The Assimilation of Satellite Sea-surface Salinity Fields in Ocean Forecast Systems

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The impacts of assimilating satellite sea-surface salinity (SSS) observations into NOAA's operational modeling are examined using the Modular Ocean Model version-4 (MOM4; Behringer, 2007) for seasonal-interannual modeling and the Hybrid Coordinate Ocean Model (HYCOM; Mehra *et al.*, 2011) for near-real-time modeling. The MOM4 effort examines the use of two different SSS fields and two different levels of temporal constraint. The MOM4, forced by daily NCEP/DOE Reanalysis-2 fluxes (Kanamitsu, *et al.*, 2002), employed relaxation to constrain surface temperature and salinity. Two sensitivities were tested: a) the response to the tightness of the assimilation temporal constraint and b) the response to observed SSS fields versus climatology. Four cases are compared: 1) **CTRL30** employed monthly-mean SSS climatology, the current operational configuration; 2) **AQ30** assimilated daily 1-degree resolution NASA Aquarius SSS fields (Tang *et al.*, 2014), employing a 30-day relaxation period (weakly constrained); 3) **AQ10,** similar to **AQ30**, used Aquarius SSS data, but used a 10-day relaxation time period (tightly constrained); and 4) **CTRL10** also employed monthly-mean climatology, but used a 10-day relaxation period (strongly constrained). All simulations spanned the period September 2011 to August 2014 and started from the same ocean initial condition. The ocean heat content (OHC) for the top 300 m was computed for each simulation and compared with OHC computed from gridded monthly Argo float temperature and salinity profiles.

The results of comparisons show that the use of satellite SSS data creates one pattern of improvement, primarily in the tropics (Fig. 1a, 1c), while the tightening of the relaxation constraint produces a different pattern (Fig 1b). The difference **CTRL10** minus **CTRL30** is not shown, but mimics Fig 1b, although with weaker intensity. Figure 1d depicts the net affect from using near-real-time satellite SSS data. **AQ10** outperforms both the **AQ30** and the **CTRL10** in the equatorial Atlantic, equatorial western Pacific and Indian oceans by 7-10%. In other regions, the picture is mixed. There are large areas in the mid-latitudes where the AQ10 is outperformed by approximately 5-15% by the AQ30 and/or the CTRL10. Our conjecture is that the coarse-resolution operational MOM4 may not be able to resolve the significant amounts of mesoscale variability found in the daily Aquarius SSS fields. We are also investigating the correlation of restoring surface buoyancy fluxes to the large-scale spatial and temporal structure of the surface buoyancy forcing to correct systematic errors.

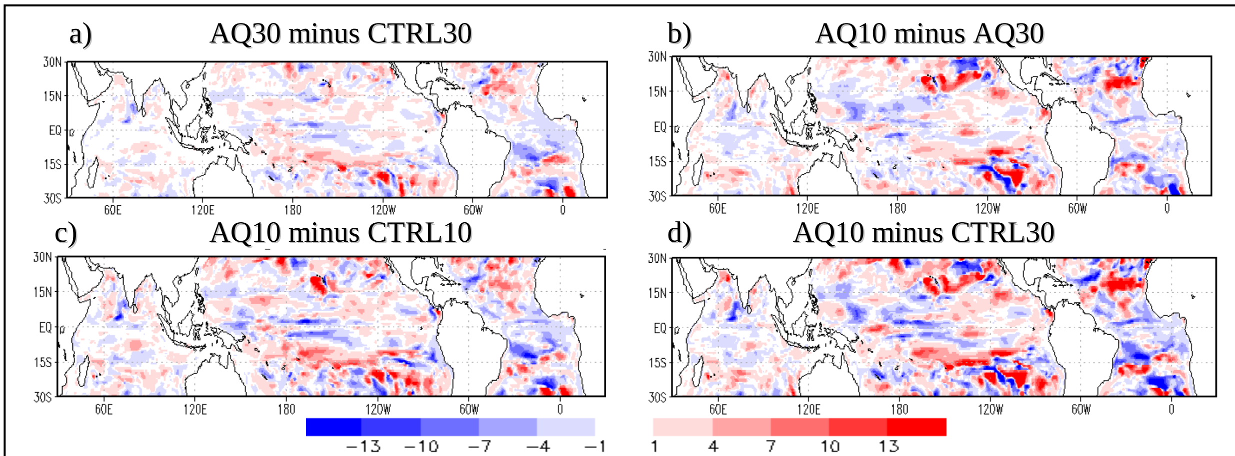

Figure 1. Change in Root-Mean-Square Error (RMSE) for ocean heat content (0-300m) for a) **AQ30-CTRL30**, b) **AQ10-AQ30**, c) **AQ10-CTRL10**, and d) **AQ10-CTRL30**; referenced to gridded ARGO monthly-mean profiles of temperature and salinity (Lebedev *et al.*, 2010).

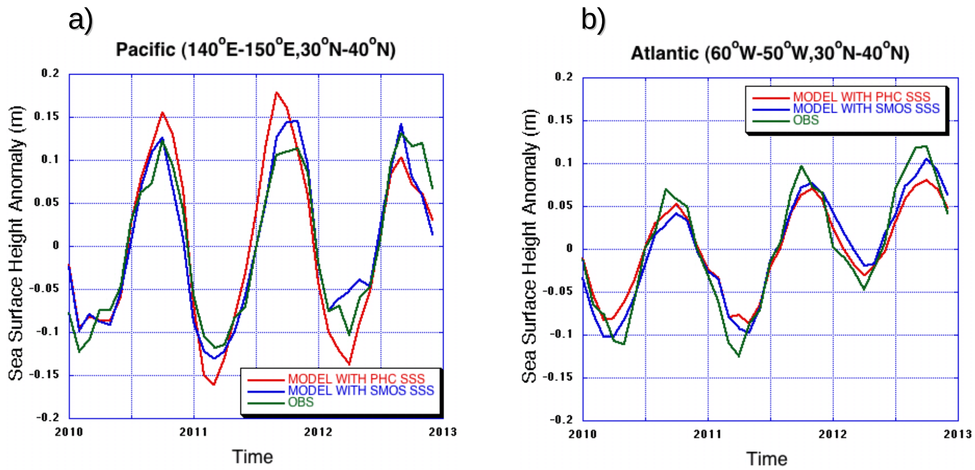

Figure 2. Comparison of mean SSH anomalies simulated by RTOFS over two sub-regions: a) North Pacific, b) North Atlantic. The satellite SSH observations are from Leuliette, *et al*., 2004.

Surface salinity in the operational near-real-time HYCOM model is relaxed to the Polar Science Center Hydrographic Climatology (PHC3; Steele *et al*., 2001). To assess the impact of near-real-time SSS data, the PHC3 climatology was replaced with monthly-mean SSS averaged from daily ESA SMOS data (Barcelona Expert Center, http://www.smos-bec.icm.csic.es/). Two sets of experiments, employing NCEP CFSR atmospheric forcings (Saha *et al*., 2010), were conducted, with the e-folding time for salinity relaxation set at 30 days × H_m/H_s, where H_m is the mixed layer depth and H_s (fixed at 15 m) is a constant reference thickness. Figure 2 shows the time evolution, 2010 through 2012, of mean sea-surface heights averaged over two selected sub-regions for both sets of experiments. The assessment validation is primarily against satellite altimetric data from NOAA/NESDIS/STAR (Leuliette *et al*., 2004). Comparisons with observations show that results with SMOS SSS data offer some improvements near the extremes of the simulated sea-surface height anomalies in the mid-latitude North Atlantic and North Pacific regions.

References:

- Behringer, D.W., 2007, The global ocean data assimilation system at NCEP. 11th symposium on integrating observing and assimilation systems for atmosphere, oceans, and land surface, AMS 87th annual meeting, San Antonio, TX, 12pp.
- Kanamitsu, M., et al., 2002, NCEP/DOE AMIP-II Reanalysis (R2), *Bull. Amer. Meteor., Soc.*, *83*, 1631-1643.
- Leuliette, E. W., et al., (2004), Calibration of TOPEX/Poseidon and Jason Altimeter Data to Construct a Continuous Record of Mean Sea Level Change, *Marine Geodesy*, *27*(1-2), 79-94.
- Lebedev, K. V., S. DeCarlo, P. W. Hacker, N. A. Maximenko, J. T.Potemra, and Y. Shen (2010), Argo Products at the Asia-Pacific Data-Research Center, Eos Trans. AGU, 91(26), Ocean Sci. Meet. Suppl.,Abstract IT25A-01.
- Mehra et al. (2011) A Real Time Operational Global Ocean Forecast System (RTOFS). US GODAE Ocean View Workshop on Observing System Evaluation and Intercomparisons, Univ. of California Santa Cruz, CA, USA, 13-17 June 2011.
- Saha, S., et al., 2010. The NCEP climate forecast system reanalysis. *Bull. Amer. Meteor., Soc.*, *19*, 1015-1057.
- Steele, M., R. , et al., (2001), PHC: A global ocean hydrography with a high-quality Arctic Ocean, *Journal of Climate*, *14*(9), 2079-2087.
- Tang, Wenqing, et al., "Validation of Aquarius sea surface salinity with in situ measurements from Argo floats and moored buoys", J. Geophys. Res. (Oceans), accepted for publication.