



Impact of Satellite Sea Surface Salinity Observations on ENSO Predictions from the GMAO S2S Forecast System

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Outline

- Methodology
- Mechanisms of SSS Improvements
- Forecast Impact on Different Phases of ENSO
- Forecast Impact of Aquarius, versus SMAP and Combined



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, $\sim 0.5^\circ$, 40 levels
- AGCM: Similar to MERRA-2, $\sim 0.5^\circ$, 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

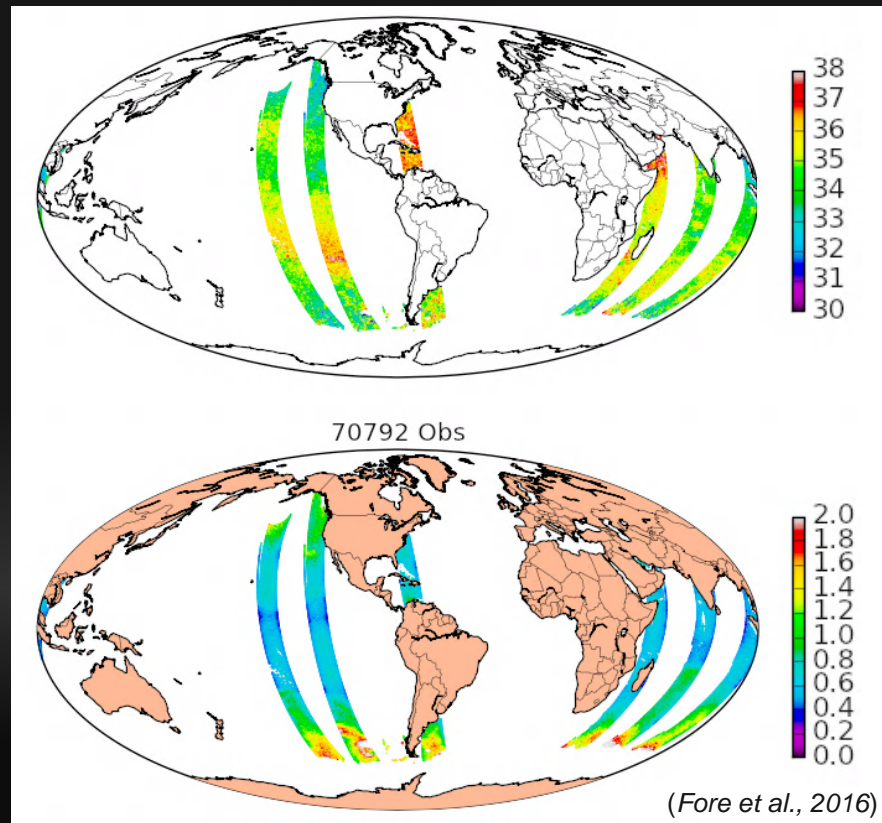
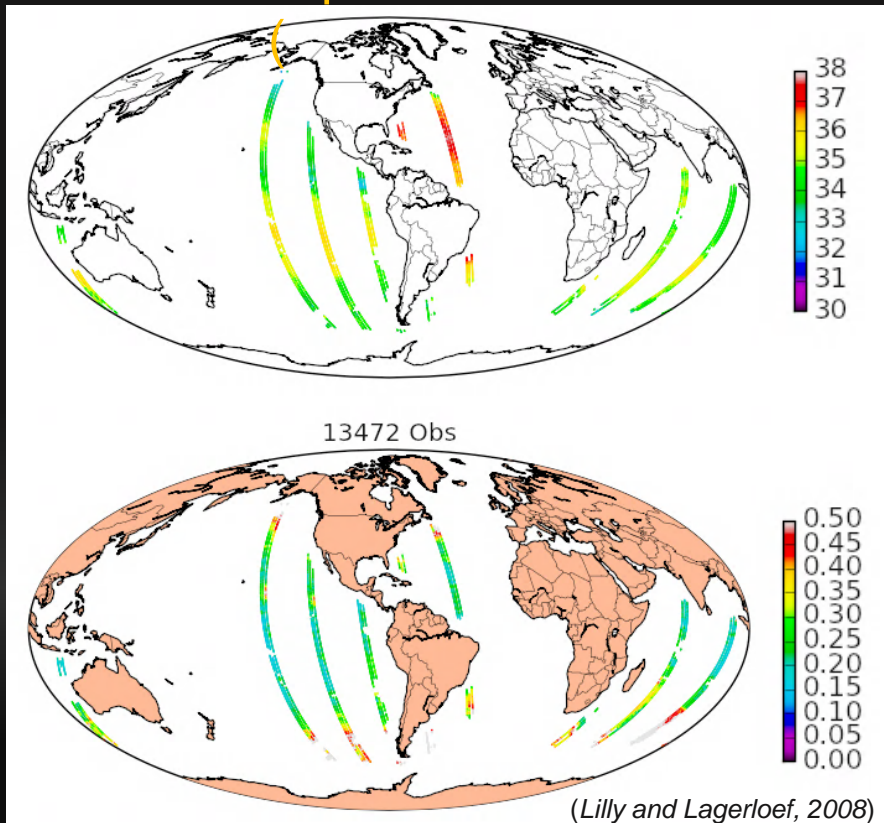
Observations

- 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) and SMAP (V4) (now running as an ensemble of near-real time S2S system)

Satellite SSS Assimilation Data

Aquarius V5

SMAP V4



Observation Error

Observation Error



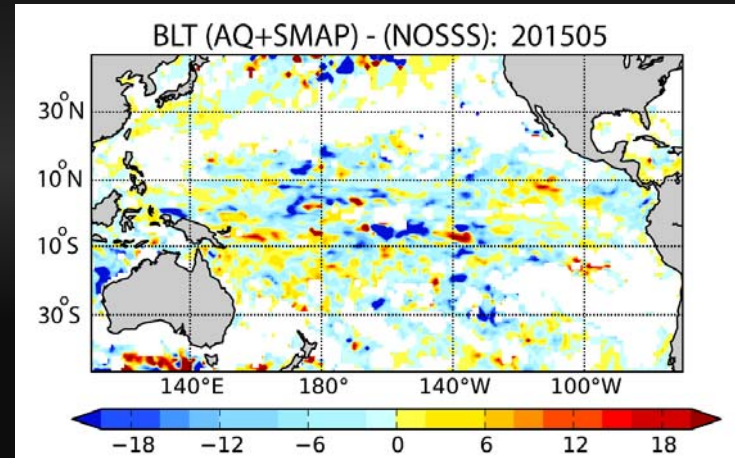
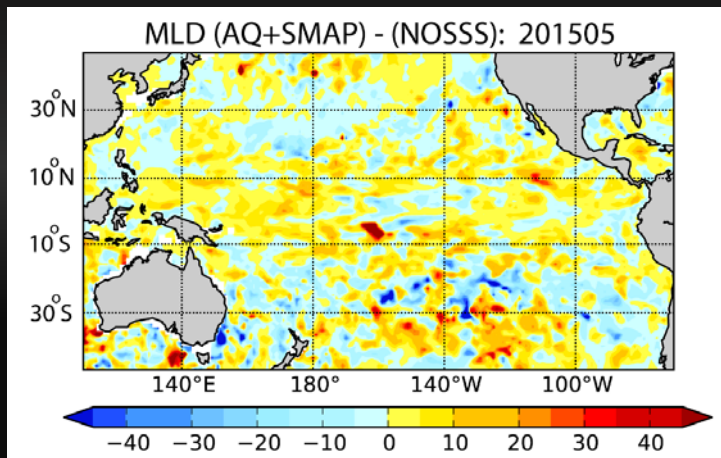
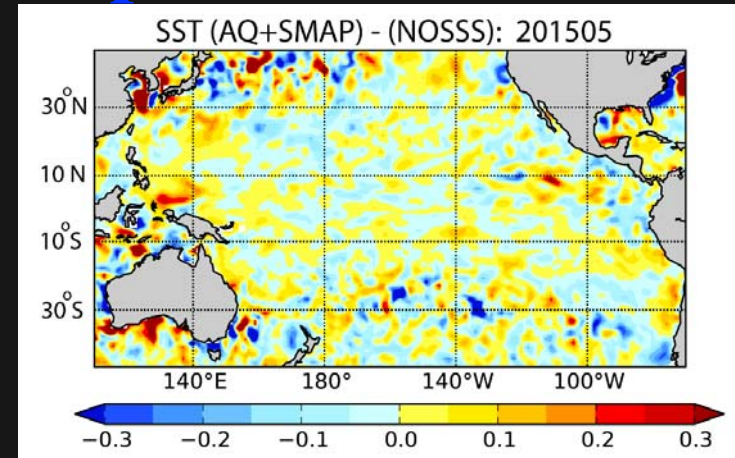
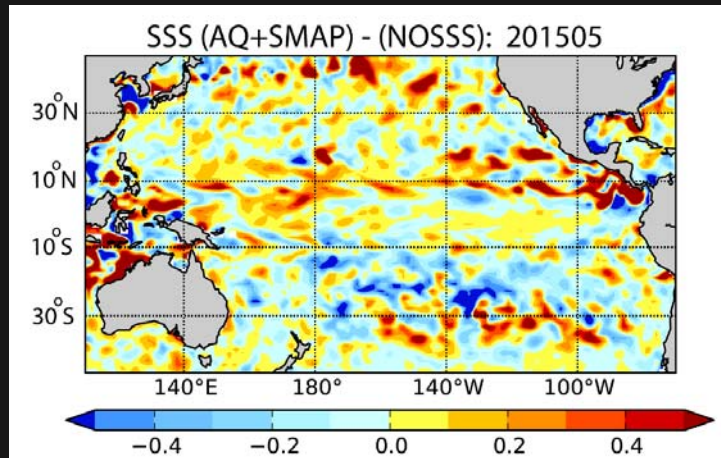
Mechanisms of SSS Improvements

- NO SSS = GMAO production system (S2S-v2.1) with no SSS assimilation
- AQ+SMAP = assimilates all available Aquarius V5 and SMAP V4 SSS

Show AQ+SMAP minus NO SSS to highlight impact of SSS assimilation.

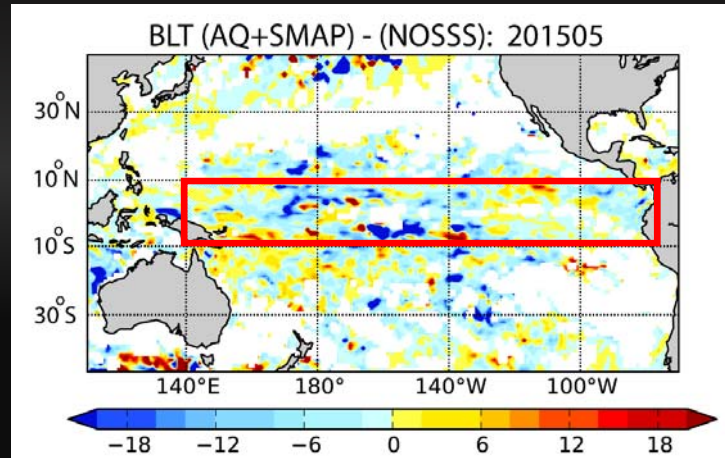
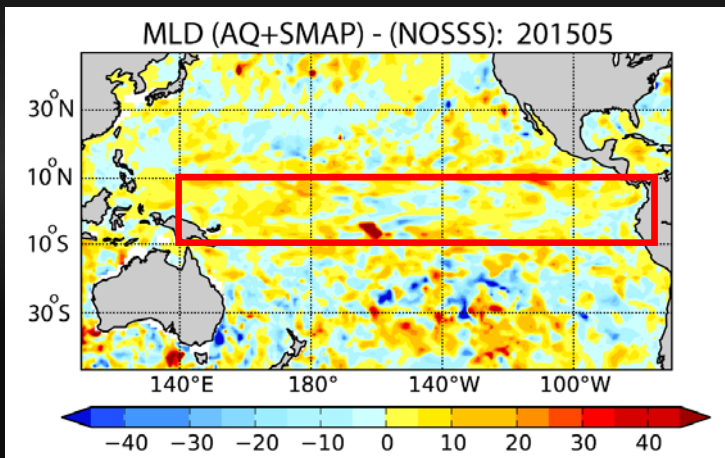
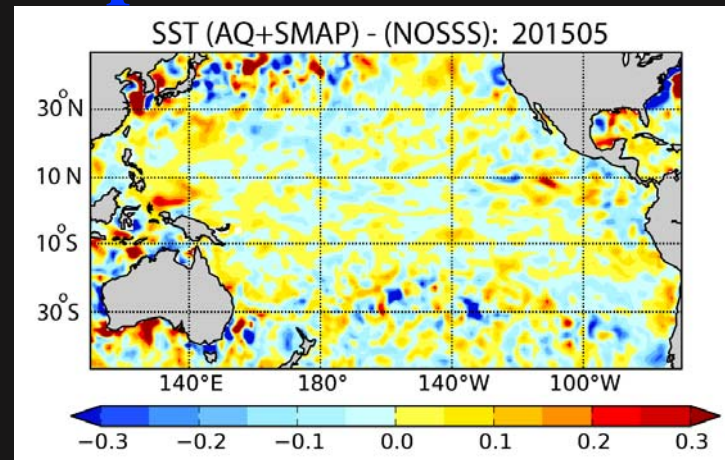
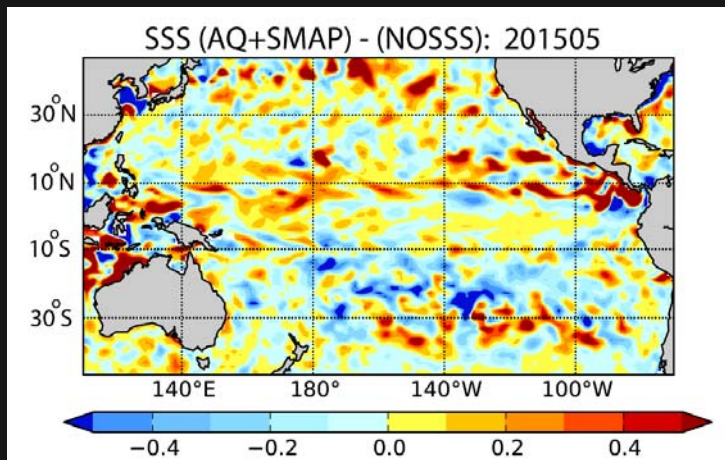
Mechanisms of SSS Improvements

Example
of May
2015



Mechanisms of SSS Improvements

Example
of May
2015

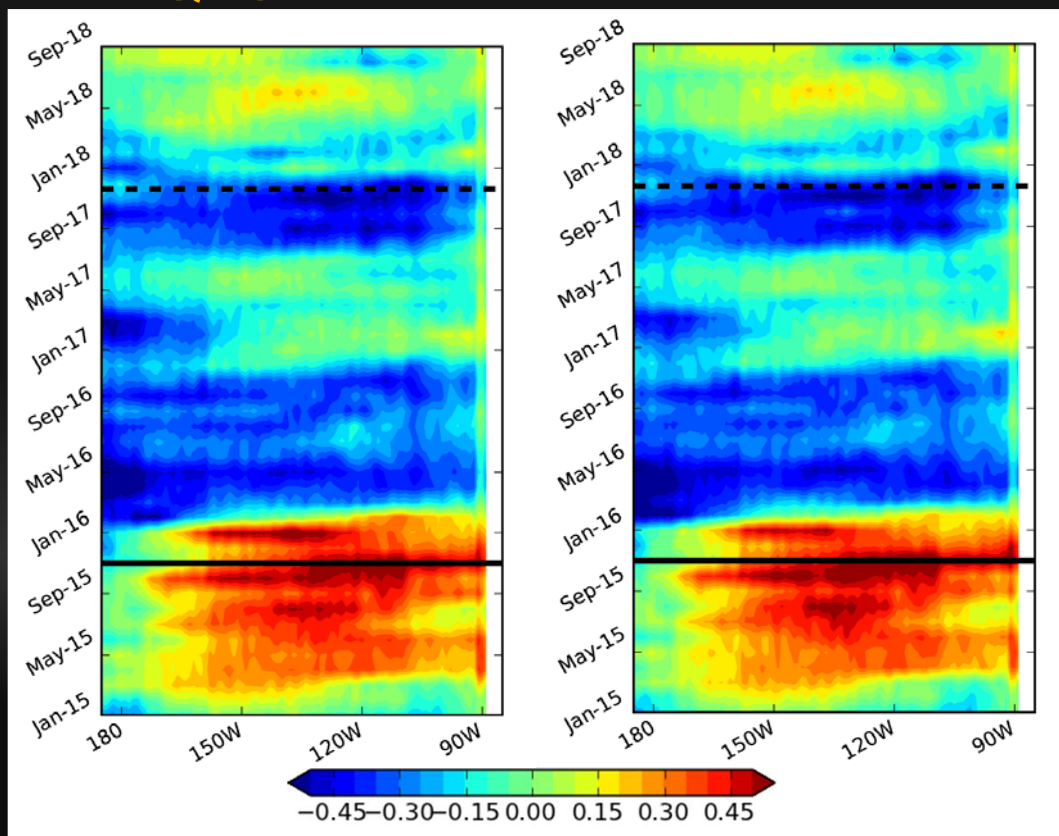


MLD
thickens
and BLT
shoals

Kelvin Wave Amplitude

AQ+SMAP

NOSSS

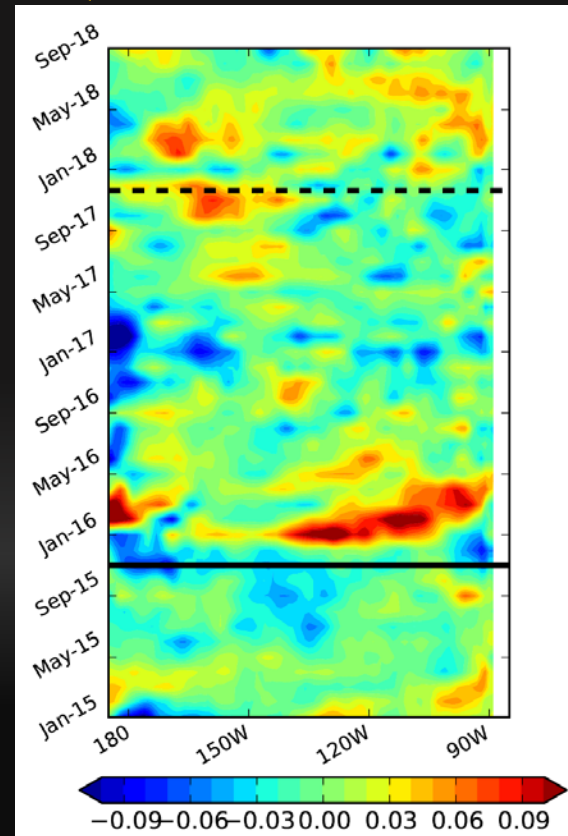
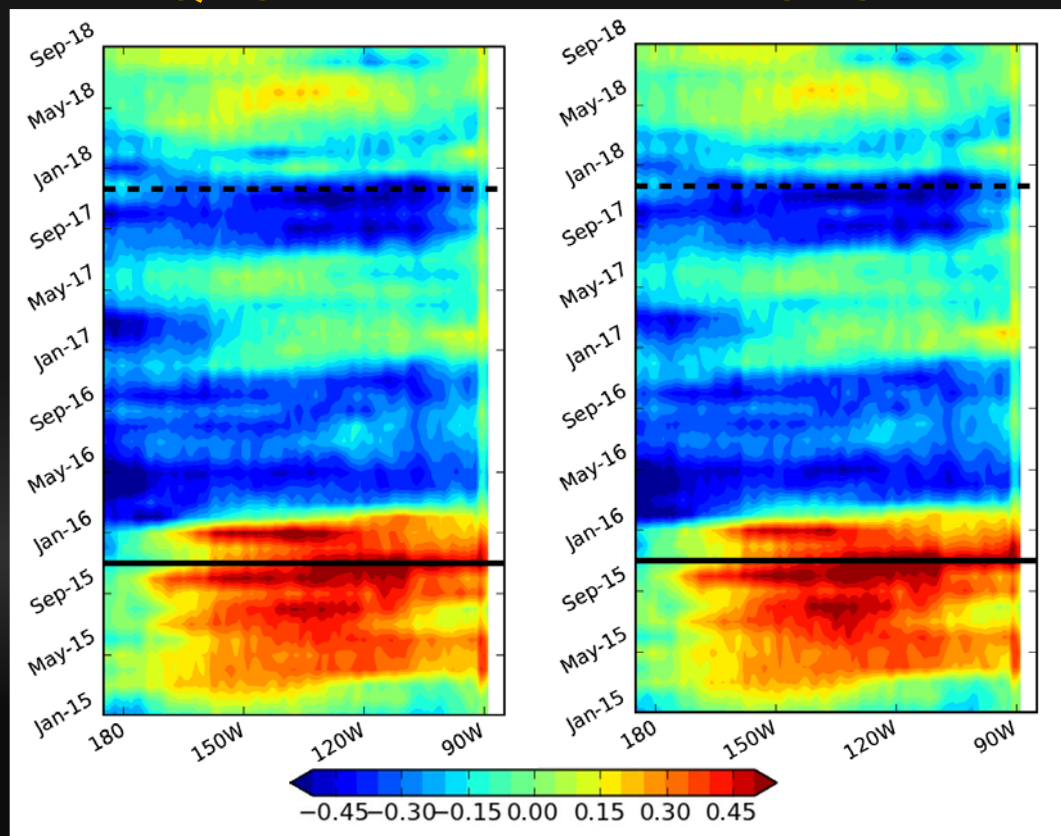


Kelvin Wave Amplitude

AQ+SMAP

S2S

AQ+SMAP – NOSSS





Impact of SSS Assimilation on Different Phases of ENSO

Forecasts:

- Apr 2015: Big El Nino
- May 2017: La Nina
- Apr 2018: Weak El Nino?

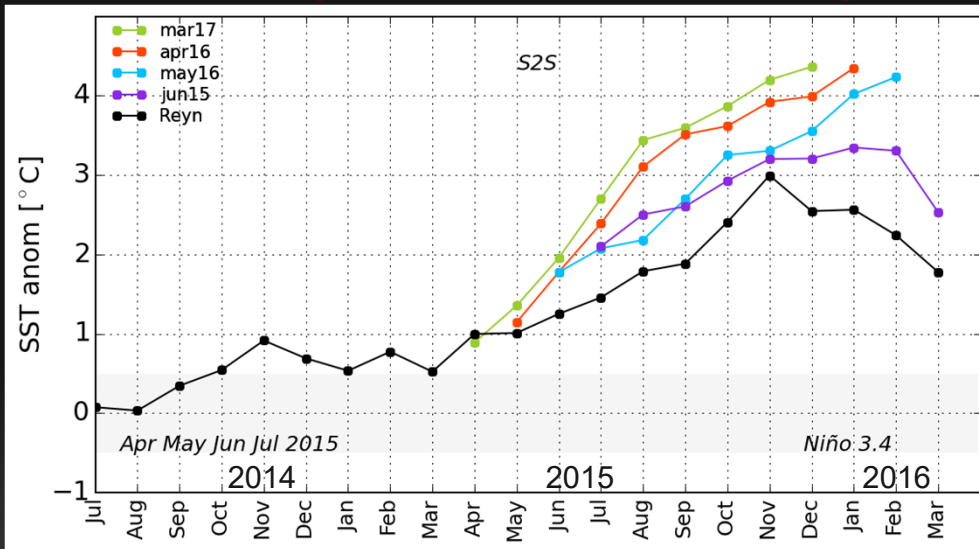
Use NINO3.4 SST Anomaly (Reynolds et al., 2002) as observations

- **No SSS** (S2S)
- **AQ+SMAP**

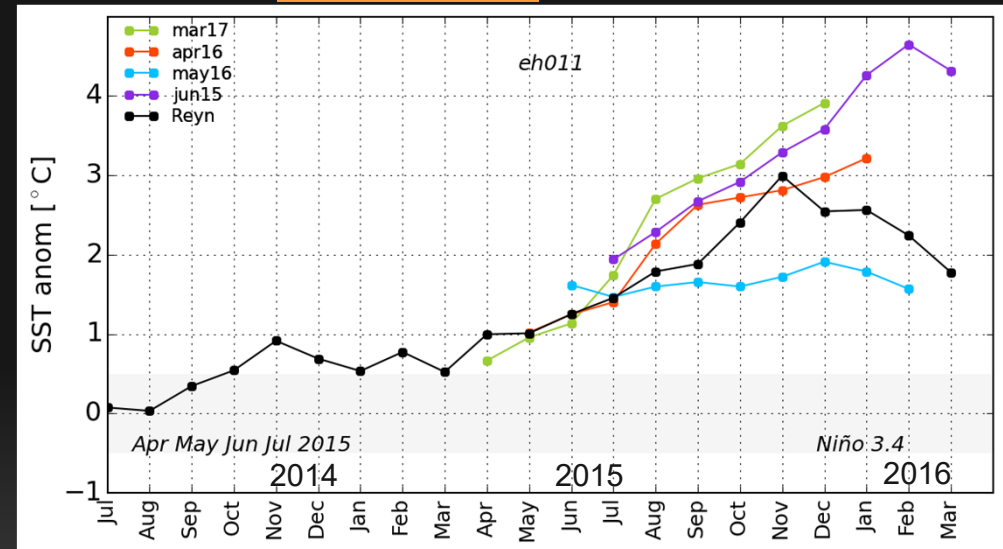


Big El Nino – Mar, Apr, May, Jun, 2015

S2S (No SSS Assimilation)



AQ+SMAP Assimilation

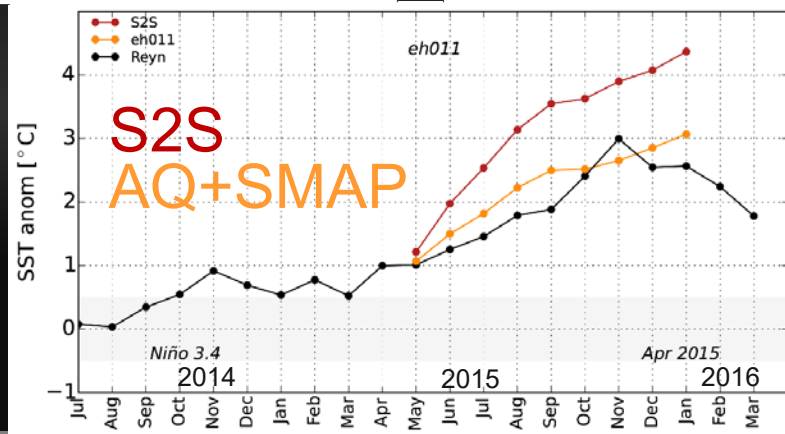
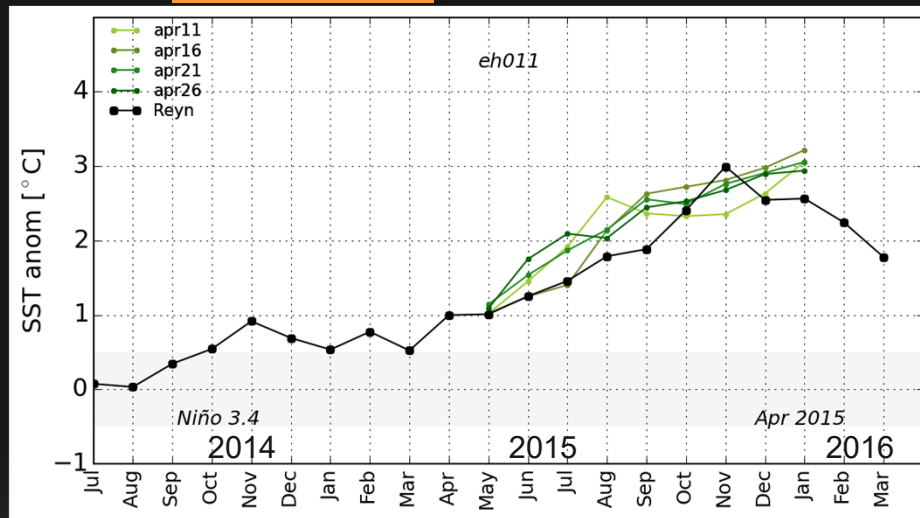
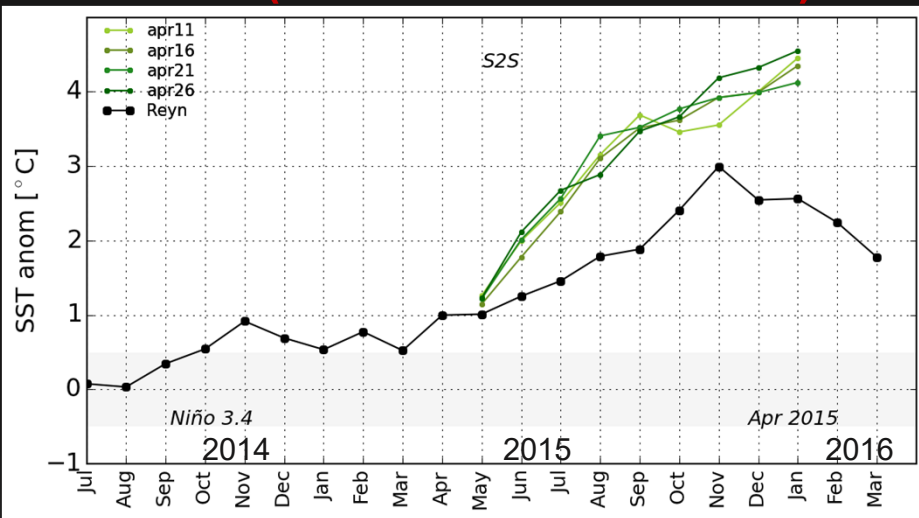




Big El Nino – Apr 2015

S2S (No SSS Assimilation)

AQ+SMAP Assimilation

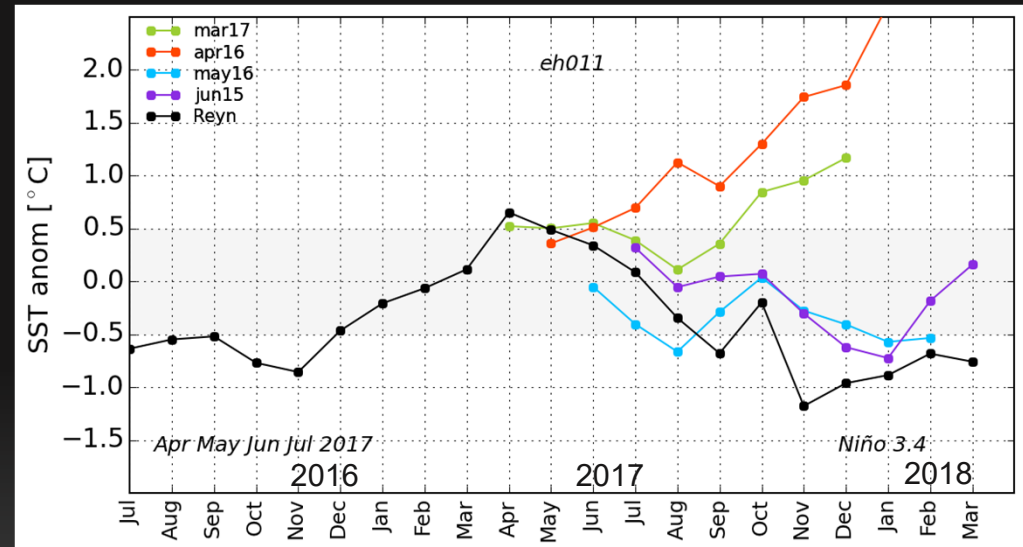
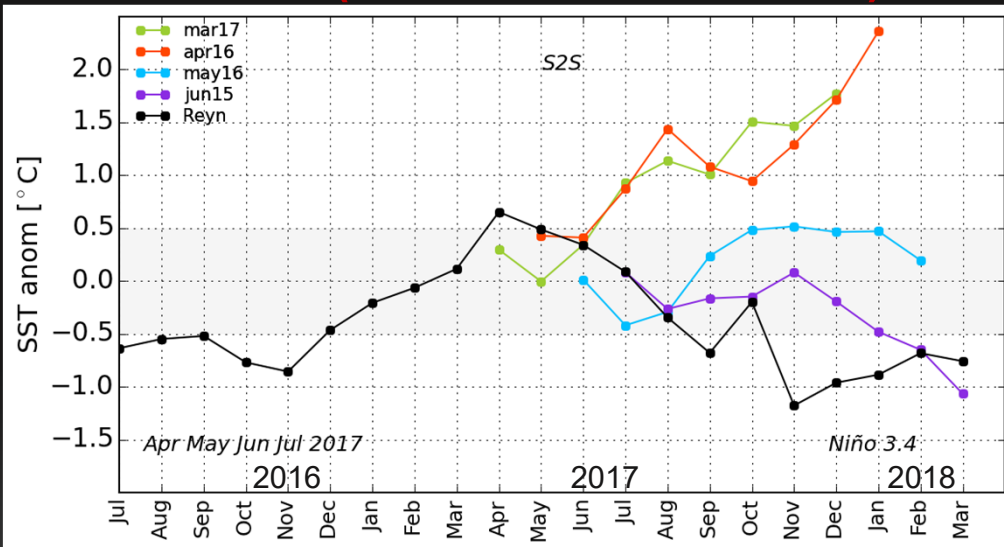




La Nina –Mar, Apr, May, Jun 2017

S2S (No SSS Assimilation)

AQ+SMAP Assimilation

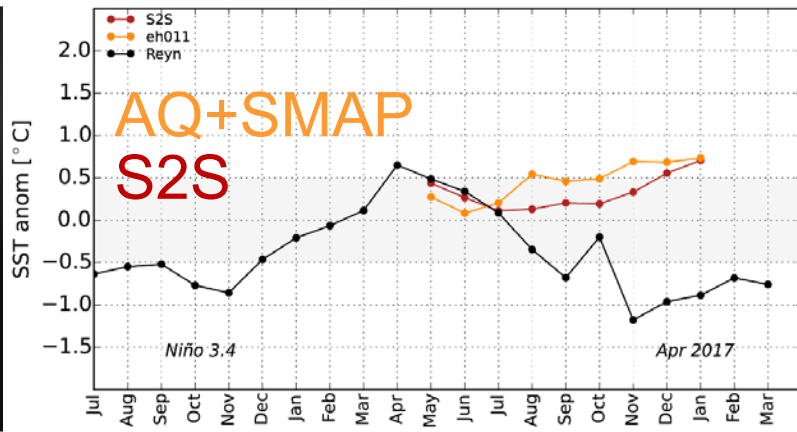
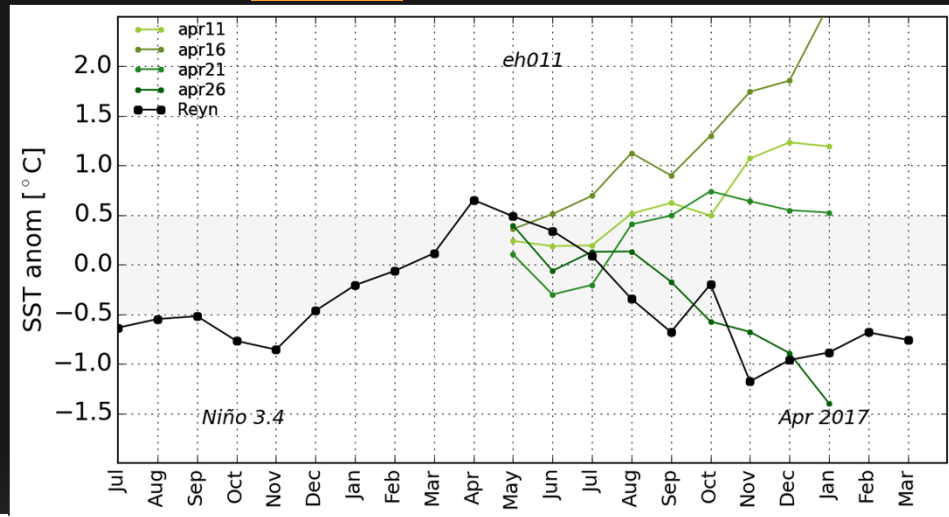
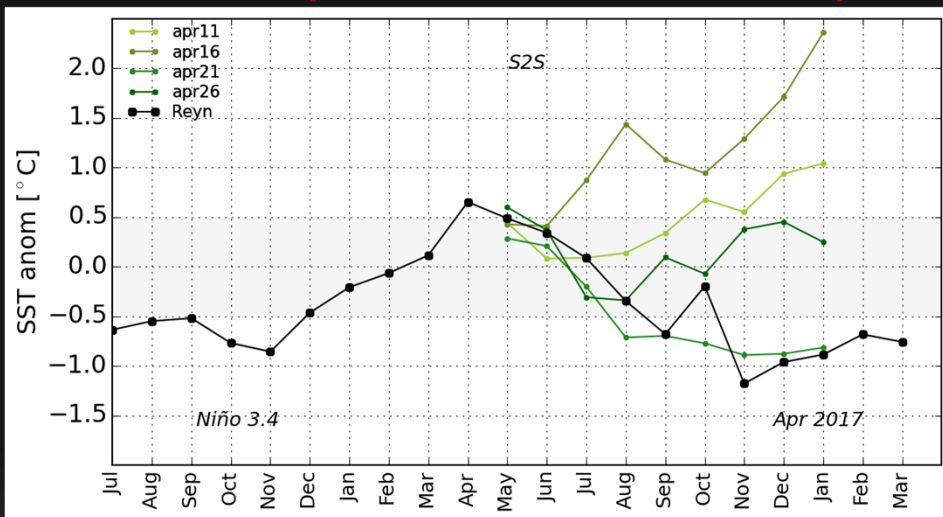




La Nina - Apr 2017

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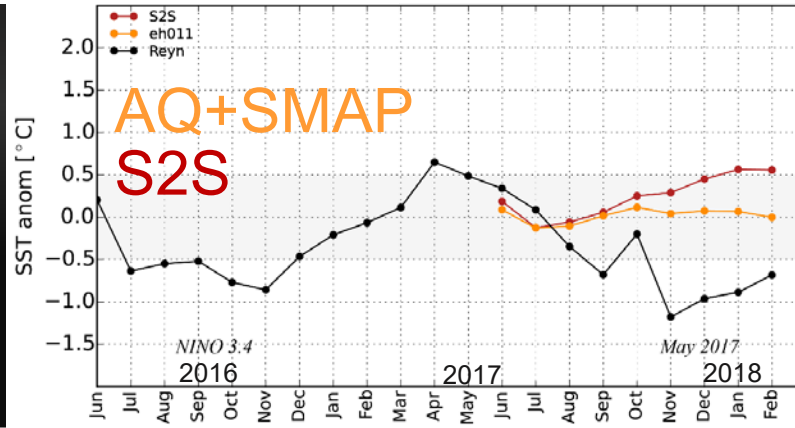
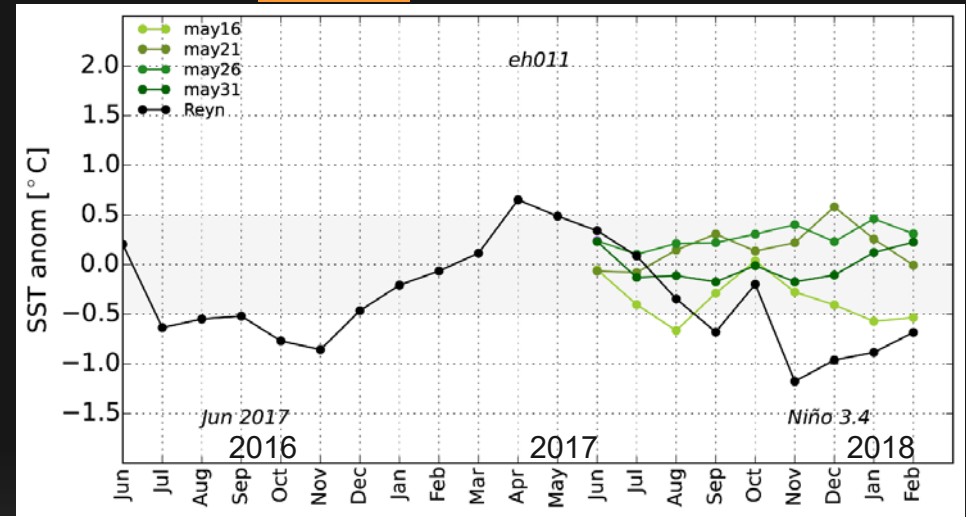
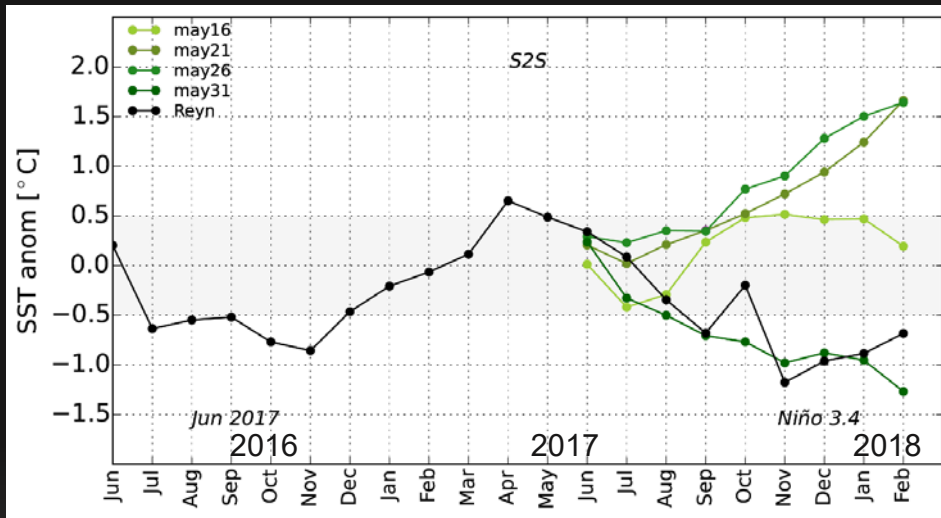




La Nina – May 2017

S2S (No SSS Assimilation)

AQ+SMAP Assimilation

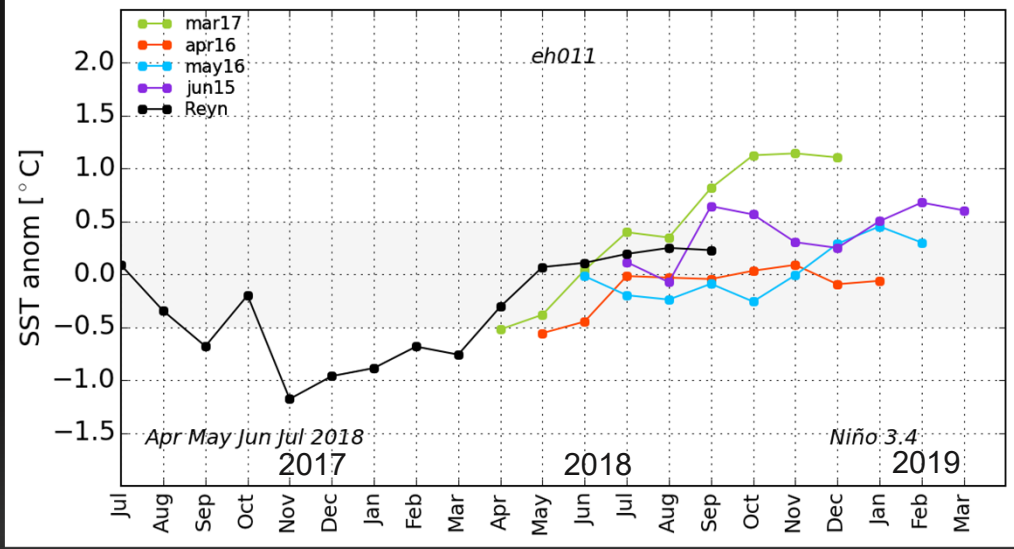
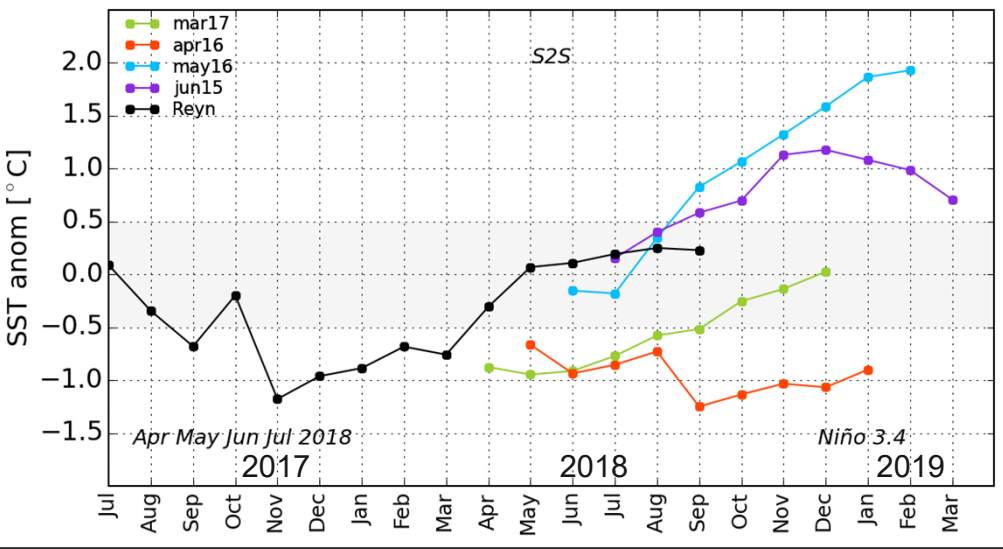




Weak El Nino? –Mar, Apr, May, Jun 2018

S2S (No SSS Assimilation)

AQ+SMAP Assimilation

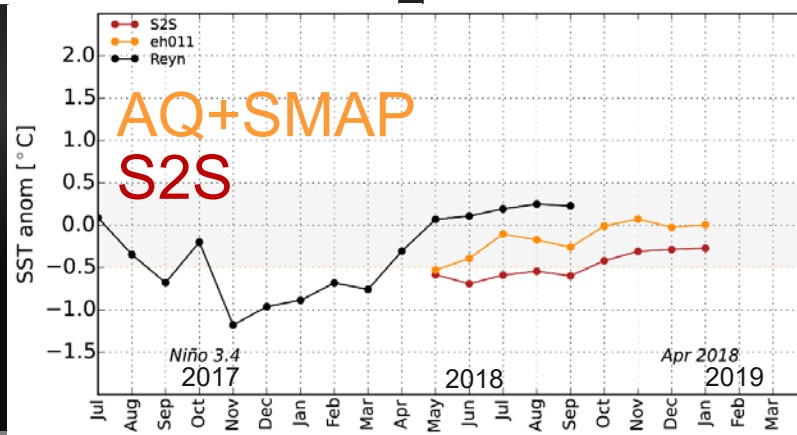
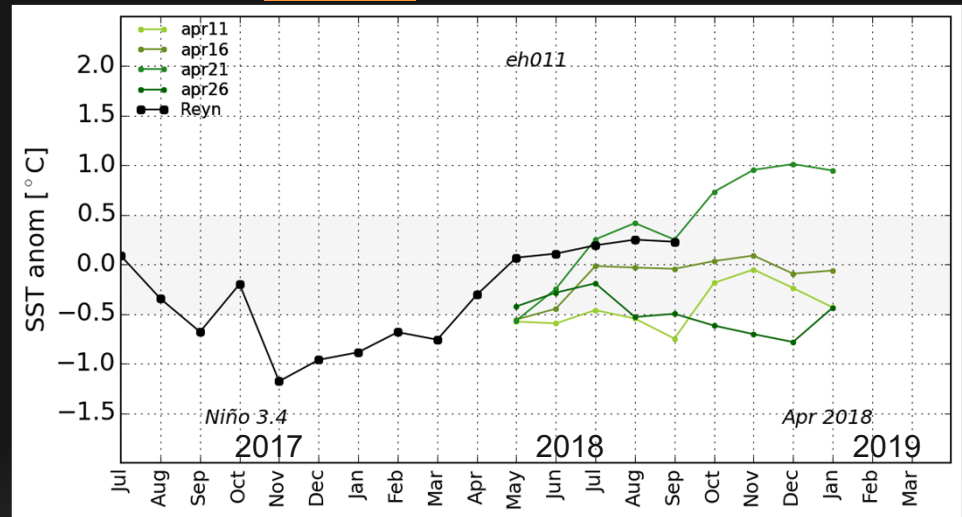
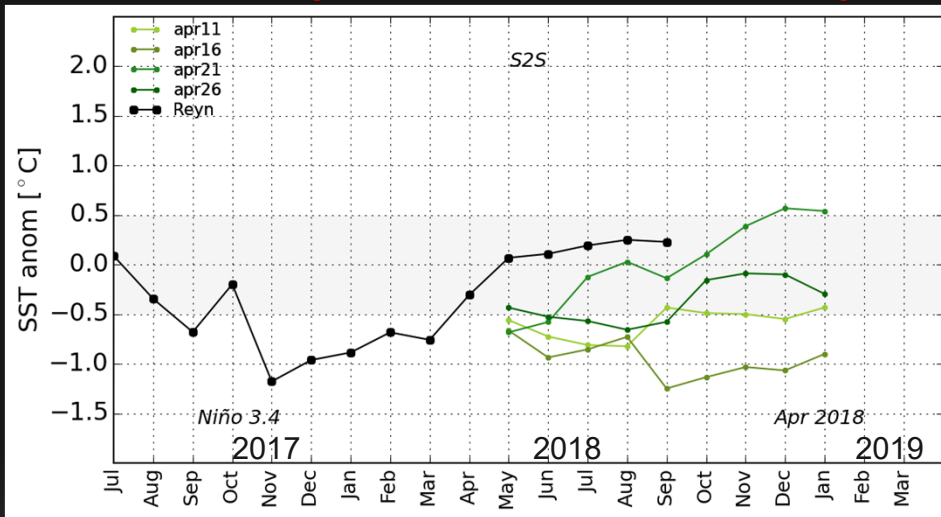




Weak El Nino? – Apr 2018

S2S (No SSS Assimilation)

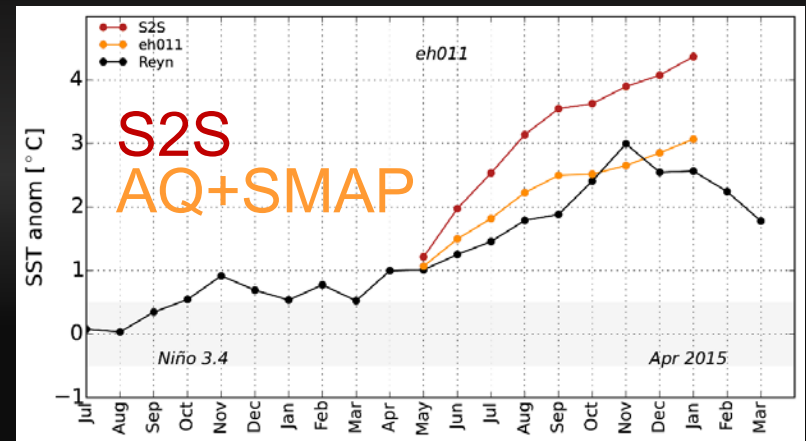
AQ+SMAP Assimilation



Preliminary Results

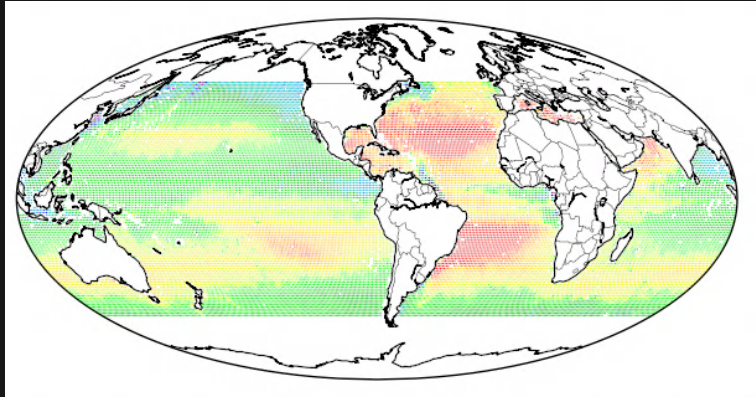
- Deeper MLD due to satellite SSS assimilation acts to dampen ENSO
- Leading to improved ENSO forecasts for both El Nino (2015, 2018) and La Nina (2017)

Best example is 2015 when both Aquarius and SMAP were available – so what is the impact of multiple SSS satellites?

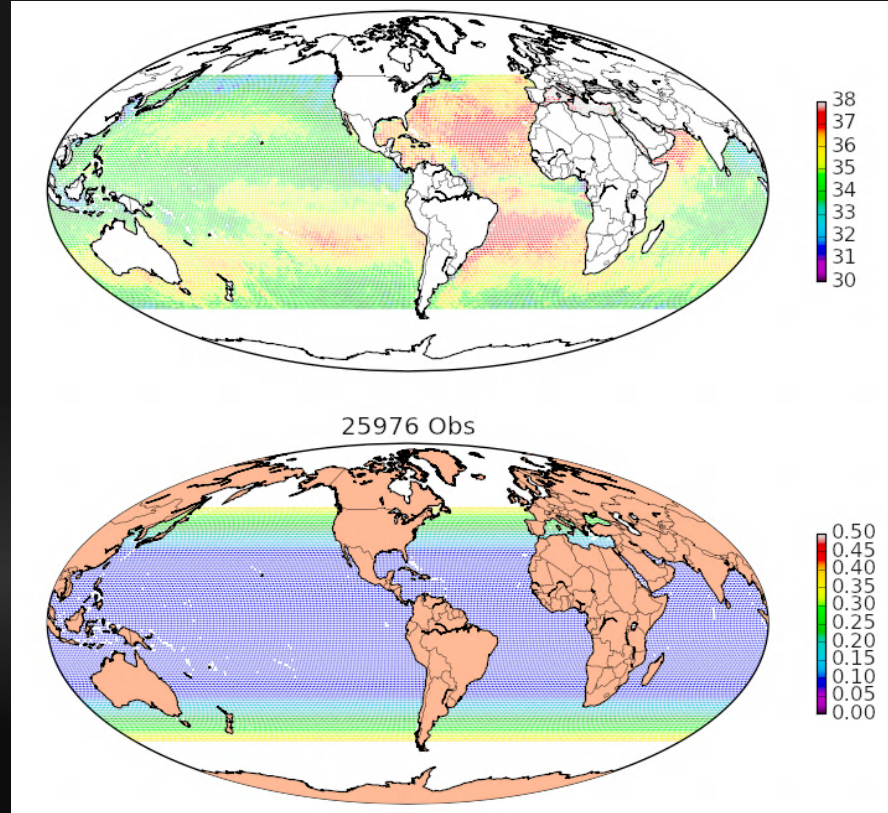


Satellite SSS Assimilation Data

Aquarius V5



SMAP V4



- Assimilate gridded fields of Aquarius V5 and SMAP V4
- Example of May 2015 (Big El Nino)

(Lilly and Lagerloef, 2008 , Fore et al., 2016)

Observation Error



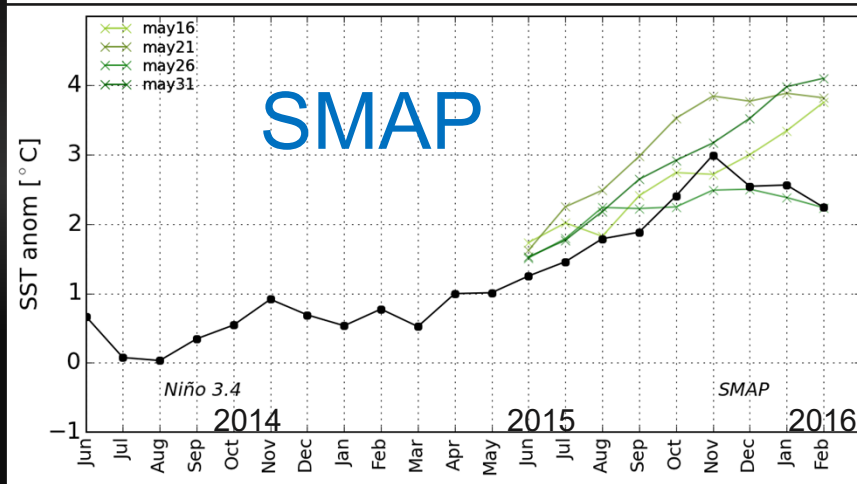
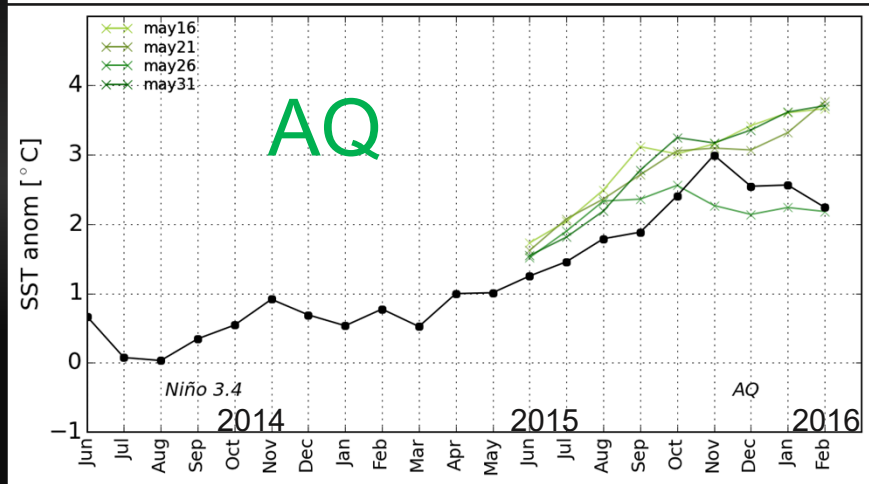
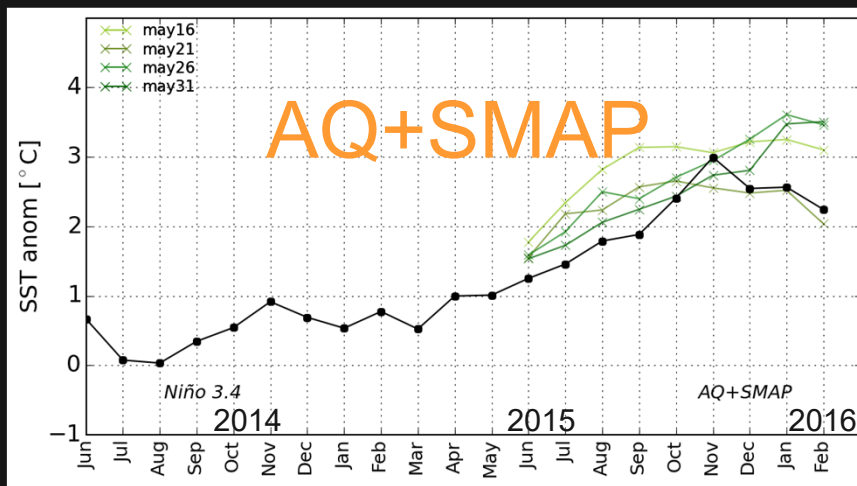
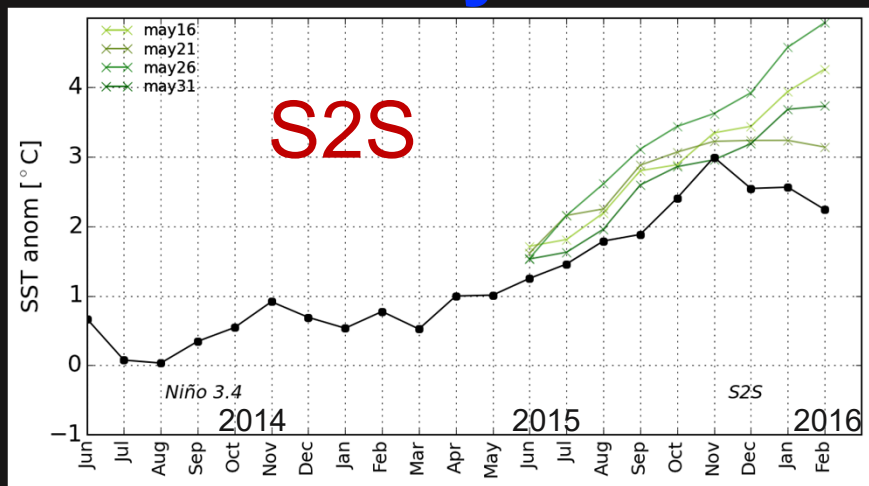
Forecast Impact of Aquarius Versus SMAP

May 2015: El Nino: May 16, 21, 26, 31

- No SSS
- AQ+SMAP
- AQ
- SMAP

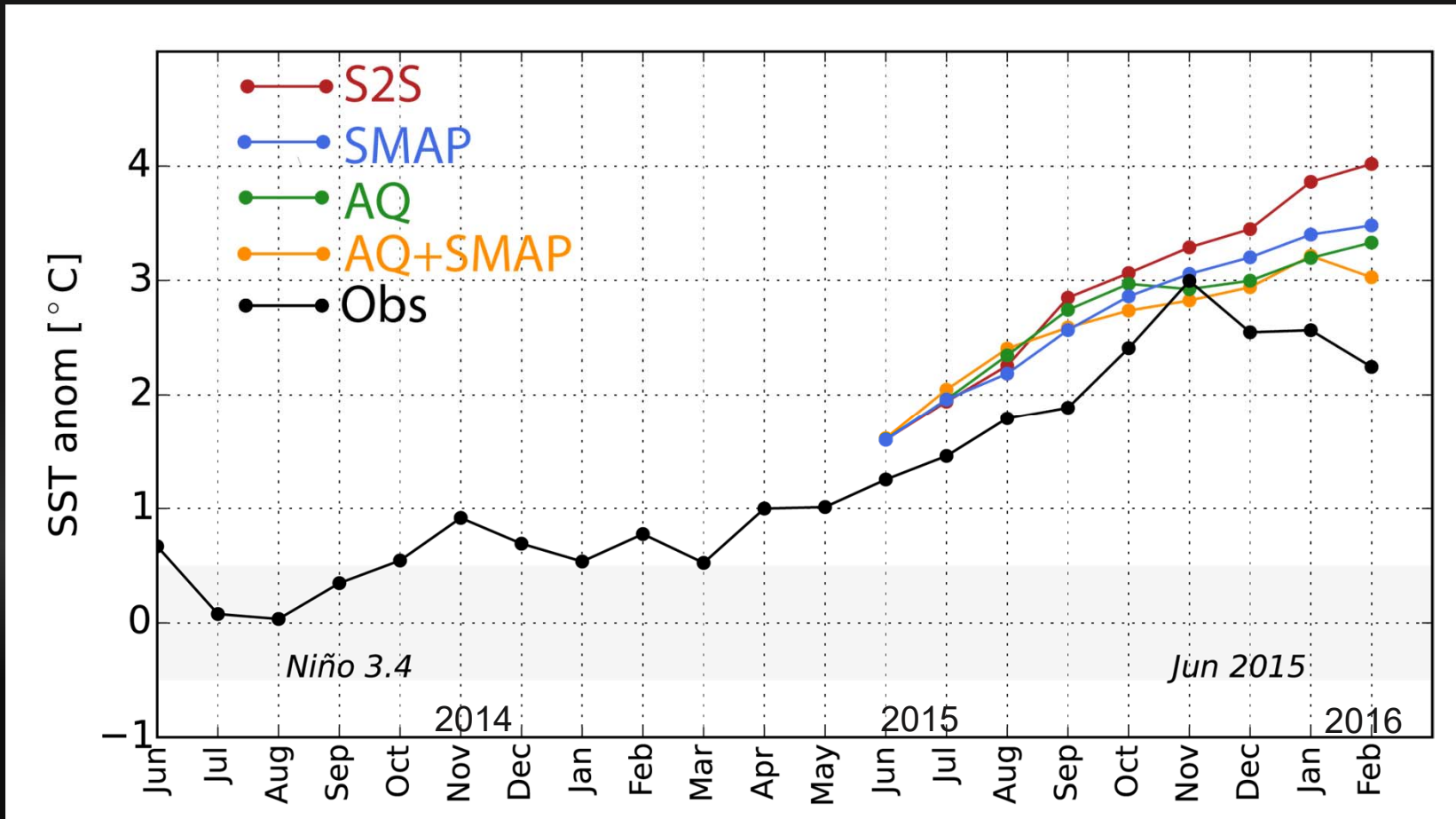


May 2015 El Niño Forecasts





May 2015 El Nino Forecasts – Ensemble Mean





Conclusions

- Assimilation of SSS leads to density changes near the surface -> deepens MLD and shoals the BLT
- Deeper MLD acts to dampen ENSO signal
- Since S2S ENSO is generally too strong, assimilating SSS leads to (mostly) improved ENSO forecasts
- For the short overlapping period of Aquarius and SMAP (Mar – Jun 2015)
 - a) Any assimilation of SSS improves El Nino forecast
 - b) Aquarius combined with SMAP produces best El Nino forecast



- Please come by and visit our poster on Thursday –

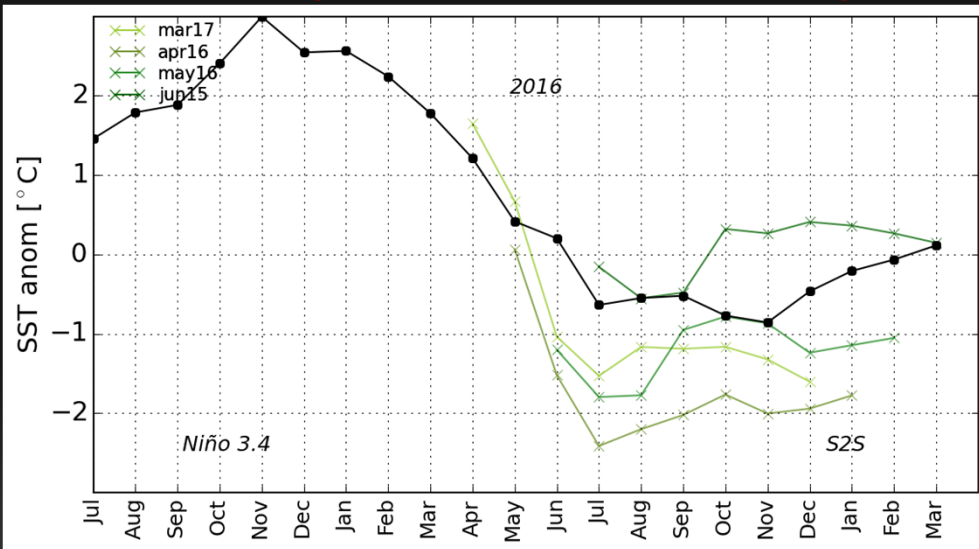
Assessment of Sea Surface Salinity Products Using a Coupled ENSO Prediction Model

Thank You

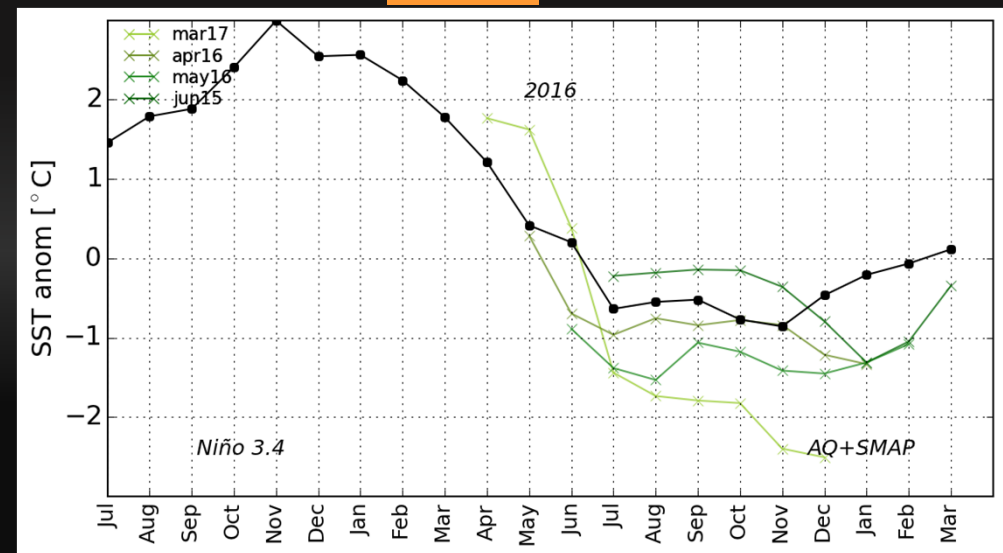


Weak La Nina – Mar, Apr, May, Jun, 2016

S2S (No SSS Assimilation)



AQ+SMAP Assimilation

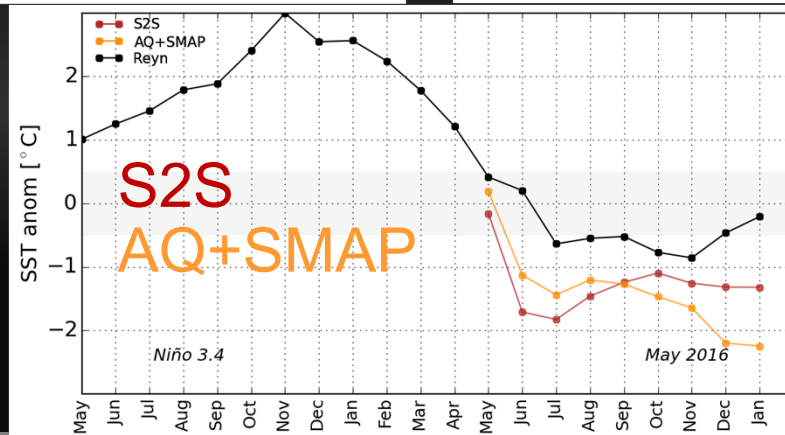
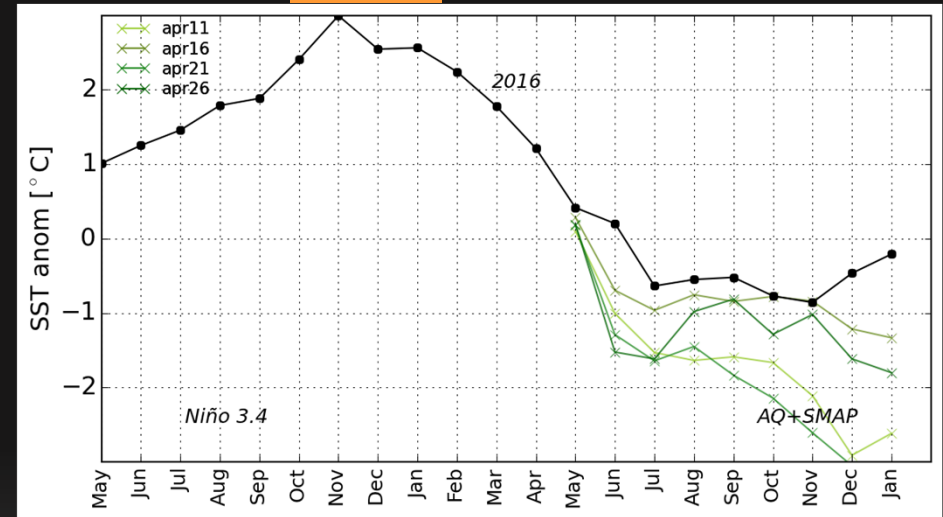
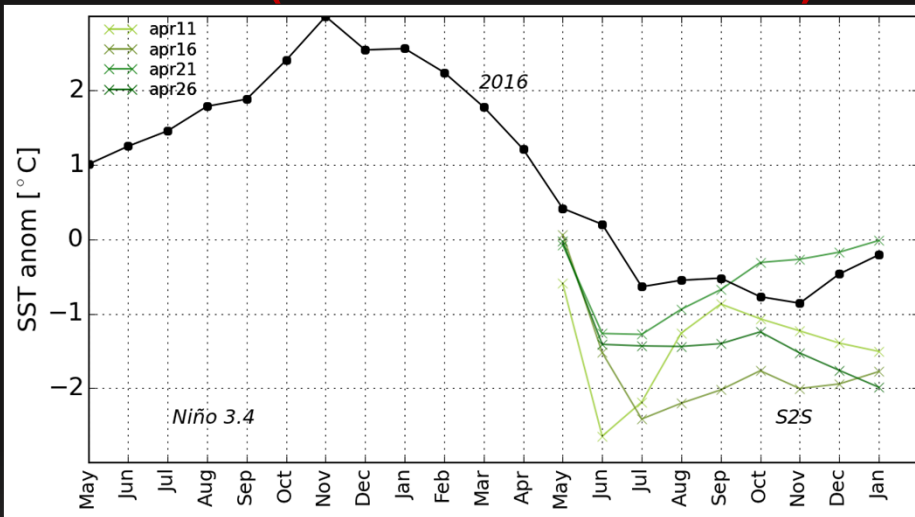




Weak La Nina – Apr 2016

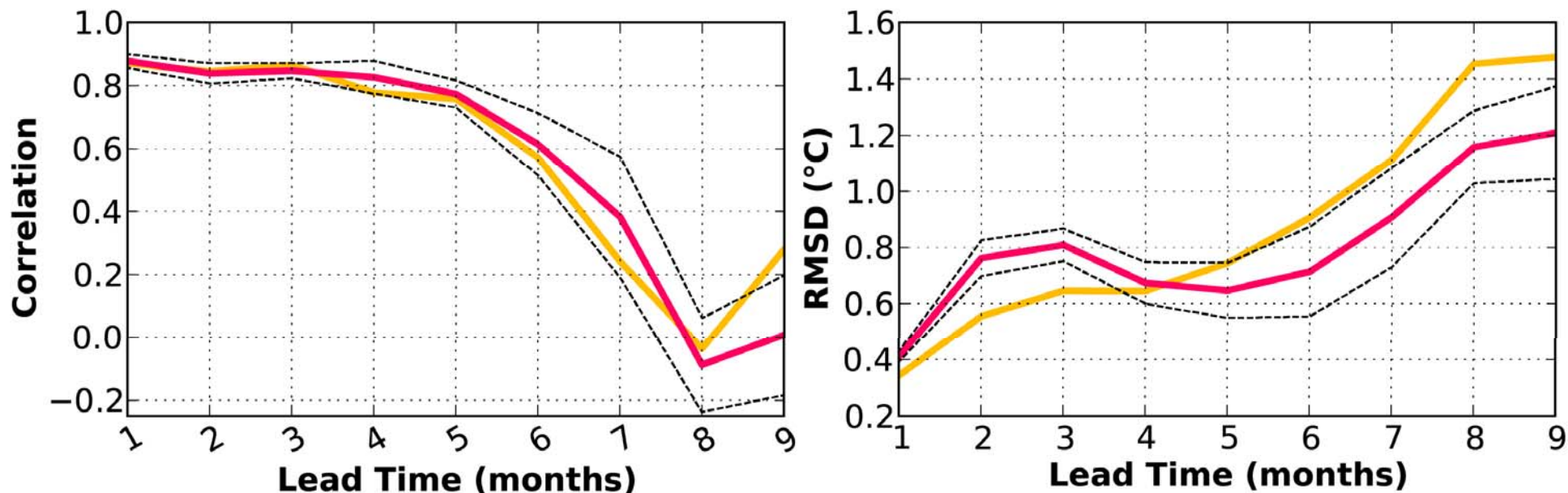
S2S (No SSS Assimilation)

AQ+SMAP Assimilation



Validation Statistics – 1/17-1/18

Forecast NINO3.4 SST' Versus Observations

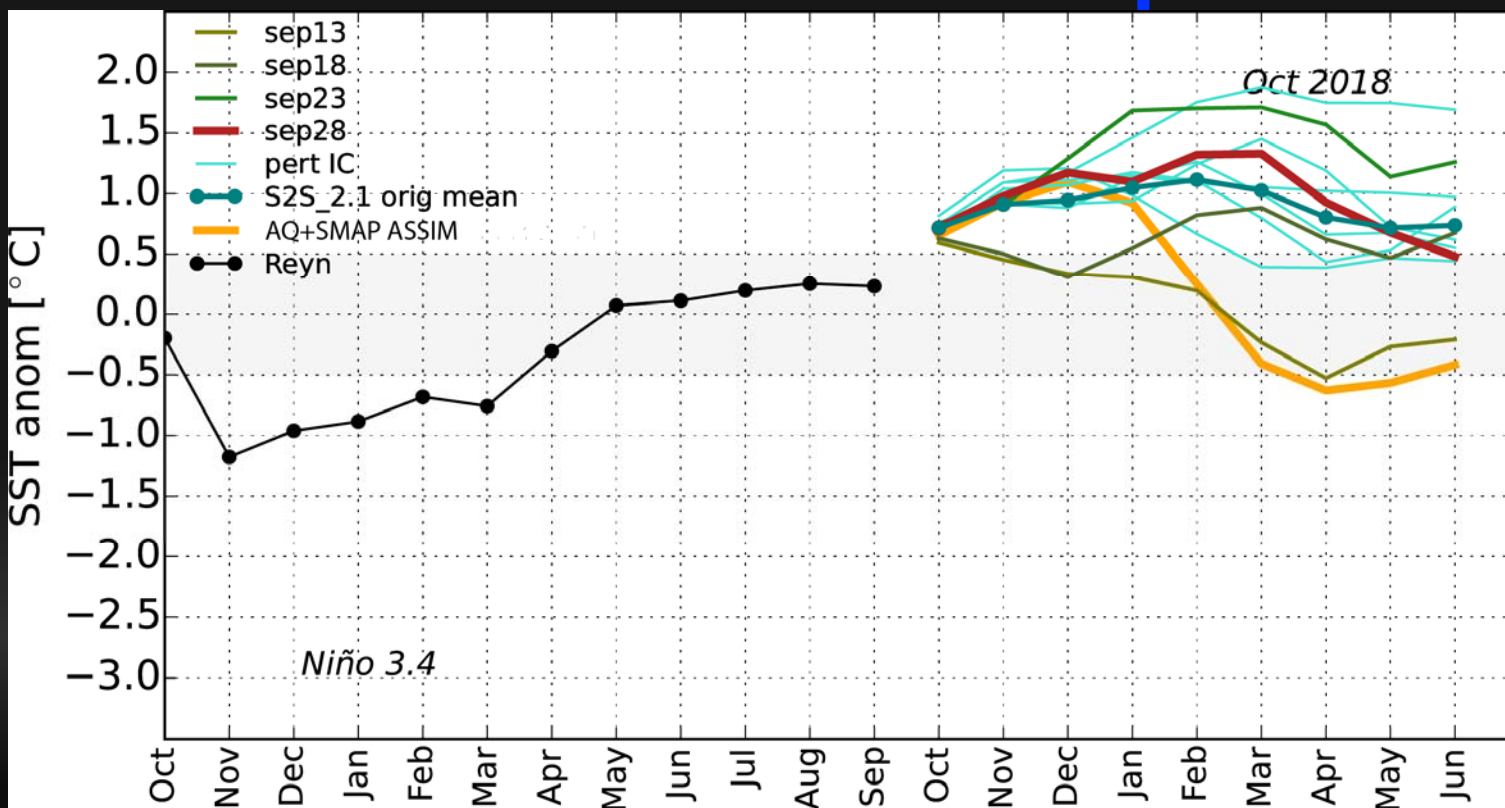


S2S (No SSS Assimilation)

AQ+SMAP Assimilation



GMAO Forecast from Sept. 2018



S2S (No SSS Assimilation)

AQ+SMAP Assimilation