→ SMOS+ Surface Ocean Salinity

Oceanic Case Studies of SMOS Sea Surface Salinity measurements

Met Office

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

LOCEAN

Ifremer

CATDS

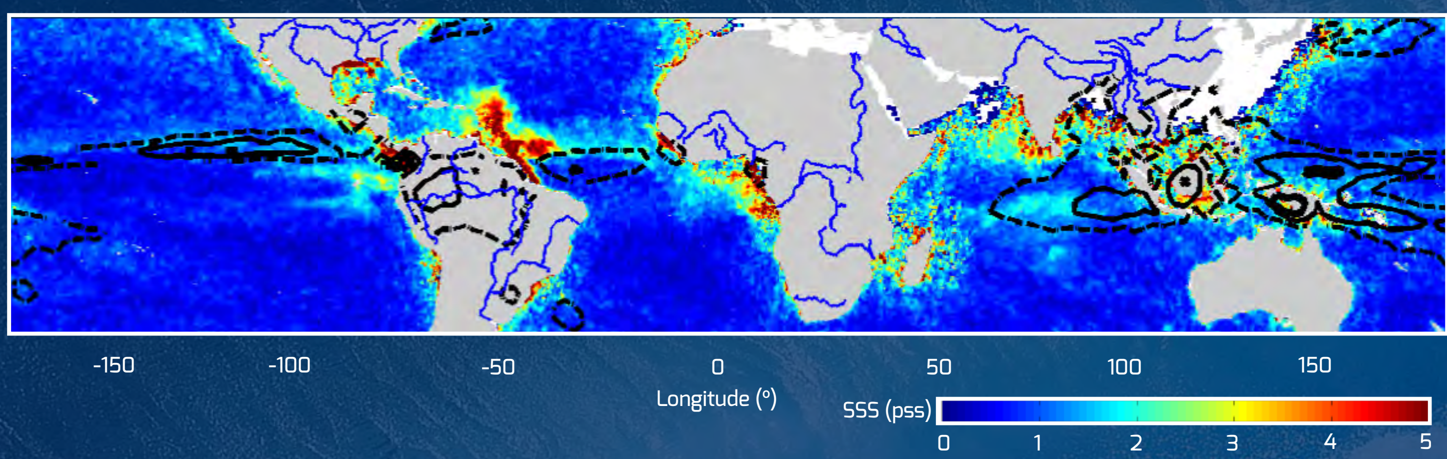
SATOC
SATELLITE OCEANOGRAPHIC CONSULTANTS

→ THE SMOS SATELLITE

Known as ESA's water mission, the Soil Moisture and Ocean Salinity (SMOS) satellite was launched in November 2009 as the first mission of its kind. The sensors make global observations of soil moisture over land, and sea-surface salinity over the oceans to improve our understanding of the water cycle. Data from SMOS is important for weather and climate modelling, water resource management, agriculture and also contributes to the forecasting of hazardous events such as floods.

→ SMOS+ SURFACE OCEAN SALINITY

SMOS+SOS is a project funded under the ESA STSE (Support to Science Element) programme to demonstrate the performance and scientific value of SMOS Sea Surface Salinity (SSS) products through five well-defined case studies. With SMOS measuring the SSS in the top centimetre of the ocean, validating SMOS against in situ salinity data taken typically at a few metres 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 surface salinity data at various depths in different regions characterised by strong precipitation or evaporation regimes.



NOC scientists are studying global variations in SSS annual range and comparing with precipitation from the GPCP project (black contours) as part of the product development and validation task of the project. The figure also shows the 8 largest rivers of the region in terms of annual discharge, according to Dai et al., 2009.

Ocean salinity is generally defined as the salt concentration in sea water. It is measured in unit of PSU (Practical Salinity Unit), which is a unit based on the properties of sea water conductivity.

This drifter buoy is one method of making direct measurements of salinity near the sea surface.

www.salinityremotesensing.ifremer.fr/sea-surface-salinity/definition-and-units

→ CASE STUDY 1: AMAZON / ORINOCO PLUMES

The Amazon river discharges about 16% of global freshwater run-off resulting in a large surface plume typically 3 to 20m deep. It is a very dynamic ocean region with strong gradients, and has been well studied using in situ and earth observation sensors. This case study is analysing the seasonal cycle and interannual variability of the freshwater plume signals in SMOS and complementary data sources.data taken typically at a few metres 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 surface salinity data at various depths in different regions characterised by strong precipitation or evaporation regimes.

REGION
South Atlantic: 70°W-30°W, 5°S-30°N

TIME PERIOD
2010 – 2012

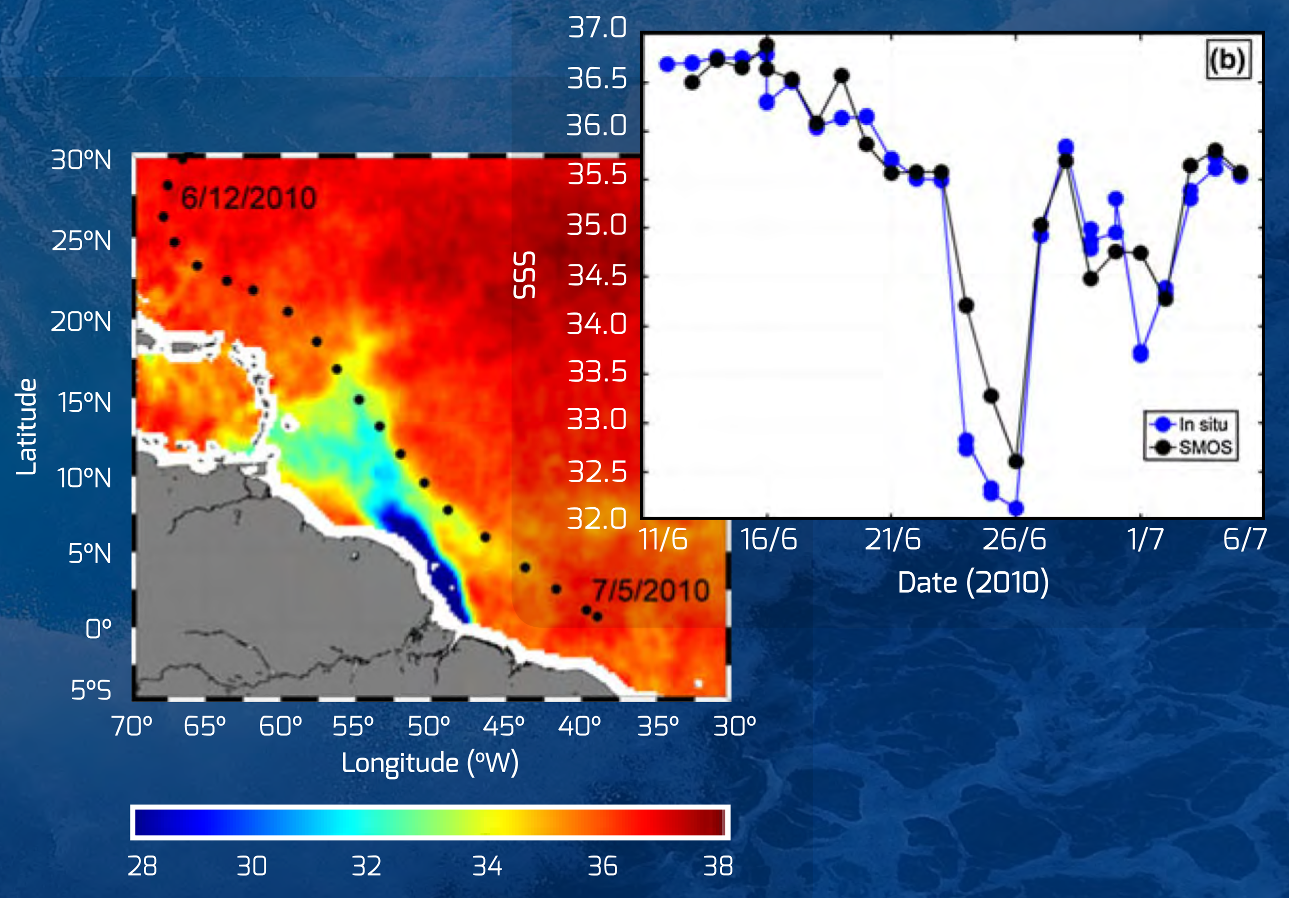
EXPERIMENTS

1. SMOS and Aquarius SSS quality assessment in the Amazon-Orinoco River Plume region.

2. Relashionships between SSS and vertical stratification in plume waters.

3. Monitoring advection pathways of the freshwater Amazon and Orinoco river plume along surface currents.

4. Spatio-temporal coherence between SSS and Ocean Colour properties over the Amazon-Orinoco river Plume.



Ifremer scientists are studying regions of high freshwater input such as Orinoco and Amazon river outflows. Comparison between satellite and 3-m depth in situ SSS data reveals an overall good agreement with a standard deviation of the difference SSSSMOS–SSSCTD of *0.45. In particular, the strong gradient and *3-unit drop observed as the R/V Pelagia leg crossed the Amazon River plume is well detected by the satellite observations.

New SSS products from satellite platforms such as SMOS allow in particular to gain insights into the advection pathways of the freshwater Amazon and Orinoco rivers plume along surface currents. For the first time, SMOS sampling capability thus enables imaging the plume structure almost every 3 days with a spatial resolution of about 40 km.

→ CASE STUDY 2: AGHULAS, GULF STREAM

Western boundary currents play a key role in global ocean circulation. They are dominated by rapidly evolving eddies and meanders with sharp boundaries between water masses. This case study will determine the usefulness of SMOS SSS to locate the position and intensity of SSS gradients in these two current regimes. The motivation is to assess the potential of SMOS data for assimilation in ocean forecasting models such as FOAM/NEMO.

REGION
Gulf Stream: 70°W-30°W, 5°S-30°N
Aghulas: 0°E-50°E, 45°S-20°S

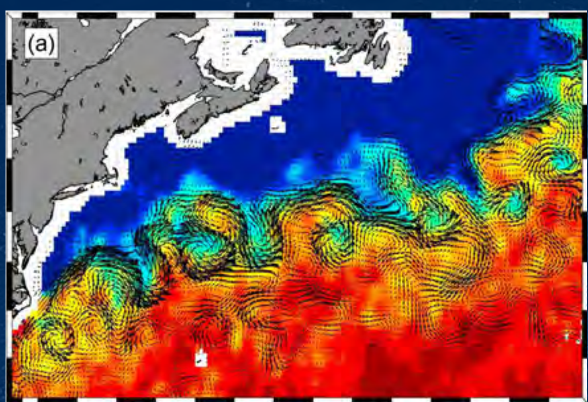
TIME PERIOD
1 December 2010 - 01 November 2012

EXPERIMENTS

1. Assessment of accuracy of FOAM, Argo, SMOS and Aquarius data.

2. Analysis of SSS gradients in Gulf Stream region.

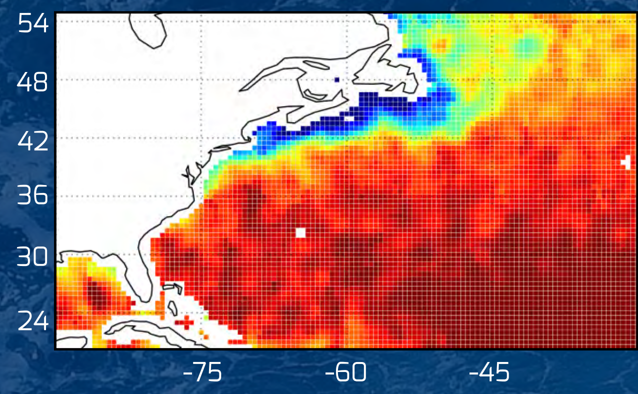
3. Analysis of SSS gradients in Agulhas region.



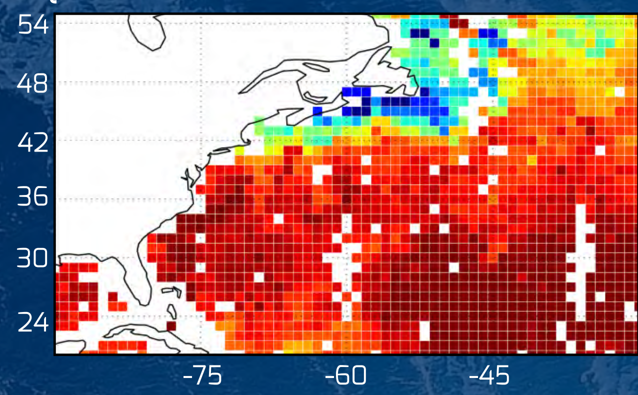
SMOS SSS averaged from 15 - 25 August 2012 with OSCAR surface currents indicated by black arrows.

Met Office researchers are working to understand various sources of salinity data (satellite and in situ) and performing the inter-comparisons necessary to prepare for assimilation of new data sources in ocean models. The figures show various estimates of the near-surface ocean salinity in the Gulf Stream region of the North Atlantic. The Argo data provide accurate salinity measurements with relatively sparse coverage; the two satellite instruments, SMOS and Aquarius, provide information with good spatial coverage but with less accuracy; the FOAM model provides good coverage at fairly high resolution and is able to provide forecasts. The various estimates provide useful information about the location of the high-resolution features of the Gulf Stream. The inter-comparison of all these data types in specific regions is the first step in understanding how the data might all be combined in a data assimilation scheme.

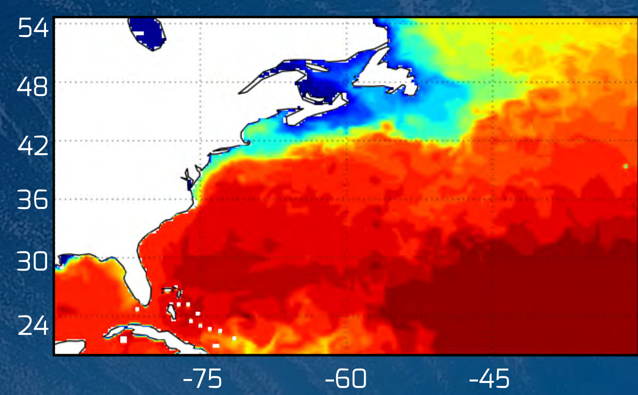
SMOS DATA FOR 5 DAYS CENTRED ON 20121130



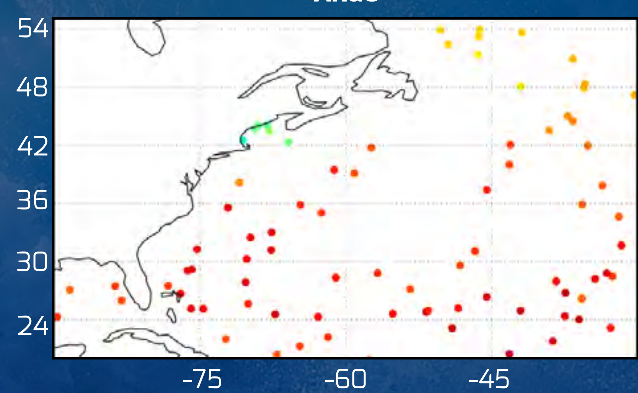
AQUARIUS DATA FOR 5 DAYS CENTRED ON 20121130



FOAM: SALINITY AT LEVEL 0 FOR 20121130

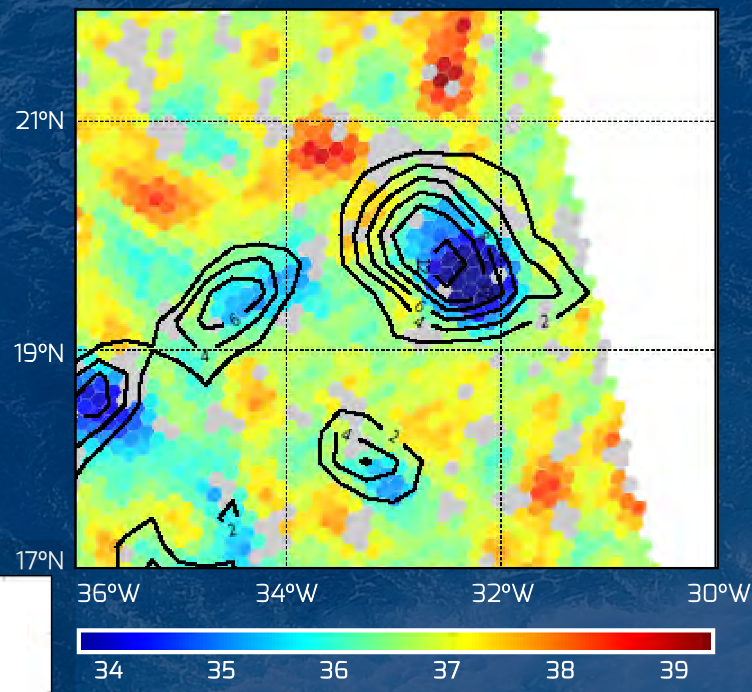


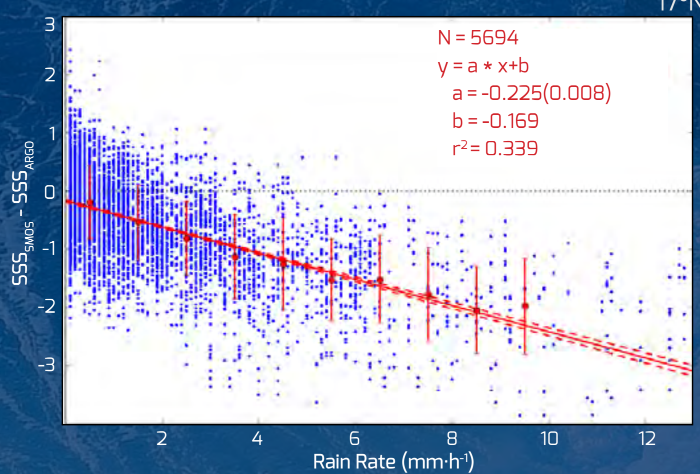
ARGO



→ CASE STUDY 3: TROPICAL PACIFIC & ATLANTIC

Tropical regions experience the highest rainfall, and there are large vertical salinity gradients after rain events. There is also evidence from these regions of long-term trends in SSS. This case study focuses on rain events using comparisons between SMOS data and in situ measurements.





REGION
Pacific: 120°E-70°W, 30°S-30°N
Atlantic: 70°W-10°E, 30°S-30°N

TIME PERIOD
2010 - 2011

EXPERIMENTS

1. SSS variability from SMOS and few metre depth in situ measurements.

2. SSS variability from SMOS and few cm-depth in situ measurements.

3. Upper ocean salinity stratification from SMOS, in situ and FOAM model.

LOCEAN researchers are working on evaluating the realism of the rain impact on sea surface salinity measured by SMOS. It is expected that just after a rain event, the top first centimeter salinity as measured by SMOS will be more affected than the salinity measured in situ at a few meters depth. However rain could also affect the physics of measurement in particular by changing sea surface roughness. The top figure illustrates the spatial variability of SMOS salinity associated with rain rate: SMOS SSS (color) and satellite rain rate (isolines from 2 to 12mm/hr) on 26 August 2012. The figure below shows SMOS minus ARGO salinity (at 10 days interval) versus SSM/I rain rate within [-30mn;+15mn] from SMOS measurement (see Boutin et al. 2014 for more details). In both cases, the observed variability of SMOS SSS linked to rain is clear and about 0.2 pss mm-1 hr. Our preliminary studies indicate that more than 70% of this variability is real, other effects (roughness, atmosphere) being relatively small. This should be deepened in the future using in situ measurements made at less than 50cm from the sea surface.

→ CASE STUDY 4: SUBTROPICAL NORTH ATLANTIC

The Salinity Processes in the Upper Ocean Regional Study (SPURS) is an ongoing experiment at JPL to study processes in the region of salinity maximum in the North Atlantic. This is a stable feature in the N Atlantic subtropical gyre, characterised by strong evaporation and intense surface heating. This case study compares SMOS measurements with in situ data and Aquarius satellite salinity measurements in this region.

REGION
North Atlantic: 50°W-20°W, 15°N-35°N

TIME PERIOD
2010 - 2012

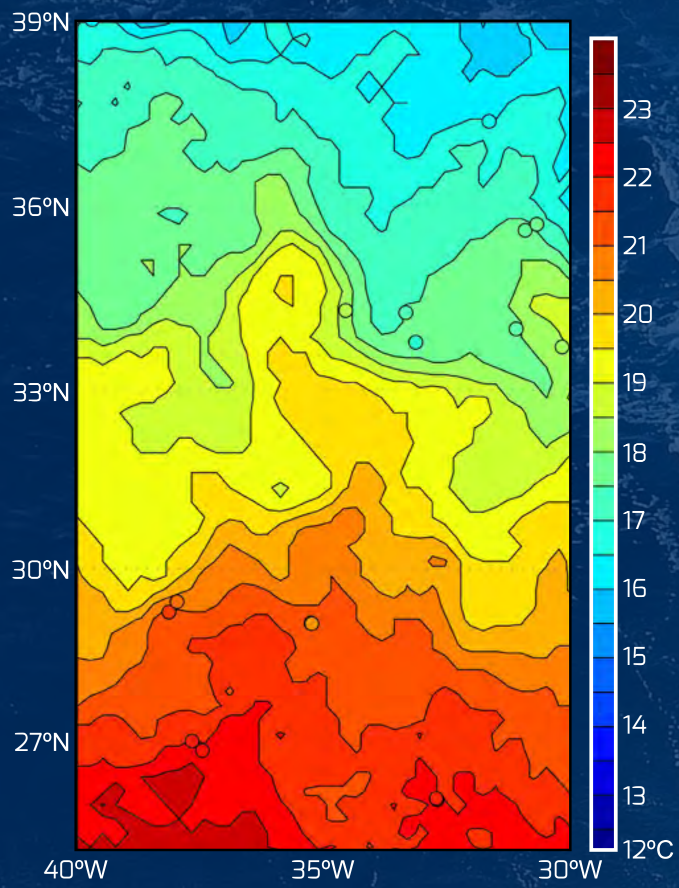
EXPERIMENTS

1. SMOS ascending-descending biases.

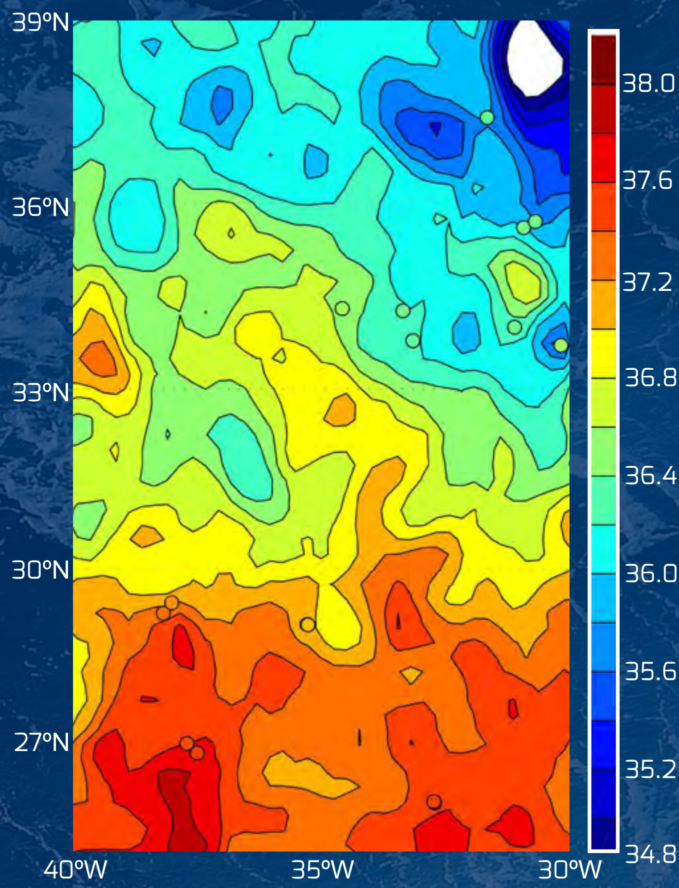
2. Aquarius ascending-descending biases.

3. *In situ* variability compared with SMOS/Aquarius.

TMI (.25° ~ 25km) – SST – 12-18 MARCH 2011



SMOS (100km) – SSS – 11-21 MARCH 2011



LOCEAN researchers study processes responsible for the sea surface variability in the subtropical and tropical north Atlantic Surface Salinity Maximum (SSM) region. This region has been particularly well monitored during the SPURS experiment and by ships of opportunity, offering a large set of in situ data very complementary to SMOS data. After having demonstrated that the sea surface salinity variability measured by SMOS is in very good agreement with in situ observations (rmse = 0.15pss) (Hernandez et al. 2014), they investigate the seasonal variability of the surface horizontal thermohaline variability from large to meso-scale. They study the horizontal fields of temperature and salinity from satellite measurements and the derived density.

In particular they show that during late winter, in north-eastern SSM, the thermohaline compensation is observed at large scale. At mesoscale, in the region of the Azores current/front (see Figure above), the satellite measurements reveal that in spite of large and sharp surface thermohaline fronts the density surface horizontal gradient is rather weak, as salinity and temperature variability compensates each other in term of density. (Kolodziejczyk et al. 2014).

This study illustrates the capability of SMOS data to detect mesoscale features in the open ocean.

→ WORKSHOP

The Ocean Salinity Science and Remote Sensing Workshop has been organised by the Project and will be held on 26th to 28th November 2014 at Met Office, Exeter, UK. This is an open meeting to review progress and future priorities for measuring ocean salinity.

- The meeting programme and discussion will be built around the following Themes:
- Sea surface salinity monitoring: past, present and future
- Complementarities between in situ and satellite SSS observing systems
- Salinity and the water cycle, including atmosphere/ocean/land/ice interactions and fluxes
- Salinity and ocean circulation (e.g. modelling, data assimilation, transports, upper ocean processes)
- Salinity and ocean biology (e.g. links with fisheries, primary productivity), biogeochemistry (e.g. CO2 fugacity) and bio-optics
- Salinity and climate monitoring / prediction
- Scientific challenges and priorities for salinity science

For more information, registration and abstract submission, visit: **oceansalinityscience2014.org**

→ CASE STUDY 5: EQUATORIAL PACIFIC

The equatorial Pacific is a region characterised by tropical instability waves and upwelling, and is important for ENSO cycles. Equatorial upwelling in eastern Pacific (cold tongue) is largest source of oceanic CO2 to the atmosphere, and results in strong salinity gradients at the boundaries. This case study looks at the signature of tropical instability waves and upwelling in SMOS data and performs comparisons with in situ data in order to asses the quality of SMOS salinity measurements.

REGION
Pacific: 120°E-70°W, 30°S-30°N

TIME PERIOD
2010 - 2011

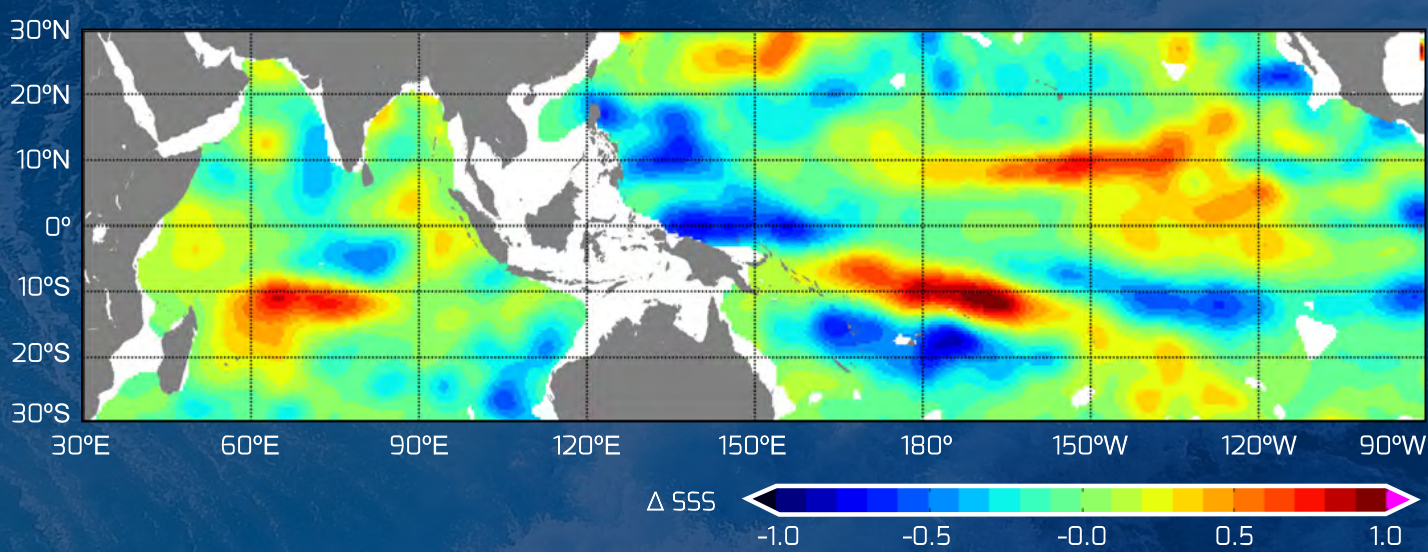
EXPERIMENTS

1. Assessment of SMOS SSS spatio-temporal variability

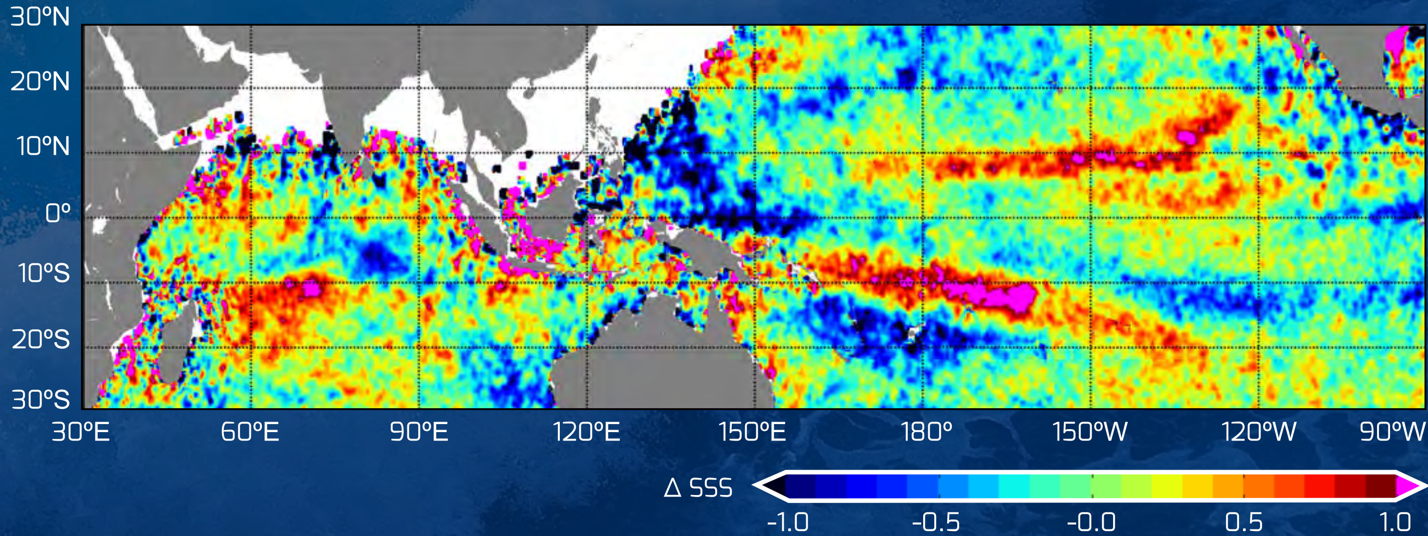
2. Signature of tropical instability waves (TIW)

3. SSS as a tracer of pCO2

ISAS 0.5° AT 3m DEPTH – JULY 2011-2010



SMOS L3LOCEAN 0.25° - ORBIT AD – JULY 2011-2010



CATDS researchers are working on the capability of SMOS data to detect large scale salinity anomalies. Figures above illustrate differences in the monthly averaged SSS between year 2011 and 2010 for month of July, linked to La Niña and Indian Ocean Dipole anomalies as derived from in situ optimal interpolation analysis products ISAS (top) (Gaillard et al. 2012) and from SMOS data (bottom) (Reul et al. 2013). While large scale patterns are remarkably well catched by SMOS, the amplitudes of the anomalies are larger on SMOS, partly because of rain induced vertical stratification but also because the in situ data interpolation smoothes the anomalies. The goal of this work is to better analyze processes behind this observed variability and to explore their possible links with other tracer (CO2) variability.

→ PROJECT PUBLICATIONS

The main scientific output of the project are peer reviewed science papers, of which a number are already published or accepted:

- Reul N., B. Chapron, T. Lee, C. Donlon, J. Boutin and G. Alory, Sea surface Salinity structure of the meandering Gulf Stream revealed by SMOS sensor, *Geophysical Research Letters, 2014.*
- Reul N., S. Fournier, J. Boutin, O. Hernandez, C. Maes, B. Chapron, G. Alory, Y. Quilfen, J. Tenerelli, S. Morisset, Y. Kerr, S. Mecklenburg, S. Delwart, Sea Surface Salinity Observations from Space with the SMOS Satellite: A New Means to Monitor the Marine Branch of the Water Cycle. *Surveys In Geophysics, 35(3), 681-722, 2014.*
- Fournier S., B. Chapron, J. Salisbury, D. Vandemark, and N. Reul, Spatio-temporal analysis of the conservative mixing between spaceborne measurements of sea surface salinity and optical properties in the Amazon plume, *submitted to Journal of Geophysical Research SMOS-Aquarius special issue, 2014.*
- Boutin J., N. Martin, G. Reverdin, S. Morisset, X. Yin, L. Centurioni, N. Reul, Sea Surface Salinity under rain cells: SMOS satellite and in-situ drifters observations, *submitted to Journal Geophys. Res.-Oceans, 2014.*
- Yin, X., J. Boutin, G. Reverdin, T. Lee, S. Arnault, N. Martin, SMOS Sea Surface Salinity signals of tropical instability waves, *submitted to Journal Geophys. Res.-Oceans, 2014.*
- Hernandez O., J. Boutin, N. Kolodziejczyk, G. Reverdin, N. Martin, F.Gaillard, N. Reul, and J.L. Vergely, SMOS salinity in the subtropical north Atlantic salinity maximum: Part I: Comparison with Aquarius and in situ salinity, *submitted to Journal Geophys. Res.-Oceans, 2014.*
- Kolodziejczyk N., O. Hernandez, J. Boutin, G. Reverdin, SMOS salinity in the subtropical north Atlantic salinity maximum: Part II: Observation of the surface thermohaline horizontal structure and of its seasonal variability, *submitted to Journal Geophys. Res.-Oceans, 2014.*
- Hasson A., T. Delcroix, J. Boutin, Formation and Variability of the South Pacific Sea Surface Salinity Maximum in Recent Decade, *Journal of Geophys. Res. – Oceans, doi: 10.1002/jgrc.20367, 2013.*
- Hasson A., T. Delcroix, J. Boutin, R. Dussin, J. Ballabrera-Poy, Analysing the 2010-2011 La Niña signature in the tropical Pacific sea surface salinity using in situ, SMOS observations and a numerical simulation, *submitted to Journal Geophys. Res.-Oceans, 2014.*

SMOS+ SOS is led by National Oceanography Centre, UK.
The Project Team includes Met Office, LOCEAN, Ifremer, CATDS and SatOC.

www.smos-sos.org
oceansalinityscience2014.org