# Desired improvements for the UFS S2S

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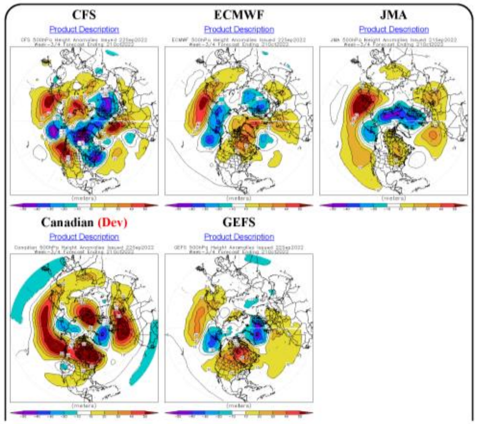
# Outline

- Use of CFS and GEFS for CPC's S2S products
- Diagnostic evaluations of dynamical forecasts
- Issues in CFS initialization

# Use of CFS and GEFS for CPC's S2S products




- Operational
  - Temperature and Precipitation Outlooks (CONUS, AK, HI):
  - Monthly and Seasonal Drought Outlooks (CONUS, AK, HI)
  - US Hazards Outlook
  - Global Tropics Hazard Outlook
  - Seasonal Hurricane Outlook
  - ENSO Prediction
- Experimental and in-development
  - Arctic Sea Ice
  - Week 2 fire weather
  - Week2, Week 3-4 severe weather
  - Week2, Week 3-4 storminess
  - Water year outlook
  - Marine heat wave outlook
  - Rapid onset drought
- CPC International Desks Prediction Products
  - Africa, Central Asia, South Asia, Central and Caribbean

# Use of CFS and GEFS for CPC's S2S products

- CFS (Climate Forecast System)
  - Week 2, week 3-4, monthly, seasonal

- GEFS (Global Ensemble Forecast System)
  - Week 2, Week 3-4

# Diagnostic evaluations of dynamical forecasts

- Global Tropics Hazard Outlook
- Sudden stratospheric warmings (SSWs)
- Soil moisture
- Ocean initialization
- ENSO long-term trend
- Air-sea coupling related to MJO and ENSO

# Week 2-3 Probabilistic GTH Outlook

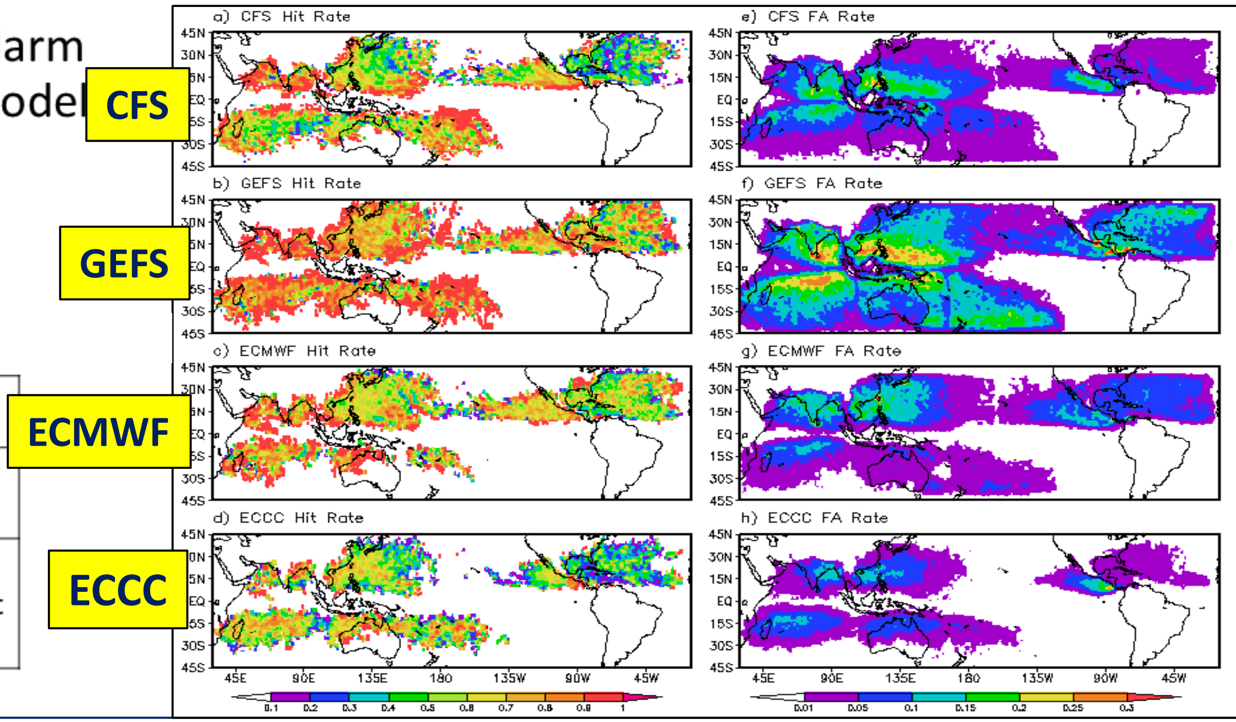
## Tropical Cyclone Skill – Track Week 2

$$Hit\ Rate = \frac{a}{a+c}$$

$$False\ Alarm\ Rate = \frac{b}{b+d}$$

- Hit Rate and False Alarm (FA) Rate for each model hindcast.
- Based on a 2x2 contingency table:

| Obs \ Model | Yes | No |
|---|---|---|
| Yes | "a" Hit | "c" Miss |
| No | "b" False Alarm | "d" Correct Null |




- GEFS has the highest hit rate, although it has higher false alarm rate than other three models
- ECWMF becomes more reliable with its lower false alarm rate

(Courtesy: Gottschalck, Long, and Novella)

# Role of Stratosphere in S2S Prediction

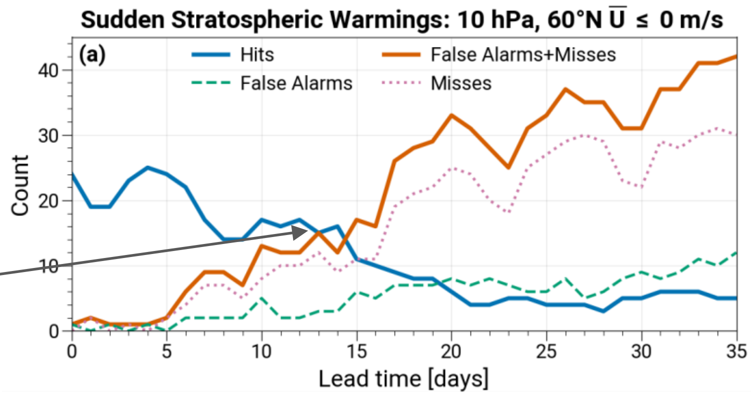
Stratospheric variability is often cited as a potentially skillful source of S2S predictability (Butler et al 2019; Domeisen and Butler (2020)

- For example, sudden stratospheric warmings (SSWs) are often highlighted as potential sources of extreme cold events

However the extent to which extreme stratosphere events can be skillfully predicted in real-time has limitations

- Models can only predict extreme events ~ 2 weeks in advance (Hits > False Alarms + Misses)
- Biases in the GEFS representation of stratospheric polar vortex can impact ability to skillfully predict extreme polar vortex events and subsequent tropospheric impacts

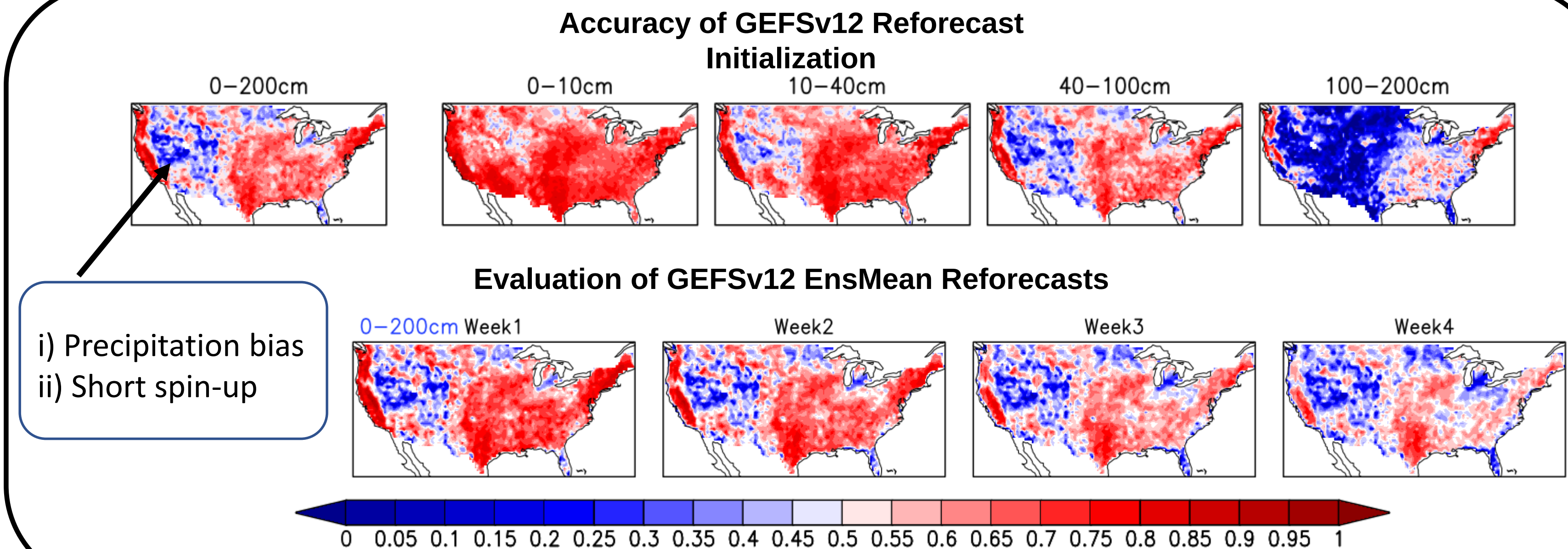
GEFSv12 hindcast categorical forecasts of SSWs
SSW is forecast if >50% of the ensemble members include the event




From Lawrence et al (in prep)

(Courtesy: Ciasto)

# Evaluation of GEFSv12 Subseasonal Reforecasts for *Soil Moisture*




***Metric***: Anomaly correlation with soil moisture from the Noah land analysis (2000-2019)

**Observational References**

*A Noah land analysis*, produced by driving Noah offline with NLDAS-2 atmospheric forcings, with a sufficient spin-up

**Evaluation**

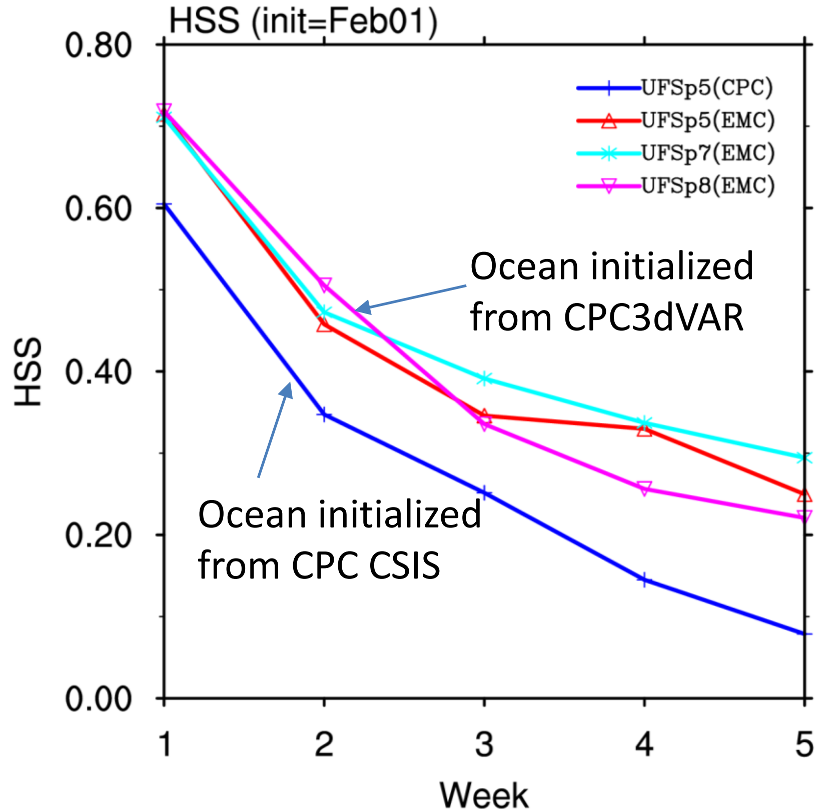
***Initial soil moisture anomalies*** contribute substantially to the soil moisture forecast skill, owing to their intrinsic memory on subseasonal timescales. ***The GEFSv12 soil moisture initialization*** shows low accuracy in the western interior U.S., which adversely impacts soil moisture forecasts in these regions.

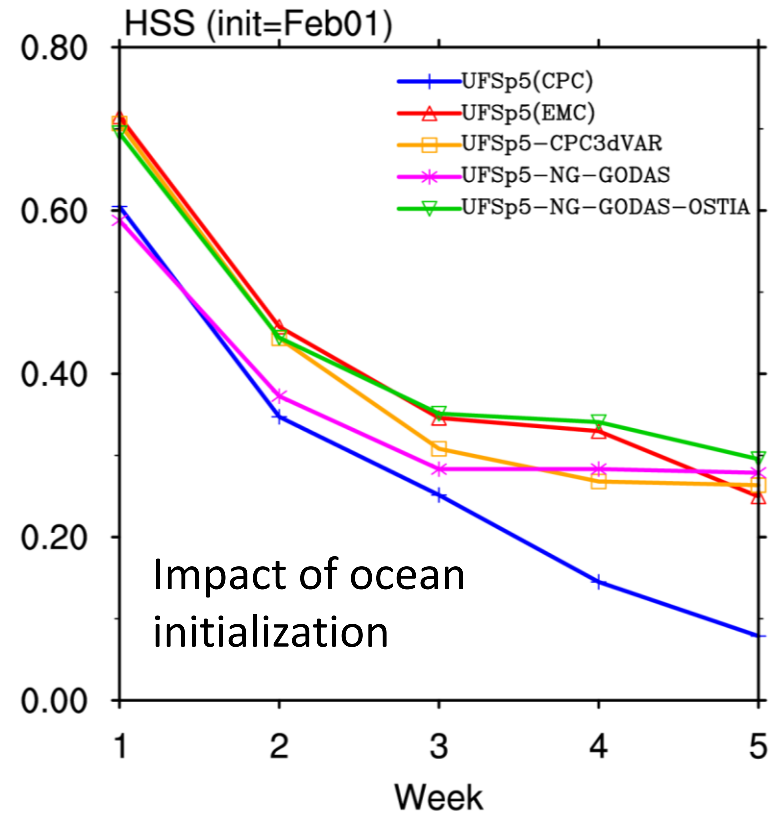
***CPC production of subseasonal soil moisture forecasts***: The forecasts are being produced by driving Noah/Noah-MP offline with bias-corrected and calibrated GEFSv12 meteorological forecasts, initialized using the Noah/Noah-MP land analysis.

(Courtesy: H. Wang)

# Impact of ocean initialization on sea ice predictions

Sea ice Heidke Skill Score (2012-2018)




- All runs were initialized from CPC ICE
- Sea ice forecast skill comparable among UFSp5, UFSp7, UFSp8
- The UFSp5 skill from CPC is lower

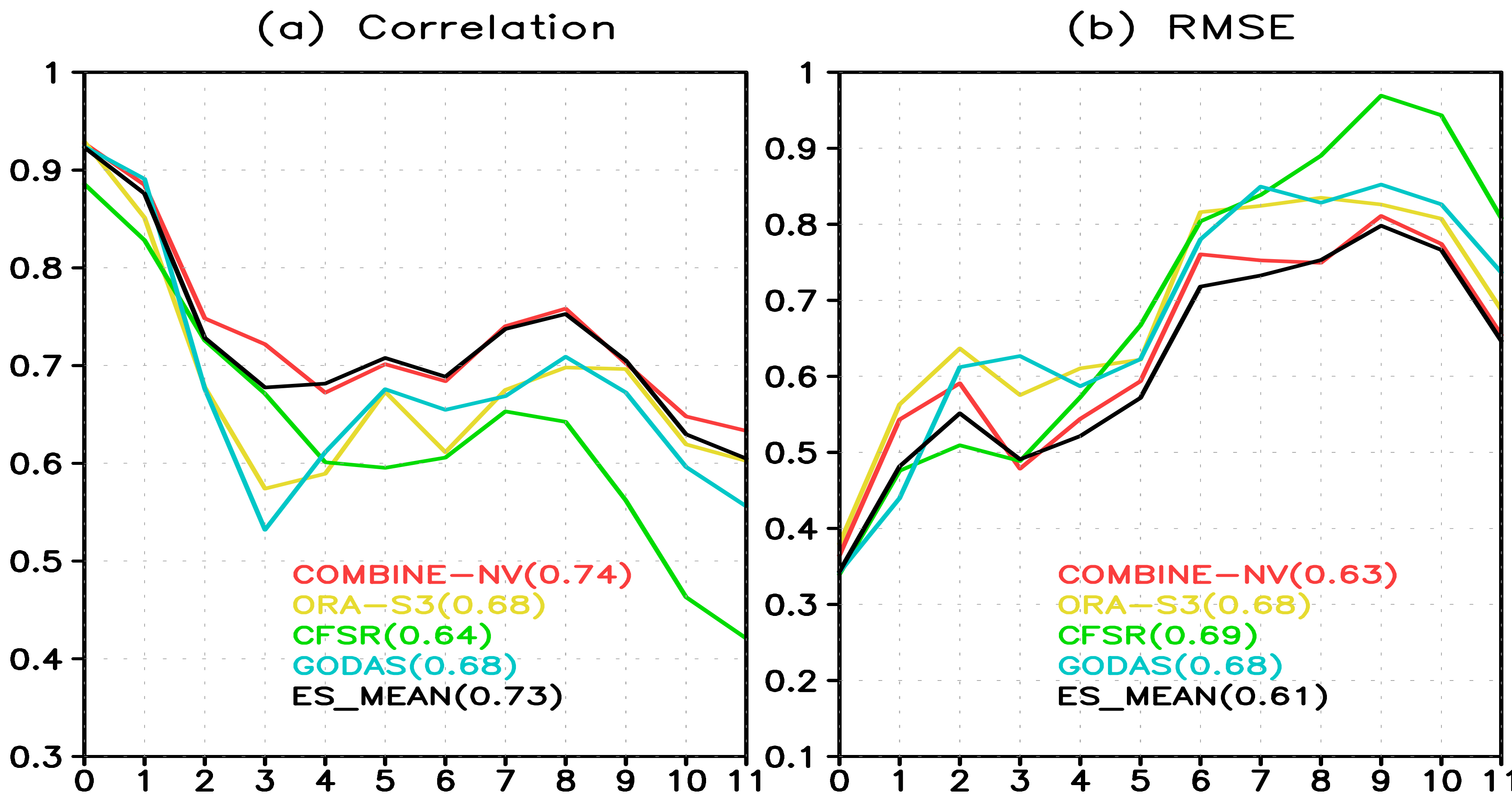
- Better skill in UFSp5, UFSp7, UFSp8 was due to the initialization from CPC3dVAR
- Reasonable skill with initialization from NG-GODAS with OSTIA SST

(Courtesy: Y. Liu)

# Impact of ocean initialization on ENSO predictions

**Prediction skill of the Nino3.4 is sensitive to OICs**

***(April ICs: 1979-2007)***

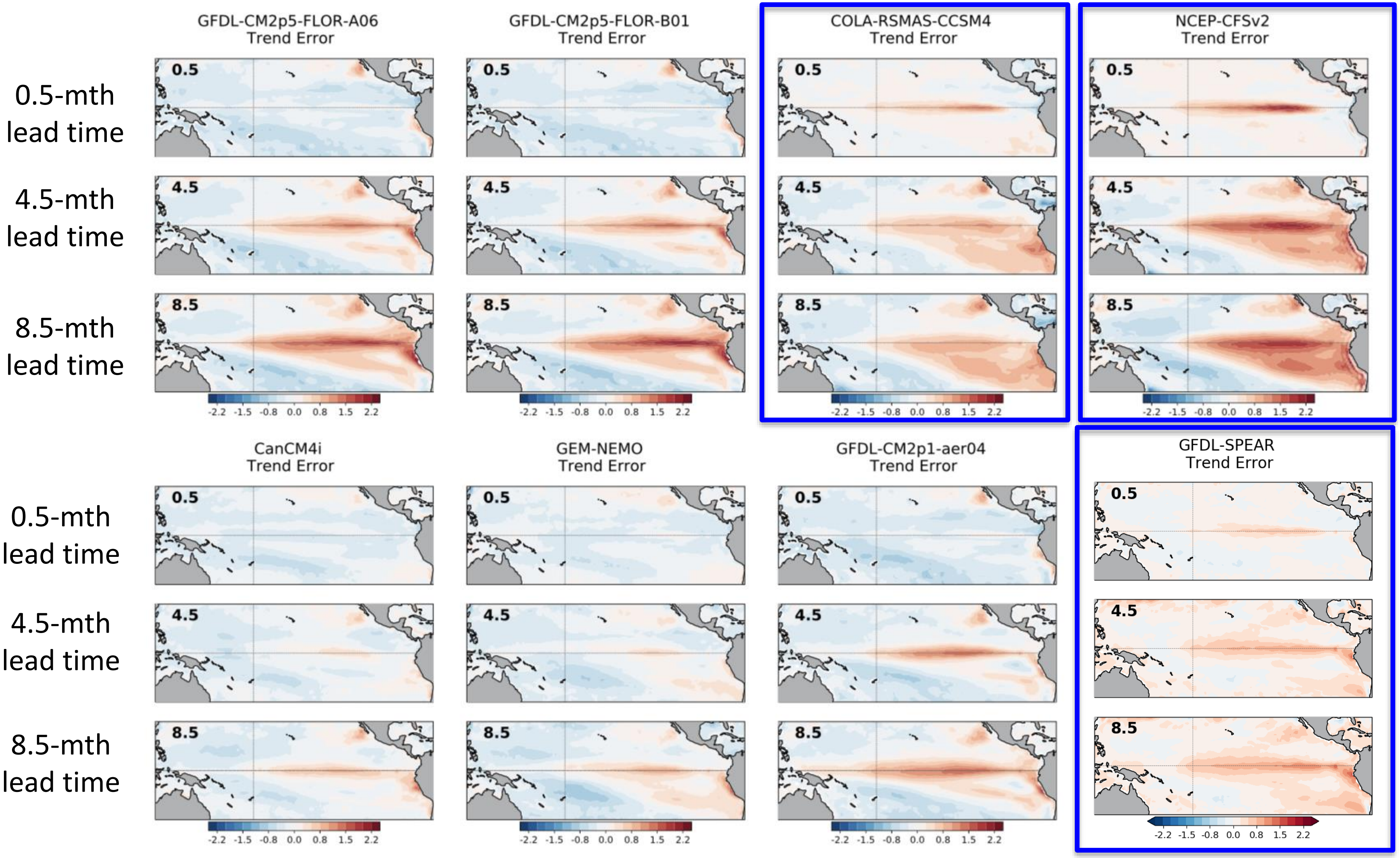



- *Predictive skills of individual OICs have substantial differences*
- *The skills are lowest with CFS initial conditions (ICs)*

Zhu et al. (2012)

# SST Trend Errors (1982-2020)

- The **linear trend error** (forecast minus the observations) is <u>too positive </u>in the eastern Pacific Ocean.  Most evident by  the ~4.5-month lead and beyond.

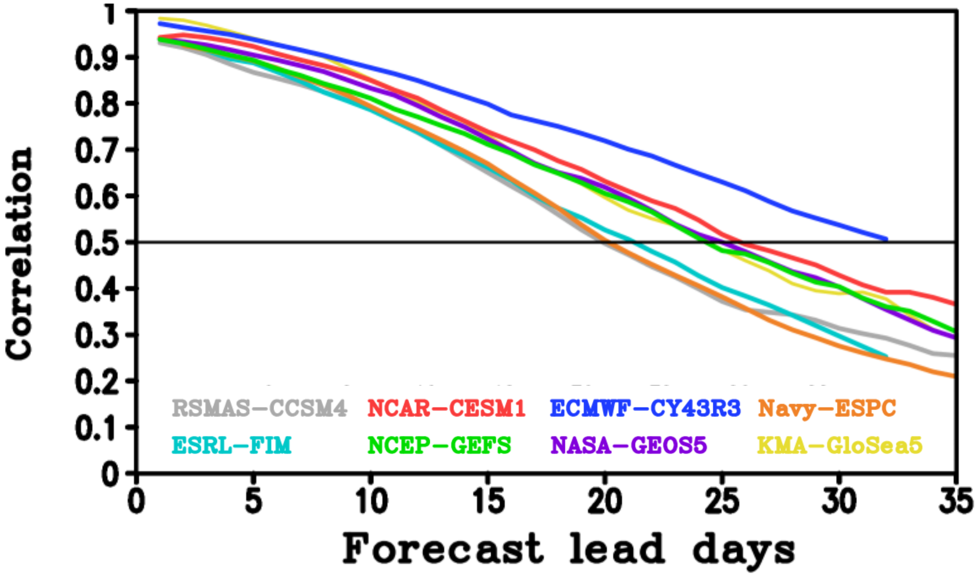


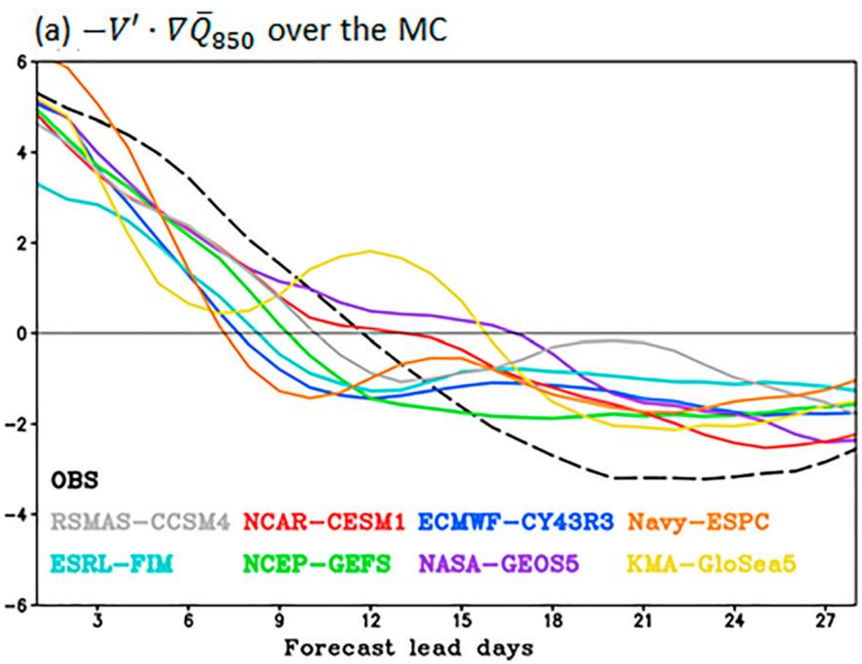

(Courtesy: M. L'Heureux)

# Air-sea coupling related to MJO and ENSO in CFS

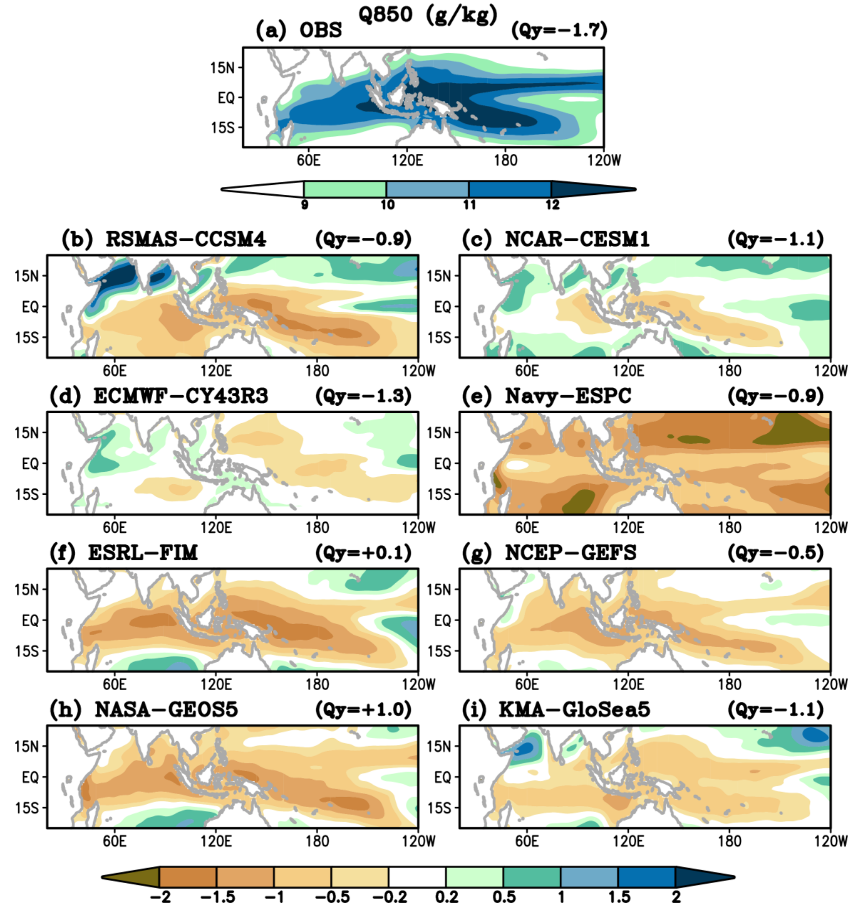
## MJO

RMM Prediction skill (bivariate correlation coefficient)




q850 observation and model biases




- ECMWF model has the highest skill
- ECMWF model has lowest moisture bias
- Moisture advection does not explain skill differences

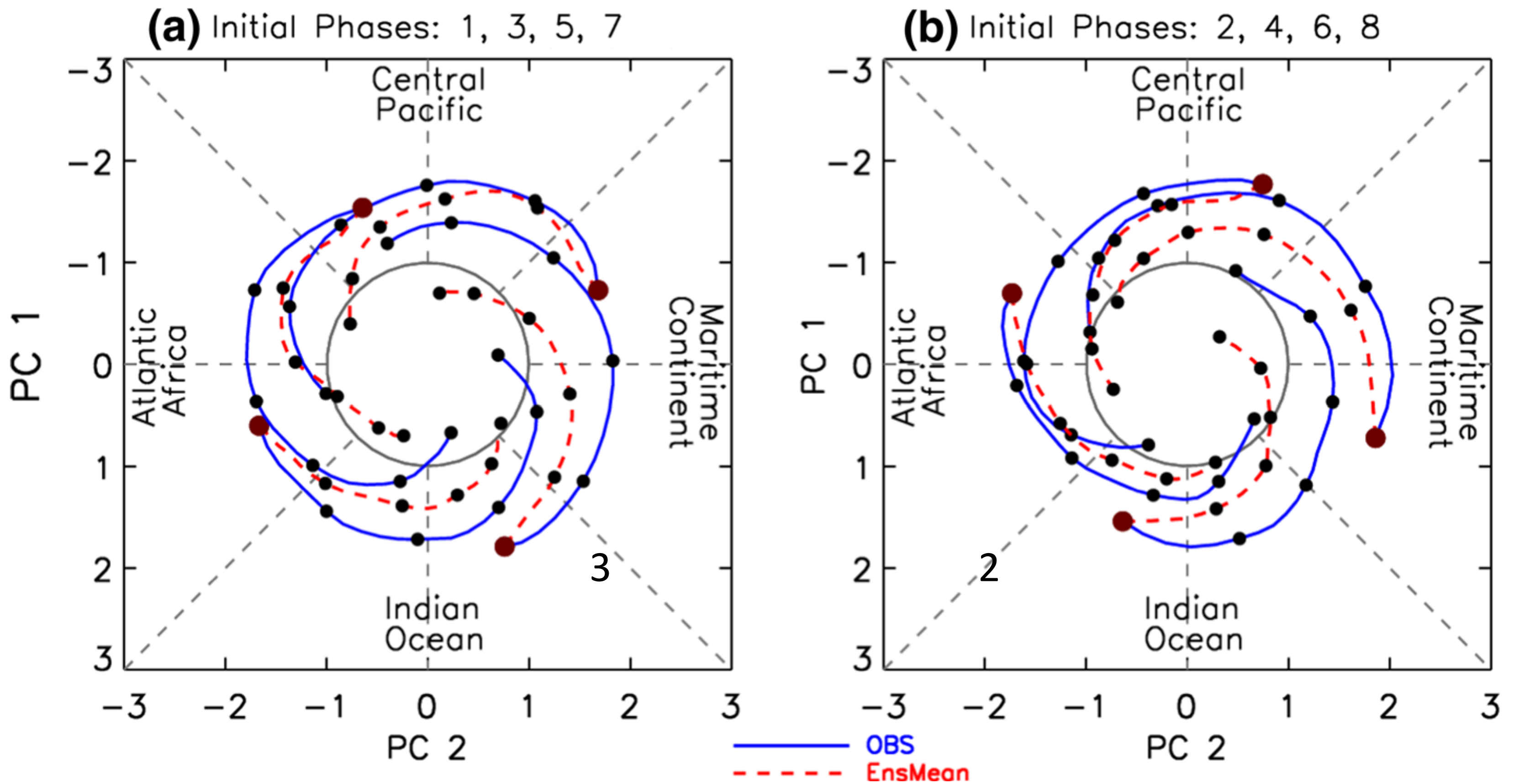
(Kim et al. 2019)

# What model physics affect MJO prediction?

- Atmospheric parameterization
  - Convection
  - Precipitation re-evaporization
  - Cloud-radiation interaction
  - …
- Air-sea coupling

# MJO

**Composite MJO Phase diagrams in CFS and observations**




- Predicted MJO propagates more slowly in the prediction than in the observation.
- Predicted MJO from all initial phases decays more quickly than the observed
- **Predictions from phase 2 and phase 3 fail to propagate across the Maritime Continent (MC barrier effect)**

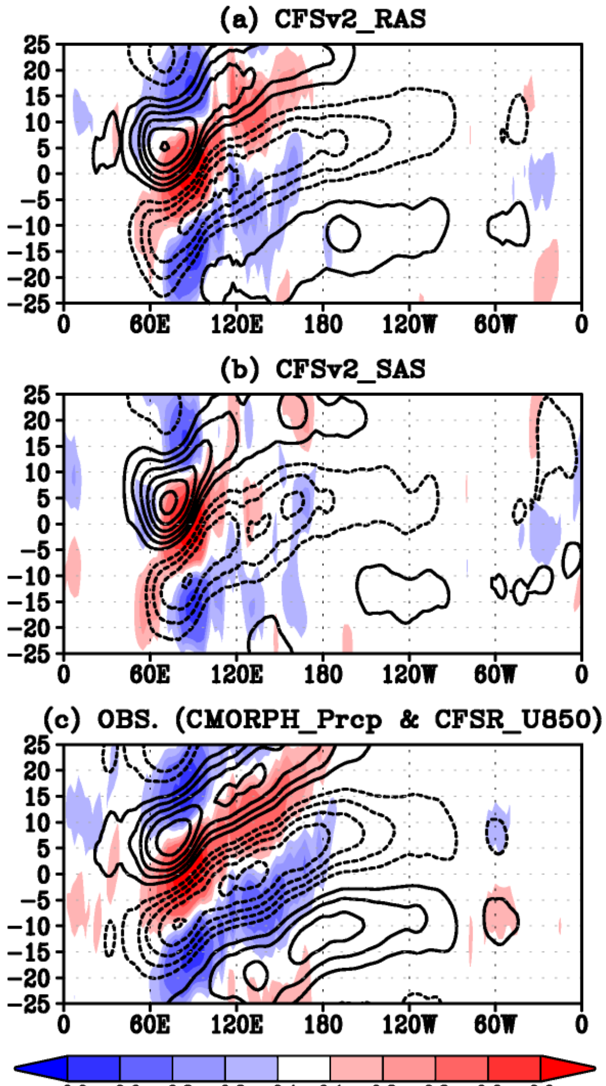
(Wang et al. 2014)

# Lagged regression against Indian Ocean precipitation (70°E-100°E)

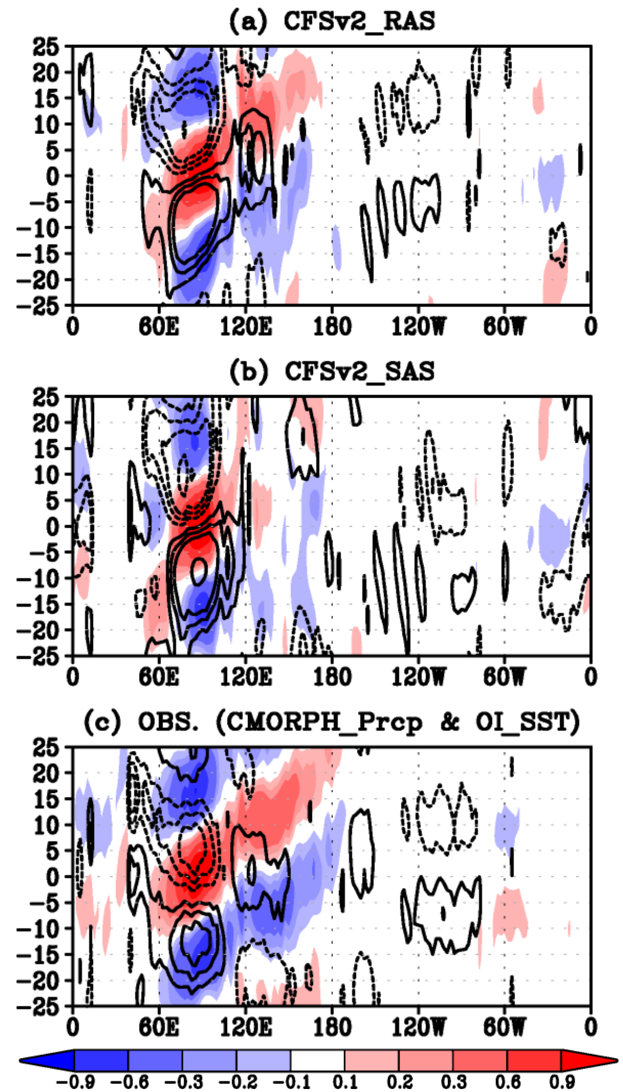
10°S–10°N average, November - April

- The model works better with CFSv2_RAS than CFSv2_SAS
- Observed SST leads precipitation by 7 days
- Warm SST conditions developed in East MC and WP when enhanced convection is in Indian Ocean
- This features is captured in the RAS run
- The SAS run failed to produce the development of warm SST anomalies in the MC and WP

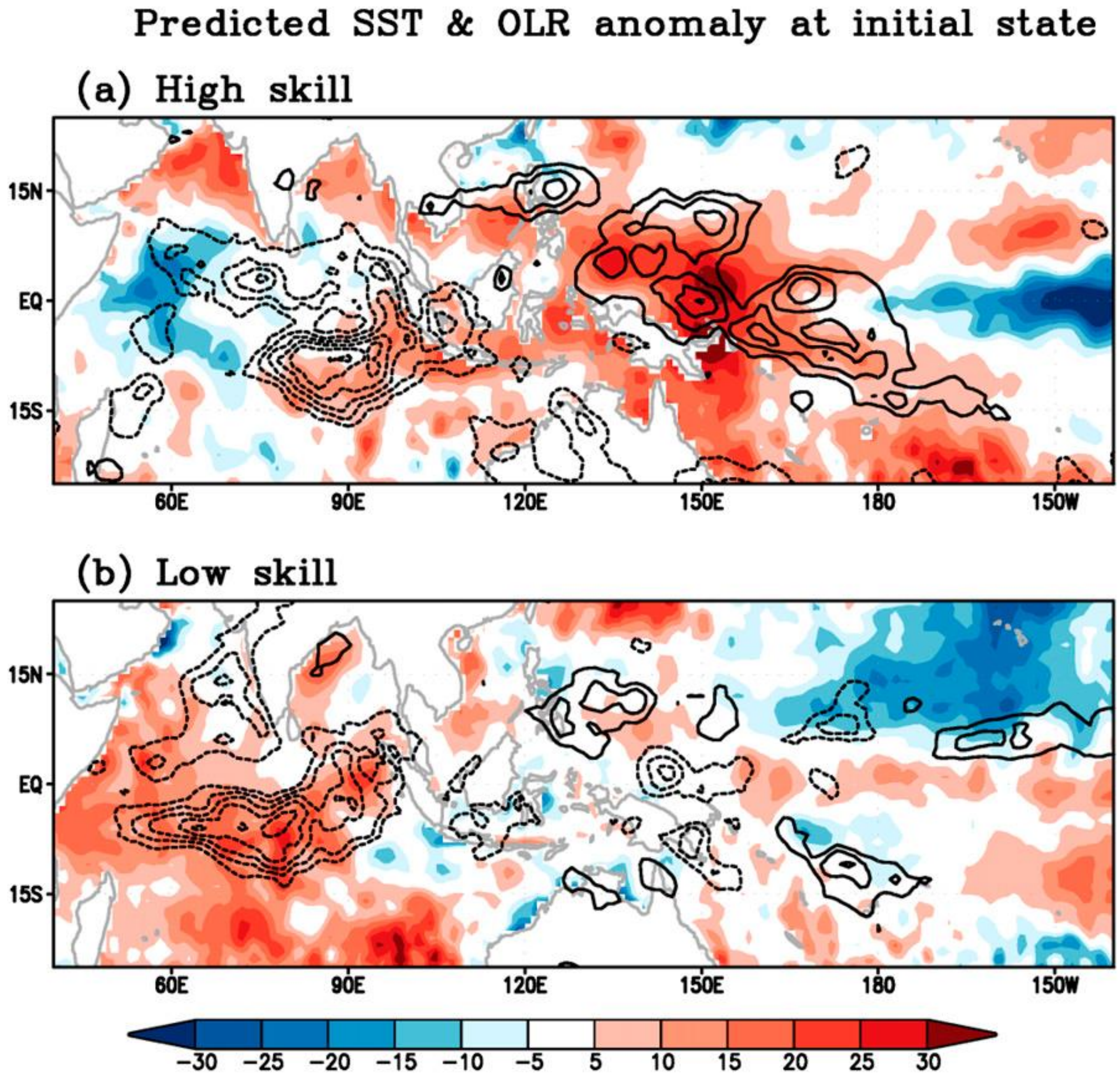
Shading: Precipitation
Contour: U 850-hPa




Shading: Precipitation
Contour: SST




(Zhu et al. 2017)




ECMWF Variable Resolution Ensemble Prediction System (VAREPS)

Shading: SST
Contour: OLR

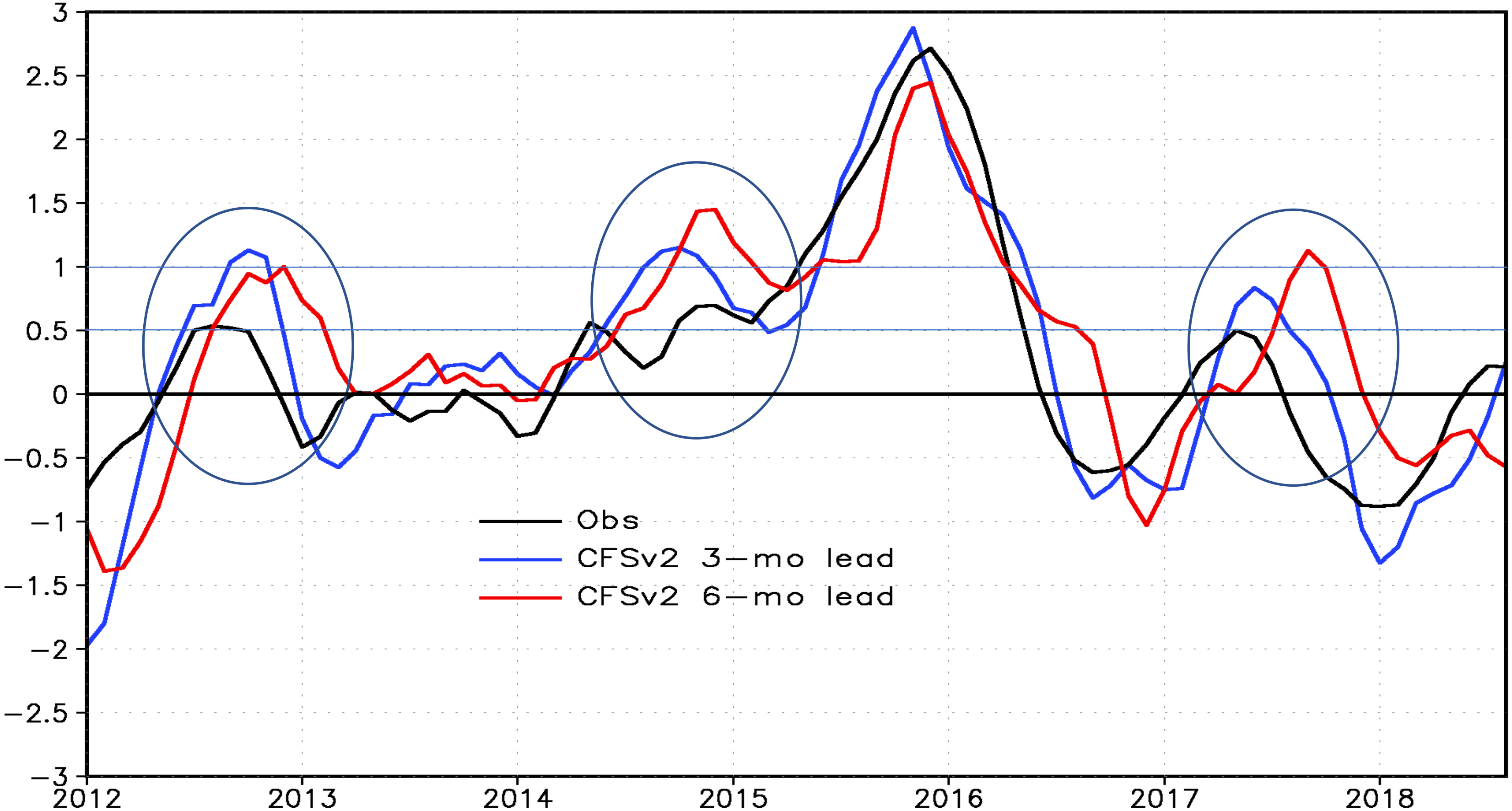
Strong (weak) positive SST anomalies in W. Pacific correspond to high (low) MJO prediction cases.

(Kim et al., 2016)

# Air-sea coupling related to MJO and ENSO in CFS

## ENSO

# False alarms in CFSv2




False alarms occurred in 2012, 2014, and 2017 in CFSv2

What caused the false alarms?

1. Errors in initial conditions
2. Long-term trend errors
3. Errors within the model, e.g., too strong convection-wind-SST interactions?

# Experiments for 2012 to test impact of convection parameterization and air-sea feedback

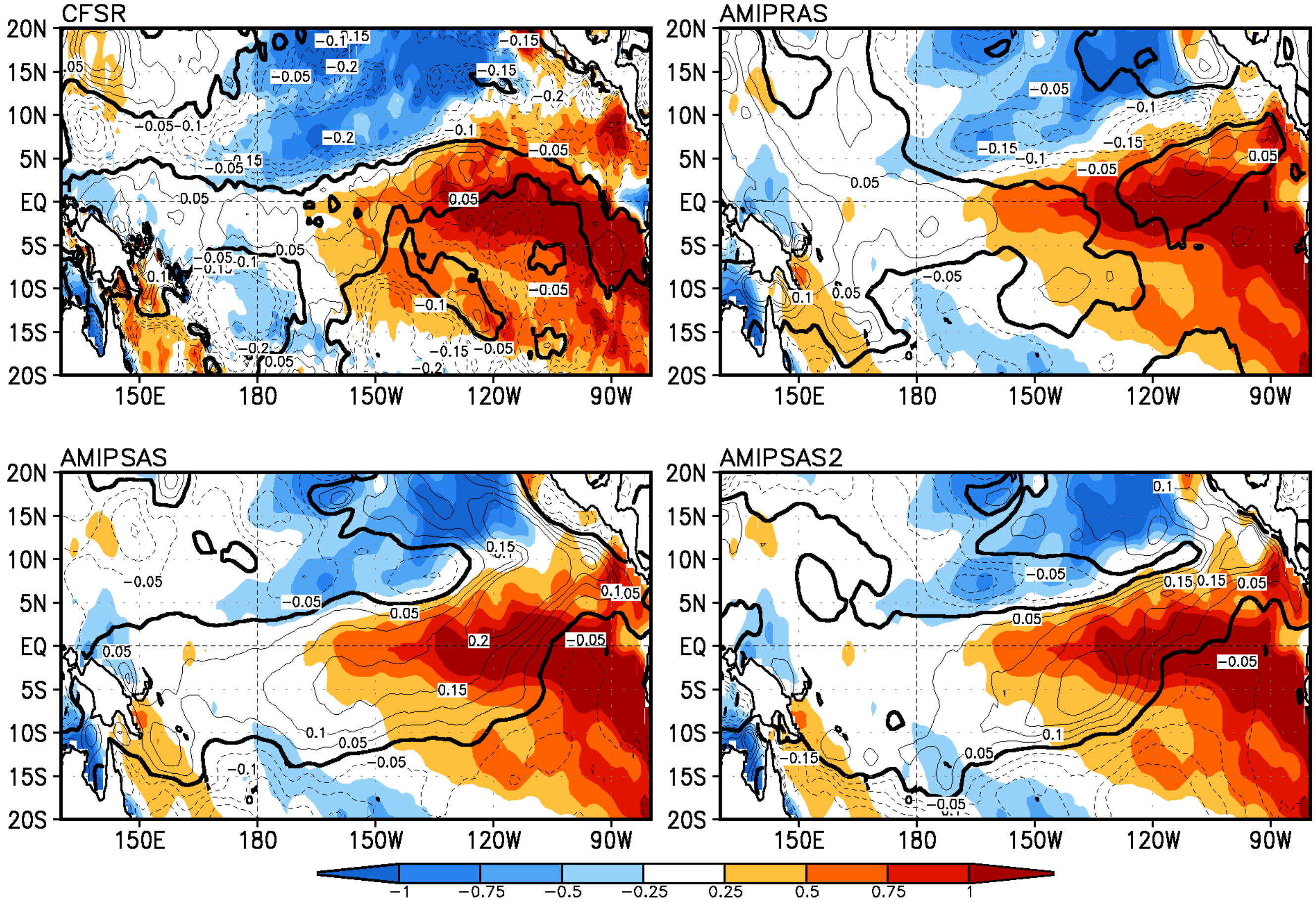
1) AMIP Simulations of atmospheric response to observed SST anomalies using three convection schemes (SAS, RAS, and SAS2)

2) Oceanic response to atmospheric forcing from AMIP simulations

3) Initialized forecasts with a coupled model

# Atmospheric response to observed SST anomalies

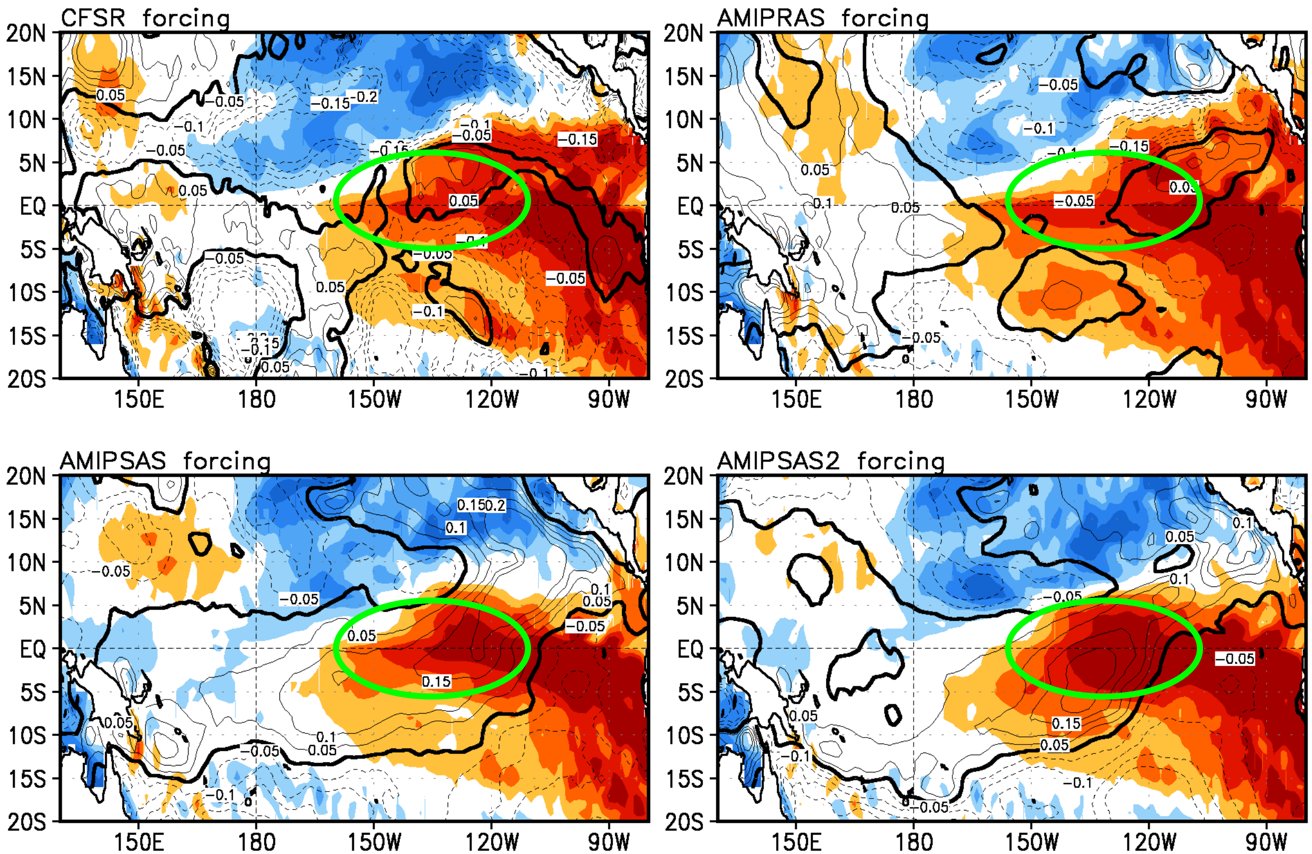
## July 2012 SST (shading), Taux(contour)




- Too strong Taux in central-eastern Pac with SAS and SAS2
- More reasonable Taux with RAS

# Oceanic response to AMIP forcing

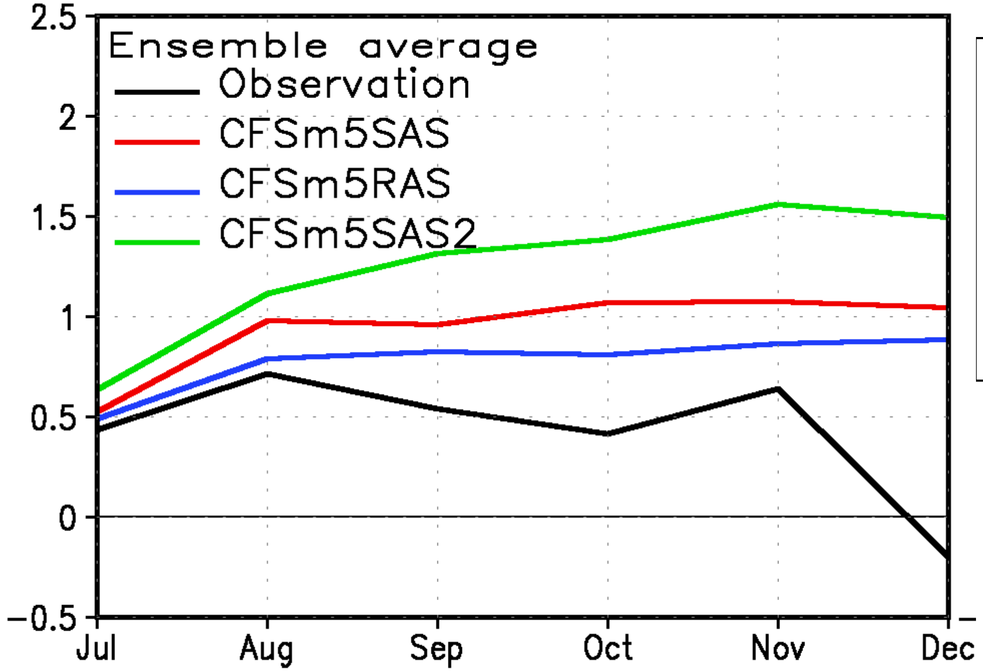
July 2012 SST (shading), Taux(contour)




- AMIPRAS forcing produced responses most comparable to that forced with CFSR
- Both AMIPSAS and AMIPSAS2 result in warmer SSTs in eastern Pacific, especially for AMIPSAS2.

# Coupled forecast runs

## Nino3.4 SST



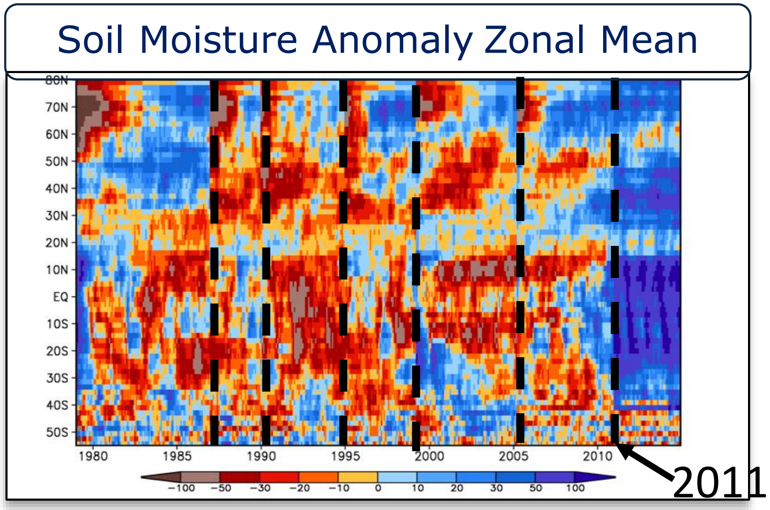

- All three convection schemes produce warmer Nino3.4 index than that observed.
- Ensemble mean Nino3.4 warmest with SAS2 and least warm with RAS

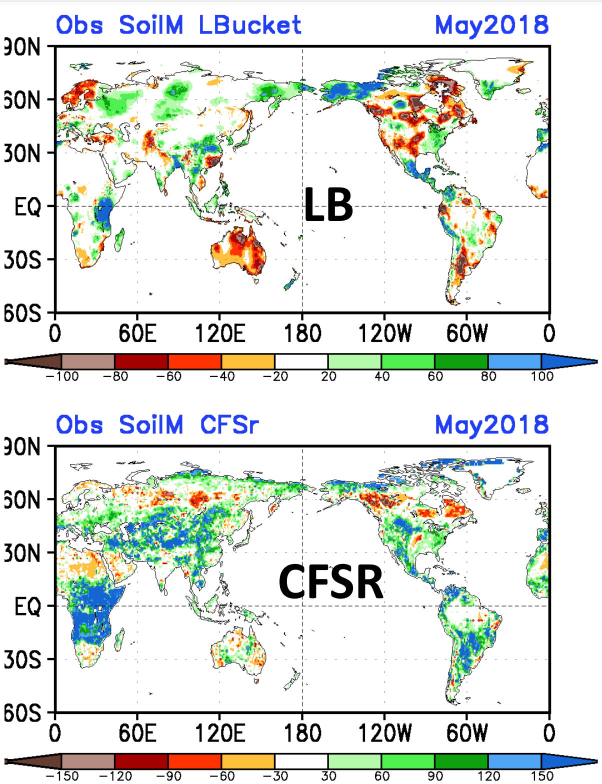
- Use of different cumulus convection schemes influence ENSO forecasts.
- One way to help test convection scheme for its suitability for ENSO prediction is through AMIP simulations to examine the surface wind response in the tropics to observed moderate SST anomalies.

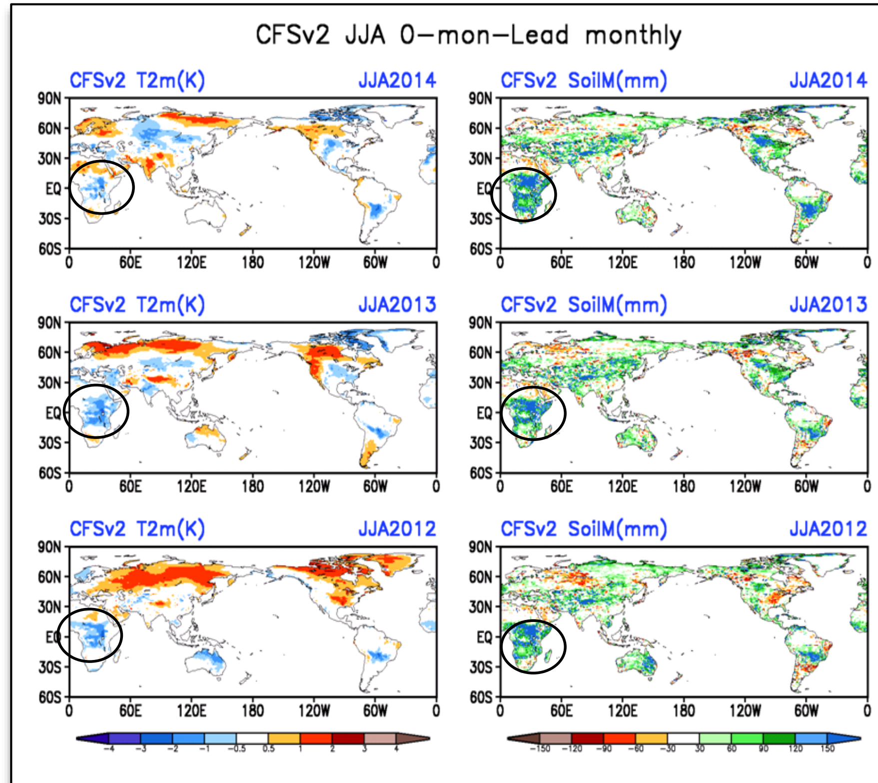
# Issues in CFS initialization

- Soil moisture
- Ocean
- Sea ice

# Issues in CFS initialization: Soil moisture



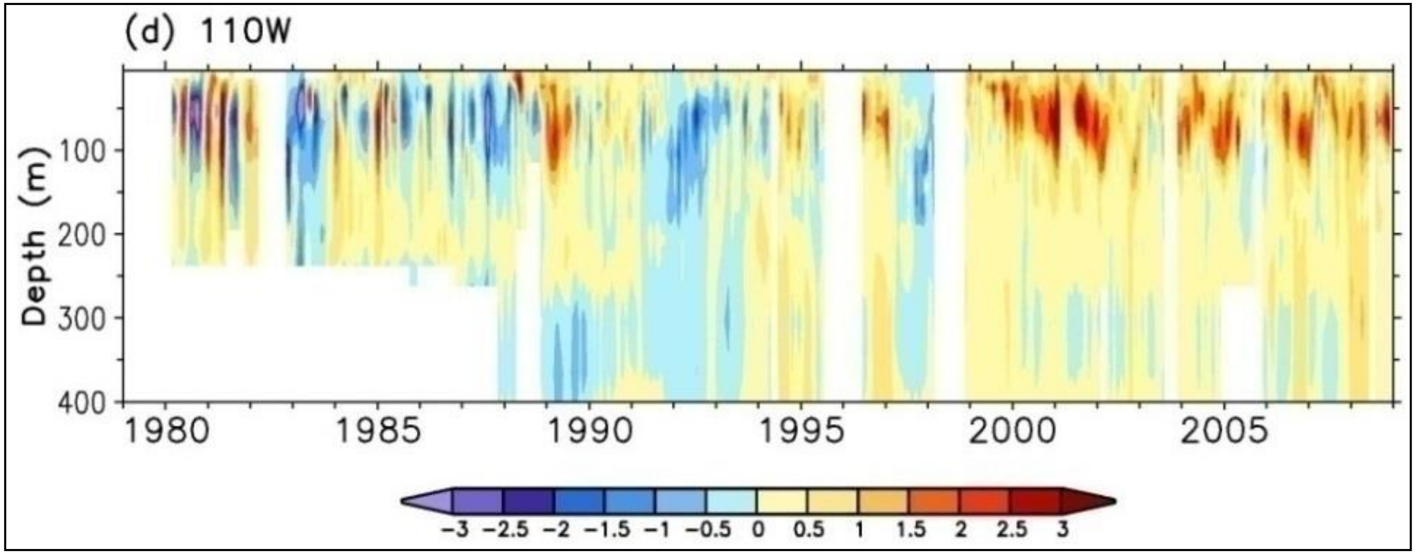



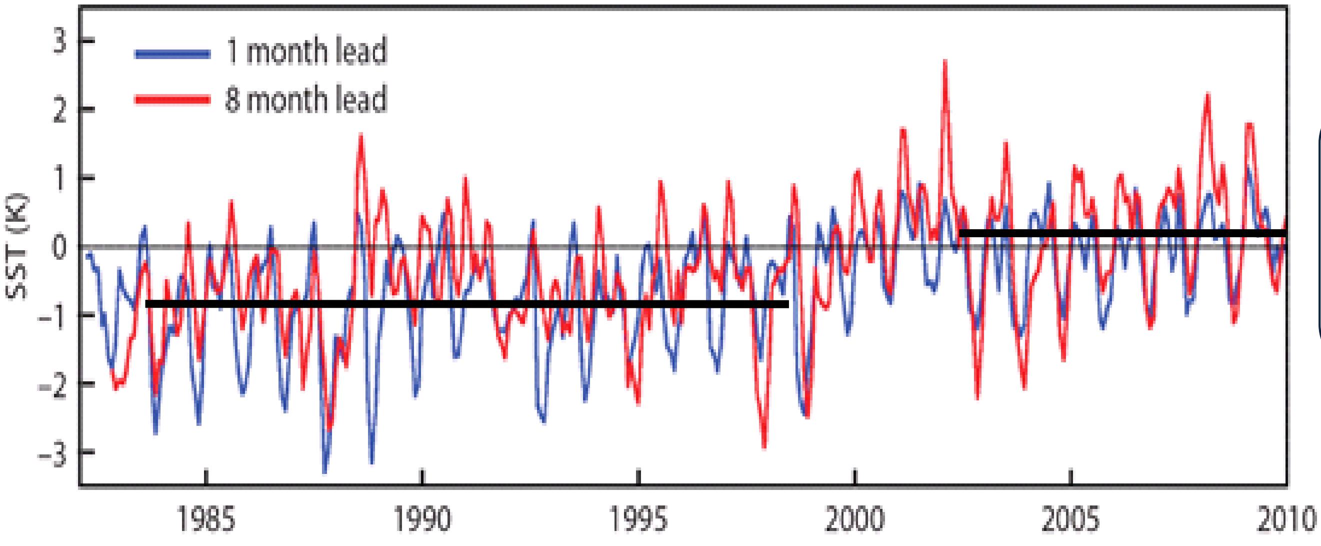

- Large soil moisture jump in 2011
- More extensive positive soil moisture anomalies in CFS than Leaky Bucket Model analysis
- Strong influence of soil moisture on T2m forecast in summer

(Courtesy: M. Chen, A. Kumar)

# Issues with ocean analysis



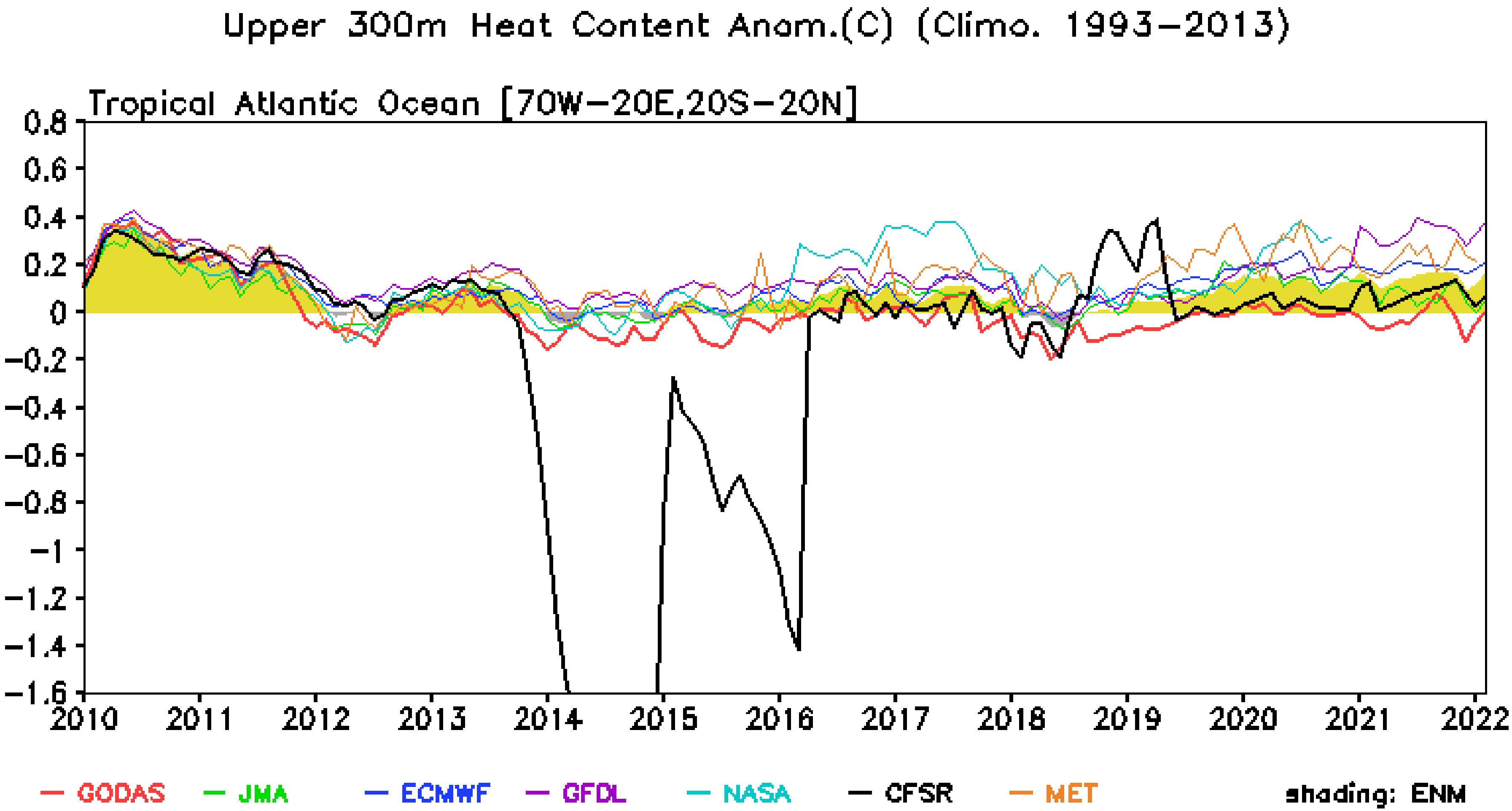

Temperature Difference : CFSR - TAO




Niño 3.4 SST Forecast Error CFSv2 - Observations

(Courtesy: A. Kumar, Y. Xue)

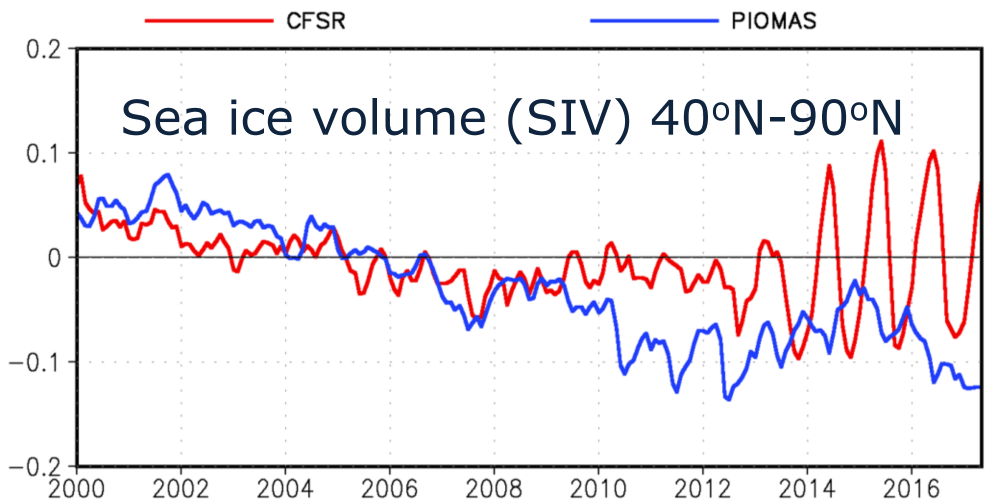
# Issues with ocean analysis



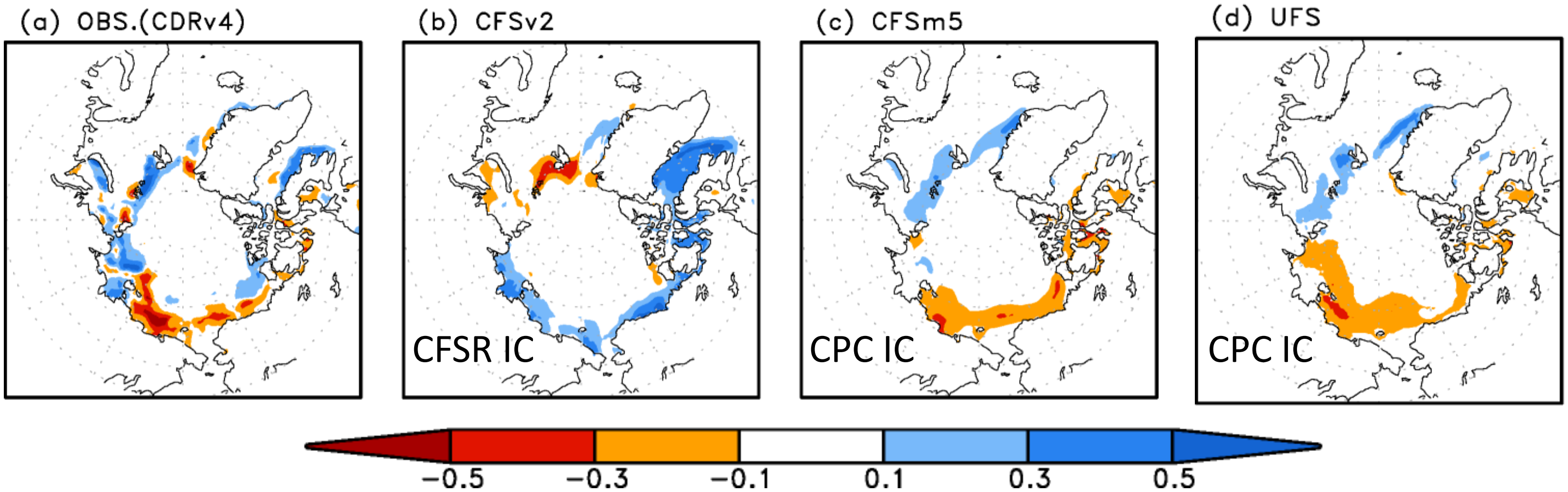

(Courtesy: C. Wen, A. Kumar)

# Issues with sea ice analysis

- 2010-2013: SIV in CFSR became larger then PIOMA
- Starting 2014: Large seasonal variation in CFSR SIV anomaly




**July 2017 sea ice concentration initialized from May 2017**



# Summary

- Systematic errors or low skills in the forecasts from the current forecast systems (CFS and/or GEFS)
  - Soil moisture
  - Stratospheric sudden warmings
  - Topical cyclone
  - MJO propagation
  - Tropical SST trend
  - ENSO false alarms

- Discontinuities in CFS initialization
  - Soil moisture
  - Ocean
  - Sea ice