Prediction Skill and Predictability of ENSO in NCEP Climate Forecast System Version 2

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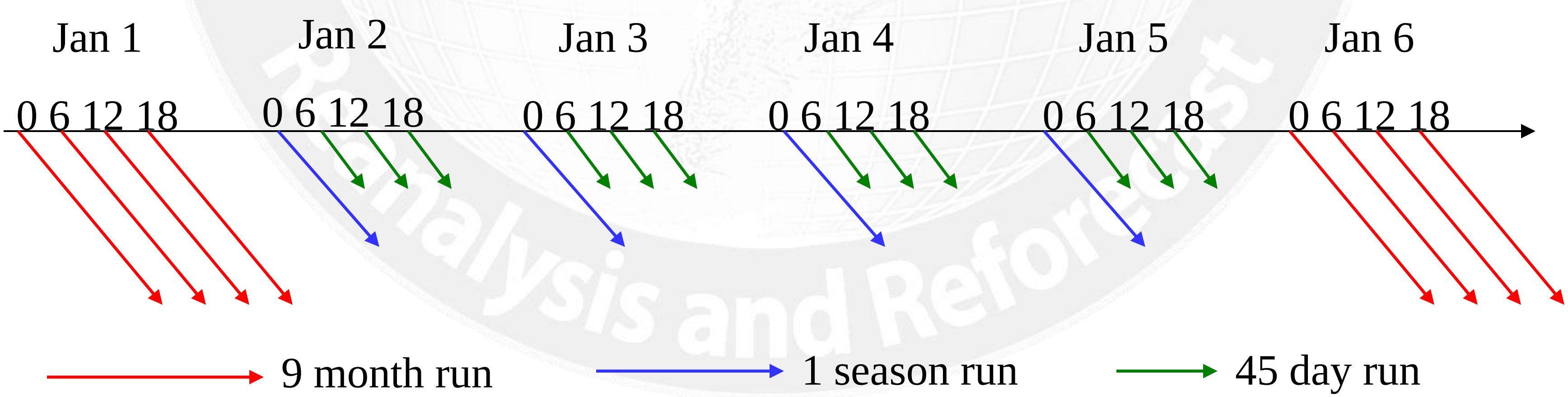
CFSv2 Retrospective Forecasts

- **9-month hindcasts, initiated from every 5th day and 4 times (0Z, 6Z, 12Z and 18Z) per day over a 29 year period from 1982-2010.**

- **123-day hindcasts, initiated from every 0Z between these five days, over the 12 year period from 1999-2010.**

- **45-day hindcasts, initiated from every 6Z, 12Z and 18Z, over the 12-year period from 1999-2010.**



Decadal Change of ENSO and Predictability

- **Central-Pacific (CP) El Nino is more frequent than eastern-Pacific (EP) El Nino since late 1990s**
  - Larkin and Harrison 2005; Kug et al. 2009; Kao and Yu 2009
- **CP El Ninos may become more frequent and intense with time**
  - Yeh et al. 2009; Lee and McPhaden 2010
- **Traditional ENSO predictors broke down since 2000**
  - McPhaden 2012 ; Horii et al. 2012; Xiang et al. 2012
- **ENSO prediction skill is less skillful since 2000**
  - Wang et al. 2009; Barnston et al. 2012

Objectives

- **Document the systematic biases in CFSv2 SST hindcasts before and after 1999 that needs to be targeted for future model improvement**

- **Inform the users of the CFSv2 about its capability in predicting ENSO variability and its decadal changes since 2000**

  - **How well does the model forecast the decadal change of ENSO variability?**
  - **What are the prospects for predicting the two flavors of El Nino?**
  - **What is the skill gap between the model forecast and persistence forecast?**
  - **How well does the perfect-model skill compares with the model skill?**

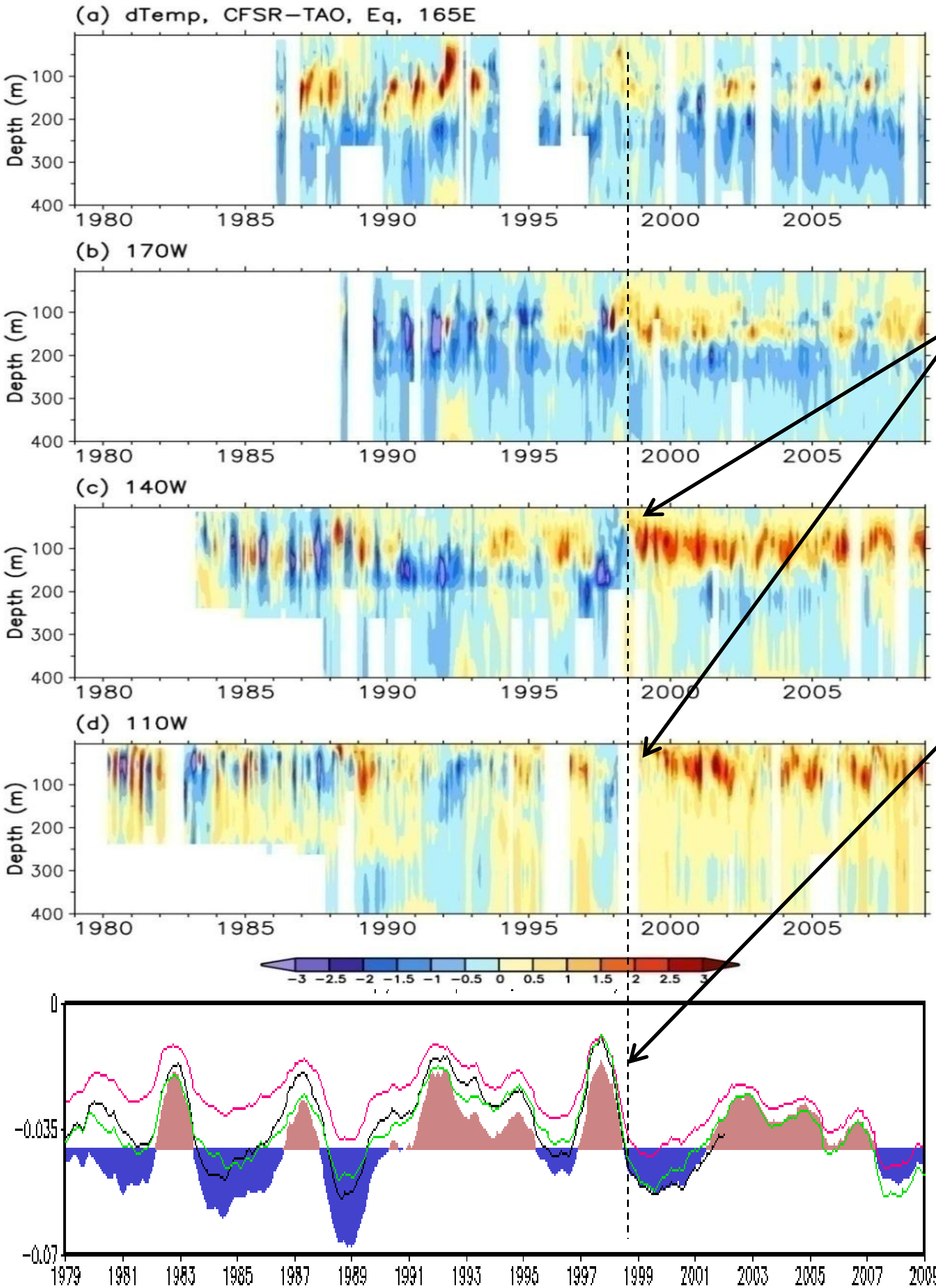
Outline

- **Model Data**
  - Ensemble mean with 20 members
  - Seasonal mean SST forecast

- **Systematic Biases**
  - Systematic bias as function of initial month and lead month
  - 1982-1998 and 1999-2010

- **Prediction of SST anomaly** (based on two climatologies)
  - Standard deviation
  - Anomaly correlation coefficient (ACC)
  - Root-mean-square error (RMSE)
  - Perfect-model skill (model predictability)
  - Persistence forecast skill
  - El Nino composites

CFSR Eq. Temperature
(difference from TAO)



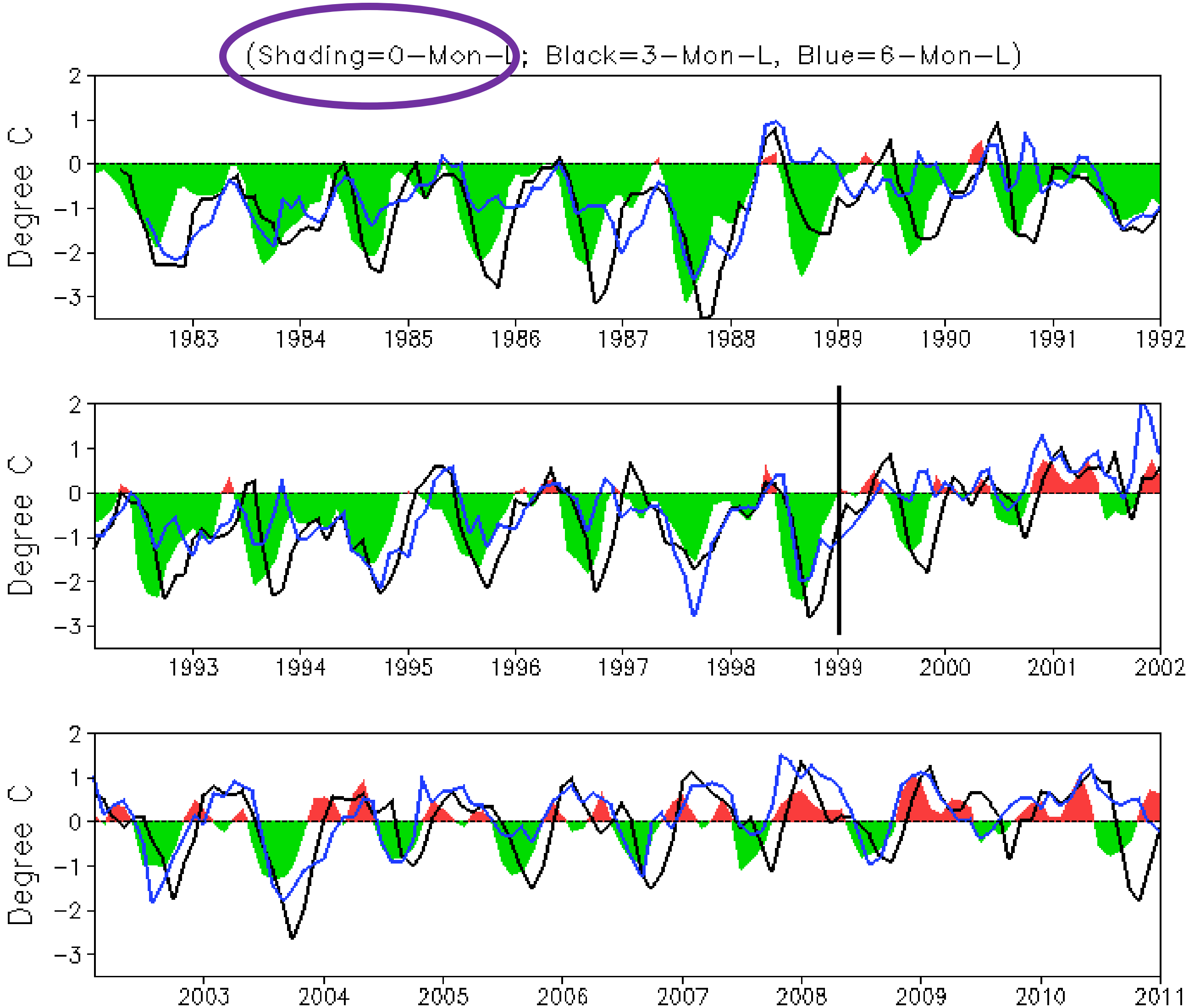
-CFSR temperature in the E. Pacific has significant warm biases after 1999, which caused a sudden shift in SST forecast bias around 1999.

-The warm biases after 1999 were probably caused by a sudden reduction of easterly wind biases in the central equatorial Pacific when ATOV satellite data were assimilated in October 1998.

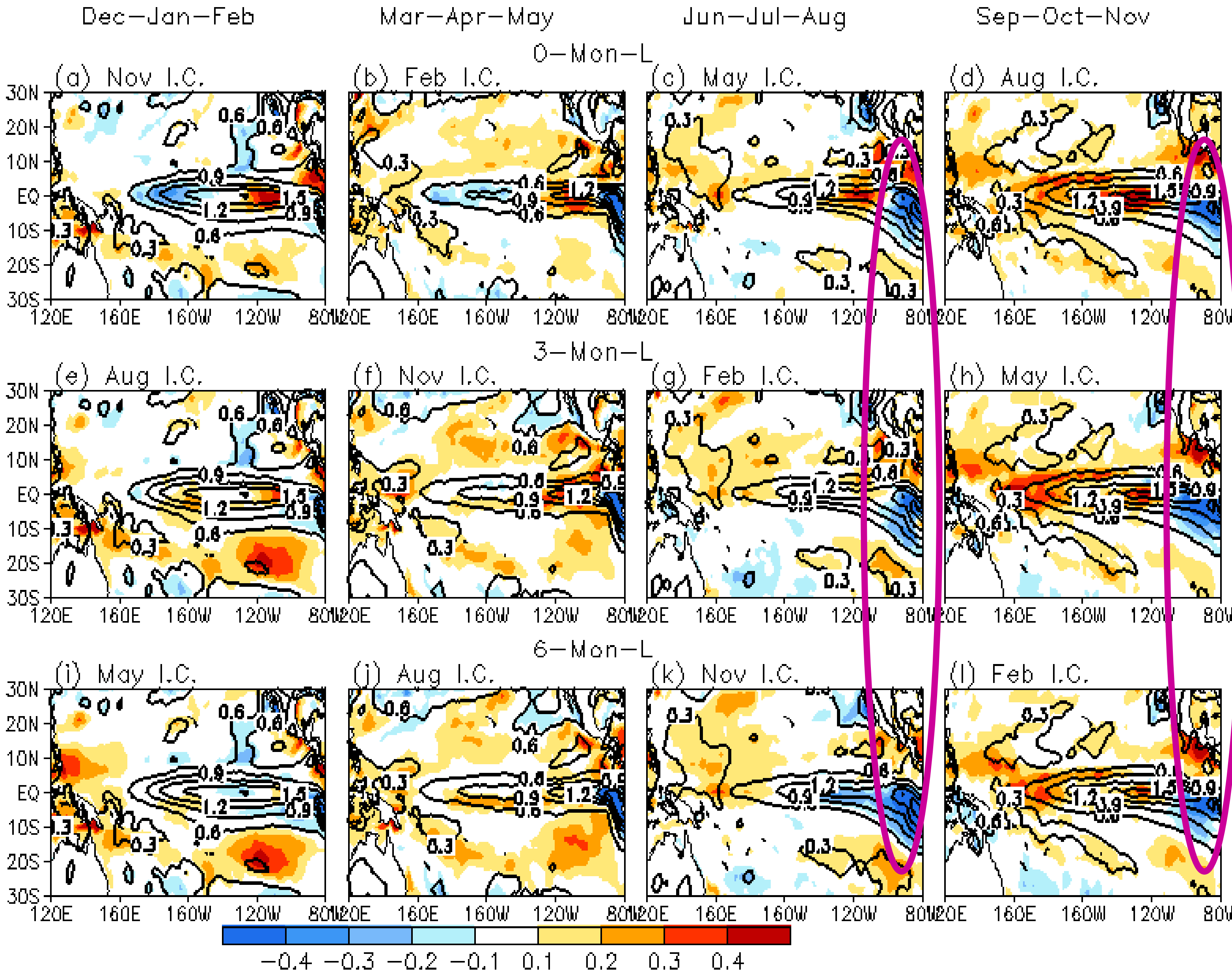
NINO4 zonal wind stress
CFSR (shading), R1, R2, ERA40

Xue et al. 2011, Clim. Dyn.

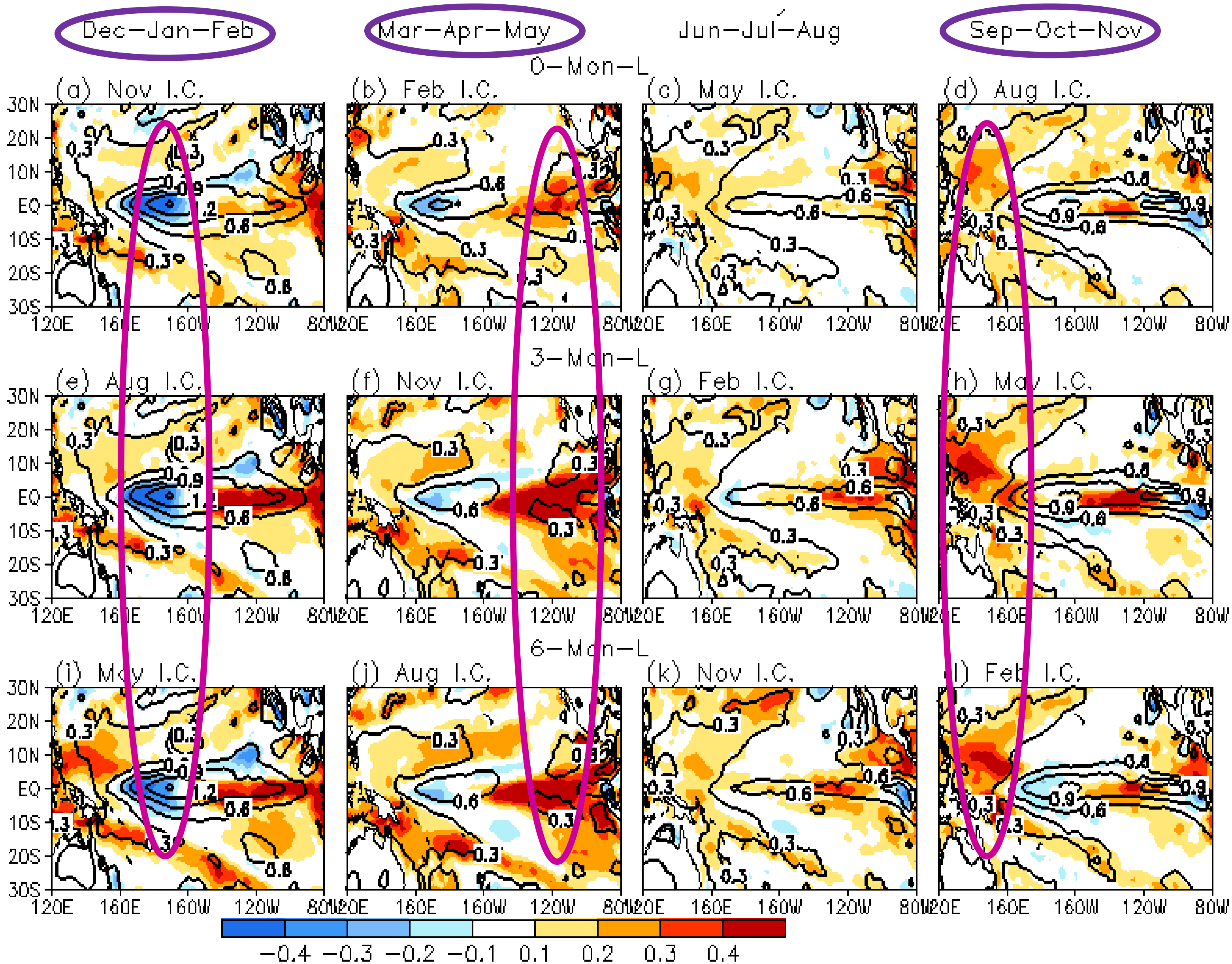
CFSv2 Nino 3.4 SST Difference from OISST



Standard Deviation of SST Anomaly in 1982-1998

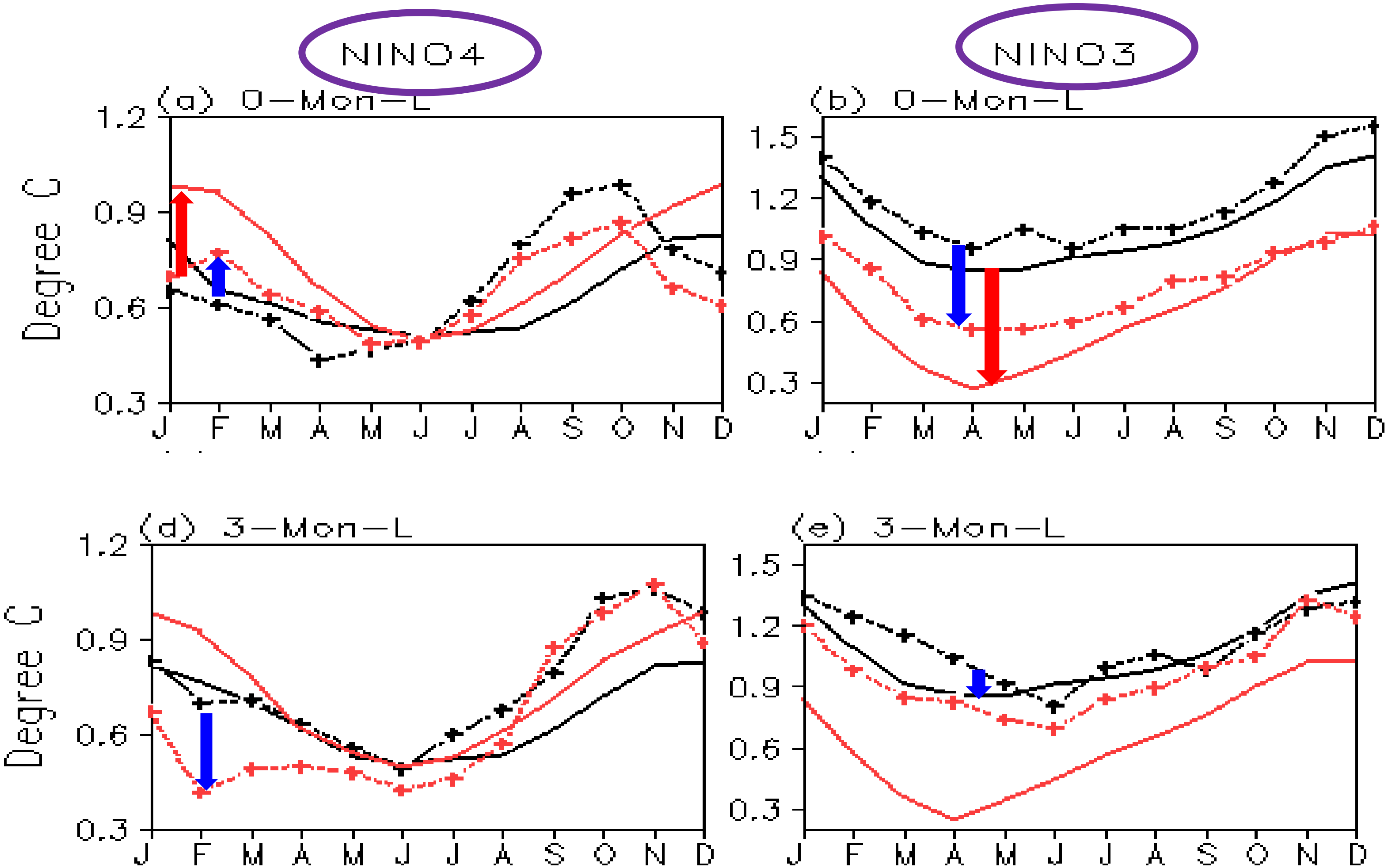


Standard Deviation of SST Anomaly in 1999-2010



Standard Deviation of NINO4 and NINO3

82-98 (black), 99-10 (red), OBS (solid line), CFSv2 (dashed line)

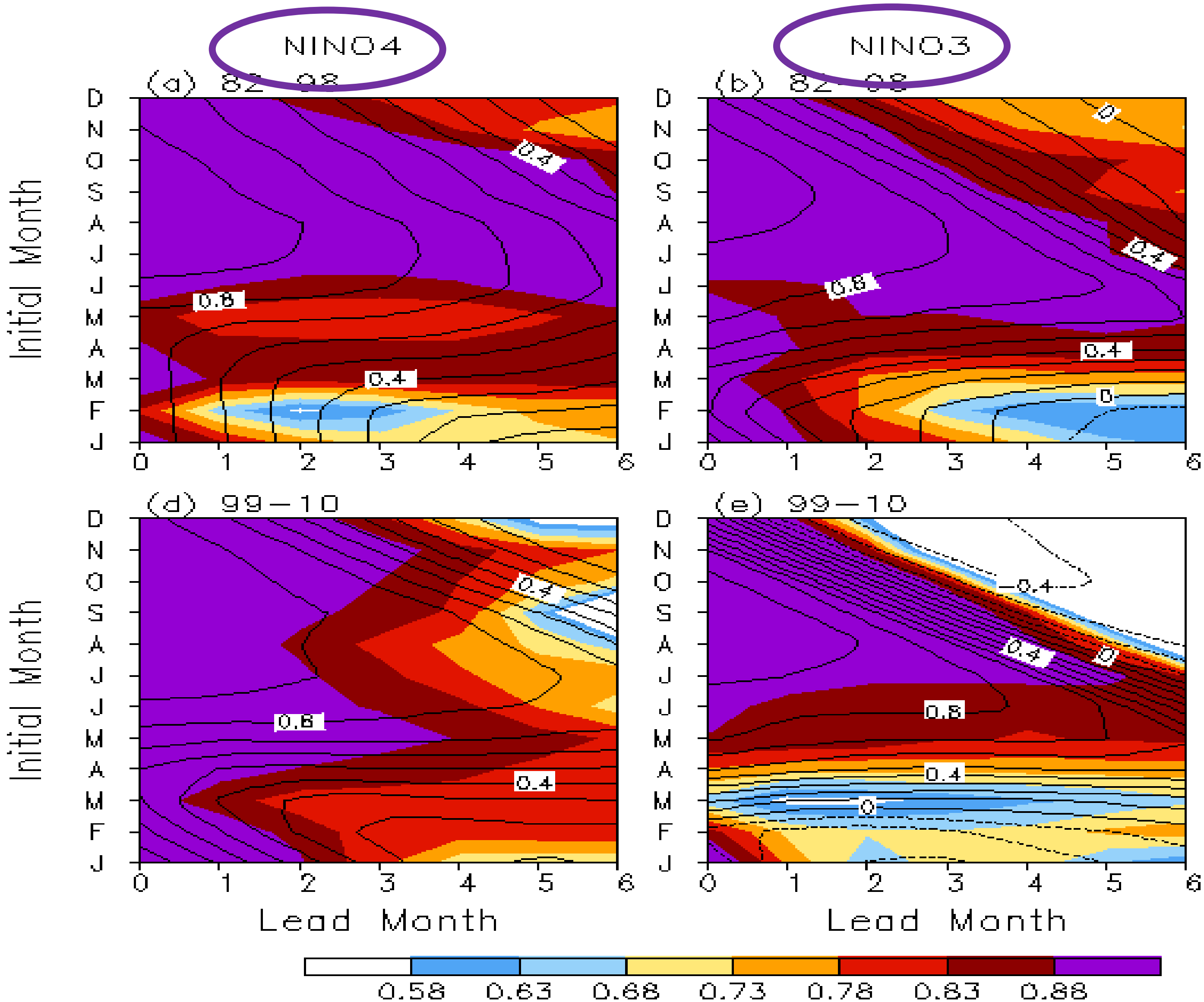


Anomaly Correlation Coefficient of NINO4 and NINO3

CFSv2 (shading), Persistence (contour)

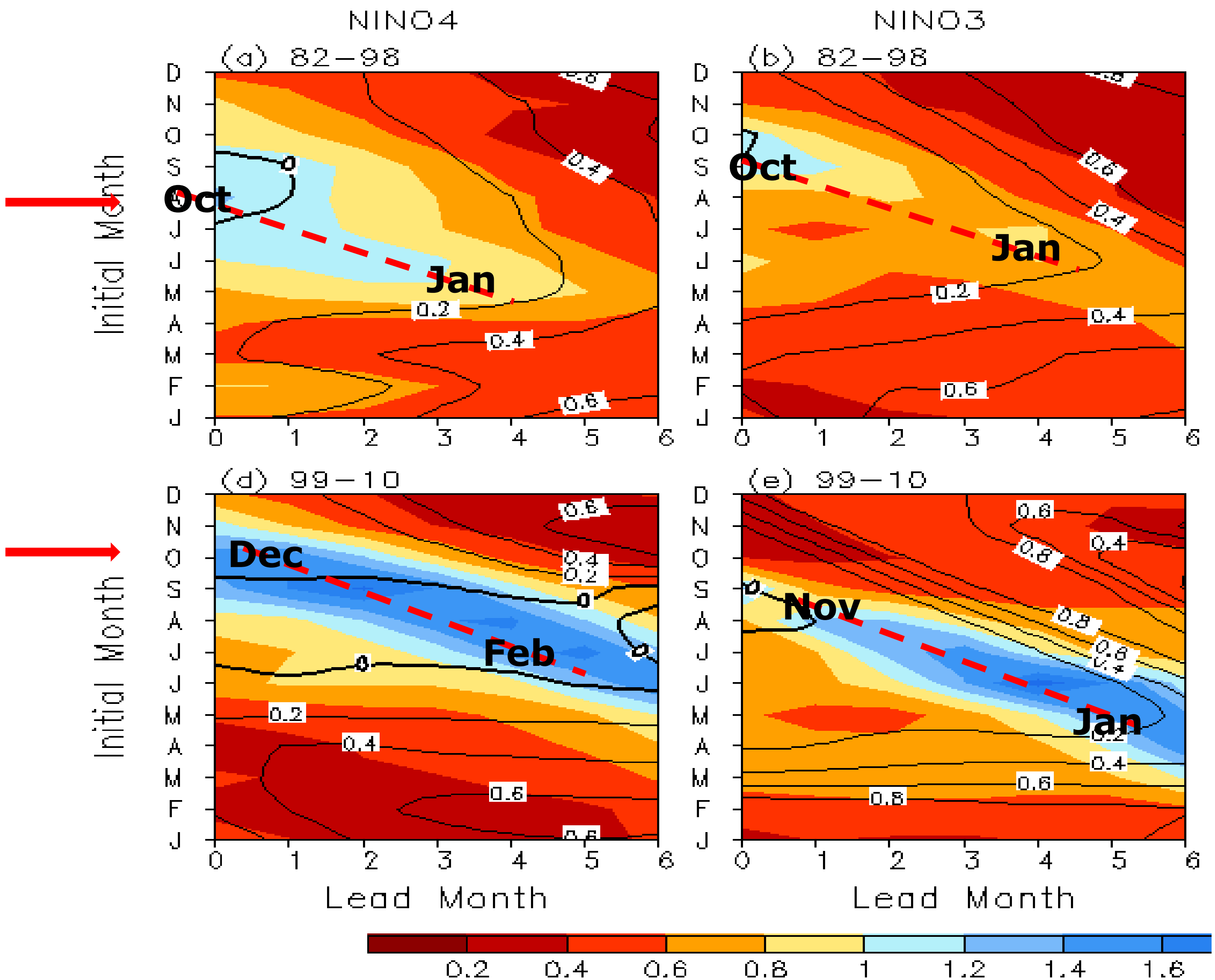
82-98

99-10

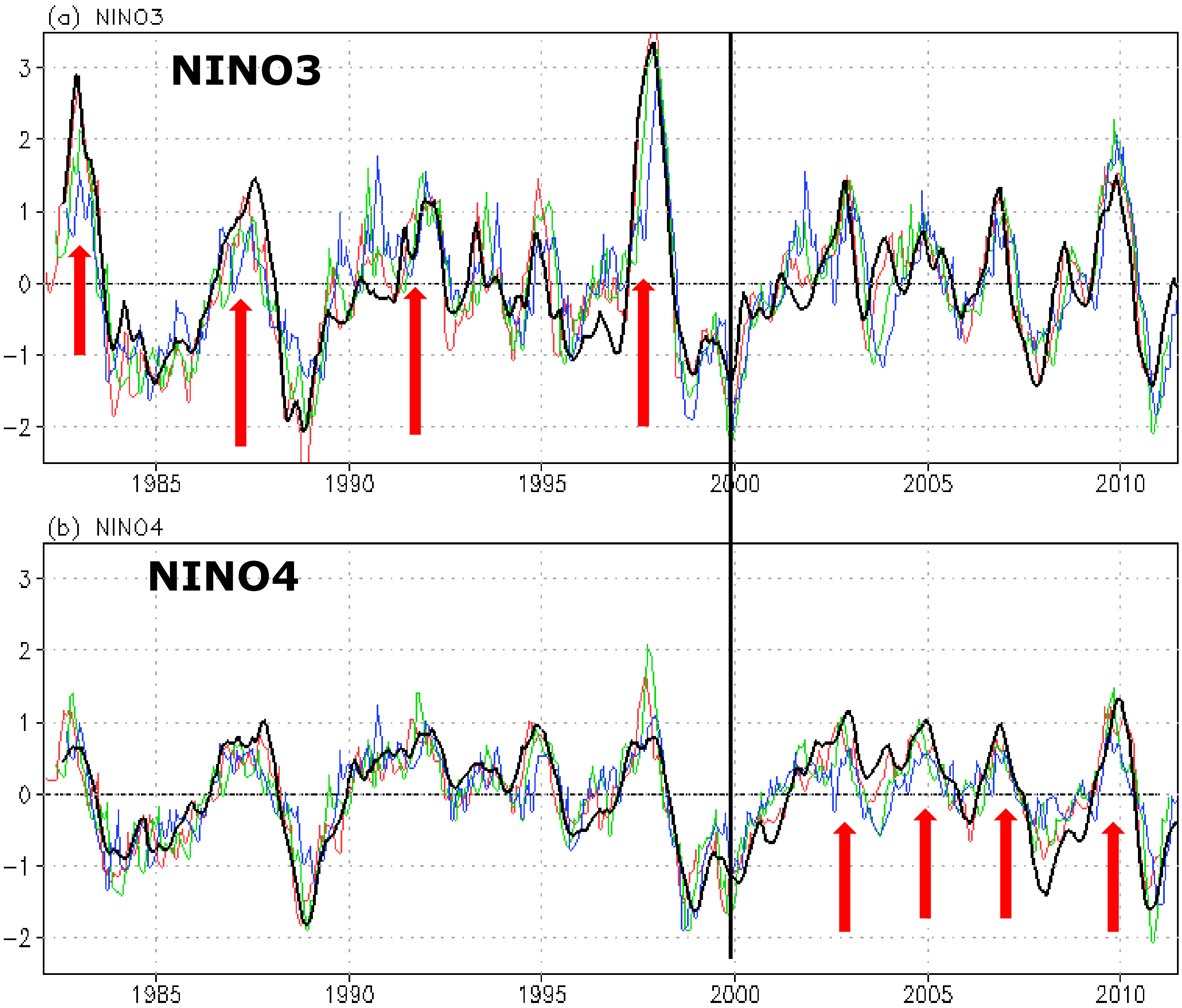


RMSE Ratio of CFSv2 and Persistence (shading)

ACC Difference of CFSv2 and Persistence (contour)

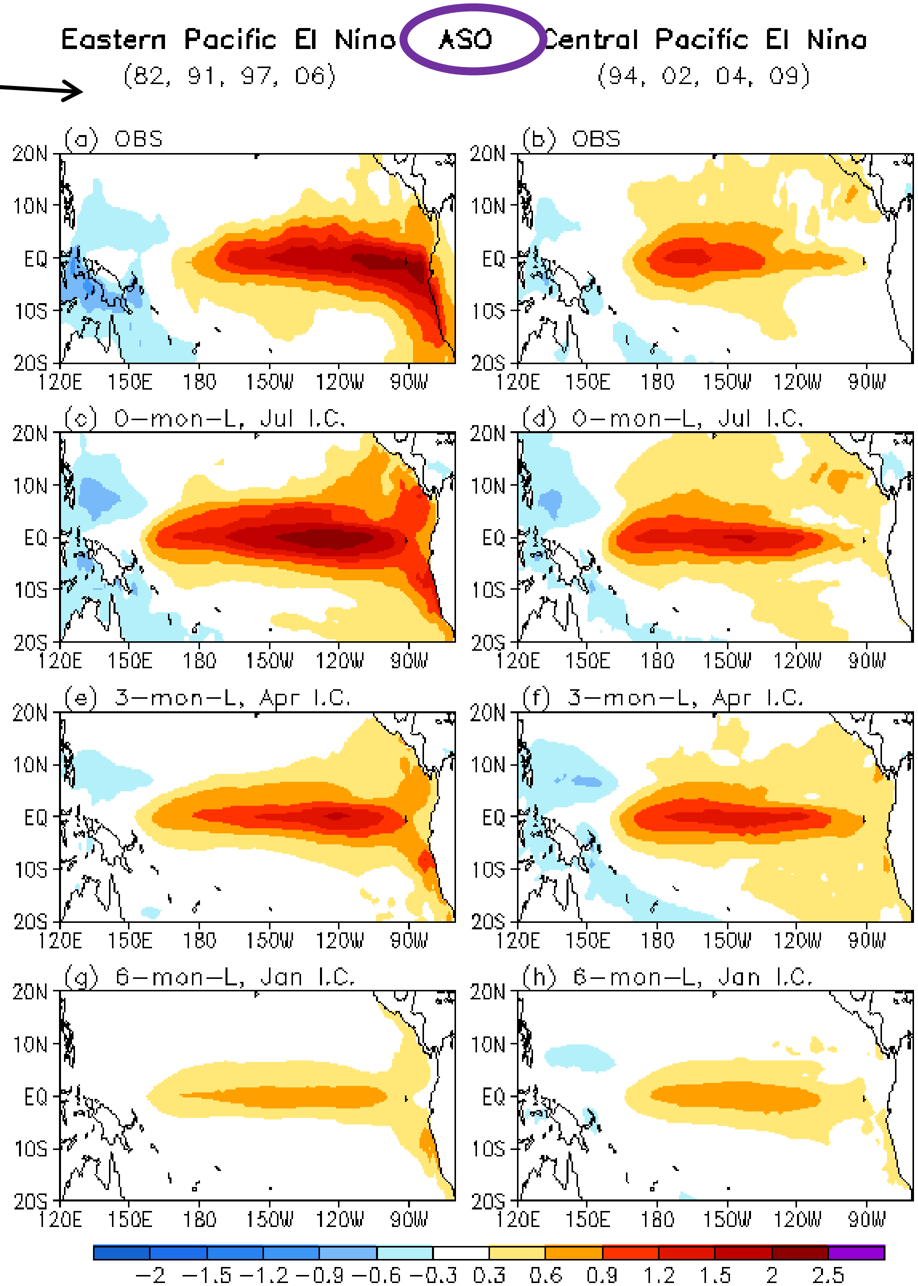


OBS (black), 0-Mon-L (red), 3-Mon-L (green), 6-Mon-L (blue)

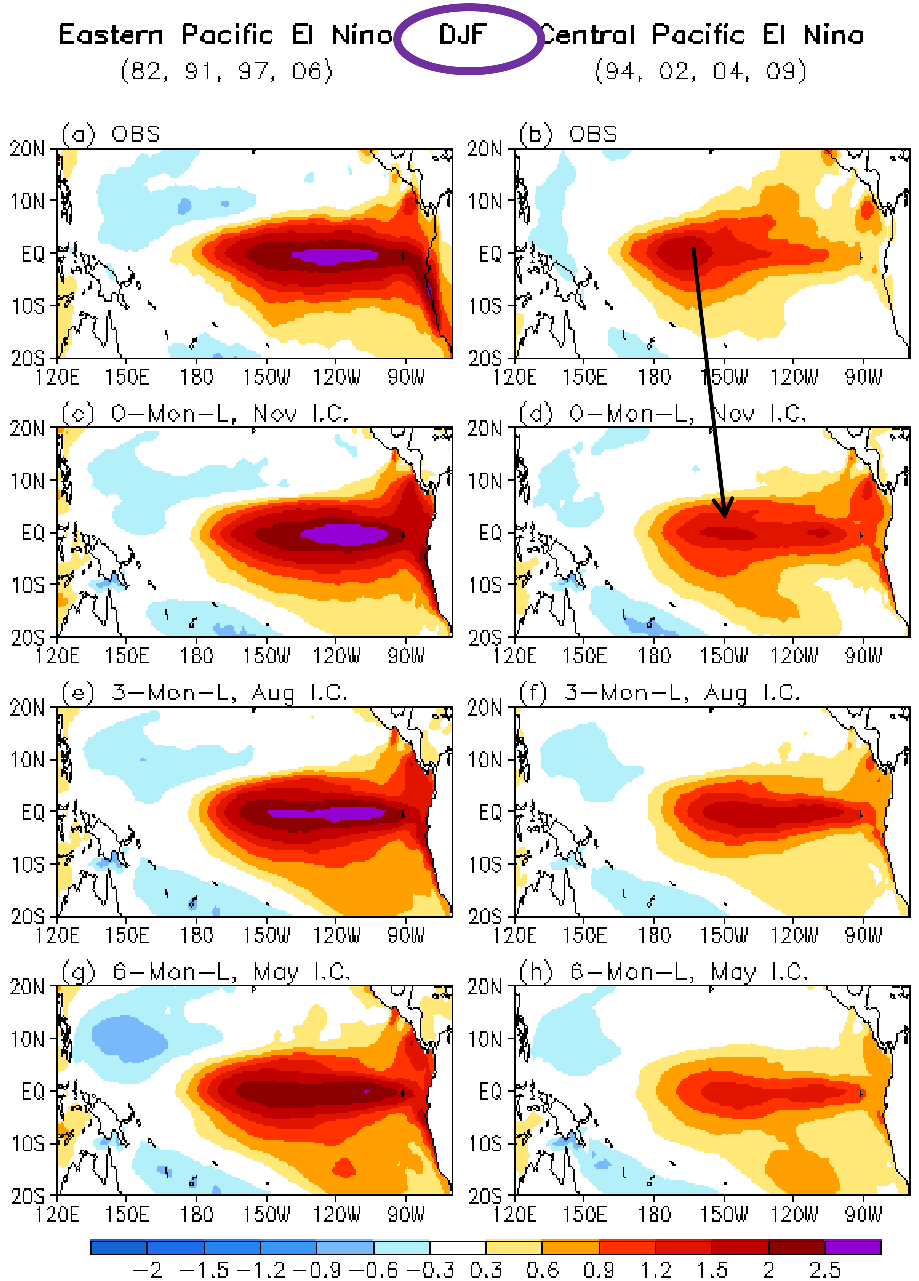


Lee and McPhaden 2010

Aug-Sep-Oct

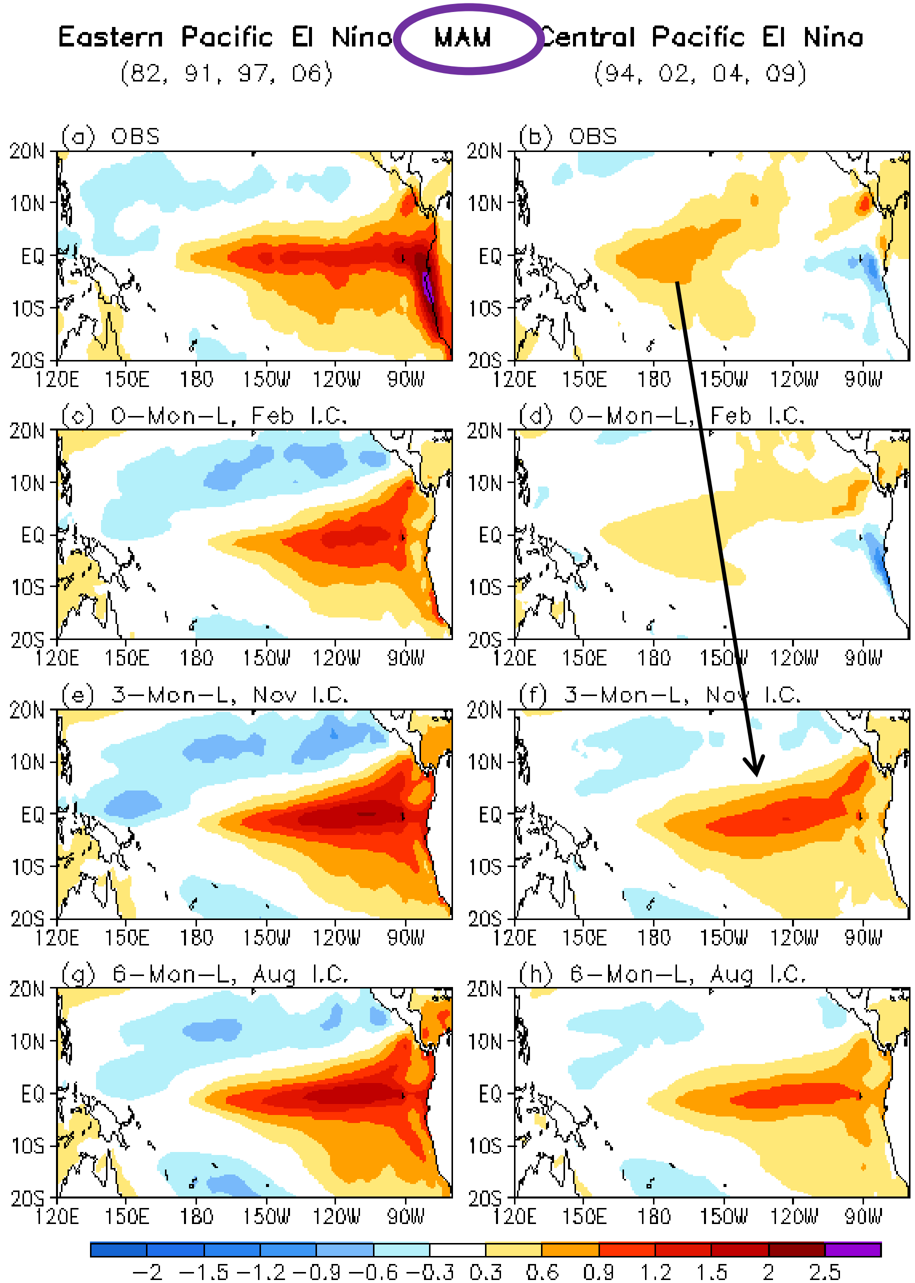


Dec-Jan-Feb



Eastern Pacific El Nino
(82, 91, 97, 06)
DJF
Central Pacific El Nino
(94, 02, 04, 09)
(a) OBS
(b) OBS
(c) 0-Mon-L, Nov I.C.
(d) 0-Mon-L, Nov I.C.
(e) 3-Mon-L, Aug I.C.
(f) 3-Mon-L, Aug I.C.
(g) 6-Mon-L, May I.C.
(h) 6-Mon-L, May I.C.
20N 10N EQ 10S 20S
120E 150E 180 150W 120W 90W
-2 -1.5 -1.2 -0.9 -0.6 -0.3 0.3 0.6 0.9 1.2 1.5 2 2.5

Mar-Apr-May



Eastern Pacific El Nino
(82, 91, 97, 06)
MAM
Central Pacific El Nino
(94, 02, 04, 09)
(a) OBS
(b) OBS
(c) 0-Mon-L, Feb I.C.
(d) 0-Mon-L, Feb I.C.
(e) 3-Mon-L, Nov I.C.
(f) 3-Mon-L, Nov I.C.
(g) 6-Mon-L, Aug I.C.
(h) 6-Mon-L, Aug I.C.
20N 10N EQ 10S 20S
120E 150E 180 150W 120W 90W
-2 -1.5 -1.2 -0.9 -0.6 -0.3 0.3 0.6 0.9 1.2 1.5 2 2.5

Summary

- **There was a systematic cold bias near the Eq. with largest amplitude (- 2.5^{o}C) during summer/fall before 1999;**
- **The cold bias near the Eq. dissipated largely in 1999-2010 related to a sudden increase in subsurface temperature in E. Pacific in CFSR when ATOVS satellite observations were assimilated in late 1998;**
- **The difference in systematic bias in hindcast SST for the period before and after 1999 reached about 1.5^{o}C during fall/winter. Therefore, SST anomaly (SSTA) was derived by removing model climatology for 1982-1998 and 1999-2010 separately;**
- **Efforts are needed to remove the discontinuity in the CFSR around 1999.**

Summary

- The standard deviation (STD) of forecast SSTA agreed well with that of observation in 1982-1998, but in 1999-2010 it was about 200% too strong in E. Pacific and 50% too weak near Dateline during winter/spring;

- The change of STD bias around 1999 was partially related to the change of ENSO characteristics - central-Pacific (CP) El Ninos were more frequent than eastern-pacific (EP) El Ninos after 2000 - and a poor performance of CFSv2 in distinguishing the CP and EP El Ninos;

- CFSv2 had a tendency to delay the onset phases of strong EP El Ninos, but predicted the decay phase very well. On the other hand, CFSv2 predicted the onset phases of CP El Ninos well, but prolonged the decay phases;

- On average, the CFSv2 forecasts beat the persistence for almost all initial months and lead months in 1982-1998, but in 1999-2010 they are less skillful than the persistence starting from summer/fall I.C., indicating a need for improvement.

Xue et al. 2013, J. Climate

Observing System Experiments for Tropical Pacific Observing System: Early Results

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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.

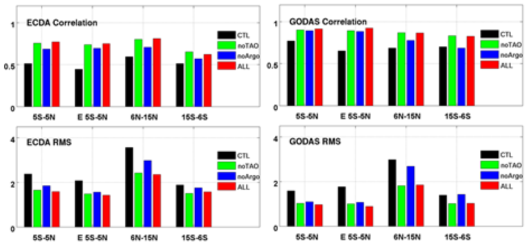
Four OSE runs are made, in which no observations (CTL), all observations (XBT, moorings, Argo) (ALL), all except the moorings (noTAO), and all except the Argo (noArgo) data are assimilated. Hindcast experiments are initialized with oceanic conditions from the four OSEs around January 1, April 1, July 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

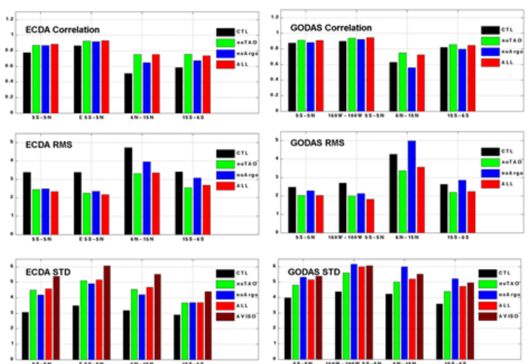
NCEP/GFDL OSE Runs

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

Annual Cycle of SSH



SSH Anomalies



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.

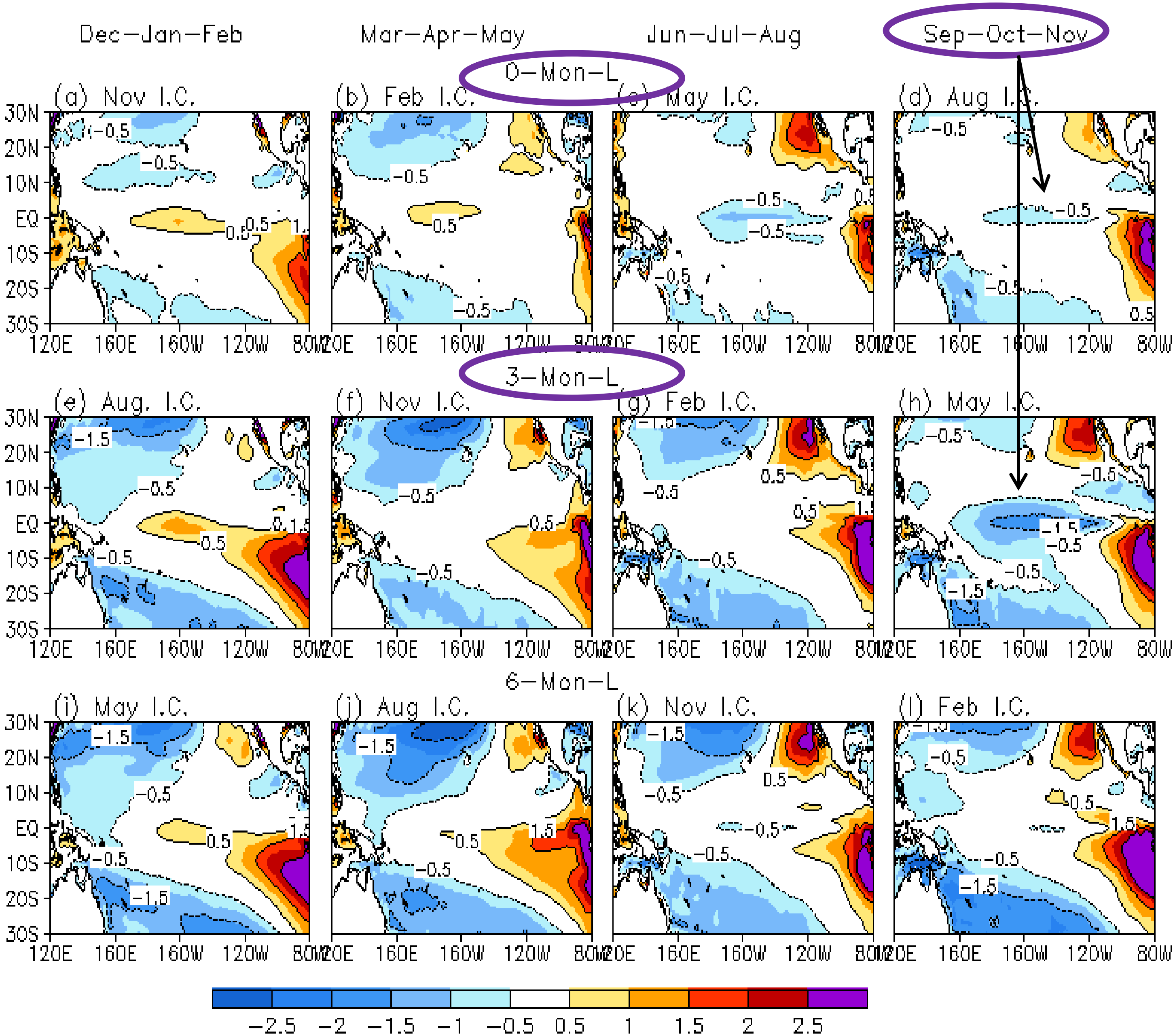
GFDL Ensemble Coupled Data Assimilation (ECDA):

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.

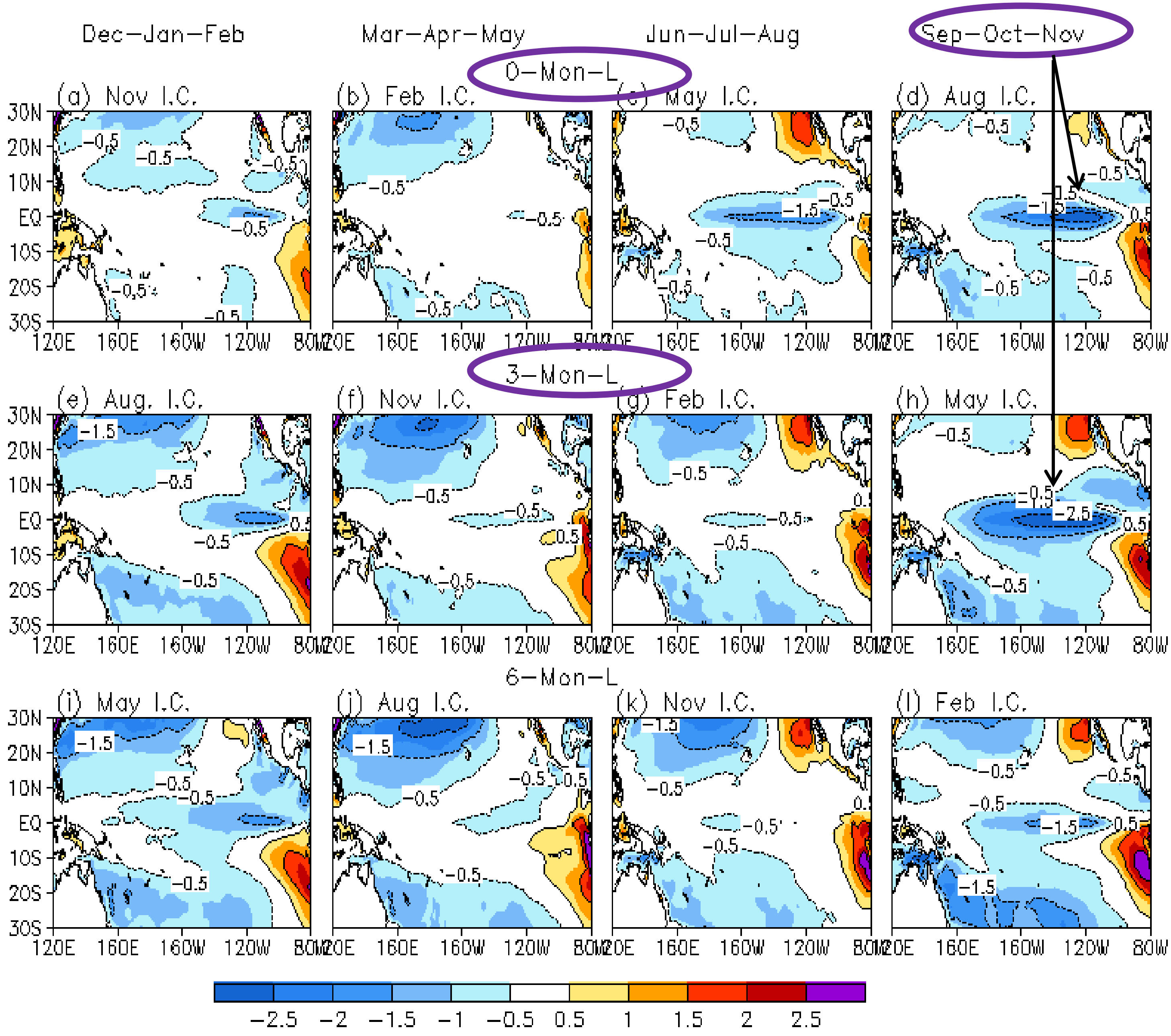
Validation SSH with Altimetry

- 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.

SST Bias in 1999-2010



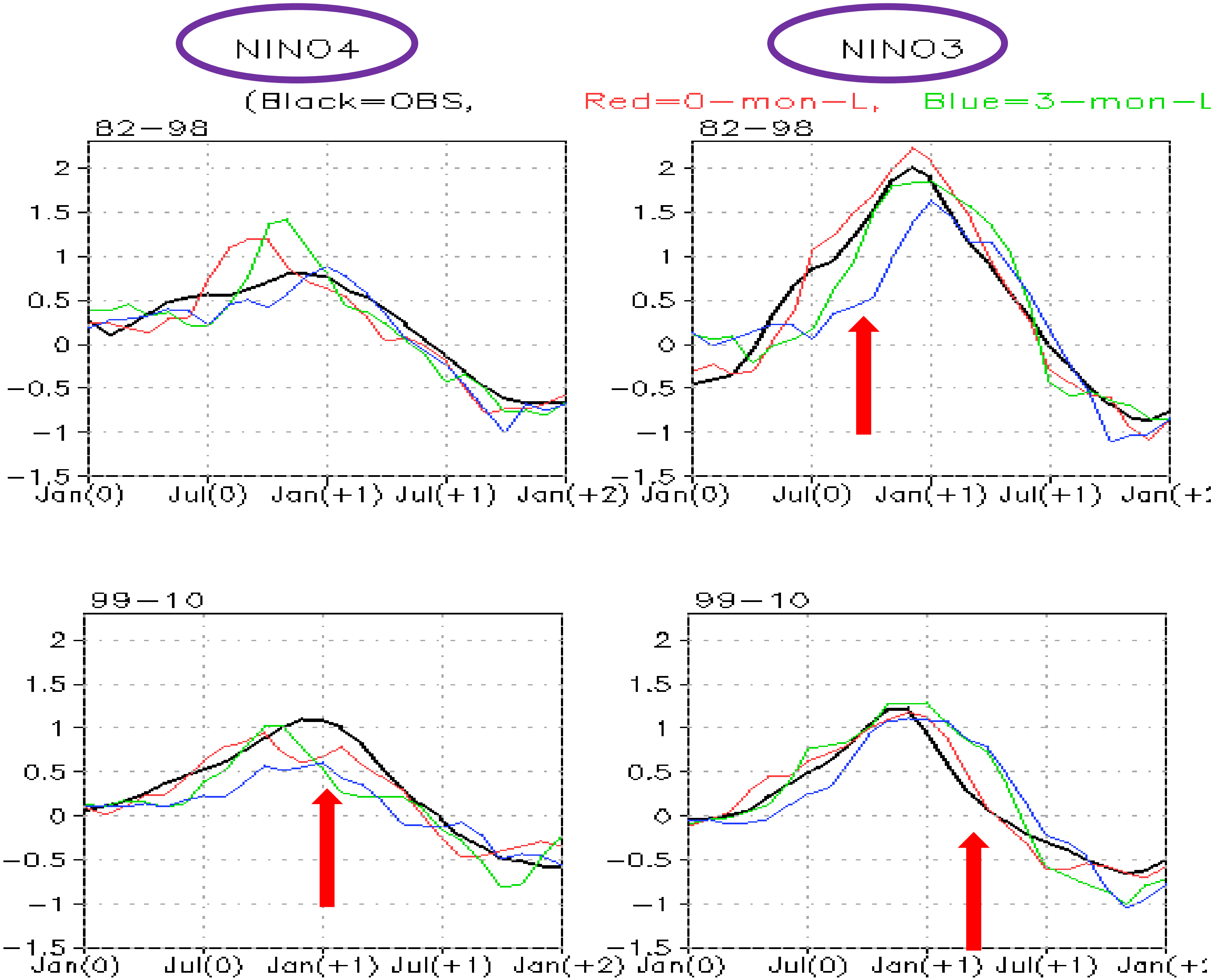
SST Bias in 1982-1998



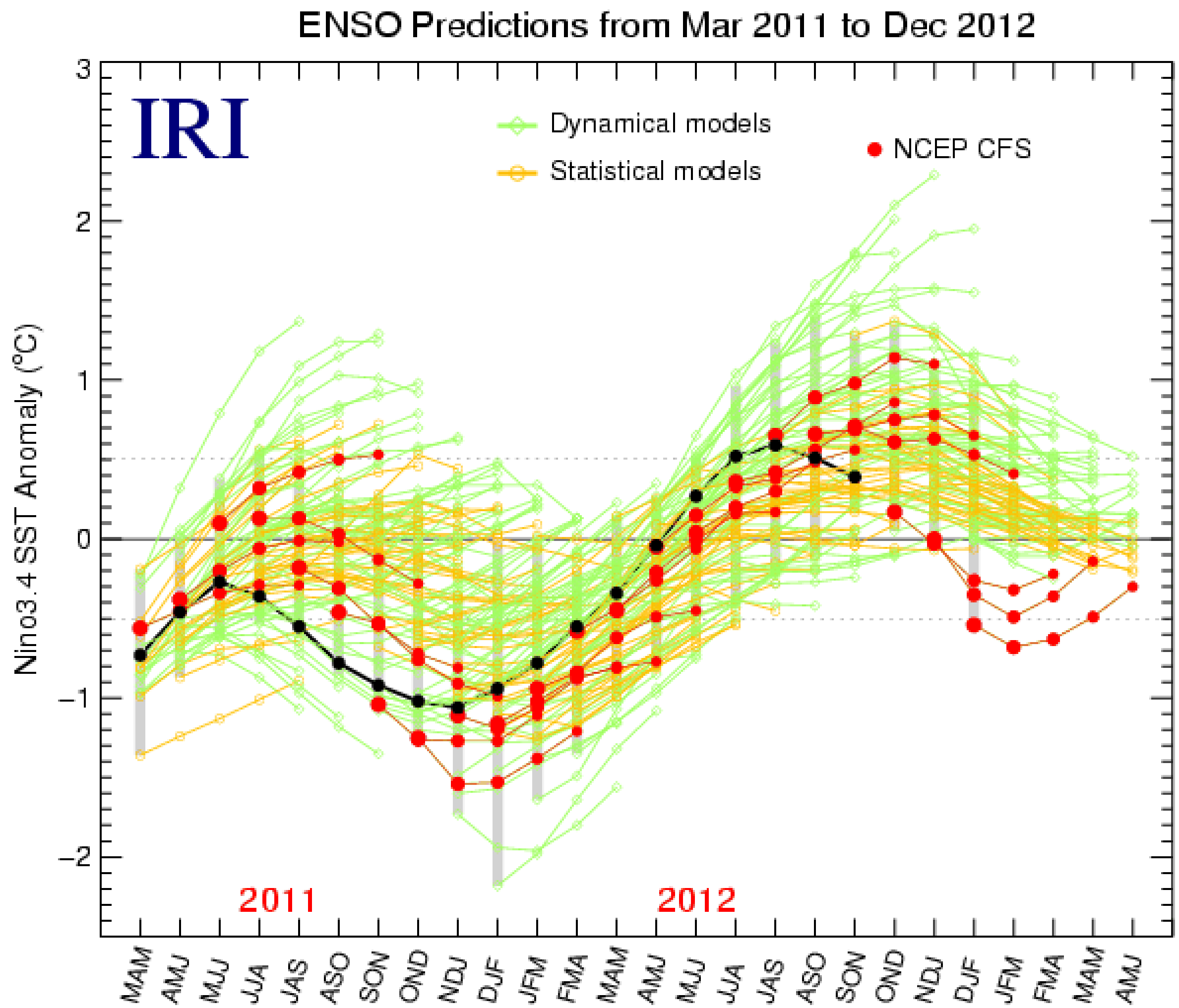
El Nino Composite

82-98

99-10

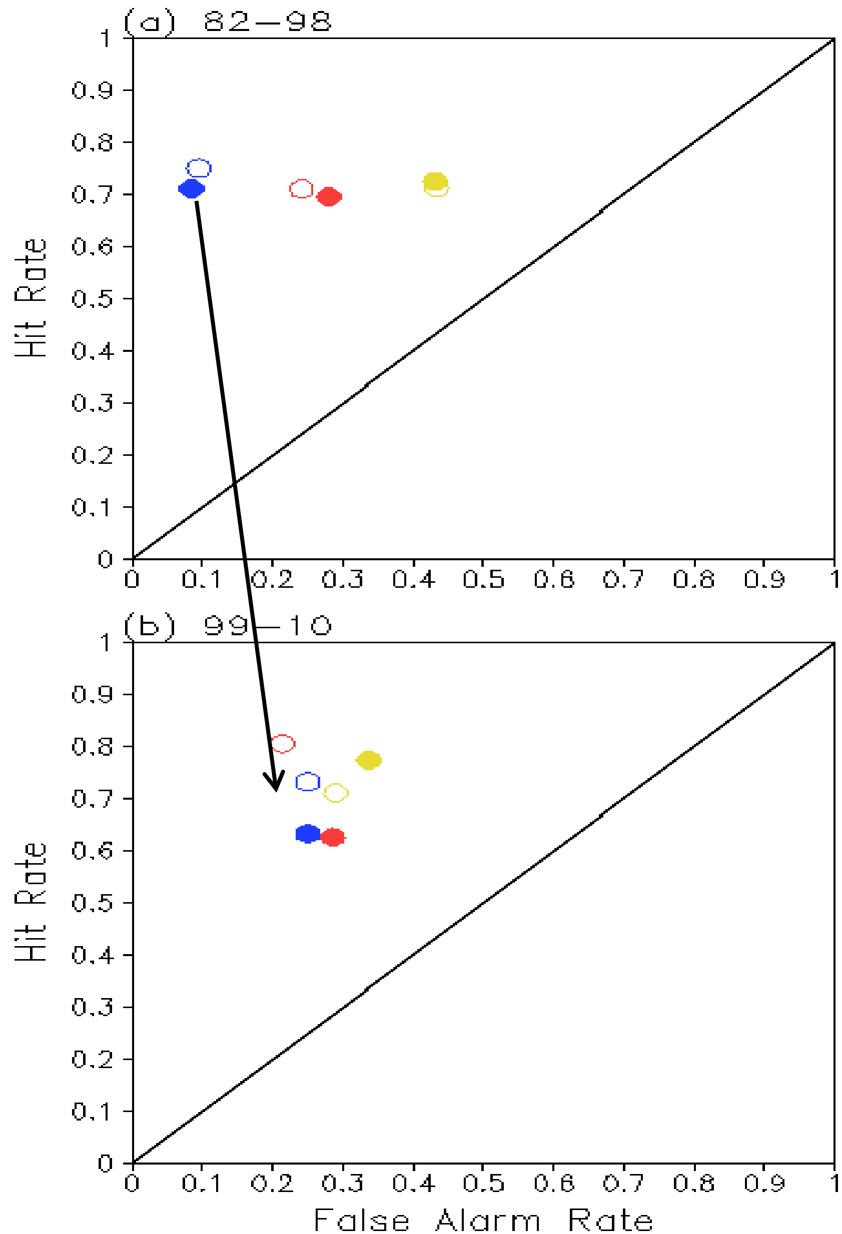


CFSv2 Forecasts over Last 22 Months



- **Recent CFSv2 forecasts are much colder than other model forecasts.**

La Nina
El Nino
Neutral



Anomaly Correlation Coefficient at 3-Month-Lead