Precursors for ENSO Diversity

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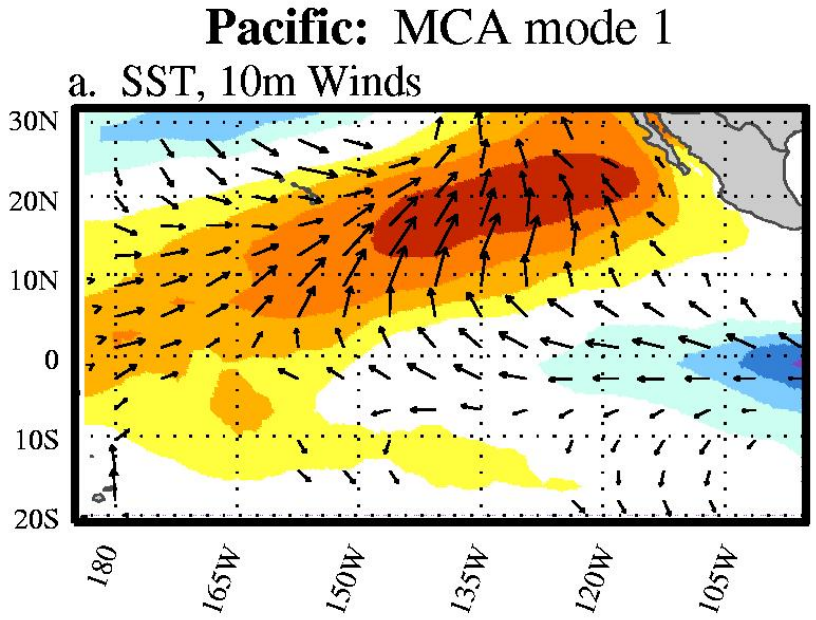
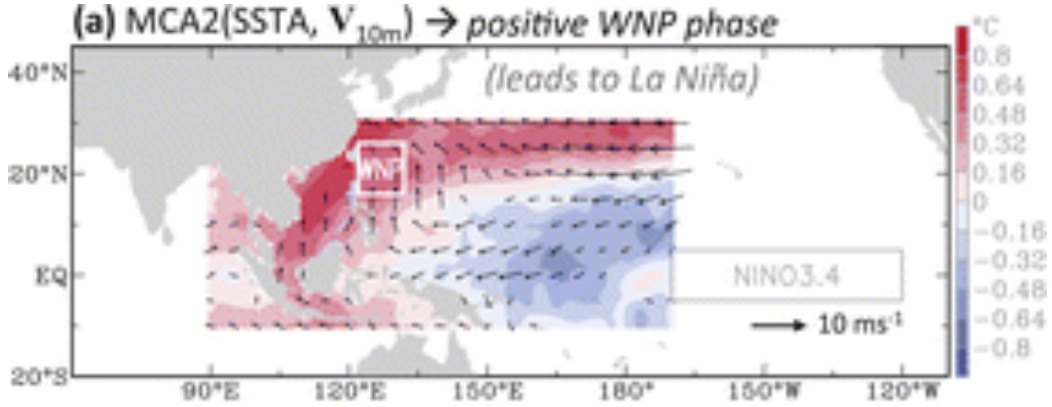
Can we identify specific precursors (large-scale, stochastic) for different types of ENSO events?

North Pacific precursors (SST)



North Pacific Meridional Mode

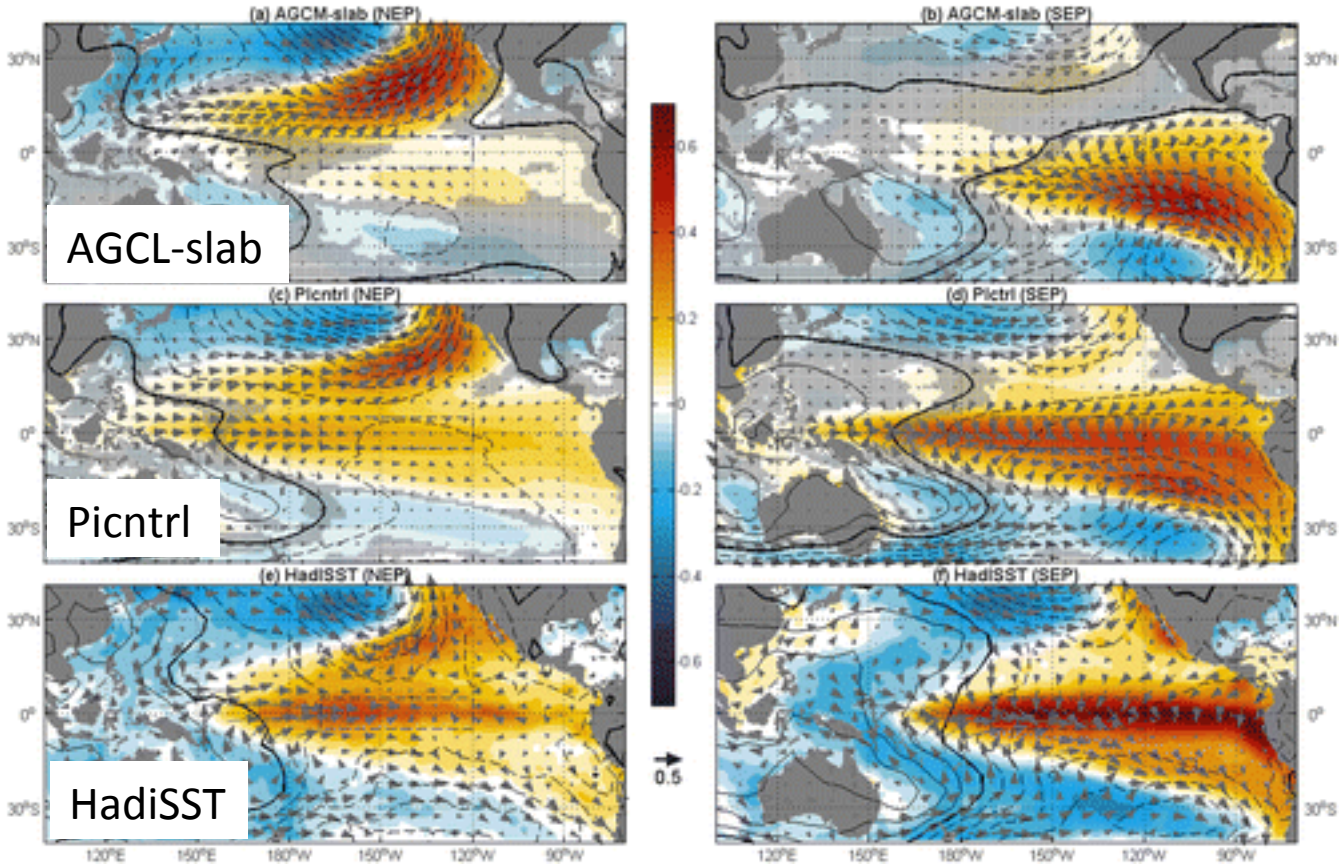
Linked to CP El Niño?



Western North Pacific

South Pacific Meridional Mode

SPMM linked to EP El Niño?



Zhang et al. 2014

Regression of anomalous SST, SLP, and surface winds onto normalized SST time series in 21°-25°N, 138°-142°W

Regression of anomalous SST, SLP, and surface winds onto normalized SST time series in 19°-15°N, 103°-107°W

Examining ENSO precursors using a Linear Inverse Modeling (LIM) methodology (Penland and Sardeshmukh 1995)

$$d\boldsymbol{x} = \mathbf{L}\,\boldsymbol{x}\,dt + \mathbf{S}\,\mathbf{r}\,(dt)^{1/2}$$

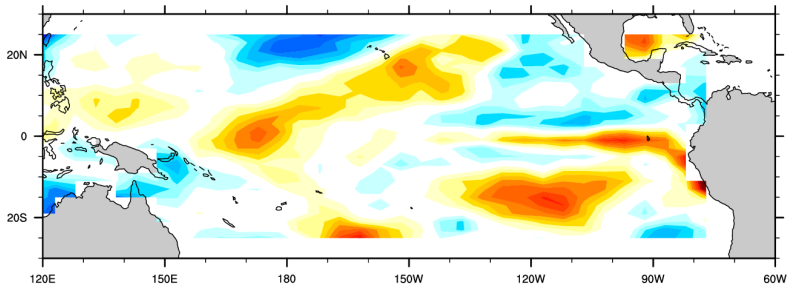
$$\boldsymbol{x}(t+\tau) = \mathbf{G}(\tau)\,\boldsymbol{x}(t) + \varepsilon$$

$$\mathbf{G}(\tau) = \exp(\mathbf{L}\,\tau) = \mathbf{C}(\tau)\,\mathbf{C}(0)$$

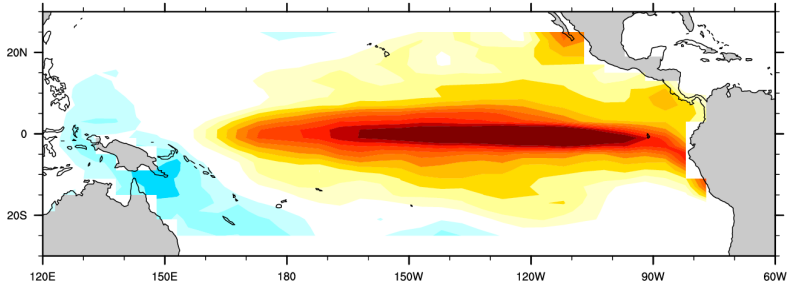
$$\gamma^2(\tau) = \frac{< x(\tau)\,x(\tau) >}{< x(0)\,x(0) >} = \frac{< x(0)\,G^T G\,x(0) >}{< x(0)\,x(0) >}$$

Eigenvectors of G^TG (ϕ_i) with eigenvalues larger than 1 lead to growth

ϕ_1
Initial



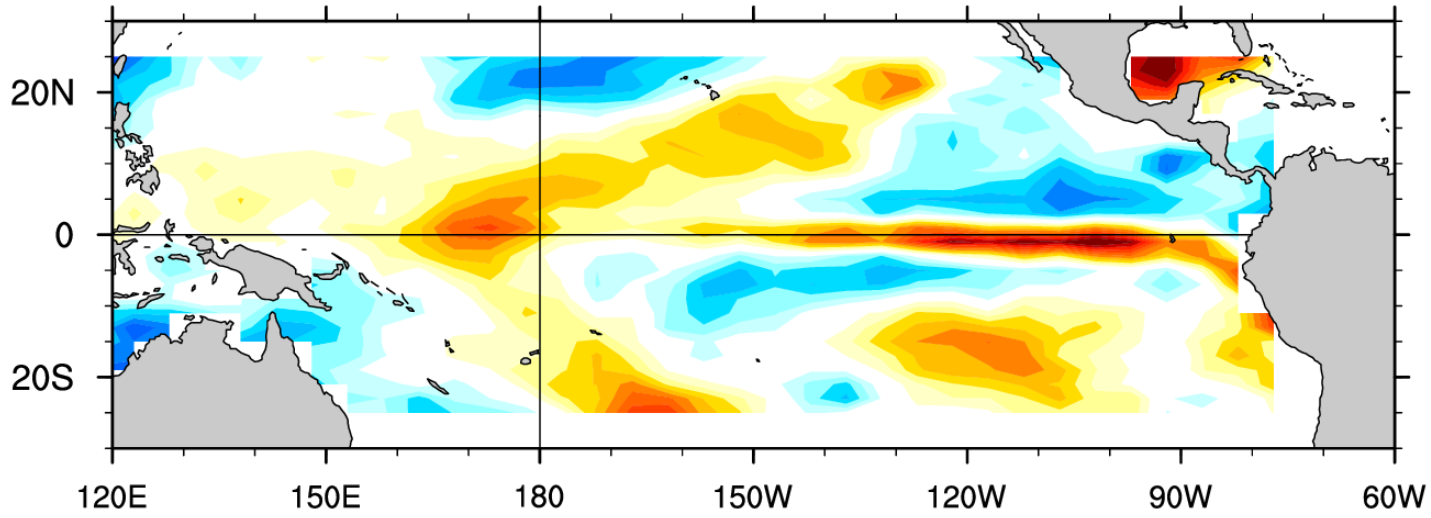
Final



SODA 1958-2007

Capotondi and Sardeshmukh, in revision

LIM optimal initial ϕ_1 has parts resembling different precursors



Q1. Are different parts of the optimal initial anomaly pattern responsible for different parts of the final evolved pattern (the ENSO pattern)?

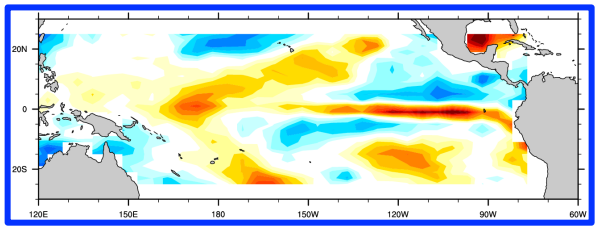
Q2. In particular are there specific parts responsible for central versus eastern Pacific warming?

$$\mathbf{x}(t) = \mathbf{G}(t)\,\mathbf{x}(0) = \mathbf{G}\,\boldsymbol{\phi}_1(0)$$

$$\mathbf{x}(t) = \mathbf{G}(t)\,[\,\boldsymbol{\phi}_1^{(1)} + \boldsymbol{\phi}_1^{(2)} + \boldsymbol{\phi}_1^{(3)} + \boldsymbol{\phi}_1^{(4)}\,]$$

Q1. Are different parts of the optimal initial anomaly pattern responsible for different parts of the final evolved pattern?

Q2. Are there specific parts responsible for central versus eastern Pacific warming?



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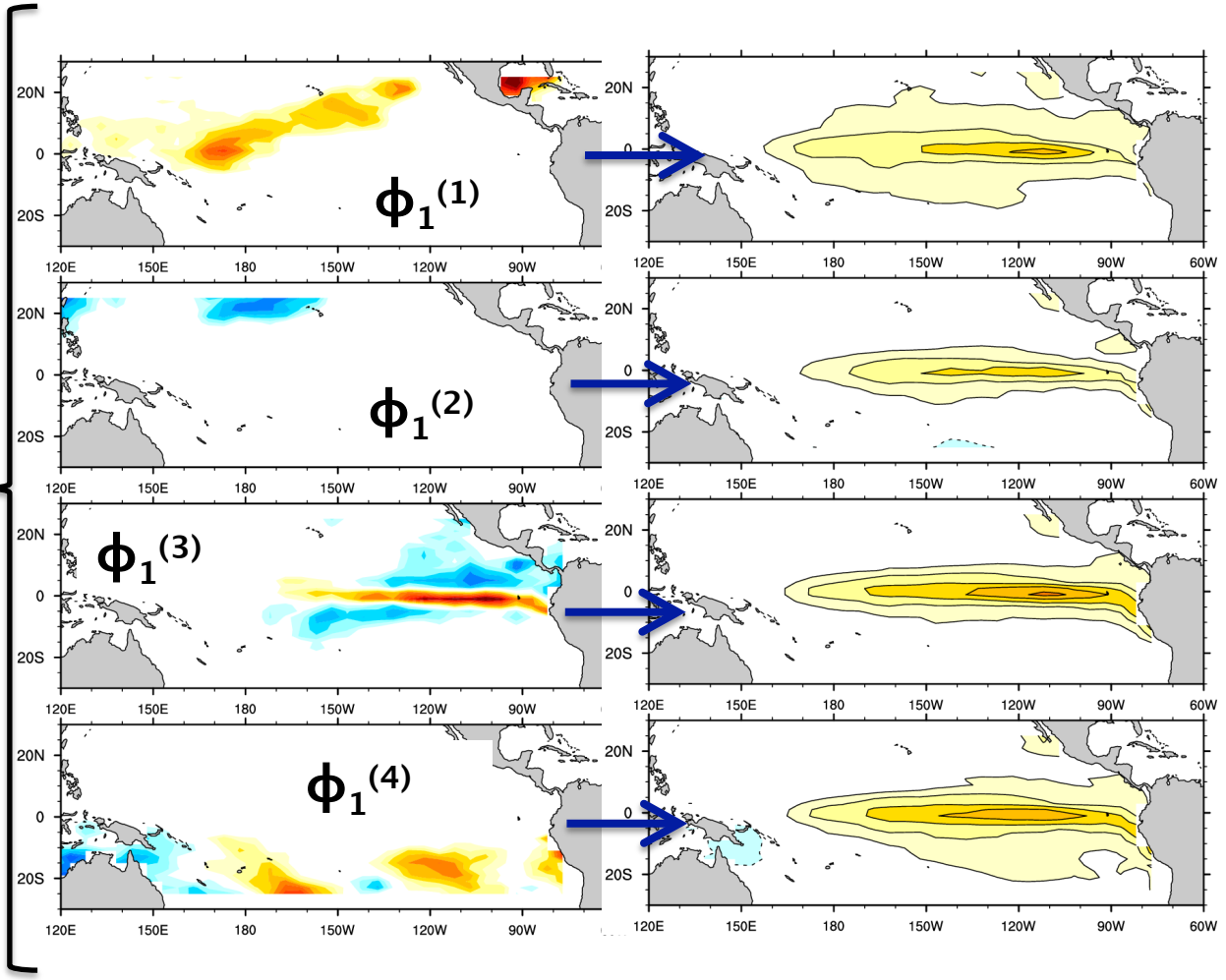


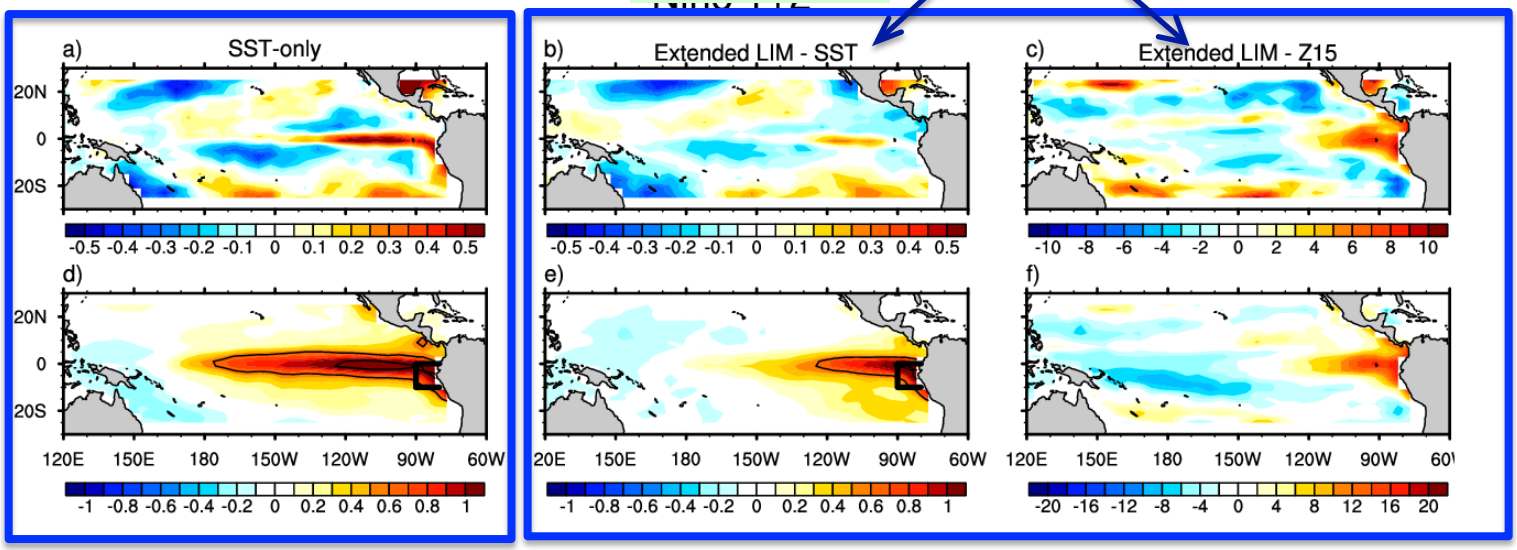
How are different ENSO types generated?

$$\mathbf{x}(t) = \mathbf{G}(t)\,\mathbf{x}(0) \rightarrow \mathbf{y}(t) = \mathbf{H}(t)\,\mathbf{x}(0)$$

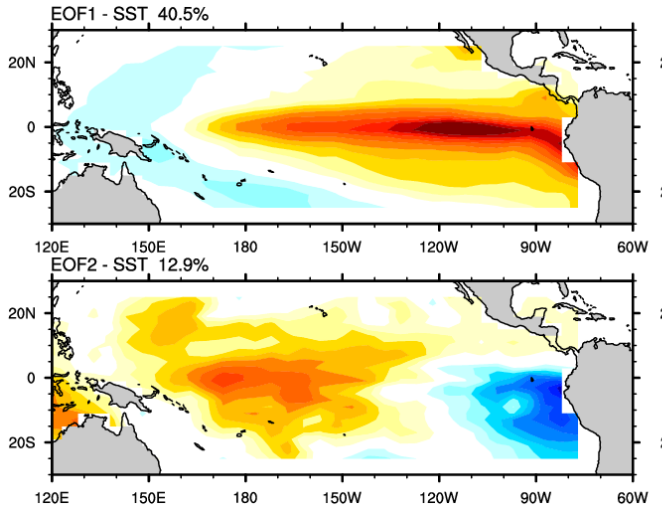
SST only LIM

NINO1+2

SST + Z15 LIM



What about events peaking in the central Pacific?



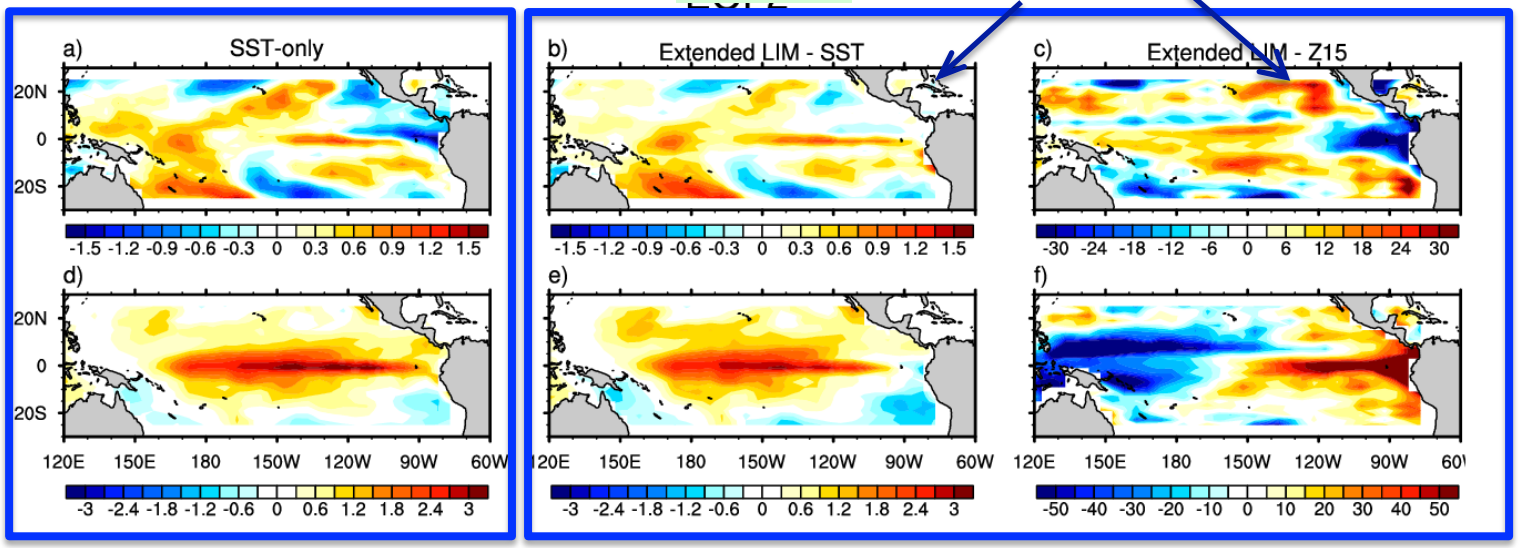
EOF1

EOF2

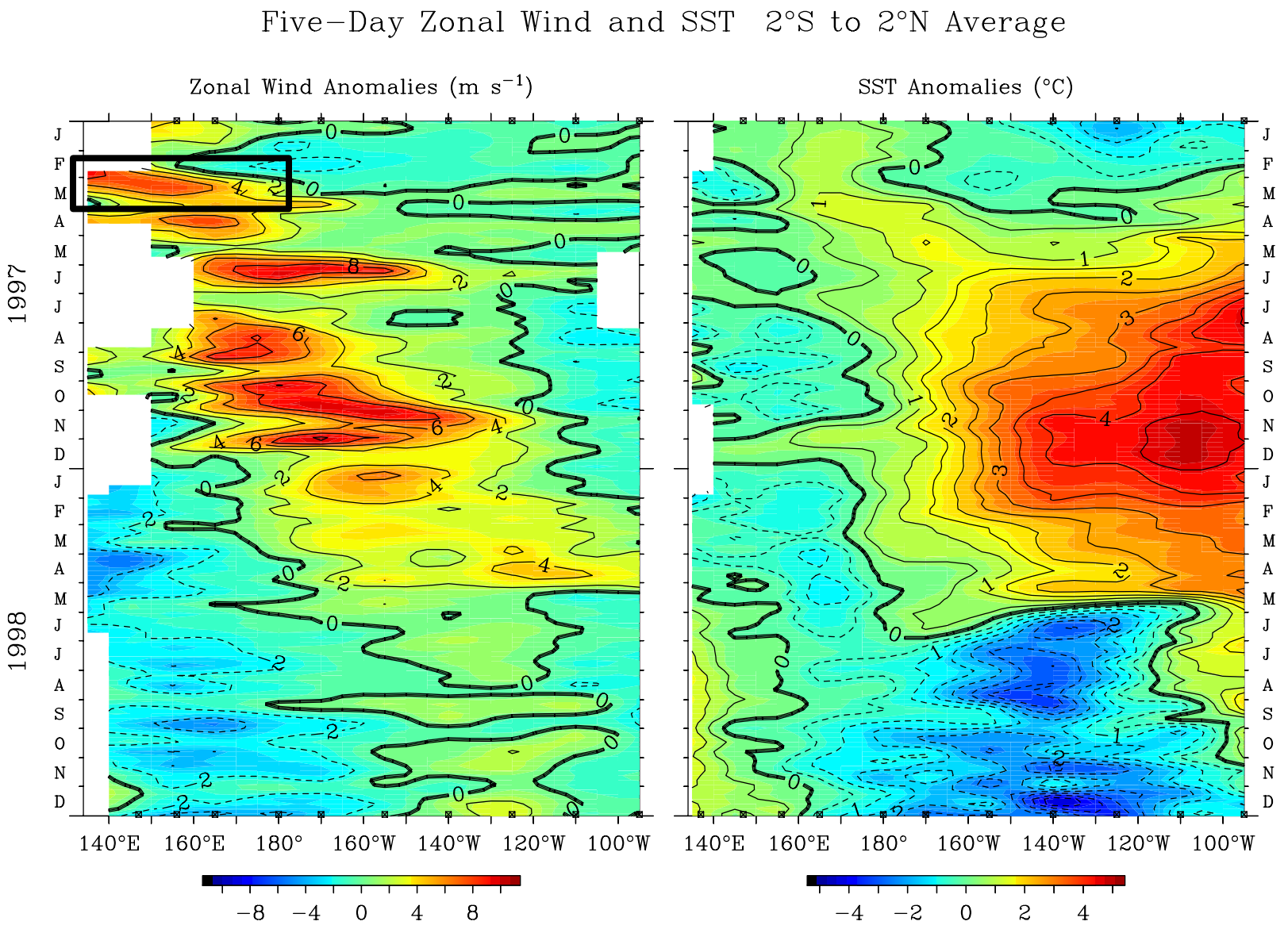
SST only LIM

EOF2

SST + Z15 LIM



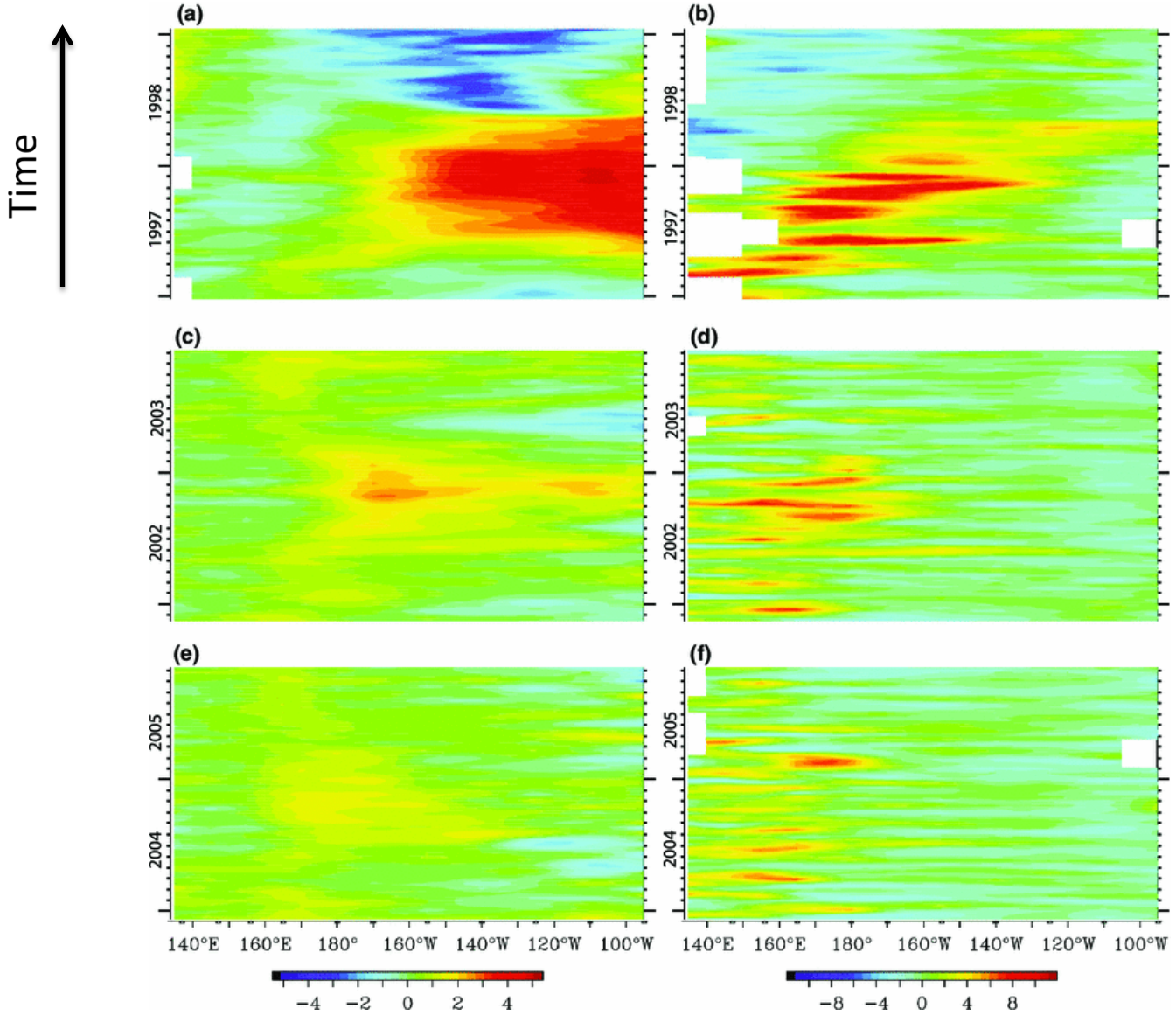
Westerly Wind Burst (WWB) in Feb-Mar 1997, preceding El Niño



TAO Project Office/PMEL/NOAA

Jan 12 2013

WWBs are present in most El Niño events, but SST spatial pattern and magnitude may differ considerably from event to event



1997-98

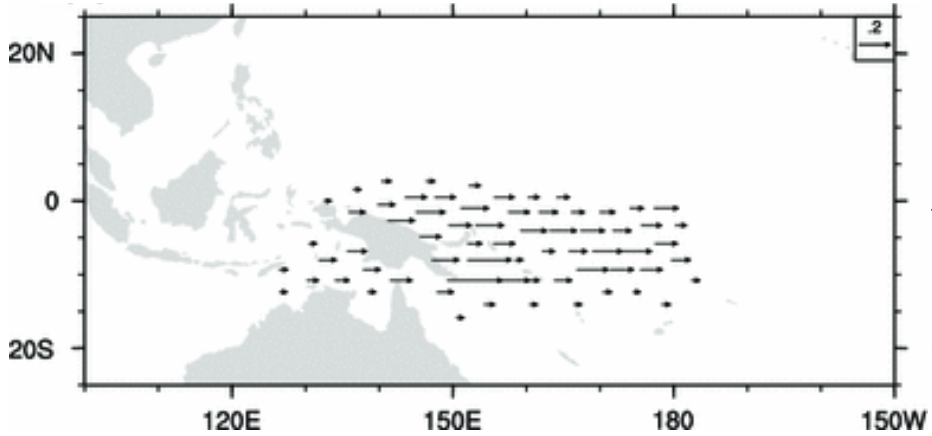
2002-03

2004-05

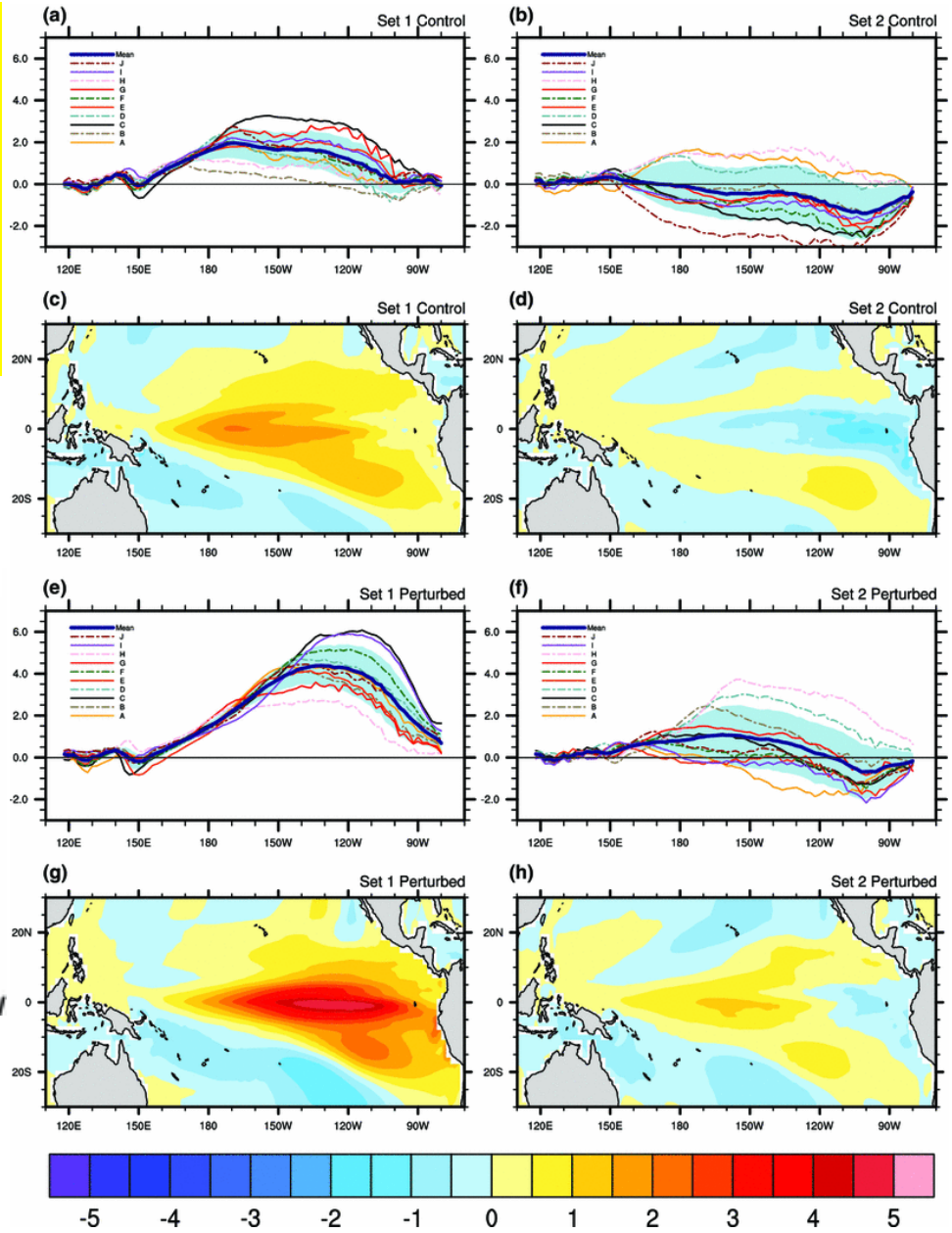
Fedorov et al. 2014

Numerical experiments indicate the importance of the ocean background state for ENSO diversity

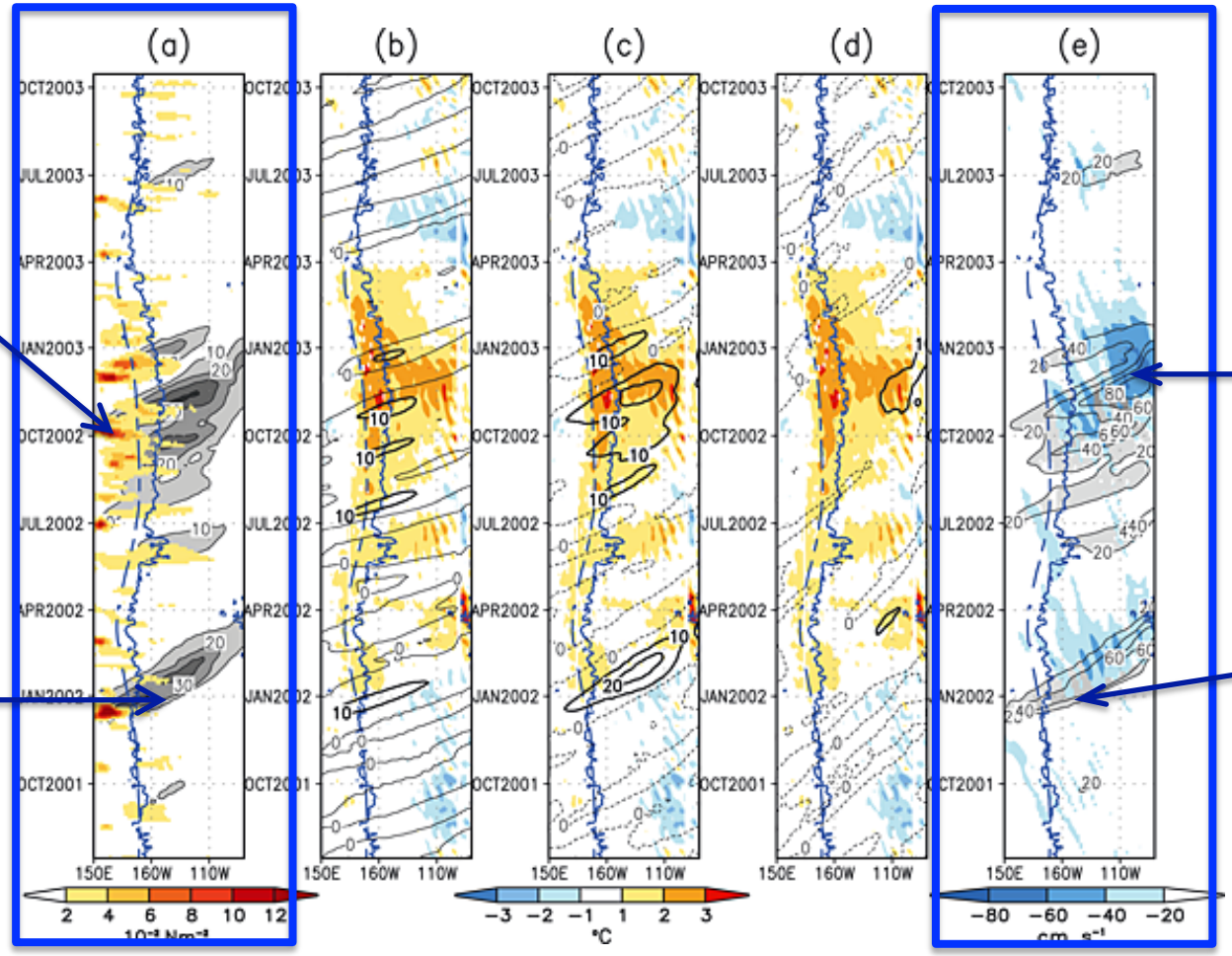
Westerly Wind Burst from observations (Feb-Mar 1997)



Fedorov et al. 2014



Downwelling Kelvin waves (modes 1, 2, 3) are excited by the WWBs. DKW are reflected as Rossby waves in the eastern basin



ZWS

DKW ampl

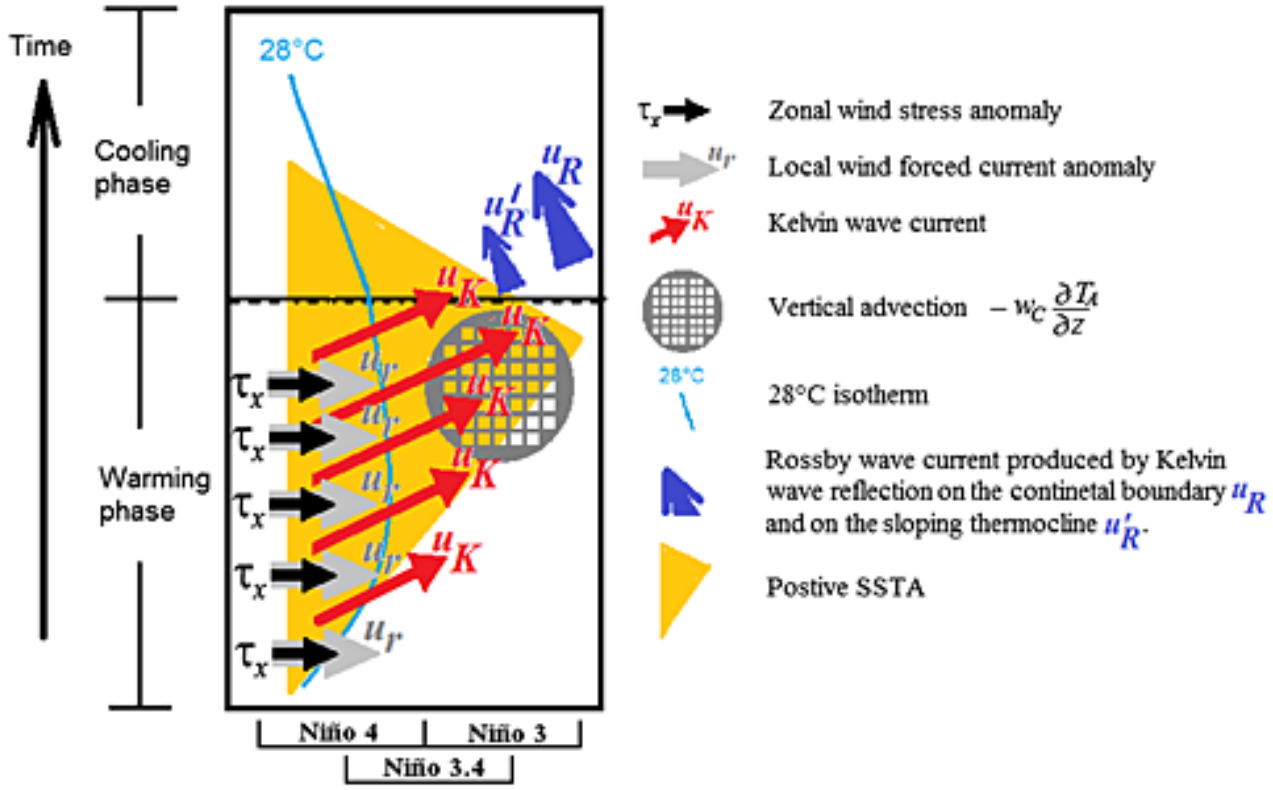
2002-03 El Niño

RW zonal vel

DKW zonal vel

Mosquera et al. 2013

The sloping thermocline in the eastern basin causes DKW energy scattering



Mosquera et al. 2013

Conclusions

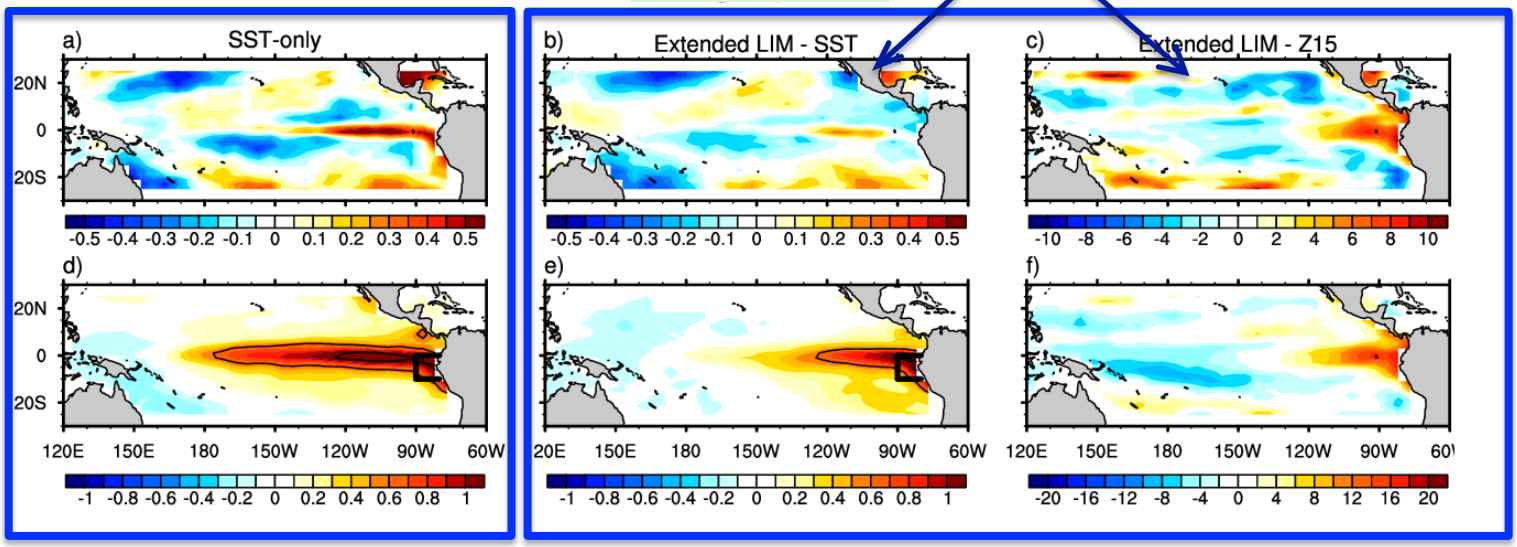
ENSO precursors span a broad range of spatial and temporal scales, that need to be resolved for proper monitoring

The influence of WWBs on the development of ENSO events is mediated by equatorial waves -> Very important to capture Kelvin and Rossby wave evolution

Initial oceanic conditions (slow evolving background state or WWB-induced thermocline depth anomalies) are very critical for the selection of ENSO types

Kelvin wave reflection and dissipation may need to be better understood

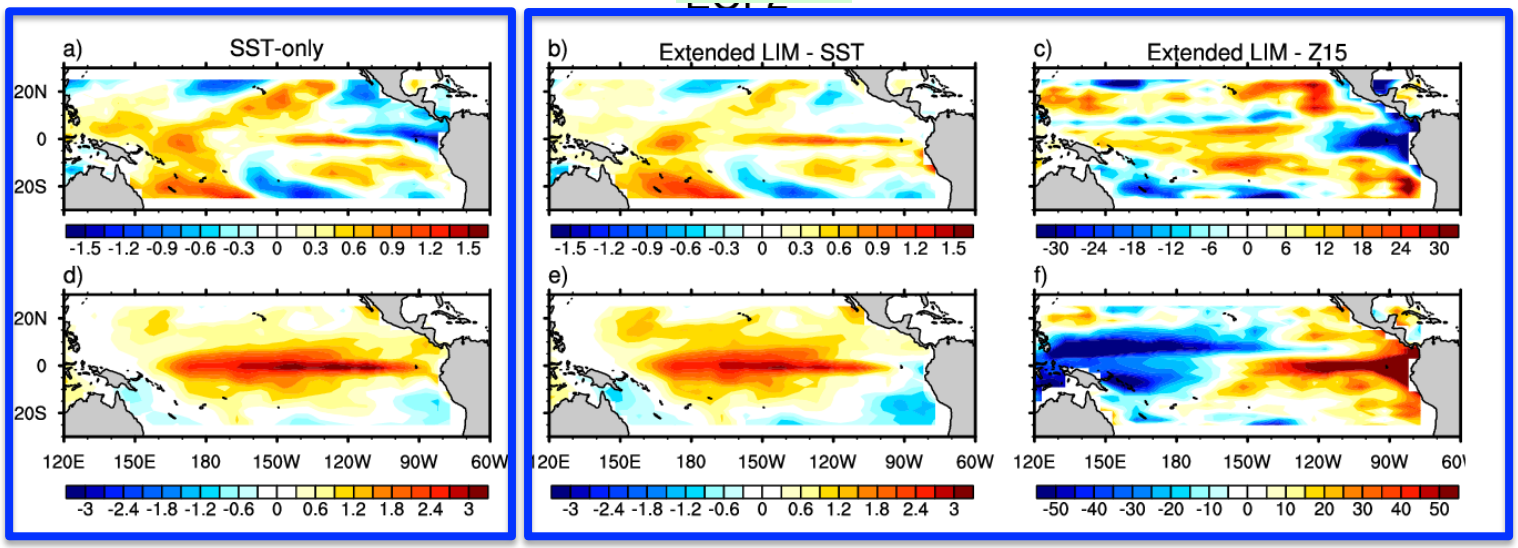
NINO1+2

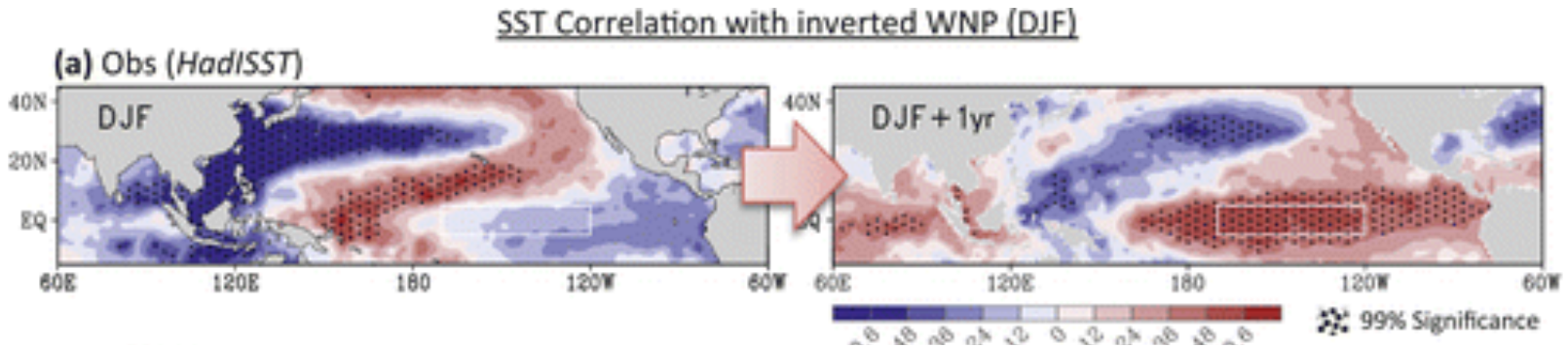


SST only LIM

EOF2

SST + Z15 LIM




SST Correlation with inverted WNP (DJF)
(a) Obs (HadISST)
DJF
DJF + 1yr
40N
20N
EQ
60E
120E
180
120W
60W
99% Significance