Bias correction of Sea Surface Salinity from space in a Global Ocean Forecasting System at 1/4°

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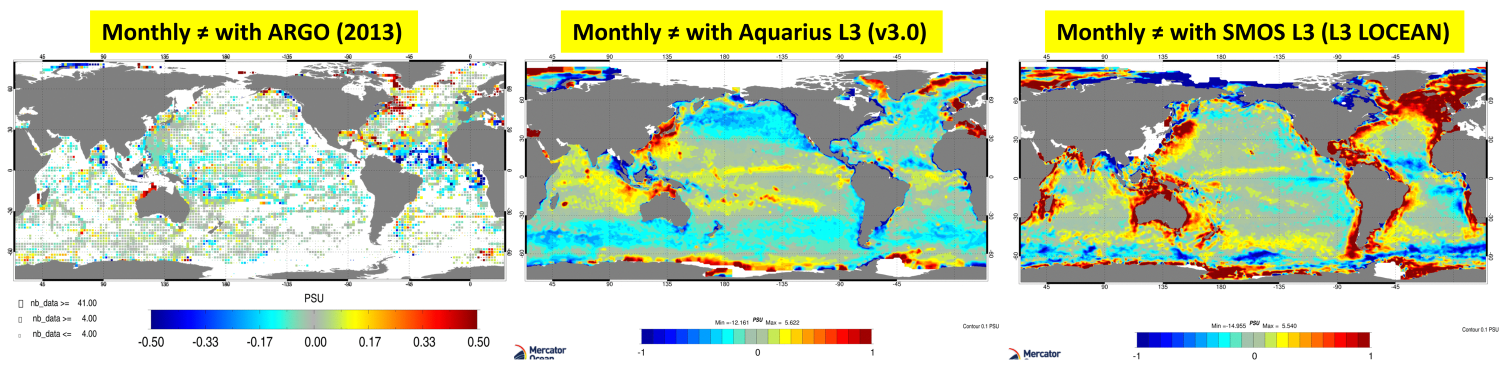
Abstract: SSS has been measured from space for the past 6 years with **SMOS and Aquarius** missions. These two missions should have filled the gaps in the current in-situ network. Few data assimilation experiments have been realized. It is largely due to large errors and biases in the data.
This needs to be addressed before assimilation in **operational ocean forecasting systems**. Our previous SSS data assimilation studies have shown that removing the systematic bias was a key issue.
In this study, we propose to estimate and remove the **large scale bias** with the operational ocean forecasting system at 1/4°.
The bias correction method is based on a **3D-Var method** already used for correcting the model bias with the in-situ data.
Results show that unbiased SMOS has a positive impact. It helps to fill the gap in particular in the tropical convergence zones.

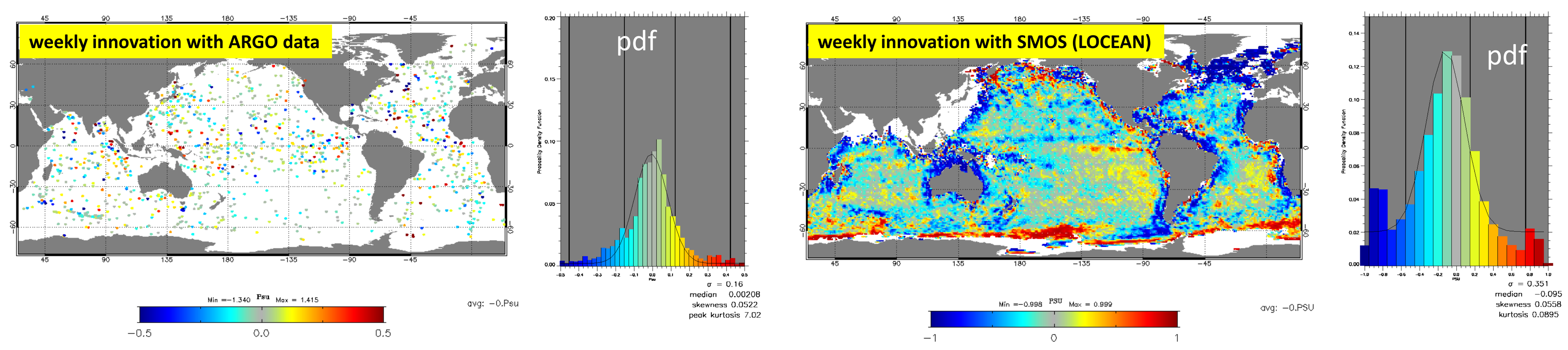
Previous results : ARGO vs Aquarius and SMOS in the global operational ocean forecasting system at 1/12°



•Global ocean forecasting system has very little biases, it is too salty in the Eastern Pacific & in the Atlantic. Largest biases and errors are located near the river mouths, in the western and Eastern Pacific along the Equator, and where the sub-meso-scale is significant.
•SSS from space (Aquarius and SMOS) are biased (latitudinal biases, RFI, etc…)
•Data assimilation of the SMOS/Aquarius data lead to introduce large biases in the ocean forecasting system. [3]
➔ Remove the large scale bias before assimilating SSS from space

One week forecast: SSS innovation

Week : 2012/01/04 - 2012/01/11



•Compared to in-situ data, the global ocean forecasting (1/4°) system has very little biases
•SSS from space should be used as a gap « filler »
➔Bias correction
➔Data assimilation between 45°S and 45°N

Objectives

•Estimation of the 2D bias in order to better assimilate SSS (space and in-situ) data in the operational ocean forecasting system[1] at Mercator Ocean
•Estimation of the observation error by an iterative scheme based on an analysis-error statistics [2]

Method

•Modification of the current bias (in-situ) correction by adding a new control
•Estimate an optimal set of parameters (weights, spatial scales etc…) of the current bias correction by maximising the impact on the SSS data.

Problem Formulation

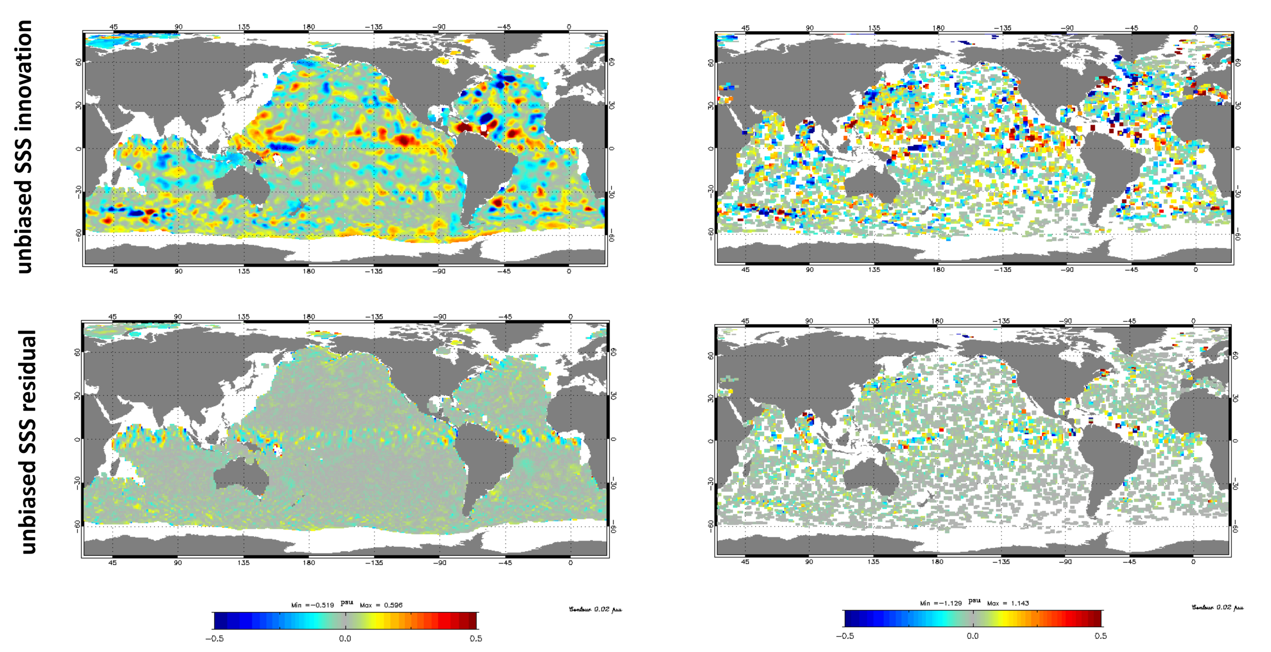
The 3D-Var bias ➔ The 3D bias of the model is estimated from the in-situ and SSS innovations.The cost function is defined in term of the control:

$$J(x,\zeta) = \tfrac{1}{2} < x , B^{-1} x > + \tfrac{1}{2} < y_d - H x , R^{-1}(y_d - H x) >$$
$$+ \tfrac{1}{2} < \zeta, B_\zeta^{-1} \zeta > + \tfrac{1}{2} < y_\zeta - x , R_\zeta^{-1}(y_\zeta - x) >$$

- x is the 3D bias to estimate and ζ is the 2D SSS bias.
- B is the background error covariance matrix of the 3D bias,
- y_d is the in-situ innovation,
- H is the observation operator , R is the observation error covariance matrix (included the representativity).
- All observations (SSS included) are binned on a 1°x1° grid ➔ correlation of observation is neglected and the error matrix is diagonal
- y_ζ is the unbiased SSS innovation and S^f is the forecast model mean (spatial/temporal) over the period of observation (1 month):

$$y_\zeta = (SSS - \zeta [*,*]) - S^f[*,*]$$

Unbiased SSS Innovation and residual



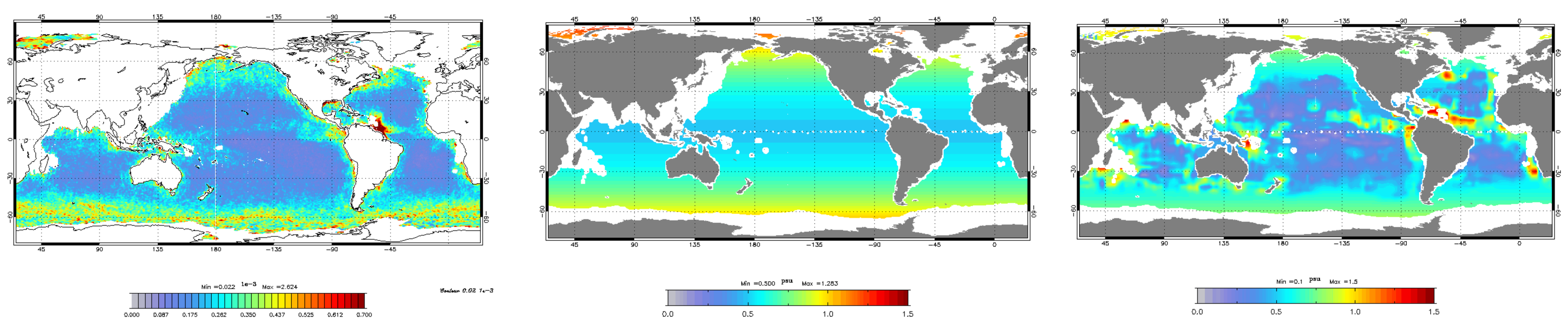
•With an important filtering (Gaussian filter width) of SMOS spatial scales and a fixed error ➔Unbiased SSS innovation from SMOS is close to that of in-situ data
•Unbiased SMOS information is consistent with in-situ data in the mid-latitudes
➔Accurate « Gap Filler »
•Few interesting signal in the residual ➔ no consistency between SMOS and in-situ data ➔ Structured noise in the tropical band

Error Estimation of SSS bias

Method: Bootstrap with the Desroziers ratio (see below) to estimate the SSS bias error R_ζ:

$$R_\zeta = D_\zeta^3 D_\zeta^2 D_\zeta^1 r_\zeta R_\zeta^0$$

R_ζ^0 is the default error, D_ζ^i are the Desroziers corrections and r_ζ is an amplification factor (scalar)



Total variation (l1-norm) | R_ζ^0 : default error (latitudinal) | R_ζ : estimated error

•The estimated error is close to the total variation
•Need to take into account the error near the coast

$$D_\zeta = \text{Desroziers ratio} = \frac{E\left[\zeta_a^o \cdot (\zeta_b^o)^T\right]}{R_\zeta^0}$$

Residual — Innovation

- Ideally, ratio=1
- ratio < 1 => obs. error overestimated
- ratio > 1 => obs. error underestimated

1. Lellouche, J.-M., Le Galloudec, O., Drévillon, M., Régnier, C., Greiner, E., Garric, G., Ferry, N., Desportes, C., Testut, C.-E., Bricaud, C., Bourdallé-Badie, R., Tranchant, B., Benkiran, M., Drillet, Y., Daudin, A., and De Nicola, C.: Evaluation of global monitoring and forecasting systems at Mercator Océan, Ocean Sci., 9, 57--81, doi{10.5194/os-9-57-2013}, 2013.
2. Desroziers et al.: Diagnosis of observation, background and analysis-error statistics in observation space, Q. J. R. Meteorol. Soc., 131, pp. 3385–3396, 2005.
3. Tranchant et al., Sea Surface Salinity Data Assimilation Improvement in a Global Ocean Forecasting System at 1/4° from SMOS and Aquarius Data, 2nd SMOS science conference, 25-29 May 2015, ESA-ESAC, Villafranca (Madrid), Spain.

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