Impact of Aquarius and SMAP Sea Surface Salinity Observations on Seasonal Predictions of the 2015 El Nino

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ABSTRACT

We assess the impact of satellite sea surface salinity (SSS) observations on dynamical ENSO forecasts for the big 2015 El Nino event. From March to June 2015, the availability of two overlapping satellite SSS instruments, Aquarius and SMAP, allows a unique opportunity to compare and contrast coupled forecasts generated with the benefit of these two satellite SSS observation types. Four distinct experiments are presented that include 1) freely evolving model SSS (i.e. no satellite SSS), relaxation to 2) climatological SSS (i.e. WOA13 SSS), 3) Aquarius and 4) SMAP initialization. Coupled hindcasts are generated from these initial conditions for March 2015. These forecasts are then validated against observations and evaluated with respect to the observed El Nino development.

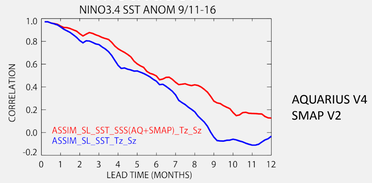
METHODOLOGY

The coupled model that is used in this project is the new S2S_v2.1 that has recently become the seasonal coupled forecast production model for NASA GMAO. This version couples the 0.5º resolution, 72 levels atmosphere (model version – Heracles-5_4_p3) with the Modular Ocean Model Version 5 (Griffies, 2012) with 0.5º resolution and 40 vertical levels. For all the initialization experiments, all available along-track absolute dynamic topography (AVISO, 2013) and in situ observations (Argo, XBT, CTD, tropical moorings) are assimilated using a scheme similar to the LETKF of Penny et al., 2013. Forecast/ocean observers/analysis is applied every 5 days using intermittent replay and 18 hour IAU. Ensemble members come from monthly averaged anomalies from 20 freely coupled experiments re-centered about the analysis. In order to minimize the transition from the NASA GMAO atmospheric reanalysis, SST is relaxed to MERRA-2 values (Gelaro et al., 2017). It should be noted that the current GMAO S2S-v2.1 neither relaxes to nor assimilates observed SSS but does replay to MERRA2 precipitation.

EXPERIMENT DESIGN

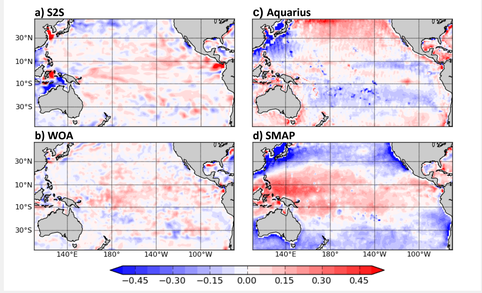
Starting from May 2012 separate spin-up experiments were executed that relax to the seasonal cycle of various SSS gridded products including WOA13 (Zweng et al., 2013), Aquarius V4 (Lilly and Lagerloef, 2008), and SMAP V2 (Meissner and Wentz, 2016) along with the control that allows SSS to vary freely with no SSS relaxation. From these initialization experiments, 12 month coupled experiments are initialized every 5-days spanning March 2015. These results are then compared against observed values (SST – Reynolds et al., 2002; ADT – AVISO 2013; SSS, MLD – EN4 of Good et al., 2013).

Motivation



Assimilation of satellite SSS into initialization of intermediate-complexity coupled models (red curve) improves validation of coupled models out to 12 month lead-times with respect to experiments withholding SSS (blue) (e.g. Hackert et al., 2014). Assimilation of satellite SSS leads to decreased density and shoaled MLD in the equatorial waveguide, enhanced Kelvin wave response, and improved coupled forecasts. This poster represents the next step to incorporate SSS into more complex coupled systems.

SSS Observation Anomalies



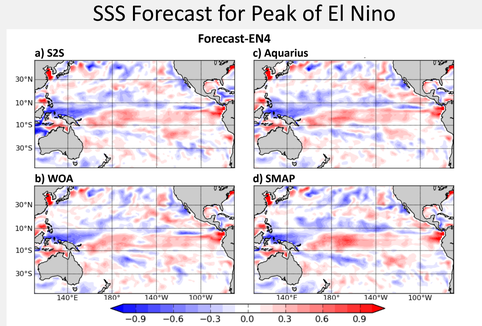
Product Differences with EN4 (period of comparison) – a) S2S (Jun 2012-Oct 2017), b) WOA (Jan 1980 – Dec 2016), c) Aquarius V4 SSS (Sep 2011 – May 2015), and d) SMAP V2 (Apr 2015 – Sep 2017). These plots show very slight salty bias for the S2S and WOA results. Aquarius has spatially coherent biases but overall small values within 10º of the equator. On the other hand, SMAP shows a clear salty bias within 15ºS to 25ºN. Relaxing using this salty bias should lead to a denser and deeper mixed layer depth (MLD).

Validation – Observation minus Forecast Statistics

	S(0-100m) PSU	T(0-100m) ºC	ADT (cm)
S2S-v2.1	-0.019	-0.037	0.571
WOA13	-0.011	-0.039	0.537
AQ	-0.009	0.004	0.358
SMAP	-0.031	-0.080	0.679
Argo Obs vs AQ	-0.04		
Argo Obs vs SMAP	-0.05		

OMF bias is averaged (0-100m) over the tropical Pacific (30ºN-30ºS) for salinity and temperature (columns 1, 2) and absolute dynamic topography (column 3) over 2013-2015. For column 1: bias values < 0 indicate that model has a salty bias as compared to observations. Blue (Red) values indicate OMF is smaller = better (larger) than S2S results. The last two rows indicate observational error of the closest collocations (1 day, 1º) of L2 satellite versus shallowest in situ observations (Aquarius Sep 2011-Jun 2015, SMAP Mar 2015-Apr 2017). WOA and Aquarius relaxation not only improve salinity with respect to S2S but also temperature and ADT validation.

SSS Forecast for Peak of El Nino

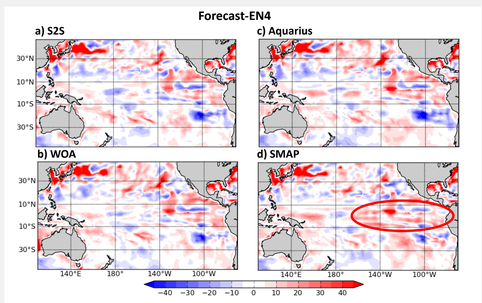


Dec 2015 forecast SSS from Mar 2015 IC - All model results show similar SSS patterns - fresh in far western Pacific, ITCZ and SPCZ and salty bias within 10º of the equator especially at the eastern edge of the fresh pool. SMAP SSS has biggest values centered at 165ºW. Increased SSS should tend to deepen the MLD in the central Pacific.

CONCLUSIONS

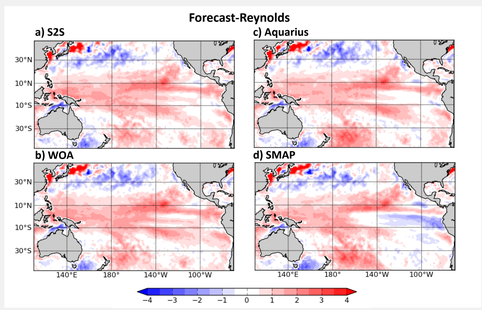
1) Relaxation using Aquarius V4 or WOA13 slightly improves validation of the reanalysis (including ADT and T(0-100m) statistics). On the other hand, SMAP V2 relaxation generally degrades validation statistics.
2) At forecast initialization, too salty SSS for SMAP within 10º of the equator leads to deeper MLD east of 165ºW. This deeper MLD leads to damping of the downwelling signal (i.e. relative upwelling), in turn leading to relatively too cool ENSO forecasts.
3) Plume plots of NINO3.4 forecasts show that ensembles created using relaxation to Aquarius result in a slight improvement with respect WOA13. Also salty SMAP relaxation leads to a consistently cool bias in the forecasts.
4) We acknowledge the immaturity of the SMAP V2 product. Therefore, we anticipate that SMAP algorithm development will lead to reduced SSS biases and lead to improved initialization of coupled forecasts.

MLD Forecast for Peak of El Nino



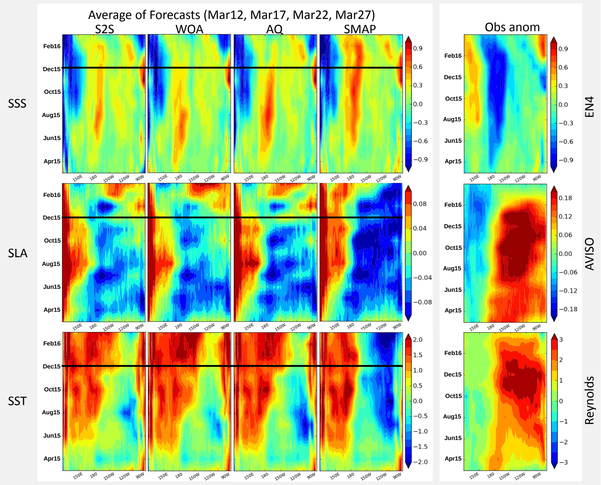
S2S, WOA and Aquarius all have similar MLD patterns for December forecast from Mar 2015 ICs. However, salty SSS leads to the deepest MLD for SMAP results, especially east of 165ºW within 10º of the equator. Deeper MLD acts to damp the downwelling signal leading to coolest SST and relative upwelling for SMAP forecasts.

SST Forecast for Peak of El Nino



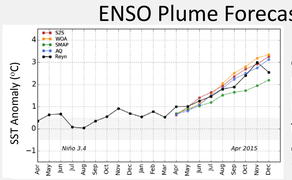
All forecasts for the GMAO coupled system show a warm bias for the western Pacific, ITCZ and SPCZ. However, increased MLD for SMAP leads to damped downwelling (i.e. relative upwelling) and comparative cooling in the eastern Pacific cold tongue. Aquarius, shows the best overall agreement with observations in the NINO3.4 region for Dec 2015.

Hovmöller Results for March 2015 Forecasts

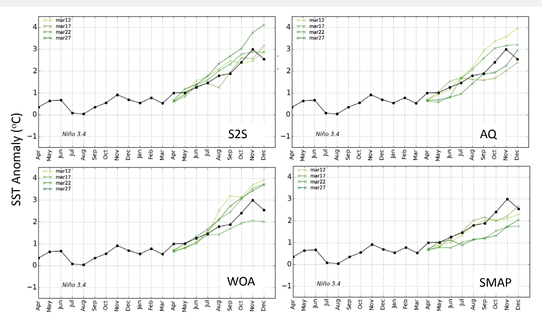


Hovmöller (2ºN-2ºS) for average March forecasts for SSS (top), ADT (middle) and SST (bottom) and Observed anomalies (far right). All forecasts clearly underestimate the observed ENSO signal - all are too fresh in the fresh pool, too salty near the eastern edge of the fresh pool (~180º) and show a predominance of upwelling (with respect to observations) and enhanced warming in the western half of the Pacific. Note that the salty IC and shallower MLD for SMAP makes this product more susceptible to upwelling and cooler eastern Pacific SST anomalies.

ENSO Plume Forecasts – March 2015



(Left) Average of all ensembles of coupled model forecasts for Mar 2015 IC. WOA and S2S have somewhat warm forecasts, Aquarius straddles observations and SMAP initialization leads to too cool ENSO prediction. For each forecast, the model trend (calculated over 1981-2010) has been removed.



Individual ensembles going into the average Mar 2015 forecast - Note that Aquarius straddles the observed 2015 El Nino (with more forecast variability) whereas SMAP clearly is too cold and S2S and WOA are generally too warm.

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