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Sea Surface Salinity spatial variability: what is detected and what is missed with current satellite generation ?

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1. Why and how to measure Sea Surface Salinity (SSS) from space ?

Salinity of the oceans

- ~¾ of evaporation and precipitation over the ocean

→ **Ocean: major role in the water cycle**

- Salinity: **Tracer of water masses; driver of thermohaline circulation (**via influence on water density***)**
- SSS: tracer of **freshwater inflow, and driver of surface stratification**

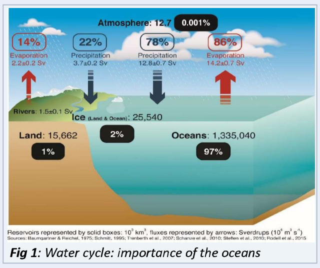


***Fig 1**: Water cycle: importance of the oceans*

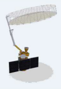
**In cold waters (SST=2 ° C), a 0.1 difference in salinity has the same impact on density as a 1 ° C difference in temperature*

In the tropics (SST=28 ° C), a 0.4 difference in salinity has the same impact on density as a 1 ° C difference in temperature

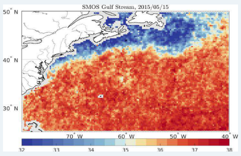
Past and present satellite missions for SSS observation (1.4 GHz radiometer)

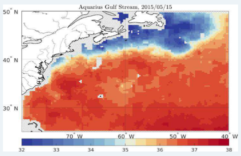
SMOS
Soil Moisture and Ocean Salinity (ESA, CNES)
Interferometric antenna
~43km of resolution, global coverage in 3 days

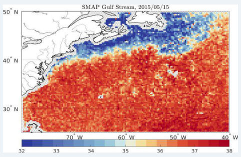
Aquarius
Argentina-USA collaboration (CONAE/NASA)
3 real aperture antennas
~150 km of resolution, global coverage in 7 days

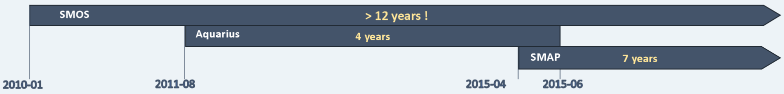


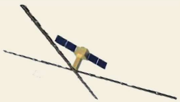
SMAP
Soil Moisture Active Passive (NASA)
Real aperture antenna
~43km of resolution, global coverage in 3 days











SMOS-HR
SMOS High Resolution (CNES)
Interferometric antenna
~15km resolution , global coverage in 3 days

Goal:
- increase the **spatial resolution** by at least a factor of 2
- preserving or improving the **radiometric sensitivity**
- ensure the **continuity of L-band observations**

In study, phase A ongoing

2. Accuracy of SMOS SSS satellite measurements

PIRATA-FR32 cruise

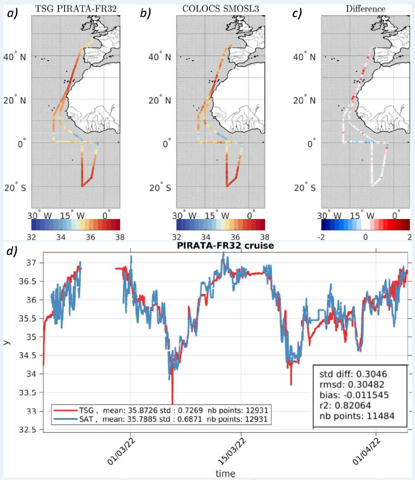


***Fig 2**: Comparisons between SMOS and PIRATA cruise; a) PIRATA measurements; b) SMOS colocations; c) Differences between both; d) Time series of PIRATA (red) and SMOS (blue)*

Argo floats

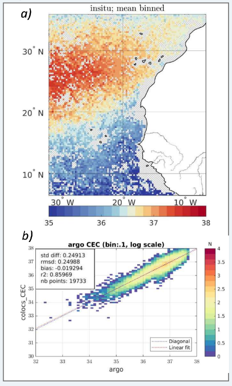
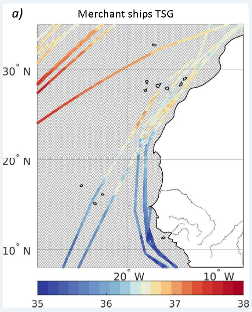


***Fig 3**: Comparisons between CCI and Argo floats; a) Argo measurements; b) Scatterplot (density of points, logarithmic scale)*

Merchant ships



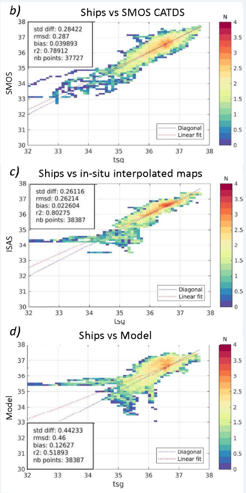


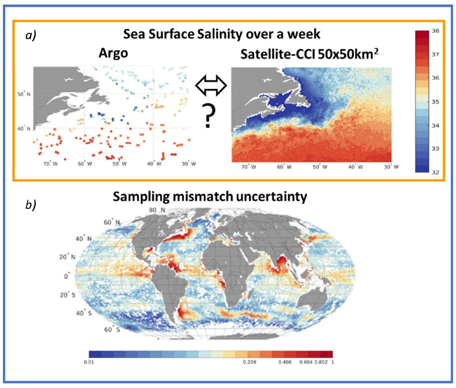
***Fig 4**: Comparisons between SSS products and Merchant ships Thermosalinographs; a) Ships measurements; b) Scatterplot between ships and SMOS CATDS SSS (density of points, logarithmic scale); c) Same with ISAS in-situ interpolated SSS maps; d) Same with SSS model*

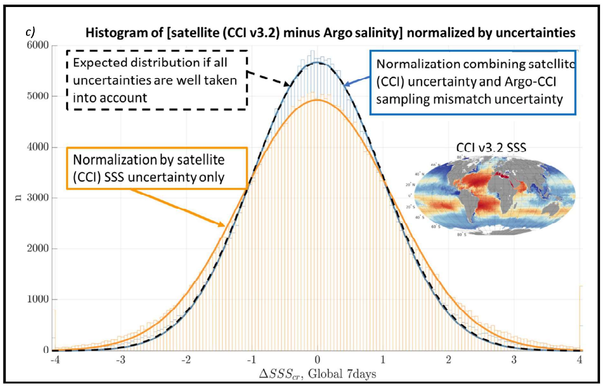
Comparing SMOS SSS to in-situ measurements demonstrates the capability of current measurements to detect SSS variability at ~50km

It brings invaluable information in regions of fresh water inflow, crucial to validate ocean models.

3. What is missed with current SMOS+SMAP (CCI); what will be improved with SMOS-HR?

Salinity variability inside satellite pixels: sampling mismatch between in-situ and satellite





Different sampling for in-situ and satellite data (a).
- SSS subpixel variability -> Uncertainty
- If the uncertainties are well estimated: differences divided by uncertainties should have a gaussian distribution
- We compute an estimation of the **sampling mismatch uncertainty** (b) using GLORYS model
- We show that the **uncertainty budget is complete (c)**
- U_{mis} contribution to Argo-CCI SSS STD diff.: **15%** (weekly CCI)

Thouvenin-Masson, C. et al.;
Satellite and In Situ Sampling Mismatches: Consequences for the Estimation of Satellite Sea Surface Salinity Uncertainties. *Remote Sens.* 2022,*14*,1878.
https://doi.org/10.3390/rs14081878

Work in progress: detection and interpretation of finer oceanographic phenomena

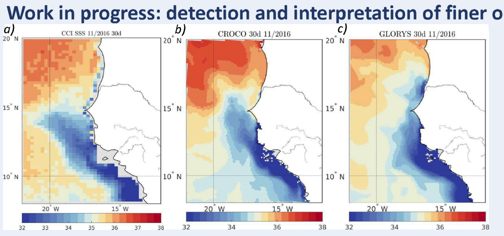


Fig 5: SSS in Senegal region, November 2016: a) CCI product; b) CROCO model (1/10°); c) GLORYS model (1/12°)

$$\underbrace{\partial_t \mathbf{S}}_{I} = \underbrace{(\mathrm{E}-\mathrm{P})\frac{\mathbf{S}}{\mathrm{H}}}_{II} + \underbrace{-\vec{\mathrm{u}}\cdot\vec{\nabla}\mathbf{S}}_{III} + \underbrace{\vec{\nabla}(\mathrm{K_h}\cdot\vec{\nabla}\mathbf{S})}_{IV} + \underbrace{(\mathrm{w}+\partial_t\mathrm{H})\frac{1}{\mathrm{H}}\delta\mathbf{S}}_{V} + \underbrace{\partial_z(\mathrm{K_z}\cdot\delta\mathbf{S})\frac{1}{\mathrm{H}}}_{VI}$$

Salinity equation:

1: change of salinity in mixed layer	4: horizontal mixing
2: forcing from the atmosphere	5: vertical advection and entrainment
3: horizontal advection	6: vertical mixing

Focus on Senegal region
freshwater propagation towards the open sea; what is the origin?
We decompose the salinity equation using CROCO model to analyse the influence of different terms:
Rain? River run-off? Advection?

Models give different results in this region