Generating SMOS Sea Surface Salinity maps with the help of Data Assimilation

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1. Introduction:

The European Space Agency's Soil Moisture and Ocean Salinity (SMOS) mission was launched on November 2009 and entered into operations phase in May 2010. SMOS provides global coverage of the Earth's surface Ocean Salinity (OS) and Soil Moisture (SM) every 3 days with a spatial resolution of 40-50 km. Knowing the diverse problems in SMOS data (RFI, Land/Sea transition, …) data assimilation is investigated here to study the possible improvement of Sea Surface Salinity (SSS) of SMOS, thanks to our ocean model used as an interpolator/extrapolator. All the study is focus on Macaronesian region, where both problems occur to retrieve SMOS data : RFI and Land/sea transition effects. So this region is a real challenge to study the ability of using a simple data assimilation method (Nudging) to generate a Level 4 SSS maps from noisy Level 3 SMOS products.

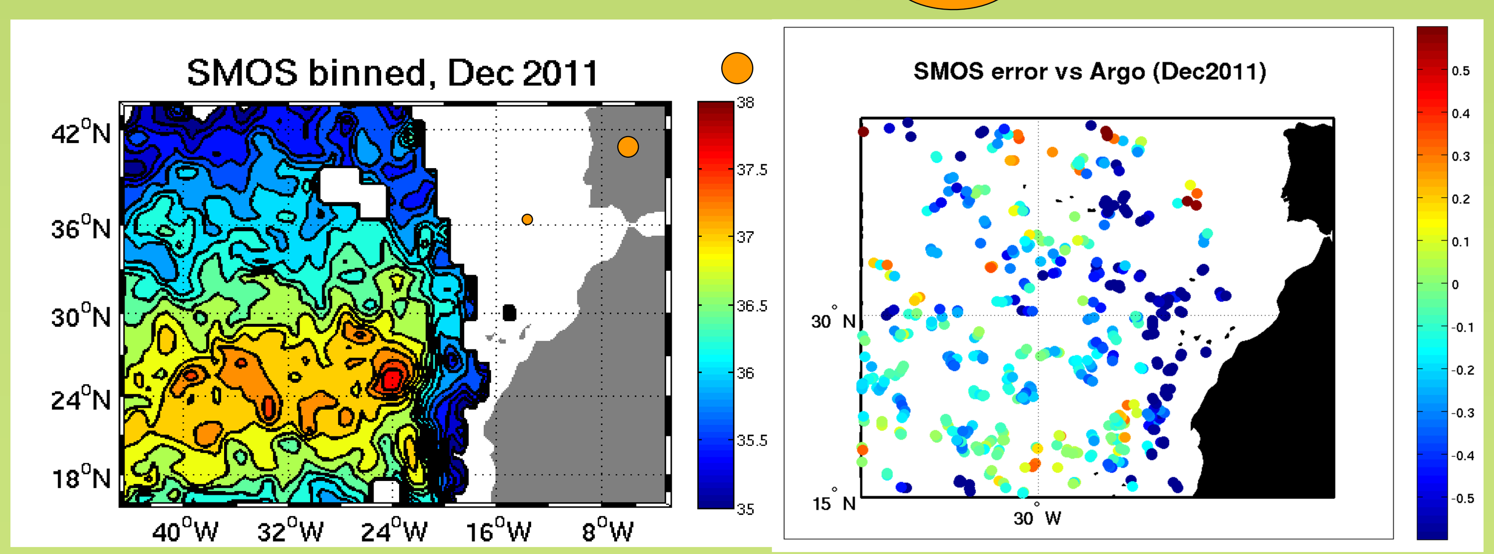
2. Data : SMOS SSS (http://cp34-bec.cmima.csic.es/)

Advantages of Satellite data:
- Global and systematic measure of SSS
- Measure of first surface cm.

Problems of SMOS data:
- RFI contamination
- Land-sea transition

SMOS L3 binned product:
10 days maps spatial and temporal average, every 3 days with ¼º resolution

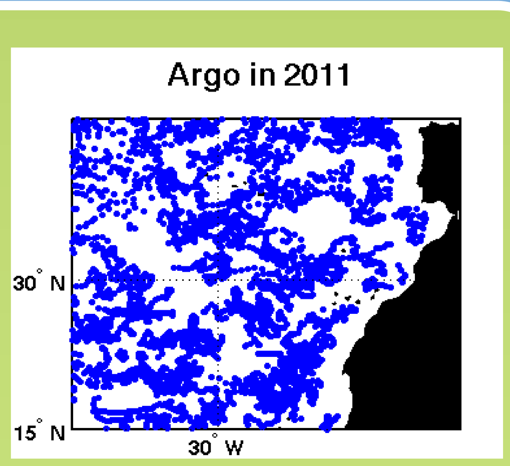
Salinity values filtered out due to low quality (RFI)



ARGO SSS

We use the Argo SSS data of 2011 distributed by CORIOLIS data centre (http://www.coriolis.eu.org). A set of 4,112 profiles are available.

Estimation of ARGO SSS is done by considering measurements deeper than 0.5 m by interpolating them to 7.5m.



Spatial distribution of ARGO data for 2011.

Used for Validation

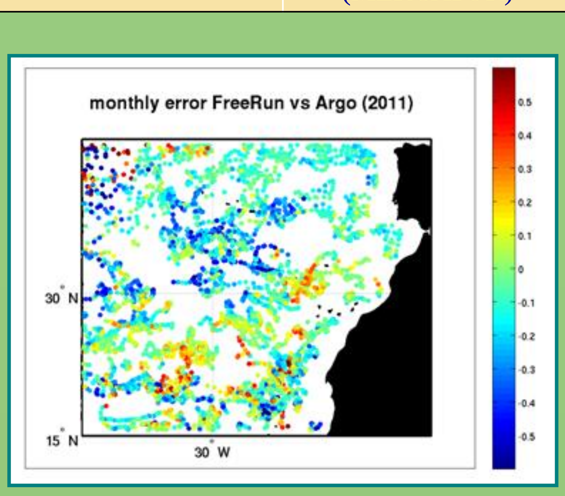
3. Primitive Equation Model: OPA-NEMO

No relaxation of SST and SSS

Basic characteristics of TARFAYA03 configuration:

Physical domain	
Boundaries	45ºW-5ºW, 15ºN-44ºN
Grid size	128 x 100 x 31
Spatial resolution	1/3º (33 km at the equator)
Time step	1800 s (48 time steps/day)
Parameterization	
Horizontal turbulent diffusivity	Laplacian, 300 $m^2 s^{-1}$
Horizontal turbulent viscosity	Bilaplacian, -1.2 x 10^{11} $m^4 s^{-1}$
Deep vertical diffusion	Laplacian, 1.0 x 10^{-6} $m^2 s^{-1}$
Surface vertical diffusion	Laplacian, 1.0 x 10^{-4} $m^2 s^{-1}$
Vertical turbulent mixing	TKE model

Atmospheric Forcing (NCEP-NCAR)	
Daily	Wind stress, 10m Wind speed, 2m Air temperature
Monthly	Precipitation rate, Cloud cover and Humidity
boundary conditions	
Open boundary	Seasonal data (MERCATOR)



4. Assimilation scheme : Nudging

$$\frac{dx}{dt} = Physics + k(x^0 - x)$$

Observations

Prognostic variable (SSS).

Relaxation coefficient (s^{-1})

- A Relaxation term is added into the equation of evolution of a **prognostic variable** (in our case SSS).
- The nudging term tends to reduce exponentially the distance between model and observations.

Nudging coefficient is $k = 5.10^{-6}$

5. Pre-process the data before assimilation?

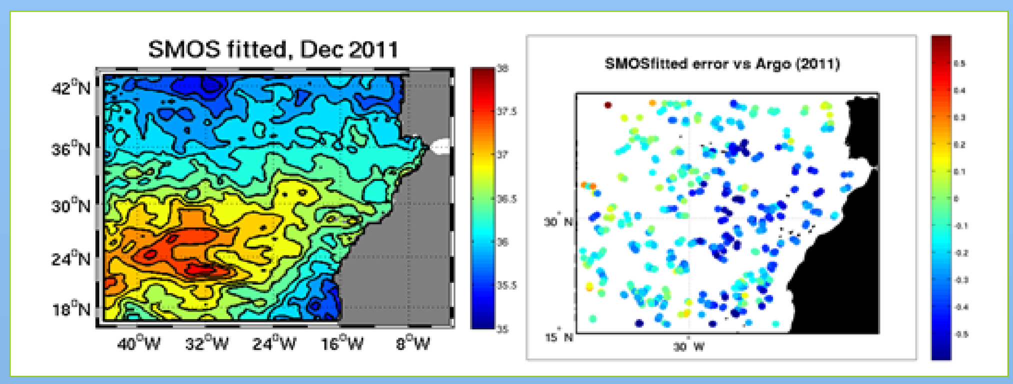


Fig. Right represents SSS maps of SMOS fitted for Dec. 2011. Left: corresponding error.

- Given the low quality of the regional estimates of SMOS SSS, we fit the SMOS data onto the EOFs of the model SSS.
- Compare the impact of such pre-process, no correspondence appears between the zonal variability of the original binned data and the fitted one, not even in the centre of the domain, where the SMOS binned fields is supposed to have smallest error.

5 experiments:

	Nudging coefficient	SMOS mask (red square)	SMOS product
Free Run	-	-	-
EXP1	5e-6	OFF	L3 Binned
EXP2	5e-6	ON	L3 Binned
EXP3	5e-6	OFF	L3 Fitted
EXP4	5e-6	ON	L3 Fitted

We study 5 experiments of data assimilation described on the table.

6. Results

submitted as *Hoareau et al.*, in RSE journal

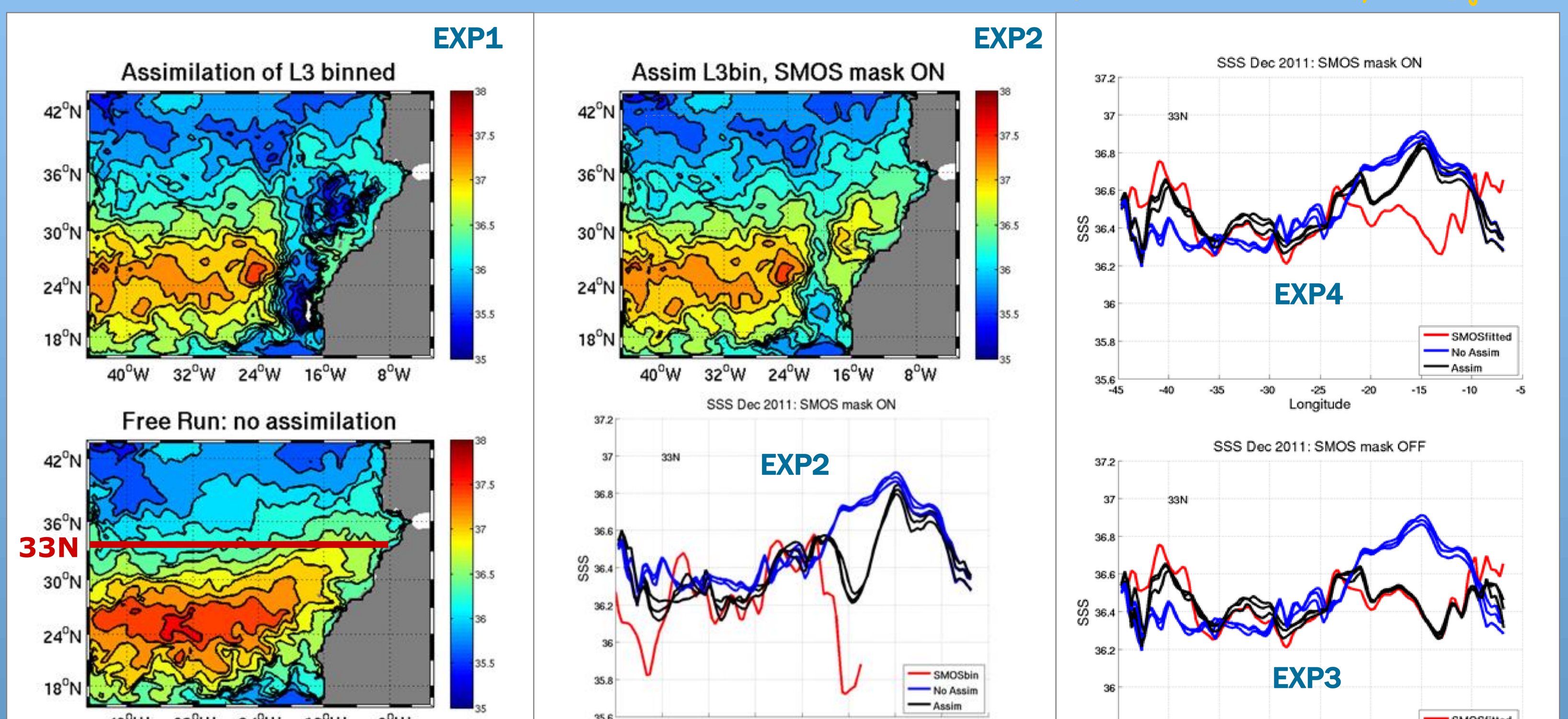


Figure [Fig: EXP1-SSS]: Two snapshots of the SSS corresponding to the 2011, December 29, i.e. towards the end of the assimilation experiment. Top: After assimilating SMOS (k=5 10^{-6}). Bottom: FREE-Run.

Top: Snapshot of the SSS (after assimilation) corresponding to December 29. Bottom: Zonal slice of the salinity at 33ºN. The assimilation has a maximum coefficient of k=5 10^{-6}, and decreases to zero east of 24ºW.

Figure **[Fig: EXP3/4 zonal]**: Zonal SSS at 33N for Dec 22, 2011. Top: Exp 4; Bottom: Exp 3.

- **All data assimilation experiments drive the system towards the SMOS original data (binned). Comparing to Argo, it is found that all the assimilation experiments produce salinity fields closer to the independent in-situ data than the original SMOS binned data.**

- **EXP2 (assimilation of the original SMOS data and with a nudging coefficient that is a function of space) provides the best result in term as: i) SSS closest to the original SMOS data; while ii) significantly reducing the difference against the independent Argo SSS values.**

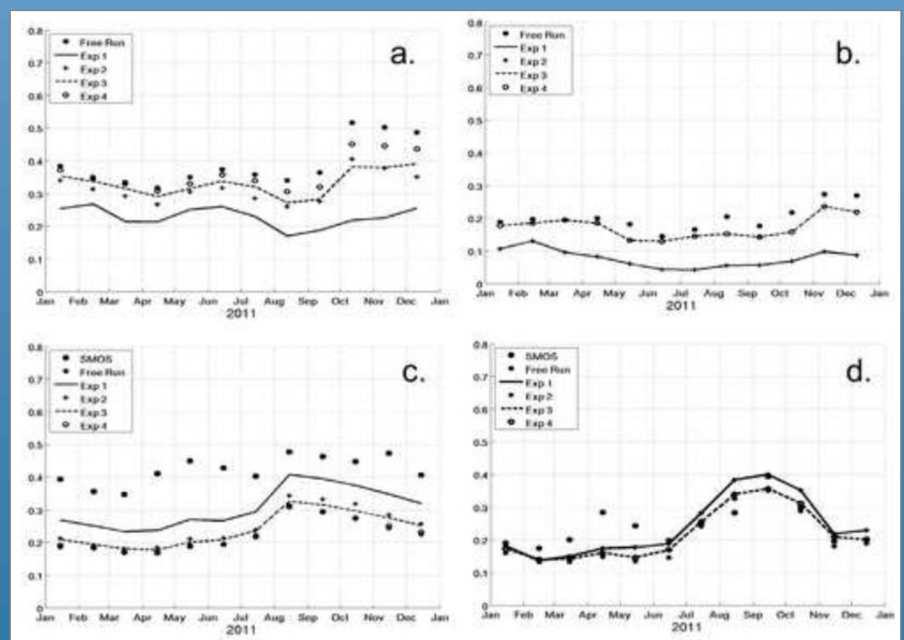


Figure 10: Time series of RMS. The RMS is calculated from the difference of Experiments with SMOS L3 binned (Top plots, *a.* and *b.*) and with Argo (Bottom plots, *c.* and *d.*). On left (*a.* and *c.*) are represented the RMS of the total domain, while on right (*b.* and *d.*) the RMS calculated only in the region in which the nudging coefficient has the maximum value (where the weighting mask is equal 1).

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7. Conclusion

✓ **The results prove that Newtonian Relaxation has the potential to be used to generate Level 4 products of SMOS SSS. The simplicity of implementation, the robustness, and low cost, makes this technique well suited for its application in basin-wide or global numerical simulations.**

✓ **The resulting sea surface field has an improved geophysical coherence (not shown here) than the original binned data.**

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