenarios and state-of-the-art models, we determine relative impacts of SLR, CHC and land subsidence on increased flood risk over the region. We also examine the role of human impacts through groundwater irrigation and polder construction on flood risk over the region. The modeling system is composed of the HyMAP flood model coupled with the Noah-MP land surface model and an irrigation module, with the assimilation of satellite-based leaf area index (LAI). Simulated flood maps from different scenarios are overlapped with population and cropland maps to quantify the socioeconomic impacts from individual factors. Results of this study could support the decision-making process on climate-induced migration and relocation, as well as the optimal spatial distribution of flood control structures and water management practices.

Daily, accurate evapotranspiration from global to local scale

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Evapotranspiration plays a critical role in the earth system, linking land surface energy, water and carbon cycles. Accurate estimates of terrestrial evapotranspiration are important for the management of land and water resources and improving water productivity in agriculture. However, the determination of evapotranspiration is a complex undertaking. This is accomplished by ETLook, a model developed by eLEAF by which evapotranspiration can be accurately determined based on remote sensing data.

ETLook is at the core of the publicly accessible WaPOR database, developed by the United Nations Food and Agriculture Organization (FAO), that provides near real time spatial data on global water productivity. The WaPOR version 3 dataset will be released in 2023 fall and includes dekadal NRT data on actual evapotranspiration and relative soil moisture content from 20m (selected irrigation schemes) to 100m (Africa and the Near East) to 300m (global).

The WaPOR v3 processing chain combines multiple satellite and model sources (VIIRS, Sentinel-2, Landsat, MSG, MODIS, ERA5, GEOS-5) into intermediate inputs (such as albedo, NDVI, land surface temperature and weather data) for the ETLook model to produce daily and gap free evapotranspiration and relative soil moisture data. Advanced gapfilling and smoothening techniques are applied as well as a data miner sharpener (DMS) approach that builds regression trees between VIIRS LST and Sentinel-2 features to estimate land surface temperature more accurately at higher spatial resolutions.

We will present ETLook, the WaPOR version 3 dataset and two use cases that implement evapotranspiration data at different spatial scales: an irrigation map of the Netherlands (field scale) and a water dashboard for the Moroccan water authority (basin scale).

A global multi-scale ET mapping system using multi-source thermal infrared imaging

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Thermal-infrared (TIR) remote sensing data provide valuable information on surface water and energy balance, enabling retrieval of latent heat and evapotranspiration (ET) estimates at the imaging resolution. The ALEXI/DisALEXI modeling system was designed to exploit time-differential temperature measurements from geostationary and moderate resolution polar orbiting systems in combination with higher resolution TIR data from Landsat to provide scalable ET data from field to continent to global scales. DisALEXI is a member of the OpenET ensemble implemented on Google Earth Engine, currently covering the western U.S. in support of water management decision making. In this paper we describe recent efforts to expand to global implementation, investigating improvements in temporal sampling by integrating microwave-based surface temperature retrievals at the coarse scale (ALEXI) and Landsat-like thermal data sources at the field scale (DisALEXI). We discuss case study applications in irrigation management, water use accounting, and hydrologic modeling. We also stress the need for an open access Harmonized Surface Temperature dataset, integrating thermal imagery from existing and upcoming field-scale thermal missions to improve temporal sampling in this key surface energy balance input.

Deforestation-induced surface warming is influenced by the fragmentation and spatial extent of forest loss in Maritime Southeast Asia

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Deforestation in the tropics causes warming which contributes to regional climate change. Forest loss occurs over a broad range of spatial scales, producing a variety of spatial patterns of cleared and forested land. Whether the spatial attributes of these patterns influence the resulting temperature change remains largely unknown. We adopted a differences-in-differences approach to analyse remotely-sensed forest loss and land surface temperature (LST) data in maritime Southeast Asia. We found that deforestation increased LST, as expected, but that the temperature increases were smaller when forest loss produced more fragmented landscapes in which non-forest and forest edges were heavily interlaced. Temperature increases were greater where the forest loss was more extensive. Warming also extended beyond the location of forest removal, so that forest loss increased temperatures in undisturbed locations up to 6 km away. Different spatial patterns of land clearing, for example, as might be produced by small-holder agriculture as opposed to large-scale deforestation, would therefore have different impacts on the local climate. Conserving forests within 4 km of farmland, urban areas or other sensitive environments may help to avoid temperature increases that reduce land productivity and worsen human health.

The FluViSat project: Measuring global streamflow with very high resolution satellite video

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Rivers are the arteries that carry water around the planet and as such are critical to the management of water and flood risk globally.

Earth observation techniques have shown considerable potential for the quantification of river flow, but have generally been constrained by factors that have limited the range of river sizes that can be observed and the frequency of observations. Furthermore, direct measurement of the critical parameter of water flow speed has not been possible.

The ESA Φ-lab supported FluViSat project addresses each of these limitations in order to enable accurate and responsive river flow observations globally.

The use of very high resolution HD video from Planet Labs' SkySat constellation, combined with recent advances in video based streamflow methods enables the accurate calculation of river discharge based upon direct observations of water surface flow speed. The 21-strong SkySat satellite constellation means that repeat observations can be made in a matter of hours rather than days and expands the potential of satellite based streamflow monitoring to even relatively small rivers.

Initial results reveal a very high degree of accuracy is possible on rivers as small as 50 metres in width.

Limitations to be addressed include cloud cover, the highly variable illumination of the reflective water surface, depending on satellite azimuth and the need for river cross-section information in remote catchments.

Conjugate Biophysical Regulation of Stomatal and Aerodynamic Conductances Determines Terrestrial Evaporation Response to Land Surface Temperature Variability

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Terrestrial evaporation is primarily regulated by ‘aerodynamic conductance’ (ga) through the land-atmosphere exchange of water vapor and heat fluxes and by the ‘canopy-stomatal conductance’ (gcs) through photosynthetic carbon exchange. While ga resembles the physical efficiency of heat and water vapor exchanges, gcs controls the biological efficiency of vegetation canopy to gain carbon at the cost of transpiration.

The evaporation regime of terrestrial ecosystems is influenced by land surface temperature (LST), which is modulated by conjugate effects of radiative warming, surface energy balance fluxes, biophysical conductances, soil moisture variability, and vegetation cover. Using the surface energy balance (SEB) principle, scientists have long sought to capture the evaporation variability from satellite LST where ga and sensible heat flux is the central focus, while evaporation is estimated as a residual component of SEB. Surprisingly, the role of gcs has been largely overlooked until now due to the overriding emphasis on eliminating the uncertainties of the aerodynamic approach. Both ga and gcs play a significant role in controlling evaporation in the complex arid and semiarid ecosystems where evaporation is tightly coupled with soil water content. Therefore, integrating the roles of these conductances using the SEB principle is a crucial step towards comprehending evaporation responses to LST variations, understanding the biophysical principles governing ecosystem water use, and advancing the monitoring of evaporation through thermal remote sensing observations.

To test the SEB theory, we first explored the conductances of heat and water flux using eddy covariance observations across semiarid ecosystems in California. This analysis revealed novel and unique hysteretic patterns showing that the evaporation response to LST variability is a result of the control of gcs on evaporation in tandem with ga, soil water availability, and atmospheric aridity. The degree of hysteresis seemed to depend on varying levels of aridity. To test the reproducibility of this behavior in the thermal remote sensing model, we employed the analytical Surface Temperature Initiated Closure (STIC) model. In STIC, both the conductances are estimated analytically based on SEB principle, and the analytical expressions of both the conductances are derived from radiation, temperature, humidity, LST, and fractional vegetation cover. As a result, it does not include any semiempirical function of surface roughness and atmospheric stability for estimating aerodynamic conductance. By pairing Landsat LST with Sentinel-2 multispectral observations and meteorological forecasts, we inspected the ability of STIC to reproduce the effects of the dual conductances in shaping up the evaporation responses to LST variability for a range of soil and atmospheric aridity at the spatial scale.

While the synergy of meteorological forecasts and thermal remote sensing observations allowed the visualization and verification of the dual conductances from space, repeating the spatial scale experiment at different times of the year reaffirmed how the interplay between energy and water supply-demand limitations influenced the conductance feedback on evaporation. The analysis offers an alternative approach of combining biological and physical explanations to investigate the highly complex evaporation variability from space. This integrated perspective lays the groundwork for future thermal remote sensing satellite missions.

Satellite-derived multivariate world-wide lake physical variable time series for climate studies

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A consistent dataset of lake surface water temperature, ice cover, water-leaving reflectance, water level and extent is presented. The collection constitutes the Lakes Essential Climate Variable (ECV) for inland waters. The data span combined satellite observations from 1992 to 2022 inclusive and quantifies over 2024 relatively large lakes, which represent a small fraction of the number of lakes worldwide but a significant fraction of global freshwater surface. Visible and near-infrared optical imagery, thermal imagery and microwave radar data from satellites have been exploited. All observations are provided in a common grid at 1/120 ◦ latitude-longitude resolution, jointly in daily files. The data/algorithms have been validated against in situ measurements where possible. Consistency analysis between the variables has guided the development of the joint dataset. It is the most complete collection of consistent satellite observations of the Lakes ECV currently available. Lakes are of significant interest to scientific disciplines such as hydrology, limnology, climatology, biogeochemistry and geodesy. They are a vital resource for freshwater supply, and key sentinels for global environmental change.

Calibration/Validation of SWOT measurements over the lake Issyk-kul

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Lake Issyk-kul is located in Kyrgyzstan (central Asia), and serve officially since 2008 as a Cal/Val site for satellite altimetry on Jason-2/3, Envisat, SARAL/AltiKa Sentinel-3A/B, and Sentinel-6. It has a length of 180 km and a width of about 60 km. Lake Issyk-Kul is surrounded by high mountains. It is the region of the world which is most far from any ocean which makes it a perfect site for calibration of cross track error in particular to roll and phase error of the Karin interferometer carried on by the SWOT satellite. The seiches are not frequent, not too high (generally smaller than 10 cm) and they are monitored in-situ as they are preferentially oriented in the East/West direction: Several in situ gauges with data time sampling of one to five minutes are already installed in the East, West, South and North sides of the lake. Permanent GNSS and weather stations have also been installed in order to complete the in-situ network and be used to calibrated and validate the SWOT measurements. Lake Issyk-kul is large enough to be crossed by SWOT several times over each cycle of 21 days and moreover was covered in the east side by the left swath of the instrument during the so-called 1-Day Cal/Val orbit. In May 2023, two full weeks of field work using two vessels were carried out, with daily passes at the same time than the SWOT satellite were passing over the lake. The campaign was conducted by LEGOS, GFZ, and Kyrgyz teams together and accumulated large number of water height profiles that are being compared to the SWOT measurements. The objective is to first asses the random and the roll errors across the swath, and to determine the precision of the instrument in LR and HR mode over such large lake. GNSS receivers were installed on the two vessels for this purpose.

Mountain lake survey in the Pyrenees from citizen science in the framework of the LOCSS project and the SWOT Cal-Val

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Despite lakes being a key part of the global water cycle and a crucial water resource, in situ networks with free access to water height, which is an Essential Climate Variable, are still sparse and not always open to the science community. In contrast, with the SWOT mission, which uses wide swath interferometry, the coverage is truly global, and nearly all lakes larger than 6 ha (around 2 million on Earth) will be monitored. The challenges and expectations over small lakes in mountain area are moreover quite high, with potential sources of uncertainties that need to be quantitatively and precisely determined. To do so, the LOCSS (Lake observatory by Citizen Scientist and Satellites) project has been initiated in 2017 seeking to better understand how the quantity of water in lakes is changing. In this project, we setup and maintain a network of worldwide lakes based on the contribution of citizen scientists who are reporting lake height by reading simple lake gauges. More than 200 such gauges have been installed over the last four years, in USA, Canada, Chile, Colombia, India, Bangladesh, Pakistan, Nepal and France. In France the network is concentrated on the lakes in the Pyrenees Mountains, some of which are located below the SWOT path of the so called 1-Day orbit. Thanks to numerous data acquired, particularly since April 2023, and thanks to additional bottom pressure gauges, we have compared the lake height measured by the SWOT instrument and collected by citizen scientists in the Pyrénées.

Preliminary Analysis of Italian Lakes Water Level Monitoring Using GEDI Altimetric Data in Google Earth Engine

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Inland surface water is the source for about two-thirds of the freshwater consumed by humans and a key component of the hydrological cycle; thus, its monitoring is fundamental to understanding climatic changes and their impact on humans and biodiversity.

Nevertheless, measuring surface water level using in situ gauge stations is directly dependent on the logistic local conditions at the ground and can be quite difficult due to the remote location of many lakes. Additional problems are the high installation and maintenance cost of these devices and the consequent small number of measurement sites over large lakes or long rivers, causing too sparse and possibly inadequate data.

In this context, the development of new techniques for the global monitoring of water levels through satellite observations is highly desired. The Global Ecosystem Dynamics Investigation (GEDI) [1,2] mission utilizes a spaceborne LiDAR altimeter to produce high-resolution measurements of Earth's canopy. GEDI has recently been added to Google Earth Engine (GEE), a cloud-based platform integrating different datasets and providing efficient analysis tools. This study aims to evaluate the accuracy of GEDI altimetric data over water bodies, comparing the levels recorded by GEDI with ground truth measurements. Furthermore, a robust procedure to remove outliers is proposed and implemented within GEE. Specifically, a number of lakes all over Italy were selected and analyzed for the period from April 2019 to June 2022.

The proposed outlier detection methodology consists of two stages. The first employs two flags provided by GEDI metadata. The "quality_flag" and "degrade_flag" provide information about the footprint validity, based respectively on GEDI signal anomalies and the degradation state of pointing or positioning information [3]. Secondly, the methodology employs a robust implementation of the standard 3σ-test, utilizing the Normalized Median Absolute Deviation (NMAD) to identify outliers: measurements not within the range of -/+3*NMAD from the median are removed [4]. After the outlier removal, we obtain an average NMAD of 0.11m over the ten lakes for the considered period.

[1] R. Dubayah, S. Luthcke, T. Sabaka, J. Nicholas, S. Preaux, and M. Hofton, “Gedi l3 gridded land surface metrics, version 1,” ORNL DAAC, 2021.

[2] GEDI - The University of Maryland, “GEDI: Home Page.” https://gedi.umd. edu/, 2023.

[3] A. Hamoudzadeh, R. Ravanelli, and M. Crespi, “Gedi data within google earth engine: Preliminary analysis of a resource for inland surface water monitoring,” The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, vol. XLVIII-M-1-2023, pp. 131–136, 2023.

[4] A. Hamoudzadeh, R. Ravanelli, and M. Crespi, “Gedi data within google earth engine: Potentials and analysis for inland surface water monitoring,” tech. rep., Copernicus Meetings, 2023.

[5] Hamoudzadeh, A., Ravanelli, R., & Crespi, M. G. (2023). Italian lakes water level monitoring through GEDI altimetric data within Google Earth Engine: a preliminary analysis. In IUGG 2023 Berlin.

LinAR: interpolating hydrological data gaps with a combination of linear interpolation and autoregressive models

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Missing data in hydrological time series is a common problem that not only limits the interpretation of historical measurements but can also have a negative impact on the quality of hydrological models. One of the most common methods for dealing with missing data is linear interpolation. This method shows a good interpolation accuracy, but on the other hand it has a tendency to underestimate the real observations, as the interpolated values are limited by the real data before and after the gap. The irregularity of hydrological time series can be described, for instance, by an autoregressive integrated moving average (ARIMA) model. However, this model does not include the linear trend between specific measurements occurring before and after the no-data gap. Therefore, ARIMA-based interpolations may result in irregular and unrealistic jumps between the last interpolated value and the first true observation after the no-data gap. In this study, we introduce the LinAR method (available on GitHub: https://github.com/MichalHalicki4/LinAR-interpolation), which combines purely linear interpolation with an autoregressive integrated model (ARI, i.e. ARIMA without a moving average part).

The performance of the LinAR method is tested on hourly time series from 28 gauges located in the Odra/Oder River basin (SW Poland), acquired by courtesy of the Institute for Meteorology and Water Management – State Research Institute. The gauges are located on 13 rivers in mountainous, highland and lowland areas. The river widths at the gauges vary from 3 to 220 m. The dataset consists of hourly water level measurements from 2016 to 2022, resulting in over 52000 observations for each gauge. To reliably validate the LinAR method, we iteratively created artificial gaps ranging from 1 to 72 hours in length. As a result, the root mean squared error (RMSE) values of the interpolation were determined for each length of no-data gap (1,2,...,72), also considering predictions of different lengths (from 1 to gap size).

Considering more than 100 million assessments (≈ 28 × 52000 × 72), it is found that in specific situations the LinAR method provides more accurate water level interpolations than the purely linear method. This statement is true for gauges on rivers of considerable size and for short no-data gaps (up to 12 hourly steps). The average percentage improvement in RMSE for a gauge can reach 10%. On the other hand, for narrow rivers with abruptly changing water levels, the LinAR approach provided slightly less accurate interpolations than the purely linear method (up to 2.5% decrease in the average gauge RMSE). In general, the differences between the absolute errors were very small. However, using statistical approaches we confirmed that the LinAR interpolations were found to be significantly more accurate than the purely linear ones.

The Python implementation of the LinAR method is freely available on GitHub. The research presented in this paper has been carried out in frame of the project no. 2020/38/E/ST10/00295 within the Sonata BIS programme of the National Science Centre, Poland.

Investigating Snow Cover Dynamics and Runoff in Snow-fed Watersheds: A SWAT-MODIS Integration Experiment

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Snowfall, snowpack, and snowmelt greatly impact the water cycle in mountainous watersheds. Inaccurate snow estimates can introduce significant bias in hydrological models. However, the lack of in situ snow data, or the insufficient resolution of such data, limit the use of spatially distributed hydrological models in snow-fed watersheds. This leads many modelers to overlook the snowpack and its effects on water distribution, thus drastically impacting model results, especially in predominantly snow-covered areas. This research focuses on the evaluation of snow dynamics and runoff in mountainous watersheds using a synergistic approach that combines the Soil and Water Assessment Tool (SWAT) hydrological model and remote sensing data from the Moderate Resolution Imaging Spectroradiometer (MODIS). The study area is the Oued El Abid watershed in the Moroccan High Atlas, known for its variable topography and sparse snow observations. The MODIS snow cover products are used to analyse the spatiotemporal patterns of snow distribution and validate the snow simulations generated by the SWAT model. The model is calibrated using the SUFI-2 algorithm, comparing two different approaches (“lumped” and “spatially-varied”) to assess the spatial heterogeneity of snowmelt/accumulation parameters. Our results show that the SWAT model accurately estimates streamflow and reproduces the properties of the snow cover distribution. The spatially varied approach demonstrates improved performance in capturing recession limb and base flow estimation compared to the lumped technique. The study highlights the potential of combining remote sensing and modelling for snow analysis but emphasizes the need for in situ measurements for validation and bias correction of remote sensing data.

Ice cover and water dynamics of large Eurasian lakes - insights from satellite remote sensing and field observations

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Large Eurasian lakes are an integrator of climate processes at the regional scale and a good indicator of climate changes. Variability of ice and snow regime is important for their physical, chemical and biological properties, and for human activity.
We present studies of ice and snow cover and water dynamics for the lakes Baikal, Ladoga, Onega, Teletskoye (Russia) and Hovsgol (Mongolia). We address the formation of giant ice rings and eddies under ice in lakes Baikal, Hovsgol and Teletskoye. Multi-mission satellite observations makes it possible to monitor ice cover evolution and water dynamics in ice-free period with high spatial and temporal resolution. We have used satellite imagery in the visible, near-, shortwave and thermal infrared (MODIS Terra/Aqua, Sentinel-2, Landsat-8, PlanetScope), complemented by active microwave observations (Sentinel-1 SAR, Jason-3 radar altimeter). We also complement these observations with in situ data from our field campaigns and loggers.
Better understanding of eddy dynamics and continued monitoring help to ensure safety for people travelling or working on the ice. There is a need for timely communication of results for non-scientific audience - fishermen, tourism agencies, tourists, journalists and local administration.
This research was supported by the CNES TOSCA Lakeddies and TRISHNA, ESA CCI+ Lakes, CNRS-Russia IRN TTS projects, P.P. Shirshov Institute of Oceanology Project N FMWE-2021-0002) and Institute of Water Problems Project N FMWZ-2022-0001.

Soil Moisture Estimation of Lorestan, Iran Using Multisource Remote Sensing Products (GLDAS, ESA CCI SM, SMAP)

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Soil moisture is a critical component of the global hydrological cycle and plays a significant role in soil parameterization. Accurate measurement and estimation of soil moisture values are crucial for various studies, including flood, drought, and weather forecasts. Remote sensing is one of the most important methods used to estimate soil moisture at different spatial and temporal resolutions. Satellite remote sensing data can provide wide spatial coverage, temporal continuity, and an acceptable level of confidence compared to in situ measurements.

The expansion of meteorological satellites and network databases has created new potential for more accurate estimation of soil moisture, such as GLDAS, ESA CCI SM, and SMAP, in areas where ground measurements and observations are limited. In this research, we investigated and analyzed the accuracy of soil moisture data estimated from these three sources against recorded data from stations in Lorestan province, Iran, using statistical tests. Additionally, we combined the multisource remote sensing SM products (GLDAS, ESA, SMAP) to improve the estimation of soil moisture and tested their accuracy against the stations.

We evaluated the estimated soil moisture data against observed data using R2, RMSE, and MAD statistics. The results showed that while the SMAP satellite is associated with underestimation, the GLDAS model and ESA satellite are associated with overestimation of soil moisture. However, the estimated soil moisture values from all three sources were generally accurate. The correlation coefficient between observed soil moisture data and soil moisture data obtained from SMAP, ESA, and GLDAS models was 0.62, 0.59, and 0.72, respectively. In the combined case of multisource (SMAP, ESA, and GLDAS), the correlation coefficient increased to 0.77. Therefore, we suggest using a combination of multisource for soil moisture estimation.

SMBA: NOAA'S NEXT-GEN BACKBONE MICROWAVE SOUNDER OF ATMOSPHERIC MOISTURE AND TEMPERATURE

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NOAA's next-generation low earth orbit (LEO) observing system—the Near Earth Orbit Network (NEON) Program —will include the new backbone microwave sounder named Sounder for Microwave Brightness and Analysis (SMBA). Like its predecessor on the Joint Polar Satellite System (JPSS) satellites—the Advanced Technology Microwave Sounder (ATMS)—SMBA will anchor part of the international operational Earth Observation system that provides the soundings of atmospheric moisture and temperature for many Hydrology applications: weather forecasting, hurricane forecasting, drought forecasting, precipitation estimates, etc.

Current plans call for nine SMBA sensors to be in orbit roughly from the early 2030s through 2050, with about a decade of overlap with JPSS. SMBA will overlap with the European MWS/MWI/ICI microwave sounder/imager/ice sensor trio.
One major difference between JPSS and NEON is that each JPSS satellite manifest includes multiple sensors—microwave sounder, IR sounder, visible/IR imager, etc., whereas the NEON sensors will likely be on "free flyer" smallsat buses. In particular, there is no requirement for the NEON microwave and IR sounders to fly together on the same bus.

Many high-level SMBA characteristics will be similar to existing or earlier microwave sounders. The basic bands still include the 18-24 GHz region around the 22.235 GHz resonance, the 50-60 GHz and 118 GHz temperature sounding bands, the 183 GHz humidity sounding band, and window-channel bands around 31-37, 50, 90, 165, and 205-229 GHz. The number of channels within each band, and their bandwidths, etc. will be settled once a specific sensor design is selected. Hyperspectral capability is an exciting new requirement that will impact the exact channel configuration. Radio frequency interference (RFI) detection capability is another new requirement that will also impact the exact channel configuration. Use of a digital backend to provide the hyperspectral and/or RFI detection capability may also enable on-orbit re-programming of the channel configuration.

In addition to backbone sensors such as SMBA, the NEON fleet architecture will accommodate "augmentation" satellites, which may be smaller/cheaper satellites with limited channels and capabilities, targeted latitudinal coverage, and so on. Inter-calibration across backbone and augmentation sensors will require new thinking, and this is the third major new element of SMBA.

SMBA Phase A trade studies are expected to begin in the very near future, and a large number of trades need to be explored, including some new tradespaces associated with hyperspectral and RFI detection capabilities, the disaggregated fleet architecture, and so on. Highlights of the notional requirements and priorities will be presented along with descriptions of some of the key trades.

A framework for improved near real-time flood mapping

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ICEYE has been a leader in the mapping and monitoring of global floods for the insurance sector and governments over the last two years. Current operational flood monitoring is based on the large-scale and systematic availability of synthetic aperture radar (SAR) data from the small satellite constellation deployed and operated by ICEYE. The main advantages of SAR images are that they provide synoptic views over wide areas, day and night and in all-weather conditions. However, SAR can be less suitable for providing flood extent information in dense urban areas and under tree canopy cover. In addition, SAR-based flood depth generation methods struggle to provide accurate depth estimations in steep terrain. There is currently a demand to aid observational flood models with physically-based flood modeling in urban areas.
Most operational real-time flood estimates are based on predictions of discharges at river flow monitoring stations using 1D hydrological models. 2D inundation models are computationally expensive and thus require special tooling for creating rapid flood maps. In this presentation, ICEYE will describe a framework that can be used for improving the robustness and accuracy of near real-time flood predictions.

High-resolution mapping of terrestrial evapotranspiration using ECOSTRESS: Insights into surface energy balance for future thermal missions

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ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) has been providing high spatio-temporal thermal infrared (TIR) observations (~70 m, 1-5 days) since August 2018. Land surface temperature (LST) retrieval obtained from TIR observations indicates the thermal status of the surface as a consequence of the land-atmosphere exchange of energy and water. It carries the imprint of vegetation water use and stress, thus serving as a pivotal lower boundary condition for retrieving evapotranspiration (ET). Taking advantage of the ECOSTRESS observations, the European ECOSTRESS Hub (EEH) funded by European Space Agency (ESA) retrieves high-resolution ET in terrestrial ecosystems.

In EEH Phase 1 (2020-2022), instantaneous ET data between 2018 and 2021 were generated from three models with different structures and parameterization schemes over Europe and Africa, including the Surface Energy Balance System (SEBS) and Two Source Energy Balance (TSEB) parametric models, as well as the analytical Surface Temperature Initiated Closure (STIC) model. The evaluation by comparing against ground measurements at 19 eddy covariance sites for 6 different biomes over Europe showed that the physically based STIC model had relatively better consistency and higher accuracy across varying aridity and diverse biomes. Also, an advantage of STIC was found as compared to the official ECOSTRESS ET product obtained using the PT-JPL model, especially over arid and semiarid regions due to the weak LST control in PT-JPL.

Taking advantage of the recalibrated ECOSTRESS Collection 2 data, EEH Phase 2 (2023-2025) analyses the impacts of LST estimates from different algorithms on ET retrieval and underlying conductances over different biomes. It is found that ET estimates of STIC driven by LST retrieved from the two most commonly used algorithms (i.e., split window, SW, and temperature and emissivity separation, TES) have similar performances over different biomes except for savanna where ET driven by SW LST has a better agreement with ground measurements due to the higher accuracy of SW LST and tight surface-atmosphere coupling. Meanwhile, EEH Phase 2 targets at developing a hybrid look-up table (LUT) approach for temporal integration of instantaneous ET acquired at any time of day to estimate daily total ET. Map-ready time series (7 years) of instantaneous and daily ET are expected to be generated with public accessibility.

Overall, the EEH is promising to provide quality assured ET retrieval for monitoring terrestrial ecosystem water use and stress. Furthermore, it will facilitate the preparation for the next generation high-resolution thermal missions, including TRISHNA (CNES/ISRO), SBG (NASA), and LSTM (ESA).

Evapotranspiration Estimation with Multi-Source Satellite Data in the OpenET platform

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Ecosystems are subject to natural and human induced change, especially under changing climate conditions. It is important to monitor these related land cover and land use changes and it is even more critical to understand the response of ecosystem health to these changes. Evapotranspiration (ET) is a key flux linking ecologic and hydrologic processes and directly links to vegetation health. The ability to robustly monitor ET changes through time at scales of human management will provide valuable information regarding ecosystem response to changing conditions. OpenET project provides field-scale (30-m) ET estimates over the United States (currently over the western states and will soon expand to cover the contiguous United States) through six well-established ET models using cloud computing on Google Earth Engine (GEE). These ET models include DisALEXI, eeMETRIC, geeSEBAL, PT-JPL, SIMS, and SSEBop. A user-friendly API and website have been built to facilitate end-user access to the model output. OpenET uses Landsat observations for ET estimation, with land surface temperature (LST) as a key input to most of the ensemble modeling systems. However, due to the relatively long-revisit time of Landsat (8-days for two Landsats), the available clear-sky Landsat observations are limited, especially for persistently cloudy areas. ECOSTRESS is a thermal-only instrument on International Space Station and has a nominal 4-days revisiting time at approximately the resolution of the Landsat thermal bands (~100-m), and provides a potential means of improving temporal sampling in OpenET retrievals. In this study, we integrate the ECOSTRESS data into the current OpenET platform by pairing the ECOSTRESS LST with surface reflectance data from Landsat and test resulting improvements in ET from the DisALEXI model over the vineyard sites in California, US. ET timeseries combining ECOSTRESS and Landsat are evaluated using flux tower observations. The integration method, evaluation results and improvement of including ECOSTRESS observations will be discussed in this presentation. This study explores integrating multi-source thermal observations into an operational ET modeling system. The lessons learned from this study can be useful when integrating future thermal observations into operational ET modeling systems.

A CONVOLUTIONAL NEURAL NETWORK FOR THE CLASSIFICATION OF LAKE SURFACE CONDITIONS FROM SAR ALTIMETRY WAVEFORMS

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Lakes are important components of Earth's hydrological system and play a significant role in regulating weather and climate. Studying lakes and their dynamics is vital for understanding freshwater resources, climate change impacts, and ecosystem health. Understanding the spatial distribution and temporal dynamics of the lake surface types is also essential for numerous applications. For instance, accurate mapping of ice cover dynamics in lakes is crucial for predicting lake ice phenology, estimating ice thickness, and assessing the impacts of climate change on lake ecosystems. Remote sensing techniques offer valuable tools for investigating lakes at regional and global scales, providing a comprehensive and cost-effective means of monitoring these dynamic water bodies.

This study was carried out using Sentinel-3A/B SAR altimetry data collected over three ice seasons (2018-2019, 2019-2020, and 2020-2021) from 11 large lakes in the Northern Hemisphere. The altimetry data underwent manual labeling using SRAL waveforms and complementary satellite data, including Sentinel-1 imaging SAR data, Sentinel-2 MultiSpectral Instrument (MSI) Level 1C data, and MODIS Aqua/Terra data, whenever possible. Reflections of radar altimeter echoes differ with varying properties/conditions of the target; thus, the resulting radar returns provides valuable information about the target surface. Through the labeling process, we collected surface type information for over 125,000 altimetry points (or radar waveforms), which were then utilized as input into a Convolutional Neural Network (CNN) model to assess its capability in classifying lake surface conditions (open water, young ice, growing ice, and melting ice) throughout the year. CNNs have gained significant popularity in remote sensing applications in recent years due to their ability to automatically learn and extract meaningful features and information from data. In our preliminary analysis, we achieved a high accuracy of ~90% using the CNN model. Notably, the consistency between training and validation accuracy (or loss) across the epochs indicates that the model performs well with new data and is not susceptible to overfitting. Implementation of our proposed method could be valuable in a pre- or post-processing step for identifying lake surface conditions under which the retrieval of water level and ice thickness may be limited or not possible and, therefore, inform algorithms currently used for the generation of operational or research products.

Extreme snowfall in the Sierra Nevada Mountains: implications for terrestrial water storage and water supply

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Seasonal snow covers over 30% of the Earth's land surface and provides the water supply for approximately one-sixth of the global population. In California, meltwater from the Sierra Nevada snowpack contributes 50% to 80% of annual runoff and provides the majority of surface water for municipal, agricultural, and industrial demands. Following the 2012-2016 drought, reservoir and aquifer water supplies in California were severely depleted, with significant water deficits that extended into the subsequent years. Record snowfall¬ during the 2022-23 winter deposited approximately 50 km3 of liquid water equivalent, representing an anomaly equivalent to 331% of the 2001-2020 long-term average. Quantification of snow water equivalent (SWE) during extreme conditions is particularly challenging given issues with spatial sampling density, cloud-cover obscuration of snow cover detection, and anomalous patterns of snow accumulation. Many independent methods can be used to estimate SWE and its spatial distribution and seasonal variability. A need exists for a systematic characterization of the record SWE in the Sierra Nevada in order to identify the degree to which long-term water deficits have been replenished. Hence, this research aims to fuse together satellite- and model-based historical reanalyses of SWE, ground-based snow measurements, and airborne data in order to estimate snow water volumes during the 2022-23 winter. Historical reanalyses of SWE will be used as information for real-time SWE estimation within statistical models. A multi-scale validation and comparison of five fine-scale SWE model-derived datasets in the Sierra Nevada Mountains, California will be compared. The optimal historical product, identified in the validation, will be used to statistically model SWE distribution in combination with terrain-based metrics and ground-based snowpack observations. Bias corrections with Airborne LiDAR data will then be used to correct regional SWE estimates. Examples of the utility of these data will be used to illustrate the value of the SWE information, including the impacts on the 2012-2016 snow-water deficit, rain-on-snow flood risk, and snowmelt infiltration impacts on terrestrial water storage.

Improved modeling of Congo hydrology by representing lake storage dynamics and data assimilation

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The Congo River basin (CRB) is the second largest river system in the world. However, despite its global importance at the hydroclimatic level and the several ecosystem services it provides to the local population, accurate knowledge of the spatiotemporal variability of freshwater in the CRB remains limited due to a complex hydrological system to simulate and the scarcity of field data. Here, a reconstructed time series of daily discharge named hydrological reanalysis of the CRB is developed spanning the last 40 years (1981-2020) through the use of: 1) a large-scale hydrologic-hydrodynamic model (MGB) with lakes storage dynamics representation; and 2) a data assimilation (DA) technique to use a consolidated database from in-situ and remote sensing observations. Results for the simulated discharges indicate that the calibration of MGB yields an average performance of KGE index of 0.84 and 0.71 for calibration and validation, respectively. Incorporating lake representation significantly improves the simulations, increasing the Pearson correlation coefficient by more than 100% (from 0.3 to 0.63). The cross-validation in DA performance shows an error reduction of about ~13% in the simulated daily discharge. This resulting performance allows us to analyze the spatiotemporal dynamics of daily discharges over the CRB with more reliability, by focusing on i) flood and drought events and ii) long-term discharge trends. Teleconnections can be established with large-scale climatic events such as El Niño Southern Oscillation (ENSO), which is the major driver of tropical precipitation. For example, the 1997-1998 flooding that affected the south and center of the CRB is mainly associated statistically to a major El Niño in the same period. Or the case of the severe droughts of 1983-1984 and 2011-2012 that mainly affected the northern and southern CRB, it is observed that they are more correlated a few months earlier (~10-12) by large El Niño and La Niña events, respectively. A trend towards a significant decrease in discharge can also be observed in the Lualaba and Central Congo region over the last 40 years, a phenomenon that has been described by previous studies, so far using only rainfall data. This study provides new insights into the complex spatiotemporal hydrological variability of the CRB, also enriching our understanding of possible interconnections with other Earth system processes.

Joint analysis of remotely sensed soil moisture and daily satellite gravimetry to describe water storage dynamics around hydrological extremes

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Changes in soil water storage can be effectively studied on a global scale using a variety of satellite observations. With active or passive microwave remote sensing, we can study the upper few centimeters of the soil, while satellite gravimetry allows us to detect changes in the entire column of terrestrial water storage (TWS). Although satellite gravimetry cannot distinguish between storage variations at different soil depths, the combination of both types of data provides valuable insights into hydrological dynamics and improves our understanding of changes in subsurface water storage.

We use daily Gravity Recovery and Climate Experiment (GRACE) data to identify extreme hydroclimatic events that occur at time scales down to sub-monthly intervals, such as it is the case for heavy precipitation or flooding. For this purpose, we analyse the correspondence between high and low percentiles in the time series of TWS and soil moisture (SM), which allows us to identify extreme events in different storage compartments. We discuss the different temporal dynamics in near-surface SM vs. TWS before and after flood and drought events to identify antecedent conditions leading to floods and recovery times after droughts in the different storage compartments.

In addition, we calculate the rate of change of anomalies, which allows us to assess the rate at which the system builds up towards floods and recovers from drought conditions in different soil layers. Quantifying the rate of change of anomalies provides valuable insights into the temporal patterns of water recharge of different storage compartments around extreme events. It helps us understand the dynamics of the subsurface and the different time scales associated with soil moisture and terrestrial water storage recovery.

Efficiency of global precipitation datasets in tropical river basins revealed by large sampling hydrological modelling

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Satellite-based precipitation products and reanalysis are widely adopted alternatives for hydrological modelling in data-scarce regions. Reliable simulations of runoff fluxes are vital to support water resources management and reduce risks under current and future conditions. However, the hydrological response driven by precipitation products is uncertain in several regions in the world. We investigated the performance of five remote-sensing global precipitation products, i.e. CHIRPS, TRMM, IMERG, PERSIANN-CDR, and ERA5, in estimating daily precipitation at the catchment scale and river discharge over 714 Brazilian unested river basins distributed. Two calibration approaches were applied to simulate the discharge of the five selected precipitation products. In approach I, the model was calibrated with observed-only precipitation data and re-run the model for the selected precipitation products; whereas in approach II the model was calibrated for each precipitation product. The results of the performance metrics of the precipitation products relative to the reference terrestrial precipitation show that satellite-based precipitation generally has a higher quality than reanalysis-based precipitation. The precipitation products show median r values above 0.55. CHIRPS, ERA5, and IMERG presented the highest median r values ($r > 0.60$). In general, the products tended to underestimate precipitation, except for ERA5, which presented a tendency to overestimate, with a median Pbias of 2.5%. The median RMSE values ranged from 6.76 mm/day (ERA5) to 7.91 mm/day (TRMM). Overall, the products performed similarly, with little difference in statistical metrics. Using model parameters based on observed precipitation for the hydrological response, the CHIRPS and IMERG forced simulations show the best performances, while PERSIANN-CDR and ERA5 show the worst performances. The calibration and validation results indicate that the GR4J lumped model can capture some characteristics of the observed hydrographs in the different Brazilian hydrological regions. For most of the catchments (86.5%), the GR4J model presents r values greater than 0.7 for both the calibration and validation phases of the simulated catchments with the reference precipitation. Implementing the specific calibration for each precipitation product significantly improves the performance of the five precipitation products, especially for TRMM. In terms of KGE, all products presented a good performance for most of the watersheds in the calibration phase. For instance, the mean KGE values were higher than 0.5 for 66.4% (approach II) and 49.4% (approach I) of the simulated catchments with ERA5; 82.9% (approach II) and 77.9% (approach I) for IMERG; 85.6% and 83.2% for CHIRPS for approach II and I, respectively. However, the performance is still inferior to that driven by observed-only precipitation dataset. Our results are consistent with several studies that concluded that hydrological simulation efficiency is enhanced by input-specific recalibration. The parameters related to groundwater exchange (X2) and water routing (X3) show greater sensitivity for most datasets, while the unitary hydrograph parameter (X4) is the least sensitive for most datasets; this result indicates that the sensitivity of the model parameters can change according to the input dataset. This study confirms the superior performance of products based only on satellite data over reanalysis-based products.

Merits of Assimilating SWOT Altimetry Observations for Flood Forecasting - A Proof-of-Concept

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Flooding is one of the most devastating natural disasters worldwide as they constantly pose a major threat to human life, livestocks, infrastructures, etc. The inclusion of Earth Observations into flood risk management presents a great opportunity to improve the ability to respond to those posed by flooding. The properties of inland water bodies can be obtained from altimetry missions that provide along-track water surface elevation (WSE) from nadir (e.g. TOPEX/Poseidon, Jason, SARAL/AltiKa, Sentinel-3, Sentinel-6) or large-swath altimeters (like SWOT), as well as from radar/optical missions (Sentinel-1/Sentinel-2) that provide high-resolution water extent maps.

Flood reanalysis and forecast capability have greatly improved in recent years thanks to the advances in data assimilation (DA). DA strategies, e.g. variational approaches or Ensemble Kalman Filter (EnKF), classically consist in combining time-series streamgage measurements with numerical models, namely TELEMAC-2D hydrodynamic models, to correct the hydraulic states and reduce the uncertainties in the model parameters, e.g. friction and upstream inflow. Leveraging multi-source flood observations allows densifying the observing network, both spatially and temporally, as well as diversifying their characteristics. This allows a better performance of the EnKF that relies on the stochastic computation of forecast error covariance matrix amongst a limited number of perturbed simulations.

This research work is undertaken within the framework of an Observing System Simulation Experiment, based on a deterministic simulation with a predefined set of time-varying controlled parameters and variables representing a flood event over the Garonne Marmandaise reach, in the south-west of France. This reference simulation is used to generate synthetic observations, using the observation operator dedicated for replicating the in-situ water level, Sentinel-1 flood extent and SWOT observations. This stands in the extraction of the true WSE values at all observation times and locations, in order to generate synthetical in-situ observations, and to extract the wet/dry pixels from flood extent maps for wet surface ratio computation. The synthetic SWOT observations are generated based on the SWOT-HR simulator processes for RiverObs (typically the L2_HR_PIXC product) along several passes over the studied area. The observation operator developed for SWOT RiverObs involves a non-weighted average of WSE of relevant pixels found at the node level.

A number of different EnKF DA experiments, built on top of the T2D model, are carried out considering different combinations of the three types of observations. Indeed, in-situ and SWOT observations relate to a hydrometric variable that is straightforward for the DA, whereas those derived from S1 are non-hydrometric and prognostic. On the other hand, S1 presents additional information regarding the floodplain dynamics that are complementary to SWOT data, but is lacking when relying on in-situ data. Quantitative assessments—consisting in performance evaluation with 1D/2D metrics measured between WSE time-series as well as Critical Success Index between the simulated and observed flood extent maps—of these experiments show promising early results. This work heralds toward a reliable methodology for flood forecasting and flood risk assessment, especially for poorly-gauged or ungauged catchments.

GPM IMERG and its constellations in capturing extreme events and hydrological utility over the conterminous united states

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Improved quantification of extreme precipitation rates using observations has far-reaching implications for environmental sciences, especially for hydrometeorological studies. Yet, uncertainties still remain in satellite precipitation estimates, especially for a merged product. This study evaluates the performance of the Integrated Multi-satellite Retrievals for GPM (IMERG) in extreme events over the conterminous US. Three approaches are followed to define and evaluate extreme events: (1) a percentile-based analysis, (2) an event-based analysis using the National Weather Service storm database, and (3) a frequency-based analysis using intensity–durationfrequency (IDF) curves. The IMERG Early Run (ER), Late Run (LR), and Final Run (FR) products and their original passive microwave and infrared (IR) sensors are intercompared against the National Centers for Environmental Predictions Stage IV ground-based radar precipitation data. In particular, we break down the performance in three types of events (rain, snow, and hail). The results reveal that: (1) three types of extreme definitions converge toward an overall agreement - the degrees of underestimation of high-end extreme precipitation rates increases with data latency (FR > LR > ER) and FR delivers overall best performance; (2) passive microwave (PMW) estimates generally exhibits better detectability and quantification of extreme precipitation than IR estimates, especially in heavy rains; (3) Amongst PMW sensors, MHS (SAPHIR)-based estimates show the best (worst) extreme detection with CSI (Critical Success Index) equaling 0.15 (0.10) while AMSR and SSMIS outperform others for quantifying extreme rates. Lastly, different sensors (e.g., imagers and sounders in PMW and IR) deliver variable performance regarding different precipitation types. These findings reveal that IMERG is not a homogeneous precipitation product when it comes to estimating precipitation extremes. There are rooms for improvement to enhance homogeneity across precipitation estimates used in IMERG. The hydrological utility of GPM satellite-based estimates are also evaluated, particularly in extreme events.

The Two-Source Energy Balance (TSEB) model formulation using thermal-infrared remote sensing for evapotranspiration estimation: Applications from field to global scales

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Since its development nearly 30 years ago, the Two-source Energy Balance (TSEB) model using land surface temperature as the key boundary condition has been integrated into proximal, airborne and satellite platforms for estimating surface energy balance and evapotranspiration (ET) over both natural and agricultural ecosystems. Recent efforts have shown the capability of applying TSEB to generate a global product and potential to provide actual ET information for improving water management at the field scale in irrigated regions, many which face increasing water shortages causing overdrafts of regional aquifers due to more frequent and extended droughts. This presentation will provide an overview of the TSEB model formulation and its application to different landscapes and climates as well as its implementation using different remote sensing platforms. Examples in how the ET product is being implemented for improving water management in irrigated woody perennial crops in California will also be presented.

Monitoring small reservoirs in semi-arid brasilian Nordeste - the SWOT perspective

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In the semi-arid Ceara (Brazil), the water resource is disseminated through more than twenty thousand reservoirs of all sizes (0.5 to 25.000 ha), from state monitored reservoirs larger than 5.000 hectares, down to small farm reservoirs of less than 1 ha.

Over the years, and as the region underwent several severe droughts, the number of small reservoirs has grown anarchically. The very large number and reduced size of these “açudes” make it challenging to inventory them, analyze the hydrological processes and to monitor the amount of water they hold.

On the other hand, there is more and more evidence that these small water bodies have a considerable impact on the water balance of the basin they belong to, and on the water resource available to fill in the state’s reservoirs. Monitoring, modeling and better understanding these small reservoirs has become a key issue for water management in Ceará (and more generally semi-arid North East of Brasil).

While the largest reservoirs in Ceara are monitored daily by the state, with in situ measurement, the vast majorities of other reservoirs do not benefit from regular measurements, and their number is too large to consider their systematic in situ observation. New techniques need to be proposed to survey a large number of reservoirs despite their small sizes. Remote sensing is a very promising approach and can play a central role for this in the future, considering the new satellite missions devoted to hydrology which are already operational (like the COPERNICUS Sentinels) or expected soon. In particular the Surface Water and Ocean Topography (SWOT) launched in december 2022 is bringing new promises : it will provide the first global monitoring of surface water elevation and extent based on high resolution Ka-Band interferometric altimetry.

To take full advantage of these new data, the processing of the satellite data and images will need to be optimized for the characteristics of the semi-arid Nordeste, coping with the challenge of detecting very small hydrological objects in a dry environment and with substantial cloud cover during the rainy season. Methods based on artificial intelligence and machine learning could help pushing the limits of what is feasible with satellite imagery for water resources monitoring.

During the first semester of 2023, the calibration orbit of SWOT, offering daily revisit, covered the western part of Ceara. In order to exploit this data a subset of eight reservoirs was equipped for intense in situ monitoring with pressure gauges to measure water surface elevation (WSE) and drone/bathymetry survey to obtain a high resolution DEM of the basins. The first results from this unique combined satellite/in situ observation campaign in semi-arid Nord Este will be presented.

Estimation of chlorophyll in Danube Lakes in Ukraine using observations from Copernicus Sentinel-2 MSI

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The use of Earth-observation satellites to assess and monitor water quality in lakes, reservoirs and large rivers has matured over recent years to such an extent that we now have operational systems producing water quality data for thousands of waterbodies in near real-time (e.g., Copernicus Global Land Service), while reprocessing's of archive data using state-of-the-art methods are also delivering long-term, internally consistent time- series data for use in climate studies (e.g., the European Space Agency's Climate Change Initiative).

Earth-observation satellites can provide information on water quality at spatial resolutions extending from approximately 0.001-1 km, with some satellite missions able to achieve repeated global coverage in 1-5 days. This observation capability has the potential to provide a unique perspective on water quality at regional and global scales. But the 'big data' generated by Earth observation missions also pose significant challenges for the storage, analysis, and distribution. For this reason, approaches to data processing are evolving rapidly with an increasing reliance on high performance computing (HPC) infrastructures and cloud-based services.

The approaches used to produce water quality products from satellite data vary markedly in their complexity. There are approaches based on comparatively simple empirical algorithms, and others that employ advanced, and computationally intensive, machine learning models. One recent development in the field has been the use of ensembles with intelligent selection of algorithms based on the optical properties of the waterbody (or even pixel) under observation. It is this approach that underlies CGLS. Despite the battery of methods available there is still no consensus on the optimum approach and all processing chains must be rigorously validated against high-quality in situ data to understand the errors and uncertainties on the derived products. The development of improved methods for the remote sensing of inland water quality remains an active field of research.

The University of Stirling, Great Britain, and the Odessa State Environmental University, Ukraine working on the project "Capacity Building in Earth observation for national water quality assessment (CORNELIA)" of the British-Ukrainian grant program with the success and innovation TWINNING. As part of this project, a summer school was held in May 2023, and expeditionary research is planned for July 2023 on the Danube lakes Yalpug, Kugurluy, Kitay and Katlabukh. The purpose of field research is to measure the chlorophyll content in lakes. The determination will be made by taking water samples, simultaneously using the Water Insight Spectrometer WISP, as well as by interpreting satellite images. The next task will be to calibrate the satellite information and interpret the received data.

This project is of particular importance for Ukraine, since the use of satellite information for water quality control of water bodies is economically justified in the face of a shortage of funds for financing scientific research in war conditions. Using of satellite information also creates opportunities for monitoring the quality of water bodies that are not yet available due to military actions. The Danube lakes within the project are used as full-scale testing ground for testing the methods that are being introduced.

Assessment of the impact of blowing up the Kakhovka hydroelectric power station dam on the quality of sea waters of the Odessa Black Sea coast using satellite information

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On the night of June 6, 2023, around 2:50 a.m., the Russian occupying forces blew up the dam of the Kakhovka HPP. As a result, on June 12, 2023, 14.4 km3 of water had already flowed from the Kakhovsky Reservoir to the lower reaches of Dnipro River, which was 72% of the volume of water accumulated in it before the destruction. For comparison, this is 27% of the total volume of the average annual runoff of the Dnipro (53.5 km3). Practically the only source of information in the conditions of military operations is satellite information, in particular the SENTINEL-3-OLCI data was used. So, according to satellite images, a total of 612 km2 of territory was flooded (554.6 km2 within the Kherson and 57.8 km2 in Mykolaiv regions). As of the morning of June 8, the average level of flooding in the Kherson region was about 5.6 m (exceeding the water level recorded at 8 p.m. on June 5, 2023).

Fuels and lubricants (petroleum hydrocarbons), pesticides and other dangerous chemicals were washed away from the flooded territories, including cities, and eventually entered the sea - from their storage places, compounds of heavy metals, including those that came with the emissions of industrial enterprises in the cities of Zaporizhzhia and Dnipro and accumulated for decades in the bottom sediments of the Kakhovsky Reservoir, the remains of dead domestic and wild animals, freshwater vegetation. Sewage pumping stations, cesspools of private sector houses, several cemeteries, and cattle burial grounds fell into the flooding zone. Because of this, there was a threat of microbiological pollution of river and coastal sea waters, as well as the development of negative consequences of eutrophication of sea waters - an outbreak of biomass ("blooming") of algae, the occurrence of a deficit of dissolved oxygen in the bottom layer of the water area, as a result of its consumption for the biochemical oxidation of allochthonous and autochthonous organic substances origin.

On June 9, 2023, polluted waters from the Dnieper-Bug estuary reached Odessa, and a few days later the entire coastal zone was covered with household and construction waste, remains of plants (trees, reeds) and animals, fish, a large number of live and scurrying amphibians. According to satellite data, the area of the sea water area occupied by polluted river waters with a high content of mineral suspension and organic substances of allochthonous origin was 616.8 km² on June 6, 1248.2 km² on June 9, and 1710 km² on June 10.

The flow of polluted river waters from the Dnipro-Bug estuary to the northwestern part of the Black Sea, including the recreational coast of the Odesa region, led to a sharp deterioration in the quality of coastal waters according to a number of chemical-biological and sanitary-biological indicators, and to the clogging of the recreational coastal zone of the region. Due to the accumulated reserves of organic matter in bottom sediments, the probability of occurrence of hypoxic conditions and death ("suffocation") of hydrobionts will increase in summer during the next 3-5 years.

Preliminary Analysis of SWOT daily measurements over rivers gained by the nadir altimeter

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Successfully launched in december 2022, SWOT will provoke a huge step in collection of water levels over world's rivers. In early 2023, SWOT was placed on a validation orbit before it is definitely placed on its scientific orbit in July, 3rd. This 3-month orbital phase gives opportunity to check 1- the limits in catching radar signal over rivers, 2- the accuracy of the retracking to actually pick up the water levels, and 3- the spectrum of water level series at times shorter than those peformed by other altimetry missions

In this presentation, we present our preliminary analysis of these data in the Amazon and Congo basins. We selected these basins since they have reaches of very different width where the SWOT nadir altimeter might have picked up water levels in very diffeent contexts. Our preliminary analysis shows that SWOT nadir successfully collected water levels on most rivers, including on narrow (< 100m) reaches. Besides, other sensors to be compared with (either in-situ an altilmetric) are availabler in these rivers and enable to assess the eficiency of the different SWOT nadir altimeter retrackings. Comparison of SWOT water levels with these external data for different retracker algorithms are ongoing and will bepresented at the meeting

Combination of satellite altimetry and hydrodynamic modelling for investigation of winter water level regime in Arctic rivers

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Studies using a combination of hydrodynamic models with altimetric measurements for rivers with seasonal ice are rare due to lack of certainty in interpretation of satellite altimetric measurements over river ice and high errors in calculation of winter water levels. However, it is the winter regime of arctic and boreal rivers that is undergoing the significant changes due to climate warming. In most sensitive regions these changes are manifested in a decrease in ice period duration and ice thickness or in an increase in winter water levels.

We study winter regime of three Arctic rivers experiencing different degree of climate change, using experimental runs of hydrodynamic models with connected and disconnected ice modules and SAR altimetry measurements of Sentinel-3 satellites. One-dimensional MIKE 11 DHI hydrodynamic model was adapted for the Kolyma River, while two-dimensional STREAM_2D model (author Belikov V.V. et al.) was run for the Northern Dvina and Lena rivers. A comparison of Sentinel-3 water level retrievals with results of water level simulations demonstrate that depending on ice conditions the retrieved altimetric height can correspond as to the surface of ice as to the table of water under the ice. Using the example of the Northern Dvina River, which is located in area of intense climate change, we demonstrate the role of an autumnal shuga and slush drift in the water level increase observed in recent winters and discuss the effect of this phenomena on the generation of spring ice jams and the resulting inundations.

The studies is supported by RNF N_22-27-00633 AltiMo (2022-2023) project.

Harmonised snow variable retrieval for hydrological applications by reconstruction of the snow surface spectrum using radiative transfer modelling

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Seasonal snow is an important component of the Earth system heavily affecting the energy balance and the water cycle at high latitudes and elevations. Earth observation is the only practical means of frequent and accurate monitoring of snow properties in these regions, where population is sparse and in-situ sensors rare. As hydrological models are gradually becoming more advanced, earth observation takes a more central role as a source of input data to such models.

A portfolio of snow variables is today retrieved from optical satellite sensors. Many of the key algorithms used have been or are now adapted to the use of Sentinel-3 and Sentinel-2 satellite sensors as these satellites deliver operational data and has a long-term perspective. However, most algorithms are working independently, even if the snow physics gives a baseline of dependencies between the snow variables retrieved. We are now developing a retrieval approach using a common physical framework model, which all algorithms can be based upon. The approach ensures physical consistency between all the snow variables and should thereby give more robust and accurate retrieval.

The basic idea is to reconstruct the snow reflectance spectrum at the ground surface level based on the satellite observations, then retrieve the snow variables from the snow surface spectrum. Various challenges need to be resolved to establish the snow surface spectrum as the satellite observations are attenuated by the atmosphere and the illumination situation, including solar and acquisition geometry combined with the terrain surface geometry and dynamic reflection properties of snow itself.

In our approach we use all the measured spectral bands for reconstruction of the snow surface reflectance spectrum. As long as no bands are seriously affected by instrumental noise, this approach maximises the utilisation of the available information. It also allows us to provide a good estimate of how well the reconstructed model corresponds to the observations by analysing the deviation between the two. This deviation is a central component in the uncertainty modelling being developed.

As the model generates surface reflectance, it needs to be calibrated and validated from accurate ground measurements. We do simultaneous measurements of ground reflectance with satellite-observed reflectance. Modelled surface reflectance is compared with surface-measured reflectance by a spectroradiometer, and deviations are applied for model tuning. Specific snow variables are measured, like grain size, impurities and liquid water content. Measurements are repeated for a large range of variability of the snow conditions to ensure that the model captures the reality. For model calibration and validation, the well-established Valdresflya test site in the Jotunheimen mountain region in southern Norway is used.

The presentation gives an overview of the new approach of snow variable retrieval, presents the results of in situ measurements and comparison with satellite observations by Sentinel-3 and Sentinel-2.

C3S: An increased spatial coverage of monitored lakes with nadir altimetry for water level products.

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Lakes play a crucial role in retaining and stocking water, and in the context of the significant global environmental changes occurring at several anthropocentric levels, the necessity to monitor water level has increased substantially over the last years, and lake water level is defined as an Essential Climate Variable by GCOS. The water stored in lakes responds (directly and indirectly) to any changes in precipitation and air temperature as well as directly to human use of water resources. Fresh water is a more and more pressured resource for the population needs as well as a societal risk for local populations. It is also a fundamental element for industry and agriculture, therefore becoming an economic and political stake. It is therefore essential to measure lake water level changes over multi-annual time scales to trace it in the context of climate change and to be used within climate models. Satellite altimetry is widely used to measure lakes and reservoirs water height changes worldwide, and their associated uncertainties. However, strategies and algorithms to calculate this variable are not straightforward and sophisticated approaches have been developed.

Originally conceived to study open ocean processes, the radar altimeter satellites have nevertheless been shown of great interest to acquire numerous measurements of decimetric to centimetric precision over lakes. With this technique, the Lake Water Level is defined as the height of the reflecting surface, in meters above the geoid. Only lakes located along the satellite's ground tracks or within few kilometres can be monitored with nadir altimetry, with a quality of measurement that not only depends of the size of the lake, but also on its surface roughness. Depending on the size of the lake, the satellite data may be gathered and averaged over long distances. It is thus necessary to correct for the slope of the geoid. The “repeat track technique” is used to solve this problem. The geoid slope is recalculated for each of the track of the satellite and then is averaged over a significative number of cycles. The result of this calculation is a mean vertical profile, along each pass per lake, which serves as correction for geoid. Additionally, many of these lakes, are observed by multiple mission and tracks, requiring a bias correction process.

For small lakes, the variation of the geoid has a negligible impact. A simpler approach can therefore be implemented to use the input L2 altimetry products and will be presented: measurements are extracted within lakes contours (from Hydrolakes dataset) and averaged for each transect. Particular attention was nevertheless required to setup editing criteria to remove possible outliers within the 20Hz input data. Indeed, given the smaller size of this lake sample, the altimeter footprint also covers lake shores and possible surrounding echogenic targets. Using this approach, water level timeseries have been generated over several thousands of lakes worldwide. The validation of the water level time series will be detailed in the presentation, emphasizing on comparisons to external data sets with either in-situ data or other altimetry-based products.

A Deep Learning Approach for Lake Ice Cover Forecasting

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Lakes comprise a large proportion of the surface cover in northern Canada and are covered by ice for several weeks to months of the year. Lake ice cover and its seasonal cycle (phenology) plays a critical role in the energy balance at northern latitudes, while also providing important socioeconomic services. Ongoing climate change is significantly impacting the duration and thickness of ice cover in northern regions, with severe consequences. The ability to accurately forecast ice cover under different climatic conditions is an important tool for understanding and mitigating the effects of climate change, as well as improving climate models. In this work we investigate the effectiveness of adapting deep learning architectures to predict ice cover across an entire lake surface (spatially), as well as through time (temporally). This study looked at the application of deep learning architectures to five lakes: Great Slave, Great Bear, Winnipeg, Athabasca, and Reindeer. Interactive Multisensor Snow and Ice Mapping System (IMS) ice cover maps (4 km grid spacing; February 25, 2004, to December 31, 2022) produced by ice analysts at the U.S. National Ice Center (USNIC) were used for the training, testing and validation of deep learning models. We used the ERA5-land and ERA5 data, from the European Centre for Medium-Range Weather Forecasts (ECMWF), to develop a dataset of predictor variables, with matching spatial and temporal dimensions as the IMS data. The deep learning paradigm of interest for this investigation was a Spatial-Temporal Transformer (STTN). The model objective during training was to forecast ice-cover over a week, given the previous week of ice cover maps along with the full two weeks of atmospheric variables (predictors). Models were then evaluated on their ability to forecast an entire year of ice cover extent, starting from a single week of samples extracted from IMS, and the full year of atmospheric predictors from ERA5. Preliminary results from training and testing using only Great Slave Lake (GSL) were generally positive. The most successful model achieved average pixel-wise errors of +/- 8 days on ice-off (thaw) date, and +/- 18 days on ice-on (freeze) date. The model's forecast also adhered to the freeze/thaw patterns seen in the IMS dataset, with the Slave River inlet thawing earliest and freezing latest. Current work is expanding on this through the addition of bathymetry data, model training on all five lakes of interest, and further validation. Initial findings indicate that deep learning has the potential to forecast ice cover with high accuracy and may help improve the performance of existing physics-based lake models used alone or as lake parameterization schemes in climate and weather forecasting models.

Field scale soil moisture retrieval by using Sentinel-1 images over an agricultural area in a semi-arid Mediterranean environment

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Superficial soil moisture is estimated at the field scale on an agricultural area over which subsurface scattering is present. A retrieval algorithm is applied to differences of Sentinel-1 data calculated with a Change Detection method. The study area is located in Spain, where a soil moisture measurement network is present. Data of single irrigation seasons are analyzed over a study period of four years. Only low vegetated areas are considered in this study, and a machine learning algorithm is applied to SAR features for detecting the dates characterized by sharp changes in Sentinel-1 data, and assumed to be associated with agricultural practices. Quite encouraging results are obtained for one third of the analyzed fields, not only over fields characterized by a direct relationships between the backscattering coefficient and the measured soil moisture, with values of correlation and RMSE up to r = 0.89 and RMSE = 0.042 m3 /m3, but also over fields showing subsurface scattering, with similar values up to r = 0.84 ad RMSE = 0.026 m3 /m3.

Advances in Novel Tropospheric Moisture and Stable Water Vapour Isotopologue Satellite Products from SWIR Sensors

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Water vapour is the most important natural greenhouse gas within the Earth's climate system, influencing the radiative balance of the Earth as well as surface and soil moisture fluxes. Though satellite observations of tropospheric moisture now cover nearly 50 years, they have been restricted to total column water vapour measurements or vertically resolved layers in the free troposphere (FT). This study presents advances in novel water vapour products developed with the University of Leicester Full Physics (UoL-FP) stable water vapour isotopologue (H2O-ISO) algorithm for satellites operating in the shortwave infrared (SWIR). Within this framework, this has been done for two sensors, the TROPOspheric Monitoring Instrument (TROPOMI) and the TANSO-FTS onboard Sentinel 5p and Greenhouse gases Observing SATellite (GOSAT), respectively.

The Sentinel 5P mission launched in 2017 can measure water isotopologue from its SWIR channels with much improved spatial and temporal coverage compared to previously available SWIR sensors, thus representing a significant advance for scientific and operational applications. We present this new water dataset obtained from Sentinel 5P and its characterisation against ground-based reference data. Furthermore, we demonstrate the potential to combine these observations with the Infrared Atmospheric Sounding Interferometer (IASI) for improved tropospheric sounding and the potential for Numerical Weather Prediction (NWP) applications.

Initially designed for monitoring greenhouse gases, GOSAT is also cable of retrieving information on stable water vapour isotopologues. Unlike TROPOMI, the spatial sampling of GOSAT has a lower spatial density; however, it is a valuable record with global observations from GOSAT approaching 15 years. In addition to total column water vapour measurements, Trent et al. (2018) demonstrated the ability also to resolve bulk estimates of Planetary Boundary Layer (PBL) water vapour from GOSAT. As part of recent advances, we present three new innovations to the GOSAT H2O-ISO product:
1. Updates to the algorithm to allow for the production of δD averaging kernels.
2. Separation of PBL and FT XH2O sub-columns with potential for information on the gradient between the two.
3. Production of surface-specific humidity variable from GOSAT for land and sunglint ocean surfaces which is used as one of the inputs for a new fusional L4 product.

All these products will be presented in the context of the ongoing evolution of the UoL-FP H2O-ISO algorithm, along with results from validation and related studies. Finally, the application to the upcoming S5 mission will also be discussed.

Evaluation of change detection techniques for soil moisture estimation from Sentinel-1 time series

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Soil moisture is an essential variable that plays a key role in various processes occurring at the soil-vegetation-atmosphere interface. As such, its monitoring is necessary for several disciplines such as hydrology, meteorology and agronomy. Microwave sensors are better suited than other Earth observation sensors for soil moisture estimation, due to the sensitivity of microwave emission and scattering to the dielectric characteristics of observed soils, which mainly depend on their moisture. Microwave radiometers and scatterometers provide operational global soil moisture products with a reasonable accuracy for most applications, but their spatial resolution is not sufficient when field scale applications are sought. SAR sensors achieve finer spatial resolutions, but soil moisture retrieval from SAR is not fully operational yet, due to the sensitivity of backscatter to perturbing factors, such as vegetation or surface roughness. Change detection techniques require dense SAR time series and might be less sensitive to these perturbing factors than traditional SAR backscatter models. The objective of this study is to evaluate three change detection techniques for soil moisture estimation over wheat fields based on Sentinel-1 time series. The evaluated techniques were the Short Term Change Detection (STCD), the TU Wien Change Detection (TUWCD) and the Multitemporal Bayesian Change Detection (MTBCD) techniques. For the evaluation soil moisture measurements acquired on eight experimental wheat fields located in Navarre (Spain) were used. Four of these fields were irrigated and the other four rain-fed. The complete Sentinel-1 record over these sites was used. SAR processing included a normalization of the incidence angle and a correction of the influence of wheat canopy in backscatter. The results obtained were similar for the three techniques evaluated, with median ubRMSE values of 0.07-0.08 m^3/m^3. However, results varied strongly from field to field and it was observed that the soil moisture content had an influence on the accuracy of the three change detection techniques evaluated, with higher errors observed for drier conditions and rain-fed fields, in comparison to wetter conditions and irrigated fields.

Validation of the cross-over calibration applied on SWOT LR products over lakes

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The Surface Water and Ocean Topography (SWOT) mission, conducted by CNES and NASA was successfully launched on 16 December 2022. It aims at providing unprecedented 2D observations of the sea-surface height and mesoscale structures as well as water surface elevation, water stocks estimates and discharge over hydrological areas. A SAR-interferometry wide-swath altimeter, namely the Ka-band Radar Interferometer (KaRIn), is designed to cover two 50-km cross-track swaths with a 21-day repeat cycle. Considering the need of different spatial scales for observations, dedicated processing methods are used to generate Low Rate (LR) products for oceanography and High Rate (HR) products for continental hydrology. For large lakes, however, LR mode is valuable as the 250x250m LR products contain a large number of measures over the lake areas.

The specificity of the interferometric-SAR technique leads to several errors included in the KaRIn measurements that must be considered. The uncalibrated systematic errors, for example the roll and phase errors, are the main components of the total error budget in hydrology. The objective of the so-called cross-over calibration is to isolate these systematic errors impacting the quality of the KaRIn measurements, in order to have a residual error which is within the performance requirements. As this approach proposes a correction based on models over ocean cross-overs that is further extrapolated over continental areas, an estimation of this correction performance over large lakes is mandatory to validate the cross-over calibration.

Our analysis will propose an assessment of the Level-2 and Level-3 cross-over corrections which will be applied on LR SWOT products over large lakes. We will take advantage of external datasets providing reliable estimates of the water surface elevation. Particularly, measurements from the Swiss network composed of georeferenced in-situ will be compared against LR SWOT products. Comparisons will also be performed with the mean profiles over large lakes, built from conventional altimetry and ICESat-2 missions, which provide reliable references of the water surface elevation.

Cal/Val of HR SWOT products using in-situ networks and in-flight nadir altimetry missions

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The Surface Water and Ocean Topography (SWOT) mission, conducted by CNES and NASA was successfully launched on 16 December 2022. It aims at providing unprecedented 2D observations of the sea-surface height and mesoscale structures as well as water surface elevation, water stocks estimates and discharge over hydrological areas. A SAR-interferometry wide-swath altimeter, namely the Ka-band Radar Interferometer (KaRIn), is designed to cover two 50-km cross-track swaths. During its Calibration (Cal/Val) phase (January to July 2023), SWOT mission provided daily measurements for each swath due to its 1-day repeat cycle. While the spatial coverage during this phase is not as large as for the nominal phase with a 21-day repeat cycle, such short revisit time is relevant for Cal/Val purposes.
The High Rate (HR) mode of KaRIn, dedicated to hydrology surfaces, provides HR SWOT products that are calibrated during the Cal/Val phase. The performance assessment of these SWOT observations can be achieved through the comparison against reference measurements. Although specific in-situ Cal/Val sites have been purposely designed for the validation of HR SWOT products on lakes and rivers, additional in-situ networks can also be useful, particularly if their spatial coverage allows a monitoring of lakes and rivers also observed by the SWOT mission. Such conditions are met for the French network (SCHAPI), providing several hundreds of georeferenced in-situ stations over rivers, and for the Swiss network (BAFU) which measures water surface elevation of main rivers and lakes. Moreover, the combination of measurements from current nadir altimetry missions (for example Sentinel-3 and Sentinel-6) has also the potential to generate reference measurements on a large number of lakes and rivers.
Our analysis will propose a preliminary performance assessment of the distinct high-level HR SWOT products during the Cal/Val phase, using both SCHAPI and BAFU networks and measurements from Sentinel-3 and Sentinel-6. We will first take advantage of hydrological areas being densely monitored below SWOT swaths, which are relevant to assess the quality and current limitations of the products. In particular, our study will be focused on a 60 km-long downstream reach of the Loire River, roughly flowing in the cross-track direction and monitored by 9 georeferenced in-situ stations. Comparisons with georeferenced in-situ measurements on the largest Swiss lakes will also be performed. In a second step, comparisons will be achieved with data of Sentinel-3 and Sentinel-6 missions that observe lakes and rivers over the same period as SWOT. The purpose for both cases is to provide a first insight of the quality of the water surface elevation and slope given by high-level HR SWOT products.

Sentinel-3 Land STM: performances of the New Hydrology Thematic Products over Inland Waters

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Sentinel-3 is an Earth observation satellite series developed by the European Space Agency (ESA) as part of the Copernicus Programme. It is currently composed of 2 satellites: Sentinel-3A and Sentinel-3B, launched on 16 February 2016 and 25 April 2018, respectively. Among the on-board instruments, the satellites carry a radar altimeter which aims at providing operational topography measurements of the Earth's surface. Over inland waters, the main objective of the Sentinel-3 constellation is to provide accurate measurements of the water surface height, to support the monitoring of freshwater stocks. Compared to previous missions embarking conventional pulse limited altimeters, Sentinel-3 measures the surface topography with an enhanced spatial resolution, due to the on-board SAR Radar ALtimeter (SRAL) which exploits the delay-Doppler capabilities.

In order to further improve the performances of the Sentinel-3 Altimetry LAND products, ESA and the Sentinel-3 Mission Performance Cluster (MPC) have recently developed specific delay-Doppler and Level-2 processing chains over (1) Hydrological, (2) Sea-Ice, and (3) Land Ice areas, the so-called Thematic Instrument Processing Facility (T-IPF). The objective is to provide new dedicated "thematic products" to the users for the three mentioned surfaces. Over hydrology, the T-IPF includes new algorithms, in particular the hamming window and the zero-padding processing. Thanks to the hamming window, the waveforms measured over specular surfaces are cleaned from spurious energy spread by the azimuth impulse response. The zero-padding allows a better sampling of the radar waveforms, particularly valuable in case of specular energy returns. The S3 LAND thematic products has entered into operational production since spring 2023 and a full mission reprocessing is currently being performed and planned to be finished by mid-October 2023.

The Hydrology Expert Support Laboratories (HY-ESL) of the MPC will propose a quality assessment of the Thematic Hydrology Sentinel-3 STM level-2 Land products over rivers and lakes, including a first insight of the impact of the latest OLTC updates planned over the summer 2023. A performance comparison of these new hydrology products against the previous operational products will be presented. Our analysis will also consist in emphasizing the contribution of the new algorithms of the T-IPF through the comparisons with in-situ datasets. This approach will benefit from the contribution of the ESA project, related to Fiducial Reference Measurement (FRM) operational provisioning, with the objective to eventually estimate the water surface height accuracy.

Developing Purely Satellite-derived Precipitation Estimation: Integrating Top-Down and Bottom-Up Approaches

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Satellite precipitation estimation with the capability of high spatial and temporal resolution and near real-time accessibility offers a valuable alternative to ground measurement, enabling various applications including water resources management and natural hazard prediction. There are two primary approaches employed for estimating precipitation from satellite data: the top-down and bottom-up approaches. The top-down approach leverages data obtained from Geostationary and Low Earth Orbiting satellites to deduce precipitation based on atmospheric and cloud information. Conversely, the bottom-up approach relies on soil moisture observations to estimate precipitation. These approaches differ primarily in their measurement strategies. The top-down approach directly measures precipitation, providing instantaneous estimations that, in some cases, may lead to underestimation. In contrast, the bottom-up approach measures accumulated rainfall, yielding a more reliable estimation of precipitation between two successive soil moisture measurements.
The objective of this study is to develop a purely satellite-based precipitation estimation product, without gauge correction, by integrating both the top-down and bottom-up information. To achieve this goal, deep convolutional neural networks (CNN) and Long Short-Term Memory Networks (LSTM) algorithms will be employed. These models will combine the information from various satellite level 1 products, including backscatter data from the Advanced SCATterometer (ASCAT), infrared (IR) and water vapor (WV) channels from geostationary satellites, and passive microwave data. By leveraging these advanced techniques, the aim is to create a skillful pure observation satellite precipitation product. In order to assess the efficacy of this framework, the CNN model was applied over Italy with a spatial resolution of 0.1° and a daily temporal resolution, utilizing six years (2016-2021) data of infrared (IR), water vapor (WV), and soil moisture (SM). The findings show that the utilization of this model holds considerable promise for global precipitation estimation.

QUANTIFYING SOIL MOISTURE FROM SPACE-BASED SAR AND GROUND-BASED GEOPHYSICAL AND HYDROLOGICAL MEASUREMENTS

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In the context of the EO AFRICA R&D program, which aims to promote the corporation between Europe and Africa, our research focuses on a 100-meter resolution soil moisture product, whose resolution is suitable for agriculture studies, as this is a characteristic size of an agricultural parcel. Our study area is located in Senegal, where two distinct seasons dominate: a dry season from roughly October to May and a rainy season from June to September. We investigate the feasibility of using Sentinel-1 C-band Synthetic Aperture Radar (SAR) data recorded in the VV (vertical-transmit, vertical-receive) and VH (vertical-transmit, horizontal-receive) polarization to retrieve 100m SM every 12 days and combined it with ground high resolution (cm) measurements to both validate and improve the estimate.

Our research, as a continuity of our previous study of hundred-meter resolution soil moisture retrieval over Catalunya [Gao et al., 2017], uses a Change Detection method [Zribi et al., 2014], includes the analysis of VH polarization and a classification method. We have looked into 7 years' data set from 2016 to 2022. The NDVI index and SAR backscatter signals are analyzed in our study area and we have retrieved the preliminary soil moisture product and validated it with ground truth data. First, ground soil moisture measurements over Ragola station from AMMA-CATCH platform are used for our validation process. Also, we carried out field campaigns in the study area by the traditional method of taking soil samples, and we will use the measurements from electrical resistivity tomography (ERT) further on to validate the results and improve our developed model.

As the behavior of SAR signal may vary over different types of crops, we are classifying the fields according to their characteristics, such as variance values considering seven years NDVI of each pixel, which can distinguish different types of land cover including water bodies, cities, and different types of crops. Studies are done to analyze the behavior of both VV and VH polarization over different types of fields. In the next period, we will focus on involving the vegetation effects and soil roughness contribution in our study, especially in the growing and harvest seasons, and validation over different sites is necessary.

For further study, our approaches aim to infer high-resolution SM by combining ground station soil moisture data and ERT data to validate and improve the spatial and temporal resolution of our existing SM products from Sentinel-1 data. Recent developments in both geophysical data acquisition and petrophysical relationships allow for obtaining robust estimates of SM variations from geophysical proxy measurements. Particularly, variations in the electrical resistivity of soil are known to be highly sensitive to variations in moisture content. Similarly, recent advances in the processing of seismic data allow for rapid assessment of soil structure, which will enable us to image the roughness of the soil. Using this geophysical information, we will be able to reduce the uncertainties in our current approach and we expect to improve our current 100-m soil moisture accuracy.

Sentinel-6/Michael Freilich performances assessment over Inland Waters during tandem phase with Jason-3

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The Copernicus Sentinel-6/Michael Freilich mission was successfully launched on November 21st, 2020. Although the primary objective of the mission is to measure sea surface topography with high accuracy, it also allows to monitor water level over inland waters. Freshwater stocks monitoring is of great interest for climate change monitoring studies as well as near real time lakes and rivers monitoring services. This benefits to domains such as flood and droughts risks management, health, agriculture, economic and political activities, transportation. Sentinel-6/MF is another essential brick in the altimetry constellation to support the validation of the recent SWOT mission swath altimetry datasets and prepare for the Sentinel next generation topography missions.

Poseidon-4 altimeter on board Sentinel-6 differs from previous conventional sensors by operating simultaneously in Low Resolution mode (LRM) and in Synthetic Apeture Radar mode (SARM), in a so-called interleaved mode which allows for continuous transmission (also refers as open burst mode). Over one year, December 18th, 2020, to April 7th, 2022, Sentinel-6 was in tandem flight with Jason-3, before this later being moved to another orbit. This configuration allowed comparing Sentinel-6 and Jason-3 data, which is of importance to ensure continuity of downstream services.

This presentation focuses on Sentinel-6 CalVal activities over inland waters exploiting the tandem phase. Comparisons between Sentinel-6 and Jason-3 continental water level retrievals will be presented, as well as assessment of the reconstructed water level timeseries with respect to insitu measurements. Precision and accuracy of water level estimates will be quantified, focusing on the improvements Sentinel-6 brings comparing to Jason-3. The benefits of SAR mode, as well as the Fully focus SAR processing it allows, will be emphasized in terms of unexpected opportunities to now monitor very small water bodies in complex hydrological geometries.

Operational Lakes and Rivers Water Level Monitoring using satellite altimetry data in Copernicus Global Land Service

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Inland water is a more and more pressured resource for the population needs as well as a societal risk for local populations. It is also a fundamental element for industry and agriculture, therefore becoming an economic and political stake. The monitoring of inland water level, proxy to freshwater stocks, conditions of navigability on inland waterways, discharge, flood prevention, is thus an important challenge. With the decreasing number of publicly available in situ water level records, the altimetry constellation brings a powerful and complementary alternative.

The Copernicus Global Land Lakes and Rivers Water Level Service keeps regularly evolving since its start in 2016. It relies on the HYSOPE software to operationally process altimetric data to generate water level timeseries products and their associated uncertainties over rivers and lakes worldwide. Thanks to the combined support of CNES (THEIA Hydroweb) and the Copernicus program, the number of operational products is in constant augmentation since 2017. The quality of these products is ensured through operational Quality Control and Quality Assessment Reports, the latter being subject to regular external reviews. Evolutions to successively integrate the Copernicus missions Sentinel-3A, Sentinel-3B and Sentinel-6A, allowing to define new targets as well as exploiting the successive and regular upgrades of the satellites onboard Open Loop Tracking Commands, that ensure the altimeters hooking on the water targets, have been performed. This yields an operational monitoring of more than 22800 virtual stations over rivers and 243 lakes worldwide (as of June 2023).

This presentation will detail both the processes yielding the definition of new targets and their qualification for operation as well as the regular quality assessment of the produced water level timeseries. These metrics and associated results will be detailed. In particular, the benefits on data precision brought by SAR altimetry as well as the Open Loop tracking mode will be emphasized. Validation of the products with respects to external datasets and in Situ measurements will be presented. The necessity of the upstream activities both in terms of CalVal – such as performed by the S3 Mission Performance Cluster (ESA) – and R&D – e.g., SWOT Aval project (CNES) – will be emphasized to fully exploit the potential of satellite altimetry in such operational services. Planned evolutions of the service will also be detailed.

EO data + physical modeling: A hybrid approach for a near real-time snow monitoring

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Snow modeling is traditionally divided in two main approaches: statistical, where the snow is spatially distributed according to terrain morphology seeking a correlation with in situ observations on a given date, and physically-based where the snow evolves according to mass/energy balance due to the weather evolution. Recently, a purely EO-based approach emerged; in particular, the Snow Cover Area (SCA) can be retrieved from multispectral sensors, providing output having a medium to high spatial resolution.

To benefit from both physical modeling and satellite data, during the eo4alps snow ESA project we adopted a hybrid modeling approach, merging physical modeling with EO. The physical model simulates the snow evolution through a fully-energy balance approach that solves the mass and energy fluxes reproducing the physical processes affecting the snowpack (accumulation, compaction and melting) as a result of the meteorological evolution. The model accounts for the full morphological complexity of the terrain, like elevation, aspect and slope, and replicates the shadowing effects responsible for the large snow heterogeneity in the mountains.

The quality of results and the scalability of the technology is assured by a novel approach for the assimilation of satellite and in situ data entailing two correction loops:

- EO correction loop: it assimilates the satellite-derived SCA to help the physical model complying with the snow line outlined by the EO along the main aspects directions, and thus to maintain a spatial coherence of snow cover and correctly follow the melting process.
- In-situ correction loop: it assimilates in situ snow observations to derive the solid precipitation in the accumulation events, improving the precipitation estimate and thus the overall mass balance.

The two correction loops allow better adaptation to the common difficulty in snow measurements acquisition. In fact, in situ data may be hard to fetch because of limitations in open data portals due to data policy or because of data absence.

This approach provides many advantages: 1) is not constrained by satellite revisit time, allowing a near real-time monitoring; 2) does not need calibrations as the main parameters are physical; 3) is not affected by the limitations of satellite data, like shadowing/vegetation; 4) follows the whole water cycle, from precipitation to melting, providing ancillary hydrological variables like evaporation and snowmelt; 5) provides very high accuracy compared with in situ observations; 6) fed with numerical weather predictions can provide forecasts.

We compare the results coming from there different configurations:

- Physical model;
- Physical model + EO-SCA assimilation;
- Physical model + EO-SCA + in situ data assimilation.

Furthermore, we analyze the main issues associated with the proper processing of EO-SCA maps to make them suitable for the assimilation in the physical model.

Results demonstrate an improvement in the accuracy of results in terms of both mass estimation and melting rate, with respect to the pure physical modeling.

j-Snow: A Digital Twin for snow monitoring at high resolution in near real-time

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The snow acts as a source of water that will be released in spring, and thus can be seen as a "water bank" that will be eventually used for agriculture and energy generation.

"How much snow is stored in that mountain and when will it melt?"
This question is generally raised by public and private institutions interested in snow for civil or industrial purposes, such as public agencies dealing with civil protection or hydrological balances, and hydropower companies that will eventually harvest water for energy production.
This question is difficult to answer for many reasons: a) costly snow measurement campaigns are needed to measure snow depth and density on selected targets; b) legal restrictions apply for the safety of operators engaged in the campaign due to the avalanche risk; c) collected data need a modeling approach to spatially distribute the snow variables requiring in depth scientific know-how; d) this "data driven" approach prevents predicting the snowmelt in the following days.

To address these problems we developed j-Snow, a portal that allows users to browse the snow evolution in the target area and conveniently download the snow reports. j-Snow stems from the previous experience in the eo4alps snow ESA project aimed at the development of a high-resolution near real-time snow monitoring platform led by MobyGIS.

The user of j-Snow, namely an officer working in an environmental agency or in a hydropower company, may access the platform and choose the required snow variable (i.e., snow depth and snow water equivalent), manually draw the contour of the area of interest, and download the data or a report.
In order to benefit from both physical modeling and satellite data, j-Snow adopts a hybrid modeling approach, merging modeling with remote sensing. The physical model GEOtop simulates the snow evolution through a fully-energy balance approach that solves the mass and energy fluxes and reproduces the physical processes affecting the snowpack as a result of the meteorological evolution. The model accounts for the full morphological complexity of the terrain and replicates the shadowing effects responsible for the large snow heterogeneity in the mountains.

The quality of results and the scalability of the technology is assured by a novel approach for the assimilation of satellite and snow data entailing two correction loops:
- EO correction loop: it assimilates the satellite-derived Snow Cover Area to correctly follow the melting process.
- In-situ correction loop: it assimilates in situ snow observations to improve the precipitation estimate and thus the overall mass balance.

Finally, to solve the issue of missing in situ observations, j-Snow proposes MySnowBot, a Telegram Bot that allows local citizens to collect snow measurements with simple means, e.g., a graduated probe or folding ruler. As it happens in many geoscience applications MySnowBot represents a new way to collect measurements over the entire world, and j-Snow can assimilate them in the modeling chain. The collected data represent a unique piece of information that can be assimilated in the model to improve the accuracy of results.

Evolution of H SAF near real-time rainfall products derived from soil moisture observations

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The EUMETSAT Satellite Application Facility on Support Operational Hydrology and Water Management (H SAF) aims in providing soil moisture, precipitation and snow products derived from remote observations with sufficient time and space resolution to satisfy the needs of an operational use.

With the goal of providing complementary rainfall estimates to the state-of-the-art techniques, H SAF started in 2019 the development and the provision of new kind of rainfall product. The proposed approach merges passive microwave estimates obtained through a constellation of operational satellites with soil moisture derived rainfall obtained through the application of the SM2RAIN algorithm to the soil moisture measurements retrieved by the ASCAT sensors onboard MetOp platforms. The obtained rainfall estimates are found to provide reliable results. Specifically, good performances are obtained using it as input of hydrological model for river discharge simulations in Europe and Africa, representing a valuable tool for poorly instrumented areas.

Guided by the good performance provided by the new approach and with the aim of creating the first operational soil moisture-derived rainfall dataset, H SAF has started the development of a climate datarecord that covers the full MetOp era (started in 2007). This product will allow better hydrological model calibrations and forecast due to the product temporal extension foreseen within the project.

Moreover, the launch of the new European Polar System – Second Generation (EPS-SG) platform, foreseen in 2025, will provide enhanced soil moisture information through the new SCA instruments. The similarities of the old and new scatterometers guarantees the soil moisture product consistency over time, assuring the provision of high-quality rainfall estimates over land up to 2046 thanks to the MetOp-SG B platform constellation, even in near real time.

Daily, accurate evapotranspiration from global to local scale

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Evapotranspiration plays a critical role in the earth system, linking land surface energy, water and carbon cycles. Accurate estimates of terrestrial evapotranspiration are important for the management of land and water resources and improving water productivity in agriculture. However, the determination of evapotranspiration is a complex undertaking. This is accomplished by ETLook, a model developed by eLEAF by which evapotranspiration can be accurately determined based on remote sensing data, using the Penman-Monteith equation.

ETLook is at the core of the publicly accessible WaPOR database, developed by the United Nations Food and Agriculture Organization (FAO), that provides near real time spatial data on global water productivity. The WaPOR version 3 dataset will be released in 2023 fall and includes dekadal NRT data on actual evapotranspiration and relative soil moisture content from 20m (selected irrigation schemes) to 100m (Africa and the Near East) to 300m (global). The ETLook methodology is publicly available.

The WaPOR v3 processing chain combines multiple satellite and model sources (VIIRS, Sentinel-2, Landsat, MSG, MODIS, ERA5, GEOS-5) into intermediate inputs (such as albedo, NDVI, land surface temperature and weather data) for the ETLook model to produce daily and gap free evapotranspiration and relative soil moisture data. Advanced gapfilling and smoothening techniques are applied as well as a data miner sharpener (DMS) approach that builds regression trees between VIIRS LST and Sentinel-2 features to estimate land surface temperature more accurately at higher spatial resolutions.

We will present ETLook, the WaPOR version 3 dataset and two use cases that implement evapotranspiration data at different spatial scales: an irrigation map of the Netherlands (field scale) and a water dashboard for the Moroccan water authority (basin scale).

Extending river discharge time series of the Global Runoff Data Center (GRDC) using satellite data: A product with uncertainty estimate

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The quantification of river discharge is essential for understanding a broad range of scientific questions focused on hydrology, hydraulics, biogeochemistry and water resource management. However, the Global Runoff Data Center (GRDC) data set has faced a decline in the number of active gauges since the 1980s, leaving only 14% of gauges active as of 2020. For extending the discharge estimates of inactive GRDC stations, we develop the Remote Sensing-based Extension for the GRDC (RSEG) data set that can ingest legacy gauge discharge and remote sensing observations.

First, we evaluated the feasibility of extending discharge estimates of gauges in the GRDC dataset benefiting from river width estimates obtained from Landsat 4-8 mission images (1984–2020) and also river water level estimates obtained from satellite altimetry missions (2000–2020). Then we employ a stochastic nonparametric mapping algorithm to extend the discharge time series for inactive GRDC stations, benefiting from satellite imagery- and altimetry-derived river width and water height observations. Finally, we conduct a rigorous quality assessment on our estimated discharge, involving statistical validation, tests and visual inspection, resulting in the salvation of discharge records for 3571 out of 6018 GRDC stations with an average discharge exceeding 10 m3/s. The RSEG data set regains monitoring capability for 85% of global river discharge measured by GRDC stations, equivalent to 8106 km3/month, providing valuable insight into Earth's river systems with comprehensive and up-to-date information.

GLOBAL DISCHARGE ESTIMATION FROM SWOT SATELLITE

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The Surface Water and Ocean Topography satellite, successfully launched on December 16th 2022, provides a global mapping of rivers wider than 100m down to 50m worldwide. Each of these rivers are observed from 2 to 7 times within the 21-day orbit cycle. SWOT uses radar interferometry with two swaths of 50 km width each, separated by a 20 km strip nadir altimeter. Hence, the collected observations cover about 100 km wide areas across track, leading to the first time two-dimensional observations of water surface elevation (WSE) globally and therefore unprecedented spatial coverage. The SWOT satellite products involve water surface elevation and slope, river width and discharge. While the onboard instrument and ground processing can directly observe the first three variables, discharge is an estimated product using SWOT discharge algorithms. The latter are running operationally through the Confluence platform.

This study focuses on SIC4DVAR algorithm, developed at INRAE, which suggests a hybrid data assimilation method designed specially to reduce the solution bias. It combines elements of Bayesian and Variational approaches to improve the algorithm robustness and stability. The method involves an estimation of the likelihood function, allowing a useful analysis of equifinality often encountered in discharge estimation problems for ungauged basins. The suggested methodology has been tested and validated on a benchmark over the Ohio River Basin using synthetic observations mimicking the SWOT observation data characteristics. Results show very promising results of SWOT discharge estimation performance, from SWOT solely, on reaches where in-situ data at USGS gauge stations is available for comparison.

The algorithm is designed for global and/or basin-scale applications given the multi-level structure of the methodology. The latter involves different levels of complexity in terms of the representation of the flow dynamics and therefore different computational requirements. Here, we investigate discharge and bathymetry estimation under strong uncertainties from SWOT simulations and their combination with optical (Landsat and Sentinel 2) and altimetry (Jason, ENVISAT, Sentinel 3) data.
The global application involves a Python low-cost algorithm that has been designed to meet the computational requirement for an operational use within the Confluence platform.

Validation of Surface Inundation Algorithm for HydroGNSS Mission

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HydroGNSS, the Scout mission selected by ESA in 2021, is designed to be a scientific demonstrator for a GNSS reflectometry (GNSS-R) constellation for the land sensing requirements. HydroGNSS is a GNSS-R mission in near-polar orbit that will conduct, for the first time from space, dual frequency dual circular polarization multi-constellation GNSS-R. And another novelty of this mission is its 'coherent channel', which will acquire complex (phase and amplitude) signals at high sampling rate during most of the duty cycle. The small size and low cost of HydroGNSS satellite increases the possibility to a larger constellation, which is of invaluable to the further understanding of climate change. The scientific goal of HydroGNSS is to densify in time and space the land related essential climate variables, which are soil moisture, above ground biomass, permafrost freeze-thaw state and surface inundation.

Water resources, including rivers, wetlands and lakes, are likely to be strongly affected by climate change, with major impacts for human societies and ecosystems. Wetlands are important sources of atmospheric methane, which is one of the most potent greenhouse gases. Rivers are a valuable source of fresh water for people all over the world, but they also cause property damage, environmental and economic losses. So, it is important to understand changes in land surface water to help identifying mitigation strategies. Many previous studies have focused on mapping inland water using optical, hyperspectral, infrared, and microwave systems, but there are inevitably problems such as low temporal or spatial resolution, inability to penetrate clouds and thick vegetation. Experiments have shown that reflectivity and power spread ratio have good performance as coherence indicators. GNSS-R with forward scatter and deeper penetration has great potential to produce finer land surface water product.

Fixed threshold methods have limitations in detecting water and cannot address spatial heterogeneity, which needs to be considered on a global scale. A surface inundation algorithm (L2) based on power observables and complex signals was developed. A random forest classifier is an ensemble classifier that produces multiple decision trees, using a randomly selected subset of training samples and variables, with high accuracy and robustness of classification. And it is a good way to build intrinsically nonlinear relationships between the multi-features and targets. So, we use coherence indicator with geolocation, land cover and roughness as inputs, which are helpful in addressing spatial heterogeneity. The effectiveness of the model was verified based on the preliminary results from CYGNSS data. Water flag derived from the model are in 95% agreement with the Pekel water mask developed from Landsat measurements, and most of the false positives occur near wetlands.

Sentinel-3 Inland waters level-2 thematic products: latest results based on full mission reprocessing validation

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The ESA level-2 Sentinel-3 Surface Topography Mission (STM) Altimetry processor has been updated to generate three thematic products optimized for the scientific processing over the three surfaces: Inland waters (HY), Sea Ice (SI), and Land Ice (LI). To obtain a continuous and homogeneous data coverage of the Sentinel-3 STM Altimetry products, a full mission reprocessing campaign has been performed.

The reprocessing of the S3 STM Altimetry mission data set covers from the beginning of the mission (1st March 2016) up to the operational deployment of the new thematic processing chains at the ESA product services, currently planned in September 2023. The reprocessing led to the deployment of the Baseline Collection 005 (BC005).

The main updates for the Inland water level-2 processor consist of the implementation of the Hamming window and zero-padding in the processor algorithm, and the application of a dedicated hydrology mask for data assimilation over defined inland water targets. The evolution introduced in the processing algorithm led to improvement of data quality and performance over inland water surfaces. A highlight of the BC005 validation results is presented in this study.

Co-variability of soil moisture, vegetation, and land surface temperature from an Earth Observation perspective

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The co-variability of soil moisture (SM), fraction vegetation cover (FVC), and land surface temperature (LST) is a key factor controlling land-atmosphere interactions which are relevant for understanding natural variability in the earth system, sub-seasonal predictably associated with land surface conditions, as well to develop process oriented observational constraints to evaluate numerical models. Earth Observations (EO) provide invaluable data to assess long-term trends, seasonal variations, and regional disparities in these interconnected environmental parameters and processes. In this study we explore the relationships between LST maximum, FVC, and surface SM based on EO. This study aims to identify when and where we observe strong relationships between soil moisture, vegetation, and land surface temperature on inter-annual timescales. The datasets to represent LST and FVC were taken from the Satellite Application Facility on Land Surface Analysis (LSA-SAF), and for soil moisture from European Space Agency Climate Change Initiative (ESA-CCI). The analysis is focused on the geostationary 0° domain (40S-70N, 70W-70E) for the period to 2004-2021, considering monthly means. In the case of LST, we use the monthly mean of the daily maximum. The temporal correlations between the different variables were computed for each grid-point and foreach calendar month (to evaluate inter-annual variability), using only data with a reduced fraction of missing data and only correlations significant at 95% are considered. Several regions in the domain exhibit a strong relationship between interannual variability of maximum LST, vegetation state, and soil surface moisture. The seasons in which this relationship is most evident are associated with land cover and climate of each region. For example, in the Iberian Peninsula, we observe a negative relationship between LST and FVC/SM mainly from March to August, with the summer season being when this relationship is strongest. This strong relationship is also observed towards the north of Europe, but only in the summer season. Also in Europe, a strong relationship is observed in the central-southern region, only in the summer months. In the southern Hemisphere, we can highlight the southern region of South Africa, with a strong correlation between LST and FVC practically throughout the year. In South America, the central east region of the continent showed a significant signal from May to August. It is also important to highlight in this analysis that the FVC and SM are fully independent products but are very consistent in the identification of the regions and to some extent the seasons. Our results provide observational evidence supporting the hypothesis that the relationship between LST and FVC/SM are associated with climate variability and vegetation cover in each region. Finally, these diagnostics provide a starting point to develop process oriented metrics to confront numerical models.

Current availability and distribution of Congo Basin's freshwater resources

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As the second-largest river system and rainforest in the world, the Congo Basin is of global significance for biodiversity, water, and carbon cycles. However, its current water availability remains uncertain. Land use practices, deforestation and climate change pose significant threats to the basin water resources, whose future evolution remains unknown. Here, we characterize the relationship between drainable water storage and river discharge across the basin, using a combination of satellite and in situ observations over the last two decades. We estimate that the Congo Basin holds 476 km³ to 502 km³ of Total Drainable Water Storage (TDWS) (close to the volume of Lake Erie). Sub-basin analysis suggests that water availability is unevenly distributed across the region, with 63% of the TDWS being stored in its two southernmost basins, Kasaï (220–228 km³) and Lualaba (109–169 km³), while the northern sub-basins Sangha, Ubangui, and Middle Congo only contribute a total of 173 ± 8 km³. We further estimate the resistance of the Congo Basin for draining its water storage as 4.3 ± 0.1 month, a value similar to the Amazon Basin. However, geomorphology and the presence of surface water can result in larger time constants such as in the Lualaba sub-basin where lakes and swamps act as resistors. This study provides a robust regional estimate of the contemporary distribution of water availability across the Congo Basin. It gives a new basis to develop strategies to address the challenge of transboundary water management and water demand for nearly 120 million inhabitants, a population that is expected to double in a few decades.

Can Earth observations improve land surface model simulations through the calibration of a simple irrigation scheme?

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Irrigation is one of the most impactful human activities, affecting different components of the water cycle while sustaining crop yields. This explains why improving the knowledge of agricultural water uses is in the spotlight of hydrological sciences and water management authorities. Additionally, climate change projections and the increasing frequency of extreme weather events (i.e., drought phenomena) exacerbate the importance of a better understanding of the water used for irrigation to develop efficient water management systems.
The hydrological modelling, remote sensing and data assimilation communities are providing a key contribution to quantify agricultural water uses, although correctly estimating irrigation is still not trivial. For instance, models are able to simulate irrigation but they are characterized by a simplistic parameterization. On the other hand, high resolution remote sensing offers an unprecedented opportunity to observe the state of the soil/vegetation system and to consequently detect irrigation. Some recent approaches have demonstrated the utility of Earth observations to either derive irrigation directly, or indirectly, via their assimilation into land surface models. However, although promising, both methods are still in their infancy due to limitations of both satellite data and models. Recent data assimilation experiments have shown the crucial role of an accurate land surface model parameterization to optimally integrate models and satellite observations. In this context, the proposed study aims at testing the benefit of directly optimizing the irrigation parameters of a sprinkler irrigation module embodied in the Noah-MP land surface model, running within the NASA Land Information System framework. A synthetic and a real calibration experiment are performed over a highly irrigated area in the Po Valley (Italy), using irrigation and soil moisture benchmark data, at a spatial resolution of 0.01°. The improvement of the poorly-parameterized sprinkler irrigation scheme through a proper parameter calibration helps to improve model forecasts of irrigation, and will subsequently improve the potential of state updating via data assimilation.

Advancing Global-Scale River Discharge Estimation: A Novel Framework for Assimilating SWOT Altimetry using CTRIP-HyDAS.

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Understanding the dynamics of river systems is crucial for comprehending the intricate processes of the continental water cycle, particularly in regions with limited in-situ observations, such as developing countries. While remote sensing technologies, including nadir altimeters, have proven invaluable in supplementing ground-based data, the current altimeters fall short of accurately capturing a significant number of continental surface water bodies. However, a groundbreaking solution has emerged with the advent of the Surface Water and Ocean Topography (SWOT) mission, launched on 16 December 2022. This mission represents a transformative leap forward, enabling unprecedented two-dimensional water elevation measurements for all rivers wider than 100 m worldwide. The SWOT mission will provide water elevation at the reach scale (about 10 km long) and discharge estimates. Building upon the immense potential of the SWOT altimetry mission, our research aimed to develop a novel framework for estimating river discharge at a global scale by integrating SWOT observations into the CTRIP river routing model using the CTRIP-Hydrological Data Assimilation System (CTRIP-HyDAS), which utilizes Local Ensemble Transform Kalman Smoother (LETKS) technique. To evaluate the effectiveness of our approach, we conducted an Observing System Simulation Experiment (OSSE), often referred to as a "twin experiment." This allowed us to simulate the "true" system state along with an ensemble of corrupted model states. Moreover, we employed the latest version of the CTRIP model, operating at a spatial resolution of 1/12 degree, to ensure compatibility with the resolution of the SWOT discharge product. By incorporating realistic errors into the discharge computation, we constructed a SWOT-like river discharge. In addition, we leveraged a realistic satellite orbit generated by the CNES Large-Scale Hydrology Simulator to determine the times and locations of available SWOT observations. Our results demonstrate that the assimilation of virtual SWOT observations led to a remarkable enhancement in the quality of river discharge estimates over a few basins under various hydroclimatic conditions (the Congo, Garonne, and Ob basins). The next step is the extension of the CTRIP-HyDAS to the global scale. These findings indicate that SWOT products hold significant potential for substantially improving hydrological simulations on both a global and continental scale. By employing our innovative framework, we can advance our understanding of the complex dynamics of river systems and their role in the broader continental water cycle.

Drought monitoring and early warning in Mozambique with satellite soil moisture data

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Mozambique strongly depends on agriculture, but the sector is challenged by the increasing occurrence of climate extremes, including droughts. Studies have shown that there is an increasing trend in occurrence of severe droughts (Arenada-Cabrera et al. 2021). Nonetheless, advanced agricultural drought monitoring, early warning and early action is still in development in Mozambique. Providing accurate, localized information on drought conditions and development is challenging, but is crucial to stakeholders such as local and regional governments, NGOs, farmers, and vulnerable households.

Soil moisture data from satellite-based microwave observations has proven to be a useful tool for drought monitoring with many different methods existing for calculating drought indices (Vreugdenhil et al., 2022). The advantages of using microwave observations are their ability to observe day and night and under cloud conditions. Furthermore, when using radar data, they can have increased spatial resolution up to tens of meters and thus provide information on spatial variability of drought. Nonetheless, uptake by stakeholders of satellite soil moisture data for drought monitoring and prediction in operational systems has been slow. This is partly due to the lack of quality-controlled, analysis-ready drought indicators. In addition, users are not familiar with the data or its benefits and have difficulties interpreting the indicators in the context of operational decision-support.

This study will address these issues, by demonstrating the benefits and challenges of using satellite soil moisture for drought monitoring over eastern Africa and provide a first recommendation for an analysis-ready drought indicator based on satellite soil moisture data. We will discuss the advantages and limitations of microwave-data in general, and the effect that limitations may have on soil moisture monitoring. We will also highlight the potential of using high resolution Sentinel-1 data for drought monitoring over 5 regions in Mozambique. Furthermore, we will show an evaluation of different soil moisture based drought indicators with existing products such as Standardized Precipitation Evaporation Index and Water Requirement Satisfaction Index and through a convergence of evidence approach using precipitation and vegetation data. We will also address the challenges related to parametric drought insurance, i.e. illustrating the impact of using different drought indicators on drought severity classification. Consequently, a suggestion for an analysis-ready drought indicator will be provided.

This research is funded by the Austrian Development Agency under the DrySAT project: Enhancing Drought Early Warning in Mozambique through Satellite Soil Moisture Data to support food security in the context of climate change, the Austrian Space Application Programme ROSSIHNI project : Remote Sensing and Social Interest for Humanitarian Insights and the World Bank SMARTDRI project: Satellite soil Moisture And Rainfall Testing for Drought Risk Insurance.

Araneda-Cabrera, R.J., Bermudez, M., Puertas, J., 2021. Revealing the spatio-temporal characteristics of drought in Mozambique and their relationship with large-scale climate variability. Journal of Hydrology: Regional Studies 38, 100938. https://doi.org/10.1016/j.ejrh.2021.100938

Vreugdenhil, M., Greimeister-Pfeil, I., Preimesberger, W., Camici, S., Dorigo, W., Enenkel, M., van der Schalie, R., Steele-Dunne, S., Wagner, W., 2022. Microwave remote sensing for agricultural drought monitoring: Recent developments and challenges. Frontiers in Water 4.

Regional-scale, high-resolution estimates of irrigation water use from satellite data

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Irrigation water use is the primary source of freshwater consumption by humans, largely prevailing on domestic and industrial water uses. Nevertheless, explicit information on irrigation dynamics (i.e., extents, timing, and amounts) are scarcely available worldwide because of technical reasons, as the lacking of proper measuring systems and also because, and of economical reasons, as this kind of information is considered as sensitive data by farmers. Recently, remote sensing technologies have been successfully employed for building methodologies aimed at monitoring irrigation dynamics. In particular, estimating the actual amounts of water used for irrigation is of essential importance for water resources management purposes. In this contribution, the first high-resolution irrigation water use data sets produced at the regional scale within two ESA (European Space Agency) projects will be presented. In the framework of the Irrigation+ project (https://esairrigationplus.org/), irrigation estimates have been obtained through the SM-based inversion approach over three major basins: the Po valley (Italy), the Ebro basin (Spain), and the Murray-Darling basin (Australia). The satellite-derived irrigation products referring to the Spanish and the Italian case studies have a spatial resolution of 1 km, and they are retrieved by exploiting Sentinel-1 soil moisture data obtained after the application of the RT1 (first-order Radiative Transfer) model. A spatial sampling of 6 km is instead adopted for the Australian pilot area, since in this case the soil moisture information comes from CYGNSS (Cyclone Global Navigation Satellite System) observations. The data sets referring to the two European pilot sites have then been updated and further refined within the 4DMED-Hydrology project (https://www.4dmed-hydrology.org/). Insights on the experimental data sets, as well as validation analyses, will be presented in this contribution. In order to foster further testing and impendent validation activities, all the produced data is made publicly available at: https://zenodo.org/record/7341284#.Y7WHsHbMKUm.

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Flash flood modeling and in urban areas using High Resolution hydrodynamic model and machine learning models

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Modeling flash floods in urban areas with complex topography is challenging. Considering fine-scale hydrodynamic 2D shallow water model to perform simulations requires a lot of manual or semi-automatic data processing before being able to run simulations. This involves the transformation of high-resolution Digital Surface Model (Lidar) into a Digital Elevation Model that conserves the main hydraulic properties of the ground (culverts, weirs, barriers, etc) as well as accurate delineation of the streets and buildings, etc.

In the context of the ExtremeXP project funded by the European Commission we assess the role of machine learning to improve the simulation and nowcasting (forecast with short term horizon) of flash flood events in the city of Nîmes in the South of France. First, we prepare all relevant datasets to design a fine scale 2D hydrodynamic model and then we calibrate it on several historical flood events. Once this model is calibrated and validated, we use it as a reference for conducting several scenarios of improvements using machine learning model. Two kinds of scenarios are analyzed. In the first kind lie all the machine learning techniques that would facilitate the design of the hydrodynamic model by either reducing the number of input data or reducing the necessary data transformation processes. The second kind of scenario consists in designing surrogates for the reference hydrodynamic model itself for nowcasting flood propagation during an event.

Contribution of the Amazonian moisture transport to the water budget at Brazilian southeastern using atmospheric modelling and reanalysis

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The moisture transport from Amazon forest to the Brazilian southeastern is a great moisture source for the regional water cycle in South America (SA). Several previous studies have shown this importance and how anthropic processes of either global warming or Amazon deforestation may affect the inputs and outputs of Amazonian moisture. The advances in the parameterization of the microphysics allow improvements in the representation in varying timescales. So, we have used 2 data set: a) the Meteorological Office Unified Model (UM) simulations for 4.5 and 25 km horizontal resolutions; b) the ERA5 reanalysis (profiles of windspeed and specific humidity). The period used in this analysis were from 1998-2007 during the austral summer (months from December up to February). The moisture transport was computed from the surface up to middle troposphere (500 hPa). We selected 2 domains in the Amazon basin and in the Brazilian southeast region (named Sao Paulo) to identify the moisture's output and input for both regions. The results showed some precipitation bias, mainly in the central/south Amazon basin (~ +2.5 mm.day-1) and extreme in Sao Paulo +1.5 mm.day-1). Some similarities between 4.5 km and observations (ERA5) vertically integrated moisture flow patterns for Amazon basin as well as northern Sao Paulo area were identified (-16% and -7%, respectively). On the other hand, the 25 km simulation overestimated the intensity of fluxes in the whole pathway by 4.5%, which represents -6.9 kg m-1 s-1. The low water input and transport was explained by some bias on the vertical moisture transport, mainly between 700 and 500hPa (~ -3.2 kg m-1 s-1 in the Amazon southern area and -2.5 kg m-1 s-1 in Sao Paulo area). This is a going Project associated with the use of Convection-Permitting Model (COM).

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Performances of SWOT Poseidon-3C altimeter over inland waters and interest of the 1 day revisit time during the fast sampling phase

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The French-US mission SWOT (Surface Water and Ocean Topography) was launched on December 16th, 2022. The objectives of the mission cover both oceanography and hydrology domains. With regard to continental surface waters, SWOT aims to measure changes affecting freshwater stocks over water bodies whose surface area exceeds 250m² and water level and discharge in rivers whose width exceeds 100 m.

To reach these scientific goals, SWOT embarks an innovative wide swath altimeter, KaRIn - Ka-band Radar Interferometer -, as well as a nadir altimeter, Poseidon-3C in the continuity of the altimeters that are onboard Jason-2 and Jason-3. This instrument complements KaRin to acquire data in between the two swaths and also provides a worthy dataset for the calibration of KaRin. The CalVal phase of the mission was performed on a 1-day revisit time orbit over the January-July 2023 period.

This poster will first present the performances of Poseidon-3C over inland waters by means of comparisons of water level estimates with insitu data, especially over SWOT Tier 1 lakes and river sites. Then, the unique 1-day revisit time offered by this dataset is used to build water level timeseries over different hydrological basins and evaluate their variability in comparison to virtual stations measured with a 10-day (Jason-3, Sentinel-6MF) or 27-day (Sentinel-3) sampling. This work underlines the added value of a high frequency revisit time over inland waters, and is key to understand the rapid changes observed in some hydrological basins. Furthermore, this dataset of the early SWOT mission will be key to assess the overall performances of this mission and help design future space missions for hydrology monitoring.

From Kaleidoscopic Space-Borne Hydrological Datasets To Data-Driven Trained Models Allowing to Build Global-scale Maps of Unobserved Hydrological Parameters: an example with a Vector Maps of River Discharge Distribution

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Although various kinds of hydrology-related parameters and variables can now be directly monitored from space; some of the essential river modeling parameters, such as surface roughness, river cross-sectional shapes and still river discharge remain challenging to characterize using only satellite products. Modelists still rely on limited field measurements with model calibrations and inverse approaches to estimate those parameters, as it is envisioned for the upcoming SWOT-based discharge product. These methods require a first estimation or first guess value of these parameters as initialization and their performances greatly depend on the quality of such first guesses.

Our work relies on the pioneer work of [Beck et al. 2015] where global gridded maps of streamflow characteristics of small-to-medium-sized natural catchments were derived from neural network ensemble models. Machine learning methods are still new to hydrological applications and have yet to be mastered. Still, given the exponential growth of available remotely sensed hydrological dataset; one could explore the possibility of taking advantage of such methods to estimate unobserved hydrological parameters.

We present here two complementary tools that would help a beginner hydrologist in machine learning to prepare and run a supervised machine learning experiment from scratch with the purpose of deriving large-scale maps of unobserved hydrological parameters.

Our first tool is a Python-based setup that helps a user to build his own data-driven parameter estimation experiment from scratch. It unifies the several Python packages dedicated to machine learning under a unified structure so that the user can more easily choose, test, and compare different approaches and play with their configurations, while being able to replay some past experiments. This toolbox is designed to be reusable and generic, so that it can be extended to other data analysis or model estimation methods. Furthermore, river-related parameters being provided at miscellaneous very disparate formats and scales – from point-based stations timeseries to gridded coarse frames through geometry-based (such as lines and polygons) features; our second tool allow the user to relate parameters from different format together given distance and hydrological-pertinent conditions (such as drainage area) and build a wide set of input parameters to feed the trained model.

Our tools were used in an experiment to reproduce the original Beck et al 2015 experiment given some updates on our part. First, the initial gridded climate, topography, land cover, geology, and soil variables were expanded with reach-based river geomorphology variables using the aggregation tool. The model was trained using different setups all available through our data-driven experiment tool. Finally, the trained model outputs were prepared at the scale of the reach-based SWOT River prior Database or SWORD; so that they can be used in the SWOT discharge algorithms later on.

AlTiS : Generating Water Level Time-Series from Radar Altimetry

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Satellite radar altimetry can be used to determine water level height of continental water bodies, if used with appropriate processing that depends on the size and geometrical configuration of the targets. AlTiS (Altimetry Time Series) is software designed to visualize and process radar altimetry data with the goal of generating time series data of radar altimetry data over water bodies of different sizes such as river, lakes and wetlands. Even if its major goal is the creation of time-series of water levels derived from the altimetry range, it can also be used to generate time series of any other altimetry parameters (e.g., corrections applied to the range, backscattering coefficients, or brightness temperatures).

Through a Graphical User Interface (GUI), without any skills in data processing, the user can handle altimetry data in order to:

- Display several parameters of altimetry data like surface height, altimetric range, atmospheric corrections (ionosphere and wet and dry troposphere path delay corrections) and also to display some characteristic parameters of the waveform like the backscatter coefficient, and peakiness.
- Graphically select altimetric measurements to remove outliers and easily done owing to Landsat background image.
- Generate water height time series from the valid altimetry data previously selected
- Export the time series into various files format as CSV and HydroWeb

AlTiS accepts CTOH altimetry products (Level 2 GDR supplied by the CTOH). CTOH GDR data have been specifically conditioned to optimize the data size by making a geographical selection and includes the right altimetry parameters for hydrological studies.

AlTiS can process several altimetric data products from followed missions : Jason-1/2/3, ERS-2, ENVISAT, SARAL, Sentinel-3A/B, and soon, Sentinel-6/Jason-CS and the nadir altimeter onboard SWOT. They are supplied for free through a web request form on the CTOH website (http://ctoh.legos.obs-mip.fr/applications/land_surfaces/altimetric_data/altis).

AlTiS is mainly employed for hydrological applications and can be used for training courses on radar altimetry at bachelor or master levels. It is also a very convenient tool to analyse the radar altimetry data contained in the GDR over any type of land surfaces.

AlTiS is a software developed by CTOH as part of its activities as a National Observation Service. AlTiS is a free software and it is released as an open source under the CeCill License. Altis is working under python3 environment and tested for GNU/Linux, Windows 10/11.

AlTiS is available on GitLab : https://gitlab.com/ctoh/altis

EUMETSAT H SAF Satellite-derived snow cover products and their applications in hydrology

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The EUMETSAT is the European operational satellite agency for monitoring weather, climate and the environment from space. In order to exploit the full potential of the EUMETSAT satellite data in a broad range of meteorological and environmental applications, a network of eight Satellite Application Facilities (SAFs) that each specialise in the delivery of products in one application area was established. Each SAF is a consortium of institutes from Member States, led by a National Meteorological Service. The Support to Operational Hydrology and Water Management (H SAF) is one of eight SAFs has been performed to provide products and services in support of Operational Hydrology, Meteorology and Risk Management. Products derived by primary EUMETSAT missions for the estimation of precipitation, soil moisture, and snow parameters are developed, verified through a quality assessment and hydro validation impact studies, responding to the request for uniqueness and competitiveness with respect to other satellite programs (e.g., Copernicus, ESA/CCI) and the other SAFs. The H SAF snow cover products are produced both for meteorological and hydrological applications. The H SAF snow cover products can be grouped in 4 groups: (1) snow extent product, (2) effective snow product, (3) snow status (dry/wet) product and (4) snow water equivalent product. In this paper,we will introduce the H SAF existing and planned snow products portfolio with a focus of hydrological applications. We will also provide use cases on use of EUMETSAT H SAF snow product in hydrological modeling.

Assessing Hydrological Connectivity in Wetlands at a Global Scale with D-InSAR

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Wetland ecosystems worldwide are experiencing degradation at increasing rates, primarily attributed to anthropogenic activities. Human interventions, such as the construction of roads, channels and water control schemes, have significantly altered natural hydrological systems and disrupted the hydrological connectivity of wetlands. Despite this, the global impact of hydrological barriers on wetland connectivity remains unexplored. Thus, we present a comprehensive assessment of the human effects on wetland hydrological connectivity worldwide. To this end, we identify obstructions and barriers to natural water flow by Differential Interferometric Synthetic Aperture Radar (D-InSAR) imagery collected across 20 iconic wetlands. InSAR data has been particularly useful for assessing the hydrological dynamics in wetlands as it provides information on lateral flow dynamics at high spatial resolutions. Here, we classify hydrological barriers on InSAR imagery created using ALOS-PALSAR 1 and 2 data collected between 2006 to 2011 and from 2014 to date, respectively. The barrier detection is automated through the implementation of Deep-Learning-based image segmentation techniques. The Neural Network architecture UNet has previously been used for detecting barriers in InSAR imagery and is employed in an improved implementation in this study to locate and quantify each barrier's length. Apart from the location and length of hydrological barriers, we quantify the temporal persistence of each hydrological barrier. Once the features are classified, the degree of hydrological connectivity for each wetland is determined by relating the length of barriers to the total area of each wetland. Our results provide insights into the extent and impact of human-induced alterations to natural water flow on each wetland. They also indicate global wetland connectivity patterns and their implications on wetland health. As such, the study's findings contribute to a deepened understanding of global wetland connectivity trends from 2006 to the present, with the potential for further expansion when incorporating data from the NISAR mission in upcoming years. They may also be used for informed decision-making in wetland conservation efforts and sustainable management of affected ecosystems.

River discharge estimation from satellite observations

Applications in the Congo River basin

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A project to support the International Commission of the Congo-Ubangi-Sangha River basin (CICOS) developed since 2016 has promoted space hydrology through a group of French institutions. Various activities have been conducted including the development of a spatial database, comparison with in-situ data and the development of an operational Hydrological Information System. An innovative methodology has been proposed by INRAE to transform altitudes into flows at virtual stations.
The methodology described in the articles Oubanas, Gejadze, Malaterre 2018-2023 called SIC4DVar works with SWOT data (height, width, slope), and is adapted to an ungauged context without any complementary in-situ data. Of course, if complementary data are available, the method can benefit from them. A disadvantage of this method along with all six operational methods of the SWOT-DAWG (Discharge Algorithm Working Group) is that it requires about 1 year of SWOT type data to cover a complete hydrological cycle. Another disadvantage is that it requires using Heights but also Widths and Slopes, at several nearby reaches, and needs substantial CPU time. For these two reasons, we developed an alternative method allowing building rating-curves Q(Z) from a Saint-Venant 1D hydraulic model (http://sic.g-eau.net) developed itself from classical altimetry data and global databases, as well as in-situ data on the studied area (2 hydrological stations in Kinshasa East on the Congo and Bangui on the Ubangi river). Powered by satellite altimetry data, these rating-curves provide flow rates. Satellite altimetry data have been available in this area since 2002 thanks to various missions: Envisat, Saral, Jason 2 & 3, Sentinel 3A, 3B, and more recently 6A. Global databases used are the width databases GWD-LR or GRWL, the mean flow databases WBM or GRADES, or the Digital Terrain Model databases SRTM or MERIT. For the Congo River, the selected area covers the 1,809 km upstream of Kinshasa (Pool Malebo). For the Ubangi river part, the selected area covers the 1,160 km upstream of its confluence with the Congo.
These data are then used in an inversion algorithm of the Manning-Strickler equation to compute a bathymetry (bottom elevation and cross-sectional shape), as well as to position and size natural or artificial devices. The hydraulic model generated allows different exploitations in simulation. The first exploitation of the model is to generate Q(Z) rating-curves by series of steady state calculations for different realistic flow rates and compare them to others developed using a hydrological model as provided in Hydroweb, or in-situ ones when available (only two on the zone). The second exploitation is to compute wave propagation times along the river and compare them to satellite observations. The third operation is to run a transient simulation on a hydraulic scenario reconstructed from the available in-situ stations.
Once these rating-curves have been generated, they can be exploited operationally and in real time (http://cicos.g-eau.net) to compute flows from satellite altimetry data from the Hydroweb base for example. Even if many steps can be improved and are still being tested, the results obtained and validated on in-situ data are encouraging.

Remote sensing and machine learning for spatio-temporal analysis of agricultural and meteorological drought: Case of Loukkos Basin (Northwestern Morocco)

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Abstract:
Droughts pose significant issues for Mediterranean water resource management. Understanding the occurrence and characteristics of drought events is crucial for effective drought management and mitigation strategies. So, this research combined remote sensing, and machine learning algorithms to enhance our understanding of agricultural and meteorological droughts in a Mediterranean watershed in northwestern Morocco from 1984 to 2021. To assess drought conditions, we utilized the Standardized Precipitation Index (SPI) on two time periods (SPI-3 and SPI-6). Furthermore, we employed multi-temporal Landsat images (4-5TM, 7 ETM+, and 8OLI) to investigate the spatiotemporal distribution of three agricultural drought indices: Vegetation Condition Index (VCI), Temperature Condition Index (TCI), and Vegetation Health Index (VHI). The SPI analysis revealed that drought conditions affected a considerable proportion of the Loukkos basin stations, ranging from 18% to 45% in most years across the SPI scales. Nevertheless, the VHI analysis revealed the absence of extreme or severe drought events in the basin during 1984–2021. Additionally, to predict drought, four machine learning models, namely Random Subspace, Random Forest, M5P, and REPTree, were employed and evaluated using statistical metrics. The findings demonstrate that the REPTree model exhibited superior reliability compared to the other models, showcasing its potential for drought forecasting and management in Mediterranean areas. This research contributes to the understanding of drought dynamics in the Loukkos basin and highlights the effectiveness of machine learning algorithms in predicting drought events. The study's findings can be used for developing drought management and mitigation strategies to maintain natural resources in Mediterranean regions.
Keywords: Spatial-temporal distribution, drought analysis, drought prediction, Mediterranean watershed, machine learning, remote sensing

EO Africa Water Management: A support to farmers and planners to improve irrigation water management

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The total water withdrawal in the Mediterranean African countries exceeds the total renewable water resource by 30% (Antonelli and Tamea, 2015). Low water availability is the defining feature of the agricultural economy in those countries as it accounts for 86% of freshwater consumption (Qadir et al. 2010). Such scarcity undermines economic development in agriculture.

Efficient and sustainable agricultural water management can have a dramatic impact on reducing water demand through improvements in soil water management. Precision irrigation via remote sensing presents the initial steps towards an accurate and cost-effective assessment of the actual evapotranspiration (ETa) of the crops using EO-derived reference evapotranspiration (ET0), leading to a precise estimation of their water requirements, and consequently optimise irrigation scheduling models and plans that improve water use efficiency.

This project, funded by ESA within the “EO Africa Explorers” framework, is led by Planetek Italia and involves Planetek Hellas and International Center for Advanced Mediterranean Agronomic Studies. Started in November 2022, it will last two years enjoying close participation of local stakeholders playing the role of Early adopters, particularly the Egyptian National Authority for Remote Sensing & Space Sciences (NARSS) and the “October sixth for agricultural projects” company.

The aim is validate an open-source innovative model, assessing ETa at the field level using a combination of ET0, crop coefficient (Kc) and water stress coefficient (Ks). The model will be integrated into a web platform as a Decision Support System (DSS) to improve irrigation water management.

Information in the thermal infrared (TIR) domain is used to assess actual evapotranspiration and soil moisture status. The ET0 is derived from thermal data acquired by ECOSTRESS sensor and hyperspectral optical data from PRISMA sensor. As a backstop, Landsat and Sentinel will be used to provide supplementary data. TIR data is used to extract the Brightness Temperature and Ks while the Prisma data offer the latitude and the appropriate bands for the NDVI’s calculation. EO data is acquired on the same dates as the in-situ measurements in Egypt; two field measurements per month are collected, in the days of satellite overpasses giving the priority to thermal sensors and having the prisma data +/-1 days. The data request occurs in two stages: the first order is made with a 30% cloud coverage requirement, which typically yields the highest success rate, and the second order is made with a 5% cloud coverage requirement.

The EO-based vegetation status will be validated using several in-situ ground data collected from a large agricultural area in Egypt. The development and validation of the model will be done through an iterative process of developing, testing, validating and refining cycle. Traditional statistical assessment accuracy methods, as well as more recent methods, will be used for the accuracy assessment of both calibration and validation.

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Improved tropospheric corrections for Coastal and inland water altimetry

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Funded under the European Space Agency Earth Observation Science for Society Programme, the HYDROCOASTAL project aims to maximise the exploitation of Synthetic Aperture Radar (SAR) and Interferometric SAR (SARin) radar altimeter measurements in the coastal zones (CZ) and inland waters (IW), by evaluating and implementing new approaches to process SAR and SARin data from CryoSat-2 (C2), Sentinel-3A and Sentinel-3B missions.

In this context, as part of the effort to develop tuned altimeter products over CZ and IW zones, the University of Porto developed enhanced dry tropospheric corrections (DTC) and wet tropospheric corrections (WTC) over these regions. The study was conducted over 25 different regions of interest, including several rivers, lakes and coastal regions, spanning a wide variety of atmospheric and surface conditions.

The new tropospheric corrections were statistically evaluated against the corresponding corrections present in the Cryosat-2 and Sentinel-3 products. The main results and conclusions are presented in this study.

The major errors in the DTC over IW regions are due to the height dependence of this correction, 2.5 cm per each 100 m of height variation. For this reason, when the reference heights have large uncertainties, the corresponding DTC provided in the current products may still possess significant errors of several centimetres, in particular over narrow rivers or high-altitude rivers and lakes. Instead of using the model orography or the altimeter measured heights, which may be incorrect or unavailable, the adoption of a global digital elevation model (DEM) improved over IW regions such as the Altimeter Corrected Elevations vers. 2 (ACE2) is recommended. Moreover, the reference height at which the tropospheric corrections (DTC and WTC) have been computed should be provided in the altimeter products, to allow for the application of corrective terms, in case more accurate retracked heights become available and these differ from the reference heights by more than 40 m.

Regarding the WTC, it is well-known that due to the land contamination, the correction derived from the on-board microwave radiometer (MWR) cannot be used near the coast nor over IW regions. Although the accuracy of current numerical weather models (NWM) has been increasing and the differences between the model-derived WTC and those based on observations are statistically small, these can still be significantly different at small scales. Moreover, the ECMWF operational model currently provided in the altimeter products is not stable and is not advisable for use in climate studies.

For coastal and IW regions, a continuous WTC such as the Global Navigation Satellite Systems (GNSS) derived Path Delay Plus (GPD+), based on available and valid MWR observations, calibrated against a stable source such as the Special Sensor Microwave Imager (SSM/I) and SSM/I Sounder (SSMIS), is advisable. Apart from incorporating most existing external WTC sources such as imaging radiometers and GNSS, the GPD+ WTC adopts the current most stable NWM, ERA5, as first guess in the estimation process, and as the final WTC in the absence of observations, making these corrections suitable for use in climate studies.

Declining Freshwater Resources of India: Challenges in Adaptation Under a Changing Climate

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Major challenge associated with the management of freshwater resources in India is the abnormalities and uncertainties in climate. India has 18 percent of the world's population, but only 4 percent of its water resources, making it one among the most water-stressed countries in the world. With changing climate, increasing water demands in the domestic, agricultural and industrial sectors, and fast deterioration of the water resources, India is heading towards a water crisis. Life of millions living in climate sensitive river basins and wetlands make India one among the countries highly vulnerable to the impacts of climate change. Drylands are potentially threatened by desertification. Indian economy and life of the majority has been traditionally linked to agriculture, the largest consumer of water. Abnormalities in rainfall seriously affect water availability and agricultural production. Extreme hydrological conditions affect hydropower generation and industrial development. Increasing rainfall seasonality in certain parts reduces groundwater recharge and summer water availability. Changes in the intensity, frequency and tracks of storms increasingly salinate coastal aquifers. In the Western Ghats Mountain area, increasing intensity of rainfall results in erosion and sedimentation, reducing reservoir capacity and summer flow in rivers. Retreat of Himalayan glaciers is likely to have large impact on water resources in entire north India. Water resources are getting increasingly polluted. Water related health issues are worsening. Vector-borne and water-borne diseases extend into new areas. Even the heavy rainfall zones face serious water shortage as a result of drawbacks in water conservation and management. Most of the surface and groundwater resources are highly contaminated. Falling availability of reliable water leads to socio-economic issues such as water disputes, migration, pricing of water that is unaffordable to millions and large investments for the adaptation and mitigation. Present economic growth is likely to be haltered. India's preparedness for the effects of climate change is poor and India was too late to develop a climate policy. Though several initiatives have been started in the water sector as part of adaptation such as action plan on major rivers, protection of wetlands, groundwater recharge and introduction of water efficient technologies in agriculture and industries, the progress is slow because of issues like lack of coordination of departments, weak and corrupt administrative mechanism, social issues and vested political interests. Vulnerable groups are often neglected in decision making and policy development. Projects lack transparency and accountability. India urgently needs appropriate policies and strategies and an efficient implementation mechanism to face the challenges in water sector. A mix of traditional, environment-friendly methods and modern technologies in water conservation and quality improvement could perform better. This paper assesses the impact of climate change on water resources of India and its reflections on different sectors. Changes in water availability in two decades from now under an altered climate have been estimated using hydrological model, based on the projections of climate models. Existing policies and adaptation strategies have been critically reviewed to suggest guidelines for adaptation and mitigation measures in the water sector to face the impending water crisis.

Hydrogeodesy for addressing key hydrological questions and water resource sustainability

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Increasing climatic and anthropogenic pressures are changing the world's water resources and hydrological processes at unprecedented rates. These pressures require ongoing evaluation of changes in the Earth's system and the water cycle. The current and rapid changes call for an urgent, global-scale, holistic assessment from both ground and space. We can address many open questions about the evolving state of Earth's water cycle and climate through the emerging field of hydrogeodesy: the science that measures the Earth's solid and aquatic surfaces to understand changes in water's availability, distribution, movement, and properties. Hydrogeodesy encompasses various geodetic technologies, including Altimetry, Interferometric Synthetic Aperture Radar (InSAR), Mass Gravimetry (e.g., the Gravity Recovery and Climate Experiment (GRACE) and GRACE-Follow On (GRACE-FO), Global Navigation Satellite Systems (GNSS) and GNSS Interferometric Reflectometry (GNSS-IR). During the last thirty years, these technologies have been used successfully to quantify changes in surface and groundwater resources from the local to the global scale. Comprehensive scientific reviews of these technologies already exist in the literature, highlighting each technology's limitations, requirements, and applications to track water. Yet, how the use of these technologies has recently evolved, and the role they play within current hydrological and sustainability frameworks remains to our knowledge unaddressed. Here, we first perform a meta-analysis of approximately 3,000 articles dealing with hydrogeodetic technologies to understand the range and trends of their application. Second, we discuss the potential hydrogeodetic technologies to transform our understanding of water sciences and climate under the umbrella of key hydrological and sustainability frameworks such as the Sustainable Development Goals of Agenda 2030, the Planetary Boundaries framework guiding towards a safe operating space for humanity, and the 21 Unresolved Questions of the International Association of Hydrological Sciences (IAHS). We find a marked and growing increase in publications of these technologies, with more studies combining several to increase the understanding of hydrological systems. Yet, we argue that hydrogeodesy can still be expanded to fill specific knowledge gaps in the hydrological community and guarantee a safe operating space for humans in terms of water resources. These geodetic technologies have reached a level of maturity that warrants their role in supporting key global water issues, including evaluating the impact of humans on water resources, sustainable consumption of water resources, and the resilience of these socio-hydrologic systems to change. The recently launched Surface Water and Ocean Topography (SWOT) mission and the upcoming NASA-ISRO Synthetic Aperture Radar (NISAR), and the European Space Agency's HydroGNSS are some of these instruments that offer the greatest hydrogeodetic potential to monitor the Earth's freshwater resources and their sustainability.

Evaluation of snowfall retrieval capabilities of the Arctic Weather Satellite mission: analysis of some case studies

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Snowfall is a fundamental part of the global hydrological cycle. Passive microwave (PMW) snowfall retrieval algorithms are necessary for global snowfall monitoring. However, in high-latitude regions, where snowfall is predominant, the weakness of the signature generated by the very light snowfall events, the contamination by the background surface signal due to the extremely cold and dry environmental conditions, and the emission signal related to the presence of supercooled cloud water make the retrieval difficult. The exploitation of a wide range of PMW channels, including low-frequency channels for background surface characterization at the time of the overpass, in machine learning techniques has been demonstrated to be effective for snowfall retrieval at high latitudes. As a part of the ESA RainCast study, which is dedicated to the assessment of snowfall observation capabilities of spaceborne microwave active and passive sensors, the snowfall retrieval capabilities of the future Arctic Weather Satellite (AWS) mission Microwave Radiometer (MWR), - a 19-channel cross-track scanning radiometer covering the frequency range 50–325 GHz - are investigated. Case studies of snowfall events extracted from a dataset of coincident observations by Cloud Profiling Radar (CPR) and currently available cross-track scanning PMW radiometers are analyzed. Cloud and precipitation vertical profiles derived from combined CloudSat/CALIOP observations using the EarthCare mission CAPTIVATE algorithm and surface emissivity spectra obtained from TESSEM-TELSEM models are used in a radiative transfer model to simulate AWS MWR measurements; coincident PMW measurements are used as reference to verify the simulation process reliability. In this study we investigate: 1) the added value of the MWR 325 GHz channels for light snowfall observations at high latitudes 2) the impact of the improved sounding capabilities of MWR combined with 89 GHz channel measurements for supercooled water detection in presence of snowfall; 3) the impact of the lack of low-frequency channels on MWR snowfall detection capabilities in cold and dry conditions.

Projecting spatiotemporal streamflow changes in a Mediterranean coastal watershed: Insights from EURO-CORDEX and CMIP6 models

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Abstract:
Understanding how climate change affects hydrological systems is critical for sustainable water resource management and adaptation planning. This study focuses on evaluating the impact of climate change on streamflow in the Loukkos basin, located in northwestern Morocco. This basin, characterized by diverse topography and land cover, is susceptible to water scarcity, especially in recent years. To evaluate these impacts, the Soil and Water Assessment Tool (SWAT) was employed to assess streamflow changes under multiple climate change scenarios for three future periods: near (2021-2040), mid (2041-2070), and far (2071-2100) compared to a baseline period of 1981-2020. To capture the range of uncertainties, a set of bias-corrected climate models, including five regional climate models (EURO-CORDEX) and four global climate models (CMIP6) along with their ensemble mean, were utilized for two representative concentration pathways (RCP 4.5, RCP 8.5) and shared socioeconomic pathways (SSP2-4.5, SSP5-8.5). Furthermore, the Land use and Land cover map used as the input model was generated using a random forest-supervised classification based on multi-temporal Sentinel-2 data. Moreover, calibration, validation, and uncertainty analysis were performed using the Sequential Uncertainty Fitting Version 2 algorithm within SWAT-CUP at ten hydrological stations. The simulation results demonstrate satisfactory performance, with Nash-Sutcliffe efficiency exceeding 0.77 and a percent bias within ±10% on a monthly basis at most stations. Overall, 82% of the models suggest a decline in future streamflow, with the largest decrease projected for the far-future period (2071-2100) under the RCP 8.5/SSP5-8.5 scenario. The study's findings provide valuable insights for water resource management and climate change adaptation in the Loukkos basin, guiding proactive measures such as constructing additional water storage facilities, promoting water-efficient technologies, and adopting sustainable water management practices. Besides, the study emphasizes the need for climate services to inform policy development and underscores the value of considering projected changes in streamflow and precipitation for sustainable water resource management. Further research is recommended to explore other hydrological processes and their future evolution.
Keywords: Climate change, streamflow assessment, Loukkos basin, SWAT model, CMIP6, Sentinel-2, water resource management

The use of hydrological modeling to determine the site index for Scots pine (Pinus sylvestris L.)

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The aim of this study was to evaluate site index estimators in Scots pine stands in selected small forest watershed located in Poland. To accomplish this objective, site index curves and hydrological factors for Scots pine stands in Poland were developed. Another objective was to uncover water-productivity relationships in Scots pine stands in the investigated watersheds. These objectives were accomplished by analyzing the potential ground water level, relative height and the distance to the nearest watercourse as well as dendrometric data collected from 45 pure Scots pine stands formed in sample plots.
In order to achieve the dendrometic and hydrology variability of Scots pine stands in the studied area, 45 plots on 5 varied watershed from the National Forest in Poland were selected. In these plots 1350 trees were bored at stump at breast height (1.3 m), additionaly information concerning the BHD (breast height diameter), height of the trees, distance to the nearest watercourse and relative height measured from the watercourse were gathered. Hydrological factors were modeled in SWAT PLUS. For analyzing all of these factors containing a high number of features per observation, increasing the interpretability of data PCA (Principal components analysts) analyst were carried out.
In summary, it can be observed that based on precise DEM (Data Elevation Model) we can indicate areas with permanent access to the ground water which has significant influence on the growing process of Scots pine, proved by annual ring analysts.

The Flood and Drought Research Infrastructure: Integrating Earth Observation Data for Hydrological Research

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The Flood and Drought Research Infrastructure (FDRI) is a £38 million investment aimed at enhancing hydrological research and improving the UK's resilience to floods and droughts. This infrastructure combines fixed and mobile catchment monitoring, digital infrastructure for data delivery, innovation platforms, and community building programs. As part of the FDRI, there is a need to engage with the hydrological community to explore the utilization of Earth Observation (EO) data.

While EO products related to hydrology are already used in operational workflows for emergency response and numerical weather prediction, wider uptake of EO datasets by practitioners delivering solutions for water resources, flooding, and agriculture requires robust data infrastructure to support access, extraction, and analysis.

FDRI aims to address this by developing a digital infrastructure that integrates EO data with traditional and new forms of in situ monitoring data. The integration of multiple data sources, including satellites, unmanned aerial vehicle (UAV), and in situ measurements, is seen as the next step-change in hydrological space observations.

To facilitate the use of EO data by the wider UK hydrological community, FDRI is engaging with users to understand their requirements and explore the potential applications of EO data. This engagement involves workshops, questionnaires, and user-driven activities to capture user needs and prioritize the development of digital infrastructure and community data access. The aim is to increase the accessibility of hydrological monitoring data, support innovation in hydrological monitoring, and enable the integration of EO data within existing analytical workflows.

By engaging with the hydrological community, FDRI seeks to bridge the gap between the potential benefits of EO data and its current underutilization. The initiative may provide a pathway for operational use of hydrological EO datasets, supporting applications such as flood management and prediction. Through ongoing user engagement and the development of digital infrastructure, FDRI aims to transform the way researchers access and use EO data, fostering advancements in hydrological research and enabling evidence-based decision-making for water resources management.

Waterjade: Digital Twin solutions for the optimization of water forecast

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"How much WATER is available for my plant?"
"How does it impact natural resources?"
"How can I manage extreme events?"
The answers to these questions are particularly important, not only to Public Authorities in charge of water resources management and civil protection, but also to many industrial operators, like hydropower companies and water utilities, that need to abstract water for their daily operations. Furthermore, climate change and the EU Taxonomy forcing the production of ESG reports contribute to the urgency of these questions.

While water in the plants is usually well monitored and optimised, water in the environment is still overlooked by the industrial sector, being commonly approached through simplistic models, e.g., low-resolution open source global portals, or through predictions exclusively tuned on historical data.

Waterjade is a novel modelling approach to account for the current climate regime. It takes as input in situ observations, satellite data and weather forecasts integrating them in a high resolution comprehensive dataset. In particular, EO data are used to measure Snow Cover Area in mountain regions and estimate water level in medium-size water bodies. These data, properly processed, feed a modelling chain composed of physical models and machine learning, that tracks the entire water cycle in the catchment.

As an example, we report a study carried out in four mountain catchments in north-eastern Italy, managed by VIACQUA water utility, to assess the variation of water availability in the medium term using ECMWF seasonal products (forecast of future months) and long term climate projections using CMIP6 products. Medium-term forecast makes it possible to identify periods of water abundance or drought and to plan the management of the resource. The long-term study, on the other hand, is necessary to verify the seasonal variations and trends of the variables connected to the water cycle and to evaluate the vulnerability of the current abstraction system. The case study first involved a historical analysis in order to calibrate the physical and machine learning models used. Different components of runoff in the basins, including snowpack evolution and evapotranspiration, were analysed in detail, all taking into account the effect of mass infiltration caused by the karst that characterises the study area.

The projection results show the trend of decreasing volumes of water available at the closure sections caused in general by an increase in evapotranspiration, correlated with increasing temperature, and a quasi-stationarity of mass made available with total precipitation. Seasonality also seems to change a lot with anticipations in snowmelt and also in recharge time of the analysed aquifers. Seasonal forecasts are updated each month using new forecasts made available by ECMWF and are made available to the customer who can consult the different scenarios and optimise their operations.

Coupled hydrological-hydraulic modeling and data assimilation of the Niger and Maroni Rivers using SWOT river products and other EO missions

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The SWOT mission (NASA, CNES, UK-SA, CSA) launched in December 2022 provides observations of surface of inland water bodies at unprecedented resolution and accuracy. Here we focus on the Level 2 river products (heights and widths at 200m scale) and we assess their usability in creating coupled hydrological-hydrodynamic simulations of large scale basin where in-situ data are sparse.
First we use an automated toolchain (see REF Abstract R&T Modélisation multi-échelle et multi-source) that generates (i) the mesh and processed input data for spatially distributed hydrological model SMASH [2], (ii) the flux coupling points to inflow the hydraulic model with for SMASH and MGB [1] models, (iii) the mesh for the hydrodynamic 1D model (DassFlow-1D [3]) using either SWOT L2 river observations of water heights and widths or other EO missions (ICESat-2, Copernicus Sentinels).
Then we perform Global Sensitivity Analysis of this model with respect to the unobserved quantities to be estimated, using data assimilation, by the toolchain (channel bathymetry and friction coefficient) and the inflow discharges estimated by the hydrological model at the coupling points.
Finally we conduct experiments of data-assimilation of the SWOT L2 river height in order to correct the unobserved quantities and the inflow discharges using advanced techniques taking into account correlated effects of control variables and simulated water surface properties. The accuracy obtained using this method is assessed by comparing with the sparse existing in-situ data and in terms of physical consistency of simulated flow signatures with some EO data selected for validation.
This methodology is illustrated on two different cases: the Niger River with a single branch river portion between Tombouctou and Niamey and the Maroni basin with a multi-branch river network.

References:

[1] https://www.ufrgs.br/lsh/mgb/what-is-mgb-iph/
[2] SMASH (Spatially distributed Modelling and ASsimilation for Hydrology) - https://smash.recover.inrae.fr/
[3] https://www.math.univ-toulouse.fr/DassFlow/

An automatic river segmentation tool for preserving hydraulic signatures

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We present a new tool for computing automatic segmentation of rivers network adapted to new fine-scale altimetry missions (for instance the SWOT mission launched in December 2022). This tool aims at preserving the visibility of hydraulic signatures and hydraulic controls. This tool first projects the water altimetric heights on a wavelets basis automatically selected to minimize the discrepancies between the original signal and the reconstructed signal from the wavelets projection. Then a novel method filters the noise in the water height profile by zeroing some of the wavelet coefficients in order to obtain a physically consistent signal that is monotonically decreasing from upstream to downstream. Finally this physically consistent version of the water height signal is filtered at a length scale prescribed by the user (that depends on the length characteristics that the user wants to detect in the signal) and applied to the multi-scale wavelet decomposition. The segmentation of a river portion is then computed by detecting maximums of curvature and inflexion points corresponding to hydraulic controls signature [Montazem et al, 2019, Montazem 2020].
Applications of this new tool, developed in Python and including its own wavelet library, are first presented on 3 river portions with synthetic data to illustrate the method. Then the application on more realistic cases on river networks with simulated SWOT observations are presented.

References:

Montazem A. S., Garambois, P. -A., Calmant S. ,Finaud-Guyot, P., Monnier, J., Moreira, D. Minear, J. T., Biancamaria, S. (2019). « Wavelet-based river segmentation using hydraulic control-preserving water surface elevation profile properties ». Geophysical Research Letters. https://doi.org/10.1029/2019GL082986

Montazem A.S. « Représentation et segmentation hydraulique effective de rivières à l'échelle globale pour le calcul de débit par altimétrie SWOT ». PhD thesis, Toulouse University, 2020

SAR, SARin, RDSAR and FF-SAR Altimetry Processing on Demand for Cryosat-2, Sentinel-3 and Sentinel-6 at ESA's Altimetry Virtual Lab

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The scope of this presentation is to provide an update on the ESA radar altimetry services portfolio for the exploitation of CryoSat-2 (CS-2), Sentinel-3 (S-3) and Sentinel-6 (S-6) data from L1A (FBR) data products up to SAR/SARin L2 geophysical data products. At present, the following on-line & on-demand services compose the portfolio:

- The ESA-ESRIN SARvatore (SAR Versatile Altimetric TOolkit for Research & Exploitation) for CS-2 and S-3 services. These processor prototypes allow the users to customize the processing at L1b & L2 by setting a list of configurable options, including those not available in the operational processing chains (e.g., SAMOSA+/++ and ALES+ SAR retrackers).

- The ESA SAMPY for CryoSat-2 service. It allows the users to append the output of the SAMOSA+ retracker to official CryoSat-2 Level-2 GOP products. The retracker has been developed within the ESA Cryo-TEMPO project and is also available open source on GitHub at https://github.com/cls-obsnadir-dev/SAMPy.

- The TUDaBo SAR-RDSAR (TU Darmstadt – U Bonn SAR-Reduced SAR) for CS-2 and S-3 service. It allows users to generate reduced SAR, unfocused SAR & LRMC data. Several configurable L1b & L2 processing options and retrackers (BMLE3, SINC2, TALES, SINCS, SINCS OV) are available.

- The TU München ALES+ SAR for CS-2 and S-3 service. It allows users to process official L1b data and produces L2 products by applying the empirical ALES+ SAR subwaveform retracker, including a dedicated SSB solution.

- The Aresys FF-SAR (Fully-Focused SAR) for CS-2 & S-3 service. It provides the capability to produce L1b products with several configurable options and with the possibility of appending the ALES+ FFSAR output to the L1b products.

In the future, these services will be extended, and the following new services will be made available:

- The Aresys FF-SAR service for S-6, including the SAMOSA+ retracker.

- The CLS SMAP S-3 FF-SAR processor (https://github.com/cls-obsnadir-dev/SMAP-FFSAR), extended to process S-6 data including the SAMOSA+ retracker.

- The ESA-ESTEC/isardSAT L1 S-6 Ground Prototype Processor.

Unfocused SAR services will be updated to process S-6 data and an enhanced graphical user interface will be deployed allowing users to inject shapefiles to better define the areas of interest.

The possible addition of innovative coastal zone & inland water retrackers is also under investigation.

All output data products are generated in standard netCDF format and are therefore also compatible with the multi-mission "Broadview Radar Altimetry Toolbox" (BRAT, http://www.altimetry.info).

The SARvatore Services have been migrated from the ESA G-POD (https://gpod.eo.esa.int/) to the Altimetry Virtual Lab, a community space for simplified services access and knowledge-sharing. It is hosted on EarthConsole (https://earthconsole.eu), a powerful EO data processing platform now also on the ESA Network of Resources. This enables SARvatore Services to remain open for worldwide scientific applications (info at altimetry.info@esa.int). This service has more than 120 users and sponsored so far more than 500 CPU years, leading to more than 30 publications and 3 PhD theses.

A brochure containing instructions can be viewed at https://earthconsole.eu/knowledge-base/.

SWOT PHENOMENOLOGY AND PROCESSING FOR HYDROLOGY

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The Surface Water and Ocean Topography (SWOT) satellite was launched on December 16th 2022. This innovative altimetry mission is a joint project of the National Aeronautics and Space Administration (NASA) and the French Space Agency "Centre National d'Etudes Spatiales" (CNES), with contributions from the Canadian Space Agency (CSA) and the United Kingdom Space Agency (UKSA). SWOT's main payload is a Ka-band Radar Interferometer (KaRIn) operating at near-nadir incidences (~1°-4°). This Interferometric Synthetic Aperture Radar (InSAR) has a High-Rate (HR) mode dedicated mainly to continental water surfaces, aiming at extracting water surface elevation, area and related parameters with unprecedented accuracy, with global coverage up to 78° latitude and two or more observations per 21-day orbit cycle.

In this introductory presentation, we will share highlights from the first months of SWOT data acquisition, focusing on the observed phenomenology in KaRIn HR images over continental water surfaces and surrounding land. We will also briefly describe the processing up to water masks with geolocated water surface elevations, represented in the L2 pixel cloud products (L2_HR_PIXC), and preliminary accuracy assessments. The subsequent processing and vector products for rivers and lakes, as well as the associated Cal/Val activities, will be described in separate presentations.

The raw KaRIn HR telemetry data undergo time-domain SAR processing to obtain interferometric pairs of single-look complex (SLC) images. Prior to phase unwrapping and computation of geolocated heights, the water bodies are identified using a binary Bayesian classifier with Markov Random Field (MRF) regularization. Geophysical corrections are also computed.

The water detection performance is strongly dependent on the water/land contrast, and the computation of water surface elevation is also dependent on backscattering power. The water backscattering mainly depends on the water roughness at the scale of the wavelength (8.6 mm at Ka-band), which is generally related to the wind speed at the water surface (and to a lesser extent water turbulence): at very low wind speed, below 1-2 m/s, the water surface is expected to be smooth and act more or less like a mirror, yielding a very weak backscattered power at 1°-4° incidence, referred to as "dark water", in which case water cannot be detected based on the water/land contrast. The SWOT HR data reveal how often "dark water" occur, and to what extent it can be mitigated based on a prior water mask.

Another concern is that bright land structures may cause false water detection. While most natural surfaces are expected to have weak backscatter at Ka-band for near-nadir incidences (forest, grassland…), some land types and in particular man-made structures (wet sand, humid soil, roads, buildings…), as well as topographic layover, may yield a strong response that can be misclassified as water. Again, real SWOT HR data allow us to assess to what extent this is a problem, and whether it can be successfully flagged based on prior data.

Many examples of power images, detected water masks and extracted water surface elevations will be shown.

Automatic toolchain for the generation of coupled hydrology-hydraulic simulations and data assimilation from multi-sources and multi-scales data fusion

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The generation of input materials for the simulation of water storage-flows within a basin using a coupled hydrological-hydraulic model is often difficult and time-consuming (e.g. Pujol et al. 2020, Malou et al. 2021, Pujol et al. 2022). This requires dealing with multiple sources of heterogeneous data in terms of nature, spatio-temporal resolution and format, multiple pre-processings and corrections (for instance the Digital Elevation Model must be corrected to remove depressions) and determination of the coupling frontiers between the hydrological and the hydrodynamic parts of the model. Most of the time these steps are manually or semi-automatically performed on GIS (Geographic Information System). However with the new fine-scale Earth Observation missions such as SWOT, the volume of data requires these steps to be automated.
Here we present a new toolchain that aims at performing all the necessary preprocessings needed to generate a coupled hydrology-hydrodynamic modeling of a basin and its river network and floodplains. This toolchain first generates the input data for the hydrological part of the model (DEM correction and computation of flow directions, colocation of physical descriptors and meteorological forcings on a same grid, etc.) and the hydrodynamic part (generation of the cross-sections profiles, etc.). Then it computes the location of coupling frontiers between the hydrological and hydrodynamic parts. Finally the toolchain can also preprocess data for assimilation (ensure location of in-situ data and computed water surface elevations and widths on the river network, etc.).
This toolchain, implemented on Python and based on open-source GIS (Geographical Information System) libraries, is demonstrated on the Maroni Basin (French Guyana) where a completely new model has been generated from multitple EO datasources (ICESat-2, SWOT) and results of data assimilation experiments are presented.

References:

Pujol, L., Garambois, P.-A., Monnier, J. (2022) Multi-dimensional hydrological-hydraulic model with variational data assimilation for river networks and floodplains. (Geoscientific Model Development) https://doi.org/10.5194/egusphere-2022-10

Malou T., P.-A. Garambois, A. Paris, J. Monnier, K. Larnier. (2021) Generation and analysis of stage-fall-discharge laws from coupled hydrological-hydraulic river network model integrating sparse multi-satellite data. Journal of Hydrology,
https://doi.org/10.1016/j.jhydrol.2021.126993

Pujol, L, Garambois, P.-A., Finaud-Guyot, P., Monnier, J., Larnier, K., Mosé, R., Biancamaria, S., Yésou, H., Moreira, D., Paris, A., Calmant, S. (2020). « Estimation of Multiple Inflows and Effective Channel by Assimilation of Multi-satellite Hydraulic Signatures: Case of the Ungauged Anabranching Negro River ». Journal of Hydrology, https://doi.org/10.1016/j.jhydrol.2020.125331

Improving inland water altimetry through retracking of radargrams instead of single waveforms

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Satellite altimetry has emerged as a crucial tool for understanding the Earth system. Originally developed for oceanography and geodesy, it has also proven valuable for monitoring lakes and rivers. However, when using altimetry for inland, there is always a gamebreaker: retracking. The current retracking methods heavily rely on a single waveform to obtain a retracker offset, resulting in a high susceptibility to every individual peak in the waveform and a strong dependency on the waveform's shape for a successful retracking. Here we propose a 2D retracking method that moves beyond a single point in the 1D waveform and instead seeks a retracking line within a 2D radargram (i.e. stack of waveforms within one overpass over a water body). By identifying this line, each radargram can be divided into two segments: the left (front) and right-hand side (back) of the retracking line. Such a segmentation approach can be interpreted as a binary image segmentation problem, incorporating spatial constraints for a more intuitive representation. We formulate this problem using Markov Random Fields (MRFs), which explicitly model the interaction between neighboring pixels (i.e., between waveform power values in two consecutive measurements) and overall probability that each pixel within the radargram receives a particular value. In this formulation, within a Bayesian framework we aim to find a specific labeling structure of the image that maximizes the posterior estimates of the MRF.

We employ our method to four small lakes—Mendota, Waubesa, Kegonsa, Houghton—and the large lake of Michigan in the USA. The resulting water level time series are validated against in situ data, demonstrating notable improvements in terms of correlation and RMSE. Our proposed retracker, which operates in both the bin and spatial domains, exhibits robustness against waveform unexpected peaks, independence from waveform type, and benefits from the spatial relationship between waveforms.

Developing Best Practices for Flood Map Validation

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The evolving field of remote sensing applications demands robust validation practices which enable map accuracy and uncertainty estimation at a variety of scales. Target-suited metrics and area estimation approaches are thus necessary, to improve the sensitivity of accuracy assessments and enable meaningful comparisons across different classification methods. Current state-of-the-art validation frameworks in remote sensing are based on the field of land use and land cover (LULC) classification, but unfortunately the recommended good practices have not yet been transferred to other fields. For instance, in the field of remote sensing-based flood mapping where knowing and communicating map accuracy is critical, the lack of standardized validation best practices leads to a lack of trust in the products, which limits their operational use and user uptake. The binary flood detection problem additionally presents the challenge of class imbalance between flood and non-flood classes, since the observed flood inundation typically only covers the satellite data tile partially. As most binary map comparison metrics are sensitive to flood magnitude, the accuracy assessments are inconsistent and not transferable in space or time, leading to low confidence for users wanting to build downstream applications, such as insurance underwriting, for example. Accordingly, the impact of current binary validation practices in the context flood mapping are evaluated here across multiple globally distributed study sites as well as flood magnitudes, and best practices for the evaluation of flood maps are identified. Through synthetically generated flood inundation maps from Sentinel-1 synthetic aperture radar data with controlled errors, binary metrics are statistically evaluated for the quantification of flood detection accuracy for flood events in India, Bangladesh, Australia, Mozambique, and France. Results indicate a strong positivity bias, wherein classifiers which overestimate flooded area are penalized lesser than those that underestimate inundation. All metrics were also found to be sensitive to the class imbalance, i.e. larger flood magnitudes result in higher scores, with the standard use of the entirety of available pixels, resulting in limited variation in metric scores with changing errors. Metric stability across error and flood magnitudes was assessed through score variance calculated by bootstrapping, where stratified sampling schemes exhibited the lowest variance across error classes and study sites. Probability sampling, random sample and proportional class allocation were found to be important factors in producing robust accuracy estimates. However, a universal approach could not be identified, only best practice guidelines could be provided, which recommend to define the validation strategy based on the target of the mapping exercise and the available reference data. Findings imply that robust estimation of map accuracy and uncertainty are possible using available reference datasets, undertaking which could increase confidence in remotely sensed flood maps for users and stakeholders alike.

High resolution estimation of SSS and SST in coastal seas from Satellite imagery

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Coastal zones are subject to a mixture of complex natural and anthropogenic influences. River plumes provide influxes of organic material, increasing ecological complexity by the introduction of nutrients, upwelling brings cooler nutrient rich water and reefs and mangroves can protect the shore from erosion and diminish impact of extreme weather events. The complexity of processes in these regions as well influences from evaporation, precipitation, vertical mixing and advection requires high resolution differentiation of different temperate and saline zones.

Typically, thermal and microwave remote sensing is employed to retrieve SST and SSS in aquatic systems. Satellite-derived ocean colour provides the opportunity to process data at a higher temporal and spatial resolution than traditional microwave remote sensing, with ocean colour satellites having pixel resolution on the tens to hundreds metre scale compared to microwave km scale. Sea surface salinity (SSS) and temperature (SST) are essential variables for monitoring and understanding ocean health.
This paper explores a new methodology to extract SST and SSS from hyper/ multispectral ocean radiance. Water leaving radiance is linked to the inherent optical properties of the water column, effected by the constituent parts for example from coloured dissolved organic matter, chlorophyll and total suspended matter. These parts contribute to the backscatter, absorption and reflectance coefficients, influencing the spectral signature of the radiance.

This paper considers multiple sources of spectral information, both multispectral satellite images from Sentinel 2 with the benefit of the 10 m resolution, which enables to monitor smaller aquatic systems. As well as Sentinel 3 hyperspectral imagery with a reduction in spatial resolution but an increase in spectral bands. The satellite images were matched with buoys measuring temperature and salinity records in 30-minute increments from 2015-2021 in the Gulf of Mexico.

The matched satellite spectral bands are used as inputs to a mixture of machine learning regression models from gradient boosting to neural networks with SST and SSS predicted independently from the spectra. These models demonstrate a link between the ocean colour/ radiance values and the sea surface physical properties temperature and salinity, with a model accurately estimating SST and SSS from just radiance.
Feature selection was trained on these models to identify the bands with greatest importance to both SST and SSS and help to remove the “black box” which is often an issue with the machine learning non-parameter based models.

This relationship between sea surface properties and spectral signatures is then tested in satellite ocean colour images which can be used to monitor these environmental properties with more regular temporal sampling, better spatial coverage and in previously inaccessible locations. These images can provide a clearer picture of the extent of the land influence in the coastal ocean and quantify the impact of e.g. riverine systems and water cycle in these seas.

Enabling Flood Inundation Forecasting Through Satellite-based Flood Extent Assimilation

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Concurrent rapid developments in the fields of Earth Observation, big data analysis, access to distributed computing and storage, can now support the development of Digital Twins of the Earth. The Digital Twin is expected to enable anticipating extreme events and accordingly test the impact of different policy interventions. A Digital Twin focused on flood disasters is proposed herein, which will contribute to increased flood resilience through early warning and improved preparedness, by providing the first of its kind inundation forecasting service. Using user-centric design principles, a multi-tier user requirement collection strategy was implemented with varying levels of engagement, to collect critical stakeholder requirements for the planned product. Users identified the provision of hourly flood extent predictions, updated daily and provided with a 72-hour lead time, with integration of local data/models to provide impact analysis at local scales as critical product features. The winter 2020 storms in the Severn Catchment, UK, was selected for the pilot study, given the extensive Sentinel-1 coverage of the event. Here the integration of existing global near-real-time flood monitoring and forecasting products offered by the Copernicus Emergency Management Services, is envisioned to match the user requirements. Specifically, the Global Flood Mapping (GFM) and Global Flood Awareness System (GloFAS) Rapid Mapping products will be combined through data assimilation, to enable short-term forecasting of hourly inundation maps and reduce predictive uncertainties. The proposed data assimilation strategy, would enable more accurate daily flood maps by allowing weighted combinations of the design flood maps used internally by GloFAS, to better represent real-world conditions observed by GFM. Data assimilation algorithms are also flexible to implement, being model and resolution agnostic (i.e. any model even local ones can be used and any spatiotemporal data resolution can be integrated), as well as spatiotemporally transferable (i.e. can be reapplied to a new test site without extensive retraining or reconfiguration). Assimilating multimodal observational data is also possible as in situ or citizen science measurements become available globally. First results indicate that the assimilation of satellite derived observations improve the prediction of flood inundation. Outcomes from this proof-of-concept study can inform future research and help bridge the global flood protection gap.

Designing an Operational Water Bodies Monitoring System from Space at National Scale to Support Civil Protection and Water Management Applications: a Feasibility Study

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This work aims at describing the design of a system capable to monitor from space – in Near Real Time (NRT) – the spatiotemporal evolution of the inland Water Bodies' (WB) extent. The final objective is to quantify the percentage of WB extension with respect to its maximum level. This information is particularly useful to support civil protection applications and the decision makers accountable for water management issues; especially during crisis period (e.g., like the occurrence of drought events), in data scarce environments (e.g., ungauged WB) and/or when this information is not shared with public authorities.
Although the system is conceived to work - operationally - at national scale (e.g., the Italian territory), its initial implementation (to be considered as feasibility study) was carried out at regional scale, in Southern Italy.
The presented system is based on Sentinel 2 (S2) data, from which different spectral indexes are extracted to automatically map the WB extent with a spatial resolution of 10-20 m (e.g., NDWI, MNDWI, etc.). For each index, a combination of an edge detector and the Otsu thresholding method is used to delineate the WB. During the processing, each WB is processed individually because the suitability of a single threshold for a whole S2 image is generally not ensured. The WB maps obtained for each index are then weighted and combined to produce a more accurate map. The final WB extent is then compared against a reference layer corresponding to the maximum WB extent recorded in the last 3.8 decades form Landsat data (i.e., the Global Surface Water dataset). The comparison against the reference layer is fundamental to understand the WB "degree of filling", in terms of percentage.
The study area selected to perform the validation of the system's retrieval algorithm was the San Giuliano reservoir. The latter is a gauged reservoir located in Southern Italy, from which in-situ data related to the WB volume were available. These data were used to assess the accuracy of the system performance during the 2017-2022 time period.

Estimating Discharge of Narrow Rivers Using Satellite Altimetry and Optical Imagery

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River discharge is an Essential Climate Variables (ECV) as defined by the UN Global Climate Observing System (GCOS). However, recently, the number of in-situ discharge stations providing free datasets is continuously declining. Therefore, we propose a method to estimate river discharge even in ungauged basins based on the past 30 years of altimetry and remote sensing data.

In our approach, water level observations from satellite altimetry are combined with high-resolution optical satellite imagery from the PlanetScope constellation to estimate the bathymetry of rivers between 50 and 100 m wide. This is used in combination with variable water surface slopes obtained from the ICESat-2 mission to derive river discharge. The roughness coefficient is estimated in an at-many-stations approach by minimizing the discharge differences between multiple stations within a river reach.

We don’t need to calibrate this approach with in-situ data so that it can also be applied at ungauged basins. Moreover, we provide realistic uncertainties, which are crucial for data assimilation, by propagating errors and uncertainties from the various input quantities. First results are close to or within the required measurement uncertainty of 10% as defined by GCOS. With this framework, we can contribute to a more comprehensive understanding of river discharge and the global water cycle.

SWOT EARLY RESULTS OVER RIVERS

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The Surface Water and Ocean Topography (SWOT) satellite was launched on December 16th 2022. This innovative altimetry mission is a joint project of the National Aeronautics and Space Administration (NASA) and the French Space Agency “Centre National d’Etudes Spatiales” (CNES), with contributions from the Canadian Space Agency (CSA) and the United Kingdom Space Agency (UKSA). SWOT’s main payload is a Ka-band Radar Interferometer (KaRIn) operating at near-nadir incidences (~1°-4°). This Interferometric Synthetic Aperture Radar (InSAR) has a High-Rate (HR) mode dedicated mainly to continental water surfaces, aiming at extracting water surface elevation, area and related parameters with unprecedented accuracy, with global coverage up to 78° latitude and two or more observations per 21-day orbit cycle.

After water detection and height extraction, the processing of KaRIn HR data divides into two branches: one dedicated to rivers, and the other one to lakes. In this presentation we will focus on SWOT observations of rivers. We will briefly describe the processing that is specific to rivers, as well as the resulting river vector products (L2_HR_RiverSP). Examples of products, preliminary accuracy assessments and associated Cal/Val activities will be presented.

The L2_HR_RiverSP products are related to the SWOT River Database (SWORD), which contains river centerlines and prior information on river reaches worldwide. The centerlines are divided into reaches that are in the order of 10 km long, which are further subdivided in nodes every 200 m along the centerline. The L2_HR_RiverSP products contain water surface area, width and average elevation aggregated to the node and reaches, as well as reach-level slope and estimated discharge.

The validation of L2_HR_RiverSP water surface elevations is based on a combination of existing gauge networks, dedicated equipment such as pressure transducers and automated lidar stations, and reach-scale height profiles from airborne or drone-borne lidar measurements. It turns out to be a challenge to obtain reference height data that have an absolute accuracy well below what is required for the SWOT river products we are validating (10 cm 1-sigma for a 100-m wide river over a 10-km long reach). The reference data are assigned and aggregated to nodes and reaches, similar to what is done when generating L2_HR_RiverSP products.

The validation of L2_HR_RiverSP water surface areas and river widths relies on reference water masks obtained mainly from (Very-) High-Resolution optical or radar satellite images (Pléiades, Sentinel-2, Sentinel-1, RCM…) and more occasionally airborne ortho-images, pre-processed so that comparisons can be made at the node and reach scales.

An overview of the Cal/Val activities will be given in this presentation, and further detailed for certain Cal/Val sites in other presentations.

IRIS Version 2: Global River Surface Slopes from ICESat-2

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The global reach-scale “ICESat-2 River Surface Slope” (IRIS, https://doi.org/10.5281/zenodo.7098113) dataset comprises average and extreme water surface slopes (WSS) derived from ICESat-2 observations as a supplement to reaches from the “SWOT Mission River Database” (SWORD, Altenau et al., 2021). WSS is required to calculate river discharge, which is among the Essential Climate Variables as defined by the Global Climate Observing System. For IRIS version 2, we switched to the latest ICESat-2 ATL13 version 6 (from version 5) with an extended observation period from October 2018 to April 2023. In addition, we use the latest SWORD version 15 (from version 2).

To gain full advantage of ICESat-2’s unique measurement geometry with six parallel lidar beams, the WSS is determined across pairs of beams or along individual beams, depending on the intersection angle of spacecraft orbit and river centerline. The combined results of both approaches are validated against in-situ data in a regional study at 815 reaches in Europe and North America with a median absolute error of 23 mm/km, almost complying with the SWOT science requirements of 17 mm/km (Scherer et al., 2022).

IRIS can be used to research river dynamics, estimate river discharge, and correct water level time series from satellite altimetry for shifting ground tracks. Additionally, by referencing SWORD as a common database, IRIS may be used in combination with observations from the recently launched SWOT mission and could be easily compared against WSS measurements from SWOT’s new wide-swath sensor.

Digital catchment twins – how holistic approaches improve decision making

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Classical data portals for Earth observation (EO) data often stop after displaying the data. However, users need to gain information from this data that supports their decision making. EOMAP is developing such digital twins for various applications, including a catchment twin. It provides an holistic view on all relevant parameters that influence the catchment's behavior, like elevation, slope, land use, soil moisture, discharge, water level, water quality, water constituents and meteorological data. The applications that are currently targeted are hydropower planning and operations, as well as river ecology twins. Although in-situ measurements are very important, these twins are especially powerful for catchments with few or no in-situ data available.

The hydropower sector can profit from EO data in several forms to improve decision making. One of the most severe problems of hydropower reservoirs is the amount of sediments that flow into a reservoir. They accumulate in the reservoir and decrease the capacity in the long-term perspective. Understanding the sediment regimes is therefore crucial for a good sediment management. EOMAP's HYPOS solution brings together well validated turbidity measurements from spaceborne optical sensors (Sentinel-2, Landsat 8/9, Planet SuperDoves), novel water level and discharge measurements from satellites, hydrological model results, and in-situ measurements. The various data form the basis for visualization, analysis, and reporting tools that improve both operational management and planning of hydropower reservoirs and dams. The holistic approach allows the calculation of sediment fluxes for almost every point in a catchment's river system – and thereby replacing several in-situ measurement stations. Another advantage is the ability to go back in time with satellite missions being in place for many years. The cloud-based processing enables extremely fast data delivery, making robust sediment analyses in a matter of hours.

Ecological disasters like the massive fish dying in the Oder River in 2022 shed light on the inability of conventional operational monitoring for whole river systems with a sparse station network, as well as difficulties that emerge from trans-national catchments. Thus, EO data in combination with historical, current and forecast information on meteorological parameters provide the means for a continuous and spatially comprehensive monitoring system. Apart from common water quality derivates such as chlorophyll-a or turbidity, hydrological parameters like river discharge and water level derived from EO (Sentinel-3, Planet SuperDoves) extend the otherwise sparse database from in-situ measurements and at ungauged locations. This expansion together with regular measurements can be exploited for a threshold-based early warning and monitoring system identifying potential hydro-ecological risks (harmful algae bloom, low flows) along the river system.

ESA/NASA Mass Change and Geosciences International Constellation (MAGIC) - Science and application prospects

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ESA and NASA are currently intensifying their long-term efforts on a collaborative implementation of a next generation mass change and gravity monitoring satellite mission under the umbrella of the NASA-ESA Joint Programme Planning Group sub-group 1. MAss-change and Geosciences International Constellation (MAGIC) is the joint NASA/ESA constellation concept based on NASA's MCDO and ESA's NGGM studies. The main objective of MAGIC is to extend the mass transport time series from previous gravity missions such as GRACE and GRACE-Follow on with significantly enhanced accuracy, spatial and temporal resolutions and to demonstrate the operational capabilities of MAGIC. The concept is based on a joint ESA/NASA Mission Requirements Document (MRD) which summarizes the goal requirements of the global scientific community (including requirements from the IGWSG report, IUGG, MCDO, etc.). The first pair of the MAGIC Constellation will be implemented via a NASA/DLR fast-paced cooperation to ensure continuity of observations of GRACE-Follow On. The second pair will be implemented by ESA with some potential NASA in-kind contributions for the Laser Tracking Instrument.

This paper will provide a status overview of MAGIC and address the novel science and applications enabled by the planned constellation for the fields of hydrology, cryosphere, oceanography, geodesy, climate change and solid Earth. Especially on hydrology, It will demonstrate the significant added value of MAGIC constellation for improving current estimations of groundwater storage, soil moisture, water balance closure, global change impacts on water cycle and for providing the capability to raise extreme events warning (e.g. drought, flood)

Modelling and Remote Sensing to estimate evaporation and water use in the Ebro Basin

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This study quantifies evaporation and its impact on water resources in the Ebro basin. The basin exhibits an uneven distribution of precipitation Although runoff is mostly generated over the Pyrenees, the water resources are mainly used in the valley for agricultural purposes. This translates into the necessity to transport and storage water from the Pyrenean slopes to the central valley by means of a complex network of dams and canals. The expansion of forests in non-agricultural areas, resulting from the abandonment of unmechanized agricultural lands, has further increased water consumption. Thus, the forest is competing with agriculture for water availability. To address these challenges, this study aims to estimate actual evaporation at fine temporal and spatial scales using remote sensing and modelling datasets, with the aim to improve the estimation of water use and help the basin managers to make better decisions.

The research consists of two main stages. Firstly, the GLEAM and Sen-ET products are compared to identify similarities and differences in space (such as rainfed vs irrigated areas, agricultural vs natural areas, and forests) and time (including seasonal variations, irrigation vs non-irrigation periods, and wet vs dry periods). Secondly, the evaporation products based on satellite data are compared with the SASER hydrometeorological modelling chain output, based on the SURFEX LSM. The objective is to assess the agreement between models and remote sensing datasets and identify potential sources of uncertainty, particularly related to irrigation and forests water use.

The outcomes of this research will contribute to a better understanding of actual evaporation patterns and their implications for water use and availability in the Ebro River basin. The findings will aid water managers to improve the estimation of evapotranspiration at different temporal and spatial scales, facilitating more efficient and sustainable water resource management practices.

Towards a Digital Twin for the Alps

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The Alps are the most densely populated mountain range in Europe and water resources play a central role in the socio-economic developments of the area (agriculture, tourism, hydropower production...). Furthermore, the Alps are particularly sensitive to the impacts of climate change. Over the last century, temperatures have risen twice as fast as the northern-hemisphere average, whereas precipitation has increased non-linearly and has become more discontinuous. As a result, geo-hydrological hazards such as floods, drought and landslides, which are expected to increase in the near future, constitute a major threat to human activity. Because of the increasing pressure on human settlements and infrastructure, there is a strong priority for policy-makers to implement climate change adaptation strategies from the local to the regional scale. To support and improve the decision-making process, numerical decision support systems may provide valuable information derived from observations or models to better manage increasing threats and weaknesses.
The main objective of the Digital Twin of Alps project is to provide a roadmap for the implementation of future Digital Twin Components, with a focus on the Alpine chain. In this context, a demonstrator (www.digitaltwinalps.com) has been developed that enables a holistic representation of some of the major physical processes specific to the Alpine context, powered by a unique combination of Earth Observation data analytics, machine learning algorithms, and state-of-the-art hydrology and geohazard models.
The resulting Digital Twin Earth precursor will provide an advanced decision support system for actors involved in the observation and mitigation of natural hazards and environmental risks including their impacts in the Alps, as well as the management of water resources. For instance, through the demonstrator users can investigate the availability of water resources in terms of snow, soil moisture, river discharge and precipitation. Furthermore, it is possible to stress the system with scenario based options to see the impacts on the various hydrological drivers in terms of drought and flood probability. Finally, the user can assess flood hazard, forecast the occurrence of shallow landslides (slope failure probability and material propagation) and predict the activity (e.g. velocity) of large deep-seated and continuously active landslides from extreme rain events through the use of a combination of physics- and AI-based simulation tools. Use cases in Northern Italy, South Swiss and South France are provided. Finally, the user can visualise maps and time series of terrain motion products over several Alpine regions generated with advanced Earth Observation processing chains and services (GDM-OPT, Snapping) available on the Geohazards Exploitation Platform and the eo4alps-landslides App, providing a consistent description of Earth surface deformation for the period 2016-2022.

Long term analysis of global surface water volume change using remote sensing data

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The availability and variations of continental water storage are of great importance for society, as they influence the agricultural, industrial and domestic water use. Among the water storage components, terrestrial surface water specifically lakes and reservoirs are essential for wildlife and human habitats as they store freshwater in the most accessible way, control seasonal floods and generate hydropower. Despite the importance, the estimation of surface water storage variation at a global scale is usually obtained from simplified models due to the absence of necessary gauge and remote sensing measurements.

In this study, we produce monthly water volume anomaly time series of 182260 global lakes and reservoirs larger than 1 km^2 from1985-2018. To do so, water area time series of lakes and reservoirs are obtained from the Joint Research Center Global Surface Water data set. We gather all publicly available in situ water level time series and generate water level time series using satellite altimetry data from various missions and data sets. For the remaining lakes and reservoirs, water height information is extracted from TerraSAR-X digital elevation model.

After collecting the required data, first the empirical water area-level model is developed for each object and then the water volume variation time series is estimated. With this data set, we can investigate the temporal and spatial variations of surface water stored in lakes and reservoirs for 1985-2018 on a global scale. This study aims to answer these fundamental questions: 1) What are the temporal behaviors of surface water volume variations in different river basins? 2) Does water volume variation trend agree with other hydrological parameters' temporal variation, And 3) what are the major natural and anthropogenic factors that explain the long-term   water volume variation?

Tracking the volume changes of shallow lakes in West Africa with remote sensing: comparison of existing methods to derive the hypsometric curve

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Water plays a crucial role in Central Sahel for agriculture, domestic use and livestock but the spatial distribution and the temporal dynamics of Sahelian water bodies is poorly known. Few in-situ networks are available in this area which make remote sensing a suitable tool for monitoring water bodies storage and variability. The hypsometric curve, a 1D model of the water body bathymetry, allows to assess water storage dynamics from water surface height and area measurements, two parameters measurable by a variety of spaceborne sensors. Several methods exists to build the hypsometric curve but few studies compare them, especially over shallow and relatively small water bodies. In this work, we compare the hypsometric curves derived using different methods and spaceborne sensors over 17 lakes and reservoirs in Central Sahel. The hypsometric curves are generated by four different methods: filling a DEM, intersecting a DEM with water contours, intersecting banks elevation transects with water contours and combining simultaneous water surface heights with water surface areas. Different elevation datasets are used: SRTM DEMs and high-resolution Pleiades DEMs, banks elevation transects from ICESat-2 ATL08 and GEDI L2A data products, and Sentinel-3 SRAL water surface heights. Water areas and contours are computed from Sentinel-2 L2A images segmented with an ad hoc threshold on the MNDWI index. Seven water bodies benefit from in situ data being either water level measurements or volume-height relationships. Our study highlights the pros and cons of each method in terms of accuracy and precision, range of observable water storage dynamics, sensitivity to remote sensing data quality and surface features, and data accessibility and availability. For most of the studied lakes our study reveals a good agreement among the different methods employed, except for SRTM derived curves, which highlights the importance of fine DEM vertical and horizontal resolutions. Hypsometric curves from Pleiades DEMs show very good results, but they require the use of external water contours to mitigate the impact of pixels correlation error, surface roughness, unconnected riparian water bodies and the uncertainty on the altitude of the lowest hydroflattened surface. Despite the low amount of data available, ICESat-2 and GEDI measurements show a hypsometric curve quality comparable to that obtained with high-resolution Pleiades DEMs, and are open-access. They also benefit from a better spatial coverage than that of radar altimeters. However, the observable water storage dynamics using lidar data, as well as DEMs, that explore the banks levels is limited to the portion of surface above the water level at the time of acquisition. Combining water surface areas by Sentinel-2 with water surface heights from altimetry needs interpolation over time because simultaneous data are rare. Moreover, radar altimeters waveforms sensitivity to soil properties and landscapes surrounding the lakes often leads to dispersion in the derived hypsometric curve. Overall, our study highlights the plurality of existing methods and the variety of combinations of remote sensing data to estimate lake water volumes and can be very useful to assess water storage dynamics in low instrumented regions.

ARARAS (Algorithm for Radar Altimetry Retracking on speculAr waveformS), a new retracking method based on physical model for nadir Low-Resolution Mode (LRM) altimetry over inland waters.

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Radar altimetry is now acknowledged as an interesting tool to monitor inland waters, both for real-time purposes and for long-term monitoring. However, the altimetry waveforms over rivers are difficult to analyse due to varying surface roughness, surrounding topography, river geometry or human facilities, and this turns their conversion into water level (WL) a challenging task. Traditional retracker such as the Offset Centre of Gravity (OCOG) is a robust and popular method to obtain WL time series (TS) from nadir LRM altimetry data. As OCOG is not specially dedicated to measurements over rivers, the difficulties of this particular environment often lead to large error in the processed WL time series. This is especially the case for Jason missions for which many waveforms are saturated over specular surfaces, and this turns the estimation of long-term WL time series from Topex/Poseidon to Sentinel-6 missions problematic.
We introduce the ARARAS (Algorithm for Radar Altimetry Retracking on speculAr waveformS), a new retracking method based on a physical model taking as inputs the centerline of the river and the characteristics of the instruments. We formulated the postulate that, when observed at nadir, only a small part of the river will interact with the emitted wave, but in a very specular way. A narrow and specular surface should be interpreted by the altimeter as a squared cardinal sine (SINC²) in the resulting waveform. This retracker looks for this typical SINC² pattern in the echoes around the assumed position of the river centreline and converts it into a WL value by applying traditional corrections. This process allows and manages the presence of multi peaks or saturated peaks in the echoes. Only a single echo is used to determine the final water surface height value and the selection is based on various criteria such as proximity to the river centerline, quality of the fitted SINC² model or the backscattering coefficient. The idea is to only use the best observation situation of the flyover to overcome as much as possible of the difficulties specific to river altimetry.

We compared our results over all the Mississippi, Amazon and Maroni basins on every available Hydroweb Virtual Stations (VS) for Sentinel-3A, Sentinel-3B and Jason-3 near an in-situ gauge station from the United State Geological Survey (USGS, United States), the Agencia Nacional de Aguas (ANA, Brazil) or the Service Central d'Hydrométéorologie et d'Appui à la Prévision des Inondations (SCHAPI, France). We assessed the quality of each TS based on three criteria: correlation, unbiased RMSE (ub-RMSE) and the percentage of points kept in the TS compared to the number of available cycles. This easy-to-implement retracking method doubles the number of "Valid TS" on the Mississippi basin compared to Hydroweb's TS. Moreover, ARARAS produces complete TS for Jason-3 due to its ability to properly process the saturated echoes, unlike OCOG, an essential step to produce long TS on Jason orbit for climate study.

Long-term Water Storage Anomalies Through GRACE Observations and Models' Estimation

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The Gravity Recovery And Climate Experiment (GRACE) satellite mission has revolutionized our ability to remotely measure total water storage anomalies (TWSA) at regional to continental scales. Carrying forward the legacy, GRACE Follow-On (GRACE-FO) was launched on 22 May 2018. Despite its various applications, the observational time span of GRACE(-FO) is limited to only 20 years of monthly data, with a one-year gap between GRACE and GRACE-FO. This relatively short record hampers the capture of global and regional climate over the long term, crucial for studies such as drought characterization and the examination of long-term climate change patterns.

To overcome this limitation, this research expands the temporal coverage of GRACE(-FO) observations back to 1980 by leveraging global hydrological, atmospheric, and reanalysis models. We compute the ensemble mean (EM) and ensemble weighted mean (EWM) of these models as the basic approach across major river basins. Additionally, we explore Non-Negative Least Squares (NNLS) together with five machine learning methods, including Multivariate Linear Regression (MLR), Decision Tree (DT), Random Forest (RF), Support Vector Machine (SVM), and Gaussian Process Regression (GPR), to hindcast TWSA prior to the GRACE era. Comparisons were made with GRACE data during the GRACE period (Apr 2002 to Dec 2012) and a high-resolution Satellite Laser Ranging (SLR) TWSA product outside the GRACE period (1992-2002).

Our findings demonstrate significant improvements over the basic approaches, highlighting the necessity for advanced and sophisticated methods to accurately reconstruct TWSA across diverse regions and climates. Among the tested methods, GPR and MLR exhibited superior performance, while SVM and DT displayed poorer performance in most basins. This research presents a solid approach for reconstructing long-term total water storage anomaly fields prior to the GRACE period (i.e., before 2002). The hindcasted GRACE dataset remarkably extends the temporal scope of TWSA observations, enriching our understanding of long-term changes in Earth's water storage.

Mapping irrigated cropland dynamics with remote sensing for water policy design and assessment

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Agriculture is the largest sectoral user of water in most semi-arid and arid regions around the world, with demands for water projected to increase significantly in future decades due to climate change and population growth. Understanding where, when, and how much water use is being used by agriculture is therefore critical for effectively managing and planning trade-offs over water between food production, the environment, and other human uses such as energy generation. Yet, in most regions around the world we have very limited information about the locations of irrigated croplands, how irrigated cropland dynamics are changing over time, or what impacts these changes are having on the wider water cycle. In this presentation, we demonstrate a solution to plug this critical data gap through using of dense Landsat time series together machine learning techniques to develop continuous fine-resolution maps of irrigated cropland areas. Through an example application to one of Africa's largest and most important transboundary river basins – the Senegal River Valley (SRV) – we demonstrate how these approaches can be used to provide spatially-rich multi-decadal data on how irrigated croplands have historic evolved over time and serve as a tool for monitoring of future system evolution. In the SRV, we show that irrigated cropland expansion has been spatially and temporally heterogeneous, with rapid expansion in irrigated croplands in the SRV post-2010 linked to food price spikes around 2007/8. Yet, we also show that expansion still lagged far behind official estimates and targets. Through this analysis, we highlight the important role that Earth Observation can play in supporting monitoring of water-food-energy nexus system intervention performance, along with also providing critical data to support projections of future system evolution and climate resilience.

Comparison of VV and VH polarization for Sentinel-1 based flood mapping

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A recent World Bank study estimates that 1.81 billion people (23% of the world population) are at risk of being affected by flooding. Climate change and rapid urbanization in zones exposed to floods are expected to further increase flood risks. Although these statistics are worrisome, valuable information on flooding can help prevent future damage and suffering, e.g., by supporting land use planning or emergency response. Earth observation can provide details such as the flood extent in a consistent and large-scale manner. Especially, spaceborn microwave sensors like onboard the European Sentinel-1 satellites show high suitability for flood mapping, thanks to their observational capacity independent of daylight and weather, and the high contrast between land and water in Synthetic Aperture Radar (SAR) images. The latter results from the low surface roughness over water, typically leading to low reflected energy received at the sensor (=backscatter), which is dependent on wavelength and polarization. However, known limitations in SAR-based flood mapping over vegetation or urban areas require the scientific community to elaborate on the existing methods. One approach is to investigate different polarization modes as input to the flood mapping.

The Interferometric Wide (IW) swath mode of Sentinel-1 generally observes land surfaces in vertical-vertical (VV) and vertical-horizontal (VH) polarization. Each polarization has its specific characteristic when being used in flood mapping. In comparison to the VH polarization, VV backscatter is generally stronger, but is more sensitive to changes in the roughness of the water surface, where wind effects and emerging vegetation result in an increase of the observed backscatter. This may conceal the low backscatter signature of water, an underestimation of the flood surface might be the consequence. On the other hand, it is generally more challenging to distinguish water from other low backscatter surfaces in the VH polarization. Furthermore, very low VH backscatter observed over water shows more noise in comparison to VV backscatter.

The Sentinel-1 based flood mapping algorithm developed by Technische Universität Wien (TU Wien) [Bauer-Marschallinger et al., 2022] performs a pixel-wise Bayesian decision by comparing an incoming Sentinel-1 measurement to the expected statistical distribution of the flood- and the noflood-class. The distribution of the noflood class is derived from a pixel-wise (local) defined harmonic model, representing the seasonality of the historic backscatter measurements. The distribution of the flood class relies on a global linear model, estimating the backscatter behaviour based on the incoming incidence angle. In the initial implementation, these paramters were based solely on VV data.

In this contribution, models for both classes are generated from VH polarized input data. Further, the algorithm is optimized to counteract the additional noise of the VH polarization, and we can assume that our approach can effectively distinguish between water and other low backscatter surfaces. To evaluate, we compare results from the TU Wien flood mapping algorithm for selected flood events one time with VV and one time with VH polarization, interpret the detected differences, and evaluate the better suited solution for specific conditions.

The Copernicus Expansion CIMR mission and opportunities for land monitoring

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The Copernicus Imaging Microwave Radiometer (CIMR) mission is a conically-scanning multi-frequency microwave radiometer planned to be launched in the 2027+ time frame to support the Integrated European Policy for the Arctic [1]. At the global scale, CIMR allows for enhanced climate records and improved monitoring capabilities based on retrieval approaches that build from previous microwave radiometers, e.g. AMSR series, SMAP and SMOS, but evolve to make advantageous use of multi-frequency and consistent temporal sampling. Over land, CIMR channels (L-,C-,X-,Ka-,Ku-bands) have varying sensitivity to the properties of the observed surface enabling complementary retrievals of soil moisture, plant water and carbon (biomass) across multiple layers of the canopy, land surface temperature, soil freeze/thaw conditions and surface water inundation dynamics. Also, the distinct spatial resolution of each band allows for the development of approaches to cascade information and obtain these properties at climatological and meteorological scales. From a temporal perspective, CIMR will provide a higher revisit than previous missions (about 1 day global, sub-daily in the poles), which allows capturing more hydrological processes such as run-off generation and infiltration dynamics, important to better model and understand land-atmosphere exchanges. Important for operational applications, CIMR will be part of the Copernicus Sentinel Program and thereby provide data in near real time for downstream services. In this presentation, the potential offered by the future CIMR mission for water cycle science, hydrology and its applications will be discussed.

[1] Donlon et al. (2019). CIMR Mission Requirements Document v5.0, ESA-report: ESA-EOPSM-CIMR-MRD-3236 available at https://esamultimedia.esa.int/docs/EarthObservation/CIMR-MRD-v5.0-20230211_(Issued).pdf

SWOT early results over lakes

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The Surface Water and Ocean Topography (SWOT) satellite, launched on December 16th 2022, is a CNES and NASA joint project, in collaboration with the Canadian Space Agency (CSA) and the United Kingdom Space Agency (UKSA). SWOT represents a major breakthrough in space altimetry by using a new technical concept based on interferometric altimetry: in comparison to conventional altimetry, which provides point data along profiles at resolutions of tenths or hundreds of kilometres, interferometric altimetry provides a two-dimensional image with a horizontal resolution of the order of tenths or hundreds of meters. Therefore, this mission will significantly improve both offshore and coastal ocean observation, while enabling global measurement of the water levels (and their variations over time and space) of rivers, lakes and flood zones, with a repeat period of 21 days.

This presentation will first recall the on lake processing and resulting products, and then make an overview of the associated Cal/Val activities.

Over land, SWOT is planned to survey lakes with a surface area larger than 250 m by 250 m (objective: 100 m by 100 m). To do so, two main products are available to the user community. The pixel cloud (L2_HR_PIXC) product provides longitude, latitude, height, corrections and uncertainties for pixels classified as water and pixels in a buffer zone around these water zones, as well as in systematically included areas (defined by an a priori mask). The product specific to lakes (L2_HR_LakeSP) is computed from the pixel cloud for each water feature observed by SWOT and not assigned to a regular river. It consists of polygon shapefiles, delineating the lake boundary and providing the area and average height of each observed lake. Furthermore, the Prior Lake Database (PLD) allows to link the SWOT observations to help monitoring lakes.

During its Calibration phase, from April to July 2023, SWOT was on a 1-day repeat cycle orbit, allowing daily measurements of the covered sites. Examples of products, preliminary accuracy assessments and associated Cal/Val activities will be presented.

The validation of L2_HR_LakeSP water surface elevations is mainly based on existing gauge networks. It is a challenge to obtain reference height data that have an absolute accuracy well below what is required for the SWOT lake products we are validating (10 cm 1-sigma at the lake level). The validation of water surface areas relies on reference water masks obtained mainly from (Very-) High-Resolution optical or radar satellite images (Pléiades, Sentinel-2, Sentinel-1, RCM…), pre-processed so that comparisons can be made at the lake scale.

An overview of the Cal/Val activities will be given in this presentation, and further detailed for certain Cal/Val sites in other presentations.

Monitoring the terrestrial water storage changes and watershed fluxes using GRACE gravity data on regional scales

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The global hydrological cycle is intensifying because of global warming. Meanwhile, on regional scales, the response to the hydrological cycle changes differs for various regions and does not necessarily follow the wet-get-wetter or dry-get-drier paradigm. One of the most critical components of water cycle is terrestrial water storage (TWS) which is considered as an essential climate Variable (ECV). Reliable estimates of TWS can help to study climate and hydrological variabilities. TWS can be modeled or obtained from measurements of temporal variations in the Earth's gravity field data obtained by the Gravity Recovery and Climate Experiment (GRACE) twin satellites mission. GRACE is a satellite mission jointly operated by the National Aeronautics and Space Administration (NASA) and the German Aerospace Center (DLR) launched in March 2002 with the aim of improving the Earth's gravity field' understanding and its changes over time, particularly regarding climate and water resources.

In this study, the TWS changes of coastal watersheds of the North Sea and Greater Horn of Africa are estimated using accurate measurements of the Earth's gravitational field derived from the GRACE mission. We will investigate variations of TWS using a time series derived from GRACE and differentiate them to obtain water fluxes and explore the mass consistency of a cluster of the watersheds with the mass changes of individual watersheds of the North Sea and the Greater Horn of Africa. Additionally, we present our progress on our project to derive climate related water flux changes in the North Sea area and the Greater Horn of Africa using GRACE data and discharge estimates.

Combining large scale in-situ network and satellite data: towards digital twins of rivers

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In a global warming and climate change context, populations all over the world are impacted by an increasing number of hydrological crisis (flood events, droughts, ...), mainly related to the lack of knowledge and monitoring of the surrounding water bodies. In Europe, flood risk accounts for 46% of the extreme hazards recorded over the last 5 years and current events confirm these figures for France and Europe. Although the main rivers are properly monitored, a wide set of small rivers contributing to flood events are not monitored at all. There is a clear lack of river basins monitoring regarding the rapid increase of extreme events. In France, 20000 km of regulatory rivers are monitored in real time while 120000 km are required. Moreover, hydrological surveys are currently insured by heterogeneous means from a country to another and even inside a country, from a region to another. It results in a high-cost level to deploy a robust, relevant, and efficient monitoring of all watercourses at risks. Therefore, there is a real need for affordable, flexible, and innovative solutions for measuring and monitoring hydrological areas to address climate change and flood risk within the water big cycle.

vorteX.io offers an innovative and intelligent service for monitoring hydrological surfaces, using easy-to-install and fixed remote sensing in-situ instruments, based on compact light-weight altimeter inspired from satellite technology: the micro-stations. It provides in real time, with a high accuracy, hydro-meteorological parameters (water surface height, water surface velocity, images & videos) of the observed watercourses. The combination of these in-situ data with satellite measurements is thus optimal for downstream services related to water resources management and assessment of flood/drought risks. Thanks to the development of the innovative micro-station and the onboard processing using artificial intelligence algorithms, the vorteX.io solution will provide an anytime/anywhere real time hydro-meteorological database to prevent communities from flood risks and secure goods anywhere at any time. The solution thus aims to cover the whole Europe through a non-binding turnkey service to ensure the resilience of territories to climate change and guarantee the safety of people and goods.

As first step, the European Innovation Council approved our WHYLD (Worldwide HYdrological Large-scale Database) project, involving the deployment of 3,000 vorteX-io micro-stations, including 1,000 in France and Croatia, to provide real-time hydrological monitoring. This project will result in the production of real-time river measurements and a predictive flood risk indicator for all the rivers equipped with the vorteX-io solution.

Innovative Autonomous UAV solution for in-situ Cal/Val of satellite altimetry over inland waters and other surfaces

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For many years now, satellite altimetry is increasingly used to monitor inland waters all over the globe, and even more with the advent of delay doppler radar altimeter embedded on the Copernicus Sentinel-3 and Sentinel6-MF missions, and the SWOT mission based on interferometric radar imagery. For these instruments, new algorithms are currently being developed to support improved data processing over hydrological surfaces in order to achieve significant accuracy improvements. There is therefore an increasing need for new in-situ systems to provide reference data for large-scale Calibration/Validation (Cal/Val) activities over inland water.

In this context, vorteX-io designed a lightweight remote sensing instrument, inherited from the specifications of radar altimeters on board altimetric satellites, capable of providing water height measurements with centimetre-level accuracy and at high frequency. Mounted on a flying drone, the system combines a LiDAR system and a camera in a single payload to provide centimetre-level water surface height measurements, orthophotos, water surface mask and water surface velocity throughout the drone flight. The vorteX-io system is a review of existing in-situ systems used for Cal/Val of satellite altimetry in hydrology or operational monitoring of water heights (used to anticipate river floods or to monitor reservoir volumes). As the lightweight altimeter is inspired from satellite altimetry, water level measurements are directly comparable to satellite altimeter data. Thanks to the UAV capability, water measurements can be performed on long distances along rivers, and at the same location and time as the satellite pass. New hydrological variables are planned to be added in the next future (water surface temperature, river discharge, turbidity, …).

To perform operational calibration and validation activities, the river profiles measured by the drone altimeter must be combined with in-situ measurement performed by fixed sensors. This processing was designed to overcome the problem of measurements not being simultaneous with those from the satellite. In fact, the ideal method to perform reference measurements is to measure the water altitude at the exact location and time as the satellite measurements. In this context, vorteX-io is developing with its partner I-TechDrone a version of the lightweight altimeter embedded on an autonomous drone.
We present here the concept and the development of this autonomous drone dedicated to hydrology measurements and the early results of the first flights performed in an autonomous mode (i.e. without any human pilot controlling the drone on the field).

The EUMETSAT Satellite Applications Facility on Land Surface Analysis – Improving our understanding of Land Surface Processes

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Water stress leaves clear signatures on land surface variables that can be monitored from space. Land surface temperature (LST), and especially LST diurnal cycle, is closely linked to available energy at the surface and its partitioning into latent and sensible heat fluxes and, hence, to surface processes controlling energy and water exchanges at the land-atmosphere interface.
The EUMETSAT Satellite Application Facility on Land Surface Analysis (LSA SAF) provides an array of satellite datasets and products that allow the characterization of all components of the surface radiation budget, the monitoring of vegetation state, estimation of atmosphere evaporative demand and, ultimately, of actual evapotranspiration. Here we will provide an overview of these LSA SAF products, now covering a period of nearly 20 years. In particular, we will show how we can benefit from the high temporal frequency provided by European geostationary satellites, namely the Meteosat Second Generation (MSG) series, which will soon be replaced by Meteosat Third Generation (MTG) launched in December 2022. MSG (and soon MTG) observations allow the characterization of LST daily maxima and amplitude, as well as accurate estimations of solar radiation at the surface, which are key variables to monitor heat stress and to quantify atmospheric evaporative demand. Also, time series of vegetation parameters, such as Fraction of Vegetation Cover (FVC), or Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) derived from these high temporal frequency observations, are fairly stable and less prone to artefacts than similar products based on observations which are far less frequent. Despite their relative coarse spatial resolution, MSG-based FVC or FAPAR are particularly adequate to monitor vegetation dynamics, capturing both smooth and sharp changes in vegetation state. We will make the case that combining information on the surface temperature diurnal cycle and on vegetation variables (FVC and FAPAR) provides insights on soil-vegetation-atmosphere feedbacks. The use of such Earth Observations datasets, therefore, allows a different approach to monitor the processes controlling water and energy exchanges at the surface, and in particular the transition between energy-limited and water-limited regimes.

Multivariate Data Assimilation for Hydrological Forecasting in Large River Basins: A Case Study on the Niger River Basin Using the HYFAA Modeling Platform

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The recent launch of new hydrology-dedicated satellite missions, exemplified by the SWOT mission in December 2022, offers unprecedented opportunities for monitoring and forecasting continental water resources. However, harnessing the full potential of these novel satellite products necessitates the development of fully automated hydrological forecasting systems. To address this need, we present the HYdrological Forecasting system with Altimetry Assimilation (HYFAA), an integrated platform which combines the MGB large-scale hydrological model with an Ensemble Kalman Filter (EnKF) module, enabling the correction of model states and parameters based on discharge observations. While discharge is conventionally employed for data assimilation in hydrological models, it has inherent limitations. Firstly, it provides only one-dimensional information regarding the hydrological flow and fails to capture lateral processes crucial in flooded areas. Moreover, deriving discharge from nadir altimetry data via rating curves introduces spatial sampling limitations. Consequently, combining discharge observations with other types of data can enhance the representation of complex hydrological processes in large basins. In the context of a CNES-funded project, our study focuses on implementing and evaluating multivariate data assimilation techniques in the Niger River basin using the HYFAA platform. Three types of observations are assimilated: water levels and discharge from the Hydroweb database, and surface water bodies derived from Sentinel-1 and Sentinel-2 data processing. We begin by evaluating and comparing the performance of the EnKF when assimilating each variable separately. Subsequently, we investigate the benefits of combining multiple assimilated variables within the system. To validate the assimilation results, we employ either in-situ or independent datasets whenever available. In their absence, a random sample of the assimilated datasets is used for validation purposes.

Data assimilation performance in large river basins can be hindered by false correlations between independent cells arising from the finite size of the ensemble. To mitigate this issue, localization algorithms are commonly employed, which assign distance-decreasing weights to correlations. Nevertheless, existing localization methods typically adopt simplistic homogeneous approaches across the entire basin. In this work, we introduce a model-based localization method that assigns an autocorrelation length to each river pixel and compare its performance against an empirical method employing a constant correlation length.

Finally, we discuss the obtained results in the context of assimilating data from future satellite missions, such as the SWOT mission. The outcomes of this study provide valuable insights into the advancements and challenges associated with multivariate data assimilation for hydrological forecasting, facilitating the utilization of emerging satellite products for improved water resource management and flood prediction in large river basins.

Remote sensing of recent extreme daily precipitation events in Madeira island

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Madeira island is the region in Portugal with the highest amounts of daily precipitation recorded by automatic weather stations in the current century. This is due to the combination of its location at a latitude around 32° N with a high moisture availability and its complex orography, with the highest peak reaching 1862 m in an area of 741 km2. As a result, Madeira island is prone to excessive precipitation events that cause landslides and debris flows, with the most extreme and high impact event in the current century happening on February 20th 2010 and causing 51 casualties. In this study we will analyse two major recent events of extreme daily precipitation over the island in the order of 500 mm or more. The first event happened on December 25th 2020 and was very localized in a relatively low altitude area in the north part of the island, due to the anchoring of convection to the orography. The second event occured on June 5th and 6th 2023, in a broader scale and due to the more common orographic forcing under a warm and moist flow over the island. Satellite estimates of precipitation will be used, namely from EUMETSAT Nowcasting SAF (https://www.nwcsaf.org/) and Hydrology SAF (https://hsaf.meteoam.it/), from both geostationary and polar orbit satellites. Additionally, precipitation estimates from a land-based C-band radar recently installed in the neighbouring island of Porto Santo to the northeast of Madeira island will be used as independent gridded measurements. Both satellite and radar measurements will naturally be compared with in situ data from automatic weather stations. The advantages and drawbacks of the different estimations will be studied.

Improving the retrieval of lake ice thickness with radar altimetry data

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Lake ice thickness (LIT) is recognized as an Essential Climate Variable (ECV) by the Global Climate Observing System (GCOS). LIT is a sensitive indicator of weather and climate conditions through its dependency on changes in air temperature and on-ice snow depth. The monitoring of seasonal variations and trends in ice thickness is not only important from a climate change perspective, but it is also relevant for the operation of winter ice roads that northern communities rely on. Yet, field measurements tend to be sparse in both space and time, and many northern countries have seen an erosion of in situ observational networks over the last three decades. Therefore, there is a pressing need to develop retrieval algorithms from satellite remote sensing to provide consistent, broad-scale and regular monitoring of LIT at northern high latitudes in the face of climate change.

This talk presents a novel, physically-based retracking approach for the estimation of LIT by using conventional low-resolution mode (LRM) and synthetic aperture radar (SAR) Ku-band radar altimetry data on both unfocused and fully-focused modes. Details will be provided about the formalism of the LRM and the SAR retracking methods and on the assessment of the retrieved ice thickness by using thermodynamical simulations. The results presented will focus on the LIT estimation obtained using Jason-1-2-3, and Sentinel-6 data over the Great Slave Lake (GSL) and the Baker lake (Canada). The first long LIT timeseries (more than 20 years) obtained with radar altimetry data over the GSL will be presented. These data are generated within the ESA CCI Lakes project and will be released in the fall 2023. The talk will highlight how these methods significantly improve the accuracy of the LIT estimations, paving the way towards a regular and robust LIT monitoring with current and future LRM and SAR altimetry missions.

The LRM_LIT algorithm has been developed in the framework of the European Space Agency's Climate Change Initiative (CCI+) Lakes project and is currently implemented to produce LIT time series from LRM data. These data will be publicly available to the scientific community through a dedicated data platform following the project schedule. The SAR_LIT and the FFSAR_LIT algorithms are developed within the ESA S6JTEX project that aims at enhancing the scientific return of the tandem phase between the Jason-3 and Sentinel-6 reference missions, allowing for continuity of observations across 30 years between conventional altimetry and SAR altimetry data. Finally, the SAR LIT retrackers will be tailored for the future CRISTAL mission within the ESA CLE2VER project.

First analysis of SWOT data on the Garonne River near Marmande

M Eliot Lesnard-Evangelista[1], M Valentin Fouqueau[1], M Jean-Christophe Poisson[1], M Guillaume Valladeau[1], M Roger Fjortoft[2], M Nicolas Picot[2], M Laurent Froideval[3], M Christophe Conessa[3]
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SWOT (Surface Water Ocean Topography) is a joint project including Nasa, CNES, the Canadian Space Agency and the UK Space Agency. SWOT's main objective is to unite the needs of the hydrological and oceanographic communities in a single satellite, by gathering unprecedented oceanographic and hydrographic data on a planetary scale, including the coastal areas. SWOT is designed to meet the challenges and demands of society in terms of water management. Following its launch on December 16, 2022, SWOT's main instrument, Karin, was switched on at the beginning of 2023, and is now providing daily measurements of sites located in the swath of its Cal/Val orbit, with a 1-day revisit. These data provide us with extremely detailed and precise information, both in terms of water height and water masks.

The new capabilities and performances offered by the SWOT mission demonstrate the need for progress and innovation in the scientific field, and for specific methodological developments (new processing methods, adaptation of existing methods, etc.), in close collaboration with scientists and operational users. Integrated into complex information systems, SWOT mission data will make it possible to maintain and improve the quality of oceanic and meteo-climatic forecasts, as well as hydrological diagnoses of recognized economic value. These analyses will only be possible if we can demonstrate the quality of SWOT measurements. This mission therefore requires the development of Calibration and Validation resources adapted to the very high precision of the expected measurements.

The Garonne near Marmande is one of the Cal/Val sites selected by CNES to evaluate SWOT's performance. In this context, the site was fully instrumented with the deployment of vorteX-io hydrological micro-stations, pressure sensors, several altimetric LiDAR drone campaigns and airborne LiDAR acquisition. Taking advantage of the 1-day Cal/Val orbit phase, the performance of SWOT is currently analysed and compared to in-situ measurements on this site. We present here the status and the results of this analysis.

Towards a dense network of in-situ water surface temperature and water turbidity measurements

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As part of the implementation of the European Water Directive and pursuant to article R.212-22 of the Environment Code, a monitoring programme has been drawn up to track the ecological and chemical status of aquatic environments, identify the causes of environmental degradation and guide action. Monitoring water temperature and turbidity is crucial for assessing ecological status. Indeed, water temperature and turbidity affect all aquatic ecosystems, from primary producers to consumers at the top of the food chain.

Taking an interest in the temperature and turbidity of a river is therefore essential for understanding its overall functioning, estimating its quality, its pollution flows and its capacity to provide satisfactory conditions for the life cycles of the species present in the rivers.
However, in-situ turbidity measurements are performed at a maximum of 12 times a year at a given monitoring site. This is insufficient to understand how rivers function ecologically when we know how these two parameters vary hourly and daily variations in these two parameters (flooding, nychthemeral cycle). Even if current and future satellite mission can provide valuable measurements of these two water parameters, a dense network of in-situ measurements is required to provide small scales information and to serve as Fiducial Reference Measurements for calibrating and validating satellite measurements.

In this context, vorteX-io is currently developing an innovative remote sensing solution on-board its micro-station to measure and monitor water surface temperature and water turbidity over all rivers. The principle relies to the adaptation to satellite remote sensing techniques to in-situ hydrological station that an provide water quality measurements at high frequency. We present here the developments and results obtained with this innovative system dedicated to being deployed at large scale all over Europe.

User Requirements and interests for Fully Focused SAR Altimetry and Innovative River Level Gauges for Coastal and River Monitoring.

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The objective of the recently completed FFSAR-Coastal Project was to evaluate the potential of Fully Focused SAR altimeter data and innovative water level gauges to make a significant new contribution to coastal and estuarine monitoring.

Two different environments were considered:

- The Severn Estuary and river: A highly dynamic mixed tidal estuary environment, with a large tidal range
- The lower Rhone Delta and Camargue: A low lying, flat river delta and wetland environment, susceptible to inundation

For FFSAR-Coastal Project, the SMAP (Standalone Multi-Mission Altimetry Processor) Fully Focused SAR processor was applied to Sentinel 3A and 3B altimeter data and used to generate time series of data which were validated against in-situ data. The in-situ data included data from four newly installed innovative “micro-gauges” provided by vortex.io (two in each region). Drone campaigns, with an embedded LiDAR altimeter, were also carried out to provide high-resolution water level profiles between the micro-gauge locations and the satellite ground tracks.

User engagement was an important aspect of the FFSAR-Coastal Project and throughout its duration we ran a series of workshops, in English and French, to provide project updates, explore results and provide access to data products through the Channel Coast Observatory data portal. Users, who included representatives from government agencies, local coastal monitoring groups and academics, were consulted to identify their priority uses for water level data and to understand problems in current data provision. We also solicited feedback on the potential applications of FFSAR data and lightweight easy to deploy river gauges in coastal and river monitoring. The user input was then compiled into a set of recommendations for further development and implementation of FFSAR, which formed part of the Application Road Map.

The FFSAR-Coastal Project was funded by ESA under the EO Science for Society programme.

Towards the provision of operational FRM measurements for Sentinel-3 over inland water: procedures, protocols and roadmap

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Validation, including the determination of measurement uncertainties, is a key component of a satellite mission. Without adequate validation of the geophysical retrieval methods, of the processing algorithms and the corrections , the computed geophysical parameters derived from satellite measurements cannot be used with confidence. In this context, and in anticipation of the operational delivery of dedicated inland water products based on Copernicus Sentinel-3 measurements, the ESA St3TART project (Sentinel-3 Topography mission Assessment through Reference Techniques), prepared a roadmap and provided a preliminary proof of concept for the operational provision of Fiducial Reference Measurements (FRM) in support of the validation activities of the Copernicus Sentinel-3 (S3) radar altimeter over land surfaces of interest (inland water bodies, sea ice and land ice).

In the framework of this project, the activities related to hydrology include a review of existing methodologies and associated ground instrumentation for validating and monitoring the performance and stability of the Sentinel-3 altimeter measurement via FRM. Methodologies and procedures have been defined considering the errors and uncertainties coming from the measurements of in-situ sensors, satellite measurements and the environment of the validation site. Based on these protocols and procedures, a roadmap has been prepared for the operational provision of FRM to support the validation activities and foster exploitation of the Sentinel-3 SAR altimeter Land data products, over inland waters.
Then, field campaign implementation and realization have been performed as demonstrators based on the procedures and protocols defined in the roadmap.

In this project, a comprehensive review of altimeter uncertainties over inland water bodies was carried out on the basis of a literature review, leading to the identification of the different sources of error with their associated uncertainty level. A full review of all in-situ sensors that have been used for many years for Cal/Val activities for inland waters has also been performed, combined with an analysis of innovative sensors that can fulfil the needs and potentially be used in the framework of the St3TART project. Cal/Val “super-sites” have been carefully selected to implement the roadmap for operational FRM provision. Several campaigns have been performed on the different super sites. In addition of the super sites, opportunity sites from existing national hydrological networks have been studied to significantly increase the number of FRM. Finally, comparison with Sentinel-3 data and FRM have been conducted on all the super sites and the opportunity sites. We propose here to present the final results of these hydrology activities.

Towards high resolution volume variation from space remote sensing

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In the frame of a changing climate which impacts rainfall patterns from one year to another, combined with an increase in human pressure on water resource, there is a compelling need of neutral and precise information on water stock variations. For remote places as to cover large areas at once, satellite data have a strong role to play. Many satellites are currently orbiting the world and provide heterogeneous sources of information related to water, mainly height with altimetry and water surfaces with optical and SAR imaging satellites. If water bodies' stock variation can be monitored hybridizing height and surface information through hypsometric curve estimation, they still suffer from a low cover of classical altimetry datasets. Indeed, they cover less than 15% of water bodies in the Hydrolake database for instance, an issue soon to be overcome with SWOT. The time-pace (10 days at best with Jason/S6 altimeters for example) might also be a limit to operational and weekly water management information.

We present here the work done to go beyond these limitations for volume variation estimation. It encompasses precise surface estimation from optical and SAR data along with the use of a priori information to use partial or degraded data, but also estimation of the shapes of small reservoirs, and bathymetry estimation from DEM using Deep Learning approaches, alongside height estimation from contours projected on DEM. The current advances we have tend to go towards regional to national estimation of water stocks at a weekly pace for surfaces larger than one hectare.

An efficient statistical method to correct large-scale precipitation products: Empirical Conditional Probability (ECP) method.

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The lack of ground observed precipitation is the main limitation of a reliable hydrological systems description, specifically in remote areas. Although satellite precipitation products show a significant bias with respect to ground observation, these products are the main solution in the areas with lack of observed precipitation data. In this study, we developed a method, Empirical Conditional Probability (ECP), to correct the information of remotely sensed precipitation products requiring less raingauges. Generally, rain gauges are assumed as a priori information (predictors) about the true precipitation and is used to provide its posterior probabilistic estimation by our proposed approach. The performance of our developed method is investigated in different experiments using the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) precipitation product and compared with the general spatial interpolation method (e.g., kriging approach). The analysis was carried out in Aosta Valley, a region located in northern Italy with a dense rain gauge network.

TOWARDS THE PARTITIONING OF EVAPOTRANSPIRATION USING REMOTE SENSING CALIBRATION-FREE MODELS

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In large-scale applications to estimate evapotranspiration (ET) physically-based methods are preferred, but they often depend on excessive simplifications of aerodynamic resistance or on locally tuned parameters. These solutions are efficient, but they limit the performance of Remote Sensing (RS) models spatially. We developed and evaluated two RS models for estimating evapotranspiration in non-rainy days, and rainfall interception loss in rainy days. Seasonal Tropical Ecosystem Energy Partitioning (STEEP, Bezerra et al., 2023) performs the energy balance at the time of the satellite overpass (instantaneous) to obtain the latent heat flux (λET) as a residual of the surface energy balance in non-rainy days. STEEP differs from other surface energy balance (SEB) models in calculating the sensible heat flux (H). The plant area index is used to represent the woody structure of the plants in calculating the momentum roughness length (z0m). The calculation of the aerodynamic resistance for heat transfer (rah) included a correction for soil moisture in the parameter kB^{-1}. The Regional Scale Gash model (RS-Gash) is a modified version of sparse Gash model (Gash et al., 1995) designed for estimating interception loss at the regional scale and it was applied in this study to estimate ET in rain days. Canopy cover fraction (c) and vegetation storage capacity (Sv) were estimated from spectral reflectance and biophysical indices from linear regression models for specific vegetation types. This allowed for a more detailed representation of vegetation characteristics. For estimating evapotranspiration on non-rainy days we obtained the correlation coefficient (r) 0.72 and root-mean-square error (RMSE) 0.81 mm/day, we concluded that using physically meaningful parameters in RS modelling can yield better results than empirical ones. We improved the accuracy of remote sensing-based estimates of total rainfall interception loss (r = 0.69, RMSE = 0.4 mm/day) when we incorporated spectral reflectance and indices as independent variables in a multiple linear regression model of vegetation parameters (c and Sv).

Bezerra, U. A., Cunha, J., Valente, F., Nóbrega, R. L. B., Andrade, J. M., Moura, M. S. B., Verhoef, A., Perez-Marin, A. M., & Galvão, C. O. (2023). STEEP: A remotely-sensed energy balance model for evapotranspiration estimation in seasonally dry tropical forests. Agricultural and Forest Meteorology. https://doi.org/10.1016/j.agrformet.2023.109408

Gash, J. H. C., Lloyd, C. R., Lachaud, G. (1995). Estimating sparse forest rainfall interception with an analytical model. Journal of Hydrology. https://doi.org/10.1016/0022-1694(95)02697-N

Toward a global long-term spatio-temporal variations of surface water storage anomaly from space from 1992 to 2015

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The estimation of surface water storage (SWS) and its variations in space and time is crucial to understand the role of continental water in the regional and global water cycle. Surprisingly, the knowledge about its spatio-temporal variability and link with climate is still poorly understood at the global scale, despite the recent efforts devoted to characterization SWS in few large river basins. This lack of knowledge prevents the better understanding of the role of SWS dynamics into the hydrological and biogeochemical cycles of several river basins. Therefore, there is a fundamental need for the quantification of SWS globally.

Here we present our current effort that aims to estimate globally the long-term spatio-temporal variations from 1992 to 2015, based on satellite-derived observations. The method based on the hypsometric curve approach consists of the combination of surface water extent (in this case, from the Global Inundation Extent from Multi-Satellite GIEMS-2) dataset with topographic data from global Digital Elevation Models (DEMs), namely Forest And Buildings removed Copernicus DEM (FABDEM). As a primary result over the South American and African continents, SWS variations at monthly time step from 1992 to 2015 have been estimated and show a strong seasonal and interannual variability. The SWS-based annual mean amplitude was compared with previous estimates from multi-satellite observations over Amazon (~901 km^3), Orinoco (~264 km^3), Congo (~101 km^3), and Chad (~52 km^3) basins and showed an overall fair agreement, although there is still some ongoing work to be carried out. For the Congo basin, SWS is strongly impacted by local and regional climate [e.g., El Niño Southern Oscillation (ENSO)]. This new SWS long-term dataset at the continental scale is therefore a breakthrough as it can now be used as a baseline for future related datasets in several basins and importantly, a new source of information that opens new opportunities for hydrological and multidisciplinary sciences, including data assimilation, land–ocean exchanges and water management. Moreover, this global dataset will be a benchmark of the Surface Water and Ocean Topography (SWOT) products in playing a key role in its evaluation and validation.

Amazon basin cal/val sites for satellite altimetry.

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In this work we will present the hydrology satellite altimetry calibration sites on the Amazon basin used by the Geological Survey of Brazil (SGB) and IRD (French Institute of Research for Development) and partner institutions (CNES, FOAM Project, universities among others). We will present two of the main sites developed for calibration and validation of satellite data on the Amazon basin, the first one on the upper Rio Negro tributary of the Amazon River and the second one at the Amazon River near the confluence with the Tapajós River, both places were also zones of the 1-day orbit for SWOT satellite calibration.

The work will present techniques for GNSS data survey to collect the water level surface information using CALNAGEO float device and GNSS receivers installed over amazon regional boats and also present techniques of GNSS data processing using IPPP (Integer Precise Point Position) method that also use multiple GNSS constellations (GPS plus GALILEO), all data were processed in the CNES GINS software. Additionally, methods will be presented to correct the effects of hydrological loads for the surveys and gauge data, hydrologic loading effects may cause vertical displacements of up to 10 cm in the Earth's crust over Amazon basin and these effects are normally not corrected in altimetric satellite data.

As final result the GNSS water level surface river profiles and leveled gauge data in be utilized to compare with satellite altimetry data (Jason and Sentinel series) all these datasets are also used to derive water slope surfaces and seasonal river slopes variation over Amazon rivers and to produce observations to evaluate the quality of Amazon river slopes data collected by the SWOT (Surface Water and Ocean Topography) mission. It´s expected, if they are already public data accessible, a comparison of these dataset results with data from the new satellite SWOT.

Operational monitoring of French Guiana rivers using spatial hydrology

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Understanding and monitoring inland waters and their cycle has become more and more necessary because of climate change and the increasing anthropic pressure on natural resources. Territories where the traditional in situ monitoring network fails at providing adequate information at all necessary space and time scales are particularly exposed. In French Guiana, in the Amazon biome, such as in several other tropical and sub-tropical basins, the current and future free and open datasets from space can provide crucial information and complement the existing in situ network.
In our study, we use set up a hydrological model (MGB) on the main rivers in French Guiana using mainly global remote sensing datasets and in situ discharge data. For real-time purposes, we use the GPM IMERG-RT (Integrated Multi-satellitE Retrievals for GPM - Real Time) precipitation product and MGB embedded inside the python HYFAA scheduler. Model's calibration resulted in KGE values higher than 0.7 in gauged rivers. We used parameters regionalization for ungauged locations. From this model run and overlapping water surface elevation (WSE) from Sentinel3 and Jason3 missions (taken on Hydroweb : https://hydroweb.theia-land.fr/), we extracted a set of stage/discharge rating curves, through which we routinely convert each WSE observation into a discharge that is assimilated in the model thanks to an Ensemble Kalman Filter (EnKF) scheme.
Such configuration enables to daily estimate of discharges all over the basins, and their short-term forecast based on current model state and statistical rainfall for the forthcoming week. The assimilation of WSE from altimetry corrects properly the model's deviations due to NRT rainfall limitations. Thanks to collaborations with the operator of the in situ network, we built a early warning system that triggers flood and droughts alerts that are compatible with the existing network and comes complementing it in case of fails or on ungauged locations. This framework will definitely be improved by SWOT data when they will be available. The use of free, open and reproducible methods and datasets, are a positive signal toward for building operational early warning systems based on satellite data.

Lake Desiccation Monitoring in Persian Plateau, Causes and Effects

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Shallow lakes, as the key elements of the hydrological cycle, play an important role in the meteorology, ecology, and economy of the surrounding regions. As the shallow lakes are highly sensitive to changes especially in arid and semi-arid regions, they have faced unprecedented impacts from climate change and anthropogenic activities in recent years. The recent development in remote sensing satellites provided a wide range of data products to study the lakes and surrounding ecosystems with a long temporal extent and high frequency. Remote sensing data and machine learning modeling facilitated the data accessibility and information extraction process in earth science studies. Since the desiccation in Iran's shallow lakes has intensified in recent years and there is no comprehensive study covering all the lakes, this study investigated on Persian Plateau shallow lake desiccation. Eight shallow lakes (Urmia, Namak, Gavkhoni, Bakhtegan, Maharlou, Jazmourian, Northern Hamoun and Southern Hamoun) across the Persian Plateau from six basins were selected as case studies for monitoring lake changes, causes and consequences. Here we used a framework based on remote sensing data to argue how climate and agriculture affected the shallow lakes conditions using machine learning techniques.

The lake area time series estimated from Landsat missions using Normalized Difference Water Index (NDWI). Through the Mann-Kendall and Pettitt tests, we found that the lake area in all basins has a significant decreasing trend that started from 1999 to 2008 with 95% confidence. Lakes area change rate ranges from 51% in Urmia to 90% in Gavkhoni (or about 78% on average). Then precipitation, air temperature, and drought indices (Palmer Drought Severity Indices, PDSI, and Standardized Precipitation Evapotranspiration Index, SPEI) were calculated to find out how much the climate has changed during the last 40 years on the consecutive dry and wet periods (Dry Spells and Wet Spells). The results indicate that before the lake area started to decrease, the drought condition had already started as has been getting worse in the last few years. For example, prior to the 1990s, PDSI was 0.41 on average and now dropped to -1.6; or the frequency of dry months based on SPEI increased incredibly after 1990s and reached to143 months on average in each basin. To consider the role of agriculture as the main source of water consumption, time series of cropland area were calculated from NOAA NDVI product for each basin. For1980s and 1990s, NDVI at 1-km was predicted by regression modeling to improve spatial detail due to the coarse spatial resolution of available product. According to the findings, the cultivated area increased since 1980s, but turned into declining trend since 2000 due to drought and water shortage. While the lake desiccation may have variety of consequences, we found that over the last 40 years, frequency of dust events over the water body increased and the concentration of particle matters (PM2.5) also increased significantly.

HiVE Mission: Revolutionizing Water Resource Management with Global Thermal Imagery

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Constellr, an innovative space data and services company, is leading the charge in revolutionizing water resource management through its groundbreaking initiative—delivering daily, global land surface temperature (LST) data for smart water management. Powered by its constellation of infrared monitoring satellites, named HiVE (High-precision Versatile Ecosphere monitoring mission), constellr aims to revolutionize the assessment and preservation of water resources on a global scale. At the heart of this mission is the precise measurement of crop temperature at a sub-field level, enabling a comprehensive view of water usage and distribution patterns across the entire globe. The primary focus of HiVE is to provide optimized LST imagery that plays a pivotal role in enhancing water management practices, high-precision agriculture, and sustainable resource utilization. As our planet's population approaches 10 billion by 2050, effective water resource management is critical to sustainably meet the growing demand for food production, notably through irrigation.

In the realm of smart water management, HiVE's advanced technology plays a crucial role. By providing LST data, constellr enables to accurately derive key parameters such as evapotranspiration (ET), which is a vital indicator of water loss from the Earth's surface. This data-driven approach enables precise and timely assessment of crop water needs, empowering farmers and water resource managers to optimize irrigation practices and ensure efficient water usage.

HiVE's ability to provide assessments of crop health by monitoring changes in plant transpiration through leaf temperature is a game-changer. This early detection of plant stress allows farmers to take proactive measures and implement corrective actions well before irreversible damage occurs, ultimately reducing the risk of crop loss and conserving valuable water resources.

The mission's strategic focus on water resources is embedded in its design and capabilities. The HiVE constellation, comprised of micro-satellites in the 100 kg class, orbits in a sun-synchronous plane at an altitude of 550 kilometers. With a remarkable 1-day global temporal resolution, 30 meters spatial resolution, and 1.5 K temperature resolution, HiVE is uniquely equipped to provide accurate and timely data for water resource monitoring.

By bridging the gap in the thermal infrared (TIR) spectrum for remote sensing solutions, HiVE overcomes the limitations of traditional ground-based and aerial methods. Its global scalability and cost-effectiveness make it an indispensable tool for water resource management on a scale that was previously unattainable.

In conclusion, constellr's HiVE Mission represents a paradigm shift in water resource management. By harnessing the power of thermal infrared imagery and cutting-edge technology, HiVE enables informed decision-making, efficient irrigation practices, and the sustainable allocation of water resources. This innovative approach to water management holds the potential to meet the increasing demand for food production while preserving one of our most precious resources—water.

Satellite observations of snow parameters in mountain regions in support of water management

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Information on the snow parameters, such as snow extent, snow state (wet / dry) and snow water equivalent (snow mass) is needed for applications in snow hydrology, meteorology, management of water resources, flood protection and avalanche warnings. Due to the high spatial variability of seasonal snow in space and time, satellites provide efficient means for comprehensive snow monitoring.

We report on the development of novel Earth Observation tools and algorithms for generation of snow products optimized for scientific and operational applications in mountain areas. The work is carried out in the AlpSnow project, a science activity within ESA's Alpine Regional Initiative. The main products refer to the extent, wetness, and mass of the seasonal snow cover. Regarding snow extent, we developed a multispectral unmixing approach that accounts for variations in illumination across mountainous terrain and offers flexibility regarding the optimum use of spectral sensor capabilities. The algorithm provides consistent snow extent estimates from satellite sensors with different spatial resolution and spectral channels, such as sensors of the Copernicus Sentinel-2 and Sentinel-3 missions. These activities prepare also for future use of the Copernicus CHIME mission. Another special feature is the provision of pixel-by-pixel uncertainty estimates by error propagation. The snow wetness product is derived from time series of Sentinel-1 radar image (SAR) data that are sensitive to the presence of liquid water in the snowpack. A change detection algorithm is applied exploiting the strong decrease of backscatter for wet snow in comparison to snow free conditions and dry snow. An uncertainty measure for the wet snow detection is provided, accounting for dual-frequency backscatter intensity and speckle statistics. The binary wet snow product is supplemented by the snow phase product, which identifies the main melting phase, melt / refreeze cycles, and periods or fractional melting snow cover. Using Sentinel-1 with 6 days repeat cycle, melt / refreeze events can be detected in cases where ascending and descending passes of the same day are available. For continuous melt / freeze detection can be achieved by combination of SAR snow melt/freeze products and snow process modelling. Shorter repeat observations would be needed for continuous diurnal melt/freeze processes. The synergy of SAR-based and optical snow extent is used for obtaining dense time series of the extent of total and melting snow areas as needed for snowpack process modelling and runoff modelling during the snowmelt phase. The project deals also with tools for retrieving snow mass (SWE) in mountain areas. SAR interferometry procedures for spatially detailed mapping of SWE are tested and evaluated, showing good performance for long wavelength SAR (L-band). For snowfall events of low intensity SWE retrievals by means of C-Band InSAR data are as well applicable. We show results of case studies on snow mass retrievals by means of InSAR using repeat L-band SAR acquisitions of the ALOS-2 PALSAR and SAOCOM missions over the Alps. Regular acquisitions, for operational applications, are expected for upcoming L-Band SAR mission, such as the European Copernicus Mission ROSE-L.

GEWEX and International Research Collaboration in Water Research

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The Global Energy and Water EXchanges (GEWEX) project of the World Climate Research Programme (WCRP) has for over 30 years supported and promoted successfully international research collaboration on climate, energy and water. During these more than 3 decades a clear change in how research has evolved from disciplinary to more inter- and transdisciplinary approaches has manifested itself. With that change the challenges regarding collaboration have grown but likewise the opportunities. In this presentation a short overview is given on past, present and future developments within GEWEX on promotion of international research collaboration and how that is relevant and applicable to our society as well as to the role of and interaction with the space agencies.

Contribution of daily observations of water surface elevation from SWOT Nadir altimeter for near-real time monitoring and short-term discharge forecasting in the Maroni River basin, French Guiana.

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In sparsely gauged tropical watersheds, data assimilation into hydrological models has proved to be a powerful tool for improving discharges estimates in near real time (NRT) and short-term forecasts, hence fostering better water resource management and flood forecasting. Yet, due to the spare temporal sampling of current operational radar altimetry missions (Sentinel3-A&B and Sentinel6), short wavelength flood events may be missed. The -now terminated- fast-sampling phase of the Surface Water and Ocean Topography (SWOT) mission offers a unique opportunity to infer in which extent such improved temporal resolution (daily revisit) could help monitoring smaller waterhseds. This study focuses on the assimilation of SWOT's Nadir altimeter into the hydrological model MGB (Large Basins Model) using rating curves derived from Acoustic Doppler Current Profiler (ADCP) measurements performed right beneath the theoretical groundtrack to ensure a consistent and realistic representation of the hydrological processes. We propose a benchmark of the predictive capability of different constellations considering or not SWOT Nadir data during the fast-sampling phase in the Maroni River basin, French Guyana.
To assess the improvements brought by SWOT's Nadir altimeter daily observations of water surface elevation (WSE), a comparative analysis is conducted between SWOT, Sentinel3, and Sentinel3/Jason-CS missions looking at the predictive discharge performance after assimilation within the MGB model. To assimilate discharge data, the ensemble Kalman filter (EnKF) method is using to combine SWOT discharge data (derive from SWOT altimetry data, rating curve information and associated uncertainties) and model estimates. The EnKF method is embedded inside the HYFAA python scheduler. This allows for the adjustment of streamflow predictions and provides a means to evaluate the advancements introduced by SWOT Nadir daily data.
The proposed assimilation approach has been applied over the past years (2000-2023) to the Maroni basin. The first semester of 2023 permitted the assimilation of SWOT Nadir altimeter WSE observations into the MGB model. The results obtained through this assimilation demonstrate the potential for improved streamflow predictions and provide valuable insights into the hydrological dynamics of the Maroni basin, contributing to better water resource management and flood forecasting in this region. Furthermore, the complementarity of the current constellation with a dense spatial sampling and a mission with fast-sampling for observing rapid flood events and improving model RT state is highlighted.

Climate change impact on flooding risks at N’Djamena (Chad basin) using remote sensing and hydrological modelling

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On a global scale, threats triggered but climate change impact on the local and regional hydrological cycle has become a subject of undeniable interest. Despite the underlying uncertainties, projections from climatic models agree on a net increase in precipitation in the central Sahel in the coming decades (+30% by 2040). Because of the hydraulic regulation under development and its major importance for the populations, it is crucial to characterize and understand the hydrological changes that may occur in this area. 2022’s dramatic flood in N'Djamena (the most significant event in the last 60 years) in the Chad Basin is a telling example. All the more so given the demographic pressure and the urban and agricultural development that characterizes this area. In order to better understand the risks and vulnerabilities for this area, it is therefore important to better understand the geo-physical processes involved in the basin.

The study aims to estimate the possible evolution of mean river discharge and extreme events at N’djamena by 2050, and to identify future vulnerabilities to flood risk from climate projections (CMIP6).

To do so we use a hydrological and hydrodynamic model (namely MGB) calibrated over the last decade against in-situ discharge and water levels (WL) from radar altimetry. The model was calibrated using radar altimetry time séries of WL from Sentinel-3 and Jason-3 missions as well as in situ discharge data over the last 12 years (2010-2022). Then the model is fed by the hydro-climatic variables from 4 models and 2 climate scenarios in order to estimate an ensemble of future river discharge time series at N'Djamena by 2050.

The daily simulations of river discharge show a clear increase in flood peaks both in number and in amplitude for most of the models tested. This illustrates the urgent need for better early warning systems and flood mitigation structures. First tests on considering possible land cover changes did not provided strong differences, evidencing that regional climate is the main driver of future hazards. Since the RD ensemble has a high standard deviation, further investigation has to be led on the hydroligical answer to modified climate inside the model.

Operational monitoring of French Guiana rivers using spatial hydrology

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Understanding and monitoring inland waters and their cycle has become more and more necessary because of climate change and the increasing anthropic pressure on natural resources. Territories where the traditional in situ monitoring network fails at providing adequate information at all necessary space and time scales are particularly exposed. In French Guiana, in the Amazon biome, such as in several other tropical and sub-tropical basins, the current and future free and open datasets from space can provide crucial information and complement the existing in situ network.
In our study, we use set up a hydrological model (MGB) on the main rivers in French Guiana using mainly global remote sensing datasets and in situ discharge data. For real-time purposes, we use the GPM IMERG-RT (Integrated Multi-satellitE Retrievals for GPM - Real Time) precipitation product and MGB embedded inside the python HYFAA scheduler. Model's calibration resulted in KGE values higher than 0.7 in gauged rivers. We used parameters regionalization for ungauged locations. From this model run and overlapping water surface elevation (WSE) from Sentinel3 and Jason3 missions (taken on Hydroweb : https://hydroweb.theia-land.fr/), we extracted a set of stage/discharge rating curves, through which we routinely convert each WSE observation into a discharge that is assimilated in the model thanks to an Ensemble Kalman Filter (EnKF) scheme.
Such configuration enables to daily estimate of discharges all over the basins, and their short-term forecast based on current model state and statistical rainfall for the forthcoming week. The assimilation of WSE from altimetry corrects properly the model's deviations due to NRT rainfall limitations. Thanks to collaborations with the operator of the in situ network, we built a early warning system that triggers flood and droughts alerts that are compatible with the existing network and comes complementing it in case of fails or on ungauged locations. This framework will definitely be improved by SWOT data when they will be available. The use of free, open and reproducible methods and datasets, are a positive signal toward for building operational early warning systems based on satellite data.

Using Satellite Data to Monitor Groundwater Drought in the Algarve Region

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Groundwater drought presents significant economic and societal challenges, highlighting the need for effective monitoring and early warning systems at local and regional scales. Despite its vital role in water supply and irrigation, groundwater drought is often not adequately monitored in national operational systems. While the propagation of meteorological drought through hydrological systems has been extensively studied in various parts of the world, there is a lack of groundwater drought monitoring based on groundwater data. Thus, long-term hydrological drought is often assessed using meteorological drought indices like SPI or SPEI with long periods of accumulation (12, 24 or 48 month time scales). However, most studies recognise that the accumulation periods necessary to achieve maximum correlation with groundwater observations exhibit high spatial variability due to the complexity of local hydrogeological conditions. This study aims to address this gap on groundwater drought monitoring in the Algarve by investigating the suitability of GRACE-based drought indices and ground-based drought indices derived from piezometer measurements for monitoring and predicting groundwater droughts.

Previous research has demonstrated the capability of GRACE to capture seasonal and de-seasonalized variations in observed groundwater storage in the Algarve region, despite its relatively small area compared to the GRACE footprint. This makes the Algarve a good case-study region to assess the feasibility of using satellite data to monitor groundwater drought. On the other hand, Log-linear models have been successfully applied to analyse drought class transitions derived from Standardized Precipitation Index (SPI) time series in Portugal. These models proved to be suitable for fitting the SPI time series and can be considered a reliable tool for capturing the dynamics of drought severity changes. In the context of groundwater drought monitoring, Log-linear models can also be used to analyse transitions between different groundwater drought severity classes. These models can help identify patterns and probabilities associated with transitions in groundwater drought severity over specific time periods.

The GRACE-based groundwater drought index (GDI) is computed from the GRACE Total water storage anomalies (TWSA) and soil moisture estimates from the H SAF and ESA Soil Moisture Climate Change Initiative. The Standardized Groundwater Index (SGI) is computed from groundwater levels available from the SNIRH piezometric network. Correlations between GDI, SGI, and meteorological drought indices such as SPI or SPEI computed from ERA5 datasets are then established. Log-linear models are finally employed to model the transitions between GDI and SGI drought classes and are used to analyze and predict transitions in groundwater drought classes one or two months in advance. The results can be used in early warning systems to mitigate the impacts of drought in the Algarve and have potential applications in other parts of the world.

Understanding inter-model variability in satellite-based estimates of irrigation water use

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As competition for water resources intensifies, especially in water-scarce regions, there is a growing need to effectively manage water usage, particularly in irrigated agriculture. However, data on agricultural water use and abstractions is often not collected or only available at coarse resolutions. Satellite-based monitoring of crop evapotranspiration (ET) provides one potential solution to this data gap, but there remain significant knowledge gaps about the uncertainty in satellite-based irrigation water use estimates and their associated implications for policy and management. This study addresses this challenge by assessing the variability in irrigation water use estimates resulting from different choices of satellite ET and precipitation datasets. We utilise six satellite-based crop ET products from the OpenET platform, along with four open-source precipitation datasets, to develop composite models of field-level irrigation water use (IWU) over a six-year time period across the High Plains Aquifer in the central United States. Our findings reveal a wide range of variability in IWU, both spatially and temporally, conditional on uncertain choices that must be made by modellers about ET and precipitation data products. Variability in estimated IWU is greatest when attempting to quantify irrigation at field-levels in specific individual seasons and reduces when aggregating IWU estimates to larger spatial and/or temporal scales. The magnitude of variability in IWU is also shown to be correlated with a number of factors including crop type and climate variability, with regions and time periods characterised by higher aridity index in particular shown to have lower variability in IWU than regions where soil moisture is not limited. Our results highlight the challenges that exist in using satellite-based data to estimate IWU, especially for monitoring water use at fine spatial and temporal scales and/or where irrigation is used to supplement precipitation during the crop growing season. Moreover, we discuss the need for better understanding and transparency about patterns and drivers of variability in satellite-based IWU estimates for water management planning in the HPA and similar regions, including how these data can be used alongside in-situ estimates to reliably inform more targeted and sustainable irrigation practices and facilitate more efficient allocation and conservation of water resources.

Assessing the Impacts of Climate Change and Regulatory Regimes on Lake Water Levels in Sweden Using Satellite and In-situ Data

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Lakes are important sources of freshwater for human activities and provide critical ecosystem services. This study combines satellite altimetry data with in-situ gauged measurements to assess large-scale changes in the water levels of 144 Swedish lakes. This approach is relatively novel in the context of Sweden, where continuous gauged water level data is limited. We explore the effects of flow regulation and hydroclimatic variability on lake water levels, shedding light on their influence in Sweden. The findings reveal that from 1995 to 2022, water levels significantly increased in 52% of the lakes, mainly in northern Sweden due to earlier snowmelt. Conversely, 43% of the lakes experienced a significant decreasing trend, primarily in Southern Sweden. The study also highlights how lake regulation in Sweden contributes to the spatial patterns and variability of water levels. The research underscores the importance of continuous monitoring of lake water levels for effective adaptation strategies in the face of climate change and understanding the downstream effects of water-regulatory schemes.

Using optimality principles to couple terrestrial carbon and water cycles in remote sensing hydrological models

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Hydrology has been historically guided by the establishment of empirical relationships between water movement through landscapes and the association of the conservation of mass law in catchments. This has led models to have many complex calibration frameworks that do not consider physical and biochemical water-related processes that link plants to hydrological processes. Analyses have revealed that some of the empirical relationships in catchments might also reflect a potential ecosystem's coevolution with climate, pushing catchments to optimise their supply and demand limits. This agrees with the eco-evolutionary optimality principles used in vegetation modelling. These principles are based on the hypothesis that canopy conductance acclimates to environmental variations by balancing the costs of carbon assimilation and maintenance of transpiration rates. In this study, we show how remote sensing products allow us to develop meaningful interfaces between simple models and approaches based on optimality and hydrology. This enables us to unveil underlying relationships between stream dynamics and water consumption by plants. Our examples are based on the application of the P-model and the use of a mass-balance approach to investigate root zone hypotheses to quantify gross primary productivity, which is then used to estimate transpiration. We also consider some ideas on incorporating root zone storage in water-stress functions in existing terrestrial ecosystem models, and we show how this approach can be used to compute the trade-off between gross primary production and hydrological fluxes at river basin scales.

Total water storage variations analysis in the Lake Tanganyika watershed over 2002-2021 for water balance monitoring and flood study.

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Lake Tanganyika in East Africa contains 17% of the free freshwater on the Earth's surface and provides important ecosystem services to ~13 million people in the region. It is one of the East Africa's great lakes for which, significant rise in water level between 2019 and 2020 has led to flooding with major environmental consequences and social impacts. Remote sensing data and altimetry-derived lake water level from the Hydroweb project have been used to: compute and analyse the Lake Tanganyika basin water balance for 2002–2021, describe the exposure of surrounding lowlands to flooding, and propose a flood early warning approach. To compute basin water balance, we combined variations of the watershed Total Water Storage derived from GRACE images, with the watershed water flux that we calculated using rainfall data (IMERG, GSMAP, ERA5, CHIRPS, MSWEP), as well as evaporation and evapotranspiration data (GLEV, MODIS, ERA5). The space-time variations of rainfall, evaporation and evapotranspiration were highlighted through multivariate statistical analysis. For flood mapping, we calculated the MNDWI spectral water index from Sentinel–2 images acquired between 2017 and 2022. Correlations between TWS and Surface Water Storage (SWS) deduced by multiplying the lake height by its area, allowed to propose an early warning approach for floods. Our study shows that, the basin water balance is only closed when combining rainfall from Era5 with evaporation and evapotranspiration from MOD16A2 and GLEV, respectively. During the 2002–2021 period, over the entire watershed, an increase of ~25 km^3 in water inflow through the lake is associated with an increase of ~90 km^3 in water inflow via the rest of the watershed. Groundwater storage corresponds to ~90% of TWS, whereas SWS conresponds only to ~8% of TWS. In 2002–2021, evaporation from the lake was stable overall, while evapotranspiration as well as rainfall mainly in the Malagarasi basin, increased significantly. On the northern shores of the lake, the worst flooding occurred in May 2021, mainly affecting the Gatumba city and the Ruzizi Delta Nature Reserve. Based on the time lag of SWS variations in response to TWS fluctuations, we developed a flood early warning approach that predicts May SWS, when flood risk is the highest, using February, March and April TWS with an accuracy of 92%, 96% and 97%, respectively.

Preliminary assessment of the SWOT L2 Lake products over small water bodies observed during the CalVal orbit in the Alsace and Lorraine regions (France)

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In mid-December 2022, on the 16th, the SWOT mission (NASA, CNES, UK-SA, CSA) was launched with well-defined hydrologic science measurement objectives : 1. To provide a global inventory of all terrestrial surface water bodies such as lakes, reservoirs, wetlands whose surface area exceeds (250*250m²; with the goal of (100*100m² and a threshold of 1km², and for rivers whose width exceeds 100m with a goal of 50m and a threshold of 170m). 2. To measure the global storage change in terrestrial surface water bodies; 3. To estimate the global change in river discharge at sub-monthly.

Additionally, SWOT will provide observations of the surface of inland water bodies at unprecedented resolution and accuracy. The surface water areas estimated using the Level-2 water mask shall have a relative error smaller than 15% of the total water body area for water bodies whose non-vegetated surface area exceeds 250*250m². For smaller water bodies, specifically those whose non-vegetated surface area is between 100*100m² and 250*250m², the relative error would be smaller than 25% of the total water body area. For lake and reservoir, height accuracy shall be 10 cm or better, for water bodies whose none-vegetated surface area exceeds 1km2 and 25cm or better for water bodies whose non-vegetated surface area is between 250*250m2 and 1km2. (Biancamaria et al, 2016; Deasai, 2018).

Over the Rhine Trier 1 CalVal site, a set of 20 lakes, with sizes ranging from 7 to 0.03km² and varying topographic settings, has been selected in order to assess the accuracy of the SWOT L2 Lake products. A preliminary work consisted in setting up a database characterizing these lakes and reservoirs. A first level consists in water surface dynamic based on the analysis of 6 years of Sentinel-2 imagery. For water elevation a multisource approach has been followed; a gathering of historical data from institutes, municipalities, state agencies (such as Voies Navigables de France, DREAL, EDF, …), the installation of limnimetric scales in the framework of the OECS initiative, and the assessment of the quality of all these water level historical records and assessment of the stations' leveling through the ICESat-2 data.

The analysis of SWOT products generated daily during the CalVal was done as following:

- Comparison between the Coherence Power and Water Detected products: the frequency of observation, noting that even if during the CalVal, SWOT acquisitions were done daily, some lakes were not viewed/detected during a third of the observation period
- Evaluation of the PIXC classes accuracy (water only, land and water, dark water, etc.).
- Exploitation of Bright Land and Dark Water flags.
- Comparison of the in situ water elevation and the ones provided by the L2 SWOT lake products.
- Comparison of water extent provided by the SWOT product and the ones derived either from VHR Pleaides imagery and HR Sentinel-2 data

These analysis highlights the high accuracy of the SWOT products and their limitations in application for small water bodies, which are often overlooked targets.

Enhancing Disaster Preparedness: Simulating Glacial Lake Outburst Flooding of the Shishper Glacier in Pakistan with 2D Hydraulic Modeling and Satellite Data

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Pakistan's Hindu Kush Himalayas (HKH) region is reported to have significant glacier retreats with alarming consequences. Glaciers melting, predominantly due to climate change, has led to the formation of lakes near their terminus. Many of these lakes are declared dangerous due to their bursting potential. The Shishper Glacier in Pakistan is one of the prime examples of retreating nature and having lakes formation at their termini. In recent years, there have been consecutive glacier lake outburst flooding (GLOF) events. Surge-type and surge-like glaciers have also been discovered in the Karakoram region, covering over 40% of the total glacier area, indicating heightened risks associated with climate change. Melting water from the Shishper Glacier has formed an ice-dammed lake by blocking the outlet stream of the adjacent Mochuwar glacier, posing threats to downstream populations, infrastructure, and livelihoods. Approximately thirty GLOF incidents have occurred along the Karakoram Highway (KKH) in the past two decades. There is an urgent need for comprehensive monitoring and assessment of each glacier and its associated lakes to protect infrastructure and vulnerable communities in their downstream areas. Implementing an early warning system and controlled release of glacial lake volumes can significantly reduce the GLOF risk posed by such lakes, including the Shishper Glacier. This study aims to develop a 2D flood model for the Shishper Glacier, replicating its 2022 GLOF event using the HEC-RAS 2D model. This model can simulate floods in different climate change scenarios and investigates their downstream impacts. Moreover, the study seeks to raise awareness among downstream communities and local authorities about the potential hazards of glacial lake outburst flooding originating from the Shishper Glacier. It encourages developing and adopting effective mitigation and adaptation strategies to prevent future calamities. By comprehensively monitoring and assessing glaciers and their associated lakes, infrastructure, and vulnerable populations can be safeguarded. Replicating the GLOF2022 event using the HEC-RAS 2D model provides insight into the potential consequences for downstream areas, enabling the implementation of proactive measures and practical strategies. An early warning system would facilitate timely alerts for downstream communities, enabling evacuation and necessary precautions. Controlled release of glacial lake volume can reduce the pressure on the ice dam, minimizing the risk of an outburst and mitigating downstream damage. These measures will protect communities, infrastructure, and livelihoods, enhancing resilience against future GLOF events. In conclusion, this study underscores the urgency of monitoring and assessing glaciers and associated lakes in the Hindu Kush Himalayas, mainly focusing on significant retreats and the formation of glacial lakes in Pakistan. The Shishper Glacier represents a critical case study due to its history of GLOF events. Protecting infrastructure and vulnerable populations requires concerted efforts to prevent further calamities.

KEYWORDS: HEC-RAS 2D, Glacier Lake outburst flooding, climate change

Increasing information content delivery for the humanitarian response using FloodSENS and recent advances in AI technologies.

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Many countries around the world are facing destructive floods and, frequently, their economical and societal condition do not allow to plan proper adaptation and mitigation strategies. Organizations like MSF and the UN are constantly increasing their efforts to support communities during a flood. This paper aims to enhance the level of preparedness of humanitarian organizations and local communities during natural events. To achieve this, we have developed FloodSENS, an algorithm that makes use of explanatory AI to efficiently reconstructs flooded areas under partial cloud cover in optical satellite images. The application uses Machine Learning and auxiliary derivative layers from digital elevation models, and water flow algorithms. This activity has been developed in partnership with ESA InCubed Programme. Here we will show our latest developments of FloodSENS, including 3D visualization of the results using the latest advances in scene generation AI-powered platforms as well as ongoing efforts to deploy FloodSENS in orbit. We will also showcase first results attempting to fine-tune FloodSENS for mapping flooding in urban areas as well as inside refugee camps, with examples of recent events in Australia, South Sudan and Mozambique.

Assessing the Influence of Nearshore Bathymetry on Coastal Overtopping due to Extreme Sea Level Events: A Satellite-Derived Bathymetry and XBeach Modeling Approach

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Extreme sea level events pose a major hazard to low-lying coastal communities, occasionally generating severe overtopping and backshore flooding. Wave breaking and dissipation in the nearshore zone, and wave runup in the swash region, are key processes that are importantly controlled by the nearshore morphology. Spatially and temporally complex nearshore morphology, such as subtidal sandbars, have the potential to alter surf zone wave dissipation patterns and therefore influence setup, swash, and runup levels observed at the coast. In this study, we combine satellite derived bathymetry (SDB) method (Capo et al., 2014), 10 m spatial resolution, to monitor spatial-temporal changes in the shallow water morphology, and XBeach non-hydrostatic numerical model (Roelvink et al., 2009) to predict the impact of extreme sea level events in a low-lying sandy beach, highly vulnerable to overtopping. The study site is a sector of Caparica beach, located in the southern coastal region of Tagus estuary (Lisbon, Portugal), exposed to an energetic wave climate (monthly averaged significant wave height during the winter season of 2.8 m) and mesotidal regime. This coastal region is under structural erosion (constantly loosing sediments and with shoreline retreat), reason why is regularly subject of artificial sand nourishment interventions, which reduces the vulnerability to extreme sea levels but alters the nearshore morphology (beach face and subtidal bars). The influence of nearshore bathymetry on extreme sea level events was analysed using the non-hydrostatic mode of XBeach. Three distinct beach profiles are considered: (1) a reference benchmark case, using the beach profile used in the calibration and validation of the model (see Garzon et al., 2023), (2) a profile with a subtidal bar located further offshore (from 2018, estimated using SDB - SDB2018), and (3) a more robust profile resulting from a beach nourishment project (from 2021, estimated using SDB - SDB2021). The simulations were focus on three major storms that had an important impact in the study area: Hercules in 2014 (caused severe erosion and overtopping), a storm in February 2017 (severe erosion, minor overtopping), and storm Emma in 2018 (severe erosion, and no overtopping). The SDB data used in the model simulations was estimated with an accuracy better than 1 m (RMSE), and model water level and wave data gathered from local in-situ observations and reanalysis data. Preliminary results show that XBeach model accurately predicts the occurrence of overtopping during these extreme sea level events, and subtidal morphology affects the number and mean flooding discharge. The most vulnerable beach profile (SDB2018) showed the double of the number of overtopping events (6) when comparing to the number of overtopping events (3) computed in the simulations performed with the beach profile after the artificial sand nourishment (SDB2021). This work demonstrates that the combination of these two methodologies (SDB and XBeach modelling) can improved the predictability capacity of extreme sea level events and associated impacts.

The H SAF EPS-SG day 1 MWI and MWS Machine Learning algorithms for snowfall and rainfall surface precipitation rate retrieval

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Precipitation is an essential element of the global hydrological and energy cycles, and its measurement is of great importance in a variety of research areas, such as climate studies, management of water resources, natural hazards and hydrology. A significant effort in the study of the precipitation is carried out in Europe within H SAF (Satellite Application Facility on Support to Operational Hydrology and Water Management), a EUMETSAT program designed to deliver satellite products (precipitation, soil moisture and snow parameters) for hydrological applications to research and operational users worldwide. H SAF precipitation products are based on the exploitation of present and future Low Earth Orbit satellites carrying passive microwave radiometers.

The development of precipitation retrieval techniques, as well as the quality assessment of satellite precipitation estimates, can currently benefit of the availability of cloud and precipitation observations by the spaceborne radars: the Dual-frequency Precipitation Radar (DPR) on board the GPM Core Observatory, available, and the CloudSat Cloud Profiling Radar (CPR) (and the EarthCare mission in the near future). These radars have demonstrated their complementarity in precipitation monitoring with the DPR more suitable for medium to intense precipitation regimes, and CPR for light rain and snowfall. Within H SAF, a new machine learning (ML) based algorithm for the Micro-Wave Imager (MWI) radiometer on board the EPS Second Generation satellites (MetOp-SG) has been developed. Different Artificial Neural Network architectures were tested in order to select the most suitable for optimizing the performance of the algorithm (for the detection and the estimate of rainfall and snowfall). The training procedure is based on the use of observational databases built from coincident measurements from active and passive microwave spaceborne sensors. Since MWI will be launched in 2025, the present study has been carried out exploiting the GMI measurements, the two radiometers having similar characteristics in terms of channel frequencies (GMI channels common to MWI have been downscaled to MWI resolution). Different databases have been created coupling GMI brightness temperatures (BT) measurements with surface precipitation rate estimates from spaceborne radars (GPM-DPR and CPR).

The algorithm adopts a modular scheme, in order to fully exploit the strengths of each radar. Separate modules for the retrieval of light rain-snowfall and heavy rainfall have been developed considering CPR and DPR as reference, respectively. Besides the measured BTs, the algorithm uses ECMWF model derived variables as additional input. Similar approach is used for the H SAF EPS-SG MicroWave Sounder (MWS) surface precipitation rate day-1 product, using observations from the Advanced Technology Microwave Sounder (ATMS) and spaceborne radars. The algorithms are designed to be used operationally as the official EUMETSAT EPS-SG MWI and MWS surface precipitation rate day-1 products. The details concerning the coincidence datasets creation, the design of the ML modules and results of both (MWS and MWI) algorithms testing will be presented. The planned activities for testing and calibrating the products during the commissioning phase, will be also described, together with the ongoing development for the day 2 products that will be based on MWI and MWS observations.

Water extent estimation over inland targets using FF-SAR data.

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The Sentinel-6 mission, launched in November 2020, carries a radar altimeter operating in open burst with a PRF high enough (~9kHz) to perform the focussing of whole target observation echoes in a fully coherent way. Furthermore, such a feature allows improvement of the along-track resolution down to the theoretical limit of around 0.5 m when processing the data with a Fully-Focussed SAR (FF-SAR) algorithm. This resolution increment actually represents a revolutionary step with respect to the ~300 m along-track resolution provided by current operational processors based on Unfocussed SAR algorithms, commonly used in radar altimeters with a closed burst chronogram, such as CryoSat-2 and Sentinel-3.

This study presents a novel technique for geo-referencing and estimating the size of inland water bodies, such as reservoirs or lakes, located on unambiguous across-track targets and that present strong seasonal extension variability, using Fully Focussed SAR (FF-SAR) processed altimetry data. Cloud coverage does not have impact on the measurements, allowing for consistent and continuous data collection.

Indeed, a FF-SAR Ground Prototype Processor (GPP), developed by isardSAT and based on the backprojection algorithm [1], has been used to generate FF-SAR radargrams of off-nadir inland targets located within certain observation constraints. Post-processing techniques were then implemented to enhance the contrast between water and land before classification. The filtered FF-SAR radargrams were segmented using unsupervised techniques, such as K-means clustering, to classify pixels based on shape or intensity similarities and extract the corresponding water regions. Subsequently, the obtained water pixels were projected onto the ground to estimate the total extent of the water bodies.

The performance of the technique was evaluated through a validation process, which involved comparing the FF-SAR water extent measurements derived from Sentinel-6 data against optical measurements from Sentinel-2 as well as in-situ observations. The results demonstrate the capability of the method to accurately estimate the size and spatial distribution of inland water bodies with substantial seasonal extension variability.

MONITORING UNGAUGED MANCHAR LAKE (PAKISTAN) USING ICESAT-2 DATA

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Inland water is crucial for global water and food security, particularly in developing nations with a growing population. Lakes are central in meeting the world's increasing water demands, making them a vital component of inland water resources. However, developing an efficient and continuous monitoring system is essential for water authorities to ensure the effective management of water resources. This study employed ICEsat2, a satellite laser altimetry technology, to monitor Manchar Lake in Dadu district, Sindh, Pakistan. Multiple satellite altimetry missions, such as Sentinel 3, ICESat2, and Jason3, traverse Pakistan's largest natural lake, providing valuable data for monitoring purposes. It is worth noting that Sentinel 3 has previously been validated for monitoring water levels in the Indus River. In the absence of an in-situ gauge in Manchar Lake, Sentinel 3 and Jason 3 were employed for comparison with the findings of ICESat2. Jason3 Sentinel 3 data were acquired, respectively, from Dahiti and EarthConsole. ICESat2 data were downloaded from NASA's official website, which had allowed open altimetry access. They utilized permanent water surfaces from HydroLakes for masking the Manchar Lake area. The correlation coefficient (R=0.534/0.928 Dahiti/S3), root mean square error (RMSE=0.443 m/0.4717 m Dahiti/S3), and mean square error (MSE=0.196/0.22258 Dahiti/S3) were calculated as validation metrics. This study has limitations, including the short time series of ICESat2 due to its low temporal resolution. Another limitation is the lack of exact matching satellite data acquisition dates, which could be addressed by installing in-situ gauges in the Lake. Reevaluating ICESat2 data in the future using in-situ gauges can significantly enhance the validation of this dataset.

Space-borne G-band radars: applications in mid/high latitude cloud and precipitation remote sensing

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Breakthroughs in radar technology (Schottky diode-based frequency multiplied sources and solid-state transmitter) have recently fostered the construction of ground-based radars within the so-called G-band (frequency between 110 and 300 GHz). The first measurements from these first prototypes confirm the potential of such systems for sizing sub-millimeter ice crystals and for better characterizing drizzle, light precipitation and ice microphysics. In fact G-band signals experience non-Rayleigh scattering in regions where Ka- and W-band signal do not; similarly G-band attenuation is considerable higher especially for small droplets and ice particles than at the lower frequency. This property allows for better quantitative estimates of light precipitation and cloud (supercooloed-)liquid water path. Because of the reduced atmospheric gas attenuation these systems are particularly apt to high latitude/ high altitude deployments.

This work discusses the possibility of the deployment of a G-band radar in a space mission in the framework of Earth weather and climate monitoring programs. Two configurations at 238 GHz will be discussed: an Earth-Explorer like mission where the G-band radar is operated in synergy with a Ka-band system both characterized by large transmitted powers and antenna dimensions and a SCOUTS-like mission with a single frequency radar more limited in terms of size and power. The performance of the two instruments will be detailed. Simulations of radar observables (reflectivity, path integrated attenuation, co-located brightness temperature) provided for high and mid-latitude scenes will be used to draw a first iteration of possible science applications and gauge the science requirements that could be achieved by the two missions.

A Deep Learning model to predict drought in the Horn of Africa using satellite data at daily scale.

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The Horn of Africa is an area which has historically been vulnerable to droughts. Recent studies suggested that droughts in the region have increased in frequency, severity and duration (Guha-Sapir et al., 2004; Meier et al., 2007; Ayana et al., 2016, Haile et al. 2019). These phenomena pose significant concerns as they result in livestock losses, crop failures, and food security emergencies (Guha-Sapir et al., 2004; Mo and Lyon, 2015), ultimately leading to increased mortality (IPCC, 2023). Integrating advancements in remote sensing with existing early warning systems can provide fundamental assistance in mitigating the severe effects of this phenomenon by promptly responding to humanitarian needs (De Coning et al. 2023). However, a recent WMO report states that currently available nowcasting products are underutilized in Africa (De Coning et al. 2023). Previous literature (West et al. 2019) has also highlighted the need for more advanced input products with better spatial, temporal and spectral resolution in order to gain a deeper understanding of the intricate nature of such events. Considering the importance of monitoring vegetation status, past research has established that constructing good quality vegetation composites using polar orbiting satellite at 10 or 16 days temporal resolution might be challenging due to the presence of clouds during drought periods (Fensholt et al., 2011). Additionally, regional studies in Africa analyzing precipitation data have revealed mixed performances of rainfall remote sensing products, making the selection of an optimal precipitation product non-trivial.

Taking into account the aforementioned issues, we explored the ability of Deep Learning algorithms to provide consistent and timely estimates of vegetative drought conditions, given the signal of a meteorological drought at an improved temporal resolution. Focusing on a subset of countries in the Greater Horn of Africa (Ethiopia, Somalia, Kenya), we modeled a vegetative drought at a daily scale using an NDVI index calculated from measurements obtained by the Meteostat SEVIRI radiometer. Furthermore, we analyzed the impact of using different types of input precipitation data products (e.g. reanalysis, rain gauges, or satellites) on the quality of the estimates. Finally, we evaluated the suitability of various Deep Learning architectures to provide efficient and timely estimations of agricultural drought. Specifically, we tested the ability of a ConvLSTM algorithm to learn spatial-temporal features and utilize this information for predicting vegetation images. We also evaluated the computational efficiency of this algorithm compared to simpler baselines (e.g. Convolutional Neural Networks) and explored the suitability of alternative non-tabular data modeling architectures (e.g. Graph Neural Networks). Additionally, we accounted for the ability of Deep Learning algorithms to forecast drought events at shorter time scales, as the main goal of this work is to enhance the response time and accuracy of early warning systems.

Global L-band Observatory for Water cycle Studies (GLOWS) - Soil Moisture continuity mission

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SMOS and SMAP radiometers have demonstrated the ability to monitor soil moisture and sea surface salinity and continue to provide high quality radiometric measurements to this day in extended mission operations. It is important to maintain data continuity for these science measurements. The proposed instrument concept (Global L-band active/passive Observatory for Water cycle Studies - GLOWS) will enable low-cost L-band data continuity (that includes both L-band radar and radiometer measurements). The objective of this project is to develop key instrument technology to enable L-band observations using an Earth Venture class satellite. Specifically, a new deployable reflectarray lens antenna is being developed that will enable a smaller EELV Secondary Payload Adapter (ESPA) Grande-class satellite mission to continue the L-band observations at SMAP and SMOS resolution and accuracy at substantially lower cost, size, and weight.

Assessing the impact of climate change on flood inundation in highly urbanized river basin in the Central Himalaya

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Climate change and urbanization are the key factors altering magnitude and frequency of flooding. Bagmati is a highly urbanized river basin where the land use changes rapidly from agricultural to the settlement, changing the hydrological regime by increasing the surface runoff and decreasing infiltration. The infrastructures, peoples and agricultural areas along the floodplain are highly exposed to pluvial flooding. A major flood event occurred in 1993, causing heavy damage on Bagmati Barrage, Kulekhani Hydropower Plant, several bridges and loss of more than thousand life. Assessment of such extreme events in the future is crucial for planning infrastructures, developing adaptation strategies and early warning systems. We, i) integrate the bias corrected high resolution climate change data from Coupled Model Intercomparison Project Phase-6 (CMIP6) and publicly available high resolution topographic data with hydrodynamic model to develop flood inundation extent and depth, ii) derive the flood inundation map for different return periods under climate change scenarios, and iii) assess the impact of urbanization on flooding. The integrated approach of flood mapping can provide useful information to urban planners, designers, decision makers, early warning system agencies, and resilient infrastructure developers.

Assessing Water Level Measurements utilizing Sentinel 3 Satellite Radar Altimetry Data in the Upper Indus River at Tarbela Reservoir

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Abstract

The surface water monitoring datasets in Pakistan currently suffer from limitations due to the lack of extensive in-situ gauging networks. This study aims to demonstrate the potential of utilizing Sentinel 3 satellite radar altimetry to enhance the existing monitoring datasets in Pakistan. Specifically, the study focuses on investigating changes in water levels at the Tarbela reservoir located in a mountainous region, with the aim of obtaining catchment-level water level data.

To ensure the accuracy of the analysis, only high-quality satellite pulses were extracted from the acquired data. This was achieved by applying criteria such as permanent water surfaces and misfit parameters, effectively eliminating noise and generating superior results. The selected pulses that satisfied the misfit criterion and exhibited surface characteristics were considered as "good" pulses. The average water level for each temporal pass was then calculated using these "good" water pulses. Multiple sub-datasets with different misfit mask criteria were compared with in-situ data after eliminating biases.

Among the various misfit mask criteria, employing the open loop tracing command and keeping misfits below 3.5 produced favorable outcomes. By applying a misfit filter of less than 3.5, the in-situ and altimetry datasets used in this experiment yielded statistically significant results. The evaluation metrics revealed a Nash-Sutcliffe Efficiency (NSE) of 0.989, an Unbiased Root Mean Square Error (ubRMSE) of 1.25m, and a Root Mean Square Error (RMSD) of 1.41m. Additionally, the water level anomalies were found to be 1.34 meters (RMSD), 1.24 meters (ubRMSE), and 0.97 meters (NSE). All cases demonstrated statistically significant Pearson correlation coefficients ($R2 > 0.9$).

It is important to note that the discrepancies observed in the measurements were not erroneous, but rather indicated a mismatch between the water levels captured by satellites and those present in the reservoir. The Tarbela Reservoir is situated in the upper region of the northwest Himalayas, characterized by the narrowest section of the Indus River valley. The uneven topography of this area can potentially affect the radar footprint, resulting in distorted or multiple-reflected signals. These differences may be attributed to variations in the reference geoid and reservoir activities, such as the opening and closing of gates. Additionally, the time difference between satellite and in-situ data collection could also contribute to potential errors. Currently, the estimated water levels are accurate to within a meter. Nevertheless, this study has also showcased the accuracy and acceptability of seasonal variations in water levels . Furthermore, adjustments were made considering the variances in spatial and temporal resolutions.

Satellite radar altimetry greatly expands and enhances water level observations for ungauged rivers, lakes, and reservoirs. It provides valuable insights into improving the accuracy of future research through the examination of geographical and temporal resolutions, necessary adjustments, and post-processing techniques. The study highlights the potential of Sentinel 3 radar altimetry in complementing existing monitoring datasets and emphasizes the importance of refining methodologies to enhance accuracy in water level assessments.

"Unraveling the Power of Sentinel-3A Radar Altimetry Waveform for Inland Water Dynamics"

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Inland water bodies, including rivers and lakes, play a crucial role in various aspects of life. Moreover, they are essential components for global climate change research. Monitoring the water levels of these inland water bodies is vital, usually done using in-situ gauges. However, in remote or isolated areas where gauges are lacking, satellite radar altimetry technology is employed to monitor water surfaces at any location and time. Synthetic Aperture Radar (SAR) altimetry satellites with high-resolution mode emit pulses that can penetrate through clouds and operate in different weather conditions, including rain and snowfall. When these pulses interact with the Earth's surface, the resulting echoes exhibit distinct waveform peaks across various regions. Analyzing these waveform shapes seasonally is crucial for both land and inland water bodies. Specularity plays a significant role in differentiating inland water bodies from land, as it helps to disregard land contamination. Waveforms over inland water bodies display diverse patterns, typically categorized into four types: Quasi-Brown model, flat patch, Quasi-Specular, and multiple peak waveforms. In the case of inland water surfaces in Pakistan during 2022, Sentinel 3 datasets were utilized to ensure accuracy. It was observed that echoes were highly specular during periods of inundation (wet months) and quasi-specular during dry months. This study focused on separating waveform shapes in different months, aiming to evaluate accuracy through variate differences, pass-to-pass repeatability, and comparison with gauge measurements. The study proposed a simple rule set to differentiate between specular, quasi-specular, and non-specular echoes for flood plains. Extracting L2 data from Sentinel 3A and applying pulse masking using the global water surface explorer facilitated isolating the pulses in the waveform over water and land. Furthermore, this research will contribute to mapping the extent and depth of inundation in inaccessible locations under all weather conditions.

Insights on deriving reservoir volumes from earth observation data, architecture for global processing

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The estimation of water-reservoir volumes from remote sensing data sources is of high interest for many applications. This involves the management of transboundary basins (including water conflict monitoring), disaster management (humanitarian actions), permit management/auditing (e.g., hydropower applications), along with the intrinsic scientific value of having global multi-decade records of surface water-storage dynamics. Currently, there are several strategies to derive water area extents from reservoirs based on multispectral or SAR satellite-based imagery, including robust methods to deal with partial occlusions, clouds, or satellite swaths cover. However, converting water area extent to volumes requires specific knowledge on the hypsometric curve (water elevation vs. basin area), characteristic of each reservoir. In this talk we will discuss several strategies that involve the use of i) Geospatially informed extrapolation of DEMs, ii) LIDAR-based altimetry (e.g., Icesat2 tracks) direct and indirect hypsometric estimations, and iii) historical knowledge on reservoir surface water dynamics, to better estimate hypsometric curves with minimal or absence of local observations. We will discuss limitations, validity and insights on mechanisms that support automation and scalability of volume derivation of reservoirs for medium to large dams. The global operational scalability of volume estimation will also be discussed from the perspective of the Global Water Watch, a platform oriented to facilitate public access to near-real-time water quantity dynamics of (>70,000) reservoirs globally. Additionally, we will present various use cases for remote-sensed regional volume estimations in Lesotho, Eswatini and Zambia.

The effect of the surface water in the calculation of the terrestrial water storage – the case of the Sobradinho reservoir

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Terrestrial water storage (TWS) corresponds to all water stored above and below the earth's surface. It is composed of water stored in the soil, groundwater, surface reservoirs, in the canopy, and water equivalent of ice and snow. In regions without ice and snow, many studies treated the TWS as being the sum of soil moisture and groundwater. These studies neglected surface water storage (SWS) in the TWS calculation, as they considered this variable to be insignificant for the TWS or, when working with data from models, excluded the surface part due to the inability of the models to simulate this component. The Brazilian Semiarid (BSA) is characterized by low precipitation rate, shallow soil layer, and high values of potential evapotranspiration, which lead to low water availability. To overcome this problem, the main water security action was the construction of reservoirs whose objective is to storage water during the rain season to be used in the dry season. The presence of reservoirs in the BSA can make unreal the calculation of TWS based on soil moisture and groundwater only. The objective of the study was to evaluate the impact of the water stored in the surrounding region of the Sobradinho reservoir over the final value of the TWS. Sobradinho is located in the São Francisco River Basin (maximum capacity of 34.1 km3), the largest reservoir in the SAB and main responsible to guarantee firm streamflow for power generation in the river. The terrestrial water storage anomalies (TWSA) given by the GRACE mission were compared with the TWSA of the model Catchment Land Surface Model (CLSM) of the Global Land Data Assimilation System (GLDAS 2.2) (which considers only soil moisture and groundwater). In order to consider the SWS from the Sobradinho, the TWSA was recalculated taking soil moisture and groundwater from the CLSM/GLDAS and SWS from the Sobradinho storage monitoring. The inclusion of the Sobradinho storage increased remarkably the TWSA, presenting an amplitude greater than GRACE TWSA. Nevertheless, the correlation improved from 0.79 (GRACE vs. CLSM/GLDS) to 0.84 (GRACE vs. CLSM/GLDAS + Sobradinho). The difference of amplitude in the TWSA could be an indication that SWS governs the TWS variation in the Sobradinho region. Conversely, more investigations are needed to precisely define the area of influence of the reservoir, considering the potential effect of the water mass scattering due to the coarse GRACE grid.

Unleashing the Potential of SAR Imagery for Water Detection: A Self-Supervised U-Net Approach with Knowledge Distillation for Semantic Segmentation

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Synthetic Aperture Radar (SAR) imagery provides a unique and potent tool for observing the Earth's surface, specifically in the context of detecting a variety of water bodies, which is a critical aspect of wetland monitoring. The task of semantic segmentation, including the detection of vegetated water bodies, can be demanding due to the intricate and noise-prone nature of SAR data. Conventional methods, which rely heavily on manually annotated data, are often constrained by the scarcity and significant expense of acquiring these resources.

In response to these challenges, our study proposes a novel method leveraging cross-modal knowledge distillation to train a convolutional neural network (CNN). This approach eliminates the need for annotated data, making it both cost-effective and efficient. Our methodology employs two specific models. The first, a teacher model, generates normalized difference water index (NDWI) masks from optical images, a trusted technique for water detection. The second, a student model that utilizes a U-Net architecture, learns to detect various forms of water bodies, including those hidden by vegetation, in SAR images.

The teacher and student models operate in conjunction, undergoing a training process that minimizes the Dice loss between their respective outputs. This synergistic methodology allows the student model to assimilate the knowledge imparted by the teacher model, leading to improved accuracy in segmentation tasks.

We have conducted a thorough evaluation of our approach on four distinct wetlands across Sweden. These wetlands, each possessing unique geographical and climatic conditions, offer a broad range for water detection tasks, testing the robustness and versatility of our method. Furthermore, we compare our approach's performance against multiple benchmark methodologies, providing a comprehensive review of its effectiveness.

The results show that our method outperforms existing methods in terms of performance accuracy, all the while requiring fewer data and computational resources. This combination of effectiveness and efficiency makes it an appealing solution for water detection in wetland monitoring tasks using SAR imagery.

In summary, this study signifies a substantial advancement towards a more efficient and cost-effective methodology for semantic segmentation in SAR imagery. By harnessing the power of cross-modal knowledge distillation and convolutional neural networks, we can enhance the detection of diverse water bodies, including those obscured by vegetation. This progress is of considerable importance to wetland monitoring, contributing notably to the field and potentially impacting environmental conservation, water resource management, and disaster mitigation strategies. The unique focus on wetlands in Sweden also lays the groundwork for future research and practical applications in similar environments globally.

Shoreline change assessment using Worldview, Sentinel, Landsat and Planetscope satellite images: a case study of the Kızılırmak Delta, Türkiye

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In this study, it is aimed to determine the temporal changes in the coastline of the Kızılırmak Delta, which is one of the most important wetlands on the Black Sea coast of Turkey. Worldview, Sentinel, Landsat and Planetscope satellite images were used to detect temporal changes in the coastline. The NDWI method, obtained by developing the Normalized Incidence of Vegetation Difference (NDVI), is generally expressed as the ratio of the difference between the green band and the near infrared band to the total band of the green band for satellite images. According to the data obtained from satellite images using the NDWI method, significant coastal changes were detected between 1975 and 2023, especially in the region where the Kızılırmak River discharge to the Black Sea. According to the measurements made at 100 m intervals, it was determined that the highest drop in the region was 783 m. With the activation of Altınkaya and Derbent Dams in the region, the amount of sediment carried by the Kızılırmak River has decreased considerably, which has led to significant coastal erosion, especially in recent years. The Kızılırmak Delta, which was taken under protection under the Ramsar contract, has a rich feature in terms of bio-ecological richness with its different habitats. It is obligatory to take necessary measures to determine the coastline of the delta and to prevent coastal erosion. Otherwise, the natural structure of the delta will deteriorate and its sustainability will not be possible.

Temporal and Spatial Analysis of Lake Eğirdir Shoreline Changes Using Satellite Images and Unmanned Aerial Vehicle

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In recent years, significant decreases in the water level of Lake Eğirdir, one of Turkey's most important freshwater sources, have been observed. This decline is primarily attributed to factors such as climate change and excessive water extraction for agricultural activities. To determine the changes in the shoreline of Lake Eğirdir, this study utilized satellite imagery from Landsat, Sentinel, and Worldview satellites, along with high-resolution orthophoto images obtained from unmanned aerial vehicles (UAVs) integrated with Real-Time Kinematic (RTK) and Post-Processed Kinematic (PPK) modules. Five different locations with the highest shoreline changes were identified, and autonomous flights were conducted using UAVs to capture aerial photographs from an altitude of 100 meters. Photogrammetric analysis of these aerial photographs obtained from the UAVs resulted in orthophoto images of the test areas. The orthophoto images obtained from the UAVs, together with Landsat, Sentinel, and Worldview satellite imagery, were analyzed using various remote sensing techniques to identify temporal and spatial changes in the shoreline of Lake Eğirdir. As a result, it was determined that the regions experiencing the most significant shoreline changes in Lake Eğirdir are the Gelendost district and the surrounding area of Yenice village.

Compound extreme sea level events on an estuarine environment: combining in-situ, satellite and modelling tools

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Coastal floods are often generated by extreme sea level events (ESLs) that result from the combination of more than one driver and stand out as some of the costliest and deadliest disasters (Hu et al., 2018). Extreme sea level drivers include storm surges, astronomical tide and/or waves, river discharge and rainfall (Hendry et al., 2019). When two or more of the ESL driving mechanisms occur simultaneously, flood severity may be exacerbated leading to increased coastal flood risk. Although many ESL events disasters are caused by compound events, the understanding, analysis, quantification, and prediction of such events is still in its infancy, reason why the aim of this work is to explore the non-linear interactions between dynamic marine (waves, storm surge and tide) and fluvial processes (river discharge) during ESLs. The study area selected for this work is the Tagus estuary, located in the central region of Portugal, facing a very energetic marine environment (wave climate), and an important river discharge contribution from Tagus River. A dynamic downscaling numerical modelling approach was developed to predict the ESL in Tagus estuary coast, using the circulation model MOHID Water Modelling System (http://www.mohid.com) coupled with SWAN wave model (https://swanmodel.sourceforge.io/) and XBeach model (https://oss.deltares.nl/web/xbeach/) for hazards estimation. In the present work we present preliminary results of the circulation model validation and sensitivity tests performed with the computational grid, using satellite derived bathymetries. Ongoing work involves the validation of the wave model and simulations of the ESL impact on the coast. A structured grid with a spatial resolution of 1 km built using in-situ bathymetric survey provided by the Portuguese Hydrographic Institute, was used in the MOHID simulations. The open boundary conditions for the model were derived from the CMEMS Atlantic-Iberian Biscay-Irish Ocean Physics Analysis and Forecast, while tidal conditions were obtained from the FES2014 (Finite Element Solution) tide model (Lyard et al., 2021). For atmospheric conditions, data derived from both AROME and WRF models was used. Additionally, river discharge and runoff data were extracted from EMODnet physics, specifically from the Almourol in-situ hydrological station; and from MOHIDLand model outputs. For the model validation a comparison with the tidal observations performed at Cascais tide gauge (within the study area) were performed, showing an accuracy of the model of about 0.08 m in predicting the water elevation during sprint and neap tide conditions. Sensitivity tests were performed using two distinct bathymetric data sources. In addition to the bathymetric data used for the model validation an updated version, using Sentinel-2 imagery (24th April 2023) and following satellite derived bathymetry (SDB) approach developed by Capo et al., 2014. Preliminary results show that a slight improvement in the water level estimations (when comparing with the Cascais tide gauge) when using the SDB grid in relation to the results obtained with the in-situ bathymetry (correlation coefficient of 0.97 and 0.95 respectively) and showing an improvement of about 6 cm in the water level predictions.

Validation of the NM method of determination of Gross Alpha And Gross Beta Activities in water By Liquid Scintillation Counting

Validation of the NM method of determination of Gross Alpha And Gross Beta Activities in water By Liquid Scintillation Counting Meriem Laassiri[2]
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To assess the radiological risk associated with the ingestion of natural mineral waters in Morocco, gross alpha and gross beta activities were determined in 14 commercially bottled mineral waters. Water samples were analyzed by liquid scintillation counting following the ISO 11704:2018 NM method for simultaneous determination of gross alpha and beta activities in each sample. Method verification was carried out using standard approaches in order to confirm the performance parameters of the NM method which is under routine use in our laboratory.

Further validation of the NM method was carried out through our participation in a proficiency test organized by the International Atomic Energy Agency (IAEA) “World-Wide Open Proficiency Test IAEA-TEL-2018-03 Part II”. The values reported by our laboratory were within the range of reference values and acceptable Z-Scores (0.53 and 0.20) were obtained.

Water cycle events in the global mass budget

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Global mean sea level (GMSL) exhibits a secular increasing trend of 3.2 +/- 0.3 mm yr-1 over the last 30 years. However, more than 43% of the variability in the de-trended global satellite sea level record occurs on 2-3 year time scales in rapid sea level 'burst' events, for which GMSL rises at more than twice the normal rate, causing increases as large as 12 mm. Here, using spaceborne gravity observations from NASA's GRACE and GRACE-FO missions, we uncover the relationship between interannual water cycle variability and global mean sea level, and demonstrate that rapid increases in river discharge and ice melt in certain regions hold the dominant influence over global mass budget closure for time scales up to 10 years. We quantify the extent of these influences and map a spatially-distributed rapid sea level rise 'potential' based on regional water cycle variability and observed land storage capacity, finding that the Amazon basin water storage and ice melt from the Greenland ice sheet exert the single largest influence on short-term changes in global ocean mass. We also bound the maximum effect that these events can have on the long-term global sea level trend and find that global hydrology variations are of sufficient amplitude to cancel the mass additions from the ice sheets on 2-3 year periods, or to offset those contributions by as much as 50% over a decade.

Information Content of L-, C-, and X-band Microwave Observations for Soil Moisture Estimation

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The upcoming Copernicus Imaging Microwave Radiometer (CIMR) mission will provide concurrent radiometric microwave observations at L-, C-, and X-bands, amongst others. In this study, we provide an information theoretic analysis of the synergies of different frequency channels for soil moisture estimation. We compare satellite observations of the Soil Moisture and Ocean Salinity (SMOS) and Advanced Microwave Scanning Radiometer 2 (AMSR2) sensors to in situ measurements of soil moisture over a variety of land cover conditions. We find that L-band observations provide a larger amount of soil moisture information as compared to higher frequencies. We also show that concurrent observations of L-band and higher frequency channels exceed the information content of L-band measurements alone, with the added value depending on the land cover conditions and other factors. The results of this study motivate the development of soil moisture retrieval algorithms from CIMR land observations and demonstrate the added value of multiple frequency observations for land parameter retrievals.

Analyses of the relationship between horizontal and vertical brightness temperatures for derivation of signal-to-noise ratio and vegetation metrics

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Passive microwave satellite sensors allow retrieving soil moisture (SM) and vegetation optical depth (VOD; i.e., vegetation attenuation) at global scale. SM and VOD are important ecological indicators which may, however, contain errors due to radiometer instrument noise of brightness temperature input to SM and VOD retrieval. While the retrievals of SM can be validated, this is not yet possible with VOD, which requires an accurate assessment of the VOD retrieval robustness depending on the quantity and quality of information available. This translates into computing different metrics based on brightness temperatures (TB) from vertical (TBv) and horizontal (TBh) polarizations such as the Degrees of Information (DoI) and the Signal-to-Noise Ratio (SNR) [1,2].

In this research, we focus on enhancing and extending the SNR metric described in [2] using global TB measurements for the period 2015-2022. First, we revisit the SNR metric by studying the distance of TBv-TBh pairs to the 1:1 line, instead of computing the SNR at a pixel-regression basis, as done in [2]. This will provide a global and consistent reference for noise evaluation. Second, we extend the approach to TB measurements from the Soil Moisture Active-Passive (SMAP) mission at L-band and from the Advanced Microwave Scanning Radiometer-2 (AMSR2) sensor at C-, X- and Ku-bands. Resulting maps of SNR at each frequency allow for the quality assessment of different VOD products from an unbiased metrics-based perspective.

Complementarily to the SNR metric, it has been observed that separate TBv-TBh metrics, such as the slope between both variables, can be reliable indicators for vegetation properties such as biomass. This is feasible as annually averaged brightness temperatures respond to both average vegetation opacity and soil moisture signals. The first is directly linked to biomass, while the second provides a proxy of annual precipitation, which is strongly conditioning biomass worldwide. Results on both SNR maps and yearly based maps of the slope of TBv-TBh as a proxy for biomass dynamics will be presented at the conference.

[1] Konings, A. G., McColl, K. A., Piles, M., & Entekhabi, D. (2015). How many parameters can be maximally estimated from a set of measurements? IEEE Geoscience and Remote Sensing Letters, 12(5), 1081-1085.
[2] Chaparro, D., Feldman, A. F., Chaubell, M. J., Yueh, S. H., & Entekhabi, D. (2022). Robustness of Vegetation Optical Depth Retrievals Based on L-Band Global Radiometry. IEEE Transactions on Geoscience and Remote Sensing, 60, 1-17.

Enhancing catchment-scale rainfall-discharge modelling through GRACE(-FO) observations of storage-discharge relationships

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The unprecedented observations provided by GRACE (Gravity Recovery And Climate) and its successor GRACE Follow-On (GRACE-FO) have enhanced rainfall-runoff models and improved monthly discharge estimations over large catchments. such an estimation has traditionally been achieved by deducing the discharge from the closure of the water balance equation or by identifying an analytical relationship between storage (S) and discharge (Q). The latter approach assumes that water storage is the primary, if not the only, quantity governing the flow. Such a hypothesis is widely used in lumped hydrological models where conceptual linear reservoirs, for instance, let flow proportionally to their storage. However, a cursory examination of the empirical S-Q relationship in numerous large catchments worldwide often reveals a hysteresis loop, which stands in contrast to the aforementioned one-to-one mapping.

Such a looped behaviour has been theoretically foreseen, demonstrated empirically, and partially explained in many natural and small scale (typical dimension ~10km) catchments well before the advent of GRACE. However, for regional basins with typical dimensions of ~ 1000km, the underlying mechanisms responsible for the observed hysteresis are unlikely to be identical.

In order to better integrating GRACE(-FO) observations in the modelling of river discharge, it is essential to first ascertain whether the observed S-Q hysteresis is the result of:

1. A simple time delay between the highly correlated terrestrial water storage (cause) and discharge (effect),
2. A truly path-dependent hydrological process
3. An incomplete representation of the different various parameters driving the discharge. In this case, the hysteresis loop is more likely an artefact resulting from the projection of higher dimensional dynamics onto the 2-dimension S-Q plane.

In this study, we investigated several Polar, Amazonian, semi-arid, and temperate catchments to delve into this matter. Specifically, we analysed the extent to which surface temperature and soil moisture integration in the S-Q relationship could reproduce the observed hysteresis cycle. Our findings indicated that surface temperature played a key role in Polar catchments, while soil moisture or precipitation history seemed instrumental in explaining hysteresis in tropical catchments. Based on these analyses, we proposed appropriate models of storage-discharge hysteretic dynamics for each catchment, considering other potential variables that control flow.

These models were coupled with the water mass balance equation, resulting in mass-conserving rainfall-storage-discharge models. Notably, these models are calibrated independently of any precipitation and evapotranspiration data. Finally, we simulated discharge and storage using different combinations of precipitation and evapotranspiration products, selecting the combination that yielded the best simulation performance.

Overall, our study highlights the significance of considering additional variables in river discharge modelling, especially for catchments exhibiting hysteresis behaviour. The integration of GRACE(FO) data in these models represents a significant step forward in accurate river discharge estimation, benefiting various applications in hydrology.

River discharge estimation from altimetry with Fully-Focused SAR technique

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The river discharge represents a pivotal measure for understanding alterations in the water cycle and the state of water resources. Accurate quantification and continuous monitoring of river discharge are essential for sustainable water resource management and predicting future conditions. In this regard, advanced radar altimeter technology plays a key role in estimating river discharge variations. By combining hydraulic equations with channel bathymetry, the water level from altimetry can be converted to the river discharge. However, the process of parameterizing the effective cross section remains a challenge, particularly in regions with ungauged and poorly gauged.

This study develops an approach to map the river cross section (RCS) of virtual stations using Fully Focused SAR (FFSAR) data. The method involves identifying water and land positions based on waveform quality and backscatter coefficient data obtained from FFSAR altimetry. Moreover, by considering both high-flow and low-flow seasons, we can determine the riverbed height effectively. To represent the submerged channel more realistically, a dynamic shape is simulated and calibrated. These derived RCSs are then integrated with water surface elevation (WSE) and slope data obtained from altimetry to estimate river discharge using three distinct approaches: the Manning method, the Bjerklie method, and the 1D Hydrodynamic Model.

Here, we use Sentinel-3A/3B and Sentinel-6 satellite data spanning the period from 2016 to 2022. We study the transferability of our method by applying it to the upstream of the Yellow River (between Jimai and Mentang with 80–580 m river width), and the Yangtze River (between Yibing and Zhutuo with 300-100 m river width), which have very different geomorphological conditions, and validate the results against gauge station data.

Effects of spatial and temporal distribution of precipitation on hydrological modelling sensitivity of small catchments

Effects Of Spatial And Temporal Distribution Of Precipitation On Hydrological Modelling Sensitivity Of Small Catchments Elena Grek[1]
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The study is aimed at the practical application of weather radar data for rainfall floods modelling using SWAT (Soil and Water Assessment Tool) model. In our study we focused on the effects of spatial and temporal variability of precipitation on the hydrological behavior of the catchment area and, as a consequence, on the results of rainfall floods modeling (time step one day). This study includes studying 3 catchment areas (from 631 to 2180 km2) located in Novgorod region (Valdai Hills). We used various sources of liquid precipitation information from May to October 2020: meteorological radar (resolution 1x1 km), rain gauge (1 day), pluviograph (1 hour) and their combination. Seven different variants of rainfall - spatially-distributed or spatially-homogenous data with temporal resolution of 1 day and 1 hour - were used as input data for hydrological model. Our work revealed that using of radar and combined data increase the quality of rainfall flood modelling, however reliability of its results depends on radar calibration. We also showed the most comprehensive understanding of pick discharge value are possible when using hourly data, depicting temporal variability of precipitation at the catchment) as an input data for modelling.

Contribution of anthropogenic and hydroclimatic factors on the variation of surface water extent across the contiguous United States

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Human pressure and climate variability are significantly threatening freshwater resources, with cascading effects on societies and ecosystems. In this context, it is crucial to understand the anthropogenic and climatic impacts on surface water dynamics. Here, we examine the interaction between the variation of surface water extent and the change in five potential concurrent drivers across river basins of the contiguous United States (CONUS) during the period 1984–2020. In particular, built-up area, population, and irrigated land are regarded as the anthropogenic drivers, while hydroclimatic drivers are represented by precipitation and potential evapotranspiration (PET). We perform statistical analyses in order to quantify the change in the considered variables and then identify significantly different spatial patterns and possible interrelations. Results show that almost 79% (169 out of 204 river basins) of the CONUS experienced an expansion of surface water extent mainly in the continental and temperate climatic regions (mean expansion 158.33 km2). Increasing precipitation is found to be the most widespread driver of the gain in surface water extent, affecting nearly 70% of river basins. The remaining 35 river basins of the CONUS, mostly located in the arid southwestern region of the country, faced a reduction in surface water extent (mean reduction −146.73 km2). The expansion of built-up areas and increasing PET resulted to contribute to the loss of surface water in all the river basins, followed by population growth (in ∼75% of the river basins), decreasing precipitation (in ∼60% of the river basins, all situated in southwestern US), and irrigated land expansion (in ∼55% of the river basins). Our findings shed light on the potential impacts of the variability of anthropogenic and hydroclimatic factors on hydrology and surface water resources, which could support predictive adaptation strategies that ensure water conservation.

Analysis of expertised data processing for the generation of SWOT L2 River products

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The SWOT mission (NASA, CNES, UK-SA, CSA) launched in December 2022 provides observations of the surface of inland water bodies at unprecedented resolution and accuracy. knowing height accuracy shall be 11 cm or better. and river water slope accuracy shall be 3cm/1km (30 µrad) or better for river widths greater than 100 m (Biancamaria et al, 2016; Deasai, 2018) .

However in some places the L2 river products may have unsatisfactory precision. Indeed the L2 river products are computed following the segmentation of the SWOT apriori River Database (SWORD [1]) and the RiverObs algorithm, which are dedicated to global applicability. Thus, for local areas with specific hydraulic behavior (for instance areas where two river channels with different elevation are present and only a single river channel is present SWORD or areas with strong effects of anthropogenic structures), alternative methods must be proposed to enhance the accuracy of the river products.

Here we present 3 methods that aim at improving the SWOT L2 river products in such areas exploiting the daily observations done during the CalVal phase. The first method uses data fusion techniques to improve the computation of river widths with a combination of the SWOT observations and the watermasks computed using the ExtractEO tool [2] from Sentinel 1B radar images. For the second method we assess the improvements when replacing some portions of the river network in SWORD with the reference database of river centerlines in France (TOPAGE [3]) modified in order to take into account the precise location of power dams, locks and weirs. Finally the third method improves the water surface elevation signal with a dedicated filter that enforces a monotonically decreasing elevation from upstream to downstream. Applications of these 3 methods are illustrated on three different rivers' types, the Garonne River (France) over more than 200km, the Rhine River (France)over 180 km of very controlled by a series of 12 dams with lateral branches and the Maroni River (French Guyana) with segments of more than 500 km, representative of large rivers. These approaches have been qualified thanks to a very dense to dense network of in situ measurements/data with for example more than 40 gauge stations along the segment of the Rhine River.

References

[1] SWORD: Altenau, E. H., Pavelsky, T. M., Durand, M. T., Yang, X., Frasson, R. P. d. M., & Bendezu, L. (2021). The surface water and ocean topography (SWOT) mission river database (SWORD): A global river network for satellite data products. Water Resources Research, 57, e2021WR030054. https://doi.org/10.1029/2021WR030054

[2] Maxant, J.; Braun, R.; Caspard, M.; Clandillon, S. ExtractEO, a Pipeline for Disaster Extent Mapping in the Context of Emergency Management. Remote Sens. 2022, 14, 5253. https://doi.org/10.3390/rs14205253

[3] Topage: http://www.sandre.eaufrance.fr/actualite/diffusion-de-la-1%C3%A8re-version-de-la-bd-topage%C2%AE-m%C3%A9tropole

Water Surface Level Measurements Over Inland Targets With FFSAR

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The Fully-Focused SAR (FF-SAR) technique for radar altimeters is well known mostly for the large improvement in terms of along-track resolution that can achieve compared to classic techniques: the typical ~300 m obtained with Delay-Doppler Processing (DDP) can be reduced to around 0.5 m. Such a step is interesting for many applications. For the specific case of inland water monitoring, the main benefit is not just the increased resolution for better resolving the shape of the targets, but the improved capabilities to remove contaminated waveforms affected by nearby scatters that allow to provide better water level estimates. Indeed, for typical km-size targets, the high number of independent waveforms available allows to apply drastic filters while keeping a large number of useful waveforms for the retracking step.

In order to evaluate the overall benefit, we apply the FF-SAR algorithm to perform measurements of the water surface level over a series of reservoirs, with typical sizes between 0.1 and 10 km. A FF-SAR Ground Prototype Processor (GPP) developed by isardSAT and based on the back projection algorithm [1] has been used to process the Sentinel-6A’s altimetry data and generate FF-SAR radargrams of the nadir targets under study.

In this contribution we will present the methodology followed, the main results, and the current status of the study. The performance of the method is assessed by processing a large number of passes over the selected reservoirs and by comparing the retrieved elevation against in-situ measurements. Precision values around ~5 cm have been obtained, and comparison against other processing methods and retrackers is also provided.

[1] Egido, Alejandro and Walter H. F. Smith. “Fully Focused SAR Altimetry: Theory and Applications.” IEEE Transactions on Geoscience and Remote Sensing 55 (2017): 392-406.

Daily Monitoring of the May 2023 Emilia-Romagna Flood Using COSMO-SkyMed data

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In May 2023 the northern Italian region of Emilia-Romagna was hit by a series of floods. The first one occurred on 2-3 May after several months of drought. More severe floods hit Emilia-Romagna starting from 16–17 May 2023. During the latter event, more than 20 rivers burst their banks, about 15 people were killed, thousands of people were displaced, and public transportation was stopped.

A daily monitoring of the flood, starting from 16 May 2023, was requested by the Italian Department of Civil Protection (DPC). Synthetic Aperture Radar (SAR) systems are particularly useful for flood mapping because of the synoptic view and the capability to provide data both day and night and in any meteorological conditions. Moreover, calm water is easily detected in SAR images because it has a distinguishable radar signature characterized by a low radar return. However, the majority of SAR systems has a revisit time that does not comply with a daily monitoring. Moreover, a complete monitoring of the Emilia-Romagna flood required to observe different areas on the same day, especially during the first days of the flood. It was therefore necessary to rely on a SAR system offering both an on-demand capability and the possibility to simultaneously observe different areas.

The COSMO-SkyMed (CSK) constellation, hosting an X-band SAR, can operate as an on-demand system to ensure a timely provision of data. Presently, also the COSMO-SkyMed Second Generation (CSG) is deployed. It provides service continuity for the first generation while improving performance, functionality, and system services for the user community.

The satellite daily monitoring of the Emilia-Romagna flood was performed in the period 17 May – 3 July 2023 using data provided from both CSK and CSG. The activity included: 1) the tasking of the satellite (at least 36 h before the acquisition time) to observe the areas mostly affected by the flood according to the information daily gathered by DPC; 2) the calibration and the geocoding of the SAR data; 3) the generation of the flood maps; 4) the generation of the maps of water depth.

To generate the flood maps, a change detection algorithm was applied. Note that only for a subset of the images of the flood it was possible to find in the archive a pre-event image acquired with the same geometry (interferometric pair). To apply change detection for the other post-event images too, a set of pre-flood images covering whole area hit by the flood was gathered. Among these images the most suitable one was selected based on the orbit (ascending or descending), the overlap with the considered post-event image, and the incidence angle. The water depth maps were obtained using the 5 meters resolution regional DTM and the FwDET algorithm (Cohen et al., 2019), the evolution of the volumes of persistent water in the area were determined to support drainage operations.

The main outcomes of the satellite monitoring of the Email-Romagna flood will be presented at the conference.

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Specular echoes on a 100 km stretch of the Rhine River

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A simplified process for ranging specular echoes, called Precision Inland Surface Altimetry (PISA) was introduced in [1]. The original version coherently summed 64 IE in Sentinel 3 bursts, producing one water level estimate per burst. An extension of PISA to coherently integrate multiple bursts (for wide rivers and lakes where there are two or more consecutive bursts over the water surface) is described in this paper. The issue of burst-to-burst phase discontinuities when extending to multiple bursts is addressed and the applied correction allows a mild surface slope.

A 100 km stretch of the Rhine, latitude 49.1 to 50.1, is the case study reported here. In this span are a wide variety of water bodies, mostly specular. Besides continuous visibility of the Rhine, there are ponds, lakes, tributaries, canals, and a marina. There is also surrounding urban and vegetation backscatter. There are a variety of geometries: water at nadir, off nadir to the furthest possible distance (7 km), and many in close proximity to one another. There are many cases of multiple water bodies within a specular echo Fresnel zone (190 m for Sentinel 3) which are a further challenge for altimetry.

We present some new results on ranging in this complex water environment. Our analysis includes a comparison of PISA with the FFSAR processing. PISA and FFSAR are compared with in situ water levels.

We demonstrate mapping the Rhine river surface level, with some gaps due to interference from lakes in close proximity to the river. We'll discuss ways to avoid the mutual interference problems.

[1] Abileah R., Vignudelli S.: Precise Inland Surface Altimetry (Pisa) with Nadir Specular Echoes from Sentinel-3: Algorithm and Performance Assessment, Remote Sensing of Environment, 264, 112580,doi:10.1016/j.rse.2021.112580, 2021.

RainGNSS : an in-situ network for altimetry, water vapor and precipitation validation of satellite-based observations

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The retrieval of water vapor from GNSS signal is a well-know application (Davis et al. 1985, Saastamoinen et al. 1972, Solheim et al., 1999). Different ground stations networks (IGS, Suominet, EUREF) already provide total, dry and wet component of the zenithal delay, allowing for the validation of observations from space (Bennartz et al., 2017). Lately, some preliminary results also paves the way to a potential retrieval of rain rate from the same networks (Manandhar et al., 2018, Liu et al., 2019, Zhao et al., 2020).

The present work makes use of the vorteX.io ground micro-stations to propose a in-situ network dedicated to the validation of altimetry, water vapor and precipitation satellite-based observations. Distributed along rivers, the vorteX.io ground micro-stations network already provides a high-frequency continuous measurement of different hydrological parameters (height, speed, turbidity) with an excellent accuracy. This system represents thus a solution to the lack of data and the increasing need for the monitoring of rivers in the context of global warming.

The RainGNSS project is using the implementation of a low-cost GNSS receiver on the vorteX.io ground micro-station to provide additional geophysical parameters with a twofold objective:
1- to complement the offer of the vorteX.io system with a rain rate product that will improve its capability to monitor and prevent flash-flood events
2- to provide water vapor and rain rate as a in-situ ground “truth” for the validation of satellite-based observations of water vapor, precipitation and altimetry (for the SWOT mission, particularly)

We will present the first results of the water vapor and precipitation retrievals from the GNSS receiver with a validation against ECMWF analysis and measurements from a Davis Vantage Vue weather station. Two retrieval algorithms for the rain rate will be compared: a physical approach based on a variational solution (Rodgers 2000) and a machine learning algorithm.

Bennartz, R., Höschen, H., Picard, B., Schröder, M., Stengel, M., Sus, O., Bojkov, B., Casadio, S., Diedrich, H., Eliasson, S., Fell, F., Fischer, J., Hollmann, R., Preusker, R., & Willén, U. (2017). An intercalibrated dataset of total column water vapour and wet tropospheric correction based on MWR on board ERS-1, ERS-2, and Envisat. Atmospheric Measurement Techniques, 10(4), 1387–1402. https://doi.org/10.5194/amt-10-1387-2017

Liu, Y., Zhao, Q., Yao, W., Ma, X., Yao, Y., & Liu, L. (2019). Short-term rainfall forecast model based on the improved BP–NN algorithm. Scientific Reports, 9(1), 19751. https://doi.org/10.1038/s41598- 019-56452-5

Manandhar, S., Lee, Y. H., Meng, Y. S., Yuan, F., & Ong, J. T. (2018). GPS-Derived PWV for Rainfall Nowcasting in Tropical Region. IEEE Transactions on Geoscience and Remote Sensing, 56(8), 4835–4844. https://doi.org/10.1109/TGRS.2018.2839899

Rodgers, C. D. (2000). Inverse Methods for Atmospheric Sounding (Vol. 2). world scientific. https://doi.org/10.1142/3171

Zhao, Q., Liu, Y., Ma, X., Yao, W., Yao, Y., & Li, X. (2020). An Improved Rainfall Forecasting Model Based on GNSS Observations. IEEE Transactions on Geoscience and Remote Sensing, 58(7), 4891–4900. https://doi.org/10.1109/TGRS.2020.2968124

Satellite-based hydrological modeling over Niger basin: characteristics, sensitivities and performances for better understanding the flood events in Niamey (the 2020 extreme event case)

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Climate change, combined with significant land use changes and increasing anthropogenic pressure on water resources, has a strong influence on the water cycle in the intertropical zone. This can lead to changes in rainfall patterns, particularly the occurrence of extreme weather and climate events, drastically impacting regions such as semi-arid areas where water accessibility remains a challenge. Consequently, tropical regions like the Sahel have experienced unprecedented occurrences of extreme droughts and floods, posing severe consequences for vulnerable populations in major urban centers. Flooding risks in Niamey, Niger are progressively increasing in frequency and intensity over the last decade. The 2020-season episode could dramatically illustrate this, with the Niger river recording a peak discharge of 2,600.0 m3s-1, leading to substantial material and human losses. Real-time monitoring of inland surface waters and their dynamics has become essential for enhancing understanding, mitigation, and minimizing direct damages to people's lives. Satellite-based precipitation products have been presented as a very effective complementary source for hydrological monitoring, being crucial in ungauged regions. The integration of near-real time (NRT) satellite-based precipitation estimates into robust hydrological models is increasingly being refined and has been demonstrated as an important tool for describing the water cycle, especially for real-time applications (e.g., monitoring hydrological extremes). However, various performance scenarios are obtained due to the characteristics of those satellite products in representing the precipitation distribution (e.g., volume and occurrence) at a certain spatio-temporal scale and over a certain rainfall regime region. As an example of application, the HYFAA scheduler, which is an experimental demonstrator for monitoring/predicting discharges at any point on the river and is based on the MGB (Large Basin Model), have been operationally used for monitoring the discharges over Niger basin using the GSMaP multi-platform rainfall product. The MGB-HYFAA uses other state-of-the-art high-resolution satellite precipitation products (e.g., IMERG, CHIRPS and MSWEP), in a single perspective or through ensemble mode, being also able to assimilate water surface elevation estimates from satellite altimetry. The framework also enables the opportunity to deal with distinct configuration scenarios, both through model parameters and data sources (dynamic inputs), such as the spatial/temporal/intensity uncertainties (the precipitation perturbation), as well as to receive present/future climate scenarios' dataset. Given that, this work aims to exploit, throughout a set of experiments using the distributed MGB-HYFAA model, various aspects that contribute to the understanding of flood dynamics over the Niger basin, through the link between the input data (i.e., multiple precipitation products) and its corresponding hydrological response. The sensitivity analysis takes into account idealized scenarios of precipitation changing that could distinctly modify the discharge response that provides extreme limits for the representation of floods, which could be fundamental for effective hydrometeorological monitoring. Thus, the role of rainfall systems, intensity, and spatio-temporal precipitation patterns in flood genesis are considered. An especial attention is given to the record floods of the 2020 season in Niamey, in order to contribute to understanding their genesis and the accuracy of MGB-HYFAA observation system for providing alerts.

Depleting groundwater in the Po River Plain, Italy as seen by observations from GRACE and vertical land motion

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The Po River Plain is a productive agricultural region in northern Italy and home to a third of the country’s population. Irrigated agriculture is supported by surface water flowing from the Alps, mainly driven by snowmelt. However, recent severe snow drought, especially during water years 2015-2017 and 2019-2022, has caused reductions in streamflow and forced farmers to turn to groundwater pumping to meet irrigation needs. In this study, we analyze changes in terrestrial water storage (TWS) using observations from the Gravity Recovery and Climate Experiment (GRACE) and the Follow-On GRACE mission from 2015-2022. To calculate the effects of drought on groundwater storage (GWS), we subtract changes in satellite derived root zone soil moisture and snow water equivalent from the change in TWS timeseries. We find a rate of TWS change of -15.5 and -19.7 mm/year and a corresponding change in GWS of -14.0 and -8.1 mm/year over the entire study period spanning March 2015-May 2022 and most recent drought period spanning October 2018- May 2022, respectively. Change in TWS also causes elastic deformation of the Earth’s crust, measurable using vertical displacements of Global Navigation Satellite System (GNSS) stations. While elastic uplift (subsidence) is mainly observed in mountainous areas with exposed bedrock and indicates a regional scale mass loss (gain); an opposing deformation response occurs locally above confined or semi-confined aquifers due to a change in GWS, showing subsidence (uplift) due to groundwater net discharge (recharge). Here, we compare TWS and GWS changes to elastic uplift and poroelastic subsidence recorded at more than 400 GNSS stations distributed across the Po River Plain and the Alps. Despite influences from other factors including sediment compaction, tectonics, and gas extraction, we find evidence of poroelastic subsidence in the Po Plain related to groundwater overdraft and an elastic uplift response in the mountains ranging from ~0.5-3 mm/year from March 2015- May2022. By analyzing both types of deformation in combination with GRACE observations, while also considering data gaps and uncertainties, we can better understand spatiotemporal changes in both TWS and GWS. This allows us to evaluate the impacts of drought on the terrestrial water cycle and rates of anthropogenic groundwater pumping, providing essential contextual information for future drought management and resiliency planning.

Improving Soil Moisture Simulations Based on Satellite Data-optimized Soil Texture Data

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Soil moisture (SM) is important for weather and climate as it serves as an intermediate medium that regulates the partitions of water and energy arriving on land. However, SM is often poorly simulated by current Land Surface Models (LSMs), because of inappropriate representation of land surface parameters and physical parameterization schemes. However, current major gridded soil texture datasets such as Global Soil Datasets for Earth system science (GSDE) and Harmonized World Soil Data (HWSD) from Food and Agriculture Organization are often extrapolated from a limited number of in-situ measurements, which could make them contain large biases. To reduce such bias, constraints from observations at large spatial scales are necessary. Such constraints were difficult to obtain in the past but can be more easily accessed now, benefiting from the advancements of satellite technologies and the development of new soil hydrological theories.

In this study, we will leverage such benefits of modern satellite products and land surface theories to improve the characterization of soil texture data at the global scale, and use the calibrated soil texture maps to improve soil moisture simulation in one example LSM. Our results show that the new soil texture maps show increased sand content over arid areas while decreased over humid areas. The results for soil clay content show the opposite pattern (decreased over arid areas and increased over humid areas). The soil organic carbon (SOC) result shows an overall increase over the entire globe. The increase is especially strong over areas with dense vegetation covers. Using the calibrated soil maps, we then conduct regional soil moisture simulation experiments. The simulated SM in experiments with updated soil maps generally outperforms those from experiments with the baseline soil maps in all cases. However, the improvement is more significant in the experiment with GSDE soil maps considering soil organic carbon, highlighting the important role of SOC in regulating soil hydraulic processes. Our results here provide successful evidence for constraining soil texture data from large-scale observations. We also show that observation-oriented calibration on soil texture maps is necessary for a better land surface simulation, which is critically important for the development of Earth System Models.

Hydrological Remote Sensing using Signals of Opportunity below 400 MHZ

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Signals of Opportunity reflectometry (SoOp-R) employs existing non-cooperative transmitters as sources of illumination in bistatic radar. In the typical application, these sources are communication satellites. Cross-correlation between a direct line of sight signal and a reflected path signal (or autocorrelation of the combined signal) can be used as an observation to estimate the surface complex reflection coefficient. SoOp-R enables microwave remote sensing observations to be made in bands allocated for communications and is thus not limited to frequencies protected for science use. Frequencies below 500 MHz are of particular value as they are capable of penetrating through the vegetation canopy and below the top few cm of the soil, to provide sensitivity to the root-zone soil moisture (RZSM). These frequencies are also heavily used for communications and have no protected bands.

An observation simulation study using actual in-situ soil moisture time histories, have been used to show the sensitivity of the sub surface soil moisture under typical agricultural vegetation to various combinations of observation frequency and polarization, signal to noise ratio, and temporal delay. This study showed that the combination of observations at multiple frequencies is necessary to accurately invert the soil moisture profile. The typical configuration would be a L-band (e.g. GNSS at 1.575 GHz) sensitive to the surface soil moisture and P-band (e.g. MUOS at 370 MHz) or I-band (e.g. ORBCOMM at 137 MHz) sensitive to the integrated soil moisture within the root zone. Although these sources are provided by transmitters in different orbits and are thus not coincident, relative time delays of up to 12 hours between multi-frequency observations was not found to significantly increase the retrieval error.

Field experiments have been conducted at the Agronomy Center for Research and Education (ACRE) at Purdue University to validate the forward models used in these retrievals. A calibrated front-end incorporating multiple reference noise sources was
designed for this experiment, producing final measurements of the received power in SI units of Watts.

Radio frequency interference (RFI) sweeping over multiple channels was observed in the 137 MHz band, which was effectively detected using a standard excess kurtosis test to neighboring un-occupied data channels. Another anomaly, a drop in signal power at 3 sec intervals, was also observed, possibly an instrument error. This was also successfully mitigated through blanking the data at the 3 sec period.

SigNals Of Opportunity P-band Investigation (SNOOPI) is a technology validation mission to demonstrate P-band remote sensing from orbit using non-cooperative signals of opportunity and with the specific technology validation objectives: (1) validate the forward model from orbit and under a variety of surface conditions, using well-calibrated in-situ observations (2) evaluate the effect of radio frequency interference (RFI) from orbit, within the frequencies of interest (3) space qualification of a prototype instrument. Originally scheduled for SpaceX CRS-27, the launch of SNOOPI has been delayed until January 2024.

Merits of Assimilating SWOT Altimetry and Sentinel-1-derived flood extent Observations for Flood Forecasting - A Proof-of-Concept

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The inclusion of Earth Observations (EO) from space into flood risk management presents a great opportunity to improve the ability to anticipate flooding, mitigate its impacts, and protect assets worldwide. The properties of inland water bodies are monitored by altimetry missions that provide along-track water surface elevation (WSE) from nadir (e.g., TOPEX/Poseidon, Jason, SARAL/AltiKa, Sentinel-3, Sentinel-6) or large-swath altimeters (SWOT), as well as from radar/optical missions (Sentinel-1/Sentinel-2) that provide high-resolution water extent maps.

Data Assimilation (DA) combines in-situ measurements with numerical model outputs to reduce uncertainties in the model inputs such as roughness, inflow discharge, channel/floodplain geometry and/or hydraulic state. Thus it allows to improve initial, boundary conditions and model parameters to issue improved forecasts. Leveraging multi-source observations, including remote sensing (RS) data allows densifying the observing network, both spatially and temporally, as well as diversifying their characteristics. Previous works have shown that this allows for a better performance of the EnKF---that relies on the stochastic computation of forecast error covariance matrix amongst a limited number of perturbed simulations---to represent the dynamics of the flow in the river bed and floodplain.

This research work is undertaken within the framework of an Observing System Simulation Experiment based on a reference simulation with a predefined set of friction parameters and input forcing discharge. The experiment is carried out with the TELEMAC-2D hydrodynamic solver, over a 50-km reach of the Garonne River, for a flood event in 2021. This reference simulation is used to generate synthetic observations, using the dedicated observation operators to replicate the in-situ water level, Sentinel-1-derived flood extent and SWOT WSE observations. This stands in the extraction of the true WSE values at all observation times and locations, in order to generate synthetical in-situ data at stream-gage stations, or to derive water masks and compute so-called wet surface ratio in several floodplain subdomains. The SWOT observations are synthetized with the SWOT-HR simulator applied on said WSE maps, providing pixel cloud data further processed by the RiverObs package. This chain aggregates WSEs over a selection of pixels and provides WSEs with high certainty at nodes every 200m along the river centerline, and at river reach every 10km, approximately. The observation operator associated with SWOT data computes the model equivalent of the pixel data aggregated over the selected TELEMAC-2D nodes. It relies on the selection of eligible pixels with appropriate water classes to issue WSEs with an error below 10cm as prescribed in the SWOT requirements.

A number of different EnKF DA experiments, are carried out considering different combinations of in-situ, S1 and SWOT observations. RS and in-situ data complement well as they present opposite characteristics in terms of frequency and spatial coverage, especially as RS provide data in the floodplain. Quantitative assessments based in 1D/2D metrics show promising results. This work heralds toward a reliable methodology for flood forecasting and flood risk assessment, for poorly-gauged or ungauged catchments, making the most of innovative EO data and paving the way for upcoming EO missions.

Discharge and water storage change from modern-era satellite altimetry

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Surface water level and discharge in rivers and water storage change in natural lakes are sensible indicators of long-term change of water cycle within a river catchment. Recently, low water levels in the river Rhine made navigation difficult, while high water levels due to intense rain events caused serious losts. Glacial lakes in the Alps are decreasing in dimension and also new lakes are built due to the melting of glaciers.
In this work, we compute river discharge and water storage change from space observations using simple equations using parameters water height, river slope and width for river discharge, water height and lake extension for the lakes.
A first set of input data over 2016-2023 is from satellite imaging and from SAR nadir-altimetry processed in Fully Focused SAR with the omega-kappa algorithm and the SAMOSA+ retracker. In rivers, the accuracy of water level is found to be better then 15 cm at 42 virtual stations and better than 10 cm in most of the lakes.

A second set of input data is from the new SWOT swath-mission which directly provides the above listed parameters. Real data of the SWOT 1-day calibration phase are used to estimate river discharge and water storage change in Germany and Switzerland. Results are assessed using simulated data from the hydrodynamical Sobek model, in-situ observations and are compared to the nadir-altimetry results.

The merging of nadir-altimetry and swath-altimetry gives an unprecedent high resolution in both time and space for both climate studies and monitoring of extremes and dedicated tools are investigated.

Estimating Daily Discharge of an Entire River Network Using Space-based SWOT Observations

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Accurate estimates of river discharge are vital to quantify the amount of water resources. In view of the steadily declining in-situ gauge network hydrological monitoring through spaceborne sensors becomes a necessity. The SWOT mission is the first satellite to conduct a global survey of Earth's surface water. It can provide measurements such as water surface elevations, changes in cross-sectional areas, river widths, and slopes.

As the SWOT data is sparse due to the 21 days orbit repeat period, we aim to develop a Kalman filter for continuous discharge estimation of an entire river network. To this end, we obtain the process model based on a physically based spatiotemporal correlation, which represents the correlation between the discharge values of river network in time and space. The observation model is derived from the discretization of the mass conservation equation, where the changes in cross-sectional areas are as the observations. The Kalman filter will be executed simultaneously in time and space domain to obtain daily discharges for river basins.

The feasibility of the approach is verified by Pepsi2 data, which is a synthetic river dataset built for testing and development of the SWOT mission discharge algorithms. This method is also very promising for combining multiple data as from SWOT, nadir altimetry, imagery and in situ.

The EOatSEE coastal total water level product: development, validation, and application

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The Earth Observation at Sea level Extreme Events Project (EOatSEE - https://eoatsee.eu/) aims to provide advanced reconstruction of relevant processes during extreme sea level events and associated coastal hazards by exploiting the novel opportunities and synergies arising from recent advances in Earth Observation (EO) data. The extreme sea level events (ESL) occur when the combination between multiple individual oceanic and atmospheric drivers result in a total water level (TWL) exceeding critical thresholds of the natural or artificial coastal defence structures. The TWL was computed using a linear summation downscaling empirical modelling approach, that consists of the sum of different drivers, including sea level anomaly (SLA), storm surge (SS), astronomical tide (AT) and wave runup (R). This methodological approach considers the co-occurrence of the different processes, nevertheless, does not account for their non-linear interactions. Python scripts were developed to collect (from raw files or toolboxes), process (e.g., remove outliers, perform spatial aggregation, etc.) and harmonise (e.g., ensure same temporal resolution) individual TWL components, resulting in a final single-point location time-series of TWL with hourly resolution. The TWL dataset can be computed at any coastal area in the world where regional X-TRACK products exist, for the period between 1993-2021 (28 years). This new product development has utilised the most recent advances in EO, such as the new regional X-TRACK (v2.0) coastal sea level product, provided by CTOH/LEGOS (Birol et al., 2017). To generate the SLA time series, all tracks from X-TRACK (except from HY2A) within a pre-defined region are used, spatially-aggregated and harmonised into a single SLA time-series with an improved temporal resolution (2-day compared to the original individual track resolution of about 10-days); the SS time-series is extracted from the dynamic atmospheric correction (DAC) derived from Mog2D (auxiliary datasets freely available at AVISO+ portal), forced by surface winds and atmospheric pressure from the ERA-interim reanalysis; the astronomical tide is computed using the FES2014 tidal model, through PYFES toolbox; and R is computed using the significant wave height and wave period derived from Copernicus WAVERYS hindcast dataset, and combined with global slopes (Athanasiou et al., 2019) to apply the Stockdon et al. (2006) empirical runup equation. Preliminary validation compared the new dataset X-TRACK SLA and SLA measured by local tide gauges with monthly temporal resolution. Results of the comparison between open ocean (Majuro Island) and on a shallow semi-enclosed sea (Dutch coast) tide gauges and X-TRACK SLA showed correlation coefficients of 0.93 and 0.69 and an RMSE of 0.036 and 0.077 on Majuro Island and Dutch Coast, respectively. In addition, this new TWL product has been evaluated regarding the prediction of the storm impact scale (SIC) during an ESL event. The impact of the extreme storm “Hercules” on the sandy beach of Carcavelos (Portugal) was analysed, and comparisons with observations indicate the capacity of this new product in predicting the correct SIC. The implementation of the present pipeline of production on different digital platforms (e.g., NextGEOSS) has been developed, thus allowing the replicability of the approach on a large variety of applications.

Modelling and Remote Sensing to estimate evaporation and water use in the Ebro Basin

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This study quantifies evaporation and its impact on water resources in the Ebro basin. The basin exhibits an uneven distribution of precipitation Although runoff is mostly generated over the Pyrenees, the water resources are mainly used in the valley for agricultural purposes. This translates into the necessity to transport and storage water from the Pyrenean slopes to the central valley by means of a complex network of dams and canals. The expansion of forests in non-agricultural areas, resulting from the abandonment of unmechanized agricultural lands, has further increased water consumption. Thus, the forest is competing with agriculture for water availability. To address these challenges, this study aims to estimate actual evaporation at fine temporal and spatial scales using remote sensing and modelling datasets, with the aim to improve the estimation of water use and help the basin managers to make better decisions.

The research consists of two main stages. Firstly, the GLEAM and Sen-ET products are compared to identify similarities and differences in space (such as rainfed vs irrigated areas, agricultural vs natural areas, and forests) and time (including seasonal variations, irrigation vs non-irrigation periods, and wet vs dry periods). Secondly, the evaporation products based on satellite data are compared with the SASER hydrometeorological modelling chain output, based on the SURFEX LSM. The objective is to assess the agreement between models and remote sensing datasets and identify potential sources of uncertainty, particularly related to irrigation and forests water use.

The outcomes of this research will contribute to a better understanding of actual evaporation patterns and their implications for water use and availability in the Ebro River basin. The findings will aid water managers to improve the estimation of evapotranspiration at different temporal and spatial scales, facilitating more efficient and sustainable water resource management practices.

Multi-scale water management and drought monitoring at the Morocco national scale

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Water is a fundamental element on Earth indispensable for human life, food and energy, which is currently threatened by climate change impacts. The United Nations (UN) identified water security as one of its Sustainable Development Goals (SDG6). Thus, water management is one of the crucial challenges due to the contrast between water supply and water demand. In fact, the more intensive use of water resources and the frequent periods of water scarcity are increasing conflicts for water use with large impacts on agriculture as well as on civil and industrial water uses. The agricultural sector is particularly vulnerable to water availability due to the strong link between food production and water use, with agriculture being the largest water user with about 70% of total freshwater consumption, which is projected to further increase due to climate change. Thus, more accurate information on water resources distribution in space and time is needed to address sustainable agriculture and to help guarantee food and water security as well as increase resilience of society and water-dependent economic sectors to hydro-meteorological extremes.

The objective of this presentation is to show and discuss the outcomes of the AFRI-SMART project “EO-Africa multi-scale smart agricultural water management”, which has as main objective the improvement of water management and the optimization of irrigation practices by combining remote sensing data and hydrological modeling, under the framework of the ESA EO Africa - National Incubators EXPRO+ call.

Present and forecasted water availability and crop irrigation water needs are assessed at multiple spatial scales from the Morocco country to the Oum Er-rbia basin with a focus on the two irrigation districts of Doukkala and Haouz.

At national scale multiple sources of information from ground observations, satellite remote sensing, and climate and hydrological models are integrated to provide the best estimate of flood and drought conditions based on the Hydroblocks modelling framework (Chaney et al., 2016; Vergopolan et al., 2021), which combines a 1-D land surface model with a cluster-based landscape representation (Hydrological Response Units (HRU)), allowing large-domain simulations of the land hydrological cycle. This includes a framework for merging SMAP/SMOS brightness temperatures with the Hydroblocks model output, through a Bayesian merging of the model outputs with satellite data. The Hydroblocks model will be coupled to the RAPID streamflow routing scheme to provide high resolution streamflow monitoring.

Instead, at Irrigation district scale actual and optimized irrigation water needs for specific crops, along with crop yield and water productivity at detailed spatial and temporal resolutions (daily and 10 m) will be predicted based on the energy-crop-water balance model FEST-EWB-SAFY (Corbari et al, 2011; 2022) driven by satellite data satellite land surface temperature (LST) from LANDSAT data and vegetation indices from Sentinel2 data.

Estimation of chlorophyll in Danube Lakes in Ukraine using observations from Copernicus Sentinel-2 MSI

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The use of Earth-observation satellites to assess and monitor water quality in lakes, reservoirs and large rivers has matured over recent years to such an extent that we now have operational systems producing water quality data for thousands of waterbodies in near real-time (CGLS), while reprocessing's of archive data using state-of-the-art methods are also delivering long-term, internally consistent time- series data for use in climate studies (ESA CCI).

Earth-observation satellites can provide information on water quality at spatial resolutions extending from approximately 0.001-1 km, with some satellite missions able to achieve repeated global coverage in 1-5 days. This observation capability has the potential to provide a unique perspective on water quality at regional and global scales. But the ‘big data’ generated by Earth observation missions also pose significant challenges for the storage, analysis, and distribution. For this reason, approaches to data processing are evolving rapidly with an increasing reliance on high performance computing infrastructures and cloud-based services.

The approaches used to produce water quality products from satellite data vary markedly in their complexity. There are approaches based on comparatively simple empirical algorithms, and others that employ advanced, and computationally intensive, machine learning models. One recent development in the field has been the use of ensembles with intelligent selection of algorithms based on the optical properties of the waterbody (or even pixel) under observation. It is this approach that underlies CGLS. Despite the battery of methods available there is still no consensus on the optimum approach and all processing chains must be rigorously validated against high-quality in situ data to understand the errors and uncertainties on the derived products. The development of improved methods for the remote sensing of inland water quality remains an active field of research.

The University of Stirling, Great Britain, and the Odessa State Environmental University, Ukraine working on the project "Capacity Building in Earth observation for national water quality assessment (CORNELIA)" of the British-Ukrainian grant program with the success and innovation TWINNING. As part of this project, a summer school was held in May 2023, and expeditionary research is planned for July 2023 on the Danube lakes Yalpug, Kugurluy, Kitay and Katlabukh. The purpose of field research is to measure the chlorophyll content in lakes. The determination will be made by taking water samples, simultaneously using the Water Insight Spectrometer WISP, as well as by interpreting satellite images. The next task will be to calibrate the satellite information and interpret the received data.

This project is of particular importance for Ukraine since the use of satellite information for water quality control of water bodies is economically justified in the face of a shortage of funds for financing scientific research in war conditions; it also creates opportunities for monitoring the quality of water bodies that are not yet available due to military actions. The Danube lakes within the framework of the project are used as a full-scale testing ground for testing the methods that are being introduced with a view to assess inland water quality across Ukraine.

SURFACE WATER EXTENT AND VOLUME IN THE INNER NIGER DELTA (IND) OVER 2000-2022 USING MULTISPECTRAL IMAGERY AND RADAR ALTIMETRY

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The surface water reservoir plays a crucial role as one of the primary sources of freshwater for ecosystems and human activities. However, its spatio-temporal dynamics at regional and global scales remain poorly understood. Satellite remote sensing presents a unique opportunity to assess surface water stocks using various techniques. Unfortunately, until now, available methods have not provided long time series of surface water volumes with adequate spatial and temporal resolution to capture the reservoir's dynamics effectively.

The main objectives of this study are twofold: (1) to quantify the extent and volume of surface water and (2) to compare our approach with a digital flooding model developed by Zwarts et al. (2018) and ICESat-2 data. The study area is the Inner Niger Delta, an extensive Sahelian floodplain in Central Mali, influenced by the West African Monsoon, resulting in a wet season from August to December. To map the surface water extent, we used MODIS product, offering a spatial resolution of 500 m, and analyzed a total of 1,028 8-day composites spanning from 2000 to 2022. Our methodology relied on the Enhanced Vegetation Index (EVI) and Land Surface Water Index (LSWI) to classify individual pixels into different categories, such as non-flooded, mixed, flooded, and permanent water bodies. To estimate water levels, we utilized radar altimetry data from ERS-2, Envisat, Saral, Sentinel-3A, and Sentinel-3B missions. We defined altimetry virtual stations at the crossing points between the altimetry ground-tracks and inland water bodies (rivers, lakes, and floodplains). By interpolating water levels over the surface water extent from multispectral imagery, we generated water level maps and quantified surface water volume for the period between 2000 and 2022.

The accuracy of the water level maps was validated using both the digital flooding model and ICESat-2 data. The comparison between our method and the digital flooding model showed a seasonal cycle each year, with a peak in November and minimum values in April-May. The maximum flood occurred in 2003 (~15,800 km²), and the minimum floods were observed in 2002 (8,460 km²), 2004 (8,407 km²), 2011 (8,104 km²), and 2017 (~6,987 km²) using our method. Our method slightly underestimated the surface water extent by approximately -19% compared to the digital flooding model for the entire period. This underestimation could be attributed to the higher spatial resolution of the Landsat-based digital flooding model compared to the 500 m resolution from MODIS, which sometimes resulted in pixels being considered as mixed. To assess the accuracy of our water level maps against ICESat-2 data, various statistical parameters such as R^2, RMSE, and bias were calculated. Out of the 64 comparisons made, approximately 58% showed an R^2 value greater than or equal to 0.5, 15% were between 0.3 and 0.5, and 27% were less than or equal to 0.3. Regarding the bias, around 45% of the comparisons exhibited a bias between -0.25 and 0.25 meters, while 25% fell between [-0.5, -0.25 meters] and [0.25, 0.5 meters], and 33% were below -0.5 or above 0.5 meters.

Evaluation of GRACE Satellite Data for Groundwater Drought Monitoring in Lorestan Province

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The GRACE (Gravity Recovery and Climate Experiment) satellite is a joint cooperation between the US and Germany. It consists of two similar and separate satellites that move at a height of 100 km from the Earth's surface with a distance of 220 km from each other. By analyzing the changes in distance between the satellites caused by the changing local gravity field through which they pass, changes in the gravity field can be obtained. Data from GRACE satellites is a new and valuable tool for monitoring groundwater. Currently, GRACE satellites are the only remote sensing satellites that have the ability to monitor changes in underground water levels. The main application of GRACE satellites is to determine hydrological changes by measuring the continuous changes of water in aquifers, soil, surface reservoirs, and snow with an accuracy of a few millimeters in terms of water height with a resolution of 300 km.

This study investigates and evaluate the effectiveness of GRACE satellite observations to monitor drought conditions in the Borojerd-Dorud (B-D) aquifer, a part of Dez watershed located Northeast of Lorestan province, Iran. For this purpose, the data of GRACE between the years 2002 and 2022 were used to monitor the fluctuations of the underground water level in this basin. Drought monitoring is a key component of drought management, and researchers are constantly seeking ways to enhance its accuracy. The Equivalent Water Thickness (EWT), derived from GRACE time-variable gravity observations, represents the total terrestrial water storage anomalies from soil moisture, snow, surface water (including rivers, lakes, reservoirs, etc.), as well as groundwater and aquifers.
The groundwater unit hydrograph of the B-D aquifer indicates a decrease in groundwater level during the period of 2002 to 2018, with a sharp drop from 2007 to 2015, while in 2016 and 2017, the groundwater level increased in general. The Standard Precipitation Evapotranspiration Index (SPEI), designed to take into account both precipitation and potential evapotranspiration (PET) in determining drought, was also calculated for the period 2002-2023. The EWT anomaly obtained from GRACE in the above-mentioned basin for the same period was used to assess drought conditions. The results of SPEI indicate that from 2006-2015 and 2016-2017, the area suffered from drought conditions, while in 2013-2014 and 2019-2020, it had wet conditions. The EWT decreased from 2007-2019, while in 2019-2020, it increased. Also, the monthly drought SPEI (1, 3, 12, 18, 24, 36) was compared and used against the EWT of GRACE as criteria to assess the best performance of EWT of the B-D aquifer. The regression analysis between EWT and SPEI (1 to 36 months) shows that the best regression happens between EWT and SPEI-24 with a correlation coefficient equal to 0.64. The result indicates that when a drought condition happens in an area, the water level decreases two years later.

Assessment and Hydrological Validation of Merged Near-Real-Time Satellite-Based Precipitation over Saudi

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Performance assessment of satellite-based precipitation products (SPPs) is critical for their hydrological application and development especially in the Kingdom, which suffers from an increase in the occurrence of floods. This study evaluates the performance of four different precipitation forecasting models: PERSIANN, PERSIANN-CCS, PERSIANN-CDR, and PERSIANN-PDIR-Now using rain gauges. From 2017 through 2022, PERSIAN family were analyzed on a yearly, seasonal, monthly, and daily scale. Correlation coefficient (CC), root mean square error (RMSE), and mean bias (MB), as well as more categorical metrics such as the false alarm ratio (FAR), probability of detection (POD), and critical success index (CSI), were utilized in this study. Results showed that the spatial-temporal distribution of precipitation across Saudi Arabia was effectively observed by PERSIANN, PERISANN-CCS, PERISANN-CDR, and PERSIANN-DIR products. When compared to the rain gauges, monthly estimates were more reliable for the PERSIANN family than their daily counterparts. In daily scale, PERSIANN-PDIR-Now performances better than rest of PERSIANN family on detecting the precipitation events. As result, PERISANN PDIR-Now is the most suitable product to conduct hydrological and climatic studies in Saudi.

Update on SWOT: Transformative data from revolutionary technology, and implications for hydrology and water intelligence

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A new satellite mission for oceanography and hydrology science called Surface Water and Ocean Topography (SWOT) was developed jointly by the U.S. National Aeronautics and Space Administration and France's Centre National d'Etudes Spatiales and launched on December 16, 2022. Using state-of-the-art "radar interferometry" technology to measure the elevation of water, SWOT will observe major lakes, rivers and wetlands while detecting ocean features with unprecedented resolution and spatial coverage. SWOT data is poised to provide critical information that is needed to assess water resources on land, track regional sea level changes, monitor coastal processes, and observe small-scale ocean currents and eddies.

SWOT will revolutionize hydrology in several areas including surface water storage and discharge in rivers by providing a global baseline set of observations for millions of water bodies. SWOT will provide the very first comprehensive view of Earth's surface water from space and will allow scientists to determine changing volumes of fresh water across the globe. These measurements are key to understanding surface water availability and in preparing for important water-related hazards such as floods and droughts. SWOT will contribute to a fundamental understanding of the terrestrial branch of the global water cycle.

SWOT will also significantly advance oceanography by detecting ocean features with 10 times better resolution than present technologies. The higher resolution will reveal small-scale ocean features that contribute to the ocean-atmosphere exchange of heat and carbon. These are major components in global climate change, and will improve the understanding of the ocean environment including motion of life-sustaining nutrients and harmful pollutants. SWOT data will be used to improve ocean circulation forecasts, benefiting ship and offshore commercial operations, along with coastal planning activities such as flood prediction and sea level rise.

SWOT is expected to achieve 1 cm precision at 1 km x 1 km pixels over the ocean and 10 cm precision over 1Km land areas. Other mission payloads include a conventional dual-frequency altimeter for calibration to large-scale ocean topography, a water-vapor radiometer for correcting range delay caused by water vapor over the ocean, and precision orbit determination package (GPS, DORIS, and laser retroreflector).

The purpose of this paper is to present the SWOT mission status, including post-launch experiences, preliminary results from the mission, and SWOT's capability for supporting downstream applications.

Mapping safe drinking water in low- and middle- income countries using Earth observation data

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Safe drinking water access is a human right, yet data on the global Sustainable Development indictor 6.1.1., used to monitor the proportion of populations using safely managed drinking water services (SMDWs) is lacking for almost half of the global population. Earth observation (EO) data on anthropogenic, geographic and environmental factors, provide an opportunity to complement traditional household survey data to estimate progress on sustainable development targets in data scarce regions.

Here we explore the contribution of EO data for predicting SMDWs use, and generate a global map of subnational estimates of SMDWs use across 135 low- and middle-income countries (LMICs). We use a geospatial random forest modelling approach combining EO covariates with 318 subnational estimates of SMDWs use in 27 countries derived from 64,723 household's survey responses. Further, we model the four constituent subcomponents of SMDWs which include: (i) the use of an improved drinking water source (a drinking water source which provides some degree of protection from faecal contamination), (ii) accessibility on premises (a water source located in the dwelling, yard or plot), (iii) availability when needed (no insufficiency of water quantity experienced within the last month), and (iv) absence of faecal contamination (no detectable E. coli in a 100 ml sample of a household's primary drinking water source). We used Shapley additive explanation (SHAP) values to quantify the relative importance of model features on estimates of SMDWs as well as its subcomponents.

We estimate that over four billion people lack SMDWs in LMICs with the lowest national coverage rates concentrated in sub-Saharan Africa. Our best performing model used 39 covariates of both environmental and anthropogenic features and performed well, capturing 53% of the spatial variation in SMDWs based on leave-one-country-out cross-validation (mean absolute error (MAE)=0.13, coefficient of determination (R^2) =0.53). Faecal contamination of drinking water was identified as the main global driver for lack of SMDWs followed by lack of drinking water accessibility on premises. These results point towards an urgent need for investments in monitoring of drinking water quality globally as well as in drinking water infrastructures and services which reach people's homes. Our results highlight the interconnectedness and importance of both environmental and human factors for predicting use of SMDWs. Anthropogenic covariates had the highest overall SHAP values, making a higher contribution to the variation in SMDWs use than biogeographic, climatic, hydrogeologic or topographic covariates. However, environmental covariates alone explained more of the spatial variation (R^2=0.45, MAE= 0.14) in use of SMDWs than anthropogenic covariates alone (R^2= 0.37, MAE= 0.14). Climatic covariates, were most important for predicting drinking water contamination whereas anthropogenic factors contributed most to estimates of the type and accessibility of the drinking water source. Biogeographic covariates, on the other hand, were most important for predicting water availability.

Our results demonstrate how EO data can be leveraged to fill data gaps on SDG target 6.1 and draw attention to high-priority regions where the mobilisation and allocation of financial resources and human capacity is most urgently needed to address the global drinking water challenge.

The Sentinel-3 Next Generation Topography (S3NG-TOPO) Mission; Enhancing Continuity, Performance and Hydrology Capabilities

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The Sentinel-3 Next Generation Topography (S3NG-TOPO) mission is dedicated to ensuring the baseline continuity of existing Copernicus Sentinel-3 nadir-altimeter measurements from 2030 to 2050 while enhancing measurement performance. The current Sentinel-3 constellation lacks sufficient temporal and spatial sampling capabilities, so improving global-scale altimeter sampling is a key objective. Additionally, hydrology has been recognised as a primary mission objective, introducing a set of stringent requirements.

To meet the enhanced baseline sampling goal of ≤5 days revisit at scales ≤50km and fulfil the latency requirements for near-real time (NRT), slow time critical (STC), and non-time critical (NTC) data delivery, a coordinated constellation of spacecraft is required for S3NG-TOPO. The mission will consist of two large spacecraft, each equipped with a nadir-looking synthetic aperture radar (SAR) altimeter and an across-track baseline line wide swath altimeter, similar to the Surface Water and Ocean Topography (SWOT) mission recently launched by CNES and NASA.

The S3NG-TOPO swath altimeter will feature two swaths of 50 km on each side of the track, with a specialised high-resolution mode designed for hydrology applications. This mode will enable the measurement of river stage height for rivers wider than or equal to 100m and the monitoring of lakes and reservoirs with areas above 250m x 250m. By combining data from both S3NG-TOPO companion satellites, unprecedented sampling of inland water bodies will be achieved, with near-real-time latencies of less than 6 hours. This capability is particularly important for critical hydrology users.

The design of the S3NG-TOPO mission addresses the need for improved altimeter sampling, enhanced hydrology applications, and the timely delivery of data. It builds upon the success of the Sentinel-3 mission while incorporating advanced technologies and configurations to meet the evolving requirements of global monitoring and hydrological studies.

Global Scale L3 River Water Level Processor for Real-Time Applications

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In the present paper, we introduce the design and applications of a new L3 ("L2-to-L3") processor dedicated to the production of river water level (RWL) time series.
The main motivations behind this new design are to unleash the real-time production of L3 RWL from current/future nadir altimetry missions and to reprocess 30+ years of data from the heritage missions.
The processor's flexibility allows for applications to range from experimental and/or custom use cases for research to operational monitoring on selected areas and/or missions.

The incremental design of the processor makes it naturally suitable for real-time applications and is able to update RWL Time Series with new L2 data in seconds on laptop computers.

The processor is split in various processing steps in which L2 data are confined w.r.t. a Water Mask database and affected basin ID and metadata from the SWORD (SWOT A priori River Database) Reaches and Nodes databases ; Dynamic Virtual Stations are created and RWL Time Series are finally produced from concatenated L2 data, with outliers rejection applied.
More precisely, L2 data are extracted at river crossings and concatenated altogether for further L3 processing where stable crossing locations over rivers (aka Virtual Stations) do provide enough data to build valuable RWL Time Series. Whenever crossing becomes unstable (orbit control issues) or changes (orbital phase change), the processor adapts and works on new crossing locations and so on.

L3 RWL data are processed and delivered per basins (as defined by HydroBASINS Level-2), with scalability ranging form basin scale to global scale.

The processor already supports L2 data from all LRM and SARM repeat-orbit missions, including the SWOT nadir Altimeter Poseidon-4.
In the future, the processor will be extended with support for non-repeat orbit data and/or non-nadir missions such as from CryoSat-2 (SARM and SARINM), geodetic orbital phases of various heritage missions and the future CRISTAL mission.

Validation results, produced in the frame of the HYDROCOASTAL ESA project over the Amazon basin, will be presented for about 54 RWL Time Series derived Sentinel-3A and Sentinel-3B data from the project.

Assessing the Spatio-Temporal Performance of Satellite-Based Precipitation Datasets in the Rhine River Basin, Germany

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Satellite-based precipitation datasets play a crucial role in various applications, including water resources management and climate change analysis. However, questions arise concerning their reliability due to differences in spatio-temporal resolution. In this study, we focus on evaluating the performance of five precipitation products (GPM IMERG v6, CHIRPS 2.0, TRMM, PERSIANN-CDR, and PERSIANN-CSS) over the Rhine River basin, encompassing German territories. The combination of ground-based observation and weather stations estimations operated by German meteorological service (DWD) is considered as a benchmark to examine grid-to-grid and point-to-point consistency of the satellite-based precipitation datasets. Utilizing the Google Earth Engine cloud platform, we acquired precipitation data spanning the period from 2000 to 2022. To evaluate the consistency of the precipitation products, we employed different goodness of fit indices, including Root Mean Squared Error (RMSE), Mean Bias Error (MBE), and Kling-Gupta efficiency (KGE). The results demonstrate promising performance for CHIRPS 2.0, TRMM, PERSIANN-CDR, and PERSIANN-CSS in both monthly and daily formats, with GPM IMERG v6 being the exception. However, despite their promising performance, we noted limitations with CHIRPS 2.0 and TRMM datasets, as they do not fully cover the entire Rhine River basin area, with an expansion region restricted to 50° N to 50° S. These findings contribute valuable insights into the suitability and limitations of satellite-based precipitation datasets for the Rhine River basin and surrounding regions, enhancing our understanding of their applicability in critical environmental and hydrological studies.

RAWSIW: a remote sensing analysis workflow for water quality retrieval in small inland waters

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Retrieval of water quality parameters, especially Chlorophyll-a (Chl-a), using remote sensing technologies has garnered significant interest recently, mostly because of the ability of satellite data in reconstructing Chl-a maps in vast spatial and temporal scales. Despite the fact that many algorithms and approaches have been developed to preprocess images and estimate Chl-a, these algorithms are still difficult to implement in different regions. Here, we introduce RAWSIW, a remote sensing analysis workflow/package for water quality retrieval in small inland waters. RAWSIW is a cutting-edge Python package that offers an integrated approach to analyzing water quality in small inland waters using satellite remote sensing. This comprehensive package unifies diverse state-of-the-art models, algorithms, and processors for processing remote sensing data into an easy-to-use package. Key modules allow users to automatically find and download cloud-free satellite images, pre-process in-situ and remote sensing data, identify coincident field/satellite matchups, calibrate/validate advanced machine learning models for chlorophyll-a (chla) retrieval, and generate chla maps and time-series for further analysis. This workflow simplifies user interactions by providing a single platform to perform these steps, eliminating the need to switch between different software. Additionally, the package supports single and batch processing, Command Line Interface (CLI) and Graphical User Interface (GUI) interactions, serial and parallel processing modes, and compatibility with both personal computers and High-Performance Computing (HPC) systems. Developed and tested on both Linux and Windows systems, RAWSIW aims to optimize the application of remote sensing for water quality estimation in small inland waters.

Evaluation of volume reservoir based on analysis of satellite images

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Dams and reservoirs play a paramount role in water management due to their importance for water storage, flood control and hydropower production.
The reservoir volume can vary over time due to factors such as rainfall, evaporation, and withdrawals. It is therefore important to be able to monitor reservoir levels in order to ensure that there is enough water available to meet demand.
These issues are especially relevant under climate change scenarios, with a consequent change in the precipitation patterns and an increase uncertainty. Dams and reservoirs may be used to mitigate the impact of droughts and water scarcity and flood management.
Accurately measuring reservoir volume is essential for ensuring sustainable use of water resources. Regular monitoring and updating of volume measurements are crucial, especially in the context where water availability may be affected over time.
Depending on the size and characteristics of the reservoir, its volume can be evaluated using different methods namely bathymetric survey, Acoustic Doppler current profiling or aerial photogrammetry.
The relationship between volume and inundated area of a reservoir depends on the shape and depth distribution of the reservoir. In general, the volume of water stored in a reservoir is directly related to the area covered by the reservoir when it is filled to a certain water level. This relationship is usually provided for the most important reservoirs as it is quite useful for systematic analysis whereas the volume is evaluated using the reservoir level (e.g. using a water level gauging) and this relationship between this level and the inundated area and volume.
The present work aims at using satellite remote sensing to evaluate the reservoir volume.
The Water Monitoring Sentinel Cloud Platform (WORSICA) was used for the remote sensing analysis. WORSICA is a service that integrates remote sensing and in-situ data for the determination of water presence in coastal and inland areas, applicable to a range of purposes from the determination of flooded areas (from rainfall, storms, hurricanes or tsunamis) to the detection of large water leaks in major water distribution networks. Sentinel 2 products and the Normalized Difference Water Index (NDWI) and the Modified Normalized Difference Water Index (MNDWI) were used to obtain the inundated area.
Taking advantage of the service provided by WORSICA in the identification of the inundated areas and the relationship between the inundated areas and the reservoir volume, the time series of reservoir volumes for several reservoirs located in Portugal were obtained and compared to the official reports from the Portuguese Environmental Agency.
It was concluded that despite some discrepancies, satellite images may provide a cost-effective and efficient way to monitor reservoir volumes over time. It could be a valuable tool for water resources management in developing countries, as it can automatically gauge water storage patterns.

Estimating river bathymetry of Cooper Creek from remote sensing datasets

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River depth is a key variable for the runoff estimation at different river reaches. It is used directly and indirectly in the rating curve discharge algorithms and hydrological modelling for the discharge measurement. However, it’s time consuming and costly to measure river depth directly from using field instruments such as ADCP, echo sounder and lidar instrument.

In this study, we offer to measure depth of Cooper River from multisource remote sensing data. This method could be the alternative for the depth estimation from the traditional depth measurement. To show the performance of this method, we selected 5 different reaches of Cooper River at different distance from the river head. We have estimated water level from Sentinel 3A altimeter datasets and river width from the Planetsky, landsat and sentinel imageries data. As a preliminary inspection, we set a threshold of channel exposure 0-50%. Using satellite datasets, we establish a nonlinear z-w relationship between the channel cross section shape. The result was improved by using the Trust-Region-Reflective (TRR) optimizer. We expect the accuracy of the depth in terms of absolute error is in between 5-10% with respect to in situ depth of Cooper River. Based on the result, our methodology gives the possibility to measure depth at different reaches of Lake Eyre Basin, where river depth is not available.

Advancing Hydrological Understanding in Environmental Hazard Risk Assessment.

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Climate change is increasingly affecting agricultural systems in Central Europe, necessitating the development of robust forecasting models for drought, heat, and fire events (DHF). These hazards pose significant threats to crop production and require proactive measures to enhance resilience and adaptation.

This research project is dedicated to constructing a thorough framework for forecasting Drought, Heatwaves, and Fires (DHF) events in Central Europe. It integrates an agro-ecosystem model aimed at examining how crops respond, particularly when it comes to water availability. The focus of this research extends to the region's awareness to climate-related threats and the robustness of its agricultural systems.

Our research methodology consists of integrated forecasting models that explore interconnections among DHF events, with a specific consideration of how these events impact water availability for crops. We're attentive to spatial and temporal variations in our analysis.

It's important to note that we are utilizing the MONICA (Model for Nitrogen and Carbon in Agriculture) crop model, a sophisticated and widely acclaimed tool recognized for its capability to simulate crop growth and response across a spectrum of environmental conditions. The MONICA model is designed to represent the complexity of crop development, considering factors such as soil properties and weather variations. MONICA model has the capacity to explore various scenarios, including heat stress and drought sensitivity, providing a comprehensive view of how crops respond to these challenges.

At this stage of the research we have collected the data for the initial study region, Germany. This comprehensive dataset includes high-resolution meteorological (1km resolution, daily), topographic, historical crop records and soil information. The dataset covers the past two decades, encompassing vital information such as crop yield records.

We have initiated the sensitivity analysis phase, a critical step in our research. This analysis aims to identify specific parameters within our models that play crucial roles in influencing crop yield, biomass, and growing degree days, especially in the context of drought and heat stress. These insights will further enhance our understanding of crop responses to environmental stressors.

We have set up the calibration and optimization routines, where we calibrate the MONICA model specifically for NUTS-3 regions within Germany. This calibration process is essential for ensuring the model's accuracy and relevance to the unique conditions of each region. Once we've successfully calibrated the model for German regions, we will expand our efforts to encompass Central Europe. This expansion will enable us to apply the calibrated model to a broader geographical scale, thereby enhancing its applicability to the entire Central European context.

In the poster presentation, we will unveil the latest findings and results of the ongoing research efforts. This includes a showcase of the calibration tools and methodologies employed. Furthermore, if the timing aligns, we anticipate presenting the yield simulations conducted over Germany. These simulations will be compared to the actual yield data, providing valuable insights into the effectiveness and real-world applicability of our forecasting and modelling approaches.

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