The Impact of Ocean Observations in Seasonal Climate Prediction

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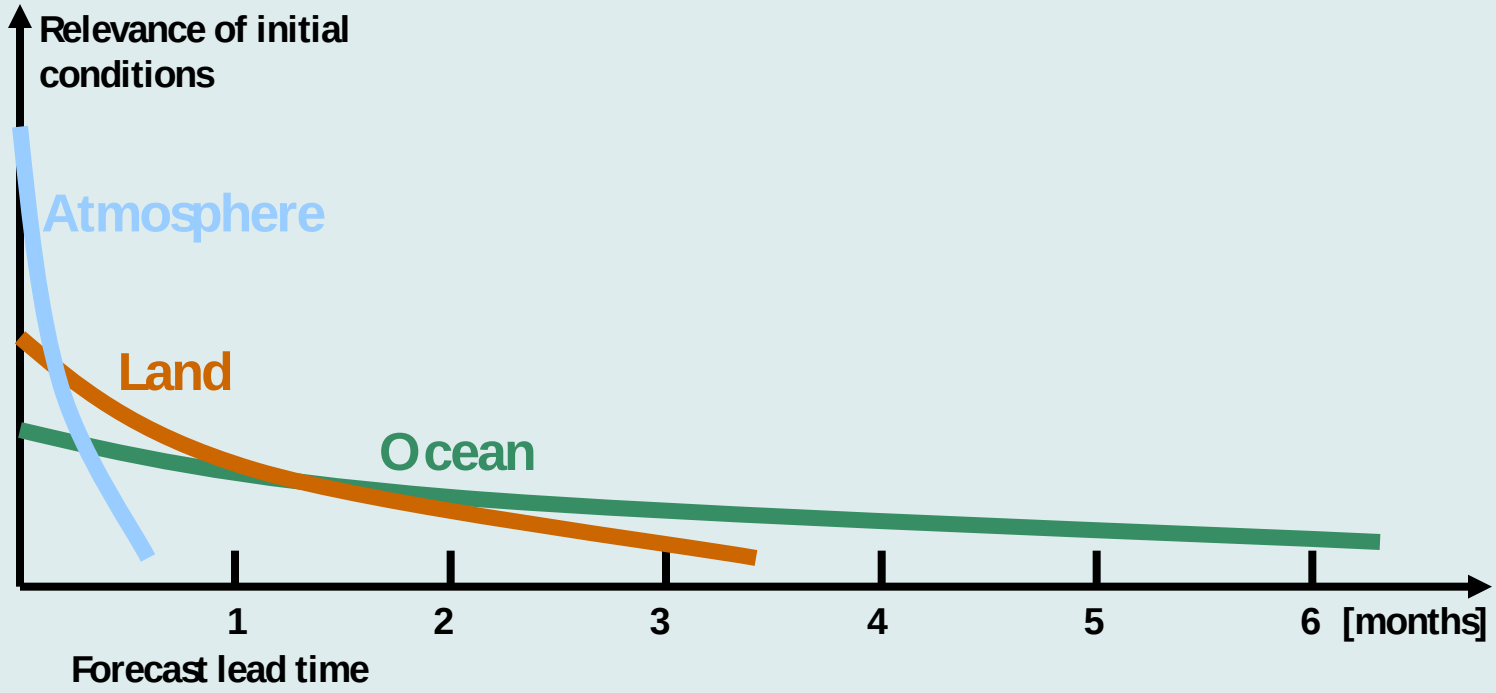
Overview

- **Initializing coupled predictions**
  - Importance of ocean, atmosphere, land
- **Ocean Observations and Assimilation**
  - GMAO's Ensemble Kalman Filter
- **Observation Impacts**
  - Altimetry (1993 – 2008)
  - Argo (2001 – 2008)
- **Salinity**
- **Summary**

Initial conditions and forecast lead time



Short-term numerical weather prediction is limited by chaos in the atmosphere.

For seasonal climate prediction, we rely on slower moving components of the Earth's system, such as ocean heat content and soil moisture.

Land initialization important at 2 week – 2 month (sub-seasonal) time scales.

Ocean initialization important from weather to multi-decadal climate time scales.

The Importance of Atmospheric Observations

From ECMWF S3 (1-7 month forecast)

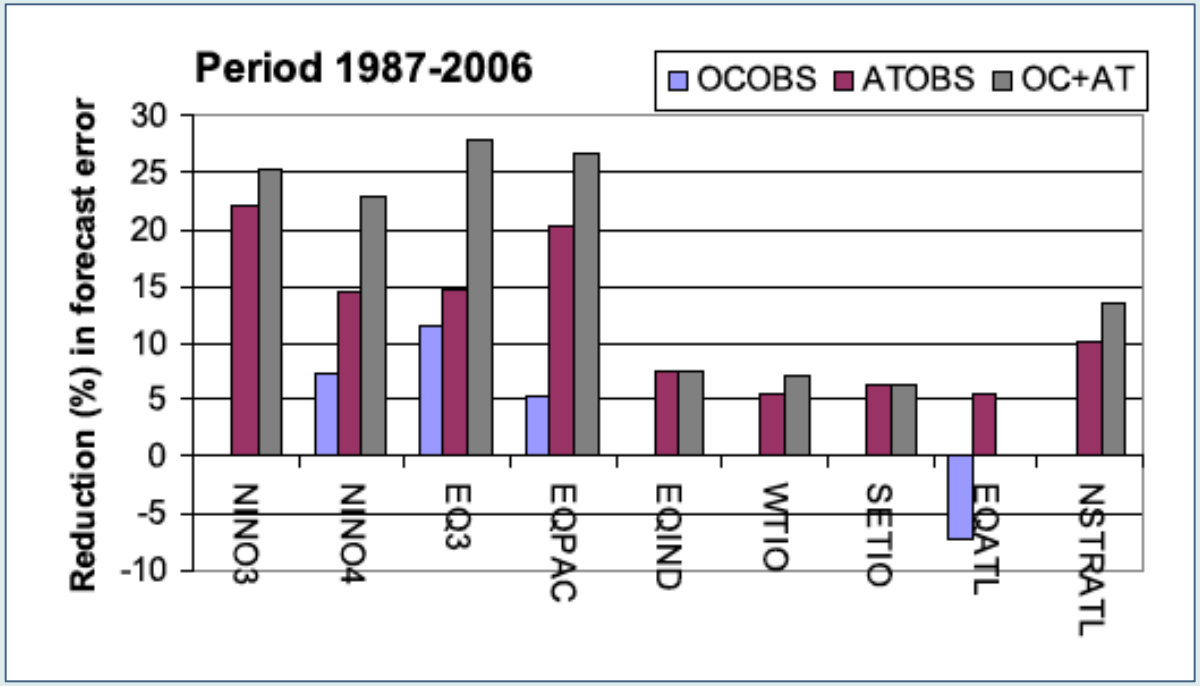
Balmaseda & Anderson (GRL, 2009)

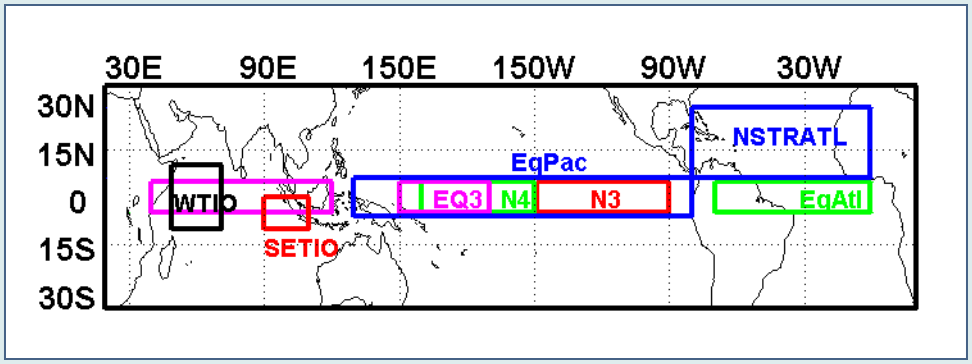
% Reduction in MAE in SST forecasts
Forecasts initialized Jan, Apr, Jul, Oct

ATOBS: use of atmospheric analyses for AGCM i.c.

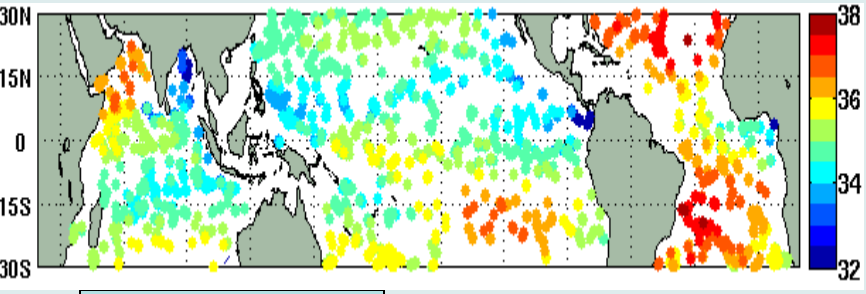
OCOBS: ocean data assimilation for OGCM i.c.

OC+AT: both

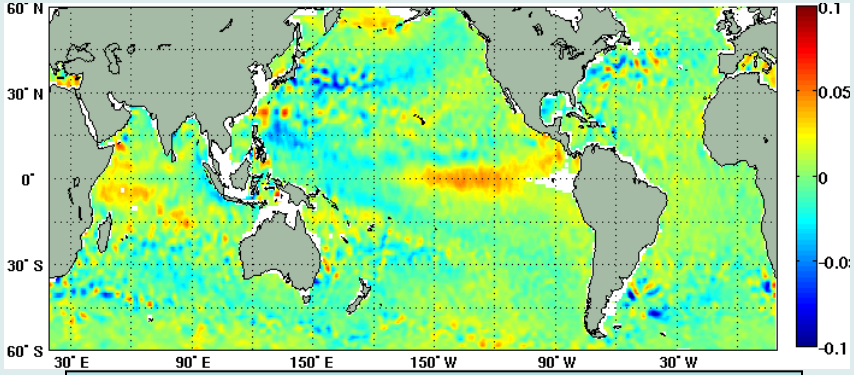




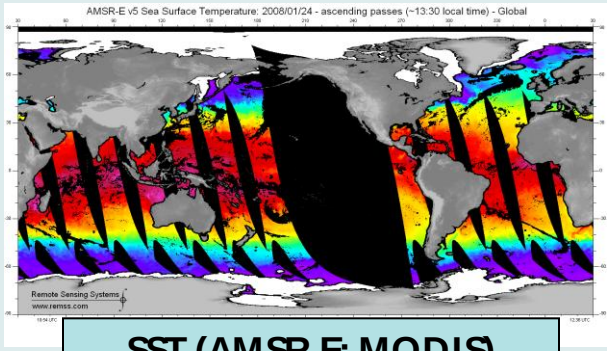
Ocean data assimilation in the GMAO



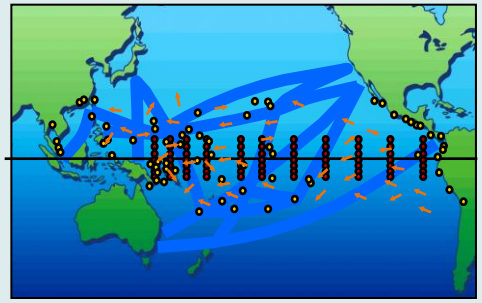
Temperature and salinity profiles from Argo floats



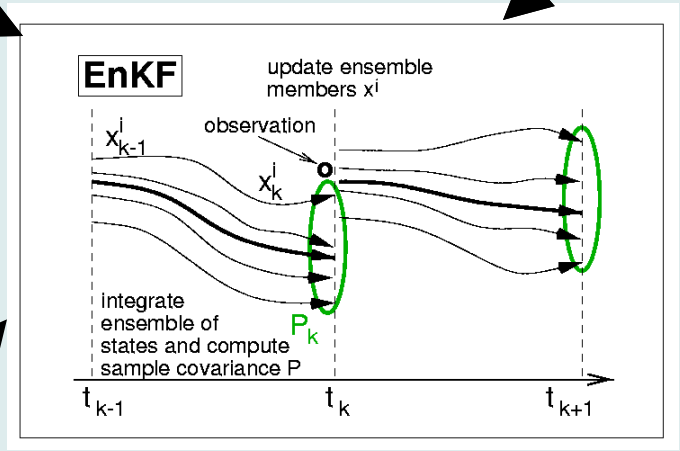
Sea Level anomalies (TOPEX/JASON)



SST (AMSR-E; MODIS)



In situ temperature profiles (TAO/TRITON/PIRATA/RAMA, XBTs)



Ocean state estimates for climate analysis and for short-term climate forecasts

GMAO's ODAS-1 EnKF

Poseidon v4 OGCM (Schopf and Loughe, 1995)

- Quasi-isopycnal
- Prognostic variables are *H, T, S, U* and *V*
- Sea-surface height (SSH) is diagnostic: $\eta = \Sigma_i \text{ buoyancy}(T_i, S_i) H_i/g$

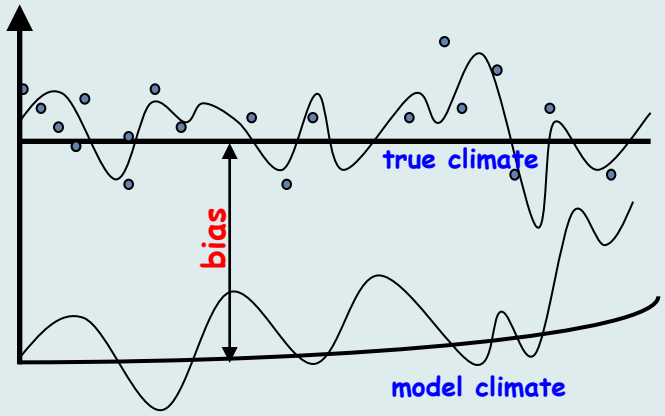
Ocean EnKF (Keppenne et al., MWR 2008 and references therein)

- Multivariate compactly supported background covariances: updates T, S, U & V
- System noise representation: Model-error and forcing-error model
- Online bias correction used in SSH assimilation
- Here: 16 ensemble members; Tests: 65 ensemble members

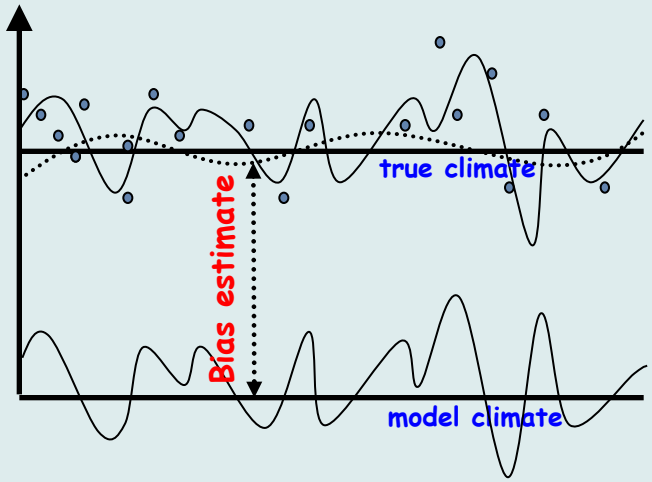
Altimeter *anomalies* are assimilated
⇒ climatology bias must be accounted for during assimilation

OBE: Side by side estimation of:
- Unbiased error
- Climatological error (bias)

a) "Standard" assimilation

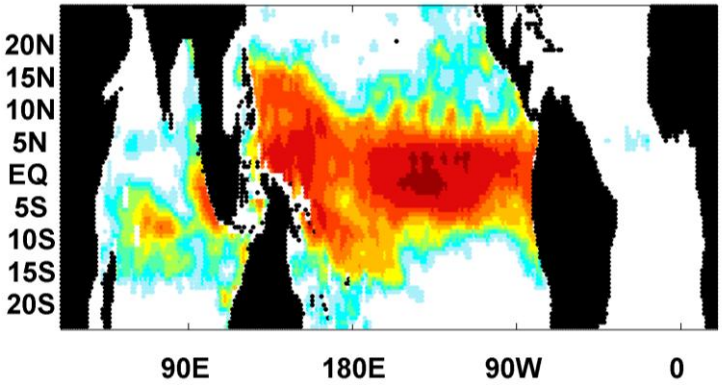


b) Assimilation with online bias estimation (OBE)

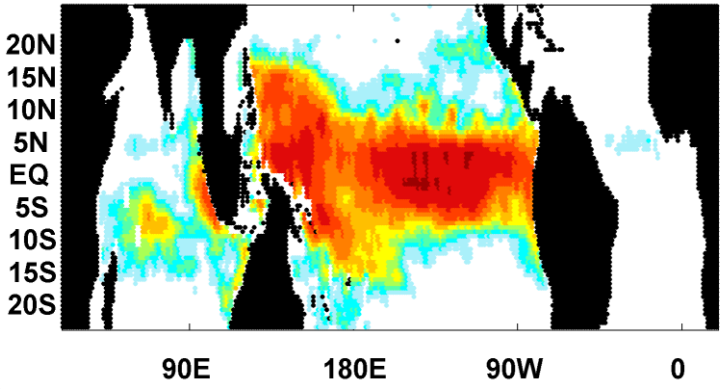


Verifying SSH analyses against Satellite Altimetry
Anomaly Correlation, 1993-2008

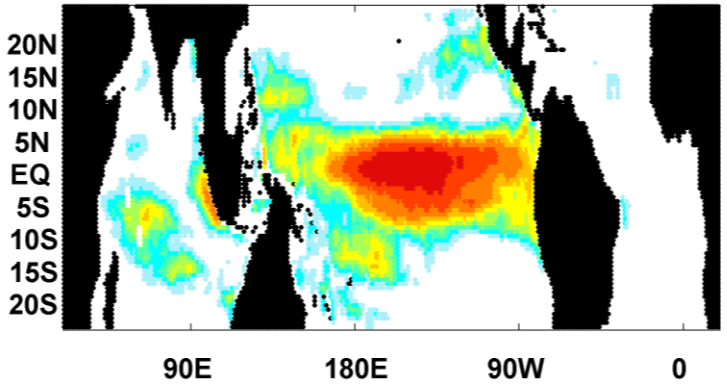
EnKF assimilates altimetry

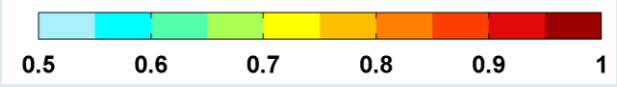


EnKF - no altimetry



No assimilation

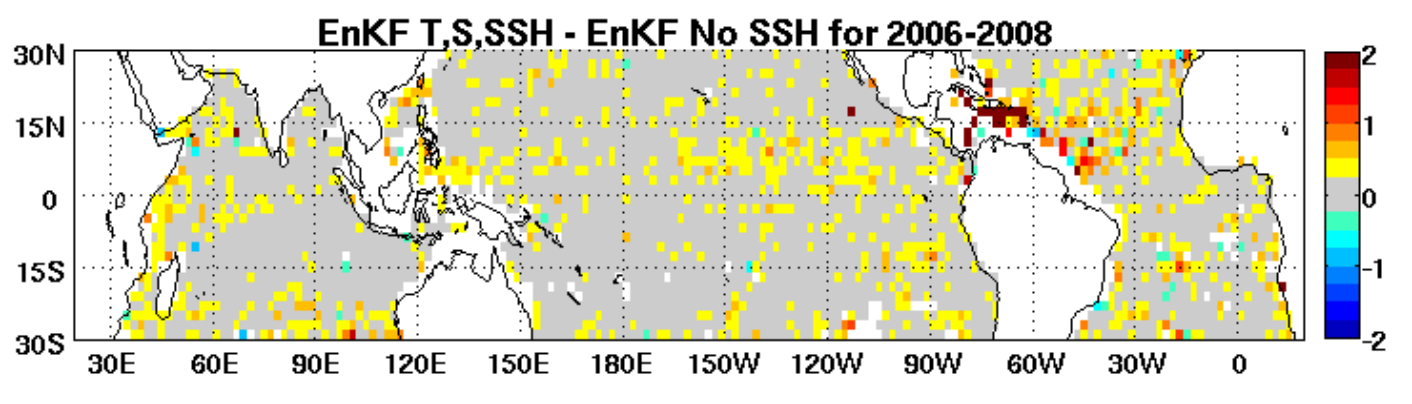




Observations working together? - Impact of altimeter assimilation

Verifying subsurface analyses against *in-situ* data
RMS(innovations): 0-300 m for 2006-2008
Salinity from Argo drifters

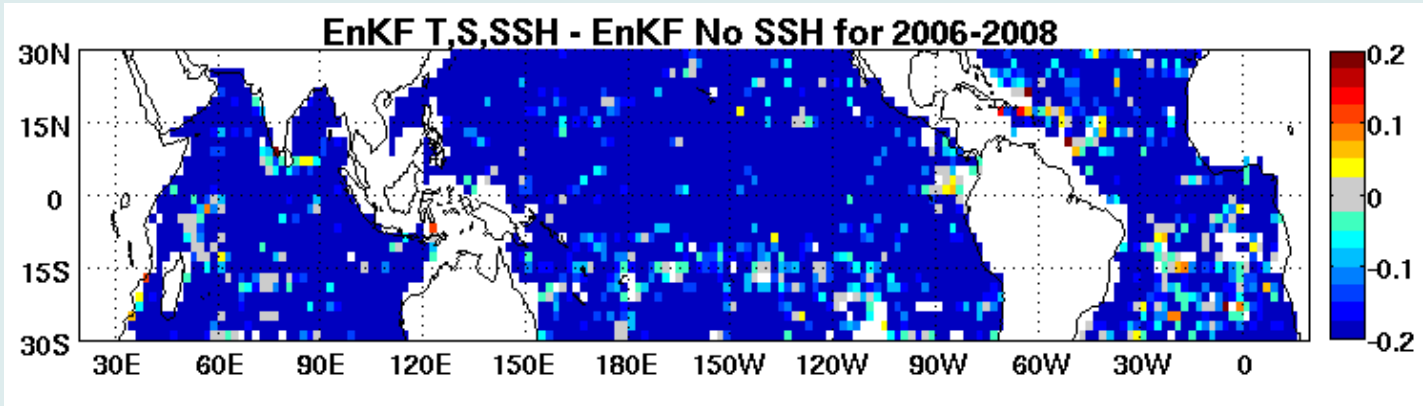
Temperature



Negative impact from altimetry

Positive impact from altimetry

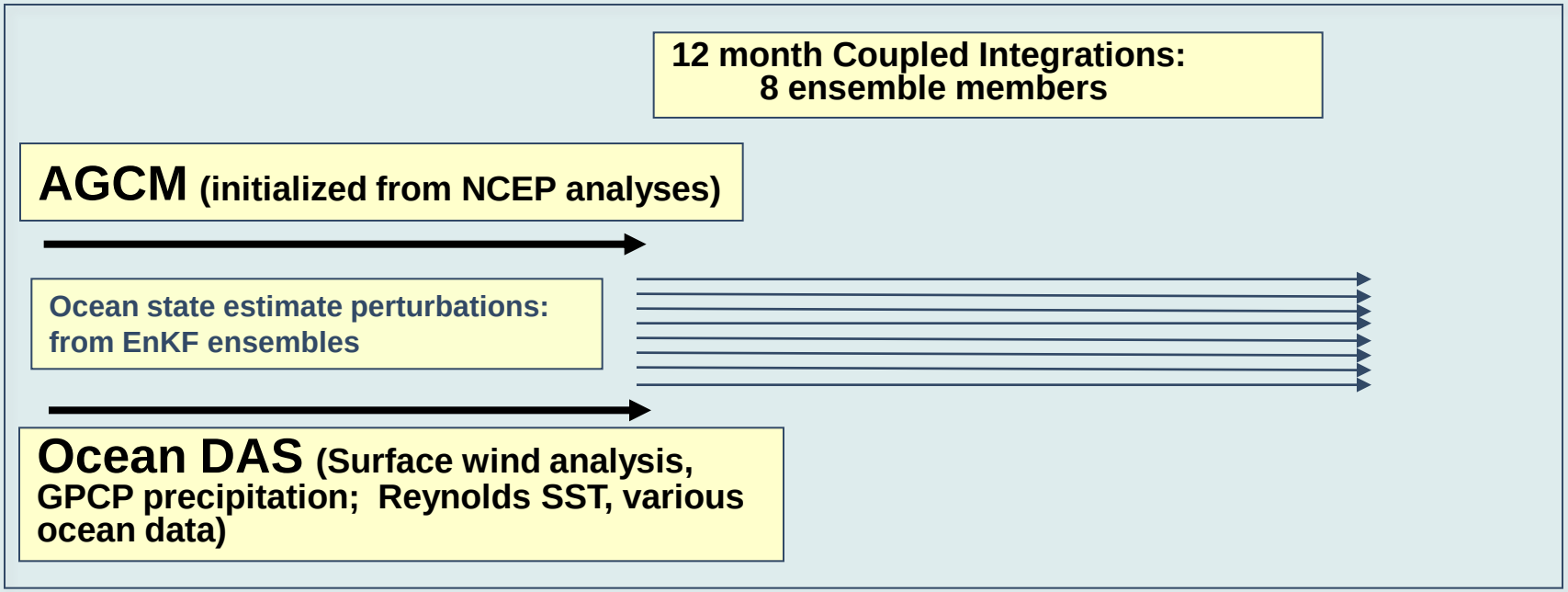
Salinity



Negative impact from altimetry

Positive impact from altimetry

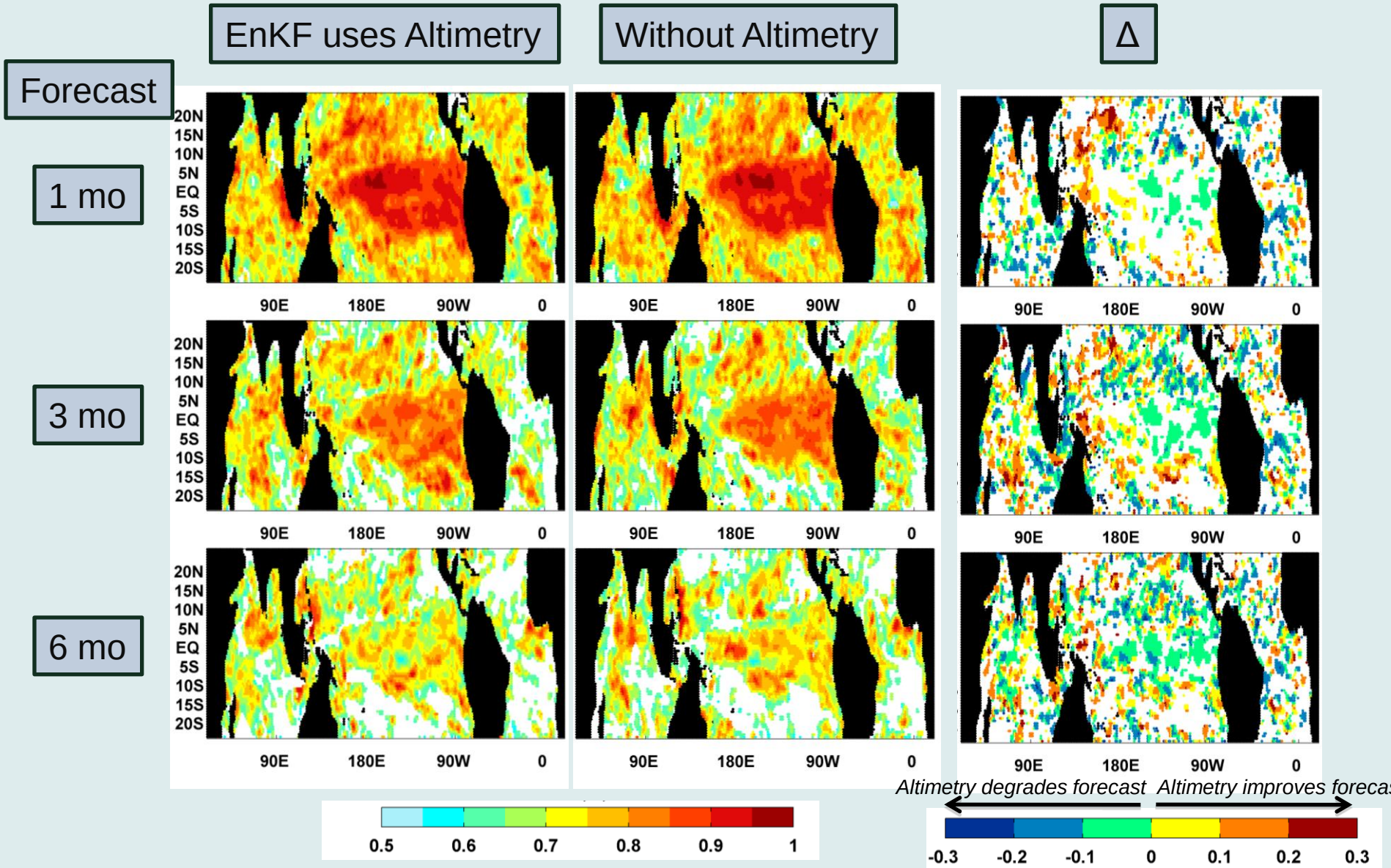
GMAO CGCMv1 Forecast Ensembles
for this study



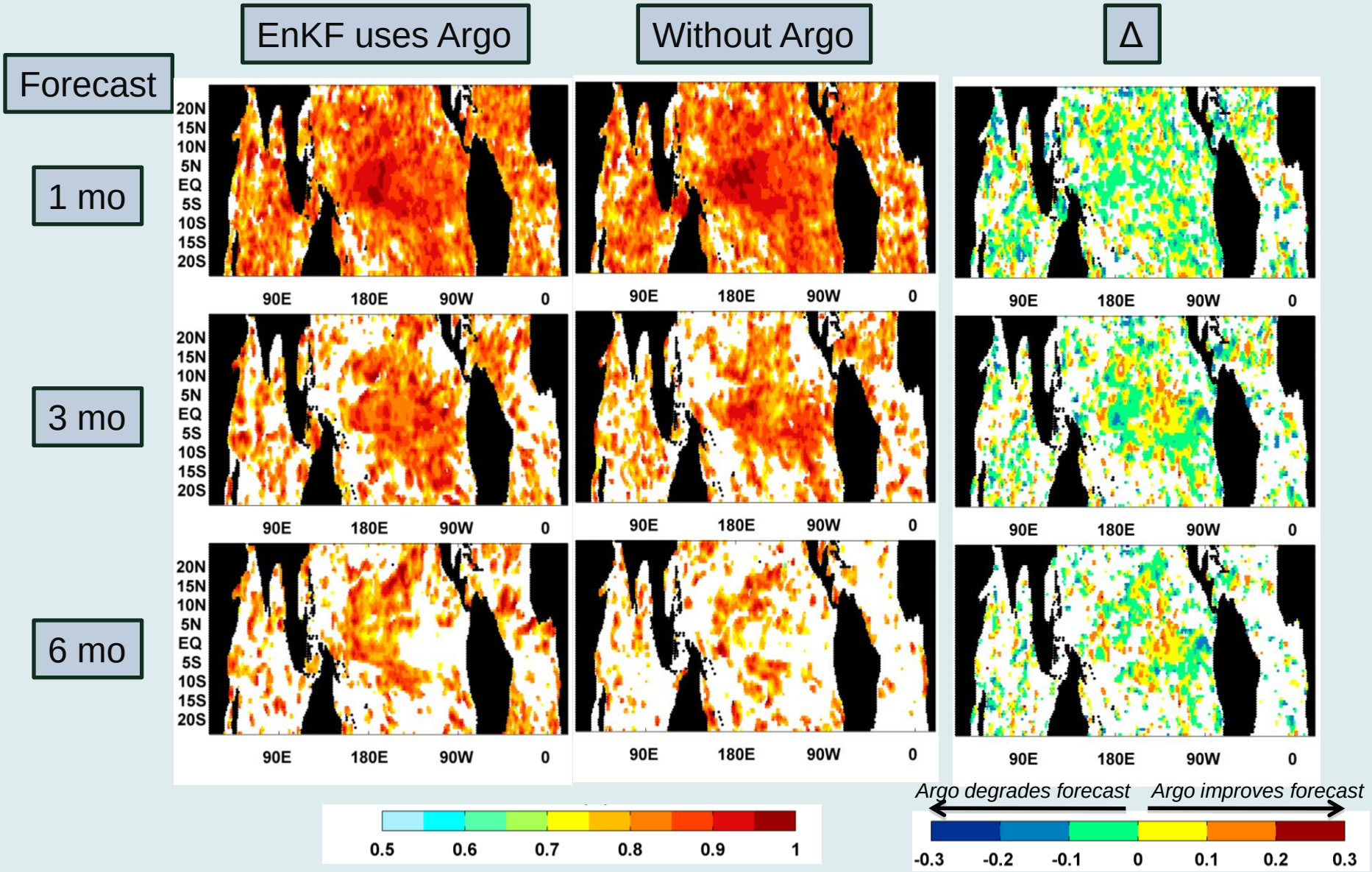
AGCM: NSIPP1 AGCM, 2 x 2.5 x L34
LSM: Mosaic (SVAT)
OGCM: Poseidon v4, 1/3 x 5/8 x L27
CGCM: Full coupling, once per day

ODAS: Ensemble Kalman Filter with *in situ* T & S, *satellite* SSH
"LDAS": Offline forced land states (recalibrated)

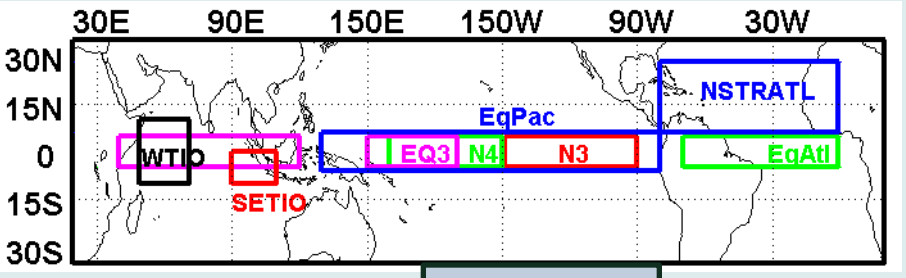
Forecast SST Anomaly Correlations (1993-2008): Jan, Mar, Jul, Oct Starts Verified Against Reynolds SST – for 1st and 3rd tercile anomalies



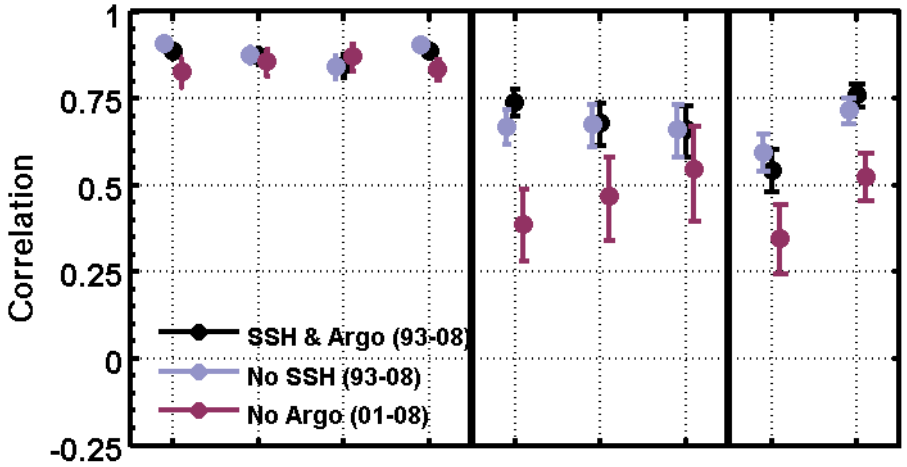
Forecast SST Anomaly Correlations (2001-2008): Jan, Mar, Jul, Oct Starts Verified Against Reynolds SST – for 1st and 3rd tercile anomalies

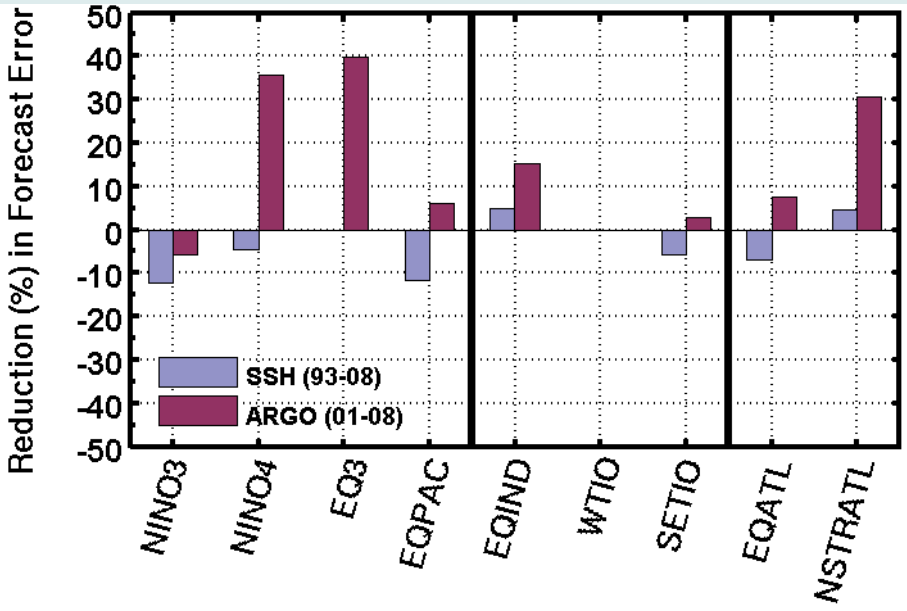


SST Anomaly Correlations & Reduction in MAE Verified Against Reynolds SST

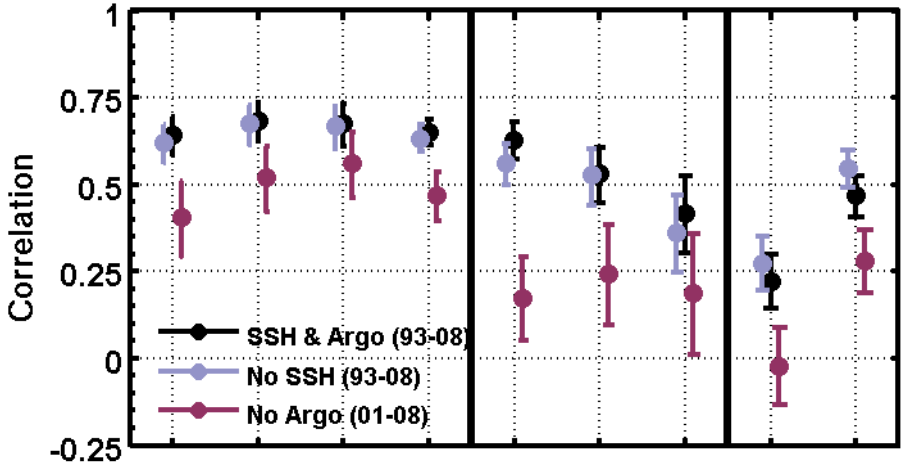


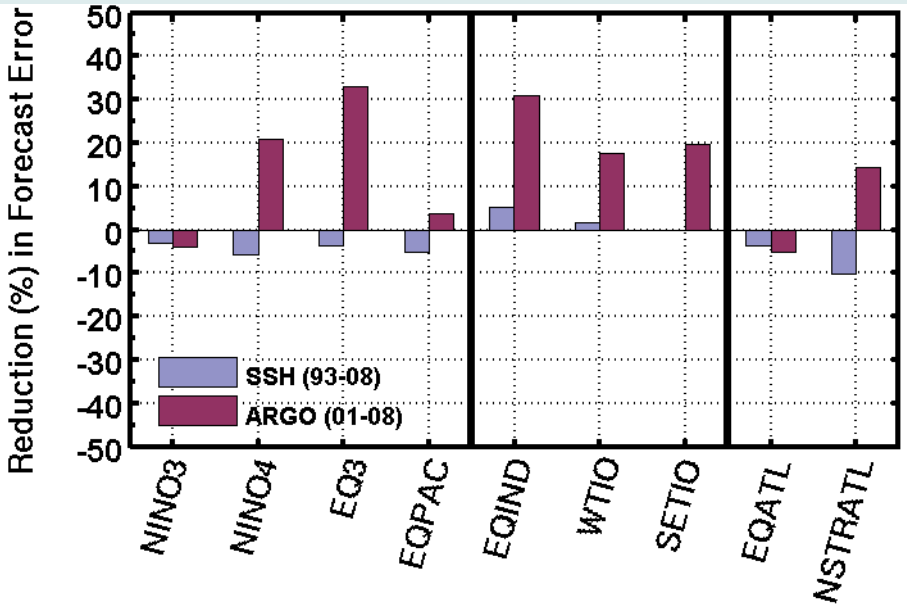
1st season



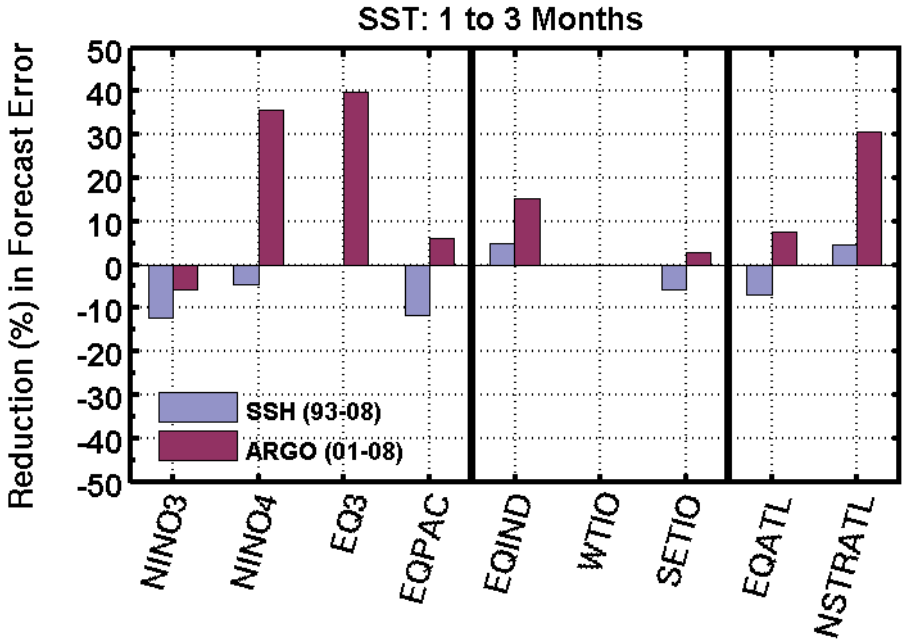


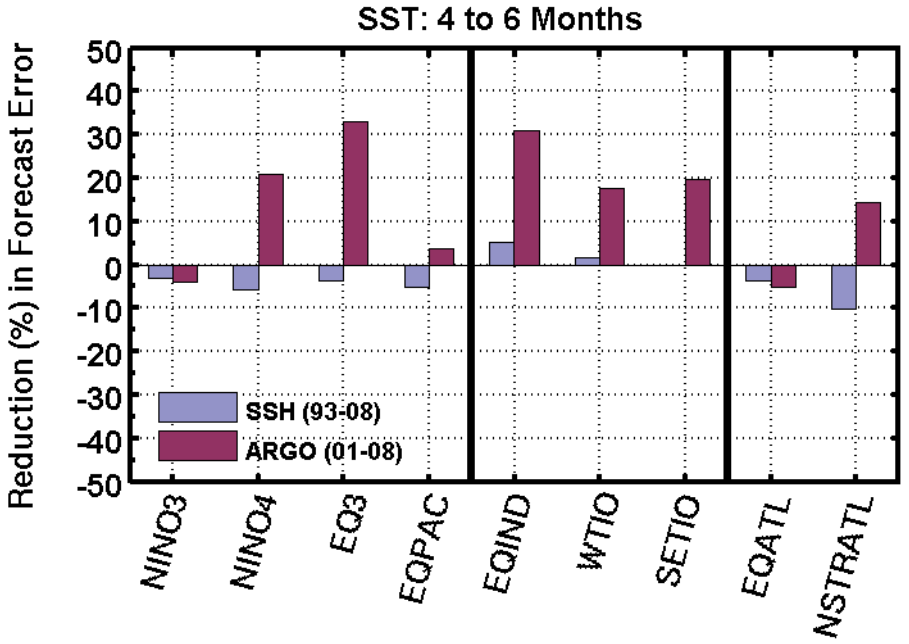
2nd season

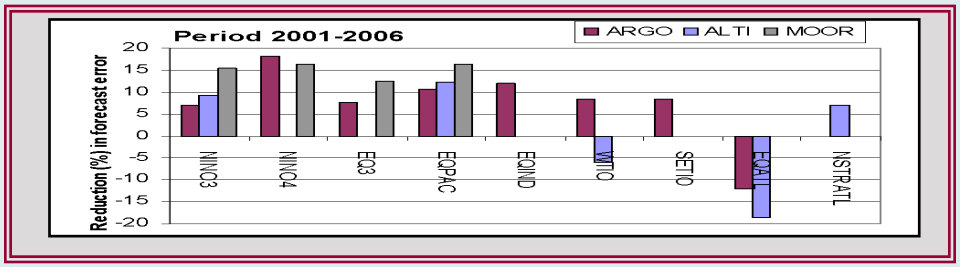




% Reduction in MAE in Forecast SST
Forecasts initialized Jan, Mar/Apr, Jul, Oct

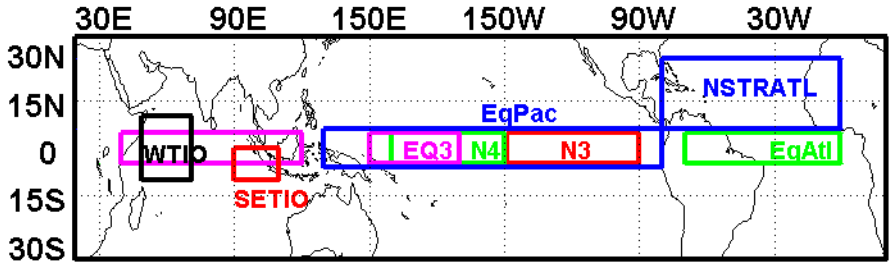




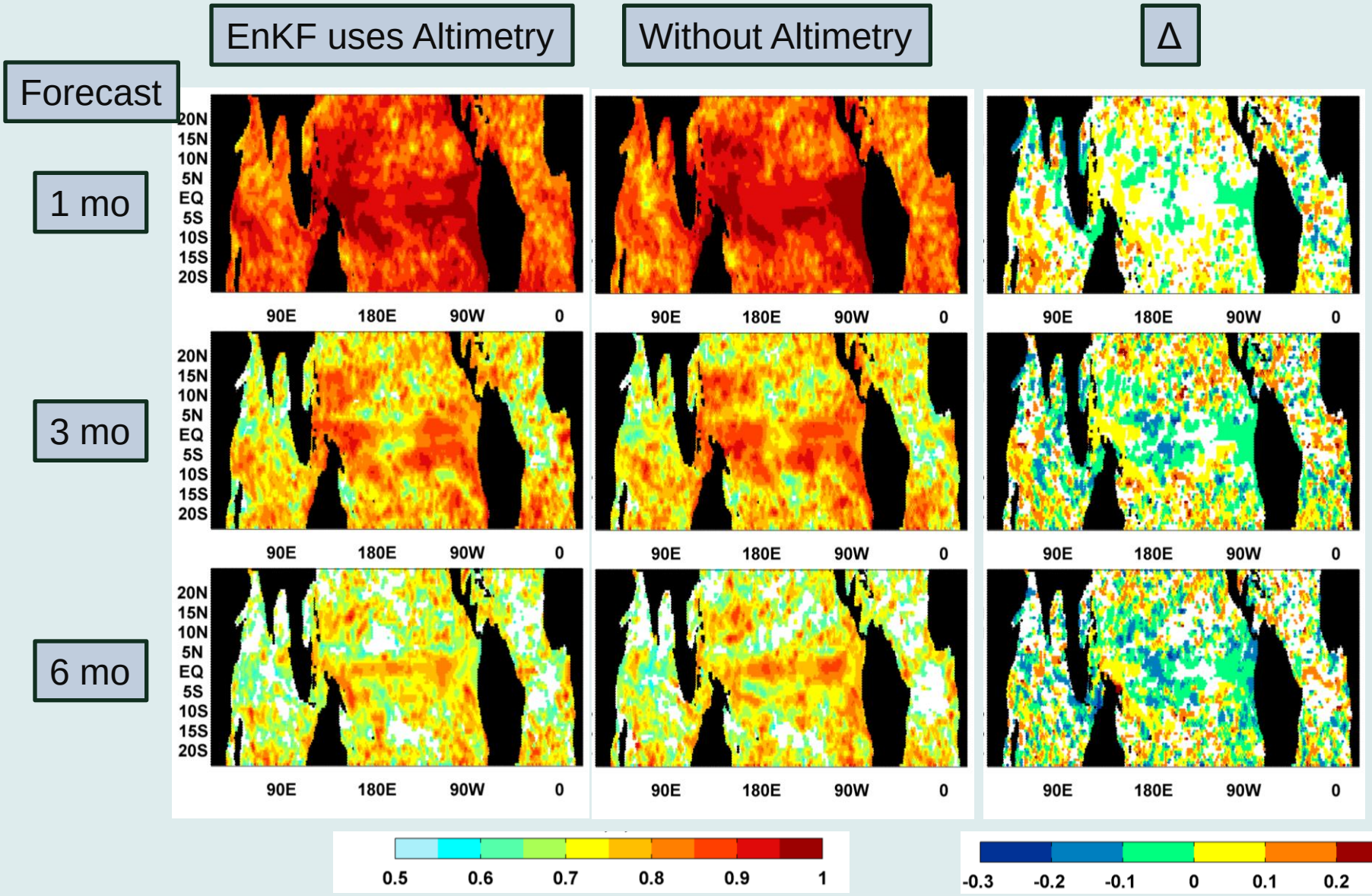


ECMWF S3 (1-7 mon forecast)

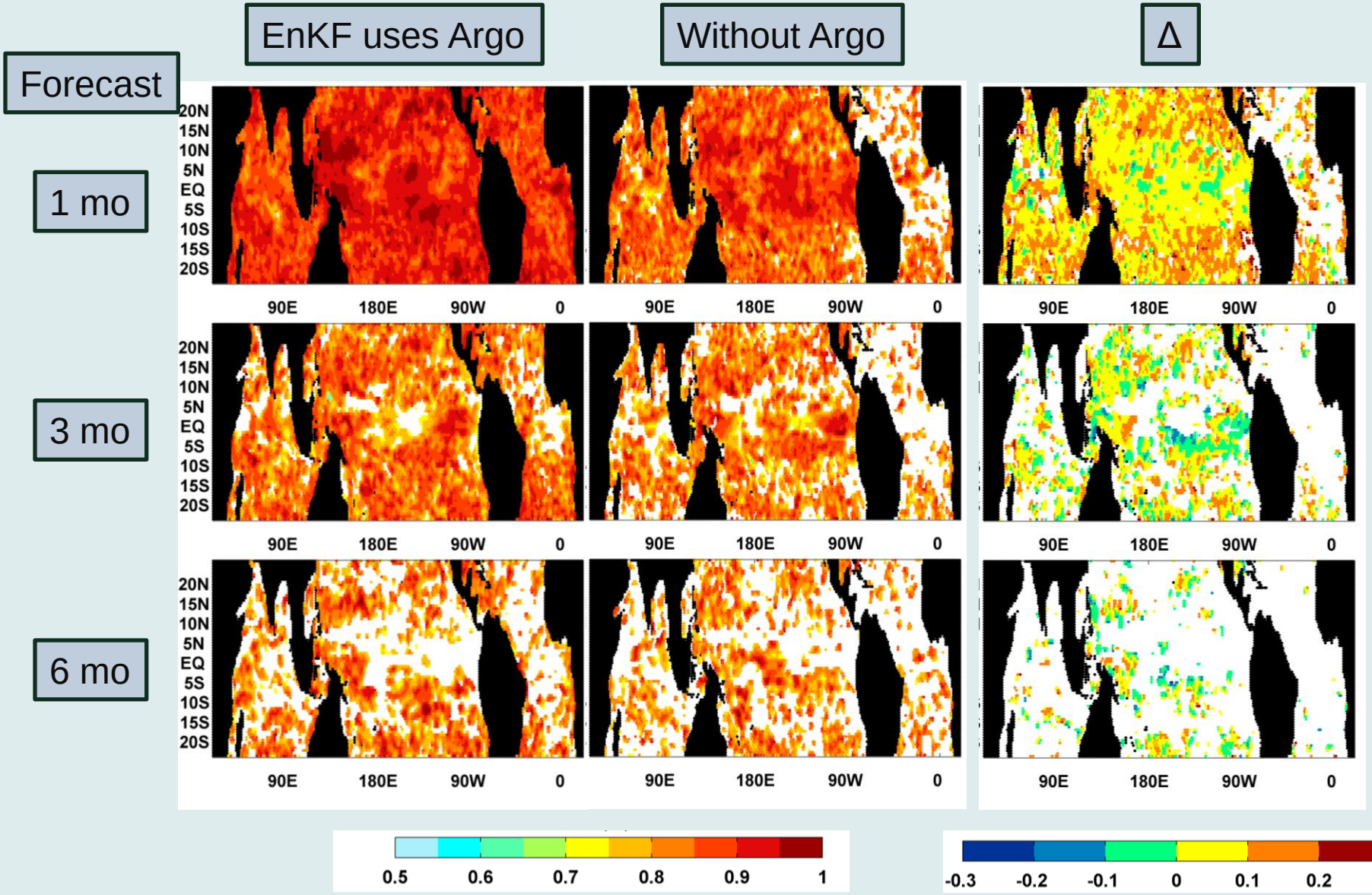
Balmaseda & Anderson (2009)



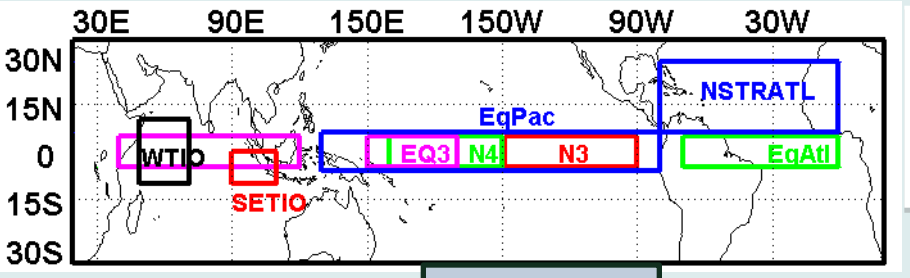
Forecast Heat Content Anomaly Correlations (1993-2008)
Verified Against Reynolds SST – for 1st and 3rd tercile anomalies



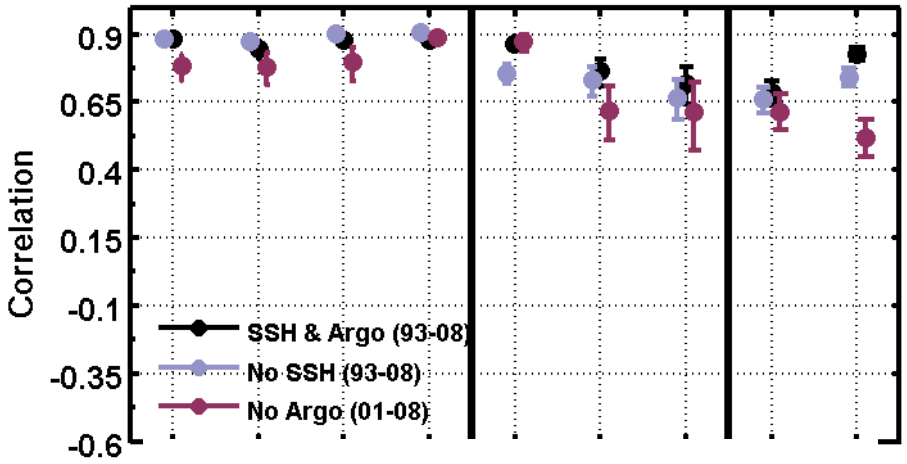
Forecast Heat Content Anomaly Correlations (2001-2008) Verified Against Reynolds SST – for 1st and 3rd tercile anomalies

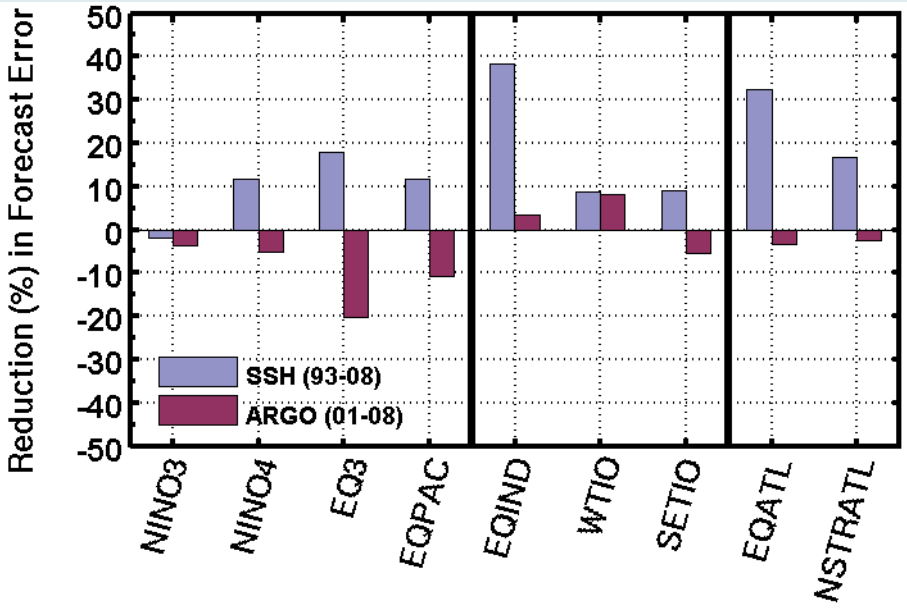


Heat Content Anomaly Correlations & Reduction in MAE Verified Against Analyses

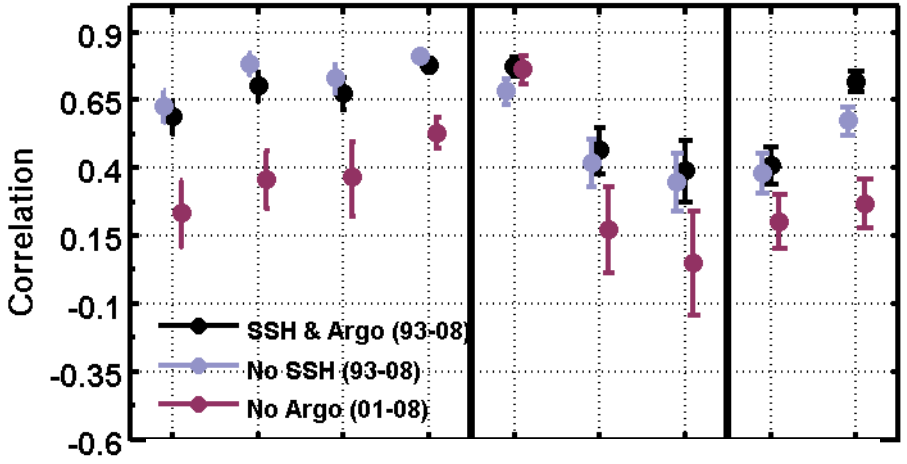


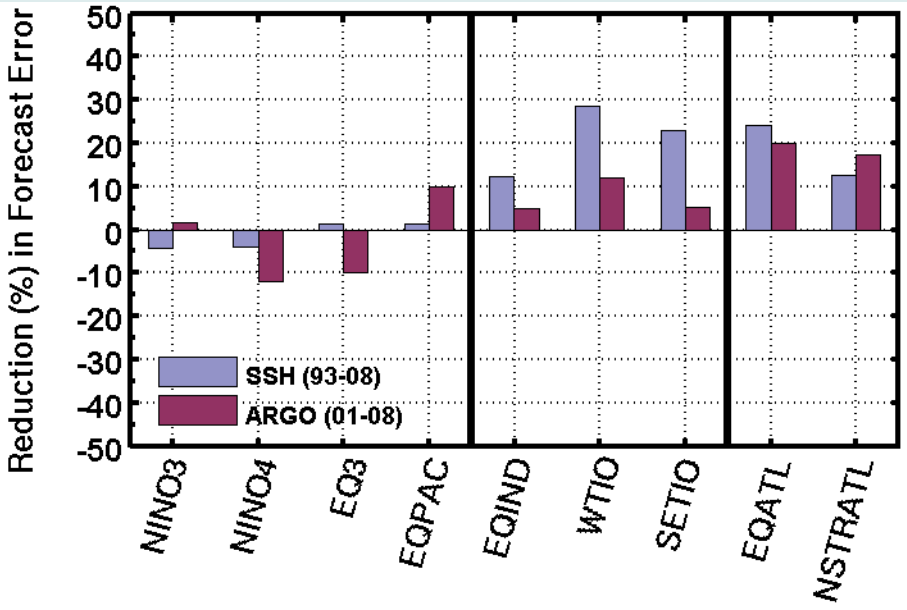
1st season





2nd season

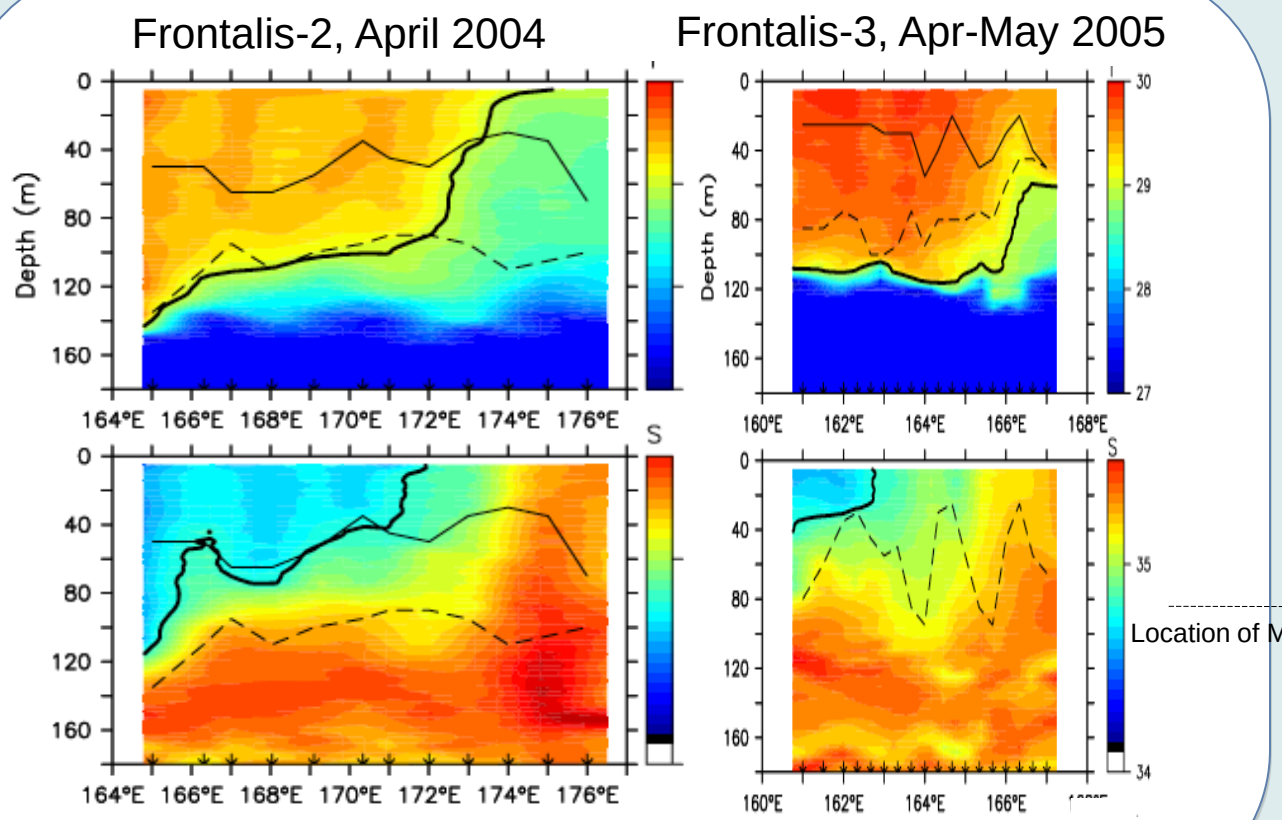




Looking forward to Aquarius
Along the equator, salinity matters…..

Temperature

Salinity



Mixed layer depth

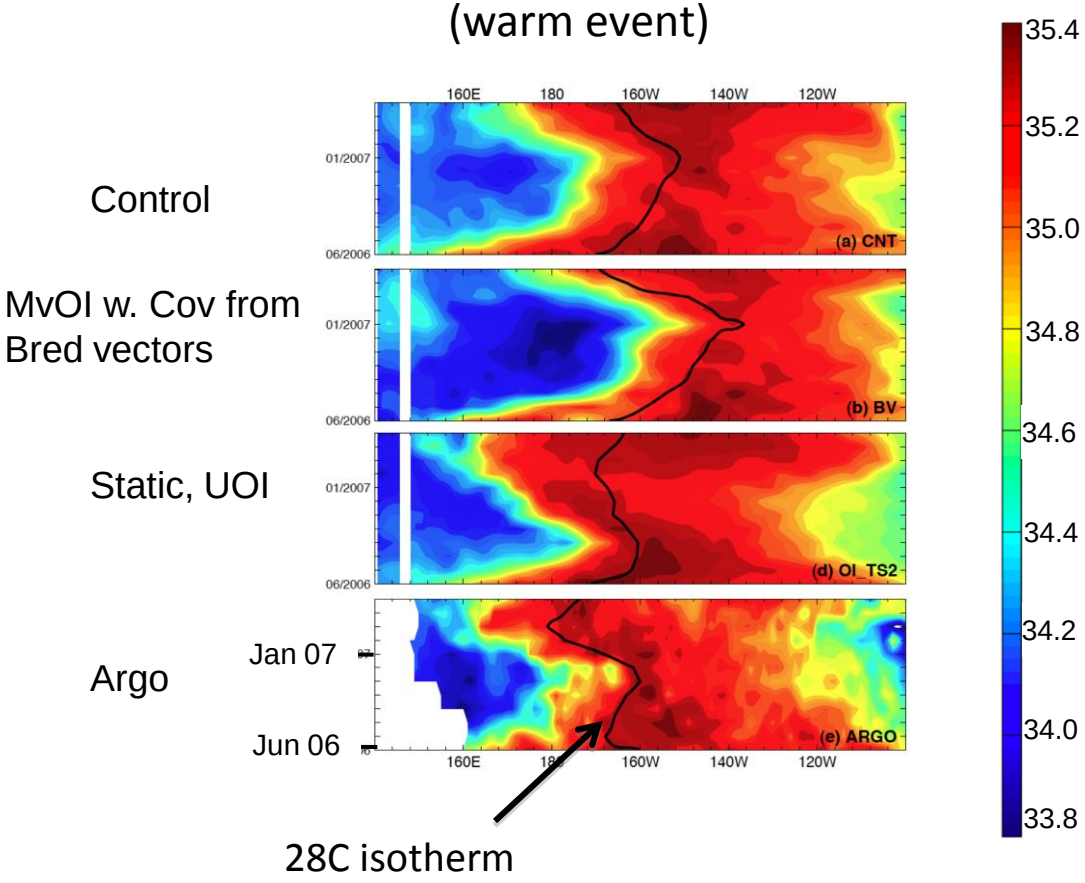
Isothermal layer depth

29C isotherm *or* 38.4 isohaline

From Maes, JGR, 2009

Looking forward to Aquarius
Salinity matters…..

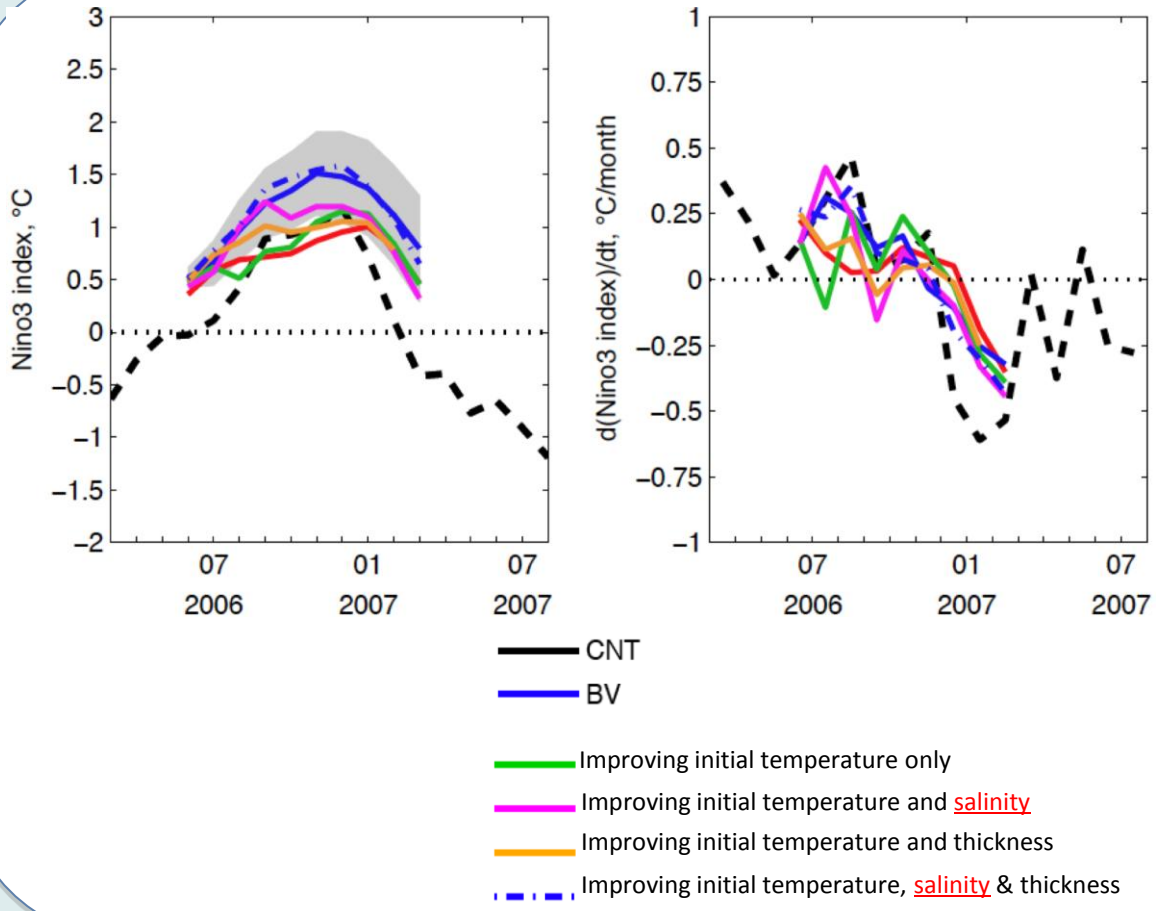
Forecast SSS evolution
depends on initial salinity distribution
Forecasts initialized 1 June 2006
(warm event)



From Shu-Chih Yang et al, J. Climate (submitted)

Looking forward to Aquarius
Salinity matters…..

Niño-3 SST anomaly and tendency
Forecasts initialized 1 June 2006
(warm event)



SUMMARY – Impact of Observations

Seasonal Prediction

- Moorings, altimeter data, Argo are complementary
- GTMBA: the backbone; provide high frequency data; *continuity important for forecast calibration*
- Altimeter: effective for the thermocline; contributes SST skill in the N. Subtrop. Atlantic skill & Indian Ocean; backbone away from TAO/Triton
- Argo contributes to SST forecast skill in all Oceans
- SST: important for mixed layer and for AGCM
- Surface forcing from the atmosphere also contributes to SST forecast skill

Decadal Prediction

- Data outside the tropical oceans; deep data? homogeneous? Long time series important

SUMMARY

• Assimilation of ocean satellite data requires sophisticated covariance modeling to project surface information to the thermocline where much of the ocean's memory resides.

• A key issue is the mean state used for the sea surface height anomaly calculation.

• Salinity matters – an important component in the mass field *and* it mediates the ocean-atmosphere exchanges in the western-central equatorial Pacific.

• **Challenges** remain in the initialization of coupled models – reducing initialization shocks requires attention to the *coupled* system (integrated analyses).

• **Changing observing systems** are a challenge to ocean climate analyses, just as for the atmosphere.