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

E. Hackert, R. Kovach, J. Marshak, A. Borovikov, A. Molod, and G. Vernieres

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, ~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

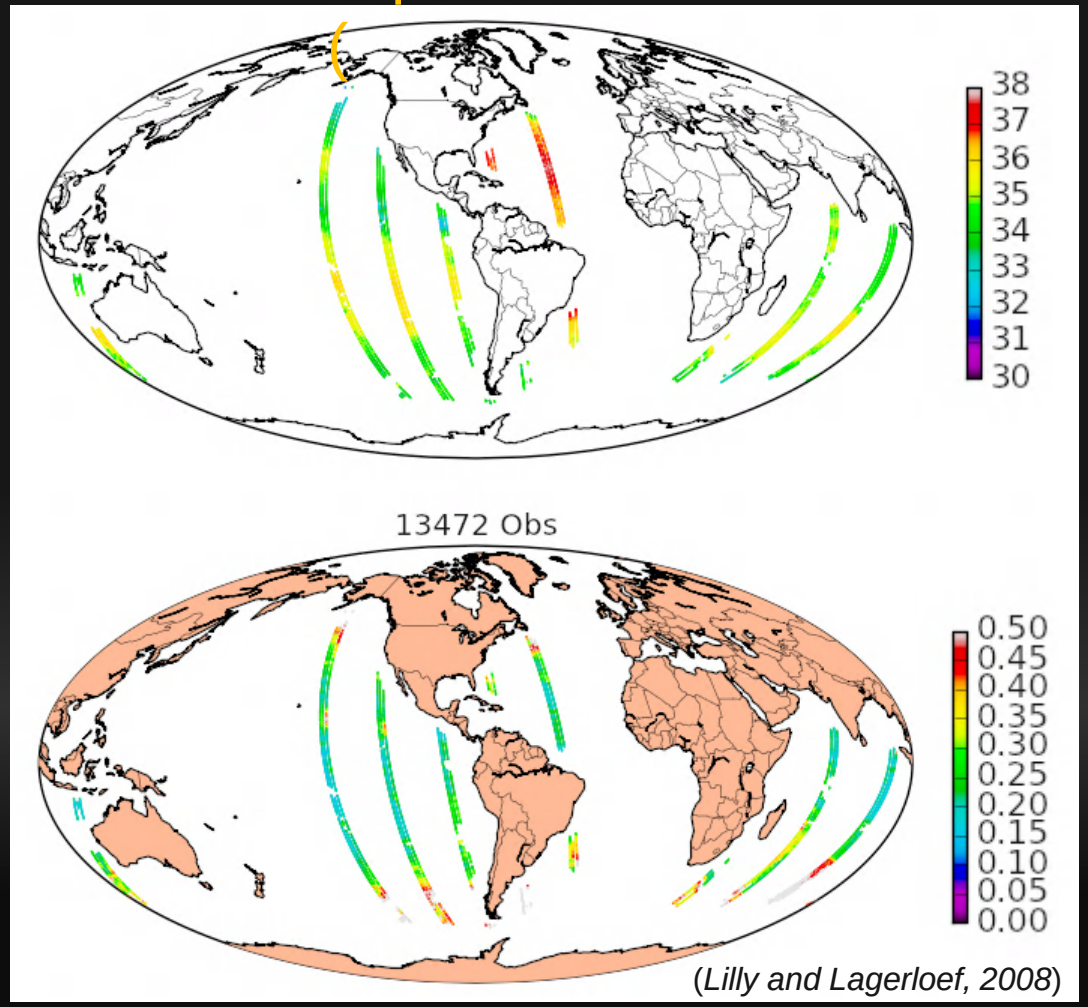
- LETKF assimilation (similar to Penny et al, 2013)
- ODAS ensemble members - monthly averaged anomalies of 20 years of freely coupled experiment re-centered around the background

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

Satellite SSS Assimilation Data

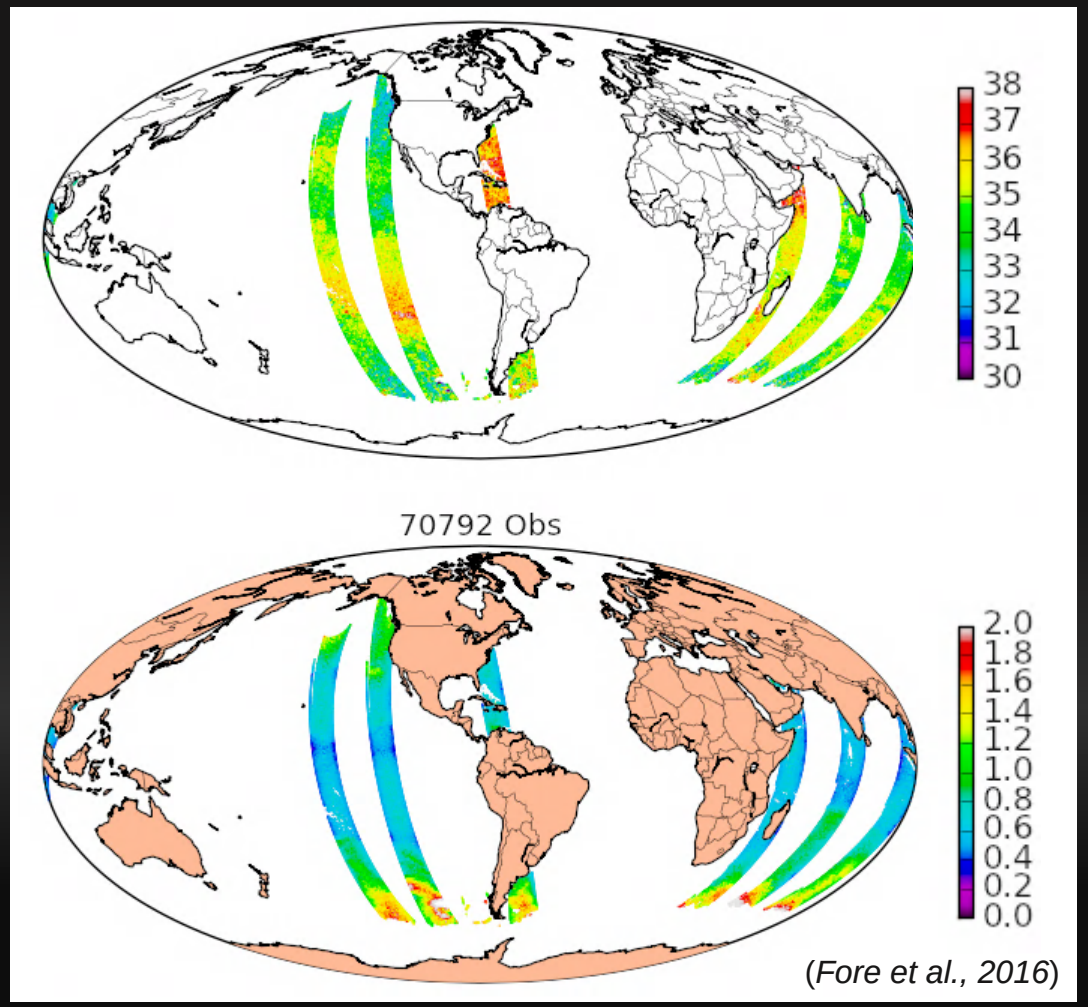
Aquarius V5



(*Lilly and Lagerloef, 2008*)

Observation Error

SMAP V4



(*Fore et al., 2016*)

Observation Error

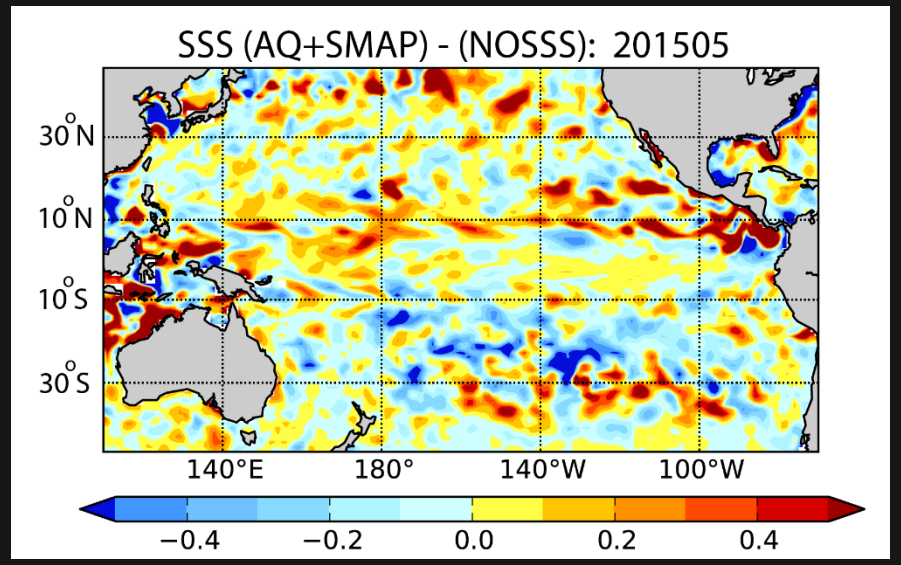
Mechanisms of SSS Improvements

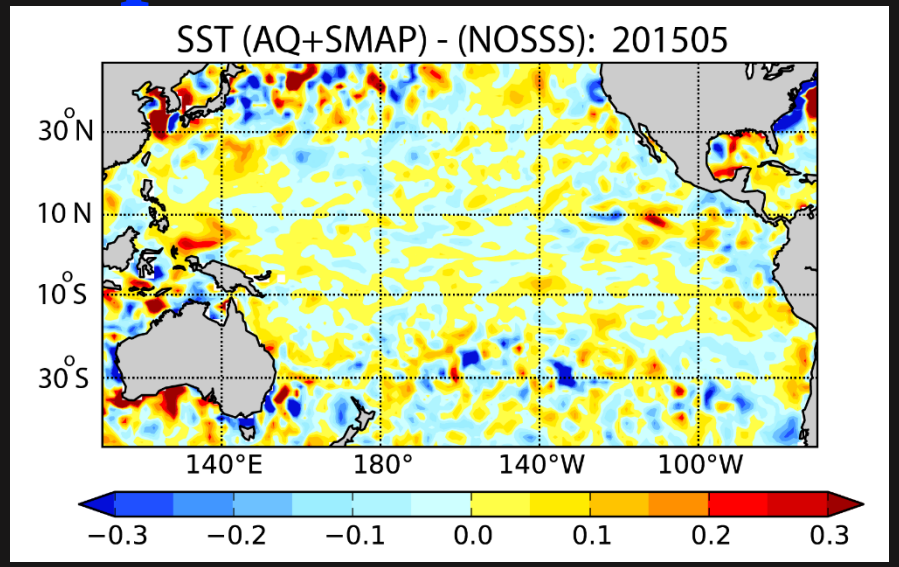
- NO SSS = GMAO production system (S2S-v2.1) with no SSS assimilation
- AQ+SMAP = assimilates all available Aquarius V5 and SMAP V4 SSS

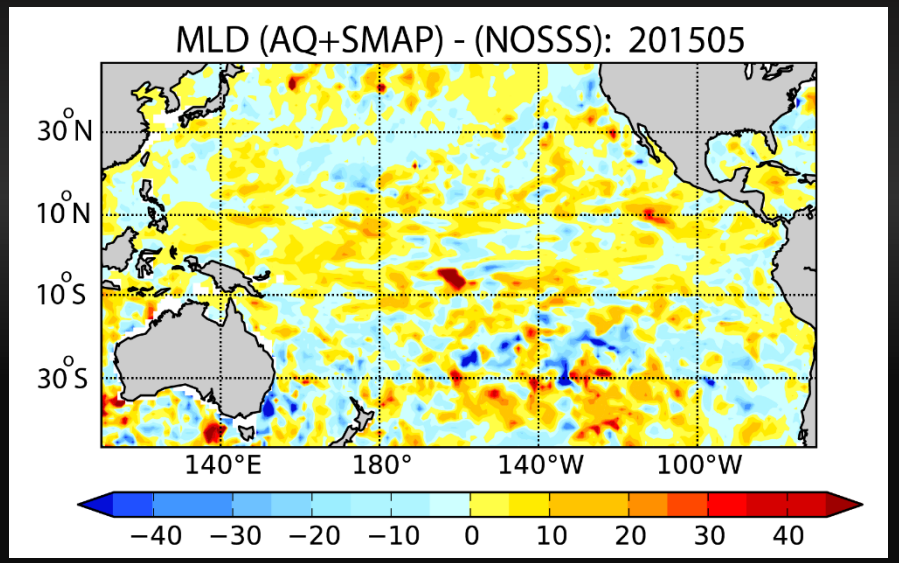
Show AQ+SMAP minus NO SSS to highlight impact of SSS assimilation.

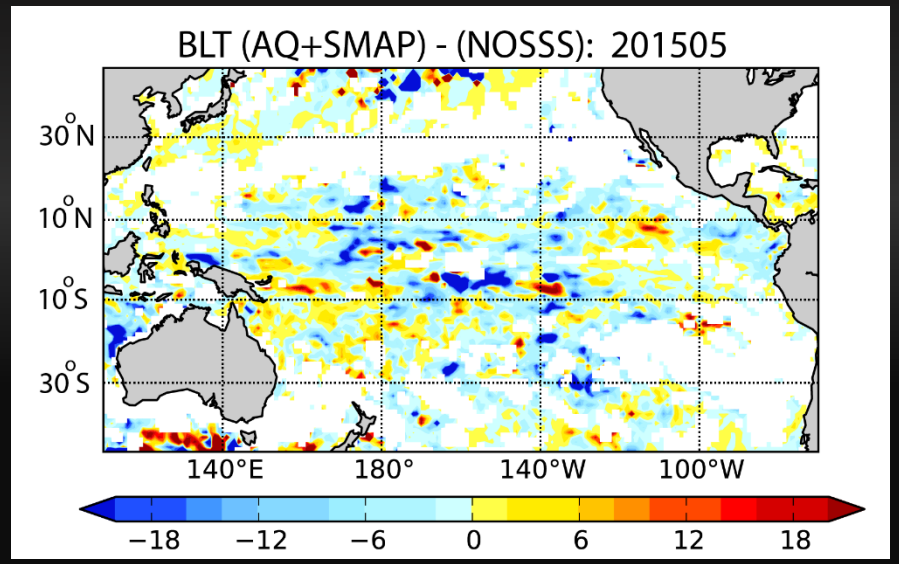
Mechanisms of SSS Improvements

Example of May 2015









Mechanisms of SSS Improvements

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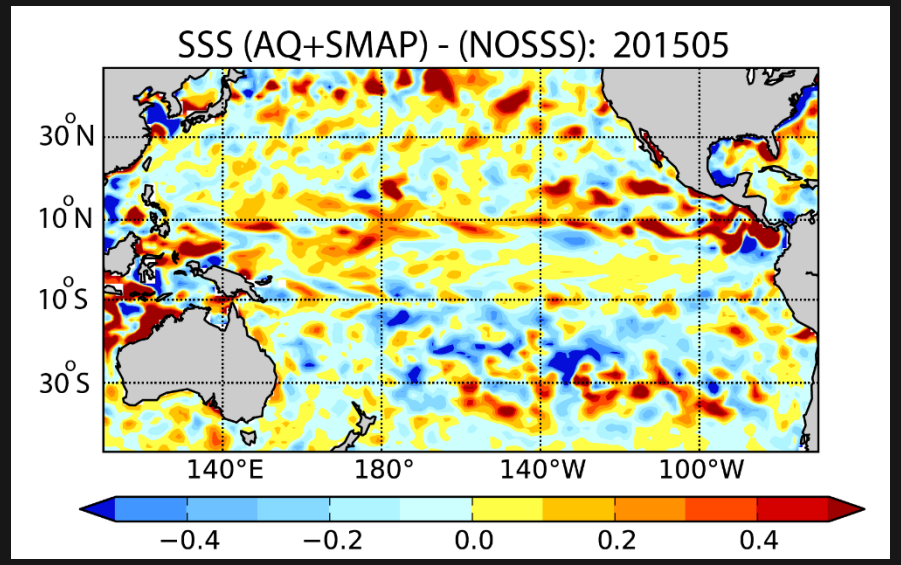
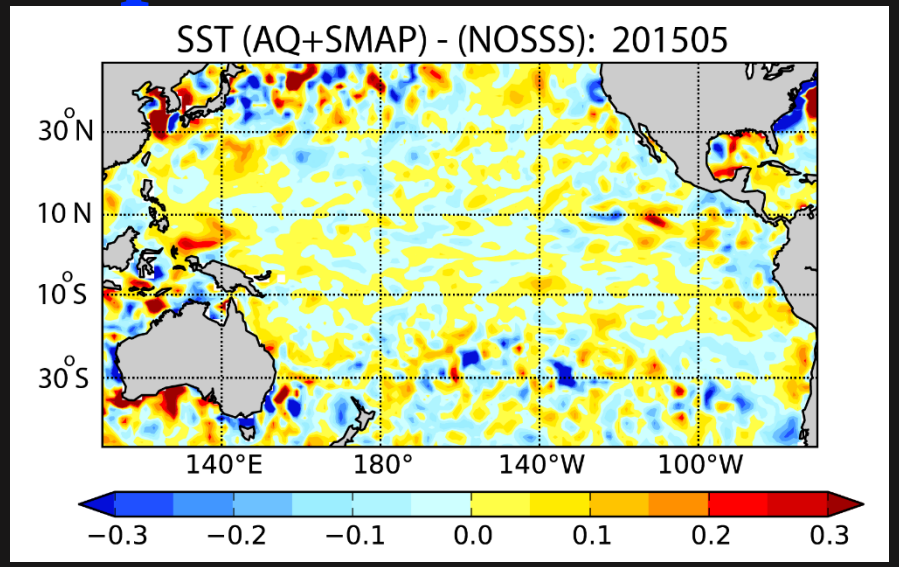
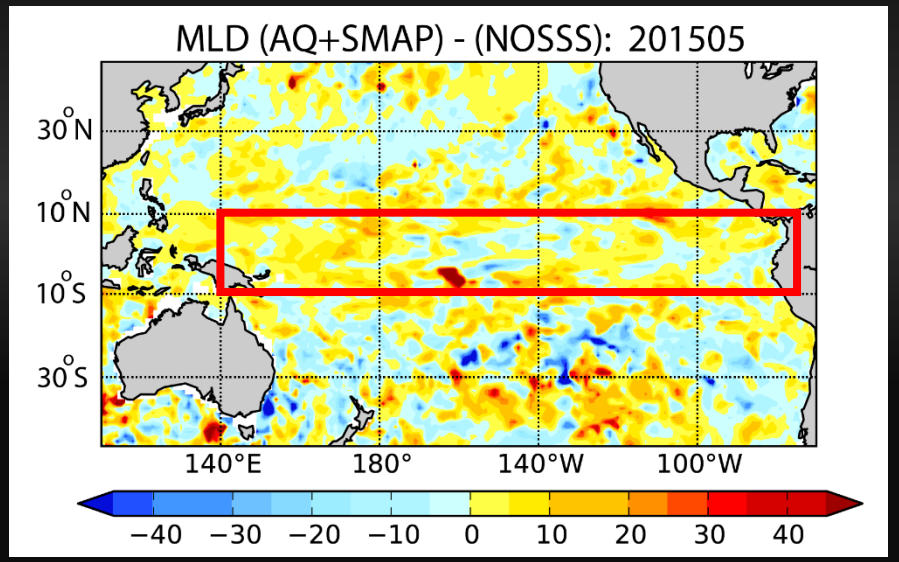
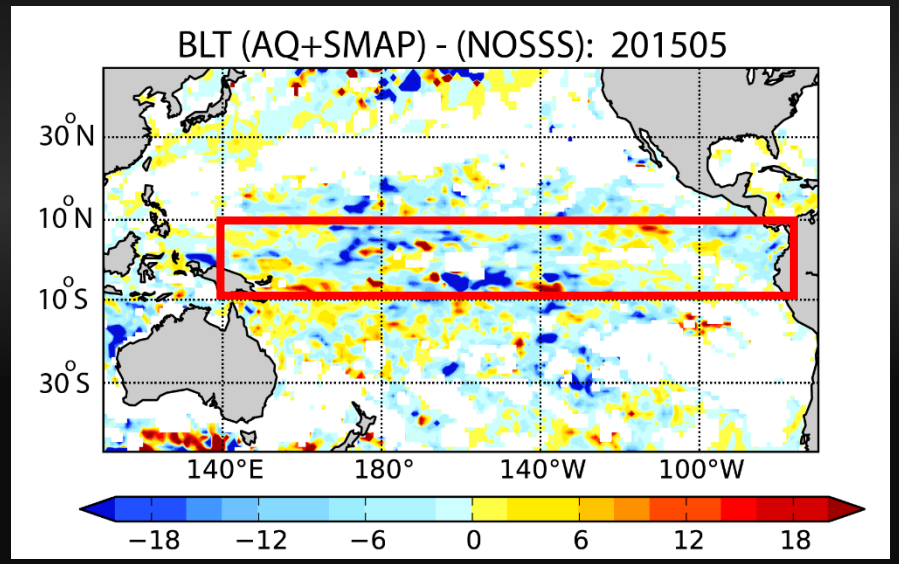




MLD thickens and BLT shoals

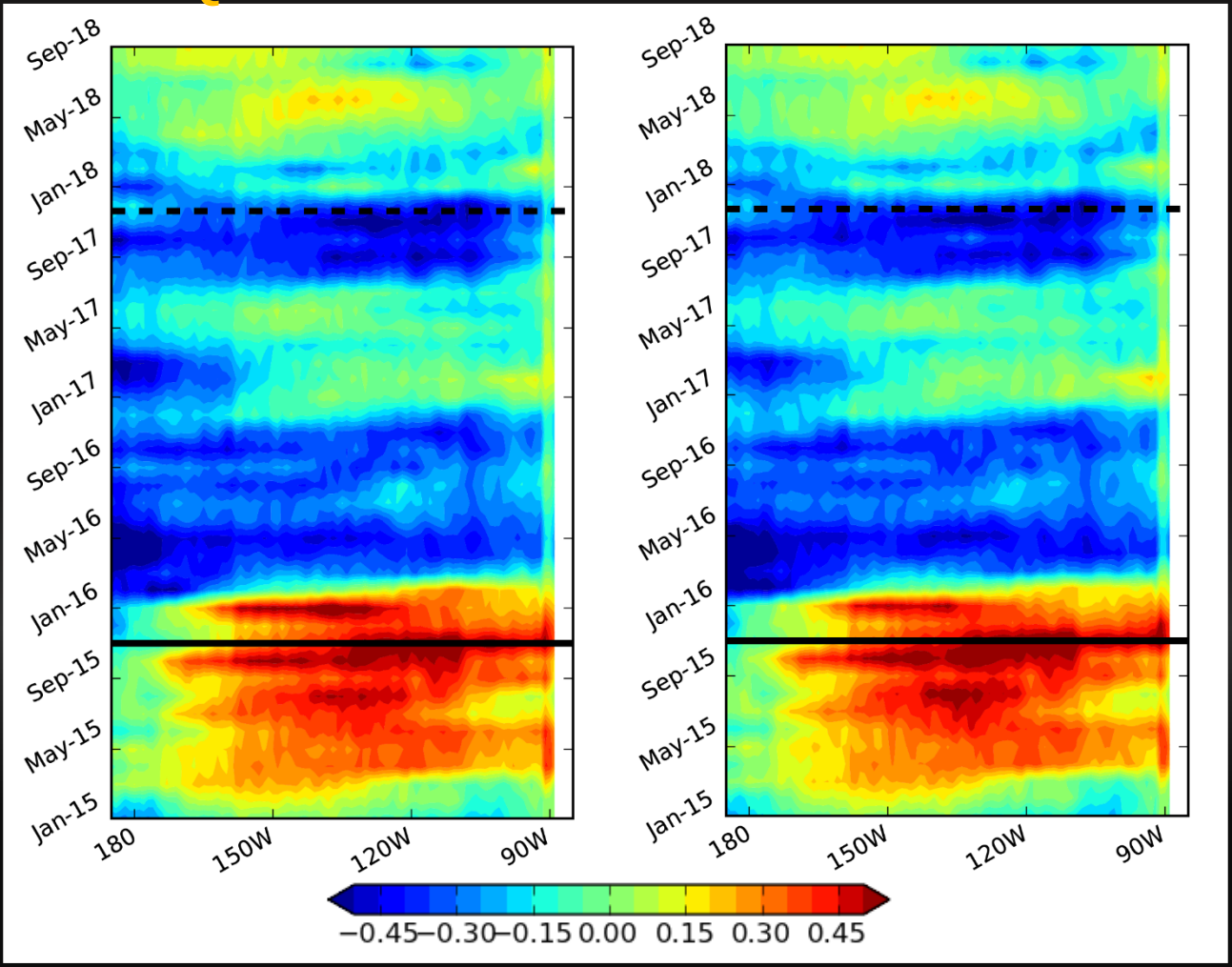




Kelvin Wave Amplitude

AQ+SMAP

NOSSS



Kelvin Wave Amplitude

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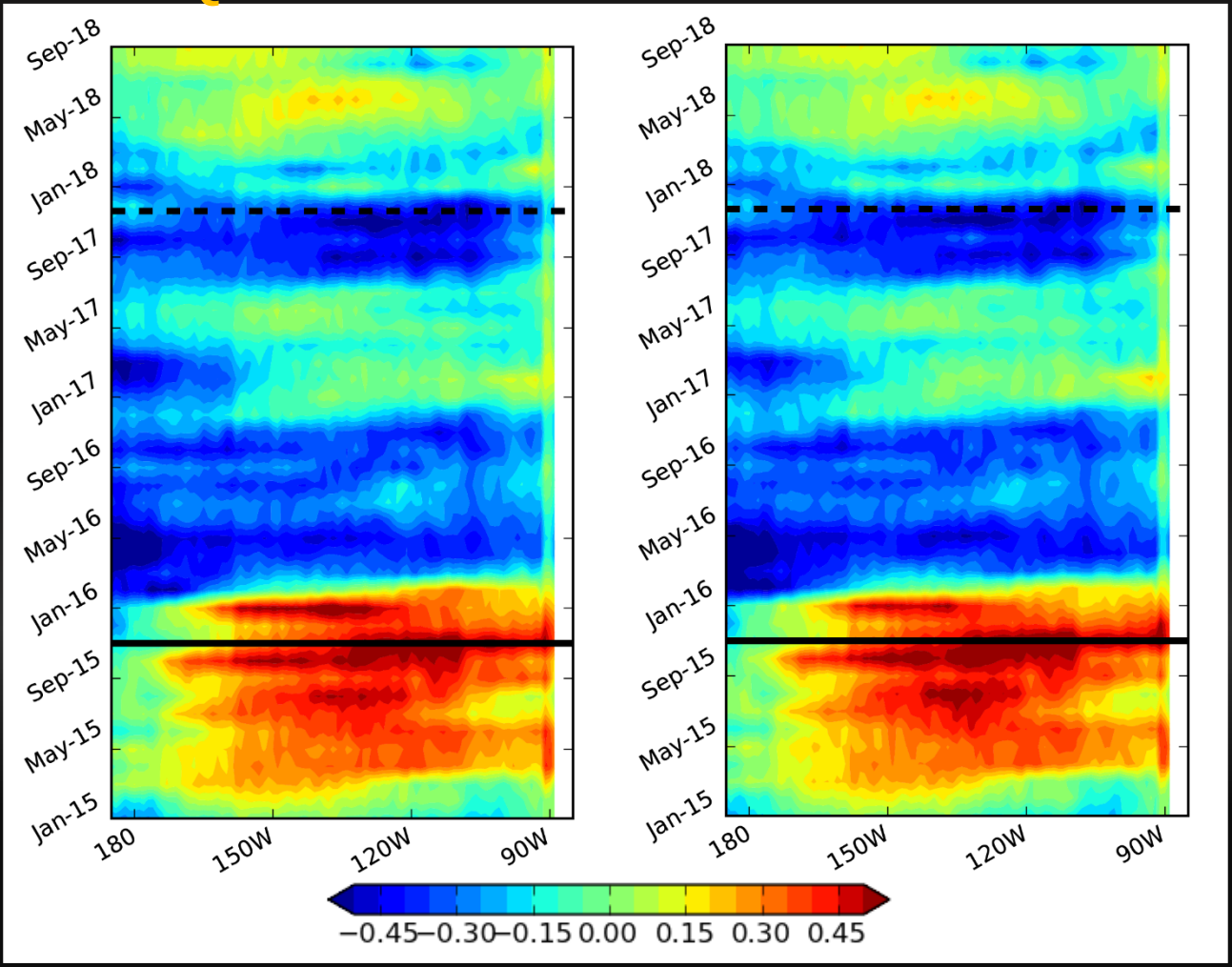
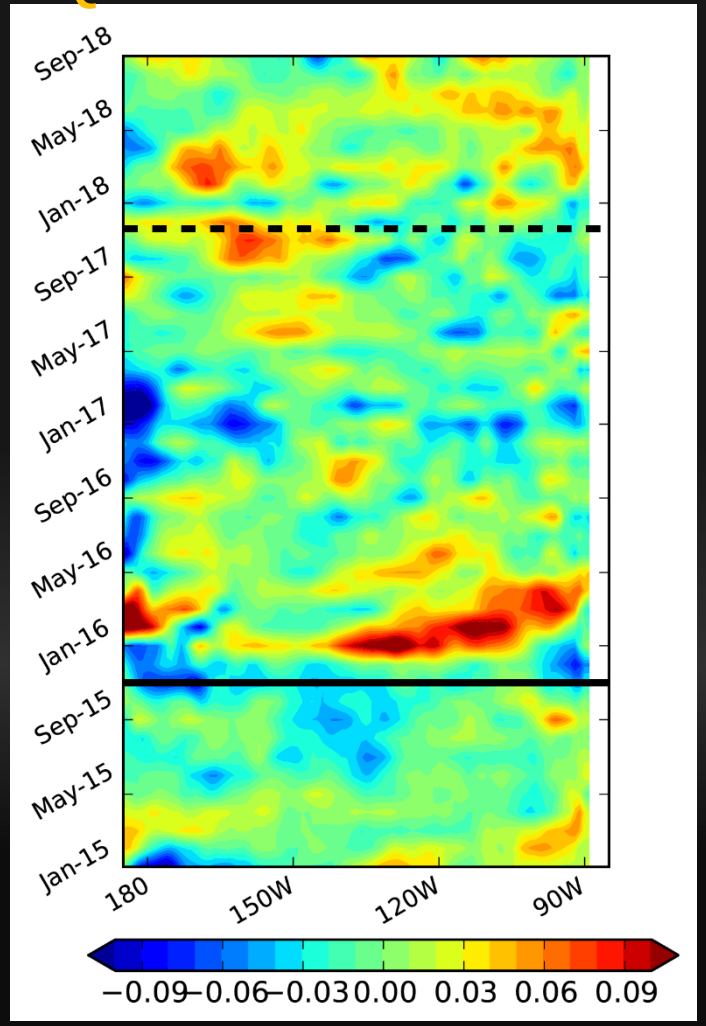


S2S

AQ+SMAP – NOSSS



Impact of SSS Assimilation on Different Phases of ENSO

Forecasts:

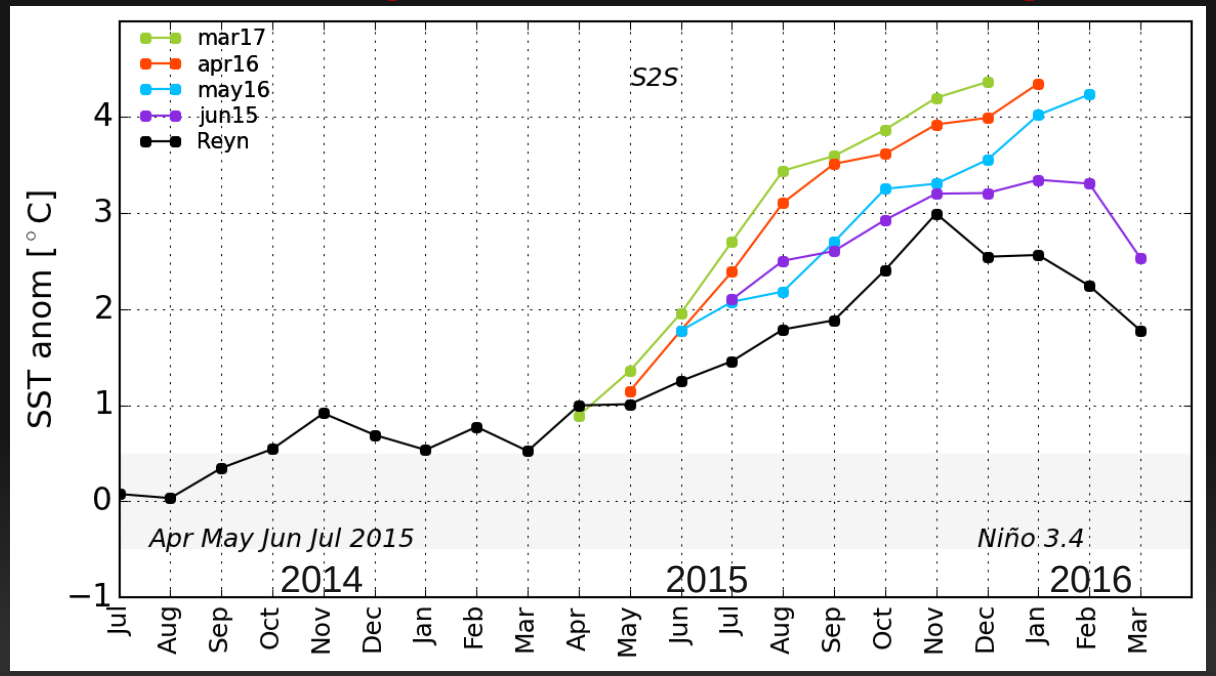
- Apr 2015: Big El Nino
- May 2017: La Nina
- Apr 2018: Weak El Nino?

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

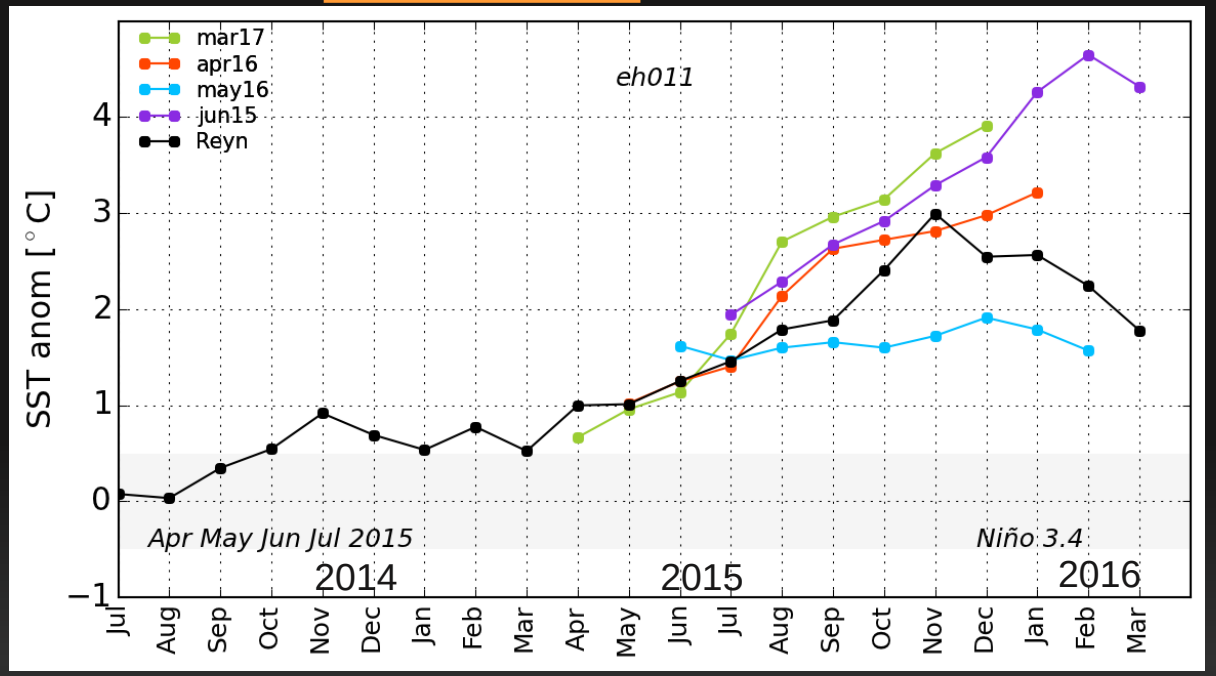
- **No SSS** (S2S)
- **AQ+SMAP**

Big El Nino –Mar, Apr, May, Jun, 2015

S2S (No SSS Assimilation)

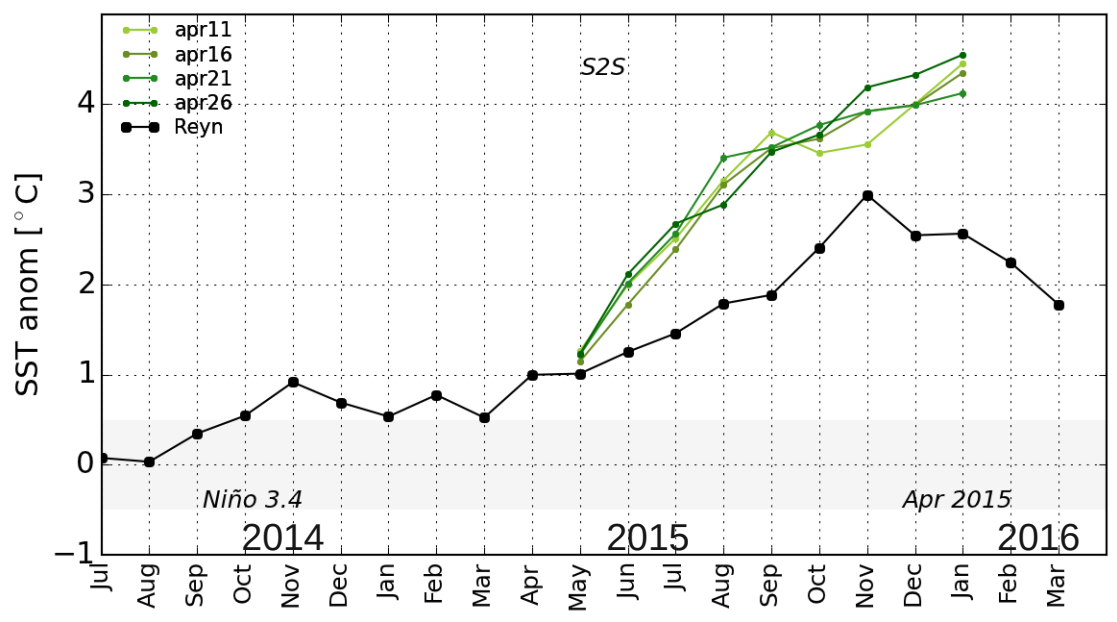


AQ+SMAP Assimilation

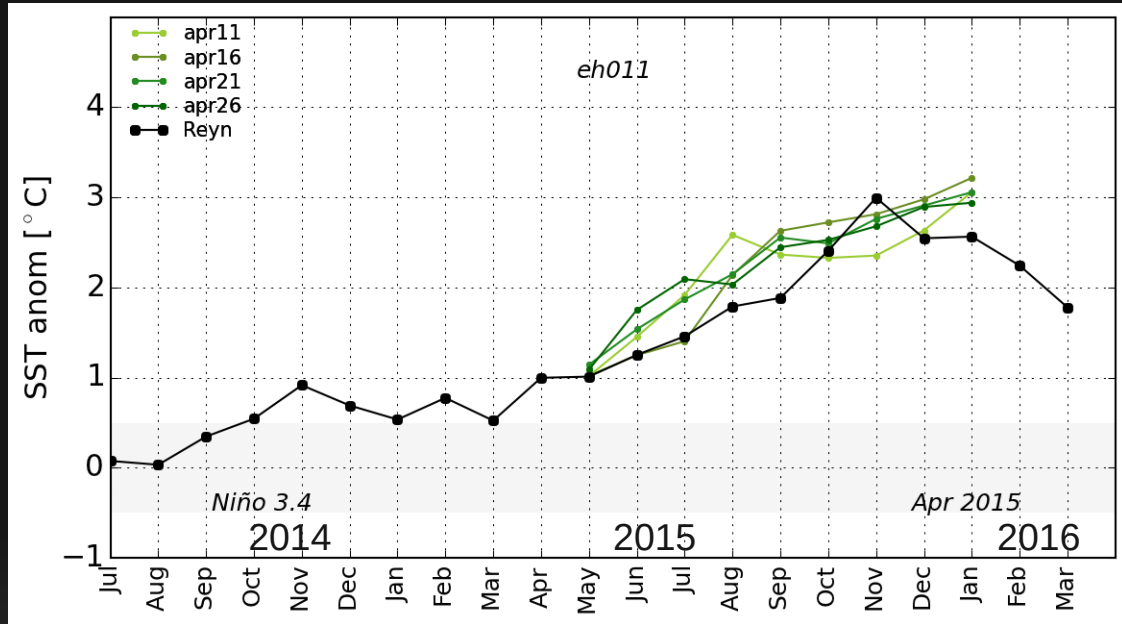


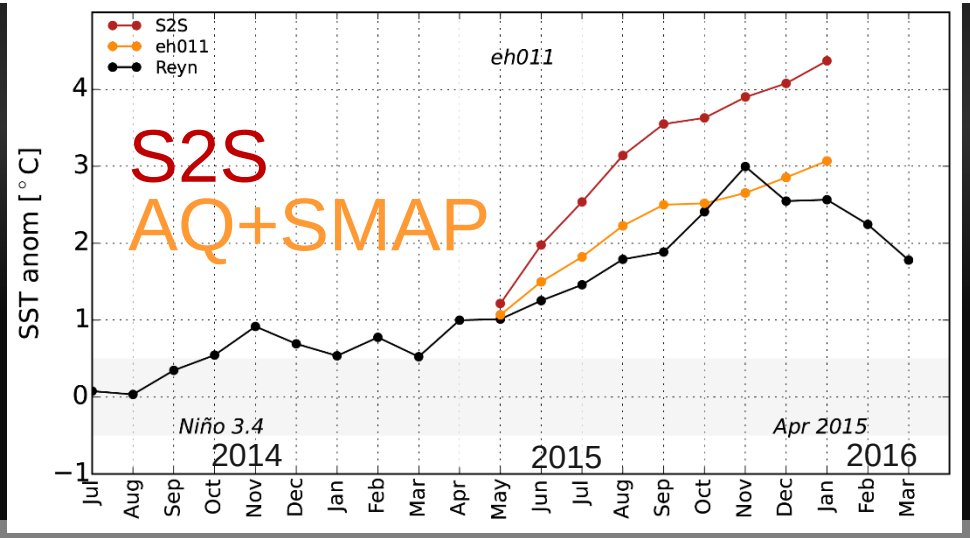
Big El Nino – Apr 2015

S2S (No SSS Assimilation)



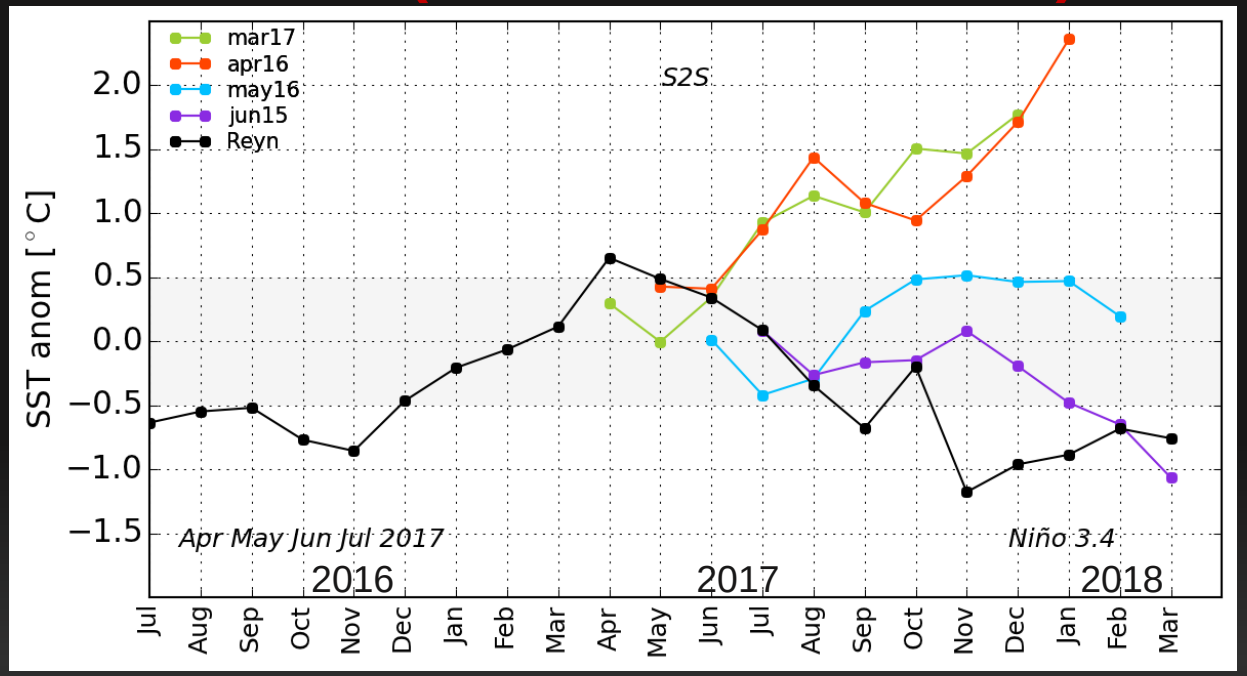
AQ+SMAP Assimilation



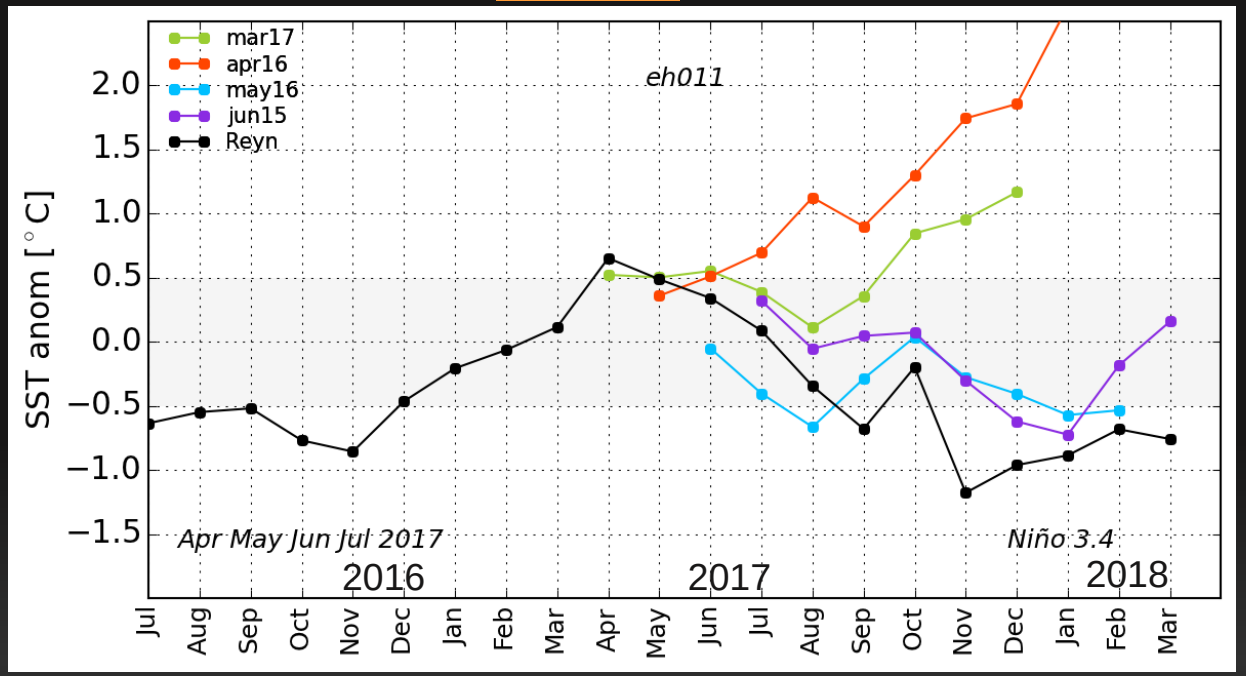


La Nina –Mar, Apr, May, Jun 2017

S2S (No SSS Assimilation)

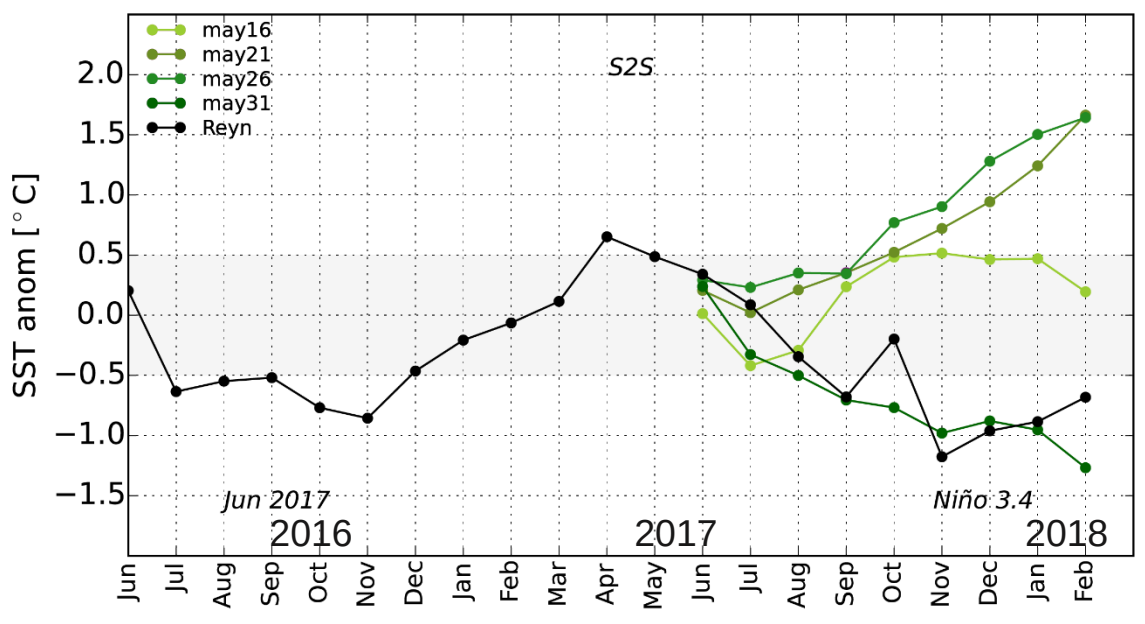


AQ+SMAP Assimilation

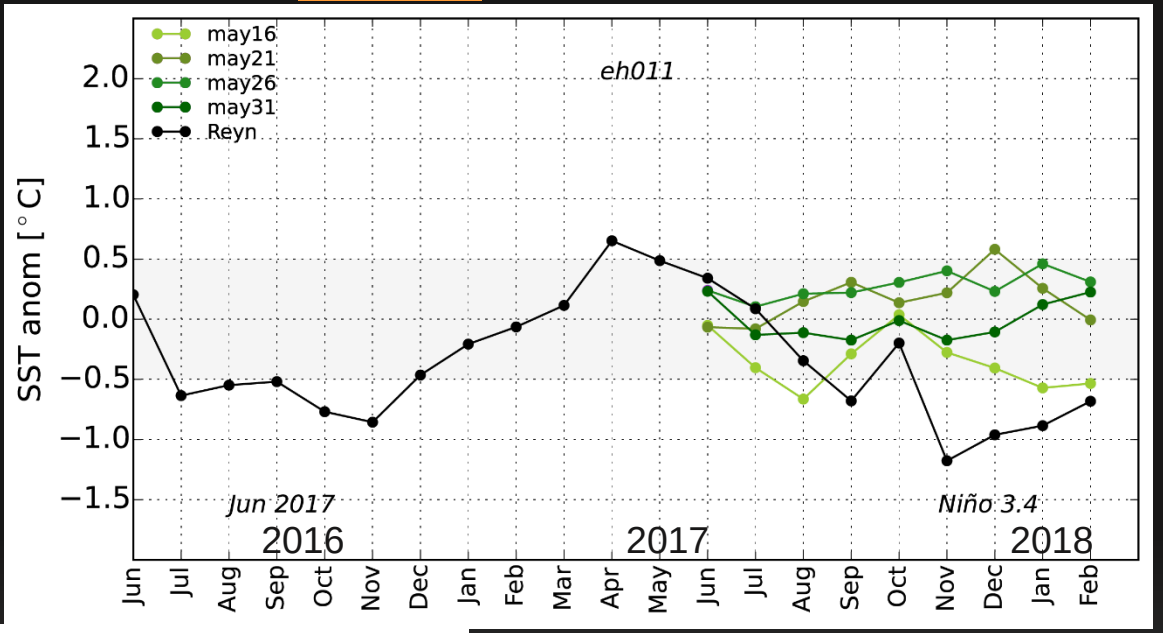


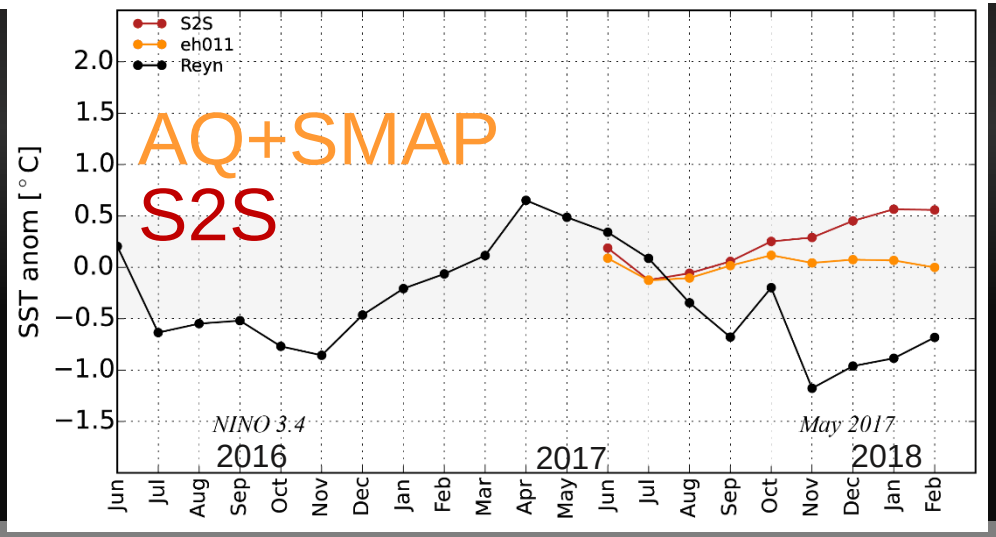
La Nina –May 2017

S2S (No SSS Assimilation)



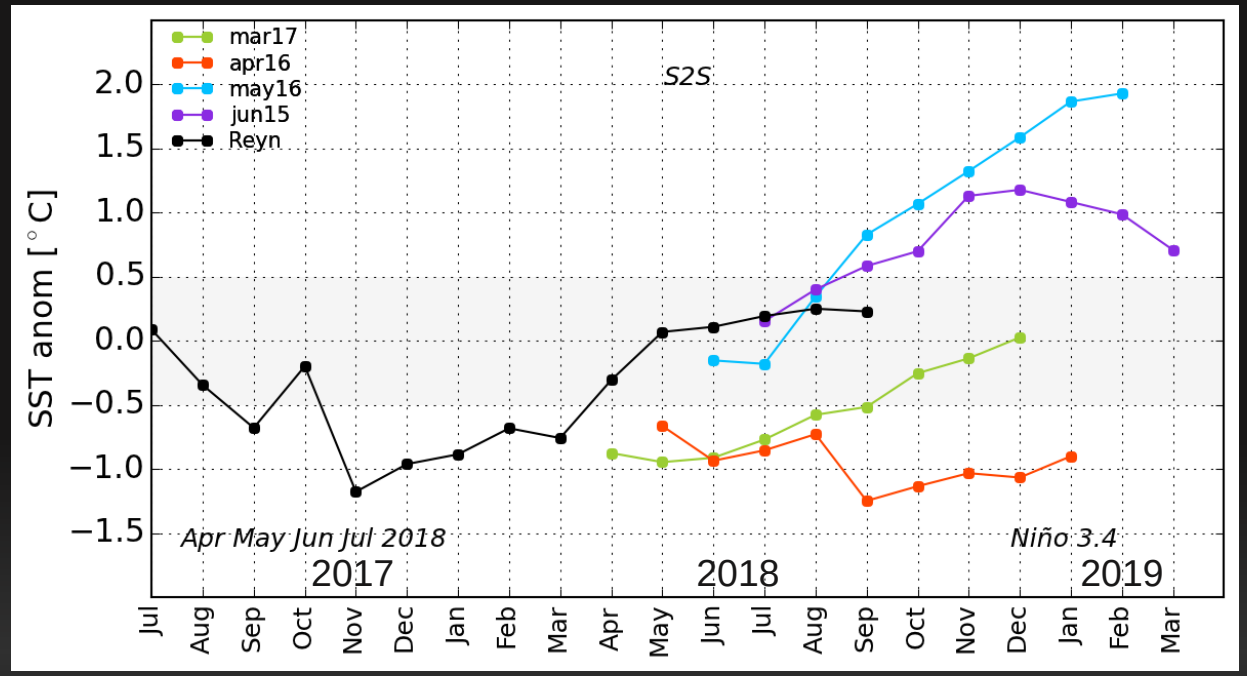
AQ+SMAP Assimilation



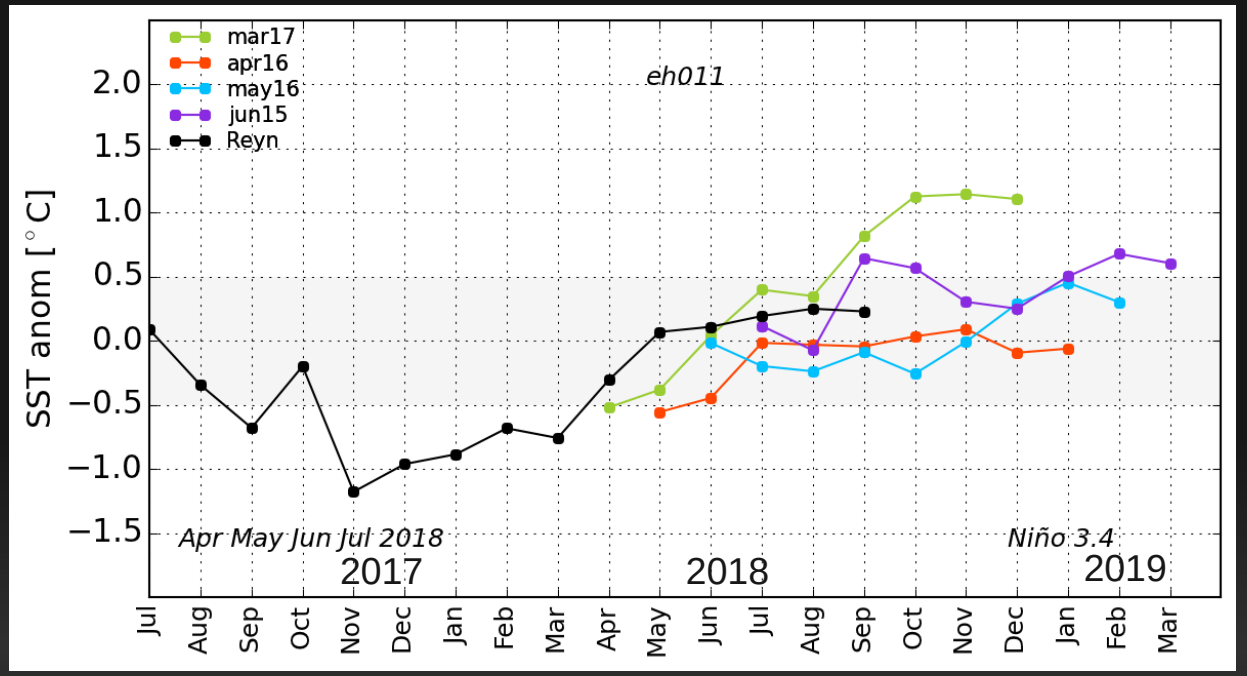


Weak El Nino? –Mar, Apr, May, Jun 2018

S2S (No SSS Assimilation)

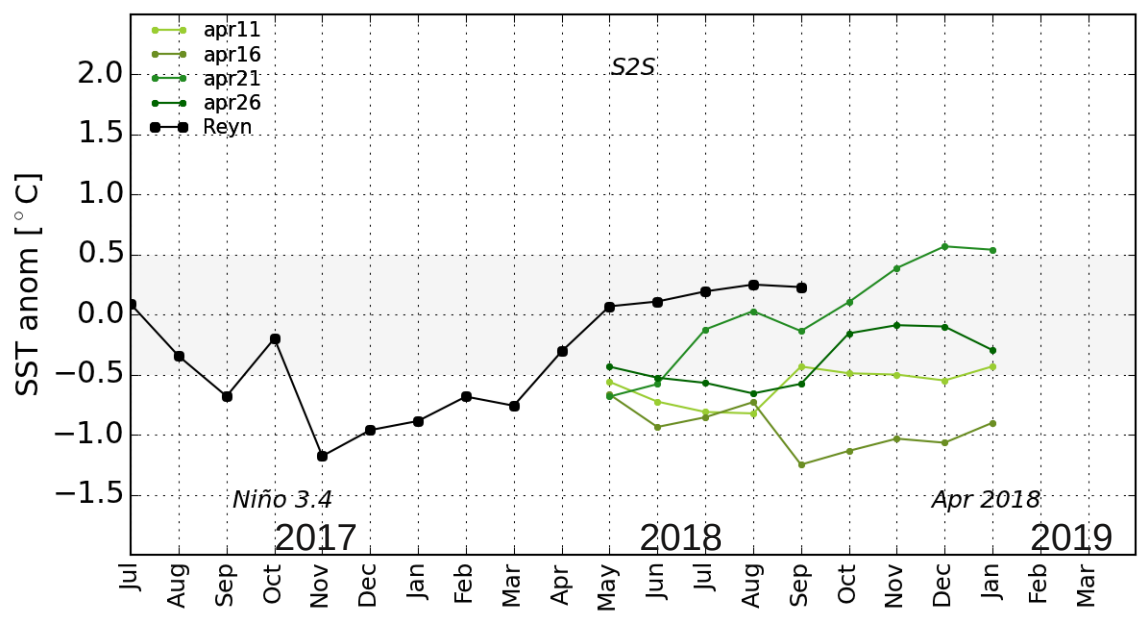


AQ+SMAP Assimilation

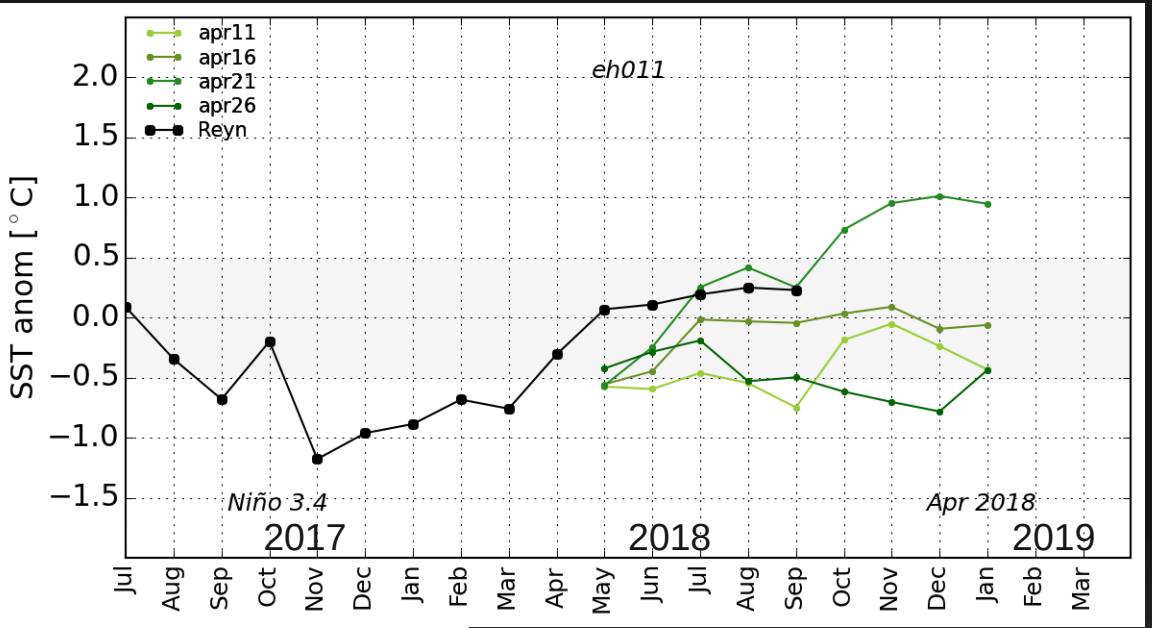


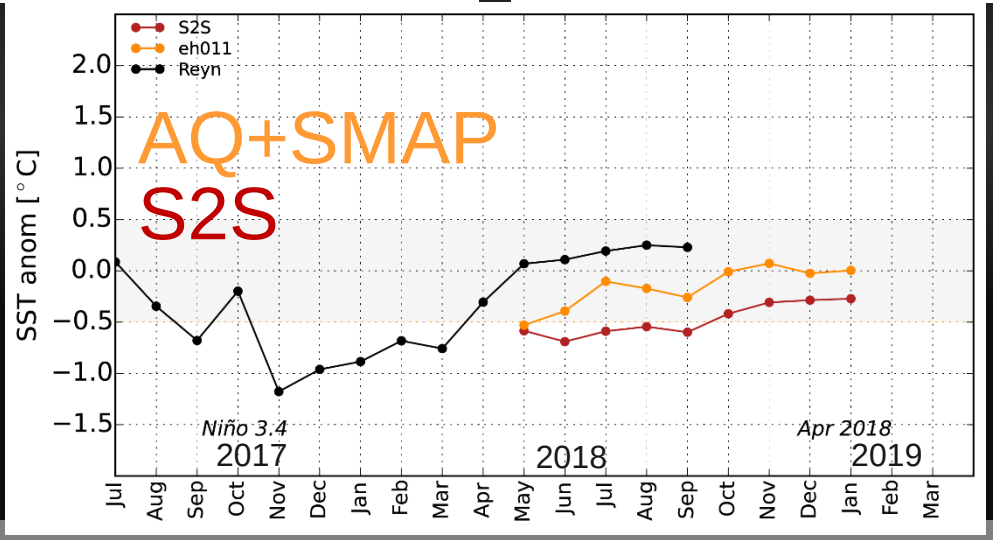
Weak El Nino? – Apr 2018

S2S (No SSS Assimilation)



AQ+SMAP Assimilation

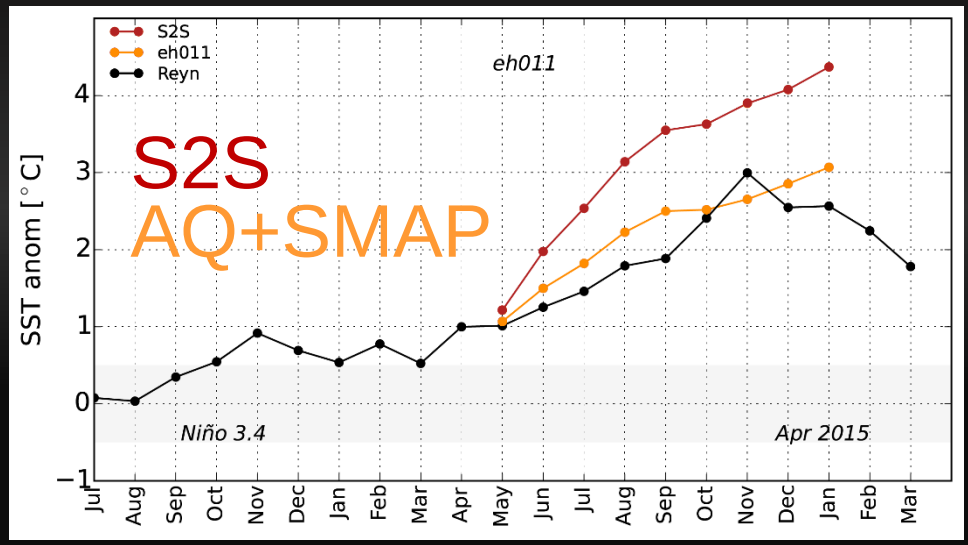




Preliminary Results

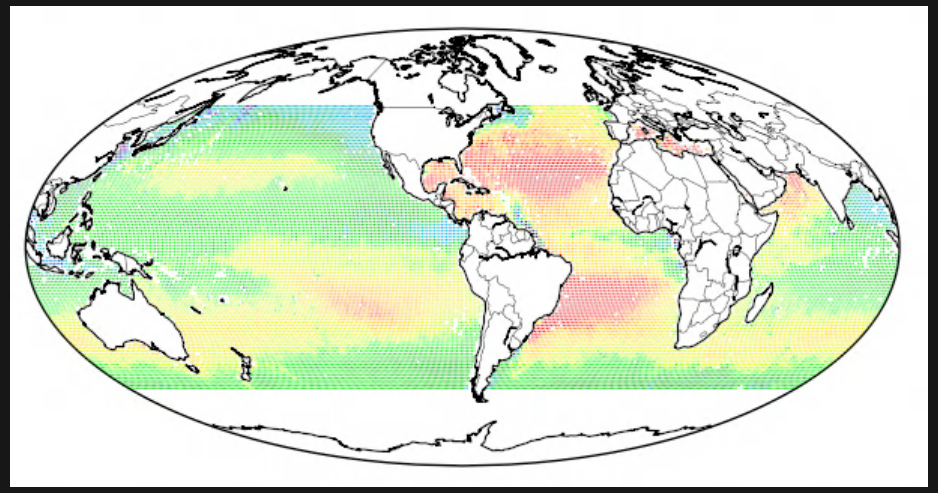
- Deeper MLD due to satellite SSS assimilation acts to dampen ENSO
- Leading to improved ENSO forecasts for both El Nino (2015, 2018) and La Nina (2017)

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

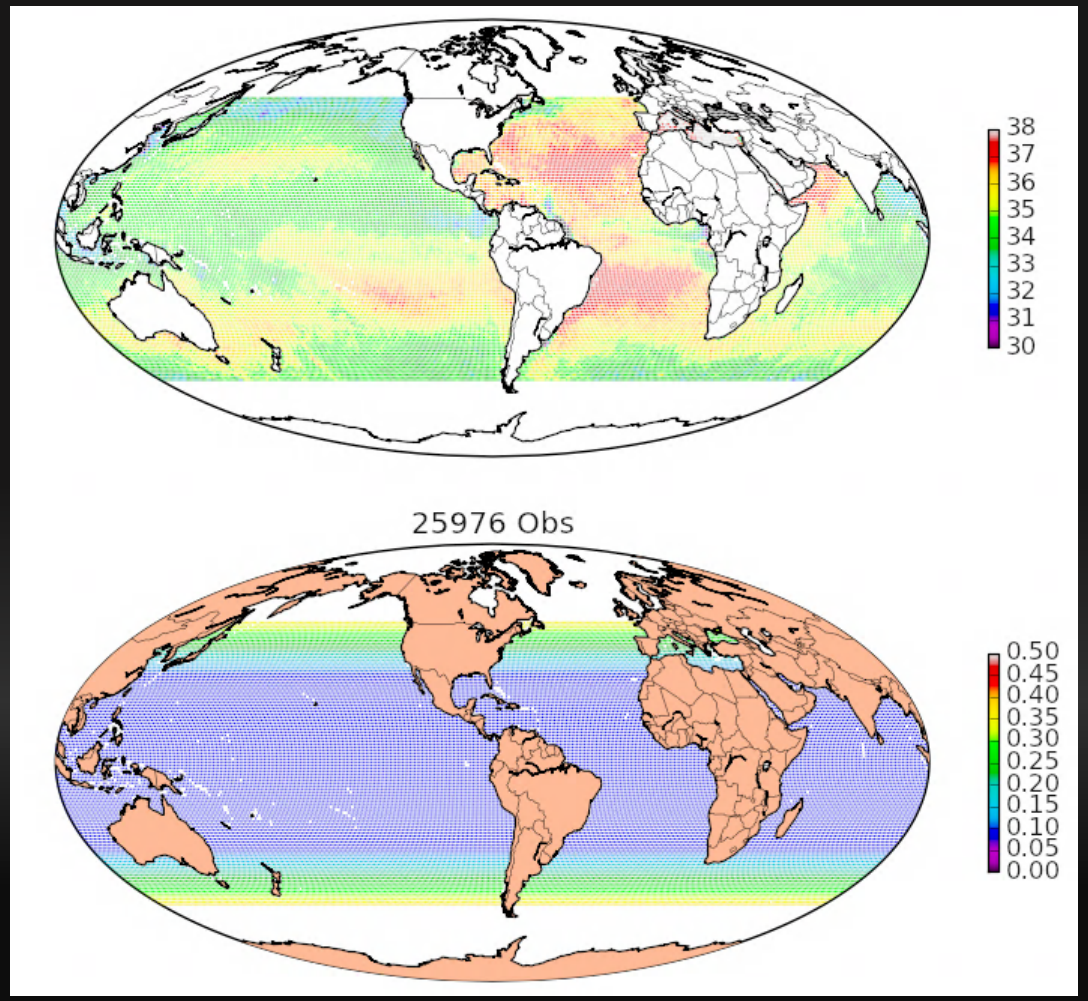


Satellite SSS Assimilation Data

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*)

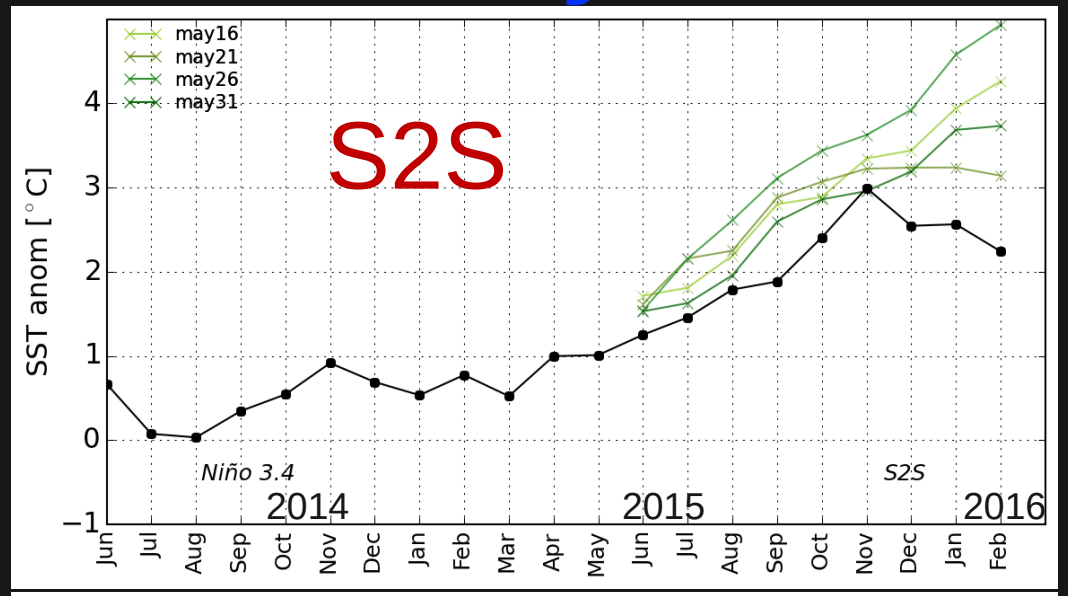
Observation Error

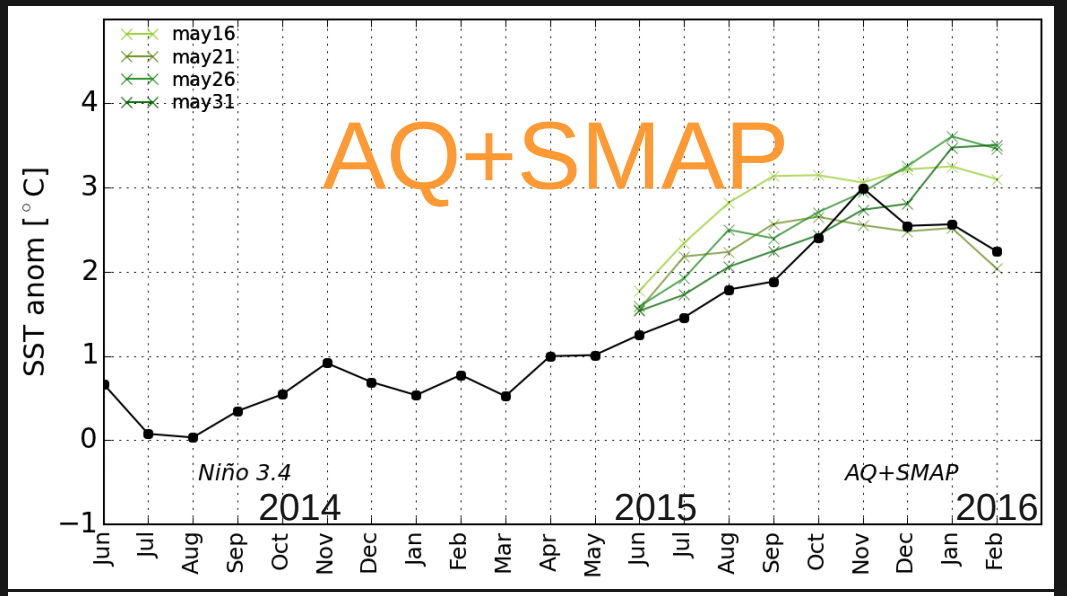
Forecast Impact of Aquarius Versus SMAP

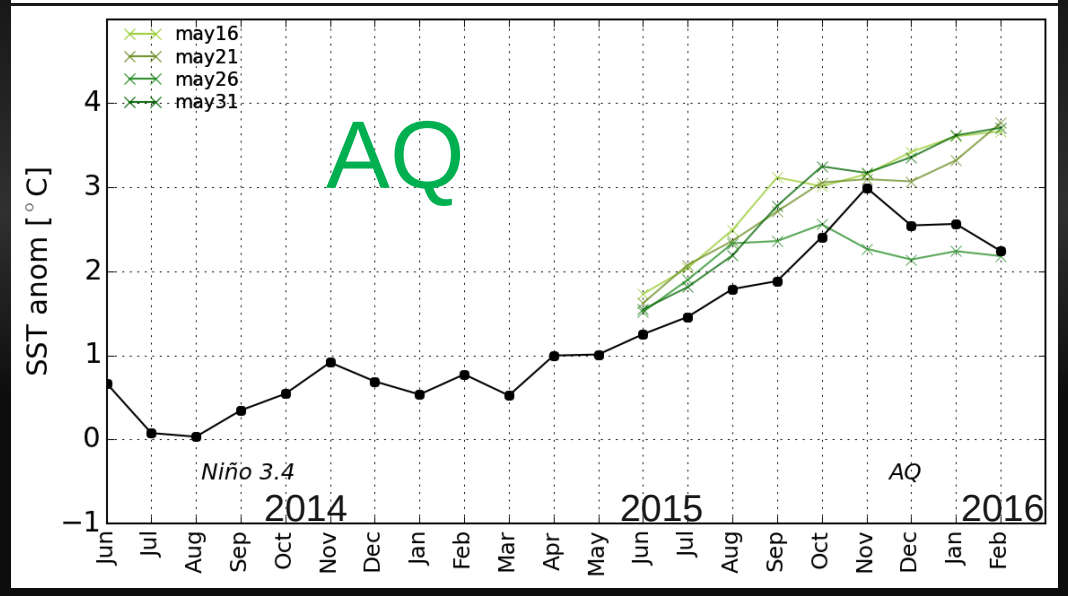
May 2015: El Nino: May 16, 21, 26, 31

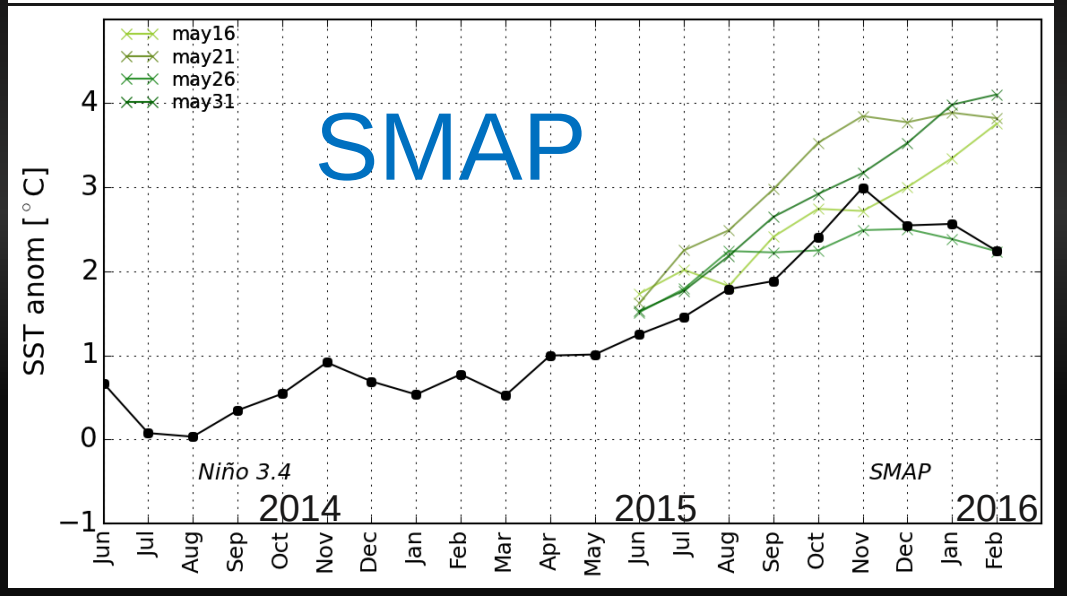
- No SSS
- AQ+SMAP
- AQ
- **SMAP**

May 2015 El Nino Forecasts

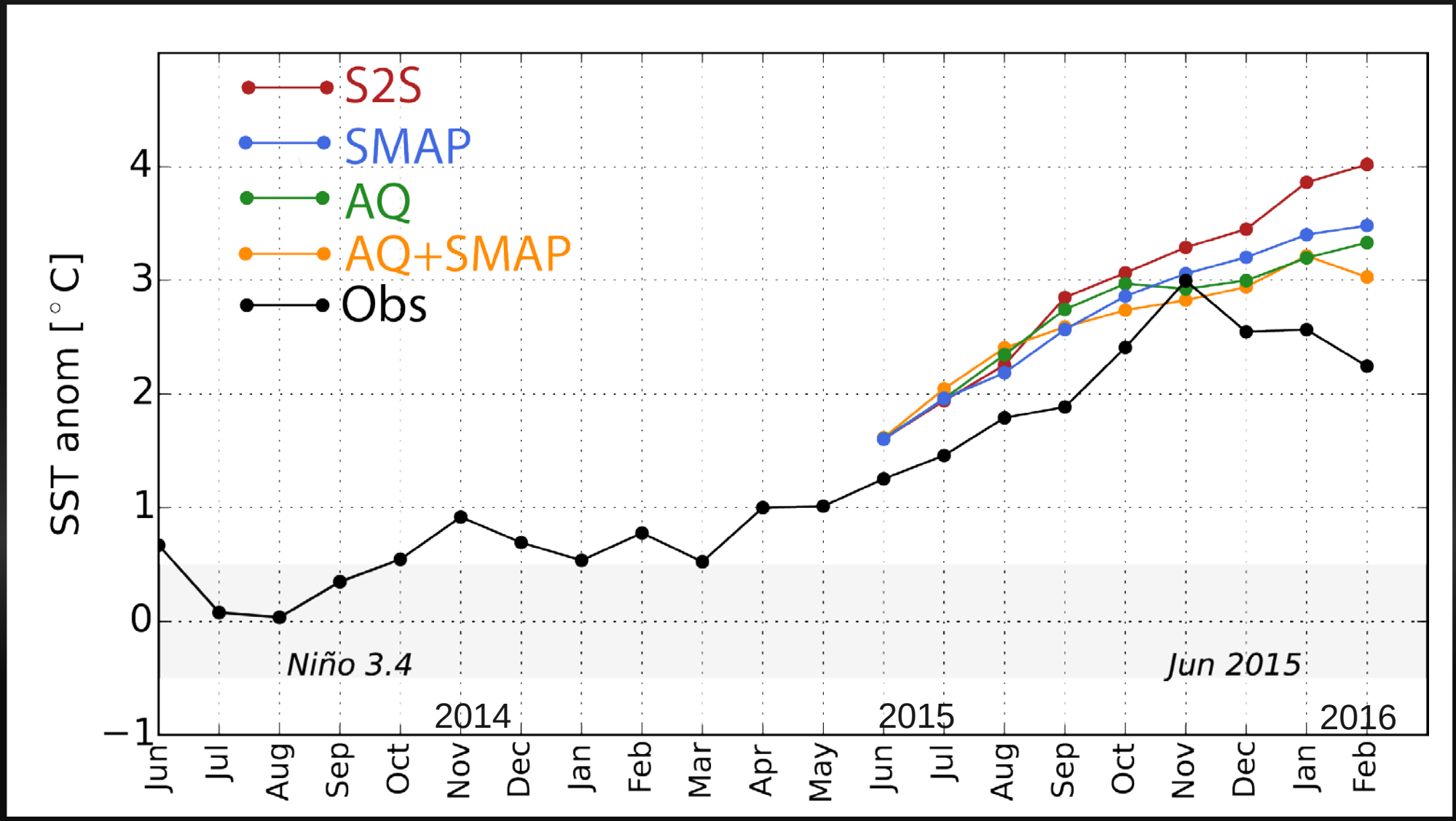








May 2015 El Nino Forecasts – Ensemble Mean



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

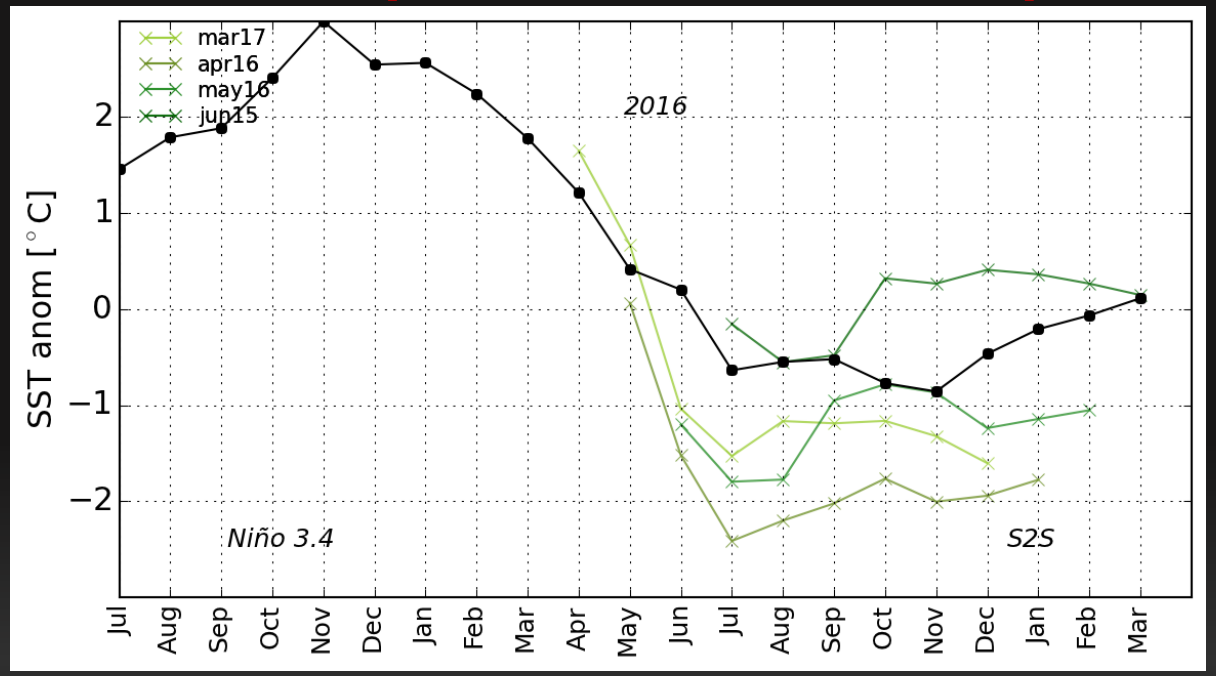
- Please come by and visit our poster on Thursday –

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

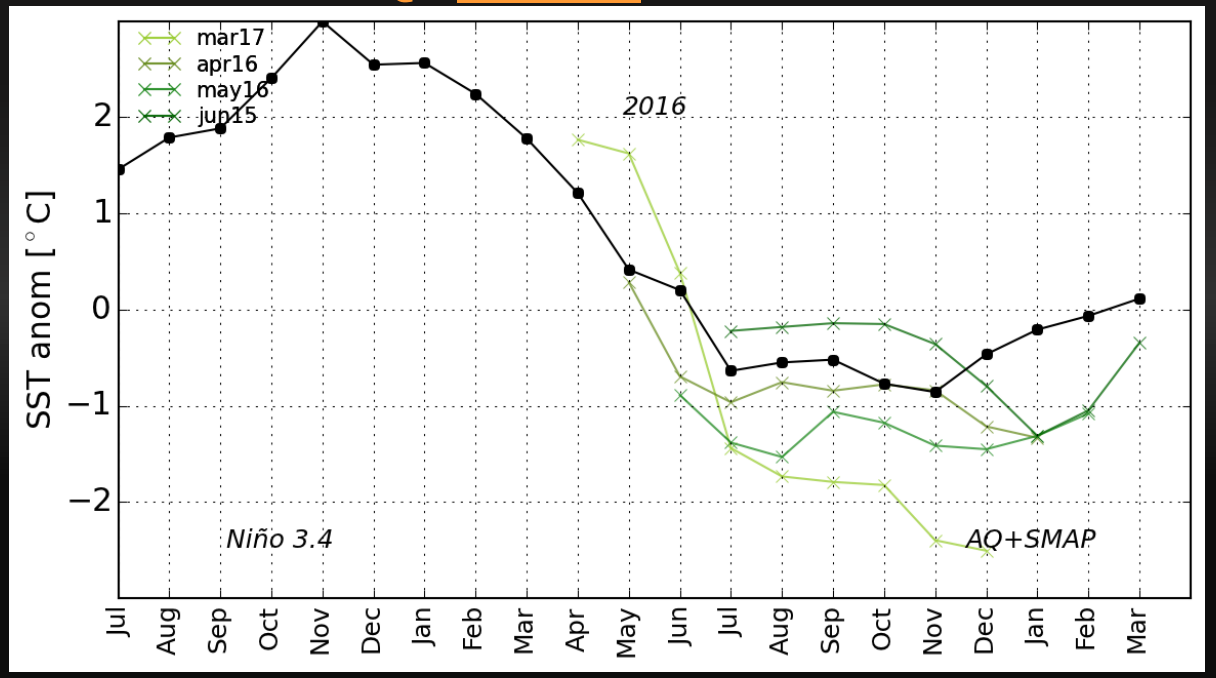
Thank You

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

S2S (No SSS Assimilation)

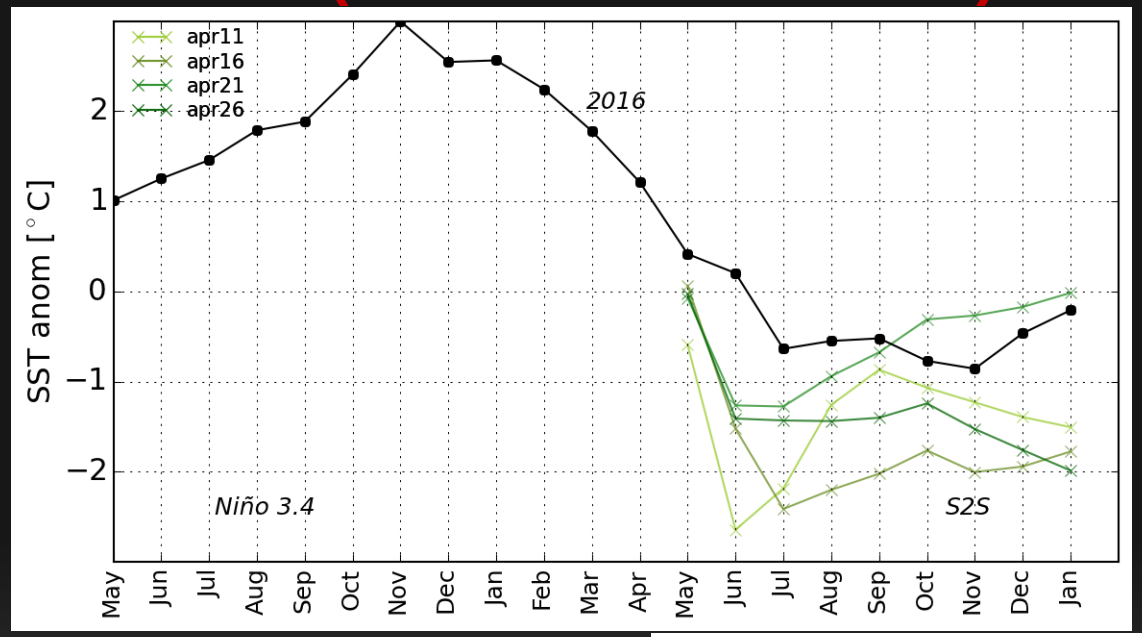


AQ+SMAP Assimilation

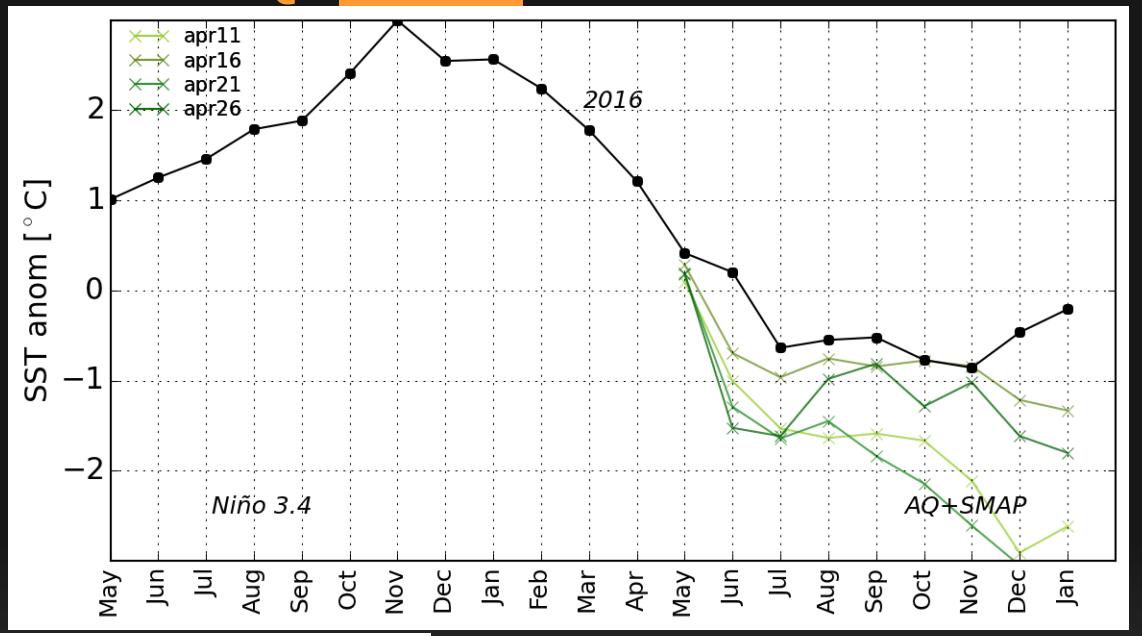


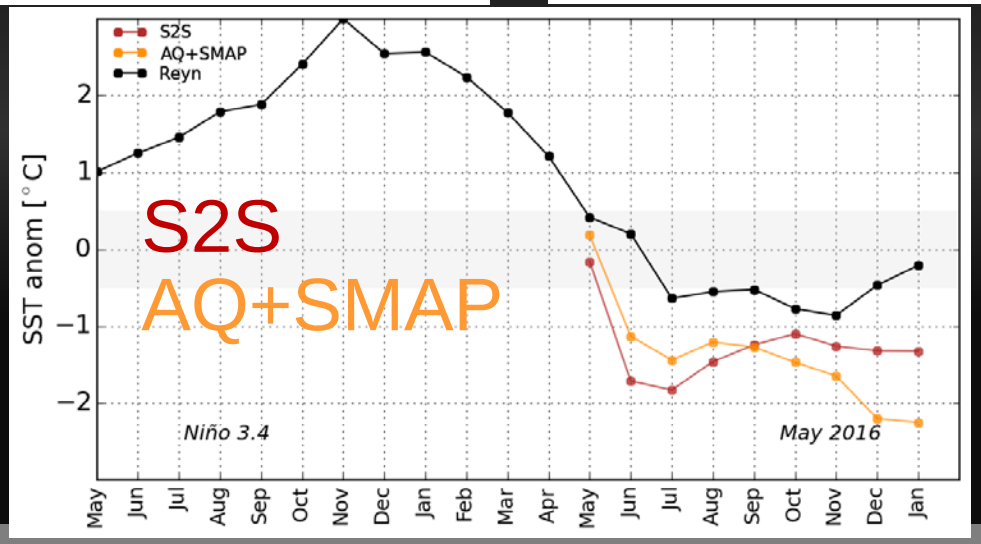
Weak La Nina– Apr 2016

S2S (No SSS Assimilation)



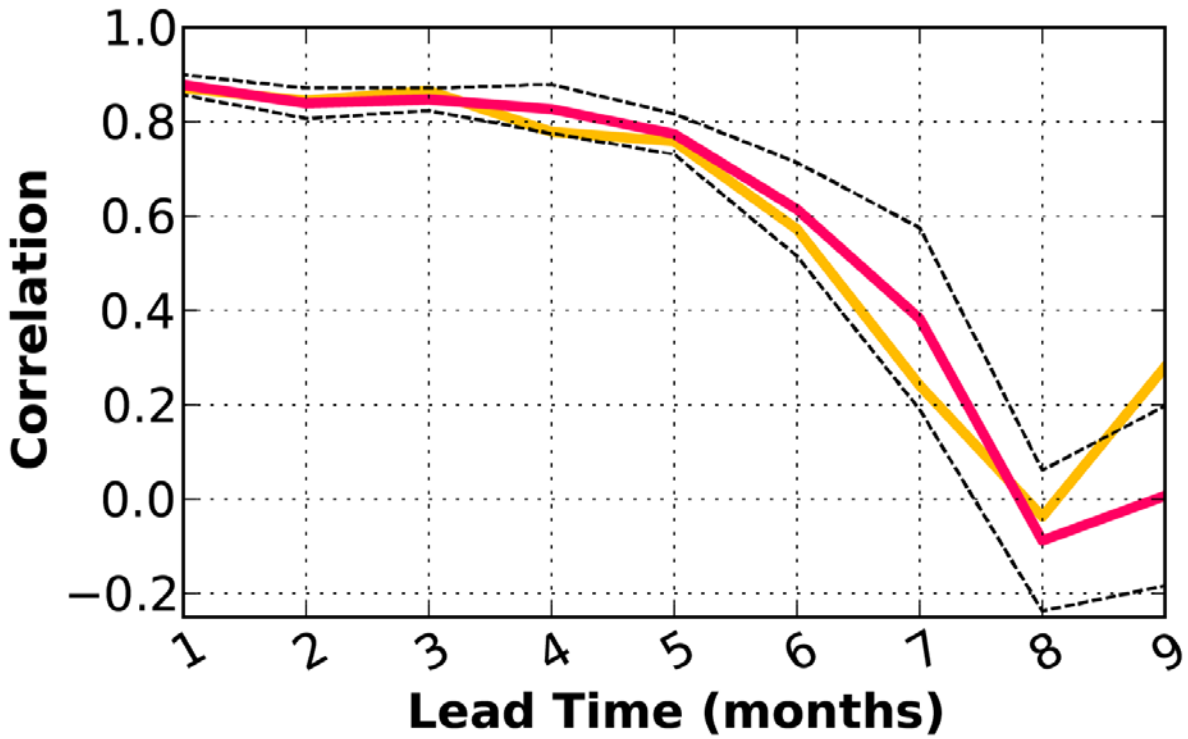
AQ+SMAP Assimilation

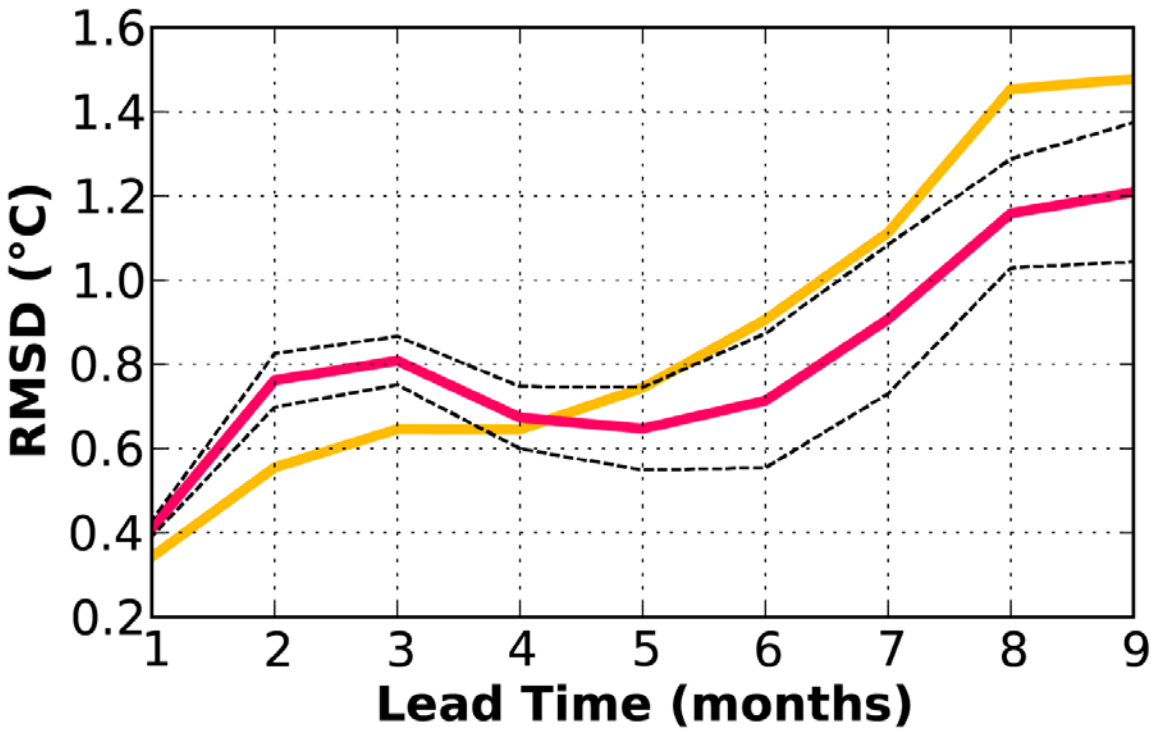




Validation Statistics – 1/17-1/18

Forecast NINO3.4 SST' Versus Observations

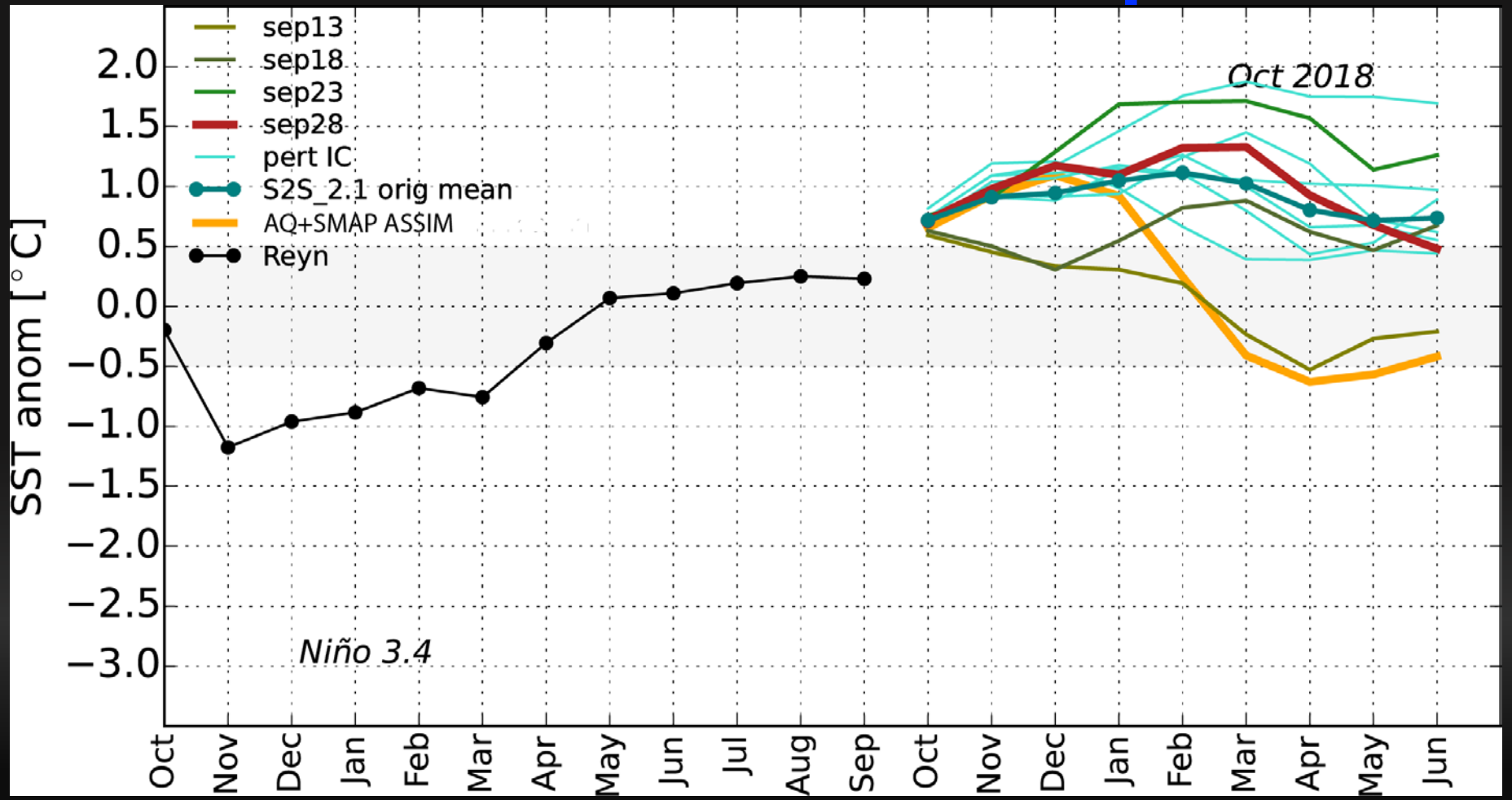




S2S (No SSS Assimilation)

AQ+SMAP Assimilation

GMAO Forecast from Sept. 2018



S2S (No SSS Assimilation)

AQ+SMAP Assimilation