ENSO Diversity in the NCAR-CCSM4

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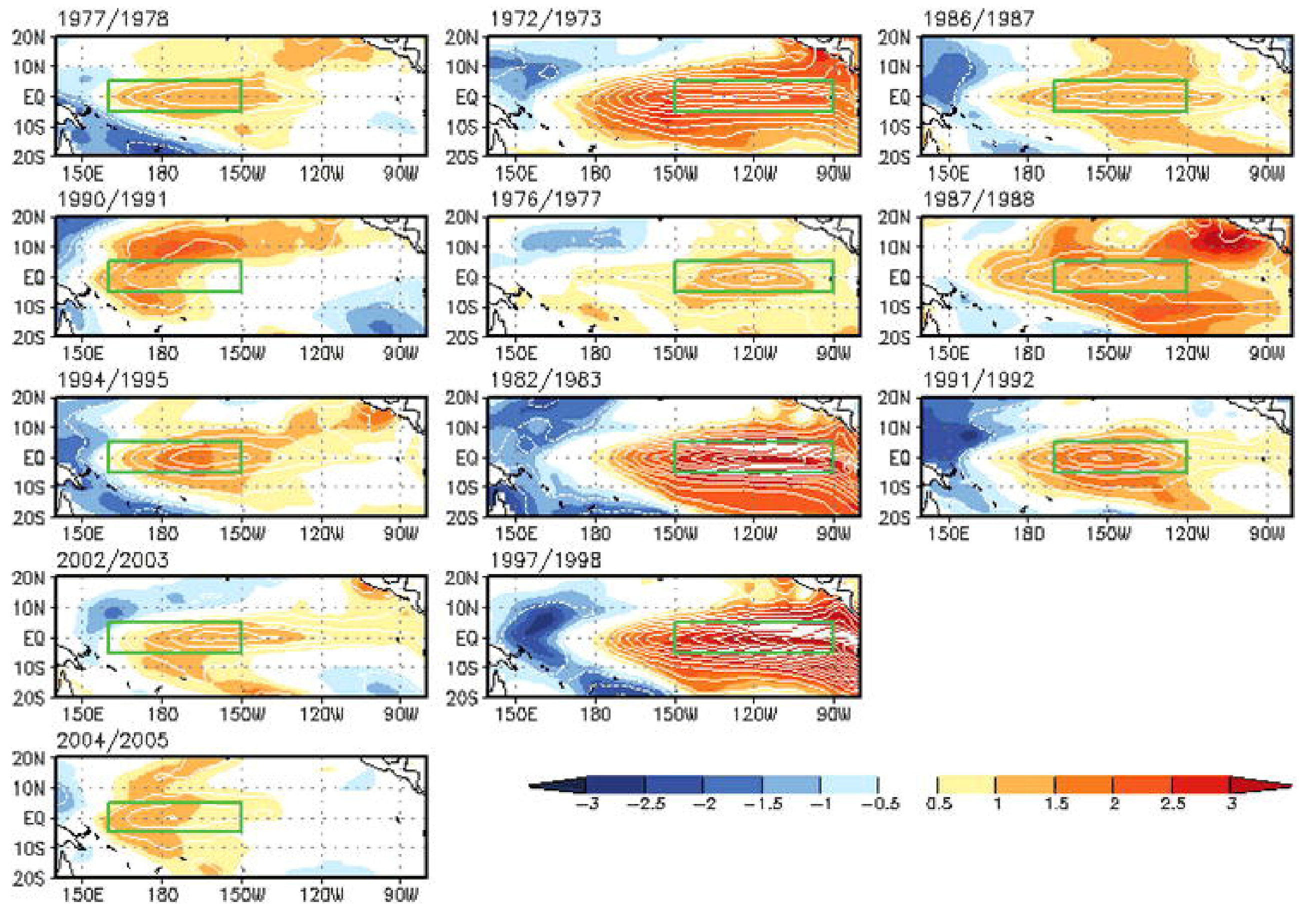
What do we mean with ENSO diversity?

Warm pool (WP) | Cold Tongue (CT) | Others



Kug et al. 2009: "Two types of El Niño: Cold Tongue El Niño and Warm Pool El Niño" (NOAA-ERSST 1970-2005)

Selection of events based on Niño3 and Niño4 indices

Definitions

“Dateline El Niño” (Larkin and Harrison 2005)

“El Niño Modoki” (Ashok et al. 2007)

“Central Pacific El Niño” (Kao and Yu 2009)

“Warm Pool El Niño” (Kug et al. 2009)

The types of El Niño may be the manifestation of a broader and perhaps continuum of ENSO flavors.

Why is ENSO diversity important?

Different locations of maximum warming are associated to different teleconnection patterns:

- It has been suggested as a forcing for the southernmost lobe of the NPO, which, in turn, appears to force the North Pacific Gyre Oscillation (NPGO, Di Lorenzo et al. 2008)

- It has been linked to changes in tropical cyclone activity (Kim et al. 2009), shifts in precipitation patterns (Weng et al. 2009), and warming in Antarctica (Lee et al. 2010, Ding et al. 2011)

It has been suggested that CP warming may become more pronounced with global warming (Yeh et al. 2009)

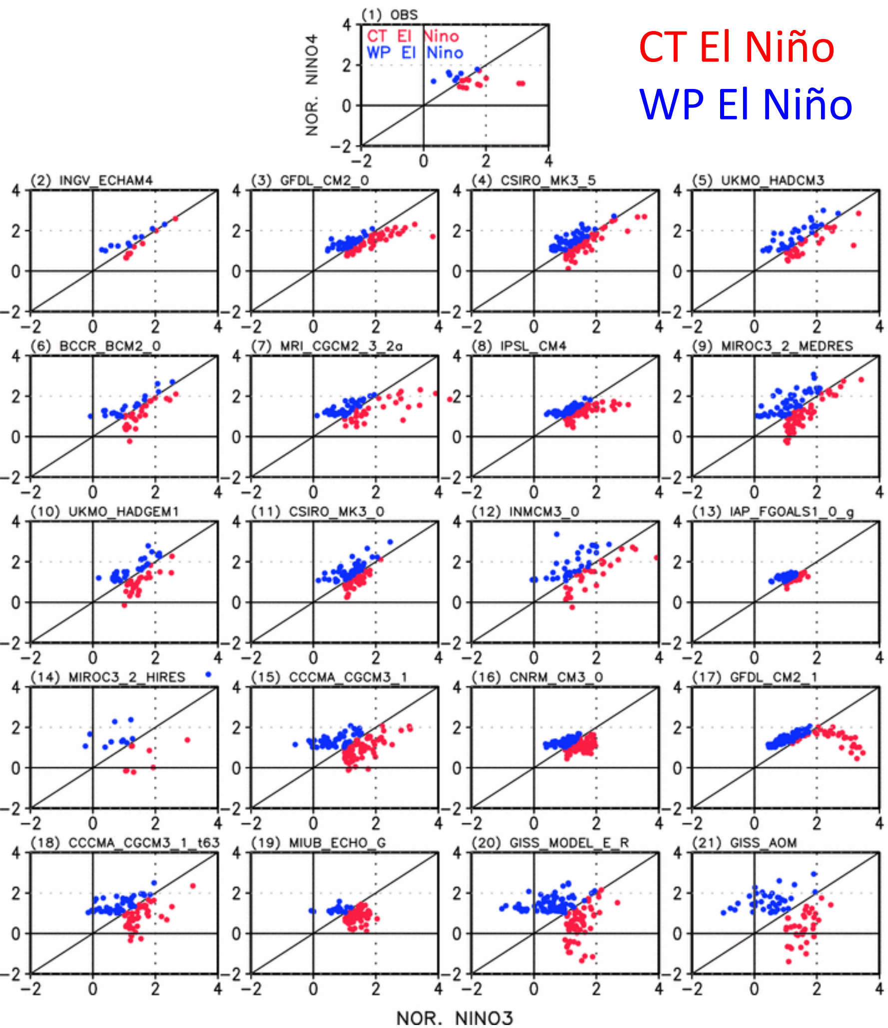
Objectives

- Use 500 years (800-1299) of Pre-industrial Control integration to assess how well CCSM4 simulates a broad spectrum of El Niño warming, adopting various approaches proposed in previous studies (Niño3 and Niño4 indices, EOF analysis)
- Use the model to have a more robust assessment of the processes involved in different types of events
- Examine teleconnection patterns associated with different patterns of warming

Compare model with SODA ocean reanalysis (1958-2007).
Forced by ERA-40 (1958-2001) and QuickSCAT (2002-2007)
Resolution: 0.4(lon) x 0.25(lat) x 40 vertical levels

CMIP3 analysis

SST obs: ERSST V.2 (1910-2009), Using JFM Niño3 and Niño4 indices

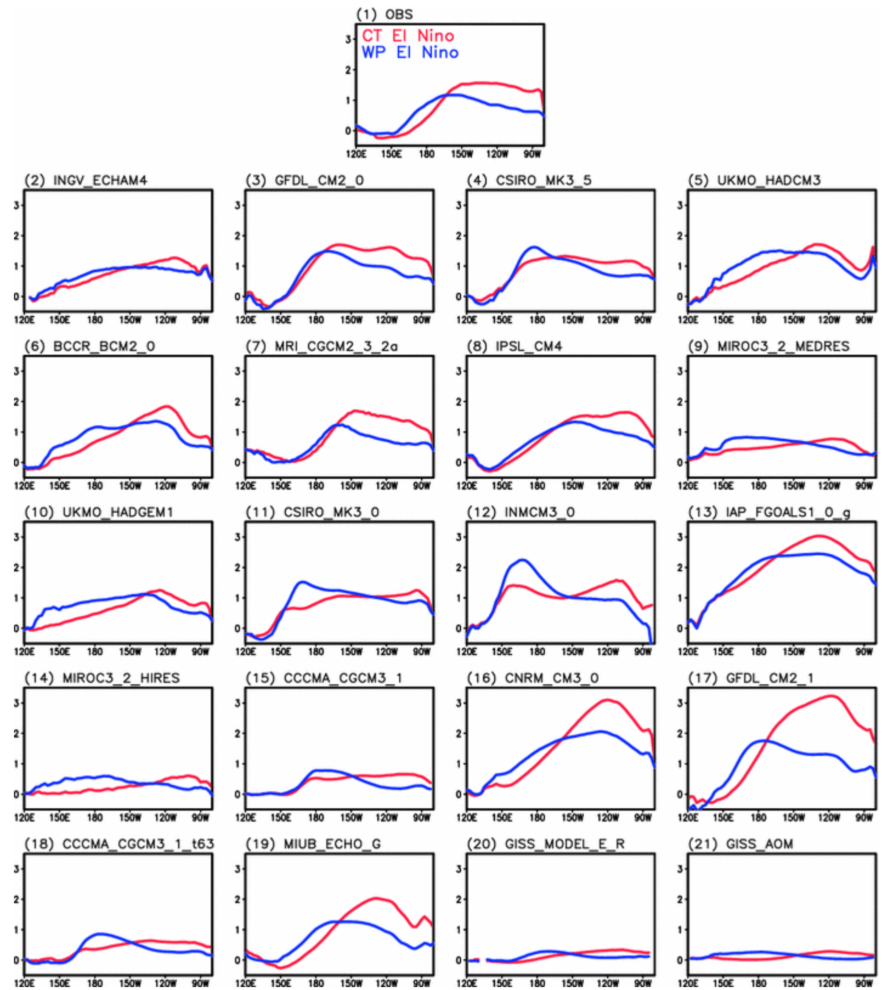


CT El Niño

WP El Niño

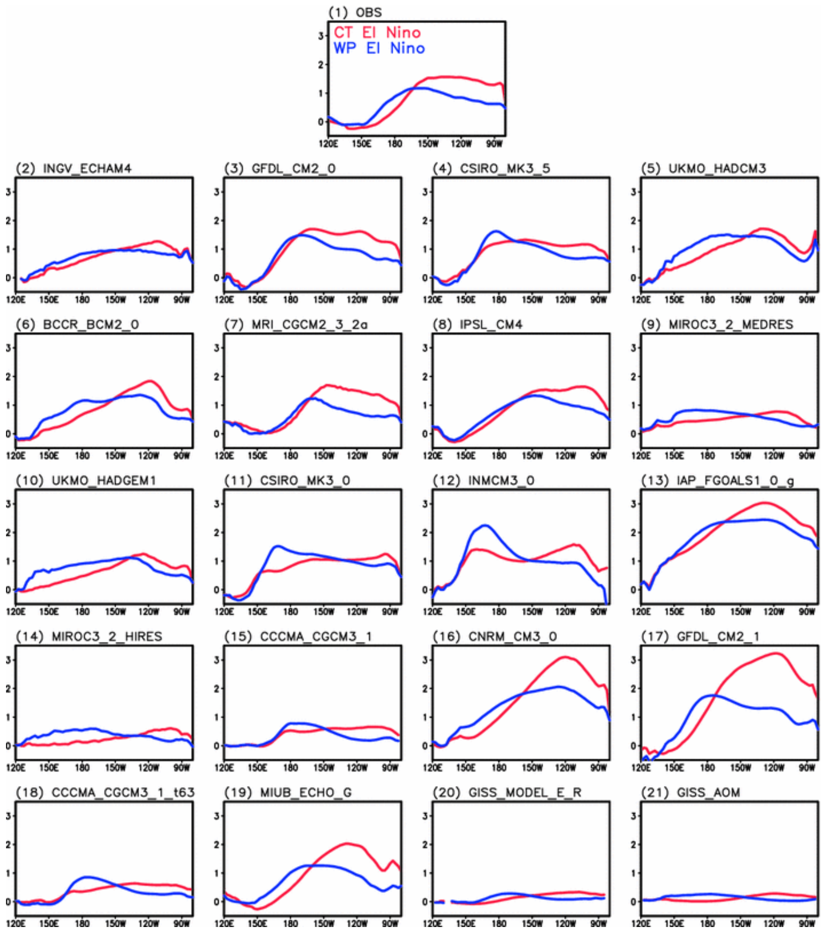
Ham and Kug 2011

Zonal SST profiles

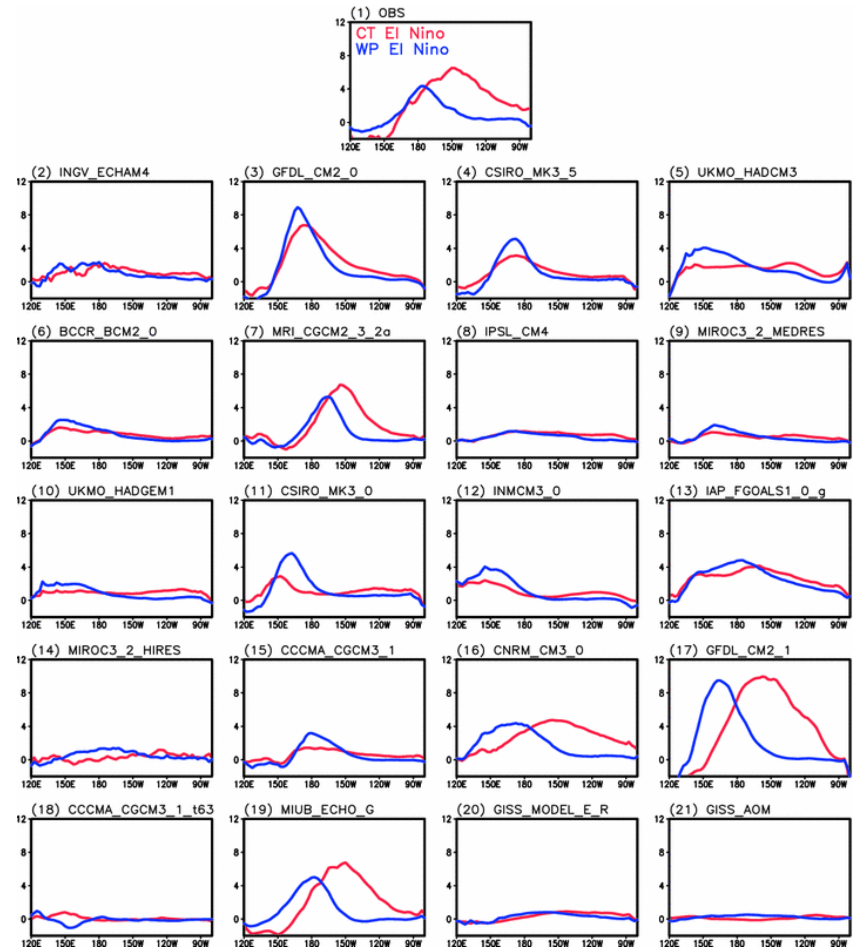


Precipitation - CMIP3 models

SST



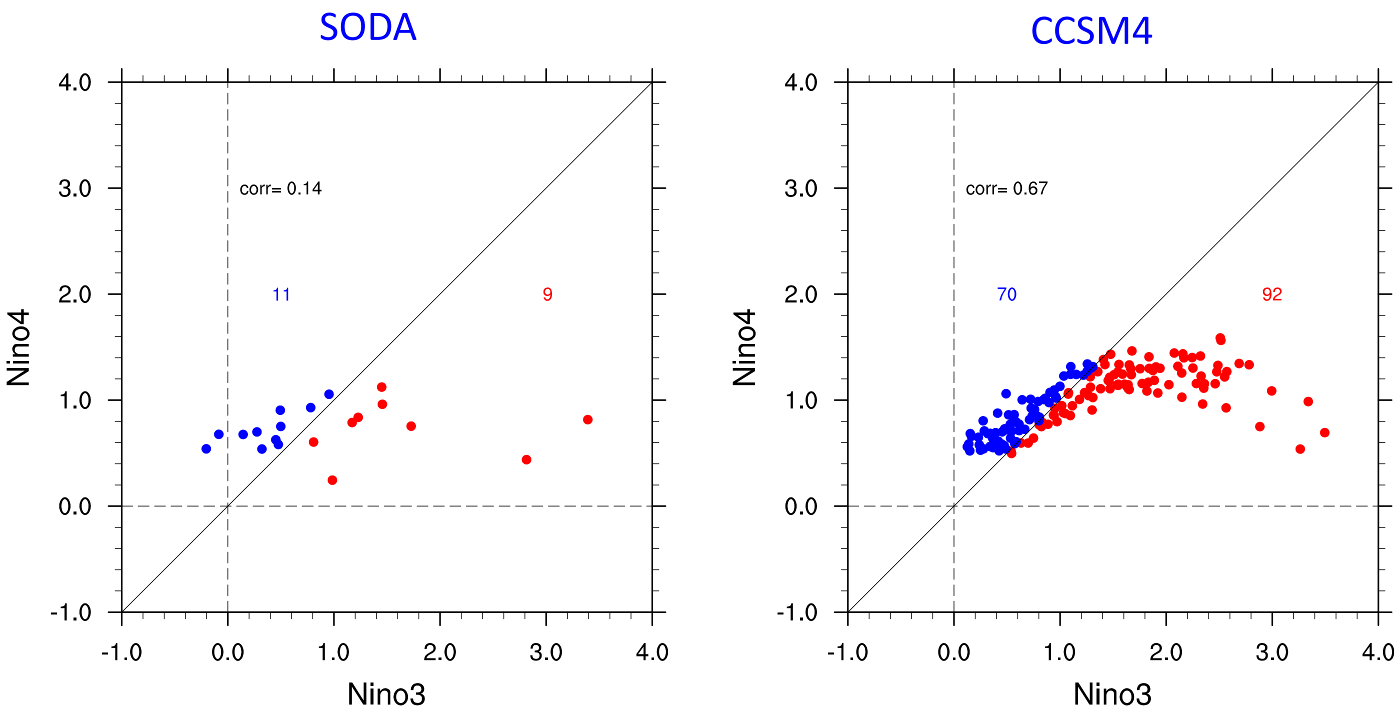
Precipitation (MERRA)



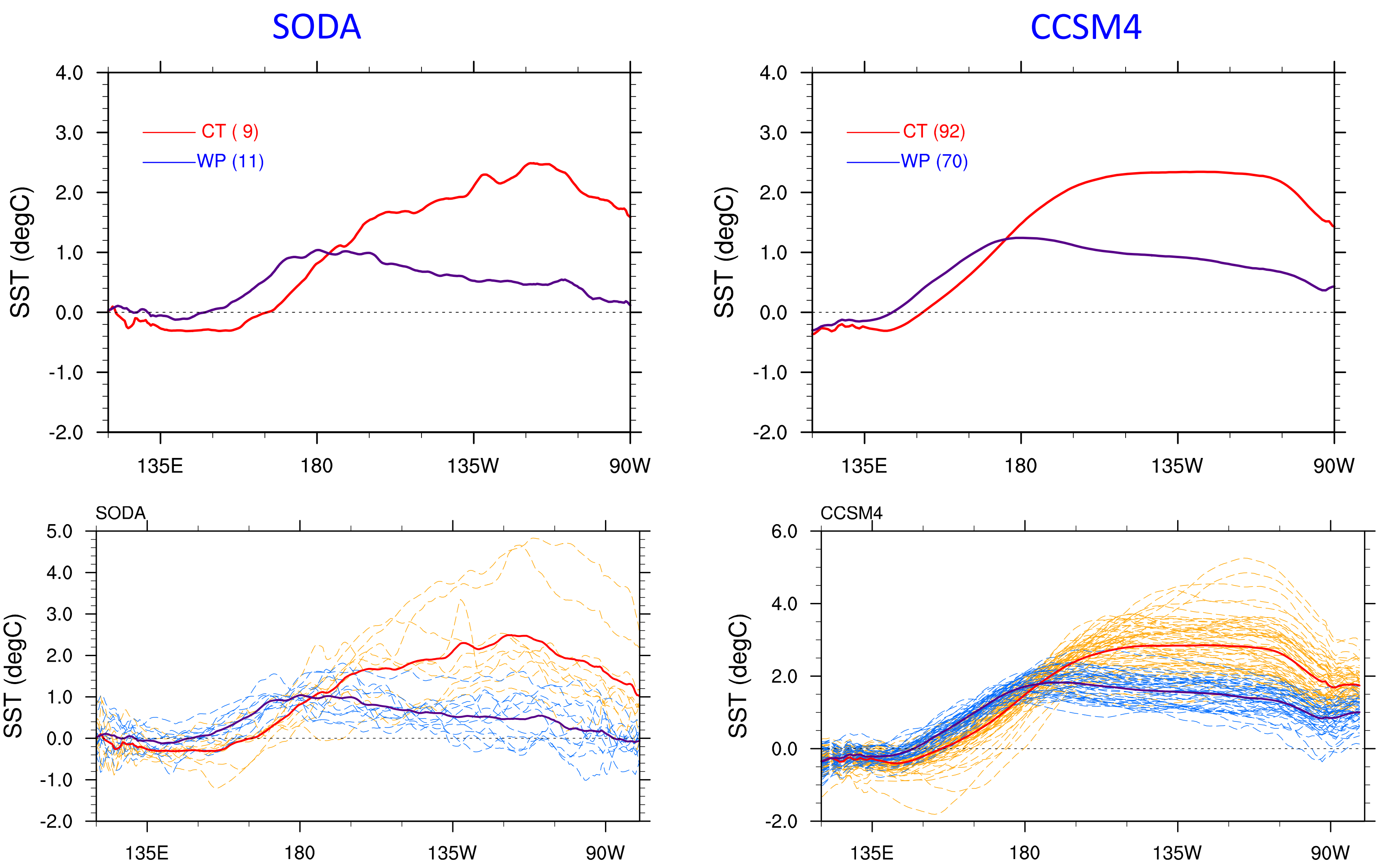
Models with a better separation of SST maxima also have shifted precipitation patterns. The lack of separation is attributed to the inability of the convection system to shift eastward due to the cold tongue bias.

Kug and Ham 2011

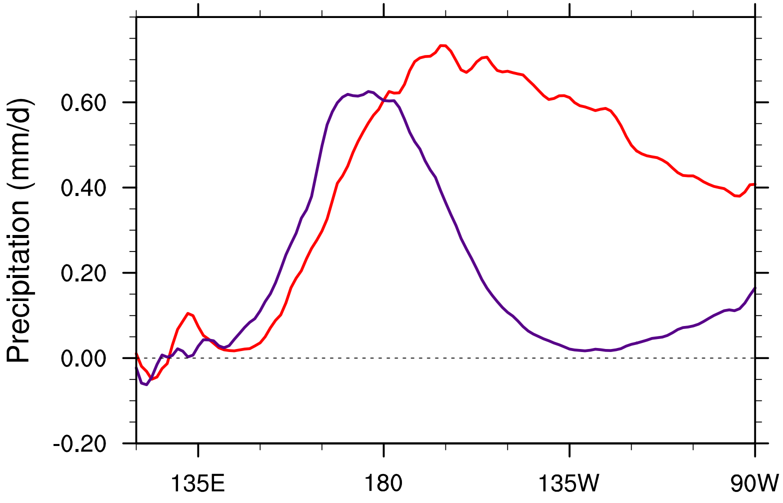
Can CCSM4 reproduce warming over a broad range of longitudes?

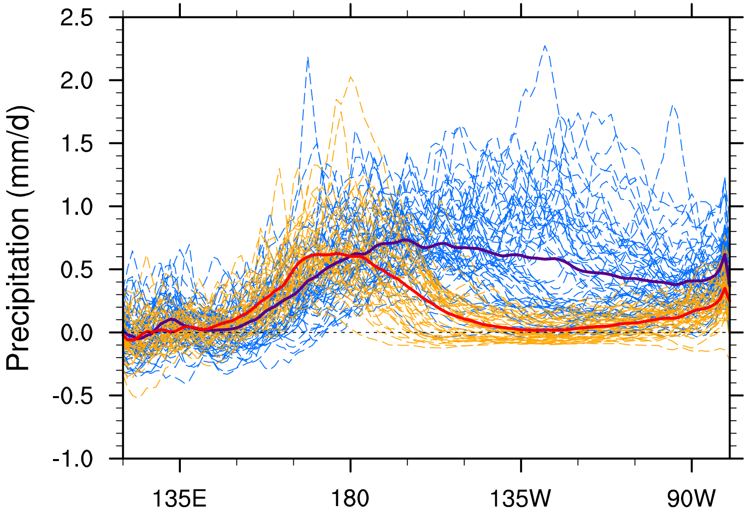


Zonal SST profiles



Can CCSM4 reproduce shifted precipitation patterns?

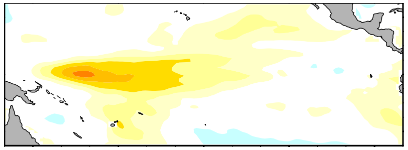




Diversity of individual events

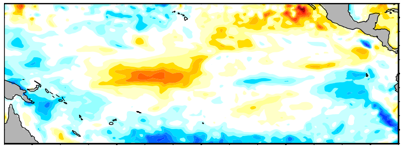
CCSM4

WP El Nino



SODA

WP El Nino



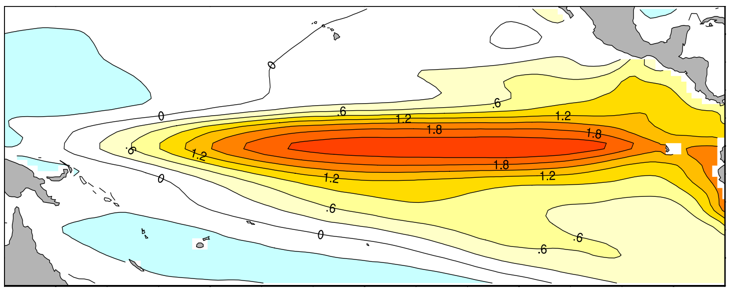
2.25 -2 -1.75 -1.5 -1.25 -1 -0.75 -0.5 -0.25 0 0.25 0.5 0.75 1 1.25 1.5 1.75 2 2.25 2.5

75 2 2.25 2.5

SST composites

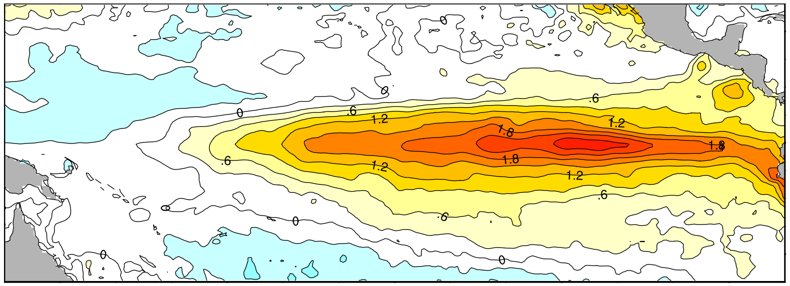
CCSM4

SST (standard inds)



SODA

DA SST



CT

WP

0 0.3 0.6 0.9 1.2 1.5 1.8 2.1 2.4 2.7 3

Thermocline depth (Z15) composites

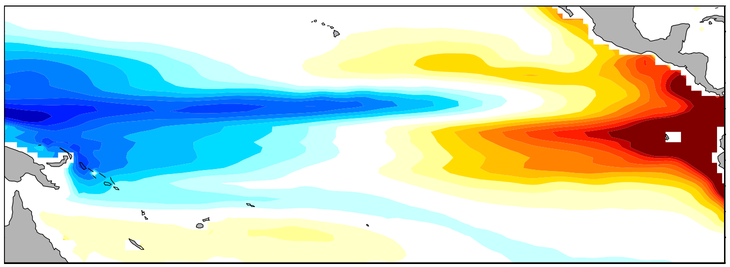
CCSM4

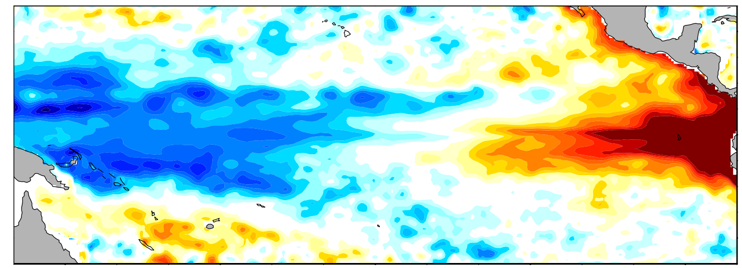
Z15

SODA

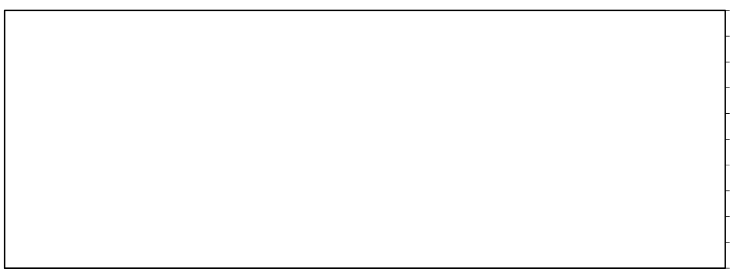
SODA Z15 (Standard inds)

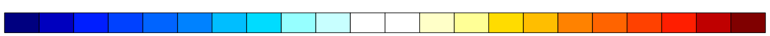
CT





WP





-12 -9 -6 -3 0 3 6 9 12 15 18 21 24 27 30

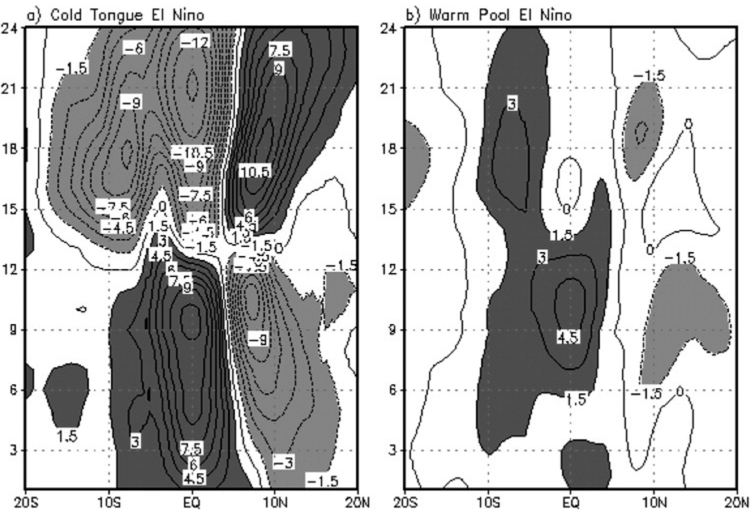
Evolution of zonally averaged thermocline depth

CCSM4

SODA

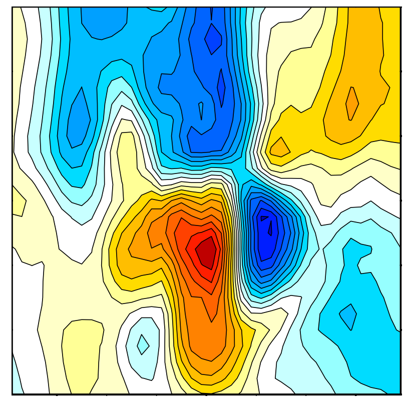
CT

WP

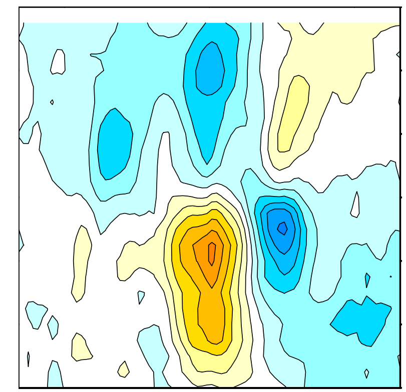


Kug et al. 2011

CCSM4

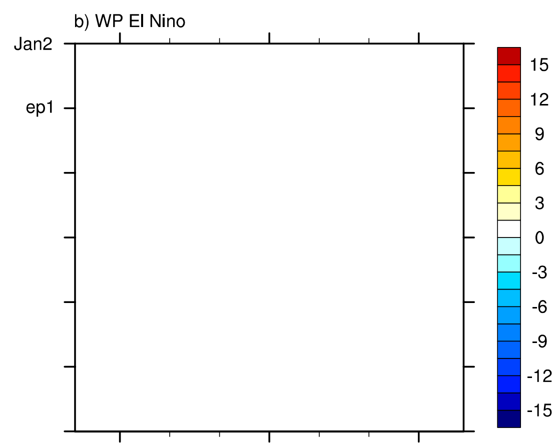


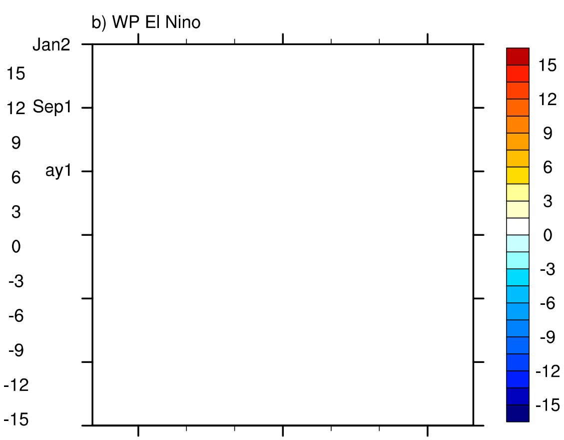
SODA



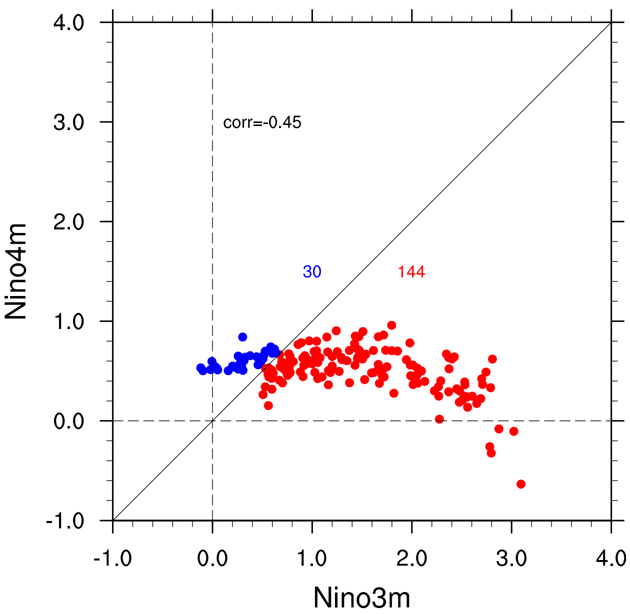
CT

W
P

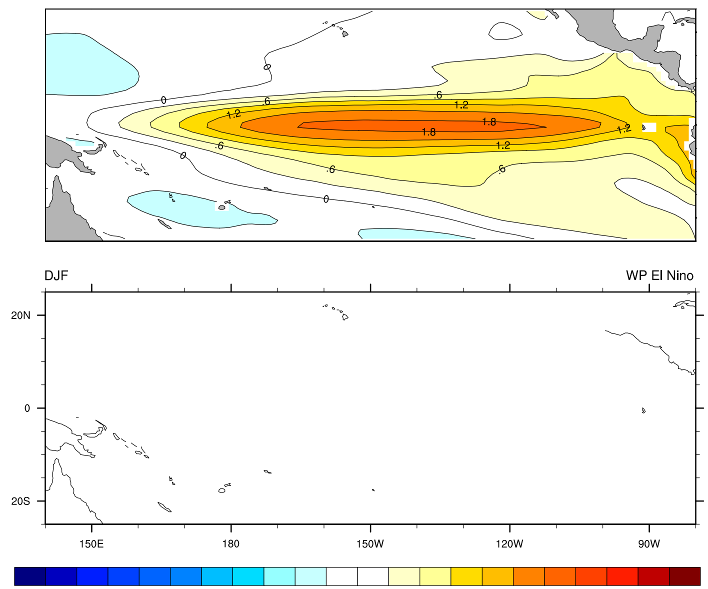




Modified Niño3 and Niño4 indices
(centers of Niño3 and Niño4 regions displaced 20° westward)



SST spatial patterns



CTm

WPm

Modified Niño3 and Niño4 indices
Z15 evolution

Z15

odif)

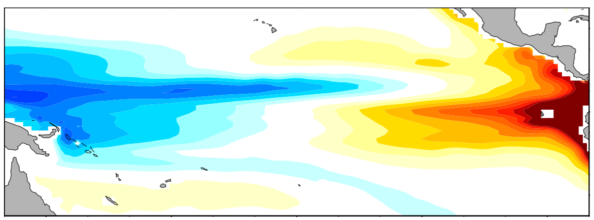
SST

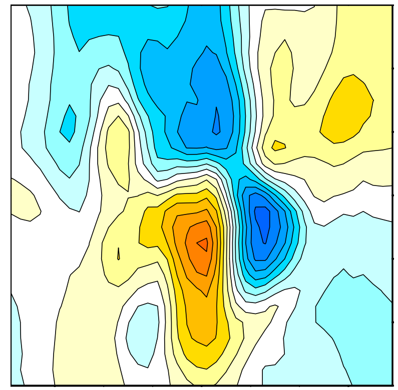
CCSM4

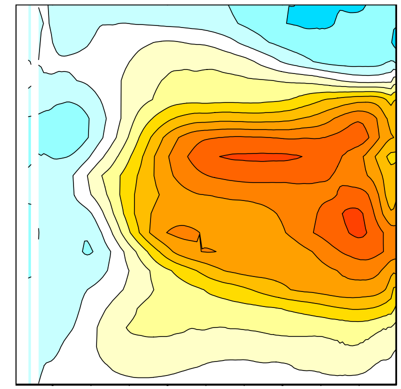
Composite of Z15 depth anomalies

dified inds)

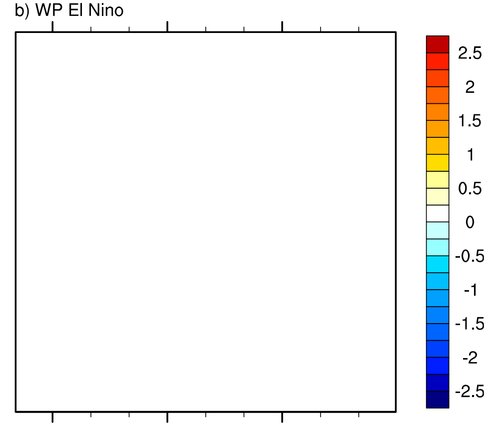
CT





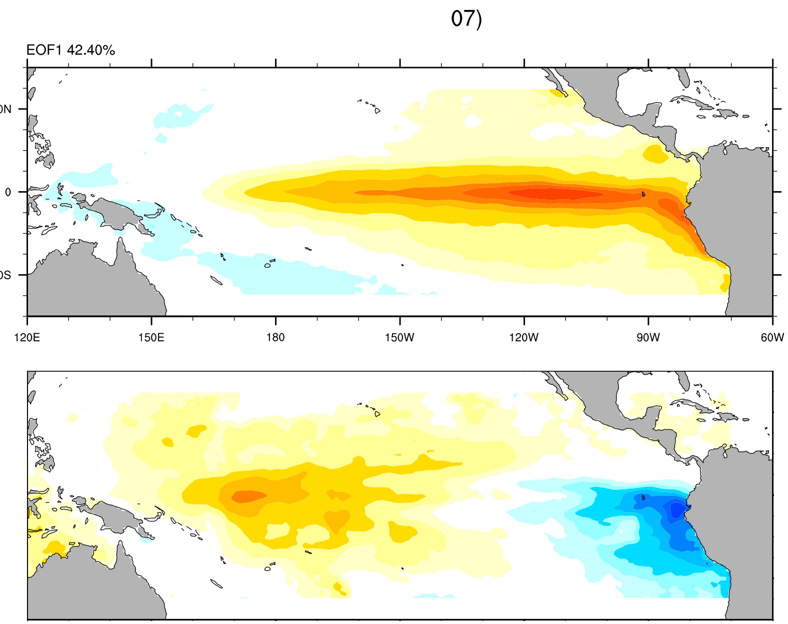


WP



EOF approach

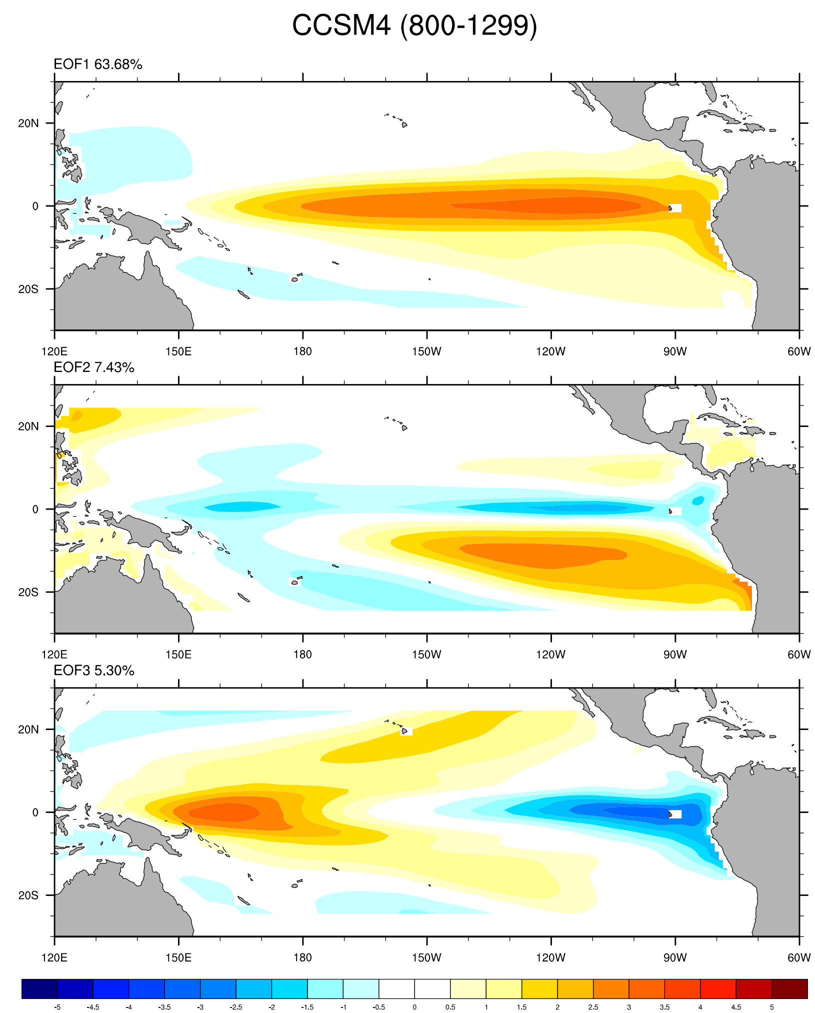
SODA



42.4%

11.7%

CCSM4



63.7%

7.4%

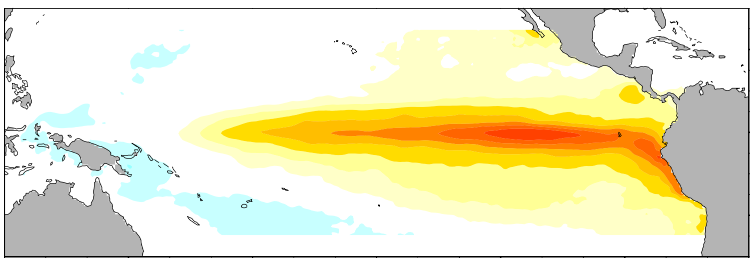
5.3%

EOF approach

SODA

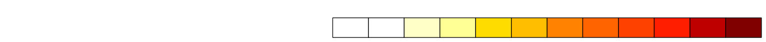
SODA (1958-2007)

42.4%



11.7%

7.1%



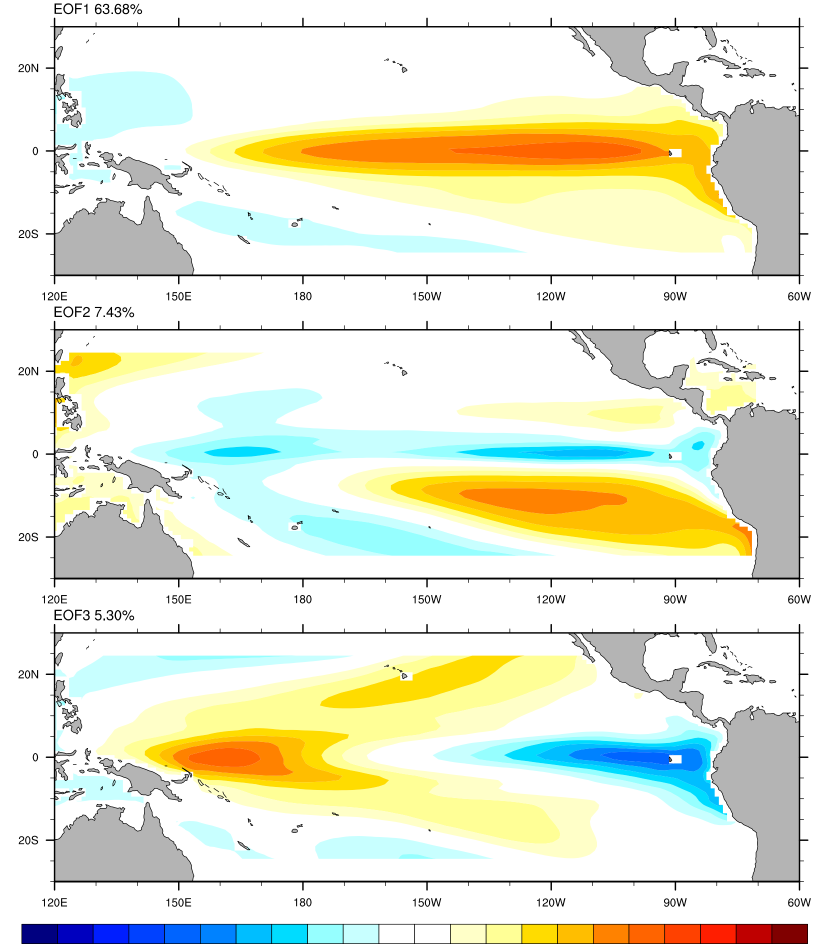
CCSM4

CCSM4 (800-1299)

63.7%

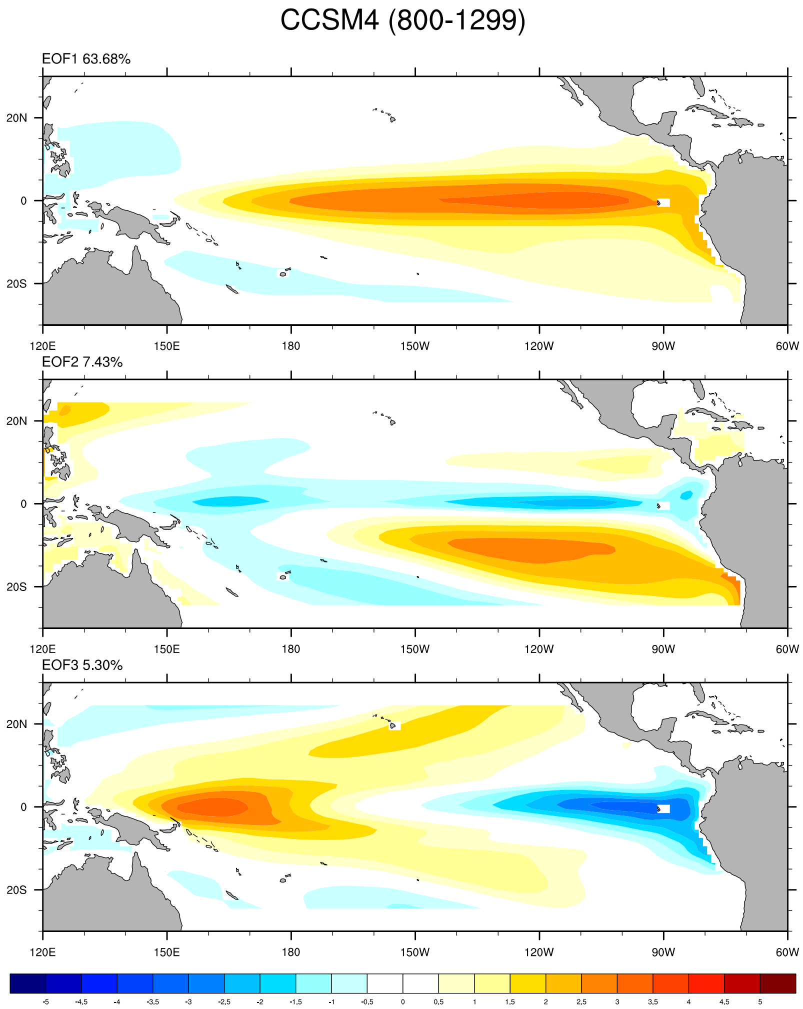
7.4%

5.3%

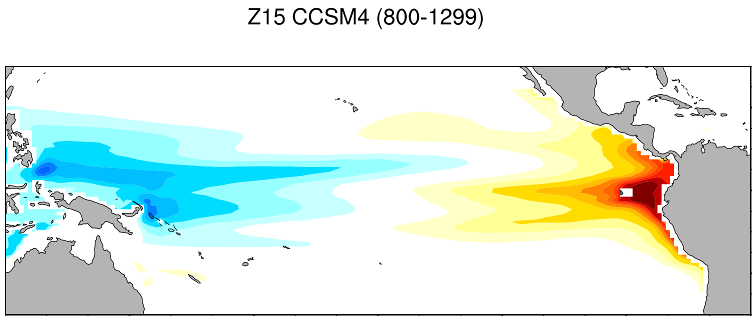


How are the two leading SST EOFs related to Z15 variability?

SST

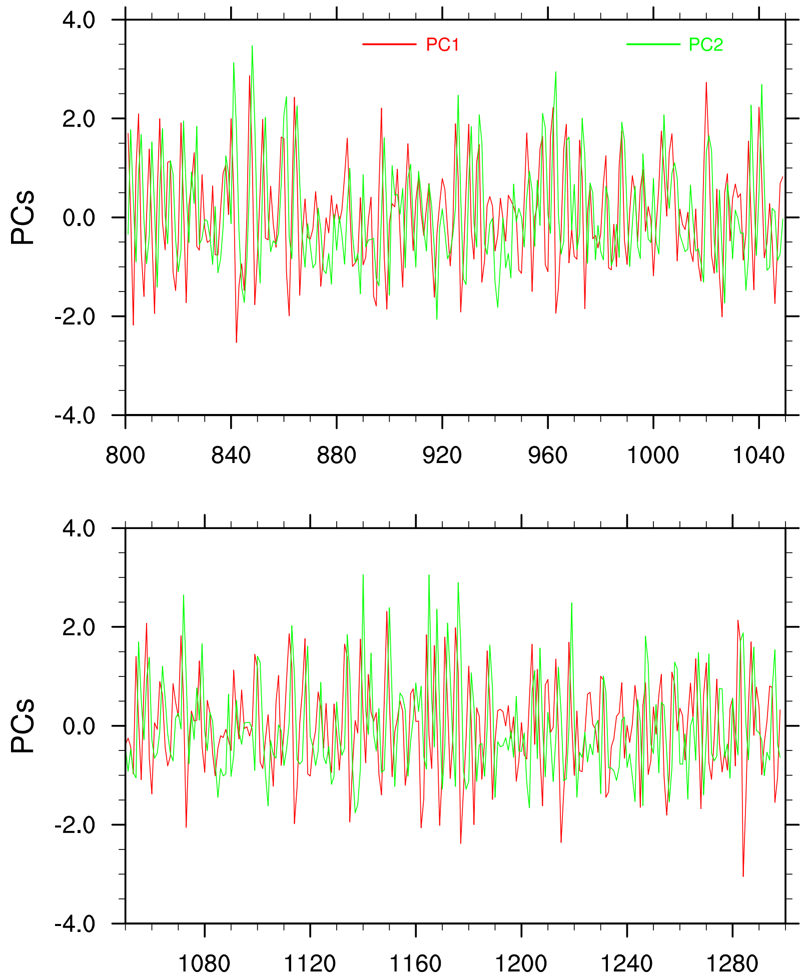


Z15

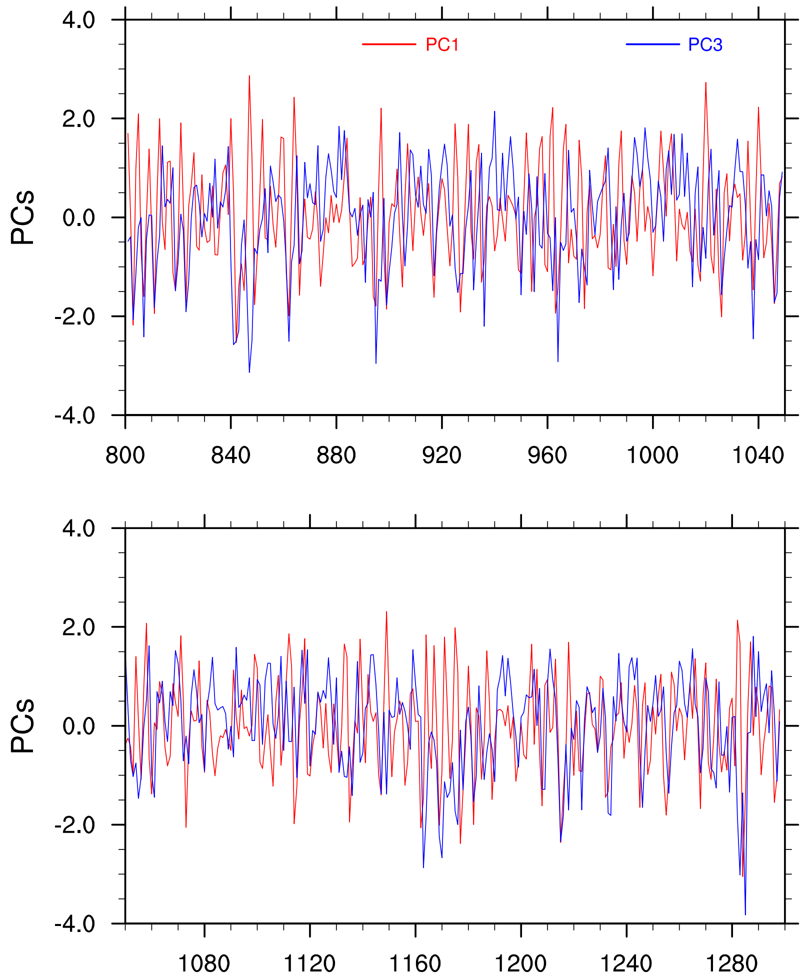


CCSM4 PCs

PC1-PC2

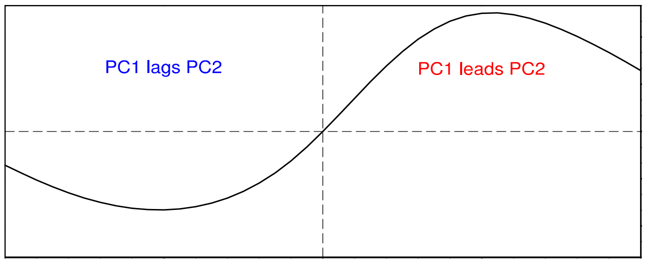


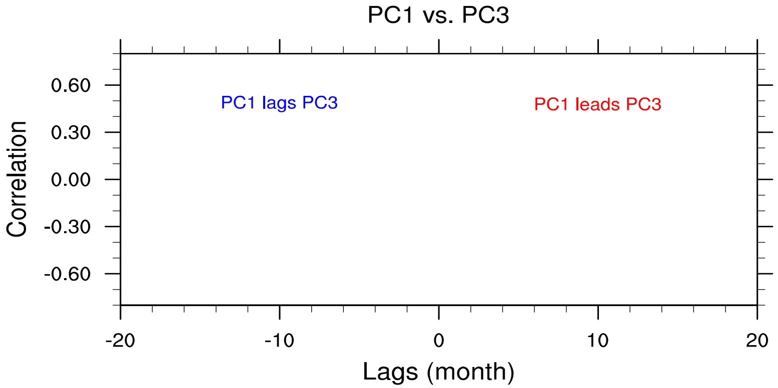
PC1-PC3



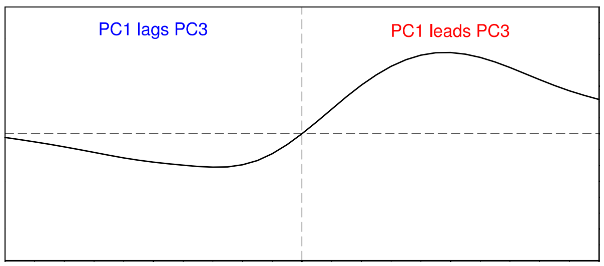
PCs lag correlation

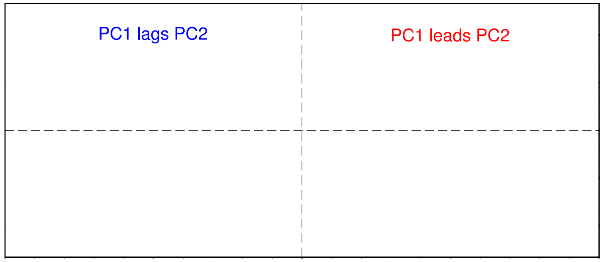
CCSM4



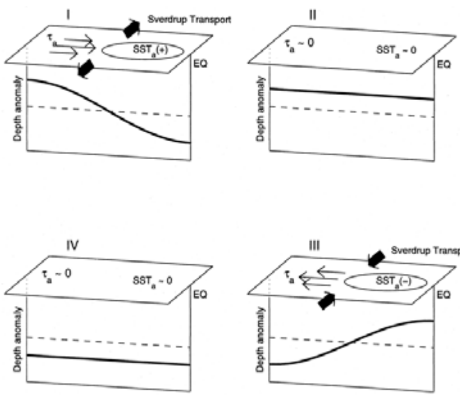


SODA

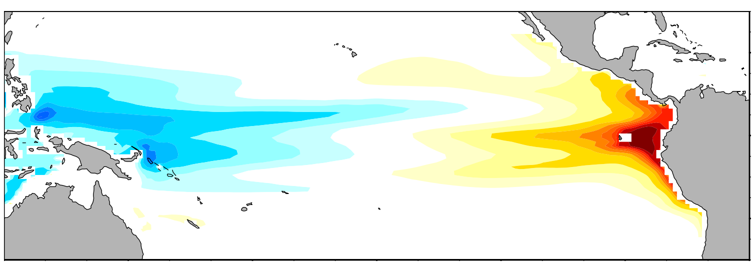


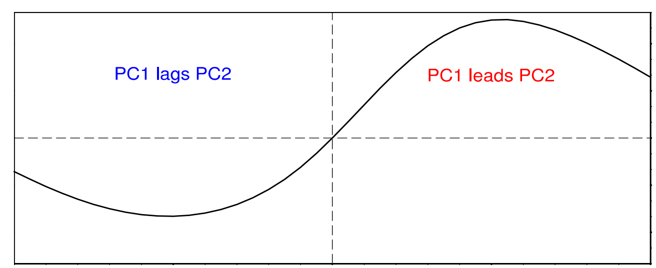


Interpretation of lag-correlation

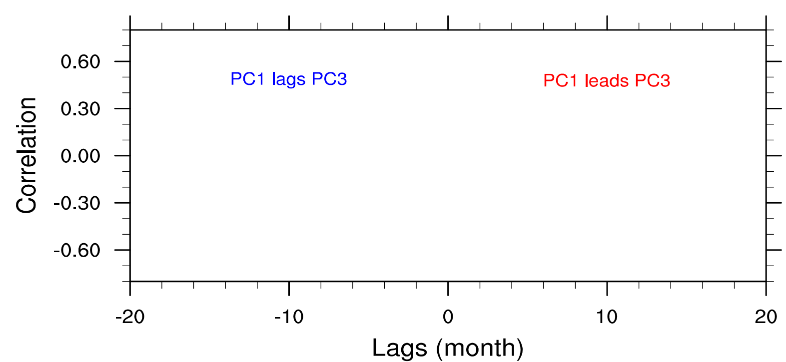


Z15 CCSM4 (800-1299)

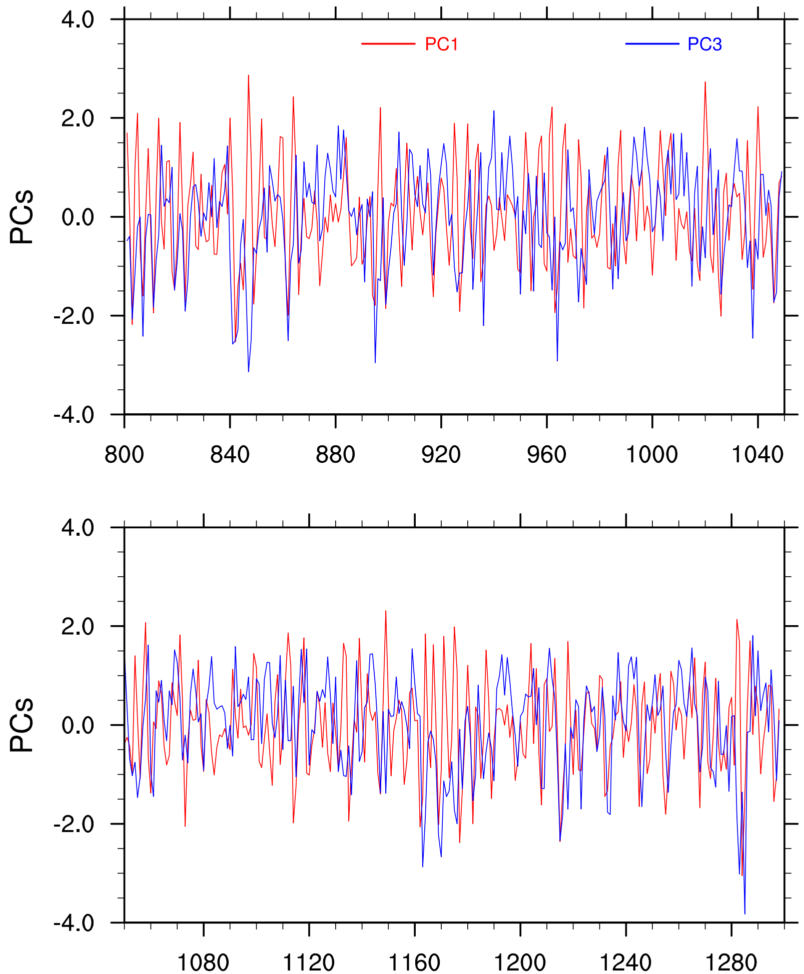


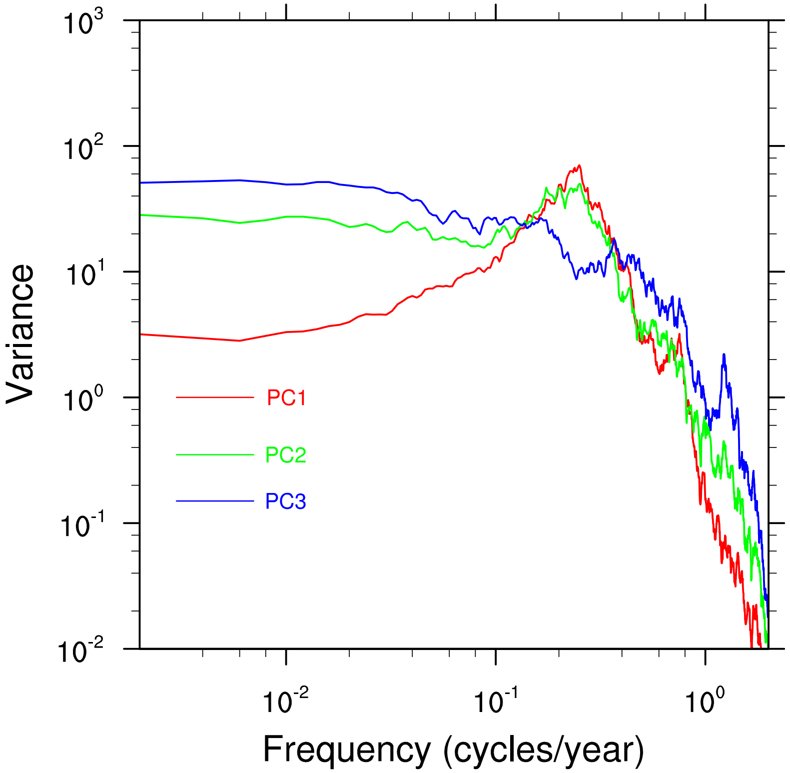


PC1 vs. PC3



Spectral characteristics





Conclusions (1)

CCSM4 shows a broad range (continuum?) of longitudes where maximum warming occurs during El Niño events in relative good agreement with SODA.

Warming in the eastern Pacific is associated with large thermocline depth anomalies, and recharge-discharge processes. The thermocline involvement becomes weaker for events in which the warming occurs further west. For events with warming in the Warm Pool region thermocline anomalies are negligible, and the SST anomalies are longer-lived.

The WP events emerge as the third EOF of SST, with the first two EOFs representing the surface manifestation of the thermocline evolution during recharge-discharge processes. This mode appears to have relative more power at low frequencies.

Conclusions (2)

<u>Other aspects</u> to consider:

1. Are there atmospheric precursors, or oceanic preconditioning that lead to a specific ENSO flavor?

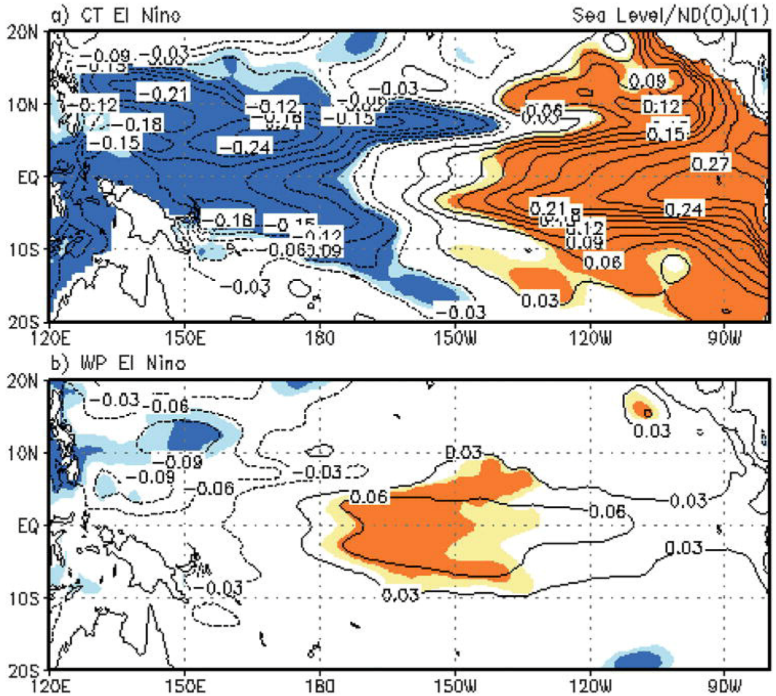
2. How do the teleconnections change as a function of the longitude of warming?

What aspects of ENSO diversity emerge from observations?

Sea surface height composites
GODAS 1980-2005

CT

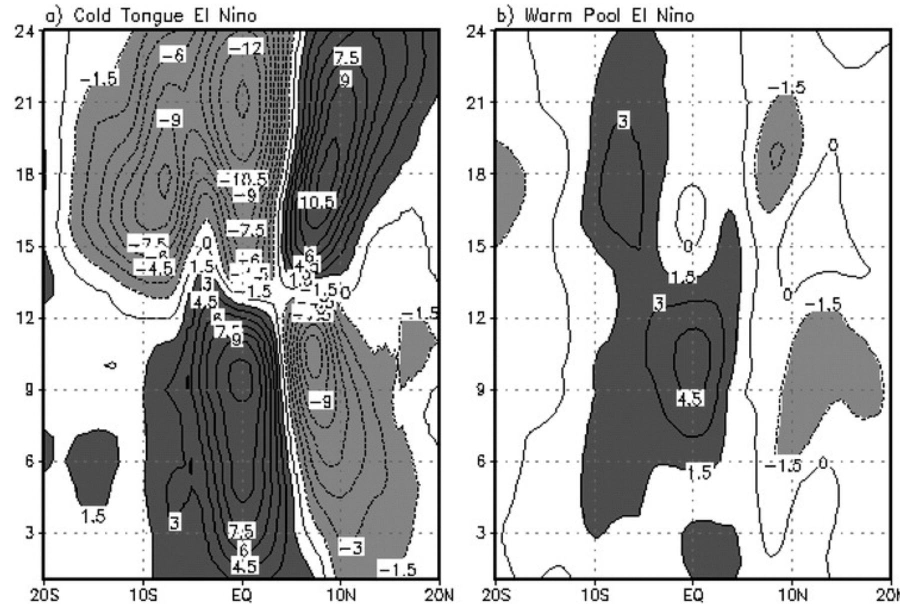
WP



Composite evolution of zonally averaged sea surface height

CT

WP



Kug et al. 2009