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, ~0.5°, 40 levels
• AGCM: Similar to MERRA-2, ~0.5°, 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
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

13472 Obs

Observation Error

(Lilly and Lagerloef, 2008)

SMAP V4

70792 Obs

Observation Error

(Fore et al., 2016)
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

S2S

Niño 3.4

2014 2015 2016

SST anom [°C]

Niño 3.4

2014 2015 2016

SST anom [°C]

S2S AQ+SMAP

2014 2015 2016

SST anom [°C]
La Nina – Mar, Apr, May, Jun 2017

S2S (No SSS Assimilation)  AQ+SMAP Assimilation
La Niña – Apr 2017

S2S (No SSS Assimilation)

AQ+SMAP Assimilation

Niño 3.4

SST anomaly [°C]

July Aug Sep Oct Nov Dec Jan Feb Mar April May June July Aug Sep Oct Nov Dec Jan Feb Mar

Niño 3.4

SST anomaly [°C]

July Aug Sep Oct Nov Dec Jan Feb Mar April May June July Aug Sep Oct Nov Dec Jan Feb Mar

Niño 3.4

SST anomaly [°C]

July Aug Sep Oct Nov Dec Jan Feb Mar April May June July Aug Sep Oct Nov Dec Jan Feb Mar
La Niña – May 2017

S2S (No SSS Assimilation)

AQ+SMAP Assimilation

AQ+SMAP

S2S
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

SST anomaly [°C] over time from 2017 to 2019, showing changes in Niño 3.4 region.
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?

S2S AQ+SMAP
Satellite SSS Assimilation Data

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

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

**S2S**

**AQ+SMAP**

**AQ**

**SMAP**
May 2015 El Nino Forecasts – Ensemble Mean

![Graph showing SST anomalies from June 2014 to February 2016. The graph includes lines for S2S, SMAP, AQ, AQ+SMAP, and Observed (Obs). The Niño 3.4 region is highlighted from December 2014 to June 2015.]
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

[Graphs showing SST anomalies for Niño 3.4 and S2S regions for different months from May to December 2016, comparing S2S and AQ+SMAP assimilation cases.]
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