MULTI-RESOLUTION MODELING AND ASSIMILATION APPLIED TO THE SOUTH ATLANTIC OCEAN

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The REMO Project

REMO – the Ocean Modeling and Observations Network - is a Brazilian initiative in ocean modeling and operational oceanography, associated with GODAE Ocean View. Ocean forecast and hindcast systems such as the ones being developed for the REMO project have diverse applications, ranging from climate studies to operational support for the offshore industry. Such modeling and forecasting systems are required to produce consistent estimates of the ocean state across a range of scales, so that the system outputs are relevant to a diverse set of applications.

As a component of the REMO project, we have been exploring the use multi-resolution modeling, and scale-recursive estimation techniques. In particular, we have developed a multi-resolution system, exploring different model configurations that include global domain eddy-permitting resolution, Atlantic basin domain eddy-resolving resolution, and regional domains along the Brazilian coast, in the western South Atlantic, including tides. These models can be thought as multi-level tree structures, where each level represents a certain scale (resolution) and are linked to levels above and below in the tree, essentially providing a connection between processes represented at different scales.

The model multi-resolution set-up

- **The Ocean Hindcast**

Results from a 10-year long hindcast (2006-2016), with focus on the Atlantic Ocean (1/12° resolution) and Western South Atlantic (1/24° resolution, with tides)

- **The Ocean Model**

HYCOM - Hybrid Coordinate Ocean Model, configured with: 32 σ_2 layers, bathymetry from Etopo-1 corrected with local data from the Brazilian Navy data set, 3-hourly surface forcing from MERRA2 (Modern-Era Retrospective Analysis for Research and Applications, version 2), and tides from TPXO

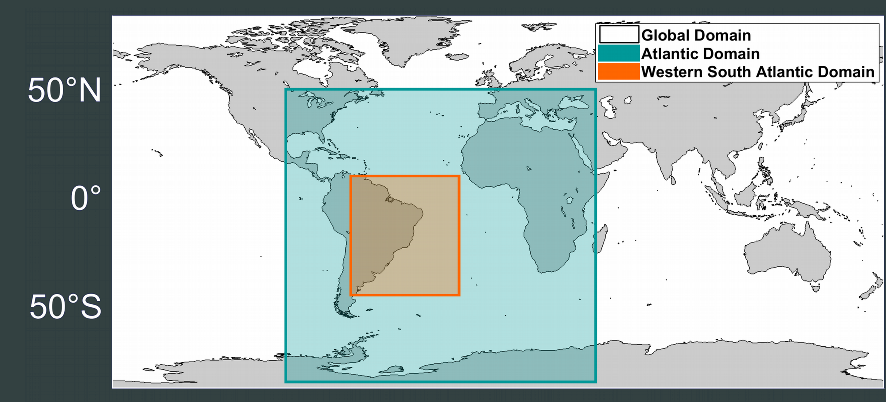


Figure 1: Multi-resolution model set-up, with 1/4 global, 1/12 Atlantic, 1/24 Western South Atlantic, nested grids.

- **The Data Assimilation System**

T-SIS – Tendral Statistical Assimilation System, assimilating daily alongtrack SLA, ARGO profiles, and sea surface temperature (SST)

Model adjustment to the assimilated data:

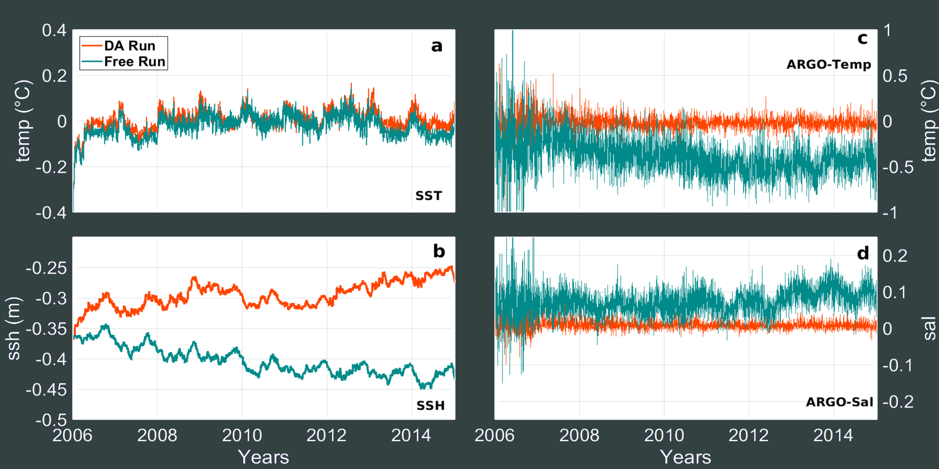


Figure 2: Time evolution of the domain-averaged model **BIAS**, in respect to (a) SST, (b) SSH, (c) temperature and (d) salinity profiles.

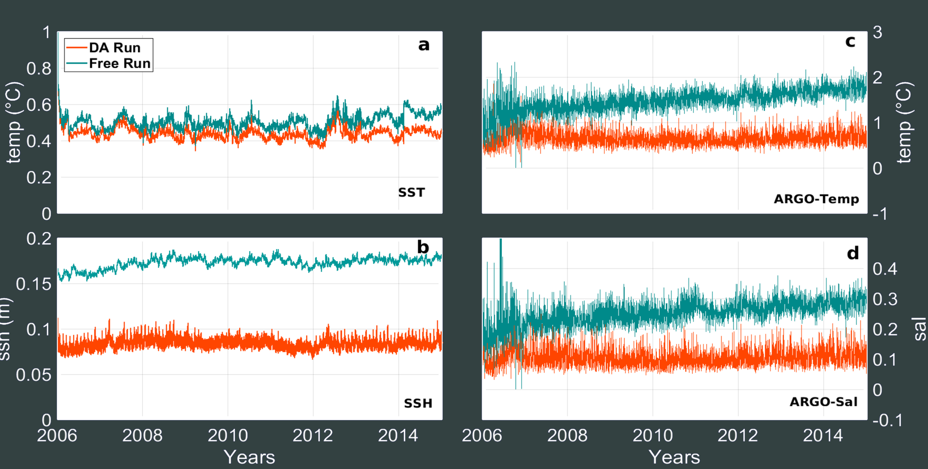
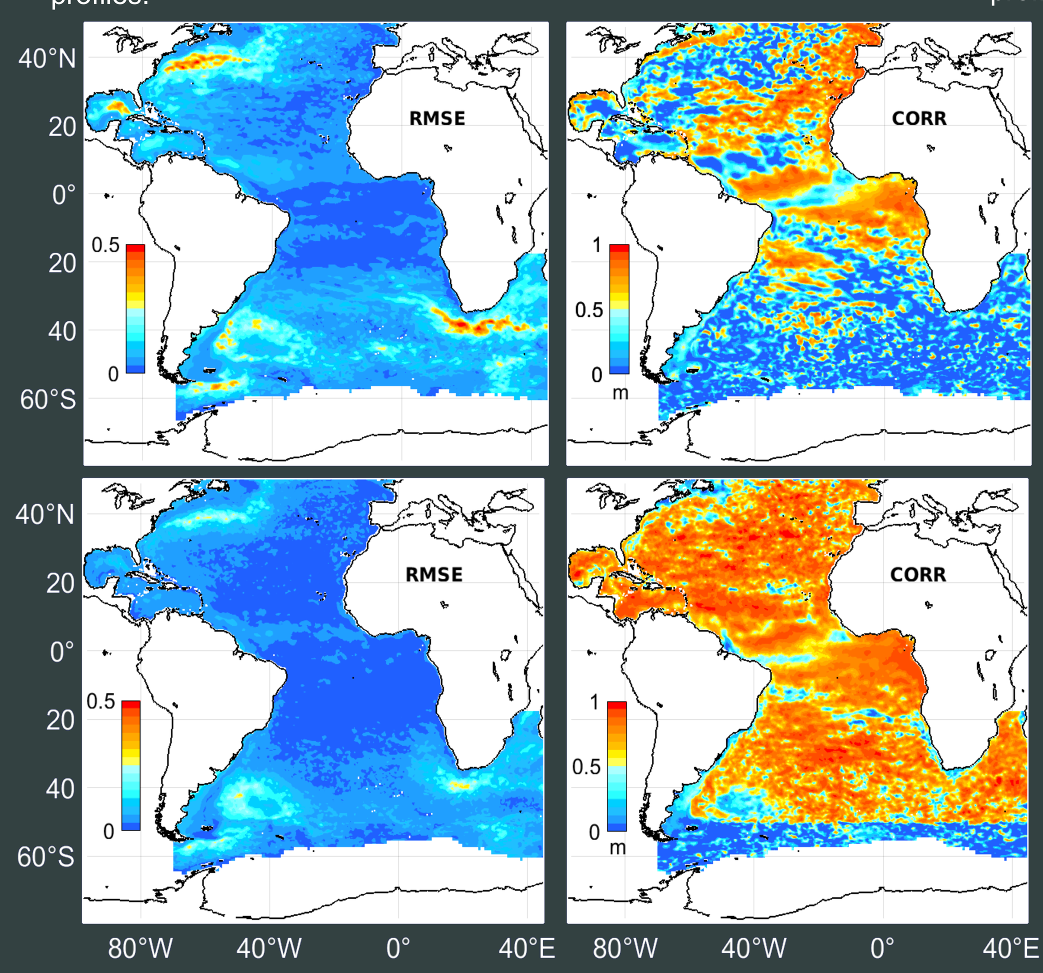


Figure 3: Time evolution of the domain-averaged model **RMSE**, in respect to (a) SST, (b) SSH, (c) temperature and (d) salinity profiles.



The significant decrease in model bias and error when compared to the assimilated data, and the associated increase in model-data correlation, indicate that the assimilation method is efficient in converging the model results towards the observed fields.

Figure 4: Model-data SLA RMSE and correlation for the first year run. Free run (upper panels) and assimilated run (lower panels).

Vertical Projection of SLA information

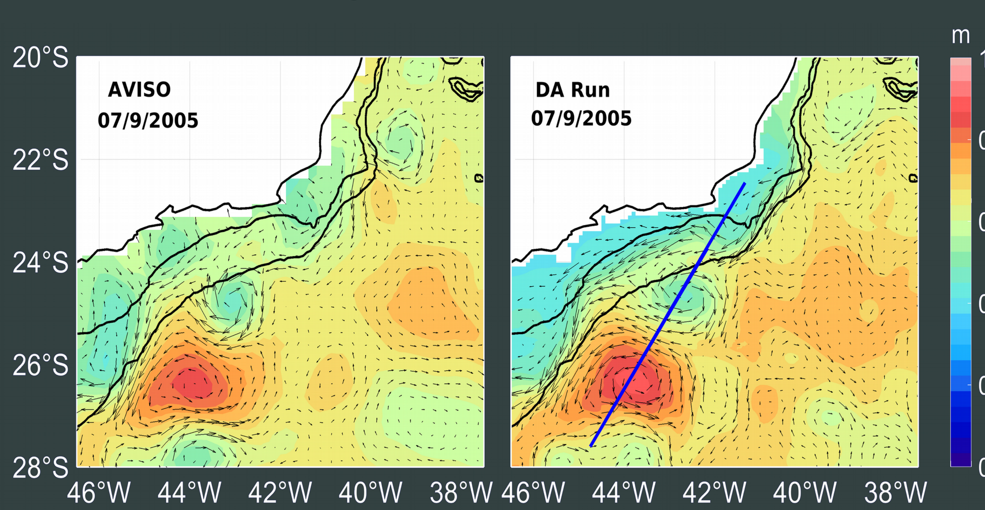


Figure 5: Snapshot of AVISO (left panel) and model (right panel) SSH.

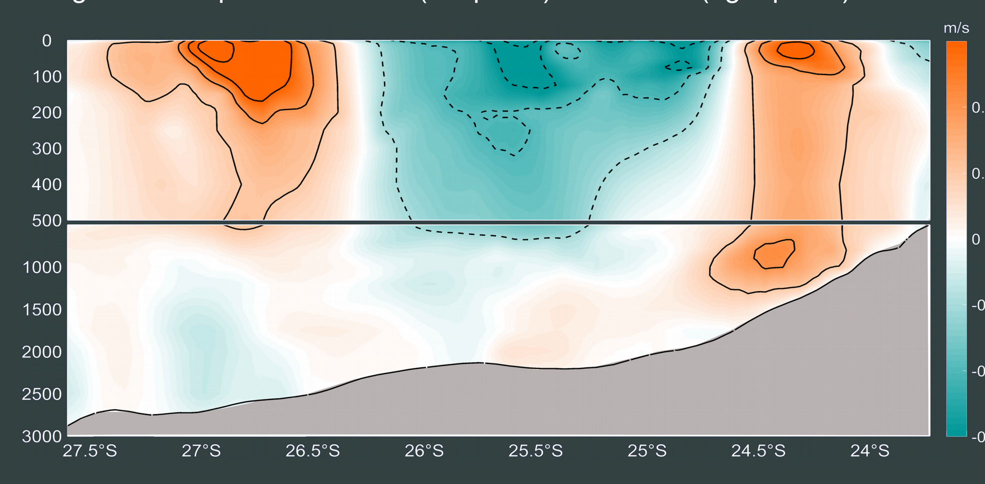


Figure 6: Cross-section model velocity along the blue line shown in figure above. Orange (eastward flow) and blue (western flow).

The western south Atlantic, near the southeast Brazil coast, is the most important area of offshore oil production (including the pre-salt). Brazil Current (BC) cyclonic frontal eddies are recurrent feature in this region and have been shown to interact with anti-cyclonic eddies generated offshore. Such eddy dipoles can lead to current velocities over 1 m/s, which are significantly higher than the mean BC flow. As can be seen on the left, the model is able to capture these features, and the assimilation scheme is able to transfer the surface signal to deeper layers, reaching the full depth of the BC.

Validation with independent data:

Comparisons between the free and the assimilated runs with independent data give extra confidence in our model strategy, and indicate not only an overall reduction of model errors, but also that mesoscale features are well collocated in key areas within the model domain.

Surface Drifters from the GDP Program provide freely-available data for validating the simulated currents, both with respect to energy levels associated with mesoscale variability, and the correct colocation in space and time of mesoscale features, such as boundary currents and ocean rings, as illustrated on the right.

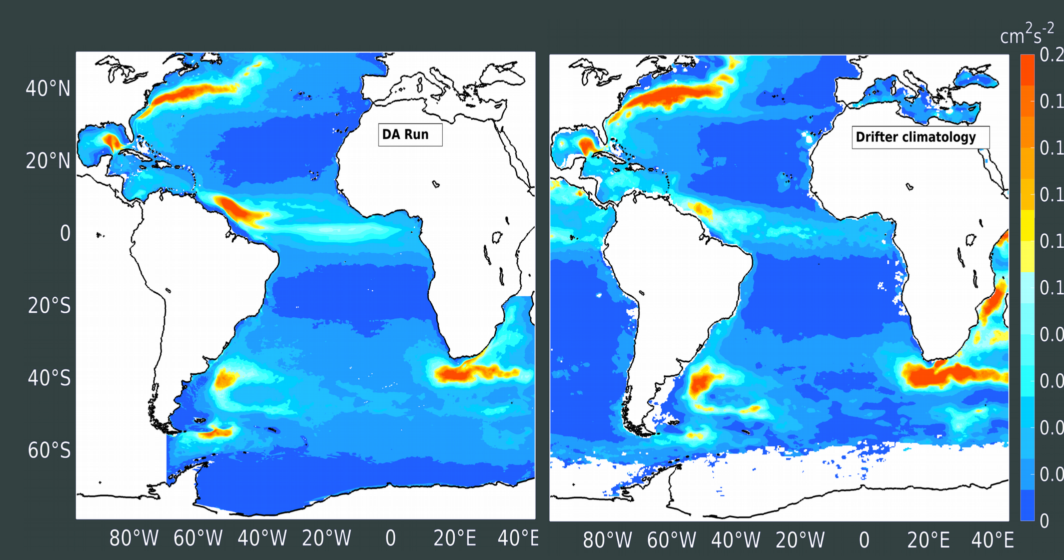
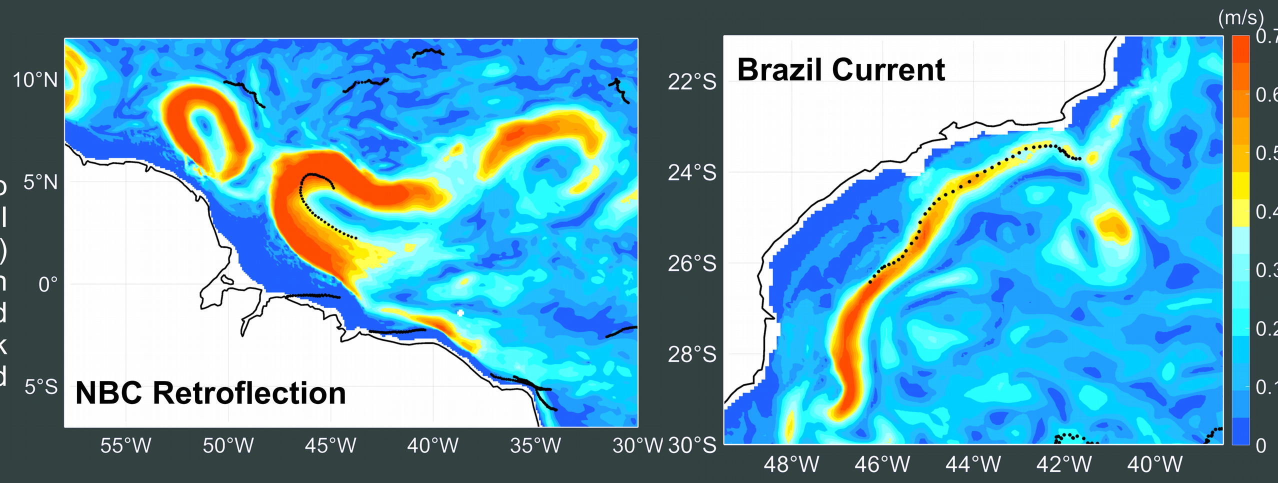


Figure 7: Surface TKE from surface drifters (left) and the assimilated run (right).

Figure 8: Surface velocities for two model snapshots at the Brazil Current (right panel – 03/17/2006) and North Brazil Current Retroflection (left panel – 12/14/2005), and corresponding drifters position (black dots) for a 5-day long window around the time of each snapshot.



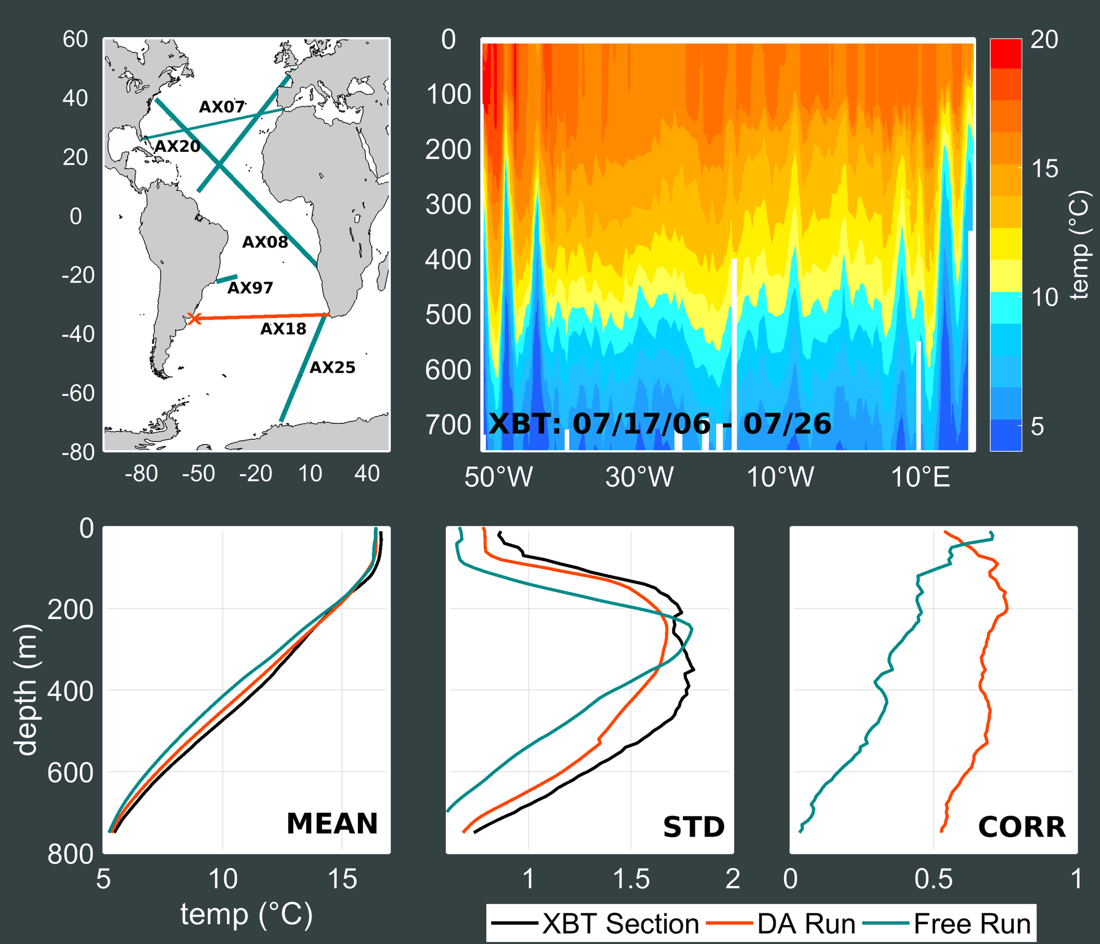


Figure 9: High Density XBT Transects in the Atlantic (upper-left panel); example of one XBT section along AX18 (upper-right), and corresponding model-data comparison (lower panels).

The High Density XBTs Transects were not assimilated in this hindcast and are been used as independent data for model validation. Compassions between model and XBT temperature data are being carried on for all the available transects, as illustrated in Figure 9.

Even in a worst-case scenario (Figure 10) of strong temperature bias in the tropics, the assimilation is able to correct the vertical profile by improving the representation of the main thermocline in the tropics.

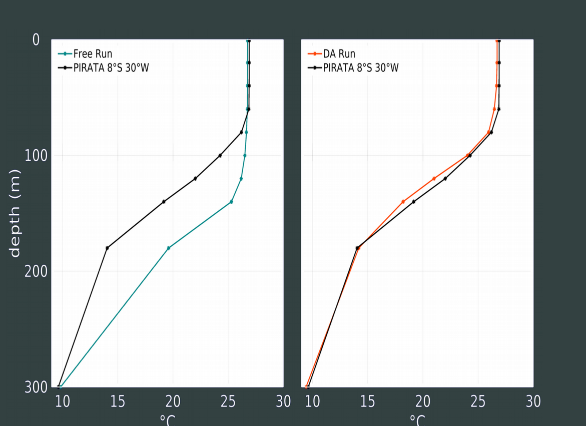


Figure 10: Vertical temperature profile for the PIRATA buoy located at 8°S and 30°W: data (black line); free run (left panel, blue line), and assimilated run (right panel, orange line).

Conclusion

Analysis of the free and assimilated runs, and model-data inter comparisons show that the assimilation that assimilation, besides dating the mesoscale features, both at the surface and in depth, was able to improve the representation of the mean circulation, and to reduce the errors through out the water column. These result indicate that the system presented here can be used to tackle environmental issues in the ocean, and can be successfully implemented as an ocean forecasting system.

ARGO Data: USGODAE Project; XBT: NOAA/AOML, High Density XBT Transects; MERRA2: NASA Goddard Earth Sciences Data; SLA Data: AVISO (Ssalto/Duacs, CMEMS); Drifters: NOAA Global Drifter Program; TPXO; Copyright 2010 Egbert&Erofeeva, COAS; HYCOM:Consortium for Data Assimilation Modeling.