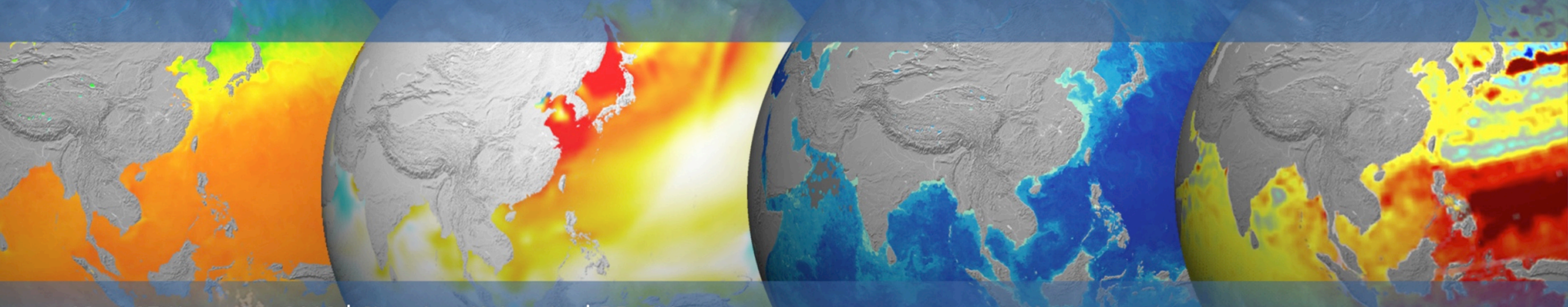
ESA–MOST China Dragon 4 Cooperation

→ ADVANCED TRAINING COURSE IN OCEAN AND COASTAL REMOTE SENSING



12 to 17 November 2018 | Shenzhen University | P.R. China

Sea Surface Salinity from SMOS data

Roberto Sabia – Telespazio/Vega UK for European Space Agency (ESA)

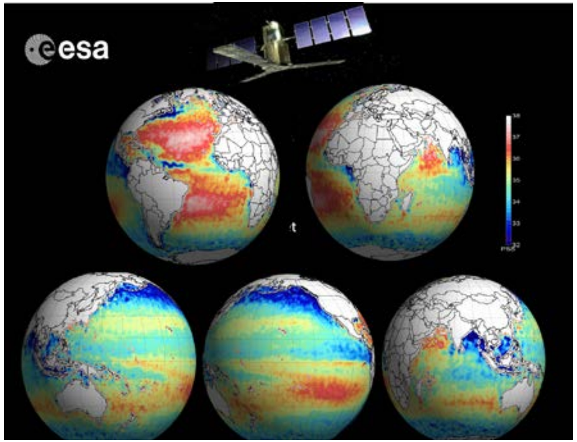
Hosted by

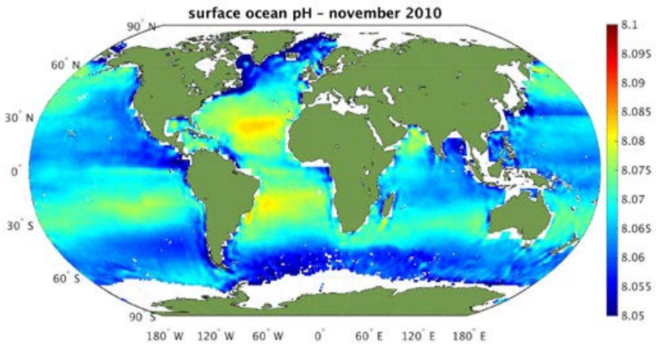
Course lectures/practical – R. Sabia

Mon 12 Nov, 16.00 – SSS from SMOS

Mon 12 Nov,, 17.00 – SSS using SNAP Pi-MEP and SMOS data (Practical)

Fri 16 Nov, 14.00 – Ocean Acidification from space





Outline

- Sea Surface Salinity (SSS)
  - Why should SSS be measured?
  - What will be measured?
  - How will it be measured?

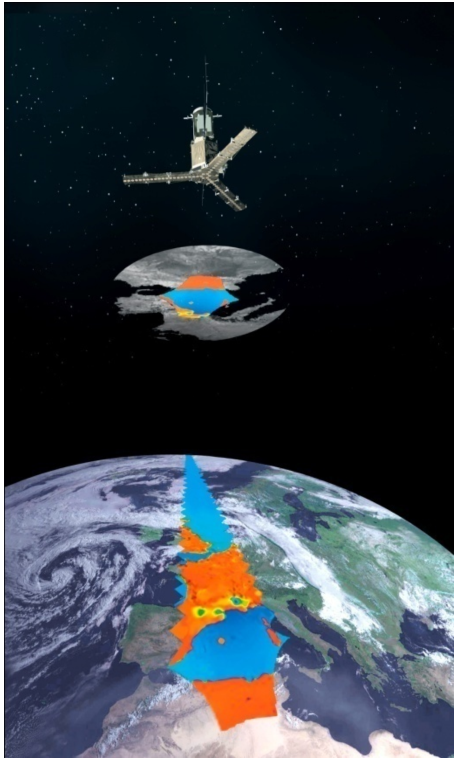
- ESA SMOS satellite SSS
  - Inversion scheme features
  - SMOS L2 OS current release and upcoming developments
  - SMOS L2 OS validation protocol

- SMOS oceanographic applications
  - air-sea interactions, ocean circulation, climate indexes monitoring, marine biogeochemistry, NWP

- SMOS Pilot Mission Exploitation Platform (Pi-MEP) for salinity

- RFI mitigation

- Summary, remarks and perspectives
- Practical presentation



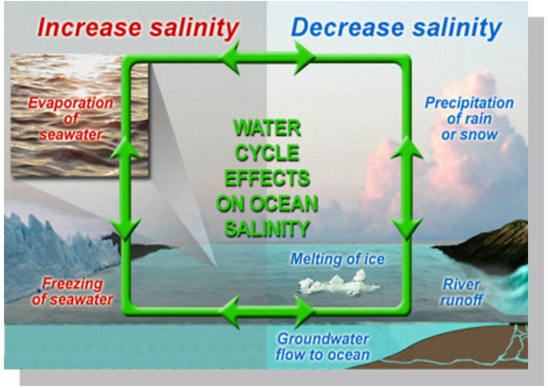
Sea Surface Salinity (SSS)

- Why should SSS be measured?
- What will be measured?
- How will it be measured?

Sea Surface Salinity – why?

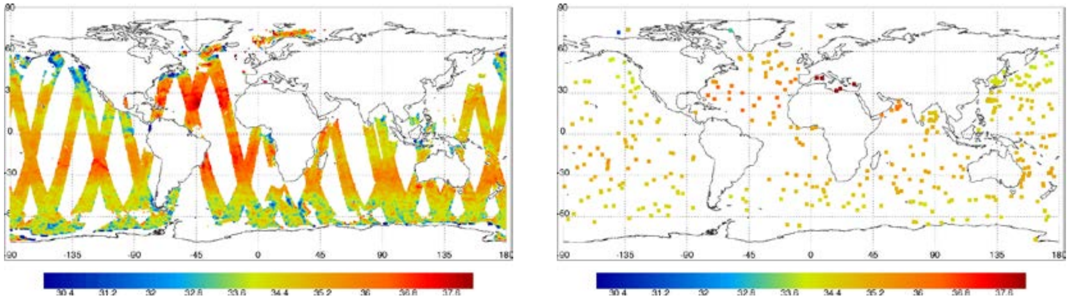
Motivation

- **Sea Surface Salinity variations governed by: E-P balance, freezing/melting ice, freshwater run-off and horizontal/vertical advection**
- **Key oceanographic parameter (density); triggers thermohaline circulation and heat redistribution**
- **SSSS as ECV by UNFCCC / IPCC**
- **Satellite salinity -> Direct response to the lack of systematic observations of SSS, aiming at further our knowledge of the water cycle.**
- **Aim: to provide dynamic global coverage of Sea Surface Salinity fields, with repetition rate and accuracy adequate for large scale oceanography**



Schematic of processes influencing SSS

Satellite SSS daily Sampling



Sea Surface Salinity – what? (i)

$$T_B = T_{ph} * e$$

$$T_B(\theta, pol) = SST\left(1-\left|R_{H,V}(\theta, \varepsilon_r(f, SST, SSS))\right|^2\right) + \Delta T_B(\theta, pol)$$

flat sea contribution

roughness contribution

Configuration Parameters

- **Frequency (*f*)**
- **Polarization (pol)**
- **Incidence angle (θ)**
- **Azimuth angle (φ)**

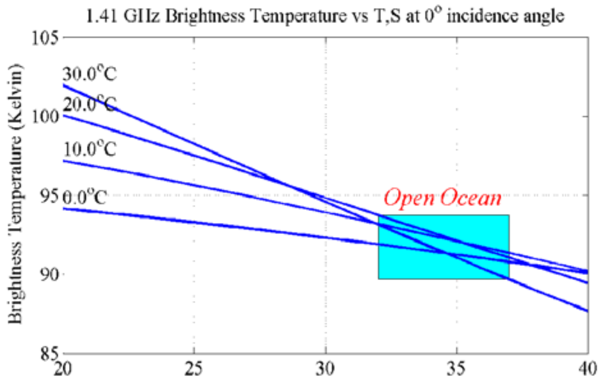
Scene Parameters

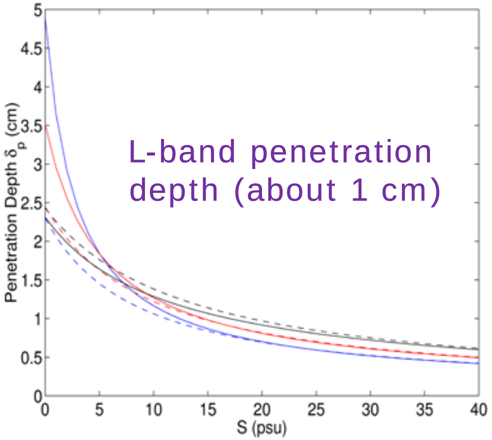
- **Sea Surface Salinity (SSS)**
- **Sea Surface Temperature (SST)**
- **Sea roughness (WS, SWH, sea state)**

TB Sensitivity to SSS in open ocean : 0.2 K to 0.8 K/psu

SSS retrieval more challenging at high latitudes

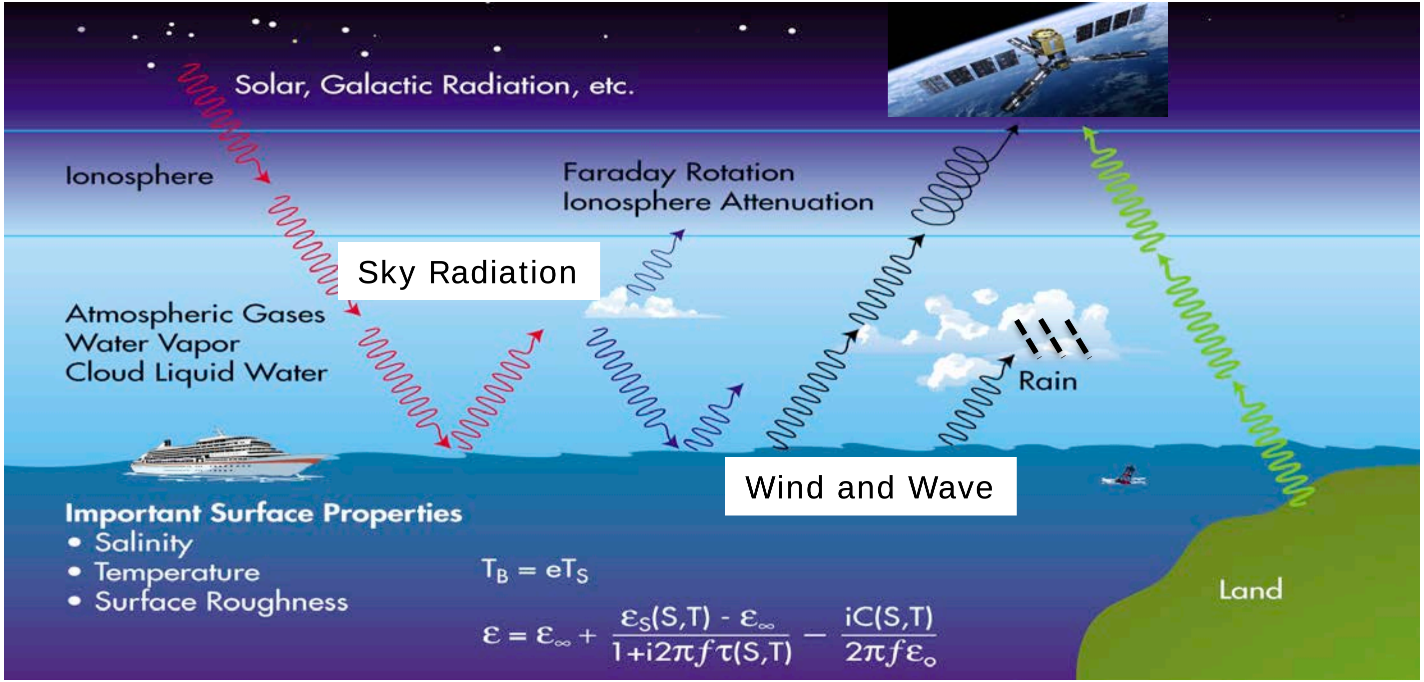
TB sensitivity to SSS increases with SST





Sea Surface Salinity – what? (ii)

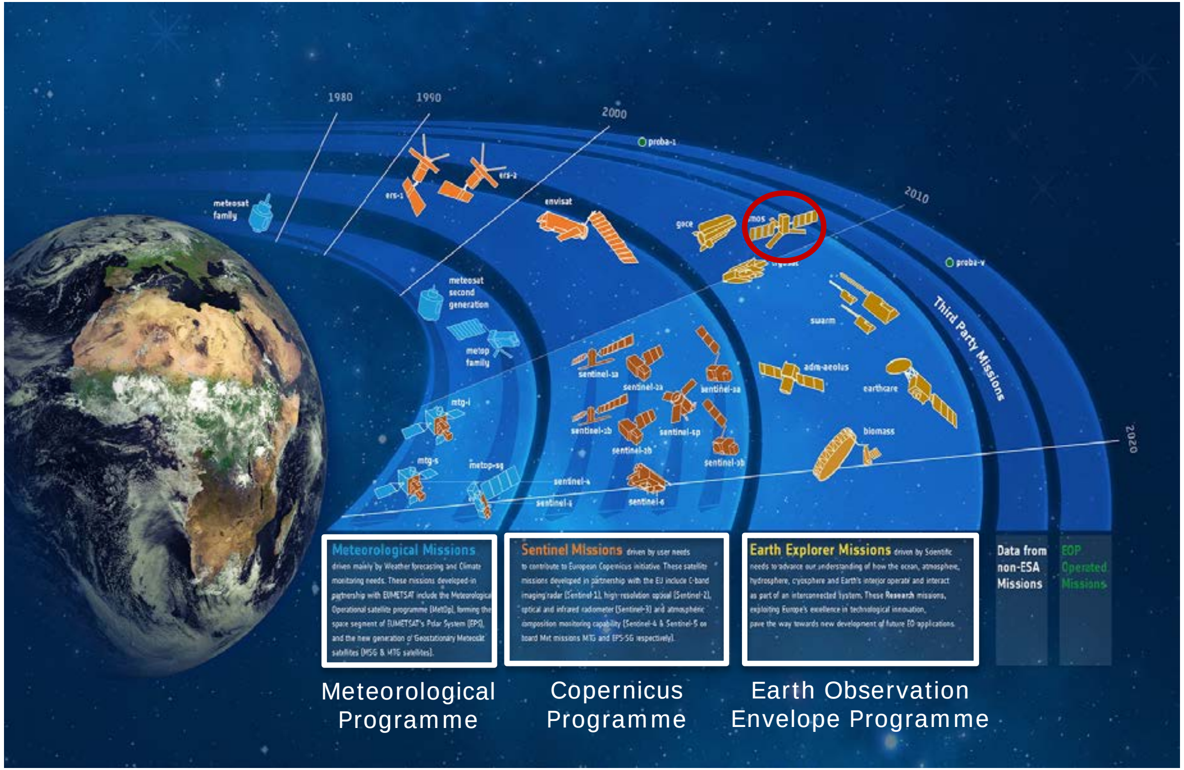
In addition to the "flat" sea surface emission, effects due to the sky, atmosphere, ionosphere, land, ice and surface roughness must be corrected.

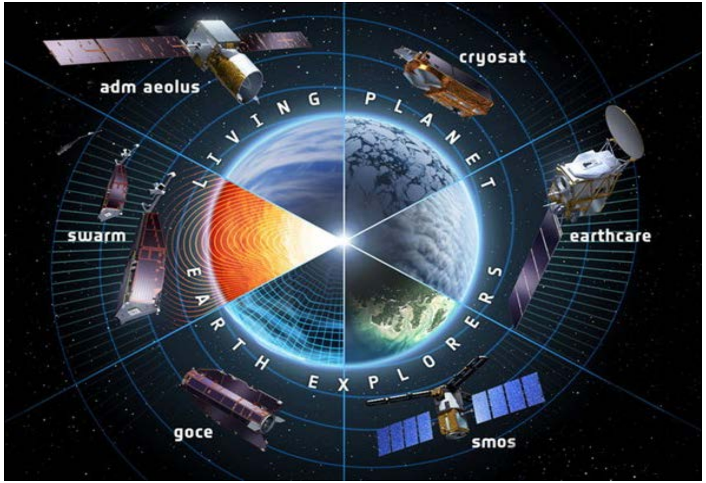


Major perturbation sources
- Sun
- Galactic Noise

Minor perturbation sources
- Water vapor
- Clouds
- Rain
- Moon

Sea Surface Salinity – how? (i)





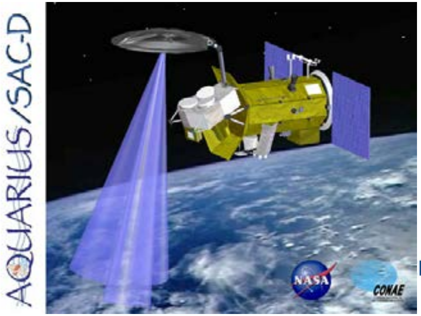
SMOS is an ESA **Earth Explorer** Opportunity Mission – Living Planet programme

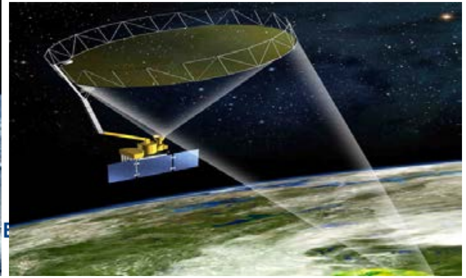
Sea Surface Salinity – how? (ii)

- **SMOS in orbit for 9 years**, Launched November 2nd, 2009 (currently extended until end of 2019)
- SMOS is in excellent technical conditions. (High data availability ~99%)
- L-Band (SMOS, SMAP) supports a **large variety of products and scientific and operational applications (incl. climate)** for the Earth Water Cycle over land and ocean

Current fleet of L-Band missions:

- **SMOS (2009- now)**
- **SMAP (2015 – now)**
- **Aquarius (2011-2015)**





Data are available from SMOS data dissemination platform:

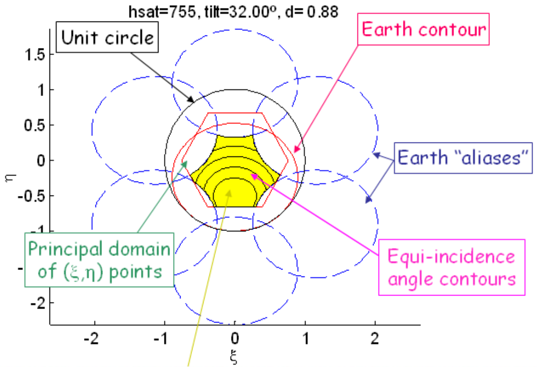
https://smos-diss.eo.esa.int/

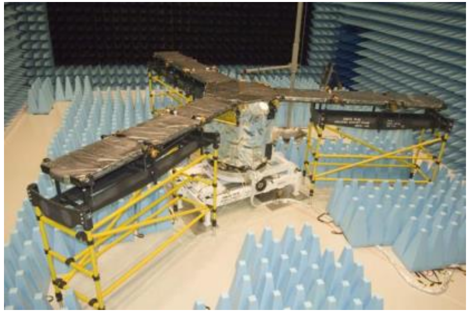
ESA SMOS satellite SSS

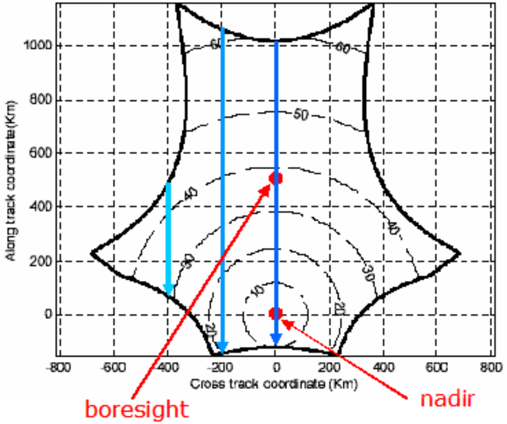
- Inversion scheme features
- SMOS L2 OS current release
- SMOS L2 OS validation protocol

Level 1 – Brightness Temperatures

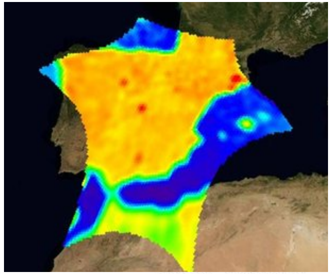
- 1.4 GHz (21 cm), L-band (dedicated): Optimum SSS sensitivity, Reasonable pixel dimension, Atmosphere almost transparent
- Microwave Imaging Radiometer using Aperture Synthesis (MIRAS) instrument
- Sun-synchronous LEO orbit, 3 days revisit time (equator), 69 elements array, Y-array: arms 120° apart, Free-alias Field Of View about 1000 km
- Fully-polarimetric, Multi-angular capabilities, Variable number of observations according to the satellite sub-track distance
- Spatial Resolution: at best 32 km (boresight)

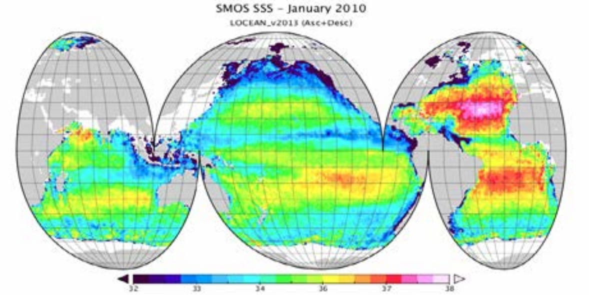


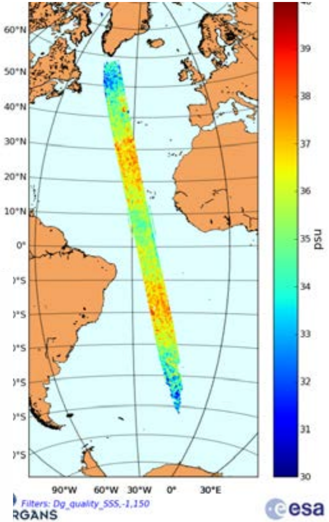




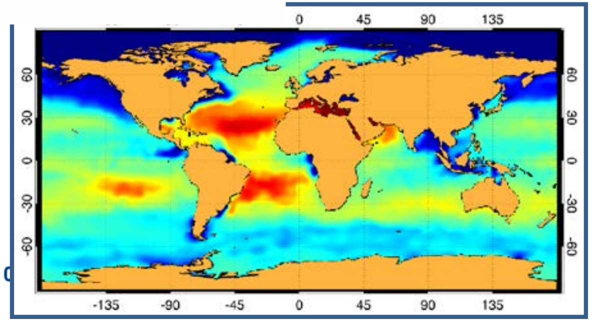
ESA SMOS satellite SSS– processing chain







- Level **0** Raw data
- Level **1A** Calibrated Visibilities
- Level **1B** T_B Fourier components
- Level **1C** T_B geocoded (ISEA4H9)
- Level **2** Salinity Maps (single-overpass)
- Level **3** Spatio-temporal averaged SSS
- Level 4 Merged product



	Accuracy (STD)	Spatial res.	Revisit time
Ocean salinity	0.5-1.5 psu for single observation 0.1 psu for a 10-30 day average for a open ocean area of 200x200 km	200 km	10-30 days

$$\chi^2 = \frac{1}{N_{obs}} \left(\sum_{n=1}^{N_{obs}} \frac{\left| F_n^{meas} - F_n^{model} \right|^2}{\sigma_{F_n}^2} \right) + \frac{(SSS - SSS_{aux})^2}{\sigma_{SSS}^2} + \frac{(SST - SST_{aux})^2}{\sigma_{SST}^2} + \frac{(U_{10} - U_{10aux})^2}{\sigma_{U_{10}}^2}$$

$$F = [\overline{T}_h, \overline{T}_v]$$

$$F = [\overline{T}_x, \overline{T}_y]$$

$$F = [\overline{I}] = [\overline{T}_h + \overline{T}_v] = [\overline{T}_x + \overline{T}_y]$$

N_{Obs} **Number of pixel observations**

F^{meas} **SMOS measured data**

F^{model} **Forward model data**

$SSS_{aux}, SST_{aux}, U_{10aux}$ **Reference auxiliary data**

$\sigma_{SSS}, \sigma_{SST}, \sigma_{U_{10}}$ ***A priori* prescribed auxiliary data errors**

Inversion scheme

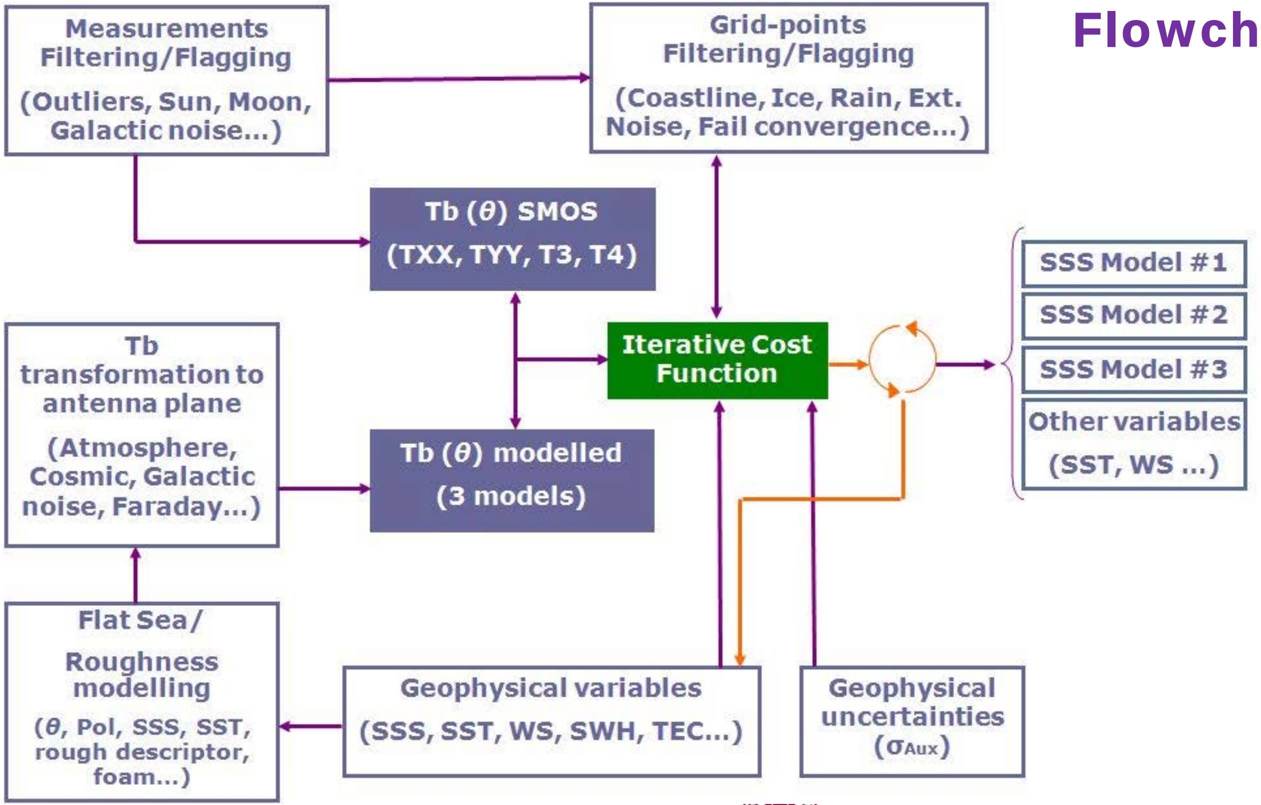
T_B → **SSS** single overpass

Iterative minimization algorithm → **Cost function**

- Levenberg-Marquardt method
- Multi-parameter (SSS, SST, U_{10}) retrieval
- Fixed upper and lower boundaries

ESA SMOS satellite – retrieval flowchart

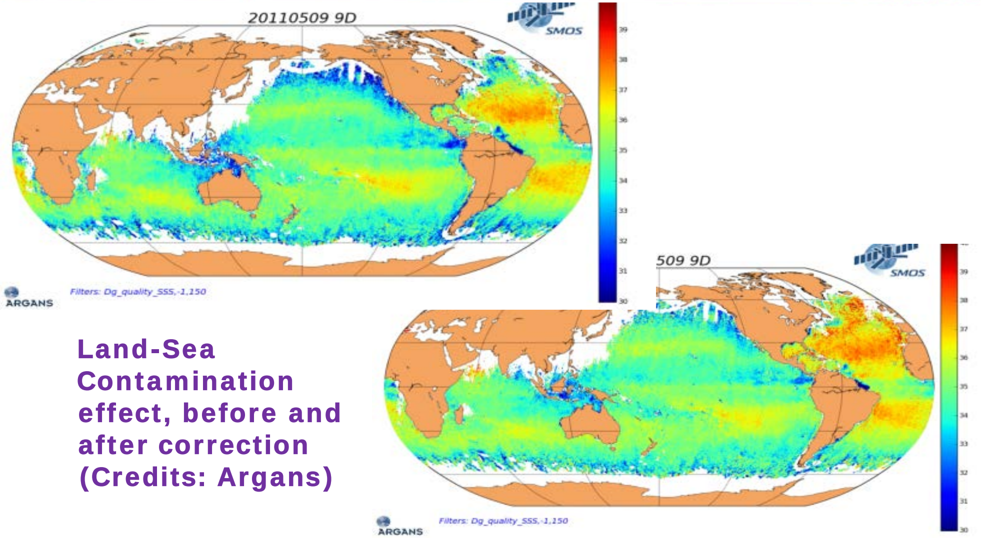
Flowchart



ESA SMOS satellite – current release v662

L2 OS v662

- Land-Sea Contamination correction implemented
- Single roughness model selected and upgraded (SSS1)
- SSS anomaly generation (currently wrt WOA-09 climatology)
- Improved data filtering (RFI and Sun)
- Increased number of retrievals in open ocean due to a better filtering technique,
- Dedicated L2OS v662 reprocessing (full archive) completed and disseminated to community May-2017



Land-Sea Contamination effect, before and after correction (Credits: Argans)

Version 7 (end 2018+)

- Characterization of a SMOS-based climatology to estimate a de-biased SSS anomaly
- Improved wind speed characterization (source and uncertainties) in the retrieval scheme
- Upgrade dielectric constant model to better characterize cold waters

L3 pixel stats, 45S-45N, Dcoast<800km, Asc			
	N	bias	std
V662(corr)-ISAS	3795642	-0.01	0.44
V622-ISAS	3795642	-0.31	0.61

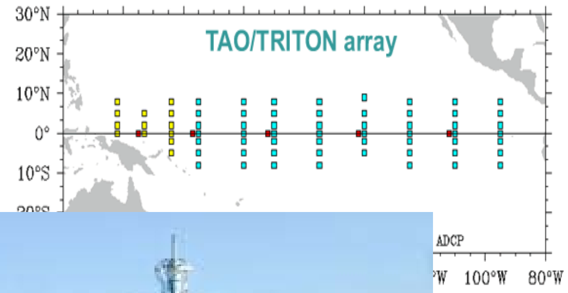
L2SSS validation statistics for global oceans near the coast (<800 km). (Credits: LOCEAN)

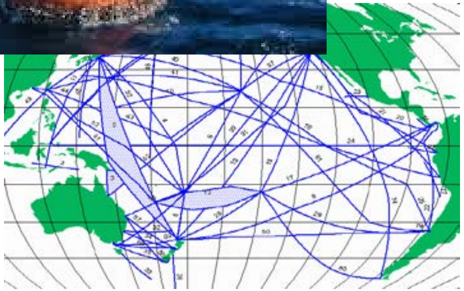
ESA SMOS satellite – in-situ data

- Argo profiling floats
- Moored buoys (mostly in the tropics)
- CTD sensors deployed from RV

Limitations:

- Sparse (e.g., averaged density of Argo floats is 1 float per 3°x3°).
- 10-day surfacing interval of Argo floats is inadequate to resolve shorter-period features
- Mooring data have a lot of discontinuities; do not allow estimates of spatial gradients.
- CTD data are available only at limited transects.

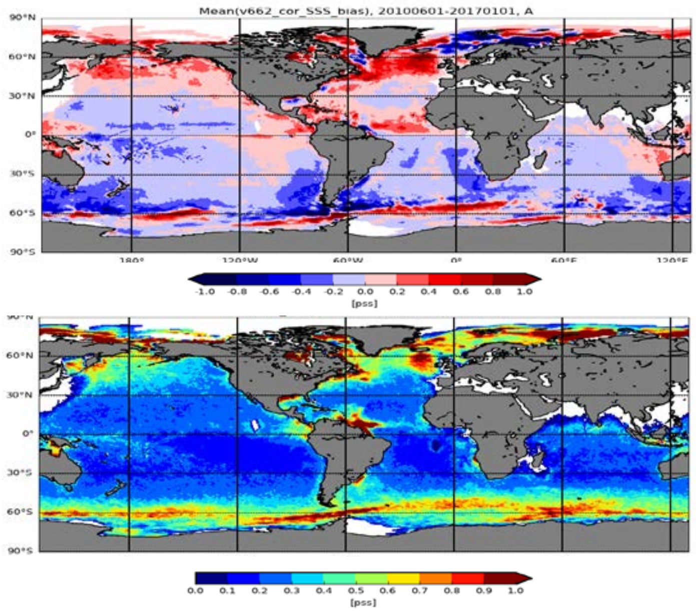




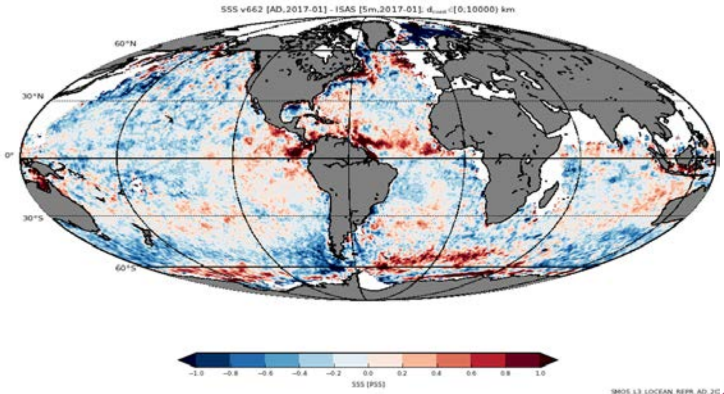
ESA SMOS satellite – validation protocol

SMOS L2 ESL standard Validation protocol

- SMOS reference: L2 **SSS1**, spatio (100km)-temporally (1 month) averaged using a weighting function; filtered for quality flags.
- *In-situ* reference: **Argo** float (4-10m) and optimally-interpolated fields of SSS (5m) generated using the In-Situ Analysis System (**ISAS**, Gaillard, 2009).
- Colocalization SMOS/In situ: spatial radius of 50km, temporal range of +/-15 days around Argo measurements.
- SMOS ESL Validation protocol will be revised and enlarged -> enhanced validation platform



Mean(SMOS-ISAS) and std(SMOS-ISAS) over the 6 years reprocessing – credits: LOCEAN



Monthly difference between SMOS (v662) and ISAS SSS – credits: LOCEAN

ESA SMOS satellite – remaining issues

L1 inaccuracies

- Bias mitigation module refinement
- Latitudinal drift correction

L2 retrieval

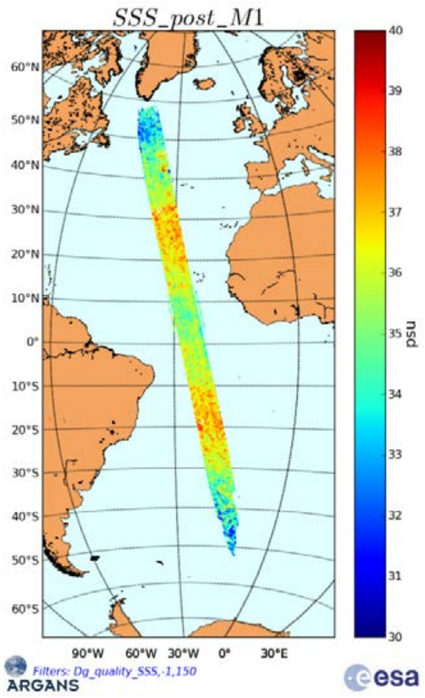
- L- band GMF: roughness estimation improvement
- Auxiliary data: SST and WS collocation and uncertainties

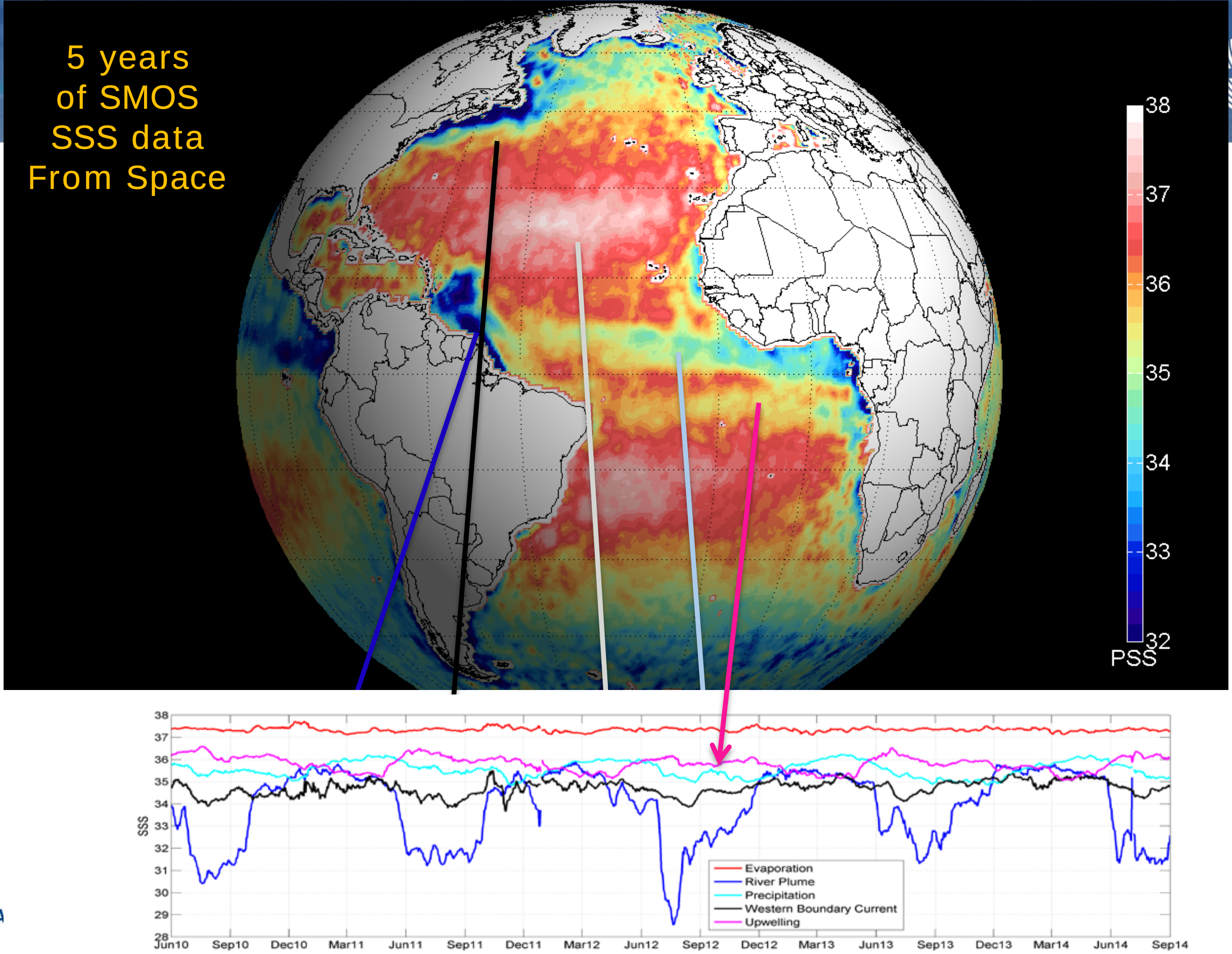
L3 averaging

- Characterization sampling error (s/t)

Perturbation sources

- Sun glint
- Galactic noise
- TEC estimation (Faraday rotation)
- RFI




5 years
of SMOS
SSS data
From Space
38
37
36
35
34
33
32
PSS
SSS
Evaporation
River Plume
Precipitation
Western Boundary Current
Upwelling
Jun10 Sep10 Dec10 Mar11 Jun11 Sep11 Dec11 Mar12 Jun12 Sep12 Dec12 Mar13 Jun13 Sep13 Dec13 Mar14 Jun14 Sep14

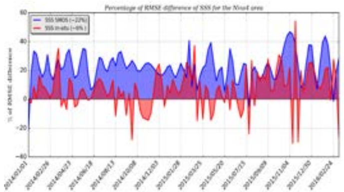
SMOS Oceanographic applications

air-sea interactions, ocean circulation,

climate indexes monitoring, marine biogeochemistry

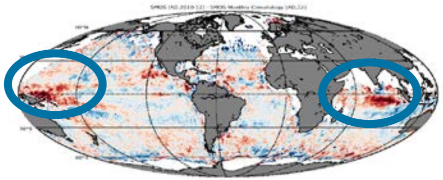
SMOS Ocean apps – overview (i)

Samples of the wide range of applications stemming from the use of SMOS SSS



SSS Data Assimilation
(Tranchant et al.)

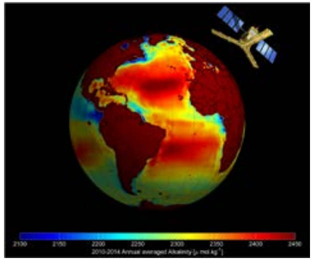
Ocean Circulation Modeling



La Niña detection
(Boutin et al.)

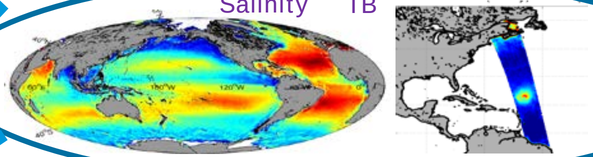
Climate indexes

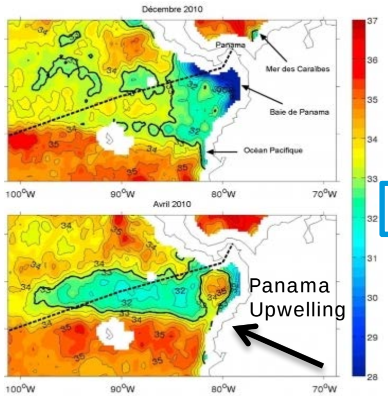
Total Alkalinity
(Land et al.)



Marine Biology & Biogeochemistry

Salinity TB

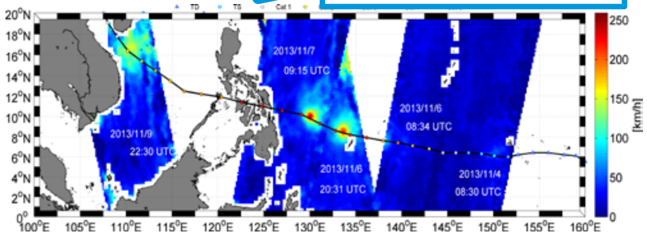




Air-Sea interactions

Upwelling detection
(Alory et al.)

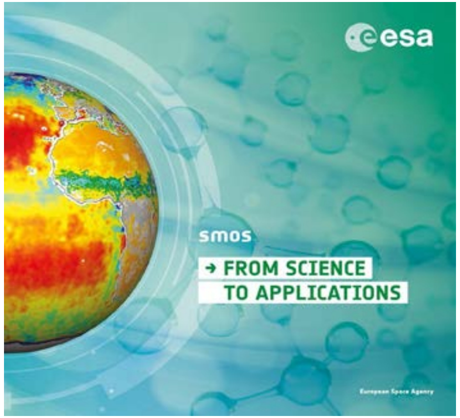
Weather Predictions



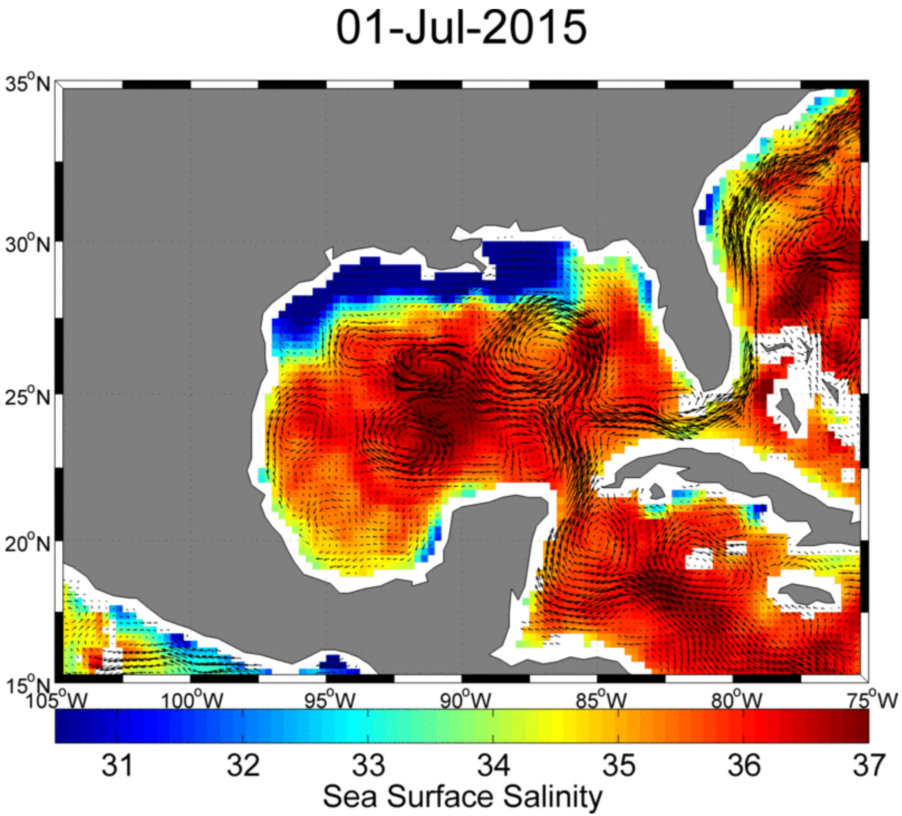
Hurricane tracking
(Reul et al.)

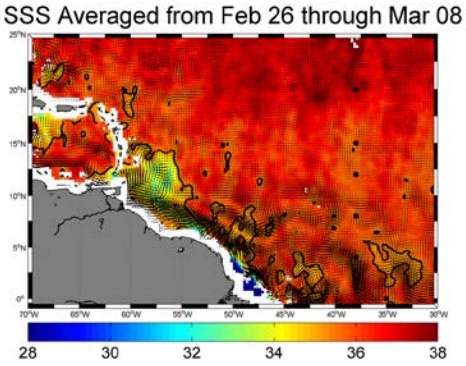
SMOS Ocean apps – overview (ii)

- **Air-Sea (or Land-Sea) interactions**
  - Monitoring freshwater river plumes (IFREMER, Univ. of Maryland)
  - Detecting Upwelling and barrier layers (LEGOS, IFREMER)
  - Monitoring precipitation-induced signals (LOCEAN, Univ. Washington, NUIG)
  - Characterizing SSS variability in high evaporation/precipitation zones (SPURS and SPURS-2)
- **Climate indexes**
  - Detection/monitoring of Large scale SSS anomalies related to climate fluctuations - ENSO and IOD (LOCEAN, BEC, Univ. S. Carolina)
- **Marine Biology / Biogeochemistry**
  - Ocean Acidification (Univ. Exeter, PML, IFREMER)
- **Numerical Weather Prediction**
  - Hurricane/storm tracking and intensity forecasting (IFREMER, UK MetOffice)
- **Semi-enclosed seas**
  - Med-Sea
- **Ocean circulation and modelling**
  - Characterizing mesoscale variability of SSS (and density) in frontal structures, eddies (LOCEAN, IFREMER, JPL)
  - Monitoring key oceanic thermohaline circulation processes: Gulf Stream (IFREMER)
  - T/S Diagrams and water masses formation (ESA)
  - Detecting Tropical Instability Waves - TIW (LOCEAN, JPL) and planetary waves - Rossby (NOC)
  - Assimilating SMOS SSS in Ocean Forecasting Systems (Mercator, UK MetOffice, Univ. Hamburg, NOAA, etc.)



SMOS Ocean apps – freshwater plumes

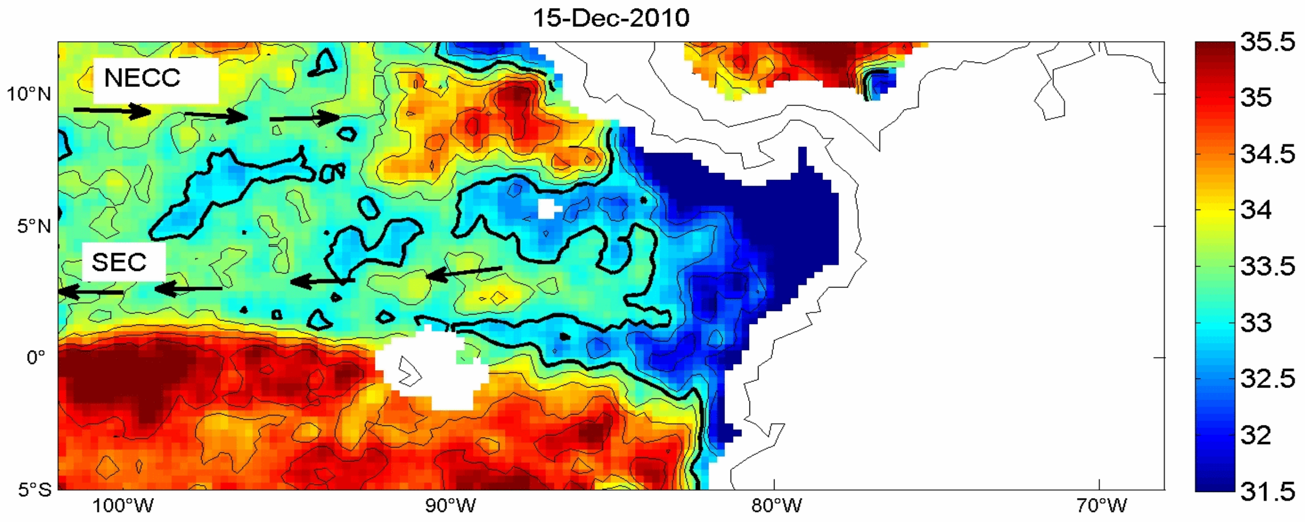




Regular monitoring of the seasonal / inter-annual variability in the discharge and dispersal of freshwater river plumes into the ocean.
Implications for stratification, barrier layers, heat and gas fluxes, hurricane intensification, fisheries

Reul et al., Rev Geophys 2014
Fournier et al., JGR, 2014
Grodsky et al., RSE, 2014

SMOS Ocean apps – upwelling

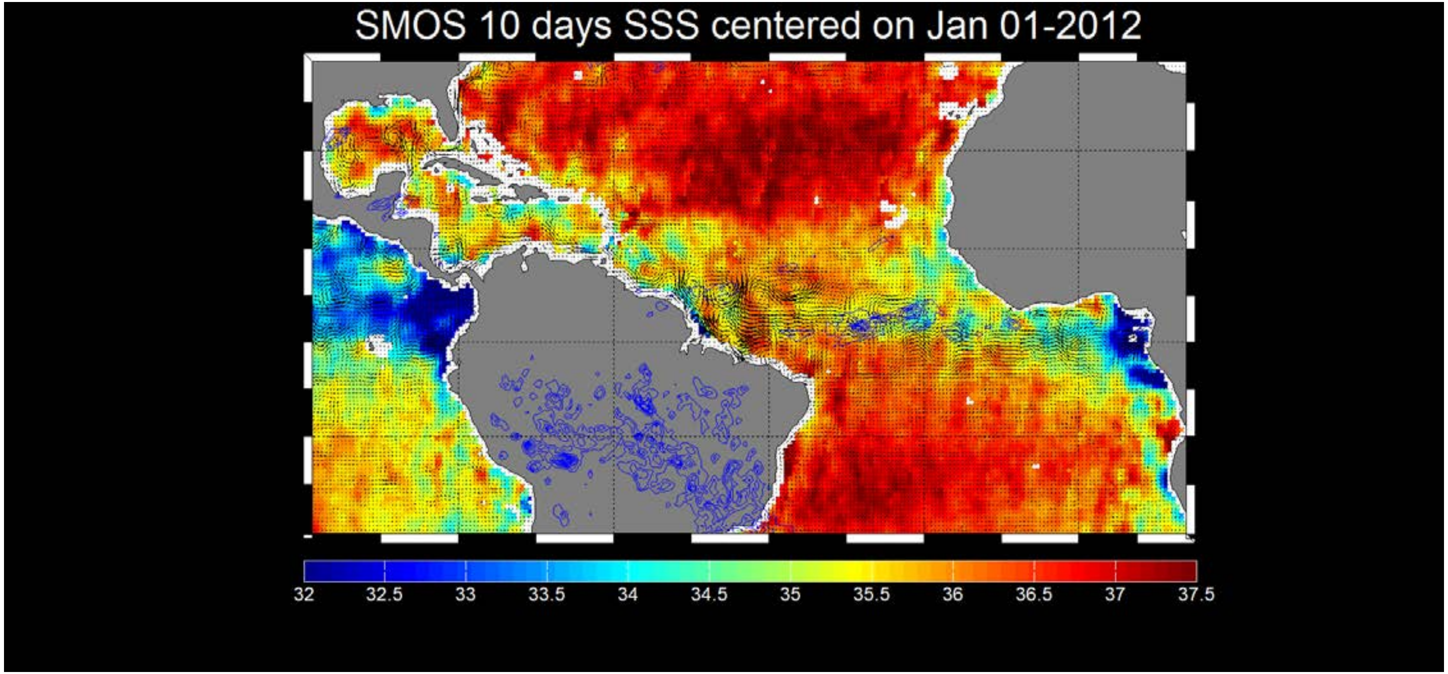


G. Alory et al, 2012

Detection of salty deep water upwelling (vertical upward motion) at the surface of the freshest waters of the Pacific (Panama)

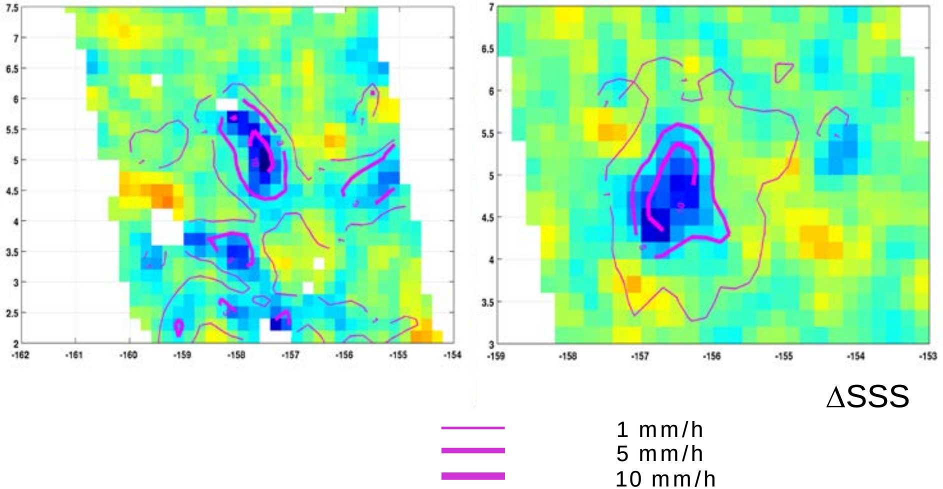
Exchanges of salt between the deep ocean and the surface during upwelling events systematically quantified.
Implications for nutrients (N-, P-) availability, phytoplankton growth, food chain, fisheries, deoxygenation, Ocean acidification

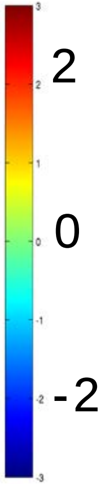
SMOS Ocean apps – precip. signature

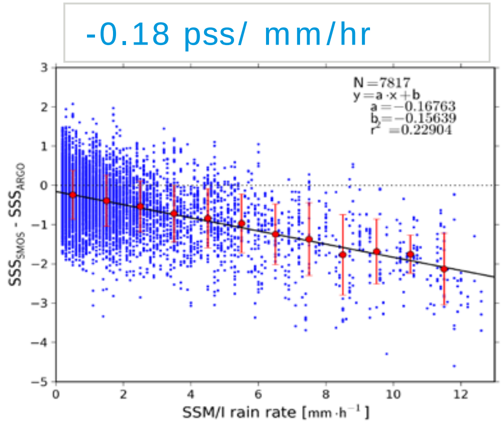


SMOS Ocean apps – freshwater lenses

Satellite rainfall and SMOS freshenings (DSSS) are closely correlated (Boutin et al. 2013, 2014) at local scale and short temporal scale (<30mn)

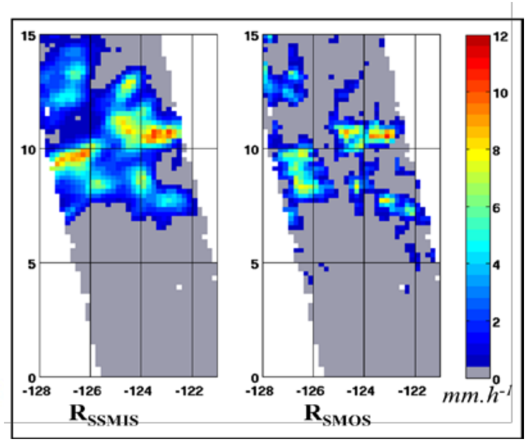


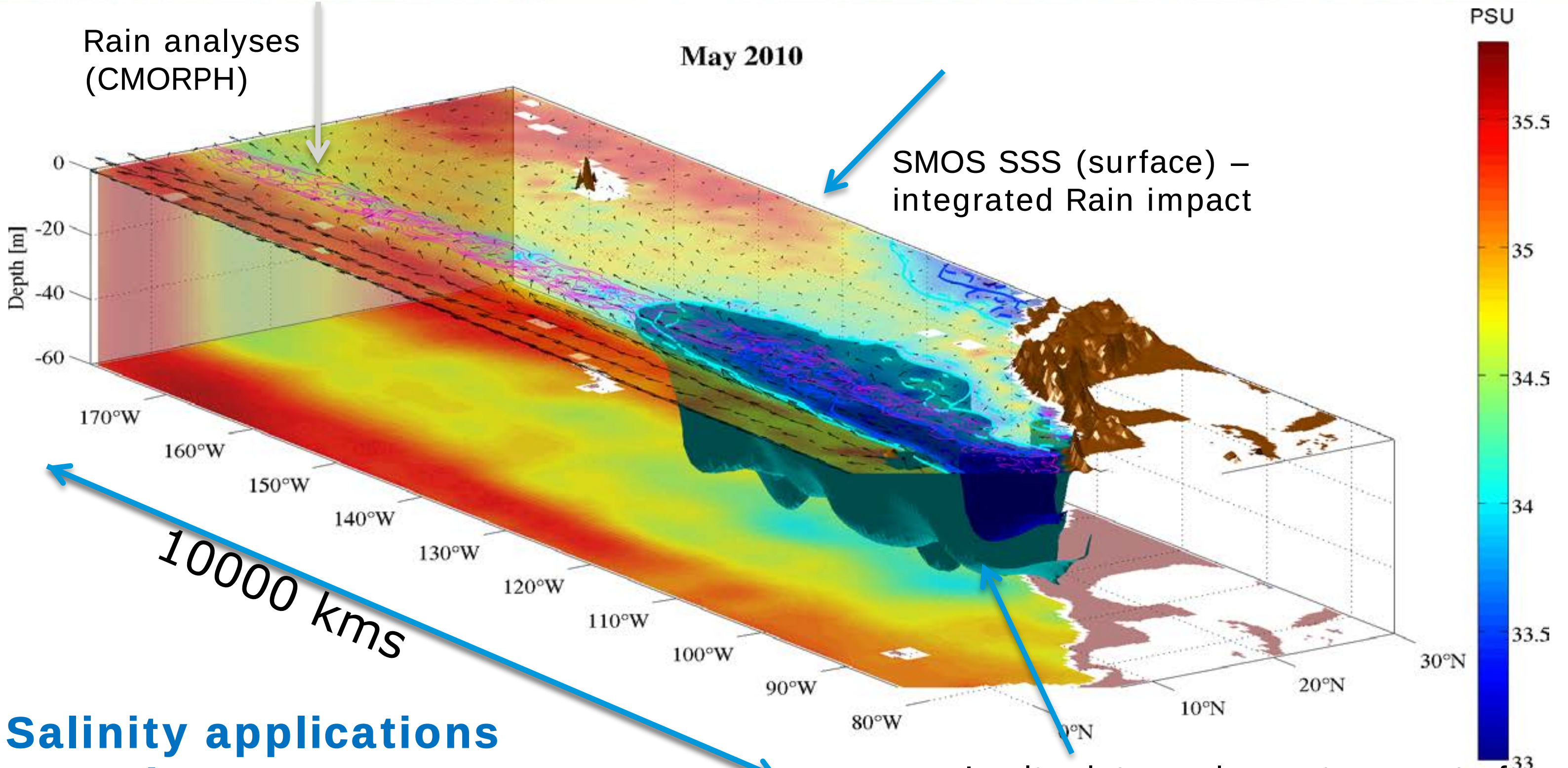




Freshwater lenses resolved by SMOS and not necessarily detected by Argo in-situ measurements -> surface stratification and barrier layers

SMOS retrieved 'instantaneous' rain rate [SMOS+ Rainfall project]
It complements spatio-temporal coverage of rain monitored by microwave radiometry (GPM constellation)

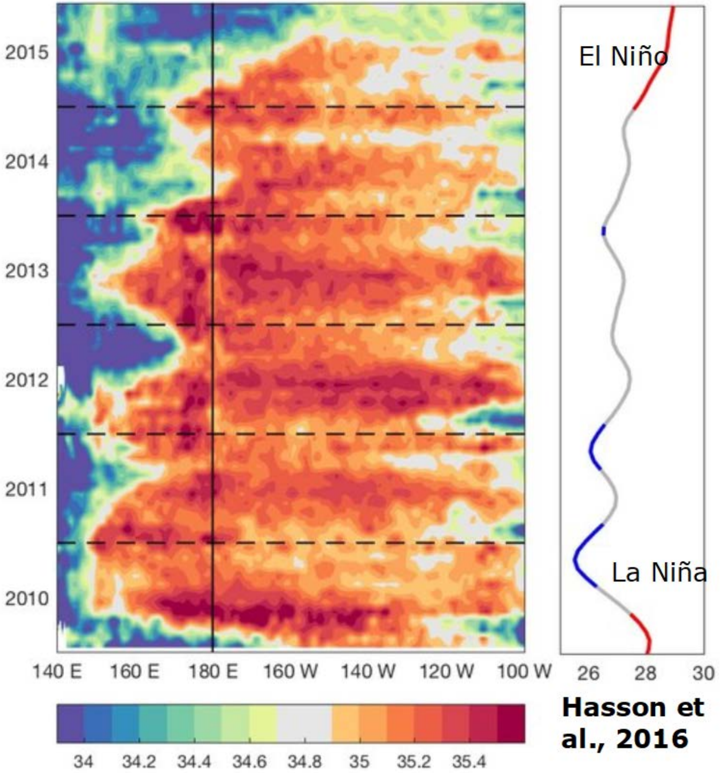




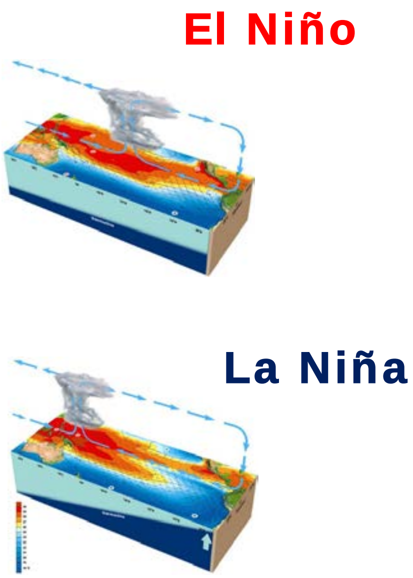
SMOS Salinity applications – 3D fw pools

S. Guimbard et al. (IFREMER)

SMOS Ocean apps – climate indexes/ENSO



Hasson et al., 2016



Hasson et al., 2017

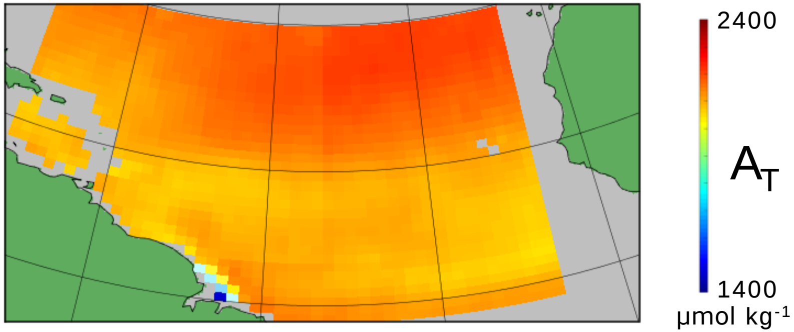
Signatures of El-Niño 2014-2015 at the Equator in the Pacific

Average SMOS surface salinity around the Equator (2°S–2°N) from 2010 to 2017 and the 'Niño 3.4 Index', which indicates El Niño events in red and La Niña events in blue.

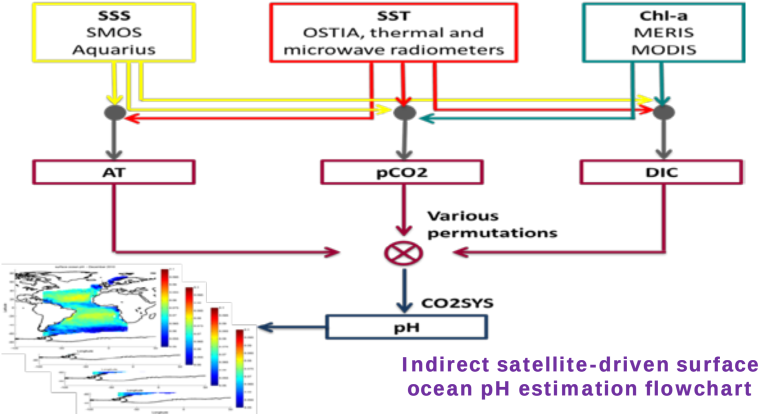
SMOS Ocean apps – acidification

Atmospheric CO2 ocean absorption causes a reduction of ocean pH in a process referred to as Ocean Acidification (OA). Remote sensing can provide synoptic and frequent OA-related observations and routinely estimate surface ocean pH.

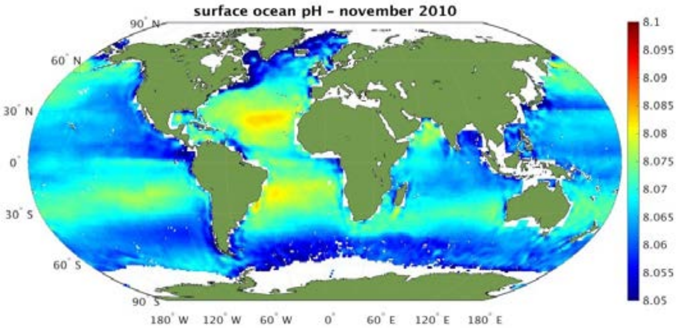
ESA STSE *Pathfinders-OA* project collated a database of EO/in-situ matchups to develop/validate algorithms to retrieve OA parameters from space. Satellite datasets (mainly SSS, SST and Chl-a) inputs have been related to carbonate system parameters in a round-robin exercise.



Total Alkalinity (buffering capacity of a water body to neutralize acids) evolution for the Amazon Plume (credits: Pathfinder-OA project)



Indirect satellite-driven surface ocean pH estimation flowchart



First-ever estimates of EO-based global surface ocean pH. (credits: ESA/R. Sabia)

Fri 16 Nov, 14.00 – Ocean Acidification from space

SMOS Ocean apps – semi-enclosed basins

The combination of several methodologies has been used in the SMOS context to obtain SSS fields over the North Atlantic Ocean and the Mediterranean Sea:

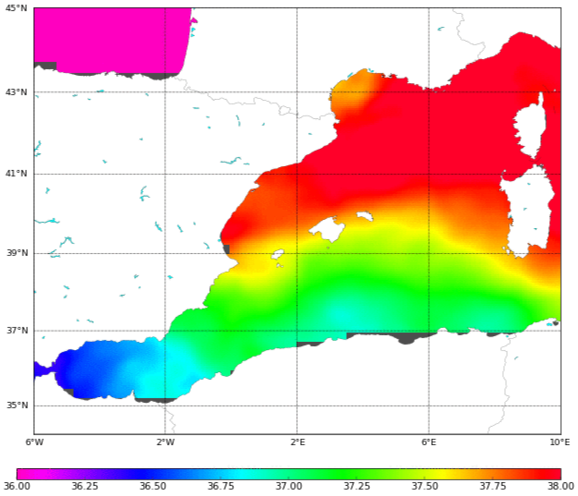
- **Debiased non-Bayesian retrieval** mitigates the systematic biases (constant in time) and improves the coverage.
- **DINEOF decomposition** allows the characterization of the time-dependent biases: seasonal and specific events
- **Multifractal fusion** improves the description of the mesoscale structures

The new **products improves the accuracy with respect to the products that are currently being produced at the BEC**:

RMSE SMOS-ARGO - MED: 0.39 (new) vs 0.70 (old)

New SMOS SSS maps in the Mediterranean Sea!

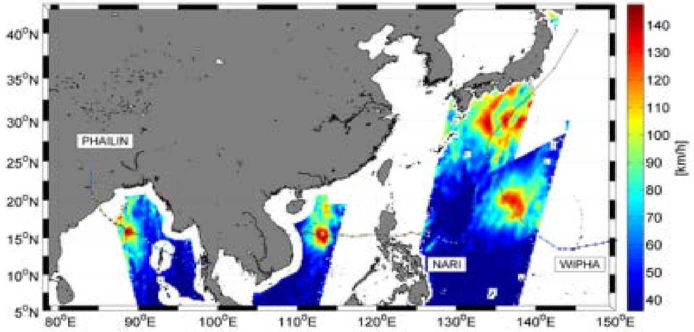
SMOS: 20121001



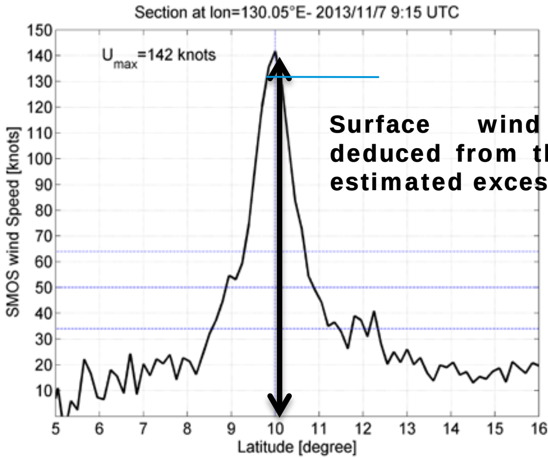
Dataset available at http://bec.icm.csic.es/

AGO-GHER-MARE
University of Liège
Belgium

SMOS ocean apps – severe WS

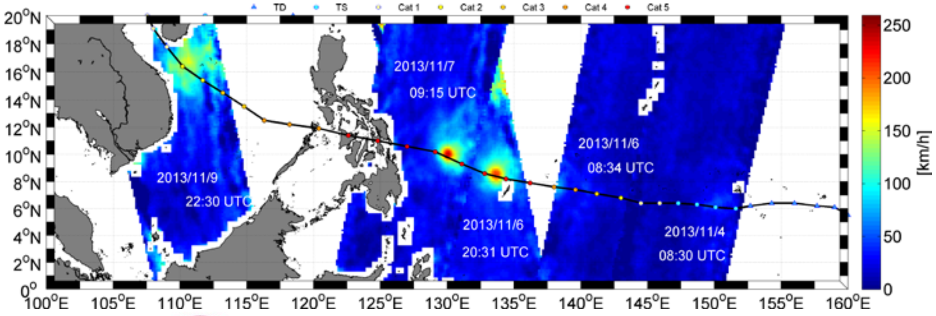


SMOS captured wind speed up to 140 km/h for these three typhoons during 10–15 October 2013. Credit: ESA/IFREMER/CLS/CATDS/CNES.



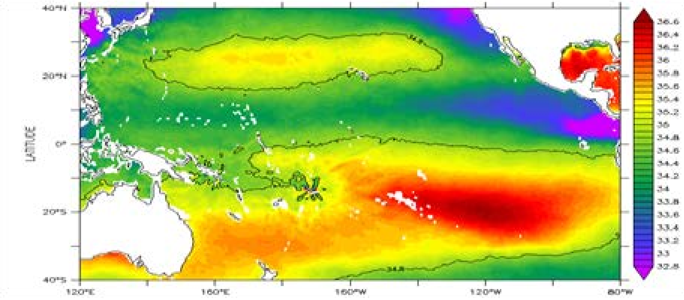
Surface wind speed deduced from the SMOS estimated excess TB.

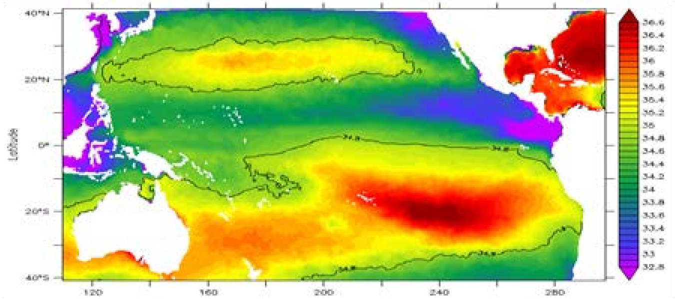
- SMOS data used to track severe winds. Emissivity/TB from ocean in microwave increases with increased wind speed (and thus surface roughness/foam).
- **SMOS can measure winds up to 70-80 m/s with an accuracy of ~5 m/s**
- Scatterometer data saturate at extreme winds (Hurricane force)
- Promising for improving TC intensity forecasts
- Storms catalogue available form www.smosstorm.org/
- **Product will be available operationally from Q2 2018 from IFREMER/ODL and ESA**



SMOS Ocean apps – DA/ocean modelling

Impact of satellite SSS DA in two different ops global ocean forecasting systems

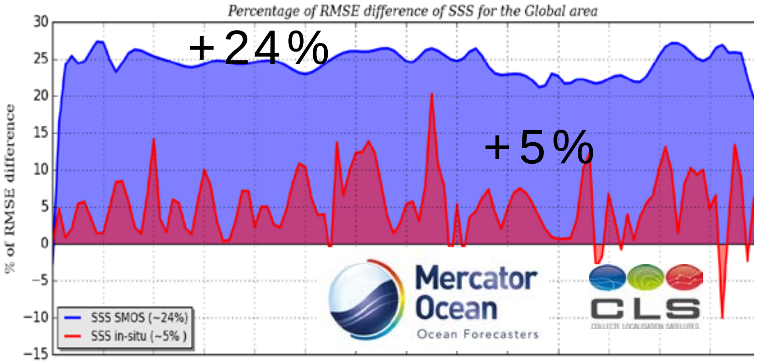




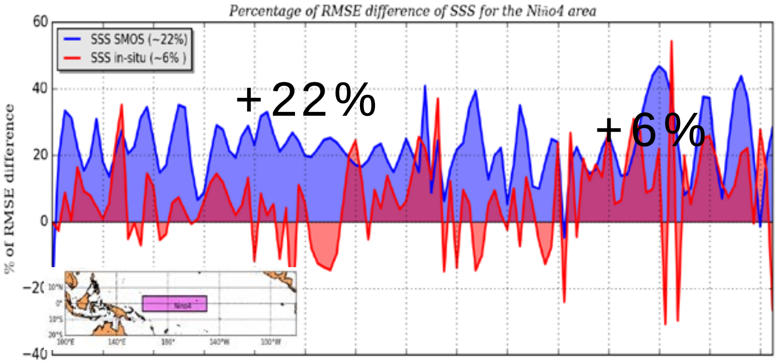
Mean 2015 SSS from: SMOS Observations (left) and ¼° Mercator Ocean reanalysis (right)

smos+ niño15 support to science element

Skill scores over the **global domain** (2014-2015)



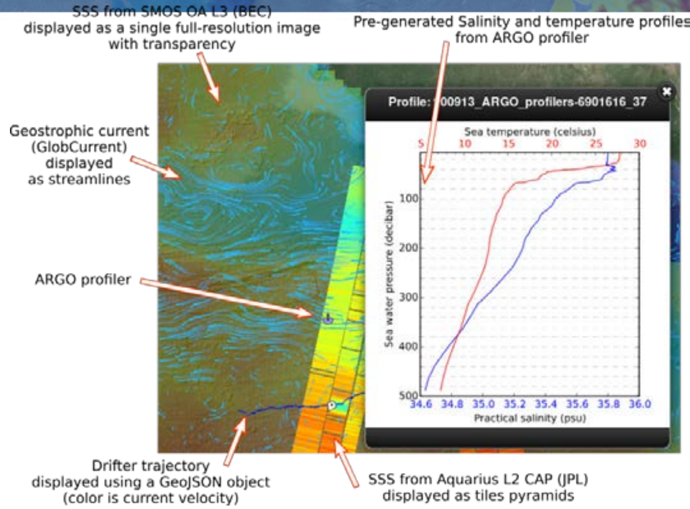
Skill scores over the Niño4 area (2014 - 2015)



SMOS Pilot Mission Exploitation Platform (Pi-MEP)

SMOS Pi-MEP - overview

- ✓ **Focus #1** – To serve as enhanced **validation platform** [matchup in-situ, filtering/QC, spatial/temporal scales, -> ESL validation testbed and “plug-in”]
- ✓ **Focus #2** – To offer a testbed to enable and monitor **oceanographic process studies** [data synergy, statistical and computational IT tools, on-demand processing]
- ✓ **One-stop-shop** for scientific validation, monitoring, assessment and exploitation of the SMOS salinity data
- ✓ **Engage user community**
- ✓ **Implementation completed**

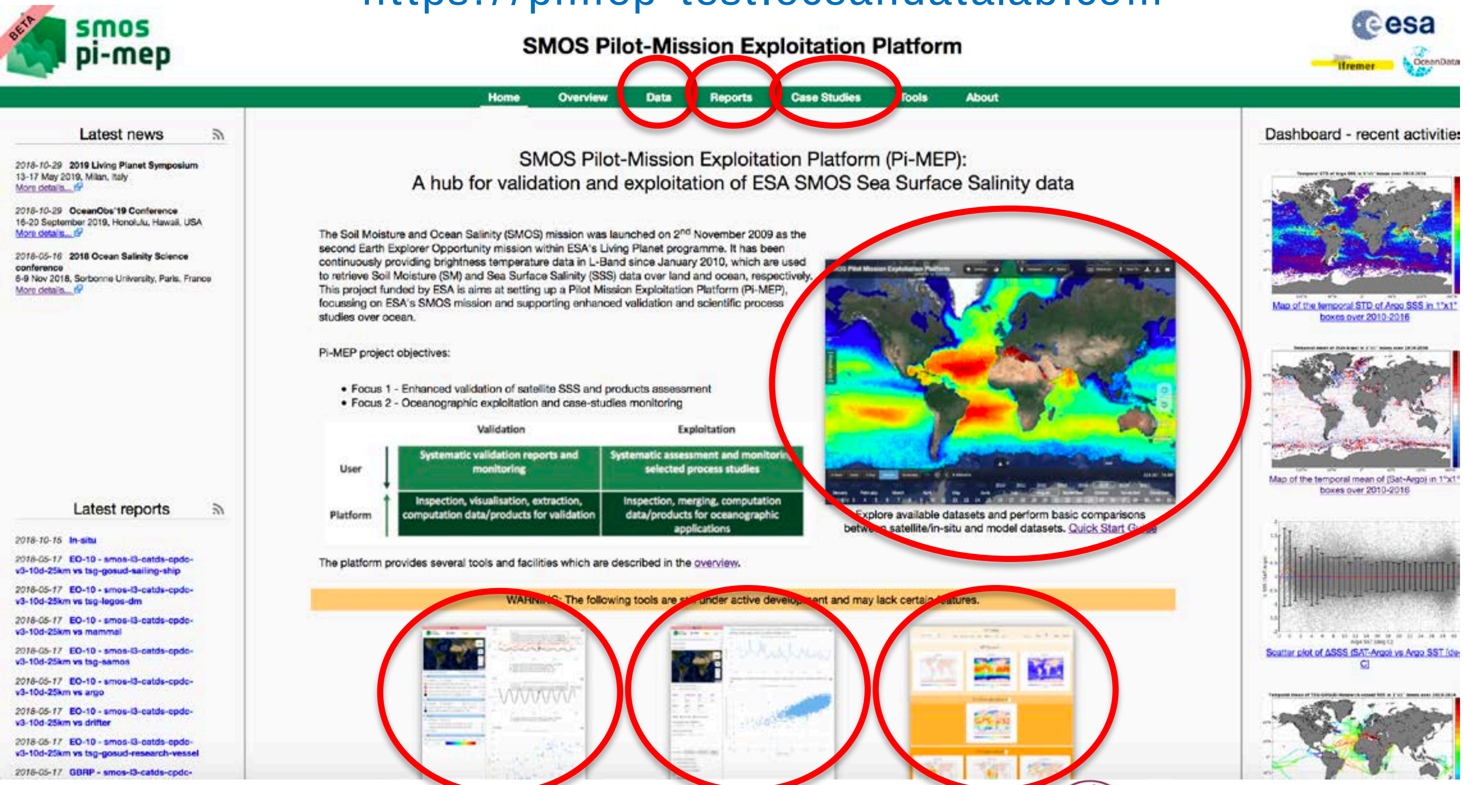


Syntool: integrated access and mutlidimensional intercomparison of EO, in-situ and model data.

smos pi-mep

SMOS Pi-MEP – website mock-up

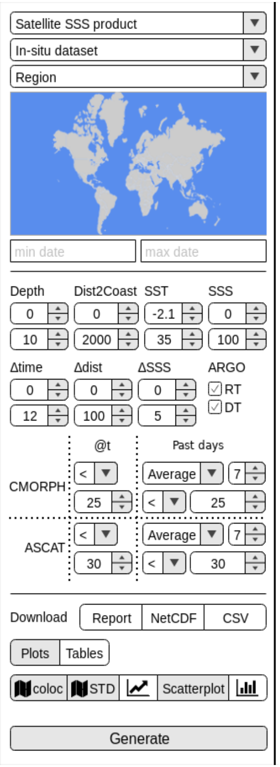
https://pimep-test.oceandatalab.com

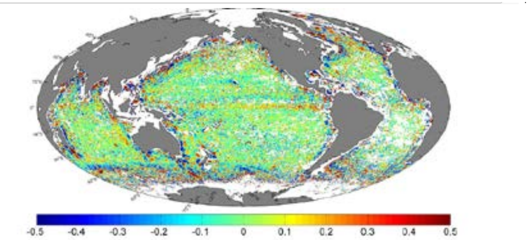


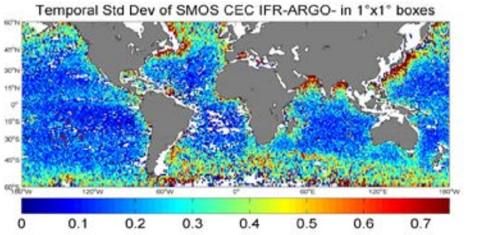
Pi-MEP salinity will provide tools for merging data and process them at user discretion (typology, scales, filtering, etc); user can interact to an extent decided by the Platform host

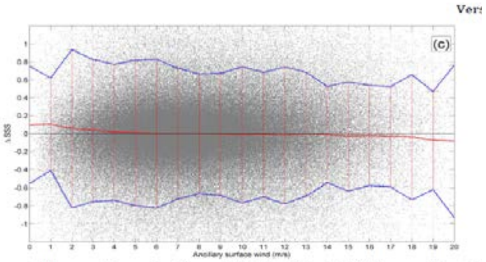
SMOS Pi-MEP – Match-up database

• Match-up databases of SMOS/in situ (e.g., Argo, TSG, moorings, drifters) data and inter-comparison reports generated via a dedicated interface allowing assessment and user-driven extractions.









Datalaps MDB intreface

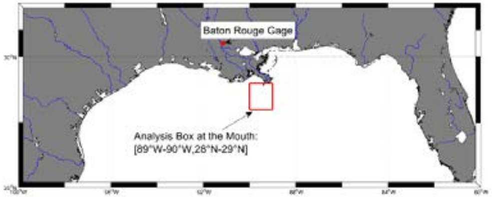
- Query and Extract match-ups (CSV, JSON or NetCDF)
- Produce customized PDF reports
- Allow a variety of filtering options
- Generate plots for match-up metrics

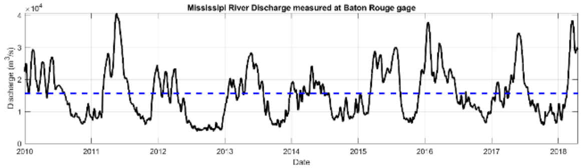
To detect/flag conditions in which significant V salinity gradients or strong SSS sub-pixel H variability are likely, the match-up data will be stratified according to several **conditions**:

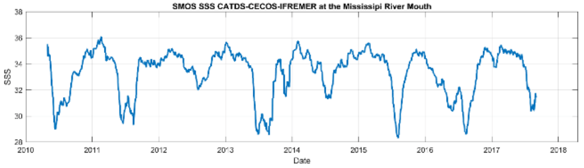
- C1 - local RR high and mean WS low
- C2 - rain history and wind high and low median values, respectively.
- C3 - both C1 & C2 are met.
- C4 - MLD shallow.
- C5 – Barrier Layer existence.
- C6 - climatological SSS standard deviation is high.
- ...

SMOS Pi-MEP – case studies: 1) river plumes

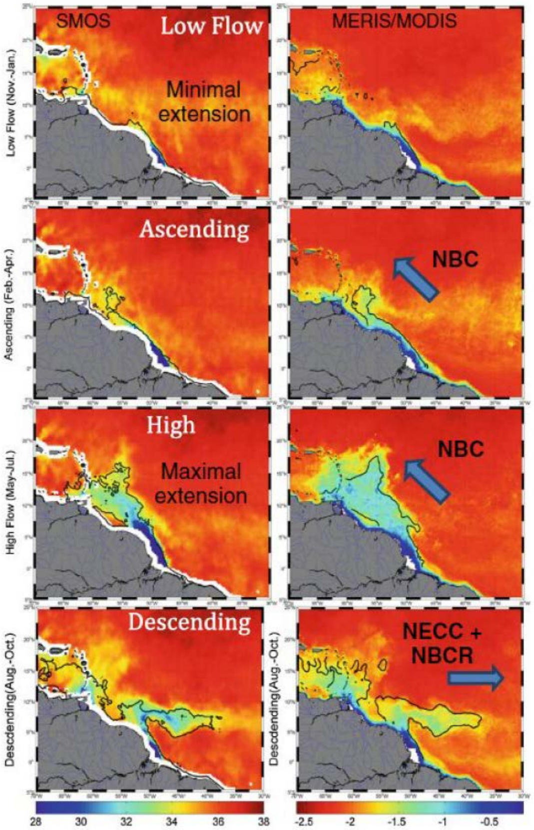
Time series at the river mouths: discharge and SSS evolution



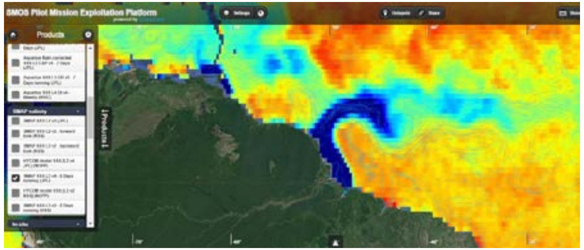




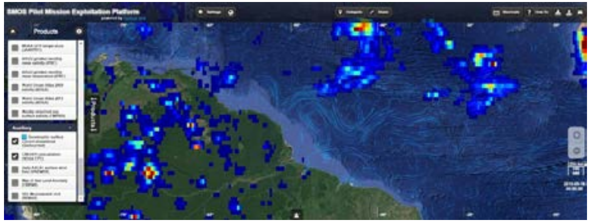
SSS & color (CDOM, Chla) seasonal cycles



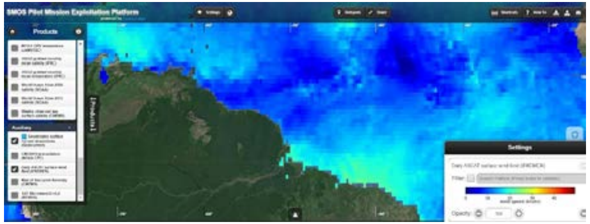
SSS and currents



SSS and rain

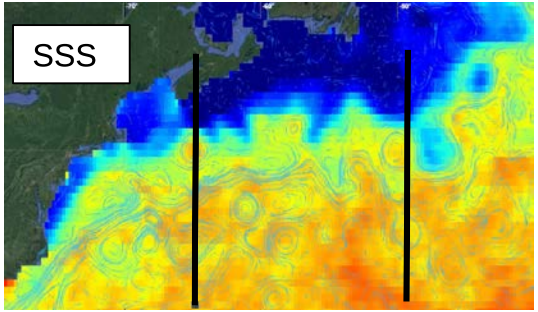


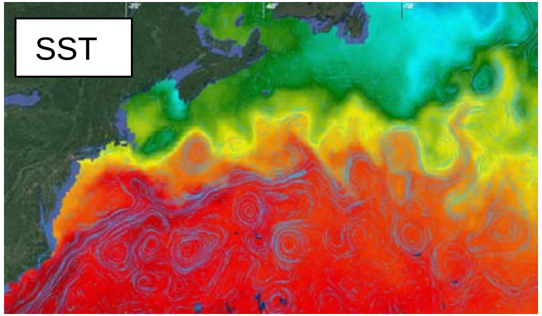
SSS and wind

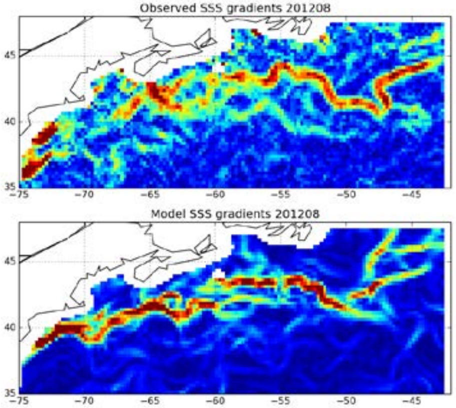


SMOS Pi-MEP – case studies: 2) mesoscale

1) SSS, SST and currents

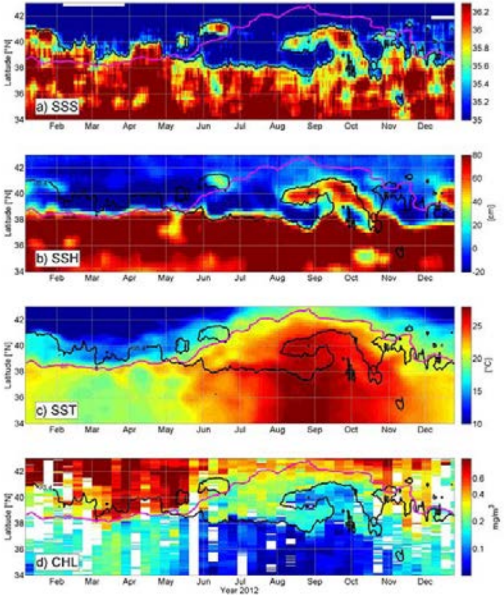




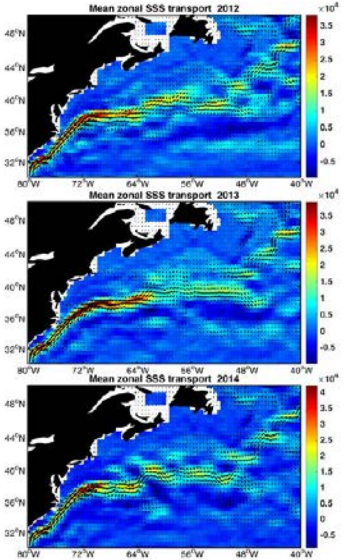


2) Front monitoring: SSS gradients: satellite and models

3) Hovmueller sections



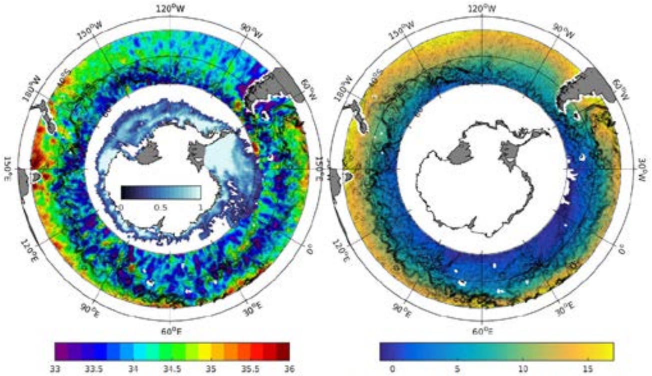
F=SSS'*v '



4) Salt Eddy Transport (zonal & Meridional)

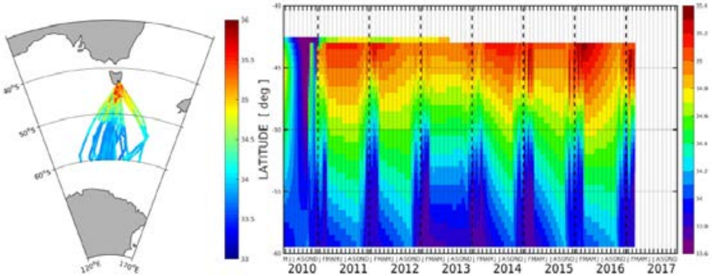
SMOS Pi-MEP–case studies: 3) challenging areas

1) SSS and SST monitoring



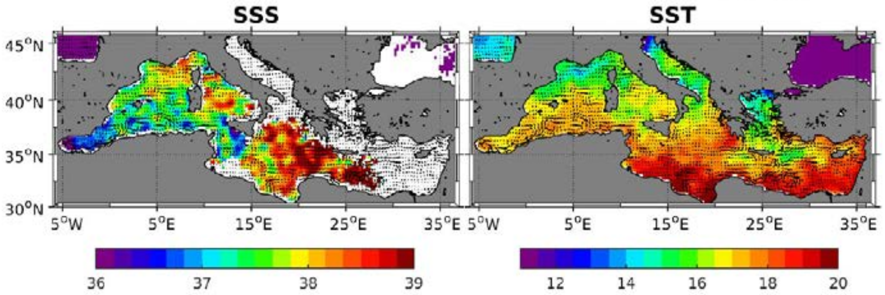
(a) SMOS SSS averaged from 01 to 07 January 2016. (b) AVHRR-OI mean SST over the same period. In both plots, OSCAR surface currents are indicated by black arrows.

2) Transect Monitoring from Tasmania to Dumont D'Urville (DDU) in Antarctica.



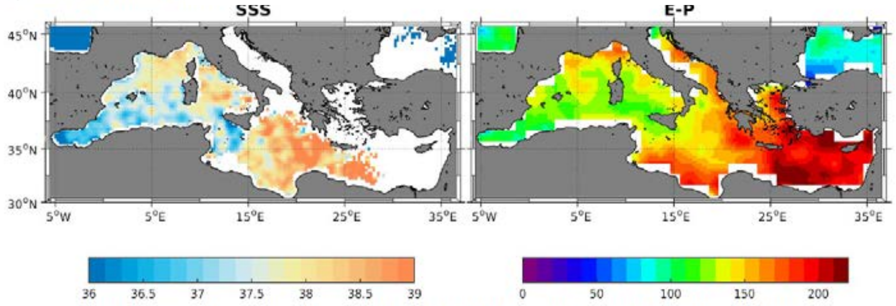
2) Transect monitoring from Tasmania to Antarctica

3) SSS & SST monitoring



(left) SMOS BEC SSS averaged from 01 to 07 January 2016. (right) AVHRR-OI mean SST over the same period. In both plots, OSCAR surface currents are indicated by black arrows.

4) SSS correlation with E-P



Monthly maps (January 2016) of SMOS SSS (left) and Evaporation (Oaflux) minus precipitation (CMORPH)

SMOS Pi-MEP – overall scope

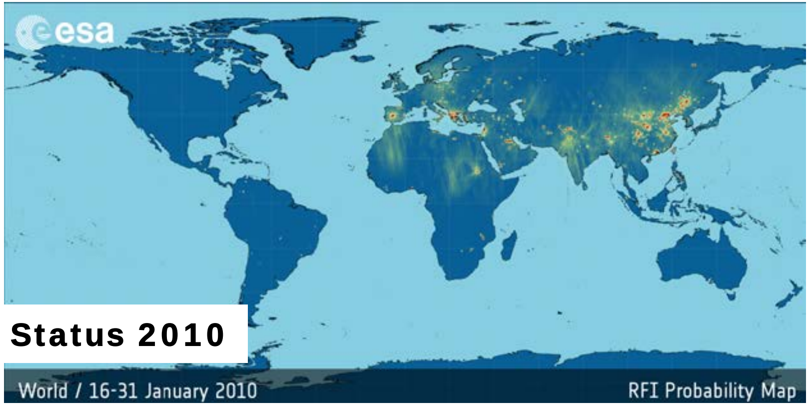
Platform

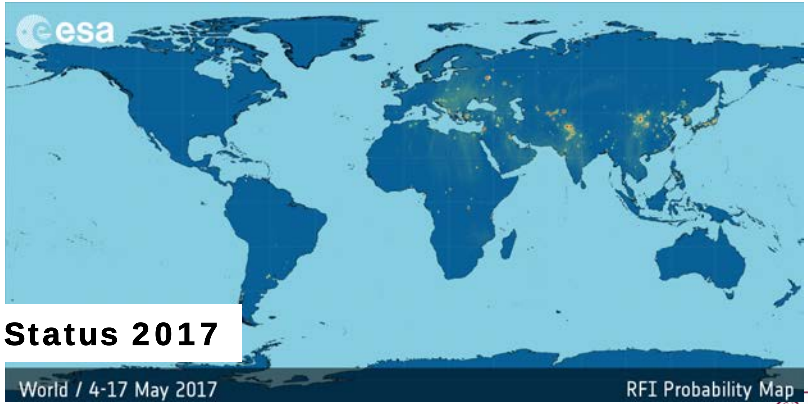
	Validation	Exploitation	
Top Down ↓	**Systematic validation reports and monitoring [eg, MDB pdf reports]**	**Systematic assessment and monitoring selected process studies [eg, case-studies reports]**	↑
	Inspection, visualization, extraction, computation data/products for validation [eg, MDB metrics extraction]	Inspection, merging, computation data/products for oceanographic applications [eg, Jupyter notebook]	Bottom up

Users

Radio Frequency Interferences (RFI)

RFI – status (i)

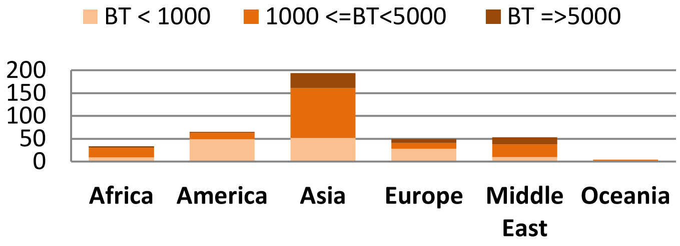




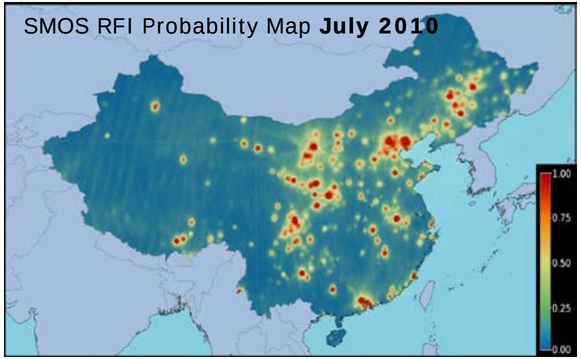
RFI CONTAMINATION WORLDWIDE MUCH REDUCED Currently more than 75 % of the RFI sources detected have been switched-off, mostly as a consequence of reporting the RFI case to the Spectrum Management Authorities. Currently, there are approximately **400 active RFI** sources worldwide, with strengths varying from **moderate** (BT < 1000 K)**, strong** (1000 K <= BT <= 500 K), to **very strong** (BT > 5000 K) sources, the latter being mainly located in Asia and the Middle East.

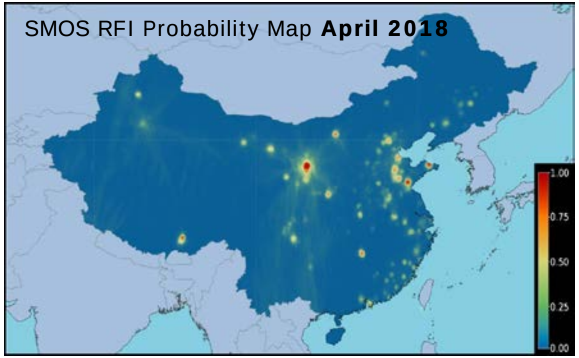
N. RFI / Strength / Continent

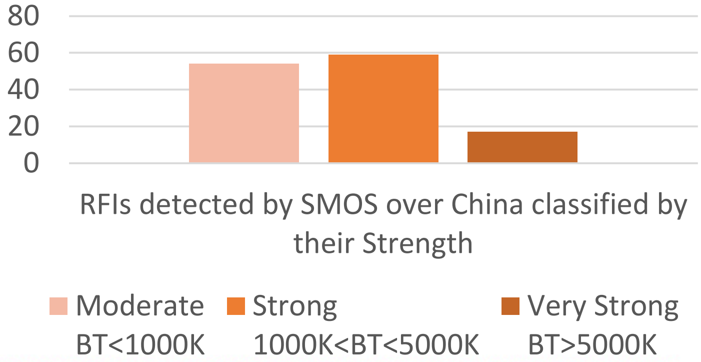
(March 2017)



RFI situation in China







Although the RFI situation has improved substantially since 2010, there are still around 130 sources of interference detected by SMOS in the territory of China. Most of them are located near the coast, polluting not only SMOS land products, but also leaving some parts of the ocean without science data.

Summary, remarks and perspectives

SMOS extension 2020/2021– ocean outlook

1. Processors and Platforms

- Major **upgrade L2 processor** (v7 onwards): novel dielectric constant model; novel auxiliary WS source/uncertainty and roughness impact; improved characterization L2/L3 SSS uncertainty; assessment potential novel retrieval scheme
- **Pi-MEP salinity**: implementation completion, pre-ops and ops release; enhanced validation, synergistic data exploitation; quantification representativeness error; potential collaboration with NASA
- **CCI+ SSS**: broad L-band (SMOS, Aq, SMAP, AMSR) round-robin intercfr of retrieval algo, errors, models and Aux data

2. Drivers for mission extension

- **Climate**: Enlargement of SSS CDR and enhanced monitoring/characterization of SSS along with crucial climate indices/oscillations (ENSO, IOD, MJO) and extreme events
- **Ops**: Enhanced SSS data assimilation into OCM and operational oceanography; Systematic production of SMOS wind speed / wind radii within TC monitoring/forecasting framework
- **Synergy**: Sustained and increasing synergy with S1/S2/S3/Cryosat/TPMs for a variety of oceanographic applications with novel sensors or with increased coverage

3. Further scientific exploitation

- **Air/sea interaction** (Upwelling, freshwater river plumes; stratification; freshwater lenses)
- **Biogeochemistry** (carbon cycle and Ocean Acidification)
- **High latitudes** (Artic) and **semi-enclosed sea** (Med) regional focus

Summary and perspectives (i)

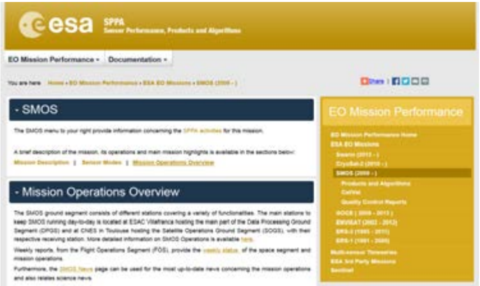
- SMOS provided the **first ever satellite** measurement of **Sea Surface Salinity**
- Being a one-of-a-kind measurement with a disruptive novel technology (synthetic aperture radiometry), was **inherently prone to technical and scientific challenges**
- With the acquired expertise over a 9-yr long mission, many of these **shortcomings** have been **addressed or drastically reduced** (RFI, LSC, external noise sources contamination)
- The recent **L2OS v662 release** represents now a solid and stable dataset to enable science and applications
- Whilst tackling these issues, a **wide range of oceanographic applications** (air-sea interactions, ocean circulation and modelling, climate indexes monitoring, marine biogeochemistry, NWP etc.) started developing, and they are further enlarging with the release of the latest OS reprocessing.
- New applications in challenging zones (High latitude and semi-enclosed seas) are emerging thanks to **new algorithm developments**

Summary and perspectives (ii)

- Recent developments provide novel platforms (**Pi-MEP**) to ensure **enhanced validation** and stimulate **oceanographic process studies** embedding salinity from space
- Recent studies in **Data Assimilation** SMOS SSS positive and upcoming efforts are foreseen

Collection of results in JGR-Ocean 2014 special issue "Early Scientific Results from the Salinity Measuring Satellites Aquarius/SAC-D and SMOS“ and in RSE 2016 SMOS special issue

SMOS Portal
https://earth.esa.int/smos



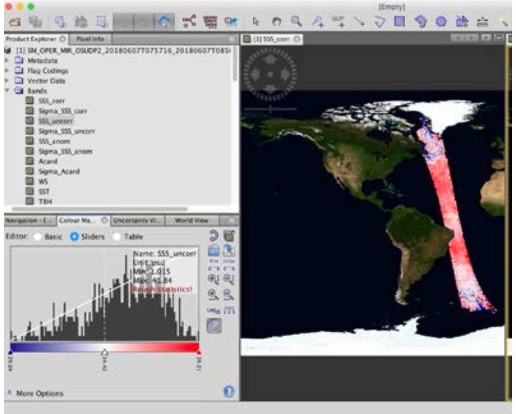
SMOS SPPA Portal
https://earth.esa.int/web/sppa/mission-performance/esa-missions/smos

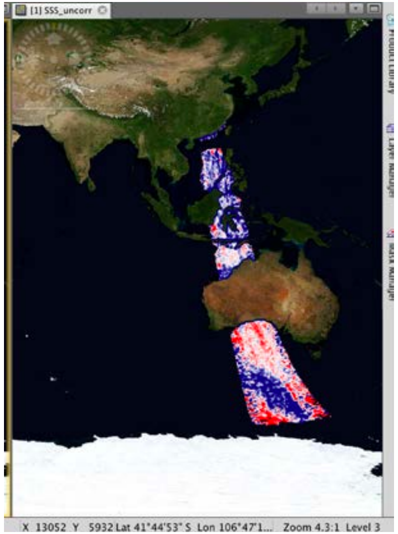
SMOS Data Quality
https://earth.esa.int/web/guest/-/data-quality-7059

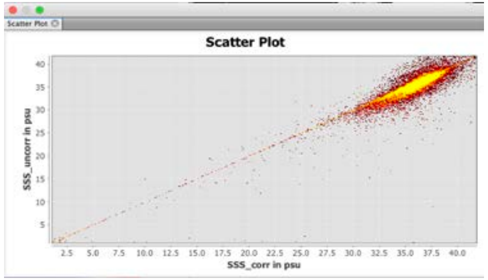
SNAP and Pi-MEP practical

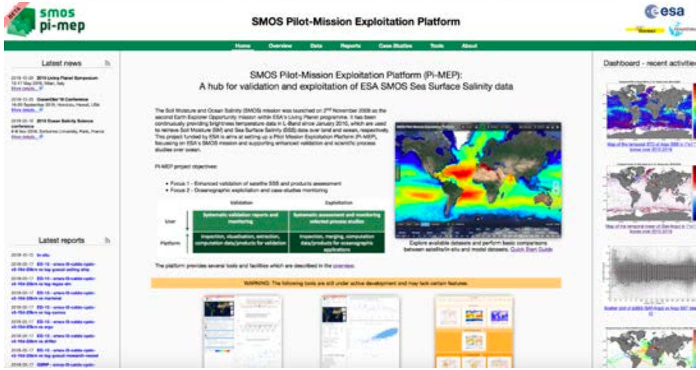
SMOS toolbox in SNAP software:

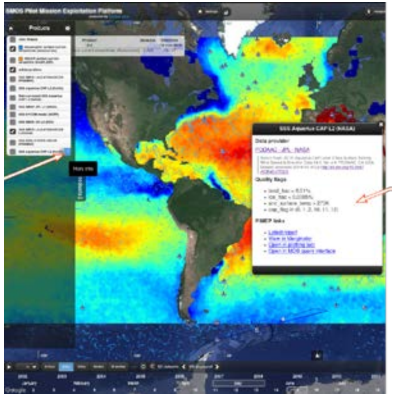
- Orbits visualization
- Flags Filtering
- Statistics computation
- Geophysical intepretation











Pi-MEP environment:

- Online beta-version platform
- Validation reports
- Tools for features extraction and statistical computation
- Case studies monitoring

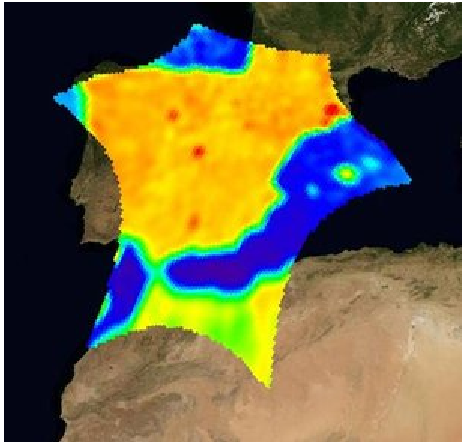
roberto.sabia@esa.int

Thank you

谢·谢！

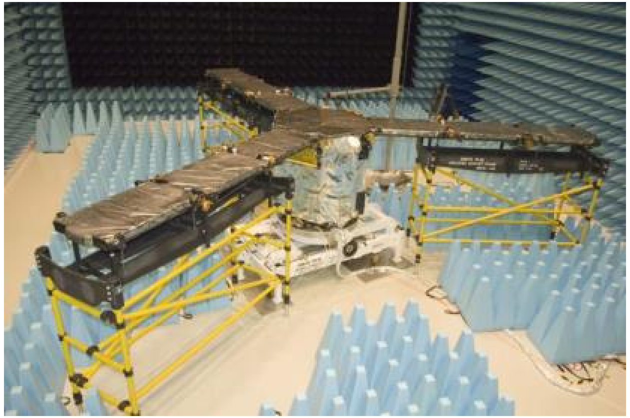
Back-up slides

MIRAS PRINCIPLE OF OPERATION



Aperture Synthesis Radiometer

- Many small, not-directive antennas pointing to the same target measuring the natural emission of the Earth.
- Cross-correlations between them are measured
- This can be related with the Brightness Temperature in front of the instrument



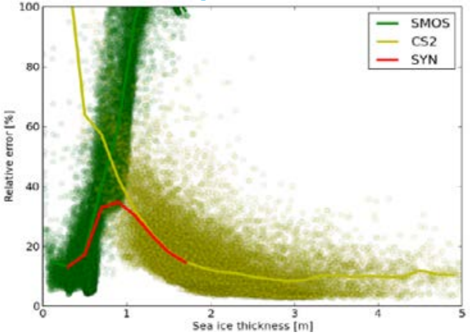
Advantages wrt Real Aperture

- There is no need for rotating antennas, so bigger instruments (and therefore resolution) are achievable
- Higher integration times leading to higher sensitivities

SMOS + CryoSAt-2 SEA ICE THICKNESS

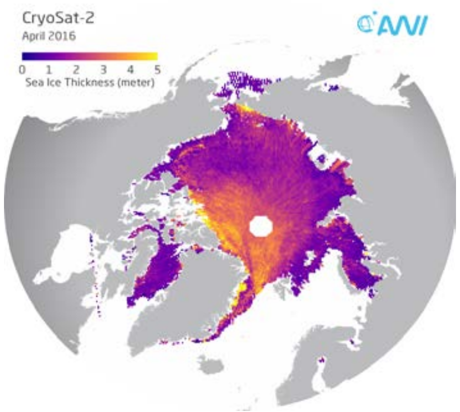
❑ New operational products in 2018:
wind speeds, SMOS+Cryosat sea ice th

Synergy ice product based on SMOS and CryoSat data

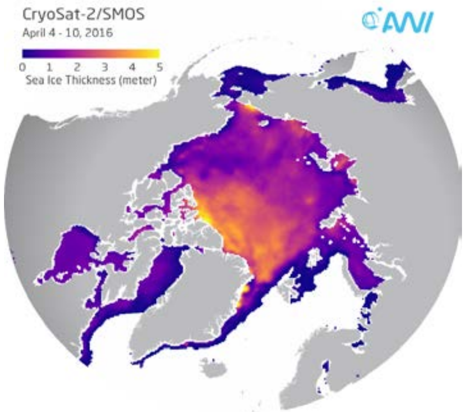


Validation with NASA IceBridge measurements

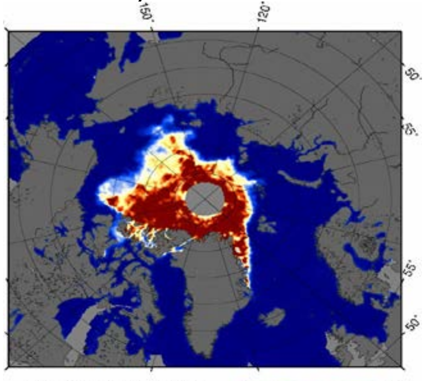
One month of CryoSat-2



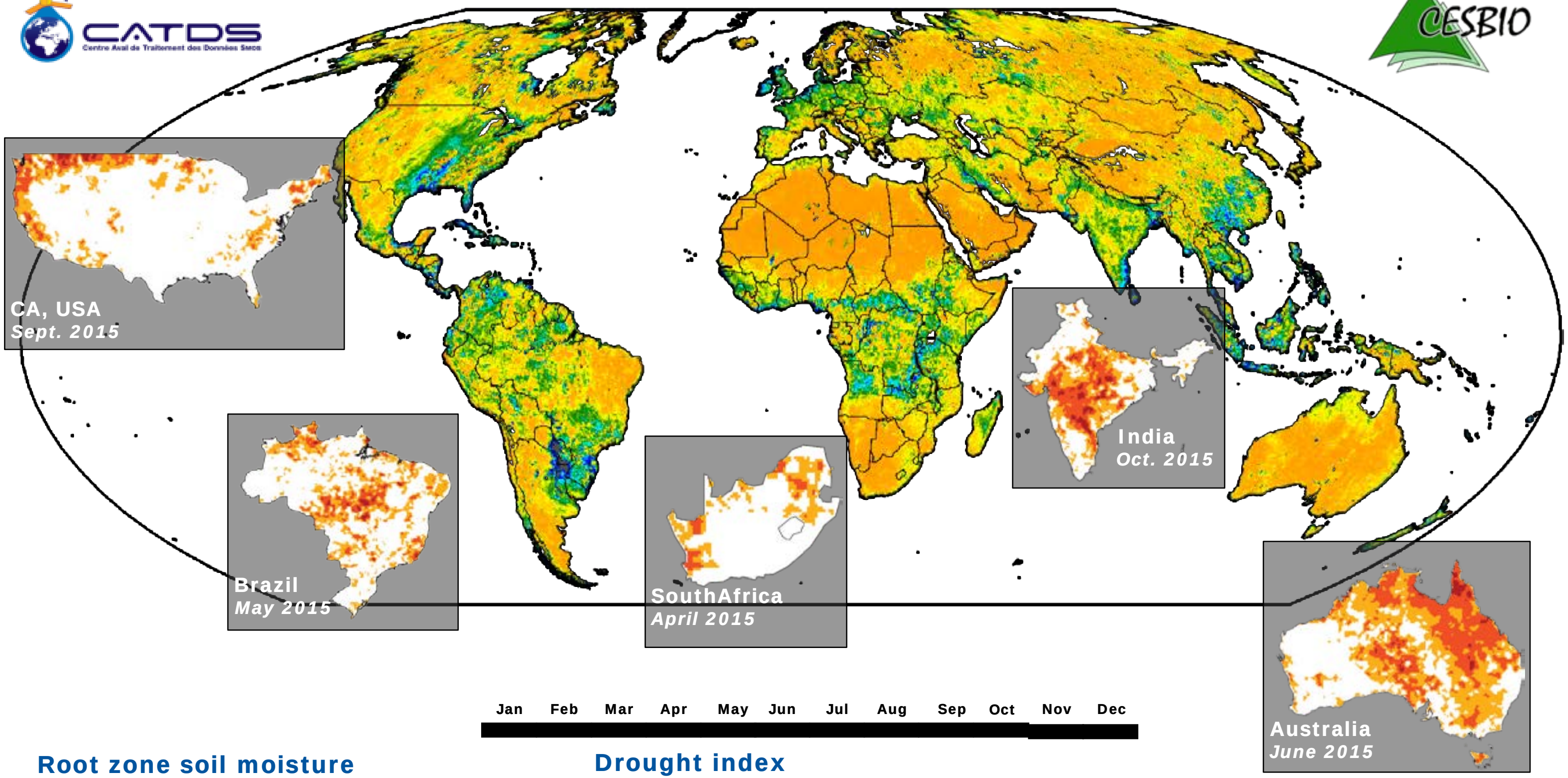
One week of SMOS + CryoSat-2



Ricker and Hendricks, AWI



SMOS monitoring major droughts in 2015



Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Root zone soil moisture

0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 (m³/m³)

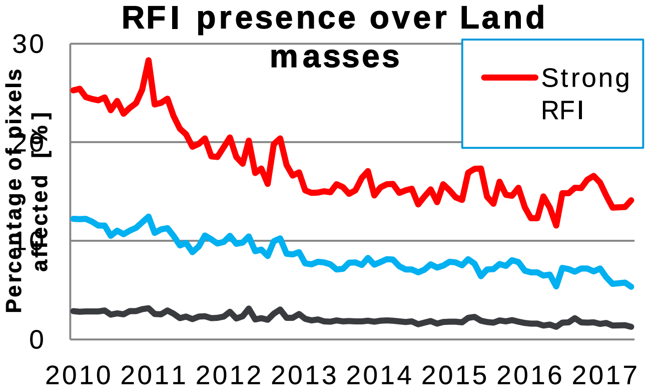
Drought index

moderat mild extre m

ahmad.albitar@cesbio.cnrs.fr

RFI Mitigation

Percentage of the number of SMOS pixels over land affected by RFI for the 8 years of SMOS in orbit. **Pixels flagged with strong RFI have decreased by 44%** over the mission life time (11% increase in clean pixels) and **pixels with RFI tail flagging (medium intensity) have decreased by 58%** (7% increase in clean pixels) **thanks to the efforts in detecting, geo-locating and reporting** the RFI cases to the Spectrum Management authorities of the relevant administrations.



RFI flagging in current processor baselines

Level	Flags	Based on
L1A	Entire Snapshot	Temporal evolution of zero baseline
L1C	Circle around RFI source	Observed intensity of RFI source from a known RFI list
L1C	Tails spreading from RFI source	Observed intensity of RFI source from a known RFI list
L2 SM	Land BT measurement (Type I pixels)	Min/max expected surface BT
L2 SM	Land BT measurement (Type II pixels)	Unnatural variations with incidence angles
L2 SM	Land BT measurement (Type II pixels)	Outliers detection
L2 OS	Ocean BT measurement	Min/max expected Surface BT
L2 OS	Ocean BT measurement	Excessive spatial standard deviation in snapshot
L2 OS	Ocean BT measurement	Outlier detection