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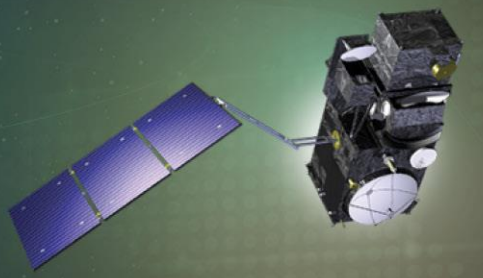

# 7th Sentinel-3 Validation Team Meeting 2022

18-20 October 2022 | ESA-ESRIN | Frascati (Rm), Italy

# Sentinel-3 Topography mission Assessment through Reference Techniques (St3TART)


**Elodie Da Silva (NOVELTIS)**

**Nicolas Picot (CNES) – Jean-Christophe Poisson (vortex.IO)**

**Henriette Skourup (DTU) – Geir Moholdt (NPI) and much others :**

# St3TART project – Main objective

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Prepare the ground to ensure an
« **operational provision of FRM (Fiducial Reference Measurement)** »
to support the S3 Land STM mission over :







St3TART
FRM for Sentinel-3 Land Altimetry

# St3TART project – Detailed objectives

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| | Land waters | Sea Ice | Land Ice | ScalSIT |
|---|---|---|---|---|
| |  © vorteX.io |  © DTU |  © IGE |  |
| Validation, FRM protocols & procedures | • Define and consolidate **methods and protocols for the validation** of the Sentinel-3 Altimetry Land products **with Fiducial Reference Measurements** (FRMs) | | | |
| Roadmap for S3 STM Land FRM operational provision | • Identify existing networks and **assess the needs** for permanent sensors and campaigns.<br>• **Prepare a roadmap for the operational provision of FRM data to support the Sentinel-3 Altimetry Land validation** | | | |
| FRM campaign preparation and execution | • **Deploy and operate** in-situ sensors, perform campaigns to collect FRM data<br>• **Provide FRM data** to the Copernicus Sentinel-3 STM validation teams | | | |
|  FRM Data Hub | • Web site, **for a centralized access** to FRM measurements<br>• Fully characterized and **documented FRM processing** and measurements | | | |
| | | | | • Super CAL/VAL site identifier tool for **inland waters**<br>• Determines the **intersections** between **Water mask** and **satellite orbits**<br>• Developped as a QGIS plugin |

# Towards a roadmap for FRM provisionning for S3

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| Correction | Average order of STD |
|---|---|
| Geoid height | Negligible impact if a sensor is +/- 1 km to the actual ground track |
| Pole tide, Solid Earth tide and Loading tide | Few milimeters |
| Orbit determination | < 1 cm |
| Ionosphere correction from models | < 1 cm |
| Dry tropospheric correction from models | < 1 cm |
| Wet tropospheric correction from models | ~ 1.5 cm |
| Range estimation | Several cms or decimeters |

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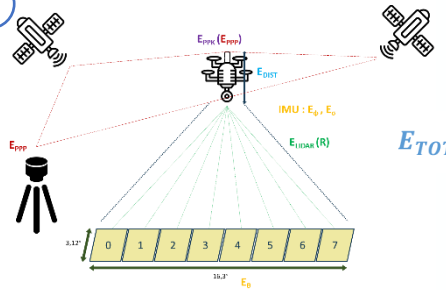



$$E_{TOT} = \sqrt{E_{PPK}^2 + E_{DIST}^2 + E_{AD_{TOT}}^2}$$

1 Identification of the measurand to focus on, reviewing altimetry measurement uncertainties

2 Review of in-situ sensors performance and adequacy to FRM needs

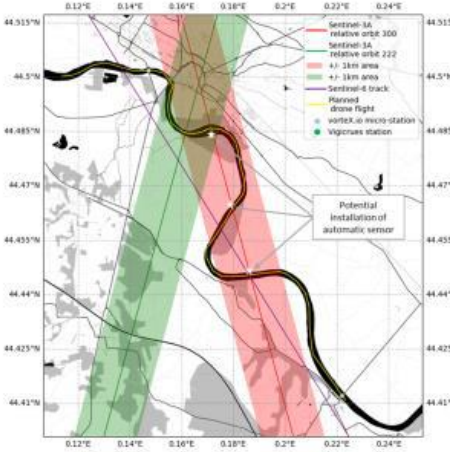
3 Identification of super sites to deploy sensors

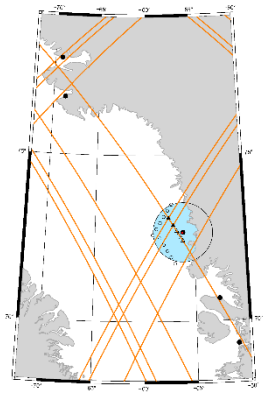
4 Deployment on the field (not over land ice)

5 Comparison of measures with S3 data (1st level of analysis) + analyse of uncertainties

6 Definition of the roadmap for FRM provisionning

3



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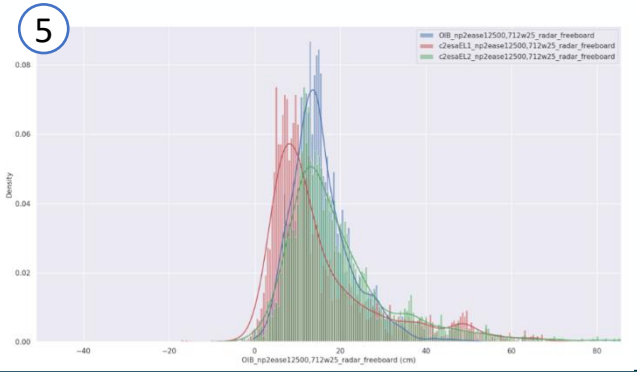
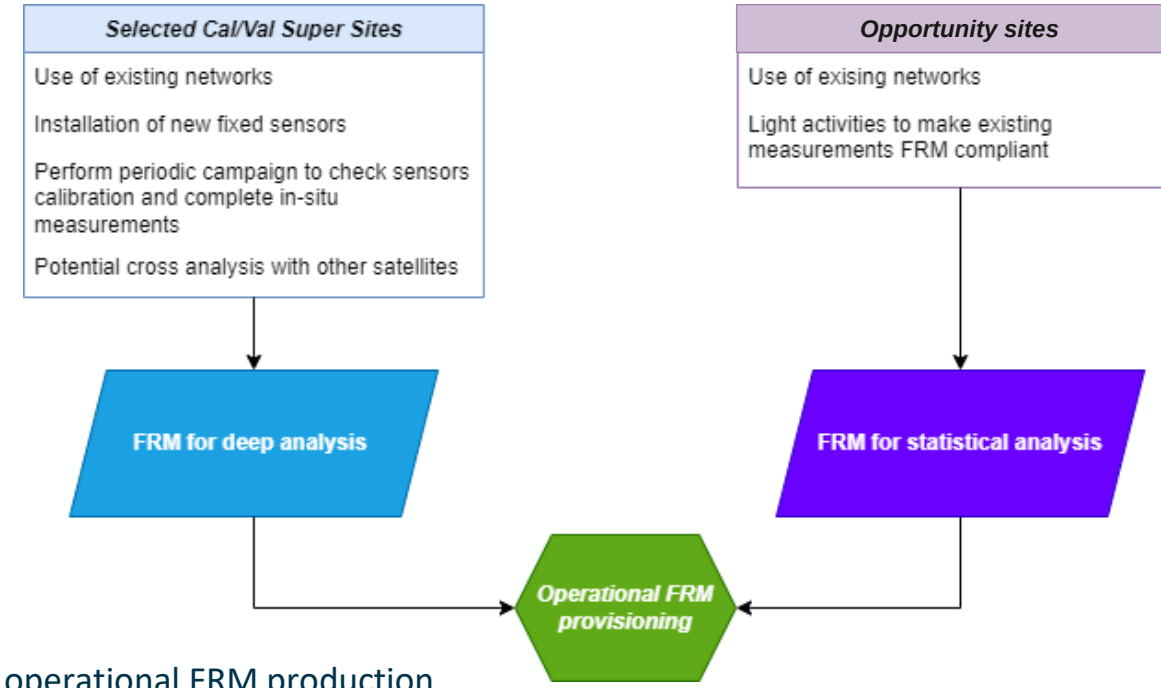


# Inland waters – Strategy for FRM provisionning

## Drivers:

- FRM quality
- Operational
- Affordable costs
- Federate international community
- Provide data within 28 days latency




## Approach:

- <u>Cal/Val super sites:</u>
  - Site instrumented with all sensors and equipment needed to ensure operational FRM production
  - Demonstrators for future deployment of other Cal/Val super sites anywhere in the world, by any entity
  - Focused in Europe
  - List of selected super sites for this project: Garonne (France), Rhine (France and Germany), Po & Tibre (Italy), Maroni (French Guyana), Issykkul (Kirghizstan)

- <u>Opportunity sites :</u>
  - Taking advantage of existing in-situ sensors


5

# Inland Waters – Campaigns

- 18 vorteX.io micro-stations installed on super-sites over Rhine (FR), Pô (IT), Garonne (FR) and Canal du midi (FR), and more to come on Rhine (DE), Tibre (IT), Seine estuary (FR)

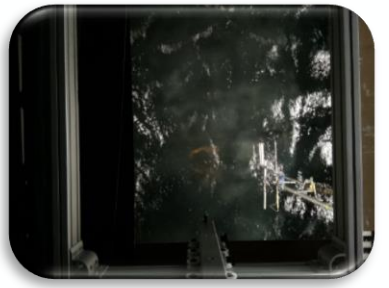

- Drone campaigns over the same rivers to perform topography measurements


- Deployment of pressure sensors (solinst leveloger) where micro-stations can't be installed, under S3 track

*Deployment of leveloger in Marmande, under S3 track*

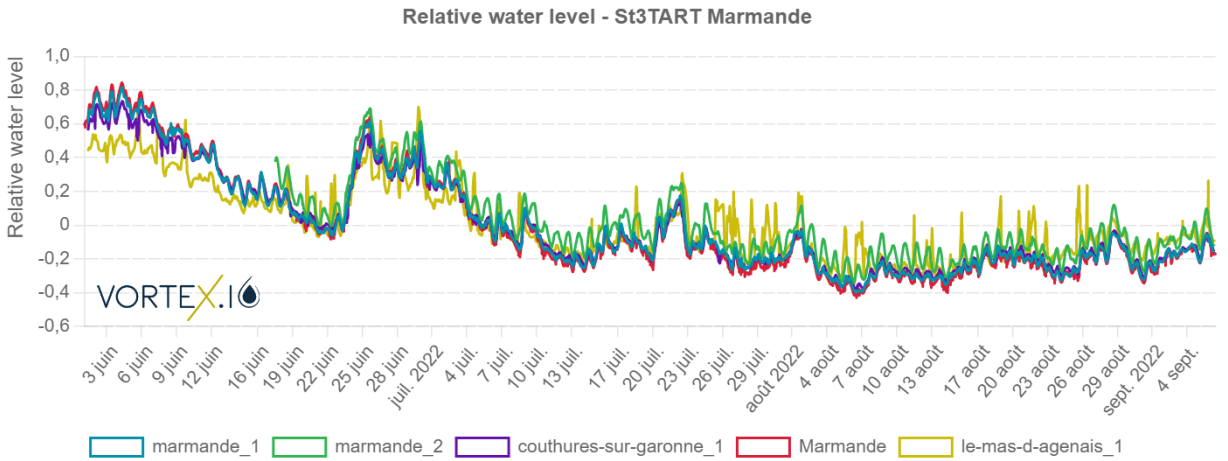
*Deployment of leveloger in Maroni river (tropical river), under S3 track*

- To meet FRM requirements : sensor performance analysis in a test basin, to evaluate the capability and absolute uncertainty of the sensors that are used in the project

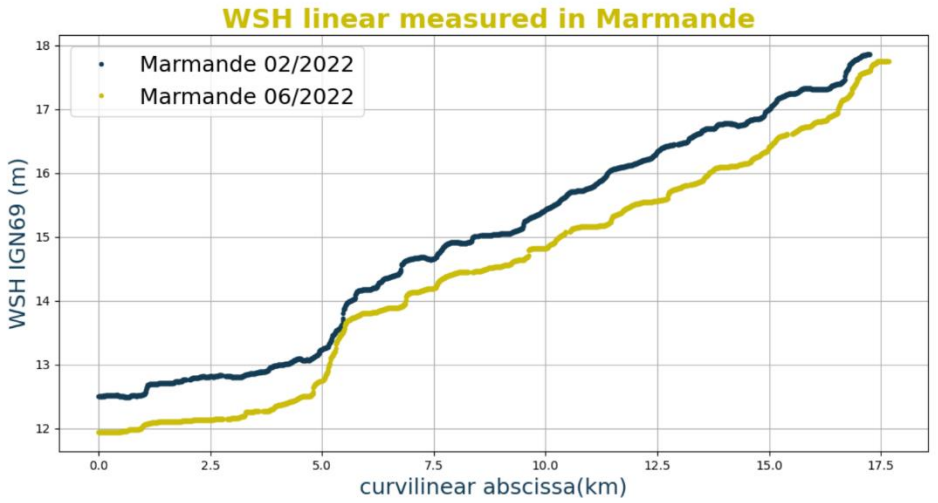


# Inland Waters – Analysis of results

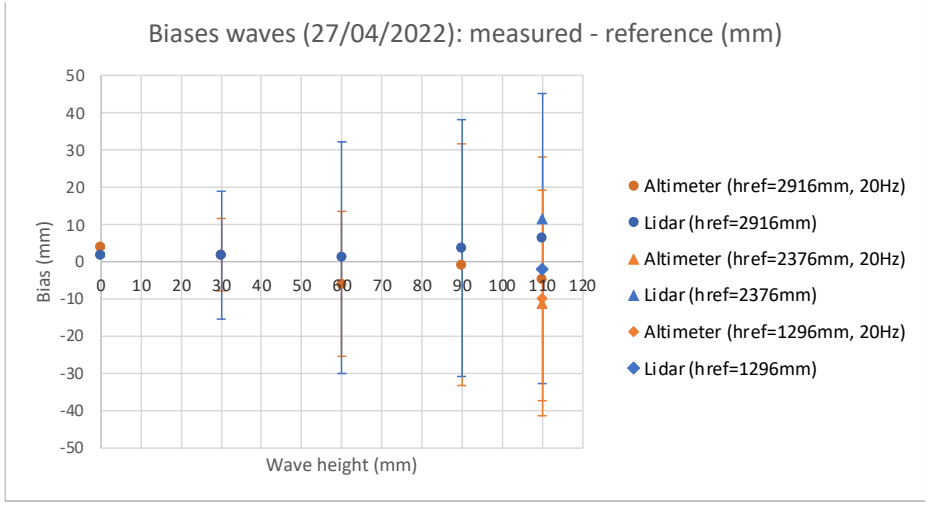
- **Comparison of the different vorteX.io micro stations measures along the Garonne**




- **Garonne topography at high/low level of water**

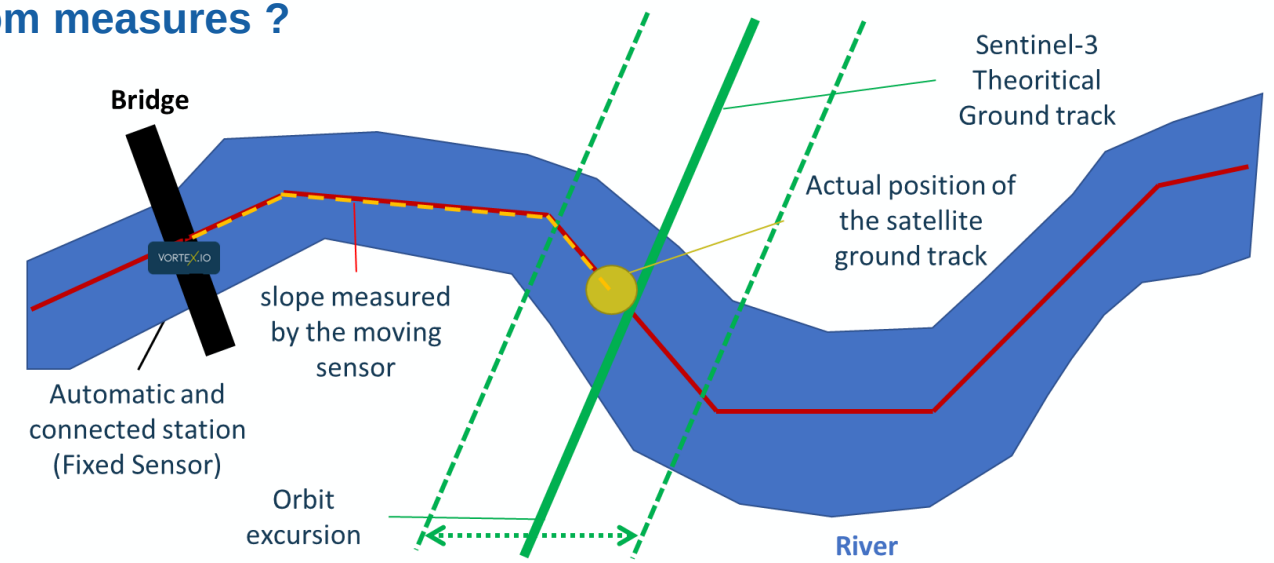



- **Example of results obtained during tests in basin**



# Inland Waters – Provision of FRM

- **How to get FRM from measures ?**




$$WSH_{FRM}(t) = WSH_{FS}(t + \delta_{ts}) + \left(\Delta WSH_{slope} - Corr_{evo\_tempo}\right)$$

- $\delta_{ts}$ : propagation time of the river between the actual position of the satellite ground track and the fixed sensor => to measure the same « water drop » than the satellite
- $\Delta WSH_{slope} = WSH_{moving\_sensor\_at\_SGT} - WSH_{moving\_sensor\_at\_IS}$
  - $WSH_{moving\_sensor\_at\_IS}$ : moving sensor measurement next to the in-situ sensor
  - $WSH_{moving\_sensor\_at\_SGT}$ : moving sensor measurement at the actual position of the satellite ground track
- $Corr_{evo\_tempo}$ : correction related to the water level evolution of the river during the campaign time.

# Sea Ice – Work in progress

- **Selecting and evaluating FRM sensors**

| Permanent | Semi-permanent | Campaigns |
|---|---|---|
| Upward looking sonar from moorings | Drifting buoys | Airborne, ice breaker, in situ, helicopter, drone |
| Continuous in time domain<br>Longterm<br>Fixed in space<br>Point measurement | Continuous in time domain<br>Longterm<br>Moving<br>Point measurement | Tend to be on the same season<br>Short-term<br>Moving<br>Regional/local |

- **Construction of a FRM compliancy matrix, and ranking of sensors according to measurand, uncertainties of measurand, tracking of the uncertainties**

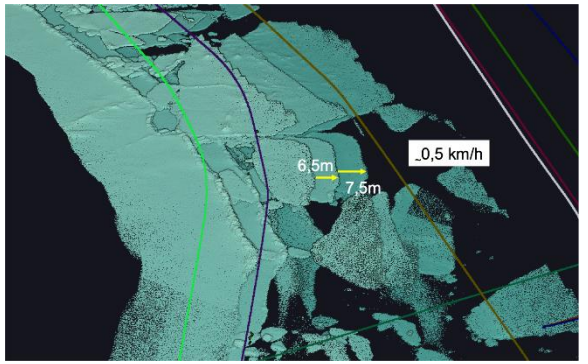
| FRM compliancy | Ranking | Examples |
|---|---|---|
| High | 3 | Airborne radar altimeter ku-band, airborne lidar, geolocated visual images (e.g. geotiff), Upward Looking Sonar moorings |
| Readiness level low but good candidate | 2 | Drone technologies, snow radar from drifting buoys |
| Low | 1 | Upward looking sonar from AUV |
| Not compliant | 0 | Visual ship observations, visual images which are not geolocated |

- **2 campaigns with two different objectives**

- Baffin Bay campaign (Greenland) :
  - Near coincident observations with multiple sensors under S3 track from aircraft, drone and autonomous buoy
  - Test of new novel techniques together with proven sensors
  - Evaluation of the different sensors and their compatibility



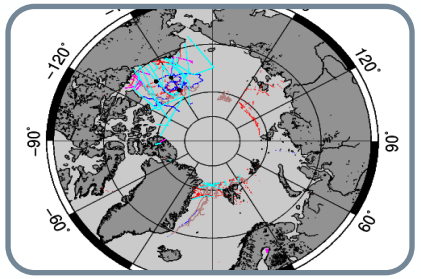
- Drone Experiment for Sea Ice Retrieval (DESIR) campaign (ARICE H2020 project) :
  - Evaluate the difficulties to **deploy a drone from an ice-breaker**
  - Evaluate the **precise positioning without differential GPS** (PPP-AR Precise Point Positioning with Ambiguity Resolution) to support the drone observations



# Sea Ice – Strategy for FRM provisionning

## Specific difficulties:

- Sea ice environment is remote and harsh environment to work and operate in
- Need for coincident measurements of different geophysical parameters : freeboard, snow depth and ice thickness = > implies a combination of sensors and platforms
- Sites shall be located south of 81.5N limiting the site locations dramatically, especially for ice areas covered by multi-year ice (whose measure is more accurate than for first year ice)




## Taking profit of all existing data / future campaigns

- Importance to maintain existing upward looking moorings
- Taking into account all in-situ measurements, not FRM compliant data is better than no data
- Cross calibration with other missions (CryoSat, ICESat-1, SARAL, SWOT, etc.)
- Importance to collaborate with other campaigns, to co-finance the different campaigns and get more data.

## Different spatial/temporal coverage example scenario

- Regional monthly repeat drone surveys at local scale
- Yearly deployment of Ice-T Buoys for continuous observation of snow depth and ice thickness
- Yearly deployment of ULS in areas not already covered to provide continuous measurement of sea ice thickness
- Yearly large airborne campaigns to tie regional studies from regional to larger scales

# Focus on metrology – Analysis of uncertainties



**MEASURAND 01**
Define the measurand and measurement function

**TRACEABILITY 02**
Establish the traceability with a diagram

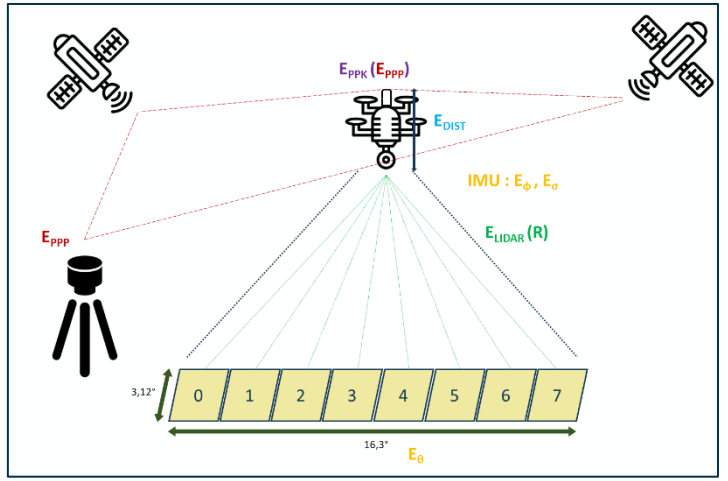
**UNCERTAINTY 03**
Evaluate each source of uncertainty and fill out an effects table

**HARMONISE 04**
If appropriate recalibrate / harmonise against a reference

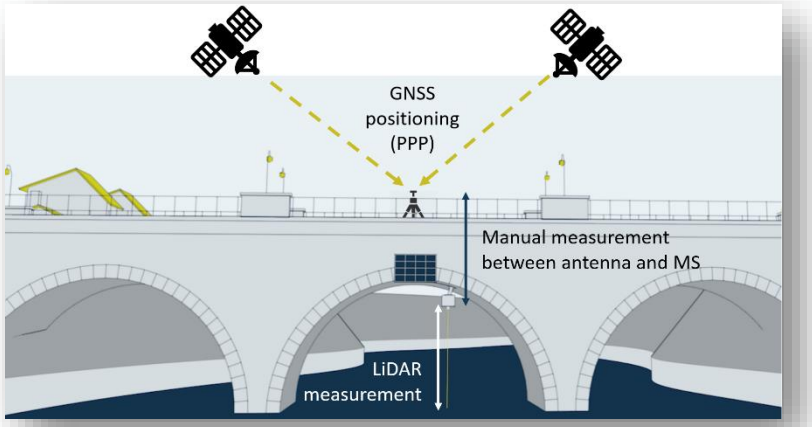
**CALCULATE 05**
Store relevant information in a Full FCDR for future users

**LTDP STORE 06**
Store relevant information in a Full FCDR for future users

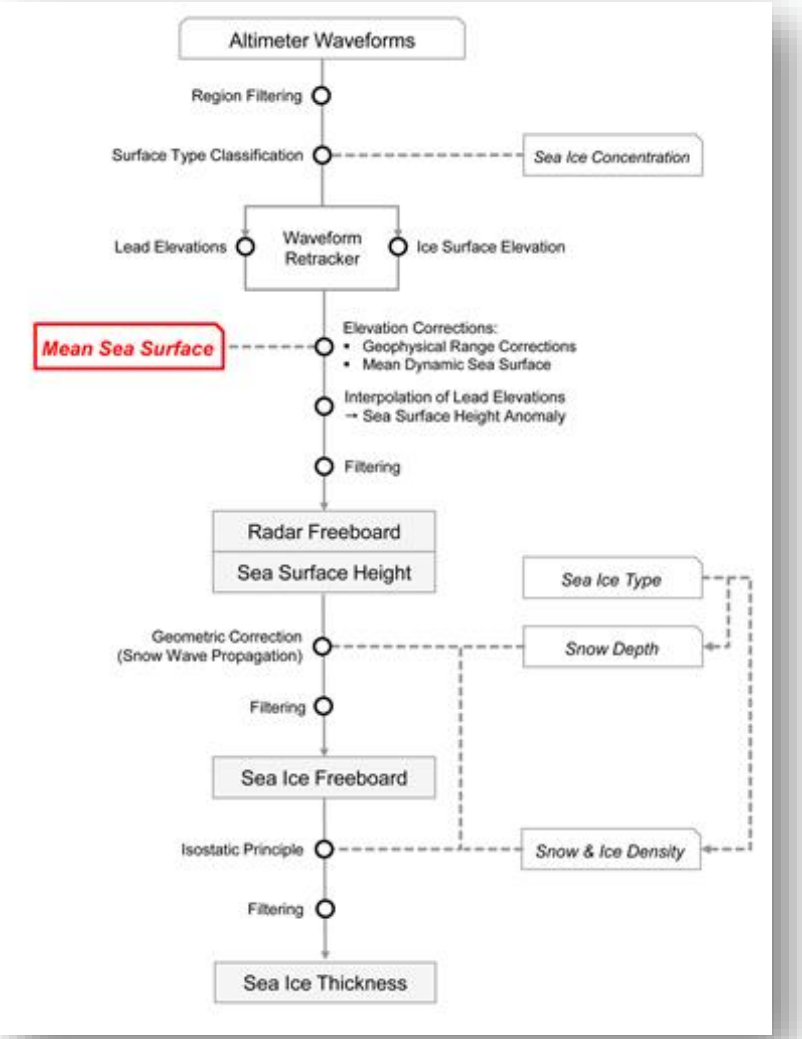
**EASY VERSION 07**
Create a simplified version with summarised uncertainty information



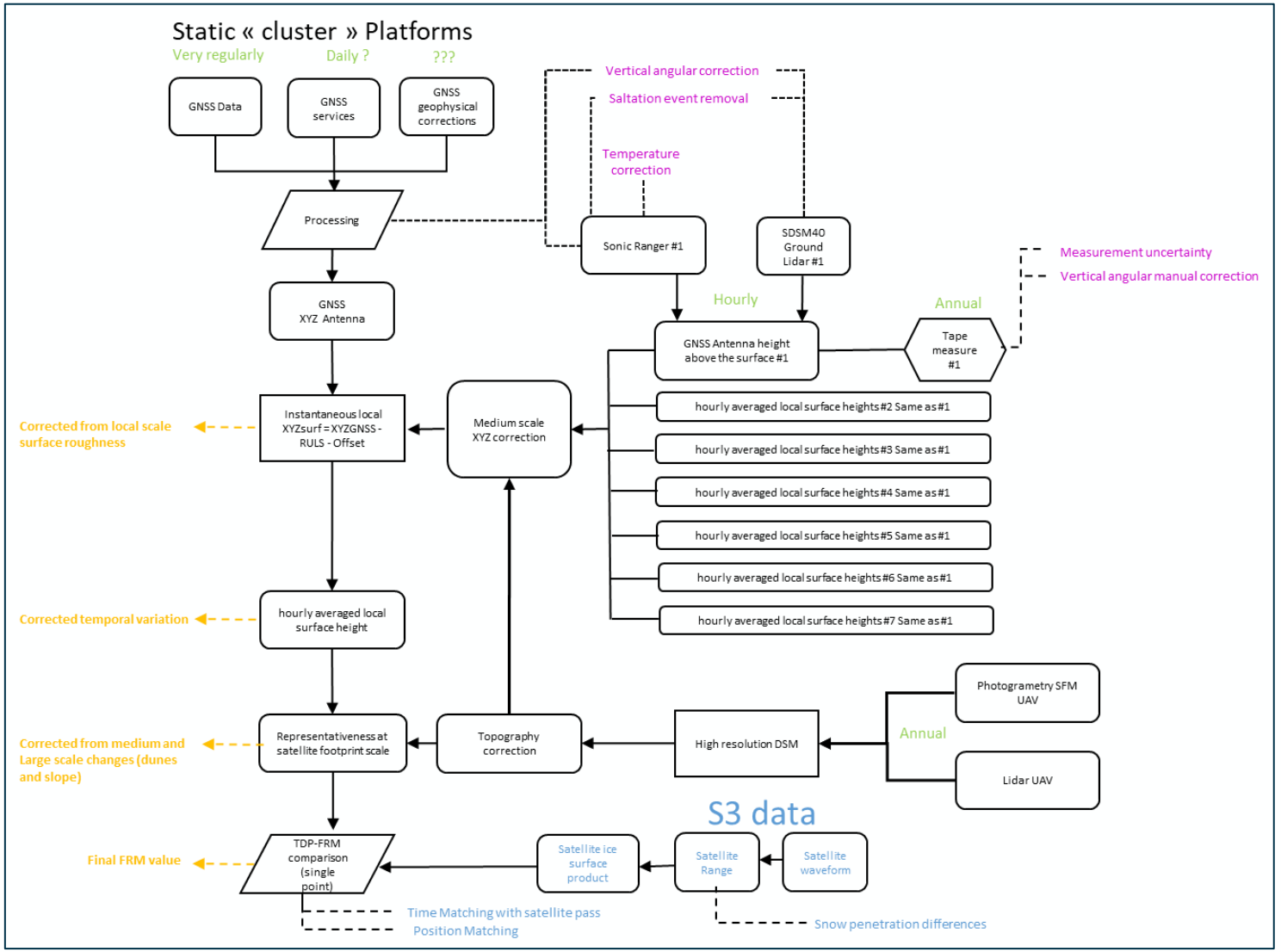

$$E_{TOT} = \sqrt{E_{PPK}^2 + E_{DIST}^2 + E_{AD_{TOT}}^2}$$




$$E_{TOT} = \sqrt{E_{PPP}^2 + E_{DIST}^2 + E_{AD}^2}$$



# Focus on metrology – Analysis of uncertainties



# St3TART tools : SCalSIT



**Inputs**

- Water surfaces mask
- Satellite orbits
- User parameters

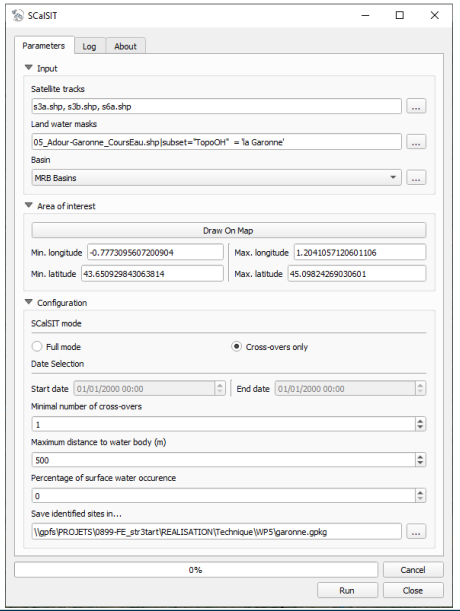
**SCalSIT**

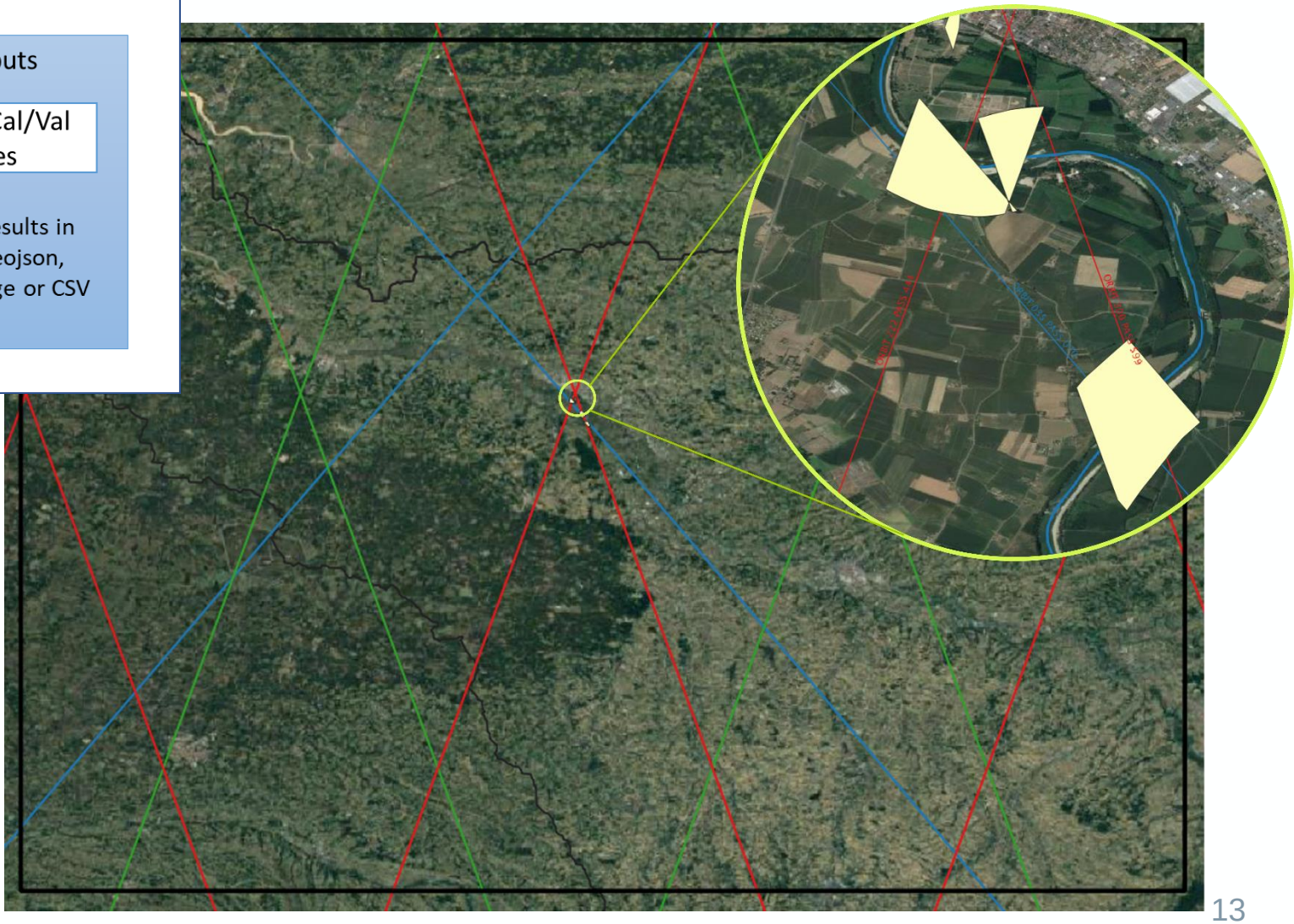
Calculation of intersection zones

**Outputs**

- Super Cal/Val sites

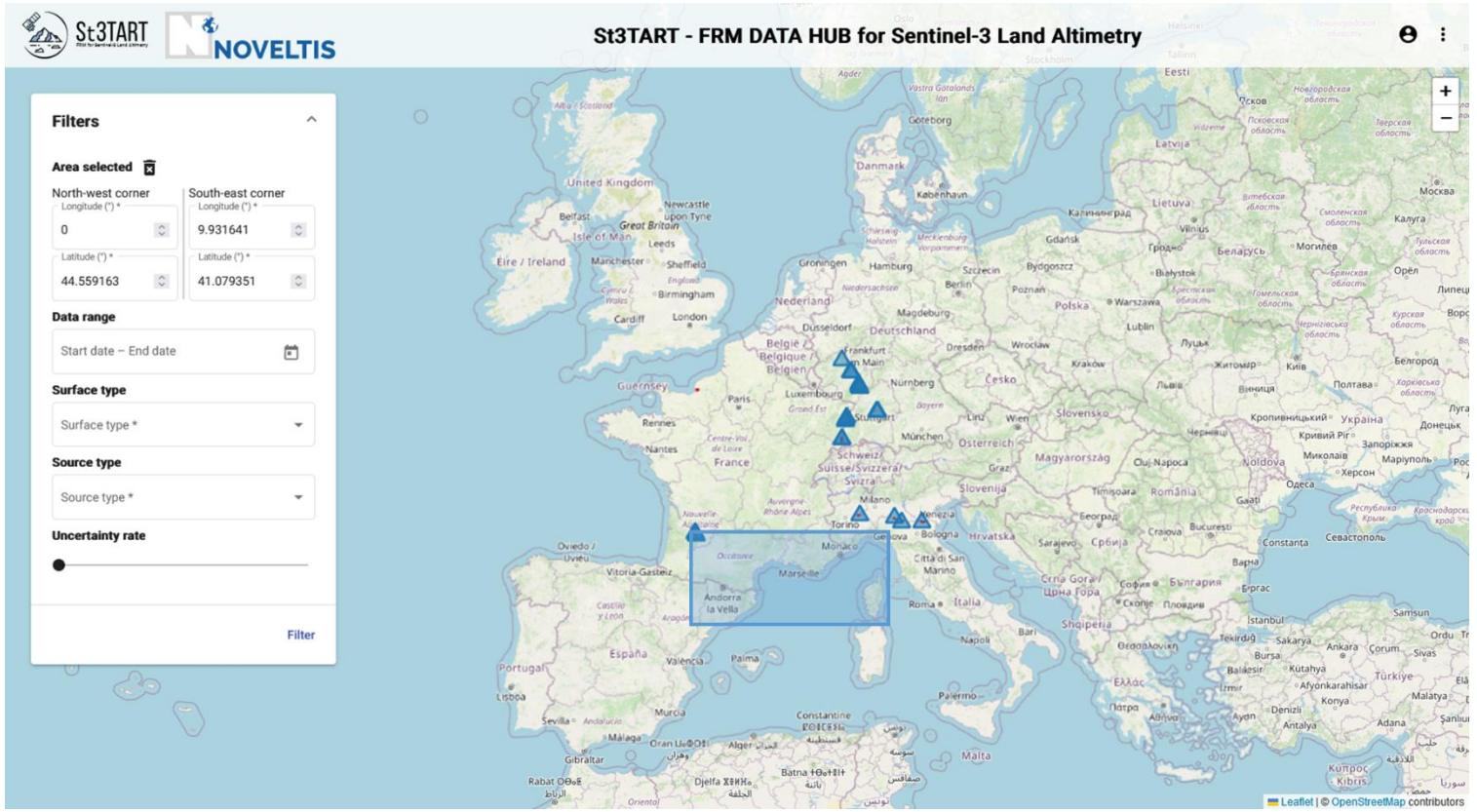
Export results in KML, Geojson, GeoPackage or CSV



# St3TART tools : FRM Data Hub

Centralized access to FRM measurements, the FRM Data Hub aims to federate the Cal/Val community to share FRM measurements in a free and accessible manner with fully characterized and documented FRM processing and measurements.




- Unified data format: NetCDF with specific attributes
- Filename convention

- **First step**: data from St3TART FRM campaigns
- **Next step** : any FRM measurements

# Thanks for your attention !

https://sentinel3-st3tart.noveltis.fr/

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