2018 Ocean Salinity Science Conference

Summary and recommendations

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The 5th "Ocean Salinity Science Conference" took place at Sorbonne University, Paris, France, on 6-9 November 2018. It was attended by more than 100 international scientists and representatives of operational services.

Ocean salinity is a key variable within the Earth's water cycle and a key driver of ocean dynamics. It has been identified as an Essential Climate Variable (ECVs) by the Global Climate Observing System (GCOS) and the Global Ocean Observing System (GOOS). Through the advent of new observing technologies and further efforts to assimilate this data into numerical models, research based on salinity measurements has gained much focus within the scientific and operational user communities over recent years.

A regular conference series focusing on salinity measurements has helped to focus the community contributing to the rapidly growing variety of applications of salinity data. The Ocean Salinity Science Conference series started in 2013 with a workshop mainly focused on the achievements of the two L-Band satellite missions measuring salinity from space at the time, namely SMOS and Aquarius. It was followed up though further conferences in 2014, 2015 and 2017 in the UK (Metoffice), Germany (University of Hamburg) and the US (Woods Hole Oceanographic Institution), respectively. Tentatively, the next topical conference will be held in the US in mid-2020. Over the years, this conference series has brought together communities working on all aspects of ocean salinity research, including analyses based on in-situ and satellite observations, numerical models and data assimilation.

1. Organisation

The goal of the 2018 conference was to review recent progress of on-going work and to identify the next challenges with regard to salinity science and technology.

The sessions, which included 60 talks and 46 posters, were:

1. **Observing ocean salinity** *primarily focused on recent improvements in satellite salinity retrieval and validation;*
2. **Process-based insights from field observations** *primarily focused on the near-surface vertical salinity stratification and the rainfall effect, as measured in situ with innovative instruments, in particular during the SPURS-2 experiment;*
3. **Role of salinity in ocean dynamics** *primarily focused on the impact of the assimilation of satellite salinity observations in ocean forecasting models;*

4. **Role of salinity in the global freshwater cycle and climate variability** *focused on the role of freshwater inputs in the ocean circulation and decadal-to-centennial changes of SSS and SST, as derived, for example, from long-term ship observations and model simulations;*
5. **Role of salinity in biogeochemistry** *focused on the coupling of salinity with biogeochemical parameters, in particular carbon, and how salinity can be combined with other variables observable from space (SST, ocean color) to trace water masses and dilution effects*;
6. **Surface freshwater fluxes, runoff, and sea ice** *focused on the utility of a) satellite salinity for monitoring river plumes in the vicinity of land, their interaction with large scale circulation and climatic events, and freshwater fluxes in the Arctic Ocean, b) isotopic measurements to identify the origin of the freshwater fluxes in the Southern Ocean,* and c) *surface salinity changes as a statistical tool to diagnose changes in air-sea water fluxes and forecasting rainfall over land;* and
7. **Challenges and requirements for future salinity observing, remote sensing and in situ** *which focused on new systems for measuring salinity from space, the CIMR ocean and sea-ice mission, and subfootprint variability of salinity.*

2. Major findings

A major highlight of the conference was the large variety of scientific studies and operational applications being presented demonstrating the unprecedented skill of currently available L-Band measurement from space through SMOS, SMAP and formerly also Aquarius. The results presented showed the invaluable information provided for i) improving our understanding of the water cycle: it has allowed to identify new freshwater origins and ocean pathways in key regions of the world's oceans (e.g. the Indonesian Throughflow, the Bay of Bengal), ii) detecting salinity anomalies, over almost 9 years, linked to climate events such as ENSO (El Niño Southern Oscillation) or the IOD (Indian Ocean Dipole), with more precise spatial extension of regional anomalies than ever observed before, e.g. in the Bay of Bengal, iii) explaining further how eddies transport ocean properties across various regions, e.g. through coast-open ocean exchanges in the Gulf of Maine, east-central equatorial Pacific ocean. Much progress was reported from process studies, in particular regarding the response of the upper ocean to tropical rainfall (SPURS-2) and potential impact on air-sea gas exchange, such as carbon dioxide. Other results illustrated how in situ data and modelling results provide long time series which can be used to estimate long-term trends, such as changes in water masses and subduction processes, and which can be related to changes in air-sea fluxes. Salinity measured from space have been used to improve ocean analyses and ENSO forecasts, and have potential for monitoring and predicting other components of the climate system, such as the meridional overturning circulation in the Atlantic Ocean or rainfall seasonal forecasts in some parts of the tropical and subtropical ocean.

The full potential of salinity estimation, validation and exploitation in current projects was also presented as part of initiatives such as the ESA SMOS Pilot Mission Exploitation Platform (Pi-MEP), the ESA Climate Change Initiative SSS (CCI+SSS) project, and the NASA Salinity Continuity Project and Ocean Salinity Science Team.

It was also emphasized that additional efforts should be devoted to a full characterization of representation errors at spatial (horizontal, vertical) and temporal scales within satellite validation exercises, in an attempt of better estimating the actual satellite uncertainties.

Current limitations of the observing and modeling systems were discussed, both during an open 'Satellite and In Situ Salinity' working group meeting and during a final discussion session. Key issues and recommendations were listed and will be further discussed during the OceanObs'19 conference (to be held in September, 2019, in Honolulu, Hawaii, US).

3. Discussion and recommendations

The following points were highlighted in the discussion at the conference:

Recommendation # 1: The scientific and operational oceanographic community highlighted the need to continue the monitoring of sea surface salinity from space with at least the same resolution and accuracy as provided by the current SMOS and SMAP satellite missions. The rationale for this is to provide continuity for a large number of scientific, in particular climate research relevant, and operational applications. This is based on the uniqueness of such data as well as the length of the data record (~decade). It will also provide the opportunity to synergistically combine such data with newly available measurements from future satellite missions. The case for this requirement is currently being elaborated in a white paper submitted for the Oceanobs'19 conference (see below), a forum that will review the decadal progress of ocean observing networks and will discuss society's growing needs for ocean information in the coming decade (www.oceanobs19.net).

In particular NOAA stressed the importance for salinity measurements in conjunction with the thin sea ice thickness measurement that SMOS provides. The European Space Agency (ESA) is currently investigating the technical feasibility and financial requirements for a number of High Priority Candidate Missions in preparation for the extension and the expansion of the European Unions's Copernicus Programme, based on the European Commission's recent user consultation. One of the candidates, the proposed Copernicus Passive Microwave Imaging Mission (CIMR), has as a secondary mission objective to include an L-Band channel in the microwave radiometer it will carry, mainly focusing on C and X band. This would ensure continuity for L-band measurements at comparable spatial resolution to the current SMOS and SMAP measurements, even though whilst using different technology to e.g. SMOS. New technological research is also ongoing at CNES and NASA for improving both the spatial resolution using new interferometry techniques, and the measurements accuracy (e.g. by extending the range of wavelength to lower frequencies than L-Band). ESA is also currently looking at improving some aspects of the mission design for SMOS based on the in-orbit experience.

Recommendation #2: The conference also recalled the essential role of in-situ salinity observations. In-situ measurements are essential for monitoring salinity below the sea surface and thus the large-scale freshwater content of the ocean, measuring near-surface and upper ocean stratification that trap fluxes exchange with the atmosphere and control vertical mixing in the ocean, pursuing process studies (e.g. understanding the spreading of rain water within the ocean), validating satellite measurements and correcting their large-scale biases. Recent improvements in isotopic measurements can be used to trace the origin of salinity freshening, a key information e.g. at high latitudes for distinguishing continental and sea ice melting from the atmospheric freshwater fluxes, or to control at lower latitudes the ratios of evaporation over precipitation.

Recommendation #3 Assimilating satellite salinity into forecasting models has been shown to improve El Niño forecasts. Collaborative efforts between satellite and modelling teams should be pursued to fully benefit from these experiments and progress them into operational applications.

Recommendation#4 There is also a need to explore further the potential in combining salinity monitoring (data and modelling) over the ocean, as indicators of the marine water cycle, with hydrological and soil moisture monitoring over land, to better understand the coupling between the different compartments of the global hydrological cycle.

Recommendation #5 Presentations and discussions in the frame of the 'Satellite and In-Situ Salinity' (SISS) working group have emphasized the requirement to better take into account the representativeness error when comparing in-situ versus satellite salinity measurements. This would help to provide objective error estimates, as different sampling and smoothing of the measurements lead to significant differences that vary spatially and temporally, which need to be better characterized. This activity is important for various on-going and future projects involving international collaboration such as the ESA SMOS Pilot Mission Exploitation Platform (Pi-MEP) platform, the ESA Climate Change Initiative SSS ('CCI+SSS') project, the NASA Salinity Continuity Project and Ocean Salinity Science Team.

Recommendation #6 New collaborations on inter-comparisons and exchanges of information about the radiative transfer models used or microwave radiometric measurements made at various wavelengths, within the SMOS, SMAP, AQUARIUS community, in particular through the ESA CCI+SSS project, and CIMR community, were suggested. It was also recommended to advance the L-band component of the Community Radiative Transfer Model. The rationale for this is to provide continuity for a large number of scientific, in particular climate-research-relevant and operational applications. This rationale is based on the uniqueness of such data, as well as the length of the data record (~decade).

4. Further community activities relevant to salinity remote sensing

The discussion also focused on the community recommendations being put forward to the OceanObs'19 conference taking place on 16-20 September 2019 in Honolulu, Haiwai'i, USA. As a background, OceanObs is a decadal conference that charts priorities for ocean observing based on the scientific and user community – similar to the Decadal Survey review by the National Academies of Sciences, but focused on global oceans.

In response to the **OceanObs'19** (www.oceanobs19.net) Programme Committee invitation, several papers relevant to the salinity science community have been submitted through the peer review process at Frontiers. The international satellite salinity community submitted a review paper "Satellite Salinity Observing System: Recent Discoveries and the Way Forward" led by Vinogradova et al. The community paper provides a review of scientific discoveries enabled by the satellite salinity remote sensing from SMOS, Aquarius and SMOS missions, highlight societal applications and end-users of satellite salinity observations, details integration and synergistic opportunities of salinity remote sensing within the global Earth observing system, and outlines potential ways forward to continue and enhance satellite observing system in the upcoming decade.

The conference also saw a detailed update and presentation on ESA funded implementation of the **Pilot-Mission Exploitation Platform for Salinity (SMOS Pi-MEP,**

https://pimep.oceandatalab.com). The platform is an effort to focus the salinity community even further through providing a tool to do extended validation of salinity data but also most noticeably to support users to perform scientific process studies using the variety of oceanographic data and tools being collocated in a single-stop manner. The finalization of the platform is currently on-going based on the feedback of a Science Advisory Group on the test-platform available since spring 2018. A demonstration of the functionality of the platform was provided at the conference. The official release is planned to coincide with ESA's Living Planet Symposium in May 2019 (www.lps19.esa.int). Following interest from NASA, options to enlarge the scope of the platform under joint ESA-NASA activities have been discussed and further interaction is foreseen over coming months.

The conference allowed numerous discussions about the ESA **Climate Change Initiative (CCI+SSS project; http://cci.esa.int/salinity**) that has just started. The goal of the project is to produce merged satellite salinity over the longest satellite period for climate users. A Salinity User Requirement questionnaire was provided to the conference participants for comments and discussions with data users will allow to better focus the needed characteristics of the products. Discussions about the algorithms used in the various instrument's processing chains have started and a working group on a L-band component of the Community Radiative Transfer Model is in construction (see recommendation 6). Preliminary results will be presented at the ESA's Living Planet Symposium in May 2019.

The presentations will be published shortly on www.oceansalinityconference2018.org.