False alarms in CFS ENSO Predictions

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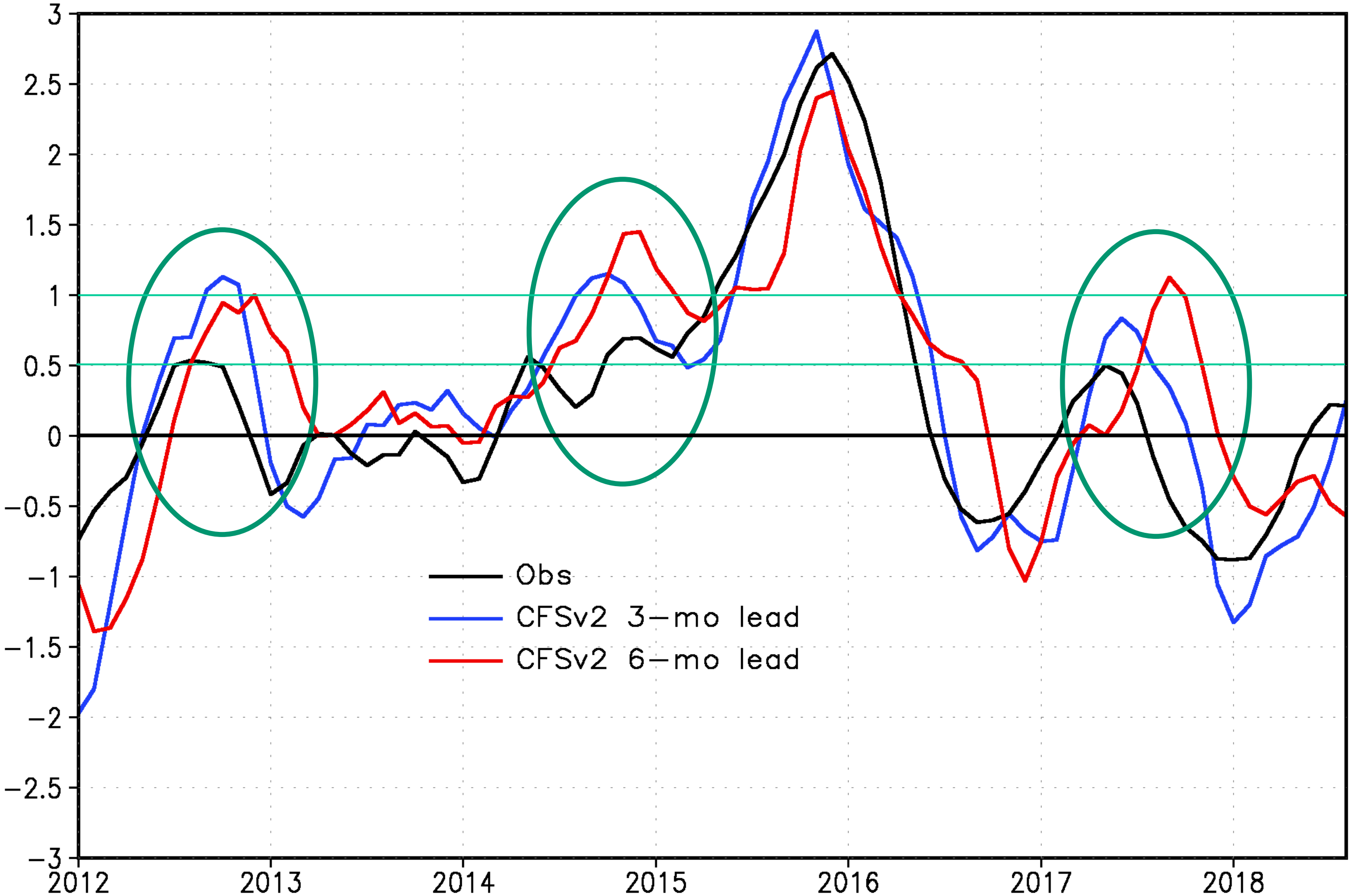
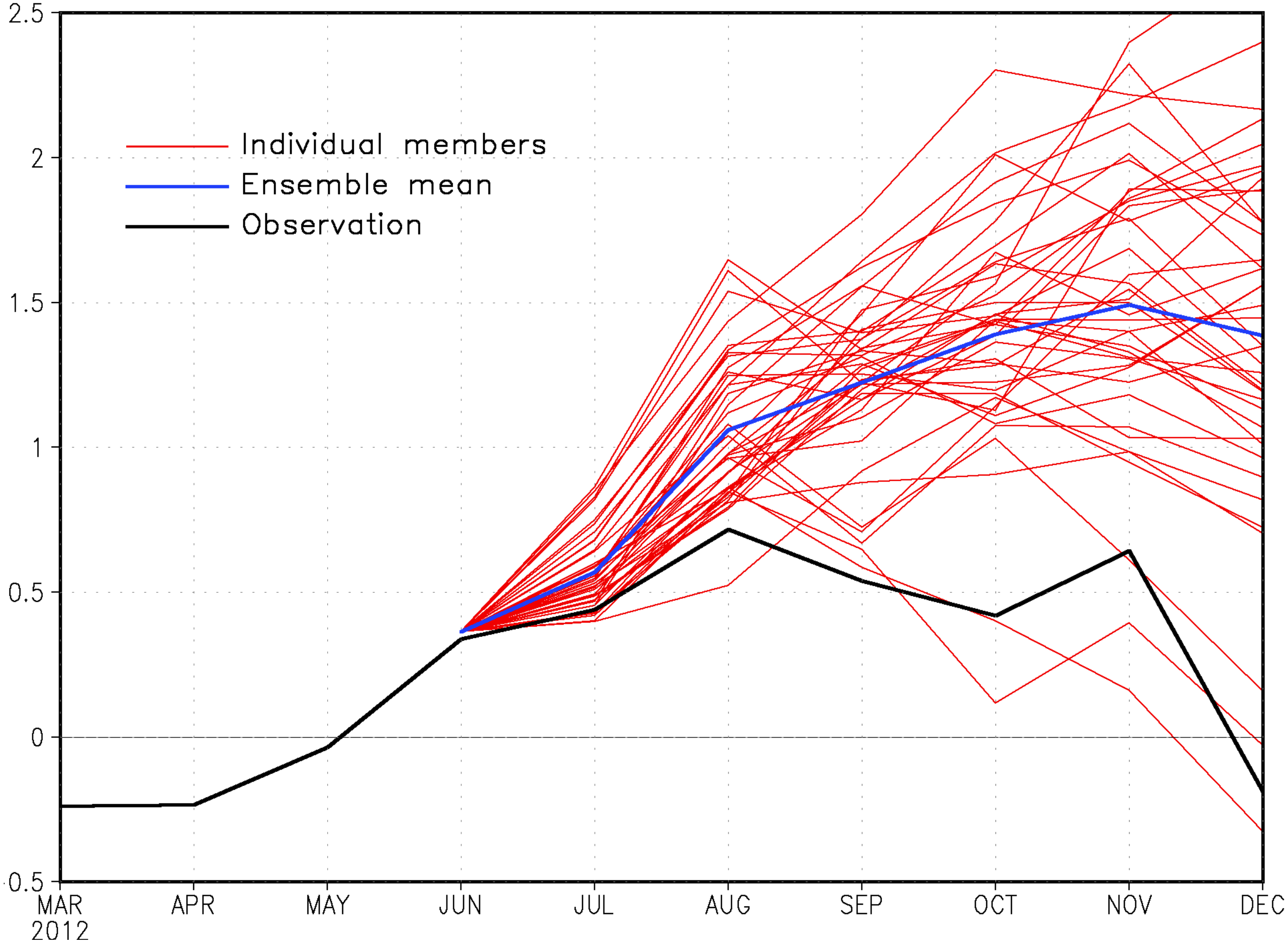
False alarms in CFSv2

Nino 3.4 index



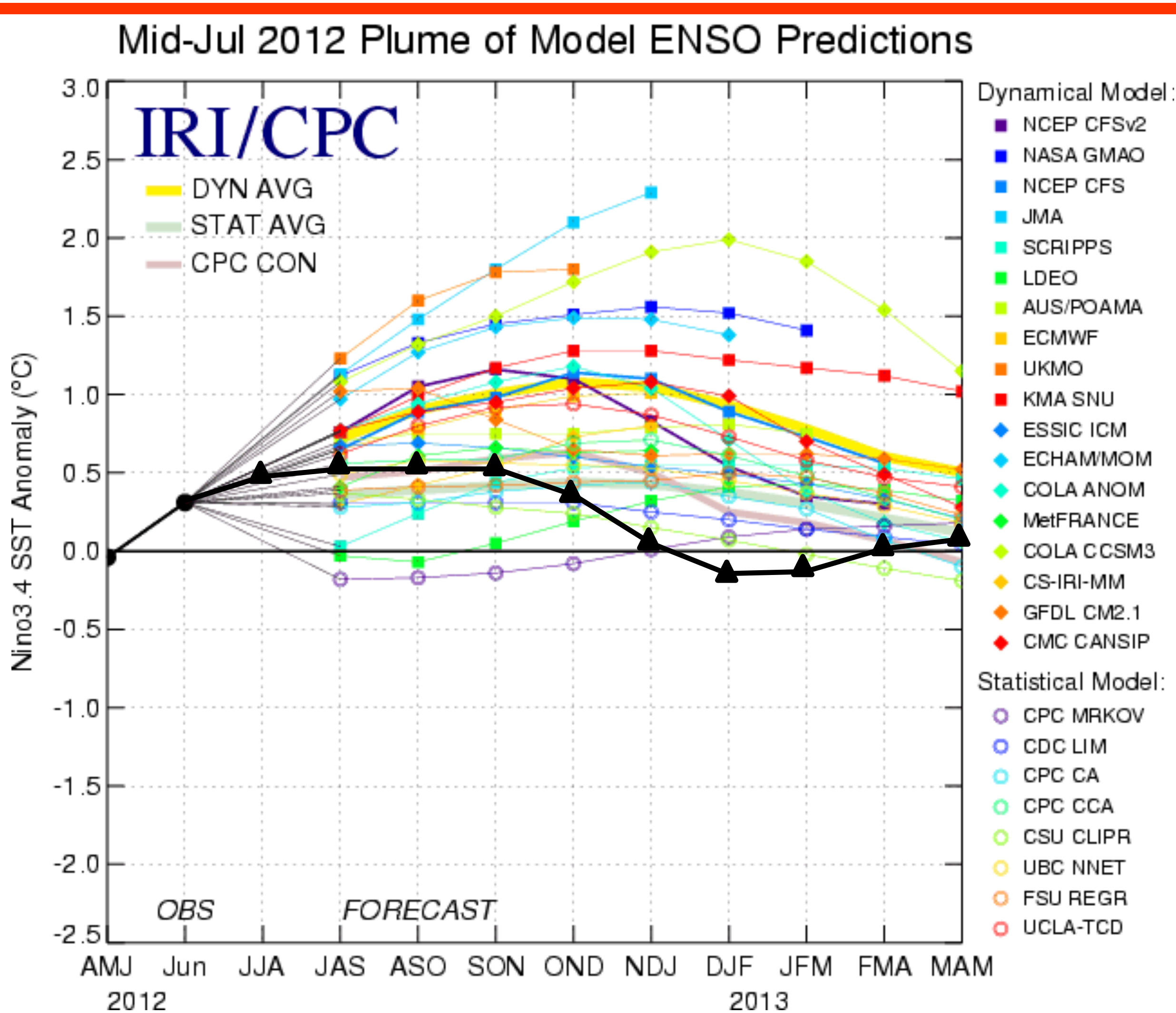
False alarms occurred in 2012, 2014, and 2017 in CFSv2 real-time forecasts.

Nino 3.4 index from CFSv2



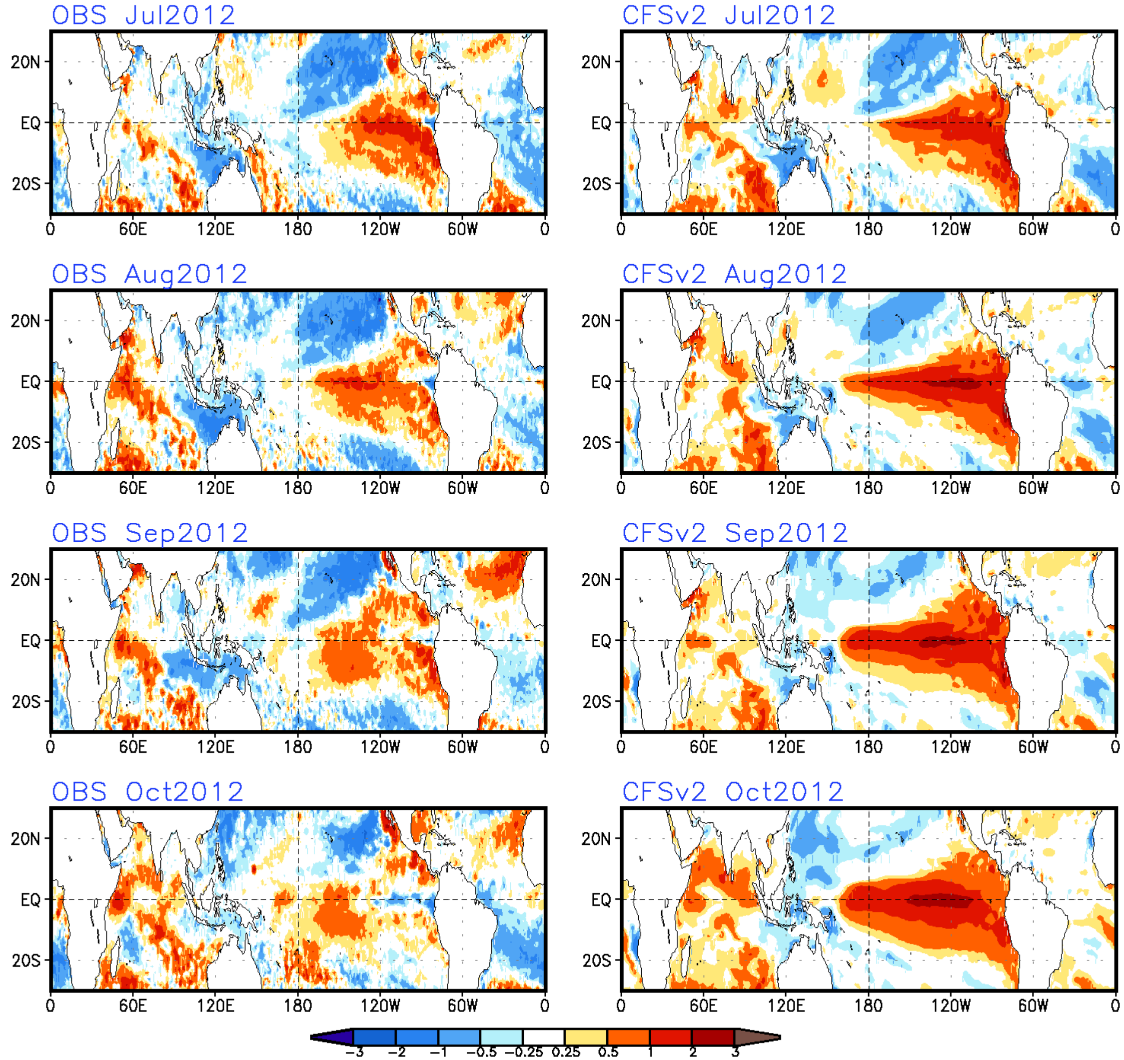
Jun 2012 forecast: After Sep, most runs were 0.5 warmer than obs.

IRI/CPC Nino 3.4 plume



Almost all dynamical models produced a false alarm in Jul 2012 ENSO plume.

CFSv2 SST forecast from June 2012



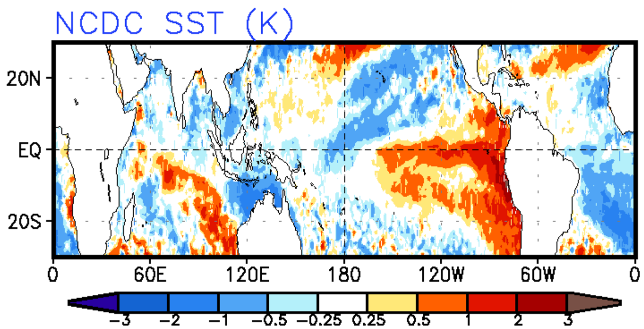
Initial anomalies decayed in the observation but enhanced in the forecast.

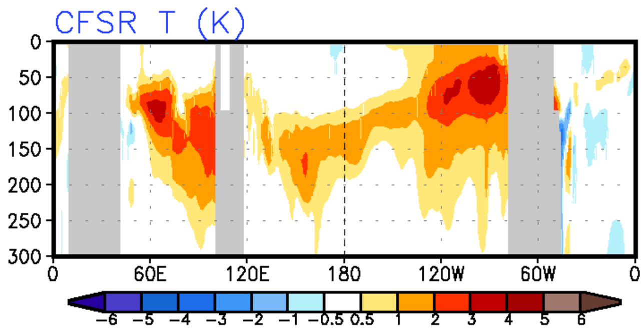
What caused the false alarms?

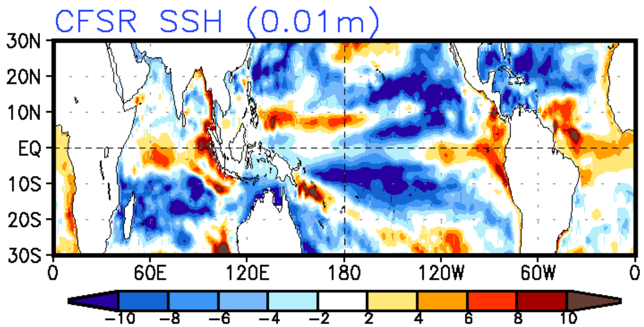
1. Errors in initial conditions

2. Errors in the model

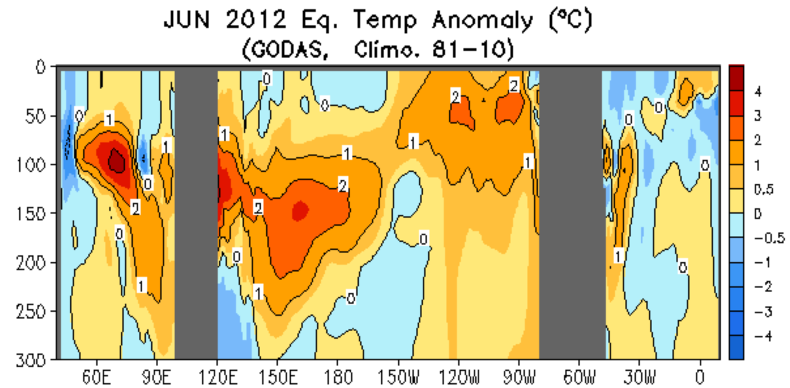
Jun 2012 oceanic state

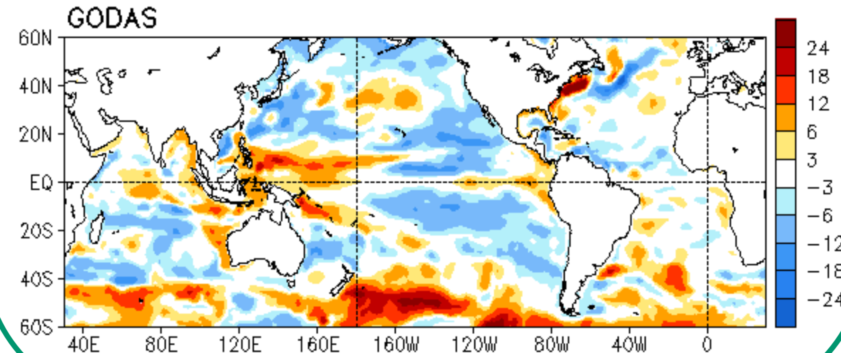






CPC Ocean Briefing

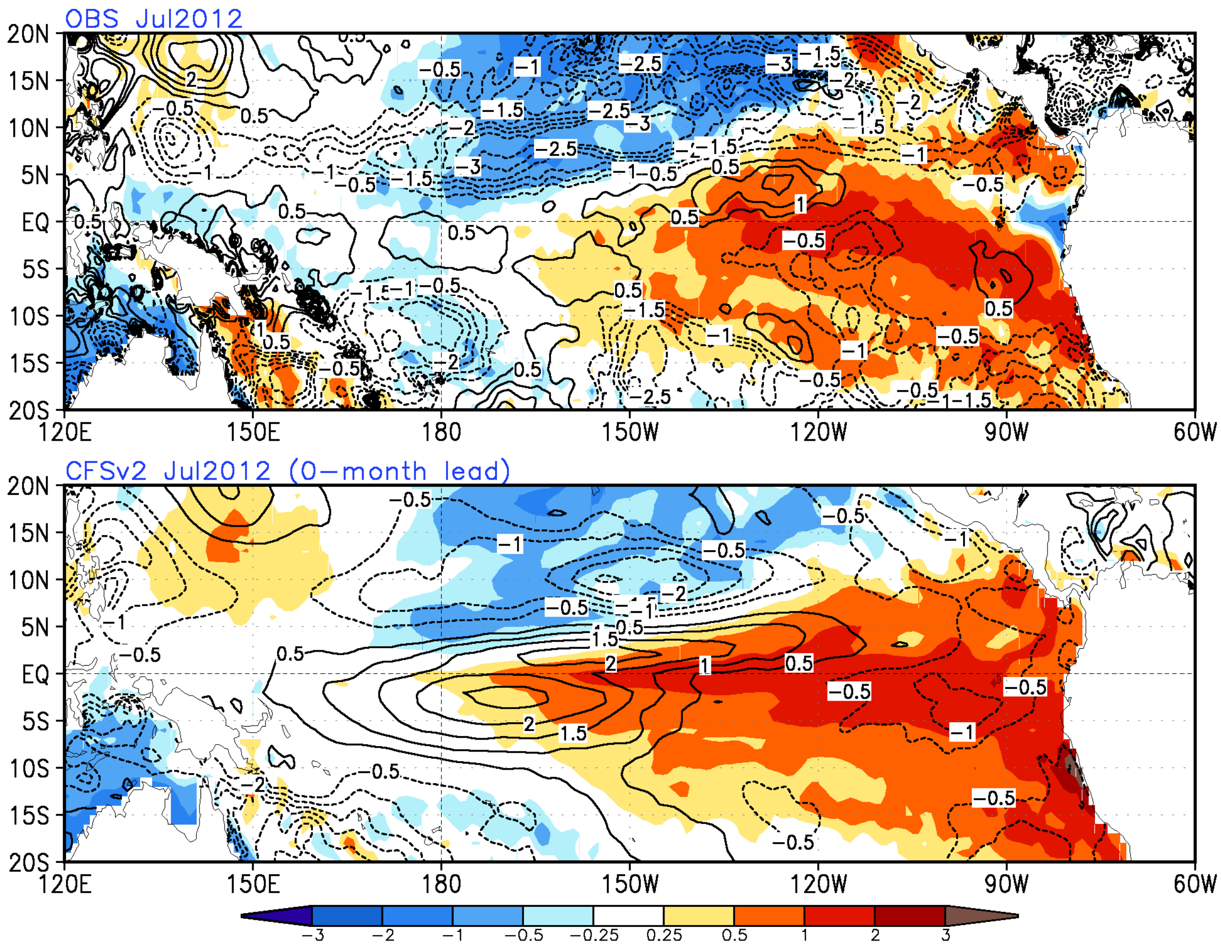




July 2012 SST (shading) and Taux (contour)

Obs

CFSv2



Forecast errors in the first month:

- Stronger westerly Taux in central Pacific
- SST started to become warmer

Hypothesis

1. CFSv2 El Nino false-alarm is due to unrealistic representation of air-sea interaction with too strong wind-stress/SST feedback.

2. Convection parameterization in the model is a cause for the unrealistic air-sea interaction.

Goals

1. Investigate air-sea interaction by analyzing atmospheric (oceanic) response to specified SST (surface forcing) in the CFS, focusing on the forecast from June 2012

2. Study impact of cumulus parameterizations on the air-sea interaction.

Outline

1) AMIP Simulations of atmospheric response to observed SST anomalies using three convection schemes

2) Oceanic response to atmospheric forcing from AMIP simulations

3) Initialized forecasts with a coupled model from 30 June 2012

Convection schemes

(1) SAS (Simplified Arakawa–Schubert cumulus convection). The SAS is used in NCEP Climate Forecast System (CFS). The SAS scheme (Pan and Wu 1995) is based on Arakawa and Schubert (AS, 1974) and simplified by Grell (1993) to consider only one cloud instead of a spectrum of clouds. Convection occurs when the cloud work function exceeds a certain threshold. A simple trigger is employed, which requires the level of free convection must exist and must be within the distance of 150 hPa of the parcel starting level.

(2) RAS (Relaxed Arakawa–Schubert cumulus convection). The RAS is used in many climate models. The RAS scheme (Moorthi and Suarez 1992, 1999) simplifies the entrainment relation and assumes that the normalized mass flux is a linear function of height rather than being exponential as in the original AS scheme. In addition, rather than requiring that 'quasi equilibrium' of the cloud ensemble be achieved each time, the scheme only relaxes the ambient atmospheric state toward equilibrium.

(3) SAS2 (Simplified Arakawa–Schubert version 2). SAS2 was used in operational GFS from 28 Jul 2010 to 18 Jul 2017. The SAS2 scheme (Han and Pan 2011) is modified from its earlier version (SAS). Instead of using a fixed distance of 150 hPa, the convection trigger in SAS2 uses a distance range of 120–180 hPa in proportion to the large-scale vertical velocity. Unlike the old SAS scheme, the revised SAS scheme specifies finite entrainment and detrainment rates for heat, moisture, and momentum above the cloud base following Bechtold et al. (2008).

1). **Atmospheric response to observed SST anomalies**

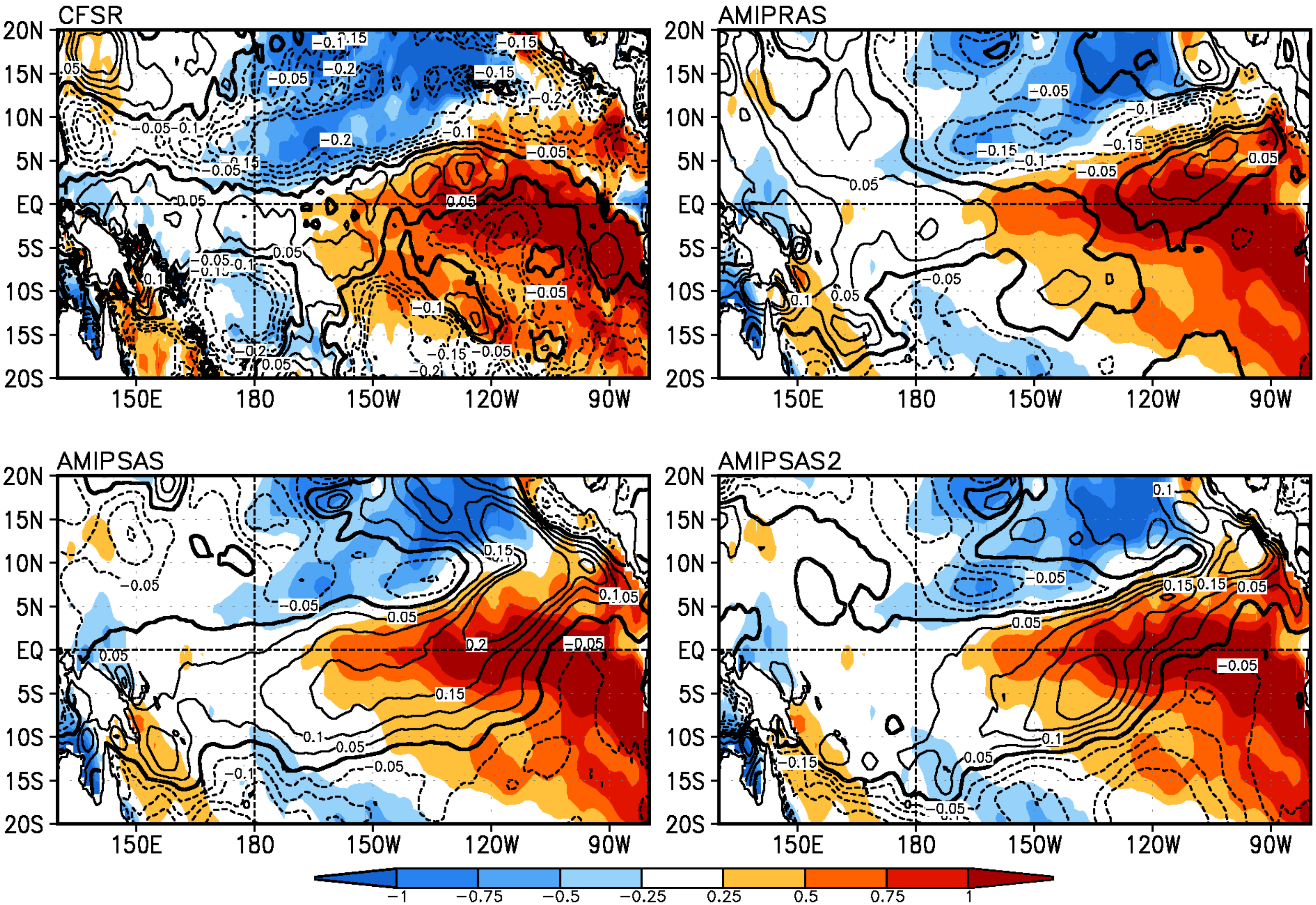
- Model

  GFS: Atmospheric component of CFSv2

- AMIP runs
  - Daily SST from NCEI analysis
  - 1999 to Dec 2010
    - ✓ One member
    - ✓ To establish climatology
  - Jan 2012 to Jul 2012
    - ✓ 18 members
    - ✓ To derive anomalous response in 2012
  - Three convection schemes
    - ✓ AMIPSAS (Simplified Arakawa-Schubert)
    - ✓ AMIPRAS (Relaxed Arakawa-Schubert)
    - ✓ AMIPSAS2 (Simplified Arakawa-Schubert v2)

1). **Atmospheric response to observed SST anomalies**

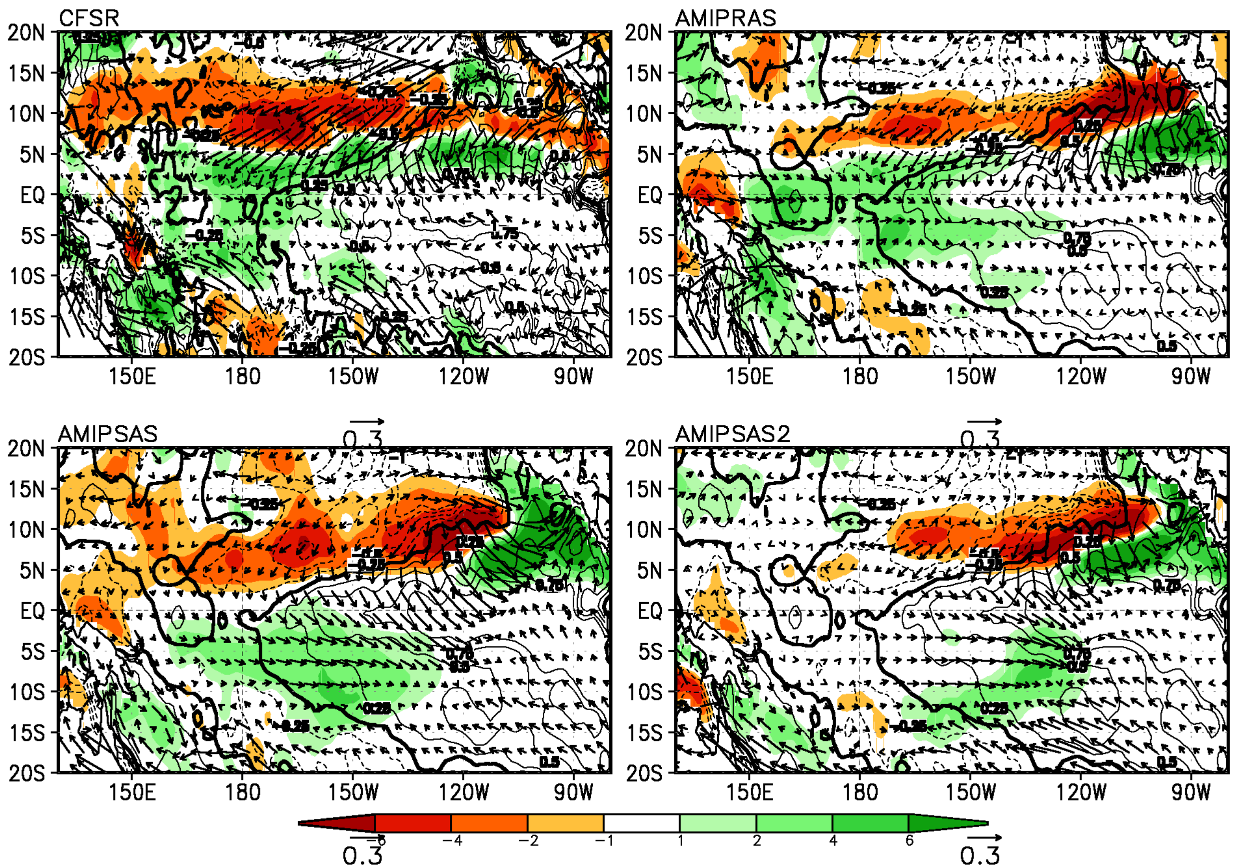
July 2012 SST (shading), Taux (contour)



1) Weak Taux anomalies in CFSR
2) Too strong Taux in central-eastern Pac with SAS and SAS2
3) More reasonable Taux with RAS

1). **Atmospheric response to observed SST anomalies**

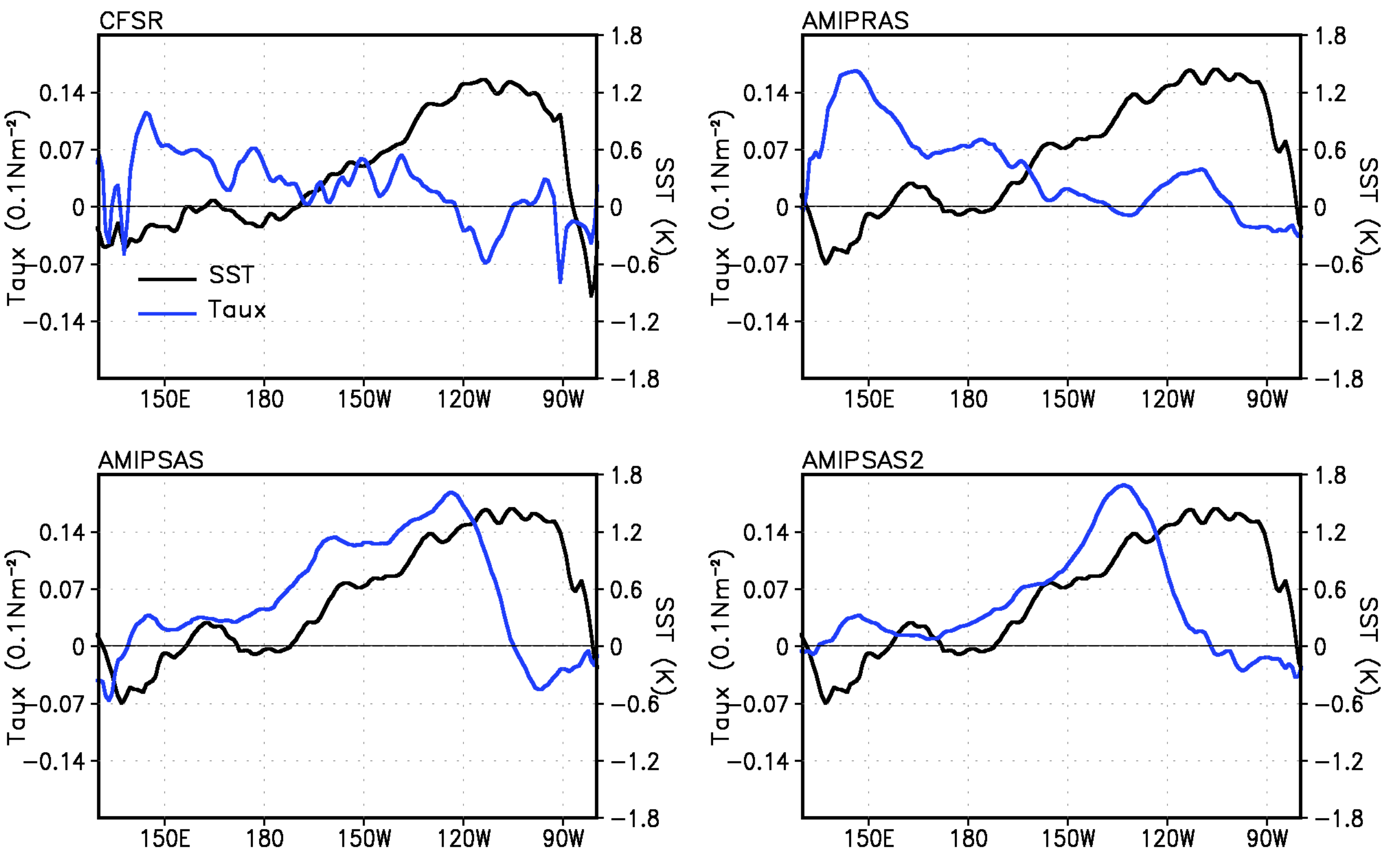
July 2012 SST (contour), rainfall (shading), Tau (vector)



- Unrealistic rainfall anomalies with SAS and SAS2, corresponding to too strong Tau in equatorial central-eastern Pacific
- More reasonable rainfall and Tau anomalies with RAS

1). **Atmospheric response to observed SST anomalies**

July 2012 SST and Taux (2S-2N average)



1) Weak Taux anomalies in CFSR
2) Too strong Taux in central-eastern Pac with SAS and SAS2
3) More reasonable Taux with RAS

How sensitive is the SST to the differences in Taux if used to force an ocean model?

2). **Oceanic response to AMIP forcing**

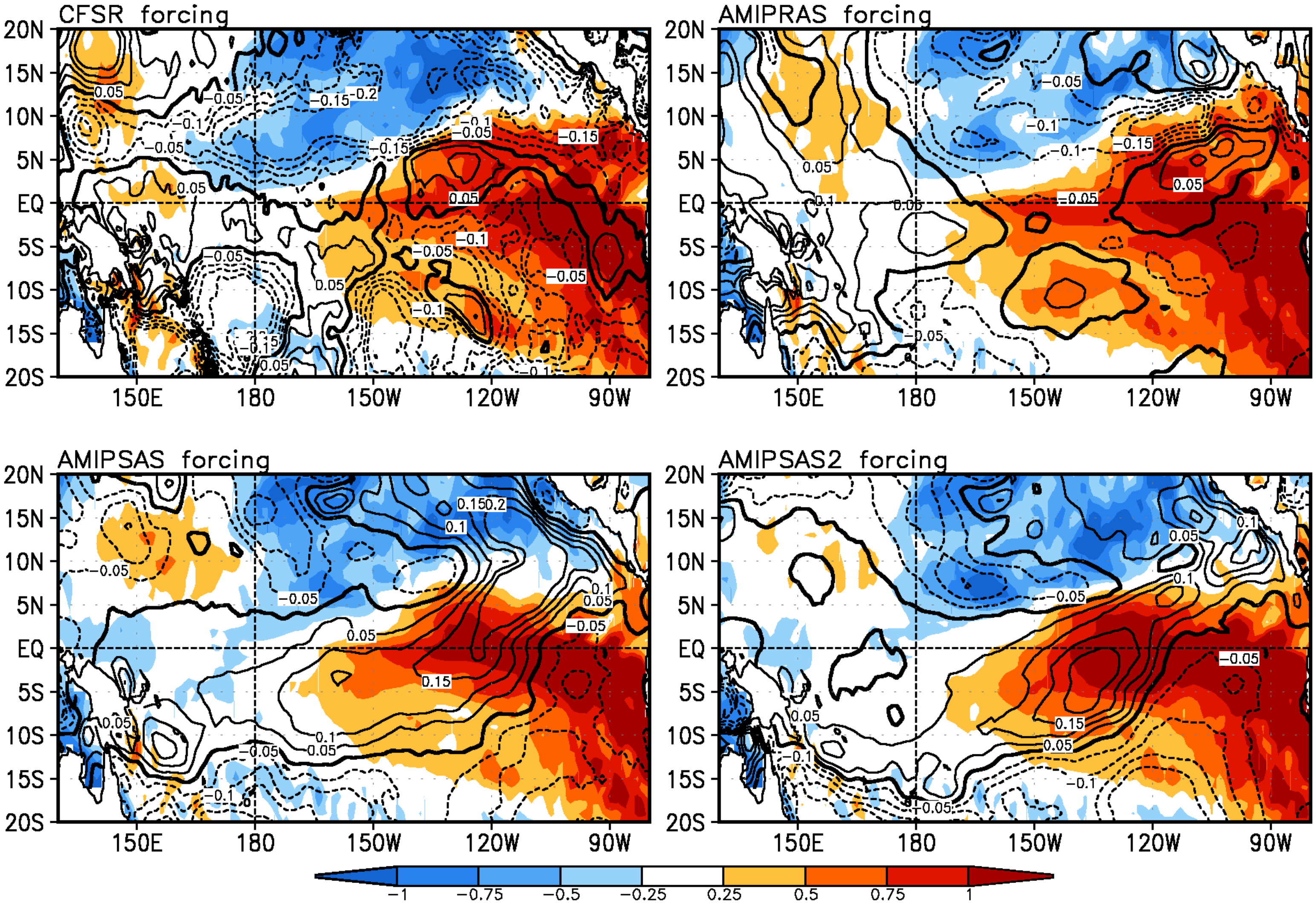
- Model

  MOM5: GFDL Modular Ocean Model v5

- MOM5 runs
  - Daily surface forcing from AMIP runs
  - 1999 to Dec 2010
    - ✓ One member
    - ✓ To establish climatology
  - July 2012
    - ✓ 18 members
    - ✓ To derive anomalous response in July 2012
  - Forcing from three AMIP runs
    - ✓ AMIPSAS forcing
    - ✓ AMIPRAS forcing
    - ✓ AMIPSAS2 forcing

2). **Oceanic response to AMIP forcing**

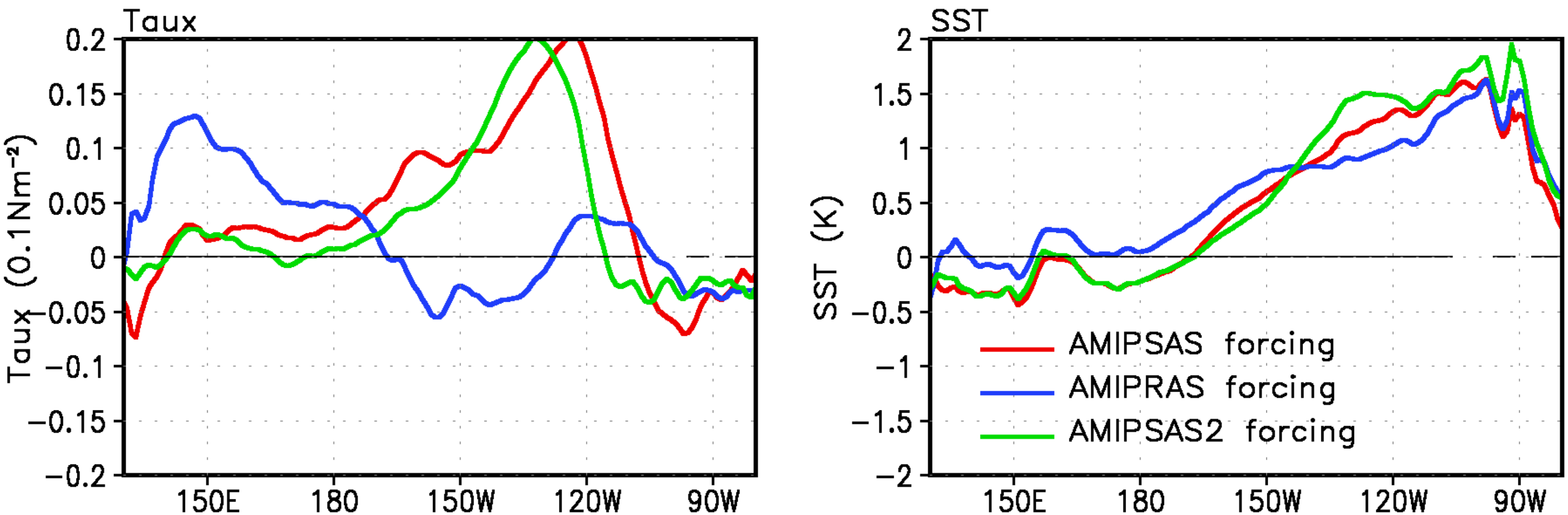
July 2012 SST (shading) and Taux (contour)



- SST anomalies consistent to Taux forcing.
- AMIPSAS and AMIPSAS2 result in warmer SSTs in eastern Pacific, especially for AMIPSAS2.

2). **Oceanic response to AMIP forcing**

July 2012 SST and Taux (1S-1N average)



- SST anomalies consistent to Taux forcing.
- AMIPSAS and AMIPSAS2 result in warmer SSTs in eastern Pacific, especially for AMIPSAS2.

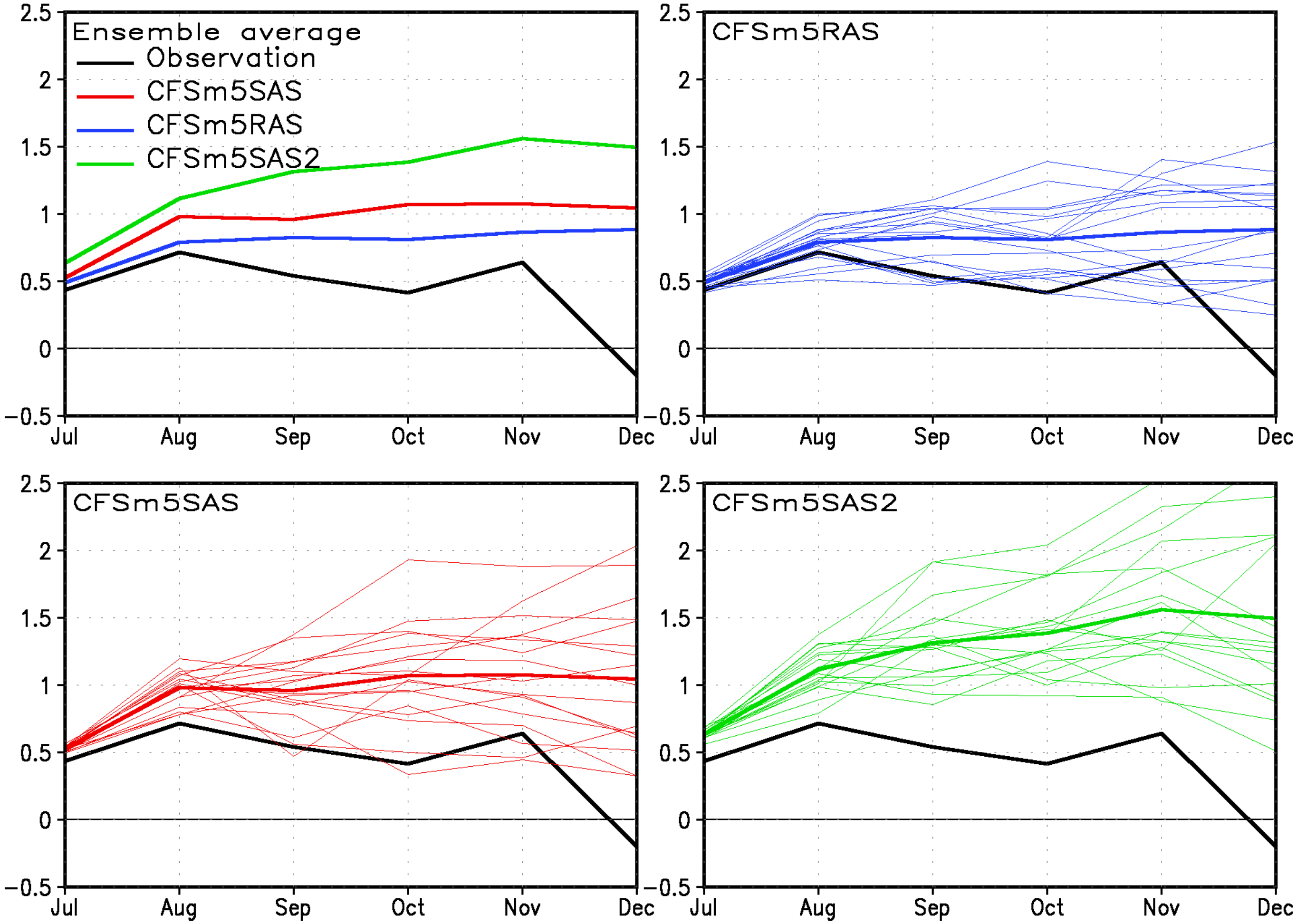
3). Coupled forecast runs

- Model

  CFSm5: GFS coupled with MOM5

- MOM5 runs
  - Initial date: June 30; Target: July-December
  - 1999 to Dec 2010
    - ✓ One member
    - ✓ To establish climatology
  - 2012
    - ✓ 18 members
    - ✓ To derive anomalies for July-December 2012
  - Three convection schemes
    - ✓ CFSm5SAS
    - ✓ CFSm5RAS
    - ✓ CFSm5SAS2

3). Coupled forecast runs



- Ensemble mean Nino3.4 warmest with SAS2 and least warm with RAS.
- Obs is more contained in CFSm5RAS
- All three convection schemes tend to produce warmer forecasts than that observed.

Summary

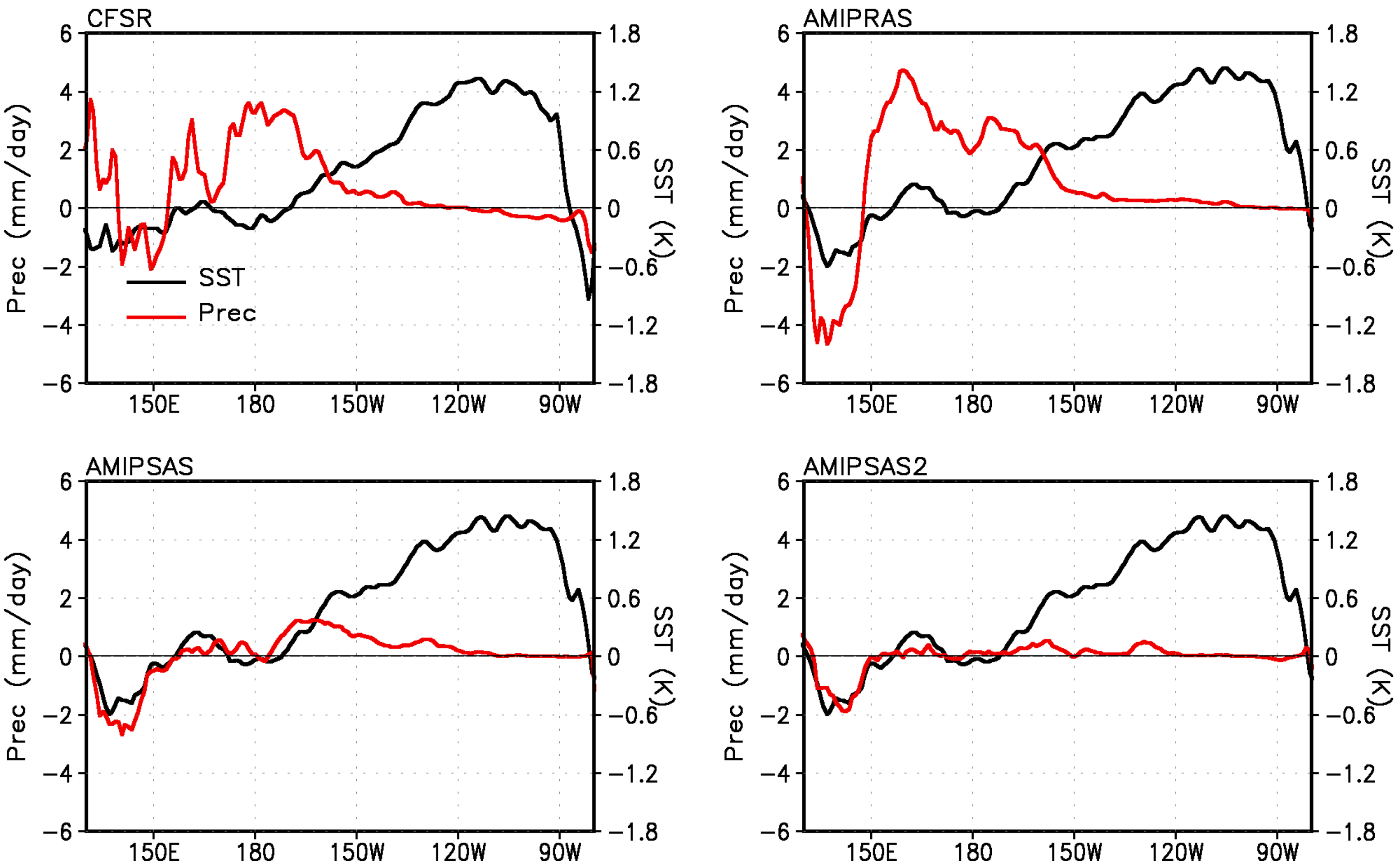
- Cumulus convection scheme is a possible cause for ENSO false alarms predictions in CFS.

- The convection scheme used in CFSv2 produces too strong westerly surface wind in response to moderate SST initial anomalies in the eastern Pacific, resulting in unrealistic positive wind-stress/SST feedback.

- An effective way to test convection scheme for its suitability for ENSO prediction is through AMIP runs to examine the surface wind response to observed moderate SST anomalies.

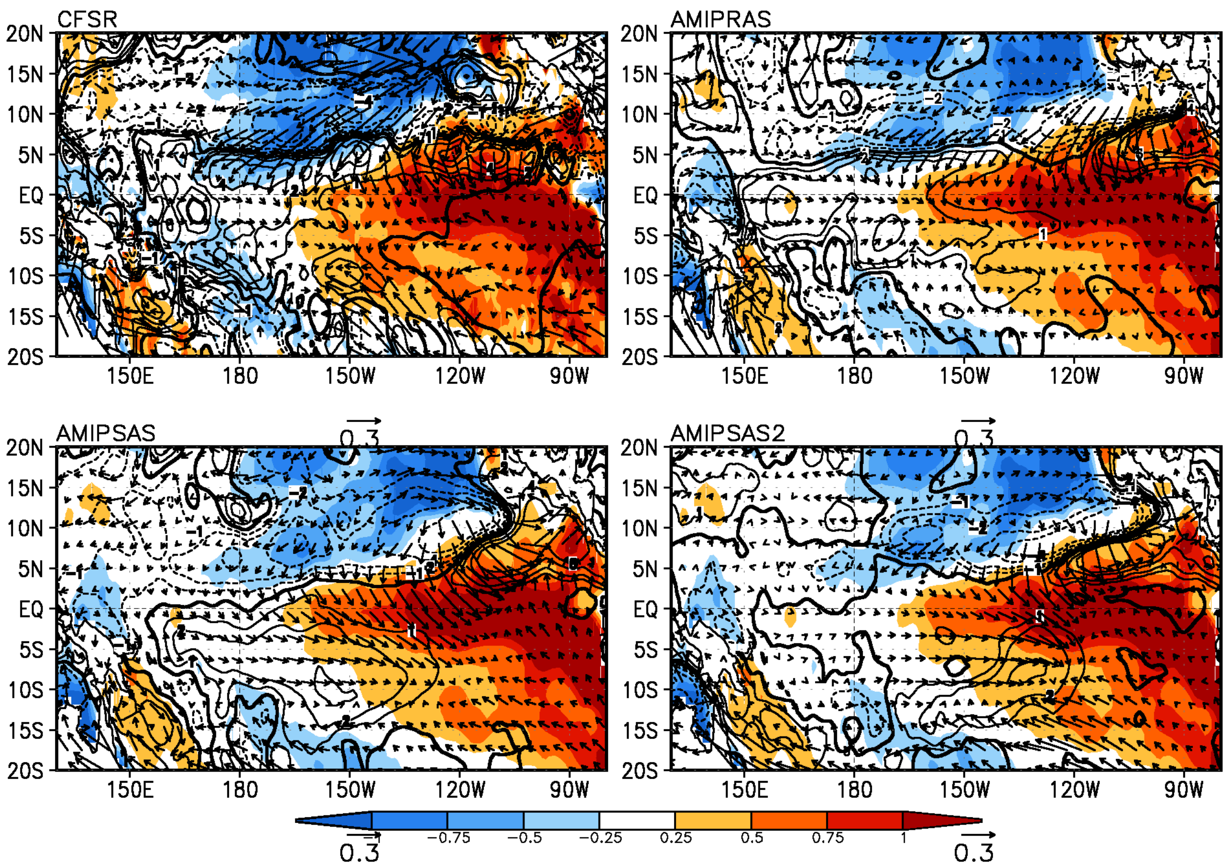
1). **Atmospheric response to observed SST anomalies**

July 2012 SST, Prec (2S-2N average)



1). **Atmospheric response to observed SST anomalies**

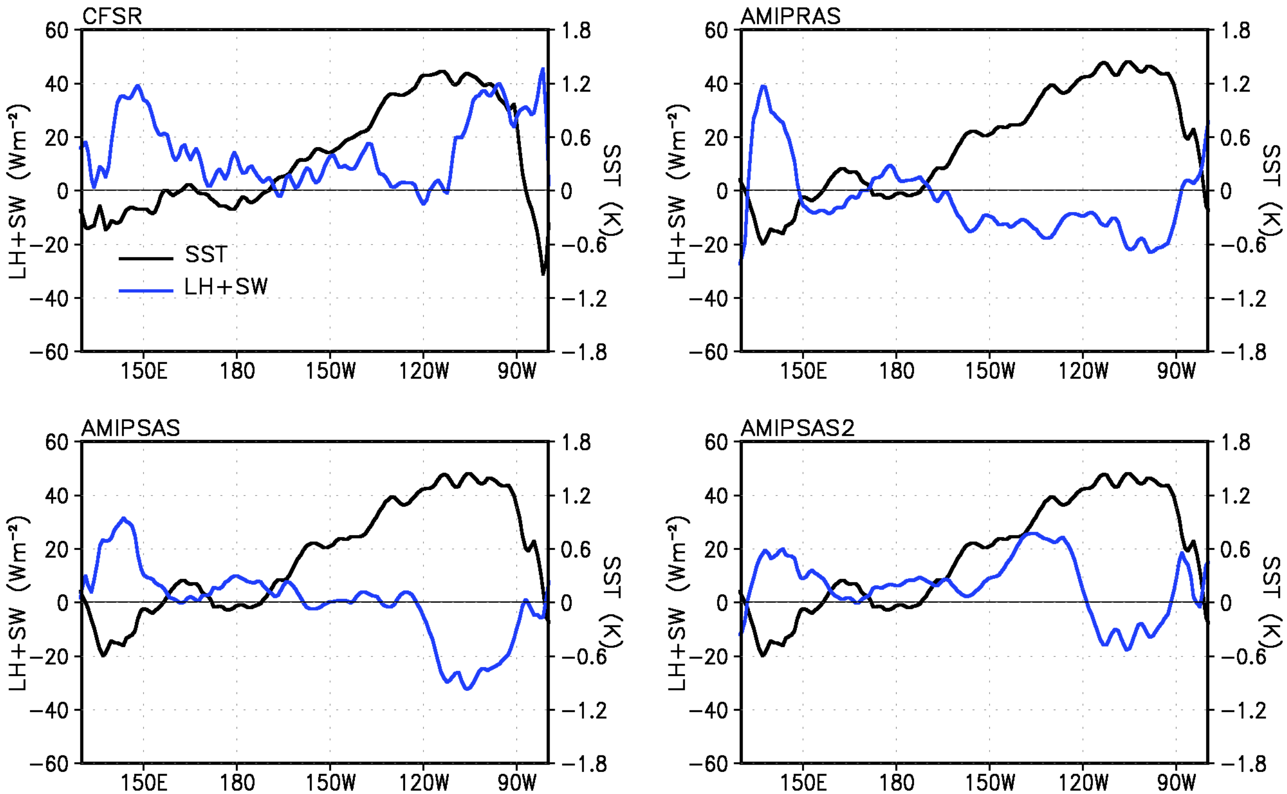
July 2012 SST (shading), rainfall (contour), Tau (vector)



- Unrealistic rainfall anomalies with SAS and SAS2, corresponding to too strong Tau in equatorial central-eastern Pacific
- More reasonable rainfall and Tau anomalies with RAS

1). **Atmospheric response to observed SST anomalies**

July 2012 SST and SW+LH (2S-2N average)

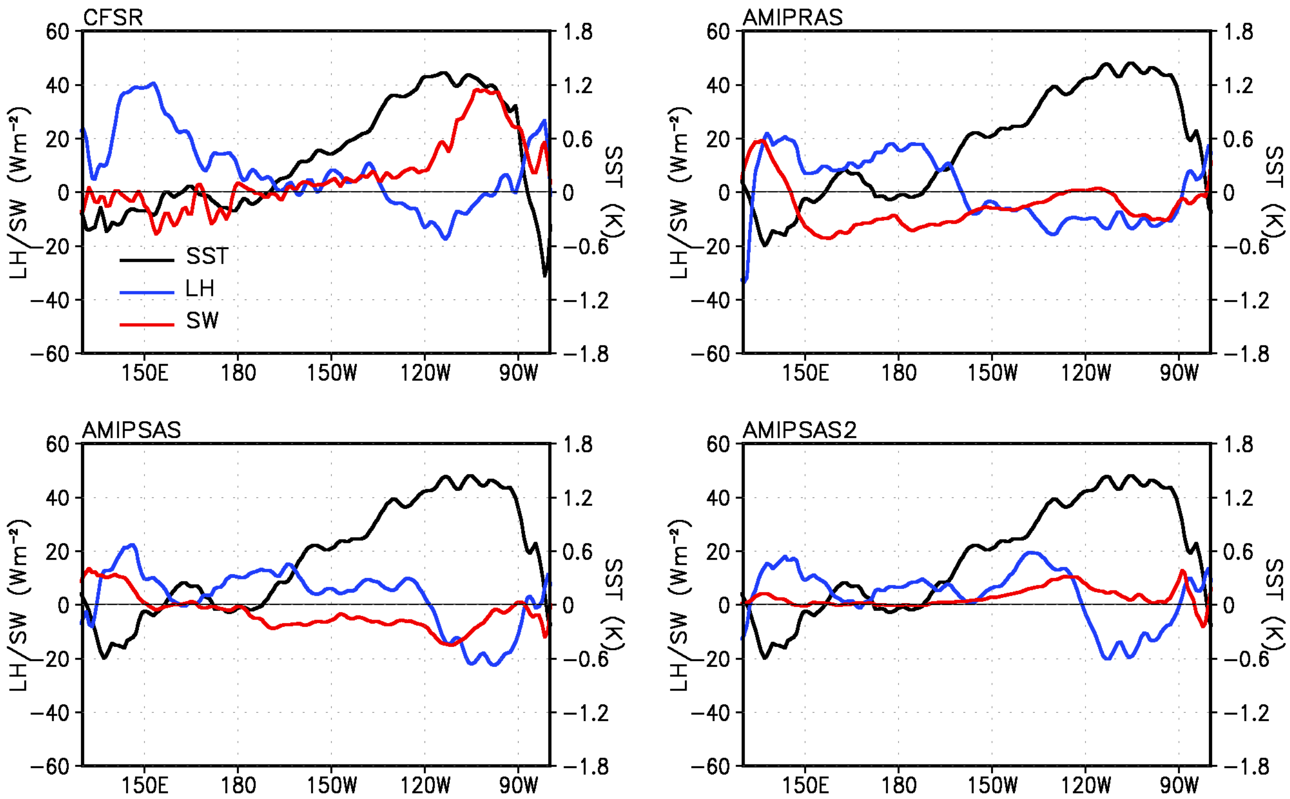


- Weak thermal feedback in Nino34 (190-240E) region in CFSR, SAS and RAS
- Positive feedback around 230E in SAS2
- All simulations failed to capture the CFSR positive feedback in far eastern (250-280E) Pacific

Thermal feedback does not appear to be the main reason for the false El Nino forecast. Similar anomalies from other observational analyses (e.g., ERA-I and CERES)

1). **Atmospheric response to observed SST anomalies**

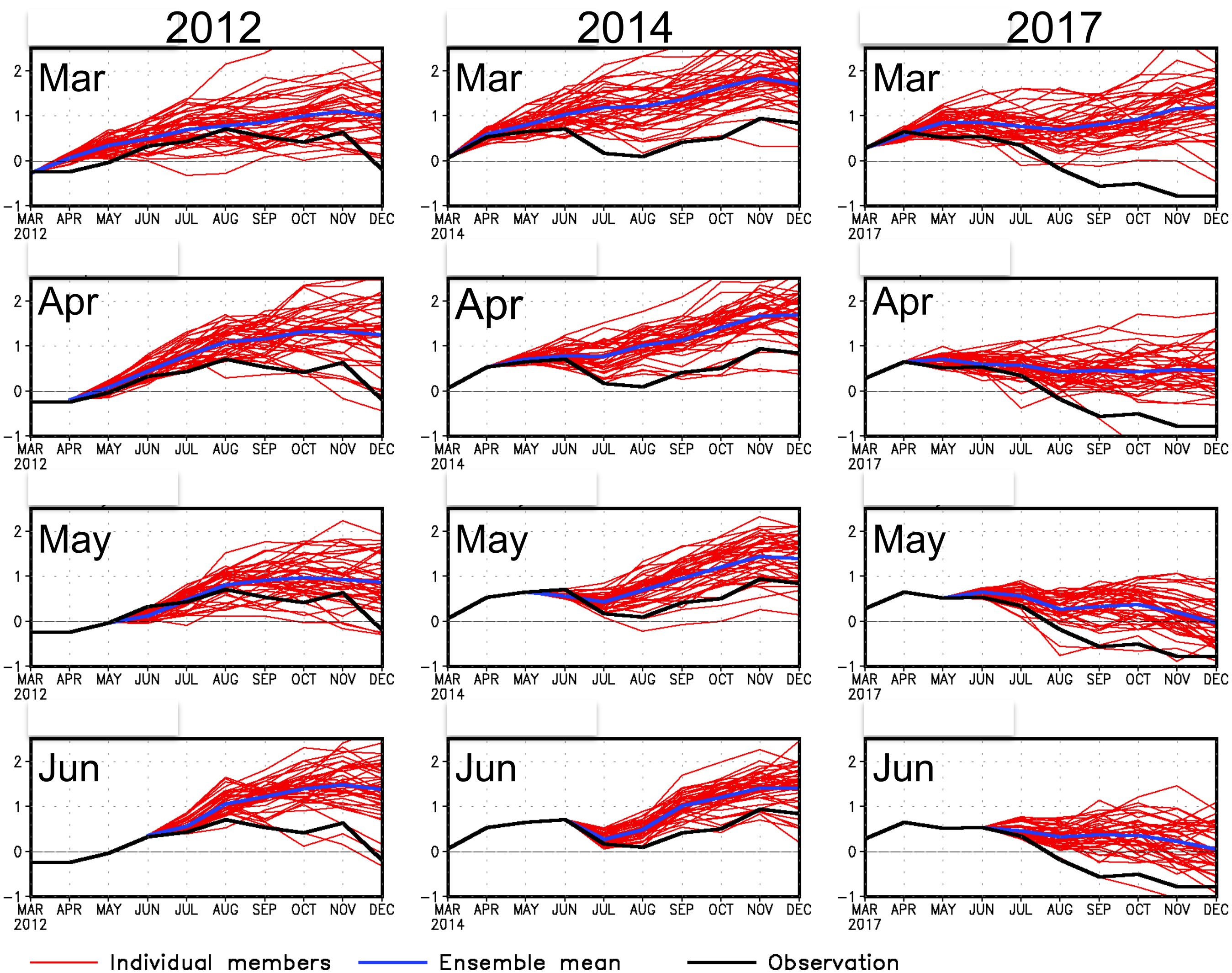
July 2012 SST, SW, LH (2S-2N average)



- Weak thermal feedback in Nino34 (190-240E) region
- All simulations failed to capture the CFSR positive SW feedback in far eastern (250-280E) Pacific

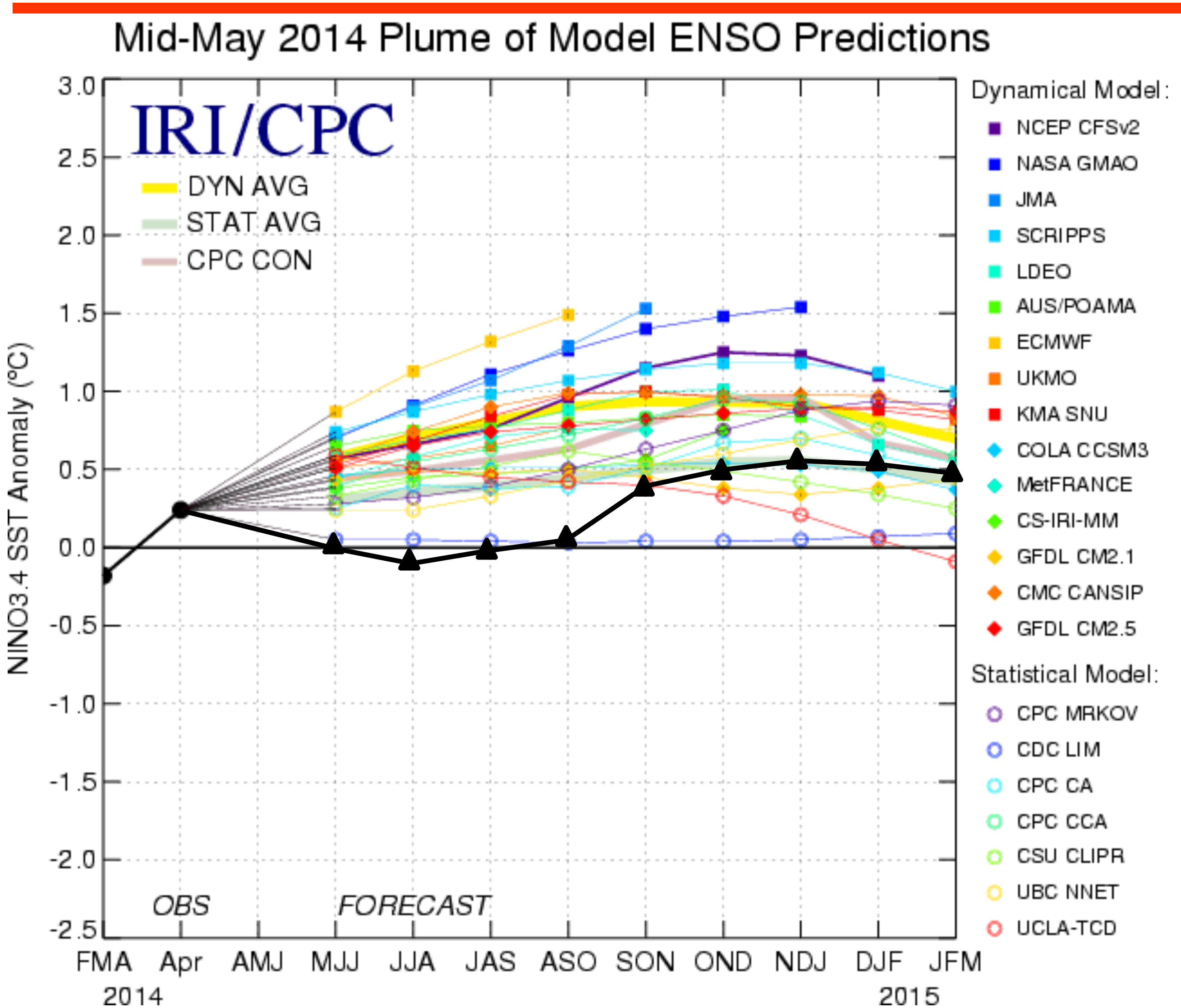
Thermal feedback does not appear to be the main reason for the false El Nino forecast. Similar anomalies from other observational analyses (e.g., ERA-I and CERES)

Nino 3.4 index from CFSv2



False alarms generally start from spring and early summer, but may be from different months in different years. Will focus on Jun 2012 forecast.

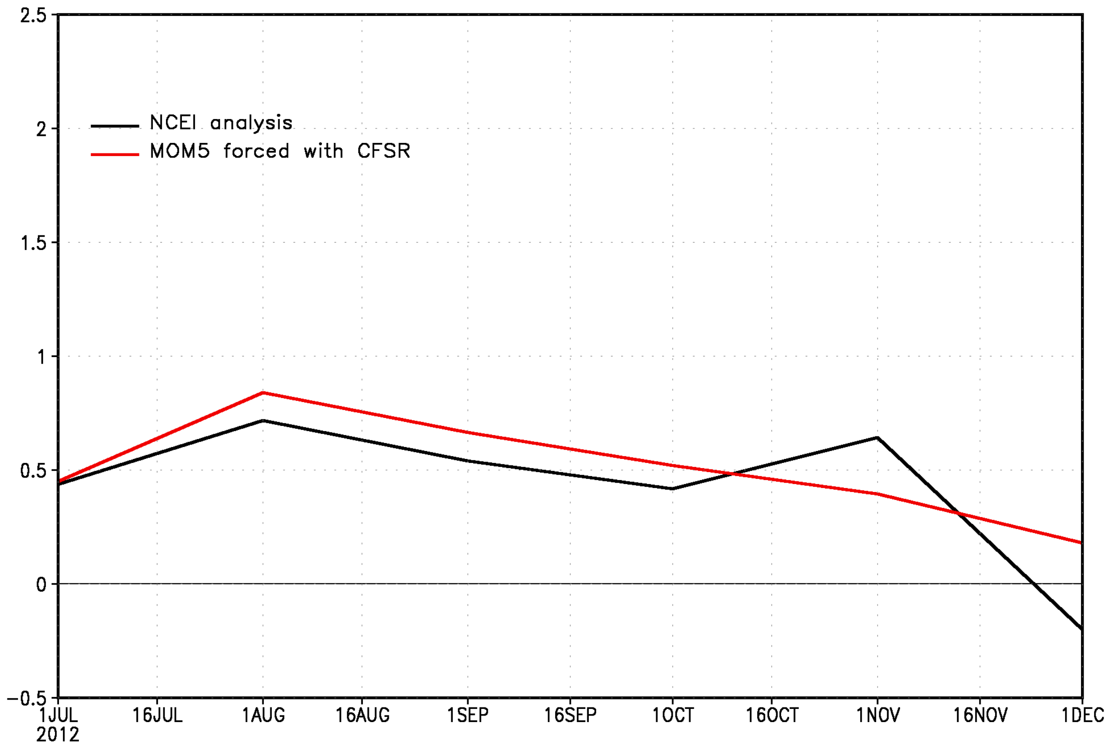
IRI/CPC Nino 3.4 plume



Alost all dynamical models produced a false alarm in May 2014 ENSO plume.

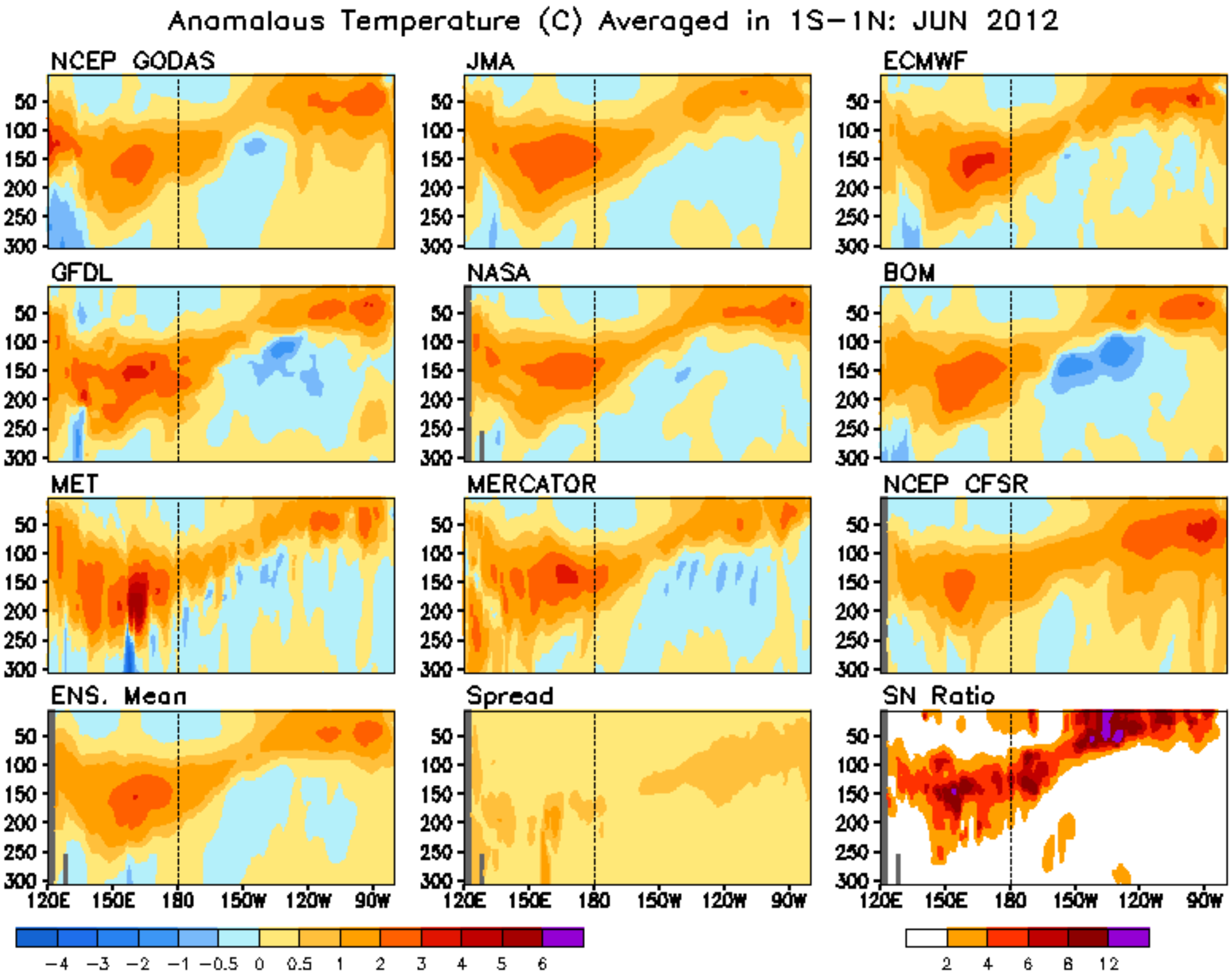
MOM5 forced by CFSR

Nino3.4 index



MOM5 forced with CFSR captured overall evolution, but failed to reproduce observed SST drop from Nov to Dec.

Jun 2012 oceanic state



- Some uncertainties among ocean analyses.
- CFSR subserface was not significantly warmer than others.