Indian Ocean SST variability: Causes, Feedbacks, and Consequences for Model Simulations

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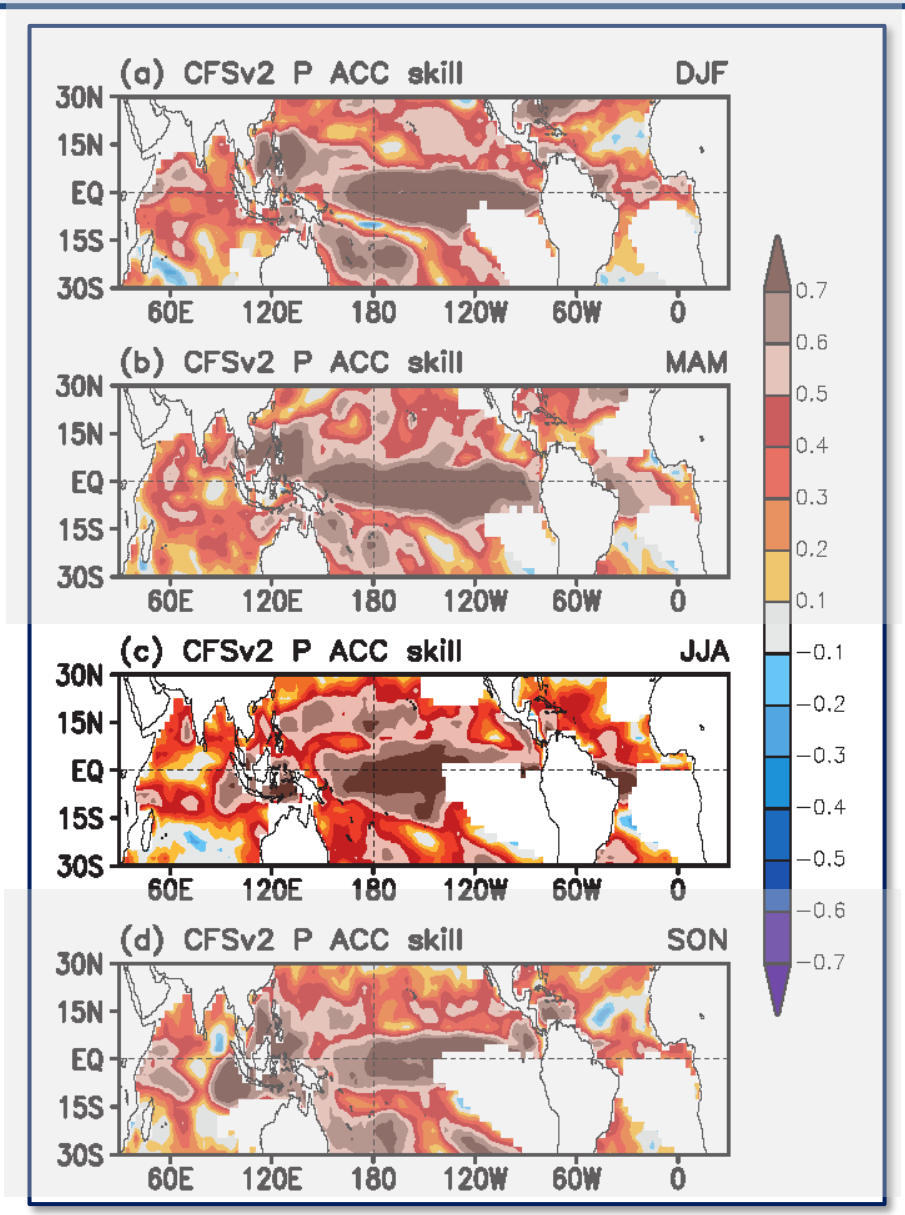
Outline

- Background
  - Spatial variations in skill of sea surface temperature and Precipitation
  - What is the cause spatial variability in skill?
- Possible explanation
- What are the implications for
  - Skill of long-range predictions?
  - Climate model simulations?
- Summary

Seamless Prediction Context

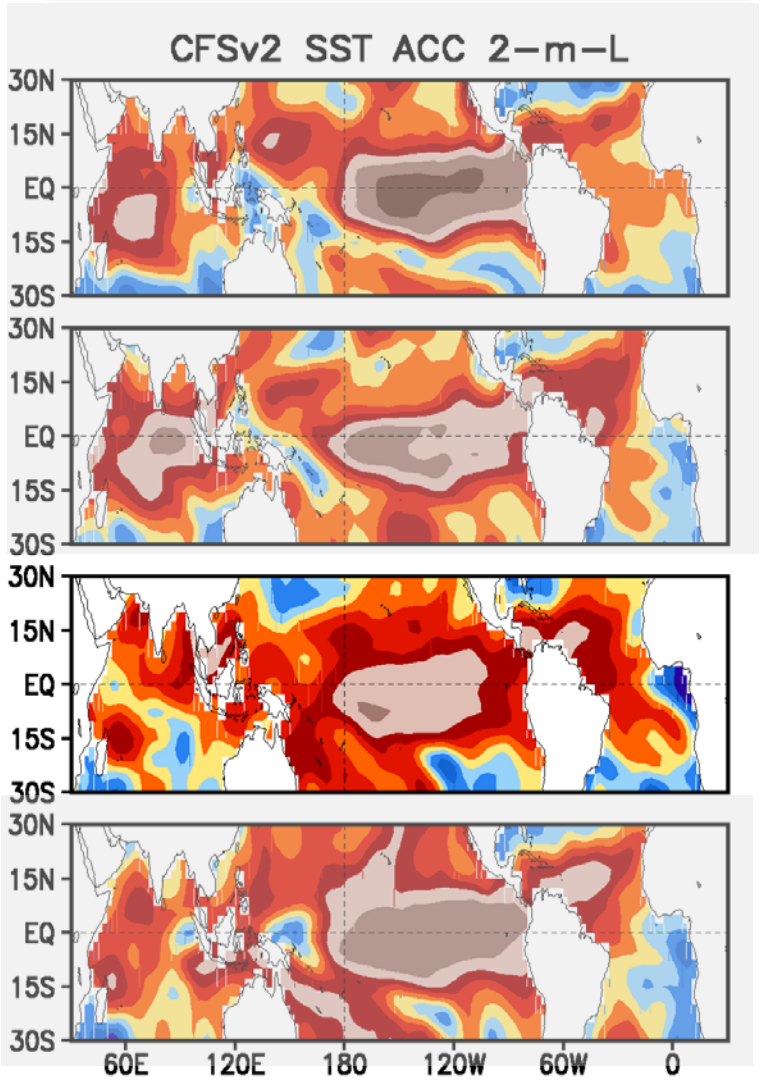
- Air-Sea interaction is important for climate variability on different time-scales
  - Cyclones & hurricanes
  - MJO
  - Global teleconnection due to ENSO
  - Trends in SSTs and precipitation
- Predictability on different time scales

Precipitation Skill for Seasonal Forecasts



JJA

SST Skill for Seasonal Forecasts



JJA

Question

- What is the cause for spatial variation in skill?
  - Model biases
  - Deficiencies in the specification of initial conditions
  - Predictability limits due to some physical constraints

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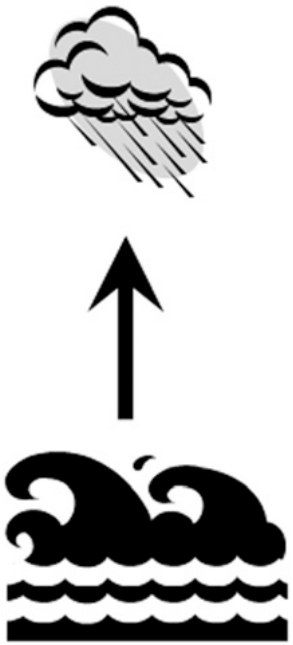
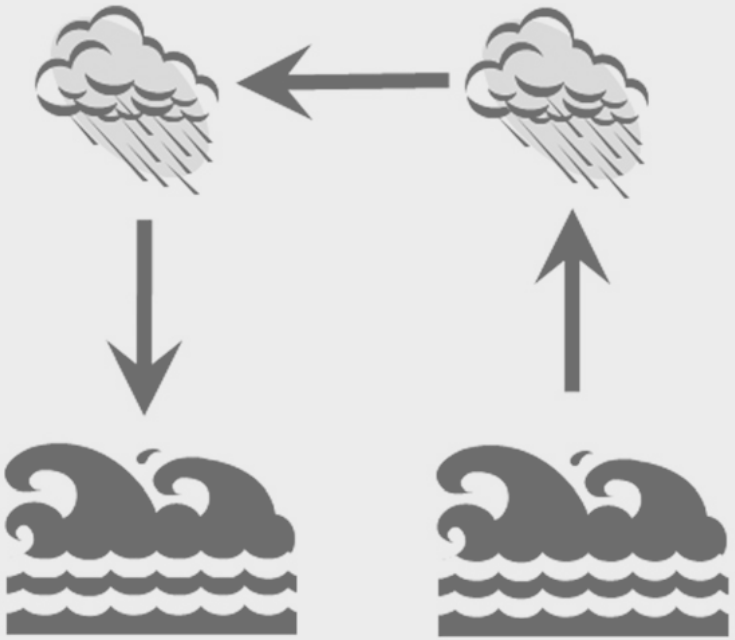
Three paradigms for ocean-atmospheric interaction…
#1: Ocean forces atmosphere variability



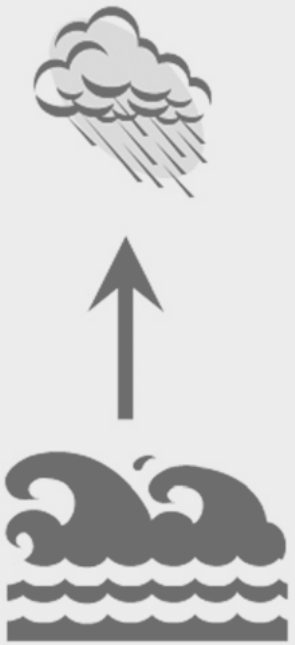
Local SST variability forces atmospheric variability

Local Atmospheric Variability Forces SST Variability

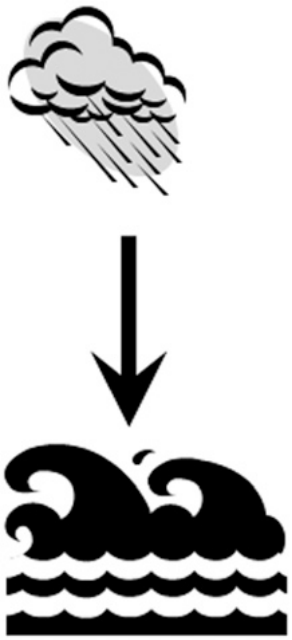


Atmospheric Variability is Forced by Remote SST Variability, that in turn Forces Local SST Variability

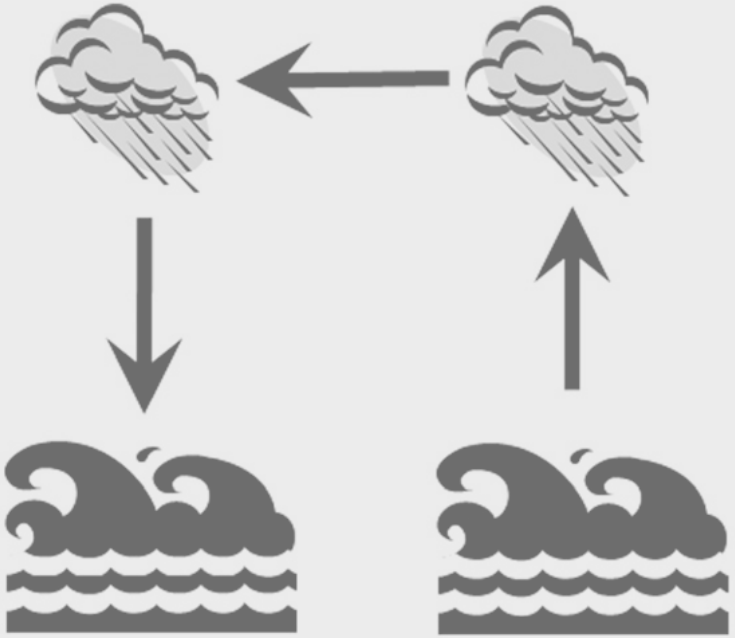
Three paradigms for ocean-atmospheric interaction…
#2: Atmosphere forces ocean variability



Local SST Variability Forces Atmospheric Variability



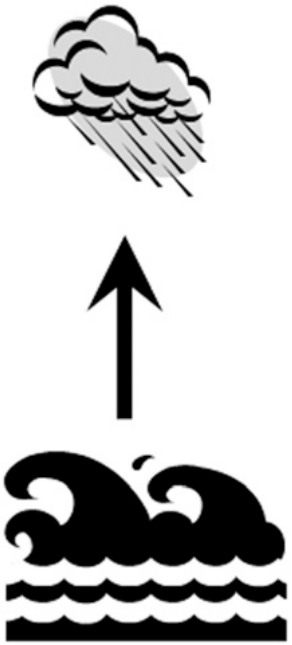
Local Atmospheric Variability Forces SST Variability



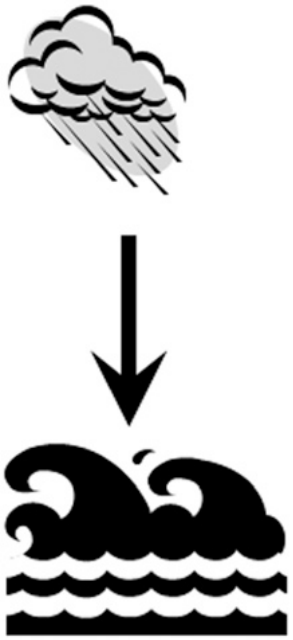
Atmospheric Variability is Forced by Remote SST Variability, that in turn Forces Local SST Variability

What are the Consequences for Different Regimes?

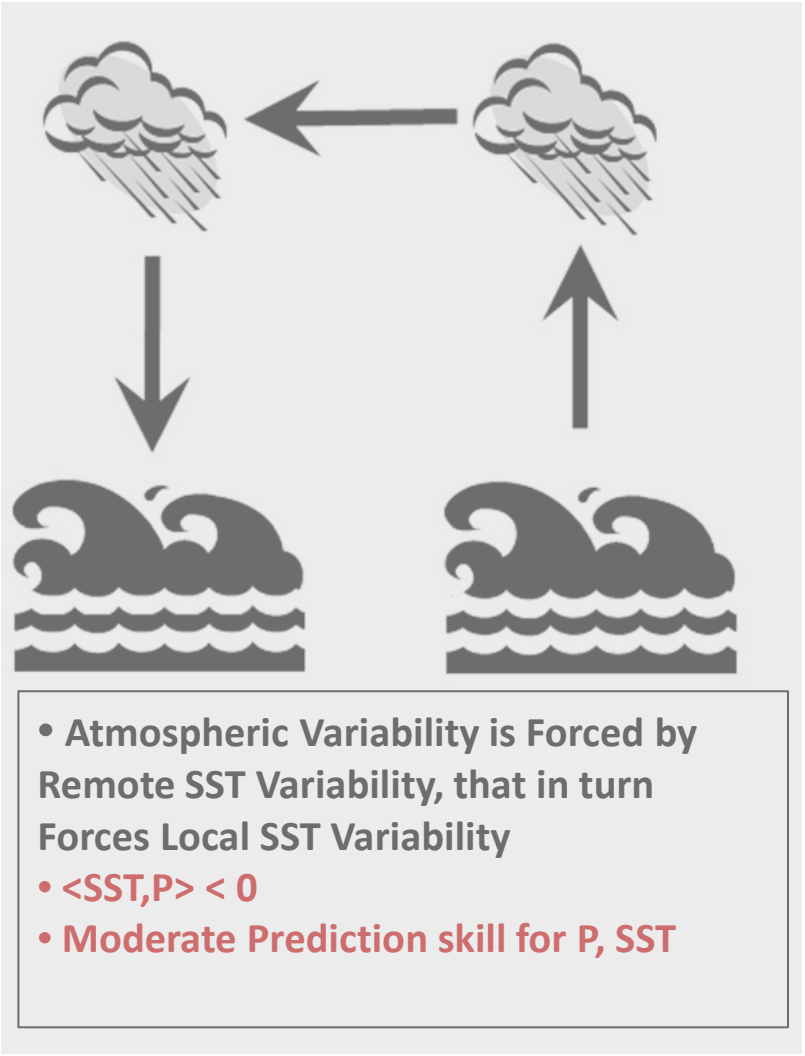
Implications for Local SST-P Relationship



- Local SST Variability Forces Atmospheric Variability
- <SST,P> > 0
- High Prediction skill for P

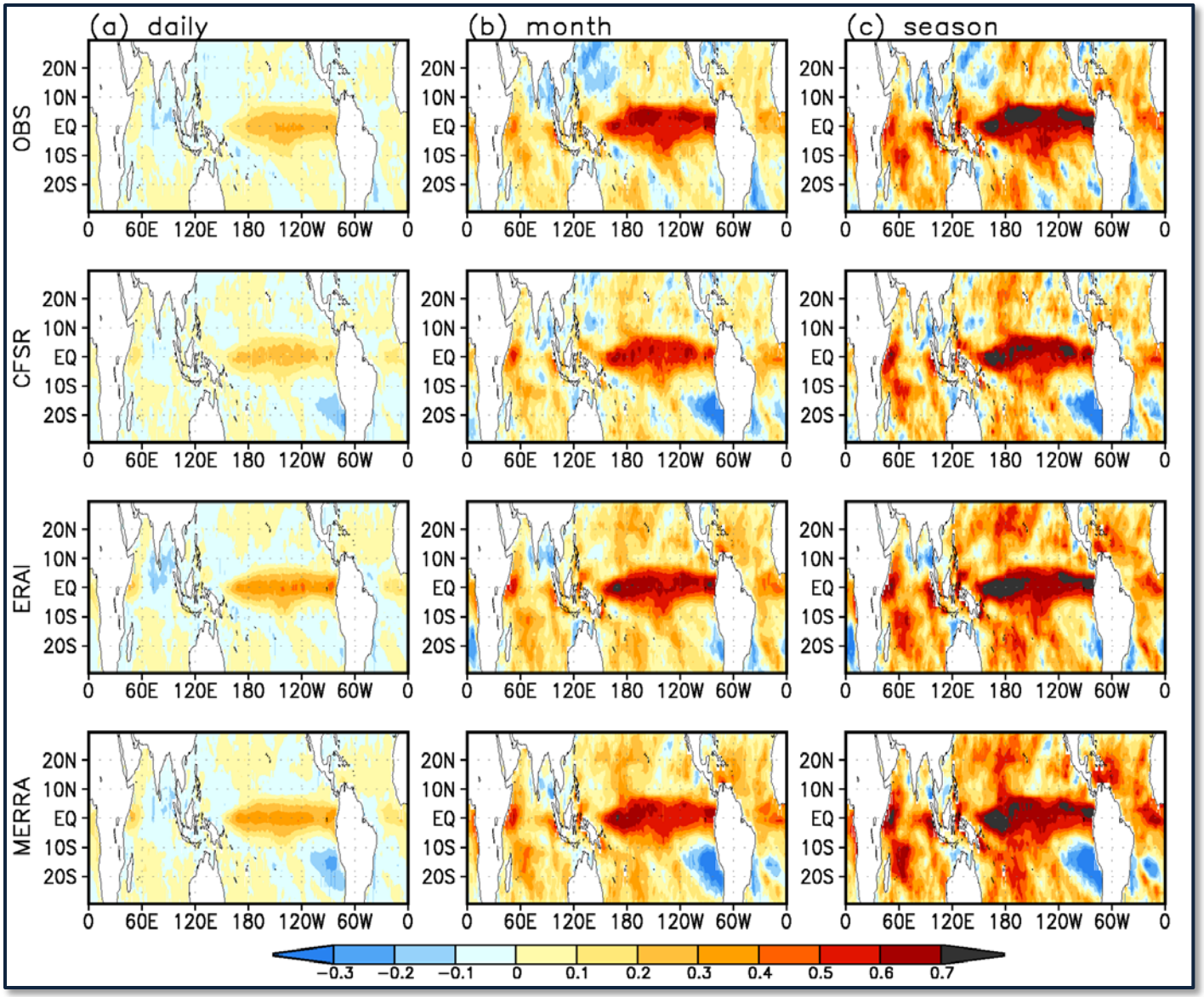


- Local Atmospheric Variability Forces SST Variability
- <SST,P> < 0
- Low Prediction skill for P



- Atmospheric Variability is Forced by Remote SST Variability, that in turn Forces Local SST Variability
- <SST,P> < 0
- Moderate Prediction skill for P, SST

<SST-P> Between Observations and Various Reanalyses for Different Time-Scales



Various Reanalyses

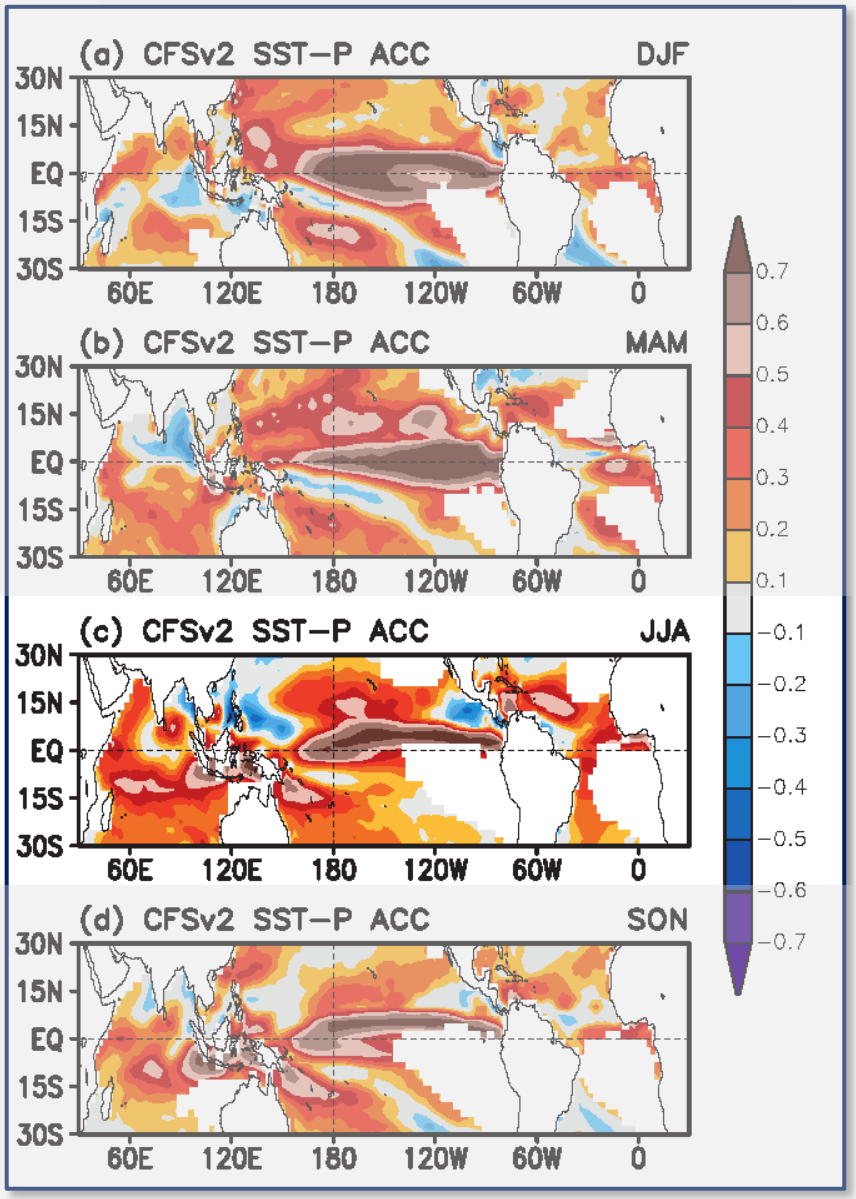
Obs

CFSR

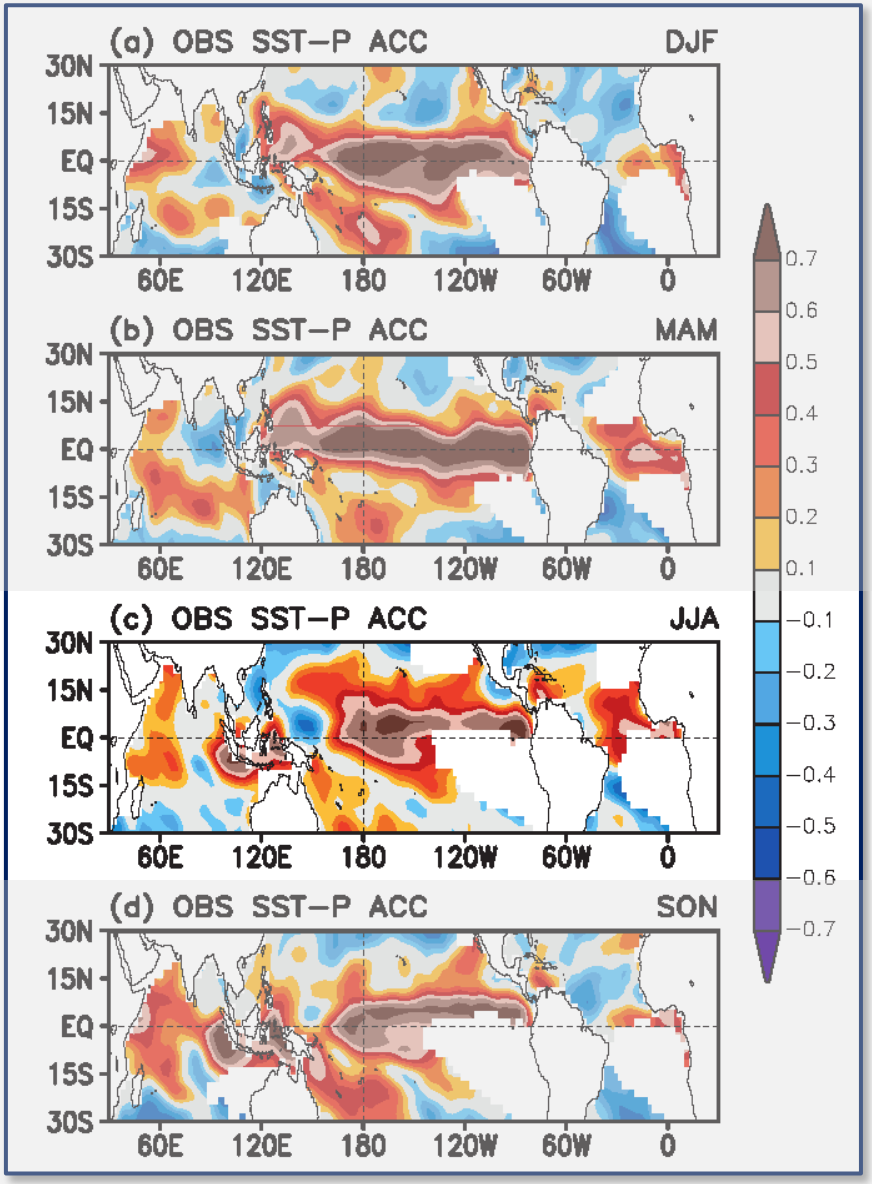
ERAI

MERRA

Model Local SST-P Correlation



Observed Local SST-P Correlation



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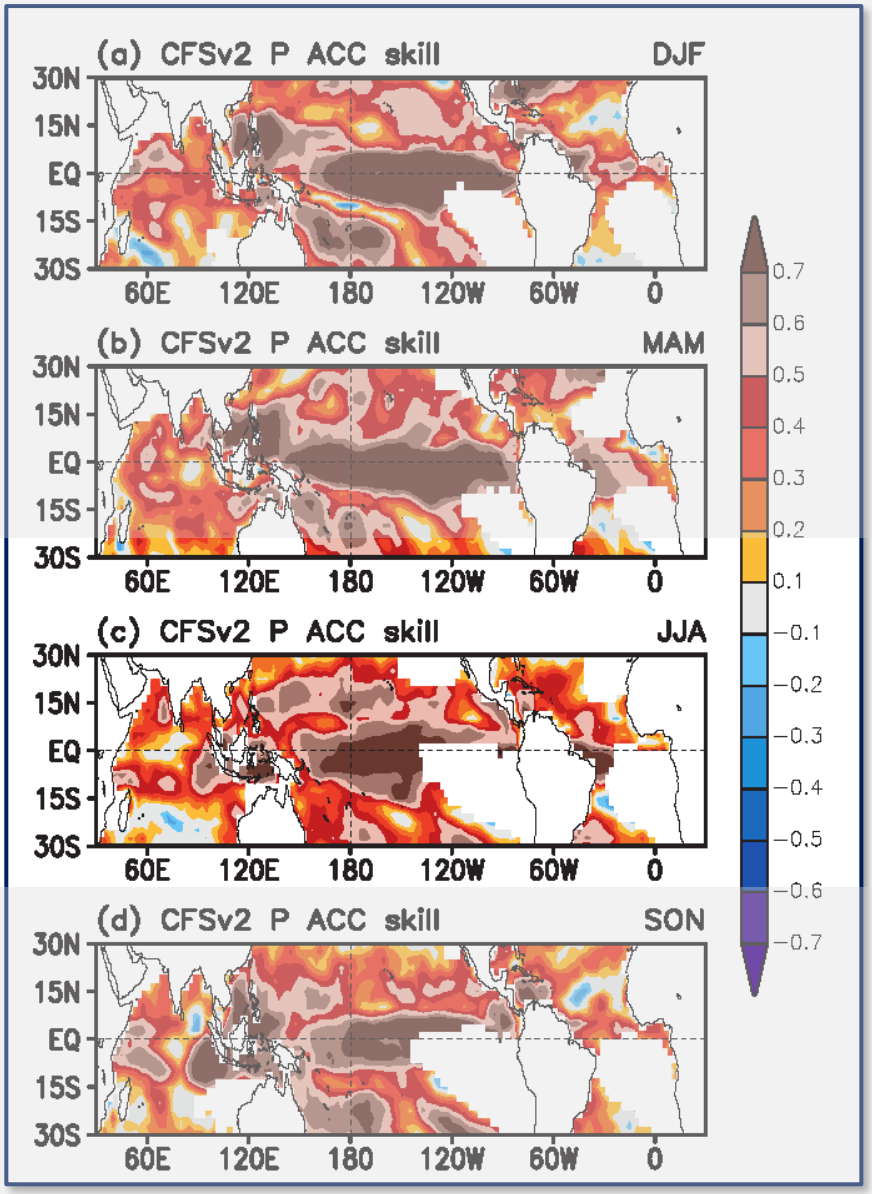
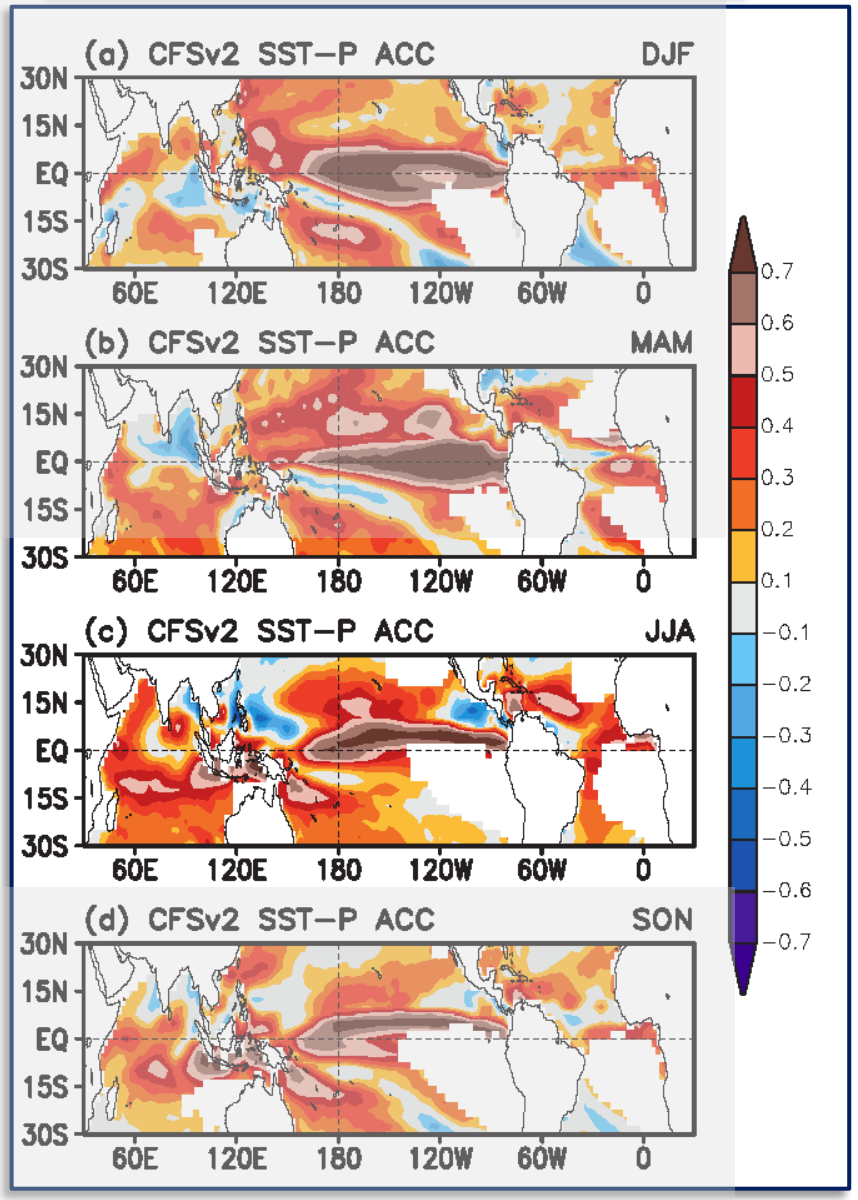
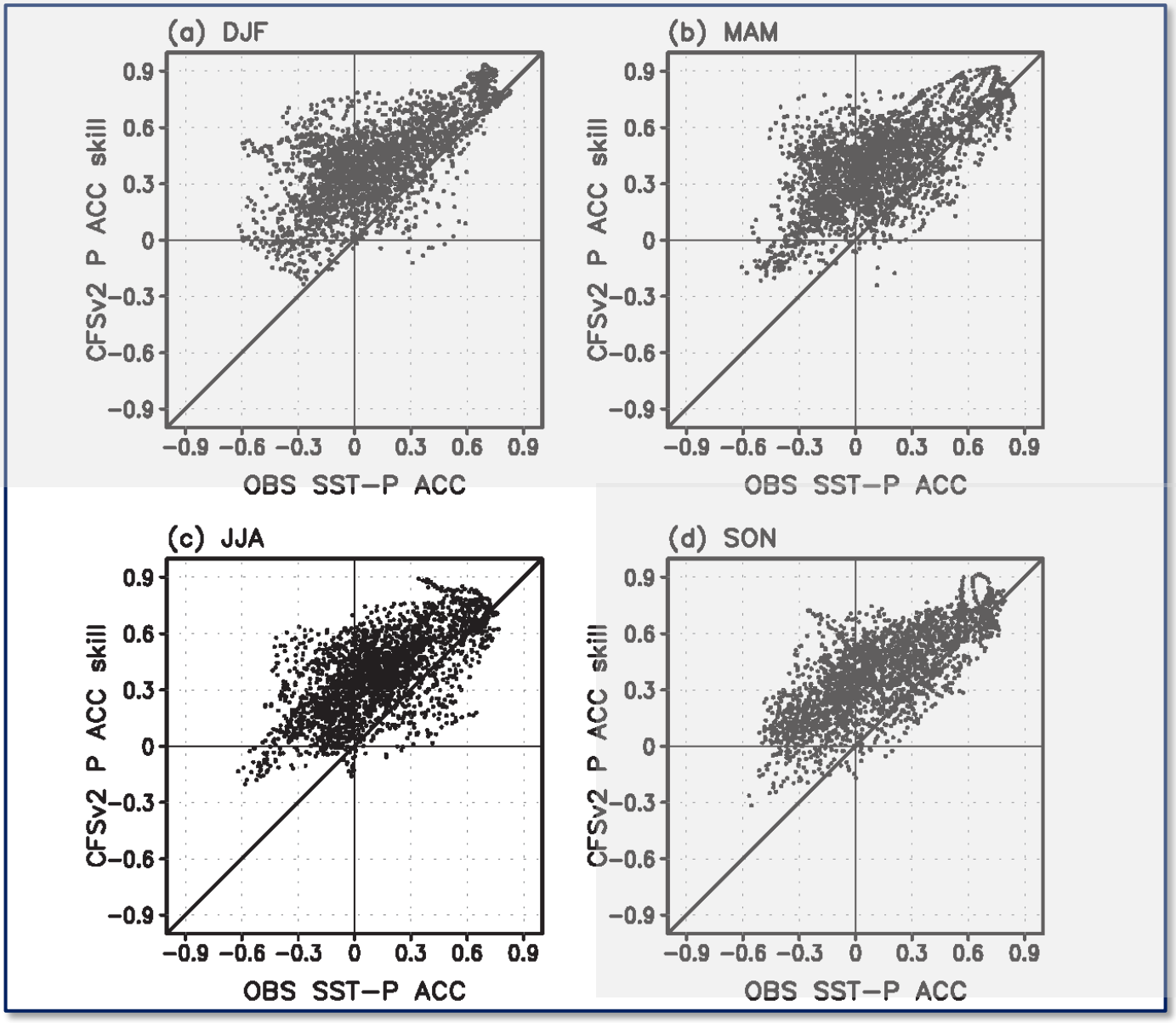
Precipitation Skill for Seasonal Forecasts

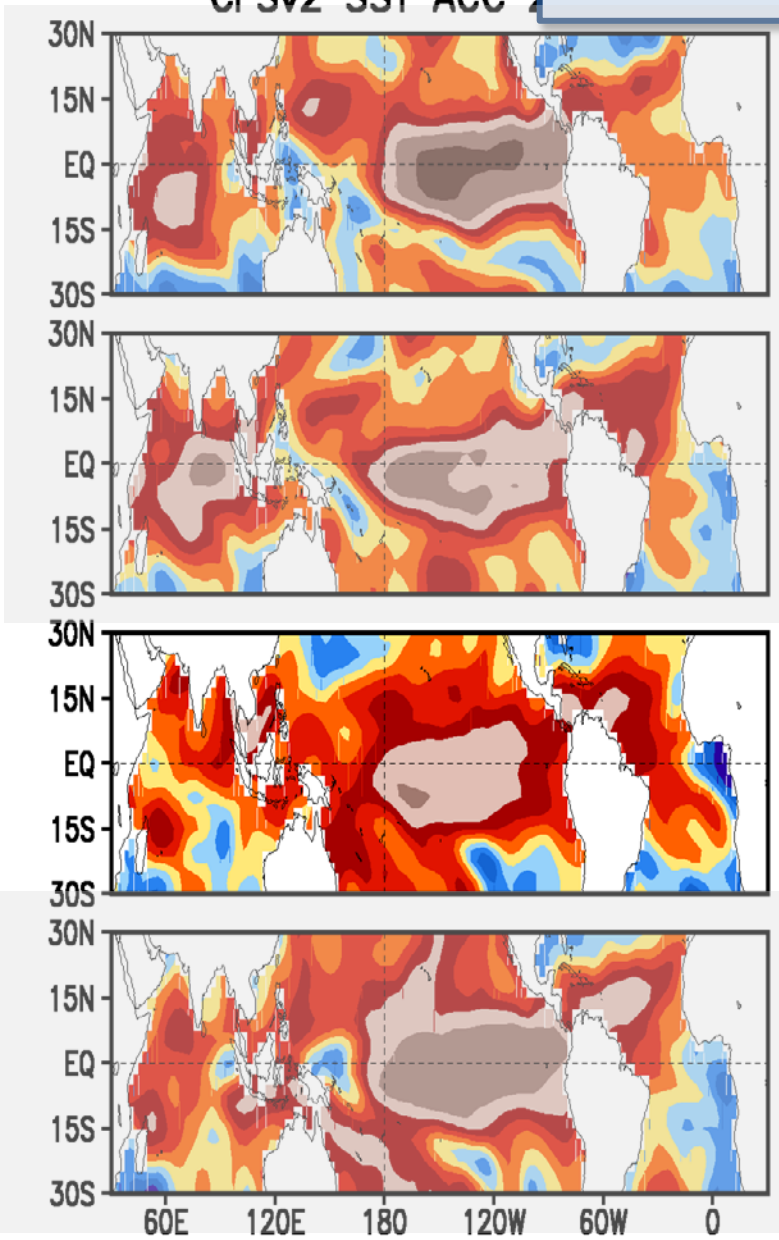


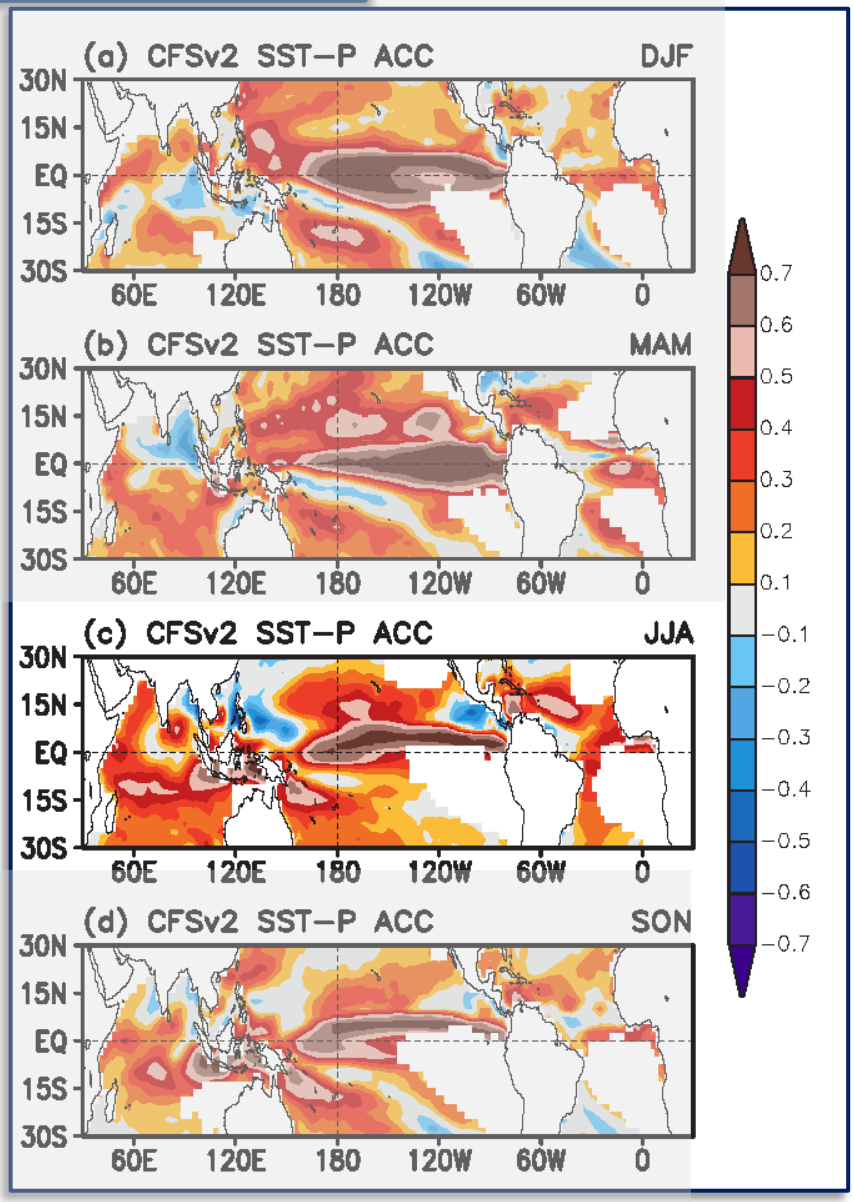
Model Local SST-P Correlation



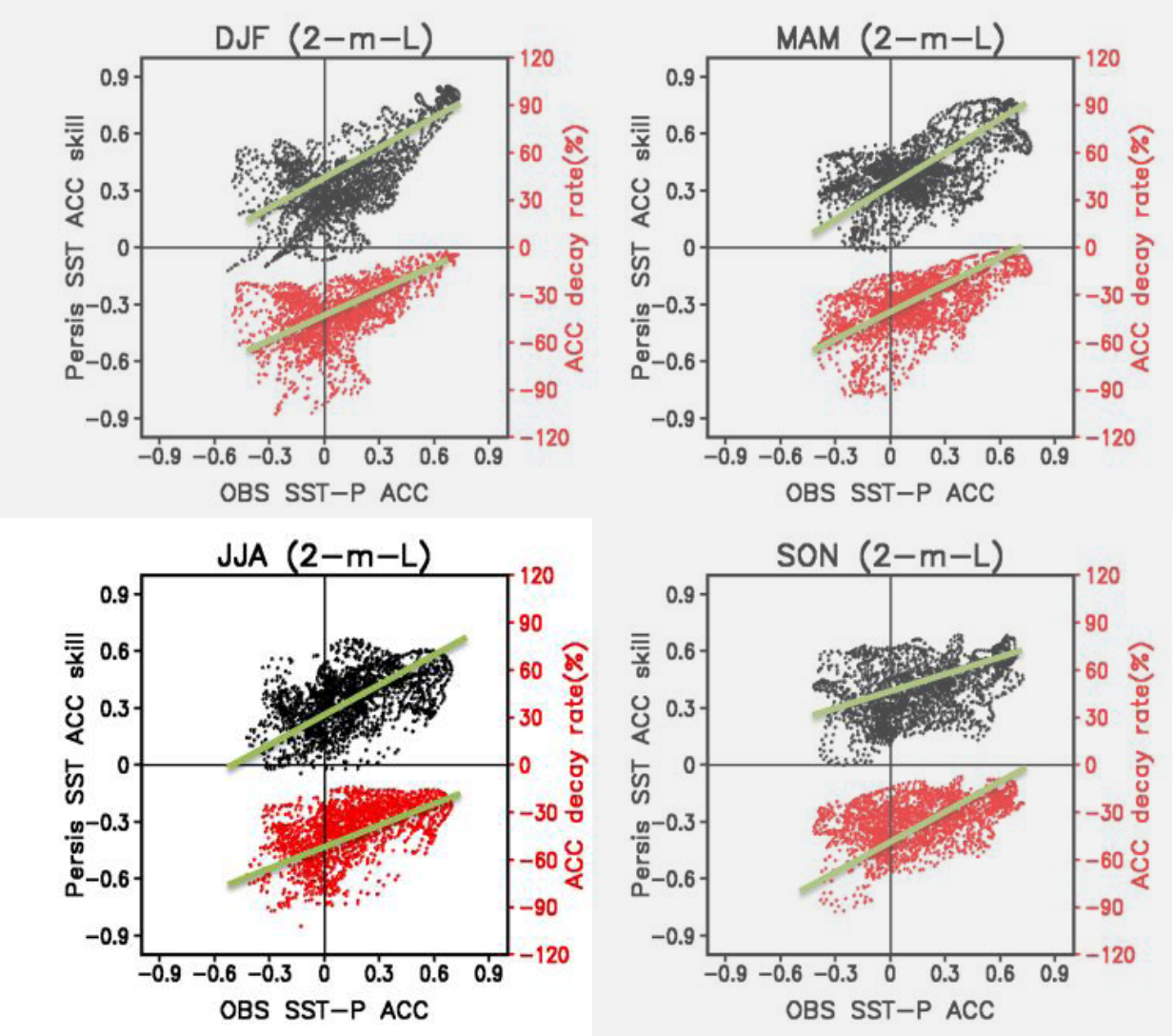

(a) DJF
(b) MAM
(c) JJA
(d) SON
CFSv2 P ACC skill
OBS SST–P ACC
0.9
0.6
0.3
0
–0.3
–0.6
–0.9

SST Skill for Seasonal Forecasts





SST Skill for Seasonal Forecasts



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AMIP Simulations

- AMIP simulations – Atmospheric general circulation model forced either with observed evolution on SSTs or with some idealized SSTs
- In AMIP simulations, atmospheric variability does not affect ocean…ocean is basically an infinite reservoir of heat. $\langle SST\text{-}P \rangle > 0$

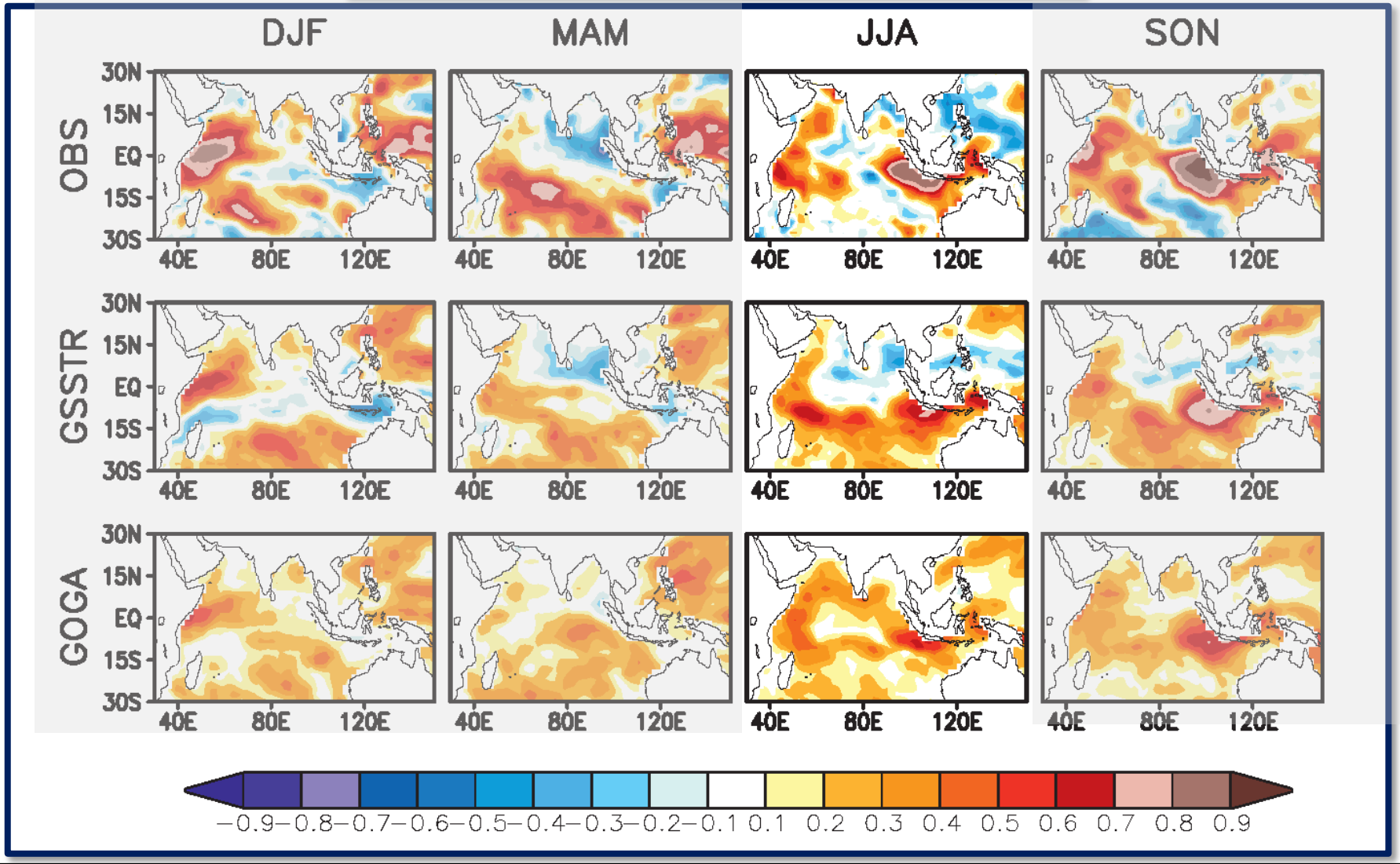
Because the ocean and atmosphere evolve as a coupled system in nature, why not do the right thing, and only work with coupled models?

Possible Reasons for Doing Uncoupled Model Simulations

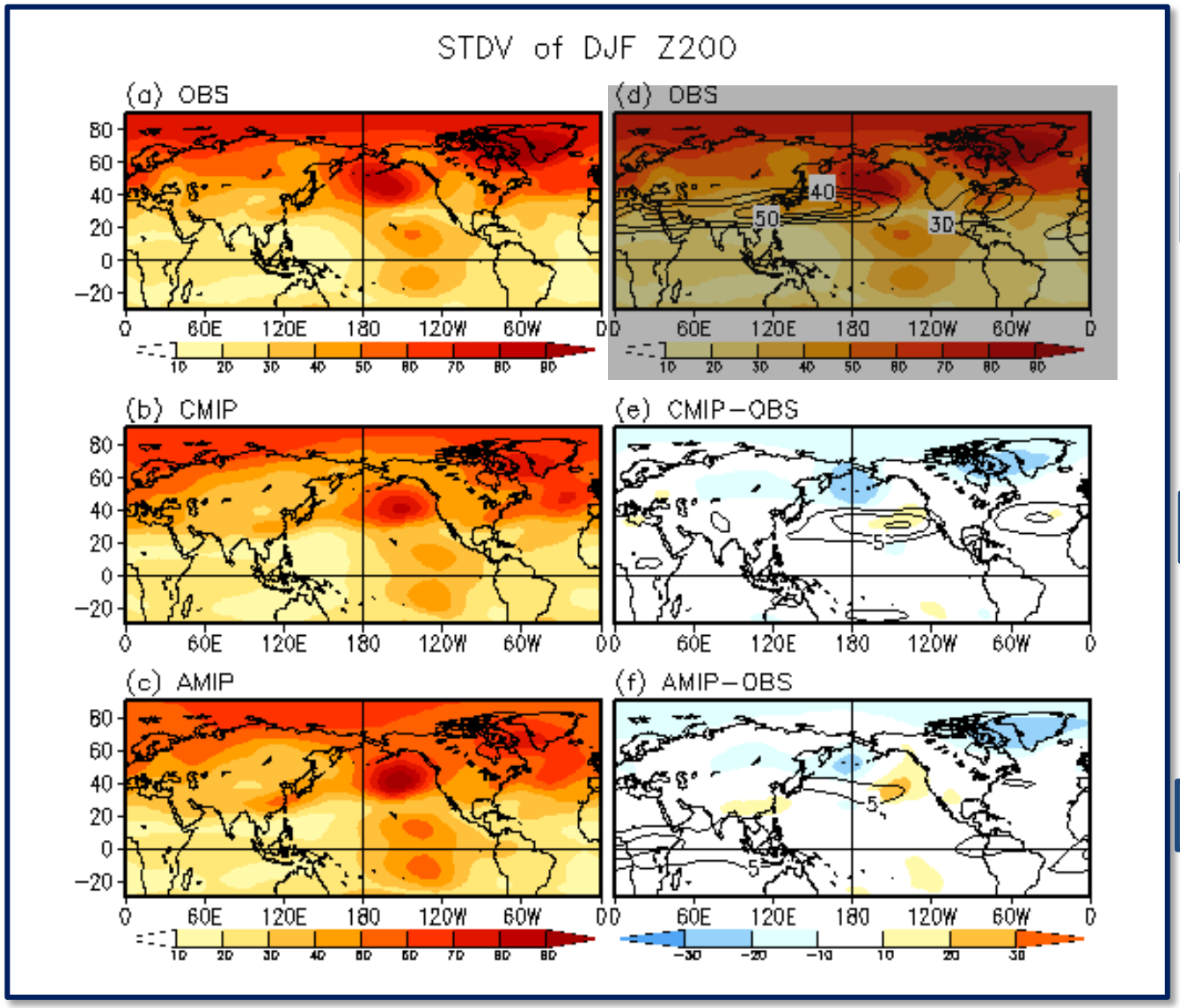
- Why use AMIP simulations?
  - Simplifies the problem and allows one to break the system apart
  - More controlled experimentation in understanding causality of observed atmospheric anomalies (aka Attribution)
  - Time-slice climate change projections for information with higher spatial resolution
- Our ability to justify AMIP simulations depends on how much atmospheric variability (and “response” to SST) differs between coupled and uncoupled (AMIP) simulations? How severe are the consequences of ignoring correct <SST-P> relationship?

Local SST-P Correlations

a. Observations
b. Coupled model
c. AMIP



Standard Deviation of 200-mb Seasonal Mean Z Observations; Coupled model; AMIP

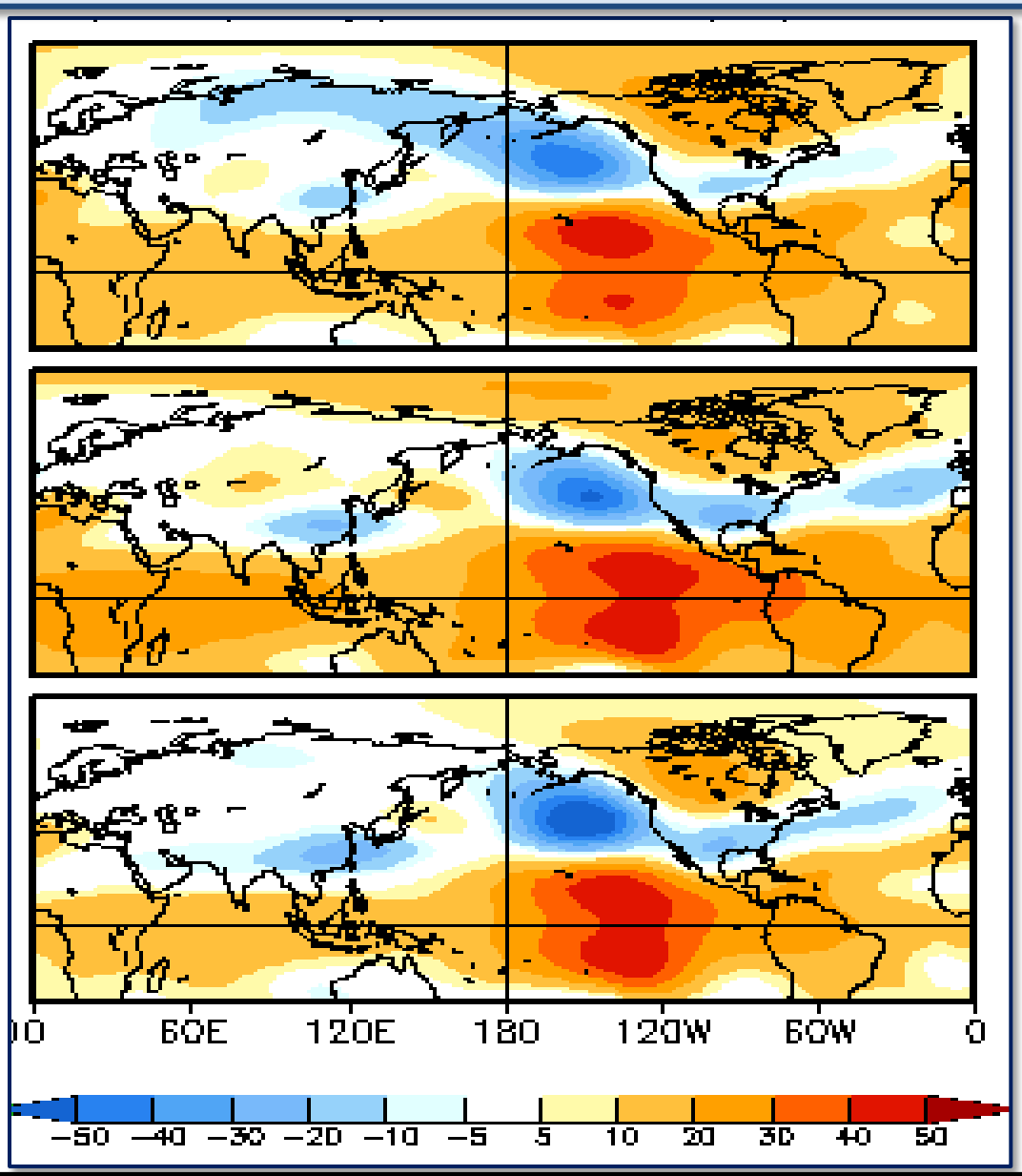


Obs

Coupled

AMIP

Response in 200-mb Z to ENSO Variability
Observations; Coupled model; AMIP



Summary

- Observed <SST-P> relationship has a large spatial variability and asymmetry in its amplitude
- This variability needs to be correctly replicated in climate models
- It can be explained by the direction of forcing, and time-scales associated with ocean and atmospheric variability. This notion
  - Helps understand spatial variability in prediction skill
- Decoupling the system provides a simplifying assumption, and more control in our attempts to understand the influence of ocean on atmospheric variability…But that understanding is only as good as the extent of consequences of the approximation.