Model error statistics for future satellite SSS data assimilation

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1. Context

Satellite observations of Sea Surface Height (SSH) and Sea Surface Temperature (SST) have largely contributed to the successes of GODAE during the last decade. Future satellite Sea Surface Salinity (SSS) observations, which will soon strengthen this satellite ocean observing system, will hopefully participate to the success of post-GODAE initiatives. The Soil Moisture and Ocean Salinity mission (SMOS) from the European Space Agency, scheduled for launch in early 2009, will initiate the era of satellite SSS observations, quickly followed by the American Argentinean Aquarius/SAC-D mission.

In an ocean analysis and data assimilation context, one of the main challenges will consist in properly integrating these new observations into ocean models. This requires, among other things, a better understanding of SSS model error. With that aim, this work investigates SSS ensemble covariances associated with uncertainties in the wind stress forcing.

2. Model and methodology

MODEL:

- Regional configuration of NEMO-OPA v9.0 (Madec, 2008)
- 1/3º
- 31 vertical levels (10-m resolution at the surface)
- 4 open boundaries (Mercator MERA11 data)
- 7-year simulation: Jan 2000 - Dec 2006, after a 15-year climatological spinup
- Daily atmospheric forcing from NCEP
- No relaxation to SSS nor SST

ENSEMBLE APPROACH:
100 simulations are performed with perturbations of the **wind stress** (shown to be the forcing parameter with the largest impact on model SSS in this region, Mourre et al., 2008).

3. Parameterization of the wind stress error

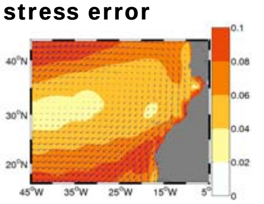

Fig1: 2000-2006 average of daily NCEP wind stress (N/m2).

- Perturbation $\vec{\tau}'$ applied to the wind stress $\vec{\tau}$ for a given month m = random combination of the 20 leading EOFs $\vec{\psi}_i$ of the 2000-2006 30-day low-pass filtered wind stress.

$$\vec{\tau}'(m) = \gamma(m)\sum_{i=1}^{20}\alpha_i(m)\vec{\psi}_i \quad \text{with} \quad \begin{cases} \alpha_i(m) \in \mathcal{N}(0,1) \\ \gamma(m) = 0.3\dfrac{\|\vec{\tau}(m)\|}{\left\|\sum_{i=1}^{20}\alpha_i(m)\vec{\psi}_i\right\|} \end{cases}$$

- Assumption of:
  - * a 30% uncertainty in the wind stress field
  - * a 30-d decorrelation time scale of the perturbations (i.e. no correlation between $\alpha_i(m)$ and $\alpha_i(m+1)$).

4. SSS ensemble mean

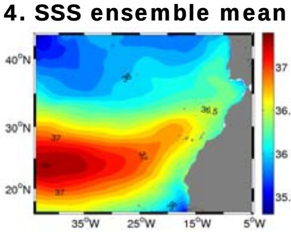

Fig3: 2006-averaged SSS ensemble mean (psu).

- Reasonable agreement with Reverdin et al. (2007) climatology.
- No spurious SSS bias.

Acknowledgements
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5. SSS ensemble spread

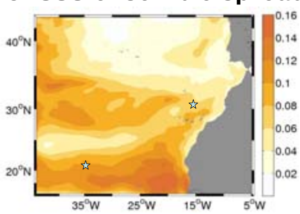

Fig4: 2006-averaged SSS ensemble standard deviation (psu).

- Values of SSS ensemble spread around 0.1 psu (which is – hopefully – the expected accuracy of satellite SSS observation products).
- Largest values found in areas with a strong influence of lateral advection on the SSS (generally corresponding to areas with strong lateral SSS gradients).

6. Vertical structure of the salinity ensemble spread

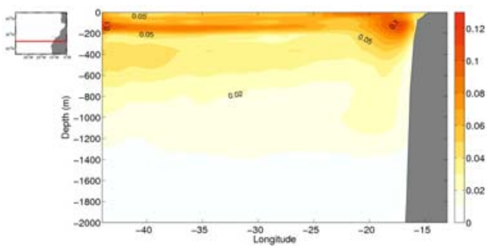

Fig5: 2006-averaged 25ºN zonal section of the salinity ensemble spread.

- Largest values found below the basis of the mixed layer in the western part of the section, due to the vertical diffusion of the anomalies into the halocine.
- Around 20ºW, maximum spread at the surface due to the predominant role of lateral advection on the local SSS.
- Close to the continent, subsurface maximum at 150m and values > 0.02 psu deeper than 1000 m linked to the perturbation of the strength of the upwelling.
- Westward propagation through Rossby waves of the salinity anomalies from the upwelling region to the western part of the section at about 450 m depth.

References

Madec, 2008, *NEMO ocean engine*. Note du Pôle de modélisation, Institut Pierre-Simon Laplace (IPSL), France, No 27 ISSN No 1288-1619.

Reverdin et al., 2007, *Surface salinity in the Atlantic Ocean (30ºS-50ºN)*. Progr. Oceanogr., 73, 3-4, pp 311-340.

Mourre et al., 2008, *Surface salinity response to changes in the model parameters and forcings in a climatological simulation of the eastern North-Atlantic Ocean.* Ocean Modelling, 23, 13-20.

Mourre et al., 2009, *Model surface salinity ensemble covariances due to wind stress uncertainties in the eastern North-Atlantic Ocean.* In preparation for Ocean Modelling.

7. Temporal evolution of SSS spread

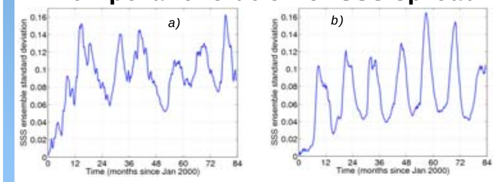

Fig6: Temporal evolution of the SSS ensemble standard deviation at a) [35ºW;20ºN] ; b) [15ºW;30ºN].

- Seasonal / interannual variations superposed to a background error level after approximately one year.
- Time scale for the error growth (periods of rapid increase) of the order of 3-4 months.
- Time persistence of error events between 3 and 7 months.

8. SSS ensemble correlation distances

The e-folding criterion is used to distinguish between significant and insignificant correlations.

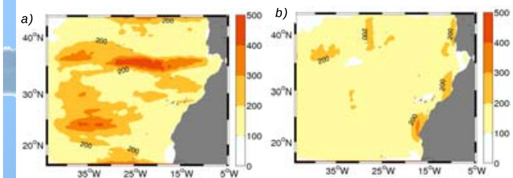

Fig7: 2006-averaged zonal (a) and meridional (b) correlation radius.

- Anisotropy and inhomogeneity of error correlation radii.
- SSS error correlation distances larger than 100 km almost everywhere in the domain.
- Azores current region and core of the subtropical salinity tongue: values up to more than 400 km in the zonal direction.
- In the meridional direction, values > 200 km along the Iberian and African Coast.

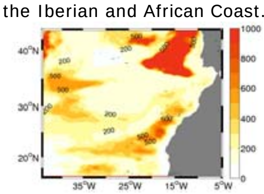

Fig8: 2006-averaged vertical correlation radius.

- Vertical correlation distances about 200 m. Values generally larger than the winter mixed layer depth (diffusion of the anomalies into the halocline).
- Correlation distances until 1000 m in regions where subduction occurs.

9. Conclusions

- Satellite SSS data assimilation will be challenging because i) the SSS error magnitude is of the order of the observation accuracy; ii) the horizontal SSS error correlation scales are only slightly larger than the spatial resolution of satellite SSS products. On the other hand, the temporal resolution of SSS products is finer than the time scales of SSS error growth.
- The use of advanced data assimilation schemes is recommended to cope with the spatio-temporal variability of model error covariances according to the model dynamics.