Prediction challenges associated with errors in linear trends of tropical Pacific sea surface temperature

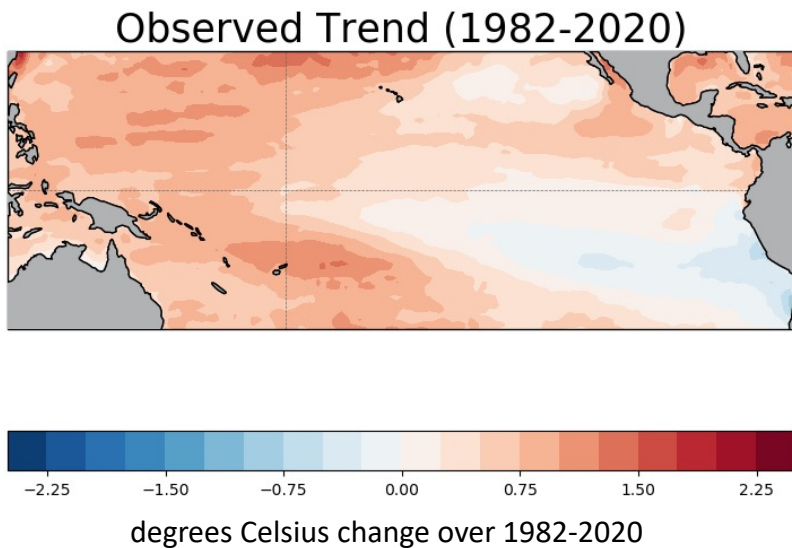Michelle L'Heureux[1], Michael Tippett[2], Wanqiu Wang[1]

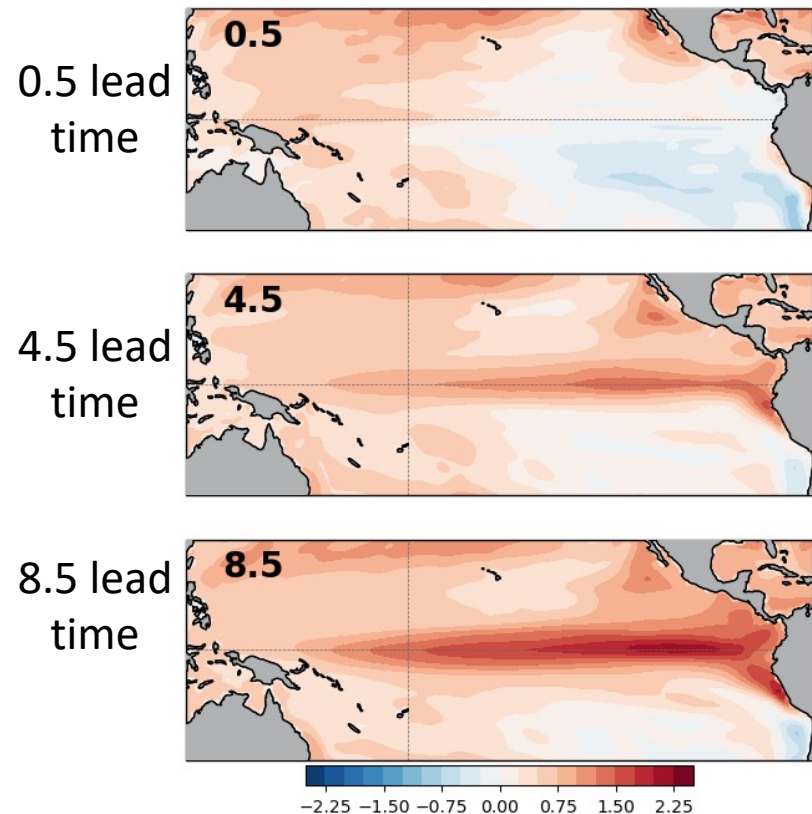[1]NOAA Climate Prediction Center
[2]Columbia University

46th Climate Diagnostics and Prediction Workshop
Virtual

Motivation

- Especially at longer leads, North American Multi-model Ensemble has sea surface temperature (SST) trends that are very different from what has been observed over the past ~40 years (**1982-2020**).

- What are the implications of these forecast errors? On precipitation anomalies over the tropical Pacific Ocean?
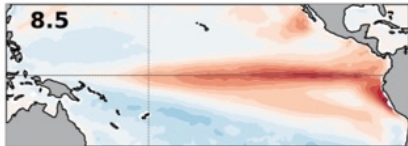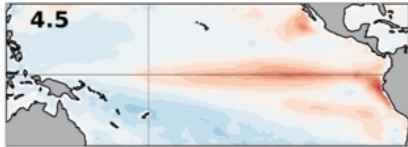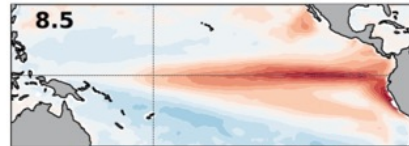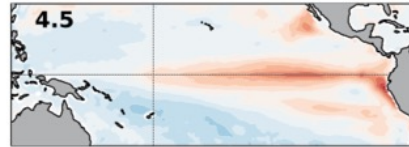
Trend in an NMME model

Observed Trend (1982-2020)

degrees Celsius change over 1982-2020

0.5 lead time

4.5 lead time

8.5 lead time

Linear SST Errors (forecast minus observations)
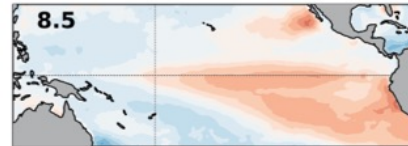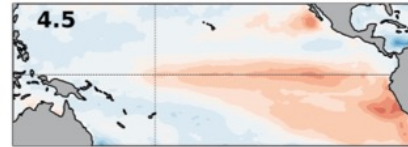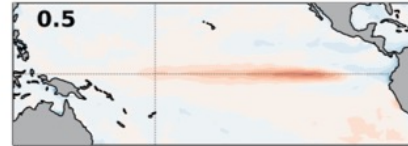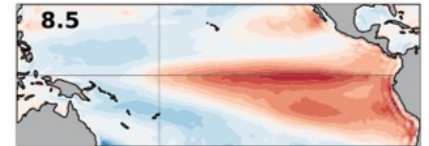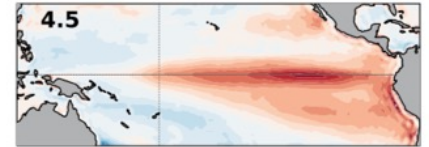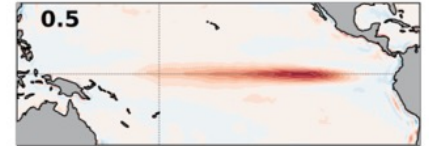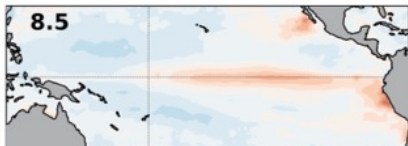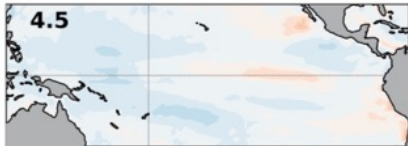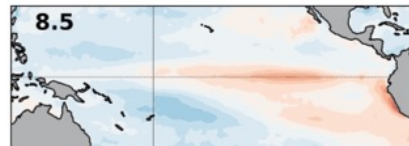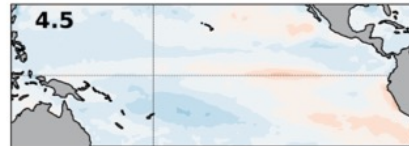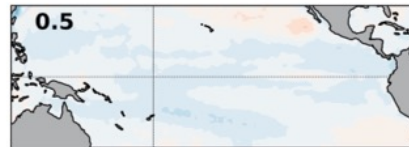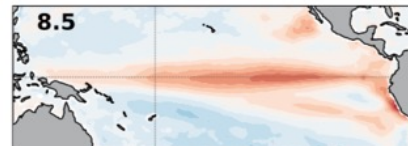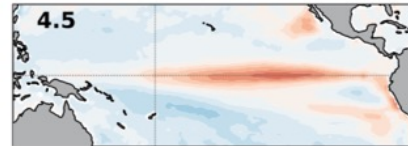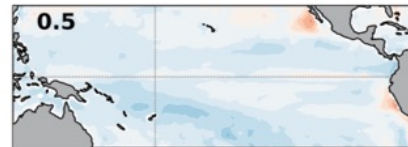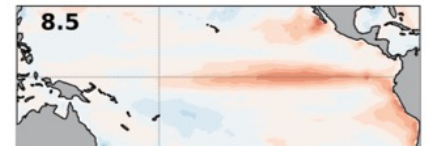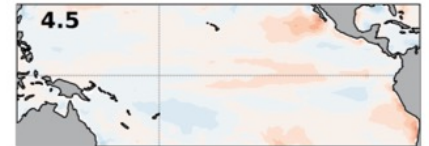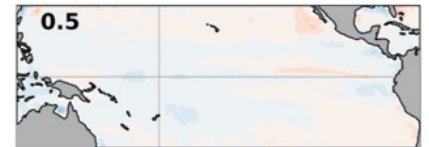
Trend in Squared Error (total SST)

Equatorial Error Increases
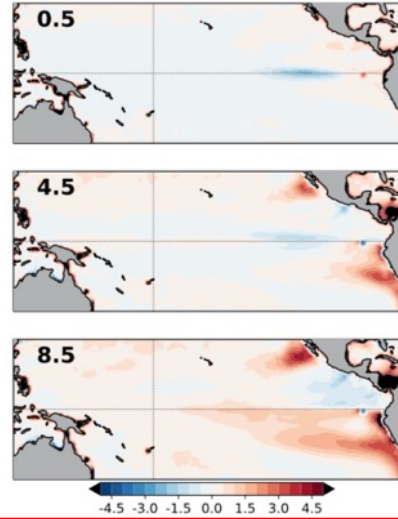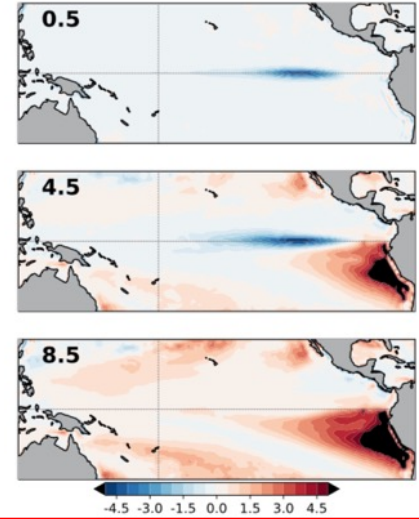
Equatorial Error Decreases
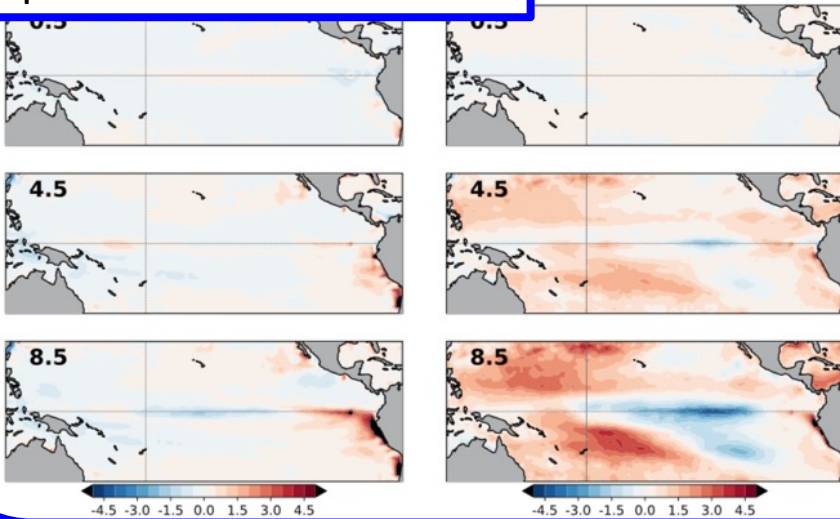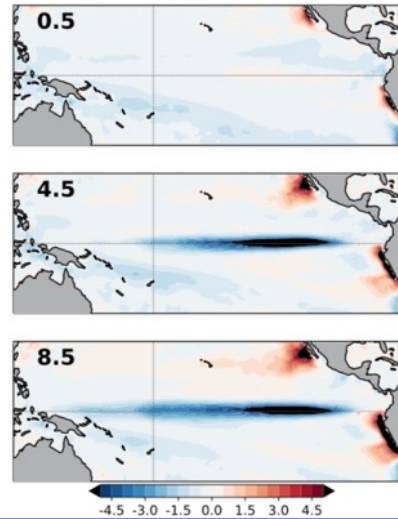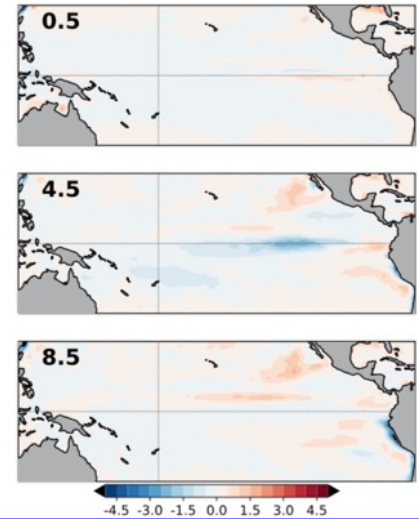
What explains the different sign in the trend?

Model Mean Bias (SST)

Warmer Mean Bias

Colder Mean Bias

GFDL-CM2p5-FLOR-B01
Mean Bias

COLA-RSMAS-CCSM4
Mean Bias

NCEP-CFSv2
Mean Bias

GEM-NEMO
Mean Bias

GFDL-CM2p1-aer04
Mean Bias
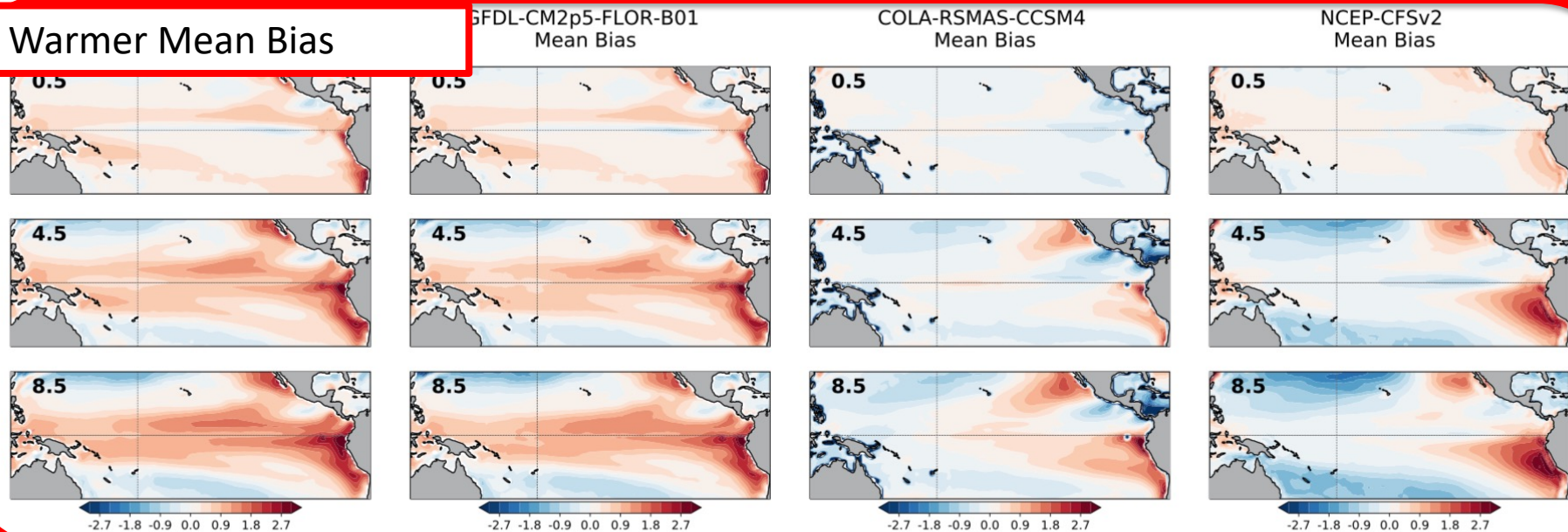
NASA-GEOSS2S
Mean Bias
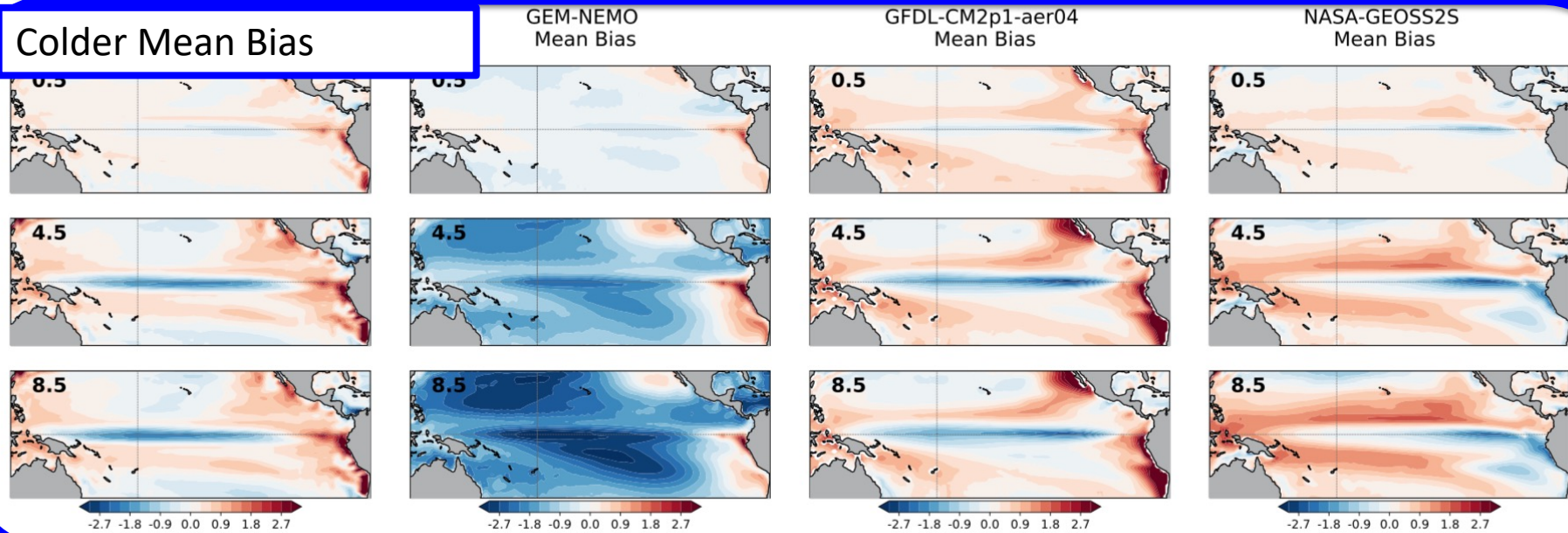
SST trends lead to trends in forecast errors, and the sign of the error is determined by the sign of the model's mean bias.
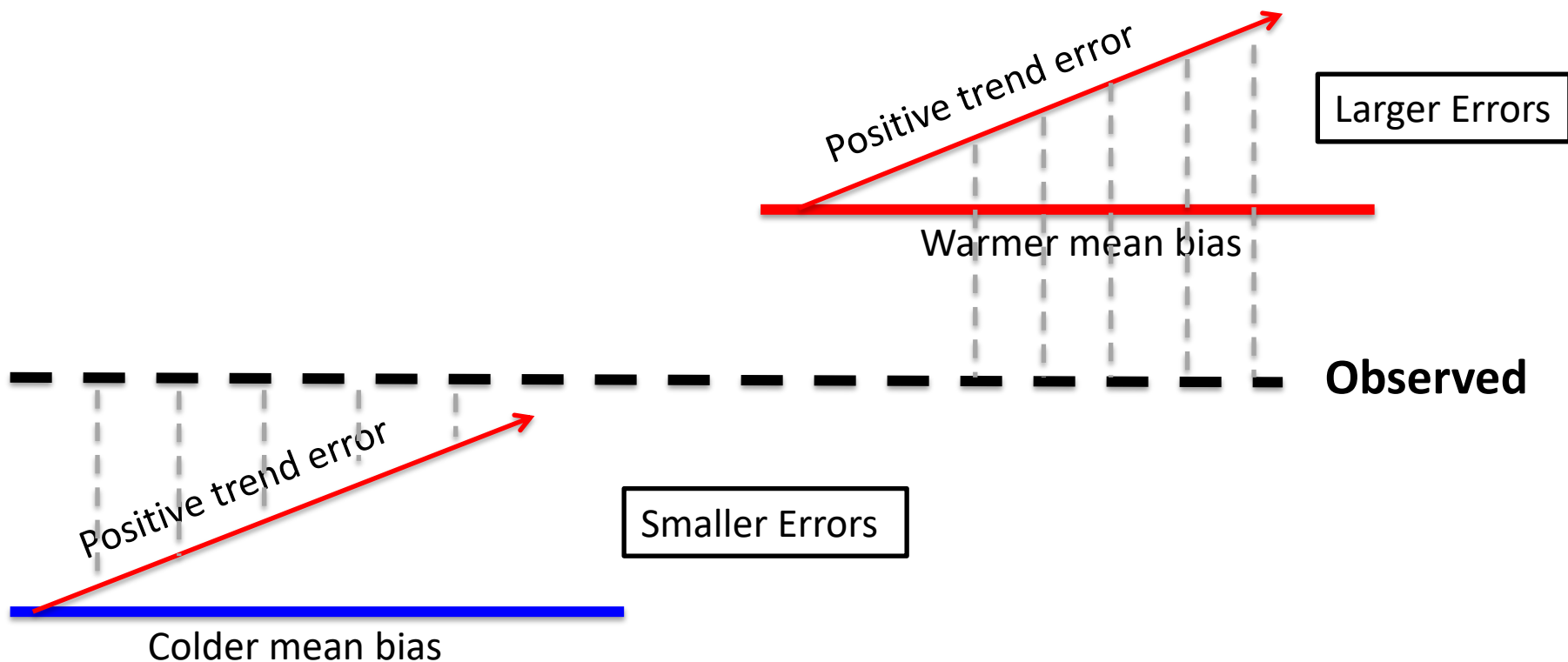
That's nifty, but who cares?
ENSO is defined using *anomalies*.

Total SSTs Relate To Precipitation Anomalies, which relate to ENSO Teleconnections
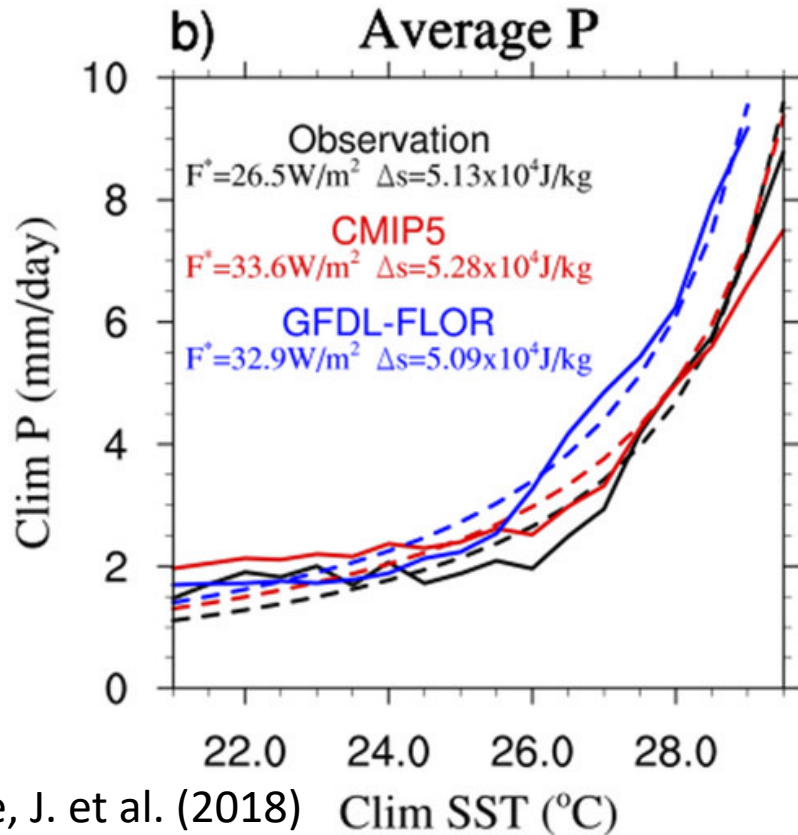
He, J. et al. (2018) *J. of Climate*.
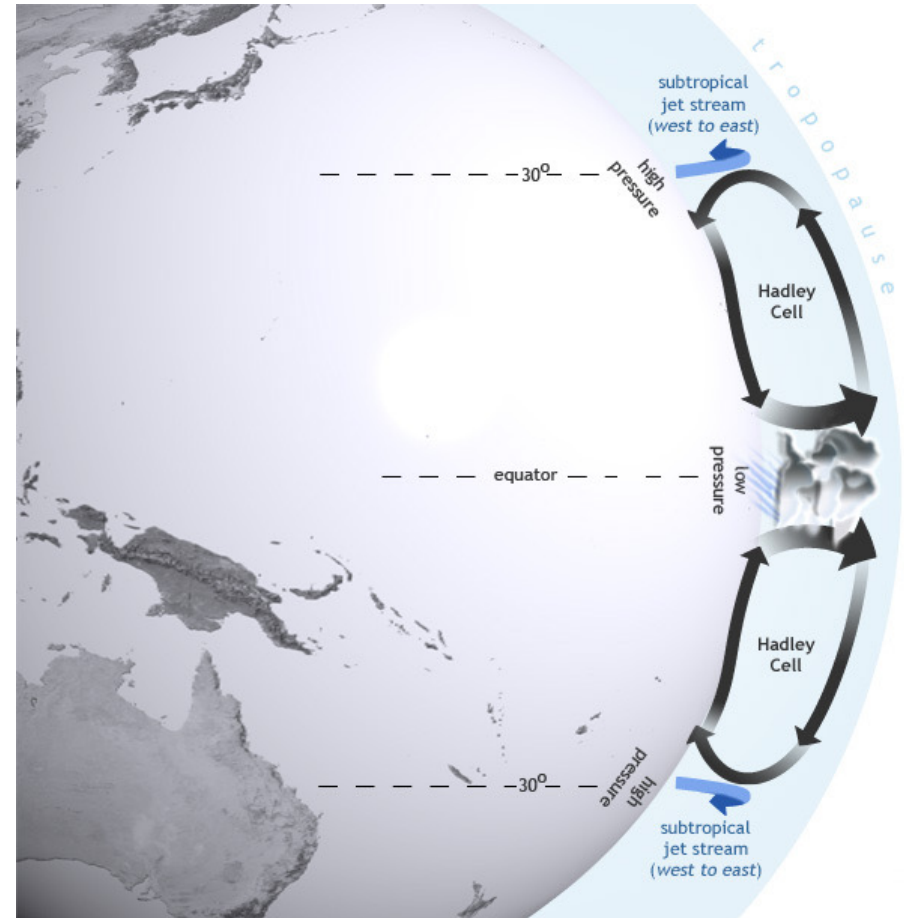
What is the forecast skill of Precipitation Anomalies?
Mean Squared Error Skill Score (MSESS)

RMSE/MSE = emphasize precip regions with climatologically large deviations.

An alternative is:

$$MSESS = 1 - \frac{MSE_{fct}}{MSE_{clim}}$$

Want to emphasize regions with amplitude departures *beyond* that expected in climatology.
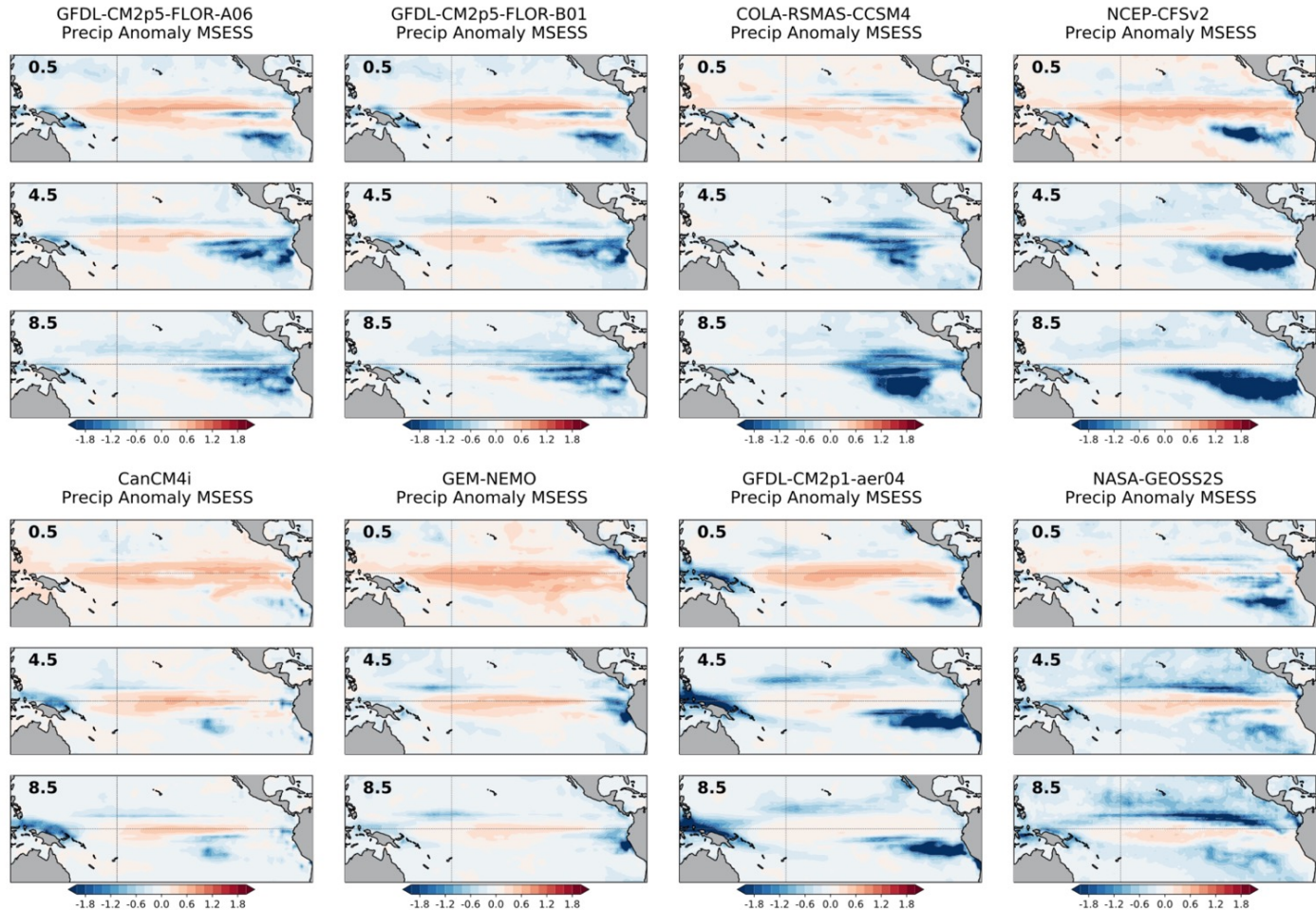
Warm colors → Positive Skill (better than climatological forecast)
Cool colors → Negative Skill (worse than climatological forecast)

Do Errors in the SST trends relate to Errors in Precipitation Anomalies?
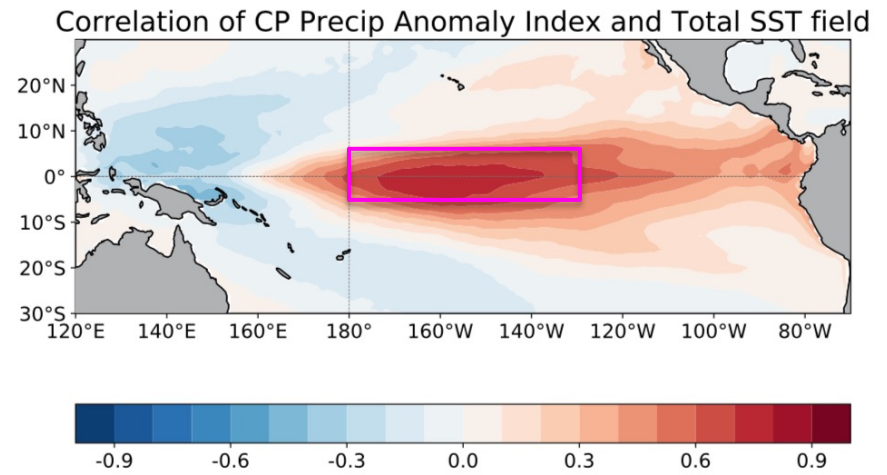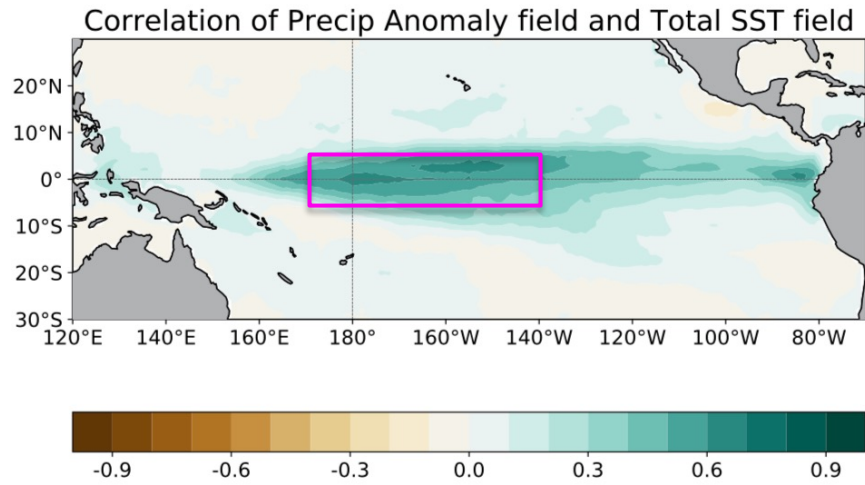
Created two indices based on precipitation anomalies and total SST correlations.

Do Errors in the SST trends relate to Errors in Precipitation Anomalies?

Mean Squared Error Skill Score (MSESS)

$$MSESS = 1 - \frac{MSE_{fct}}{MSE_{c\lim}}$$

Root Mean Squared Error (RMSE)
(more familiar measure)
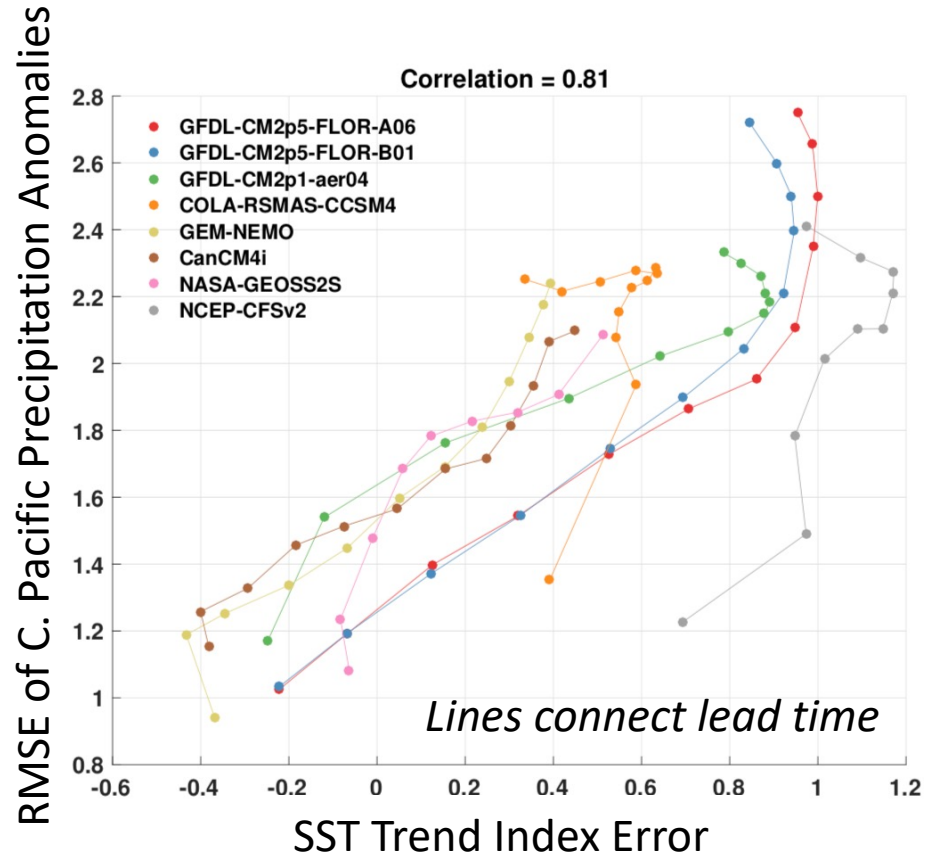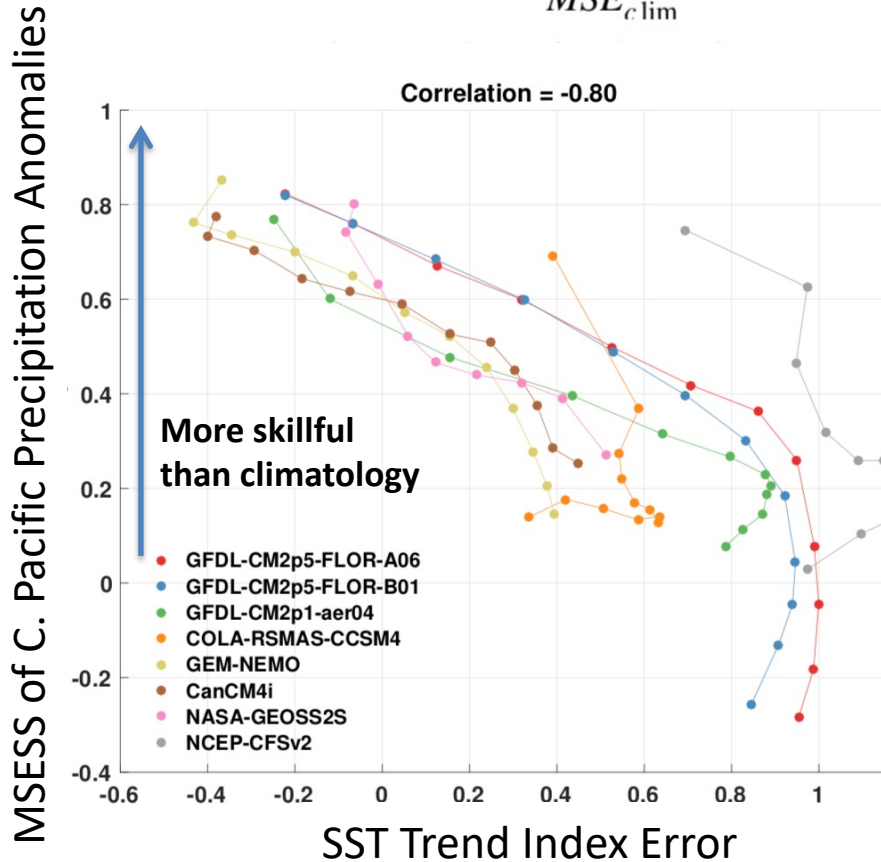
Are these anomalous precipitation errors changing over time? Does it impact the El Niño evolution?

Precipitation Anomaly Errors (Multi-model Average)

El Niño Events (after 2000)

Jan → Dec
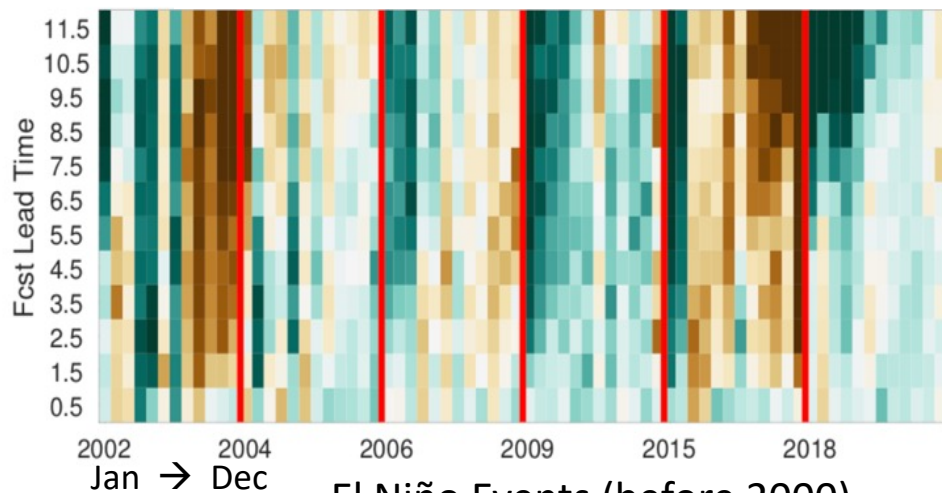
El Niño False Alarms (5 since 2000)

First Year Target (Jan to Dec)
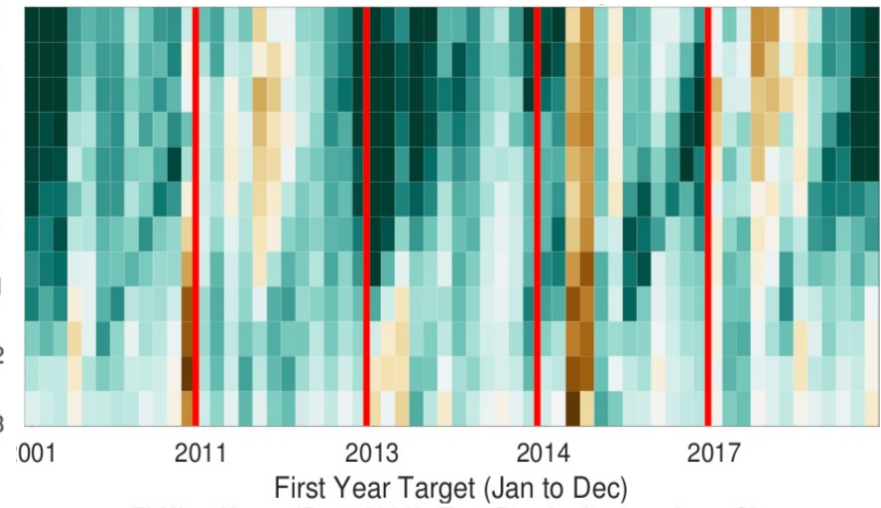
El Niño Events (before 2000)
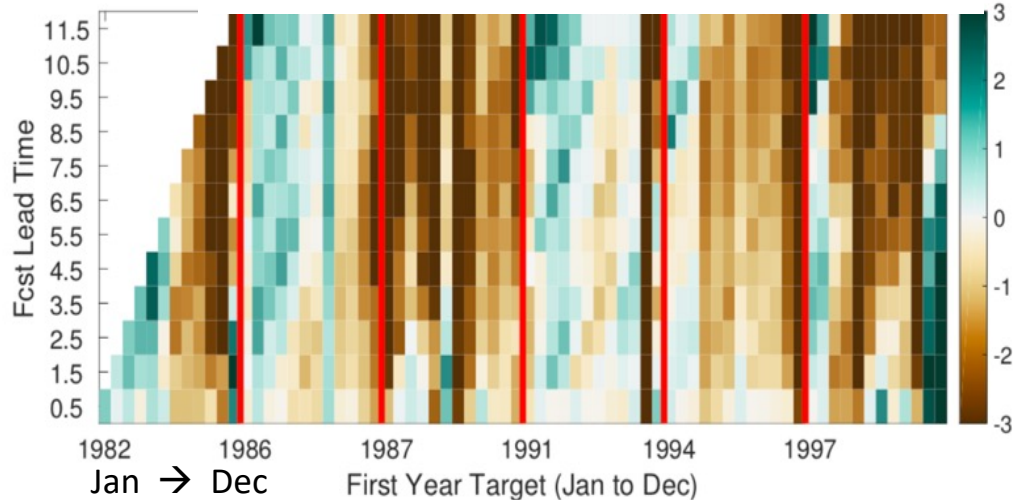
Jan → Dec   First Year Target (Jan to Dec)

Evolution of Precipitation Anomaly Errors during El Niño is wetter after 2000 than before. More El Niño False alarms (and wet errors) following 2000.

False Alarm Rate increases with the introduction of a linear trend

Joint Gaussian Model False Alarms (green dots) r=0.84 FAR=0.18

Joint Gaussian Model False Alarms (green dots) r=0.76 FAR=0.33

With linear trend added to ensemble mean fcst
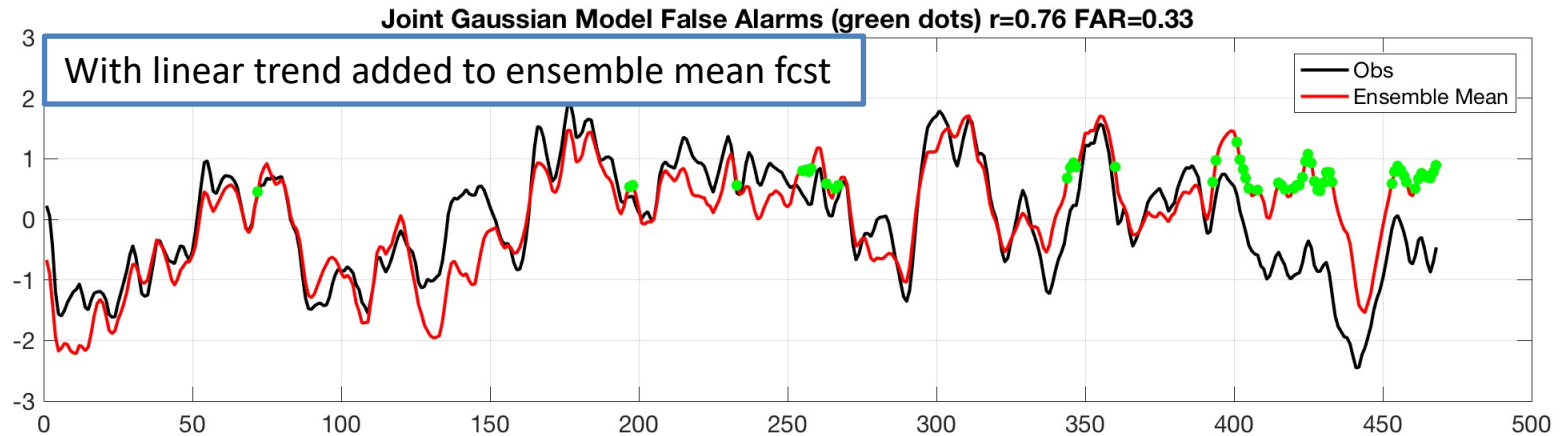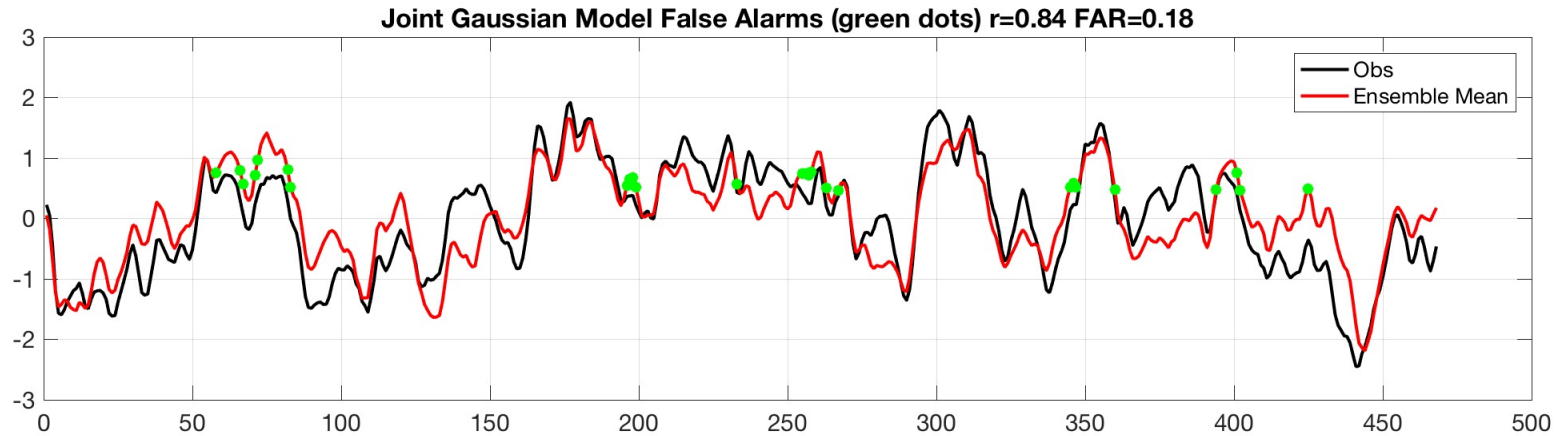
"Perfect" 100 member AR2 model experiment of Niño-3.4 index with lead=8.5 FLOR-A linear trend added to ensemble mean.

Summary

- Errors in Sea surface temperature trends → Trends in squared error of SSTs (sign determined by model bias)

- The amplitude of the error in the SST linear trend is strongly related to errors in the amplitude of of precipitation anomalies in the Central Pacific Ocean.

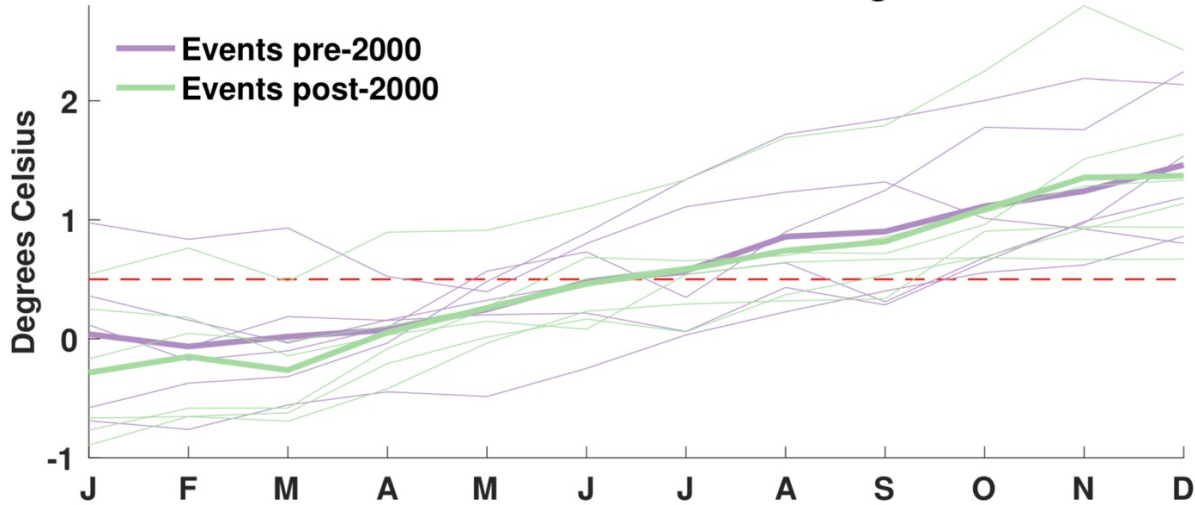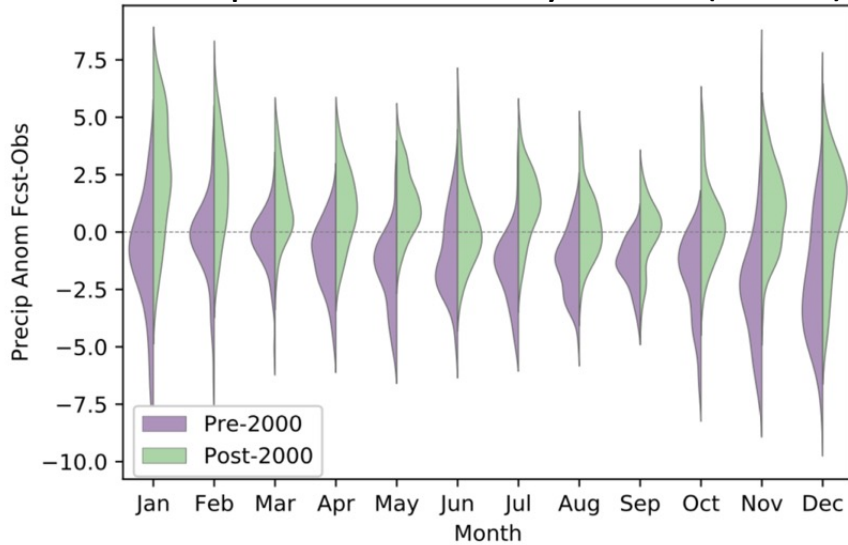- During El Niño events, precipitation anomaly forecast errors are wetter after 2000 than before 2000.

- El Niño False alarms have occurred more frequently in recent years (also see Tippett et al., 2000 in GRL).   Model errors in SST trends may partially explain an increase in false alarms.
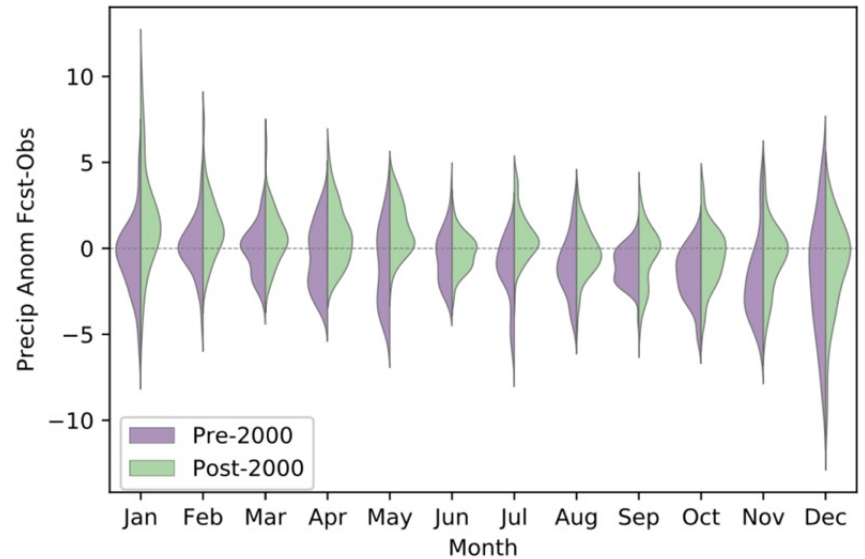
Extra Slide

Observed Jan-Dec Nino-3.4 Index Evolution during First Year of El Nino

Precipitation Anomaly Errors (CFSv2)

Precipitation Anomaly Errors (FLORA)

Evolution of Precipitation Anomaly Errors during El Niño is <u>wetter</u> after 2000 than before (particularly true for models with warm mean bias).