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Impact of observed salinity assimilation in MOM5-GODAS

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1. Abstract

The National Centers for Environmental Prediction (NCEP) produces ocean-only global ocean analysis and reanalysis operationally based on the Global Ocean Data Assimilation System (GODAS). The GODAS is based on a quasi-global configuration of the GFDL MOM.v3 and 3DVar assimilation techniques. The model domain extends from 75 °S to 65 °N and has a resolution of 1° by 1° enhanced to 1/3° in the N-S direction within 10° of the equator. The Global Ocean Data Assimilation System (GODAS) adopted from NOAA/NCEP has been operationalized at INCOIS (INCOIS-GODAS) in 2013. This model is configured globally from 80 °S to 90 °N. The meridional resolution is 1/4° between 10 °S and 10 °N, gradually increasing to 1/2° poleward of 30 °S and 30 °N. Zonal resolution is a uniform 1/2°. This system uses state-of-the-art ocean general circulation model MOM4p0d and 3DVar assimilation techniques. NCEP GODAS assimilates observed temperature profiles and synthetic salinity profiles to produce analysis and reanalysis. In contrast, INCOIS-GODAS assimilates temperature and salinity profiles from all in-situ observations over the global ocean. In this study, we upgraded the GODAS with MOM5. The upgraded GODAS with MOM5 shows improvements in ocean analysis/reanalysis. In this study, we show the impact of assimilating actual observed salinity over synthetic salinity assimilation over the global ocean. Notable improvements are seen near the equatorial oceans by using actual salinity. Although not much difference can be seen between the SST of the two experiments, there is an improvement in upper ocean properties with the use of actual salinity. The upper ocean salinity and currents along the equator show improvement in the experiment with actual salinity when compared with EN4 analysis, OSCAR, and ADCP observation data.

2. GODAS

Global ocean Data Assimilation System (GODAS) consists of an Ocean General Circulation Model (OGCM),the Modular Ocean Model (MOM) coupled to a 3DVar assimilation scheme. At NCEP, MOM3 is used for the stand-alone ocean reanalysis products, and MOM4p0d is used for CFSR reanalysis. At INCOIS, MOM4p0d is used for the generation of operational analysis products.
The MOM5 ocean configuration used for this study is the same as CFSR. It has a uniform zonal resolution of 0.5°. The meridional resolution is 0.25° till 10° from the equator and decreases exponentially from 10°N (10°S) to 30°N (30°S) so that 0.5° uniform resolution is maintained north(south) of 30°N (30°S). There are 40 layers in the vertical direction, with the top 24 layers placed every 10m. The model is forced with NCEP-R2 atmospheric fluxes2.
The 3DVar assimilation scheme implemented in GODAS assimilates observed in-situ temperature and salinity profiles as well as synthetic salinity within 65 °S-65 °N and from surface to 750 m depth. The assimilation is performed every 12 hrs. For the assimilation, observations during -10 days to +10 days of the assimilation cycle are used.

3. MODEL RUNS

Exp 1: Assimilate observed temperature and salinity from all sources of in-situ observations such as Argo, Buoy, XBT, XCTD, etc.
Exp 2: Same as Exp 1, but instead of using observed salinity, synthetic salinity profiles are used, which are computed from the temperature observations.
Both these simulations were performed for 2003-2009.Five-day (pentad) outputs were used for the evaluation studies.

4. DATA USED FOR VERIFICATION

ADCP (Acoustic Doppler Current Profilers) data from TAO, PIRATA, and RAMA moorings at Pacific, Atlantic, and Indian Oceans for the sub-surface current evaluation.
OSCAR (ocean surface current analyses – real-time, Bonjean and Lagerloef 2002, JPO) for the spatial surface current comparisons
EN4 analysis dataset was used to compare the Sea Surface Salinity

5. ACTUAL AND SYNTHETIC SALINITY DATA USED FOR ASSIMILATION

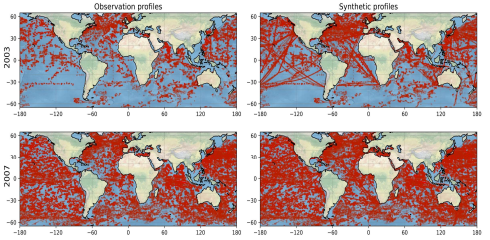

Fig. 1: Spatial distribution of salinity profiles from FNMOC used for the sensitivity experiments. The Argo array reached its original design target of 3000 floats in November 2007. In 2003, the number of synthetic salinity significantly enhanced the distribution and reduced the spatial gaps. However, in 2007, not much difference can be seen in actual and synthetic salinity spatial distribution.

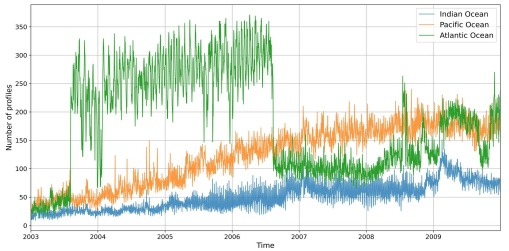

Fig. 2: Time series of daily spatial average salinity profiles from FNMOC used for the sensitivity experiments over the different ocean basins. A significant drop is seen in the daily observed salinity profiles in mid-August 2006 over the Atlantic Ocean.

3. IMPACT ON SUBSURFACE CURRENTS (EVALUATION WITH INSITU OBSERVATIONS)

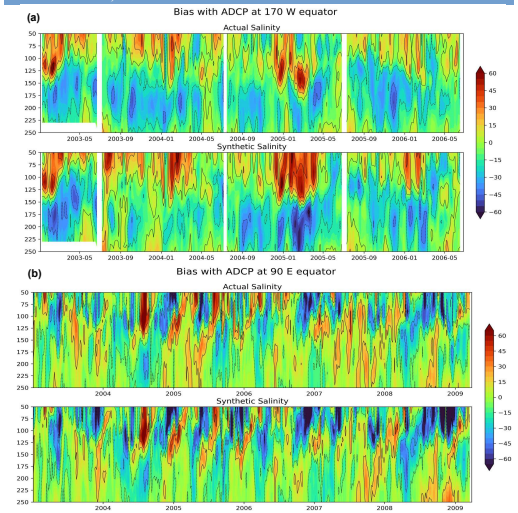

Fig. 3: Zonal Current Speed bias (cm/s) of actual salinity assimilation and synthetic salinity assimilation with respect to ADCP observations over (a) the Pacific (170 W) and (b) the Indian Ocean (90 E).

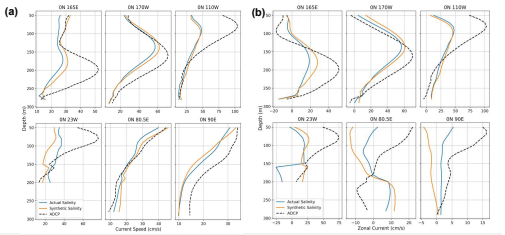

Fig. 4: Vertical profile of currents for actual salinity assimilation, synthetic salinity assimilation, and ADCP observations over the Pacific, Atlantic, and Indian Oceans at ADCP mooring locations. (a) Total Current Speed (b) Zonal Current Speed.

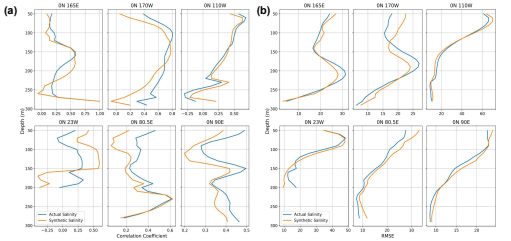

Fig. 5: (a) Correlation and (b) RMSE (cm/s) of current speed for actual salinity assimilation and synthetic salinity assimilation with respect to ADCP observations over the Pacific, Atlantic and Indian Oceans.

5. IMPACT ON SURFACE CURRENTS (EVALUATION WITH OSCAR ANALYSIS)

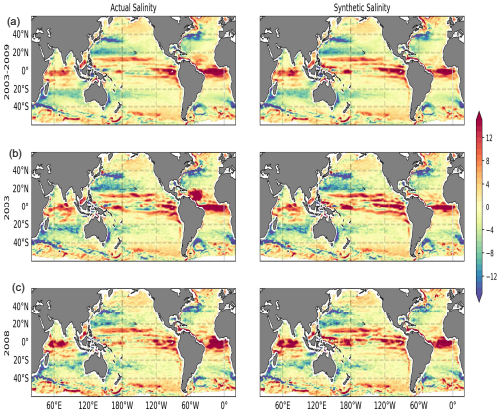

Fig. 6: Current speed bias (cm/s) (a) 2003-2009 mean of actual salinity assimilation and synthetic salinity assimilation with respect to OSCAR observations over the Global Oceans. (b) same as (a) but for 2003 (c) same as (a) but for 2008.

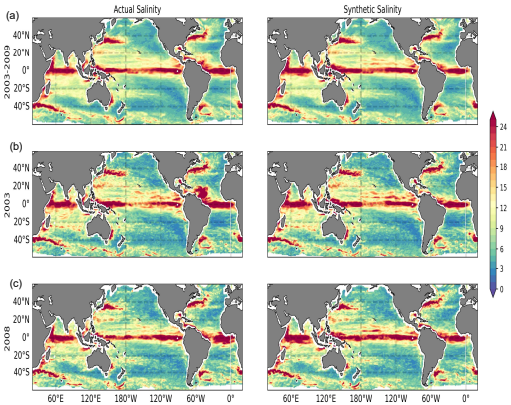

Fig. 7: RMSE of Current Speed (cm/s) (a) (2003-2009) actual salinity assimilation and synthetic salinity assimilation with respect to OSCAR observations over the Global Ocean. (b)same as (a) but for 2003 (c) same as (a) but for 2008.

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- Hasibur Rahaman, David Behringer, Steve Penny and M Ravichandran (2016) Impact of an upgraded model in the NCEP Global Ocean Data Assimilation System: The tropical Indian Ocean. J. Geophys. Res. Oceans, 121, doi:10.1002/2016JC012056

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7. IMPACT ON SALINITY

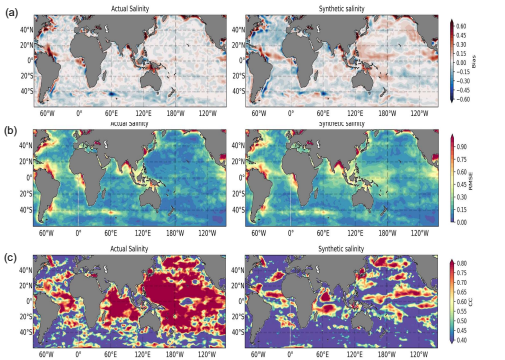

Fig. 8: (a) Bias, (b) RMSE, and (c) Correlation of sea surface salinity(SSS) for the actual salinity and synthetic salinity assimilation with respect to EN4 observations over the global Oceans (2003-2009).

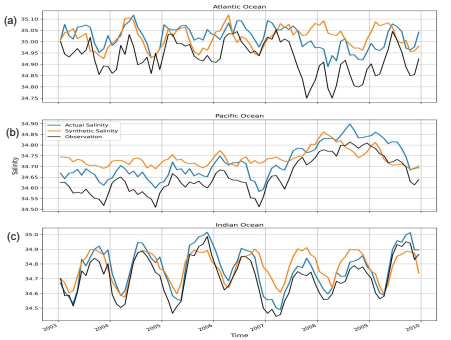

Fig.9: Time series of SSS of actual salinity assimilation and synthetic salinity assimilation and EN4 observations over equatorial a)Atlantic b) Pacific and c)Indian Ocean.

8. Summary & Conclusions

- The impact of observed salinity assimilation with respect to synthetic salinity was evaluated for 2003-2009 simulations in GODAS-MOM5.
- Surface and sub-surface current observations are used, which is independent since it was not assimilated for the evaluation studies.
- The Argo array reached its original design target of 3000 floats in November 2007, which is reflected in the spatial distribution plots. In 2003, distinct differences were seen between actual and synthetic spatial patterns; however, in 2007, the difference was minimal.
- The abrupt change in salinity observations over the Atlantic Ocean in 2006 mid-August significantly impacts the current simulations. The impact of synthetic salinity was more prominent in 2003 as compared to 2008. This signifies the importance of synthetic salinity during the pre-Argo era.
- Upper ocean currents are more accurately represented in actual salinity assimilation as compared to synthetic Salinity
- Surface salinity significantly improved in actual salinity as compared to synthetic salinity assimilation.