Conbined assimilation of real-time altimeter and in situ data in the MERCATOR system

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introduction

MERCATOR is an operational forecasting system that provides in near real time realistic and 3D view of the ocean state: temperature (T), salinity (S) and currents. It is currently implemented for the North Atlantic ocean, based on a primitive equations OGCM (OPA) including 43 levels on the vertical, a 1/3° horizontal resolution, and a sequential data assimilation system based on Optimal Interpolation. Assimilation occurs every week on Wednesday, the model forecast being updated to reflect the newly collected near-real-time observations. Real-time analysis and forecast and project details can be found on the WEB (www.mercator-ocean.fr) .

In the current operational version of the MERCATOR Assimilation System, satellite altimetry Sea Level Anomalies (SLA) are assimilated using a Reduced Order Optimal Interpolation and Cooper and Haines method. **The system has been recently improved to assimilate T and S observations, in particular, ARGO data transmitted in real-time to CORIOLIS**.

In the most recent version (PSY1v2), the system assimilates SLA from recent satellites: Jason-1, Envisat and GFO; weekly Reynolds Sea Surface Temperature (SST) analysis; Sea Surface Salinity (SSS) from the Reynaud climatology; **and T and S vertical profiles provided by the CORIOLIS centre, including the ARGO profilers, in a fully multivariate way**. This is a new statistical method based on vertical empirical modes (EOFs of T(z), S(z) and the barotropic streamfunction Ψ).

Methodology

The Mercator forecasting system is operated weekly. Sequential assimilation is used to provide a more realistic ocean state using real-time data collected over the previous week:

1) The differences between SLA, T and S observations and model forecast are computed at appropriate time and data locations for a full week model integration.

• These differences "the misfists" are projected in a 2D reduced space using a fully multivariate OI:

- ✓ **The estimation state vector is the vertical profiles of temperature and salinity, and the barotropic streamfunction**.
- ✓ EOFs of the estimation state vector are computed once at each point of the model grid from hindcast simulations of the operational MERCATOR system.
- ✓ The OI gain is computed for each of the EOFs independently (EOFs orthogonality) for a given number of dominant EOFs (order reduction).

• The model state is updated by the sum of the contribution of each selected EOF to the gain multiplied by the innovation vector

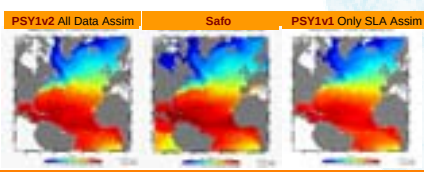
• The baroclinic velocity increments (which are not in the estimation state vector) are computed assuming geostrophy.

2) A new model state analysis is updated, using the innovation vector computed above

3) Starting from this new ocean state, the model runs for the next week of prediction, using the atmospheric forcing forecast fields provided by the ECMWF

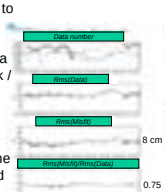
Sea Surface Temperature

The new multivariate system presents weaker biaises the univariate one, relatively to the composite **Safo** SST issued by Météo-France. Warm pool water, coastal upwelling, Gulf Stream and supolar front are now well reproduced.

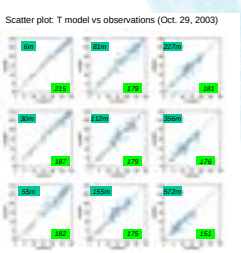


Diagnostics of assimilation

Satellite altimetry used to constrain weekly the geostrophic currents (here in 2002). The data number (Jason-1, black / GFO, yellow / ERS-2, blue) exhibits the data availability in real-time. The misfits (i.e., correction to apply to the model) reach 8 cm, and represents 75% of the data variability.



The lack of Jason-1 data during the summer, associated with a misfit increase show the improving impact of the third satellite.



Assimilating now T(z) and S(z) allow a realistic constraint on the forecast model water masses. Here observed temperature are compared to the model forecast **before assimilation**.

Impact of In situ and Altimeter data on MERCATOR

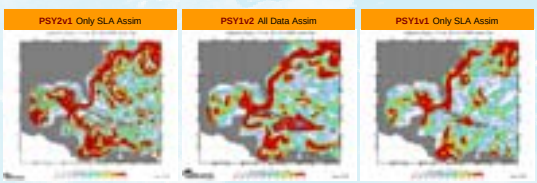
Forecast error in Temperature and salinity with (blue) and without (yellow) assimilatio of in situ data after 2 months.

The impact of the in situ data in the multivariate system is clear. If the data are not used, performances deteriorate, both in term of thermohaline structure and sea level.

Forecast error in Sea level with (left) and without (right) assimilation of SLA after 3 months.

Gulf of Mexico and Caribbean Sea…

If the univariate system was mostly relying on Law conservations, the new system in entirely statistical. This does not degrade the physics. Indeed, shelf and subpolar circulation is improved.



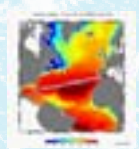
PSY2v1: the "Prototype Atlantique Mediterranée" (PAM) between 9°N and 70°N. The horizontal resolution is 1/15° and 43 levels used on the vertical.
PSY1vx: the "Maquette Atlantique Nord" (MNATL) between 20°S and 70°N. The horizontal resolution is 1/3° and 43 levels used on the vertical.

Salinity Section 29-10-2003 Florida-Gibraltar

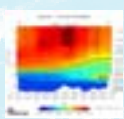
Across the north atlantic ocean, the model salinity is modified by the assimilation of in-situ data:

The low resolution (PSY1v2) configuration **is strongly improved by in-situ observations and ARGO data**, compared to the altimetric-only assimilation configuration (PSY1v1), getting closer to the climatology, and **providing a description of the mesoscale variability at depth**. The mediterranean water and meddies signatures are clearly reproduced at the right depth.

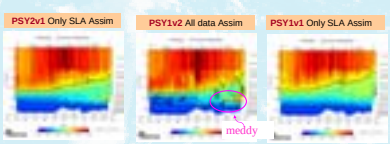
Note that assimilation altimetric and in-situ data on the low resolution model (1/3°) allow to match the realism of the high resolution configuration of Mercator (PSY2v1, 1/15°) that only assimilates satellite altimetry.



The model SSS and the section



Reynaud salinity climatology



Conclusion

This poster presents the new assimilation scheme. It gives good results, better and more detailed than the operational one. It is still CPU consuming which limits to 12 the number of modes that can be used for real time operations.

References

- Cooper, M. and Haines, K., 1996 : Altimetric assimilation with water property conservation. J.Geophys. Res, 101, 1059-1077
- De Mey, P. and Benkiran, M. 2002 : A multivariate reduced-order optimal interpolation method and its application to the Mediterranean basin-scale circulation. In Ocean Forecasting: Conceptual Basis and Applications, editor, N. Pinardi, Springer.

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