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 in 12 d. logical SSS (i.e. WOA13 SSS, 31), 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 2SS_v2.1 that has recently become the seasonal coupled forecast production model for NASA-GMAO. This version couples the 0.5° resolution, 72 levels atmosphere (model version – Herakles 5.4.3d) with the Modular Ocean Model Version 5 (Eckel, 2012) with 0.5° resolution and 40 vertical levels. For all the initialization experiments, all available along-track absolute dynamic topography (AVISO, 2015) and in situ observations (Argo, XBT, CTD, tropical moorings) are assimilated using a scheme similar to the LETKF of Penny et al. 2013. Forecast/atmospheric observations/analysis is applied every 5 days using the assimilation system. Ensemble members come from monthly updated 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 climatological values (Giorgetta et al., 2002). It should be noted that the current GMAO 2SS_v2.1 neither relaxes nor assimilates observed SSS but does rely on 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 (Xue et al., 2013), Aquarius V4 (Lilly and Lagerloef, 2008), and SMAP V2 (Minisher 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 (St – Reynolds et al., 2002, ADT – AVISO 2013, SSS – EN4 of Good et al., 2013).

Validation – Observation minus Forecast Statistics

OMF bias is averaged (0-100m) over the tropical Pacific (30°N-30°S) for salinity and temperature (columns 2, 3) and absolute dynamic topography (column 3) over 2015-2015. 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. The last two rows indicate observational error of the closest observations (Aquarius Sep 2011-Jun 2015, SMAP Mar 2015-Apr 2017). WOA and Aquarius relaxation not only improve salinity with respect to WOA13. Also salty SMAP relaxation leads to a denser and deeper mixed layer depth (MLD).

SST Forecast for Peak of El Nino

All forecasts for the GMAO coupled system show a warm bias for the western Pacific, ITCC and SPCC. However, increased MLD for SMAP leads to damping 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.

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 10° of the equator leads to deeper MLD east of 165°W. 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 intermittency 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.

ENSO Plume Forecasts – March 2015

(left) Average of all ensembles of coupled model forecasts for Mar 2015 IC. WOA and S25 have some warm forecasts, Aquarius straddles observations and SMAP initialization leads to too cold ENSO prediction. For each forecast, the model trend (calculated over 1985-2010) has been removed.

Hovmöller Results for March 2015 Forecasts

Hovmöller (2°N-2°S) 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 cool in the fresh pool, too salty near the eastern edge of the fresh pool (~180°) 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.

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