Impact of Satellite Sea Surface Salinity Observations on ENSO Predictions from the GMAO Seasonal Forecast System

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Outline

- Methodology
- Mechanisms of SSS Assimilation Improvements
- Forecast Impact on Different Phases of ENSO for NO SSS, AQ+SMAP, and SMOS assimilation

Seasonal Prediction System - GEOS S2S Version 2

Coupled Model (Sub-seasonal to Seasonal Prediction System)

- Same as NASA's current contribution to North American Multi-Model Ensemble (NMME)
- OGCM: MOM5, ~0.5º, 40 levels
- AGCM: Similar to MERRA-2, ~0.5º, 72 hybrid sigma/pressure levels
- Ice Model: CICE-4.0

Coupling Techniques

- Forecast, ocean observer, and analysis is applied every 5 days using intermittent replay, 18 hour IAU
- Atmosphere is "replayed" to like MERRA-2 – like atmosphere

Seasonal Prediction System - GEOS S2S Version 2

Ocean Data Assimilation System

- LETKF assimilation (similar to Penny et al, 2013)
- ODAS ensemble members - monthly averaged anomalies of 20 years of freely coupled experiment re-centered around the background

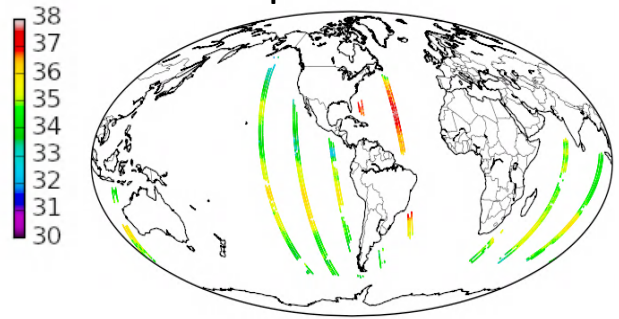
Observations

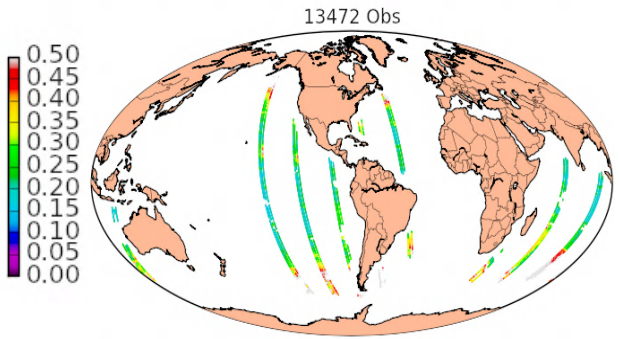
- Strong relaxation of SST and sea ice fraction to observations
- Assimilation of in situ T_z and S_z (including Argo, XBT, CTD, tropical moorings)
- Assimilation of satellite along-track sea level (T/P, Jason, Saral, ERS, GEOSAT, HY-2A, CryoSat-2, Sentinel)
- Note that the current system neither relaxes to nor assimilates observed SSS (but does replay to MERRA2 precipitation)
- S2S has been modified to assimilate Level 2 SSS from Aquarius (V5), SMAP (V4_) and SMOS L32Q (now running SMAP as an ensemble of near-real time S2S system)

Satellite SSS Assimilation Data

Example of May 15 2015

Aquarius V5

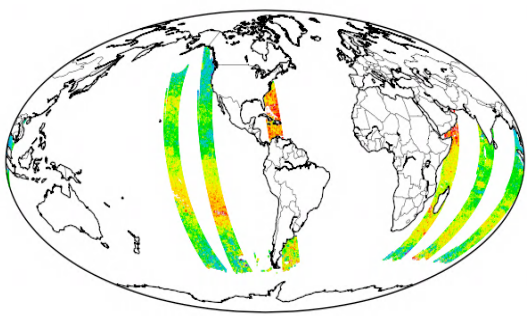


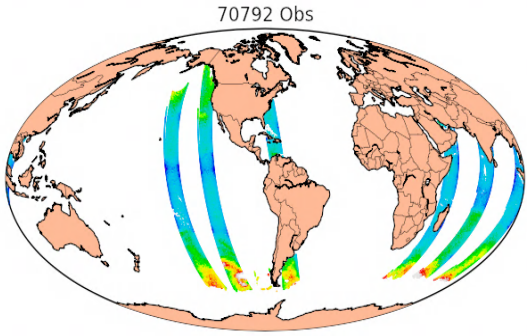


(*Lilly and Lagerloef, 2008*)

Observation Error

SMAP V4.1

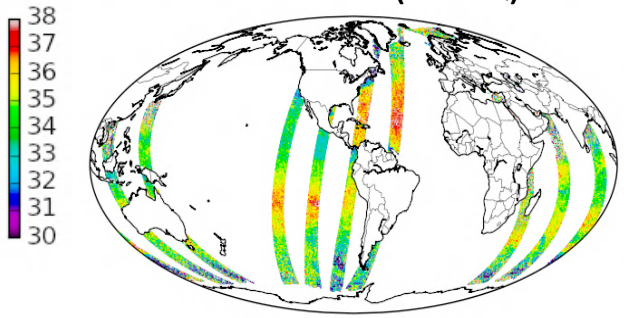


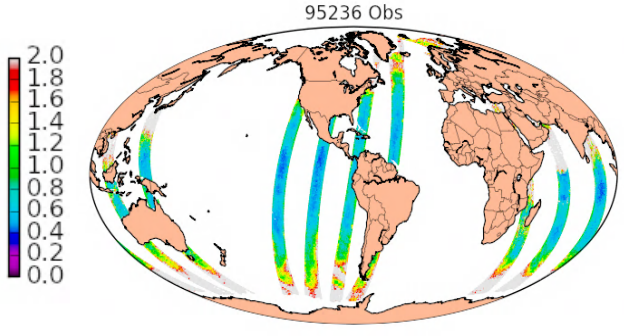


(*Fore et al., 2016*)

Observation Error

SMOS V3 (L32Q)





(Boutin et al.., *2018*)

Observation Error

Mechanisms of SSS Improvements

- NO SSS = GMAO production system (S2S-v2.1) with no SSS assimilation
- AQ+SMAP = assimilates all available Aquarius V5 and SMAP V4_ SSS
- SMOS = assimilates all available SMOS L32Q SSS

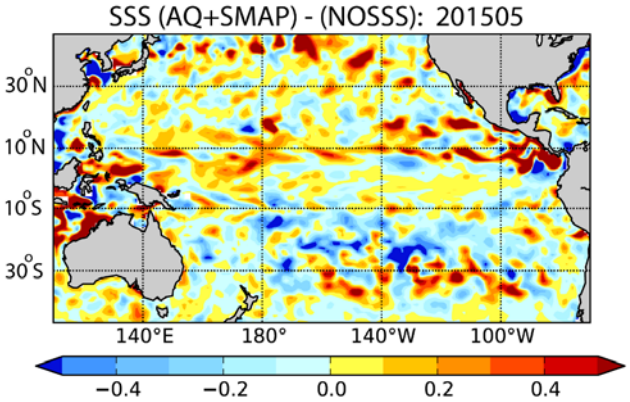
Show AQ+SMAP - NO SSS

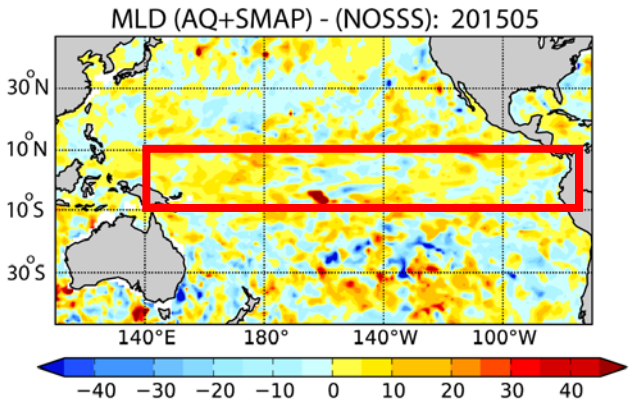
SMOS - NO SSS

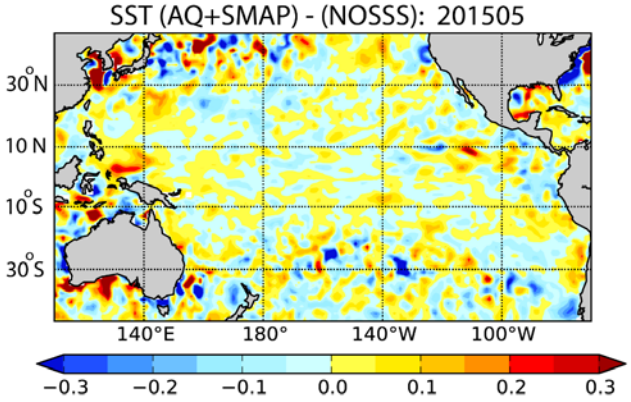
to highlight impact of SSS assimilation.

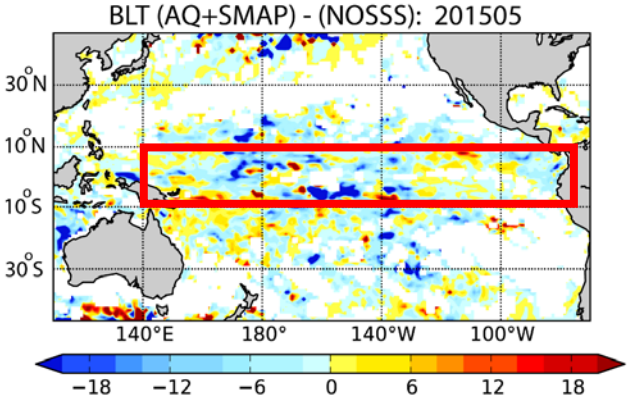
Mechanisms of SSS Assimilation Improvements

Example of May 2015
AQ+SMAP - NOSSS





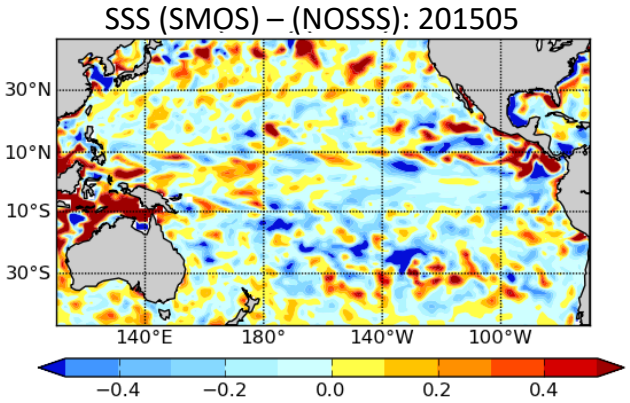


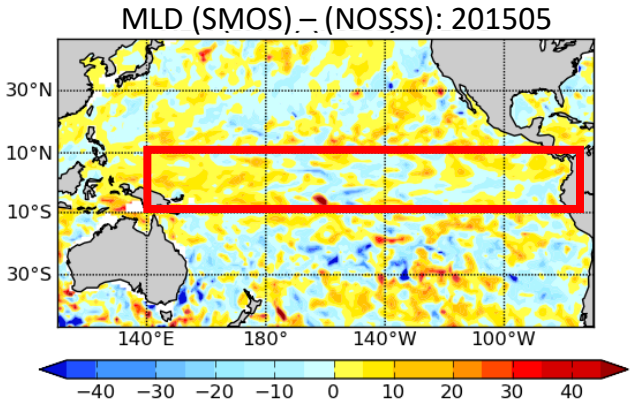


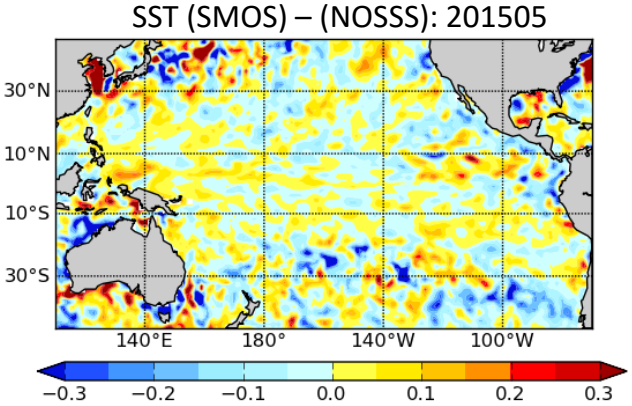
MLD thickens and BLT shoals

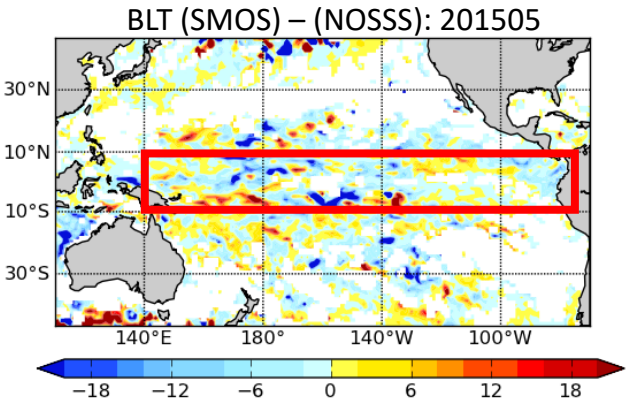
Mechanisms of SSS Assimilation Improvements

Example of May 2015 SMOS – NOSSS





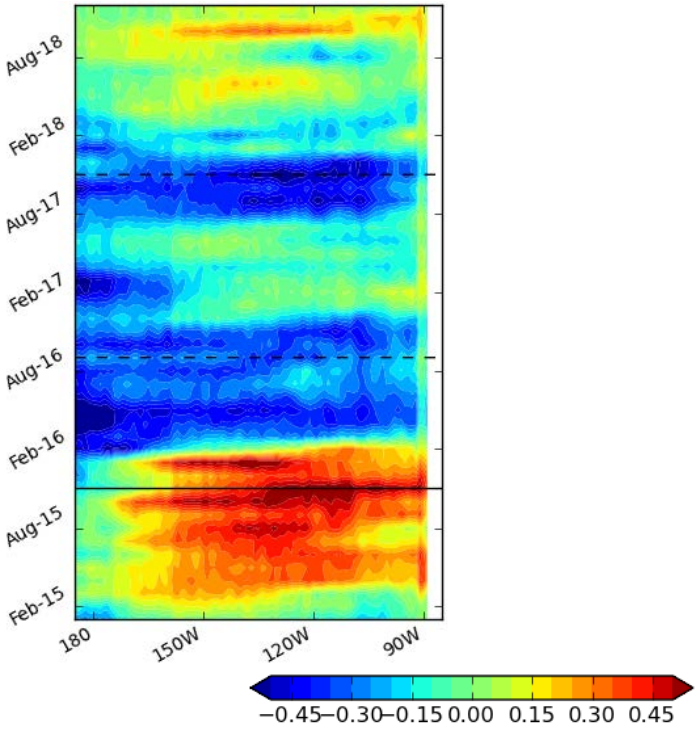




MLD thickens and BLT shoals

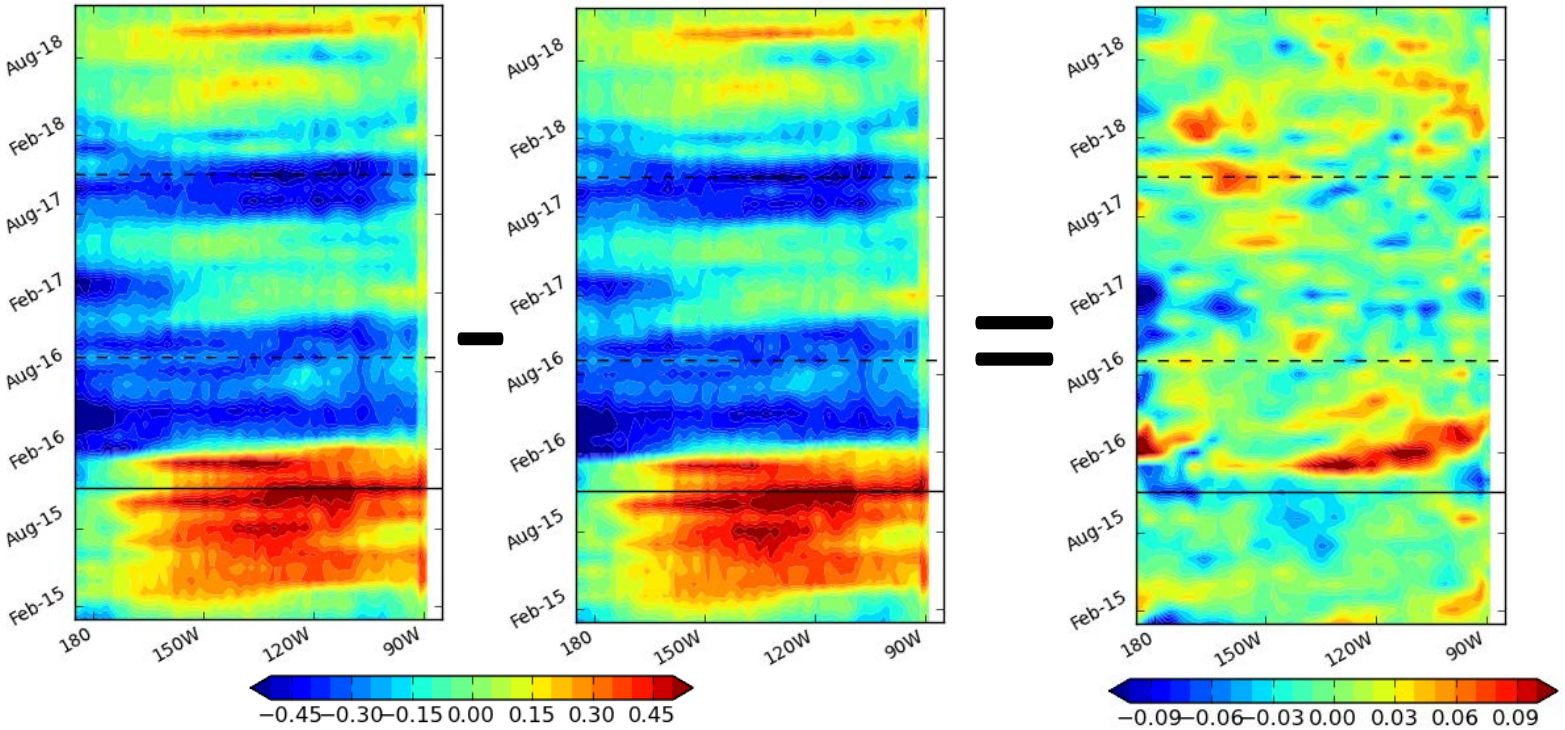
Kelvin Wave Amplitude

AQ+SMAP



Kelvin Wave Amplitude

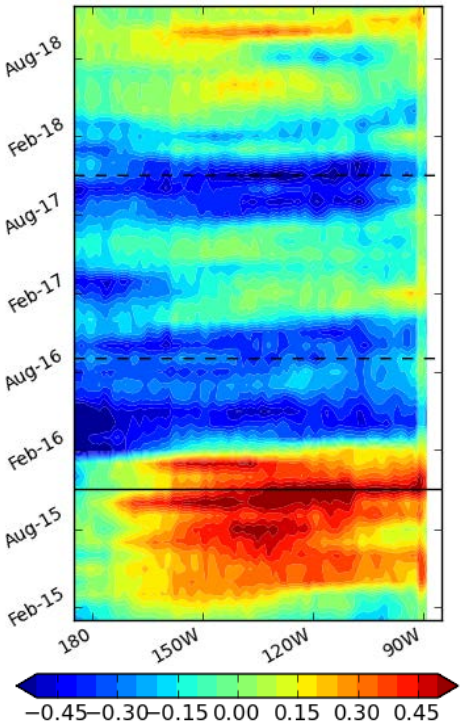
AQ+SMAP – NOSSS = AQ+SMAP – NOSSS



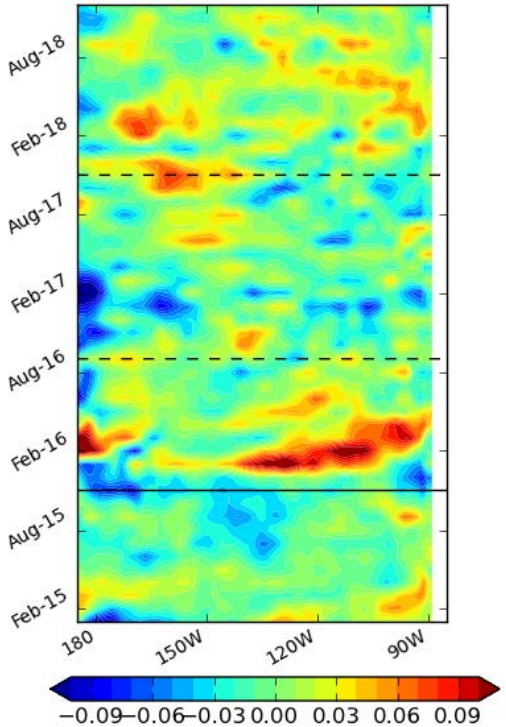
NINO3.4 (NOSSS) vs (AQ+SMAP-NOSSS) r = -0.37 (95%)

Kelvin Wave Amplitude

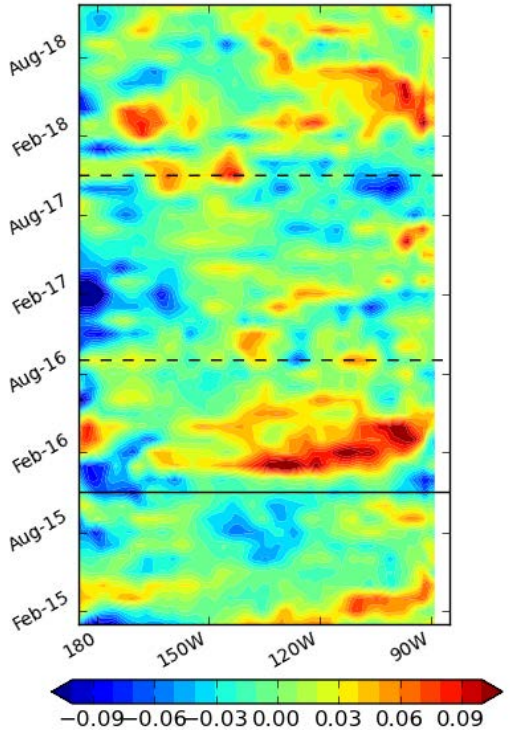
NOSSS



AQ+SMAP – NOSSS



SMOS – NOSSS



Impact of SSS Assimilation on Different Phases of ENSO

Forecasts:

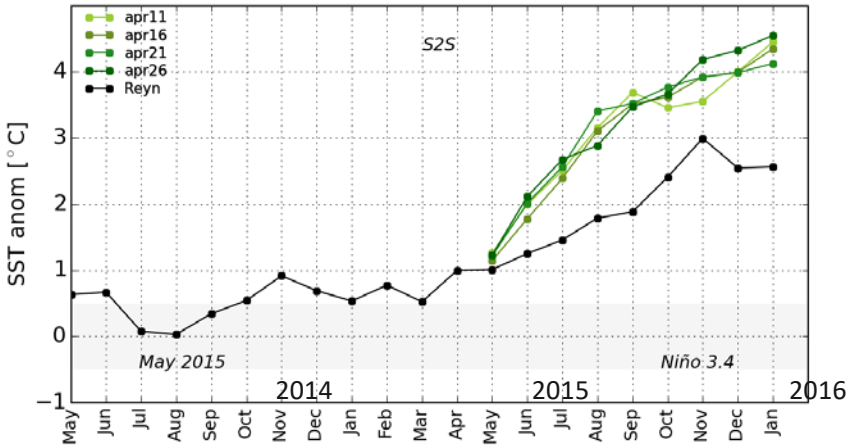
- 2015: Big El Nino
- 2017: La Nina
- 2018: Weak El Nino

Apr 11, 16, 21, 26, OBS SST Anomaly

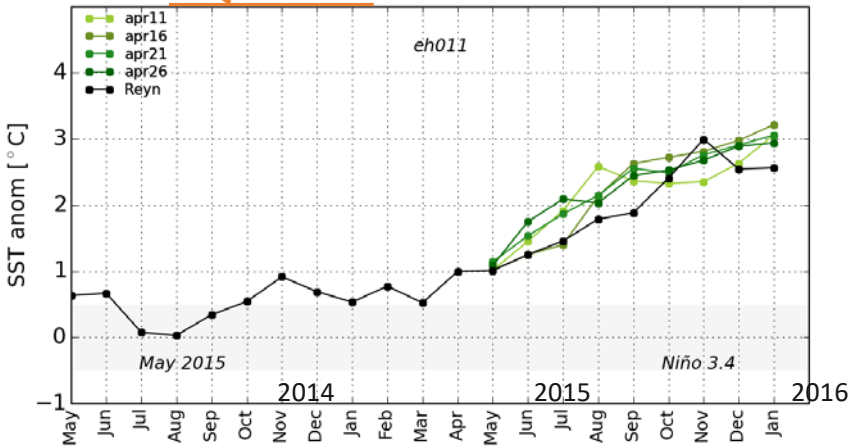
- **No SSS (S2S)** **AQ+SMAP**
- **SMOS** **Average of the 4 ensembles**

Big El Nino – Apr 2015

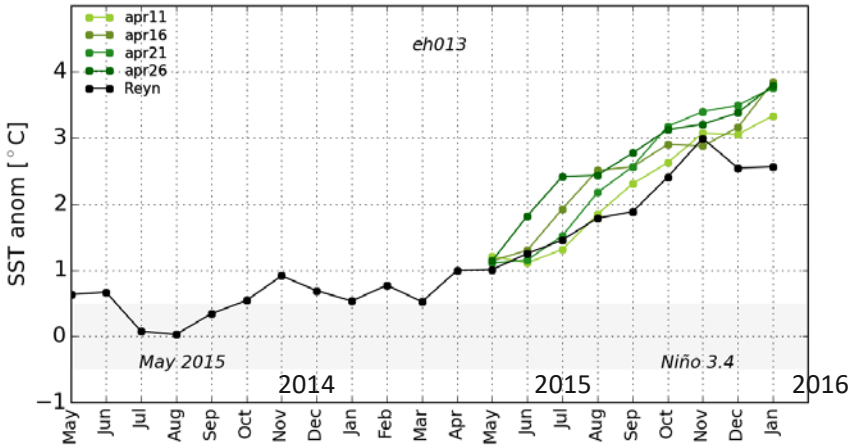
S2S (No SSS Assimilation)



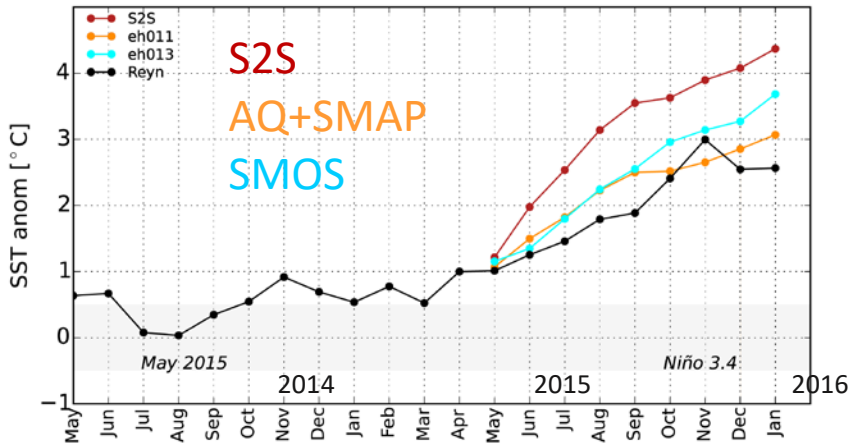
AQ+SMAP Assimilation



SMOS Assimilation

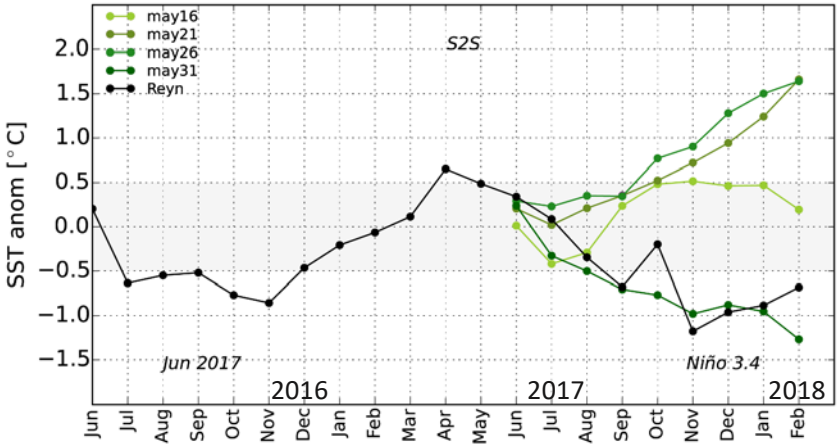


MEAN FORECASTS

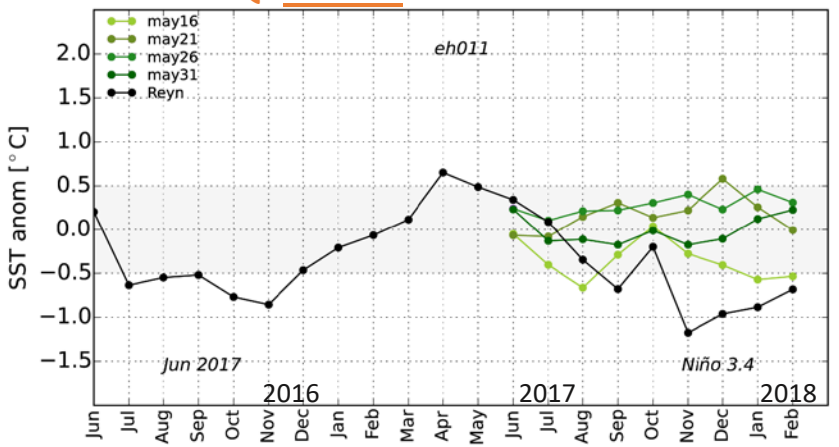


La Nina –May 2017

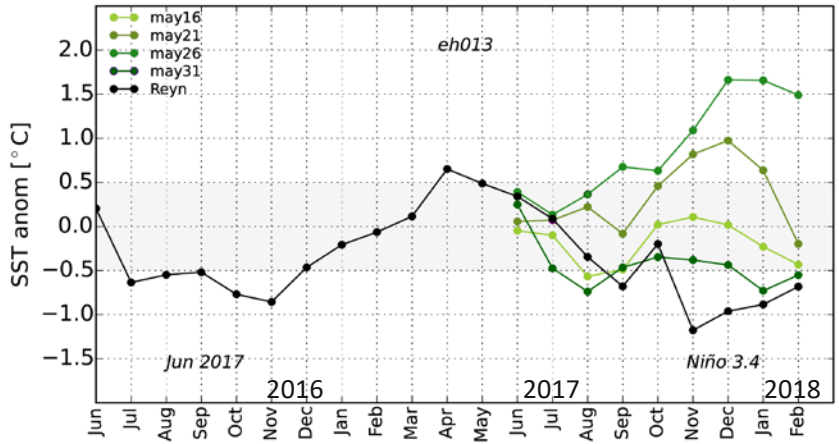
S2S (No SSS Assimilation)



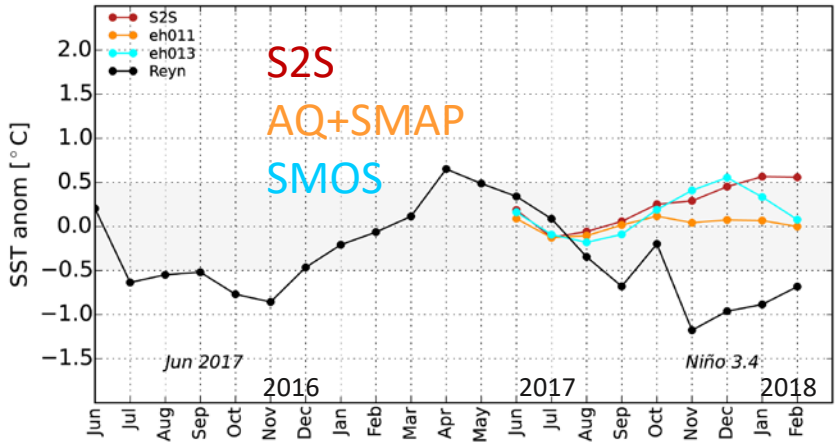
AQ+SMAP Assimilation



SMOS Assimilation

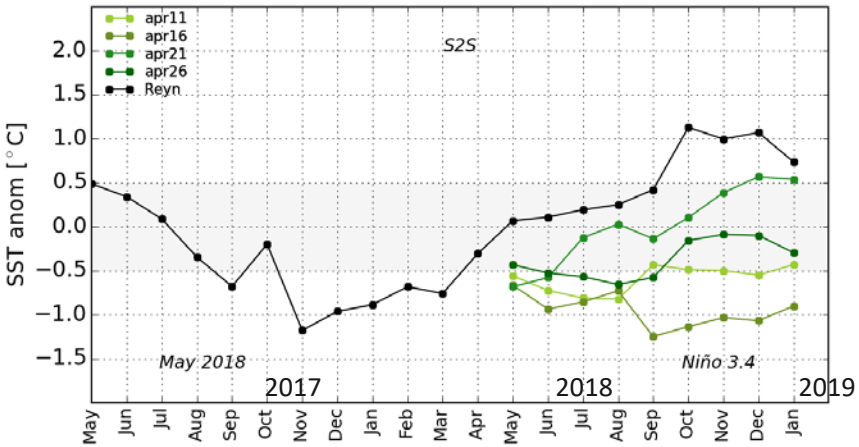


MEAN FORECASTS

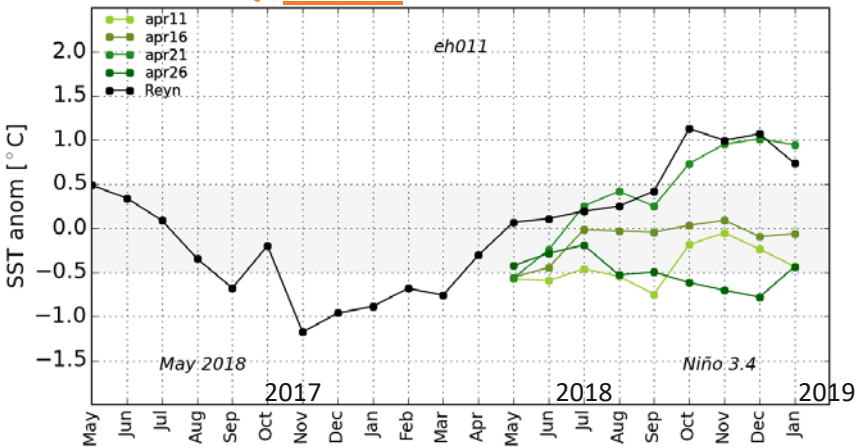


Weak El Nino – Apr 2018

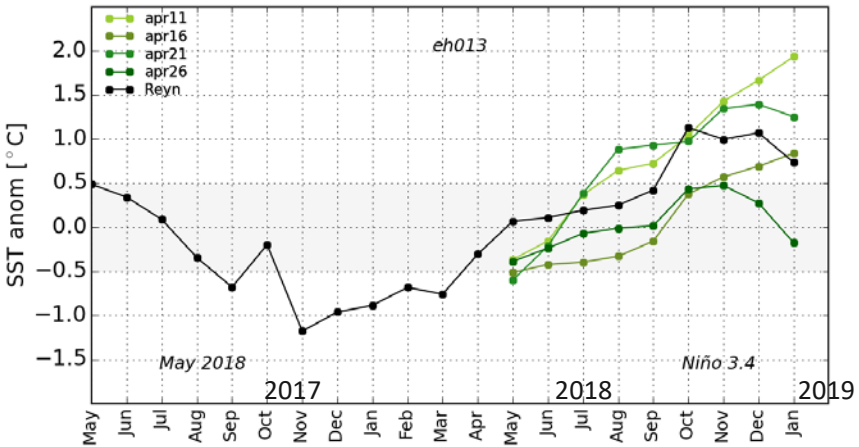
S2S (No SSS Assimilation)



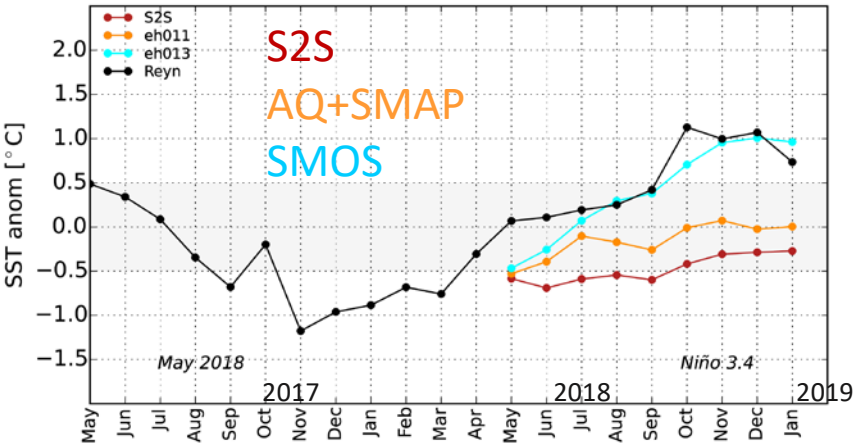
AQ+SMAP Assimilation



SMOS Assimilation



MEAN FORECASTS



SUMMARY

- Assimilation of SSS leads to density changes near the surface -> deepens MLD and shoals the BLT

- Deeper MLD due to satellite SSS assimilation acts to dampen ENSO Kelvin waves

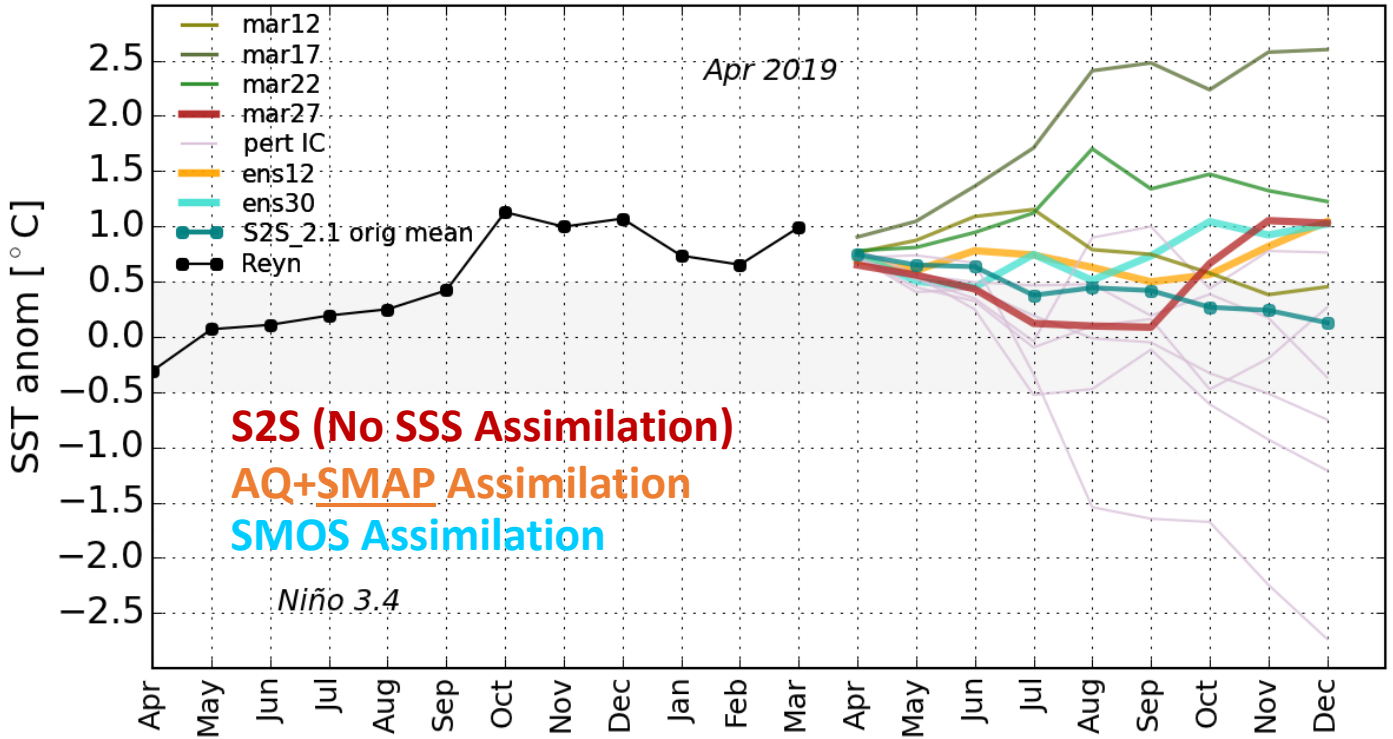
- Since S2S ENSO is generally too strong, assimilating SSS leads to (mostly) improved ENSO forecasts for both El Nino (2015, 2018) and La Nina (2017)

Recommendations

- Seasonal prediction centers should consider including satellite SSS assimilation in their operational ODAS

- The oceanographic community should ensure continuity of space-based salinity measurements

GMAO Forecast from March 2019



Thank You