Joint ECMWF/OceanPredict Workshop on Advances in Ocean Data Assimilation, May 1—14, 2021

OceanPredict — Advancing the science of ocean prediction

Skills and Biases of an 11-yr Renalysis Produced by the HYCOM+REMO Ocean Data Assimilation System (RODAS) in the South Atlantic

Clemente A. S. Tanajura, Filipe B. Costa, Geoff S. Dorfschäfer, Rafael C. Santana, Janini Pereira, Vitor S. Vidal, Larissa N. Nogueira

Physics Institute, Graduate Program in Geophysics & Center for Research in Geophsyics and Geology (CPGG), Federal University of Bahia (UFBA), Brazil

Introduction

The Brazilian Oceanographic Modeling and Observation Network (REMO) is a member of OceanPredict and it was a member of GODAE OceanView. REMO is a consortium formed by the Federal University of Bahia (UFBA), Federal University of Rio de Janeiro (UFRJ), the Brazilian Navy Hydrographic Center (CHM) and the Research and Development Center of the Brazilian-state oil company Petrobras (CENPES) formed in 2008. From 2008 to 2011, the University of São Paulo (USP) and the Federal University of Rio Grande (FURG) were also REMO members.

CHM hosts the operational ocean forecasting system. It produces short-range forecasts (5 days) in a daily basis with the Hybrid Coordinate Ocean Model (HYCOM) and REMO Ocean Data Assimilation System (RODAS) configured in three different grids: (i) a large-scale grid over the Atlantic Ocean (78°S-50°N, 100°W-20°E excluding the Pacific Ocean) with 1/4° horizontal resolution; (ii) an eddy-resolving grid (46°S-10°N, west of 18°W) focusing on Metarea V (36°S-7°N, west of 20°W) with 1/12° horizontal resolution; and (iii) a high-resolution grid off the Brazilian S-SE shore (35°S-12°S, 54°W-32°W) with 1/24° resolution also forced with tides. All grids use 21 vertical layers. The forecasts are forced with the NCEP Global Forecasting System (GFS) for the large-scale grid and with the German COSMO with 10 km resolution for the other two grids. A new nested grid system with higher resolution is also implemented operationally and it should replace the current system in 2021.

RODAS is based on the Ensemble Optimal Interpolation (EnOI) scheme (Evensen, Ocean Dyn., 2003; Tanajura et al., Ocean Dyn. 2020). It can assimilate OSTIA sea surface temperature (SST) analysis from the UK MetOffice, along-track or gridded sea level anomalies (SLA) data from AVISO-CLS, gridded absolute dynamic topography (ADT) data from AVISO-CLS, temperature (T) and salinity (S) profiles from Argo and CTDs, and T profiles from XBTs and PIRATA employing synthetic salinity data (Dorfschäfer et al., Ocean Dyn., 2020).

The basic formulas employed in RODAS are

$$X^a = X^b + K(Y - HX^b) \qquad K = \alpha(\sigma \circ B)H^T[\alpha H(\sigma \circ B)H^T + R]^{-1}$$

where X^a is the analysis, X^b is the background, Y is the observation vector, H is the observation operator, B is model error covariance matrix, R is the observation error covariance matrix taken as diagonal, and $\propto$ is a scalar, $\propto \in (0,1]$. B is given by

$$B = \frac{A' A'^T}{(N-1)} \qquad A' = [A'^1 A'^2 \dots A'^N] \qquad A'^m = (X^m - \frac{1}{N}\sum_{n=1}^{N} X^n)$$

where X^m is the model state vector of member $m = 1, N$, $N = 126$ ensemble members. The members are chosen according to the assimilation day from a 6-yr model free run (21 members per year), so that the annual cycle and the intraseasonal variability is considered in the estimation of B. Innovation of vertical T/S profiles were calculated with two different strategies: one projecting T/S observations into the vertical model isopycnic layers (Xie and Zhu, Ocean Sci., 2010; Mignac et al., Ocean Sci., 2015; Tanajura et al., Ocean Dyn., 2020); and the other in observational space. Two reanalyses were produced with these different strategies. They were called B_H_MV.1 and B_H_MV.2, with T/S innovation in model vertical layers and in observational z-coordeinate, respectively.

The present work

Two 11-yr reanalysis – B_HMV.1 and B_H_MV.2 - were produced from January 1, 2008 to December 31, 2018 employing the 1/12° grid with 32 vertical layers (Fig. 1) nested in a lager-scale domain. HYCOM was forced with atmospheric fields from NCEP/NOAA CFSR each 6 h. Assimilation was performed at 00UTC each 3 days. Data from OSTIA SST and 45,325 Argo T/S profiles were assimilated in both reanalysis. B_HMV.1 assimilated gridded SLA and B_H_MV.2 assimilated gridded absolute dynamic topography from AVISO. In addition, B_H_MV.2 assimilated 1,718 CTDs, 13,988 XBTs and 8 PIRATA buoys. All assimilations employed ∝ = 0.5.

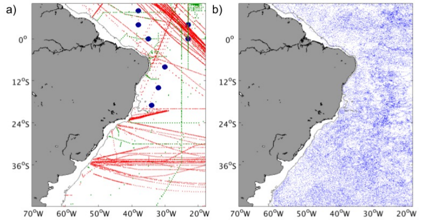

Fig. 1. Locations of the in situ data assimilated in the reanalysis from January 1, 2008 to December 31, 2018. On the left, 13,988 XBTs are in red, 1,718 CTDs in green and 8 PIRATA buoys in blue. On the right, 45,325 Argo T/S profiles are in blue.

Results

The SST root mean squared deviation (RMSD) of both reanalysis with respect to OSTIA showed a reduction of 50% of both reanalysis in comparison with the Control run, from 1.05°C to 0,51°C. The RMSDs obtained were very close to the COAPS/FSU HYCOM+NCODA system, 0.49°C.

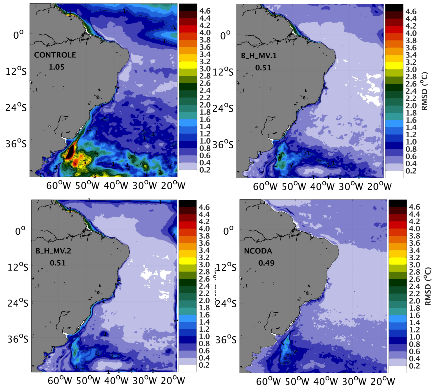

Fig. 2. SST RMSD (°C) with respect to OSTIA,with respect to AVISO for the 11-yr reanalysis period for the Control free run, B_H_MV.1, B_H_MV.2 and the COAPS/FSU HYCOM+NCODA system.

The sea surface height (SSH) correlation with respect to AVISO data of the Control run was 0.24, and HYCOM+RODAS could improve it to 0.59 and 0.63 for B_H_MV.1 and B_H_MV.2, respectively (Fig. 3). HYCOM+NCODA produced 0.60.

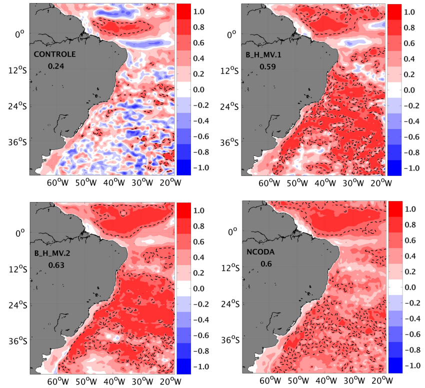

Fig. 3. SSH correlation with respect to AVISO for the 11-yr reanalysis period for the Control free run, B_H_MV.1, B_H_MV.2 and the COAPS/FSU HYCOM+NCODA system.

The vertical average of RSMD of T and S with respect to Argo data (Fig.4) showed also a substantial improvement produced by the HYCOM+RODAS system in the top 400 m and the top 2000 m. The best thermohaline structure was produced by the Mercator Ocean GLORYS reanalysis.

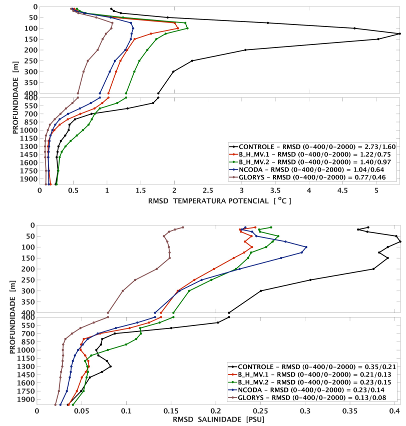

Fig. 4. Vertical profiles of RMSD for T(°C) in the top and S (psu) in the bottom) for the Control run, B_H_MV.1, B_H_MV.2, HYCOM+NCODA and GLORYS. The vertical average for the top 400 m and the 2000 m column are shown in the figures.

The currents in the top ocean region were well captured by the HYCOM+RODAS reanalysis (only B_H_MV.2 is shown) according to the HYCOM+NCODA and the GLORYS reanalyses (Fig. 5). However, in deeper regions, the HYCOM+RODAS reanalysis overestimates its magnitude along the Brazilian shelf break and in regions of the open ocean. This signal is in the Control run as well.

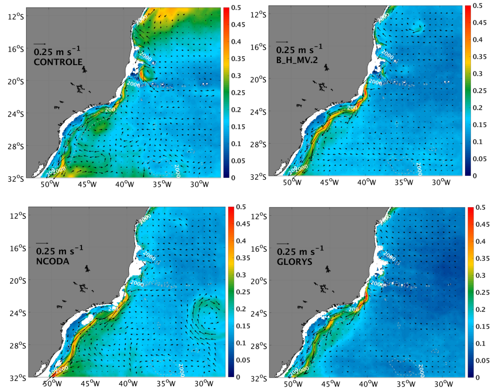

Fig. 5. Mean 50 m currents (m/s) for the Control run, B_H_MV.2 HYCOM+NCODA and GLORYS.

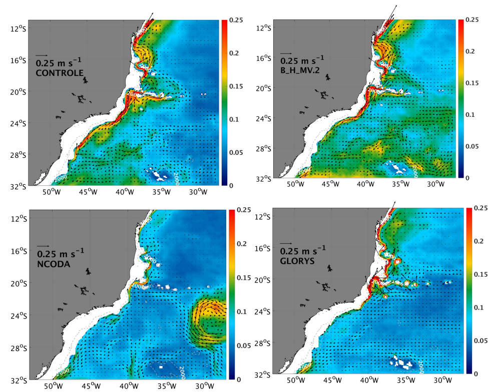

Fig. 6. Mean 800 m currents (m/s) for the Control run, B_H_MV.2 HYCOM+NCODA and GLORYS.

Conclusions

The SST, SSH, thermohaline structure and surface currents of the HYCOM+RODAS reanalysis have a good skill comparable to other internationally famous reanalyses. However the circulation in deeper waters needs to be improved probably by a more accurate free run and by adjustments in the data assimilation scheme.