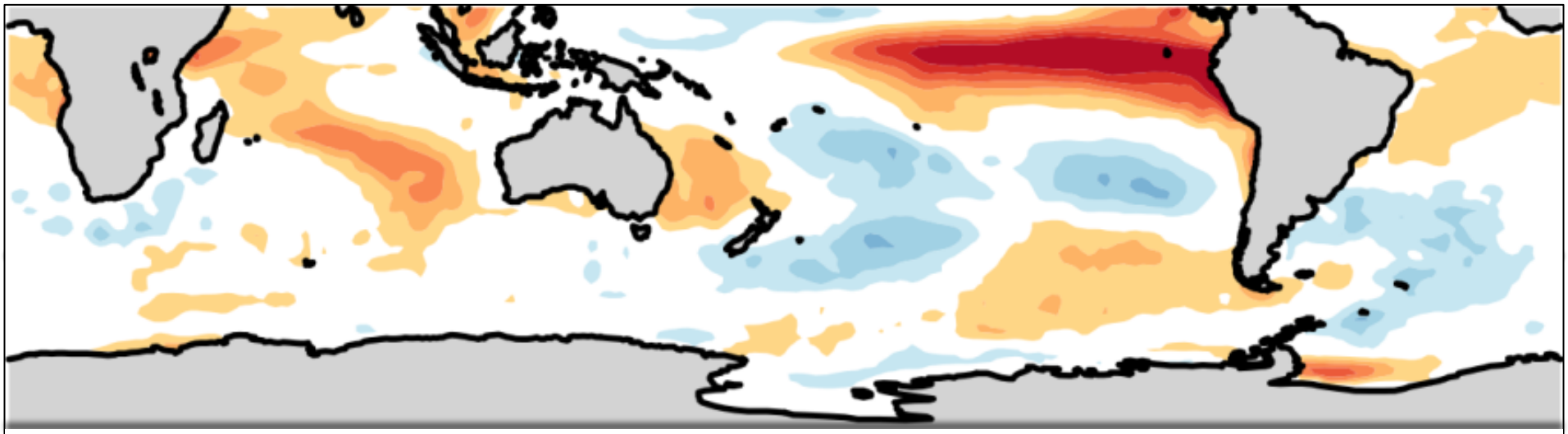

Simulating Anomalous High-Southern Latitude Atmospheric Circulation Mutually Forced by the Southern Annular Mode and El Niño flavors

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The Ohio State University

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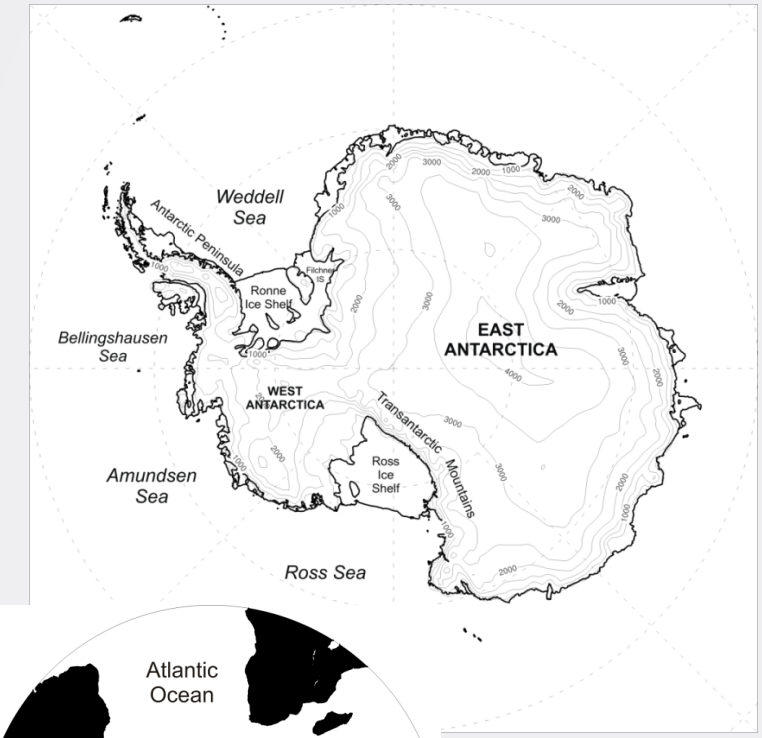
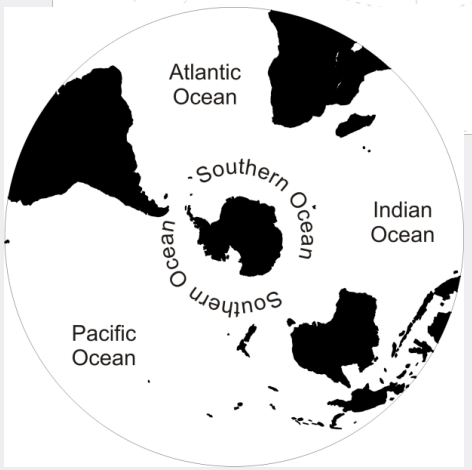
Why study *atmospheric circulation variability* in the Southern Hemisphere?



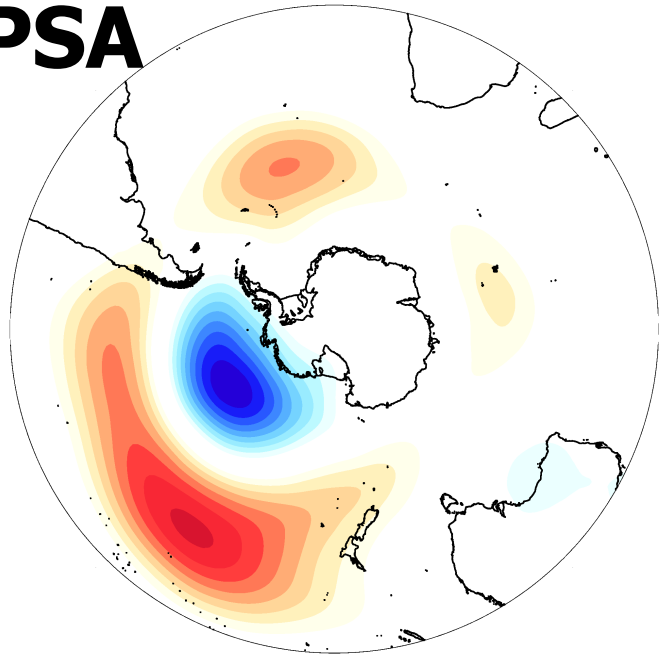


- Large Antarctic Ice Sheet Important for Earth's Climate
- Climate of W. Antarctica is sensitive to regional atmospheric circulation changes (Bromwich et al. 2013)
- Warming on Antarctic Peninsula and West Antarctica -> Potential Future Societal Impacts
- Large degree of uncertainty in complex system (PDO, AMO, IOD, ENSO, SAM)

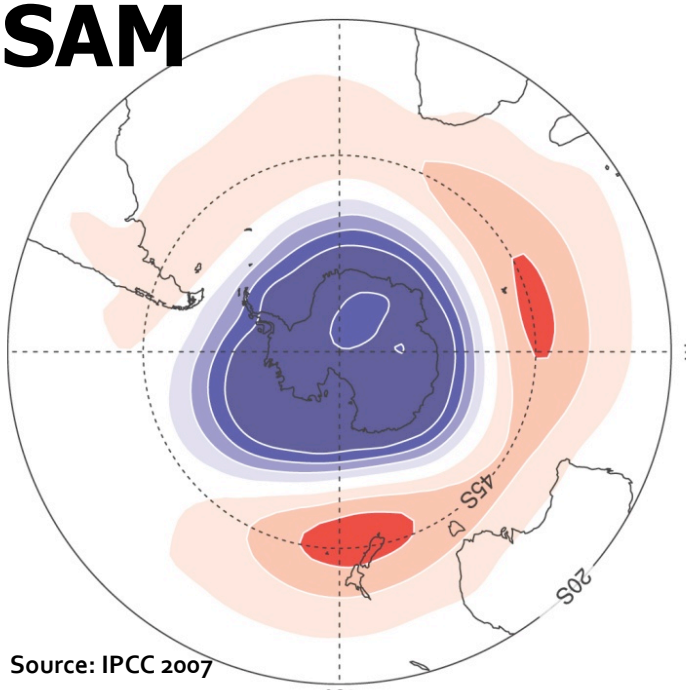
The Co-variability of ENSO and SAM

- ENSO and SAM share area of action in the SE Pacific Ocean – Pole of Variability
- Decadal variability
  (Fogt and Bromwich 2006; Clem and Fogt 2013)
- In-phase enhancement of circulation through transient eddies
  (Fogt et al. 2011)
- SAM significantly correlated with central Pacific SST during JJA
  (Ding et al. 2012)

PSA

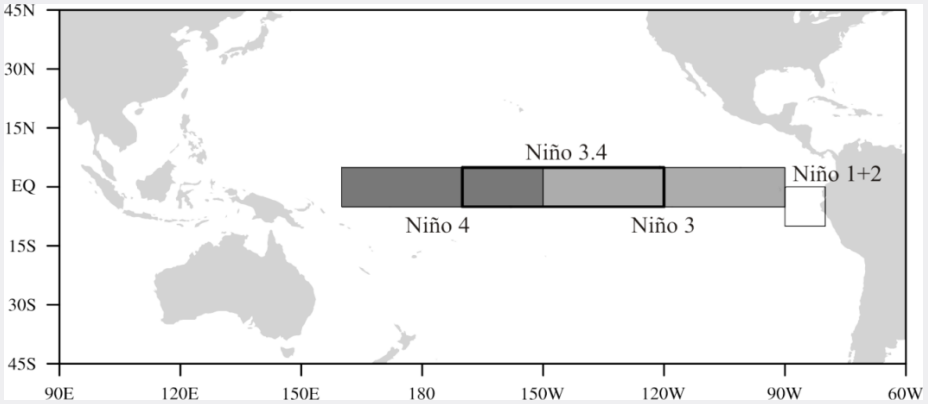


SAM



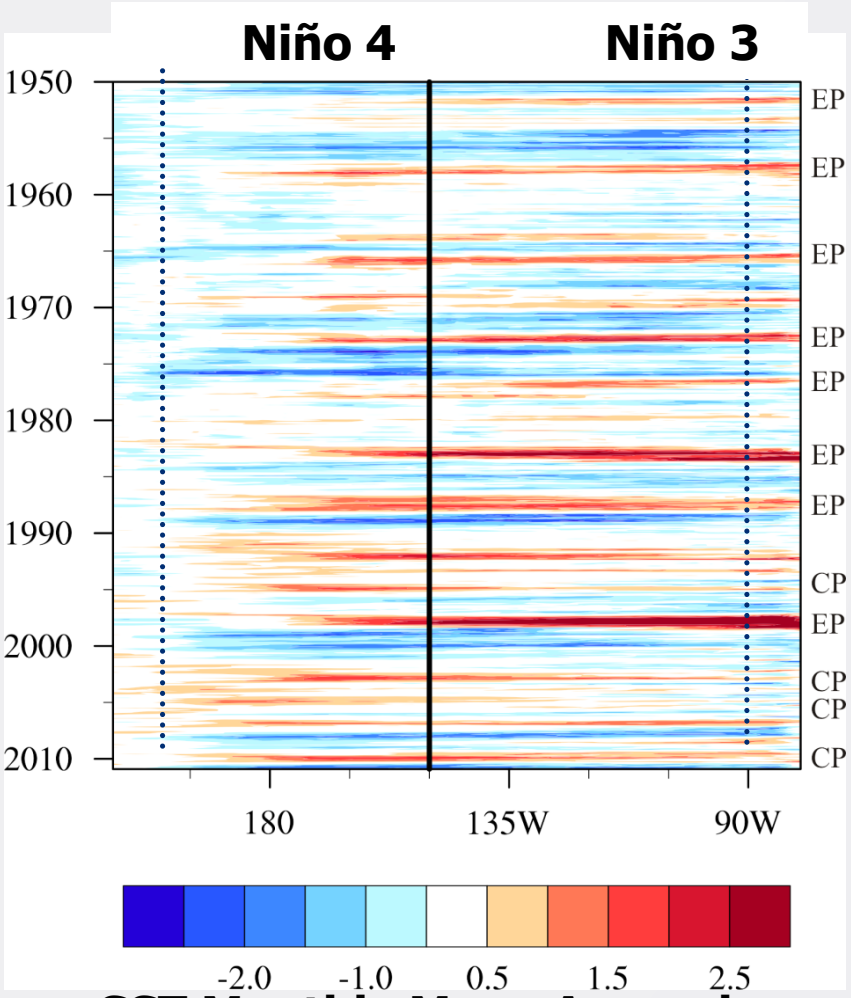
Source: IPCC 2007

What are ENSO *Flavors*?



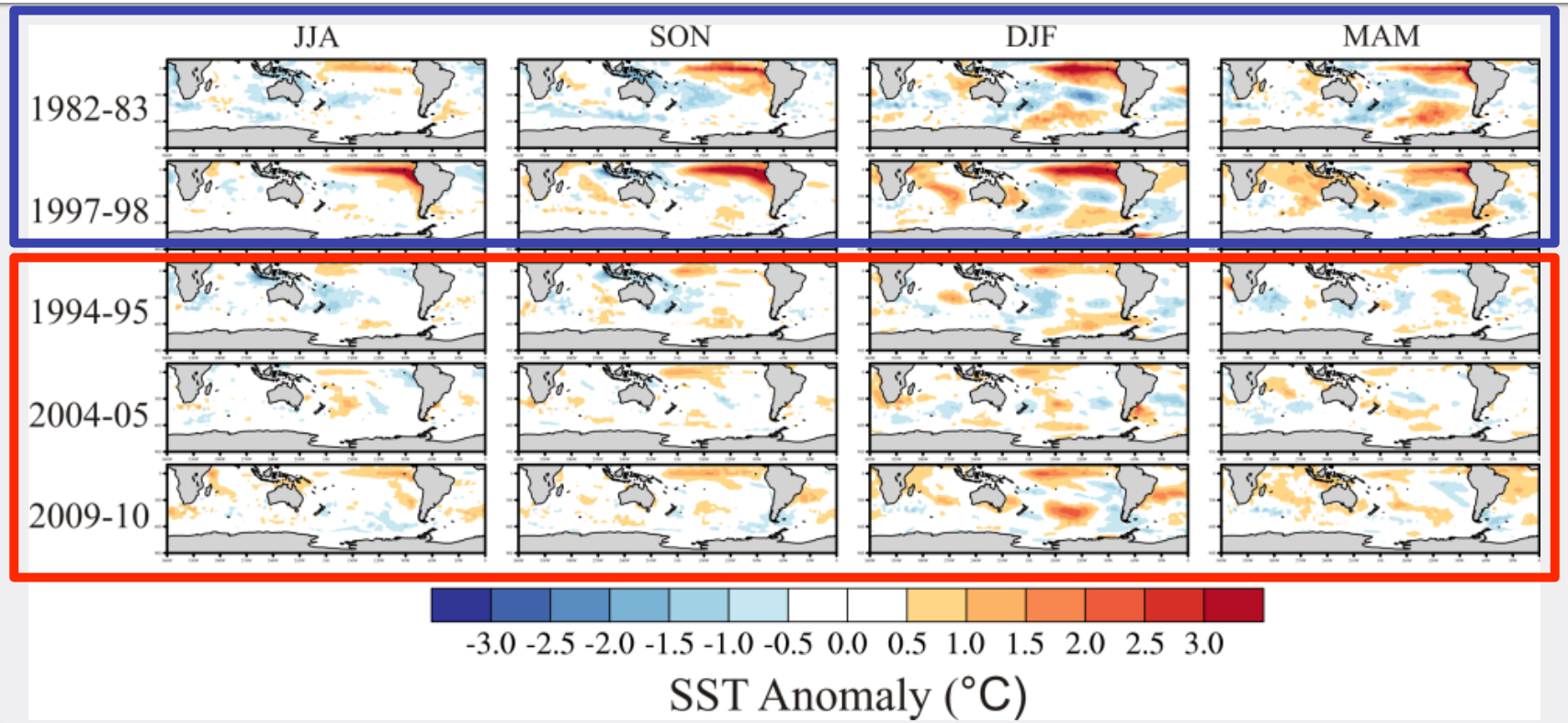
- EP events: Niño 3 > Niño 4
- CP events: Niño 4 > Niño 3

- CP events are linked to strong anticyclonic blocking over Australia and southward shift of STJ in eastern Pacific Ocean (Ashok et al. 2009)



SST Monthly Mean Anomaly (5°S-5°N) from 1950-2011

A Continuum of Events



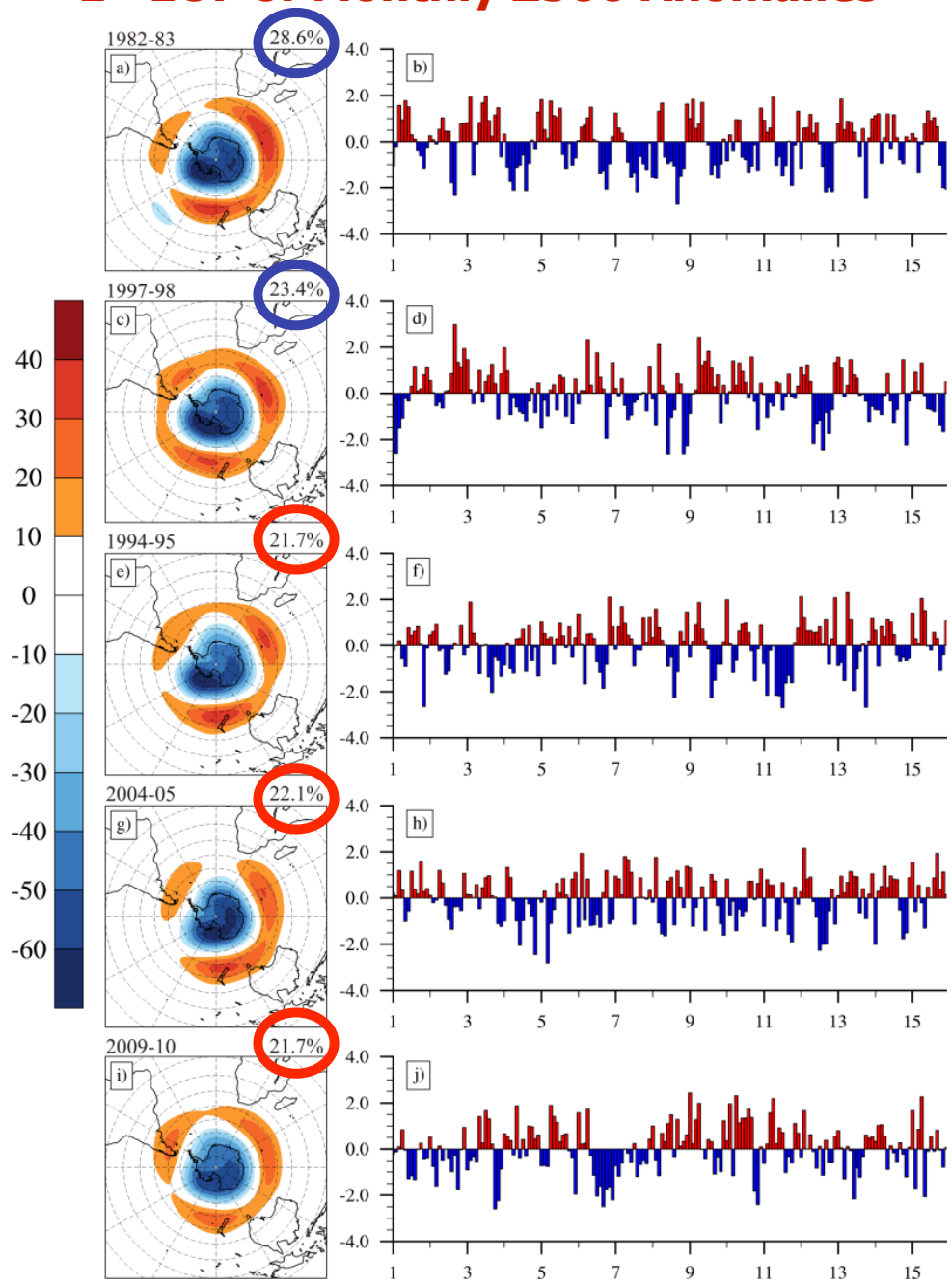
- EP events with warm tongue and anomalous rising motion over eastern tropical Pacific
- CP events with warmest SSTs primarily in the central tropical Pacific

What is the motivation and modeling strategy?

- **Examine** the atmospheric circulation differences between EP and CP El Niños in the SH particularly at high-latitudes
- **Model** changes in circulation using an the NCAR Community Atmosphere Model version 4 (CAM) with prescribed El Niño flavor sea surface temperatures (SSTs)
  - Improved tropical variability and zonal winds in the SH
  - Spectral Eulerian Core, 26 vertical levels, T85 –128 x 256 horizontal grid) ~1.4°
- **Compare** the modulation of transient eddy processes by both the ENSO and the SAM in atmospheric circulation variability in the South Pacific

Simulation	Lower Boundary Conditions (SSTs and SICs)	CO_2 and Ozone
Control 1	Observations from Sep 1979-Nov 2005	Observations from Sep 1979-Nov 2005
Control2	Climatological	Fixed CO_2 (1990) with climatological ozone
Idealized EP	15 years of cyclic LBCs based on composite of 8 EP El Niños (1950-2010)	Fixed CO_2 (1990) with climatological ozone
Idealized CP	15 years of cyclic LBCs based on composite of 4 CP El Niños (1950-2010)	
~~1982-83~~	15 years of cyclic LBCs based on observations between June (first year) and May (second year)	
1997-98		
1994-95		
2004-05		
2009-10		

1st EOF of Monthly Z500 Anomalies

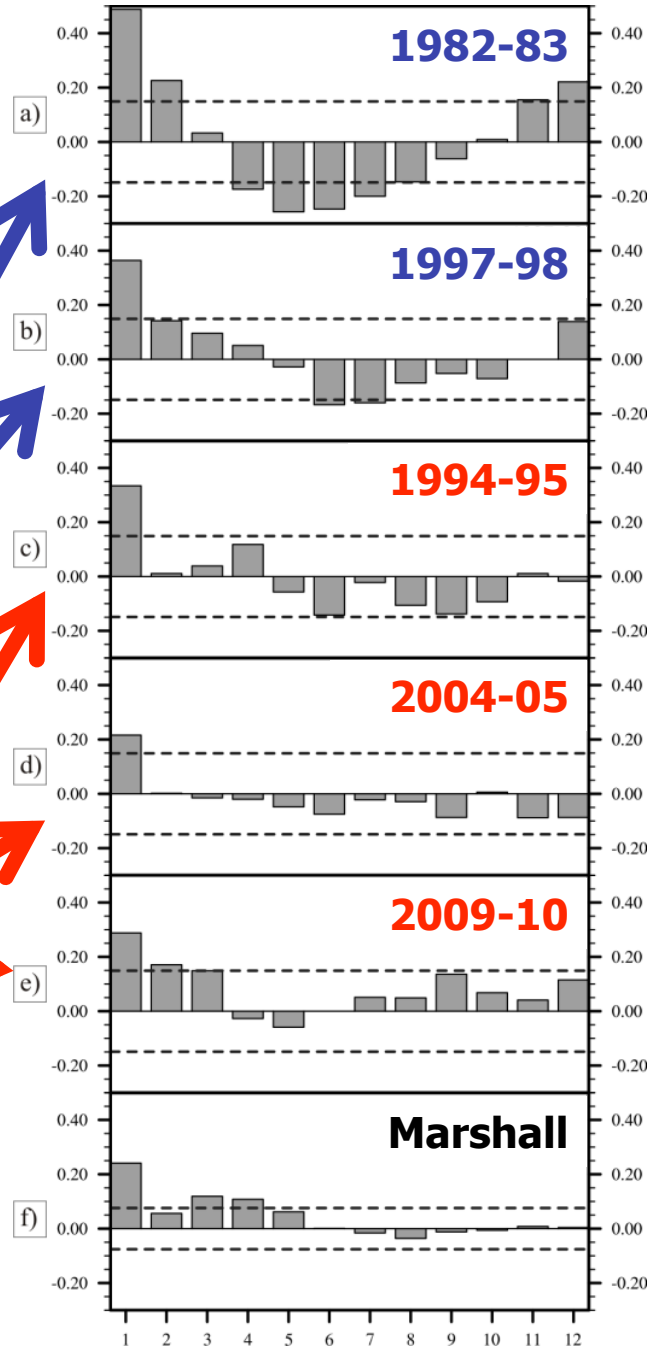


CAM SAM

- Consistent SAM pattern of opposite loadings between mid- and high latitudes
- EP and CP variances range from 21.7-28.6%: comparable to observations
- Both positive and negative phases of SAM depicted despite persistent El Niño LBCs

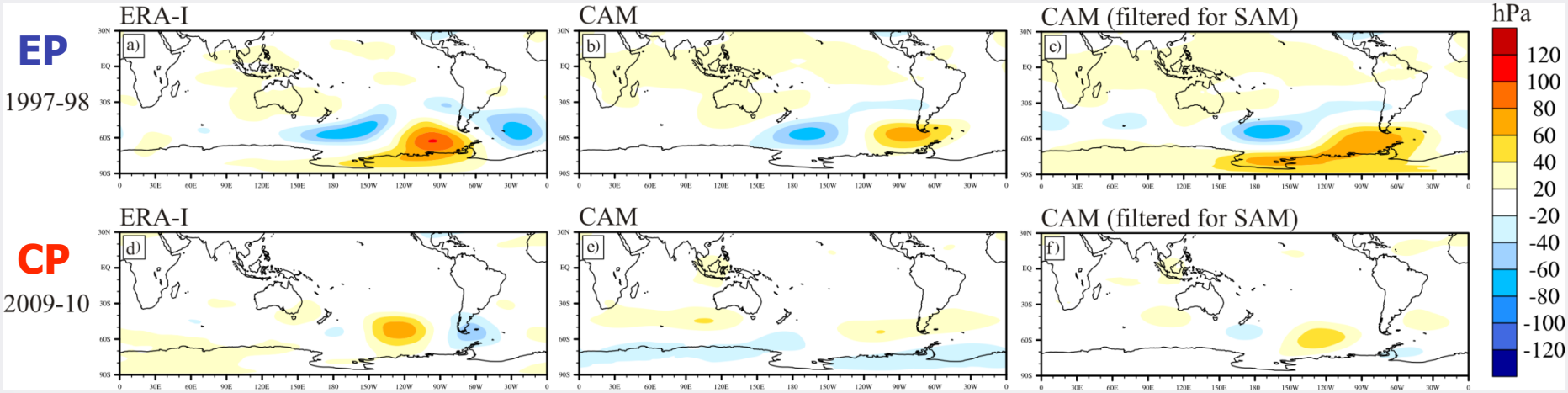
The Persistence of SAM

- All show significant autocorrelation at lag 1 (1 month) – consistent with observations (Marshall)
- EP Simulations: Significant autocorrelation at longer lags, particularly for 1982-83
- Decreased autocorrelation for CP simulations suggests tropical influence on high-latitudes is less robust for these types of El Niño events



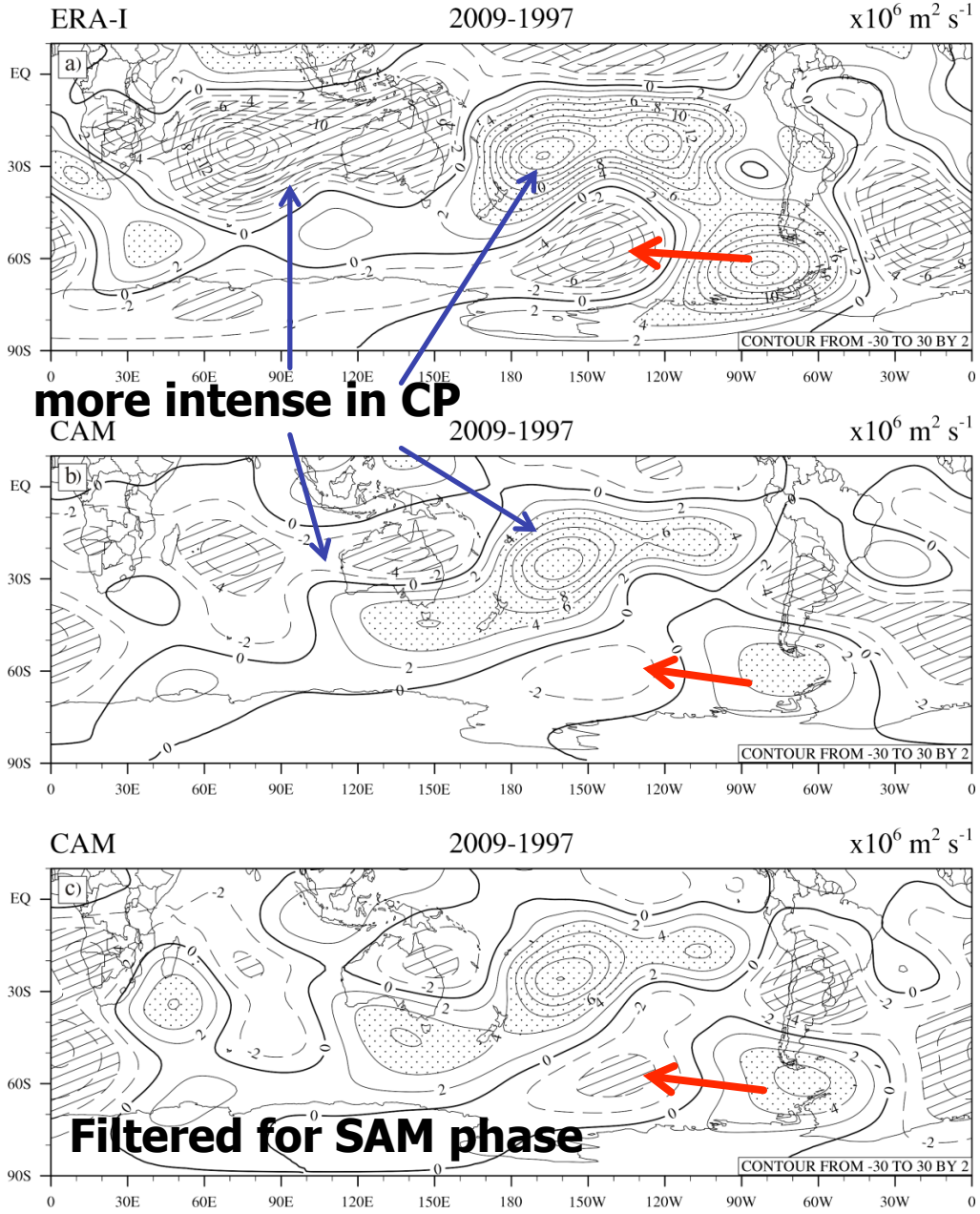
It Takes Two!

SOND Z500 Anomalies



- EP: Alternating wave train with blocking in the SE Pacific
  - CAM response is spatially similar yet anomalies are weaker
  - More consistent with ERA-I when filtered for same SAM phase
- CP: Heights ↑ (↓) in the South Central Pacific (Drake Passage)
  - Weakly reflected in CAM unless filtered for same SAM phase
- Thus, circulation variability in high-latitudes forced by ENSO and SAM

200 hPa Eddy Streamfunction

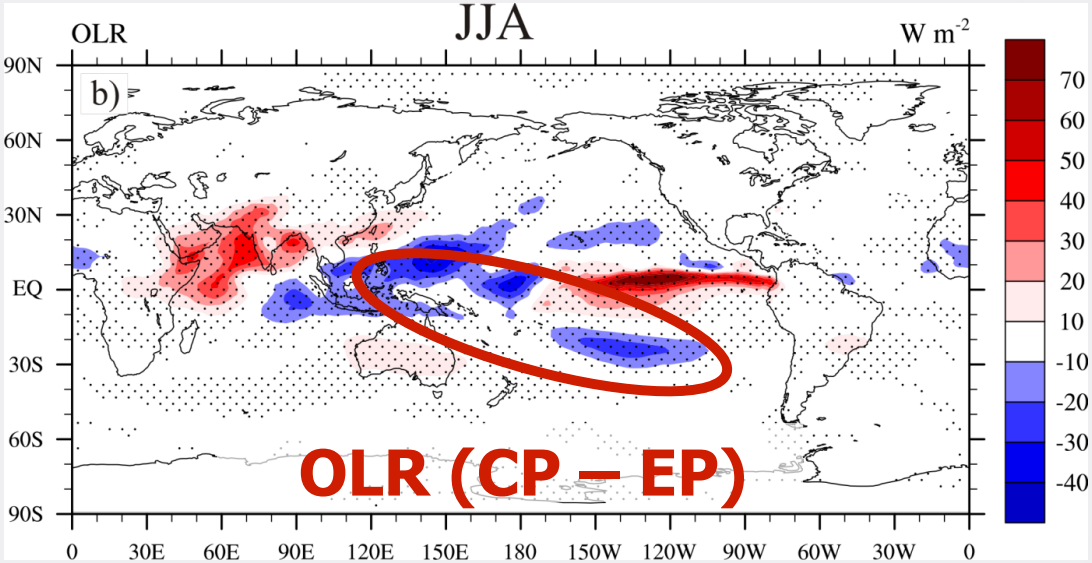


Changes to the Stationary Wave Pattern

- Increased anticyclonic circulation over Australia and W. Pacific
- Westward shift in PSA leads to the decreased heights in ABS
- Impacts heat and momentum fluxes associated with the Antarctic Dipole (Yuan 2004)

Tropical changes also affect the SPCZ

- EP events shift the SPCZ NE
- SE-oriented OLR minimum in CP events is shifted SW relative to EP

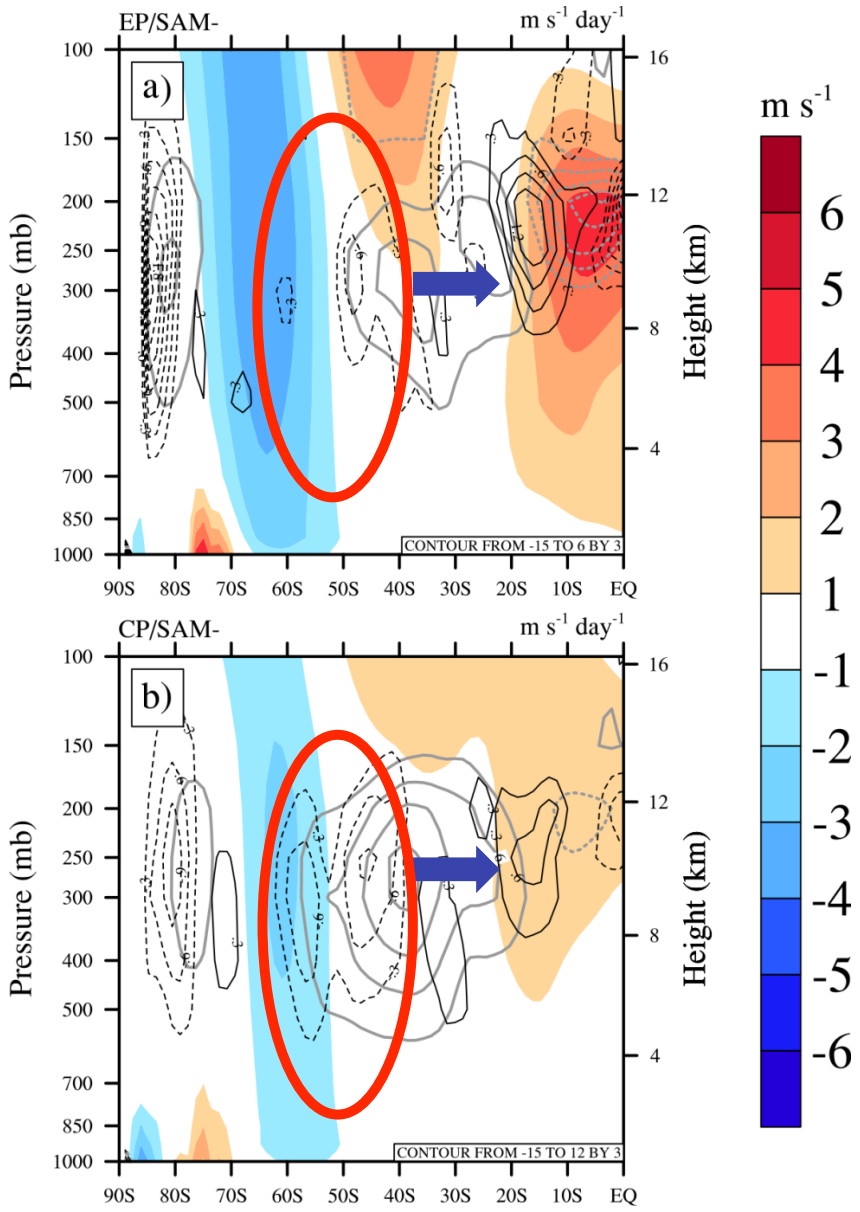


- ↑ upper level divergence & westward shift in PSA concomitant with ↓OLR and deeper convection
- ↑ poleward eddy momentum flux breaks down anticyclone in the Drake Passage.
- ↑ divergence induces ridge-building north of the Ross Sea in the South Central Pacific

Anomalous JJA *Zonal* Mean Circulation

- Low Latitudes
  - EP/SAM-: Strong Hadley circulation with intense STJ contracted toward the equator
  - CP/SAM-: Hadley not as strong with weaker STJ
- High latitudes
  - Both show weaker zonal mean zonal wind between 50-70° due to equatorward transient flux near 40° - leads to transient eddy divergence in high latitudes

IN-PHASE EVENTS

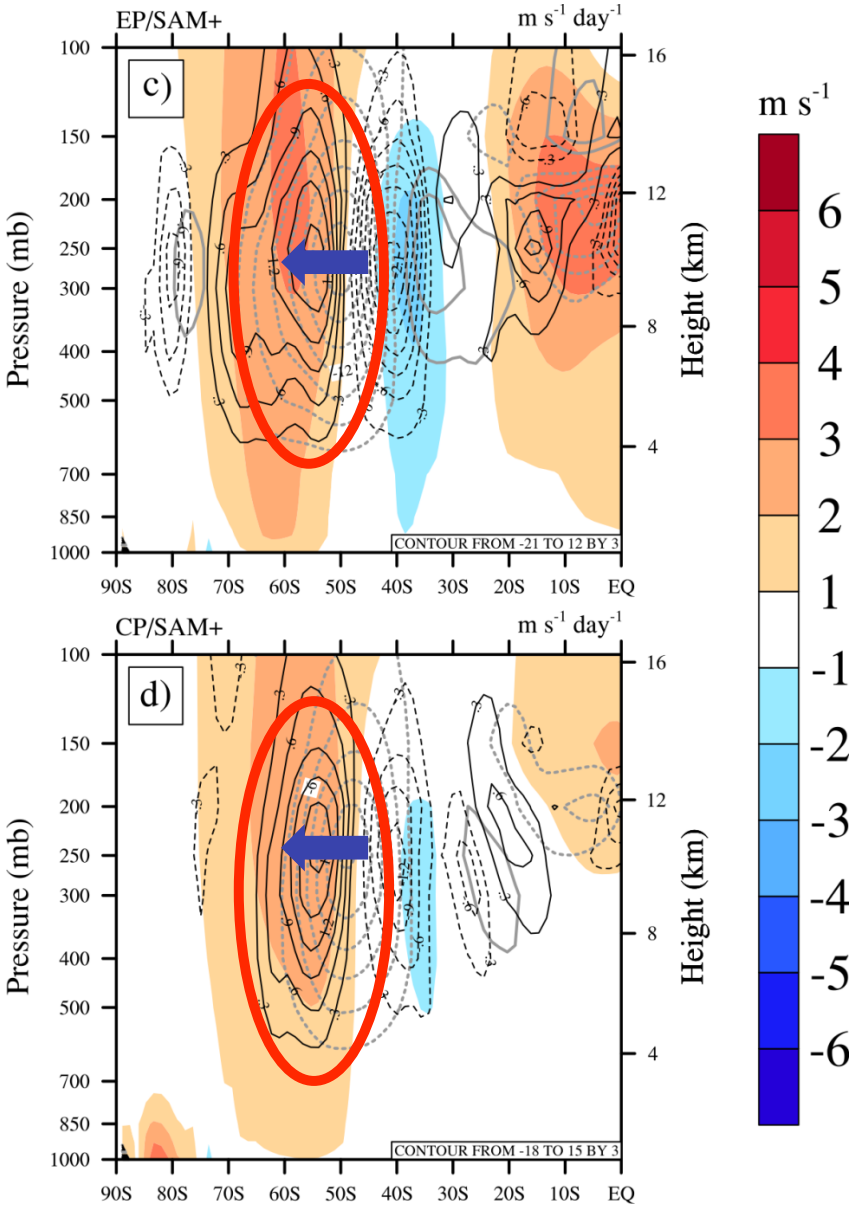


Anomalous transient eddy momentum flux: Gray Lines
Anomalous transient eddy momentum flux convergence: Black Lines

Anomalous JJA *Zonal* Mean Circulation

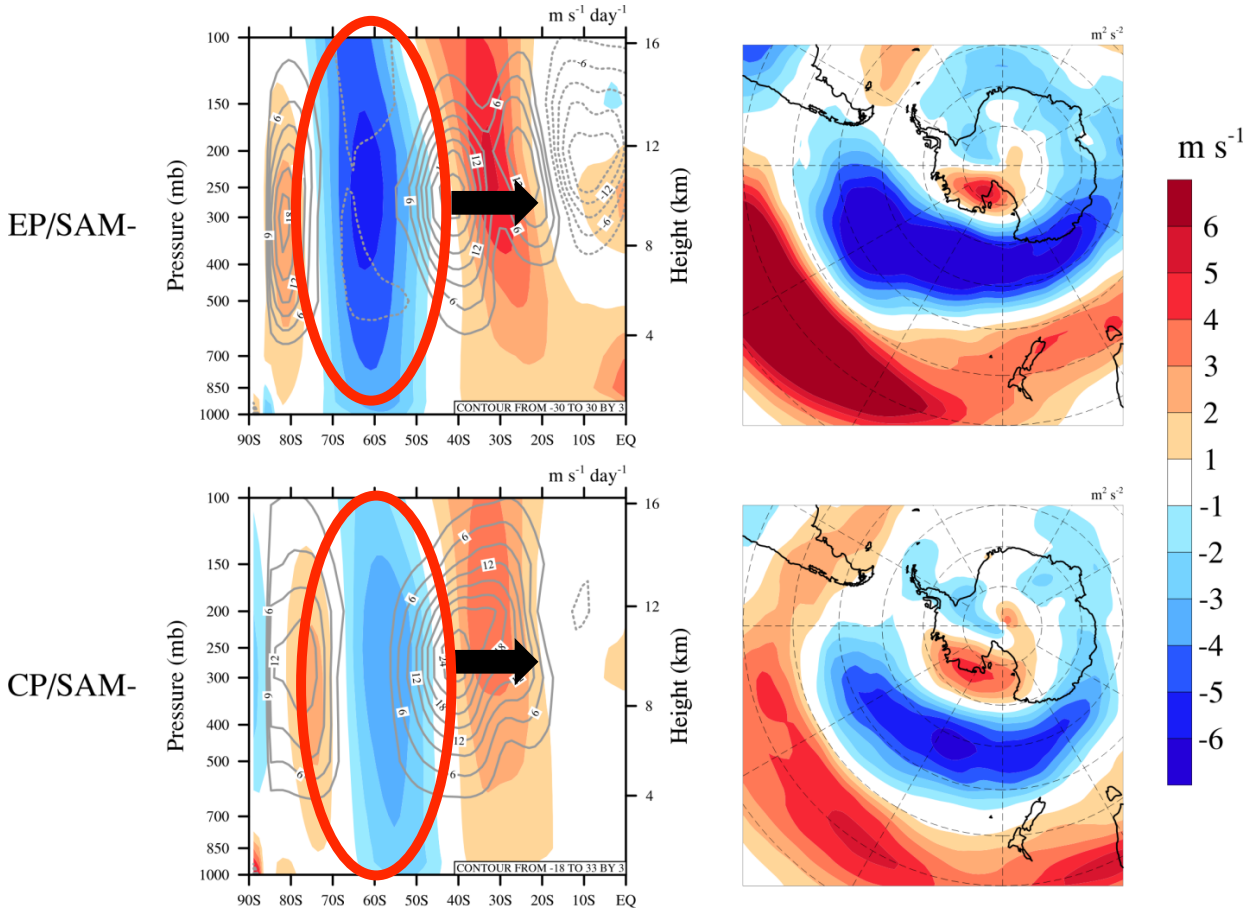
- Low Latitudes
  - Environment still promotes stronger STJ than control, weaker in CP than EP
- High latitudes
  - Anomalous poleward flux centered at 50° and equatorward flux near 35° leads to transient eddy divergence between 30-40° indicating a change in mid-latitude behavior compared to in-phase events
  - Anomalously strong high latitude zonal wind

OUT-OF-PHASE EVENTS



Anomalous transient eddy momentum flux: Gray Lines
Anomalous transient eddy momentum flux convergence: Black Lines

Anomalous JJA *Pacific* Mean Circulation



Anomalous transient eddy momentum flux: Gray Lines

- Much stronger equatorward transient eddy momentum flux near 40° leads to weaker zonal wind in high-latitudes
- Strong modulation of jets in Pacific for EP events that is weaker in CP events

Summary and Conclusions

- CAM captures well the variability associated with the SAM during EP and CP El Niño events demonstrating significant autocorrelation at longer lags for EP events.
- High-latitude atmospheric circulation variability in the South Pacific is induced by both tropical (ENSO) and high-latitude forcing (SAM).
- CAM confirms a westward shift of the PSA, SW shift in the SPCZ, and westward shift high-latitude blocking at high latitudes.
- Though patterns of anomalous transient momentum flux are similar, with most of the forcing taking place in the Pacific Ocean, their magnitudes are weaker in CP events.

An EP El Niño Underway?

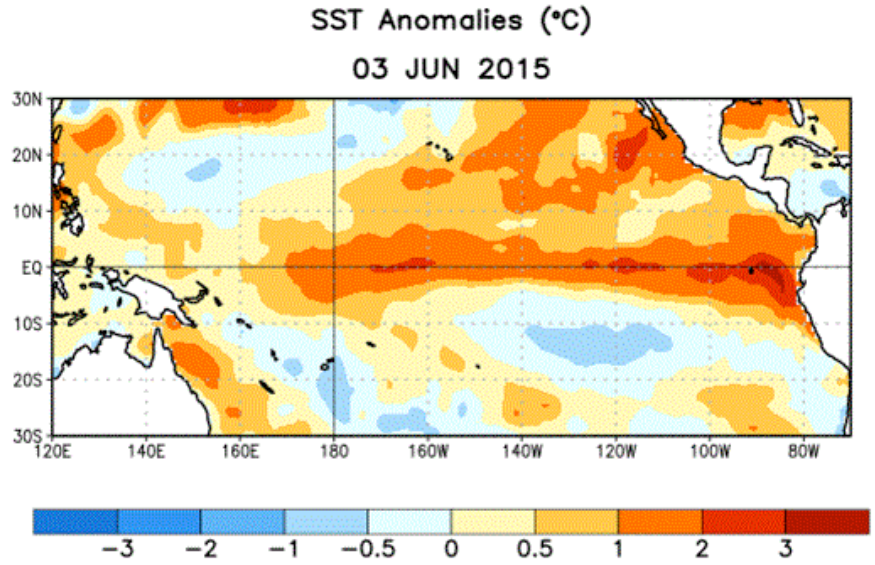


Figure 1. Average sea surface temperature (SST) anomalies (°C) for the week centered on 3 June Anomalies are computed with respect to the 1981-2010 base period weekly means.

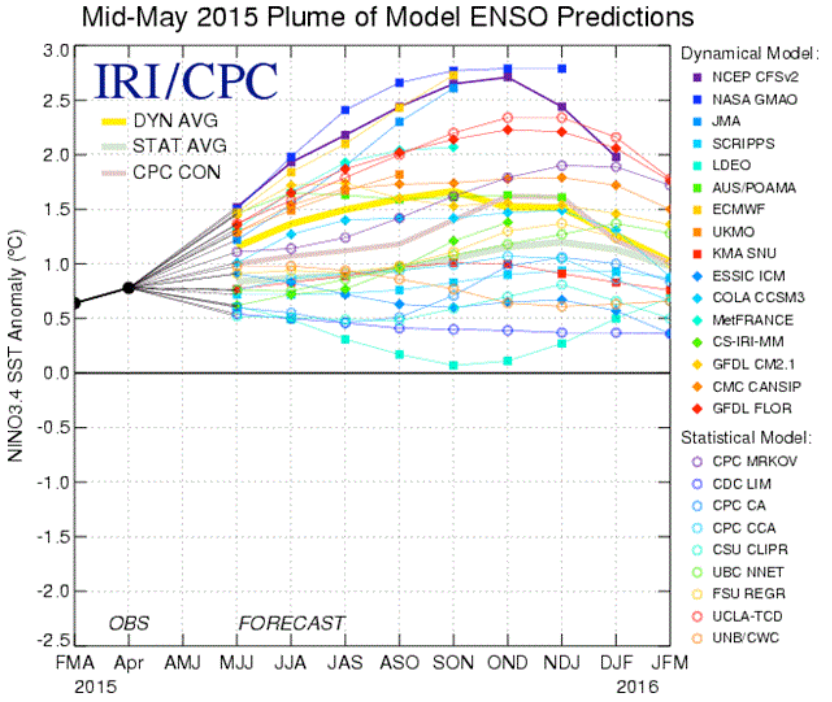


Figure 6. Forecasts of sea surface temperature (SST) anomalies for the Niño 3.4 region (5°N-5°S, 120°W-170°W). Figure updated 19 May 2015.

"There is a greater than 90% chance that El Niño will continue through Northern Hemisphere fall 2015, and around an 85% chance it will last through the 2015-16 winter. "- CLIMATE PREDICTION CENTER/NCEP/NWS – ENSO Diagnostic Discussion 11 June, 2015

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This work is detailed in the following two manuscripts:

Wilson, A. B., D. H. Bromwich, and K. M. Hines, 2015: Simulating the mutual forcing of anomalous high-southern latitude atmospheric circulation by El Niño flavors and the Southern Annular Mode. *J. Climate*, submitted.

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