SMOS-AQUARIUS SCIENCE WORKSHOP

Summary

The SMOS-AQUARIUS science workshop took place on 15-17 April at IFREMER (France). The workshop was jointly organised between ESA, NASA and IFREMER, with support from CNES and the EC's COST action SMOS-MODE. Even though it was the first event of this kind, it presents a natural extension of a long-standing cooperation between the SMOS and AQUARIUS satellite teams, which started already in the respective development phases. On a working level, members of both teams are regularly attending relevant science and advisory boards on either side. More than 120 scientists from research institutes worldwide attended the workshop, with more than 80 contributions being submitted.

1. Objectives of the meeting

The main objectives of this workshop were to:

- Provide the SMOS and Aquarius science communities with
  - an overview on the present quality of the provided data, and
  - an outlook on future algorithm developments.
- Explore common L-band sensor and algorithm issues for sea surface salinity and soil moisture retrievals derived by SMOS and Aquarius data.
- Present broader science achievements of both missions, including modelling results.
- Explore synergistic use of and validation approaches for SMOS, Aquarius and other sensors' data over land and ocean.
- Provide a forum for discussion on specific topics related to improving sea surface salinity and soil moisture retrievals through dedicated working groups.

2. The workshop programme

The above objectives were addressed in five sessions, with associated poster sessions. For the detailed programme and all presentations and posters see www.smosaquarius2013.org.

Session 1 - Opening session: This session included programmatic overviews from ESA, NASA and CNES (Mecklenburg, Lindstrom, Lambin), the overall mission status for SMOS and Aquarius (Kerr and Lagerloef) as well as from the ocean user perspective (Reul) and an introduction to the scope of the two working groups on stratification and inter-calibration (Boutin and LeVine), that were established at the workshop.

Session 2 -Instruments' performance and inter-calibration, algorithm development: the first set of presentations in this session focussed on the quality and expected processor improvements for SMOS level 1 data (Martin-Neira), inter-calibration and inter-comparison between SMOS and AQUARIUS (Cabot, Bindlish, Macelloni and Skou), and detailed aspects of the processor/retrieval evolutions for level 1 brightness temperatures for both missions (Misra, Colliander, Kainulainen, Kao, Turiel). The second set focussed on retrieval algorithm

issues for sea surface salinity data products at level 2 for both missions, including dielectric constant modelling, Galactic noise and sea surface roughness corrections etc (Dinnat, Yueh, Meissner, Spurgeon, Tenerelli and Gourrion) and impacts of ascending/descending biases in Level 1 data on the quality of the retrieved sea surface salinity (Banks). This session also provided the input for the discussion in the working group on inter-calibration.

Session 3 -Product validation & stratification: the first part of the session focussed on problems encountered when comparing/validating satellite derived sea surface salinity with in-situ measurements from ARGO and drifters (Drucker, Ward, Reverdin, Boutin, Chao, Asher), these presentations provided the input for the discussion in the working group on stratification. The second part included presentations focussing on the validation of both SMOS and Aquarius derived sea surface salinity in different regions (Lagerloef, Abe, Button, Bulusu) and an error budget estimation due to small-scale horizontal and vertical variability in salinity fields (Vinogradova).

Session 4 - SMOS and Aquarius science application and synergies: Presentations in this session explored the value of both missions' data for monitoring (multi-annual) oceanographic features/anomalies (Durand, Lee, Reul) and climate change aspects (Hasson, Reul), the link to the global and local features of the water cycle (Gordon, Sato) and synergistic use of both missions' data (Xie, Liu).

Session 5 -Beyond salinity: soil moisture, storms and cryosphere: contributions in this session were all presented as posters and comprised storm monitoring (Reul, Calla), cryospheric applications of SMOS and Aquarius data for sea ice monitoring and freeze/thaw detection (Maass, Huntemann, de Matthaeis, Miernecki, Tian-Kunze, Xu), land applications (Miernecki) and iceberg tracking (Slominska).

3. Working groups

Further to the science programme two working groups were established, one on surface stratification and the other on inter-calibration/inter-comparison issues. The summary of the respective discussions and a brief indication how to organise future work can be found below.

3.1 Satellite & In Situ Salinity (SISS) Working Group (WG): *Understanding Stratification and Sub-Footprint Processes*

Co-Chairs: J. Boutin (LOCEAN/CNRS), Yi Chao (RSSI), C.Banks (NOC)

Contact: To join this working group please contact Jaqueline Boutin at jacqueline.boutin@locean-ipsl.upmc.fr or Yi Chao at ychao001@gmail.com; A common working group mailing list and webpage/webforum, including document sharing and data links is planned.

Scope: The major goal of this WG is to improve our understanding of the link between L-band satellite remotely sensed sea surface salinity (SSS), as provided by SMOS and Aquarius at approximately 1 cm below the sea surface, and *in-situ* measured salinity, routinely measured at a few meters' depth by ships and ARGO floats and recently accessible up to a few cm depth by new profilers, surface drifters etc. and to develop methodologies for relating satellite derived salinity to other estimates of sea surface salinity.

This working group will, amongst others, address the following main questions:

- What is the salinity vertical distribution (stratification) in the first 10m below the sea surface and what is the relation with atmospheric forcing including wind and rain? Under which conditions are the new satellite SSS able to provide new reliable information on SSS within the first cm complementary to existing deeper in-situ information for studying air-sea exchange processes? In case of a rain event, what is the order of magnitude for rain-induced vertical gradients and how to best correct for other perturbing effects impacting L-band radiometric measurements (squall, downdraft/updraft, falling droplets induced roughness, atmospheric rain-induced contribution to the mission)?
- What is the magnitude of SSS variability within a satellite footprint (SMOS (40 km) and Aquarius (50-150 km)); how could this variability be taken into account for in-situ/satellite SSS comparisons?
- How can satellite derived SSS be assimilated/used as input to ocean circulation models? Are current ocean circulation models configured in a way to deal with the surface layer processes inherent in satellite derived SSS?
- Which kind of experimental/numerical experience could support investigations related to the questions above (e.g. field campaigns)?

First activities will concentrate on better defining the physical meaning of the satellite and *in-situ* sampled salinity, and how L-band satellite salinity and ocean salinity measured at a few centimetres/meters depth should be referred to.

The working group findings and results should be summarized in a report and/or a white paper to be published on the working group webpage. Further publishing could be done in scholarly journals (e.g. BAMS).

3.2 Working group on salinity inter-comparison/cross-calibration

Co-Chairs: David LeVine (NASA), Gary Lagerloef (ESR), Yann Kerr (CESBIO),
JordiFont (ICM/CSIC), M.Portabella (UTM-CSIC)

Contact: To join this working group please contact David LeVine at David.M.LeVine@nasa.gov, who will form a working group mailing list and begin an email "conversation".

Scope: The focus of this working group is on identifying an approach for inter-comparison/cross-calibration of SMOS and AQUARIUS data. This will include an agreement on the techniques and reference sites being used for this purpose. Before entering the actual inter-comparison, some fundamental issues in the understanding of L-Band remote sensing need to be addressed, specific to both instruments. In the long run this working group aims toward a merged and validated data product using commonly agreed standards. It will need to be confirmed on what level of data the merged product should occur, i.e. level 1 brightness temperatures (i.e. Fundamental Climate Data Records) or level 2 sea surface salinity (i.e. Thematic Climate Data Records).

This working group will, amongst others, address the following main questions:

- Even though both instruments measure in the same spectral region, both data sets are based on
    - different technology (SMOS microwave interferometric radiometer versus AQUARIUS conventional pushbroom radiometer and scatterometer);
    - a different approach to calibration (SMOS uses cold sky and warm targets and AQUARIUS uses ocean and cold sky);
    - differences introduced through the instrument hardware itself (orbital and long-term drifts, uncertainties in antenna pattern, pointing, etc);
    - differences in the retrieval algorithms for the Level 2 sea surface salinity data product (e.g. in the choice of auxiliary data and the models used).

  Hence it will be necessary to first address these differences and their impact on the results of an inter-comparison. Initial work will concentrate on solving several key common geophysical modelling issues related to galaxy, roughness, emissivity, ascending-descending biases, RFI. This will lead to inter-comparable data sets, even though it is recognised that residual uncertainties will remain related to the above differences.

- The next step will concentrate on agreeing on the approach for inter-comparison (e.g. using a double difference or a tuned-location approach).

4 Areas of research that we should encourage more

- Assimilation of SSS data into ocean circulation models.
- Real synergistic use of the SMOS and AQUARIUS data to exploit their complementarity.

5 Recommendations

- Long-term data continuity required to establish merged/synergistic data products and provide answers in climate change research; how will continuity be ensured beyond SMOS, AQUARIUS and SMAP? What could be possible implementation routes for future concepts such as SMOS Ops or SMOS Next?
- Funding agencies should work together in considering long-term plan to provide L-Band observations continuity.
- Common problems should be pursued on international level: RFI!
- Establish a nomenclature and agreed standard for inter-comparisons between satellite derived and *in-situ* salinity observations, which will be a pre-requisite for merged products between SMOS and AQUARIUS, also in sight of SMAP.
- Sea surface salinity has already been recognised as an Essential Climate Variable (ECV) but is presently not yet pursued as part of the ESA Climate Change Initiative (CCI) studies. SSS CCI study should be initiated as part of the second phase of ESA's CCI studies.
- Recognising the benefit of this event, SMOS-Aquarius workshops could be continued in the future, possibly every 1-2 years.