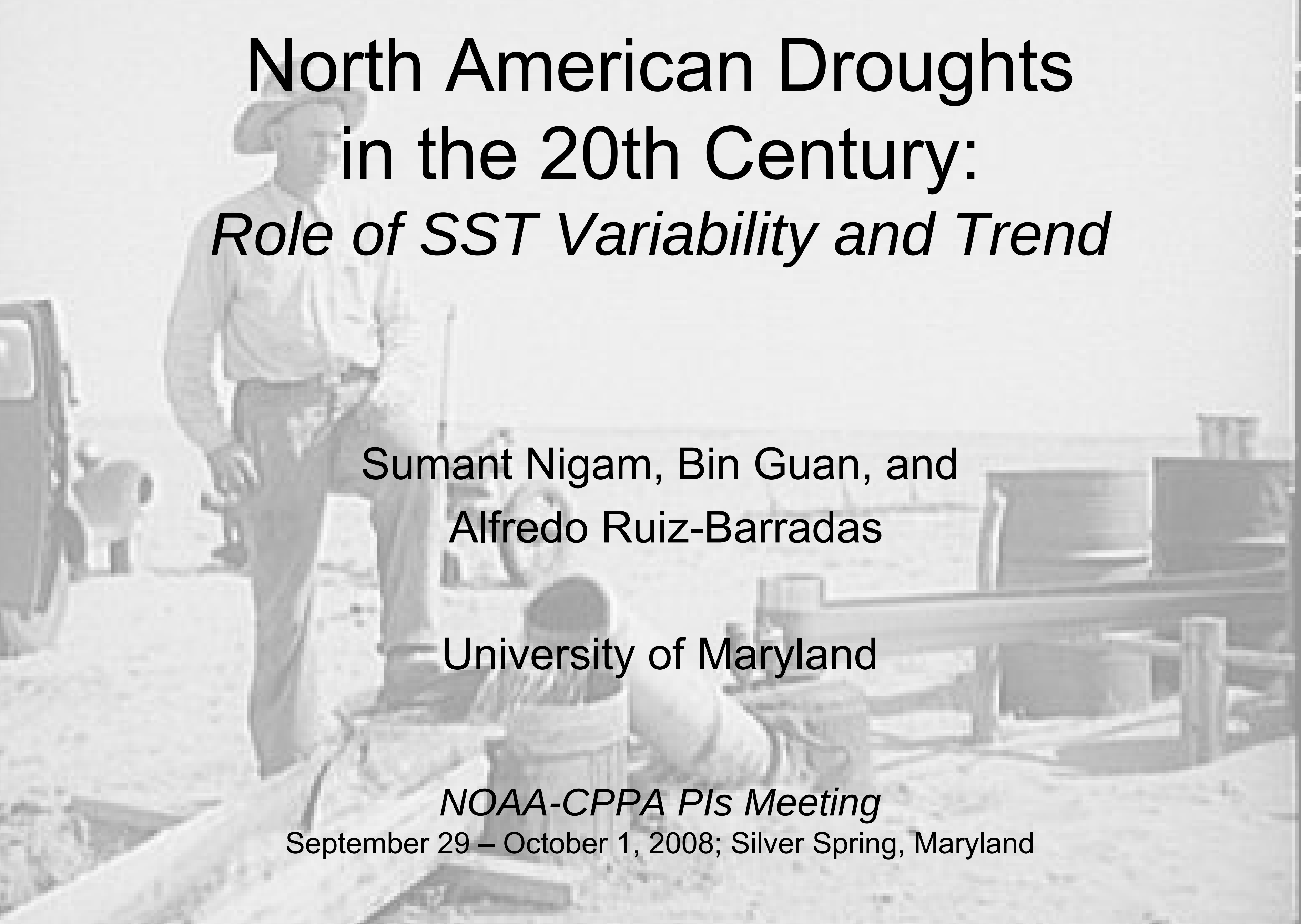
Dust Bowl Drought,, Cimarron County, Oklahoma. (Arthur Rothstein, Farm Security Admin., April 1936.)



North American Droughts in the 20th Century: *Role of SST Variability and Trend*

Sumant Nigam, Bin Guan, and
Alfredo Ruiz-Barradas

University of Maryland

NOAA-CPPA PIs Meeting

September 29 – October 1, 2008; Silver Spring, Maryland

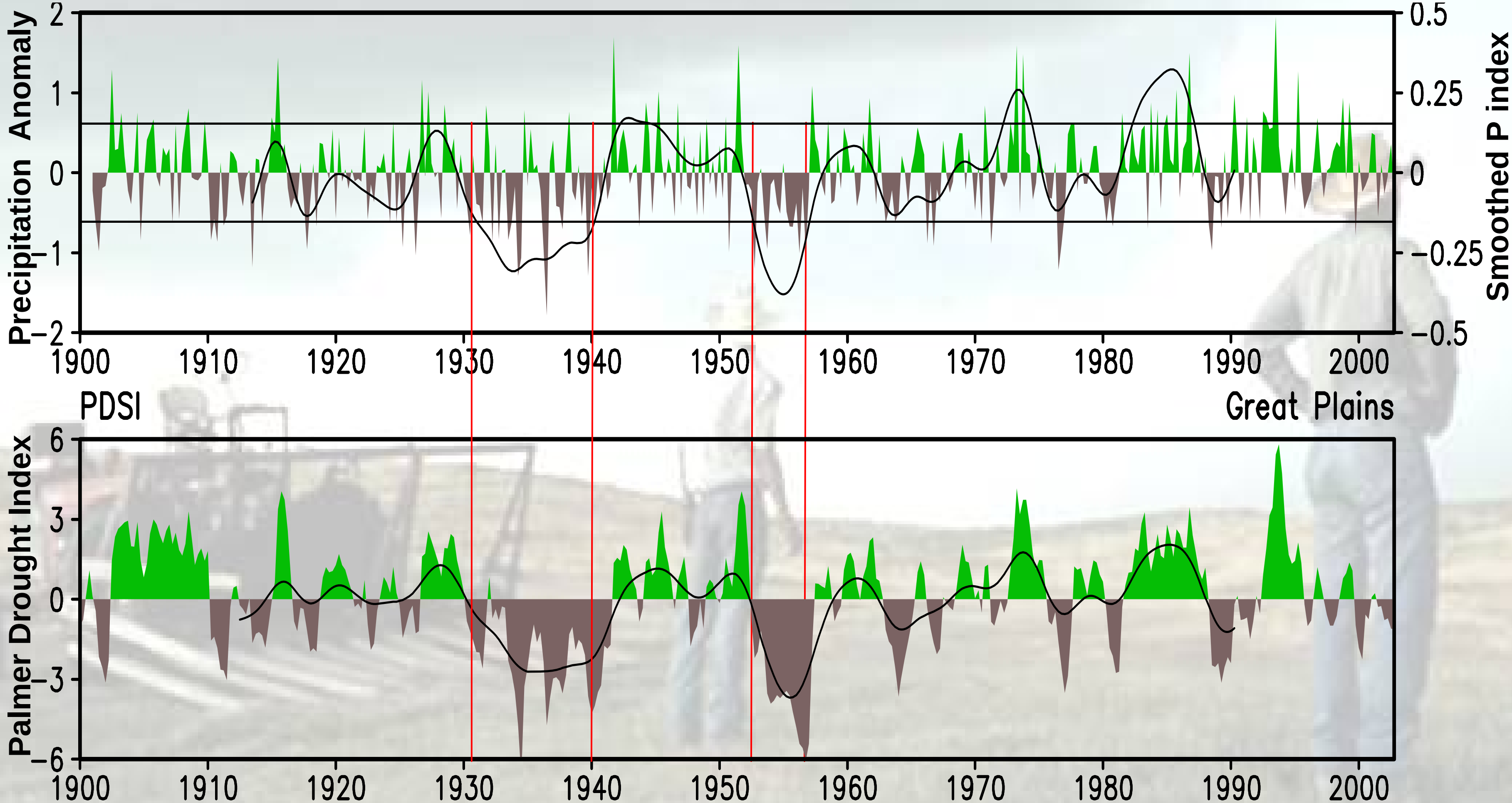
Outline

- The 20th Century droughts: Dust Bowl and the 1950s Drought: Structure
- Simulation of the Great Plains droughts: Realistic?
- Can analysis of the 20th Century observational record provide lower bounds on the extent of the SST influence on droughts?
- Drought reconstruction : Atlantic SSTs are equally important
- From the Great Plains to the Gangetic Plains

The Great Plains

(35-45N; 90-100W; almost a million Km^2)

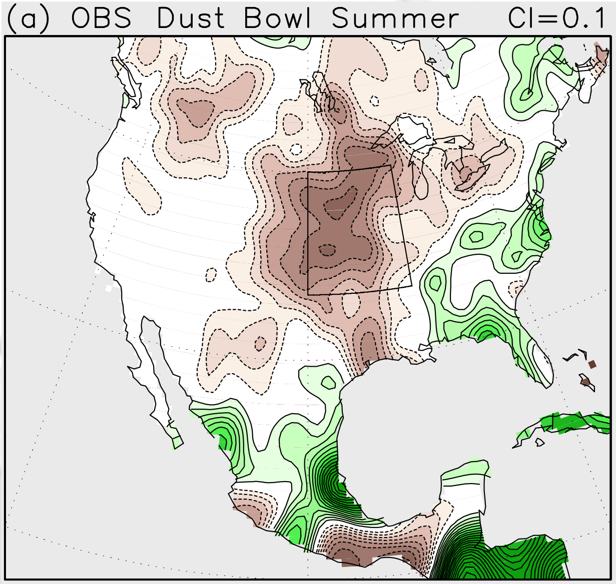
r (P, PDSI)=0.54
r (P_{smth}, PDSI)=0.75
r (P_{smth}, $PDSI_{smth}$)=0.91



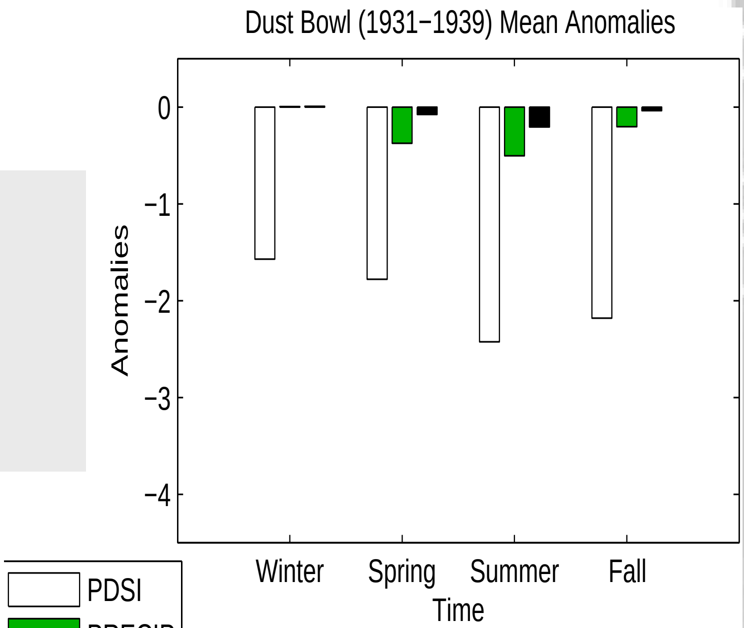
'Dust Bowl' drought
1931 Summer – 1939 Fall

The 1950s drought
1953-1956

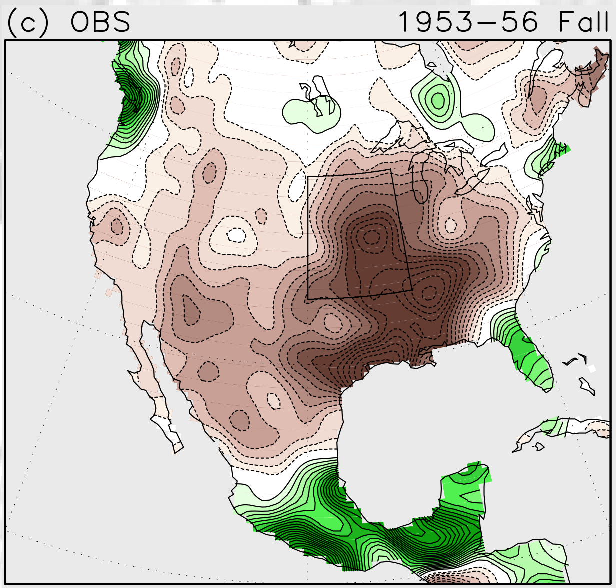
Great Plains Droughts



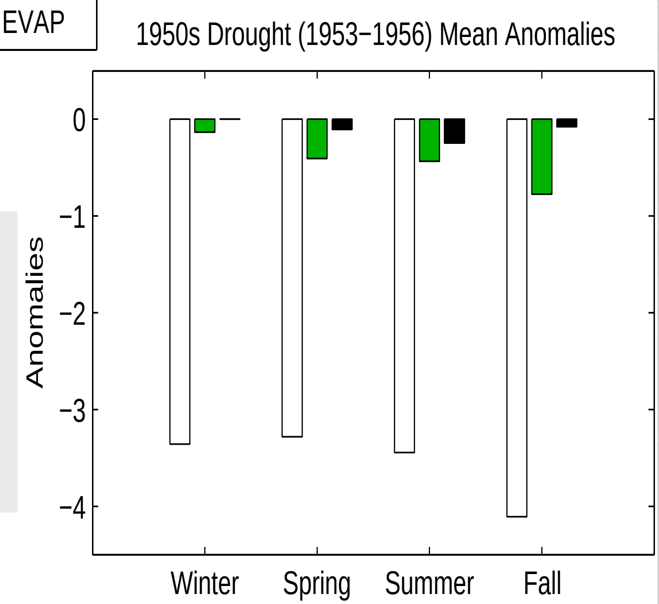
The Dust Bowl
1931-1939
*A Spring-**Summer** drought*



Precipitation Anomalies contoured at 0.1 mm/day



The 1950s Drought
1953-1956
*A Summer-**Fall** drought*



<u>Drought Modeling-I</u>

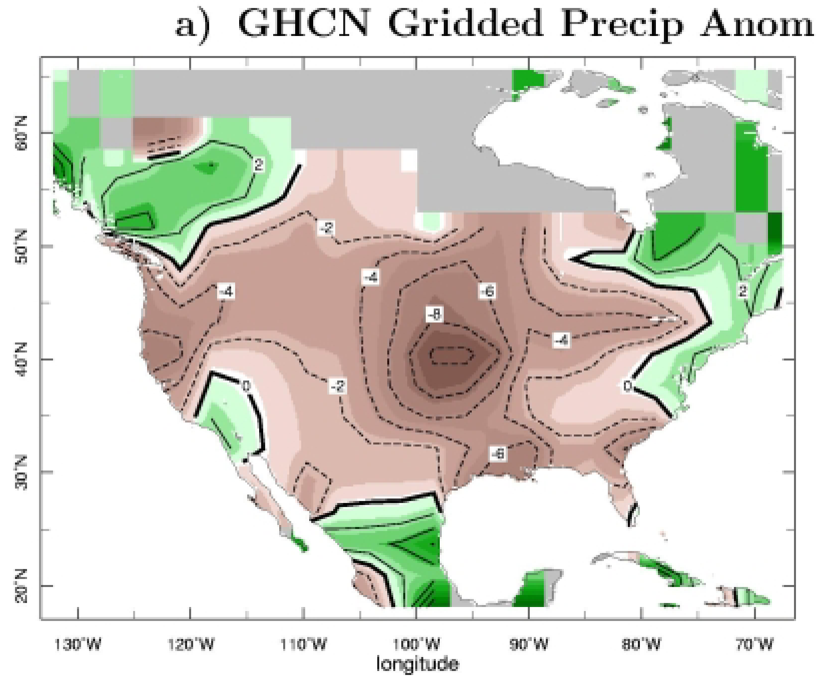
LDEO Simulation of Dust Bowl

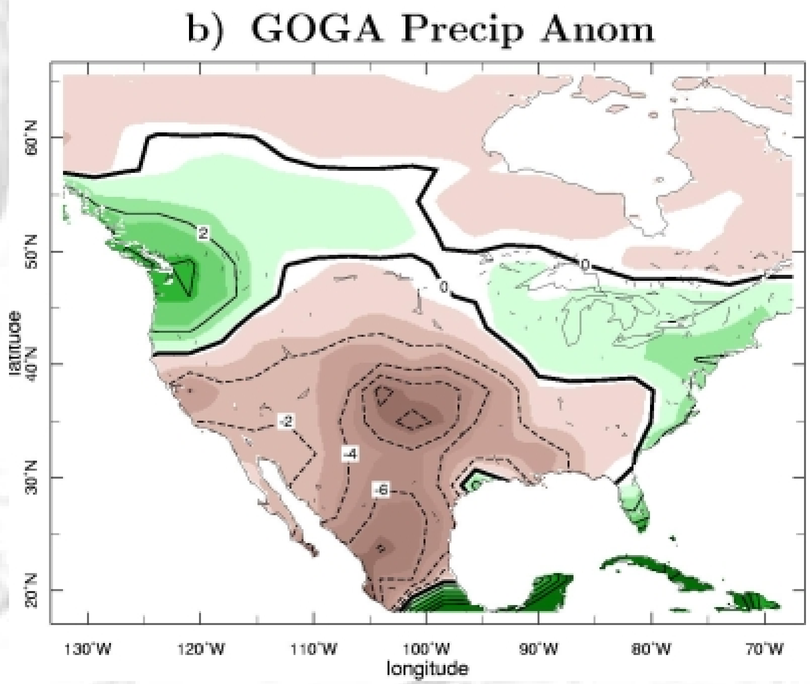
(Seager et al.)

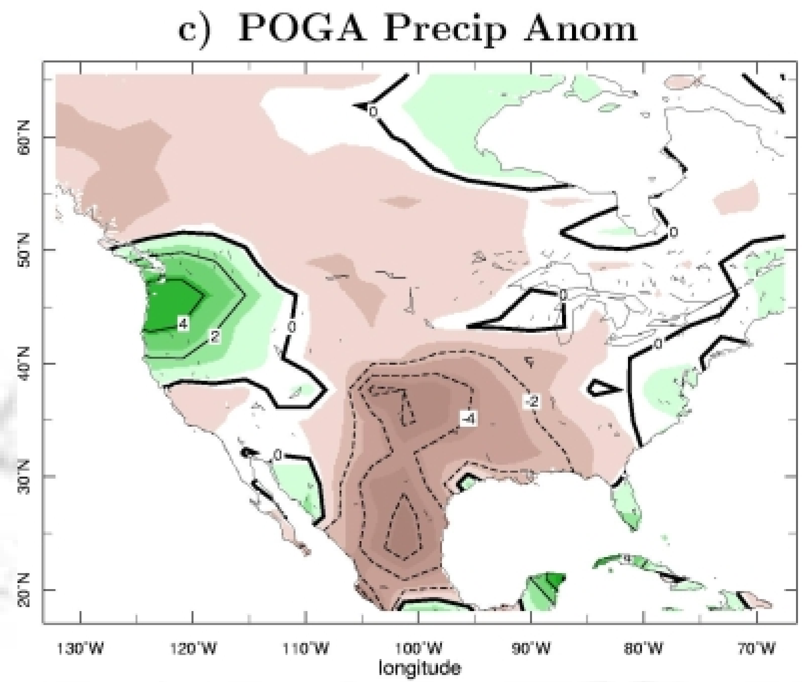
http://www.ldeo.columbia.edu/res/div/ocp/drought/

Ensemble-mean (16-member?)
Annual Precipitation Anomaly (1932-39)
contoured at 2 mm/month interval

Simulation: Realistic?







Drought Modeling-II

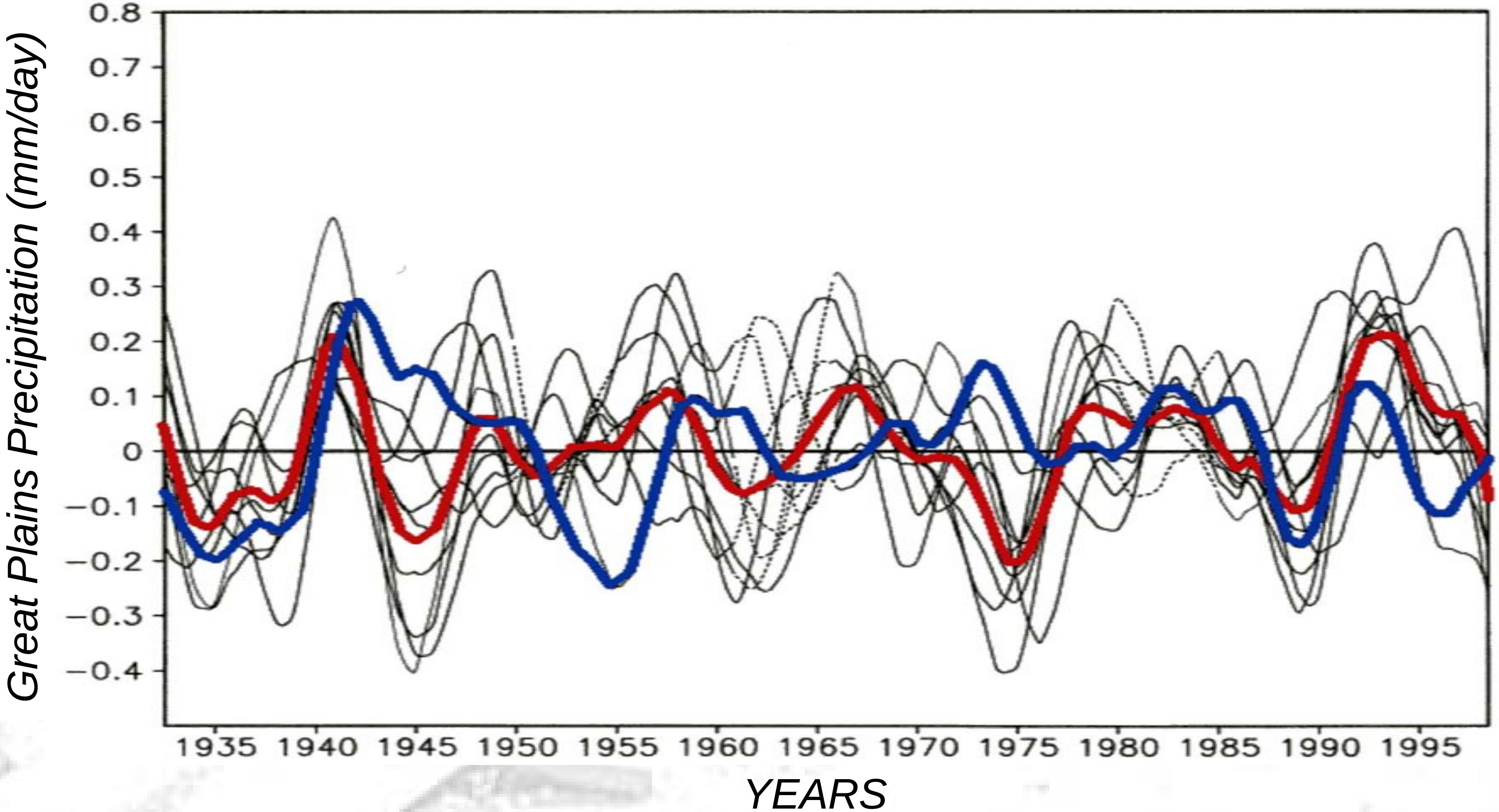
NASA/GSFC Simulation of Great Plains Droughts

(Schubert et al., J. Climate 2004)

Observed

Ensemble-mean (9)

Simulation: Realistic?



The Extent of SST Influence on North American Summer Hydroclimate

- Climate models rapidly improving but not quite ready for making the assessment for *regional* extreme events (e.g., droughts)
- Can the 20th Century observational record be analyzed for scoping the SST influence?
- Yes, if it can be unraveled for “natural” variability and secular trend components
- Given the drought time scales, we lean on the SST record for this separation

Evolution-centric analysis of 20th Century Pacific SST variability

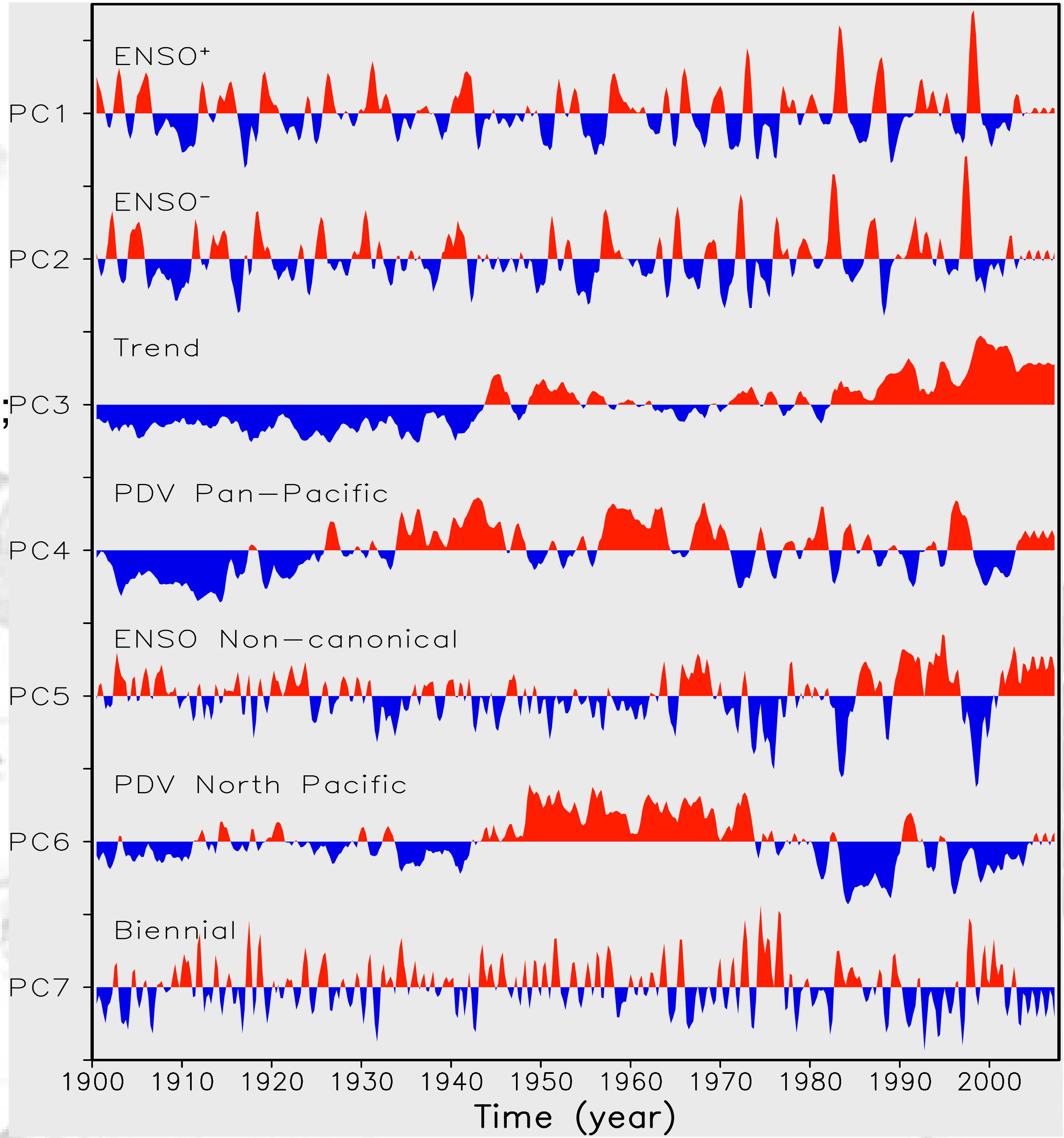
(Guan and Nigam, J. Climate, June 15, 2008)

GOAL

Obtain robust characterization of *all* non-seasonal modes of Pacific SST variability (including trend) from a *single* spatio-temporal analysis of *unfiltered* data.

The 7 Leading SST Principal Components

(Pacific basin analysis; 1900-2007)

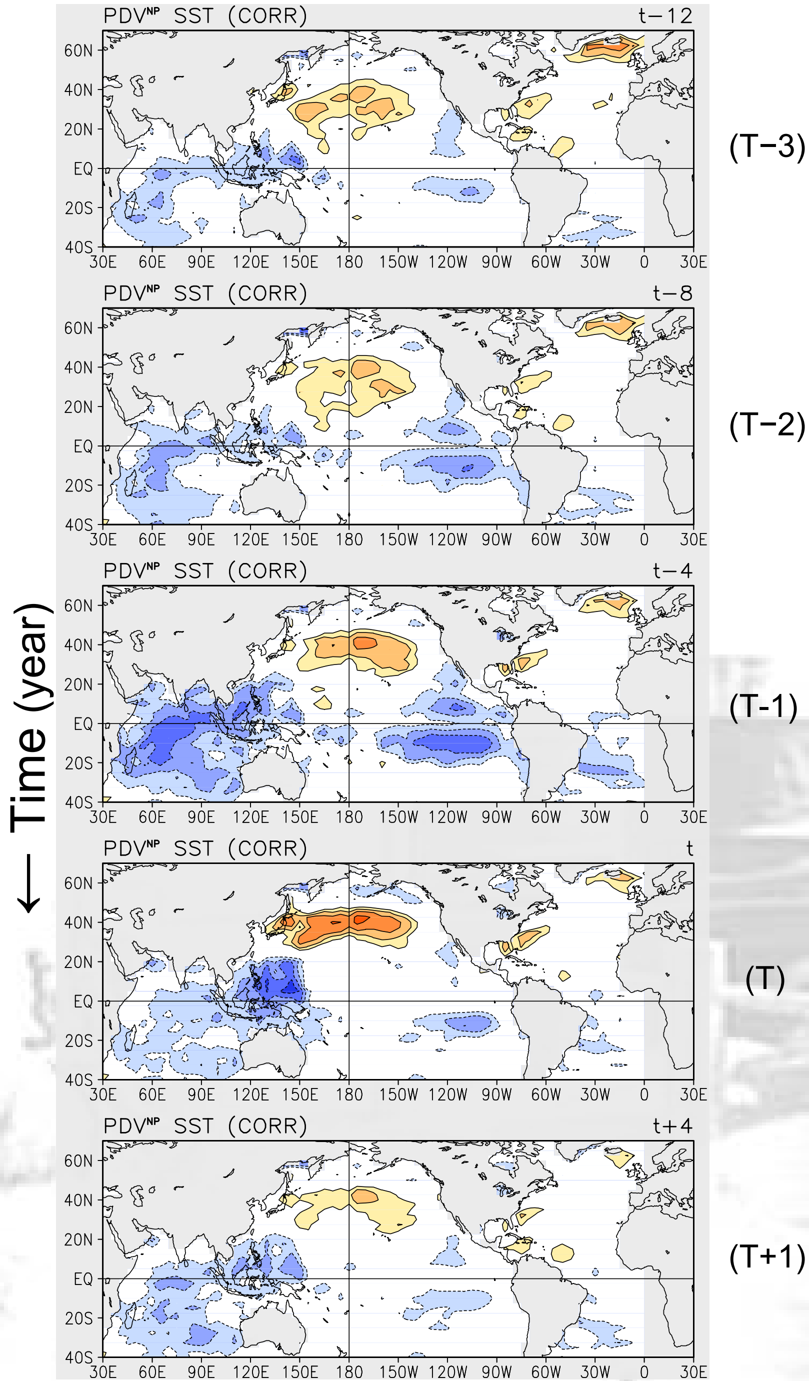


North Pacific
<u>Decadal Variability</u>

SST Correlations
CI=0.1, beginning at 0.2

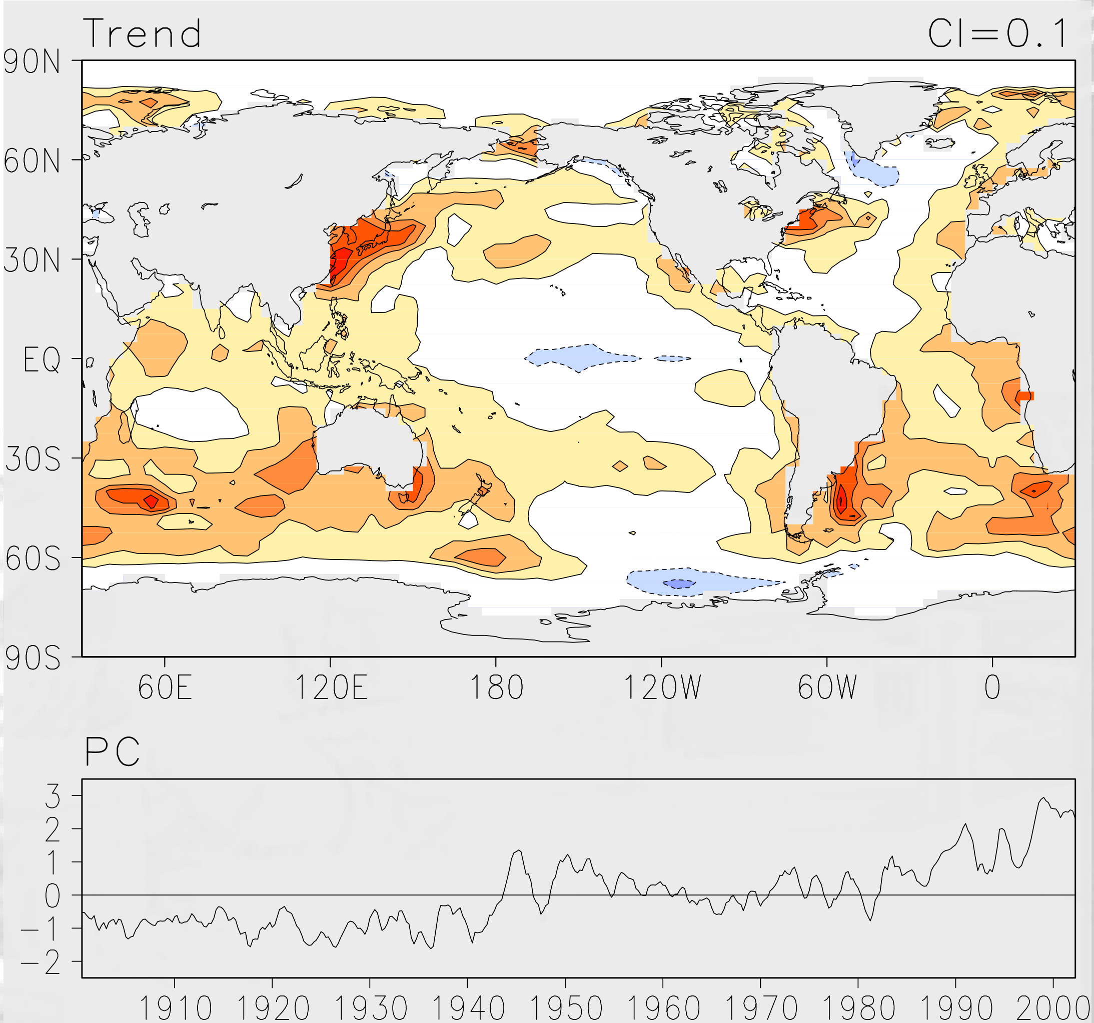
Features

- Zonal band in the midlatitude Pacific
- Weak links to the eastern Pacific
- Strong connection to Indian Ocean and the western tropical Pacific
- Interesting link to the North Atlantic
- Captures the 1976/77 climate shift
- PDO correspondence (r=−0.57)



Secular Trend in 20th Century Pacific SSTs

Global SST regressions
CI=0.1K



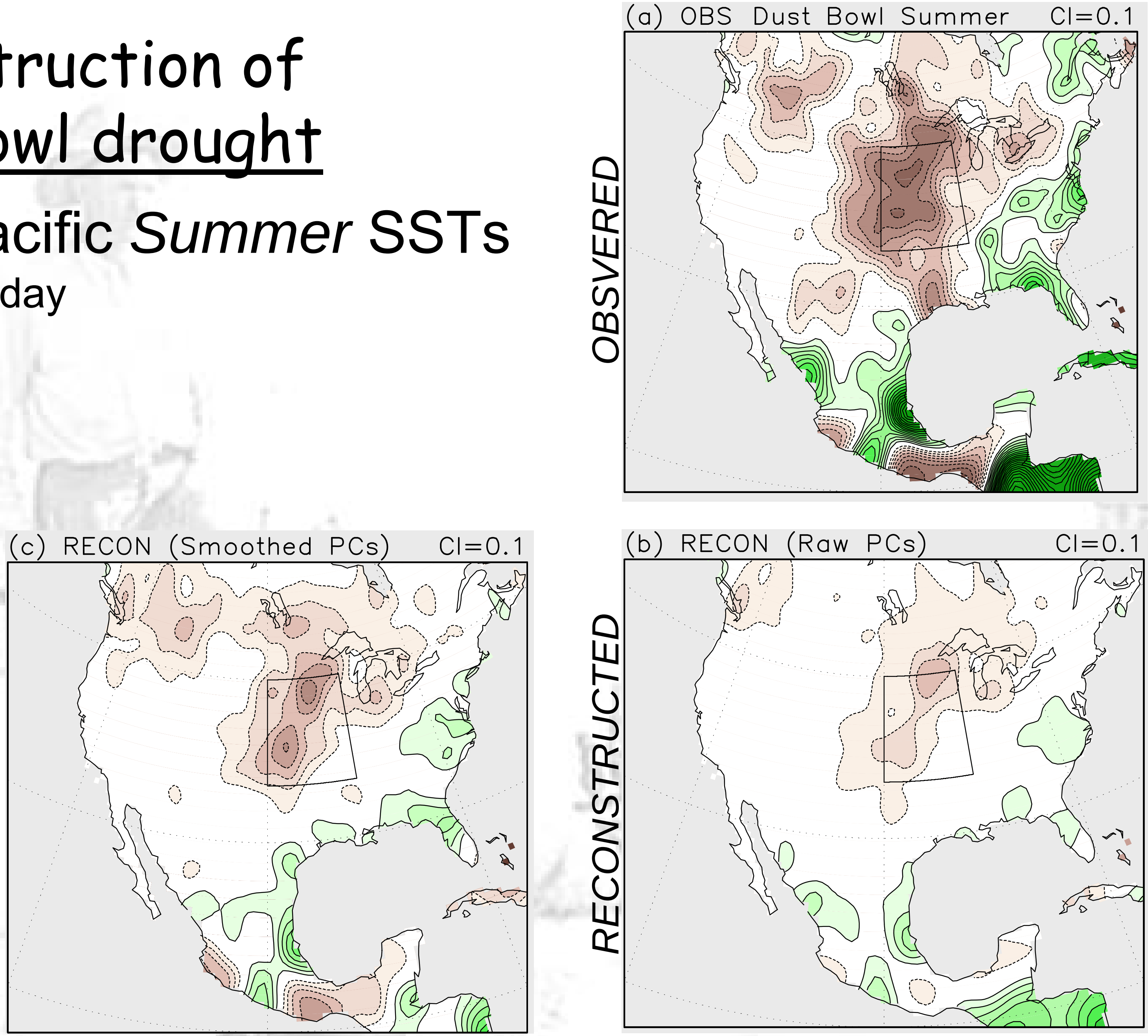
Features

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

Reconstruction of Dust Bowl drought

From Pacific *Summer* SSTs

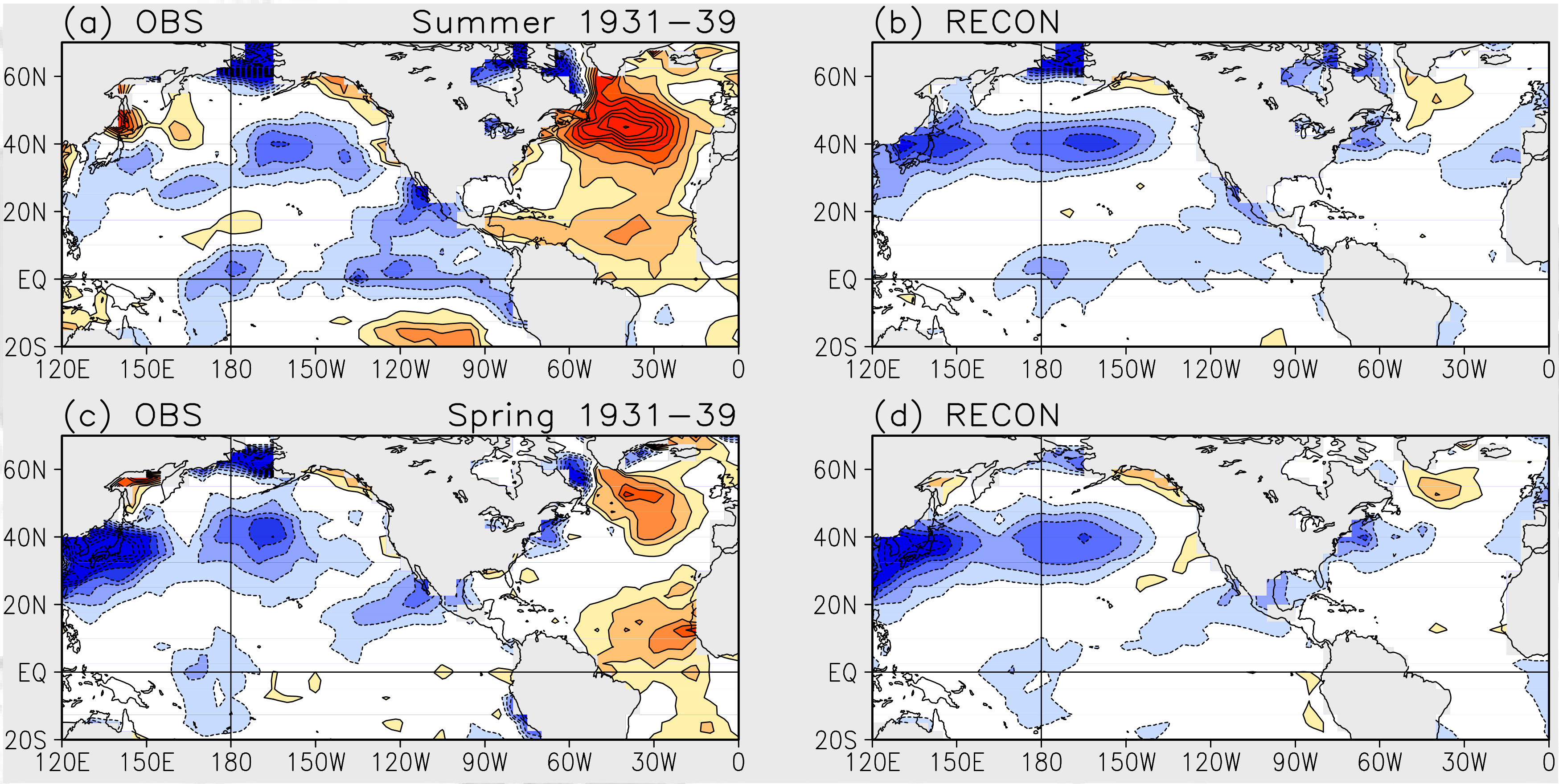
CI=0.1 mm/day



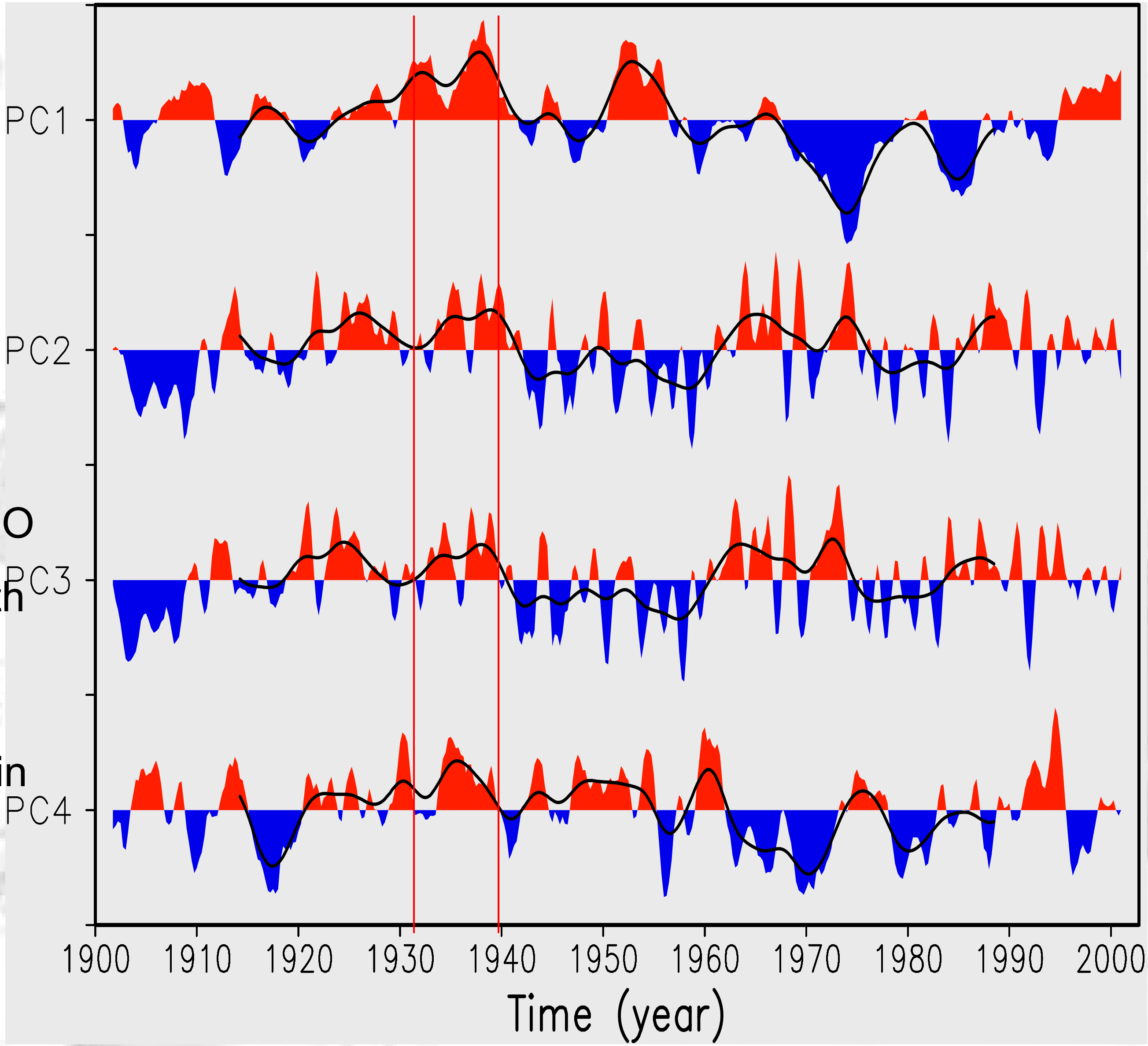
Reconstruction of Dust Bowl SSTs

(Pacific basin analysis)

CI=0.1K



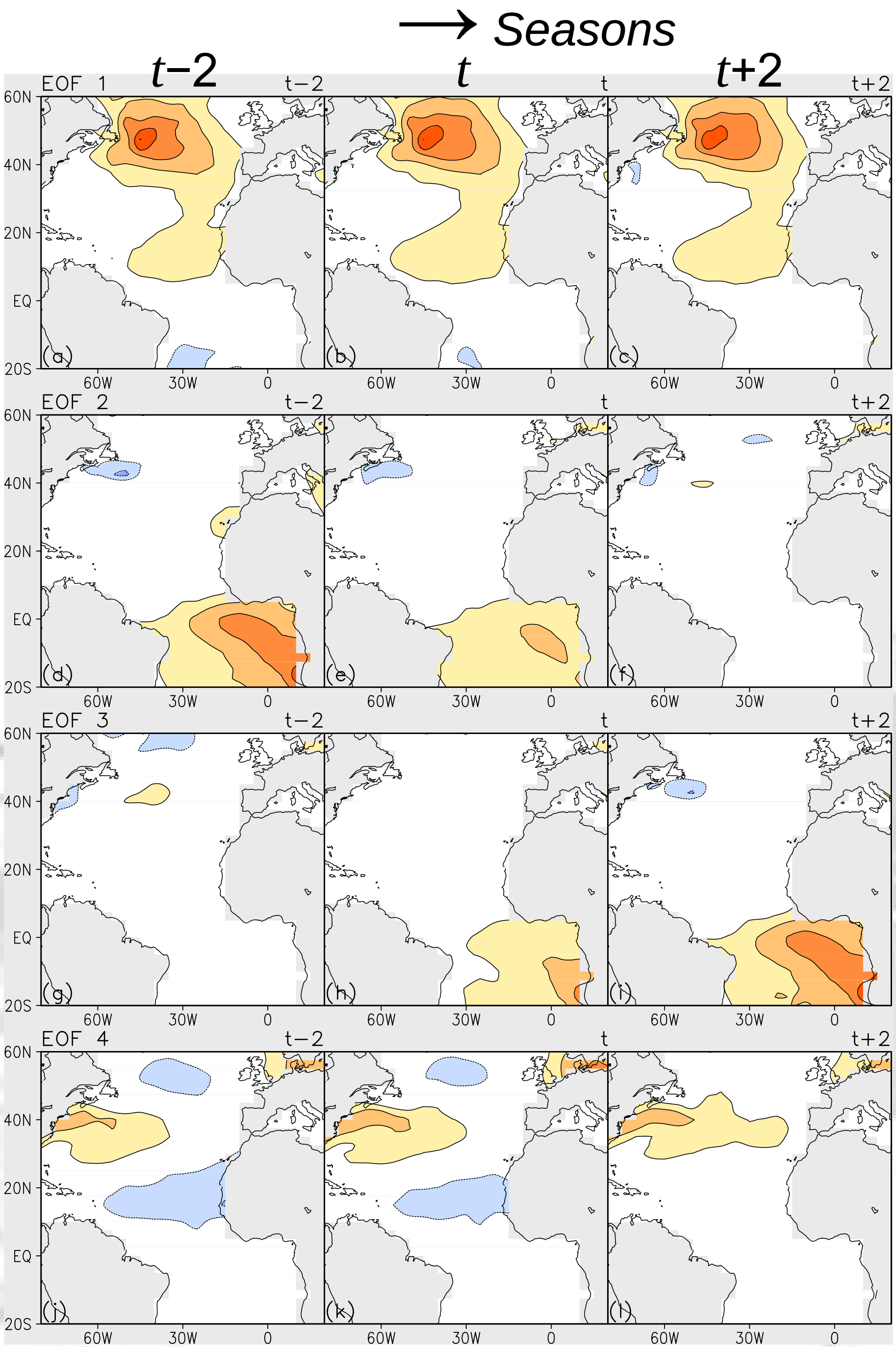
The 4 Leading PCs of Residual Atlantic SST Variability



- PC1 correlated with AMO
- PC2 and PC3 linked with tropical SST variability (Atlantic Nino like)
- PC4 related with SSTs in the northern basin (tripolar structure?)

The 4 Leading EEOFs of Residual Atlantic SST Variability

CI=0.1K



Precipitation Reconstruction

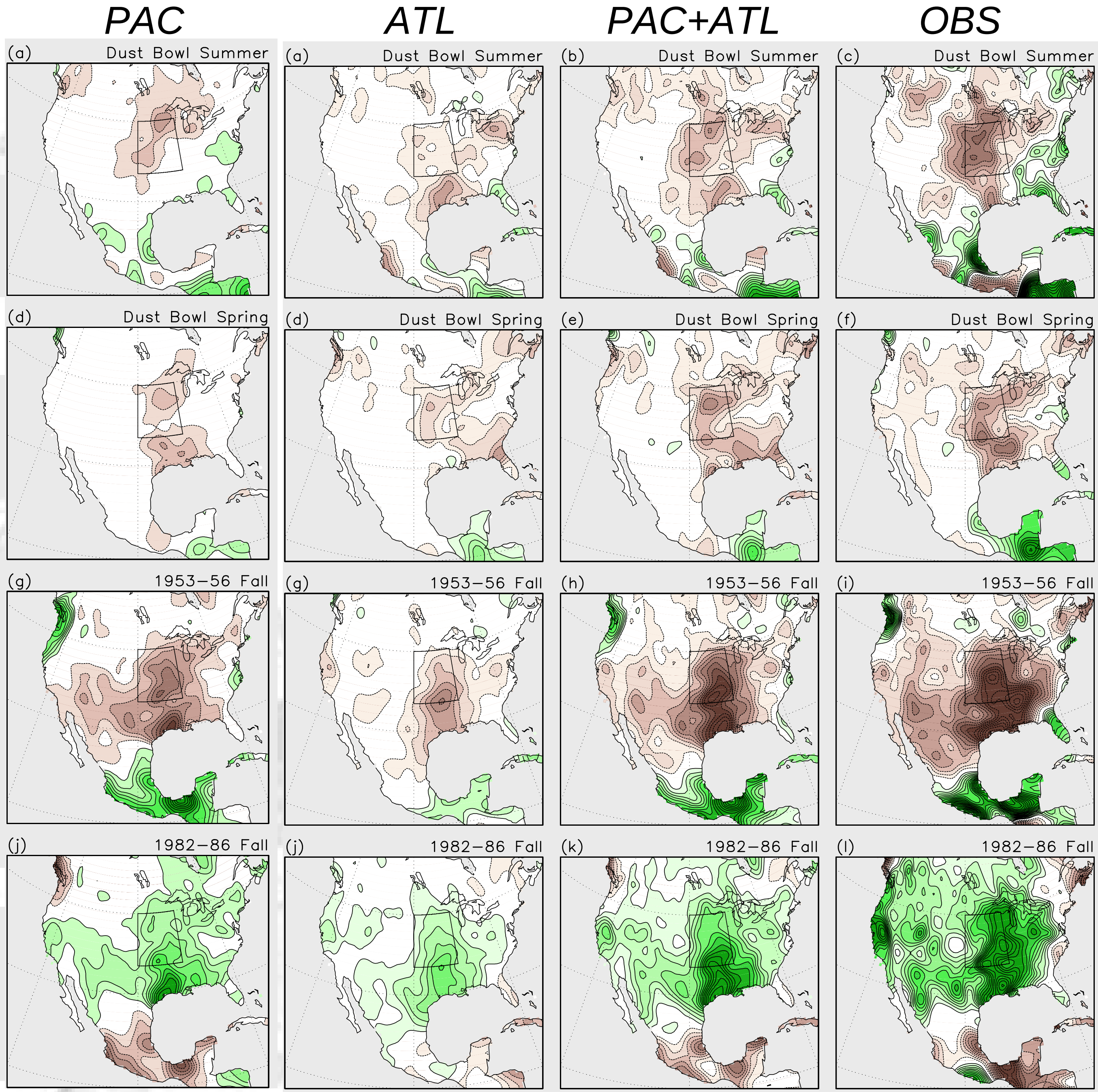
CI=0.1 mm/day

Dust Bowl
Summer

Dust Bowl
Spring

1950s
Drought
Fall
(Summer reconstruction FAILED)

1980s
Wet Period
Fall



SST Reconstruction

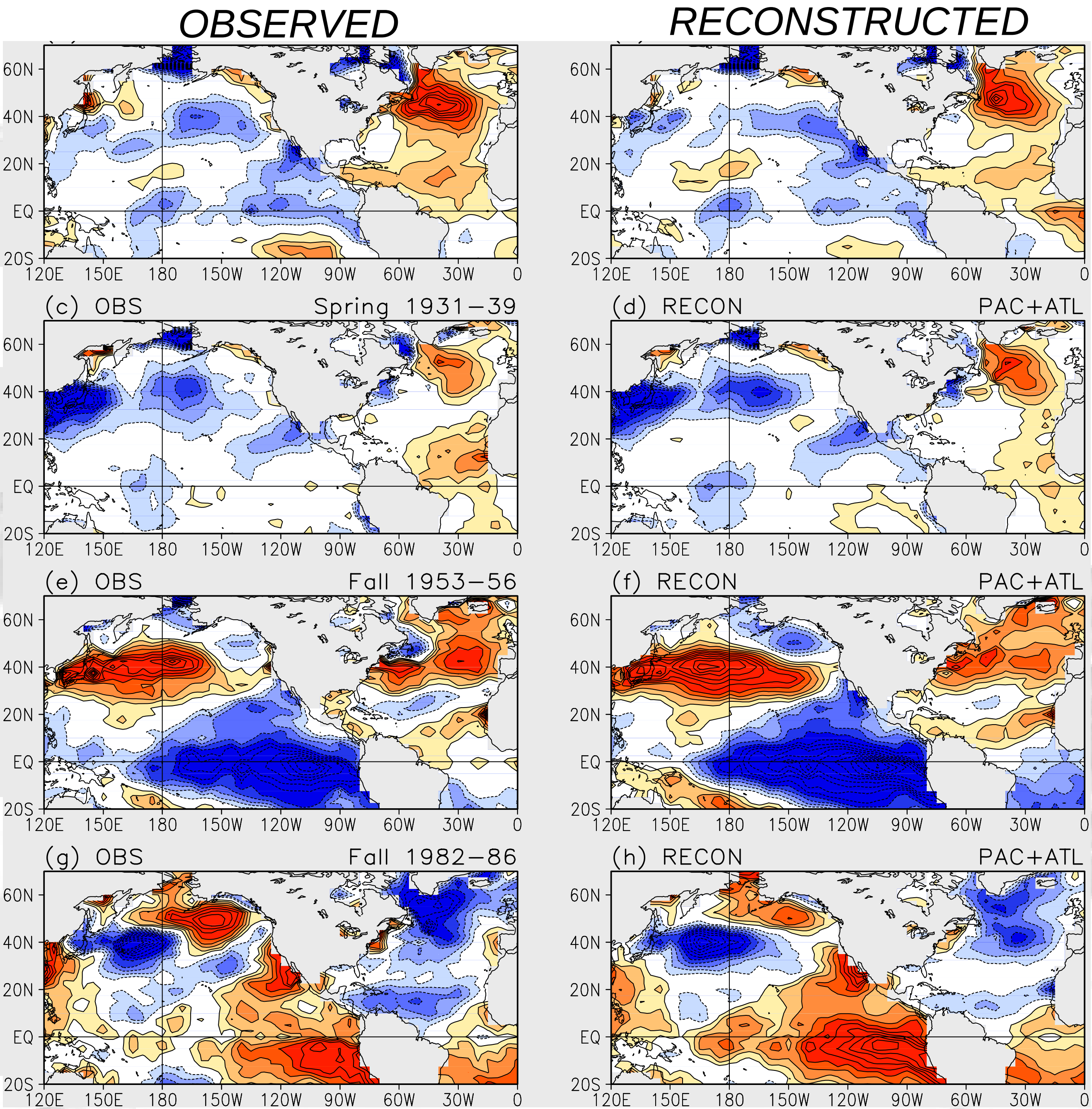
CI=0.1K

Dust Bowl
Summer

Dust Bowl
Spring

1950s
Drought
Fall

1980s
Wet Period
Fall



Percentage contribution of the Pacific and Atlantic SST modes to SEASONAL precipitation anomalies over the ***Great Plains*** ***(90–100W, 35–45N).***

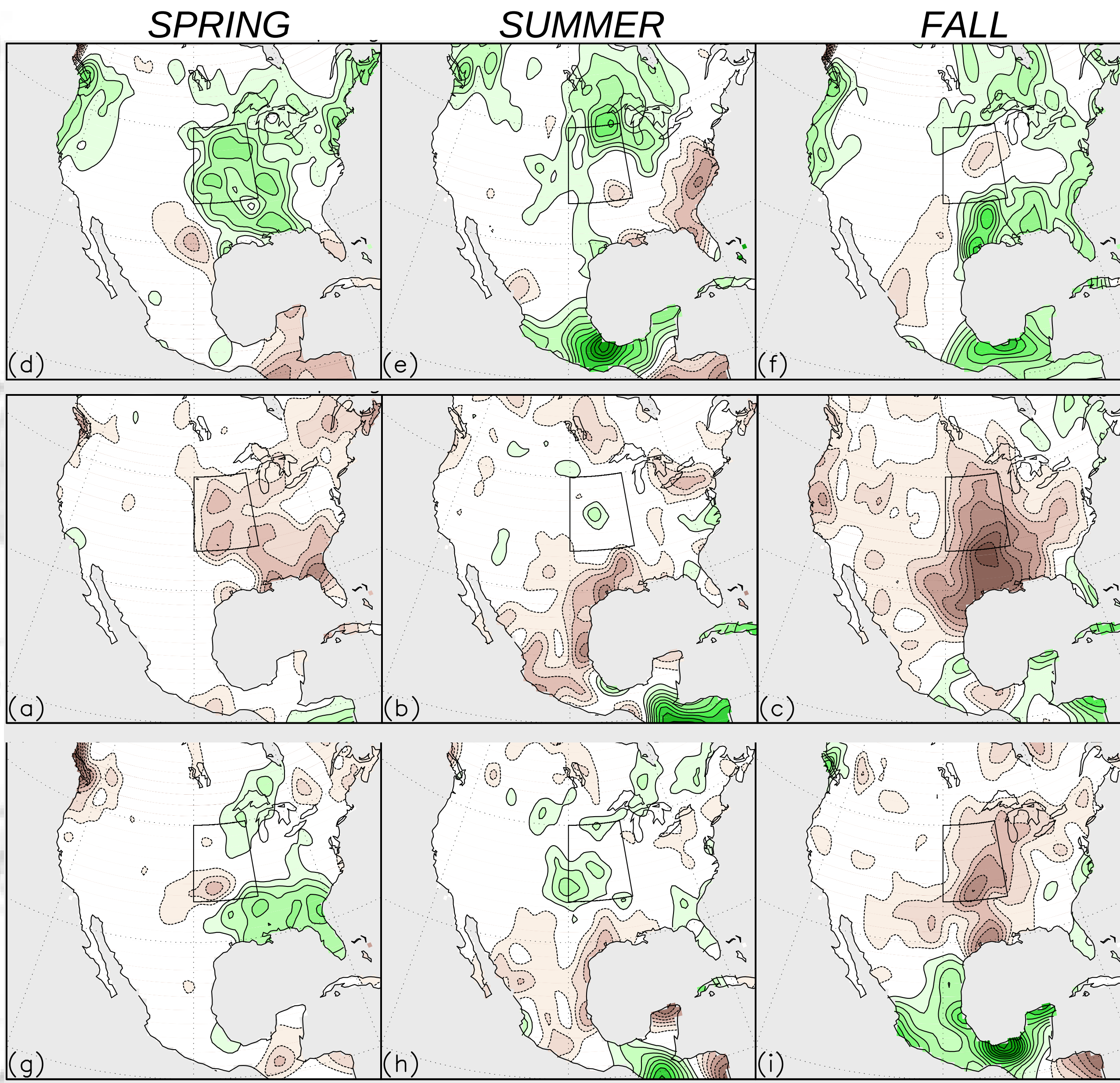
Case	Obs. Precip (mm/day)	Mode 1	Mode 2	Mode 3	Mode 4	*Sub Total*		*Total*
						ATLANTIC	***PACIFIC*.**	
1931–39 ***Summer***	−0.51	−3.0	20.2	9.4	1.7	28.3 (Mode-2)	**29.1 (ENSO-NC)**	**57.4**
1931–39 ***Spring***	−0.35	52.5	13.6	0.0	−15.5	**50.6 (Mode-1)**	39.5 (Trend)	**90.1**
1953–56 ***Fall***	−0.78	26.2	0.6	6.6	1.1	34.5 (Mode 1)	**49.3 PDV-NP**	**83.8**
1982–86 ***Fall***	0.82	37.3	−0.1	1.1	0.2	**38.5 (Mode-1)**	36.7 PDV-NP	**75.2**

SST-Hydroclimate Links

Secular Trend
Anticipated +ve

Atlantic EOF1
AMO-related; warm phase (+ve) since mid-90s

PDV-NP
in transition, to warm phase? (+ve)?



Synopsis

- Models are improving but still challenged in simulating the regional-to-subcontinental scale hydroclimate anomalies, especially in summer
- Insights into the SST potential can, perhaps, be obtained in the interim by mining the observational record itself
- An evolution-centric analysis of Pacific SSTs (and residual Atlantic SSTs) allows reconstruction of some summer/fall droughts and wet periods over the Great Plains, but is by no means unique
- To be insightful, empirical reconstruction will need grounding in mechanisms; analysis underway
- Observational analysis indicates an important role for the Atlantic basin SSTs (both tropical and extratropical) in North American summer/fall droughts

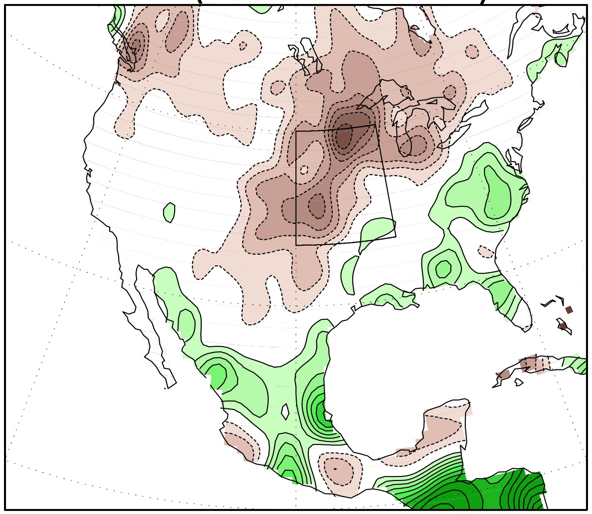
Reconstruction of Dust Bowl drought

From Pacific *Summer* SSTs

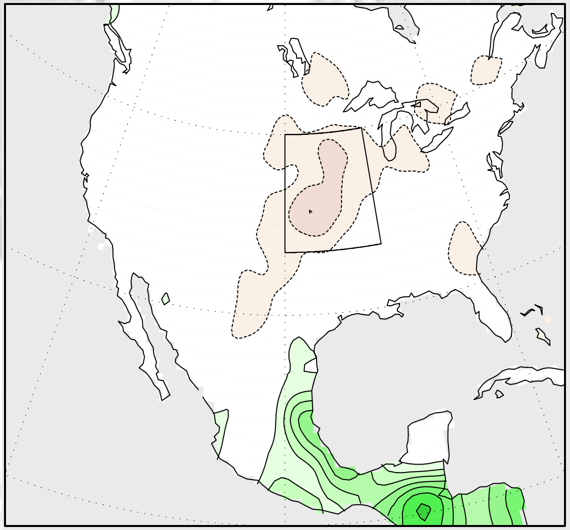
(Leading mode contributions)

CI=0.05 mm/day

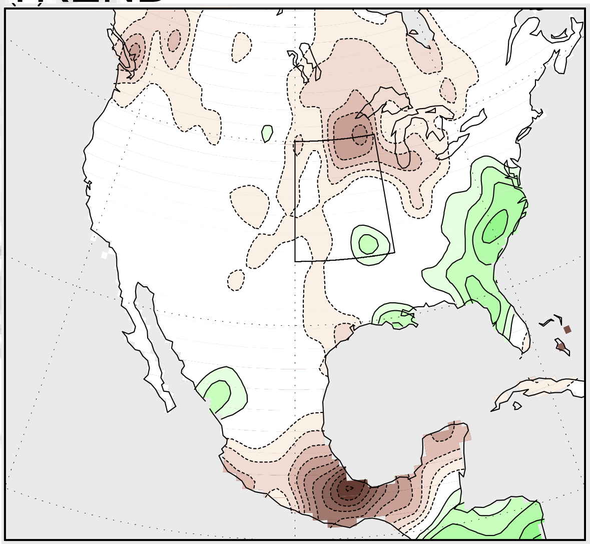
RECON (from all 7 PCs)



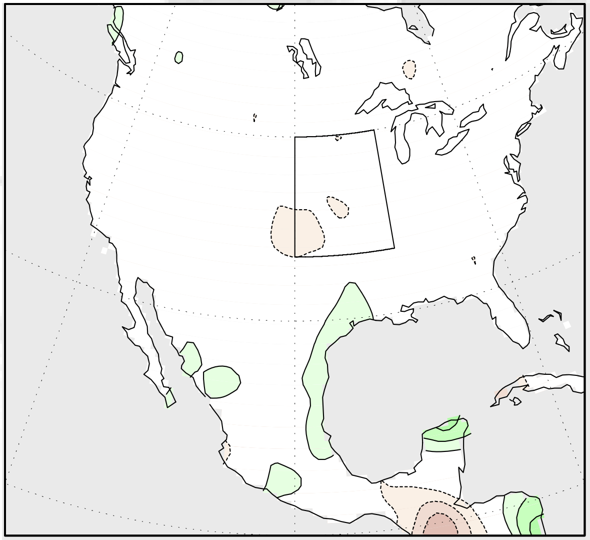
ENSO-NC



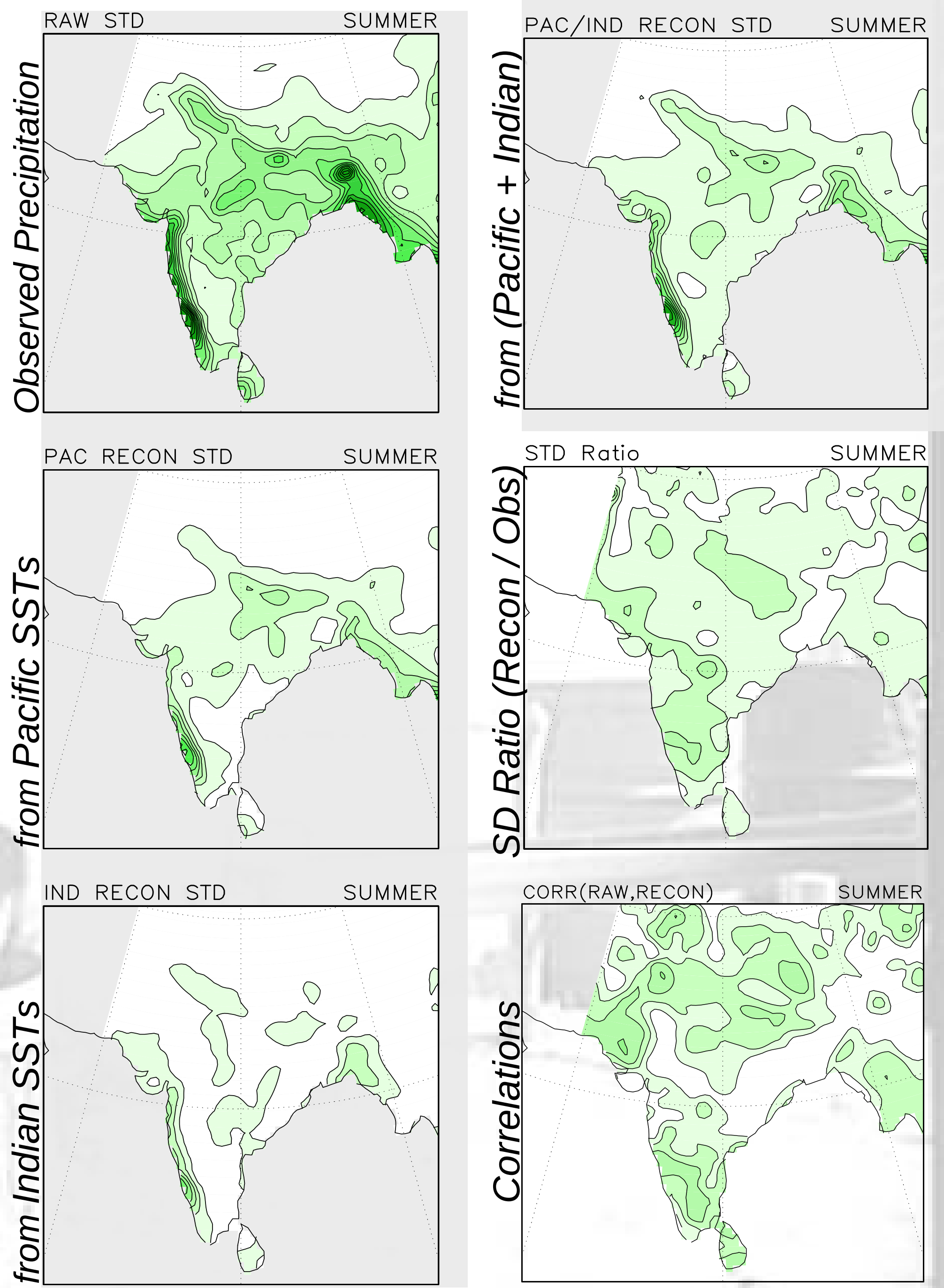
TREND



PDV-NP



Reconstruction of JJA Rainfall from Contemporaneous SST Links



Standard Deviation 1958-1997

CI = 0.5 mm/day

Shaded ≥ 0.5 mm/day

Standard Deviation Ratio

CI = 0.2 beginning at 0.4

Shaded ≥ 0.4

Correlation of RECON and OBS

CI = 0.1 beginning at 0.4

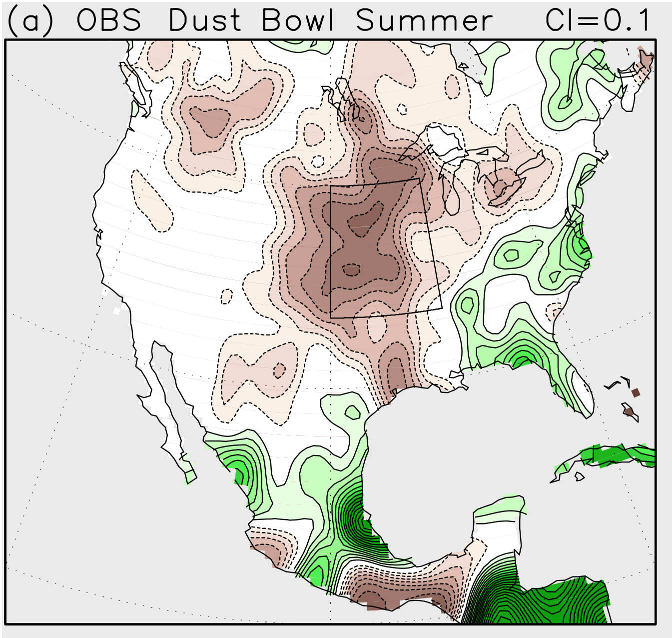
Shaded ≥ 0.4

Drought Modeling-III

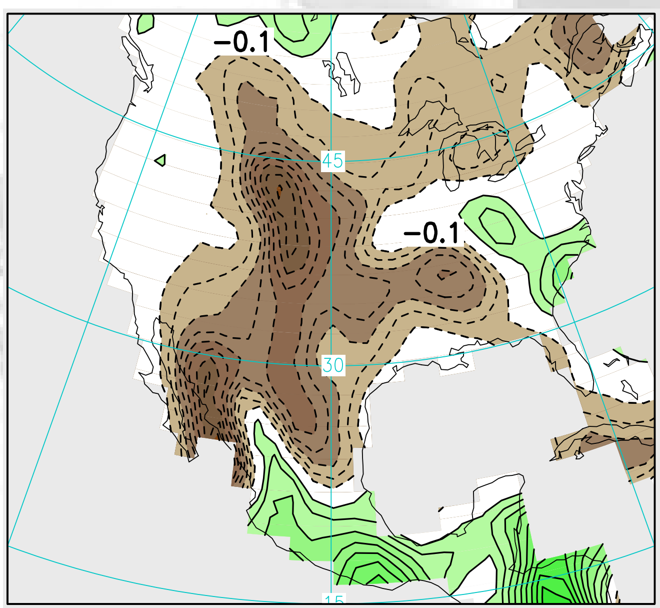
NCAR/CAM3.5 Simulation of the Dust Bowl (CVWG, 2008)

Summer precipitation anomaly (0.1 mm/day)

OBS



CAM3.5 (1 simulation)



Pan-Pacific <u>Decadal Variability</u>

SST Correlations
CI=0.1, beginning at 0.2

Features

- Clockwise development leading to ‘horse-shoe’ Pacific structure
- Quiescent central/eastern Eq. Pacific
- Strong links to the western Atlantic
- Modest link to the Indian Ocean
- Not “ENSO-like”
- Not the PDO either (r=0.23)
- Captures the 1920s climate shift
- Linked to the AMO?