Teleconnection Sensitivity to El Niño Diversity

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Do Atmospheric Teleconnections Significantly Differ Among Various ENSO Flavors?

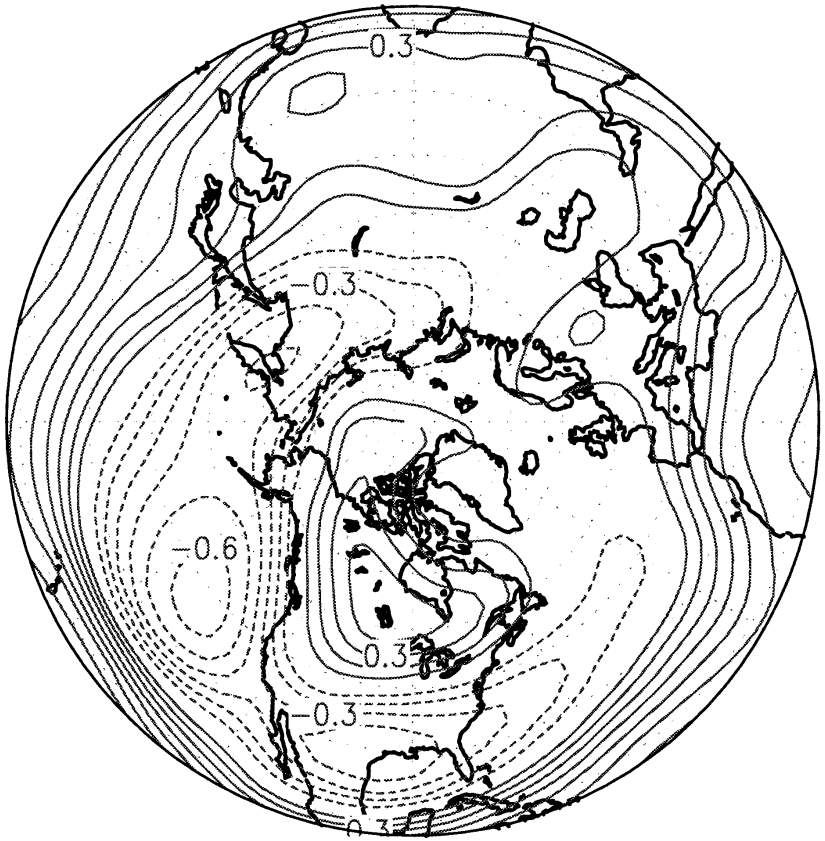
Yes.

What Dynamical Processes are Responsible?

Illustrate for ~~summertime Indian monsoon~~ & wintertime North American climate variability.

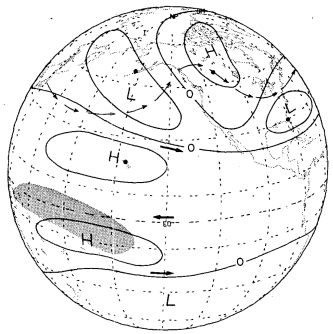
The Observed Wintertime ENSO Teleconnection Pattern at 500 hPa

Is This the Only One?



Linear correlation between OBS DJF 500 hPa height and an ENSO SST index*

see Horel and Wallace 1981, MWR



*** PC time series of the first EOF of tropical Pacific SST variability**

Multiple ENSO Teleconnection Patterns: *El Niño vs La Niña*

Based on Observations; from Hoerling et al. 1997; JCLIM

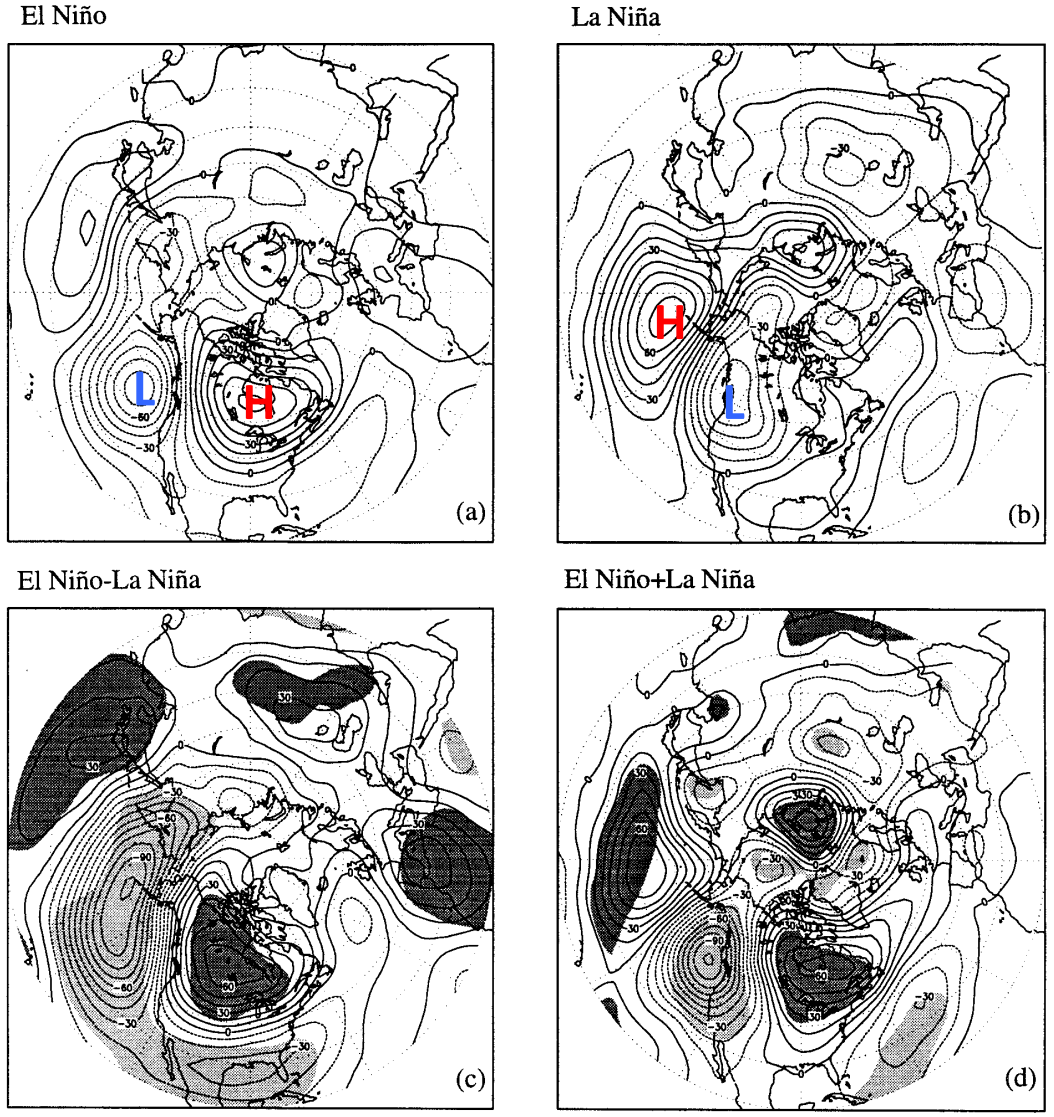


FIG. 3. Same as in Fig. 1 except for the observed eddy 500-mb heights. Eddy refers to the departure of the height from its zonal mean value and indicates the stationary wave behavior. Contour interval is 10 m. Polar stereographic projection extends to 20°N.

Model-based confirmation of multiple ENSO patterns (multi-linearity/nonlinearity) :

Hoerling et al. 1997;Kumar and Hoerling 1997; Sardeshmukh et al. 2000; Hoerling and Kumar 2000; 2002, Lin and Derome 2004; Kumar et al. 2005; Yu et al. 2012

Multiple Teleconnection Patterns : *Flavors of El Niño*

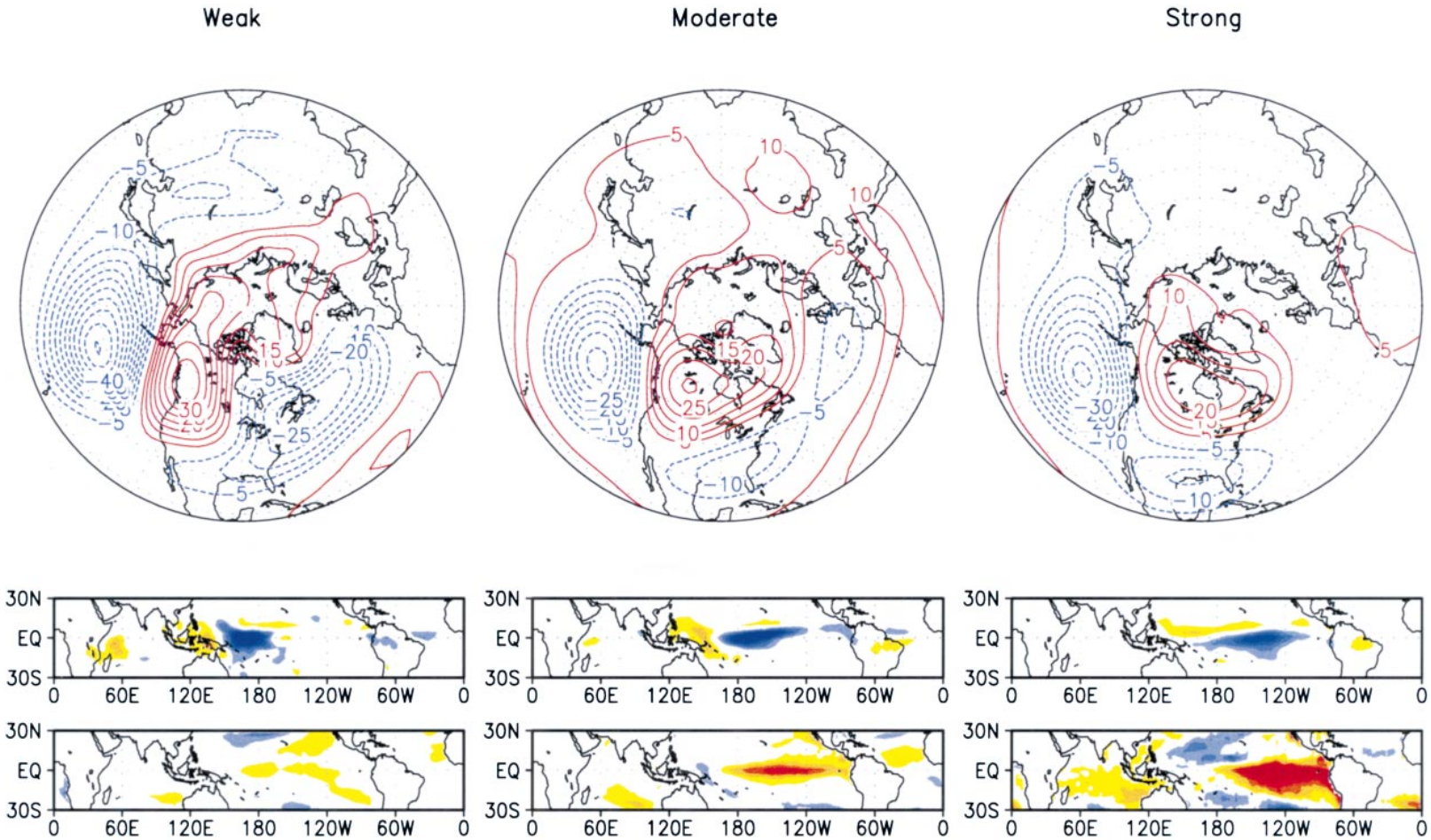
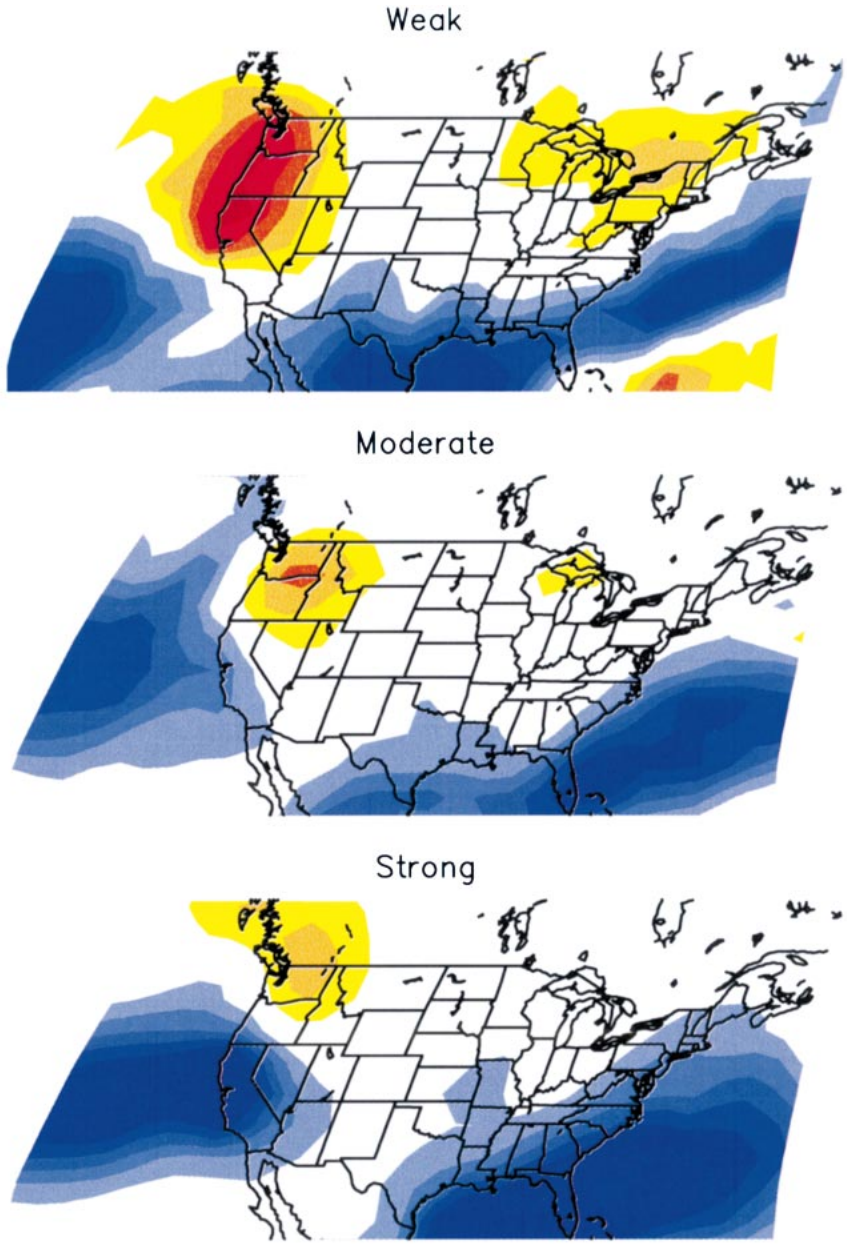


FIG. 13. GCM ensemble winter (DJF) anomalies of (top) 500-hPa height, (middle) tropical rainfall, and (bottom) tropical SST for varying strengths of equatorial Pacific warm events during (left) 1980, (middle) 1958, and (right) 1983. The year refers to the Jan of the season. The height and rainfall anomalies have been scaled by the amplitude of the EOF1 index of ENSO for each case. Contours for height are drawn every 5 m, with positive (negative) values solid (dashed). Shading interval for rainfall is every 1 mm day^{-1}, with positive (negative) anomalies in blue (red). Shading interval for SST is every 0.5°C, with positive (negative) anomalies in red (blue).

Based on 4-model, 46-member AMIP ensemble; from *Hoerling and Kumar 2002, JCLIM*

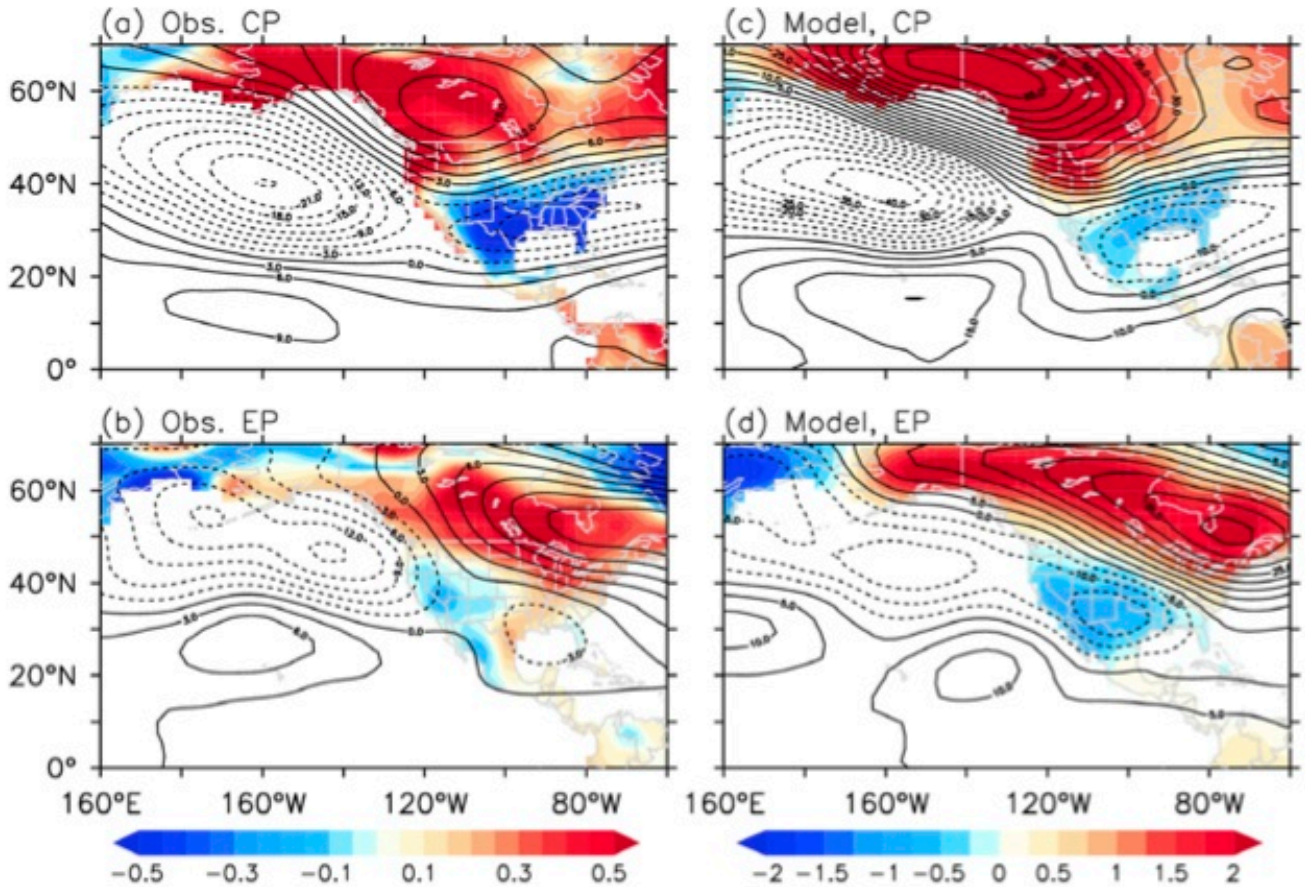
Getting the Signal Right Matters

US Pcpn, based on Hoerling and Kumar 2002, JCLIM



Getting the Signal Right Matters

North American SfcT, based on Yu et al. 2012, GRL



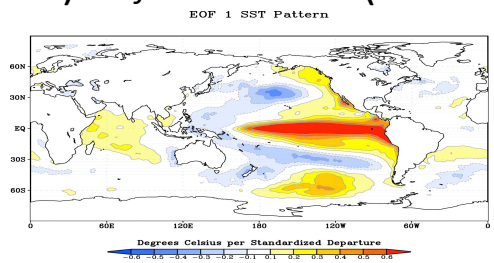
OBS Composite. ~10 cases

CAM4, T42; 10-member

Large Ensemble AGCM Simulations
AMIP

Institution	Model	Ensemble Size
ECHAM (IRI)	ECHAM4.5 (T42)	85 (1950-2003)
NCEP (ESRL)*	GFSv2 (T126)	50 (1979-2010)
NCEP (ESRL)*	GFSv2 (T126): *eof1 SST*	24 (1979-2010)

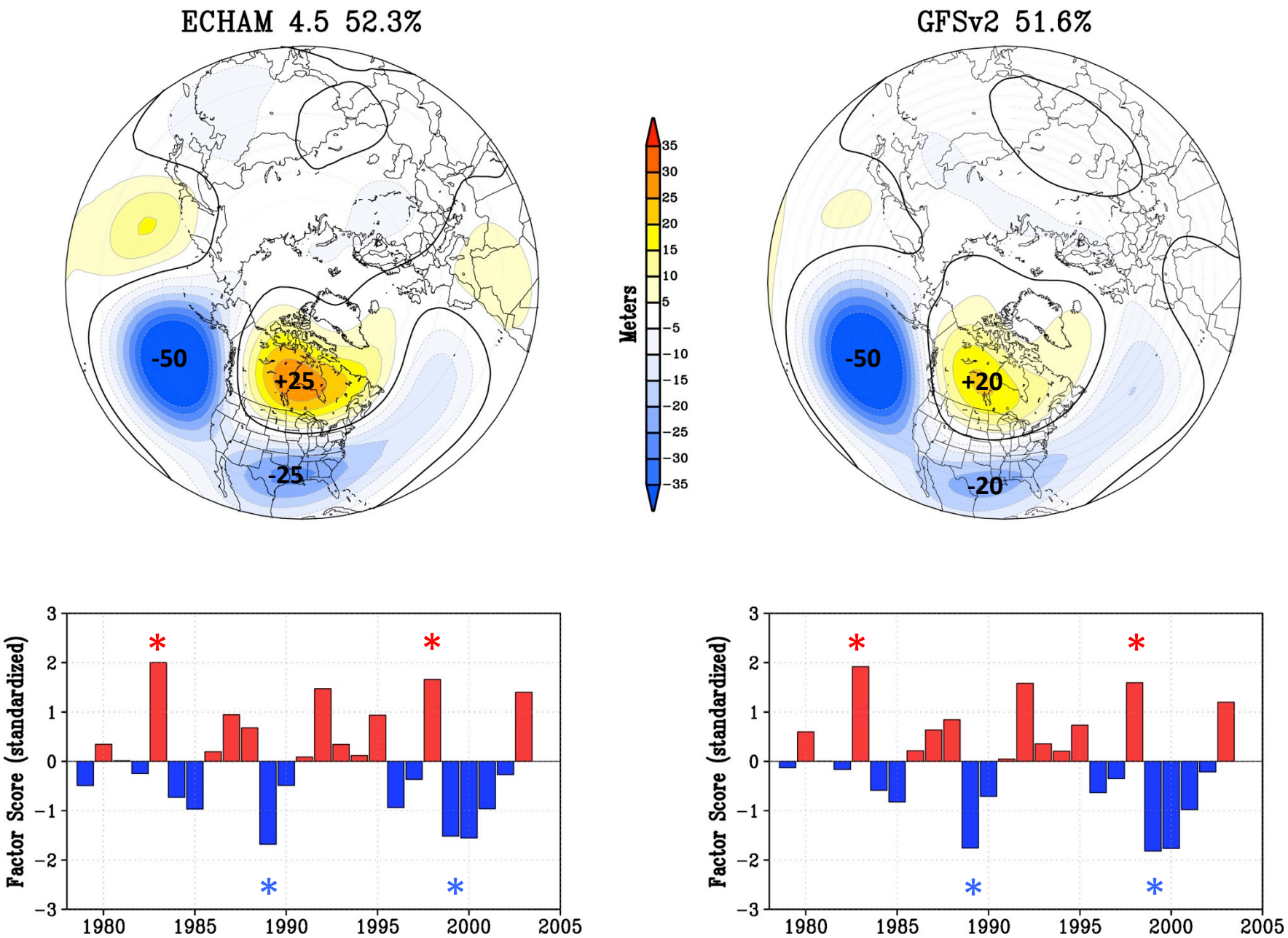
* *Simulations conducted by Tao Zhang*



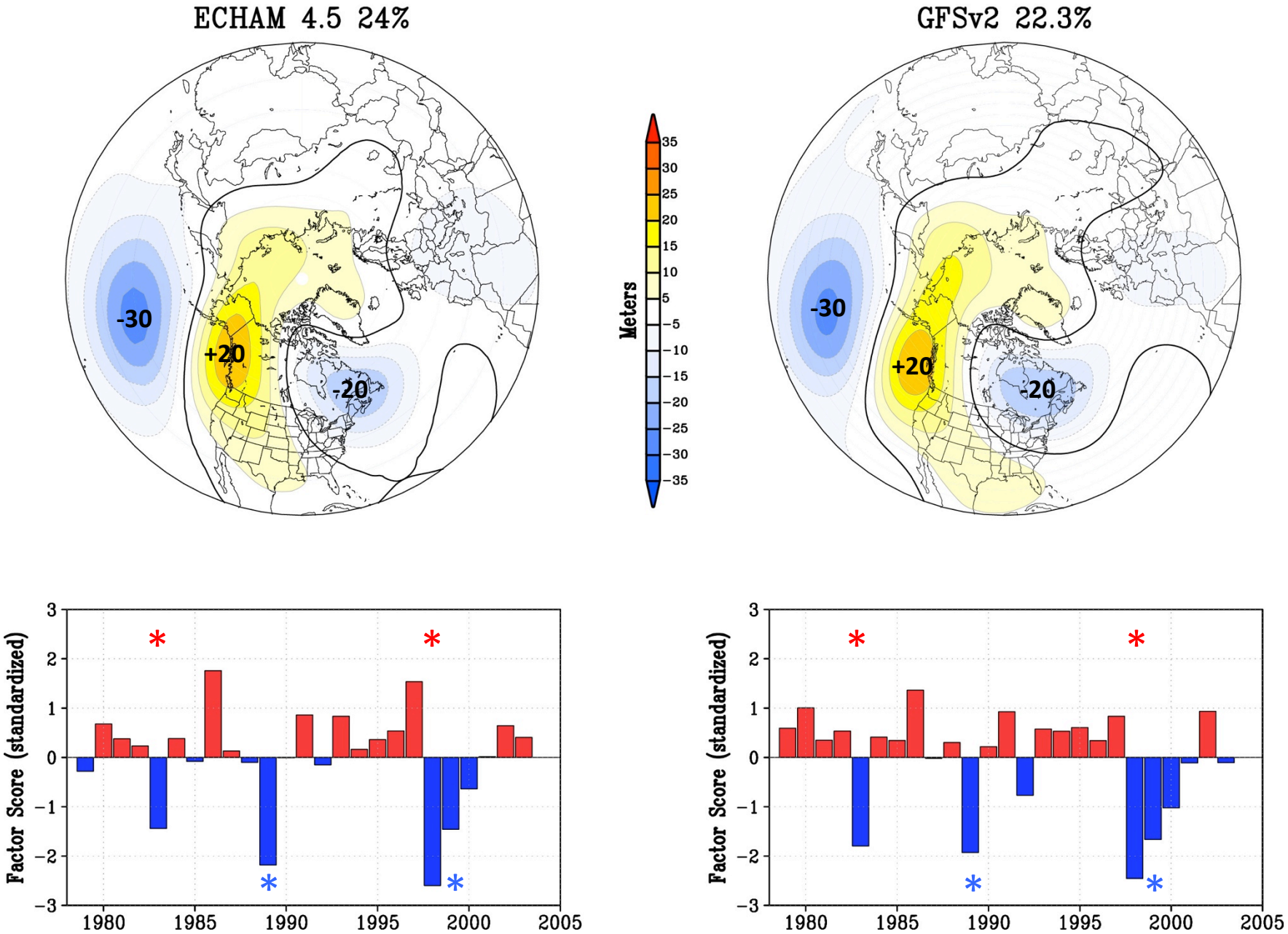
from detrended global monthly SSTs, 1978-2011: 18% variance

- Conduct an EOF analysis of each model's ensemble averaged 500 hPa height
- Perform a DJF analysis for the NH (poleward of 20°N)
- Apply the analysis over the common model simulation period, 1979-2003

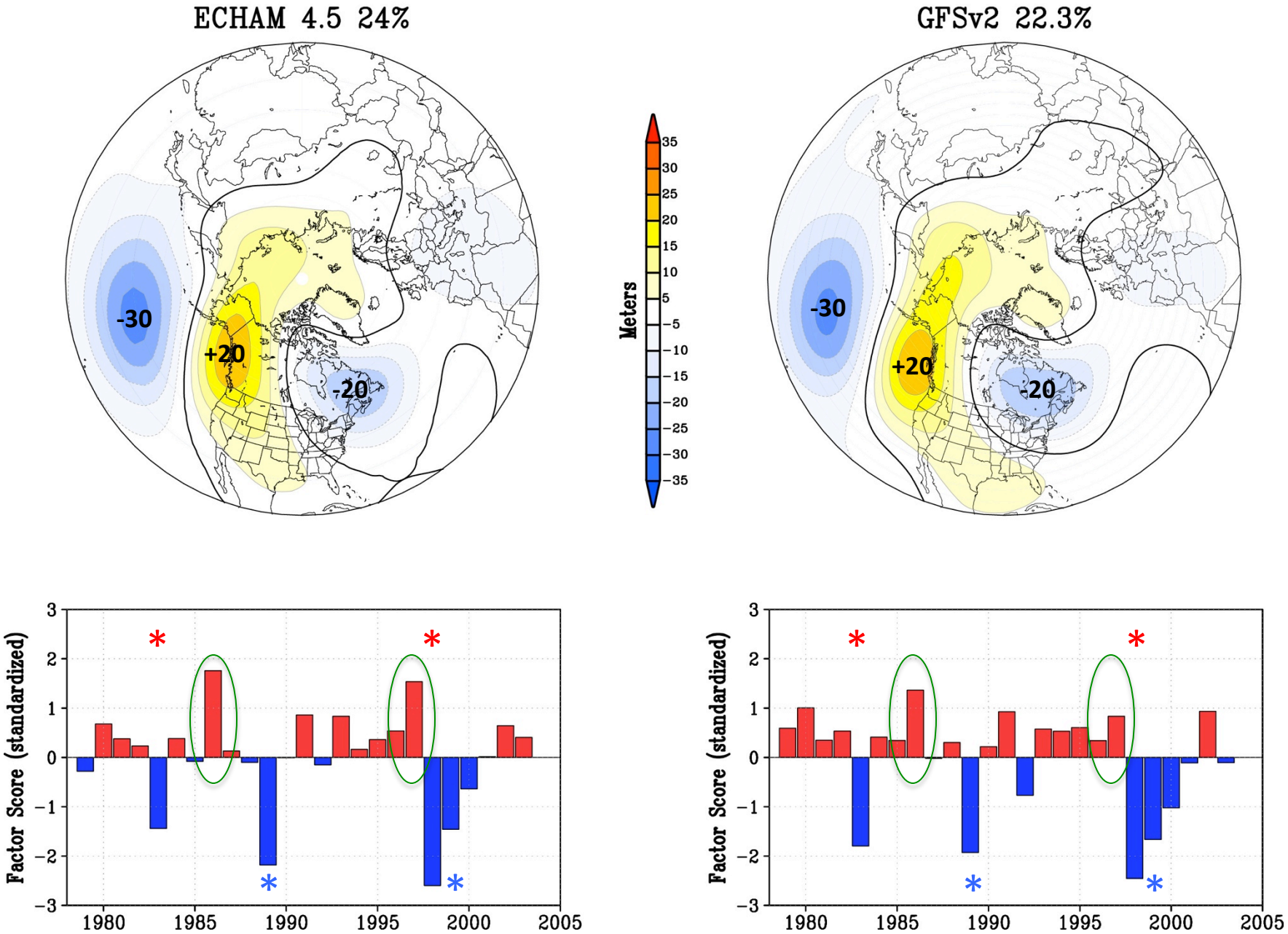
DJF EOF 1: 1979–2003



DJF EOF 2: 1979–2003

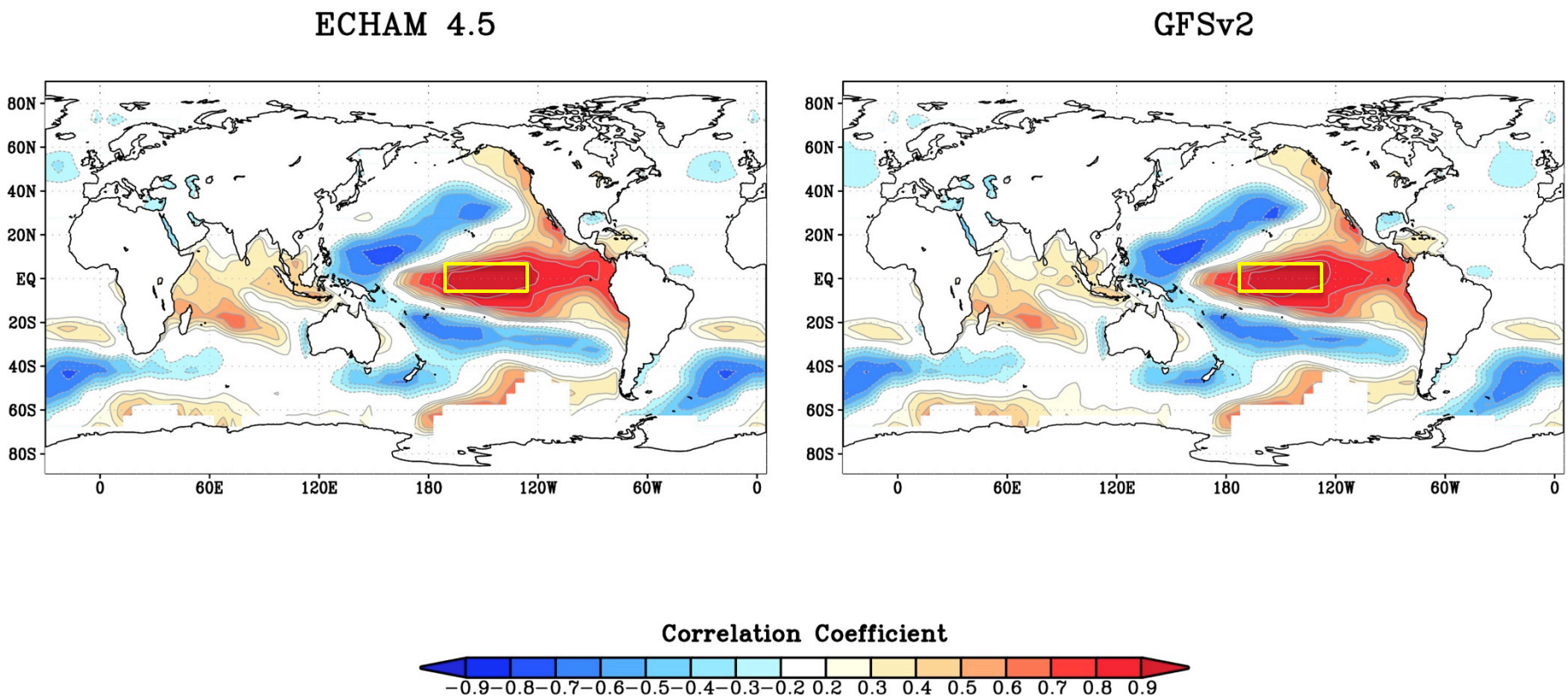


DJF EOF 2: 1979–2003



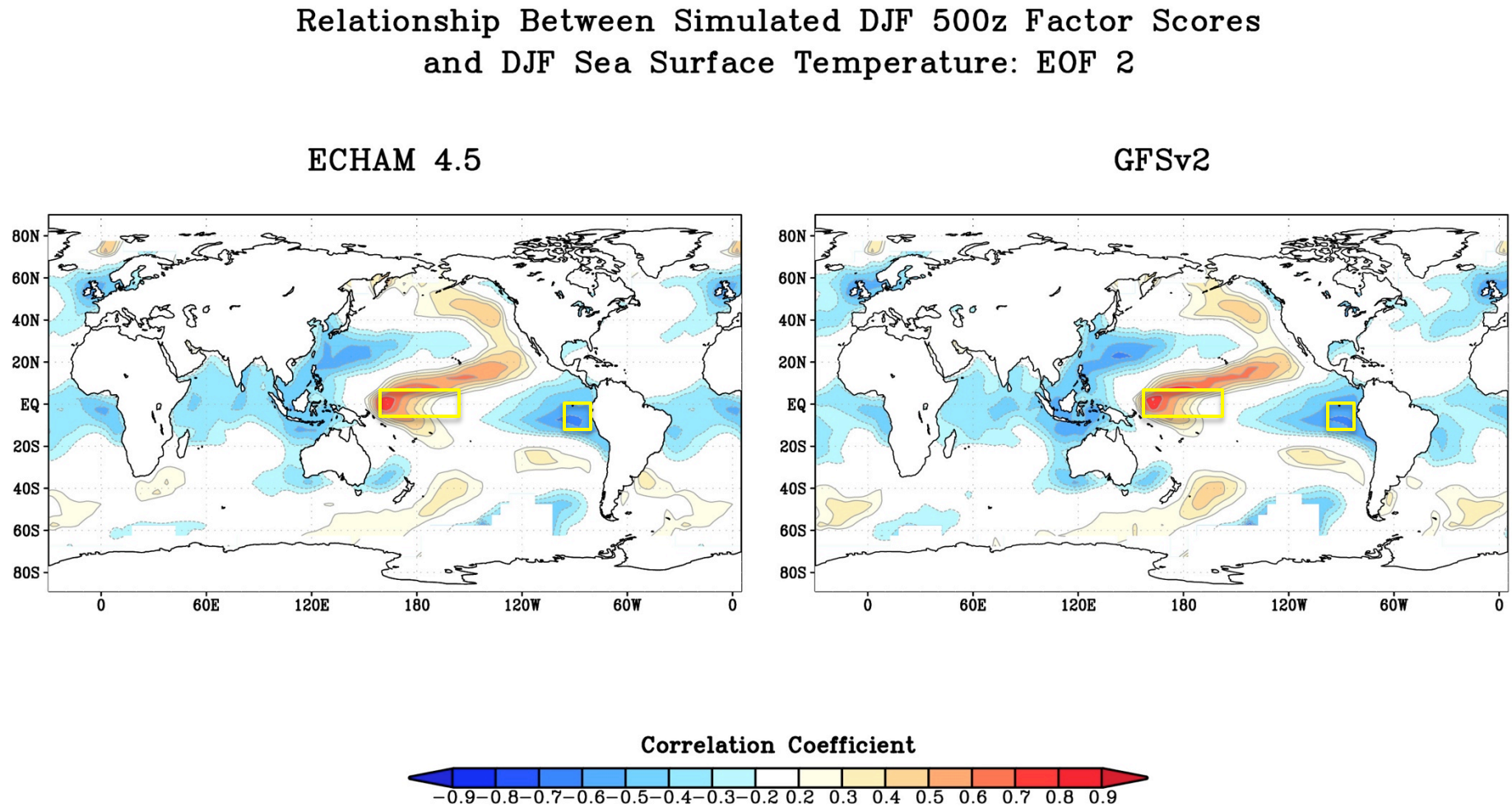
Leading SST-Forced Teleconnection Bound to Leading SST Pattern:

Sensitivity to the Equatorially-Avgd Pacific SST east of the Dateline

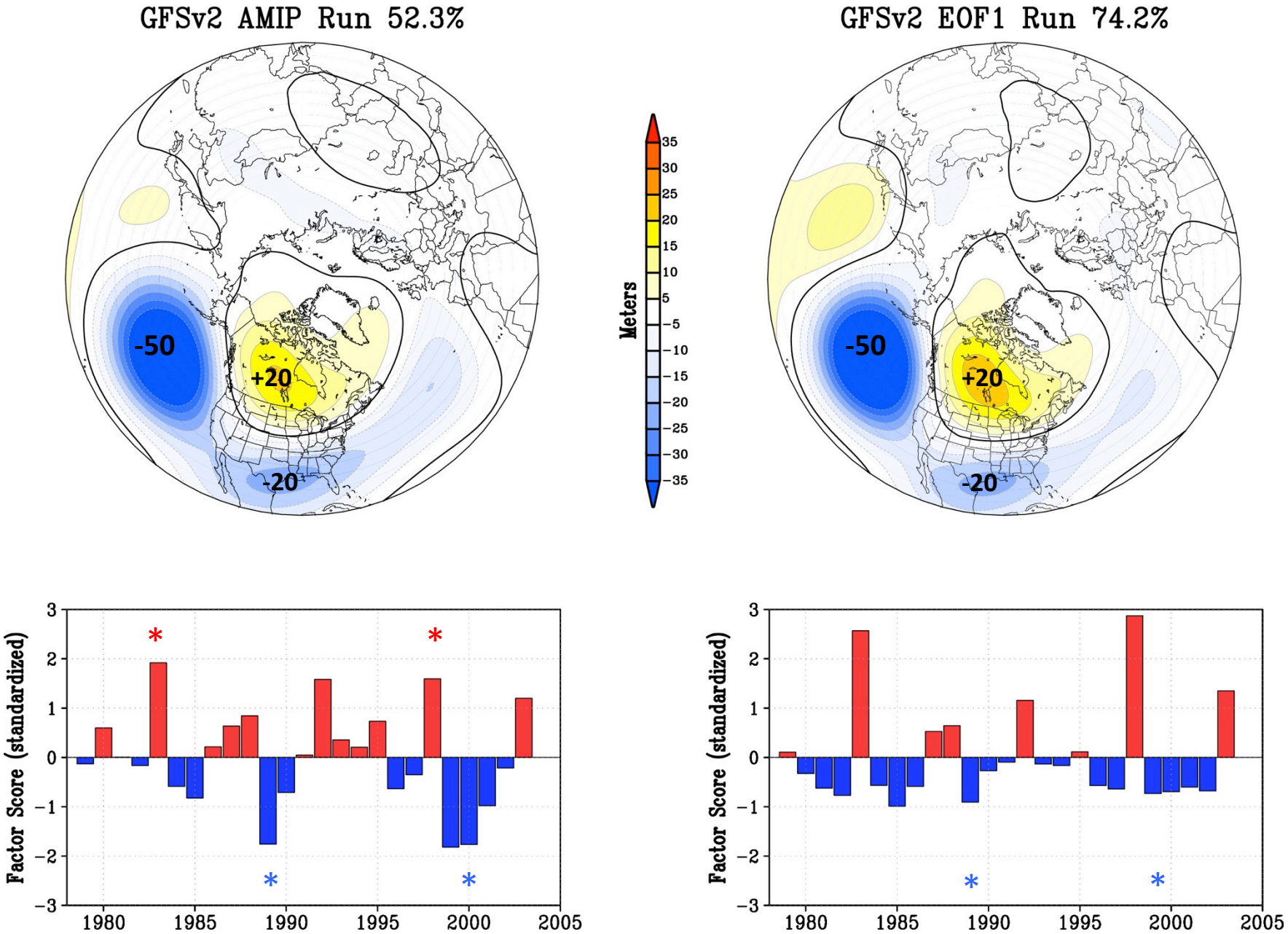


Second SST-Forced Teleconnection Link to Second Tropical SST Pattern:

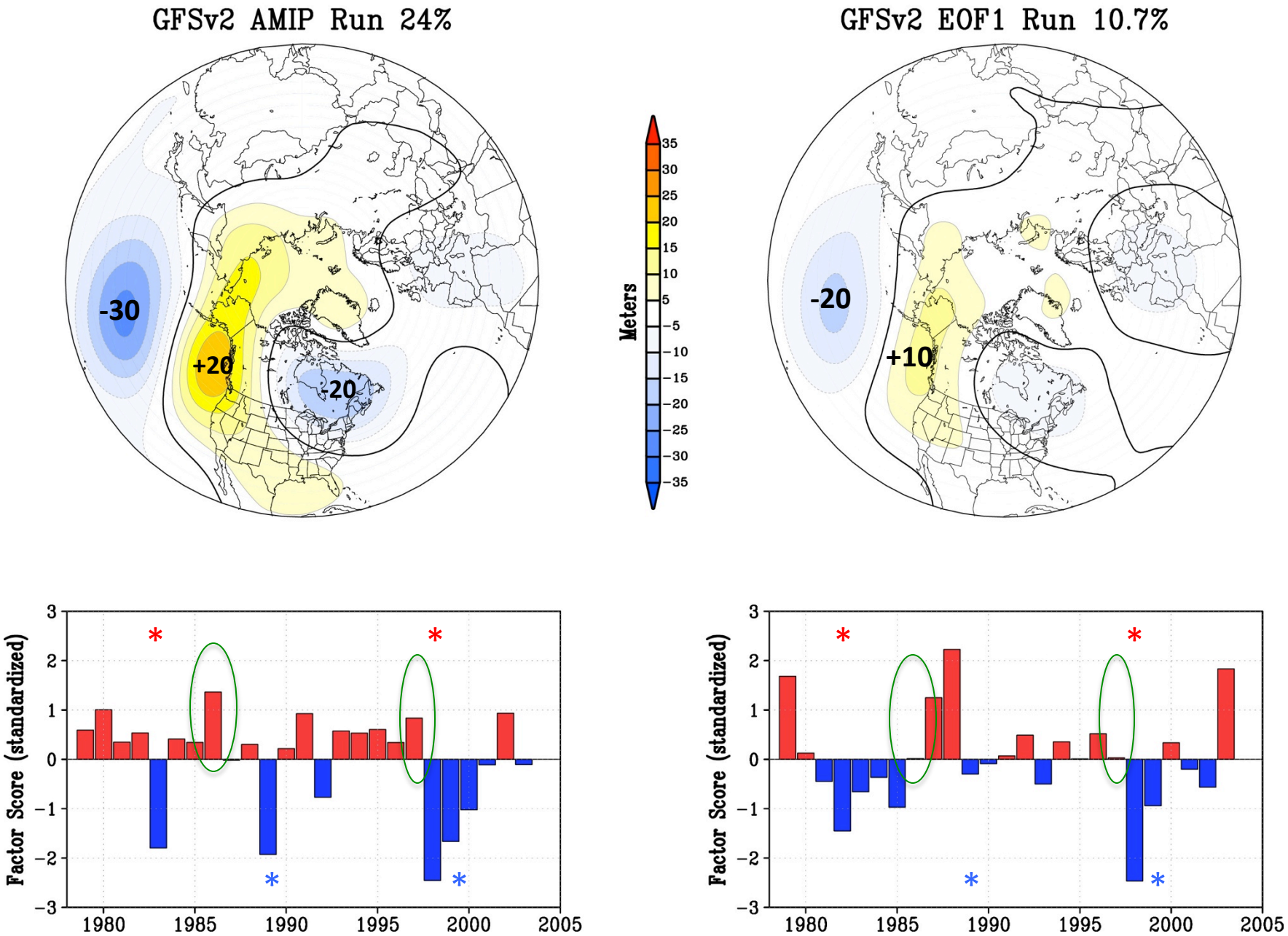
Sensitivity to the Gradient in SSTs Across the Tropical Pacific

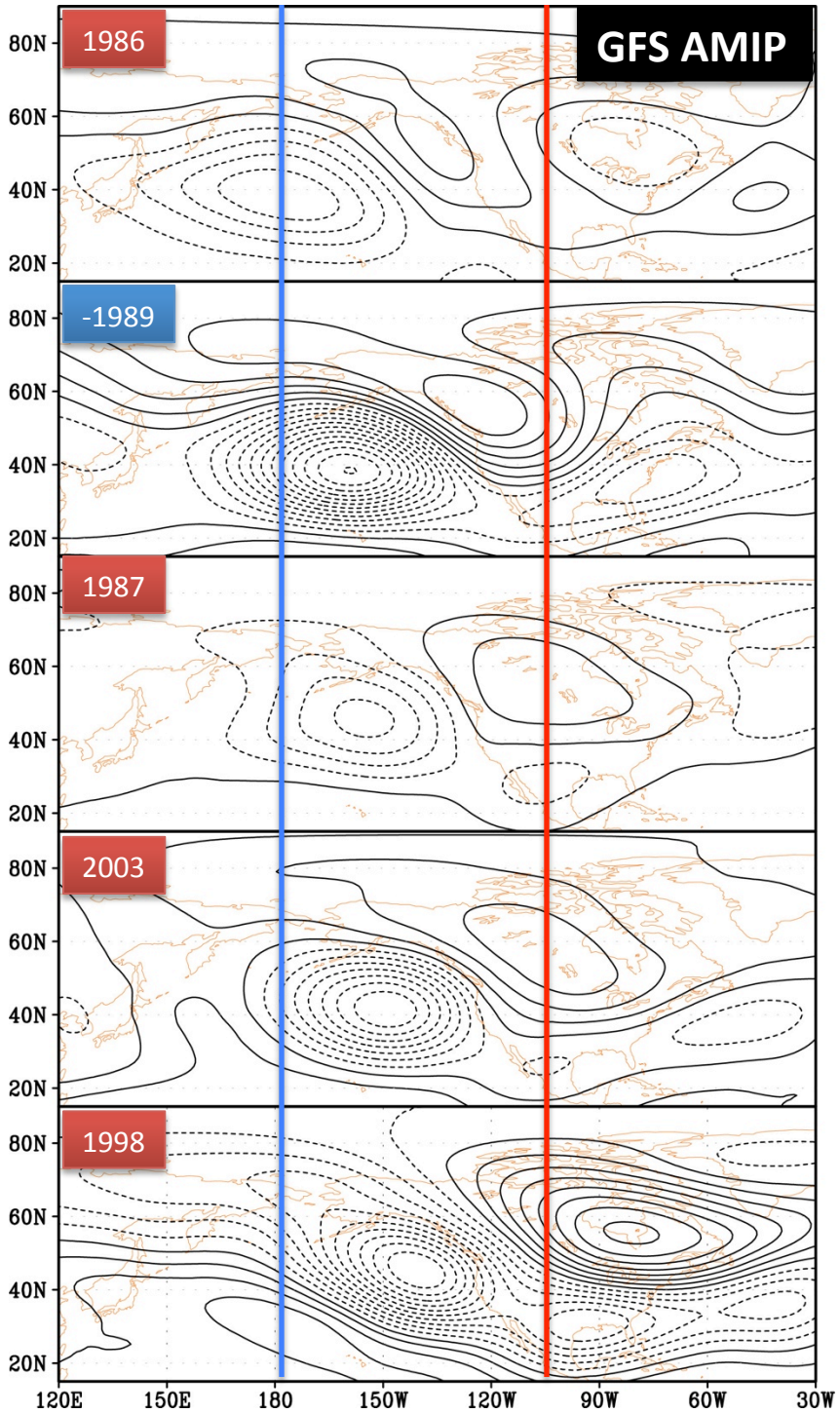


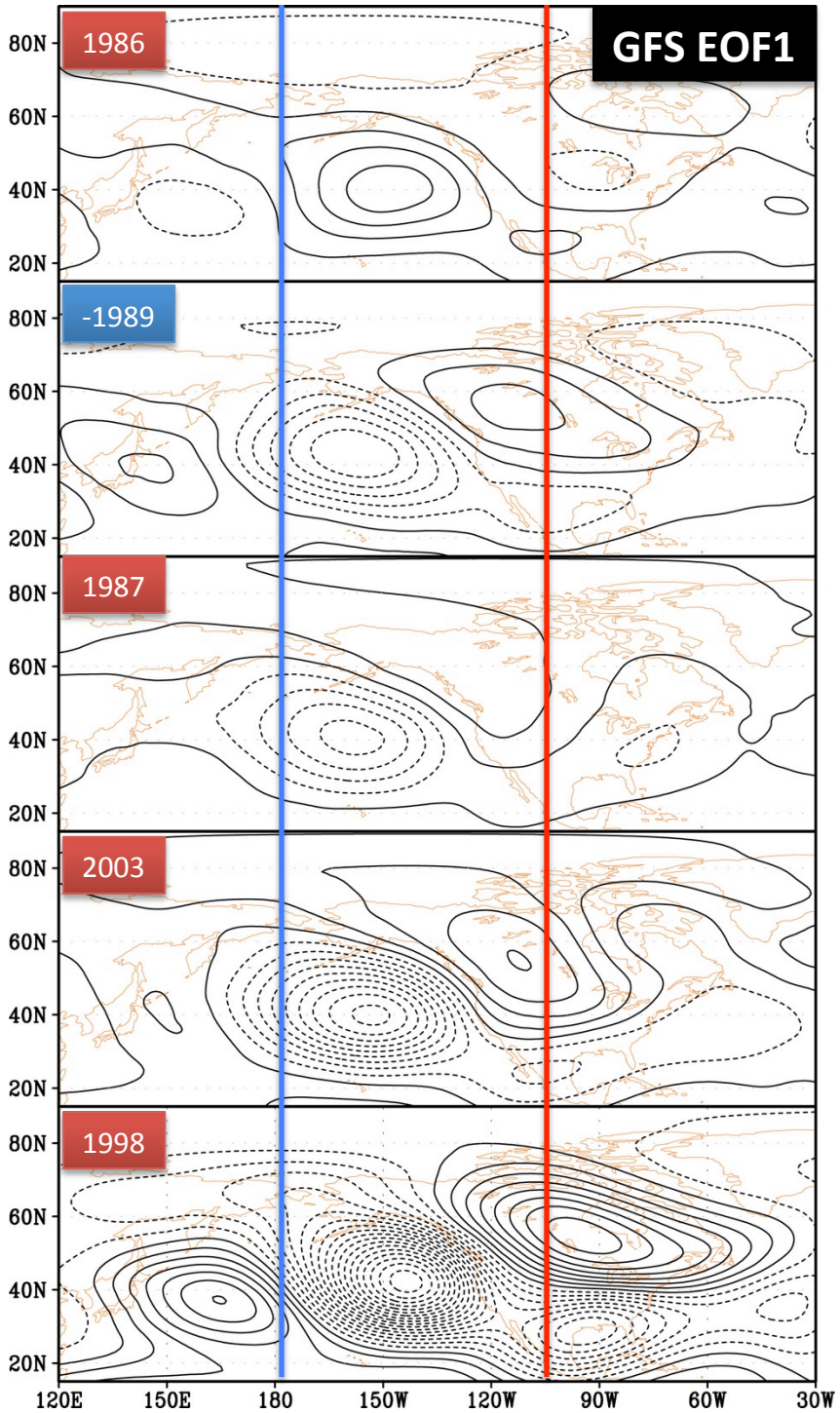
DJF EOF 1: 1979–2003



DJF EOF 2: 1979–2003

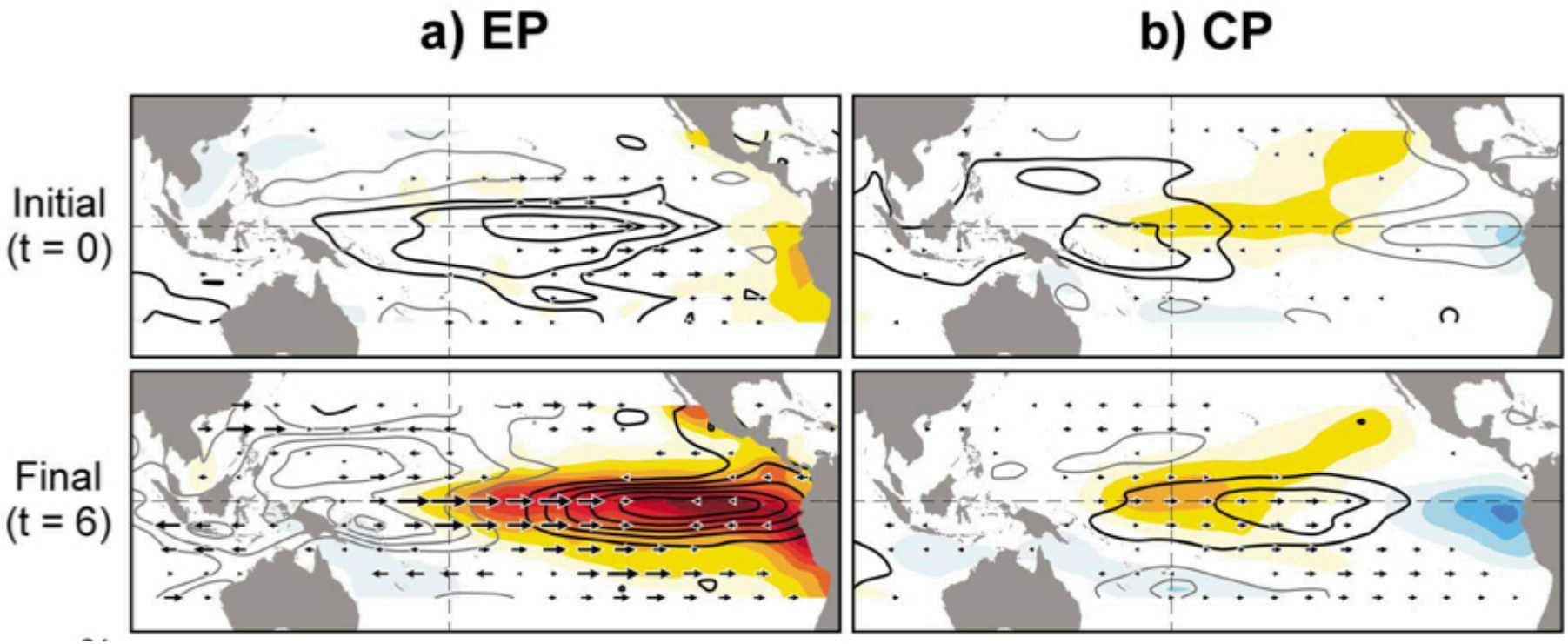



GFS AMIP
1986
-1989
1987
2003
1998
80N
60N
40N
20N
120E
150E
180
150W
120W
90W
60W
30W


GFS EOF1
1986
-1989
1987
2003
1998
80N
60N
40N
20N
120E
150E
180
150W
120W
90W
60W
30W

Naturally Varying ENSO Flavors

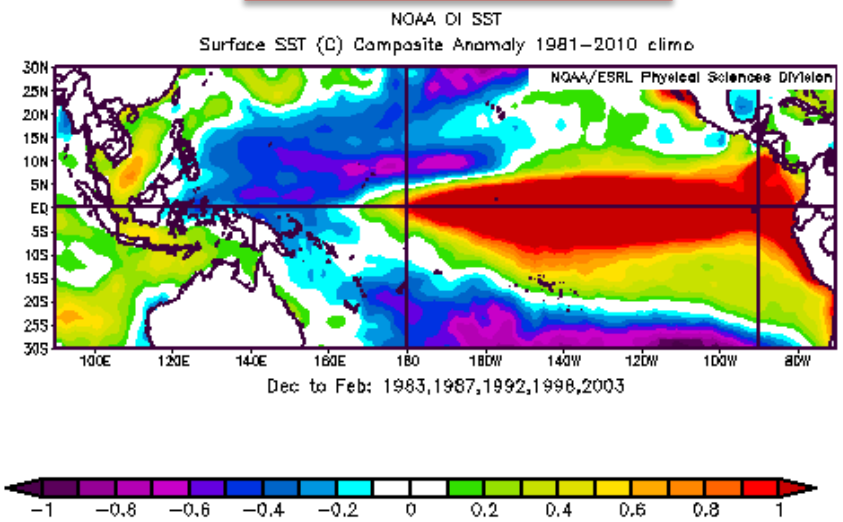
Newman et al. 2011, GRL



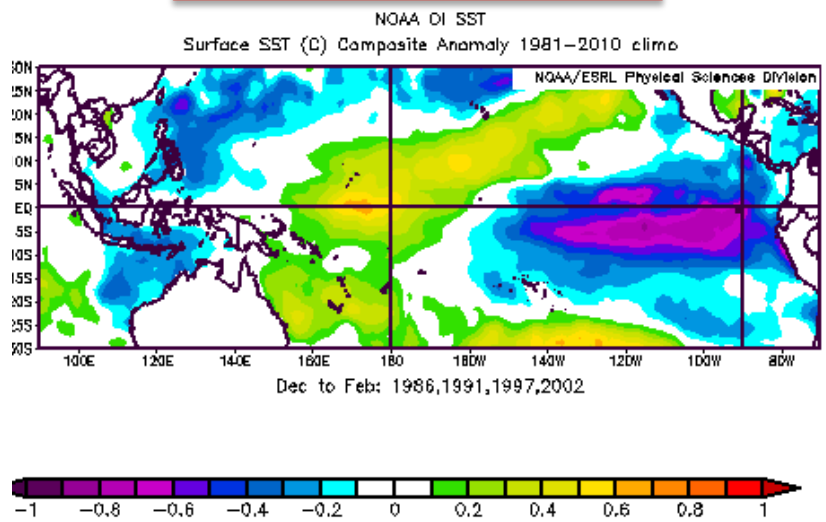
Two Leading Patterns of SST Anomaly Growth Over a 6-Month Period

Observational analysis, 1959-2000, using LIM

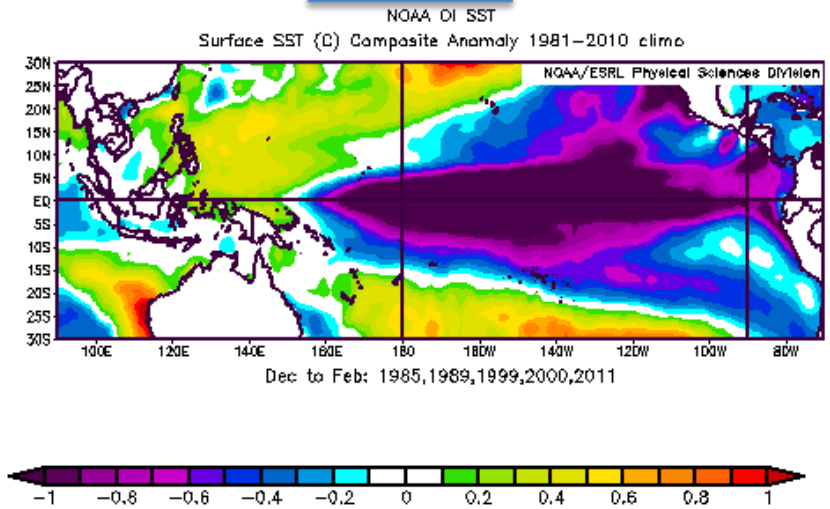
East Pacific El Niños



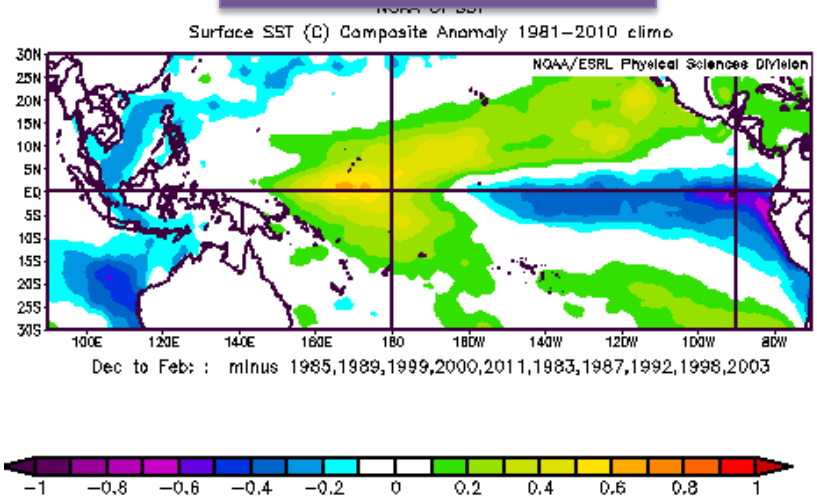
Central Pacific El Niños



La Niñas



Asymmetry of ENSO



Do Atmospheric Teleconnections Significantly Differ Among Various ENSO Flavors?

Yes --- There is "Signal Diversity"

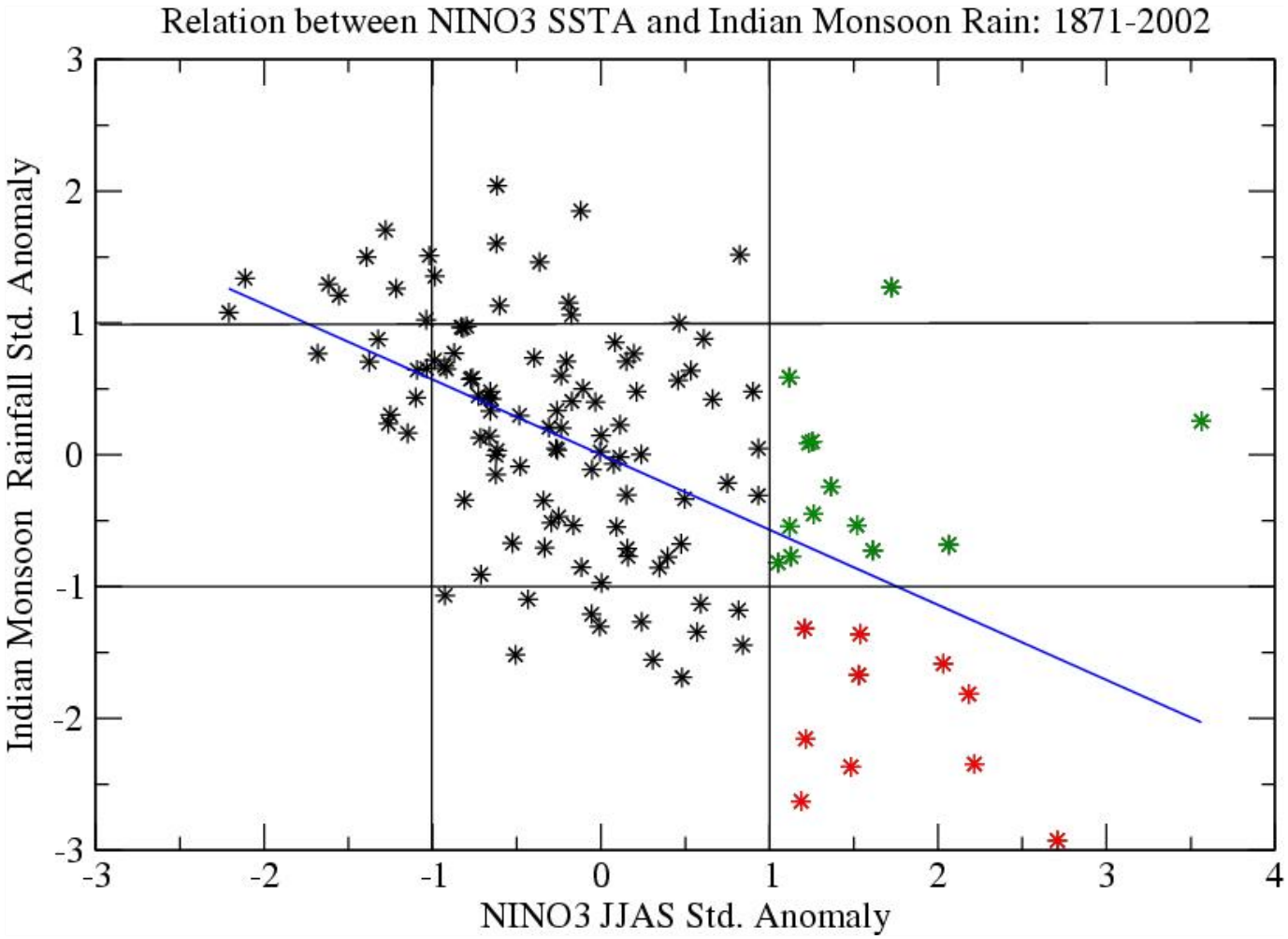
Q2: What Dynamical Processes are Responsible?

- *There are Two Dominant Flavors of El Niño*
- *There are Two Distinguishable Teleconnections Associated With The El Niño Flavors*
- *El Niño/La Niña SST Asymmetry Also Yields Two Distinguishable Teleconnections*
- *Amplitude Variability of Leading SST EOF Yields Two Distinguishable Teleconnections*

The Indian Monsoon Story

A Mystery of Indian Monsoon Failure during El Niño*

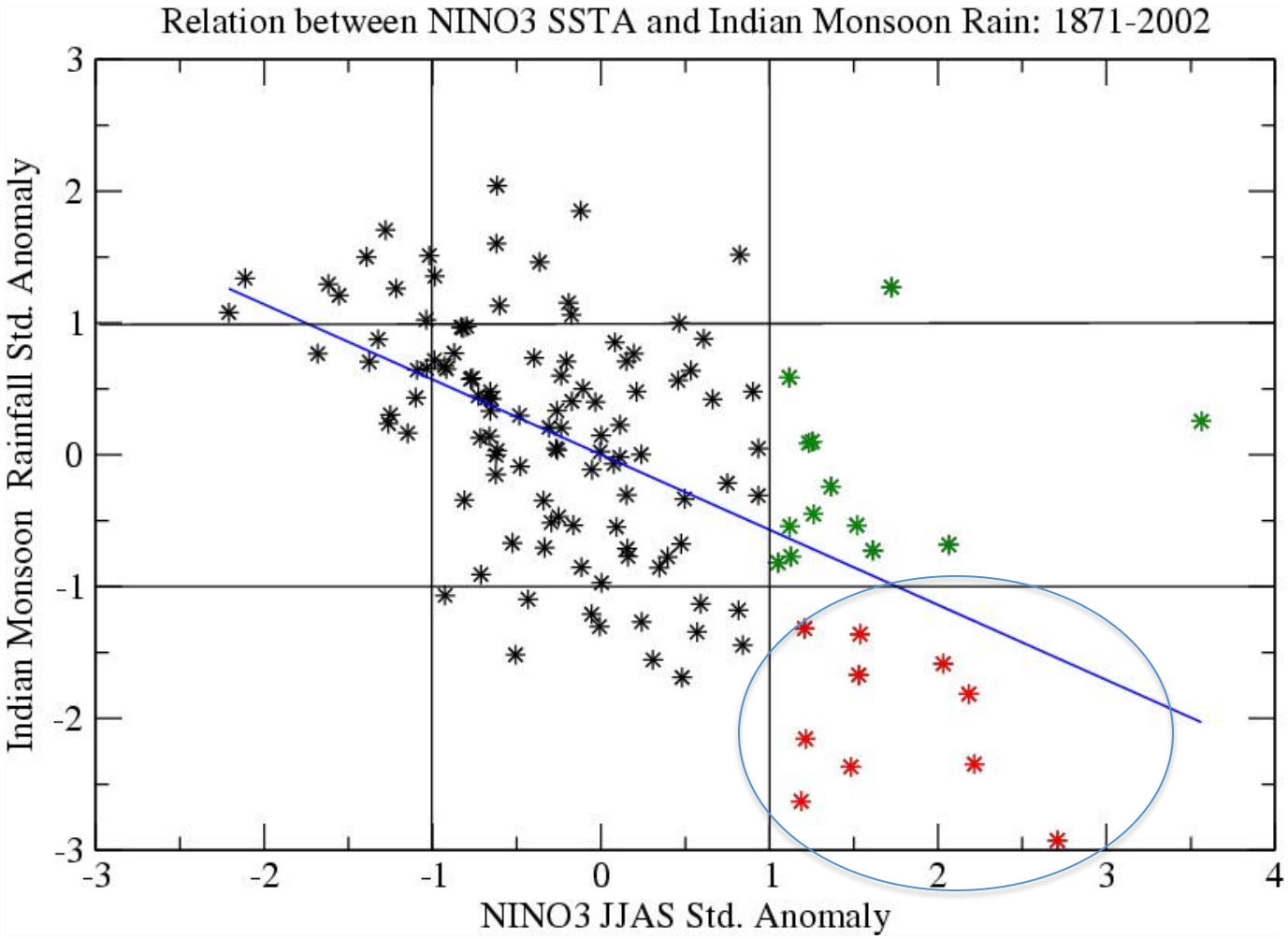
Why have warm events of the tropical east Pacific not consistently yielded Indian drought?



KKumar et al. 2006 *Science

A Mystery of Indian Monsoon Failure during El Niño

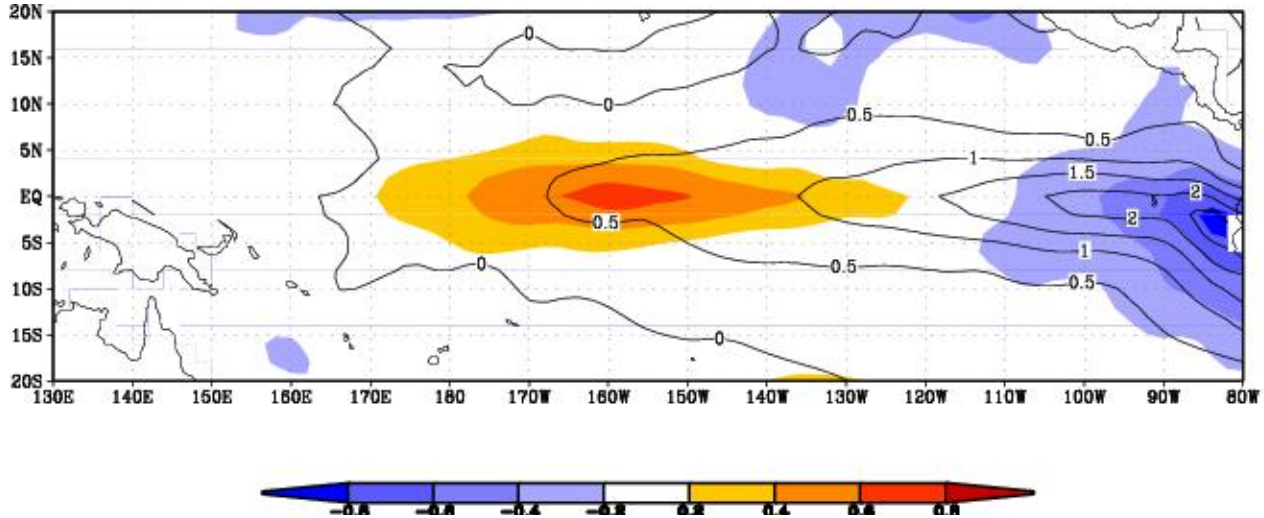
Why have warm events of the tropical east Pacific not consistently yielded Indian drought?



Disaggregate El Niño Years

According to "Severe Drought" vs "Drought Free" Cases

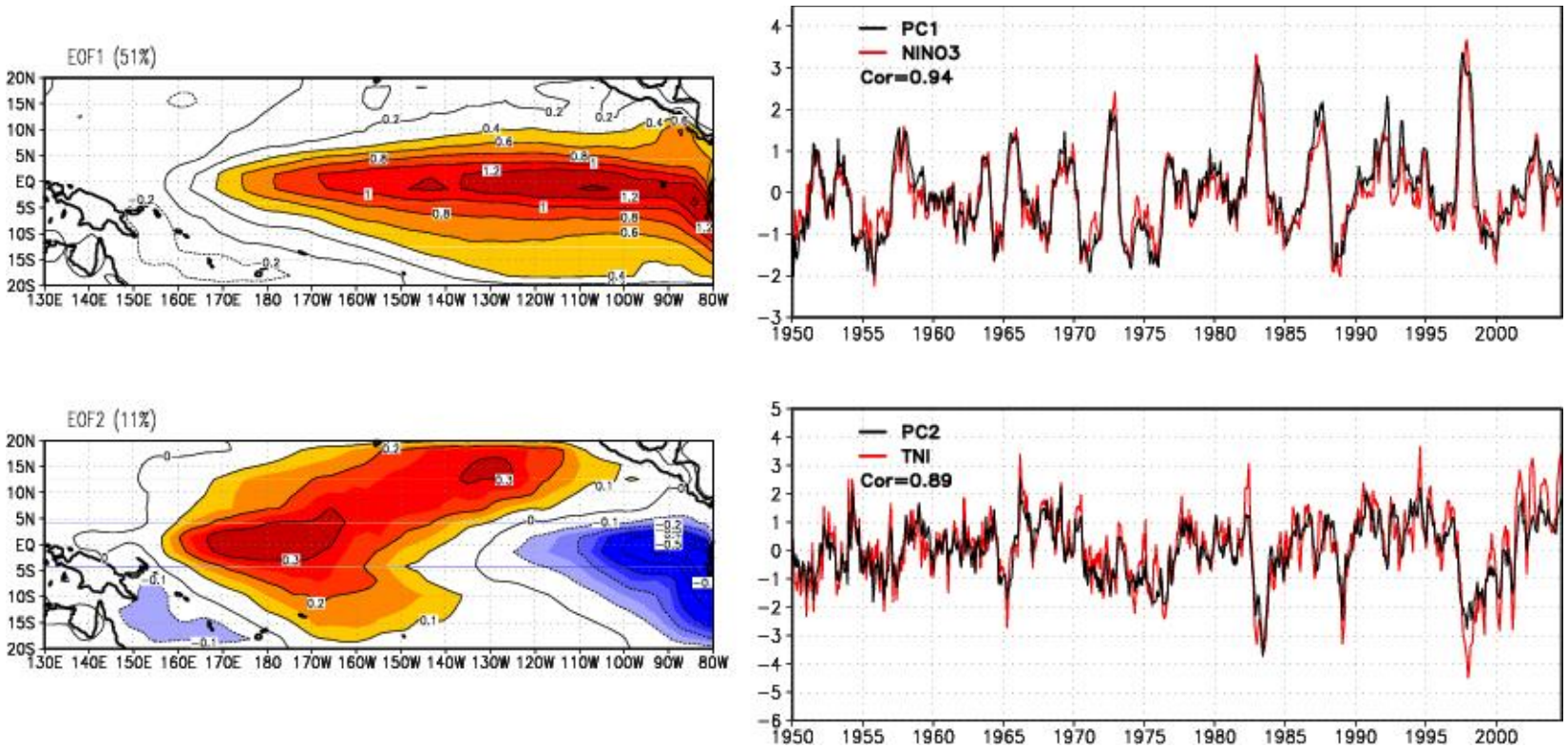
India Monsoon Failure and the Flavors of El Niño



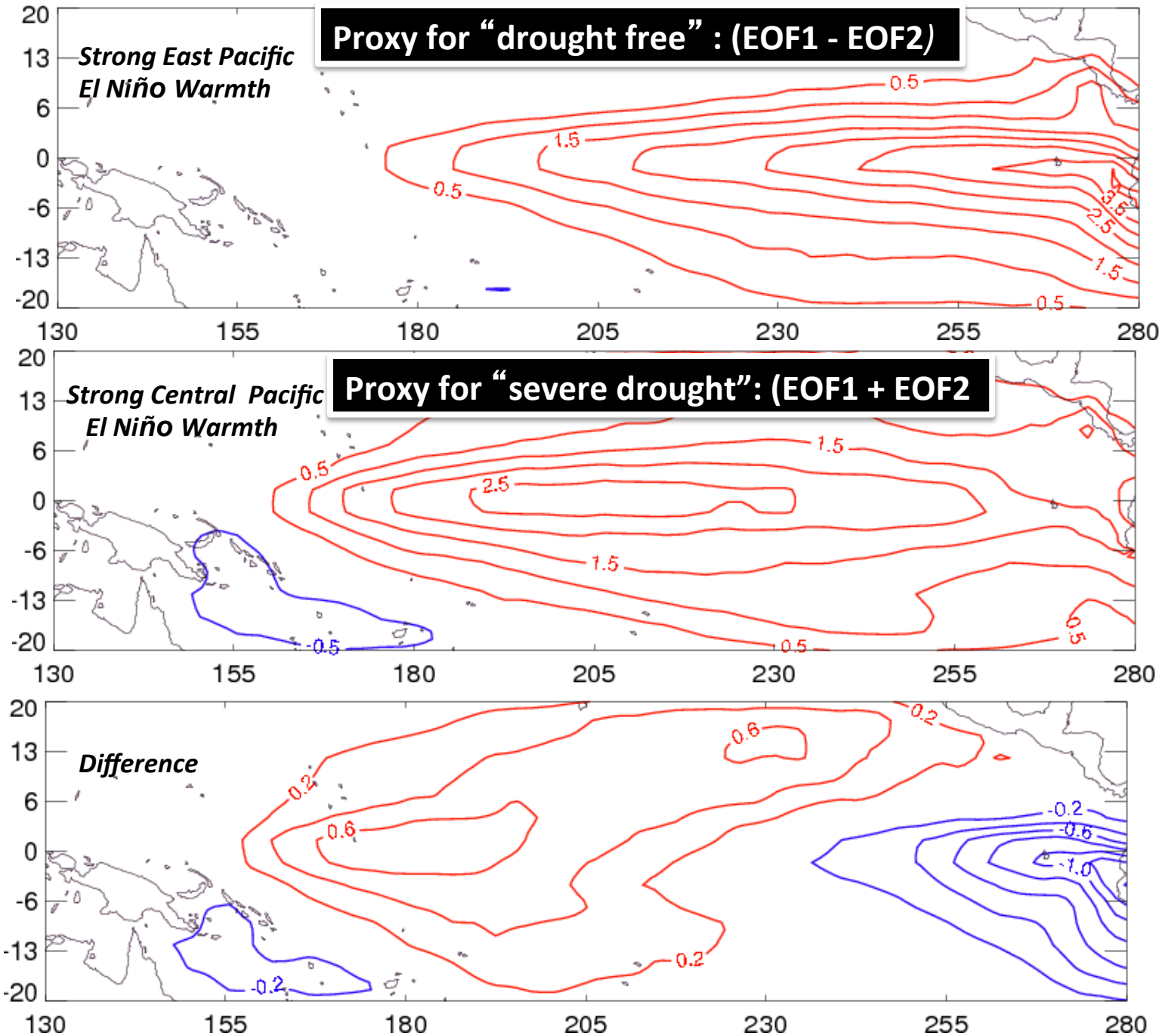
Contours: *SST Anomalies during "drought-free" El Niños*
Shading: *SST difference between "severe drought"- "drought free" El Niños*

SST Composites Indicate Increased Warmth in the Tropical Central Pacific During Severe Drought-Producing El Niños

Leading Patterns of Tropical Pacific SST Variability



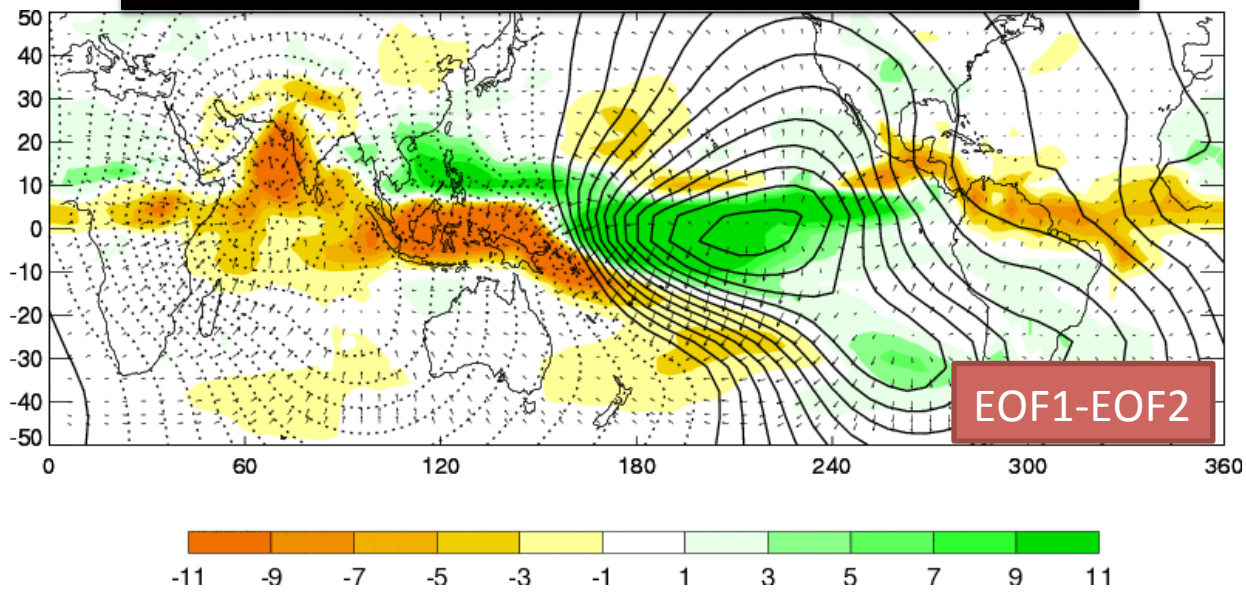
Two leading EOFs provide a useful empirical basis
for reconstructing inter-El Niño differences in tropical Pacific SSTs


Proxy for "drought free" : (EOF1 - EOF2)
Strong East Pacific
El Niño Warmth
Proxy for "severe drought": (EOF1 + EOF2
Strong Central Pacific
El Niño Warmth
Difference
20
13
6
0
-6
-13
-20
130
155
180
205
230
255
280
0.5
1.5
2.5
-0.5
0.2
0.6
-0.2
-0.6
-1.0

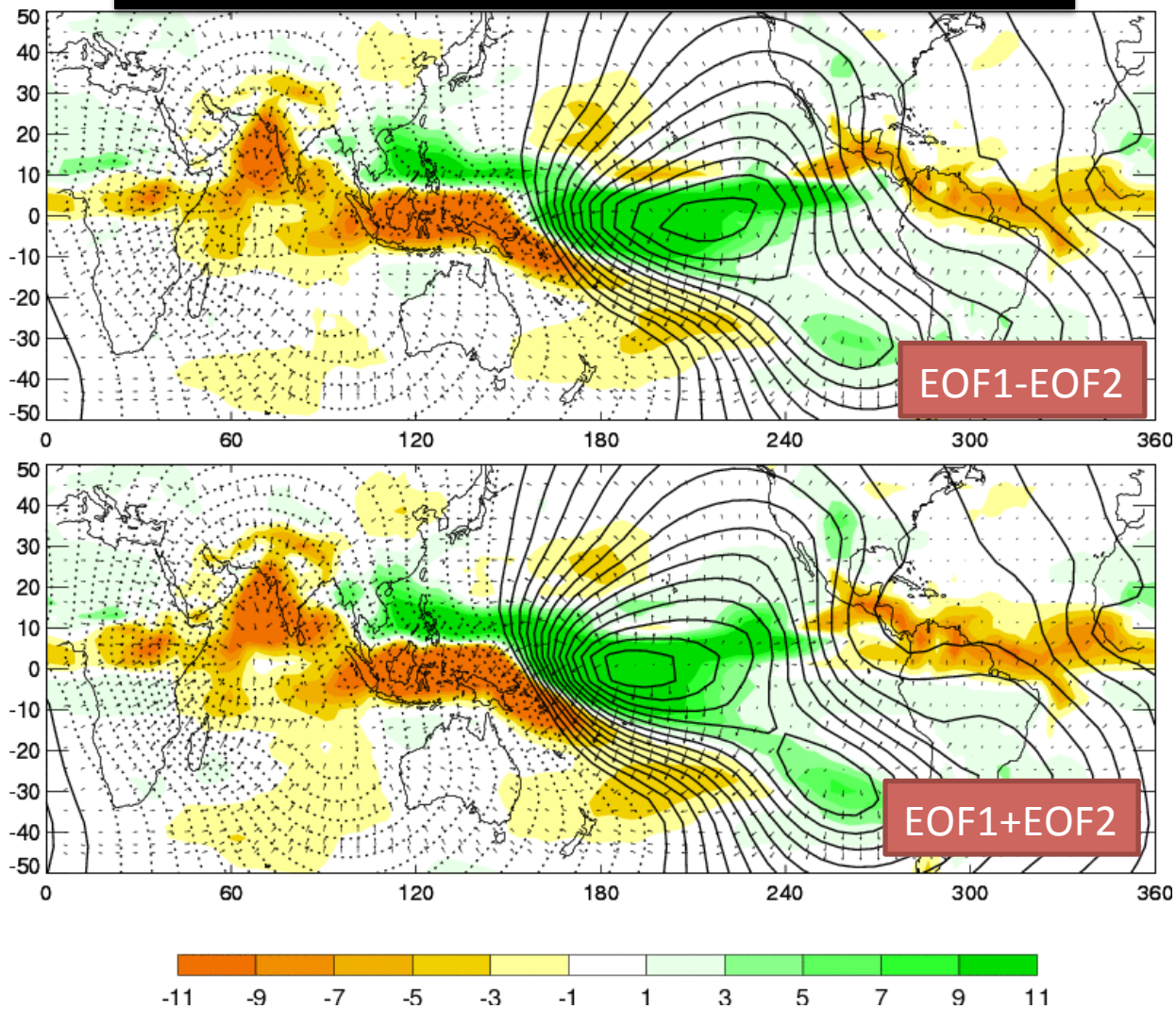
Multi-Model Atmospheric GCM Forced by EOF1 and EOF2 Pacific SST

Institution	Model	Ensemble Size
GFDL	AM2 (2°x2.5°)	20
NCEP	GFS (T62)	30
NCAR	CCM3 (T42)	20

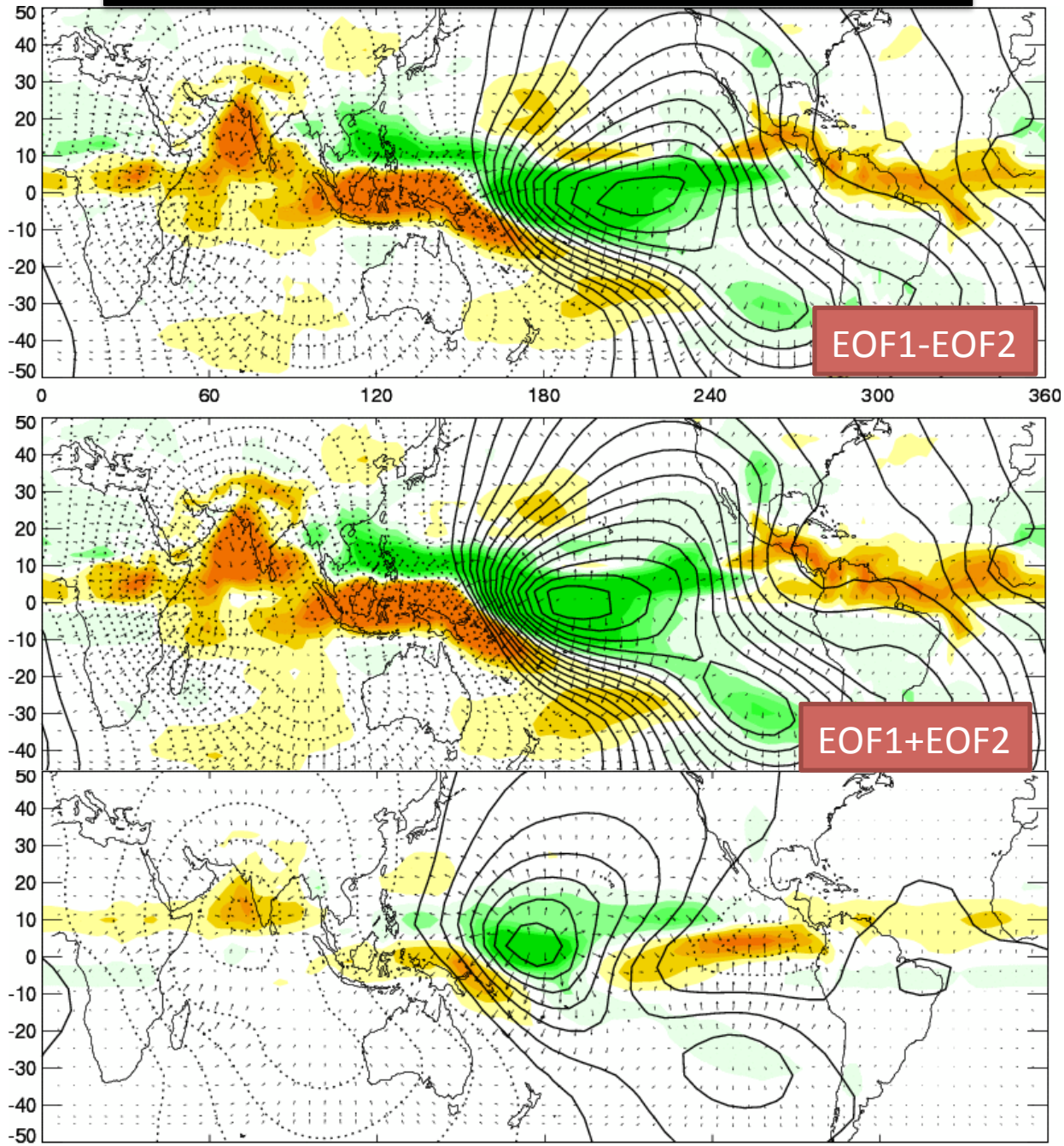
Rainfall and 200 hPa Velocity Potential Responses

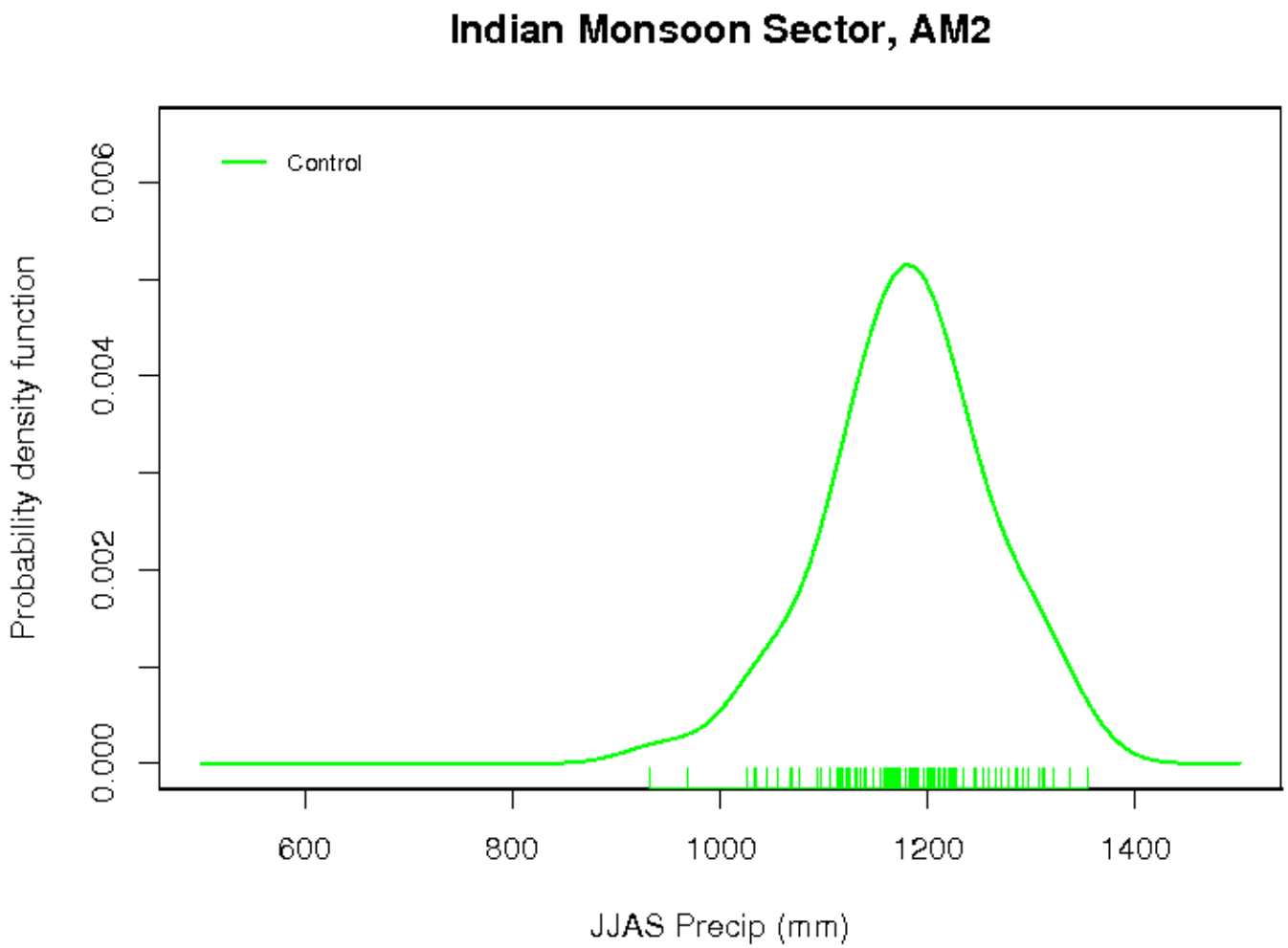


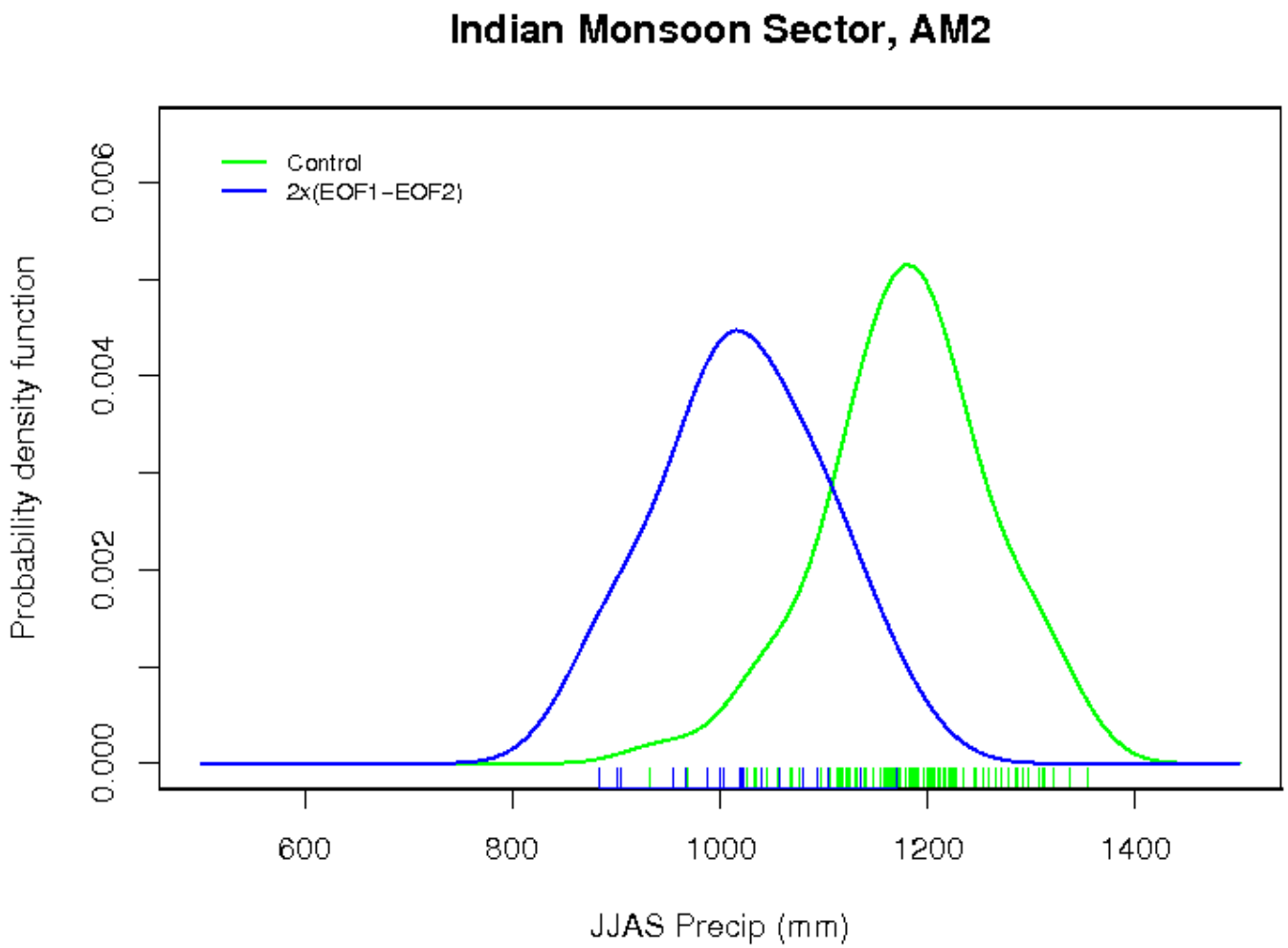
Rainfall and 200 hPa Velocity Potential Responses

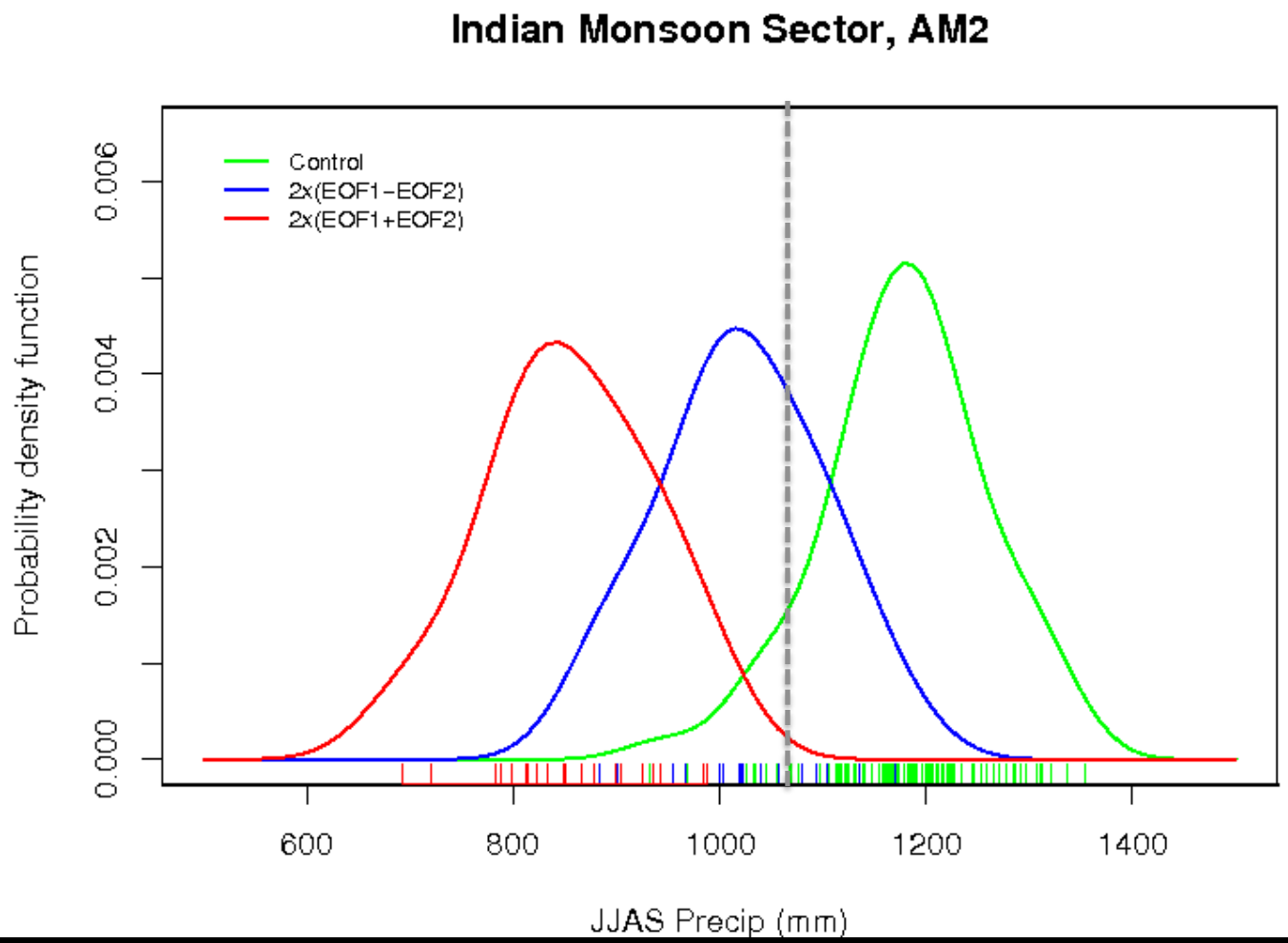


Rainfall and 200 hPa Velocity Potential Responses




Indian Monsoon Sector, AM2
Control
Probability density function
0.000
0.002
0.004
0.006
600
800
1000
1200
1400
JJAS Precip (mm)


Indian Monsoon Sector, AM2
Control
2x(EOF1−EOF2)
Probability density function
0.000
0.002
0.004
0.006
600
800
1000
1200
1400
JJAS Precip (mm)



Probability of Indian Monsoon Drought Is Increased By Canonical El Nino Forcing,
It is Further, and Equivalently, Increased by Shifting El Nino's Centroid Toward the Warm Pool