The NCEP/GFDL Observing System Experiments for Tropical Pacific Observing System: Early Results

Yan Xue[1], Arun Kumar[1], Gaberial Vecchi[2], David Behringer[1], Caihong Wen[1], Xiaosong Yang[2], Hui Wang[1], Wanqiu Wang[1]

(1) Climate Prediction Center, NCEP/NOAA, Maryland, U.S.A., (2) Geophysical Fluid Dynamics Laboratory, OAR/NOAA, New Jersey, U.S.A.

Yan.Xue@noaa.gov

Abstract

The TAO/TRITON array is the cornerstone of the ENSO observing system because it systematically measures upper ocean temperature, salinity, current and air-sea fluxes that contribute to the dynamics of ENSO, and are essential for ENSO monitoring and prediction. One tool to assess the value of the TAO data in the presence of the Argo is to conduct Observing System Experiments (OSEs). We conducted coordinated OSEs and hindcast experiments using the NCEP and GFDL ocean data assimilation systems and seasonal forecast models for the post-Argo period 2004-2011. The relative roles of the TAO and Argo data towards constraining the upper ocean thermal structure in ocean reanalysis are assessed. Hindcast experiments initialized from the OSEs are used to assess if the seasonal forecast skill of the current generation seasonal forecast models are able to quantify the benefits of enhanced ocean observing systems.

Four OSE runs are made, in which no observations (CTL), all observations (XBT, moorings, Argo) (ALL), all except the moorings (noTAO), and all except the Argo (noArgo) data are assimilated. Hindcast experiments are initialized with oceanic conditions from the four OSEs around January 1, April 1, July 1 and October 1 during 2004-2011. For each start time, an ensemble of 6 (10) coupled forecasts with perturbed initial conditions is integrated up to 12 months ahead using the seasonal forecast model CFSv2 at NCEP (CM2.1 at GFDL). For the OSE runs, we examine the mean bias, standard deviation, root-mean-square error (RMSE) and anomaly correlation coefficient (ACC) with observations. For the hindcast experiments, we examine the systematic bias, RMSE, ACC and mean squre skill score (MSSS) of the tropical Pacific SST. The results from the two seasonal forecast systems are compared and the common characteristics on the impacts of different observing systems on ocean analysis and forecast skill are summarized. This project is part of the efforts to build a multi-model capability in NOAA for assessing impacts of ocean observing systems on seasonal forecast.

NCEP Hindcast Runs

Ocean Initial Condition Date	CTL (ensemble number)	ALL (ensemble number)	nTAO (ensemble number)	nArgo (ensemble number)
Mar 27 & Apr 1	6	6	6	6
Jun 25 & Jun 30	6	6	6	6
Sep 23 & Sep 28	6	6	6	6
Dec 27 & Jan 1	6	6	6	6

- CFSv2 (T126L64 for atmosphere, 0.5 degree for ocean)
- 2004-2011, Four initial months
- Six ensemble members (three finished), 12 month integration

GFDL Hindcast Runs

Ocean Initial Condition Date	CTL (ensemble Number)	ALL (ensemble number)	nTAO (ensemble number)	nArgo (ensemble number)
Apr 1	10	10	10	10
Jul 1	10	10	10	10
Oct 1	10	10	10	10
Jan 1	10	10	10	10

- CM2.1 (T64L12 for atmosphere, 1 degree for ocean)
- 2004-2011, Four initial months
- Ten ensemble members, 12 month integration

CM2.1:

- Starting from Jan 1 I.C., CM2.1 underestimates the amplitude of the 2009/10 El Nino, particularly from noTAO ocean initialization. CTL has the best forecast.
- CM2.1 continues to underestimate the amplitude of the 2009/10 El Nino from Apr 1 I.C.
- CM2.1 agrees with observation well from Jul 1 and Oct 1 I.C.

CFSv2

- Starting from Jan 1 I.C., CFSv2 forecasts a false El Nino in 2005.
- Starting from Apr 1 and Jul 1 I.C., CFSv2 misses the 2007/08 La Nina and overestimates the amplitude of the 2010/11 La Nina.
- Starting from Oct 1 I.C., CFSv2 agrees with observation well except it overestimates the amplitude of the 2010/11 La Nina.

NCEP/GFDL OSE Runs

In Situ Data	CTL (no profile data, OISST included) (2004-2011)	ALL (all profile data) (2004-2011)	nTAO (all except moorings) (2004-2011)	nArgo (all except Argo) (2004-2011)
XBT	×	√	√	√
TAO	×	√	×	√
Argo	×	√	√	×

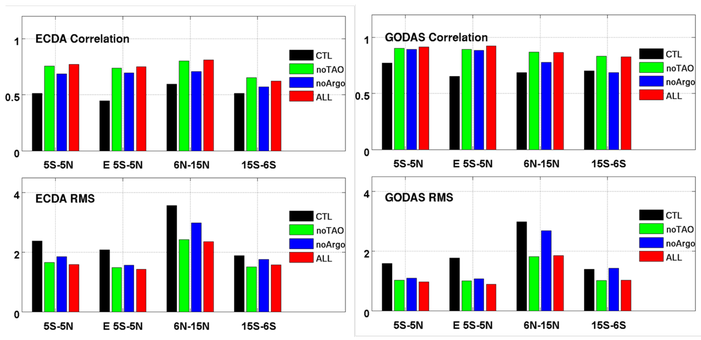
NCEP Global Ocean Data Assimilation System (GODAS):

Xue, Y., B. Huang, Z.Z. Hu, A. Kumar, C. Wen, D. Behringer, S. Nadiga, 2011: An Assessment of Oceanic Variability in the NCEP Climate Forecast System Reanalysis. Clim. Dyn., 37, 2511-2539.

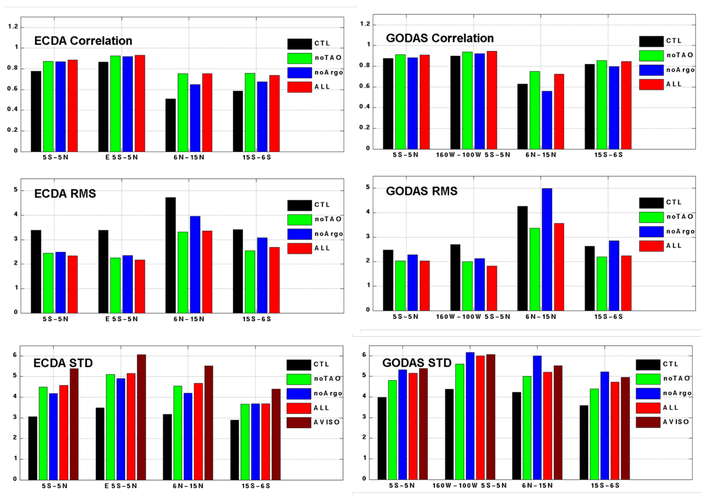
GFDL Ensemble Coupled Data Assimilation (ECDA):

Zhang, S., M. J. Harrison, A. Rosati, and A. Wittenberg, 2007: System design and evaluation of coupled ensemble data assimilation for global oceanic studies. Mon. Wea. Rev., 135, 3541-3564.

Annual Cycle of SSH



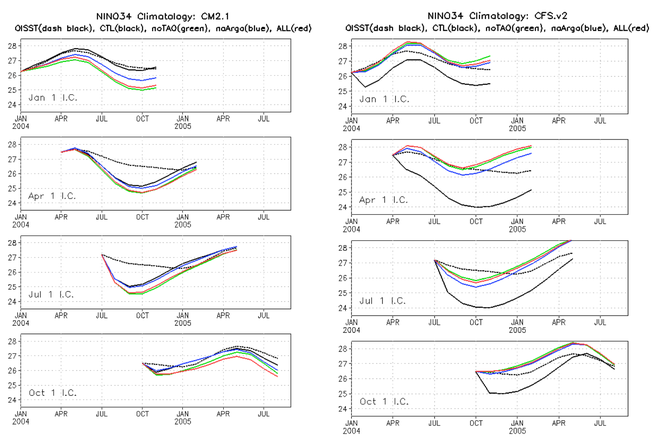
SSH Anomalies



Validation SSH with Altimetry

- Both TAO and Argo improve the mean and annual cycle of SSH. Argo is particularly important to constrain errors off the equator.
- For SSH anomaly (SSHA), assimilation of Argo while not TAO (noTAO, green bar) improves SSHA compared to CTL in both GODAS and ECDA. The improvement is more significant in ECDA than in GODAS.
- For both GODAS and ECDA, assimilation of TAO while not Argo (noArgo, blue bar) improves SSHA similarly as noTAO. This suggests that SSH variability in the equatorial Pacific is generally well constrained by either TAO or Argo.
- In off-equatorial regions (6N-15N, 15S-6S), assimilation of Argo while not TAO (noTAO) reduce RMSE by 30% in ECDA and 21% in GODAS in 6N-15N compared to CTL, while assimilation of TAO while not Argo (noArgo blue bar) reduce RMSE in ECDA but increase RMSE in GODAS. So Argo data is needed to constrain SSH variability off the equator.
- In the equatorial Pacific, standard deviation (STD) of SSH is underestimated by 43% in ECDA CTL and 26% in GODAS CTL. Assimilation of TAO while not Argo (noArgo) improves STD of GODAS. However, STD of ECDA is still about 15% weaker than observation, even when both TAO and Argo are assimilated (red bars). In summary, data assimilation is necessary to realistically simulate the amplitude of SSH variability, and the TAO data is particularly helpful for a realistic simulation of the amplitude of SSH variability in the eastern tropical Pacific where ENSO variability is the strongest.

NINO3.4 Biases



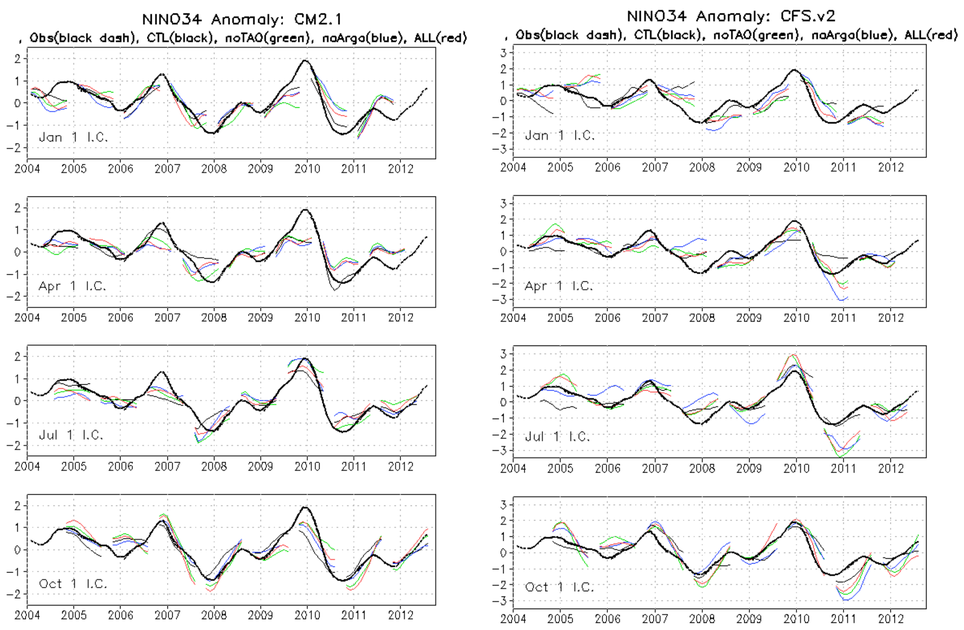
CM2.1:

- Large cold bias from Apr 1 and Jul 1 I.C. that is insensitive to ocean initialization.
- CM2.1 agrees with observation well from Jan 1 and Oct 1 I.C.

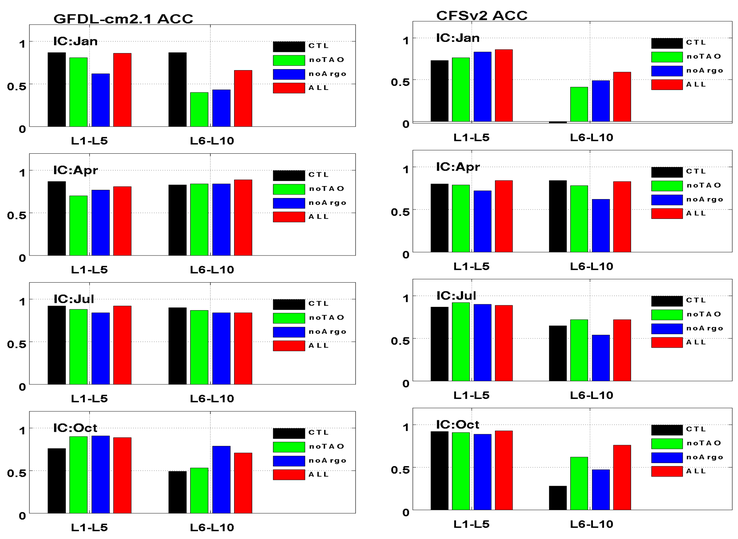
CFSv2:

- CFSv2 agrees well with observation except starting from CTL, which is too cold particularly from Apr 1 and Jul 1 I.C. This suggests data assimilation is effective in reducing model systematic bias.

NINO3.4 Time Series



NINO3.4 Anomaly Correlation Skill



- The impacts of ocean initialization on hindcast skill are investigated using various skill measures such as ACC, RMSE, absolute error and MSSS. The ACC is shown here.
- The ACC for seasonal mean SST is calculated for each initial month and averaged over lead months 1-5 and lead months 6-10.
- For CM2.1, the ACC for January 1 I.C. is highest starting from CTL when both TAO and Argo are not included, particularly at long lead time when spring barrier is crossed. This suggests that including more data such as TAO and Argo may not help prediction to across spring barrier. However, data assimilation is critical for CFSv2 to cross spring barrier. Including both TAO and Argo has the best forecast.
- For April 1 and July 1 I.C., the ACC of CM2.1 is insensitive to ocean initialization. On the other hand, the ACC of CFSv2 is lowest when Argo is excluded.
- For October 1 I.C., both CM2.1 and CFSv2 suggest that including TAO or Argo help improve prediction skill. CM2.1 suggests that excluding TAO hurts skill more than excluding Argo. On the other hand, CFSv2 suggests that excluding Argo hurts skill more than excluding TAO, and the highest skill is achieved by including both TAO and Argo.