



Ocean-Atmosphere Structure of Pacific Decadal Variability

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Outline

- Another Pacific SST analysis? Why?
- Method, Findings, Evaluation
- ENSO Variability: Canonical & Non-canonical
- Pacific Decadal Variability: Pan-Pacific & North Pacific
- Inter-Basin links and Atlantic Multidecadal Oscillation
- Application (Terrestrial): North American Droughts
- Upper-air and subsurface PDV structure: Preliminary



Another Pacific SST Analysis?

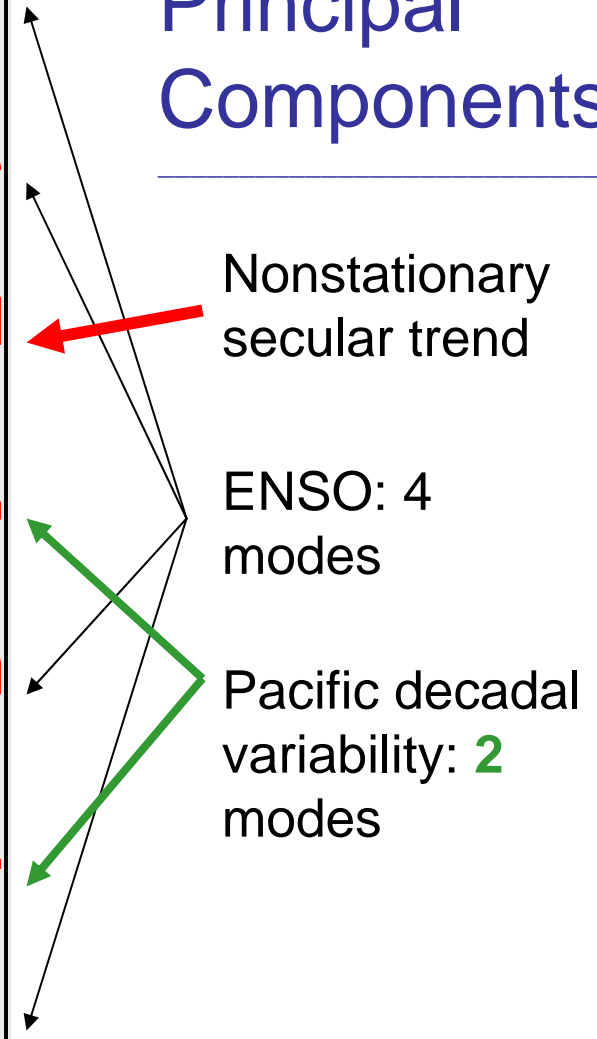
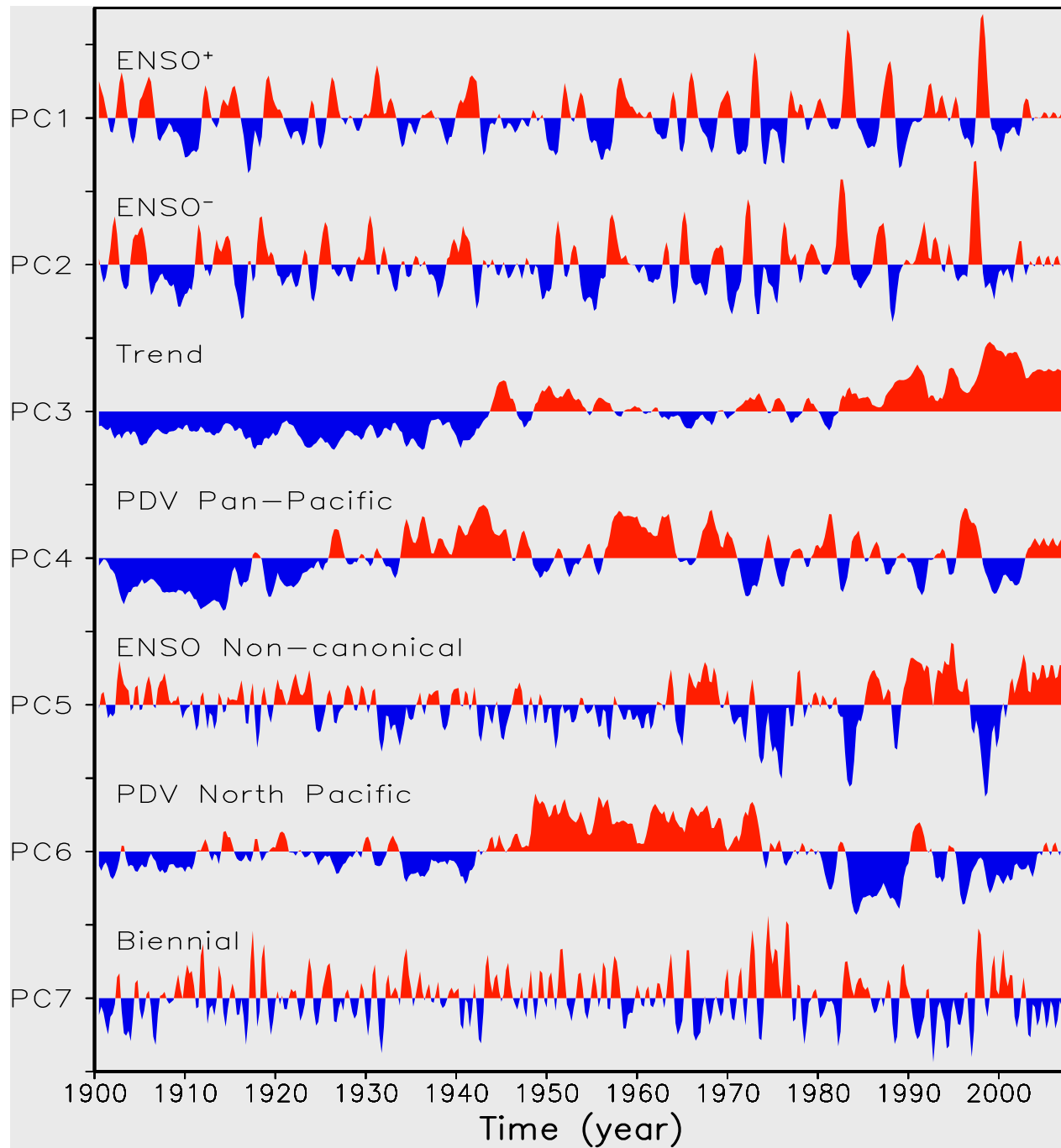
Perhaps, one leading to refined *evolution* descriptions from *contextual* separation of natural variability and the secular trend without any advance filtering (and potential aliasing) of the SST record.

GOAL: Obtain robust characterization of *ALL* non-seasonal modes of Pacific SST variability, including trend, from a *single* analysis of *unfiltered* data.

Extended EOF Analysis

- Targets both spatial and temporal recurrence
- No temporal periodicities are imposed
- EEOF differs from EOF only in anomaly definition:
EOF: $\psi(x,y,t_0)$
EEOF: [..., $\psi(x,y,t_0-\Delta t)$, $\psi(x,y,t_0)$, $\psi(x,y,t_0+\Delta t)$,...]
- Temporal recurrence analyzed with a 1-year sampling window; 5 staggered seasonal data bands
- Hadley SSTs are analyzed; an all-season, covariance-based analysis
- Pan Pacific analysis domain: 120E-60W; 20S-60N
- EEOFs are rotated
- Mode physicality assessed from analog counts and correlations with biological time series

The SST Principal Components



Canonical ENSO

SST regressions
CI=0.1K

Time
↓

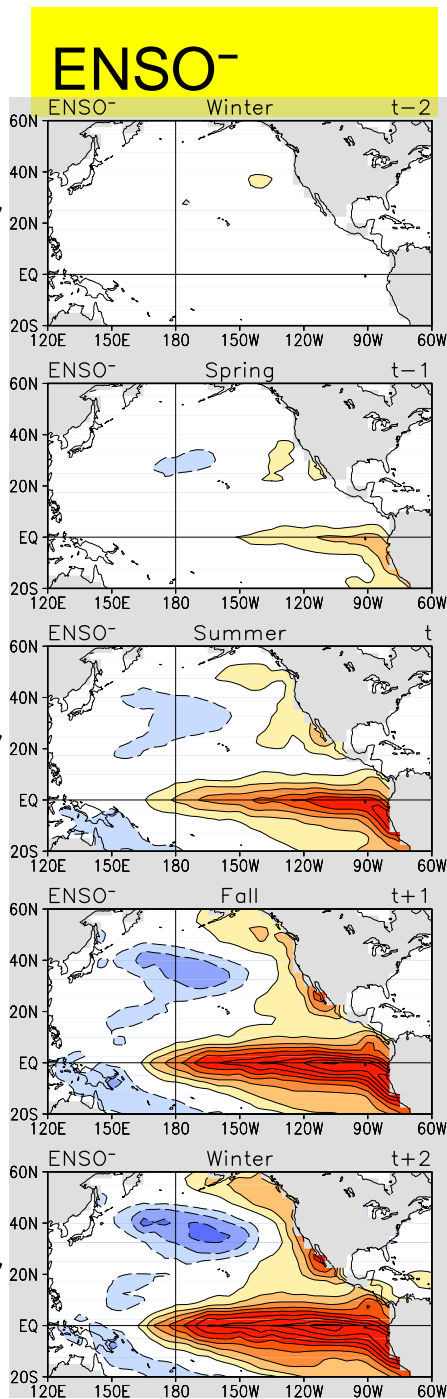
Winter

Spring

Summer

Fall

Winter



ENSO⁺

Fall

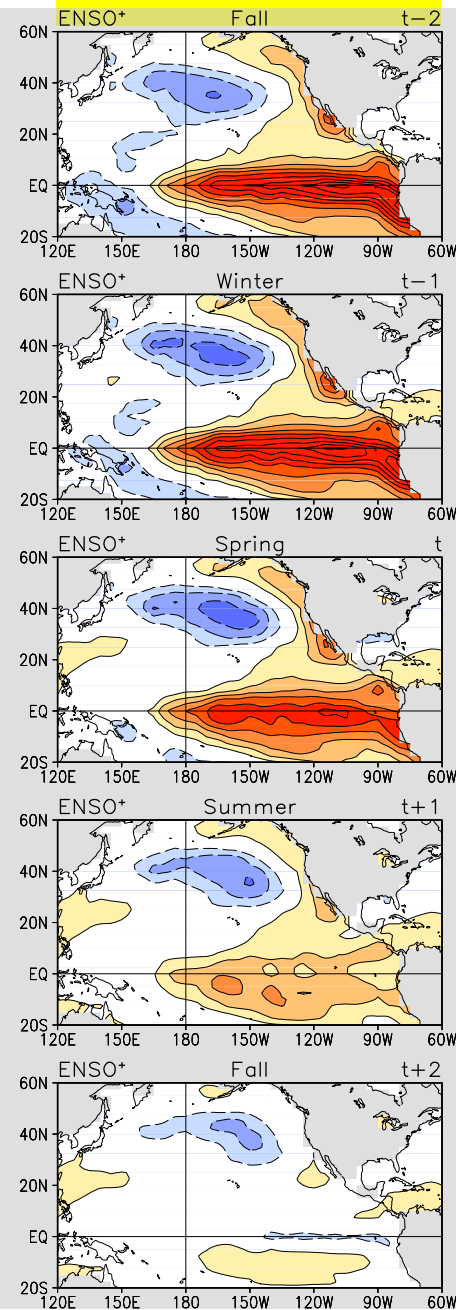
Winter

Spring

Summer

Fall

Time
↓



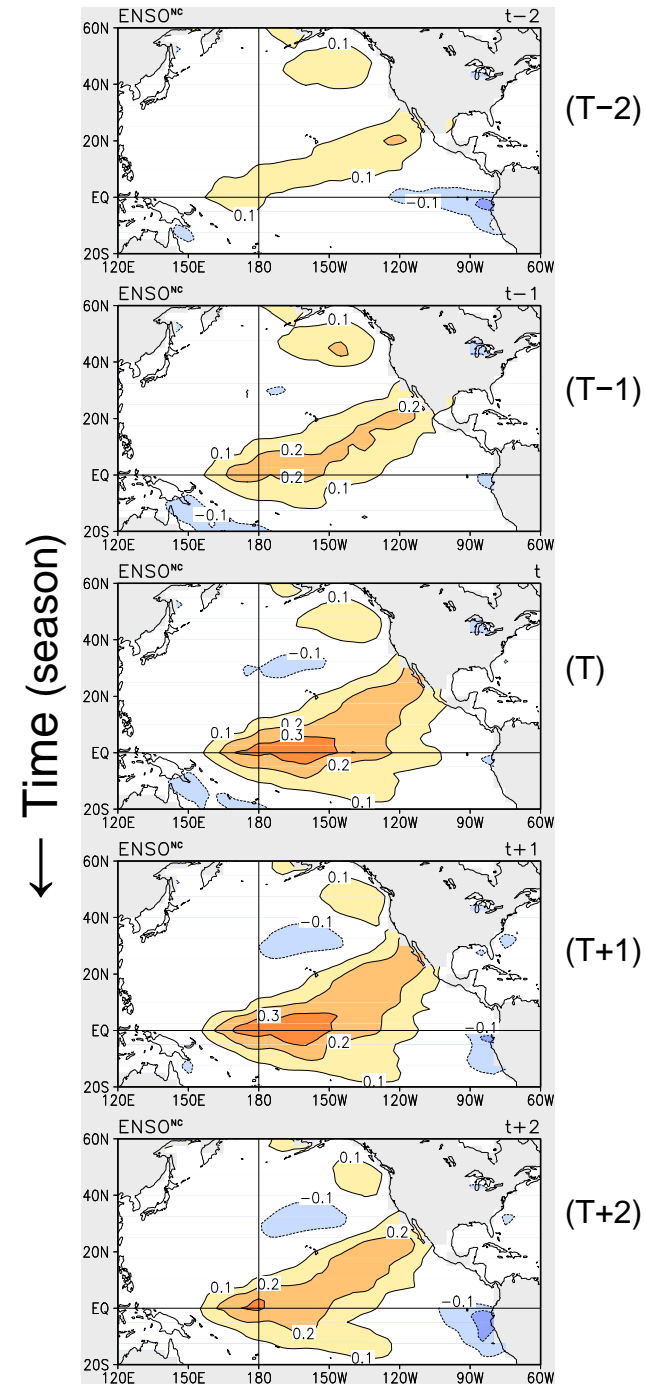
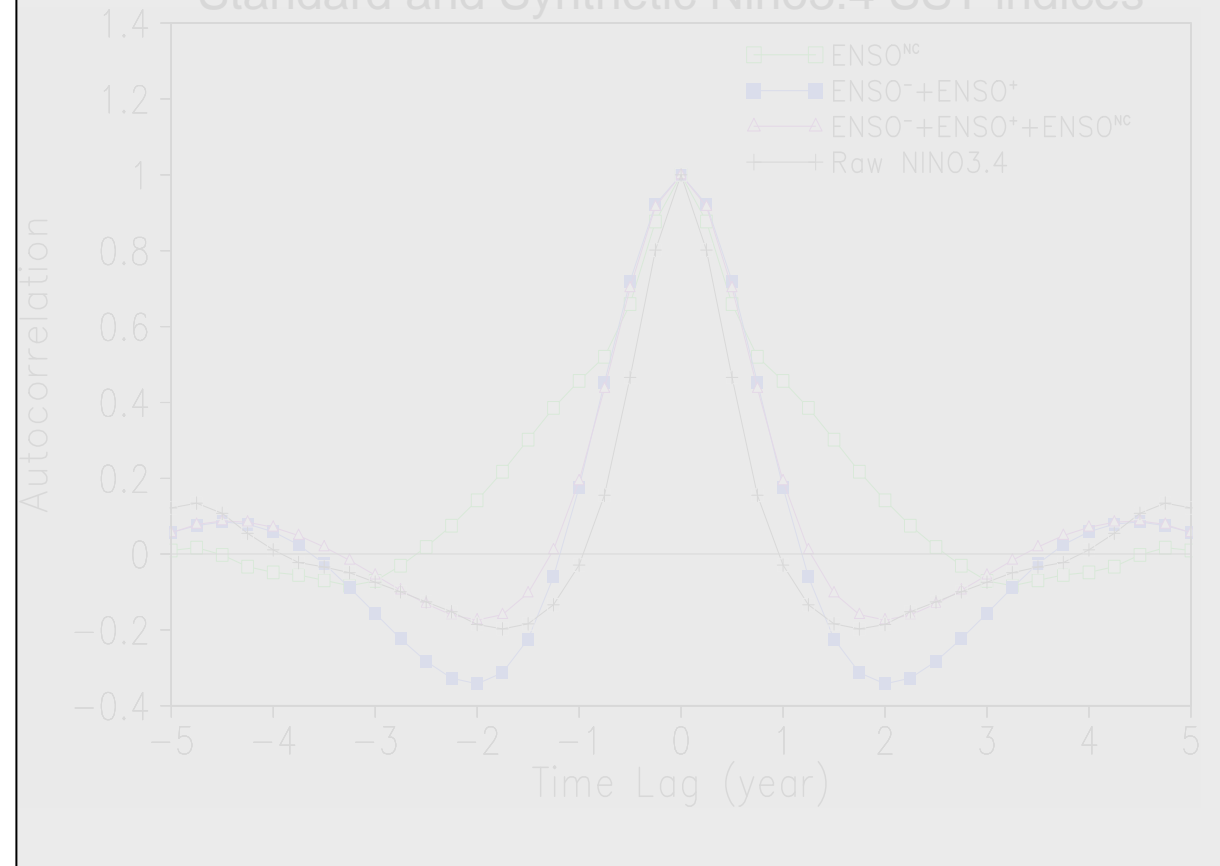
Non-Canonical ENSO Variability

SST regressions

CI=0.1K

Autocorrelation of ENSO PCs and the Standard and Synthetic Nino3.4 SST indices

7.6 ps, Sat Jul 21 23:29:45 2007



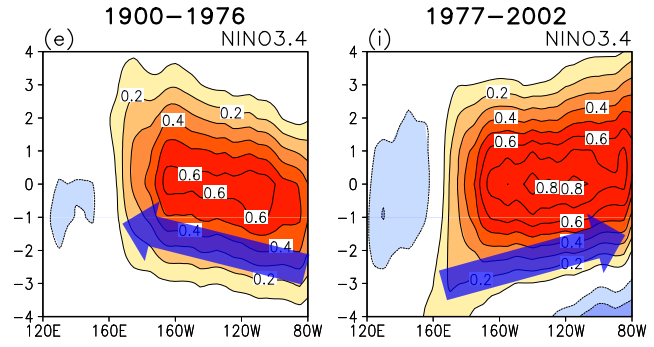
SST Evolution at the Equator: ENSO^{NC} Impact

SST regressions
CI = 0.1 K

Time ↑

W Pac

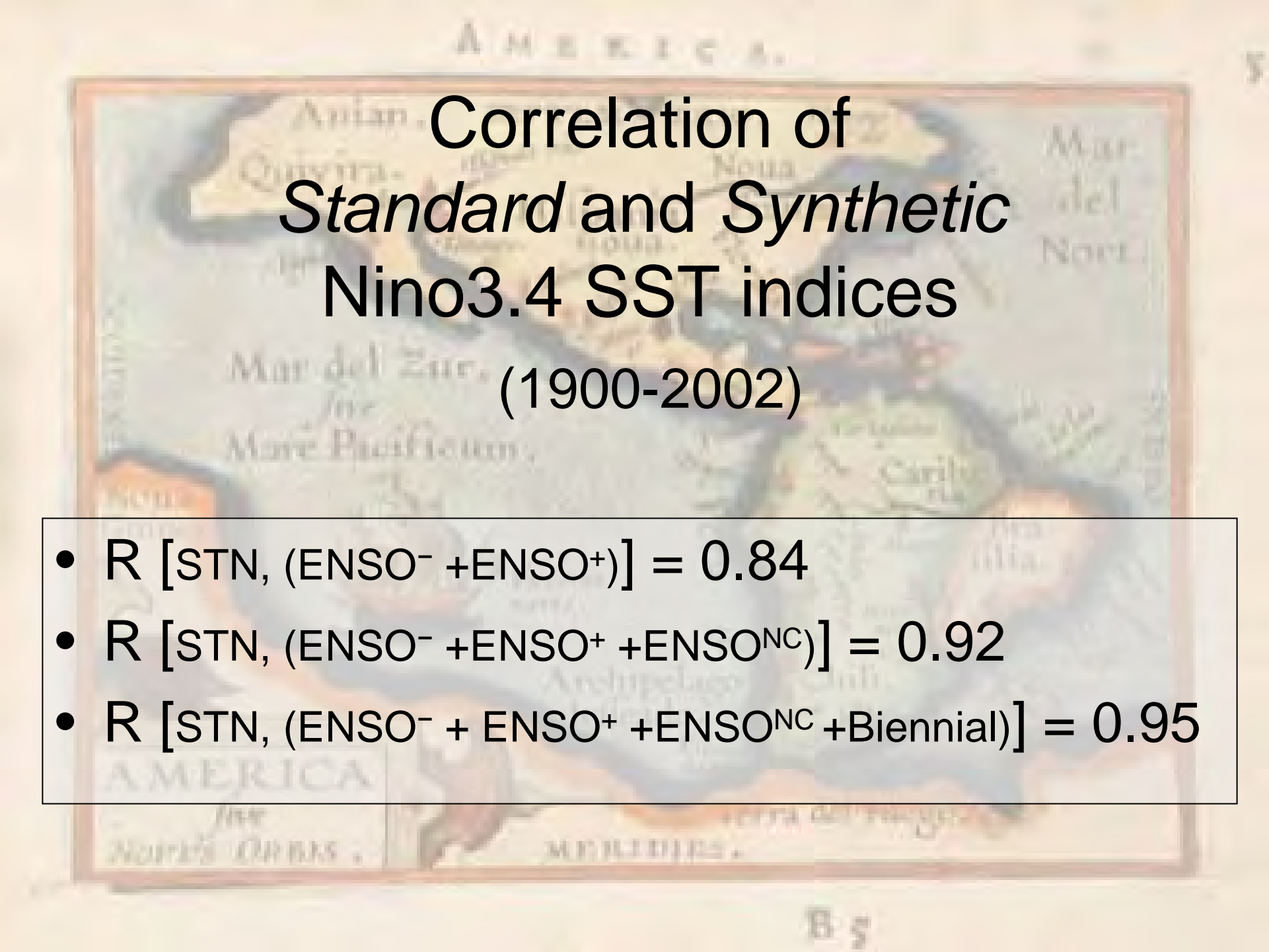
Before 1976/77 After



Raw SST regressed on raw Niño3.4 index

Above +
BIENNIAL
(4 modes)

E Pac



Correlation of *Standard and Synthetic* Nino3.4 SST indices

(1900-2002)

- $R [\text{STN}, (\text{ENSO}^- + \text{ENSO}^+)] = 0.84$
- $R [\text{STN}, (\text{ENSO}^- + \text{ENSO}^+ + \text{ENSO}^{\text{NC}})] = 0.92$
- $R [\text{STN}, (\text{ENSO}^- + \text{ENSO}^+ + \text{ENSO}^{\text{NC}} + \text{Biennial})] = 0.95$

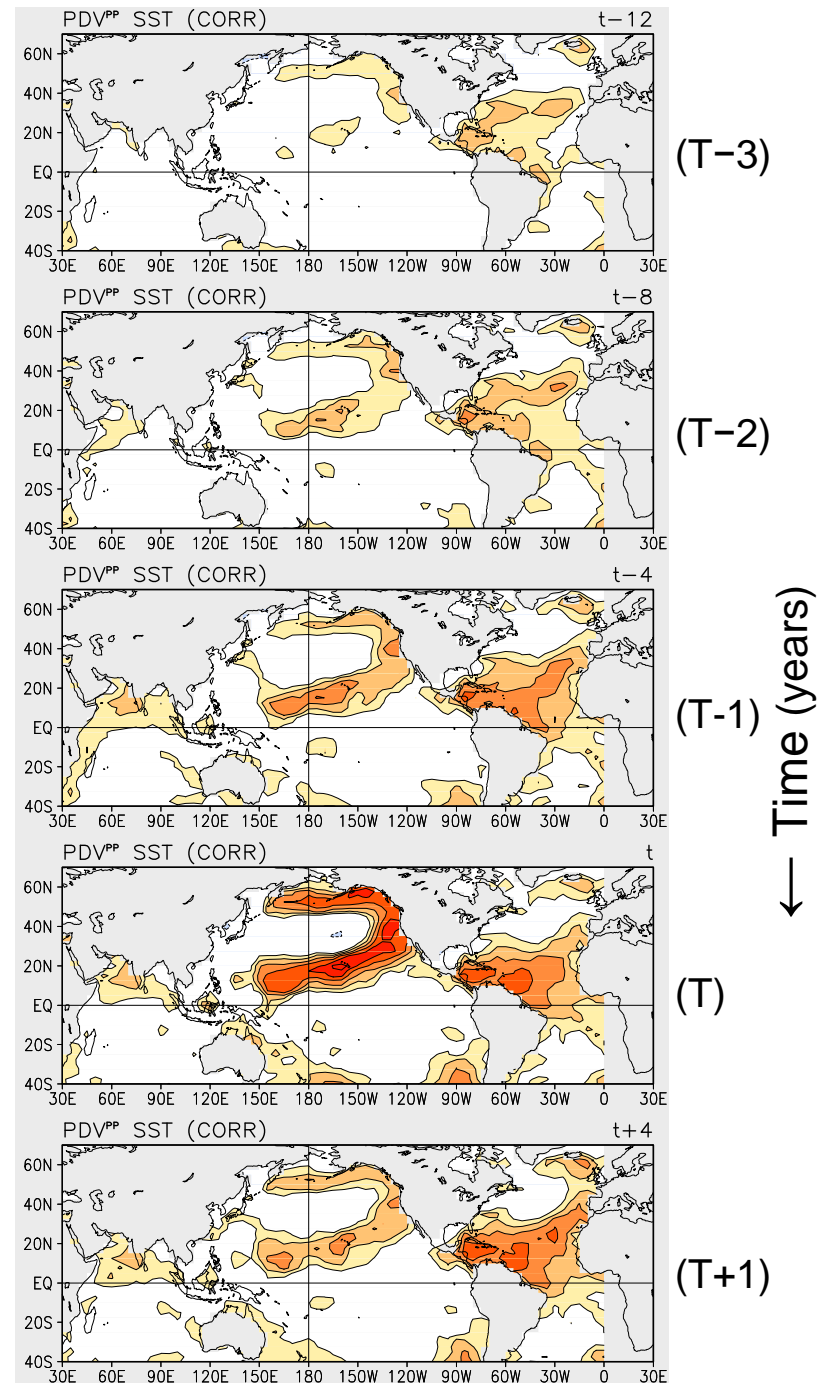
Pan-Pacific Decadal Variability

SST Correlations

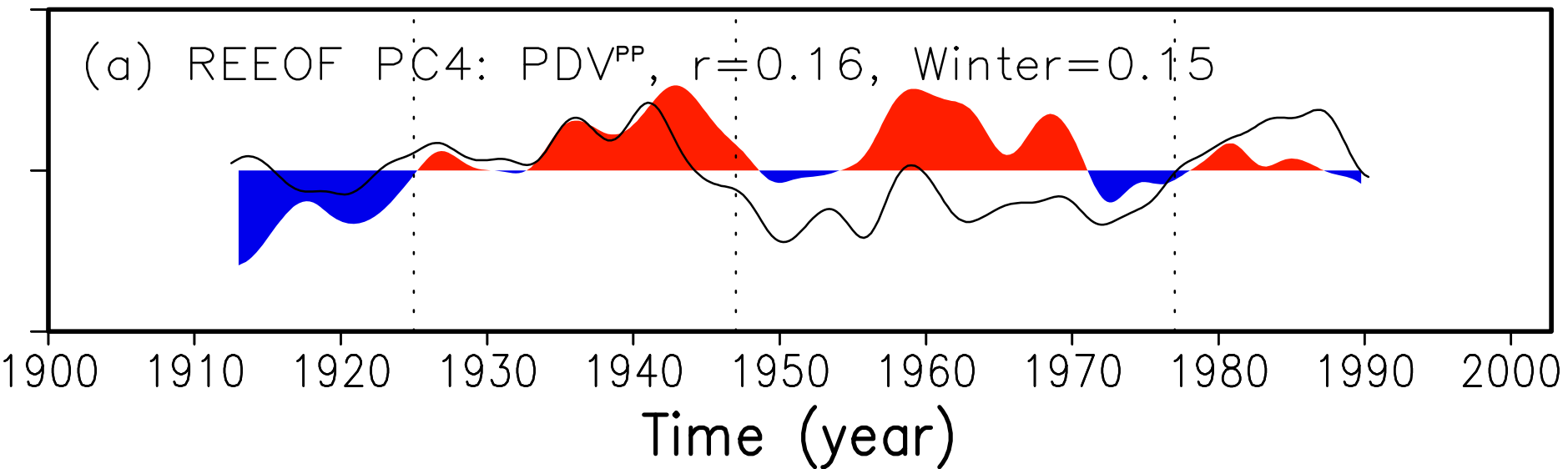
CI=0.1, beginning at 0.2

Features

- Clockwise development leading to 'horse-shoe' Pacific structure
- Quiescent central/eastern Eq. Pacific
- NOT "ENSO-like"
- Strong links to the western Atlantic
- Weak links to the Indian Ocean
- Not the PDO either ($r=0.23$)
- Captures the 1920s climate shift
- Link to the AMO??



PDV-Pan Pacific and the PDO



Curve: PDO index **Shading:** PDV-PP (both smoothed)

North Pacific Decadal Variability

SST Correlations

CI=0.1, beginning at 0.2

Features

- Zonal band in the midlatitude Pacific
- Modest links to the eastern Pacific
- Strong connection to Indian Ocean and the western tropical Pacific
- Captures the 1976/77 climate shift
- PDO correspondence ($r=-0.57$)

(T-3)

(T-2)

(T-1)

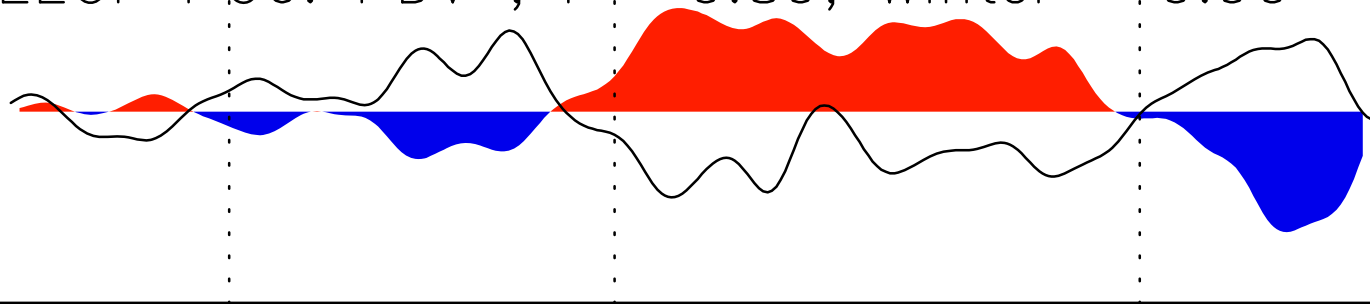
← Time (years)

(T)

(T+1)

PDV-North Pacific and the PDO

(a) REEOF PC6: PDV^{NP} , $r = -0.89$, Winter = -0.90



1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000

Curve: PDO index Shading: PDV-NP (both smoothed)

Physicality of the PDV Modes

- Biological evidence?

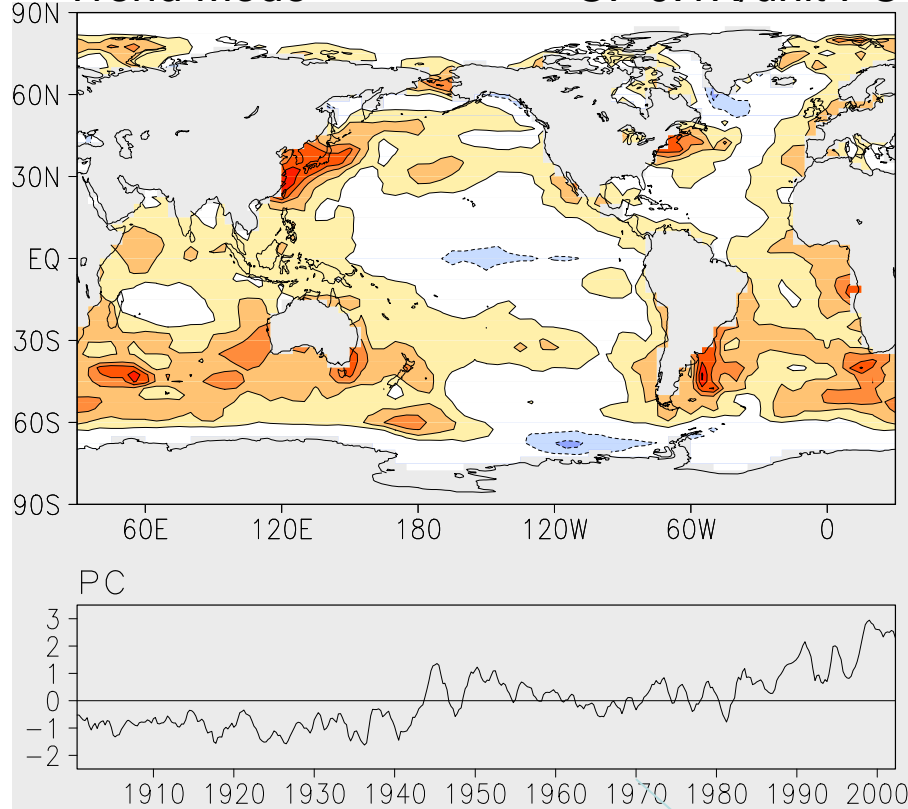
Biological time series	PDV^{PP}	PDV^{NP}	PDO
Eastern Pacific zooplankton biomass	0.54		0.10
British Columbia coho salmon catch	-0.42		-0.17
Gulf of Alaska halibut recruitment		-0.74	0.73
West Coast mackerel recruitment		-0.73	0.66

(Biological time series courtesy of Nate Mantua)

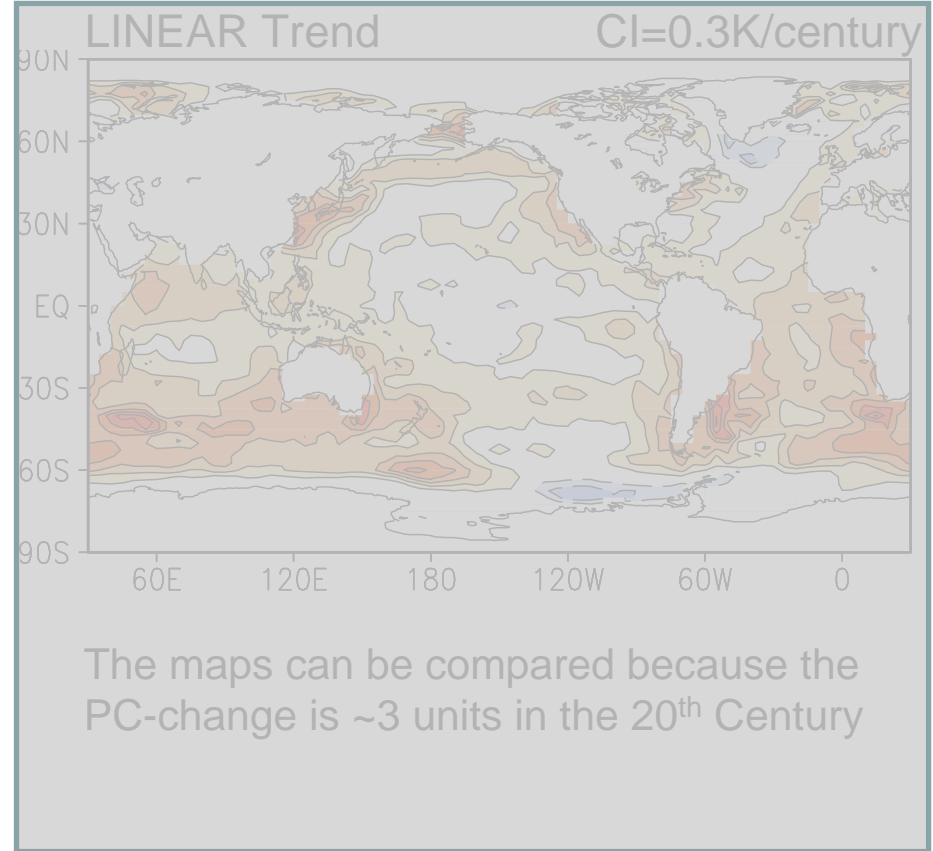
Secular Trend in 20th Century Pacific SSTs

Global SST regressions, CI=0.1K

Trend Mode CI=0.1K/unit PC



LINEAR Trend CI=0.3K/century

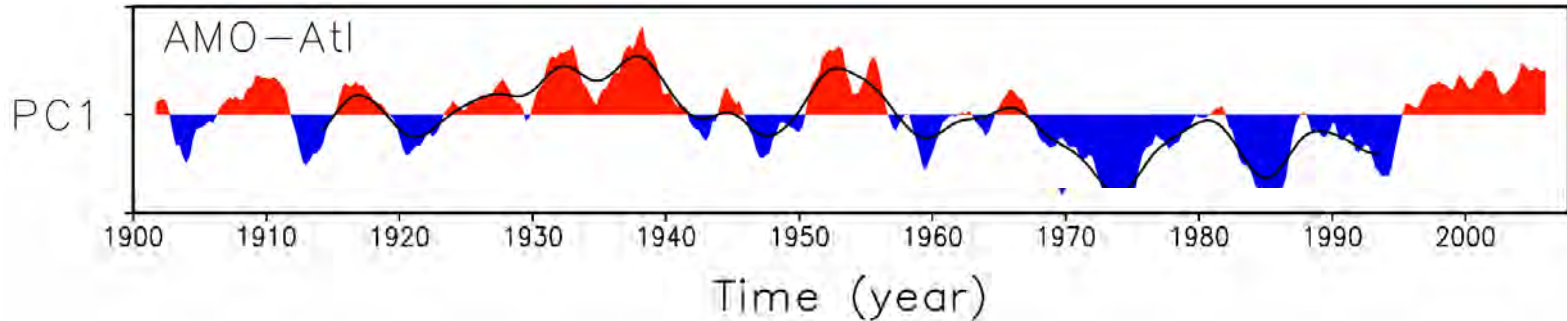


Features

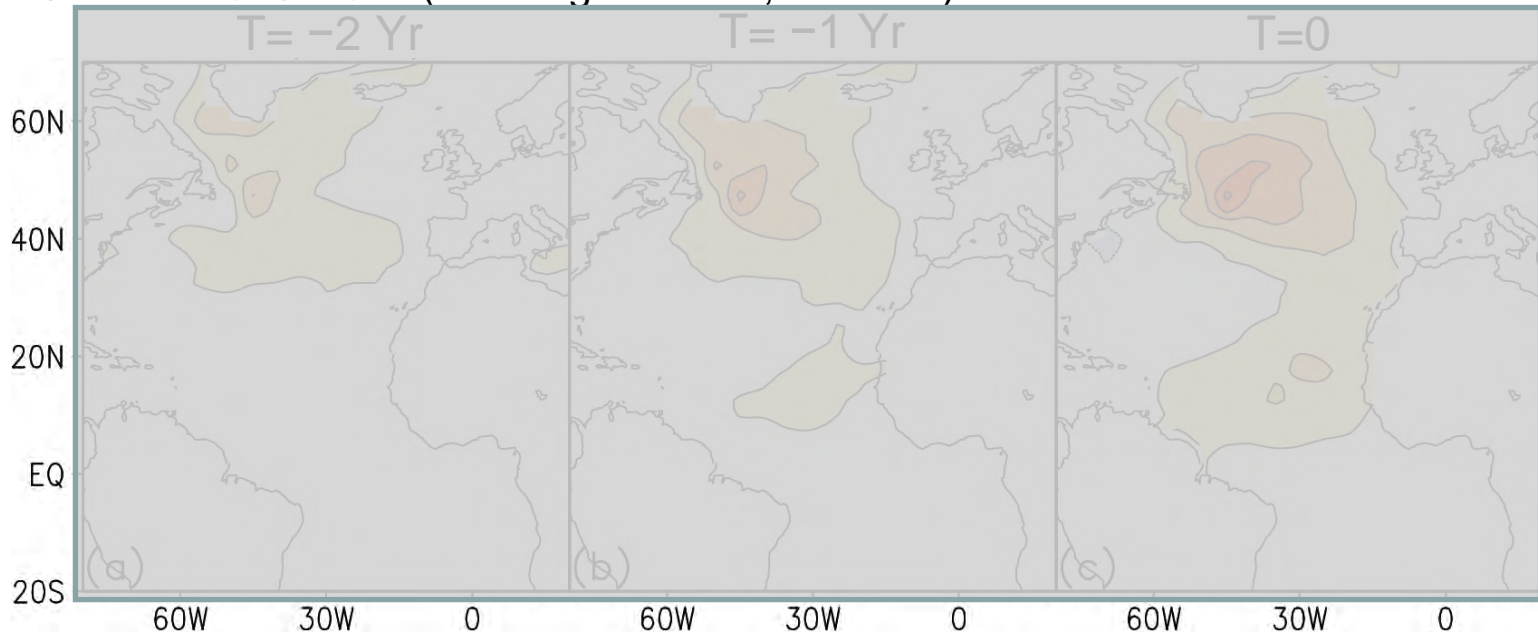
- Non-stationary trend, with mid-century cooling
- Largest signal off the east coast of Asia and North America
- PC very similar to SAT and ocean heat content trends
- Pervasive warming except in the central equatorial Pacific & off the tip of Greenland

Inter-basin links and the AMO

AMO-Atl: The leading mode of *residual* Atlantic SST variability
(Residual: Leftover after filtering Atlantic footprints of Pacific SST variability)



Pattern Evolution (SST regressions, CI=0.1K)





AMO-Atl

AMO-Pac

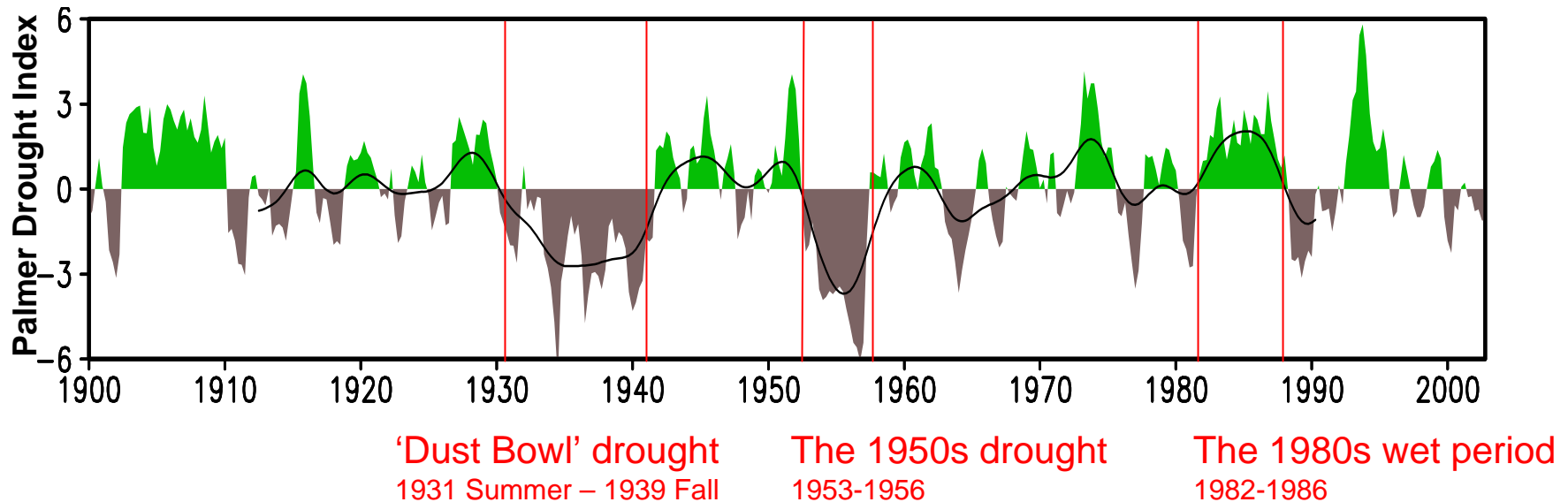
AMO-Con

Terrestrial Application

North American Multi-Year Droughts

The Great Plains

(35-45N; 90-100W; almost a million Km²)



Precipitation Reconstruction

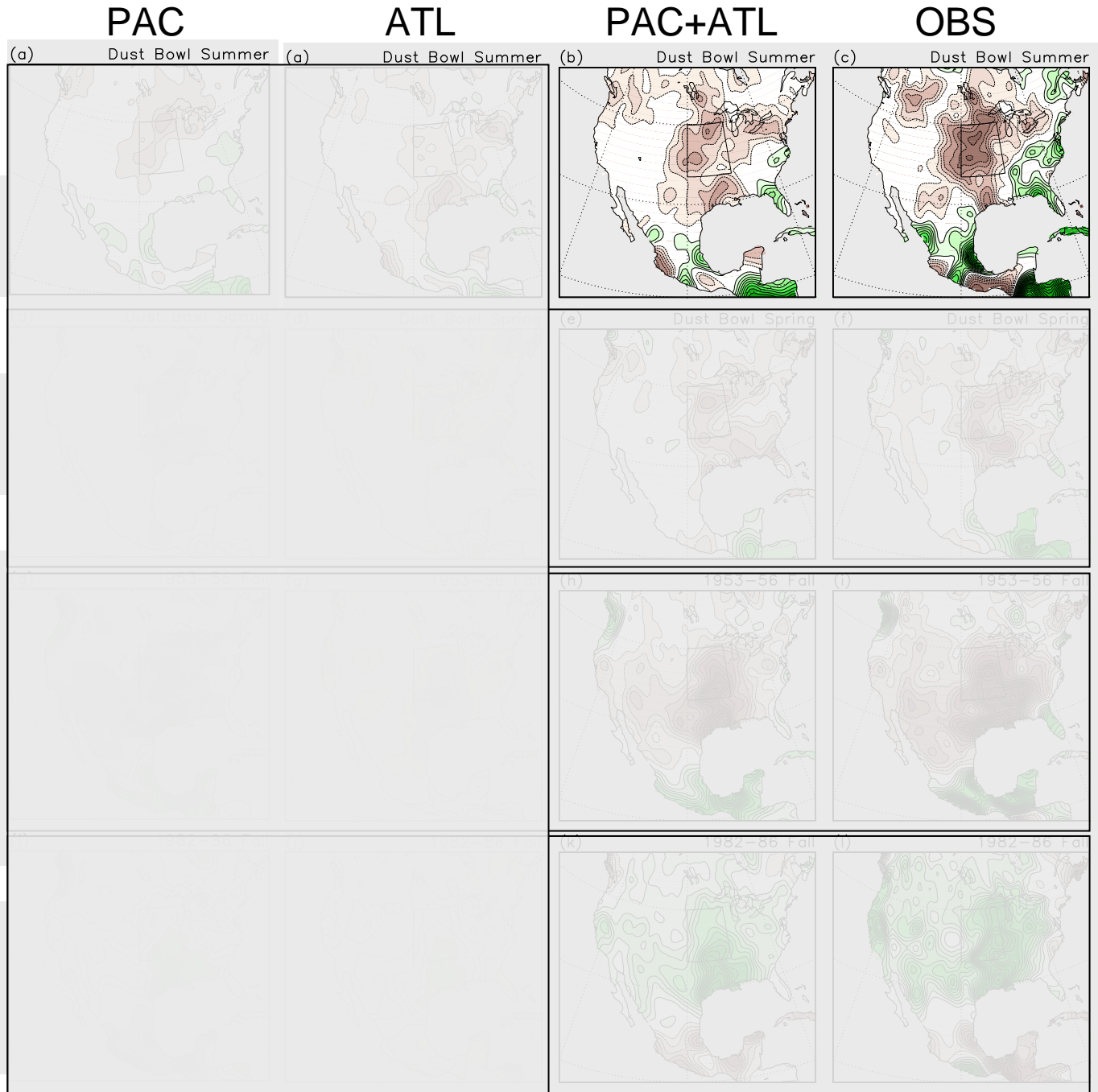
CI=0.1 mm/day

Dust Bowl
Summer

Dust Bowl
Spring

1950s
Drought
Fall
(Sum recons.
FAILED;
hypothesis)

1980s
Wet Period
Fall

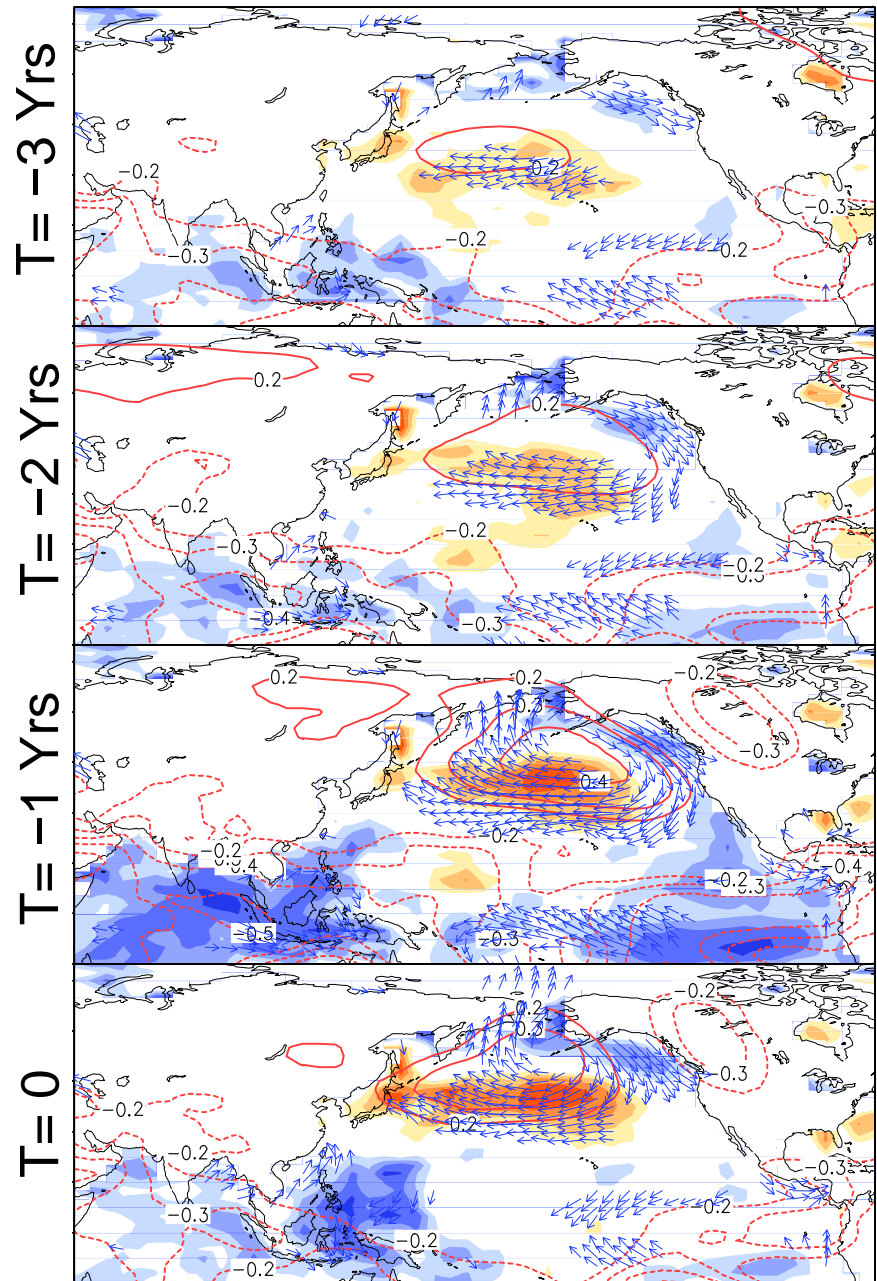


PDV-NP

Atmospheric Structure (WINTER)

(1908 – 2002; Preliminary)

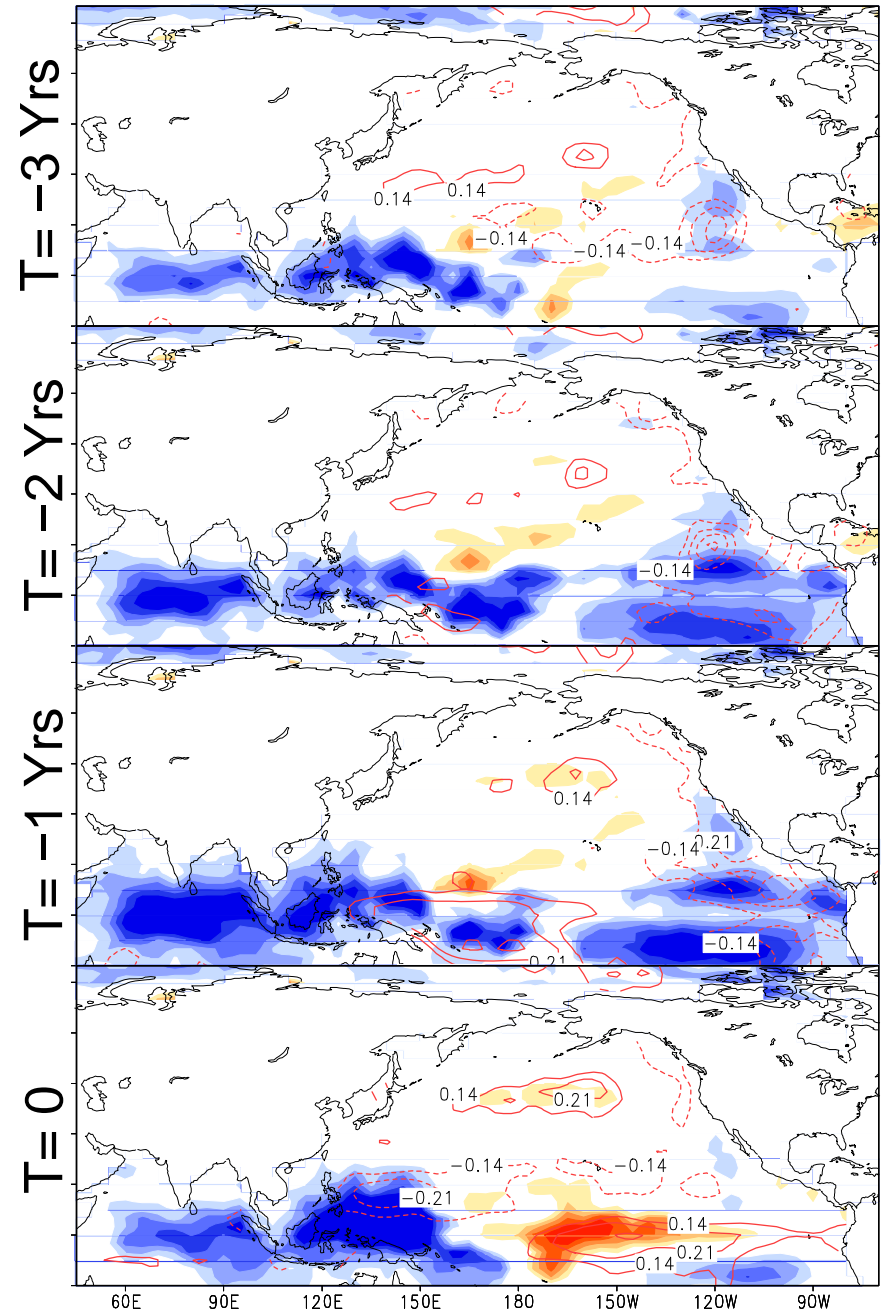
- SST correlations: $Cl=0.1$, shaded red/blue when >0.2
- Geop_700 correlations: $Cl=0.1$; contoured in red when >0.2
- 1000 hPa wind regressions, plotted when speed >0.4 m/s



PDV-NP Subsurface Structure (ALL-season)

(1958 – 2001; Preliminary)

- SST correlations: $Cl=0.05$, shaded red/blue when >0.1
- OHC500 (from SODA1.4.2) correlations: $Cl=0.07$ contoured in red when >0.14



Concluding Remarks

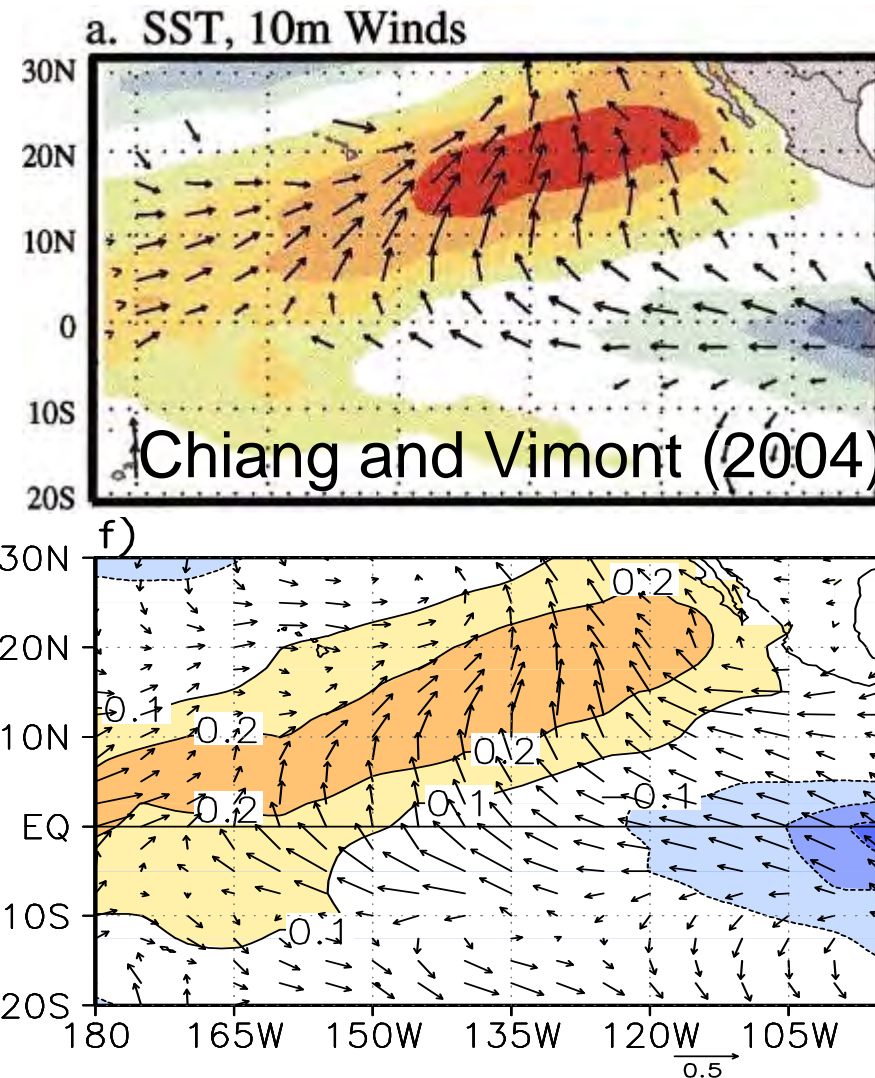
- An evolution-centric analysis provides interesting characterization of PDV, and some insights into its origin
- PDV consists of two modes: North Pacific & Pan Pacific; neither is “ENSO-like”; ENSO^{NC} is the LF ENSO-like mode
- PDV-NP exhibits strong links to the Tropics (IO, WP, EP)
- PDV-PP exhibits interesting links to tropical/subtropical Atlantic; factoring these leads to clarified AMO structure
- Unprecedented extent and efficiency with which multi-year continental droughts are reconstructed is reassuring for the SST analysis scheme: Oceanic droughts – a future target?
- Preliminary analysis of atmospheric and subsurface PDV structure: Trepidations in leaving *Terra Firma*

Based on

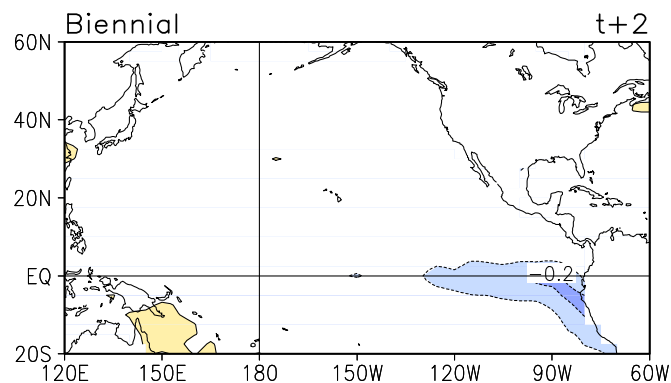
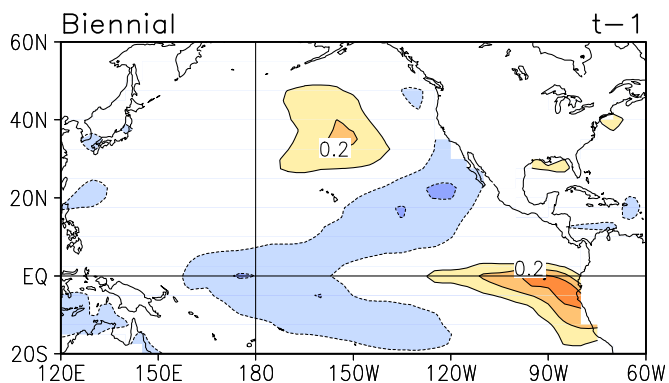
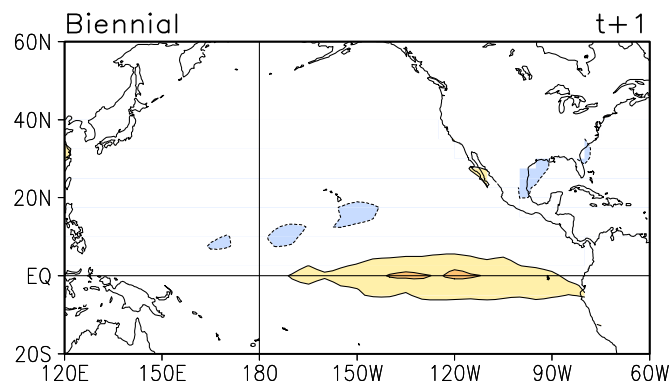
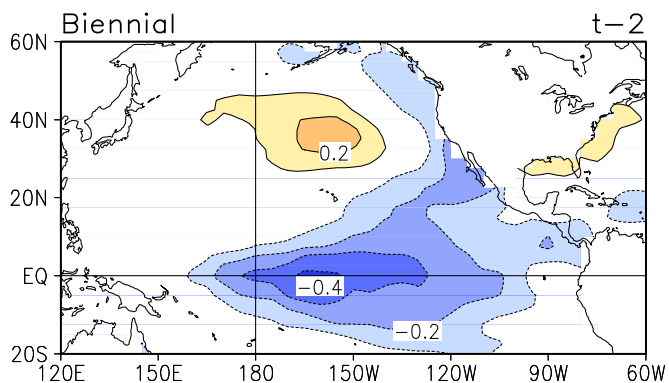
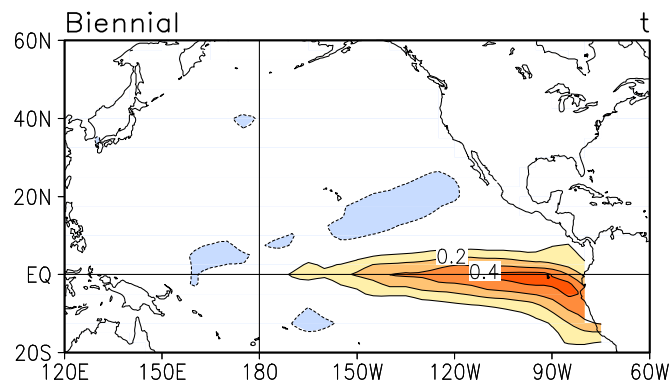
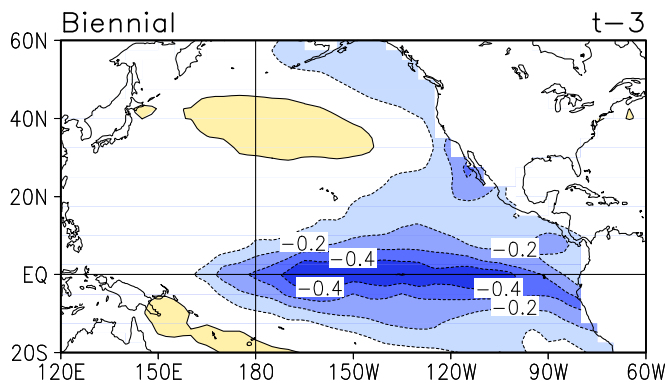
- **Guan, B., and S. Nigam, 2008:** Pacific Sea Surface Temperatures in the Twentieth Century: An evolution-centric analysis of variability and trend. *J. Climate*, **21**, 2790-2809.
- **Guan, B., and S. Nigam, 2009:** Analysis of Atlantic SST variability factoring inter-basin links and the secular trend: Clarified structure of the Atlantic Multidecadal Oscillation. *J. Climate*, **22**, 4228-4240.



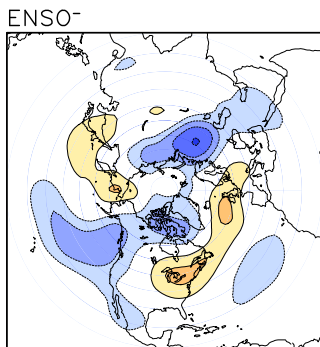
Pacific Meridional Mode vs. Non-canonical ENSO



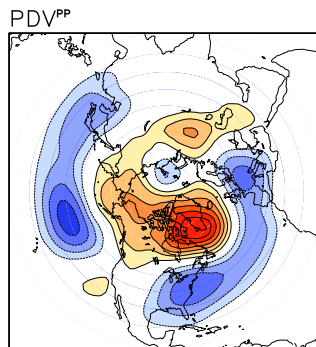
Biennial Variability (3.5%)



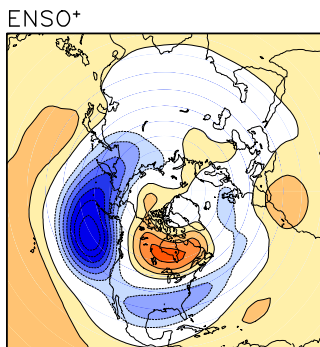
ENSO⁻



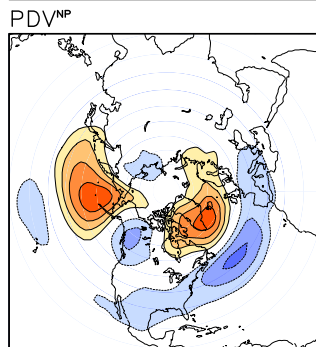
PDV^{PP}



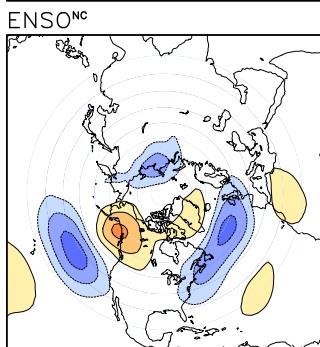
ENSO⁺



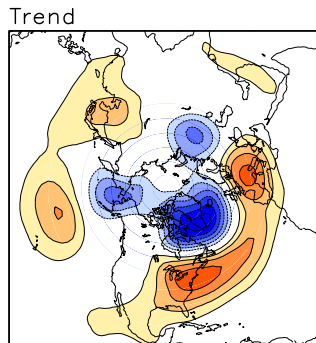
PDV^{NP}



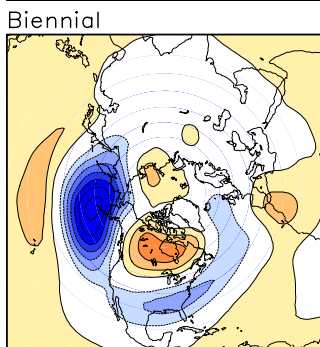
ENSO^{NC}



Trend



Biennial

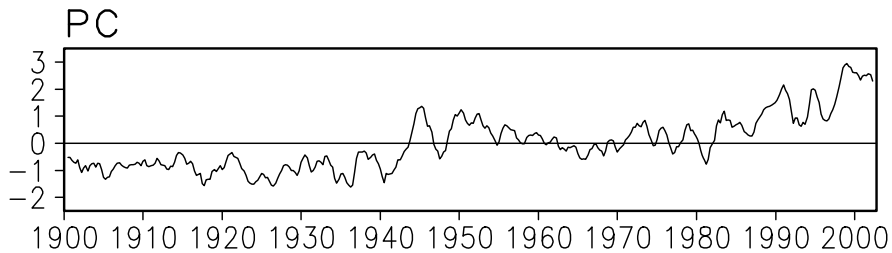
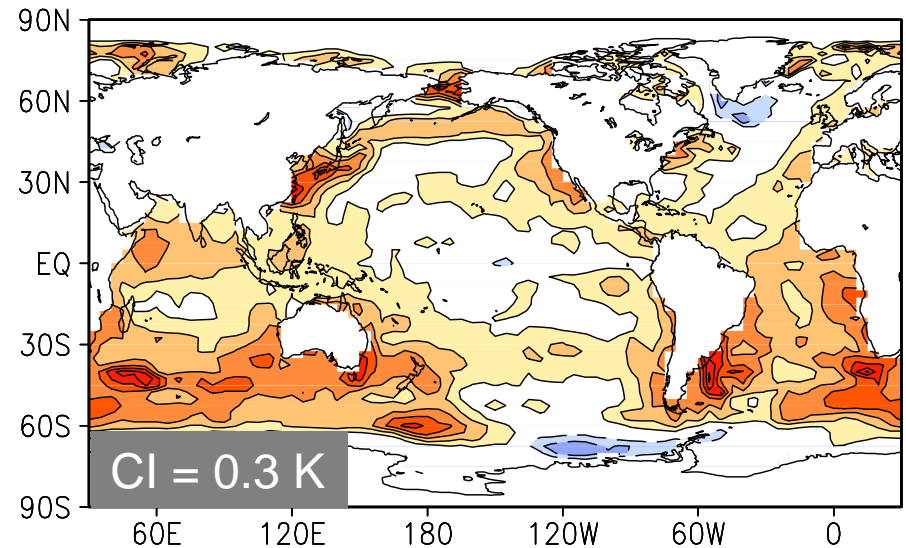
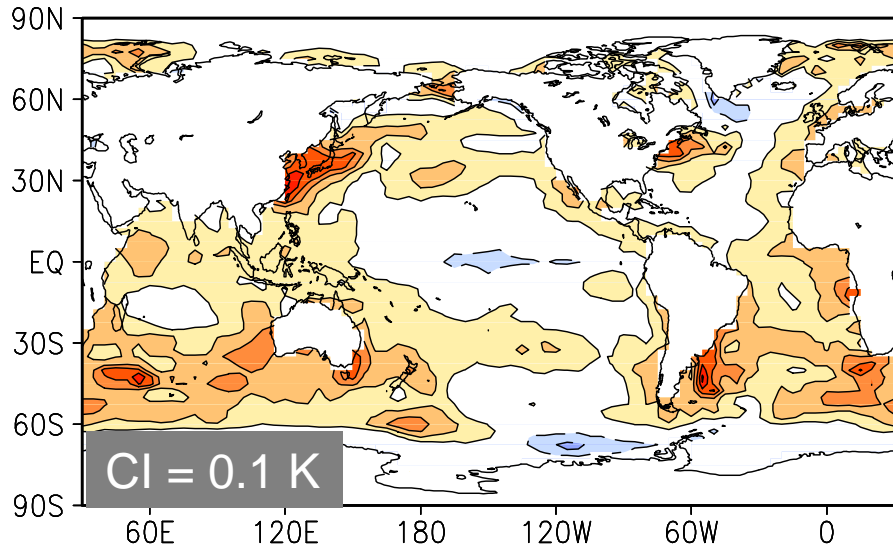


Winter Z500 Regressions

Trend

Trend Mode (K per unit PC; 10.2%)

Linear Trend (K per century)



$\Delta PC \approx 3$ units per century