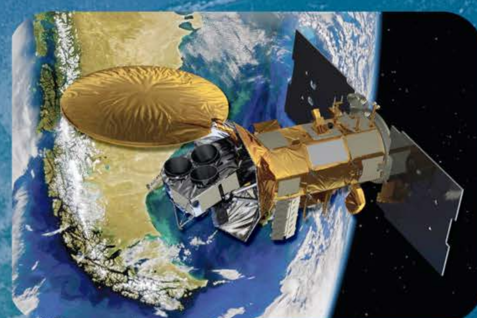
→ SMOS & AQUARIUS SCIENCE WORKSHOP



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15–17 April 2013 | IFREMER | Brest, France

ABSTRACT BOOK

DAY 1: Monday 15 April		
11:00-14:00	Registration	
Opening session & mission status		
Chairman: Susanne Mecklenburg		
14:00-14:10	Workshop opening and objectives	Susanne Mecklenburg, ESA
14:10-14:20	Ocean Salinity Programme at NASA	Eric Lindström, NASA
14:20-14:30	Science programme at CNES	Juliette Lambin, CNES
14:30-15:00	From SMOS to Aquarius and beyond	Yann Kerr, CESBIO
15:00-15:30	Aquarius mission status	Gary Lagerloef, Earth & Space Research
15:30-16:00	SMOS mission status from the ocean's perspective	Nicolas Reul, IFREMER
16:00-16:10	Working Group Intercalibration: introduction	David Levine, NASA
16:10-16:20	Working Group Stratification: introduction	Jacqueline Boutin, LOCEAN

Session 2 Instruments' performance and inter-calibration, algorithm development			
Chairman: David Levine and Yann Kerr			
16:50 - 17:10	Martin-Neira	Manuel	SMOS Instrument Performance and Calibration After 3 Years in Orbit
17:10 - 17:30	Cabot	Francois	Intercalibration of SMOS and Aquarius over land, ice and ocean.
17:30 - 17:50	Bindlish	Rajat	Intercomparison Of Aquarius And Smos Brightness Temperature Observations
17:50 - 18:10	Macelloni/ Skou	(combined presentation)	Macelloni: L-band brightness temperature at Dome-C Antarctica: intercomparison between DOMEX-3, SMOS and Aquarius data,Skou: DOMECair Campaign in Support of SMOS Calibration
18:10 - 20:00	**Ice Breaker & Posters**		

DAY 2: Tuesday 16 April			
Session 2 Instruments' performance and inter-calibration, algorithm development			
Chairman: David Levine and Yann Kerr			
9:00 - 9:20	Misra	Sidharth	Development Of On-Earth Brightness Temperature References At L-Band For Characterizing Long-Term Calibration Drifts
9:20 - 9:40	Banks	Chris	Investigating the Temporal Variability in Salinity from Ascending and Descending Passes in SMOS and Aquarius
9:40 - 10:00	Colliander	Andreas	Ocean Reference for SMOS Zero-Baselines Based on Aquarius Brightness Temperature Simulator

10:00 - 10:20	Kainulainen	Juha	Long and short term radiometric stability of SMOS measurements with different NIR front-end models
10:20 - 10:40	Kao	Hsun-Ying	Remove the Detectable Errors in Aquarius from Inter-Beam Comparisons
10:40 - 11:00	Turiel	Antonio	New reconstruction algorithms for the improvement of SMOS L1c images: preliminary results
11:00-11:30	*Coffee break*		
11:30 - 11:50	Tenerelli/ Gourrion	Joseph/ Jérôme	Continuing Challenges in Salinity Retrieval for the SMOS Mission & Towards an improved characterization of instrumental biases and forward model errors in SMOS observations over the Ocean
11:50 - 12:10	Yueh	Simon	Aquarius: CAP Ocean Surface Salinity and Wind Products and Their Applications to Water Cycle Research
12:10 - 12:30	Dinnat	Emmanuel	Sea Water Permittivity Model and Differences in Sea Surface Salinity Retrieved from SMOS and Aquarius
12:30 - 12:50	Meissner	Thomas	Recent Developments in the Aquarius Level 2 Salinity Retrieval Algorithm
12:50 - 13:10	Spurgeon	Paul	Evolution and application of the SMOS Level 2 Ocean Salinity Ocean Target Transformation
13:10 - 14:20	*Lunch*		

SESSION 3 product validation & stratification			
Chairman: Jacqueline Boutin and Yi Chao			
14:20 - 14:40	Asher	William	The Effect of Environmental Forcing on the Stability of Near Surface Salinity Gradients in the Ocean
14:40 - 15:00	Drucker	Robert	Comparison of Aquarius sea surface salinity with Argo near-surface salinity
15:00 - 15:20	Ward	Brian	Upper Ocean Profiles of Surface Salinity from the Air-Sea Interaction Profiler
15:20 - 15:40	Reverdin	Gilles	Upper ocean stratification from drifters for SMOS/Aquarius cal-val
15:40 - 16:00	Boutin	Jacqueline	SMOS and in situ salinity: rain and near-surface vertical stratification effects
16:00 - 16:20	Chao	Yi	Upper Ocean Salinity Stratification: Challenges To Validate Satellite Remotely Sensed Sea Surface Salinity
16:20 - 16:40	*Coffee break*		
16:40-18:15	Working groups on (in parallel)		
	Intercalibration: Chairman: G. Lagerloef, D. Le Vine, Y. Kerr, J. Font and M. Portabella *Stratification: Chairman: J. Boutin, Y.Chao and Chris Banks*		

DAY 3: Wednesday 17 April			
SESSION 3 product validation & stratification			
Chairman: Jacqueline Boutin and Yi Chao			
9:00 - 9:20	Lagerloef	Gary	Aquarius V2.0 data accuracy assessment and residual errors
9:20 - 9:40	Abe	Hiroto	Evluation of Sea Surfase Salinity observed by Aquarius and SMOS
9:40 - 10:00	Button	Nicole	Validation of SMOS and Aquarius Salinity Data in the Agulhas Region
10:00 - 10:20	Bulusu	Subrahmanyam	Validation of Aquarius and SMOS salinity measurements in the Indian Ocean
10:20 - 10:40	Vinogradova	Nadya	Estimates of Observational Errors Related to Small-Scale Horizontal and Vertical Variability in Salinity Fields

Session 4 SMOS and Aquarius science application and synergies			
Chairman: Nicolas Reul and Antonio Turiel			
10:40 - 11:00	Gordon	Arnold L.	Ocean Eddy Freshwater Flux
11:00-11:30	*Coffee break*		
11:30 - 11:50	Durand	Fabien	SMOS Reveals the Signature of Indian Ocean Dipole Events
11:50 - 12:10	Lee	Tong	Aquarius brings new understanding to tropical instability waves
12:10 - 12:30	Vazuez	Jorge	Initial Results on the Variability of Sea Surface Salinity from Aquarius/SAC-D in the Gulf of Mexico
12:30 - 12:50	Sato	Olga	Salinity variability associated with changes in the hydrological cycle variables
12:50 - 14:00	*Lunch*		
14:00 - 14:20	Xie	Pingping	NOAA In Situ & Satellite Blended Analysis of Sea Surface Salinity: Preliminary Results for 2010 – 2012
14:20 - 14:40	Hasson	Audrey	Analysing the Recent Signature of ENSO in the Tropical Pacific Ocean using In Situ, SMOS and Model Salinity Data
14:40 - 15:00	Liu	W. Timothy	Ocean Surface Salinity Features as Observed by SMOS and Aquarius
15:00 - 15:20	Reul	Nicolas	Eastern Pacific Fresh Pool SSS variability observed by SMOS and Aquarius sensors over the period 2010-2012
15:20-15:50	*Coffee break*		
15:50-16:30	Summary of Working Groups on stratification and intercalibration (20 min each)		
16:30 -18:00	Discussion/ Summary of day's sessions		
End of Workshop			

Oral Presentations

Session 1: Opening Session and Mission Status

From SMOS to Aquarius and Beyond

Kerr, Yann; *Cabot, F.; Leroux, D.; Rougé, B.; Albitar, A.*
CESBIO, FRANCE

The SMOS (Soil Moisture and Ocean Salinity) satellite was successfully launched in November 2009. This ESA led mission for Earth Observation is dedicated to provide soil moisture over continental surface (with an accuracy goal of 0.04 m3/m3) and ocean salinity. These two geophysical features are important as they control the energy balance between the surface and the atmosphere. Their knowledge at a global scale is of interest for climatic and weather researches in particular in improving models forecasts. In June 2011, The Aquarius mission, on board SAC-D was successfully launched. Tailored to monitoring sea surface salinity this NASA led mission differs on several aspects from SMOS. Finally, between the SMAP mission to be launched and the SMOS NEXT mission in early phase A stage there are number of venues to be considered to go towards the establishment of long term data records. The purpose of this communication is to present the SMOS mission results after more than three years in orbit as well as to describe how it compares to similar Aquarius' so as to try to identify the advantages and drawbacks of the two approaches. A special attention will be devoted to land related products and possibly Cryopsheric results.

Methodology

SMOS data

The SMOS instrument measures the passive microwave emission of the Earth surface at a frequency of 1,4 GHz (L-band). It has been demonstrated that this frequency is well adapted to monitor surface soil moisture (first 5 cm) and sea surface salinity [2]. The instrument is an interferometer and provides brightness temperatures with an average resolution of 40 km, at several angle and dual polarizations. It means that a point at the surface is seen several times with different incidence angles. Data are acquired at two times in a day at 6 am and 18 pm (local time) and insure a complete coverage of the Earth surface in 3 days. This concept has some similarities with subsequent systems either in orbit (Aquarius) or to be launched soon (SMAP).

Aquarius data

However Aquarius on top of the fact that it uses a real antenna, has an active system coupled to the passive one, has some differences in terms of spatio temporal sampling (100 km and 8 day coverage of the earth) and sensitivity (at least an order of magnitude better for Aquarius). The Calibration scheme is also different. SMAP bears some similarities with Aquarius the trade offs are more oriented towards land applications.

Over land

Over land SMOS the level 2 algorithm delivers data with a fairly adequate accuracy as long as the perturbing RFI are not too strong. Soil moisture has been monitored continuously with extensive cal val exercises over areas well covered with ground measurements. Droughts and floods have been monitored, etc. Now the focus is on higher level products including obviously level 3 but also drought indices and Root zone soil moisture. Similarly lots of interesting results have been obtained over forested areas, marshes and organic rich soils as well as over frozen or snow covered soils. In parallel other retrievals approaches are being tested (empirical, neural networks) as well as approaches to infer high resolution results (dis-aggregation) soil moisture maps leading to use in irrigation monitoring and management. Aquarius land products are more in infancy as it is not the main science goal but nevertheless some results are beginning to emerge. The spatio temporal is there a handicap but an efficient use of active sensor information coupled with a better RFI processing may prove to have some advantages.

Next SMOS Aquarius and SMAP were designed a few years ago to meet the challenges then. Now, with the increasing resolution of NWP models, with the needs for risk assessment or water management a much better spatial resolution must be sought after typically an order of magnitude. The SMOS design cannot do that as it is optimised for the concept and if gains can be made, they would be small and at a significant cost. Real aperture antennas would become intractable. So as to solve this issue, dis-agregation techniques have been tested. They work up to a factor 5-8 but not for all cases and with a degradation of the signal. Consequently, though very promising, they do not fit the bill completely.

Having an in depth knowledge of SMOS it was relatively easy to find another technical approach solving this issue and we have now a design which enables to gain a factor 10 in terms of spatial resolution (i.e., 4 km spatial resolution, very comparable to SMAP after dis-aggregation) with a system still tractable in space.

Using dis-aggregation techniques could bring the SM field within the km range resolution which would make such a mission a really innovating tool.

This presentation shows in SMOS products and results and compares with Aquarius.

SMOS mission status from the ocean's perspective

Reul, Nicolas[1]; SMOS team members, [2]
[1]IFREMER, FRANCE; [2]LOCEAN, IRD, CLS, ICM, FRANCE

In this talk, we shall present an overview of the SMOS mission status regarding oceanic observations. The young SSS remote sensing experience from Space will be first discussed in light of the now more than 50-years old ocean satellite observations of sea surface temperature, sea level and ocean color.
After 3 years of acquisitions and continous improvements, SMOS SSS data still present some well identified flaws (spatio-temporal drifts, biases, uncertainties) associated with either calibration issues, image reconstruction processing unknowns, brightness temperature forward modelling issues (corrections of sea surface roughness, extra-terrestial sources) or radio-frequency interference contaminations. Some of these problems are purely-SMOS related issues (e.g. interferometric concept) and some are common to both SMOS and Aquarius missions (forward models, asc-desc biaises) but can also take different forms (e.g; rfi, glints..). Solutions to correct for these problems are not unique and several methods were proposed by different teams working on both missions. We'll briefly review these issues & solutions.
In addition, both mission products help us now discovering what the global skin salinity of the ocean looks like. The centimeter depth SSS sensing by satellites potentially differs from traditional deeper in situ measurements and add uncertainties in interpreting salinity estimates from Space.
Nevertheless, several very interesting science application already emerged from the analysis of the first three years of SMOS data over the ocean . In particular, we shall review results which will be discussed more in depth during the meeting oral & posters presentations such as large tropical river plume monitoring, rain-induced freshening imprints in the tropics, upwelling event signatures, tropical instability waves, ENSO/La Nina interannual signals, tropical cyclone/freshwater pool interactions and exchanges of salt across large western boundary currents. Combined with other ocean observing systems, the new products from SMOS and Aquarius clearly add key previously missing informations to better monitor our changing climate.

Session 2 Instruments' performance and inter-calibration, algorithm development

SMOS Instrument Performance and Calibration after 3 Years in Orbit

Martín-Neira, Manuel[1]; Corbella, Ignasi[2]; Torres, Francesc[2]; Kainulainen, Juha[3]; Olivia, Roger[4]; Closa, Josep[5]; Cabot, François[6]; Castro, Rita[7]; Barbosa, José[7]; Gutierrez, Antonio[7]; Anterrieu, Eric[8]; Tenerelli, Joe[9]; Martín-Porqueras, Fernando[10]; Buenadicha, Guillermo[4]; Delwart, Steven[11]; Crapolicchio, Raffaele[11]
[1]ESA, NETHERLANDS; [2]Remote Sensing Laboratory, Universitat Politècnica de Catalunya, SPAIN; [3]Aalto University School of Electrical Engineering, FINLAND; [4]ESA, SPAIN; [5]EADS-CASA Espacio, SPAIN; [6]CESBIO, FRANCE; [7]DEIMOS, PORTUGAL; [8]IRAP, FRANCE; [9]CLS, FRANCE; [10]IDEAS, SPAIN; [11]ESA, ITALY

ESA's Soil Moisture and Ocean Salinity (SMOS) mission has been in orbit for already over 3 years which has allowed the calibration and data processing team consolidating both the calibration strategy and the Level-1 processor which transforms the raw visibility samples into polarimetric brightness temperature images. The payload on board SMOS, MIRAS, is quite unique in that it is the first microwave radiometer in space ever capable to generate wide field of view images at every snapshot measurement. This means that most of the calibration as well as image processing techniques are being developed for the first time with little heritage from any previous space mission. Issues intrinsically attached to its wide field of view such as spatial ripples across the snapshot images are particular to MIRAS and to no other earlier radiometer. Even the fundamental theory behind the instrument was put at test, first on ground inside an electromagnetic compatibility chamber, and now in orbit when imaging the Cosmic Microwave Background Radiation of the cold sky. A groundbreaking effort is being carried out by the SMOS project team to understand and master all calibration and image reconstruction issues of this novel microwave interferometer payload. MIRAS in-orbit performance is driven by the amplitude of spatial ripples across the image and orbital and seasonal radiometer stability. Spatial ripples are unique to interferometric radiometers and are produced by (a) a limited knowledge of the antenna patterns and, in general, of the model of the instrument, (b) some fundamental limitations related to the inverse problem of image reconstruction in undetermined conditions and (c) subtle processor software inconsistencies which are discovered and corrected. To reduce the spatial ripples sea surface salinity retrievals are performed by first removing the brightness temperature spatial errors using a uniform region of the Pacific Ocean. In addition, brightness temperatures tend to be negatively biased in the region around nadir, an artifact dependent of the processing technique and which is likely to be corrected in future processor versions. The 3 year long data set has enabled the computation of the drift of the instrument, at orbital, seasonal and yearly scales. Orbital and seasonal drifts are dominating the stability of the brightness temperature images while the yearly drift is lower but clearly measurable. An important question about these drifts, still under study, is how much of them is coming from the instrument itself and how much is due to other effects influencing the metrics, like the Sun tails or the reflected galaxy. The most recent efforts have therefore focused in the correction of the Sun tails from the images by acquiring the Sun response in orbit through external calibration maneuvers. In parallel new calibration techniques to reduce further any instrumental variation are being investigated as an improved thermal model for the NIR receivers of MIRAS or the so called ALL-LICEF mode. An overview of the good progress achieved in both calibration and image reconstruction issues in SMOS after these first 3 years in orbit, as described above, shall be presented in this contribution, with focus in ocean imaging.

Intercalibration of SMOS and Aquarius over Land, Ice and Ocean

Cabot, Francois[1]; Kerr, Yann[1]; Lagerloef, Gary[2]; Anterrieu, Eric[3]
[1]CESBIO, FRANCE; [2]ESR, UNITED STATES; [3]IRAP, FRANCE

SMOS mission has celebrated 3 years in orbit in early November 2012. Throughout these 3 years, it has been made clear that final quality of the geophysical retrieved products, both over land and ocean, highly depends on the brightness temperature map quality. And because of the very specific way SMOS is acquiring brightness temperature measurements; careful attention has been given to the image reconstruction process. Yet, absolute radiometric accuracy is also a major contributor to overall performance budget at level 2, especially for ocean salinity. Since June 2011, SMOS has been joined on orbit by Aquarius, more dedicated to ocean surface issues. In order to prepare for joint products, one needs to guarantee a very good consistency between the brightness temperatures retrieved by the two instruments and first experiments to this end have already been conducted over oceans [1], [2].

The comparison relies on two approaches: i) Making use of a stable target to assess the consistency and stability of both data sets. This is done over the area surrounding Dome Concordia in Antarctica. After careful selection and filtering, statistics of the comparison are retrieved along with long term trends in both data sets. ii) Once every so often, both satellites overpass the same area within a very short time period. Due to different inclinations these alignments occur essentially along the equator, but over different surfaces, giving access to wide dynamic range in brightness temperature. This method has been introduced and tested over limited data sets and extended in the present paper. [3]

Various improvements have been incorporated in processing on either side. Impact of these improvements and effectiveness of the successive processor versions can be evidenced through these comparisons. Complete results of these comparisons over ice, land and ocean will be detailed and analyzed. Performance assessment of both instruments will also be presented based on these results.

This presentation will summarize the results of these comparisons over the whole lifetime of both missions, giving special attention to comparison methods.

REFERENCES

[1]. Lagerloef, G., Kerr, Y., Anterrieu, E., Jackson, T., Bindlish, R., Kao, H., Aquarius Status And SMOS Cross-Calibration Over Oceans, EGU General Assembly 2012, 22-27 April, 2012, Vienna, Austria. [2]. Anterrieu E., Kerr Y., Cabot F., Lagerloef G., LeVine D., A synergy between SMOS & AQUARIUS: Resampling SMOS maps at the resolution and incidence of AQUARIUS. IGARSS 2011, 24-29 July 2011, Vancouver, Canada. [3]. Cabot F., Anterrieu E., Picard G., Macelloni G. and Kerr Y., Validating SMOS brightness temperatures over land, MicroRAD2012, 5-9 March 2012, Frascati, Italy.

Intercomparison of Aquarius and SMOS Brightness Temperature Observations

Bindlish, Rajat[1]; Jackson, Thomas[1]; Zhao, Tianjie[2]; Lagerloef, Gary[3]; Le Vine, David[4]; Yueh, Simon[5]; Kerr, Yann[6]

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A comparison is reported of Aquarius and SMOS brightness temperatures over land and ocean. This is done by reprocessing the SMOS data to match the footprints of the Aquarius radiometers. Although the focus of Aquarius has been calibration over the ocean to retrieve sea surface salinity, it is planned to provide a soil moisture product and consequently calibration of the full dynamic range from ocean to land is important. It is a challenge to validate TB over land (as opposed to oceans) using models because there are more factors that contribute to TB and the footprints are more heterogeneous. On the other hand, the inter-comparison of the two sensors provides a consistency check on the calibration.

Observations made at the same frequency, polarizations, and incidence angle by multiple instruments/platforms (at concurrent locations and times) should be consistent with each other. Both SMOS and Aquarius have an equatorial overpass time of 6 AM (SMOS-ascending; Aquarius-descending). Thus, the TB observations from the Aquarius and SMOS missions should be similar. This provides us with an opportunity to cross-calibrate and compare the TB observations. Consistent calibration across all satellite missions is critical to eventually developing a long term climate data record of L-band TB observations. A physically-based algorithm that spans multiple L-band missions requires consistent input observations for the development of a long term environmental data record.

The SMOS data were reprocessed to match the incidence angles and sizes of the three Aquarius radiometer footprints. Only the alias free portions of the SMOS orbit were used in the comparison. The alias free portions of the orbit provide brightness temperatures with the lowest NeÄT. The current version of the Aquarius TB (v1.3.7) shows a very strong correlation with the SMOS observations. The Aquarius TB compared well with SMOS observations over oceans, however, the Aquarius brightness temperatures are biased warmer than the SMOS observations over land. There is a bias of about 8K for h-pol and 6K for v-pol observations. These combined results provide strong evidence of inconsistencies in the relative calibrations of Aquarius and SMOS. The analysis will be re-done with the Aquarius data v2.0 (to be released in February 2013). USDA is an equal opportunity employer.

L-Band Brightness Temperature at Dome-C Antarctica: Intercomparison Between DOMEX-3, SMOS and Aquarius Data

Macelloni, Giovanni[1]; Brogioni, Marco[1]; Pettinato, Simone[1]; Monti, Fabiano[2]; Casal, Tania[3]
[1]IFAC - CNR, ITALY; [2]CVA-ARPAV, ITALY; [3]ESA - ESTEC, NETHERLANDS

With the purpose of evaluating the brightness temperature long-time temporal stability of a possible SMOS external calibration reference target an experimental activity, called DOMEX, was carried out in the past years at the Italian-French base of Concordia (Antarctica). The activity consists in the observation of the plateau using a ground based L-band radiometer installed on an observation tower. The first experiments, called DOMEX-1 and DOMEX-2 respectively, featured a ground-based L-band radiometer operating 24 hours per day for one month in 2004-2005 and for two years from 2008 to 2010. The data collected during these experiments confirmed that the microwave emission of the Dome C site at L-band can be considered stable (especially at V polarization) for periods several months long. The results obtained demonstrated that DOME-C represents a unique "high- temperature" extended target that provides a temporally-stable reference which potentially meets existing requirements for assessing the long-term stability of space-borne L-band radiometric instruments. Long-term monitoring of DOME-C is also crucial to investigating further and to modeling variations in H-pol observed during the DOMEX-2 experiment. In addition, the data set will be instrumental for satellite sensor product intercalibration ensuring a harmonized Level 1 data set of passive microwave observations at L-band covering the SMOS - Aquarius - SMAP era and for future climate applications. In order to meet this objective, a new experiment called DOMEX-3 started in December 2013. The instrument used in the campaign is an improved version of the Radomex radiometer built by the Institute of Applied Physics in Florence, Italy, which was used successfully in 2008-2010 period. The newly-designed Radomex radiometer is able to operate autonomously and remotely transmitting data daily to Europe. The instrument was accurately tested and calibrated before the shipment using standard procedures.
Data acquired in the first months of the experiment confirm the results obtained in previous campaign, in particular the temporal stability of the site at V polarization. DOMEX-3 time-series data, collected at 42° of incidence angle, were also compared to SMOS and Aquarius data collected over the same area. The last version of reprocessed SMOS data was used here. The L1C data was transferred from Antenna to Top of Atmosphere (TOA) level (XY to HV) by applying Faraday and geometric rotations and the Brightness temperatures were averaged within an incidence angle of between 37.5 and 47.5 degrees, and only for nodes within the alias-free part of the SMOS field of view. The Aquarius dataset consisted of Level-2 data (version 1.3) without land correction collected at 45.6 deg of incidence angle. Although DOMEX-3 collects measurements at a fixed incidence angle (42°) it occasionally performs incidence angle scans in the 20°-60° range. These data were compared to SMOS and Aquarius data collected in the same period. For Aquarius data acquired at the three different incidence angle were considered. Besides the area of Concordia another large area, exhibiting a triangular-shape and located 200 Km far from the station in the west direction, was observed in both SMOS and Aquarius data. From a preliminary investigation, this area appears to be very homogenous in space and able to contains several SMOS and Aquarius pixels. Time series of both satellite sensors collected over that area were considered and compared to the data acquired at Concordia. For SMOS the mean difference of the Tbv time series between the triangular area and Concordia base was 2.6 K (is higher over Concordia). Moreover, this difference remained stable in time (the temporal standard deviation was 0.24K), and it was thus possible to correlate the measurements collected at Concordia to those acquired over this large area. For Aquarius data the difference between the triangle and Concordia was 2 K at V polarization.

DOMECair Campaign in Support of SMOS Calibration

Skou, Niels; Kristensen, S.*; Soebjaerg, S.*
Technical University of Denmark, DENMARK

1. Background

ESA's SMOS mission is faced with the challenging task of measuring the salinity of the oceans as well as the soil moisture over the continents, based on radiometric measurements of the natural emission from Earth. This is done using a microwave radiometer system operating in the protected radio astronomy band near 1.4 GHz (L-band). Especially the salinity measurements impose severe requirements to the brightness temperature measurement fidelity concerning stability and absolute calibration accuracy. Thus the SMOS instrument features several internal calibration loops, but the important antenna system is outside these loops, and in the end, checks of overall calibration, measuring known external targets, is a necessity throughout the lifetime of SMOS. The problem is that such calibration targets have to be not only stable and well known, but also of very extended size, hundreds of kilometers, due to the imaging properties of sensors like SMOS. One of the few feasible earthly targets that might live up to all expectations is the area around Dome-C in Antarctica. This will provide SMOS with a hot calibration point. Analysis of existing radiometric measurements (at higher frequencies) from a range of space missions (SMMR, SSM-I, AMSR-E) shows good stability and spatial homogeneity. An analysis conducted on SMOS data over a two years period confirms the good spatial and temporal stability not only for the area around Dome-C but over a large area of the East Antarctic Plateau. Moreover, the results obtained from ground radiometric measurements (i.e. DOMEX-2 experiment), provides the final confirmation of the good temporal stability. What remains to be finally proven is good spatial homogeneity. This can only be done by launching a suitable airborne campaign. Another natural, extended calibration target is free space, and indeed SMOS measures this on a regular basis through suitable pitch maneuvers. Free space, when corrected for galactic radiation, provides a cold calibration point. Seen from a radiometer designer's point of view this is an ideal situation: the sensor in question regularly measures both a cold and a hot calibration target, meaning that instabilities can be monitored. Since the cold sky can only be measured occasionally (once each fortnight) the Dome-C hot target becomes extremely important as it is measured several times per day! Moreover, and very important: by having both a hot and cold calibration point, problems with possible simultaneous offsets and multiplicative calibration errors can be disentangled. The temporal stability of the area has already been verified by operating a ground based L-band radiometer from a tower at Dome-C for a full year, which demonstrated that especially at V polarization the brightness temperature is very stable showing an annual standard deviation lower than 0.5 K whilst at H polarization it is larger than 1 K because of the effect of snow layering as also demonstrated in several papers.

Irrespective of this promising result, an outstanding issue to be investigated is the spatial variation of TB at SMOS sub-pixel scale, which is expected to be very small around Dome-C, but has, however, never been measured at L-band. Also, a potential azimuth variation (due to for example a pre-dominant wind direction) must be investigated. These issues are deemed important uncertainties and problems in relying on Dome-C as a major SMOS calibration site.

In order to fill this gap a measuring campaign is carried out in the Dome-C area using a suitable airplane equipped with the EMIRAD L-band radiometer system. This radiometer system was designed for use in a range of airborne campaigns supporting the development of geophysical algorithms for SMOS, as well as being an important instrument in the Cal/Val campaigns. Detailed measurements are made over a 350 x 350 km area centered at the Concordia Station, but also important are the measurements that can be performed during the transits to and from Dome-C. There is a high interest in transects out to the coast, and also in a transect between Dome-C and the South Pole.

2. EMIRAD-2 L-band Radiometer System

The EMIRAD-2 L-band radiometer system has been developed by DTU, and operated by DTU in a range of campaigns, known as the CoSMOS campaigns, in support of SMOS. It is a fully polarimetric (4 Stokes parameters) system with advanced RFI detection features (kurtosis and polarimetry). The system has operated successfully on different aircraft (C-130, Aero Commander, Skyvan) in Denmark, Norway, Finland, Germany, France, Spain, Australia). The main features of the system are:

- Correlation radiometer with direct sampling
- Fully polarimetric (i.e. 4 Stokes parameters)
- Frequency: 1400.5 - 1426.5 MHz (-3 dB BW) 1392 - 1433 (-60 dB BW)
- Digital radiometer with 139.4 MHz sampling
- Digital I/Q demodulation and correlation for accurate estimation of 3rd and 4th Stokes
- Advanced analog filter for RFI suppression.
- Additional digital filter bank: 4 sub-bands.
- RFI flagging by kurtosis and polarimetry.
- Data integrated to 1 msec recorded on primary storage PC.
- "Fast data" pre-integrated to 14.4 ìsec. recorded on dedicated PC.
- Sensitivity: 0.1 K for 1 sec. integration time
- Stability: better than 0.1 K over 15 min. before internal calibration.
- Calibration: internal load, noise diode, and Active Cold Load (ACL).
- 2 antennas - one nadir pointing, one side looking at 45 deg. incidence angle
- Antennas are Potter horns with 37.6 deg & 30.6 deg HPBW
- Nadir horn has 415 m footprint from 2000 ft flight altitude
- Tilted horn has 490 m by 640 m footprint, again from 2000 ft flight altitude.
- Each data package time stamped using GPS 1PPS signal with 100 ns accuracy.
- Minimum operating altitude: 250 m above terrain @ 140 knots

Further information about EMIRAD-2 is found in [Skou et al, 2006] and [Skou et al, 2010]. For the current campaign, EMIRAD is installed a Basler BT-67 aircraft owned and operated by AWI. The radiometer system features 2 large Potter horns as antennas. One antenna is mounted nadir looking, the other is tilted nominally 40 deg. The antennas are mounted in existing apertures in the fuselage. The radiometer itself is installed very close to the antennas to ensure short antenna cables (low loss). Also the inertial navigation unit is mounted close to the antennas in order to measure attitude correctly.

3. Flight Patterns

In order to evaluate the homogeneity of the area around Dome-C a raster pattern is flown. The area around Concordia is covered by a grid of long lines, such that an area of 350 x 350 km is covered. The area around the tower, where the DOMEX experiment took place, is covered more intensely by a star pattern. The star pattern is centered on the observation tower at Concordia, and one arm of the star is in the view direction of the tower. In addition to the raster pattern and the star pattern, circle flights are carried out to examine a potential azimuthal signature. In order to obtain sufficient radiometric resolution, several circles must be flown and integrated during data processing. In order to take proper precautions against a possible Sun effect, the circle patterns must be carried out 2 times, many hours apart - for example early morning and late afternoon. This way it is possible to separate a potential azimuth signature from the ice surface and from the Sun intrusion. The Sun azimuth signature can be used also to correct the raster pattern measurements if necessary.

When investigating azimuth signatures, an alternative to the circle flight pattern is the star pattern already described. Here fewer azimuth angles are sampled, but the crucial TB data are gathered during relatively short and straight flight lines making attitude stability easier to obtain. Thus the star pattern supports the circle pattern when azimuthal issues are investigated.

4. Data Processing

The data processing takes place at DTU following the campaign, and it includes the following tasks:

- Calibration using the internal calibration loops and external liquid nitrogen cold target calibration carried out in the field before each mission.
- RFI detection and mitigation using kurtosis and polarimetry.
- Production of TB map of the area covered by the grid pattern, including estimates of uncertainties in the measurements and the final map product. Main descriptive statistics could be mean, variance, histograms,
- Analysis of the homogeneity of this map. Spatial statistics like spatial covariance functions, power spectra, estimate of correlation lengths.
- Production of the circle flight and signatures.
- Production of star pattern signatures.
- Analysis of azimuthal signatures in the morning and the afternoon circle flights. Extract Sun signature.

- Correct raster pattern measurements for Sun effects.
- Analysis of azimuthal signatures in the star pattern.
- Estimates of biases between tower measurements and airborne measurements.
- Cross comparison of airborne measurements with ancillary geophysical information.
- Comparison of airborne data with SMOS data.

5. References

Skou, N., S. S. Sobaerg, J. Balling, and S. S. Kristensen: "A Second Generation L-band Digital Radiometer for Sea Salinity Campaigns", Proceedings of IGARSS'06, 4p., July 2006.

Skou, N., S. S. Sobjaerg, J. Balling, S. S. Kristensen, and A. Kusk: "EMIRAD-2 and its use in the SMOS Cal/Val Campaign", DTU Space, AR 502, pp. 1-59, June 2010.

Development of on-Earth Brightness Temperature References at L-Band for Characterizing Long-Term Calibration Drifts

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Previous high frequency microwave radiometers such as TOPEX, Jason-1, Jason-2 have all utilized external brightness temperature references as calibration targets. Global mean brightness temperature measurements (or vicarious cold brightness temperatures) from the Ocean are used to calibrate the instrument at one end of the temperature spectrum and hot targets such as the Amazonian rainforests are used at the other end of the temperature spectrum. The external calibration sources provide a wide dynamic range to back out gain and offset variations from the instrument. Even though the Aquarius mission science measurements are made over a very small dynamic range, it is important to correctly identify the contribution of individual drift mechanisms. SMOS and NASA's upcoming SMAP mission's science measurements cover a wide brightness temperature range, necessitating gain and offset corrections.

The external calibration sources developed for high frequencies cannot be directly applied at L-band. This has required the development of L-band brightness temperature calibration models over Antarctica and depolarized regions of the Amazon. The Antarctic region is a very attractive stable calibration source due to the deep penetration depth at L-band and potential annual stability of less than 0.2K. We have developed an advanced ice microwave emission model to predict brightness temperatures at L-band. This model includes in-situ surface data from AWS (Antarctic Weather Stations) and is coupled with a heat transport model to determine ice temperature profile. The MEMLS radiative transfer model is used to determine L-band Tb, constrained by other ancillary measurements such as AMSR-E or WindSat. We have used Aquarius measurements to determine a large homogeneous and temporally stable region of Antarctica to use as a stable calibration reference. Measurements from the Antarctic L-band modeling have aided in the determination of a gain-based drift in Aquarius.

At L-band forest regions are expected to be slightly transparent. We have developed an Amazon rainforest calibration model that selects depolarized heavily vegetated areas. WindSat and TMI data is used to constrain the Amazon model and further uncertainties due to canopy temperature are removed by comparing inter-channel differences only. The Amazon model coupled with the Antarctic and Ocean model successfully identified the offset-component of drift in SMOS.

A brief description of the drift observed by Aquarius channels will be presented. A description of the on-Earth reference models at L-band will be given followed by a discussion of the results.

Investigating the Temporal Variability in Salinity from Ascending and Descending Passes in SMOS and Aquarius

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The launch of the SMOS and Aquarius satellites marked a new era in satellite oceanography allowing routine monitoring of the salinity of the world's oceans on synoptic scales. However, there are significant issues affecting the performance of SMOS related to the satellite direction (ascending/descending passes) although the magnitude has decreased with revised versions of the processor. On-going work has shown that Aquarius also has a bias between SSS from ascending passes and SSS from descending passes. The ascending/descending bias in SMOS SSS is significant and is likely, in part, linked to changes in galactic glint and sun contamination through the year. The ascending/descending bias for Aquarius is less pronounced but is still significant.

SMOS has a sun-synchronous orbit such that at ~6 a.m. (local time) SMOS is ascending (satellite moving from south to north) and at ~6 p.m. is descending (satellite moving north to south). Similarly, Aquarius is in a sun-synchronous orbit but the direction of passes is 12-hours out of phase so that Aquarius is ascending at ~6 p.m. and descending at ~6 a.m. This paper reviews work-to-date at the UK National Oceanography Centre on a study concerned with looking at differences amongst SSS derived from SMOS and Aquarius from ascending and descending passes. The aim is to take advantage of data from both satellites and utilise the phase difference to investigate whether time of day is a factor (e.g. biases due to diurnal warming effects or the tendency for heavy precipitation to occur mid-afternoon in tropical regions).

The study region is the global oceans between 60°S and 60°N and the data are from 1 September 2011 to 31 October 2012 for Aquarius (processor V1.3) and 1 September 2010 to 31 October 2012 for SMOS (processor V5_50). For SMOS and Aquarius separately, the mean, daily SSS from all descending passes is subtracted from the mean daily SSS from all ascending passes (SSSA-D). Both satellites show temporal variability in SSSA-D but the variations are not in phase. The study considers results globally as well as smaller regions and over latitudinal ranges.

Ocean Reference for SMOS Zero-Baselines Based on Aquarius Brightness Temperature Simulator

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SMOS [1] and Aquarius [2] are ESA and NASA missions, respectively, to make L-band measurements from the Low Earth Orbit. SMOS makes passive measurements whereas Aquarius measures both passively and actively. SMOS was launched in November 2009 and Aquarius in June 2011.The scientific objectives of the missions are overlapping: both missions aim at mapping the global Sea Surface Salinity (SSS). Additionally, SMOS mission produces soil moisture product (Aquarius data will eventually be used for retrieving soil moisture too). The consistency of the brightness temperature observations made by the two instruments is essential for long-term studies of SSS and soil moisture.

For ensuring the consistency, the calibration of the instruments is the key. The basis of the SMOS brightness temperature level is the measurements performed with the so-called zero-baselines [3]: SMOS employs an interferometric measurement technique which forms a brightness temperature image from several baselines constructed by combination of multiple receivers in an array and in which the zero-length baseline defines the overall brightness temperature level [4]. The basis of the Aquarius brightness temperature level is resolved from the brightness temperature simulator combined with ancillary data such as antenna patterns and environmental models [5]. Consistency between the SMOS zero-baseline measurements and the simulator output would provide a robust basis for establishing the overall comparability of the missions.

The footprints of the SMOS zero-baseline and the beams of the Aquarius are fundamentally different. This is due to the fact that the SMOS zero-baseline is designed to measure the average brightness temperature of the entire SMOS scene and, therefore, the 3-dB footprint spans over 1000 km in the cross-track direction and includes a piece of sky in the along-track direction, whereas Aquarius is a real aperture pushbroom system which has footprints of size about 70 km to 150 km on the surface of the Earth. Although the primary purpose of the Aquarius simulator is to simulate antenna temperature corresponding to Aquarius footprints, it is able to determine the brightness temperature of a wide beam such as that of the SMOS zero-baseline because it includes the entire field-of-view of the antenna including the side and back lobes of the antenna for accuracy. Accordingly the simulator has the capability to simulate the brightness temperature emitted by sea, land, atmosphere, microwave background and celestial objects over the full view angle of the antenna. The comparisons of this study will be made over ocean where the model is the most accurate (and which is most relevant for the SSS retrieval of the missions) and the largest contribution comes from the sea with partial effect from the sky.

The ability of the simulator to predict correct brightness temperature level for the SMOS zero-baseline has been verified in [6]. The Aquarius antenna pattern was replaced by the antenna pattern of a zero-baseline element of SMOS in the simulator, and simulations were carried out in the actual measurement geometry of SMOS. The level of the resultant antenna temperature was very close to the actual zero-baseline measurement.
Full simulations of the SMOS zero-baseline observations are being carried out. The simulations focus on observations over the Pacific Ocean where the surface conditions are climatologically relatively constant, the full field of view is as free as possible from the effect of land, and the interference from the galaxy and the sun is minimal (but the significance of these interference sources will also be studied). The simulations include all observations carried out since the end of the SMOS commissioning phase which yields a data set of almost 3 years long. This allows investigation of seasonally driven anomalies in addition to short term and instantaneous effects.

The presentation will show the 3-year simulation of SMOS zero-baselines compared with the actual measurements. The similarities and differences will be analyzed and the implications on the consistency of the brightness temperatures of SMOS and Aquarius will be assessed. Although the comparison is not done at the retrieval resolution of SSS, the results will give important direction where corrections are potentially required for building a continuous SSS product between the missions.

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REFERENCES

[1] Y. Kerr et al., "The SMOS Mission: New Tool for Monitoring Key Elements of the Global Water Cycle", Proc. of IEEE, Vol. 98, No. 5, May 2010.
[2] D. Levine, G. Lagerloef, S. Torrusio, "Aquarius and Remote Sensing of Sea Surface Salinity from Space", Proc. of IEEE, Vol. 98, No. 5, May 2010.
[3] R. Oliva, M. Martin-Neira, I. Corbella, F. Torres, J. Kainulainen, J. Tenerelli, F. Cabot, F. Martin-Porqueras, "SMOS Calibration and Instrument Performance After One Year in Orbit", IEEE Trans. Geosci. Rem. Sens., Vol. 51, No. 1, January 2013.
[4] A. Colliander, L. Ruokokoski, J. Suomela, K. Veijola,J. Kettunen, V. Kangas, A. Aalto, M. Levander, H. Greus, M. Hallikainen, J. Lahtinen, "Development and Calibration of SMOS Reference Radiometer", IEEE Trans. Geosci. Rem. Sens., Vol. 45, No. 7, July 2007.
[5] D. Le Vine, E. Dinnat, S. Abraham, P. de Matthaeis, F. Wentz, "The Aquarius Simulator and Cold-Sky Calibration", IEEE Trans. Gesci. Rem. Sens., Vol. 49, No. 9, September 2011.
[6] A. Colliander, E. Dinnat, D. Le Vine, J. Kainulainen, "Synthesizing SMOS Zero-Baselines with Aquarius Brightness Temperature Simulator", Proc. IGARSS 2012, Munich, Germany, July 22-29, 2012.

Long and Short Term Radiometric Stability of SMOS Measurements with Different NIR Front-End Models

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The Soil Moisture and Ocean Salinity (SMOS) satellite has measured the L-band brightness temperature of the Earth over three years. The payload instrument MIRAS (Microwave Imaging Radiometer using Aperture Synthesis) measures two-dimensional brightness temperature maps of the L-band radiation by means of interferometry in order to obtain a reasonable angular resolution.

One key aspect in interferometric imaging is that the average brightness temperature level of each measured image is obtained from an independent measurement. In SMOS, there are three special Noise Injection Radiometers (NIR units) for this purpose. Obviously, accuracy of these NIR units, or reference radiometers, plays an important role in the performance of the whole MIRAS.

Performance of any radiometer is often characterized by thermal and temporal stability of its measurements. Especially, since the scientific mission requirements of the SMOS mission rely on averaging data from several orbits, the stability of the measurements play an enhanced role. Throughout the SMOS mission the performance of the imaging system, as well as the performance of the NIR units, has been monitored with measurements of some well-behaving natural targets. Such targets have been the sky (which is also the only external calibration reference of MIRAS), Antarctica, and Pacific Ocean. These targets have been analyzed by Level 1 and Level 2 teams e.g. in terms of temporal stability, spatial ripple, and thermal stability of measurements.

One key result from the investigations of the three years is that there has been a clear change in thermal and electrical properties of the MIRAS hardware during the first months of the mission, and that this change has settled or at least decreased along with the mission. This change has been attributed to changes in thermal and electrical conductivity in the ground plane cover around the antennas. By possibly affecting to the attenuation, efficiency, matching, and antenna patterns of individual units, these changes restrict the performance of MIRAS and the NIR units.

Within the NIR units, different models have been proposed to compensate these effects. Mainly, the methods are based on relating some NIR unit parameter with the physical temperature of the antenna patch. These models have been clearly enhancing the performance of the units; however, room for further improvements still exists in this field. In this contribution we review the front-end models of the NIR units that have been developed during the three-year life time of SMOS. We explain measurements which are used to assess the different models and the key results which yield in the development of them. Especially, we show measurements of the validation targets (sky, Antarctica and Pacific Ocean) with different NIR front-end models. From these results we conclude the current radiometric stability of the measurements of SMOS, and point out possible new ways to further improve the performance.

Remove the Detectable Errors in Aquarius from Inter-Beam Comparisons

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The Aquarius is designed to use three horns to measure the sea surface salinity (SSS) at the same time. Taking the advantages of this particular design, here we compare the SSS in three beams and attempt to identify the signal and noise within. It is noticed that the measured SSS in three beams can have significant difference due to the local rainfall, as the distances among the three horns are around a hundred kilometers. Therefore, the rain signals may be removed if the adjustments are done to unify the SSS values in three beams. On the other hand, the observed freshening caused by the regional rainfall is usually washed away in one day. Different from the small-scale inter-beam differences, which are hard to identify signal or noise, longwave (large scale) inter-beam differences are expected to be negligible in reality, as the distances of the footprints of the three horns at the same time cannot be longer than 390 km. As verified in the reference field from HYCOM, it's reasonable to consider the longwave inter-beam difference as bias. As a result of the longwave inter-beam bias removal, we are able to remove most of the stripes on the L3 gridded maps, suggesting the efficiency of bias removal using this simple method. Improvements in buoy matchup are also shown in the results. However, the ascending and descending differences are still an unsolved issue, and should be further investigated in the future.

New Reconstruction Algorithms for the Improvement of SMOS L1c Images: Preliminary Results

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Due to its interferometric design, the direct measurements by SMOS payload, MIRAS, are the visibilities of the signal defined on an hexagonal grid. The visibility field can be expressed as the Fourier transform of brightness temperature in real space modulated by the antenna gain pattern. Retrieving brightness temperatures (the actual physical variable of interest) from visibilities requires to implement an appropriate reconstruction algorithm. Different approaches to this reconstruction algorithm have been proposed so far, trying to improve the quality of the signal and to diminish side-lobes and other effects associated to incorrect spatial phases. One important difficulty when reconstructing the signal is that visibilities are not evenly sampled by MIRAS on a translational invariant cell but on a star-shaped subset, so no tiling can be defined and hence any inverse Fourier transform will require to introduce zero coefficients at high frequencies. Those lacking coefficients may generate Gibbs-like phenomena and spread side-lobes from any sharp transition present in the original scene.

The simplest reconstruction algorithm consists in calculating the inverse Fourier coefficients associated to the minimum hexagon embedding the MIRAS visibility star by direct application of the Fourier series formulas. However, this approach is very sensitive to the presence of high amplitude, small spatial extent sources in the original scene, that will spread side lobes that may eventually corrupt all the retrieved scene. Even if the coefficients for the full embedding hexagon were known and even if the version of Fourier series adapted to hexagonal grids to avoid introducing spurious zeros at high frequencies were applied, any delta-like high-amplitude signal in the original scene will significantly corrupt the scene retrieved with this algorithm. This makes RFI sources, land-sea transitions and even the presence of Sun very disturbing, as they may generate so large side-lobes that scenes get irredeemably corrupted over large areas.

An alternative reconstruction algorithm, able to eliminate side-lobes associated to delta-like sources, can be proposed by accepting some degree of representativity error in the retrieved signal. This new algorithm is based on the observation that when the visibility star is embedded in hexagons of larger scales and the inverse Fourier coefficients are calculated, the nodal points - the zeros of the sinus function associated to side-lobes- remain invariant under changes in scale. We call the grid formed by the nodal points the nodal grid. As scale is increased nodal points are representative of pixels with smaller footprint, so they become less and less representative of the associated geographical area; but if the geophysical signal to retrieve has a slow-enough spatial pattern of variation the retrieved value is still very representative of the actual geophysical average on the coarser grid. Nodal grids sampling hexagons of large enough scales lead to a maximum reduction of side-lobes on synthetic images.

Direct application of uniform nodal grids on SMOS visibilites corrupted by high levels of RFI-induced noise leads to highly attenuated side-lobes, too. However, due to imperfections in the antenna distribution the spatial pattern of nodal points associated to MIRAS is not completely uniform. Even worse, changes in local phase between consecutive calibrations make the nodal grid not constant with time. The implementation of a fast, adaptive algorithm capable to retrieve a non-uniform nodal grid is hence in order. Non-uniform adaptive nodal grids lead to the highest reduction of side-lobes while preserving a good enough representativity of the retrieved geophysical signal.

Our results show a promising way to diminish the impact of side-lobes on SMOS images, but they are just a starting point. Future work include the design of appropriate metrics for evaluating the final quality of a given adaptive algorithm, to use those metrics to optimize the algorithm and to include the effect of new fusion schemes to enhance even further the retrieved brightness temperatures.

Continuing Challenges in Salinity Retrieval for the SMOS Mission

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The European Space Agency's Soil Moisture and Ocean Salinity (SMOS) mission has provided nearly continuous global record of fully polarimetric brightness temperatures at L-band (1.4135 GHz) since November 2009. The single payload of the SMOS satellite, MIRAS, is a two-dimensional aperture synthesis radiometer that measures the cross-correlations between the signals from many L-band antennas distributed in a Y-shape array. These cross-correlations are transformed by ground processing into brightness temperature images that extend over a swath several hundred kilometers across. Over the ocean, these brightness temperature images are used, together with a forward model of the L-band scene brightness, to derive maps of surface salinity over the global oceans, with full earth coverage approximately every five days.

Over the global oceans the surface salinity varies between about 32 and 38 on the practical salinity scale, with the strongest variations in the vicinity of river outflows and heavy rainfall. The sensitivity of the brightness temperature at L-band to a change in salinity depends somewhat upon polarization and sea surface temperature but, in tropical latitudes, is about +1 K in the first Stokes parameter per unit decrease of salinity on the pratical salinity scale. Thus, the dynamic range of L-band brightness temperatures over the open ocean is only several kelvin. As one goal of the mission is to produce global maps of salinity with an accuracy of 0.1 after averaging over 10-30 days, strict requirements must be placed upon the accuracy and stability of the brightness temperatures. Efforts to reach this goal continue, but challenges related to interannual, seasonal, and orbital stability of the retrieved salinity remain. These challenges stem from difficulties in the instrument calibration, image reconstruction, and modeling of the scene brightness over the ocean. On the one hand, the instrument calibration and image reconstruction are plagued by the sun which impacts the accuracy of the brightness temperatures indirectly, through variations in the thermal characteristics of the instrument, and directly, through its impact on the visibilities. On the other hand, the scene modeling is plagued by emission from the rough ocean surface, emission from foam, and galactic radiation scattered towards the instrument by the wind-roughened ocean surface. Moreover, the sun-synchronous orbit of the SMOS satellite is such that both the solar (direct and indirect) and galactic impacts exhibit orbital and seasonal cycles that, if not properly accounted for, will contribute to bias in the salinity.

A key factor complicating progress is the fact that the aforementioned problems can produce similar bias evolutions, and so disentangling the various sources of bias is difficult. Using open-ocean model solutions for the brightness temperature images as well as the antenna temperatures (which provide the mean brightness temperature level for the images), this paper will examine the spatial and temporal structures observed in the biases over the nearly four years of continuous data. An attempt will be made to exploit the recent oscillatory character of the sun L-band brightness in order to separate the impacts of the sun and scattered galactic radiation. In parallel, improvements in the modeling of the scattering of galactic radiation will be presented, and a comparison will be made with the impact on the brightness temperatures and salinity maps from the Aquarius mission.

Finally, recognizing that adequate calibration and forward scene modeling may not be achieved in the near future, the paper will examine practical alternatives to bias correction, with an emphasis on finding an approach that minimizes impact on the range of applications of the SMOS salinity maps.

Towards an Improved Characterization of Instrumental Biases and Forward Model Errors in SMOS Observations over the Ocean

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The Soil Moisture and Ocean Salinity (SMOS) satellite was launched on November 2, 2009 in the framework of the European Space Agency's (ESA's) Earth Explorer opportunity missions. Over the oceans, Sea Surface Salinity (SSS) is retrieved on a global basis with a spatio-temporal sampling appropriate for Ocean dynamics and Earth water cycle studies (Font 2010). The single payload onboard SMOS is the Microwave Imaging Radiometer using Aperture Synthesis (MIRAS), a novel fully-polarimetric L-band radiometer which estimates the brightness temperature by means of two-dimensional aperture synthesis interferometry. It consists of a Y-shaped set of 72 receivers (McMullan, 2008). More than 3 years after launch, the salinity product accuracy has still not reached the mission objective, even in the RFI-free open ocean domain. Main reasons are: 1) the challenging but intrinsically low sensitivity of L-band brightness temperature to sea surface, 2) the imperfection of the forward model used in the inversion procedure, 3) the spatio-temporal biases still present in the reconstructed brightness temperature. The present work is a contribution to adressing above-mentioned points 2 and 3.

Several forward model deficiencies have been identified which propagate down to the retrieved salinity. If different studies have recently pointed out roughness dependent SSS errors and proposed updated formulations for the increment of emissivity due to surface roughness (Guimbard et al., 2012; Yin et al., 2012), the agreement in their results suggests that a robust improvement has been achieved. Nevertheless, another critical component of the forward model is the celestial signal scattered by the rough sea surface (Tenerelli 2008). The complexity of the biscattering problem and the large number of parameters involved makes highly difficult the procedure to improve its description empirically from real data. In spite of this, a recent work by J.Tenerelli has produced very promising results. The amplitude of the modeled signal near the specular direction is improved and better mimics the changes due to surface roughness variations. Nevertheless, there is still some discrepancy between parameters obtained when using different datasets, especially when using ascending or descending passes, and between different geometrical observation conditions i.e. incidence angle. Such inconsistency in the model parameters suggest an imperfection of the model physics.

As mentioned in the introduction, latitudinal and seasonal biases are also affecting SMOS reconstructed TB ocean images (Tenerelli et al. 2010, Oliva et al. 2012) and retrieved salinity fields (Reul et al. 2012). Results suggest a correlation of the error with the sun illumination of the instrument through thermal effects, but attempts to cancel the corresponding biases at the calibration level are still not conclusive. In this work, it is assumed that such biases are essentially uniform across the field of view.

A key point in this discussion is that celestial reflection model errors and thermal instrumental biases both vary at latitudinal and seasonal scales. In the current approach, forward model updates are contaminated by the imperfect instrumental biases estimates and vice versa. The present work is an attempt to uncouple these two important steps. First, for a specific data subset where the celestial reflection signal is expected to be time-invariant, the temporal biases are estimated, an empirical correction applicable to the brightness temperatures is derived and a corrected data subset obtained. Second, the corrected dataset is used to obtain celestial reflection residuals. Their inconsistency with the current galactic model, primarily in terms of incidence angle dependence is analyzed to derive a modification of the model. Finally, after evaluating its performance, the updated model is evaluated for a much larger dataset and the instrumental biases are now evaluated both at the temporal and orbital scales.

For a given latitudinal band, i.e. orbital position, and a limited set of locations in the FOV, a specific geometrical configuration is identified for which the celestial contamination does not significantly vary along the year. A data selection strategy developed for the antenna frame systematic errors study (Gourrion et al., 2012) is refined to characterize the instrumental temporal biases in that particular latitudinal range. Assuming that the thermally-induced instrumental biases are homogenous across the FOV, celestial reflection residuals are derived from a wide range of FOV locations but the same orbital location. Their analysis points out an imperfection in the shape of the bistatic scattering coefficients used in the computation of the celestial signal as scattered by the rough sea surface. Both theoretically-based and empirical ad-hoc modifications are tested to propose a modification of the bistatic scattering function.

J. Font, A. Camps, A. Borges, M. Martyn-Neira, J. Boutin, N. Reul, Y. Kerr, A. Hahne, and S. Mecklenburg, "SMOS: The Challenging Sea Surface Salinity Measurement From Space," Proceedings of the IEEE, vol. 98, pp. 649-665, May 2010.

K. McMullan, M. Brown, M. Martyn-Neira, W. Rits, S. Ekholm, J. Marti, and J. Lemanczyk, "SMOS: The payload," IEEE Trans. Geosci. Remote Sens., vol. 46, no. 3, pp. 594-605, 2008.

Guimbard, S.; Gourrion, J.; Portabella, M.; Turiel, A.; Gabarró, C. & Font, J., "SMOS semi-empirical ocean forward model adjustment", IEEE Trans. Geosci. Rem. Sens., vol. 50, pp. 1676-1687, 2012.

Yin X., Boutin J., Martin N., Spurgeon P., "Optimization of L-Band Sea Surface Emissivity Models Deduced From SMOS Data", IEEE Trans. Geosci. Rem. Sens., vol. 50, pp. 1414 -1426, 2012.
Tenerelli, J., N. Reul, "SMOS Brightness Temperatures over the Global Oceans: Contaminating Effects and Salinity Retrieval", In Proceedings ESA Living Planet Symposium, 28 June-2 July 2010, Bergen, Norway, ESA SP-686.

Oliva R., M. Martin-Neira, I. Corbella, F. Torres, J. Kainulainen, J. Tenerelli, F. Cabot, and F. Martin-Porqueras, "SMOS calibration and instrument performance after one year in orbit," IEEE Trans. Geosci. Remote Sens., 2012.

N. Reul, J. Tenerelli, J. Boutin, B. Chapron, F. Paul, E. Brion, F. Gaillard, and O. Archer, "Overview of the first SMOS Sea Surface Salinity products. part i: quality assessment for the sec- ond half of 2010," IEEE Trans. Geosci. Remote Sens., vol. 50, pp. 1636-1647, May 2012.

Gourrion J., S. Guimbard, M. Portabella, R. Sabia, "Towards an optimal estimation of the SMOS antenna-frame systematic errors", submitted to IEEE Trans. Geosci. Remote Sensing, July 2012.

Aquarius' CAP Ocean Surface Salinity and Wind Products and Their Applications to Water Cycle Research

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Aquarius is a combined passive/active L-band microwave instrument developed to map the sea surface salinity (SSS) field from space. This paper describes Aquarius' version-2.0 (V2.0) Combined Active-Passive (CAP) retrieval algorithm for simultaneous retrieval of surface salinity and wind. The CAP V2.0 product is available through the JPL Physical Oceanography Distributed Active Archive Center.

The CAP V2.0 algorithm includes updates to the geophysical model functions (GMF) and water dielectric constant to remove systematic salinity retrieval bias with respect to significant wave height (SWH) and sea surface temperature (SST). We use more than one year of Aquarius and NOAA WaveWatch3, SSMI/S, and NCEP wind matchup data to explicitly parameterize the L-band backscatter and excess surface emissivity as a function of wind speed, wind direction and SWH. The empirical GMF is found not only effective in removing the systematic bias, but also in reducing the Root-Mean-Square-Error (RMSE) of SSS retrieval.

The other key update is the water dielectric constant model. We find that at low SST the retrieval using the Klein and Swift model will produce a small positive bias, while the use of Meissner and Wentz model will result in a small negative bias. We use a linear combination of these two water dielectric constant models for retrieval. Both systematic bias and RMSE of retrieved SSS are reduced with respect to SST and wind speed.

The previous cost function for the CAP algorithm uses the Aquarius data only. However we find that the wind speed is less accurate at crosswind direction due to the reduced sensitivity of L-band backscatter along that direction. A less accurate wind speed estimate in turn negatively impacts the salinity retrieval. We therefore include the NCEP wind as a priori by adding another term in the cost function to improve the retrieval at crosswind direction.

We assess the accuracy of CAP V2.0 wind by performing comparison with SSMI/S wind and triple collocation. The root-mean-square (RMS) difference with respect to the SSMI/S wind speed is about 1 m/s. The triple collocation using the SSMI/S, CAP and ECMWF winds indicates that the accuracy of CAP wind speed is about 0.7 m/s, essentially the same as that of SSMI/S wind speed and less than the 0.85 m/s error for the ECMWF

We estimate the accuracy of CAP's monthly average salinity by comparison with HYCOM's model salinity. We compute the mean and standard deviation of the differences between CAP and HYCOM salinities on 1x1 degree latitude and longitude grid. We find that the standard deviation is in the range of 0.1 to 0.2 psu for many bins globally, but could be larger than 0.3 psu at high latitude and in the tropics. The average of RMSD is computed for every 10 degrees latitude bands, and is found to be in the range of 0.2 to 0.25 psu between +/- 40 degree latitudes. If the HYCOM error is 0.17 psu, the corresponding Aquarius CAP's error will be between 0.1 and 0.2 psu.

We finally demonstrate the application of Aquarius data to water cycle research by examining the time series of salinity in the Bay of Bengal and Aquarius soil moisture, GRACE mass and river discharge observations in the Indian subcontinent. We find the expected time delay of about 1 to 2 months between the changes of water mass on land and salinity in the Bay of Bengal.

Sea Water Permittivity Model and Differences in Sea Surface Salinity Retrieved from SMOS and Aquarius

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The ESA Soil Moisture and Ocean Salinity (SMOS) mission and the NASA Aquarius instrument share the common scientific objective of mapping the global Sea Surface Salinity (SSS). To that end, they both use radiometers at L-band to measure microwave emission from the sea surface. The principle for the measure of SSS by means of L-band radiometry relies on the change of sea water permittivity with the salt content. Yet, our knowledge on the influence of salt and temperature on sea water permittivity is still imperfect, and it is a potential source of error in the retrieval of SSS. The permittivity models used for L-band radiometry [e.g. Klein and Swift, 1977; Meissner and Wentz, 2004] exhibit differences of less than a percent. Yet, this leads to differences of the order of a few tenths of a Kelvin in brightness temperature (Tb), depending on the temperature and salinity of sea water, and the sensor's incidence angle. The difference in retrieved salinity between these models should be a few tenths of practical salinity unit (psu) most of the time, but it will vary regionally and seasonally according to changes in environmental conditions.

Differences between SSS retrieved by SMOS and Aquarius are mostly between -1 psu and +1 psu, with a significant regional and latitudinal dependence. Part of this difference is expected to be due to the different sea water permittivity models used for the two missions. Aquarius uses a slightly modified version of the model by [Meissner and Wentz, 2004] while SMOS uses the [Klein and Swift, 1977] model. Both models differ in their dependence on salinity and temperature, leading to differences in Tb between +/- 0.3K that will exhibit regional and seasonal patterns. The permittivity model is used at two stages during the salinity retrieval: 1/ to calibrate the instruments by comparing radiometric measurements to simulation using a forward model, and 2/ at the final stage of the retrieval, to compute SSS from retrieved surface Tb. For Aquarius, the calibration involves correcting the measured antenna temperatures (Ta) for a constant bias of the order of a few Kelvin, and for a temporal drift that is composed of an exponential decrease of the order of 1K over 6 months and of 0.2K oscillations with monthly time-scales. In order to assess how much of a contribution the difference in permittivity model has on the SSS difference between SMOS and Aquarius, we reprocess the Aquarius data using the [Klein and Swift, 1977] permittivity model, adjusting the calibration of the Ta's and performing the inversion with the new model.

We will present global maps of the difference between the original Aquarius data and the reprocessed Aquarius data using the same permittivity model as the one used for SMOS. The difference varies at global scale mostly within 0.5 psu, with a few localized larger variations. Significant seasonal variation occurs, particularly at mid and high latitudes. These SSS differences due to permittivity model will be compared to the SSS differences observed between SMOS and Aquarius in order to determine the impact of the permittivity model on the SSS inconsistency between the two instruments. We will focus on a few areas of interest to compare the performances of the permittivity models in reproducing in situ measurements.

References

Klein, L. A., and Swift, C. T., 1977, *An improved model for the dielectric constant of sea water at microwave frequencies.* IEEE Transactions on Antennas and Propagation, AP-25, 104–111.
Meissner, T. and Wentz, F. J., 2004, *The Complex Dielectric Constant of Pure and Sea Water from Microwave Satellite Observations.* IEEE TGARS 42(9): 1836-1849.

Recent Developments in the Aquarius Level 2 Salinity Retrieval Algorithm

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The Aquarius L-band radiometer/scatterometer system is designed to provide monthly salinity maps at 150 km spatial scale to an accuracy of 0.2 psu. The sensor was launched on June 10, 2011, aboard the Argentine CONAE SAC-D spacecraft. The L-band radiometers and the scatterometer have been taking science data observations since August 25, 2011.

Our presentation describes recent developments in the Aquarius Level 2 salinity retrieval algorithm, which is run in the Aquarius Data Processing System ADPS at Goddard Space Flight Center. We discuss the most important advances in the algorithm that have occurred since the currently released ADPS version 2.0.

Specific topics are:
1. Correction for effects of the wind roughened ocean surface.
2. Correction for intruding celestial radiation, foremost from the galaxy.
3. Use of the SAC-D K/Ka-band microwave radiometer MWR for correcting atmospheric liquid water absorption and rain flagging.

The most important improvement in the performance of the salinity retrieval is due to an update in the surface roughness correction (item 1). This effect turns out to be a major driver in the salinity retrieval error budget. The surface roughness correction that is used in the current version 2.0 ADPS data product is based on auxiliary input of wind speed and direction fields from NCEP and VV-pol backscatter measurements form the Aquarius L-band scatterometer.

The accuracy of the surface roughness correction improves significantly if one use an Aquarius retrieved wind speed instead of the NCEP fields. This Aquarius wind speed is derived from a combination of HH-pol scatterometer and H-pol radiometer observations and assimilates the NCEP wind speed as background field. We have validated this Aquarius wind speed and shown that its accuracy is about 0.7 m/s, which matches the accuracy of other satellite derived wind speed products, e.g. from SSM/I or WindSat. It is a major improvement compared to the NCEP wind speed, whose accuracy is only about 1.2 m/s. This increased accuracy of the surface wind speed, which is the crucial input to the surface roughness correction algorithm, leads in turn to more accurate salinity values. Further smaller improvements in the performance of the surface roughness correction can be achieved by including significant wave height data from the NOAA Wave Watch 3 Model as auxiliary input. The RMS between the Aquarius salinity and the HYCOM reference salinity field drops from about 0.55 psu in the current version 2.0 to about 0.41 psu in the new version.

The Aquarius salinity data exhibit biases between the ascending and descending swaths during certain times and in certain locations. The main cause for these biases is the intrusion of reflected galactic radiation (item 2). The algorithm that is employed in the current version 2.0 data release leads to an overcorrection at low wind speeds and an undercorrection at high wind speeds. The situation improves significantly in the new algorithm with the use of an Aquarius derived wind speed instead of the NCEP wind speed in the correction for the reflected galactic radiation. Nevertheless, residual errors in the correction for the reflected galactic radiation and accordingly some of the ascending – descending biases remain also in the new L2 algorithm. We will analyze the reasons and discuss possible mitigations.

The MWR, on-board SAC-D, provides spatially and timely collocated observations with Aquarius at 23.8 GHz and 36.5 GHz after appropriate resampling (item 3). These observations can be used to calculate the atmospheric absorption due to cloud liquid water at L-band, which needs to be removed in the Level 2 retrieval algorithm. They also provide a method to flag the Aquarius observations for rain. The availability and use of the real-time MWR data lead to a small additional improvement of the Aquarius salinities over the current version 2.0 data, which utilize NCEP cloud water profiles as auxiliary input for this purpose. Our talk gives an overview over the MWR cloud liquid water retrieval algorithm and its application in the Aquarius L2 processing.

The last part of our presentation contains a validation study for the new salinity product, which consists in a 3-way intercomparison between Aquarius, SMOS and in-situ salinity measurements from moored RAMA, TRITON, TAO, and PIRATA buoys. The Aquarius – moored buoy comparison shows that that the new Aquarius salinity meets the aforementioned mission requirement of 0.2 psu. By comparing SMOS and Aquarius salinity fields we assess the importance of the roughness correction and the presence of the L-band scatterometer for reaching this level of accuracy, which is a major difference between the SMOS and Aquarius missions.

Evolution and Application of the SMOS Level 2 Ocean Salinity Ocean Target Transformation

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Soon after launch it became clear there was a consistent and drifting mismatch between SMOS reconstructed L band sea surface temperatures (TBs) and Level 2 processor forward models, due to temporal changes in the instrument and Level 1 performance. To mitigate this the Level 2 OS team decided to apply a snapshot correction (Ocean Target Transformation, OTT)) to Level 1 TBs, generated periodically by smoothing the difference between forward model and Level 1 TBs over a region in the South Pacific ocean where salinity is relatively stable and SMOS measurements are reasonably free from contamination from external sources such as RFI and land.

With over 3 years of continuous data, the temporal and spatial evolution of OTTs will be shown, revealing periodic and long term drift variations driven by external sources (thermal, solar and galactic radiation), and spatial bias patterns due to reconstruction issues. OTTs therefore provide both a diagnostic for Level 1, and a correction for Level 2 in order to successfully retrieve salinity. Analysis and evolution of algorithms for accurate computation and application of OTTs will be presented, together with proposals for more effective correction of real-time ground processing and reprocessing.

Session 3: Product validation & stratification

The Effect of Environmental Forcing on the Stability of Near Surface Salinity Gradients in the Ocean

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Salinity gradients in the top few meters of the ocean surface can exist due to precipitation or evaporation. If present, they will complicate comparing salinity measured by ARGO drifters at typical depths of five meters to salinities retrieved using L-band microwave radiometers such as SMOS and Aquarius, whose measurement depths are on order of 0.01 m. Therefore, understanding the spatial scales and temporal persistence of these gradients and the conditions under which they form will be important in understanding sea surface salinity maps provided by SMOS and Aquarius. Salinity gradients in the top two meters were also measured using a towed profiler that was capable of resolving gradients on the same vertical scale as the radiometric measurement depth. Measurements of near surface salinity profiles using a towed profiler were made in December, 2011 aboard the R/V Kilo Moana and in 2012 during STRASSE have shown that both positive (i.e., salinity decreasing with increasing depth) and negative (i.e., salinity increasing with depth) gradients can form at the ocean surface. The data are used to understand how environmental forcing leads to the formation and collapse of these gradients. From this it is possible to estimate the likelihood that gradients with large enough change in salinity and of sufficient spatial scale and lifetime to affect microwave radiometric measurements of salinity will form at the ocean surface. Initial results show that precipitation produces gradients in near-surface salinity with horizontal spatial scales comparable to the footprint of Aquarius and that the magnitude of these gradients can be significant in terms of the overall accuracy of the satellite.

Comparison of Aquarius Sea Surface Salinity with Argo near-Surface Salinity

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We compared Aquarius level-2 V1.3.9 sea surface salinities (SSS) with near-surface salinities from Argo floats for a period of 15 months. For this period, near-surface salinites were collected from all delayed-mode Argo profiles worldwide. Approximately 11,000 profiles occurred within the Aquarius footprint within ±24 hours of acquisition. After filtering for various contaminations, approximately 8700 data pairs remained for direct comparison. Results and conclusions from these comparisons will be presented.

Upper Ocean Profiles of Surface Salinity from the Air-Sea Interaction Profiler

Ward, Brian; Sutherland, G.; ten Doeschate, A.; Reverdin, G.; Font, J.

Measurements of upper ocean in-situ salinity were conducted during the STRASSE and MIDAS campaigns, which are contributions to the SPURS salinity experiment. Both of these cruises were conducted in the Sub-Tropical North Atlantic in a strong evaporative region. We deployed the Air-Sea Interaction Profiler (ASIP) which has the capability to acquire data from below the mixed layer to the air-sea interface. Here we present an overview of the results from these field experiments in the context of sea surface salinity.

Upper Ocean Stratification from Drifters for SMOS / Aquarius Cal-Val

Reverdin, Gilles[1]; Reverdin, G[2]; Boutin, J[2]; Martin, N[2]; Kolodziejczyk, N[2]; Gaillard, F[3]; Rolland, J[4]; Blouch, P[4]
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Since 2005, we have deployed SVP-BS drifters and attached floats to measure ocean temperature and salinity at different depths within the top 60 cm layer in order to provide information for calibrating and validating new L-band radiometer satellite data. Temperature and haline stratification have been investigated from these data both during large daily cycles and also during rain events.

We have collected in 2009-2012 more than 15 years of multi-parameter drifter data that have been validated and that are used to qualify the near-surface stratifications. Close to half these data are in the wet tropics. We find that isolated rainfall event in the tropics can be followed for a few hours by the drifters and that they correspond usually both to temperature and haline stratification in the top 50 cm for at least one hour following the event (between 15 and 50 cm, the difference in salinity averages 20% of the total salinity drop, and in temperature 0.22°C for a 1 psu salinity drop). We confirm from colocated SSMI wind data that stratification and recovery are dependent on wind intensity during and after rainfall, and of course tend to be proportional to the total rainfall rate. However, we are limited in that the wind and rainfal estimates are no simultaneous to the freshwater events.

The multi-sensor drifters also provide information on the temperature stratification in the upper 60 cm top layer that happens for the large daily cycles (typically, for 4% of the days in the tropics and subtropics). For these daily cycles larger than 1°C near the surface, we find that there is a tendency for a delayed cycle at 50 cm or deeper, with a vertical gradient in the mid-day to early afternoon that tends to be nearly homogeneous in this layer, and a strong reduction afterwards near the surface, as the mixing penetrates deeper. For the very large daily cycles, the straitification on the other hand is not linear through this layer. We have also indication that these are associated with a daily cycles in surface salinity with a late afternoon maximum, that even for some relatively small/intermediate daily cycles in T (0.5°C) can reach 0.01 psu. What we used did not allow to estimate the salinity daily cycles for large near-surface vertical gradients.

We recently developed a new small wave rider Surpact that can both measure T and S close to the surface (at 4-5 cm) and short wave spectra. From the spectra, we estimate a wind in the previous hour. This is validated during deployments in the Spurs/Strasse cruise in August/September 2012. One Surpact prototype was then deployed which experiences five rain events. The data are promising and for these cases in the autumn 2012 subtropical North Atlantic there is no significant wind increase during the rainfall events.

SMOS and In Situ Salinity: Rain and Near-Surface Vertical Stratification Effects

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The ESA/SMOS (European Space Agency/Soil Moisture and Ocean Salinity) satellite mission provides new measurements of the Sea Surface Salinity (SSS) using L-band interferometric radiometry since end of 2009. It is the first time that this technology is used for measuring SSS from space, providing global ocean coverage every 3 to 5 days and a spatial resolution of up to 40km.

We first assess the accuracy of the SMOS SSS reprocessed by ESA (version 5) with respect to in situ measurements, and then discuss observed differences, with a focus on rainy conditions in tropical oceans.

Between 45°N and 45°S, SMOS SSS is in relatively good agreement with SSS derived from traditional in situ measurements (rms error between SMOS SSS averaged over 10 days and 100x100km2 and ARGO SSS on the order of 0.5). In tropical and subtropical regions, the rms error is on the order of 0.3 but we evidence that monthly SMOS SSS are systematically fresher by about 0.1 than ARGO SSS in the tropical Pacific Intertropical Convergence Zone. At large scale, in the tropical oceans, SSS anomalies between 2010 and 2011 detected by SMOS are in good agreement with the ones derived from in situ measurements using an optimal interpolation (the LPO/IFREMER In Situ optimal Analysis System version 6 (ISAS)). Nevertheless, fresh anomalies linked to rain anomalies are often fresher on SMOS SSS than on ISAS SSS maps.

This apparent SMOS rain-freshening effect may originate from various effects: salinity stratification between 1cm and 5m depth (an important feature for air-sea interactions studies), rayleigh scattering by rain dropplets in the atmosphere, changes of sea surface roughness during rainfall. The atmospheric effect is expected to be much smaller than the observed effect. Although the roughness effect remains badly known, in situ measurements recently performed at ~45cm depth support strong stratification between the sea surface and 5m depth (Reverdin et al. 2012) and large sudden decrease of SSS in rainy regions. In this presentation, we will discuss the stratification effect hypothesis in view of the salinity variability recently sampled in situ in the upper 50cm of the sea surface by surface autonomous drifters.

References:

J. Boutin, N. Martin, G. Reverdin, X. Yin and F. Gaillard, Sea surface freshening inferred from SMOS and ARGO salinity: Impact of rain, Ocean Science, 2013, in press (Ocean Sci. Discuss., 9, 3331-3357, doi:10.5194/osd-9-3331-2012, 2012).

Reverdin, G., S. Morrisset, J. Boutin, and N. Martin, Rain-induced variability of near sea-surface T and S from drifter data" Journal of Geophysical Research - Oceans, VOL. 117, C02032, doi:10.1029/2011JC007549, 2012.

Upper Ocean Salinity Stratification : Challenges to Validate Satellite Remotely Sensed Sea Surface Salinity

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Validating satellite remote sensing data against in situ measurements is always a complex task. For the Aquarius and SMOS salinity satellites, one additional challenge arises due to the fact that the salinity value retrieved from the satellite observations represents salinity at a "skin" depth no more than a few centimeters below the sea surface, while the validation data sets are usually collected at the "bulk" depth of several meters below the sea surface. The "skin-bulk" salinity difference can be as large as 0.2 psu, comparable to the accuracy requirement established by the Aquarius satellite mission.

Salinity Processes in the Upper Ocean Regional Study (SPURS) research effort is actively addressing essential role of the ocean in the global water cycle. A series of cruises is exploring the salinity maximum region in the Atlantic Ocean using a plethora of oceanographic equipment and technology, including salinity-sensing satellites. Researchers are studying salinity changes that span thousands of miles simultaneously with those happening in one centimeter of water. SPURS is also providing much-needed data for computer models to improve our basic understanding of the water cycle over the oceans and its ties to climate.

To quantify the "skin-bulk" difference of salinity, this talk will analyze the upper ocean salinity stratification using in situ measurements collected from the SPURS (Salinity Processes in the Upper Ocean Regional Study) field experiment during September-October 2012. A variety of in situ platforms were deployed during the 33-day cruise. The wave glider measures salinity at 0.2 m. Surface drifting buoys (i.e., drifters) measure salinity at 0.6 m below the sea surface. While conventional profiling floats stop measuring salinity at about 5 m, the newly developed STS (Surface Temperature/Salinity) floats can measure salinity all the way to the skin layer close to the surface. Results describing the upper ocean salinity stratification from these in situ data and their comparisons with the Aquarius data will be presented.

Aquarius V2.0 Data Accuracy Assessment and Residual Errors

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The Aquarius project released V2.0 data in February 2013. This was the first release to have an accompanying validation analysis based on in situ data, along with other supporting documents, whereas previous versions V1.X were for "evaluation" only. For SST>5C and wind speed < 15m/s, the Aquarius V2.0 data is shown to have a global rms error of ~0.30 psu on 150 km and monthly averages, and ~0.27 psu for seasonal (3-month) averages. The previous publically released data version (V1.3) had corresponding estimated rms errors of 0.44 and 0.38 psu respectively. The important changes between the two versions include a 0.5 degree pointing angle offset (which affected both geo-location and a number of geophysical models), new antenna gain pattern, and a radiometer calibration correction that applies a secular exponentially decaying gain correction and non-monotonic quasi-monthly offset corrections (aka "wiggles"). It is evident from differences between ascending and descending passes that there are remaining errors with a distinct annual cycle, likely due to the roughness-adjusted galactic reflection coefficient, and regional static errors due to low-level RFI. This presentation will review the current understanding of the V2.0 data and a number of these issues, as well as plans for the next data version, and includes input from several members of the Aquarius team.

Evaluation of Sea Surface Salinity observed by Aquarius and SMOS

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Sea surface salinity (SSS) derived from the Aquarius and SMOS missions were validated using in-situ salinity data focusing on physical process around the sea surface. The Aquarius and SMOS SSSs were collocated with in-situ observations from Argo floats and offshore moored buoys and outputs from ocean optimal interpolation (OI) system and operational ocean assimilation system. In this abstract, results from the comparisons with observations by Argo floats and outputs from the OI system are reported. The Aquarius SSS Levels 2 and 3 data product version 1.3.7 released by the NASA PO.DAAC at JPL and the SMOS SSS Level 3 data product version 300 released by the SMOS Barcelona Expert Centre were analyzed. For the Level 2 SSS, salinity profiles of Argo floats released by the Global Assembly Data Center (shallower than 12.5 dbar) were used for a period from August 25 2011 to November 30 2012. Spatial and temporal separations were limited less than 200 km and 24 hours, respectively. For the Level 3 SSS, monthly gridded salinity field released by Japan Agency for Marine-Earth Science and Technology (JAMSTEC) were used for the same period. This gridded SSS data are constructed by an optimal interpolation method using salinity profiles of Argo floats and hydrographic reports with resolutions of 1° x 1° and 1 month. The salinity data in the shallowest level (10 dbar) were used to compare with the Level 3 SSS. The Aquarius Level 2 SSS generally agreed well with the Argo salinity in the low and mid latitude. The standard deviation of SSS residual was 0.54 psu at 45°S - 45°N. To the contrary, the Aquarius Level 2 SSS was highly deviated in the high latitude with a value of the standard deviation of 0.96 psu at 60°S - 45°S. Since the SSS estimation is based on the intensity of radiation emitted from the sea surface, it is expected that the SSS estimation depends on oceanic conditions on the sea surface such as sea surface temperature (SST), wind speed and wind direction. Large deviations of the SSS residual under low SST condition were detected, as expected from the low sensitivity of the brightness temperature to salinity at low SST. In addition, the SSS residual showed large values under high wind speed condition because the roughness correction did not work well under severe weather conditions. Dependence of the SSS residual on the azimuth angle between the wind direction and the sensor looking direction was not significant. The standard deviation of the SSS was expressed as a function of the SST and wind speed. The deviation was large (>1.0 psu) under low SST and high wind speed conditions (<5 °C and >15 m/s), while it was considerably smaller (<0.5 psu) under high SST and low wind speed conditions (>20 °C and <5 m/s). These results correspond to the large deviation in the high latitude.

In the analysis of Level 3 data, spatial patterns of Aquarius and SMOS SSSs agreed well with those of the outputs from JAMSTEC OI system. Spatial patterns of the SSS residual (satellite SSS minus OI SSS) for Aquarius were also qualitatively consistent with those for SMOS. Bias and standard deviation of the SSS residual at 45°S - 45°N for Aquarius V1.3.7 were -0.04 psu and 0.35 psu, respectively, which were smaller

than those of the SMOS SSS (-0.23 psu in bias and 0.64 psu in standard deviation). Temporal variations in the bias with a period of several months and amplitude more than 0.1 psu were found in the SMOS SSS and Aquarius V1.3, while those were significantly reduced in the Aquarius V1.3.7. Negative bias (Aquarius SSS < OI SSS) was found in the tropical oceans through a year and along western boundary currents in the North Hemisphere in wintertime. The former correlated with distribution of precipitation in the Intertropical Convergence Zones and is considered to be due to the salinity stratification beneath the sea surface. However, the latter did not show any correlation with distributions of precipitation or evaporation.

Validation of SMOS and Aquarius Salinity Data in the Agulhas Region

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Western boundary currents are important to study because they influence regional climates and may impact climate change. The Agulhas Current, in particular, is vital to transport of heat and salt from the Indian Ocean to the Atlantic, especially through Agulhas rings. In order to better understand and assess the role of these rings in the global climate system, accurate measurements of the salinity within the current must be made. This study validates data within the Agulhas region from the recently launched NASA Aquarius/SAC-D salinity mission and ESA's Soil Moisture and Ocean Salinity (SMOS) mission. Argo float data and HYbrid Coordinate Ocean Model (HYCOM) estimates serve as the best in situ and model comparisons to the satellite data respectively. There are approximately 100 Argo floats in the Agulhas Return Current that contribute to the monthly average. The in situ data is important because of its accuracy; however, it lacks in being able to provide spatial and temporal salinity measurements of the entire current. Also, these measurements stop 5-m below surface. The satellite data are able to provide the coverage that Argo data cannot. It is crucial that the satellite data is as accurate as possible within the Agulhas Current for use in for future studies. The data sources were compared by focusing on five regions, both inside and outside of the current. The regions inside the current were compared to the areas of high and low salinity outside of the current. Results show that Aquarius salinity measurements tend to be higher when compared to SMOS measurements as well as both observed (Argo) and modeled values. Through the analysis of the salinity measurements within these regions, this study determined the accuracy of salinity measurements within the Agulhas region from the NASA Aquarius/SAC-D salinity mission and ESA's SMOS mission.

Validation of Aquarius and SMOS Salinity Measurements in the Indian Ocean

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The non-availability of global-scale salinity observations has been a challenge in many studies that require salinity data. The Aquarius salinity mission is currently providing complete global coverage of sea surface salinity (SSS) measurements with a temporal resolution of 7 days. In this study, we assess the validity of preliminary Aquarius salinity measurements in the Indian Ocean by comparing it to the Soil Moisture and Ocean Salinity (SMOS) mission SSS, Argo float SSS data and the 1/12<degree> high resolution HYbrid Coordinate Ocean Model (HYCOM) SSS output. Comparisons of Aquarius passes with HYCOM, SMOS, and Argo indicate Aquarius is performing better than the SMOS mission for daily measurements. However, contamination of SSS measurements still occurs at this resolution. Analysis of monthly Aquarius data with other SSS measurements indicates Aquarius is highly correlated with HYCOM and Argo in the open ocean and on average, the differences in SSS rarely exceed above 0.4 psu at this temporal resolution. Aquarius SSS is able to capture the salinity features and distribution in the Indian Ocean. Notably among these are the high SSS in the Arabian Sea, the low SSS in the Bay of Bengal and the low salinity tongue from the Indonesian Throughflow (ITF). Boxed-averaged comparison of salinity differences and root mean square error statistic suggested that the most differences between the salinity products occur in the Bay of Bengal, possible the consequence of high salinity variability, precipitation and river runoff in that region.

Estimates of Observational Errors Related to Small-Scale Horizontal and Vertical Variability in Salinity Fields

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One of the challenges in collocating and comparing satellite and in situ data is the mismatch in their spatial coverage and the depth of sampling. In this study, we quantify how much of a difference is expected between in situ and satellite measurements of sea-surface salinity (SSS) in the presence of small-scale horizontal variability and near-surface vertical stratification. For this purpose, we make use of a solution from a global, eddy-resolving ocean data assimilation system. Sampling errors related to small-scale horizontal variability and vertical SSS gradients are typically small (<0.02 psu), but can be significantly larger locally (>0.1 psu), particularly near river mouths, boundary currents, parts of the ITCZ and in the Bay of Bengal. In such regions, sampling errors related to unresolved horizontal and vertical variability largely exceed in situ instrument noise and become an important source of uncertainty when comparing in situ and satellite data. The values and spatial patterns of the derived errors are discussed in the context of the Aquarius/SMOS overall error budget and can be used as a lower bound on expected differences between satellite and local estimates of SSS.

Session 4: SMOS and Aquarius science application and synergies

Ocean Eddy Freshwater Flux

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Improved in situ and remote sensing observational tools, along with high resolution models, allow us to ask the question (which we have a chance to answer): What role does the ocean mesoscale play in compensating the air-sea flux of heat and freshwater? In situ ocean observations suggest that the answer might be 'substantial', at least in the salty subtropical regimes, where conventional wisdom looks to the Ekman transport driven shallow meridional overturn circulation for compensation of net evaporation. Within the salty North Atlantic subtropics regime the annual evaporation minus precipitation (E-P) is over 1 m/year. While E-P is always positive, greater in January-July, minimum in October, the SSS cycle is out-of-phase, with a maximum in October, minimum occurs in April. It is hypothesized that the lower SSS of the winter/spring period marks increased winter freshwater flux. Using the in situ database as assimilated in the SODA model, we find that the eddy field can accomplish ~50% of the required freshwater compensation. The combination of Aquarius ocean surface salinity with mesoscale sea level from satellite altimeter offers an opportunity for more of complete spatial/temporal evaluation of the role of the mesoscale in compensating for the regional subtropical E-P.

SMOS Reveals the Signature of Indian Ocean Dipole Events

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The Indian Ocean Dipole (IOD) is the dominant mode of interannual climate variability in the equatorial Indian Ocean. It consists of a basin-scale modification of the upper ocean thermal structure, associated with drastic changes in the rainfall patterns. During a positive IOD year, a pool of warm water forms in the western half of the basin in fall, and triggers convective rainfall there. Conversely, during a negative IOD year, warm waters build up at the eastern edge of the basin off Indonesia, along with the convective rains. This basin-scale coupled oscillation is irregular in time, with typical occurrence periods of a few years.

In fall 2010, a year after the launch of SMOS, a negative IOD event struck the Indian Ocean. A year later, in fall 2011, it was replaced by a positive IOD event. Our study investigates the signature of this oscillation in sea surface salinity (SSS), as revealed by SMOS level-3 products. Depending on the version of level-3 processing, the SSS difference between these contrasting years in the Indian Ocean may be the largest interannual signal captured by SMOS since its launch, consistently with available in situ observations. We then investigate the possible mechanisms responsible for the salinity anomalies, based on a suite of in situ and spaceborne observational datasets. Rainfall appears as the main driver of salinity anomalies. This opens up bright prospects for a routine spaceborne monitoring of SSS and related climate variability in the tropical oceans.

Aquarius Brings new Understanding to Tropical Instability Waves

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Sea surface salinity (SSS) measurements from Aquarius/SAC-D satellite provide the first satellite observations of the salinity structure of tropical instability waves (TIWs) in the Pacific and Atlantic Oceans. In the tropical Pacific, the associated SSS anomaly has a magnitude of approximately ±0.5 PSU. Different from sea surface temperature (SST) and sea surface height anomaly (SSHA) where TIW-related propagating signals are stronger a few degrees away from the equator, the SSS signature of TIWs is the strongest near the equator in the eastern equatorial Pacific. This is because the salty South Pacific water meets the fresher Inter-tropical Convergence Zone water near the equator to create a large meridional gradient of background SSS. In contrast, the meridional gradient of background SST is the largest at the edge of the cold tongue a few degrees away the equator (but is smaller near the equator because of the relatively uniform SST in the center of the cold tongue). The dominant westward propagation speed of SSS near the equator is approximately 1 m/s. This is twice as fast as the 0.5 m/s TIW speed widely reported in the literature in the past few decades, typically from SST and SSHA away from the equator. This difference is attributed to the more dominant 17-day TIWs near the equator that have a 1 m/s dominant phase speed and the stronger 33-day TIWs away from the equator that have a 0.5 m/s dominant phase speed. The difference of TIW speed at and off the equator has important implications to eddy-mean flow interaction. Moreover, the stronger SSS signature of TIWs at the equator suggests that salinity may play a more important role in energy conversion between eddies and mean flow there than temperature. The structure of TIWs in the tropical Atlantic observed by Aquarius will also be presented.

Initial Results on the Variability of Sea Surface Salinity from Aquarius/SAC-D in the Gulf of Mexico

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Using version 1.3 of the Aquarius dataset, the spatial distribution and seasonal variability of sea surface salinity (SSS) was examined in the Gulf of Mexico (GoM). Results are compared with chlorophyll a (chl-a) content from the NASA MODerate Resolution Imaging Spectroradiometer (MODIS) on board the Aqua spacecraft over the period August 2011 through July 2012. To determine possible relationships formation of the Loop Current (LC) and eddies comparisons will also be made with sea surface temperature (SST) data. Comparisons will be done using the Aquarius V2.0 and the Combined Active-Passive Algorithm (CAP). Initial results are descirbed below. Mean values for salinity range from approximately 35 PSU in the Eastern GoM to 36 PSU in the Western GoM. A band of significant negative correlation between SSS and chl-a is observed running southeast from the Central Gulf Coast to the Western Coast of South Florida. A significant negative correlation also occurs along parts of the Western GoM. Negative correlations indicate that low salinity water in the GoM is associated with maximum chl-a concentrations. The location of the minimum along the Gulf Coast to the west coast of Florida indicates that the freshwater source is likely associated with the Mississippi River and maybe transported by GoM dynamics (i.e., the Loop Current and eddies). Seasonal maps of SSS and chl-a will be shown to corroborate the probable source of freshwater in the GoM and dynamics responsible for the observed spatial distribution. Results are significant in showing the ability of Aquarius to detect SSS signals in semi-enclosed basins.

Salinity Variability Associated with Changes in the Hydrological Cycle Variables

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As the western boundary current in the South Atlantic subtropical gyre, the Brazil Current transports warm and salty water southward while the Malvinas Current carries colder and fresher water northward. The excursions of the Brazil Current over the southern limit of the gyre brings saltier water to that region that could undergo to intensive cooling and subsequent subduction due to loss of buoyancy. The heat exchanged between the atmosphere and the ocean is associated with the rate at which the water is subducted due to convective processes. Interannual to intra-decadal changes in the air-sea interaction variables have important impact on water subduction and thus on ocean circulation because of their effect on ocean stratification. The analysis of salinity profiles from Argo data, World Ocean Database and models (GODAS and ECCO) allows us to investigate the salinity variability in the ocean interior. Surface salinity from the Aquarius mission provides us information that connects the ocean signals with the hydrological cycle. Spatial and temporal variability of parameters measured from the microwave radiometer's data (TRMM and AMSR-E) are used to correlate the salinity trends with the hydrological cycle's variables at basin scale. Preliminary results indicate that the moisture fluxes (E-P) using satellite data show increasing (decreasing) trends right over the regions where the salinity increases (decreases).

NOAA In Situ and Satellite Blended Analysis of Sea Surface Salinity: Preliminary Results for 2010 - 2012

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A technique has been developed to produce analyses of sea surface salinity (SSS) over the global ocean through blending information from in situ measurements and satellite retrievals. Three data sets are employed as inputs to the blended analysis: in situ SSS measurements aggregated and quality controlled by NOAA's National Oceanographic Data Center (NODC); and passive microwave (PMW) retrievals from both the Aquarius/SAC-D and SMOS satellites, received and post-processed at NOAA's Center for Satellite Applications and Research (STAR). The in situ SSS measurements used here are mainly from the Argo program, but also include measurements from tropical moored buoys (TAO/TRITON, PIRATA, RAMA), CTDs, and gliders.

The blended analysis comprises two sequential steps. First, the biases in the satellite retrievals are removed through probability distribution function (PDF) matching against temporally / spatially co-located in situ measurements. The blended analysis is then achieved through optimal interpolation (OI), where the analysis for the previous time step is used as the first guess while the in situ measurements and the bias-corrected satellite retrievals are employed as the observations to update the first guess. Cross-validations are conducted by randomly removing in situ SSS measurements and validating the blended analysis against the withheld in situ data. Results show improved accuracy of the blended analysis, compared to the individual inputs, with reduction in bias and random errors over most of the global oceans. However, uncertainty of large magnitude in the blended analysis exists for high-latitude oceans and coastal regions where the in situ networks are sparse and current-generation satellite retrievals have limitations.

The blended monthly SSS analysis, called the NOAA "Blended Analysis of Sea Salinity" (BASS), is constructed for a three year period from 2010 through 2012. Our in situ satellite blended SSS analysis shows good agreements with the NODC in situ - based analysis over most of the tropical and sub-tropical oceans, with large differences observed for high-latitude oceans and along coasts. Combined empirical orthogonal function (EOF) analysis of the SSS from the BASS analysis, precipitation (P) from CMORPH and evaporation (E) from OAFlux reveals global patterns of the co-variability between the SSS and oceanic fresh water flux (E-P) in association with the evolution of the El Niño Southern Oscillation (ENSO).

Analyzing the Recent Signature of ENSO in the Tropical Pacific Ocean using In Situ, SMOS and Model Salinity Data

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The tropical Pacific Ocean has been in a La Nina phase from mid 2010 to early 2012. In this presentation, we will describe and analyze the well-marked signature of this ENSO phase, using a combination of in situ, SMOS- and model-derived sea surface salinity products. The in situ data include high-resolution voluntary observing ship TSG measurements and gridded SSS products. We use a newly derived SMOS product (based on ESA L2 v5.5). The model outputs are from a validated Drakkar eddy-permitting forced simulation in which all mixed-layer salinity budget terms are computed at each time-step. Comparisons of all near-surface salinity products will be presented first and discussed, focusing on SMOS ability to capture small-scale to basin wide features. The observed basin-scale La Nina SSS signal from SMOS will then be compared to historical La Nina events as represented by irregularly distributed in-situ data. It will be shown, in particular, that an unusual strong bi-polar anomaly has been captured by SMOS in the western Pacific. This anomaly will be described and discussed using all datasets and processes at work will be quantified with the model.

Ocean Surface Salinity Features as Observed by SMOS and Aquarius

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One year of coincident observations of ocean surface salinity by Argo, SMOS, and Aquarius are compared in their identifications of the temporal and spatial characteristics of major ocean features. In the Circumpolar Current, neither SMOS nor Argo shows any seasonal variation of surface salinity, but Aquarius shows a summer peak and a winter low. All three data sets agree well under the intertropical Convergence Zone (ITCZ) in central Pacific, with broad high in spring and low in autumn. All three data reveal two peaks under the ITCZ in the eastern Pacific, but SMOS has higher magnitudes. Aquarius data capture the outflows of major rivers. - Amazon, Ganges, Congo, and the Yangtze, but SMOS and Argo are limited by coverage and spatial resolution. At the northern end of Bay of Bengal, near the mouth of the Ganges River, SMOS data are mostly missing and too noisy to identify the summer high and the autumn low as Aquarius and Argo data. Argo data show much reduced range compared with Aquarius. In West Africa, all data sets show same annual cycle caused by outflow of the Congo, but Argo shows less range. An area of intense salinity deficit is revealed by both SMOS and Aquarius, north of the Amazon estuary, but not seen in Argo data. In this area, the salinity is higher in January to June, but drops sharply at the end of June. Only Aquarius data are available in the East China Sea to examine the outflow of the Yangtze River, with higher salinity (less discharge) in autumn. We did not acquire sufficient Argo data in the Gulf of Mexico to characterize the outflow of the Mississippi, and SMOS salinity is lower than Aquarius data in this area. We have also examined the complementarity between Aquarius and SMOS data in the characterization the major oceanographic processes.

Eastern Pacific Fresh Pool SSS Variability Observed by SMOS and Aquarius Sensors over the Period 2010-2012

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The seasonal and interannual variability of the Sea Surface Salinity (SSS) deduced from SMOS and Aquarius-SAC-D satellite missions are analyzed over the period 2010-2012 in the Far Eastern Pacific Fresh Pool. The lowest values of salinity in surface layers (≤33) in the tropical Pacific Ocean are found in this region of intense precipitation, associated with the northward migration of the Intertropical Convergence Zone (ITCZ) over Central America (Alory et al., 2012). During the boreal winter, as the ITCZ moves southward, the north-easterly Panama gap wind creates a south-westward jet-like current in its path with a dipole of Ekman pumping/eddies on its flanks. As a result, upwelling in the Panama Bight brings cold and salty waters to the surface which erode the fresh pool on its eastern side while surface currents stretch the pool westward. The present study focuses on the fresh pool patterns ranging from the seasonal and interannual variability over the last 3 year period. Each year, satellite SSS products reveal the erosion of the fresh pool by the Panama upwelling. Compared to the SSS climatology from the World Ocean Atlas, satellite SSS data systematically exhibit fresher surface water (by ~0.5 to 1 unit in SSS) just after the occurrence of the maximum SSS reached in the region during the Panama upwelling events (April-May). Using Tropical Rainfall Measuring Mission (TRMM) data, we found that these fresh anomalies coincide with local excess precipitation. Moreover, except during the boreal winter 2011, saltier surface waters than in the climatology were observed during the intensification phase of the Panama upwelling events (Fev-March). Using ASCAT sensor surface winds, TRMM data, surface current deduced from altimeter data combined with the satellite SSS, the study will analyze how these observed SSS anomalies could be related to the interannual variability in the dominant physical mechanisms involved in the freshpool dynamics. A particular focus will be set on the consistency between SMOS and Aquarius observations and on the potential role of the surface freshwater induced-barrier layer processes in modulating the interannual signals.

Reference:

Alory Gael, Maes Christophe, Delcroix Thierry, Reul Nicolas, Illig Serena (2012). Seasonal dynamics of sea surface salinity off Panama: The Far Eastern Pacific fresh pool. Journal Of Geophysical Research-oceans, 117

Posters

Session 2 Instruments' performance and inter-calibration, algorithm development

Quantile Regression Methods Applied to Aquarius Data in the Eastern Tropical Pacific

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Salinity affects the interaction between ocean circulation and the global water cycle, which in turn affects the regulation of the Earth's climate through the ocean's capacity to store and transport heat. In 2011, NASA launched an exciting satellite mission to measure sea-surface salinity and provide the global view of salinity variability needed for climate studies. Using Aquarius level 2 sea surface salinity data from Aug 25, 2011 to Dec 31, 2012, we investigate the time and space scales of variability in the Intertropical Convergence Zone between 30S and 30N latitude. Diagnostics are compared to calibrate the spatial and temporal agreement of Aquarius and the well-utilized in situ ARGO float data. In order to better forecast the oceanic circulation and ultimately improve climate models, it is essential to quantify the relationship between salinity and meteorological factors such as wind and precipitation. Methods to account for the sampling bias and change-of-support issue between satellite data and smaller-scale rainfall events and wind-speed measurements will be considered. A case study of the region near the Costa Rica Dome examines the relationship between salinity and location, wind-speed and rainfall. To characterize the tails of the distribution of salinity, a spatially varying quantile regression approach is explored.

Current ESA Validation Campaigns in Support of SMOS

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In the framework of its Earth Observation Programmes the European Space Agency (ESA) carries out ground based and airborne campaigns to support geophysical algorithm development, calibration/validation, simulation of future spaceborne earth observation missions, and applications development related to land, oceans and atmosphere.

ESA has been conducting airborne and ground measurements campaigns since 1981 by deploying a broad range of active and passive instrumentation in both the optical and microwave regions of the electromagnetic spectrum such as lidars, limb/nadir sounding interferometers/spectrometers, high-resolution spectral imagers, advanced synthetic aperture radars, altimeters and radiometers. These campaigns take place inside and outside Europe in collaboration with national research organisations in the ESA member states as well as with international organisations harmonising European campaign activities.

ESA campaigns address all phases of a spaceborne missions, from the very beginning of the design phase during which exploratory or proof-of-concept campaigns are carried out to the post-launch exploitation phase for calibration and validation. We present four current campaigns illustrating the objectives and implementation of such campaigns in support of SMOS (Soil Moisture and Ocean Salinity), ESA's fourth Earth Explorer and ESA's water mission dedicated to further improving our knowledge of the Earth's hydrological cycle through a global monitoring of surface soil moisture and ocean salinity.

For SMOS calibration purposes, DOMEX-3 is a multi-year continuous campaign where a L-Band radiometer (RADOMEX) mounted on a tower in the DOME-C region is making long-term observations of the Antarctic ice-sheet surface. Domex-3 is a follow-on to two previous successful campaigns, DOMEX and DOMEX-2, where it was observed that brightness temperatures (Tb) in particular at V polarization, were very stable. However, since DOMEX and DOMEX-2 lasted around one month and one year respectively, the long-term

stability and target characteristics, that may affect the long-term signal, have yet to be analysed. For this reason, the DOMEX-3 campaign was set up, and following a successful upgrade of RADOMEX and installation in the Concordia tower, data is being acquired since December 2012, and expected to last till 2016. However, there is still a need to connect the DOMEX-3 point measurements with the satellite scale Tb and characterize the spatial variability at larger scales. This can only be achieved through a series of airborne measurements currently taking place in the region with the DOMECair campaign. This airborne campaign is using the EMIRAD-2 fully polarimetric radiometer to collect Tb in a area spanning 350 by 350 km, which includes the RADOMEX tower.

Another important component of SMOS validation is the multi-year ELBARA-II campaigns that have been running since 2009. ELBARA-II is a ground-based dual polarization, L-band radiometer designed to better understand L-band emission processes in support of algorithm improvements and validation of SMOS data products. Currently, three ELBARA-II instruments are deployed at three European sites with different vegetation and site characteristics: Spain, in a typical Mediterranean sparse vegetation ecosystem, Finland, in a typical representative of the Eurasian taiga belt and France, in a mountainous site. Results have led to models for frost detection, better understanding of vegetation indexes and complex topographic features.

With a direct relevance to the Ocean Salinity community, SMOS-ASIP is an activity whose purpose is to provide a unique and dedicated data set for better understanding the variability of ocean salinity in the upper few cm of the ocean surface. This project will consolidate available high-resolution ocean profile data from the SkinDEeP and ASIP (Air-Sea Interaction profiler) deployments, process and document data to a common format and provide an error characterisation of the resulting data.

ESA campaigns remain fundamental and an essential part in the preparation of new Earth Observation missions, as well as in the independent validation of their measurements and quantification of error sources. For the different activities a rich variety of datasets has been recorded, are archived and users can access campaign data through the EOPI web portal [http://eopi.esa.int].

A Comparative Study of Third Stokes Parameter from SMOS and Aquarius Measurements

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SMOS and Aquarius have been successfully providing L-band brightness temperature since 2009 and 2011, respectively [1, 2]. Since both missions provide Low Earth Orbit observation at the same frequency, comparison of brightness temperatures measured from these two missions has drawn attention. As one of such, comparison of third stokes parameters (T3) from these two missions are of interest. The primary utility of the third Stokes parameter at L-band is to estimate the Faraday rotation caused by the Earth's ionosphere which affects the balance of vertical and horizontal brightness temperatures. The inter-comparison analysis on similarity and difference of T3 from two missions will provide helpful insights on Faraday rotation estimation using L-band microwave radiometer.

Currently, SMOS L1C data are being processed for the Aquarius-SMOS inter-comparison study. The data are designed to include both land and ocean for separated ascending and descending paths for all Stokes parameters. Incident angles are binned with 38 degree points. Spatial points are gridded with 0.25 degree bin which results in 1440 longitude and 720 latitude points. All data are RFI-flagged and mitigated [3]. Maximum RFI values are stored also. Initial analysis on T3 shows that T3 is dependent on incidence angle and paths (ascending/descending). This is one of the topics that will be discussed in the presentation.

The presentation will include the comparison results using at least one year SMOS and Aquarius T3 data. Similarity and difference of T3 between the missions will be analyzed and accessed. The results will provide useful data and insights on the impact of error sources on T3 measurement using L-band microwave passive measurement.

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Reference
1. Y. H. Kerr et al., "The SMOS Mission: New Tool for Monitoring Key Elements of the Global Water Cycle," Proceedings of the IEEE, vol. 98, No. 5, May. 2010.

2. D. M. Le Vine et al., "Aquarius Third Stokes Parameter Measurements: Initial Results," IEEE Geosci. Remote Sens. Lett., vol. 10, No. 3 Jan, 2012.

3. S. Misra et al., "Analysis of Radio Frequency Interference Detection Algorithms in the Angular Domain for SMOS, " IEEE Trans. Geosci. Remote Sens., vol. 50, no. 5, May. 2012.

SMOS Brightness Temperature Enhancement in Coastal Areas

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SMOS observations near coastal areas and inland water bodies are not of practical use in the retrieval of the geophysical parameters. This is due to the instrument's limited spatial resolution and the Gibbs phenomenon, which appears near abrupt transitions such as coastlines. Hence, the enhancement of the SMOS brightness temperature products in these zones is important, since it will significantly improve the quality of both soil moisture and sea surface salinity retrievals.

This paper is focused on the development of an algorithm to enhance the quality of SMOS brightness temperature products near coastal areas. The original SMOS brightness temperature (TB) image is first decomposed in two images using a land/sea mask with higher spatial resolution (e.g. 5 min for the ETOPO5 grid) than SMOS (~40 km). One of these images containing the land pixels of the initial image and the other containing the sea pixels. Both images are then screened out to discard TB data close to the coastline (~200 km), since these pixels are highly affected by the Gibbs phenomenon. A dedicated exemplar-based region filling algorithm is applied to these two images. Then, the final brightness temperature image is obtained by combining the obtained land and sea TB images. This image has a high resolution coastline and does not present most of the land-sea contamination effects. At present, we are working on refining these techniques to better detect small TB gradients (i.e. deltas) close to the coast.

In order to assess the quality of the enhanced brightness temperatures obtained with the proposed technique, we compare them to forward models. After that, the sea surface salinity and soil moisture retrievals obtained using the improved TBs will be compared to in-situ measurements. First results of this added-value brightness temperature product will be presented at the workshop.

Ocean Roughness Correction for Aquarius Sea Surface Salinity Measurements

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The retrieval of ocean surface salinity is a challenging task. Since the launch of the Aquarius (AQ) instrument in summer of 2011, the AQ Calibration/Validation (Cal/Val) working group of the Sea Surface Salinity (SSS) Science Team has been working to improve the SSS retrieval algorithm including the L-band radiometer brightness temperature (Tb) calibration. This paper deals with one of the major sources of salinity retrieval error, namely the changes in ocean Tb caused by increasing ocean roughness due to surface winds.

When wind blow over the ocean it generates small-scale waves that increase the root-mean-square slope of the ocean's surface thus causing a "roughness effect". This roughness reduces the surface reflectivity monotonically, which increases the surface emission by an additive scalar (delta-e - excess emissivity due to wind effect). Even though the delta-e is dominated by the wind speed effect, there is also a zero-mean anisotropy directional feature that is a function of wind direction relative to the beam azimuth angle.

The baseline approach adopted by Aquarius, combines observations from both the L-band radiometer and scatterometer to infer the roughness correction. The purpose of this paper is to present an alternate approach that uses dual polarized Tb data at 37 GHz from the on-board Microwave Radiometer (MWR) to derive this delta-e. The basis of this technique is to use an electromagnetic radiative transfer model (RTM) to correct for the L-band roughness effect caused by both wind speed and direction. This RTM has been tuned using the on-orbit Aquarius Tb's (roughly 10 million observations per beam for the three incidence angles 29°, 38° and 46°) and associated surface truth from ancillary sea surface temperature (SST), numerical weather model surface wind speed and direction, and HYCOM sea surface salinity. The excess roughness correction is produced using this RTM that is driven using collocated and simultaneous wind speed retrievals from the MWR and that are coupled with NOAA GDAS wind directions and SST as the input. This roughness correction is validated using AQ SSS retrievals, which are compared with the SSS surface truth: HYCOM SSS oceanographic model and in-situ AVDS buoy salinities. Results with be presented that compare the AQ baseline and our roughness corrections as a function of surface wind speed. Also a discussion of "how these results may be applied to the SMOS SSS retrievals" will be presented.

Inter-satellite Radiometric Calibration of Ocean Brightness Temperature between SMOS and Aquarius

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The ocean surface brightness temperature at L-band is significantly different than the antenna temperature measured at the satellite. At the satellite, the predominant signals are from the earth's surface; however there are a number of unwanted brightness components that must be removed to a high degree of accuracy (low residual) to derive the surface brightness temperature (Tb). It is from this surface Tb that the SMOS ocean salinity and soil moisture science products are derived. This process is challenging but well understood and this is not the topic of this paper.

In this paper, we start with the vertical and horizontal ocean surface Tb derived by the SMOS and Aquarius (AQ) projects, and we will preform an inter-comparison between these products to derive radiometric biases between the two. This paper describes the results of a forward radiative transfer model (RTM) tuned to the AQ ocean surface Tb's. This model uses the AQ dielectric constant model for sea water, which is a function of the physical parameters: sea surface (physical) temperature (SST), the sea surface salinity (SSS), and the ocean surface wind speed and direction. Further the ocean emissivity is a function of the sea water dielectric constant, the geometry (earth incidence angle, EIA), frequency and electromagnetic wave polarization. Using the three AQ beams at EIA of 29° to 46° and more than 10 million observations (per beam) with surface truth, we have tuned our model to match the AQ observations to a high precision. We have employed the highly developed inter-satellite radiometric calibration (X-CAL) procedure to examine the direct biases between the corresponding EIA's between AQ and SMOS. These results will be presented and plans to extend this EIA's range using our ocean surface emissivity RTM to the entire nadir to 55° range for SMOS. Results will also be presented in a companion paper to describe the ocean surface roughness correction that has been applied to AQ and which can be extended to SMOS salinity retrievals.

Improved GW Model Function Based on Additional Seawater Measurements

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This paper presents new measurement data of the dielectric constant of seawater at a salinity of 33 psu and its effect on the GW model function. In the past, The George Washington University (GW) has employed a cavity technique to determine the complex permittivity of seawater at L-band (1.413 GHz). This technique is a perturbation method that uses the change in the resonant frequency (f) and the quality factor (Q) of the cavity when seawater is added to determine its complex dielectric constant. Based on the measurement data, the GW model function of seawater permittivity has been developed.

Currently, the GW model function is a second-order polynomial in variables S (salinity) and T (temperature) based on the measurements of seawater with salinities of 30, 35, 38 psu in the temperature range of 0^{o} C to 35^{o}

Towards an Optimal Quality Control of L2 SMOS Data

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A comprehensive quality control of the SMOS Level 2 data is essential for a successful retrieval of sea surface salinity (SSS) maps. In particular, a poor filtering at Level 2 (L2) will in turn negatively impact the quality of the spatio-temporally averaged SSS maps (i.e., Level 3 or L3 maps). On the other hand, overfiltering (i.e., having a high false alarm rate) will substantially reduce the number of SSS data available for averaging at L3, thus increasing the noise level of L3 SSS maps.

In this study, the impact of the different quality flags provided in the operational SMOS L2 User Data Product (UDP) in the quality of the SSS retrievals is assessed. SMOS data has been filtered following several combinations of flags. The flags can be grouped in geophysical filters (filters related to geophysical conditions prevailing in a given area), retrieval filters (filters related to the reliability of the SSS retrieval method) and geometrical filters (filters related to the geometry of the snapshots taken by SMOS). Filtered data in such a way, have been compared with ARGO buoys data, both at L2 (i.e., at swath grid level) and L3.

On the other hand, the distribution of the SSS Bayesian-based inversion residuals (which indicate the consistency of the measured brightness temperatures (TBs), the forward model, and some a priori or background information) have also been analysed. These residuals, from a theoretical point of view, should follow a chi square distribution. The L2 products provide two quality flags that are based on the theoretical distribution of the residual. However, since measurement errors are not Gaussian nor uncorrelated, the real residual distributions are not always close to the theoretical one and, as such, the residual theoretically-based flags/thresholds become less effective. Moreover, the theoretical chi square distribution depends on the degrees of freedom of the problem. In the case of a SMOS grid point, the degrees of freedom correspond to the number of valid measurements used for retrieving SSS plus the (relatively small) number of geophysical parameters present in the inversion a priori or background term (typically SSS, sea surface wind speed, sea surface temperature, and total electronic content) in every point. The number of measurements used in the computation of salinity changes for each grid point (depends on the position on the Field Of View). However, one of the quality flags provided by L2 UDP and related with the chi square distribution of the residual, assumes that the number of measurements (i.e. the degrees of freedom of the theoretical distribution) is constant. This produces an inconsistency in the quality control of the SMOS data.

A new filtering approach consists of adjusting the real distribution of residuals to the desired chi square distribution. This filter is based on geometric assumptions about the number of retrieved measures across swath. Alternatively, one can estimate the shape of the distribution of residuals as a function of the degrees of freedom and empirically set a threshold value for each distribution or for each interval of degrees of freedom (when the distribution of residuals does not vary significantly over a specific interval). Preliminary results of these two new approaches will be presented at the conference.

Towards an Optimal SMOS Bayesian-Based Inversion Scheme for Salinity and Wind Speed Retrieval Purposes

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In this study, a simplified parallel version of the operational Soil Moisture and Ocean Salinity (SMOS) Level 2 data processor (L2OS) is used to assess the optimal configuration of both the SMOS Bayesian-based cost function and the corresponding Levenberg-Marquardt based multi-parametric minimization scheme for sea surface salinity (SSS) and sea surface wind speed (U10) retrievals. Within such a framework, realistically simulated brightness temperature measurements (TBs) and a post-launch derived semi-empirical forward model (FM) are used. As already anticipated in pre-launch studies, the results carried out in this work demonstrate that the SMOS cost function needs to be constrained by a priori information on the sea-surface related geophysical parameters, due to the low TB sensitivity with respect to both SSS and U10 changes. Furthermore, the present study, in which a variety of marine scenarios are simulated, confirms that the operationally used SMOS L2OS cost function configuration is optimal for SSS retrieval purposes. As a novelty, this study shows that the optimal SMOS cost function configuration for U10 retrievals is different from the one used for SSS retrieval purposes. This is mainly due to the TB sensitivity to SSS changes being different to the TB sensitivity to U10 changes. Current work focuses on the verification of the simulation results with SMOS real data, using collocated in situ observations and numerical weather prediction model output. The most relevant results of this study will be presented at the workshop.

SMOS RFI Status Worldwide

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European Space Agency's (ESA) Soil Moisture and Ocean Salinity (SMOS) mission was launched on 2 November 2009 with the objective of providing global observations for soil moisture and ocean salinity. SMOS carries the first-ever spaceborne L-band Microwave Imaging Radiometer using Aperture Synthesis (MIRAS) in two dimensions [1].

MIRAS operates within the Earth Exploration Satellite Service (EESS) passive band at 1,400-1,427 MHz. The 1,400 - 1,427 MHz frequency range is a purely passive band where all emissions are prohibited by the ITU Radio Regulations footnote 5.340. Furthermore, the maximum level of unwanted emissions from active services operating in neighbouring bands are defined in ITU-R Resolution 750, which was adopted at the World Radiocommunication Conference in 2007 (WRC-07). In this resolution, ITU-R urges administrations to take all reasonable steps to ensure that the unwanted missions of active services do not exceed the specific recommended maximum levels, noting that EESS passive sensors provide worldwide measurements that benefit all countries [2].

Despite the existing regulations at international level, SMOS´ objective is disturbed by RF Interferences (RFIs) that jeopardize part of its scientific use in certain areas of the world, especially over continental areas in Europe, Southern Asia, and the Middle East.

In order to improve SMOS images over those areas affected by RFI sources, the SMOS team has put several strategies into place within the short, mid and long term timeframe [3]. These strategies cover multiple areas: from data flagging and RFI image mitigation techniques to increase the RFI situation awareness, lobbying to improve the regulatory framework to ensure protection of the 1,400-1,427 MHz passive band and requesting cooperation of the spectrum management authorities at national level to enforce the radio-regulations. The current paper focus on the latter, which needs the SMOS team to provide accurate coordinates of the RFI sources for the national spectrum management authorities to locate the interference emitters and enforce compliance of the regulations: - For RFI sources operating within the passive band, those responsible of the transmitters are instructed to switch them off.

- For RFI sources operating in adjacent bands but producing excessive unwanted emission levels, investigations are necessary to detect if the cause is due to malfunctioning equipment with high level of harmonic emissions, or equipment with high level of out-of-band emissions. The authorities at national level are then responsible to take the necessary actions to solve, or at least to minimize the impact of the different RFI cases. This strategy was initiated early in the mission (Jan 2010) and has seen important improvements in the World RFI situation, especially in North-America and over Europe. In total, more than 500 RFIs have been reported to the national countries and out of those, 200 cases have been successfully switched off. The interface with the spectrum management authorities is not always successful and so far no improvement (or very little improvement) has been achieved in the RFI situation in several countries such as China, Russian Federation, Turkey, Israel or Middle-East. In some areas, suddenly strong RFIs that can blind the instrument measurements have appeared (e.g. Poland, United States or Russian Federation) and urgent contact with the spectrum authorities has proven to be an effective tool. Finally to mention that an important RFI degradation has been detected since September 2011 over Japan. This sudden increase of RFI interference, which appears in to extensive areas around the major cities, has been reported to the Japanese authorities and it is being investigated. It is very important to monitor the evolution of these RFIs that could be due to new systems operating in adjacent bands and that would represent a clear threat to current and future L-band passive remote sensing missions. Poland exhibited one of the worst examples of very high RFI in SMOS, with brightness temperature above 60,000 K. A single interference source located in polish territory blinded all SMOS observations far beyond the source origin. No soil moisture retrievals were obtained in central Europe for about 6 months due to the effects of this single source. Although the situation today is less severe, the problem is not yet being resolved. Finally, the feedback collected from the national authorities world-wide has provided very valuable information about the type of interference and services that are perturbing the SMOS data. The majority of the sources that have been switched off were security wireless cameras and TV radio-links operating within the protected band or in a neighbour band. Then, at least 25 % of the sources observed correspond to military radars operating in the lower neighbour band.

REFERENCES

[1] McMullan, K.D., M. Brown, M. Martin-Neira, W. Rits, S. Ekholm, J. Marti and J. Lemanczyk,"SMOS: The Payload". IEEE Geosci. Remote Sens., 2008. 46(3).

[2] ITU-R Radioregulations. Edition 2012. http://www.itu.int/pub/R-REG-RR-2012

[3] R. Oliva, E. Daganzo, Y. Kerr, S. Mecklenburg, S. Nieto, P. Richaume, C. Gruhier, "SMOSRadio Frequency Interference Scenario: Status and Actions Taken to Improve the RFI Environmentin the 1400-1427 MHz Passive Band". IEEE Trans Geosci. Remote Sens., Special issue on SoilMoisture and Ocean Salinity Mission. Vol. 50, No 5, pp.1427-1439, May 2012.

Inter-Comparison of SMOS and Aquarius Brightness Temperatures at L-Band over Selected Targets

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The European Space Agency (ESA) launched the Soil Moisture and Ocean Salinity (SMOS) satellite on November 2, 2009, to globally monitoring surface soil moisture over the landmasses and salinity over the oceans. Its single payload is the first two-dimensional Microwave Imaging Radiometer with Aperture Synthesis (MIRAS), an instrument that provides multi-angular L-band measurements in the field of view (from 0† to 65°) and has full-polarimetric capabilities (measures H, V and HV polarizations).

The next satellite devoted to global sea surface salinity monitoring is the Aquarius/SAC-D, which was launched on June 9, 2011, by a collaboration between the US National Aeronautics and Space Administration (NASA) and the Argentinian Comisión Nacional de Actividades Espaciales (CONAE). It includes three beam push-broom L-band real aperture radiometers and real aperture scatterometers, both full-polarimetric and feeded by the same reflector at three incidence angles (28.7°, 37.8° and 45.6° for the inner, the middle and the outer beams).

A radiometer is an instrument capable of measuring the natural electromagnetic energy of the bodies as brightness temperatures (TBs). In the ideal case, the result of measuring the Earth's TBs at the same area and at the same frequency by different radiometers would be the same. To date, SMOS and Aquarius are providing unprecedented L-band observations of the Earth's surface. However, differences between the two instruments, such as the configuration (synthetic or real aperture), the antenna patterns, the calibration schemes, the strategies to obtain the images according to the topology and the spatial resolution (~40 km or ~100 km) may lead to different collected TBs.

Any study using a long term environmental data record that spans multiple L-band missions would require consistent input observations. Hence, the inter-comparison of SMOS and Aquarius TBs is a key requirement needed to use the data of both radiometers for meteorological, hydrological and climatological studies on a large time scale.

A method to compare SMOS and Aquarius TBs is proposed to verify the continuity of the data and detect possible differences or biases. The procedure involves the selection of a suitable method to study a large amount of data and provide robust statistics for assessing the consistency between SMOS and Aquarius data (or Soil Moisture Active Passive (SMAP) data in a near future).

Note that SMOS and Aquarius radiometers are both on board Sun-synchronous satellites, but with opposite equatorial ascending crossing times, 6 a.m. and 6 p.m. respectively. Due to this, the use of simultaneous nadir overpasses (SNOs) between polar orbiting satellites with collocation to overcome a certain space (same location) and time criteria (within 30 min, eliminating the effect of change in physical temperature) means that data at high latitudes should be discarded, limiting results to low latitudes between [-20°, 40°]. Moreover, the operating dataset of Aquarius, before the commissioning phase, began on September 1, 2011. These facts highly reduce the amount of available data. So, an alternative approach which does not require SNOs was decided to be used.

The proposed inter-comparison approach consists of the evaluation of the TB statistics over several relatively stable and homogeneous targets. Different locations at the Earth have been selected, such as the South Pacific Ocean, the Dome-C zone in the Antarctica, the Sahara desert and the Amazon rainforest. They are expected to have nearly constant observed TBs. Also, measurements from the cold sky views will be used. The TB measurements at the same frequency band (L-band centered at 1.413 GHz) will be compared at the three Aquarius Earth incidence angles along an entire year.

Thereby, the obtained TBs and their statistics will be computed to characterize each radiometer. The main objective is to analyze the TB statistics (i.e. mean, standard deviation, cumulative distribution function) of the SMOS and Aquarius radiometers over the selected targets. Representation and inter-comparison of these statistics could reveal key differences between SMOS and Aquarius TB products.

Dependence of SMOS/MIRAS Brightness Temperatures on Wind Speed: Sea Surface Effect and latitudinal Biases

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SMOS (Soil Moisture and Ocean Salinity) has been successfully launched in November 2009 and its only payload, Microwave Imaging Radiometer using Aperture Synthesis (MIRAS) instrument, is the first interferometric radiometer at L band (1.4GHz) in orbit. MIRAS employs aperture synthesis in 2D with a Y-shaped antenna structure to create an image of emissions from the Earth surface at L-band over a range of incidence angles (0° to 65°) with a spatial resolution of 35 to 110 km. More than two years after launch the level 1C (L1C) brightness temperatures (TBs) reprocessed with the up-to-date ESA level 1 processing version (the Level 1 processor V5.04 and V5.05), have been released. It has been shown during the commissioning phase that the receivers onboard of MIRAS are affected by a short-term drift during each orbit, and a seasonal variation due to the thermal drifts of the antenna patch. Although a new antenna model is incorporated in the ESA L1 V5 processing to account for these variations, latitudinal and seasonal drifts in L1C TBs are still observed. In this presentation, we first investigate the impact of the TB drifts on the sea surface emissivity roughness model we derived in Yin et al. (TGRS 2012) from multi-latitude level 1

V3.44 TBs. We then study dependencies of TBs at multi-incidence angles with wind speed separately for various latitudinal bands and different seasons in order to separate artificial effects of TB drifts from sea surface effects. We then propose a new roughness/foam forward model. We estimate the quality of SMOS retrieved SSS by comparing it with ARGO measurements, and discuss SSS quality given the imprecision of the forward model and of the wind speed used as prior value in the level 2 ocean salinity processor.

Spatial Bias on SMOS Full-Polarimetric Images over the Ocean

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By taking into account the co- and cross-polar antenna patterns, SMOS full-pol visibilities can be inverted by the so called full-Pol G-Matrix. This produces polarimetric images where spatial bias has been mitigated to a large extend, mainly in the Extended Alias Free Field of View. The improvement is very significant on the 3rd and 4th Stokes parameters since the artifacts that are produced in the nominal processing are very much reduced and spatial bias is now smoothly distributed across the EAF-FoV. The enhanced performance given by the Full-pol G-Matrix processing can improve geophysical parameter retrieval since the 3rd Stokes parameter can be used for geophysical parameter retrieval and the 4th Stokes parameter can be effectively used to improve Faraday rotation corrections. The presentation will assess the performance of the full-pol G-matrix inversion by comparing the full polarimetric images to an accurate Ocean model (LOCEAN model).

Session 3: Product validation & stratification

Validation of Surface Salinity Retrieved by SMOS and Aquarius Satellites in the Bay of Bengal

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The Bay of Bengal presents a unique configuration to assess the performance of SMOS and AQUARIUS salinity retrieval in the tropics. The monsoon indeed induces strong river discharge and rainfall, generating low salinities in the Northern Bay and a strong seasonal cycle. The strong haline stratification in the bay is also believed to play a key role in many climate phenomena. There is however still a dearth of in situ SSS observations, and even the seasonal cycle is not well described, particularly near the coasts. Salinity remote sensing thus offers interesting promises for this region. In this work, we validate SMOS V02 level-3 (May 2010 to July 2012) and Aquarius level-3 (August 2011 to September 2012) 10x10 gridded monthly data against a novel gridded in situ sea surface salinity (SSS) product in the Bay of Bengal. Our product comprises all available SSS observations (ARGO, thermo-salinographs, RAMA buoys, and a newly released set of surface water samples collected along two repeated shipping tracks crossing the basin). To carry out the validation, we co-locate spaceborne and in situ datasets, to avoid the spurious effects of interpolation/extrapolation in spatio-temporal data gaps. This is a critical step in the Bay of Bengal, as both spaceborne and in situ datasets largely sub-sample the SSS features of the basin (and particularly so in the coastal domain, where SSS variability is highest). Our results first show that both satellites capture the mean large-scale SSS gradient; however, variability is only accurately captured in the south-central part of the basin. On the contrary, throughout the periphery of the basin, none of the two spaceborne products offer any significant performance improvement as compared to the historical SSS climatologies. The Bay thus appears as a place where drastic improvements of the SSS retrieval algorithms are required.

Seasonal Variability of Sea Surface Salinity on a Global Scale

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The seasonal variability of surface layer salinity (SLS), evaporation (E), precipitation (P), E − P , advection and vertical entrainment over the global ocean is examined using in situ salinity data, the National Centers for Environmental Prediction's Climate System Forecast Reanalysis and a number of other ancillary data. Seasonal amplitudes and phases are calculated using harmonic analysis and presented in all areas of the open ocean between 60◦ S and 60◦ N. Phases of SLS have a bimodal distribution, with most areas in the Northern Hemisphere peaking in SLS in March/April and in the Southern Hemisphere in September/October.

The seasonal cycle is also estimated for surface freshwater forcing using a mixed-layer depth climatology. With the exception of areas near the western boundaries of the North Atlantic and North Pacific, seasonal variability is dominated by precipitation. Surface freshwater forcing also has a bimodal distribution, with peaks in January and July, 1-2 months before the peaks of SLS.

The amplitudes and phases of SLS and surface fluxes compare well in a qualitative sense, suggesting that much of the variability in SLS is due to E - P . However, the amplitudes of SLS are somewhat different than would be expected and the peak of SLS comes typically about one month earlier than expected.

The implications of these results for the global freshwater balance will be discussed.

Comparative Study of Sea Surface Salinity obtain from AquariusSAC-D Mission and Argo Floats over Indian Ocean

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Aquarius is NASA's new Earth orbiting mission launch on June 10, 2011 which employ advanced technologies to make space-based measurements of ocean salinity across the globe-an important observation for ocean and climate studies. Briefly, the Aquarius instrument measures the brightness temperature (BT) of the sea surface at L-band, 1.413 GHz, with three separate radiometers with ellipsoid footprints ranging in width from 94 to 156 km for a total beam width of 390 km. These data, in combination with concurrent sea surface temperatures, scatterometer measurements, and other auxiliary data, are used to estimate Sea Surface Salinity (SSS). Aquarius can detect changes in ocean salinity as small as the equivalent to 0.2 grams salt per kilogram of seawater hence it is an essential task for the scientists to ensure that the accuracy requirements are achieved.

This study demonstrates the behavior of Aquarius SSS with respect to in-situ SSS form Argo's. Argo is a global array of 3,000 free-drifting profiling floats that measures the SSS and SST of the upper 2000 m of the ocean. A key objective of Argo is to observe ocean signals related to climate change. This includes regional and global changes in ocean temperature and heat content, salinity and freshwater content. Although not specifically it is designed to measure the salinity at surface, but it is possible to use the shallowest salinity measurement from Argo floats to estimate SSS.

For this study, Argo profiles are obtained for a couple of months over the Indian Ocean from Coriolis Argo Global data Assembly Centre. Similarly the Aquarius Level-2, version V1.3 was taken over the same locations and time period. By analyzing these data and comparing versions 1.3 of Aquarius, one finds that Aquarius SSS generally agreed well with Argo salinity. As a result, the error range obtained for a short time period in all beams: -0.17 to 0.48 psu Beam 1, -0.2 to 0.62 psu Beam 2, -0.18 to 1.04 psu Beam 3. Anticipating that the spatial and temporal average reduces random errors in the observation, the mission objective of Aquarius which is to have SSS with an accuracy of 0.2 psu monthly average can be fulfilled. However, Aquarius SSS need to be tested further with extensive in-situ dataset for more accurate output that will be presented in full paper.

SMOS Level 3 and Level 4 Research Products Provided by the Barcelona Expert Center

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More than three years have passed since the launch, on November 2, 2009, of the European Space Agency's (ESA) Soil Moisture and Ocean Salinity (SMOS) satellite carrying a microwave synthetic aperture radiometer working at 1.4 GHz. The aim of the mission is to provide Sea Surface Salinity and Soil Moisture observations, with a spatial resolution of 30-50 km, and an accuracy suited for climate studies.

From the brightness temperature observations, experimental sea surface salinity (SSS) and Soil Moisture (SM) maps are being developed and distributed at the SMOS Barcelona Expert Center (SMOS-BEC) to take the most out of SMOS observations. Data are distributed in NetCDF format using THREDDS and maps are served through a Web Map Service (ncWMS), both at the SMOS-BEC distribution data website (http://cp34-bec.cmima.csic.es/).

For ocean applications the following SSS products are being served at spatial resolution of 0.25°:

- Level 3 maps by spatial and temporal weighted average of level 2 SSS data. Three- and nine-day averaged maps are produced every 3 days. Monthly, seasonal and annual maps are also computed.
- Level 3 maps from optimal interpolation of level 2 SSS data. Nine-day averaged maps are produced every 3 days, as well as monthly, seasonal and annual maps. <\li>
- Level 4 maps from SMOS SSS fused with satellite-derived SST [1]. Similar to Level 3 data, nine-day averaged maps are produces every 3 days, as well as monthly, seasonal and annual maps.<\li>
- Singularity Exponents products obtained by applying singularity analysis on OSTIA SST products (http://myocean.eu/) are also served. <\li>

Three versions of each product are generated using ascending passes, descending passes, and full orbit passes (i.e., ascending + descending). Both absolute salinity value and its anomaly (difference between the absolute value and climatology data (WOA 2009)) are stored in the product. L3 and L4 maps are validated with near-surface measurements provided by Argo profilers, and their expected accuracy is 0.2-0.4 depending on processing level and the region of interest.

For land applications, SMOS spatial resolution has proved useful for improving our understanding of water and energy fluxes between the atmosphere, the soil surface, and subsurface. Still, it is insufficient for regional applications, such as land and water resources management or drought mitigation, which require a spatial resolution of 1 to 10 km. For this reason, a downscaling algorithm which combines SMOS with MODIS VIS/IR satellite data into 1km SM maps has been implemented at SMOS-BEC [2]. High resolution (1 km) soil moisture maps are derived with this technique over the Iberian Peninsula and are distributed through SMOS-BEC maps server web page in near real time (delay < 6h).

Moreover, soil moisture level 3 products are computed by monthly, seasonal and annual temporal averages of level 2 soil moisture data at 0.25° spatial resolution. They are also distributed at the SMOS-BEC web site.

[1] A. Turiel et al., "The multifractal structure of satellite sea surface temperature maps can be used to obtain global maps of streamlines", Ocean Science 5, 447-460 (2009)

[2] M. Piles et al.,"Downscaling SMOS-derived Soil Moisture Using MODIS Visible/Infrared Data", IEEE Trans. Geosc. and Remote Sens., vol 49, pag.352-374 (2011)

SMOS and AQUARIUS SSS in and around the SPURS/STRASSE Experiment

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In the frame of the 'Salinity Processes in the Upper Ocean Regional Study' (SPURS) experiments, the STRASSE (Subtropical Atlantic surface salinity experiment, PI G. Reverdin) campaign took place in August-September 2012, centered in 26°N, 35.5°W. It provides a very high resolution monitoring of the salinity variability in the high salinity region of the subtropical north Atlantic. In addition to this survey, Sea Surface Salinity (SSS) monitoring in the vicinity of this region is performed every month by ships of opportunity (Toucan and Colibri) which cross the maximum SSS region. In this poster, we take advantage of this wide in situ SSS monitoring for validating the SMOS (European Space Agency (ESA) real time version 5 and Centre Aval de Traitement des Données SMOS (CATDS) expertise center version 2) and AQUARIUS (level 3 version 2) SSS.

Our comparisons show that the absolute calibration of the satellite SSS remains imperfect in 2012, with particularly large biases on SMOS SSS. In the ESA v5 reprocessing in 2010 and 2011, the SMOS SSS biases have been partly mitigated by an empirical bias correction (the so-called 'Ocean Target Transformation') computed in the eastern southern Pacific (5°S-45°S) every two weeks with reasonnable results. On another hand, in the 2012 real time processing, the OTT correction was applied only every month and with several weeks delay leading to large observed SSS biases. In order to get rid of them, we test two additionnal bias corrections derived from the mean SMOS-climatology SSS difference either in the OTT region or in the northern subtropical latitudes.

After removal of large scale biases, we concentrate on the spatio-temporal SSS variability at scales larger than 100km derived from SMOS and AQUARIUS data, and at the capability of SMOS to sense SSS variability at scales shorter than 100km. Using transects of Toucan-Colibri ships over this region, we find that once a correction derived from mean bias computed in the OTT region is applied on SMOS SSS, the rmse of SMOS SSS (averaged over 18days and 100km around ship measurements) minus ship SSS is less than 0.3.

Quality Control of remotely sensed Sea Surface Salinity in The Yellow Sea

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Retrieving sea surface salinity (SSS) in the Yellow Sea from the European Space Agency (ESA) Soil Moisture and Ocean Salinity (SMOS) sensor on the MIRAS satellite is challenging because of the enormous amount of data contaminated by Radio Frequency Interference (RFI). However, it is possible to remove contaminated data by using an empirical quality control method that utilizes climatological and in-situ data means and standard deviations. The method matches up SMOS data geographically with quarter degree cells of the World Ocean Atlas 2001 (WOA01) and initially filters the data by rejecting SMOS retrieved SSS that differs by more than 1 psu from the WOA01 SSS. Secondly the data are further filtered by asymmetrically tightening down on the remaining data such that the mean and standard deviation (STD) of differences between SMOS and WOA01 SSS are close to those between the independent in-situ data sets collected by the Korea Oceanographic Data Center (KODC) and the WOA01. The filtered SMOS data compares much better to the in-situ data for not only KODC but also the Ieodo ocean research station by Korea Hydrographic and Oceanographic Administration (KOHA). This quality control process removes much of the SMOS data which can greatly reduce coverage. To compensate we are investigating augmenting the SMOS data with similarly quality controlled data from the NASA Aquarius mission.

Assessment of SMOS and AQUARIUS Performance in the Arctic

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Sea Surface Salinity (SSS) distribution derived from SMOS Level-2 data and AQUARIUS Level-3 data taken over the European Arctic (20W - 100E, 60N - 80N) have been inter-compared and assessed using auxiliary data.

The satellite SSS fields have been compared with SSS fields derived from the TOPAZ coupled ocean and sea ice modeling and data assimilation system run at the Nansen Center. The modeled SSS fields were computed as monthly climatology values from the TOPAZ reanalysis data for 2003 - 2008.

MODIS/Aqua data was processed with locally tuned algorithm for deriving concentration of dissolved organic carbon (DOC). DOC distribution maps were compared with SSS from SMOS and AQUARIUS in the plumes of large Arctic rivers Ob and Yenisey. The analysis shows that High accuracy retrievals of SSS from SMOS data in the North Atlantic is seriously hampered. One of the main reasons is too low sea surface temperature that limits the sensitivity of measurements in L-band. Critical temperature, at which average error in SSS retrieval reaches 1 psu, is 14oC. Wind (proxy for surface roughness) plays less significant role, but limits accuracy when exceeds 8 m/s. In coastal waters SMOS shows realistic patterns of SSS. Although estimated relative error is small (10%) the absolute values are questionable. Due to reasonably high resolution, and high sensitivity to fresh water signal Aquarius data is usable for studies of river discharge. Strange high values are observed near rough terrain.

Optical data is applicable for retrieval of SSS only in estuaries of large rivers. Analysis of time series reveal strong dependence on river discharge rates. More SSS measurements (contact or remote) are required for establishing seasonal relations between DOC and SSS and studying dilution processes.

Comparison of different approaches of SSS retrieval shows similar spatial distribution in coastal areas. Absolute values of SSS differ by 10-15 psu in coastal waters and 5 psu in open waters.

Comparison Analysis between NODC In Situ Analyzed Sea Surface Salinity and Aquarius Sea Surface Salinity

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The Aquarius satellite mission provides globally mapped level-3 monthly sea surface salinity (SSS) fields from August 2011 to present on a one-degree grid. The US National Oceanographic Data Center (NODC) has globally analyzed monthly SSS fields from January 2009 to present on a one-degree grid. The NODC fields were created through an objective analysis scheme utilizing calculated salinity climatologies and quality controlled in situ data. The majority of in situ SSS data was from Argo floats; however, Conductivity-Temperature-Depth (CTD), bottle, tropical moored buoy arrays, and glider data were also included. Because surface ("skin") salinity is a difficult variable to measure, all in situ profiles with a salinity observation less than 5.25m from the surface were considered to be surface observations. With two different products offering a global view of SSS at monthly time scales, a comparison analysis was conducted to look at global and regional differences as well as differences in the annual cycle. To partially eliminate systematic biases in both the Aquarius SSS and NODC SSS fields, we calculated monthly SSS anomaly fields. These fields were calculated by subtracting off the respective product's 1/2012-12/2012 mean SSS from each month. From this information we investigated global and regional differences to see if they arise from a lack of in situ data in the area, inability of the objective analysis scheme to accurately depict regions of high SSS variability (e.g., Gulf Stream, Amazon River outflow), or issues with the satellite data. Furthermore, a Fourier decomposition was applied to the first full calendar year of Aquarius SSS monthly fields (1/2012 - 12/2012) and to the NODC SSS monthly fields for the same time period. The first two harmonics from the Fourier decomposition were compared to reveal any similarities and differences in the annual cycle between Aquarius SSS and NODC SSS.

Scales of Sea Surface Salinity Variability from In Situ Observations and Numerical Model Results

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The SMOS Sea Surface Salinity (SSS) is retrieved with a theoretical accuracy of 0.1. However, reaching this GODAE accuracy requirement is quite challenging. Since the SMOS SSS is quite noisy, due to several reasons, one method to gain a more accurate SSS from the satellite is to average the measurements both in space and time. Several long term moorings, thermosalinograph sections, Argo near surface data, measurements from surface drifters and a high-resolution model are used to analyze in more detail the salinity variability in the Atlantic Ocean. The gridded Argo data and the model results show where and how much of the salinity signal is dominated by the seasonal cycle. From the high-resolution data, spatial and temporal decorrelation scales were calculated. The model data was also used to derive the decorrelation scales after removing the seasonal signal. The results reveal salinity variability on scales similar to the averaging scales of 100 km and 10 days used for the SMOS measurements. It is shown where care should be taken when interpreting SSS variability from the averaged satellite measurements.

Session 4: SMOS and Aquarius science application and synergies

The Tropical Atlantic North Equatorial Counter Current Dynamics from SMOS and Altimetry

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The ESA/SMOS (European Space Agency/Soil Moisture and Ocean Salinity) satellite mission provides measurements of the Sea Surface Salinity (SSS) since the end of 2009. It is the first time that this technology is used for measuring SSS from space, providing global ocean coverage every 3 to 5 days and a spatial resolution of up to 40km. In this presentation, we assess the additional information these new satellite products bring, with respect to altimetric and in situ measurements, for tropical ocean circulation. The region is the North Equatorial CounterCurrent (NECC) region, between 0° and 15°N in the tropical Atlantic. The NECC is an eastward current which plays an important role in transporting surface warm waters from western to eastern Atlantic and thus in impacting the climate of the neighbouring countries.

We first compare the characteristics of SMOS SSS time and space variability to ARGO ones. For instance, the tropical Atlantic Intertropical Convergence Zone (ITCZ) is tracked using the SSS minimum. Both SMOS and ARGO data succeed in showing expected latitudinal displacement over the basin during the year.

A singular value decomposition between SSS and altimetric dynamic topography (ADT) indicates the dominance of a single mode which explains ~90% of variability at a seasonal scale. This mode is clearly related to this latitudinal migration. The SSS data are analyzed together with geostrophic currents computed from altimetric ADT to infer the NECC variability. It reveals that the NECC is in Sverdrup balance not only east of 32°W as hypothesized by previous studies, but from ~40°W until ~20°W. Double NECC cores structure is also depicted in this analysis and related to different ITCZ characteristics.

Generating SMOS Sea Surface Salinity Maps with the Help of Data Assimilation

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Since its launch in November 2009, the Soil Moisture Ocean Salinity (SMOS) satellite has been sending measures of the brightness temperature emitted by the earth surface at the microwave L-band. This information is being used to retrieve values of the sea surface salinity (SSS) and soil moisture. A hierarchy of SSS products has been defined in the SMOS data processing chain. This work focuses on the so called Level 3 (binned maps of SSS) and Level 4 (products combining SMOS data with any other source of information).

In this work it is proved that a simple, but robust, data assimilation technique may be used to produce Level 4 maps of SSS by assimilating Level 3 SSS data. The numerical ocean model used here is a regional simulation of the North-Atlantic ocean. The resulting SSS is closer to in-situ (independent) SSS estimates, and the geophysical distribution of the singularity exponents has similar features that to the ones present in the singularity maps of sea surface temperature.

The ESA SMOS+SOS Project: Oceanography using SMOS for Innovative Air-Sea Exchange Studies

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We report on the work plan of the SMOS+Surface Ocean Salinity and Synergy (SMOS+SOS) project. SMOS+SOS is funded through the Support to Science Element (STSE) component of the European Space Agency's (ESA) Earth Observation Envelope Programme. The SMOS+SOS consortium consists of four organisations namely the National Oceanography Centre (UK), the LOCEAN/IFREMER/CATDS research team (France), the Met Office (UK) and Satellite Oceanographic Consultants Ltd (UK). The end of the SMOS+SOS project will be marked by a final open workshop most likely hosted by the UK Met Office in September/October 2014.

The project is concerned with demonstrating the performance and scientific value of SMOS Sea Surface Salinity (SSS) products through a number of well-defined case studies. The case studies include: Amazon/Orinoco plumes (freshwater outflow); Agulhas and Gulf Stream (strong water mass boundary); Tropical Pacific/Atlantic (strong precipitation regime); sub-tropical North Atlantic (ie SPURS; strong evaporative regime); and Equatorial Pacific (equatorial upwelling).

With SMOS measuring the SSS in the top cm of the ocean, validating SMOS against in situ salinity data taken typically at a few meters depth introduces assumptions about the vertical structure of salinity in the upper ocean. To address these issues, the project will examine and quantify discrepancies between SMOS and in situ sur- face salinity data at various depths in different regions characterised by strong precipitation or evaporation regimes.

Equally, data editing and spatio-temporal averaging play a central role in determining the quality, errors and correlations in SMOS SSS data. The project will explore various processing and spatio-temporal averaging choices to define the SMOS SSS products that best address the needs of the oceanographic and data assimilation user community. One key aspect of this project is to determine how one can achieve useful accuracy/uncertainty in SSS without jeopardising SMOS's ability to capture rapidly-varying or small scale features such as rain cells or the mesoscale variability associated with river plumes and major western boundary currents.

Finally, the study explores the ability of SMOS SSS to provide insights into new oceanographic processes when used in synergy with other data. Hence, synergy with Aquarius will be used to seek evidence of the possible impact of diurnal warming on the SMOS SSS data, and to explore differences in the salinity signatures of Tropical Instability Waves observed in the Pacific with SMOS and Aquarius.

Application of SMOS Ocean Salinity Data

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The application of SMOS ocean salinity data is new in modelling and impact assessment studies. The main challenge is low resolution of SMOS data, restricting direct applications in local and regional studies. However, combined with other data sources SMOS can provide very valuable information on salinity parameter already used in suitability modelling for aquaculture, the Co-Exist EU FP 7 framework project. Two more applications are proposed and still pending, on using SMOS in Building with Nature and assessment of spatial and temporal changes in seasonal dynamic of primary production at Caribbean Netherlands, Bonaire, Saba and St Eustatius. To extent regional application, the SMOS data is provided to East China Sea Fisheries Research Institute, Chinese Academy of Fishery Sciences, to analyze the relationship of salinity parameter and formation and development of fishing grounds.
It is anticipated to continue research on application of SMOS data, and to extent the promising results.

Spatio-Temporal Coherence between Spaceborne Measurements of Salinity and Light Absorption in the Amazone Plume Region

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Two of the major low salinity pools in the western part of the Atlantic basin are the Amazon and Orinoco river plumes spreading offshore from the South America North-eastern coasts, and influencing a large fraction of the western Tropical North Atlantic. The Amazon river discharges into the Atlantic Ocean at the equator with an approximate contribution of 16% of the global freshwater run-off. This results in large-scale low salinity 'lenses' at the Tropical Atlantic surface possibly traced over distances ranging from several hundreds up to thousands of kilometers at the ocean surface. These lenses are characterized by relatively small thicknesses as well as by distinct and strongly seasonal spatial extents. Tracking the temporal variability of their locations over synoptic scales is essential with regard to ecology, biogeochemistry and bio-optics. Primary production is indeed first stimulated by the nutrient inputs carried by the run-off of the rains over the land and by the flood of the larger rivers, and sinking fluxes will then results in carbon sequestration. As freshwater input by river decreases ocean surface salinity, it indeed reduces concentration of total inorganic CO2 and CO2 fugacity (fCO2). Undersaturations have been reported in the western Tropical Atlantic due to the influence of Amazon waters causing strong biological uptake. Several authors already identified a significant negative linear relationship between SSS and bio-optical parameters such as the diffuse attenuation coefficient at 490 nm (K490) and the absorption coefficient for dissolved organic and detritus material (CDOM) originating from river discharge in the Tropical Atlantic. High correlations generally found in the equatorial region between biogeochemical and bio-optical parameters (fCO2, Chl, K490, CDOM) and SSS thus further stresses the need for high spatial and temporal resolution SSS data. Analyzing SMOS data, we can unambiguously detect the Amazon plume water in the measured SMOS brightness temperatures. Distinguished surface signatures corresponding to very low salinity, below 32 psu, are generally associated brackish water from the river. SMOS data can then be used in conjunction with Altimetry, SST and ocean color data to better characterize the Amazon and Orinoco plumes seasonal cycle evolution. As demonstrated, this helps first, to document the spatial coherence between Amazon discharge, SSS, CDOM, and the nature of the salinity-CDOM relationship, second, to obtain the temporal and spatial variability of CDOM along the trajectory of the low-salinity Amazon plume, and third, to explore the departure from conservative mixing behavior along the plume trajectory into the open ocean.

Reconstruction of Decadal Time Series of Sea Surface Salinity in the Amazon River Plume using SMOS and MODIS/Aqua Data

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A robust relationship between spectral normalized water leaving reflectance (Rrs) and sea surface salinity (SSS) in the Amazon river plume was established using neural network approach. The neural network was trained and tested on SMOS L3 weekly data taken during August of 2010, 2011 and 2012 and on corresponding L2 MODIS data. The SSS/Rrs relationship is valid for range of SSS from 29 to 35 psu, for period of the highest rates of Amazon discharge into the ocean (July - October) with the average retrieval error of c.a. 1.5 psu. Errors of SSS retrieval from optical data were analyzed with regard to seasonal cycle of river discharge, MODIS and SMOS measurement accuracy, limitations of the neural network approach. A linear correction approach was developed for extrapolation of the found SSS/Rrs relationship on other months when concentration of DOC end-member in the riverine waters is different. The neural network and linear correction was applied to MODIS L2 data from the period 2002 - 2012 and monthly fields of SSS for August, September and October were reconstructed at 10 km resolution. Time series of SSS, plume area and shape were analyzed with regard to the Amazon discharge rates and behavior and fate of passing hurricanes.

Fusion of SMOS and Aquarius Level 3 SSS Maps by Spatial Optimization of the Error Matrix

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The retrieval of Sea Surface Salinity (SSS) with SMOS and Aquarius missions is very challenging, due to the limited sensibility of brightness temperatures in L-band to SSS. However, salinity is one of the worst known Essential Climate Variables and its acquisition is crucial for the full understanding of the water cycle and utterly of Earth's climate system.

Errors in SMOS and Aquarius acquisitions are of diverse origin: incorrect geophysical modeling, systematic antenna patterns, galactic noise, land-sea contamination, RFI sources, seasonal biases... In spite of all those problems the quality of SSS retrieval has increased steadily since the beginning of the missions.

Having two independent missions working with two different technologies has been beneficial in improving the quality of the maps of SSS. For instance, intercomparison of SSS maps from the two missions is very useful for the characterization of errors and biases. The question is hence posed of how to produce SSS maps of the best quality by an appropriate combination of both missions.

A simple point-wise average of SMOS and Aquarius maps leads to a small reduction of error, of order 2 on the variance (assuming that errors in SMOS and Aquarius are small). Point-wise average, however, is not capable to appropriately tackle with biases. In fact, point-wise averages only makes sense if errors are supposed to be spatially independent, and that the signals have no particular spatial structure. However, none of those two hypotheses are correct in general.

As SSS maps are strongly spatially correlated, the correlation matrix can be used to reduce the noise level. This is the basis for the Optimal Interpolation (OI) method. The main drawback associate to OI is the necessity of having good prior estimates of the background term and of the spatial correlation matrices what, in turn, implies having large prior datasets of SSS maps - what we are lacking of, in fact. Taking profit of having two independent estimates of SSS, as SMOS and Aquarius, can only be profited if we include the mutual correlation matrix - also very demanding in data. Alternative ways to improve the quality of SSS maps are use singularity-based fusion methods, but in that case we need a third variable of high quality (not necessarily of the same type: high resolution SST is usually employed to this end).

Having two independent variables such as the ones provided by SMOS and Aquarius allows for a different approach. If errors in SMOS and Aquarius were spatially decorrelated the optimal estimate of SSS would be the point-wise average of both variables, while the error on each of them will be given by half the difference of both SSS's, that we will call point-wise error estimate. However, the point-wise error estimate has significant two-point spatial correlations which decays like a power law with distance, what means that errors are correlated over significant distances.

In this presentation, we will show a method for obtain a better estimate of SSS by jointly minimizing error correlation on SMOS and on Aquarius which improves point-wise averages and gives more spatially consistent maps. We will discuss the role of biases in the minimization and how this can be employed to enhance the intercomparison.

South Atlantic Circulation and Salinity

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This presentation will summarize the preliminary advances of a collaborative US/Argentina research project that aims to use Aquarius sea surface salinity data to improve our understanding of the South Atlantic Ocean circulation, including its linkages to interocean exchanges, its response to hydrological cycles and its role in climate variability. Our research concerns aspects of both large-scale circulation and shelf-deep ocean exchanges. Our overall objectives are to discover new features of the South Atlantic circulation and to improve our understanding of its seasonal and inter-annual variations.

Cross-Frontal Exchanges of Salt in the Gulf Stream Monitored with SMOS Satellite

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With an unprecedented space and time resolution, SMOS surface salinity data now bring additional information on the evolution of the meandering Gulf Stream. Off Cap Hatteras, strong lateral gradients are caused by the convergence of subtropical water carried northward by the Gulf Stream with sub-polar water carried southward along the east coast of North America by the Labrador current. Stirred by mesoscale (50-100 km) and larger scale processes, SMOS observations help delineate meanders pinching off from the current to form Gulf Stream rings. Saltier (fresher) water parcels from the southern (northern) water masses are then trapped in these eddies, to further propagate in distinct ocean salinity environment on both sides of the stream. Horizontal stirring and vertical mixing processes are inextricably linked, but still poorly known. Comparison of SMOS data with in situ observations (ARGO, TSG) over year 2012 reveal an rms difference on the order of 0.5 to 0.7 in this region with reduced quality in water colder than about 12-13°C. The spatio-temporal patterns of SSS inferred from space are compared with Sea level height, temperature and chlorophyll patterns. SMOS data are shown to bring new insight into the near surface transport pathways by which salt is exchanged across the current boundaries and further carried out poleward in the North Atlantic and European waters. This is key to a better understanding of the 'conveyor-belt' thermo-haline oceanic circulation.

Satellite-based T/S Diagrams and Surface Ocean Water Masses

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Temperature-versus-Salinity (T/S) diagrams are characteristic property-versus-property plots traditionally used to emphasize the mutual relationships between these two variables with the aim of identifying and tracing water masses. Intensively used in oceanography, they basically capitalize on the broad collection of spatial and temporal in-situ measurements, principally from vertical profiles. In contrast, the purpose of this study is to rely on satellite measurements, which, despite the accuracy of the representation, benefit from synopticity and frequent temporal coverage. This study has become feasible thanks to recent satellite missions measuring Sea Surface Salinity (SSS), allowing derivation of spaceborne T/S diagrams through the concurrent availability of Sea Surface Temperature (SST) estimations. This study inherently relates to the horizontal surface section of T/S diagrams, which poses some challenges in interpreting results.

The Soil Moisture and Ocean Salinity (SMOS, [1]) and the Aquarius/SAC-D [2] satellite missions, through their estimation of SSS, provide a means to study, for the first time, the temporal variation of surface water masses on a global scale. The ESA SMOS mission, launched in November 2009, has been in its operational phase since May 2010. An iterative inversion scheme [3] provides SSS estimations (Level-2 product) from passive multi-angular MIRAS brightness temperatures (TB, Level-1 product) by minimizing the difference between measured and modeled TBs, employing constraints on the SST and wind speed auxiliary fields. The mission-prescribed Level-3 SSS accuracy, after adequate spatio-temporal averaging, is 0.1 pss over 2° x 2° boxes in 30 days.

As a parallel effort to SMOS, Aquarius/SAC-D is a US/Argentine combined active-passive mission, launched in June 2011 and operational since December 2011. Aquarius aims to estimate surface salinity fields with an accuracy of 0.2 pss, after temporally averaging over a month [4]. A crucial capability of Aquarius lies is the collocated roughness information provided by its L-band scatterometer, a necessary auxiliary parameter for proper SSS retrieval.

Characterizing the variability of satellite SSS in relation to the existing climatology is key to understanding 1) the unique information provided by SMOS and Aquarius SSS data and 2) the processes governing the distribution and variability of SSS. In [5], T/S diagrams derived from World Ocean Atlas (WOA) climatology are used to obtain surface baseline patterns for comparison to satellite-based T/S diagrams and analysis of geographical differences on a regular 1°x1° resolution grid for the month of September 2011. The approach used is to cluster water masses by appropriately splitting the oceans into seven regions using the 19 world ocean upper-water masses classification of [6]. This methodology allows the segmentation of the T/S maps into several geometric loci, for which differences in each class have been analysed.

Subsequently, in [7], ad-hoc mismatch indices were derived to emphasize the SSS/SST deviations from climatology in terms of the combined modulus and angle (relative under/over-estimation in terms of SSS and SST). Additionally, several months of data were analysed to provide a first dynamic time-series view of the T/S diagrams in each region.

Currently, the T/S diagrams are produced from a growing ensemble of satellite datasets: 1) SSS data distinguished into binned and Optimally-Interpolated (OI) products, namely SMOS L3 and Aquarius L3; and 2) SST data from the Advanced Microwave Scanning Radiometer for Earth Observing System (AMSR-E) and WindSat instruments, as well as the Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA, [8]). In addition to WOA climatology, the satellite-based T/S diagrams are compared to ARGO-interpolated In Situ Analysis System (ISAS) fields [9]. Ongoing efforts address the interpretation of the geographical deviations in each region with respect to the baseline, refining mismatch indices and analysing different thresholds. In order to relate these mismatches to identifiable oceanographic structures and processes, additional satellite datasets of ocean currents, evaporation/precipitation fluxes, and wind speed are being super-imposed.

Future work will explore additional SSS and SST datasets, refine the water mass classification, and try to relate the surface T/S signal to the vertical structure and buoyancy-driven ocean circulation processes. Longer time series will help to identify seasonal to interannual variability and shifts or trends in surface water mass formation.

Eventually, comparison with ARGO-based T/S diagrams might provide evidence of SSS biases and errors currently experienced by the satellites (e.g., due to roughness models applied in the SSS retrieval or external noise sources, such as galactic noise, ionosphere, sun glint, or radio-frequency interference (RFI) [10]), and, in a wider context, may provide an alternative means for gaining insights into the oceanic branch of the hydrological cycle.

References

[1] Font, J., A. Camps, A. Borges, M. Martin-Neira, J. Boutin, N. Reul, Y. H. Kerr, A. Hahne, and S. Mecklenburg, "SMOS: The challenging sea surface salinity measurement from space," Proceedings of the IEEE, vol. 98, pp. 649-665, 2010.
[2] Lagerloef, G., "Satellite mission monitors ocean surface salinity, " Eos Trans. AGU, 93(25), 233, 2012.
[3] Zine, S., J. Boutin, J. Font, N. Reul, P. Waldteufel, C. Gabarró, J. Tenerelli, F. Petitcolin, J.L. Vergely, M. Talone, and S. Delwart, "Overview of the SMOS Sea Surface Salinity Prototype Processor," IEEE Trans. Geosc. Remote Sens, 46 (3), 621-645, 2008.
[4] Le Vine, D.M.; Lagerloef, G.S.E.; Torrusio, S.E.; "Aquarius and Remote Sensing of Sea Surface Salinity from Space," Proceedings of the IEEE , vol.98, no.5, pp.688-703, May 2010, doi: 10.1109/JPROC.2010.2040550.
[5] Sabia, R. et al., "Derivation of an Experimental Satellite-based T-S Diagram", Proceedings of IGARSS '12 (International Geoscience and Remote Sensing Symposium), Munich, Germany, July 2012.
[6] Emery, W. J., Water Types and Water Masses, Ocean Circulation, Elsevier science, pp 1556-1567, 2003.
[7] Sabia, R., J. Font, C. Donlon, M. Talone, D. Fernández-Prieto, E. Bayler, J. Ballabrera, G. Lagerloef, Y. Chao, "Preliminary Results on the Derivation of Satellite-Based T/S Diagrams,"AGU Fall Meeting, San Francisco, USA, December 2012.
[8] Donlon, C. J., M. Martin, J. D. Stark, J. Roberts-Jones, E. Fiedler and W. Wimmer, 2011. The Operational Sea Surface Temperature and Sea Ice analysis (OSTIA). Remote Sensing of the Environment. doi: 10.1016/j.rse.2010.10.017 2011.
[9] Gaillard, F., E. Autret, V.Thierry, P. Galaup, C. Coatanoan, and T. Loubrieu , 2009 : Quality control of large Argo data sets. JAOT, Vol. 26, No. 2. 337-351.
[10] Font, J. et al., "SMOS first data analysis for sea surface salinity determination," International Journal of Remote Sensing, Vol. 34, Iss. 9-10, 2013.

Artificial Intelligence Techniques for Downscaling SMOS Soil Moisture using MODIS Land Surface Temperature

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Statistical downscaling is an essential process to convert coarse domain satellite data into finer spatial resolutions for local/regional applications. In this study, three artificial intelligence techniques- Artificial neural network (ANN), Support Vector Machine (SVM) and Relevance Vector Machine (RVM) along with the generalised linear model (GLM) are used to improve the spatial resolution of Soil Moisture and Ocean Salinity (SMOS) derived soil moisture available at a coarse scale of ~40km. Moderate Resolution Imaging Spectroradiometer (MODIS) Land Surface Temperature (LST) is chosen for downscaling SMOS, because of its daily availability. Soil moisture deficit (SMD) derived from a hydrological model called Probability Distribution Model (PDM) is used to train the models and evaluate the downscaling performances. The performance indices for validation such as R2 and RMSE indicate that the ANN (R2=0.751; RMSE=0.011), SVM (R2=0.700; RMSE=0.013), RVM (R2=0.698; RMSE=0.013) and GLM (R2=0.698; RMSE=0.013) models are very promising for downscaling as compared with the original SMOS data (R2= 0.418; RMSE=0.017) with the best performance achieved by the ANN model.

First Results of Aquarius SSS Data Assimilation in the Mercator Ocean System.

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An important issue for ocean forecasting systems is the occurrence of sea surface salinity (SSS) bias at various scales which comes from ocean model errors and forcing uncertainties, mainly precipitations. It is not yet possible to fully remove SSS biases with the Argo network data near the surface (depth < 5m) due to a poor sampling. That is one of the reason why Mercator Ocean investigates the best way to deal with SSS data from space (SMOS and Aquarius) by taking into account different errors associated with different scales and possibly fill this data gap. Since several years, Mercator Ocean has designed and built a hierarchy of ocean analysis and forecasting operational systems delivering weekly and daily services in real time. The ocean and sea ice models are based on the NEMO/LIM codes. The data assimilation algorithm relies on a reduced-order Kalman filter with a 3D multivariate modal decomposition of the forecast error. Altimeter data, satellite sea surface temperature (SST) data and in situ temperature and salinity vertical profiles are jointly assimilated. In this study, we show that by assimilating Aquarius SSS data, a complementary information is brought. First results with the global 1/4° system show to what extent it should be possible to improve the meso-scale prediction and to correct sea surface salinity (SSS) bias.

Tropical Atlantic salinity variability: new insights from SMOS

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Observations from the SMOS satellite are used to reveal new aspects of Tropical Atlantic sea surface salinity (SSS) variability. In the Tropical Atlantic, the salinity balance is expected to be influenced by variations in precipitation and evaporation associated with the north-south movement of the Intertropical Convergence Zone (ITCZ) and outflow from two of the largest global river systems, the Amazon/Orinoco and Niger/Congo. Therefore, we initially use the first full year, 2010, of SMOS SSS observations in combination with the latest version of the GPCP precipitation (P), the OAFlux evaporation (E) and river flow (R) from the Dai and Trenberth and the ORE-HYBAM datasets, to determine SSS changes throughout the annual cycle and investigate the key processes that control this variability in this region. The Tropical Atlantic has a relatively constant salinity throughout the year 2010 varying by just 0.08 pss when averaged over the region as a whole. However, strong local variations are evident at two poles on opposite sides of the basin

that are close to the outflows from the Amazon/Orinoco and Congo/Niger river systems. The SMOS measurements reveal large amplitude seasonal cycles up to 6.5 pss at these two 'poles' that are out of phase by 6 months and compensate each other in their influence on the whole region's mean salinity. The western sub-region shows a clear relationship between SSS, P and R; SSS varies in-phase with P and lags R by 1-2 months (E has little seasonal variability). In contrast, a more complex relationship holds for the eastern pole. Moreover, the amplitude of the seasonal cycle in SSS for the full region doubles to about 0.16 pss if either pole is excluded from the full regional mean, indicating the sensitivity of the Tropical Atlantic salinity budget to their influence. Variations in the amplitude or phasing of the salinity variability in either pole thus have the potential to significantly modify Tropical Atlantic SSS with consequences for higher latitude Atlantic circulation. Such variations may be expected as result of natural variability (e.g. through the influence of El Niño) and anthropogenic climate change. Thus, our analysis next considers whether the seasonal compensation of SSS between the eastern and western poles of the Tropical Atlantic is an isolated event in 2010 or may continue to hold at multi-annual timescales. Among others, our novel results clearly demonstrate the potential of harnessing satellite data alone for the two principal fields of SSS and P to develop our understanding of controls on SSS, and their value in monitoring salinity variability over Tropical regions that have the potential to influence the larger scale ocean circulation.

Using SMOS Data to Evaluate AMSRE and WINDSAT C-Band Radiometer Salinity Inversion in River-Influenced Basins

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This study follows on from an earlier demonstration in the tropical NW Atlantic where AMSRE ocean radiometer measurements were used to infer salinity mapping across the plume of the Amazon River. Now, using weekly and monthly SMOS sea surface salinity products, one has a much expanded ground truth dataset to help improve upon and quantify inversion performance. We report on new results in the warm ocean waters (T > 26 degC) with a focus on the Amazon plume and Bay of Bengal regions. Recalling that C-band sensitivity to salinity is at least 10 times weaker than for the L-band SMOS or Aquarius instruments, these efforts are considered to be potentially complementary in coastal regions and for enhanced understanding and verification of flat surface emissivity models currently employed in community radiative transfer models. Here, WINDSAT data are added into the approach with two objectives being enhanced data coverage and solidification of the C-band SSS inversion approach. This includes looking at potentially systematic errors in the requisite atmospheric corrections that impact surface brightness temperature estimates. Data across the year 2010 are used to evaluate empirically-observed wind, SST and salinity dependence in both X-band and C-band data and to develop a SMOS-informed algorithm training set. Combined AMSRE/WINDSAT mapping of SSS for these regions will be discussed.

Session 5 Beyond Salinity: Soil Moisture, Storms and Cryosphere

Microwave Remote Sensing Sensors On-Board Satellites Tracks Cyclone Thane: SMOS and OCEANSAT-II

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Natural Disasters occur frequently around the world, and their incidence and intensity seem to be increasing in recent years. Millions of people living in the coastal areas of the west Atlantic, east and south Pacific and north and south Indian Oceans, regularly face the hazards of cyclone, also known as hurricane in the Western Hemisphere, typhoon in the western Pacific, willy willy near Australia and Baguios in the Philippines. These disasters often cause significant loss of life, large-scale economic and social impacts, and environmental damage.

Tropical Cyclone is a generic term for a warm-core low pressure system that forms in the tropics or subtropics. The North Indian Ocean is a potentially energetic region for the development of cyclonic storms. The occurrence of tropical cyclones is not as many as in other basin but overall contribution is around 7% for Bay of Bengal and at the same time Arabian Sea contributes about 2% of the annual tropical cyclones. Most of the tropical cyclone causes loss of human life and property. Hence, the accurate and correct prediction, track and intensity forecast are essential.

The detection of cyclones is a difficult issue when done manually. Satellite digital photography and data makes it possible to carry out such task by aid of modern remote sensing technique and computer means of processing. Microwave Remote Sensing satellites are best used as a tool for tracking and identifying cyclones due to their unique all weather penetration capability.

In year 2011 Cyclone Thane was the strongest tropical cyclone on record in the North Indian Ocean. Cyclone Thane developed as a tropical disturbance within the monsoon, to the west of Indonesia. Over the next couple of days the disturbance gradually developed further while moving towards the northwest, and was declared a depression during December 25, before being declared Cyclonic Storm. It was a cyclone with wind speed of 140 kmph, and waves measuring 1.5 meters height resulting in heavy loss of life and property.

In this paper identification and tracking of Cyclone Thane has been done using the Brightness Temperature data provided by Soil Moisture Ocean Salinity (SMOS) as well as wind speed (WS) data. SMOS L-band radiometer sensor has the unique ability to see through clouds and rains to provide reliable estimates of the surface brightness temperature and wind speeds under extreme storms. The quality of the SMOS high wind speed is being verified with the additional data set from Ku band scatterometer working at 13.515 GHz onboard Oceansat-2 satellite. The analysis is done for ten days starting from 20-12-11 to 30-12-11 in order to map the track of the cyclone. This analysis positively demonstrates the strong potential of L-band radiometers for ocean surface monitoring in cyclone conditions.

Preliminary Analysis of Aquarius Data for Cryospheric Applications

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The poster will illustrate some initial analysis of Aquarius data over the polar regions. In order to take advantage of Aquarius capability of collecting spatially and temporally co-located active and passive microwave measurements at different polarizations, both brightness temperature and backscattering coefficient are analyzed. In particular, the behavior of passive and active polarization ratios is considered. In addition, the standard deviation of the raw radiometer and scatterometer samples, that are averaged together to derive the antenna temperatures and backscattering coefficients, is also used in the investigation. The analysis includes discrimination between water and sea ice, correlation with sea ice concentration, classification of first-year ice and multi-year ice, and sensitivity to snow depth over sea ice.

Comparisons are made with different data sets and algorithms, including the National Centers for Environmental Prediction (NCEP) sea ice concentration analysis [1], the Nasa Team 2 algorithm [2], the National Ice Center Arctic Sea Ice Charts [3,4], and the Canadian Ice Service digital archive [5]. Results are presented in the form of correlation plots, analysis of individual Aquarius orbits, temporal evolution, and maps of spatial distribution.

References .

1. R.W. Grumbine, "Automated passive microwave sea ice concentration analysis at NCEP", NCEP/EMC/OMB Tech. Note 120, March 1996. .
2. T. Markus and D.J. Cavalieri, "An enhancement of the NASA Team sea ice algorithm," Geoscience and Remote Sensing, IEEE Transactions on , vol.38, no.3, pp.1387-1398, May 2000. .
3. F. Fetterer and C. Fowler," National Ice Center Arctic Sea Ice Charts and Climatologies in Gridded Format" (Digital Media). National Snow and Ice Data Center, Boulder (CO), USA, 2006 .
4. S.R. Helfrich et al., "Enhancements to, and forthcoming developments in the Interactive Multisensor Snow and Ice Mapping System (IMS)", Hydrological Processes 21, pp. 1576–1586, 2007. .
5. Environment Canada, "Manual of Standard Procedures for Observing and Reporting Ice Conditions (MANICE)", Meteorological Service of Canada, 2005

Retrieval and Validation of Sea Ice Thickness from SMOS-Data using Polarisation Information

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Sea ice is one of the essential climate components as suggested by the World Meteorological Organization (WMO). The sea ice concentration has been observed with passive microwave instruments on satellites since more than 30 Years. The lower the frequency, the lower is the atmospheric influence and the higher is the effective penetration depth of the microwave radiation into the sea ice. Satellites observing at L-Band (1.4 Ghz) such as SMOS and Aquarius are able to retrieve the thickness of the Arctic sea ice up to about half a meter. We developed an algorithm using polarisation and intensity information at 40° to 50° degree incident angle to estimate the sea ice thickness in the freezeup season from SMOS data. An operational product using SMOS L1C data is provisional validated with other instruments (MODIS, AMSR-E), modeled (HIGHTSI, TOPAZ) and in-situ (Airborne EM-Bird from April 2012) data. A near real time processing chain using ESA provided BUFR data delivers daily sea ice thickness data since Oktober 2012.

Retrieval of Snow Thickness over Thick Multi-Year Sea Ice using SMOS Data

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In L-band, the radiation measured above sea ice originates from considerably deeper parts of the ice than the radiation measured by previous passive microwave sensors, which operate at higher frequencies. Thus, L-band brightness temperatures measured with SMOS can be used to retrieve sea ice thickness up to about 50cm under cold conditions in the Arctic. Until now, ice thickness has been retrieved from SMOS brightness temperatures using a dielectric slab model for one ice layer. However, this one ice layer model neglects a potential snow layer on the ice and we use a multiple layer model instead to theoretically examine the impact of a snow cover on the brightness temperature of sea ice. Although snow is assumed to be almost transparent in L-band, we find that snow has a twofold impact on the brightness temperature of sea ice. On the one hand, snow has a thermal insulation effect on ice; the bulk ice temperature of snow-covered sea ice is generally higher than the ice temperature of bare sea ice. Because the ice temperature determines the dielectric properties of ice, snow thus alters the brightness temperature of sea ice. On the other hand, the self-emission of snow particularly impacts the horizontally polarised brightness temperature of sea ice. In order to test the validity of our theoretical considerations, we use our multiple layer radiation model to simulate brightness temperatures and we compare these simulated brightness temperatures with SMOS measurements. Here, we show the results of our brightness temperature simulations for ice and snow thicknesses measured during NASA's Operation IceBridge flight campaign in spring 2012 in the Arctic. The horizontally polarised SMOS brightness temperatures correlate well with the simulated ones, and the root mean square deviation between the SMOS measurements and the simulations reduces from more than 20 K to about 4 K, when the radiation model with only one ice layer is replaced by the model that also includes a snow layer. The IceBridge measurements were mainly carried out over sea ice with thicknesses higher than the maximum retrievable thickness and there is no information on ice thickness in the SMOS brightness temperatures. However, we find that due to the thermal insulation effect of snow and the brightness temperatures' dependence on the ice temperature, the SMOS measurements contain information on the thickness of the snow layer. Here, we show the potential for the retrieval of snow thickness from SMOS brightness temperatures over thick Arctic multi-year sea ice.

Comparison of SMOS and SMAP Retrieval Algorithms Based on In Situ L-Band Observations at the VAS Site

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The objective of this study was to compare several approaches of Soil Moisture (SM) retrievals from L-band microwave radiometry. The comparison was based on a brightness temperature (TB) data set acquired by the L band radiometer ELBARA-II over a vineyard field. ELBARA-II, developed by ESA within the cal/val SMOS scientific program, was set up on a 17 m tower at the VAS site, close to Valencia, since 2010 (Schwank et al., 2012; Wigneron et al., 2012). The instrument was programmed to register brightness temperature in horizontal and vertical polarization for a range of incidence angles (30°-60°). Based on this 3 year data set (2010-2012), several SM retrieval approaches developed for SMOS, AMSR-E and SMAP were compared. The methods include:

-the 2 parameter (SM and TAU) retrieval method based on multiangular observations and developed for SMOS (Wigneron et al., 2000, referred to as 2P-LMEB)

-the Single Channel Algorithm (SCA) for horizontal (SCA-H) and vertical (SCA-V) polarizations, and the Dual Channel Algorithm (DCA) as described in the NASA SMAP Algorithm Theoretical Basis Document (O'Neill et al., ATBD, 2012). SCA-V and SCA-H require additional information about the vegetation dynamics to estimate the vegetation optical depth TAU from optical remote sensing sensors.

-the Land Parameter Retrieval Model (LPRM) proposed for AMSR-E (Owe et al. 2001)

In addition, two simplified methods based on statistical regression were tested : linear regressions proposed by Saleh et al. (2006) and Mattar et al. (2012) (referred respectively to as 'Saleh' and 'Mattar' methods). In this study, measurements of NDVI required for three algorithms (SCA-H , SCA-V and Mattar) were obtained from MODIS time series. A reference for Soil Moisture values was required in this study. It was assumed that this 'reference' SM data set was obtained from the multiangular 2P-LMEB algorithm. Roughness in all methods was parameterized according to Wang and Choudhury et al. (1981). The values of the roughness parameters HR & QR were computed from in-situ measurements of correlation length and standard deviation of heights based on the equations developed by Lawrence et al. (2012). The formulation developed by Mironov et al. (2009) was used to estimate the soil dielectric constant.

The results obtained with the current base line algorithm developed for SMAP (SCA-H) are in very good agreement with the 'reference' SM data set derived from the multi-angular 2P-LMEB method ($R2=0.92$, bias=-0.04 m3/m3, RMSE=0.08 m3/m3). This result shows that the SCA-H algorithm, based on observations for one angle and one polarization and additional information from MODIS, can provide results very close to SMOS for this typical Mediterranean crop. The other algorithms were found to be slightly less successful in retrieving the 'reference' SM time series, especially when the vegetation was well developed (end of spring and summer period). All results for the different methods are presented and discussed, in the context of the improvement & development of the SM algorithms for SMOS, Aquarius and SMAP.

Using Current and Future L-Band (1.4GHz) Missions for Sea Ice Thickness Retrieval

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In the past three decades average sea ice thickness in the Arctic has dropped dramatically. Furthermore the loss of summer ice is more rapid than any model predictions. This new con- ditions enable the usage of new sea routes such as the Northwest Passage, and exploitation of natural resources. Satellite sea ice products based on passive microwave are well estab- lished navigation aid. Those techniques are useful in estimating ice concentration however, the thickness measurements pose more difficulties. L-band missions: ESA SMOS, NASA Aquarius, NASA SMAP could supplement this data with direct measurements of the sea ice thickness up to 0.5 m. This thin sea ice is important from the scientific point of view, since it controls the gas and heat exchange in Ocean - atmosphere system. Knowing the thickness of the ice together with its concentration will also allow to extend the short navigation season for vessels with strengthened hull. Promising results presented by Kaleschke et.al 2012 [1,2], encouraged me to make a general study of possible advantages and disadvantages of each mission with respect to sea ice measurements. Although none of those missions was originally designed for this particular purpose such usage of the data could be an interesting scientific and commercial project.

Tropical Storm Monitoring with SMOS Sensor: An Overview of the SMOS+STORM Project

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The Soil Moisture and Ocean Salinity (SMOS) mission provides multi-angular L-band (1.4 GHz) brightness temperature images of the Earth. Because upwelling radiation at 1.4 GHz is significantly less affected by rain and atmospheric effects than at higher microwave frequencies, the SMOS measurements offer unique opportunities to complement existing ocean satellite high wind observations that are often erroneous in these extreme conditions. In this talk, we shall provide an overview of the results of the SMOS+STORM STSE project which aimed to exploit the identified capability of SMOS L1 Brightness Temperatures to monitor wind speed and whitecap statistical properties beneath Tropical Cyclones and severe storms. Such new capability at the core of the project was recently demonstrated by analysing SMOS data over the category 4 hurricane IGOR that developed in September 2010. Without correcting for rain effects, the wind-induced components of SMOS ocean surface brightness temperatures were co-located and compared to observed and modelled surface wind speed products. The evolution of the maximum surface wind speed and the radii of 34, 50 and 64 knots surface wind speeds retrieved from SMOS were shown to be consistent with hurricane model solutions and observation analyses. During the project this feature has been extensively verified in other cases (such as for hurricane SANDY in 2012), with the aim of producing a SMOS-derived storm catalogue. The SMOS sensor is thus closer to a true all-weather ocean wind sensor with the capability to provide quantitative and complementary surface wind information of great interest for operational hurricane intensity forecasts. As an additional application, the relevance of using SMOS salinity measurement for assessing hurricanes strength intensification and decline over waters were upper ocean density stratification is salt-driven (barrier-layers over the Amazon-Orinoco river plumes, Bay of Bengal,..) has also been analysed. We shall present an overview of these new capabilities.

Impact of Icebergs Size on SMOS Brightness Temperature Measurements

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Tracking iceberg positions can be important for safety and navigation reasons as well as for understanding many geophysical, chemical and biological processes. For example, icebergs affect shipping lanes, outline ocean currents, and influence biological productivity. The impact of an iceberg on its environment is related to iceberg properties such as physical size, spatial orientation, relative velocity, and composition. Because of the importance and scope of these parameters, an understanding of iceberg processes is necessary.

In this analysis, we present a study which aimed to evaluate potential relationships between the size of the iceberg and the shape of polarimetric characteristics obtained with multi-angular SMOS measurements.

Presented case study review three examples of icebergs spotted and tracked by SMOS in the Southern Hemisphere along the coasts of Antarctica. Even though, examined three examples can be categorised as the massive icebergs, their sizes vary, what has a direct impact on acquired SMOS polarimetric characteristics.

Using derived set of brightness temperatures observations for B15-J, C19-C and B15-F icebergs, the scope of conducted analysis is to estimate minimal size of drifting iceberg, that can be detected by SMOS. Furthermore, the study defines the range of L-band brightness temperature values, typical for drifting icebergs and briefly summarizes dynamics of observed iceberg motion.

SMOS Derived Sea Ice Thickness in the Polar Regions

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Thin ice plays an important role in the Arctic ocean-atmosphere heat exchange. The steady and dramatic decline in the Arctic sea ice extent and thickness leads to less multi-year ice and more thin first year ice in the central Arctic. However, measurements of thin ice thickness are sparse and limited. L-band radiometer on board SMOS has a large penetration depth in sea ice. A previous study has demonstrated the possibility to derive sea ice thickness up to half a meter from SMOS brightness temperature under cold conditions. However, the semi-empirical retrieval algorithm used in the study made strong simplifications assuming constant ice temperature and ice salinity as well as closed ice cover. This can cause significant errors. Therefore, we improved the retrieval algorithm using a forward sea ice emissivity model coupled with a thermodynamic model including ice salinity, ice temperature, and ice concentration. Ice concentration is measured by passive microwave sensors. Ice salinity and ice temperature are calculated using the air surface temperature from atmospheric reanalysis data and the sea surface salinity climatology as boundary conditions. SMOS derived sea ice thickness is then compared and validated with MODIS-based ice thickness in the Kara Sea and EM-bird ice thickness measurements in the Laptev Sea. More than three years of daily average ice thickness is now available in NSIDC polar-stereographic projection with a grid resolution of 12.5 km at the University of Hamburg. This data set can be used in a sea ice forecasting system for ship route optimization or for the assimilation of sea ice in weather forecasting systems.

Freeze / Thaw Detection Using Aquarius' L-band Passive / Active Data

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The landscape freeze/thaw state dominates the seasonal cycle in high latitudes and provides a sensitive indicator of global climate change. The timing of the freeze/thaw transition influences critical processes such as land surface energy balance and carbon cycle dynamics related to vegetation growth. In this paper, we produce the daily freeze/thaw state classification map of 2011~2012 water year based on L-band radar and radiometer data from Aquarius. The Aquarius satellite carries a combined passive/active L-band microwave instrument that observes the Earth surface globally in a week. Data from Aquarius acquired over land are made use of in this study to extend the Aquarius applications to observations of large-scale land hydrologic and ecological phenomena. The spatial resolution of Aquarius swath is approximately 100 km and all three beams have been re-gridded into 36km resolution of Equal-Area Scalable Earth Grid (EASE-Grid) with incidence angle normalized to 40 degree. The daily freeze/thaw maps are averaging over 7 day moving window.

The active freeze/thaw detection algorithm described here is based on a seasonal threshold approach being developed for application to higher-resolution (3 km) radar measurements that will be provided by NASA's Soil Moisture Active/Passive (SMAP) mission (to be launched in October 2014). When the ground state changes between frozen and thawed states the soil and vegetation permittivities change significantly, and these changes are reflected in changes in microwave emissivity and backscattering from the surface. The passive algorithm is also based on the seasonal threshold but using the polarization difference of the two co-polarization brightness temperature.

Surface air temperatures from a distributed network of weather stations and the in situ data from SNOTEL stations are used as ground validation data to assess algorithm performance. The analysis of the Aquarius data will also support SMAP freeze/thaw algorithm development by providing a capability to assess L-band data in advance of the SMAP launch.

OTHER

Sharing the Importance of Ocean Salinity Beyond the Scientific Community

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Thanks to Aquarius, Soil Moisture and Ocean Salinity (SMOS), and the Salinity Processes in the Upper Ocean Regional Study (SPURS) expeditions, the scientific community is gaining unprecedented insight into salinity's role in science and society. In anticipation of data and findings from Aquarius and SPURS, NASA's salinity-related Education and Public Outreach (EPO) activities have focused on the themes of the water cycle, ocean circulation and climate. Examples will be shared of how these "public-friendly" themes have and will be applied to formal education through workshops, webinars, and dissemination of authentic salinity data.

Leading up to the launch of Aquarius/SAC-D in June 2011, international collaboration was necessary to develop key messages, create educational products, coordinate media opportunities, and facilitate the broader impacts of the mission's scientific goals. Collectively, the Aquarius/SAC-D mission was featured in more than 2500 news stories, through wire services, radio stations, television news broadcasts, and internet media. For SPURS, NASA held a "Media Day" event at Woods Hole Oceanographic Institution just prior to departure of the first U.S. expedition on 06-Sep-12. In terms of public outreach, the highlight of this SPURS mission was the extensive blogging effort spearheaded by Dr. Eric Lindstrom (NASA Physical Oceanography Program Scientist) during the monthlong cruise.

With good planning, products developed for public outreach can also be used for formal education at the upper primary and secondary levels. However, there are two crucial elements that foster the use of such materials in U.S. classrooms: (1) the subject matter must appear in the national science standards; and (2) educators must be properly prepared to teach that topic. Thanks in large part to several years of "ocean literacy" efforts by the Centers for Ocean Sciences Education Excellence (COSEE), the soon-to-be-published "Next Generation Science Standards" will likely specifically mention salinity in its "Earth Systems" standards.

In terms of teacher preparation, Aquarius has spent considerable effort to conduct, evaluate and refine effective professional development of formal educators, primarily though workshops and webinars. To ensure that the content is accurate, the EPO program has regularly involved research scientists in its teacher training programs and events. For example, a week before the launch of Aquarius/SAC-D, a three-day workshop for K-12 educators was held at the Jet Propulsion Laboratory (JPL) which featured NASA scientists who worked collaboratively with educators to examine connections between the water cycle, ocean circulation, climate and sea surface salinity. Prompted by the success of the pre-launch workshop, second event was held at JPL in November 2012. Together these workshops involved 95 educators and 11 scientists. Evaluation of both events revealed that 98% of educators agreed that, because of the workshop, they will "be more effective in teaching concepts" related to salinity and 97% planned to "use the resources" presented during the workshops.

Feedback from six webinars held between May 2011 and October 2012, including one Spanish-language event, revealed the potential breadth of audience for educational content associated with Aquarius. Each of these webinars used interactive concept maps, which "deconstruct" scientific content into simpler graphical formats, as the primary mode of presentation. Featured presenters included NASA research scientists (i.e., Yi Chao, Gary Lagerloef, David Le Vine), NASA Goddard Space Flight Center engineers (i.e., Amri Hernandez-Pellerano, Shannon Rodriguez, Fernando Pellerano) and formal educators (Susan Lozier, Duke University; Ted Taylor, Bangor High School, Maine). These webinars were directly attended by over 275 participants in 30 U.S. states and over 10 non-U.S. countries. Nearly all educators who responded to post-webinar surveys agreed that they could "immediately apply what they learned into their teaching about science, technology, engineering or mathematics (STEM)." Long-term access to these materials continues via online archives, greatly expanding the reach of the content. Based on the success of these events, a three-part webinar series is being held in conjunction with the March 2013 SPURS expeditions.

The release of Version 2 (V2) Aquarius data provides a great opportunity to leverage existing NASA portals designed for ease of data use by educators and their students. Two examples are MY NASA DATA (MND) and , NASA Earth Observations (NEO). MND's Live Access Server provides tools to generate charts, plots and graphs, along with a large number of lesson plans. NEO provides a repository of readily-accessible global data imagery highlighting NASA research in climate and environmental change. In addition, an engaging interactive globe is being designed for the Aquarius public webpage (aquarius.nasa.gov) which will feature monthly V2 data, points of interest (e.g., Amazon/Orinoco outflow, Cordoba ground station), and allow visitors to see the latest position of the Aquarius/SAC-D observatory.

The time is right to expand the synergistic use of salinity data from various sources to highlight key connections between the water cycle, ocean circulation and climate. Continuing to engage public and educational audiences with content from additional missions will reinforce the core themes that resonate with scientists and society.

Tools, Services & Support of Aquarius / SAC-D Data Distribution through PO.DAAC

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The Physical Oceanography Distributed Active Center (PO.DAAC) serves as the designated NASA repository and distribution node for all Aquarius/SAC-D data products in close collaboration with the project. Here we report on the status of Aquarius data holdings at PO.DAAC, observed patterns of usage of these data sets, and the range of data services and access tools that we provide in support of this mission. Particular emphasis is placed on new tools and services that have come online since the release of the validated v2.0 Aquarius data. These range from OPeNDAP and THREDDS data access services, to web-based visualization via PO.DAAC's State of the Ocean (SOTO) tool and LAS, to PO.DAAC's new, advanced L2 subsetting tool called HITIDE (High-level Tool for Interactive Data Extraction). Dataset discovery via the PO.DAAC web-portal, and user services are also described.