Use of the Combined Pacific Variability Mode for Climate Prediction in North America

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Presentation Outline

Motivation for understanding what drives climate variability in our region

Current state of seasonal prediction

Development of a Pacific SST-based index for climate monitoring and prediction, emphasizing the monsoon

- Relationship of to monsoon interannual variability via retrospective RCM simulation
- Relationship to transient upper-level troughs

What may be in store for this year's monsoon

Concluding points and future directions

Cool season: Winter storms

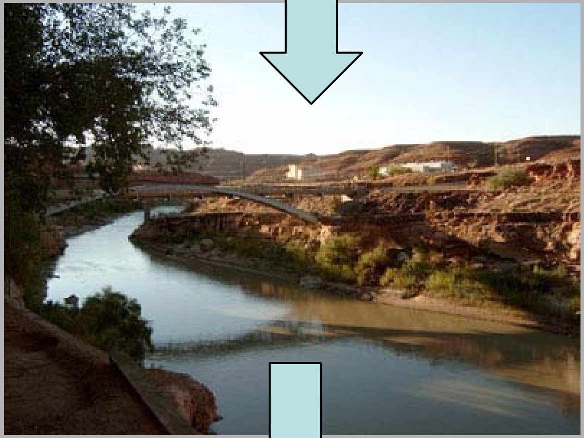
Primarily affects the amount of winter snowpack for water supply

Major control on long-term drought.

Seasonal forecasts are fairly good here because:

1. A well-known strong dependence on large-scale climate signals (e.g. ENSO).
2. Global forecasts models can resolve the associated teleconnection patterns + precipitation mechanisms good enough.

Snowpack in southern Rockies



Colorado River

CAP and Salt River Projects

Warm season: Monsoon

Sesaonal forecasts are typically worse here because GCMs do a far worse job representing warm season precipitation.

...BUT, large-scale teleconnections do still exist!

More important in Mexico, too!

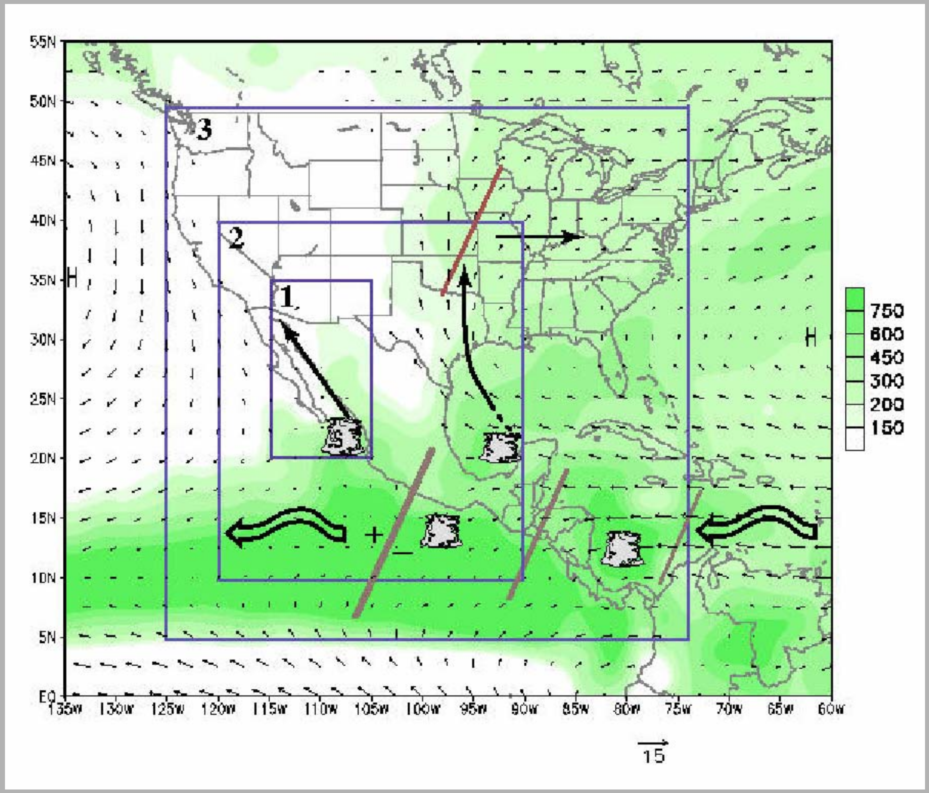
Severe weather

Wildfire

Water supply and demand

Ranching and agriculture

Principal factors to consider with respect to large-scale forcing of NAMS (Tiers II and III)



Mid-latitude teleconnections, forced principally by Pacific SST variability

Madden-Julian Oscillation

Synoptic transients: tropical easterly waves, inverted troughs, tropical cyclones

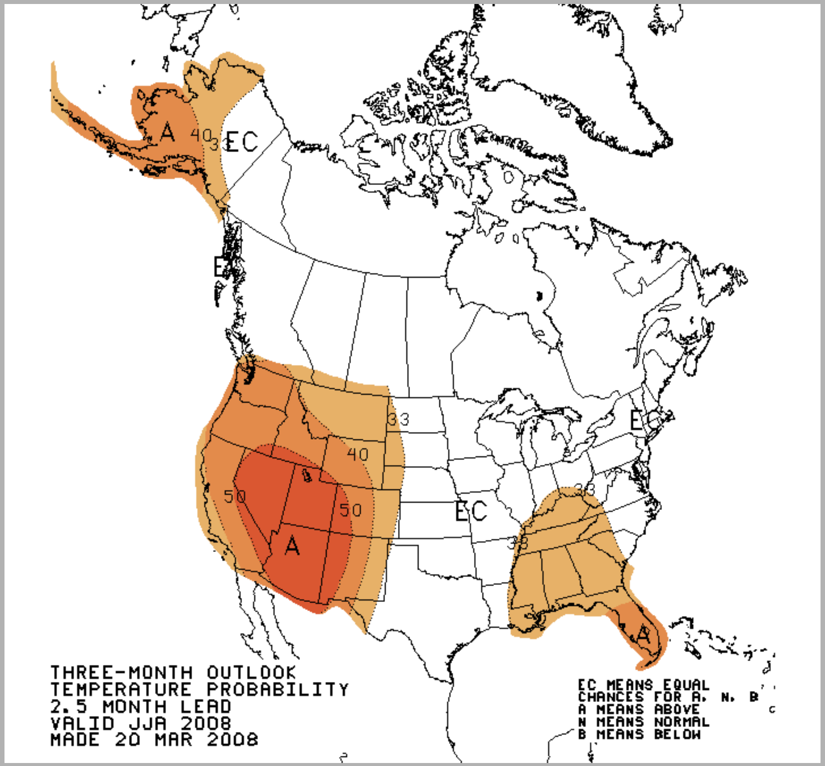
Moisture transport and possible teleconnections from Atlantic and inter-American seas

Land surface feedback processes

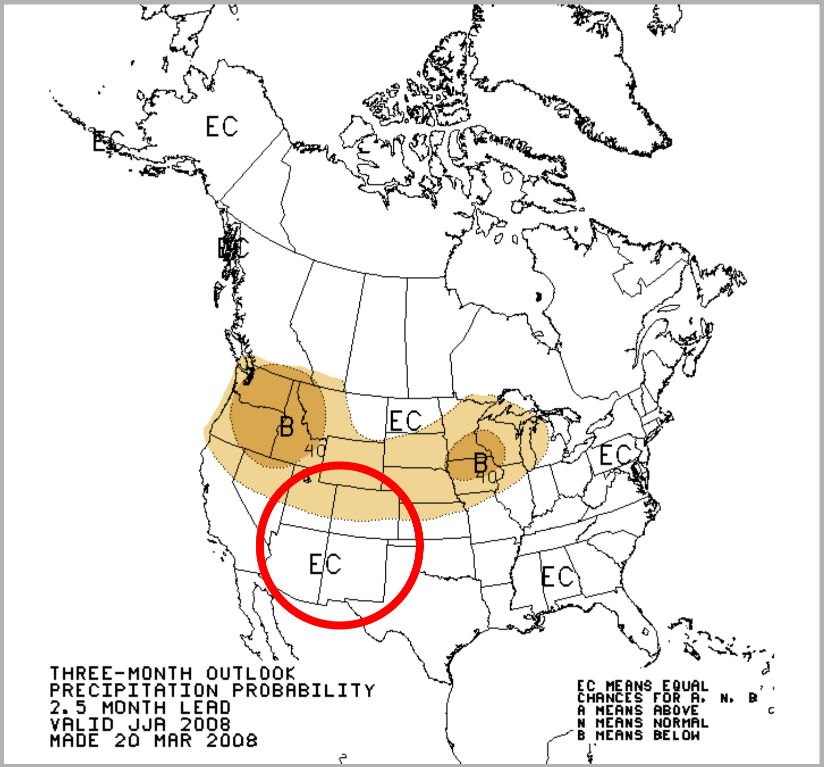
Anthropogenic climate change

THESE ARE LIKELY NOT INDEPENDENT OF EACH OTHER!

Current state of seasonal prediction: CPC Forecasts

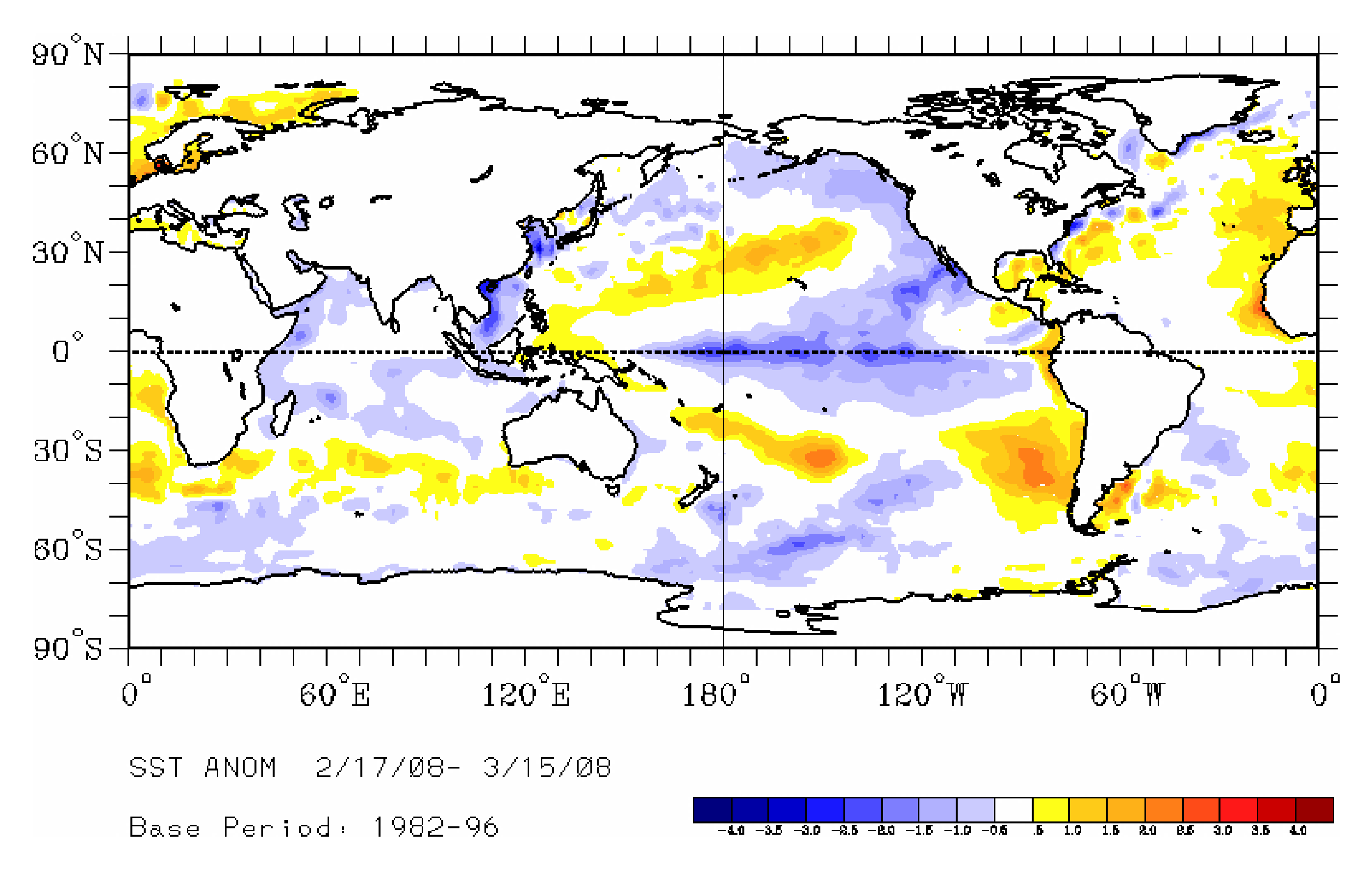


Temperature forecasts are becoming more dominated by long-term trends, probably due to climate change.



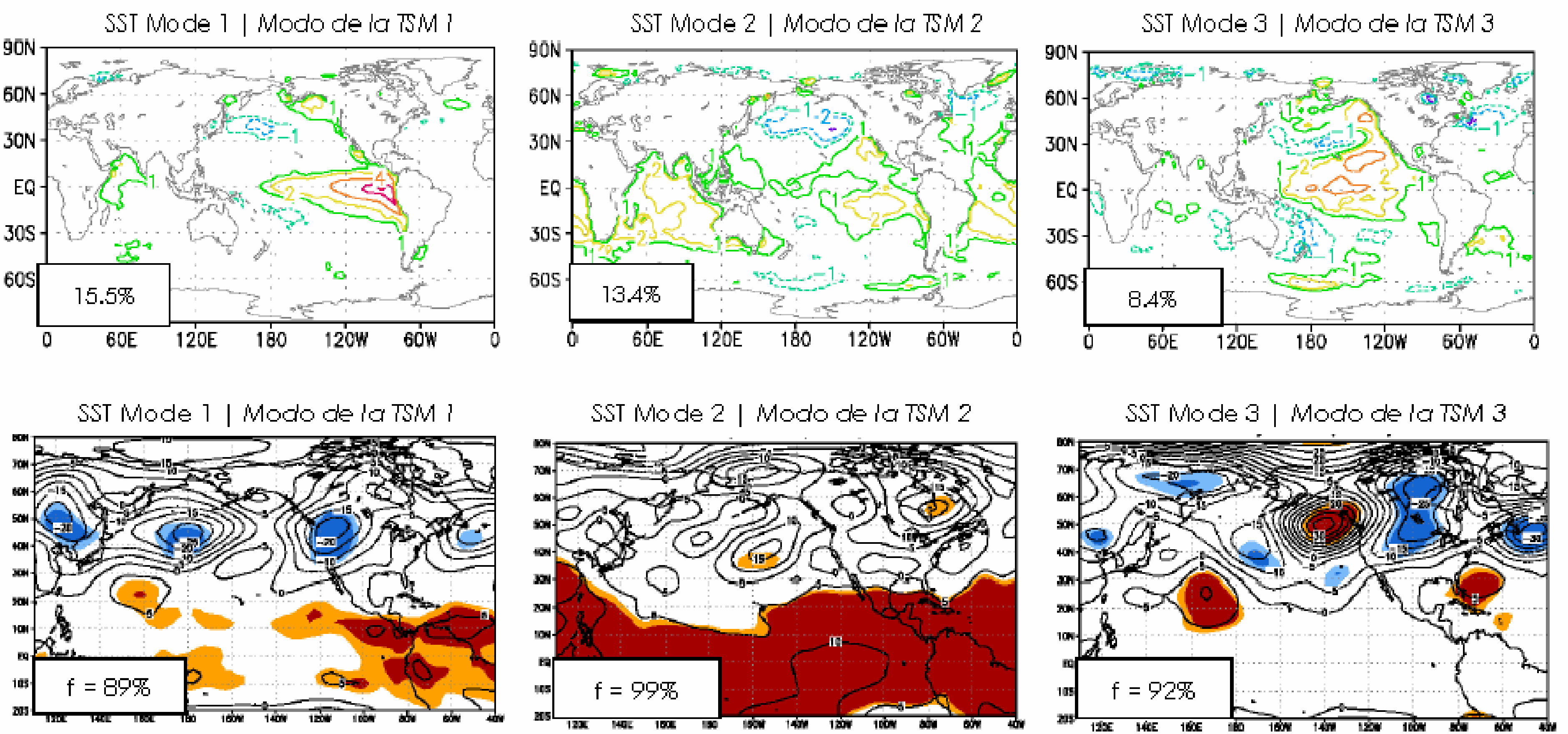
“Equal chances” for monsoon precipitation in the Southwest.

Current global SSTAs



Given a SSTA pattern like this, can we do better than an "equal chances" forecast for monsoon precipitation?

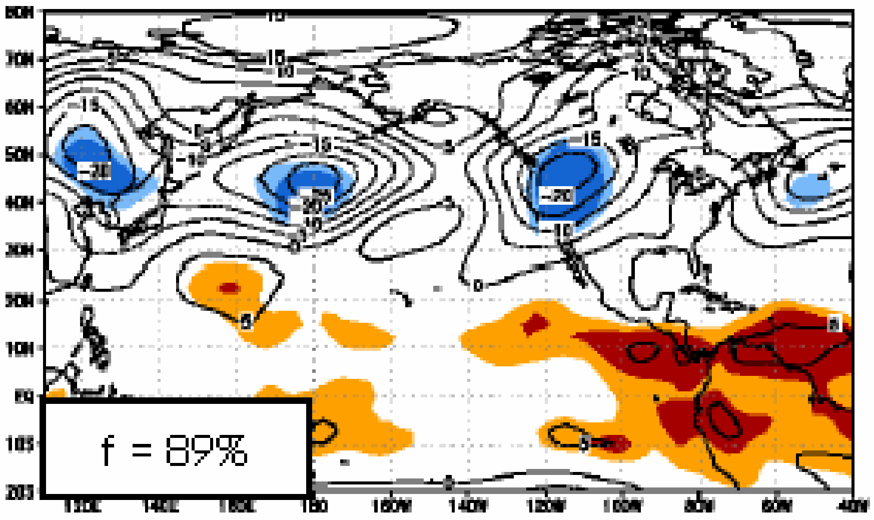
SST-based climate indices and corresponding 500-mb height anomalies at NAMS onset (late June, early July)



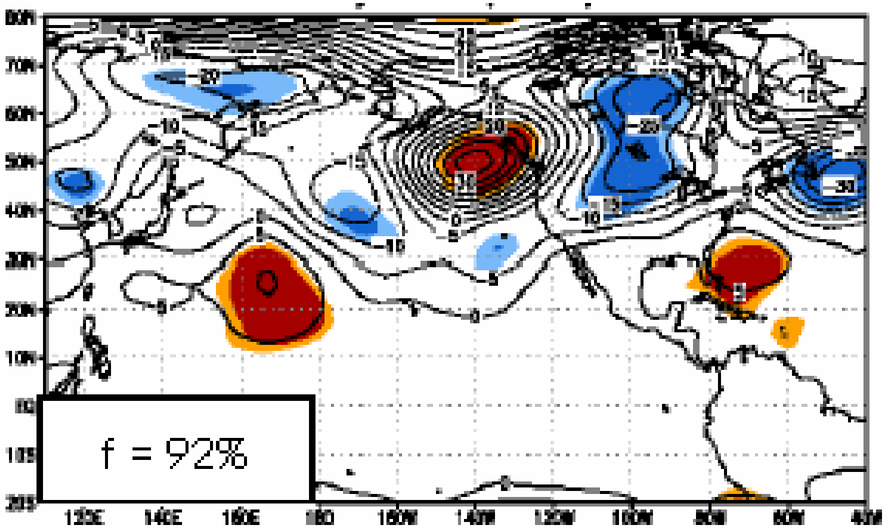
(Castro et al. 2007)

Summer teleconnections during monsoon onset related to Pacific SST variability

SST Mode 1 | *Modo de la TSM 1*



SST Mode 3 | *Modo de la TSM 3*



ENSO

Decadal variability (PDO-like??)

Monsoon Ridge Position at Onset (Late June, July)

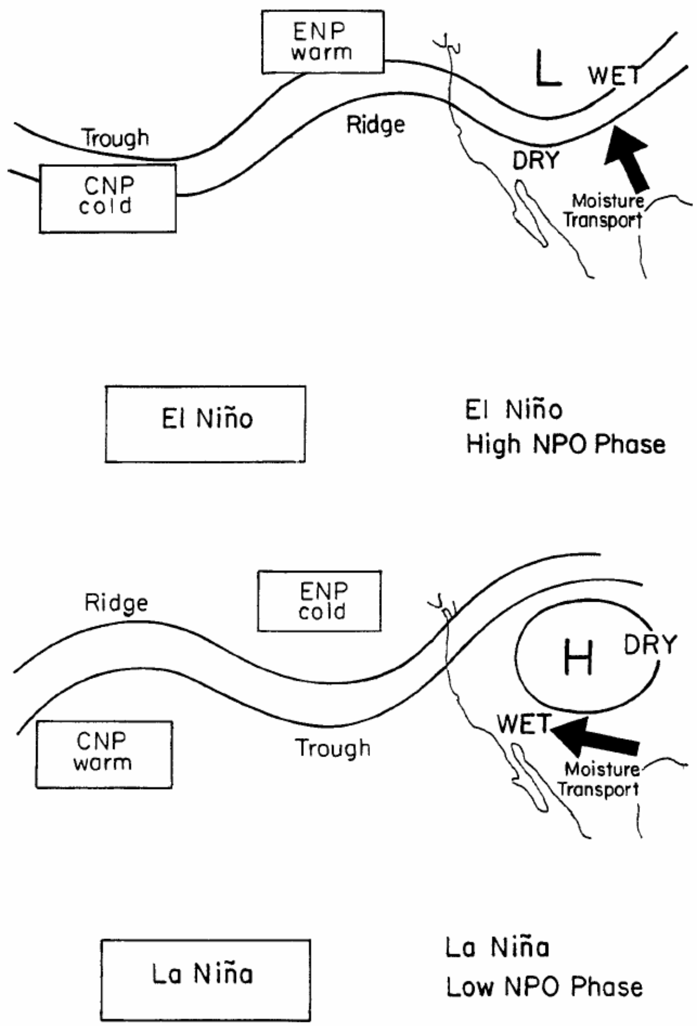


FIG. 14. Idealized relationship of monsoon ridge position and midlevel moisture transport to Pacific SSTs at monsoon onset.

Climatology delayed

Climatology accelerated

(Castro et al., 2001)

Combined Pacific Variability Mode (CPVM)

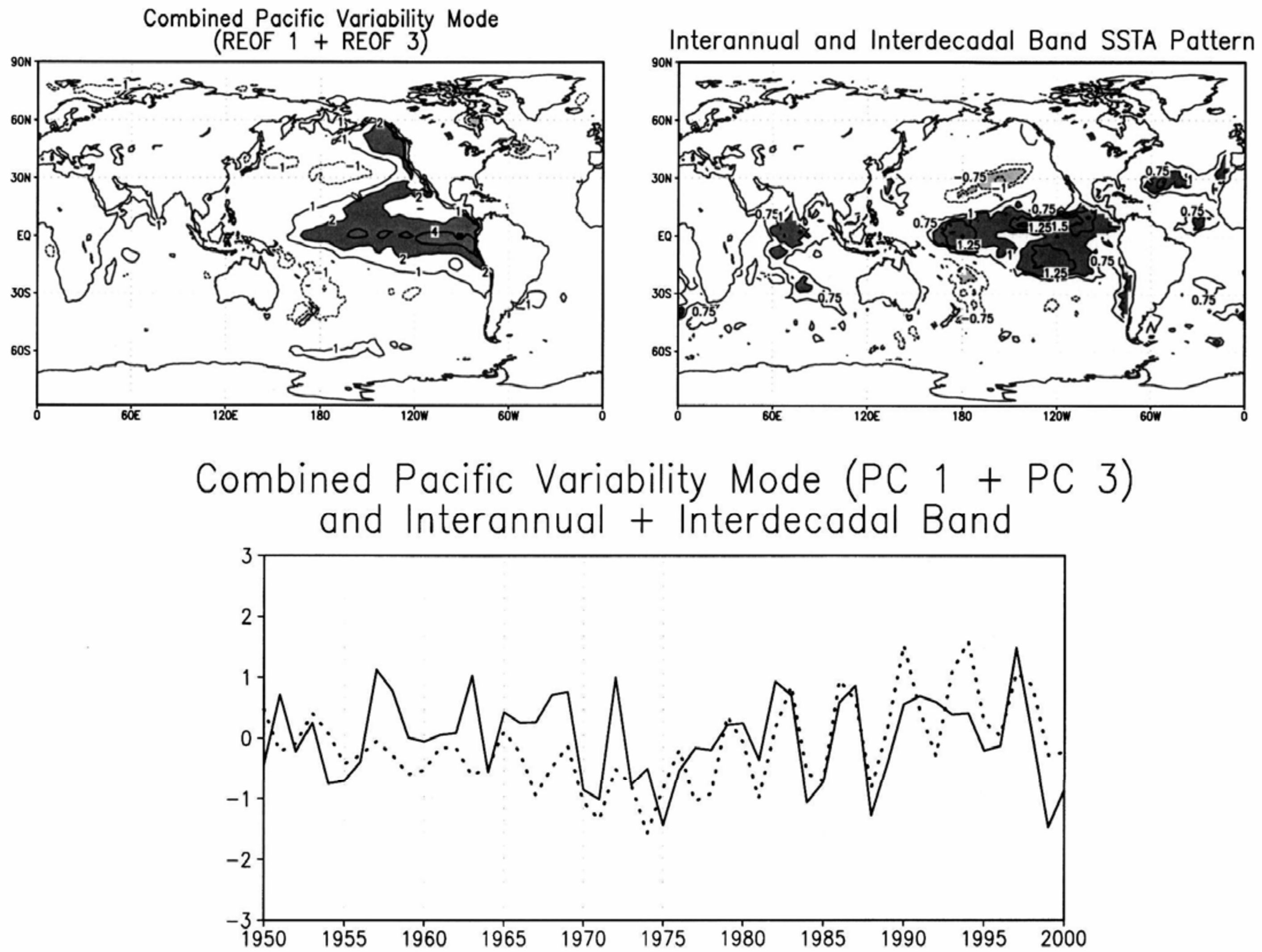


FIG. 4. As in Figs. 1 and 2 but for the combined Pacific variability mode and the combination of interannual and interdecadal band SSTA.

(Castro et al. 2007)

Similar looking SSTA patterns from NAMS-related studies Grantz et al. (2007)

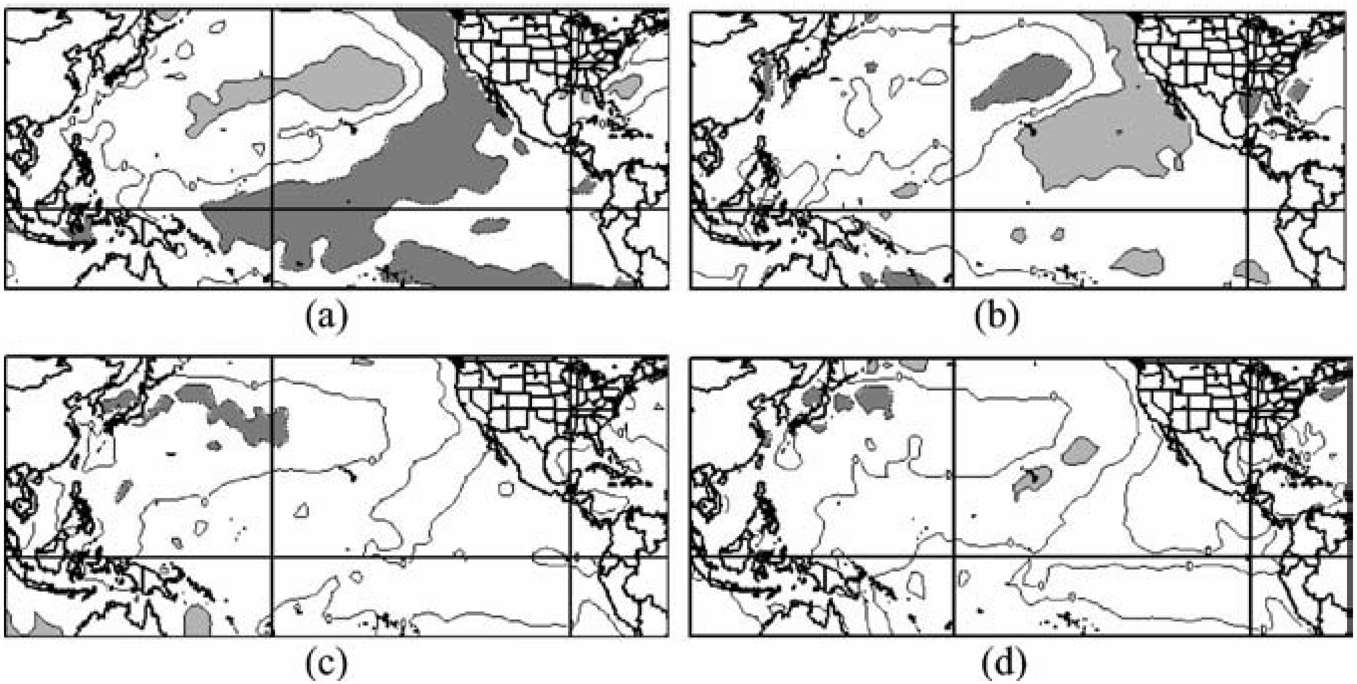


FIG. 10. Same as in Fig. 9 except for correlations between the winter–spring (December–May) SSTs and the first PC of the (a) July, (b) August, (c) September, and (d) July–September monsoon rainfall.

SSTA pattern in Hu et al. (2002)

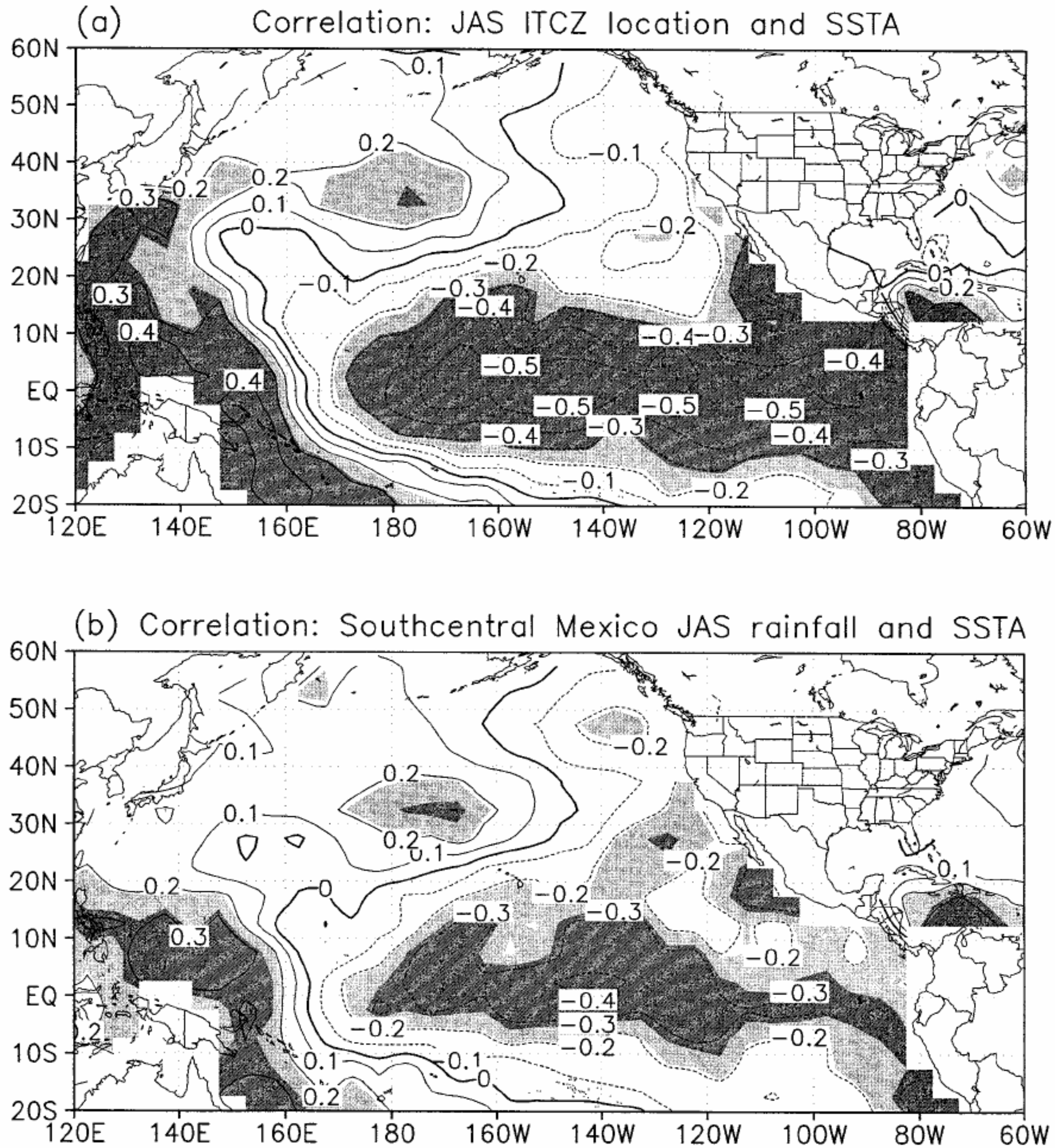


FIG. 4. (a) Distribution of the correlation of the JAS average ITCZ location vs the same-time SSTA in the North Pacific Ocean, and (b) distribution of the correlation of south-central Mexico JAS rainfall vs the same-time SSTA in the North Pacific Ocean (contour interval is 0.1, solid line for positive correlation, and dashed line for negative correlation). Light (dark) shading indicates 95% (99%) confidence level of correlation.

SST Modes related to wet and dry conditions in the central U.S (Schubert et al. 2004)

The lower frequency mode is actually the more important one!

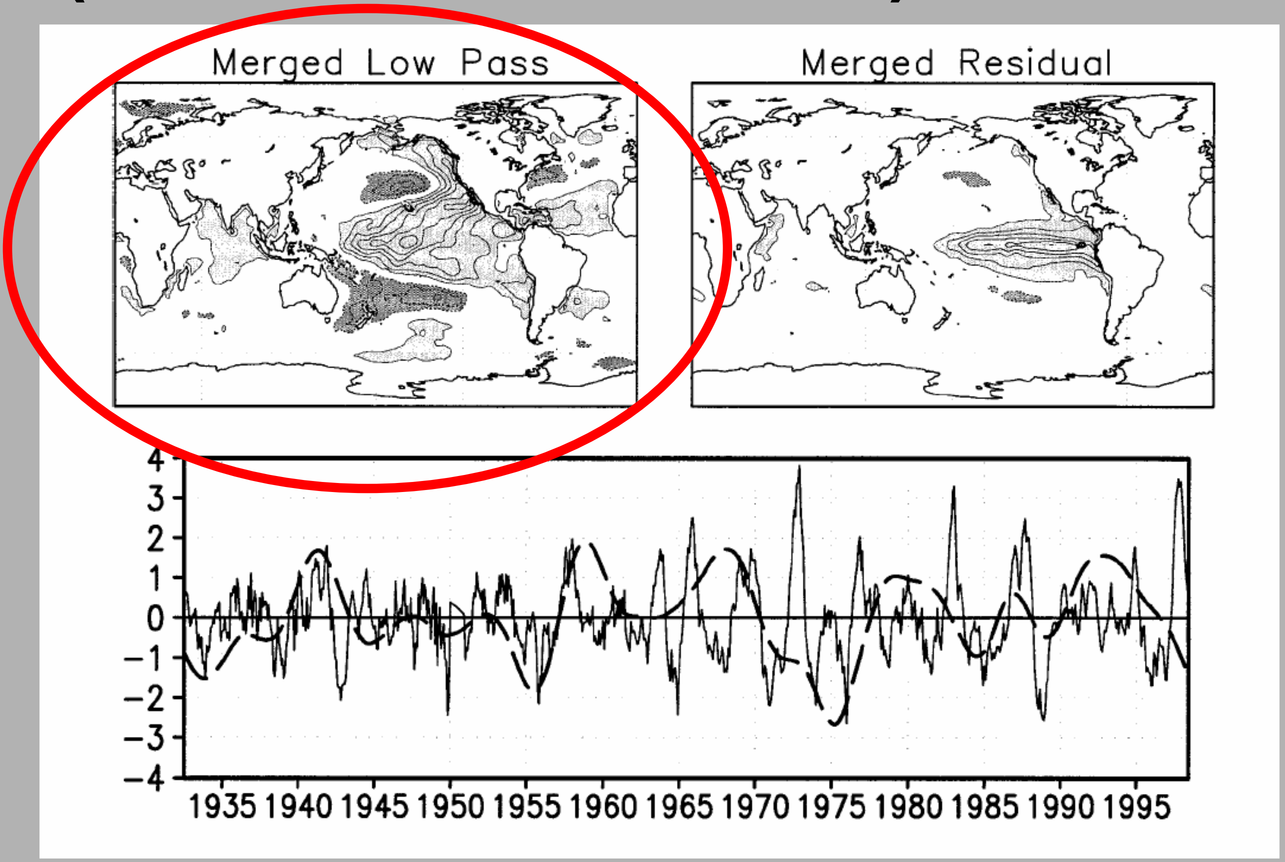
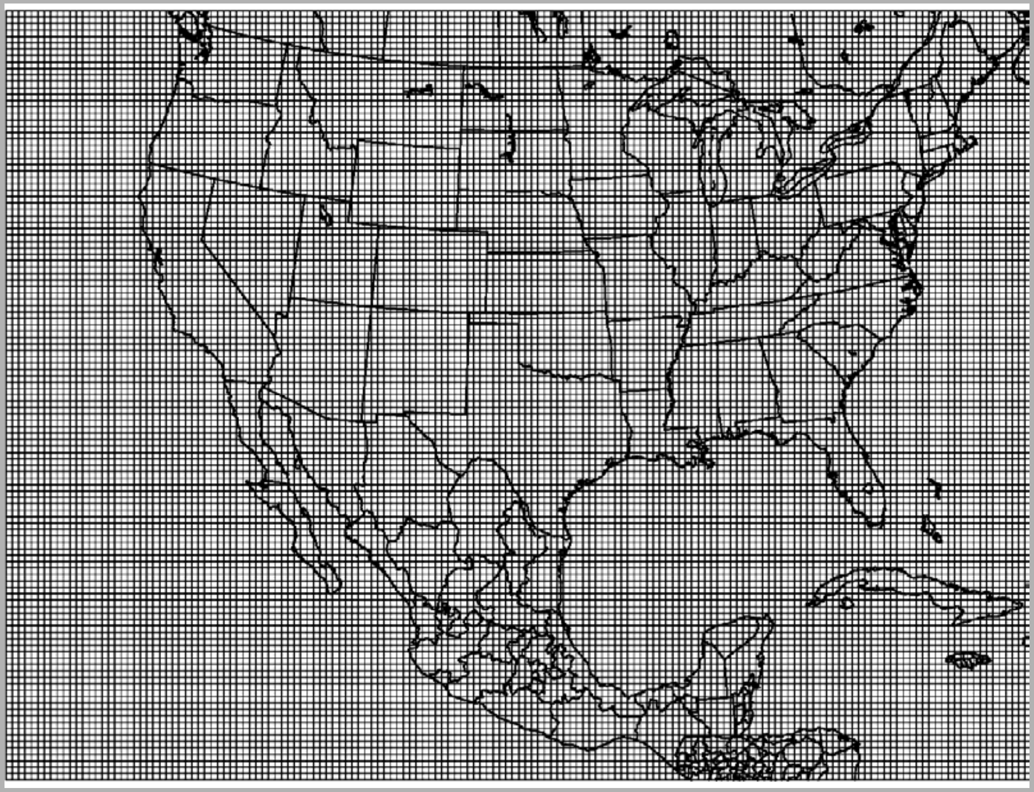


FIG. 4. (top left) The leading EOF of the low-pass-filtered (greater than 6 yr) merged SST for the period 1932–98. (top right) The leading EOF of the residual SST (unfiltered annual mean − low pass). Contour interval is 0.05 (top left) and 0.15 (top right). The zero contour is omitted. Negative values have dashed contours and dark shading. Positive values have solid contours and light shading. (middle) The time series of the PCs of the leading low-pass (heavy dashed curve) and residual (thin solid curve) merged SST EOFs. Units of the PCs are std devs. The product of the PCs and the spatial maps are given in units of °C. (bottom left) Same as (top left) but for the HadISST data. (bottom right) The difference between the leading low-pass SST EOFs computed from the merged and HadISSTs.

RAMS Setup for NAMS Study

(Castro et al. 2007, *J. Climate*)



Grid spacing: 35 km

160 x 120 grid points horizontal

30 grid points vertical

Simulation length: 15 May – 31 August

Years downscaled: 1950-2002 (using retrospective NCEP reanalysis)

30-day average precipitation anomalies associated with CPVM through the summer

Simulated by the RCM

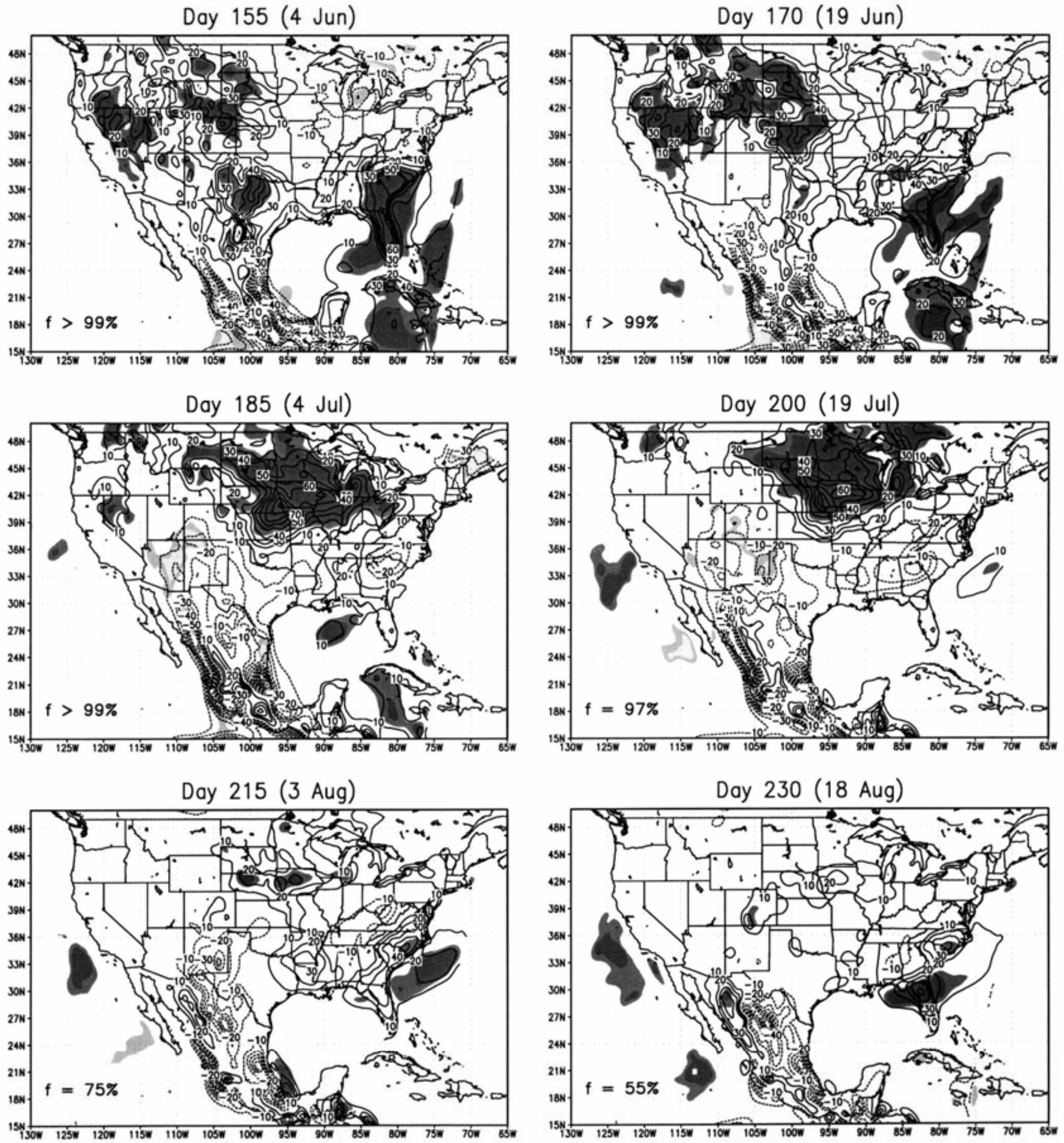
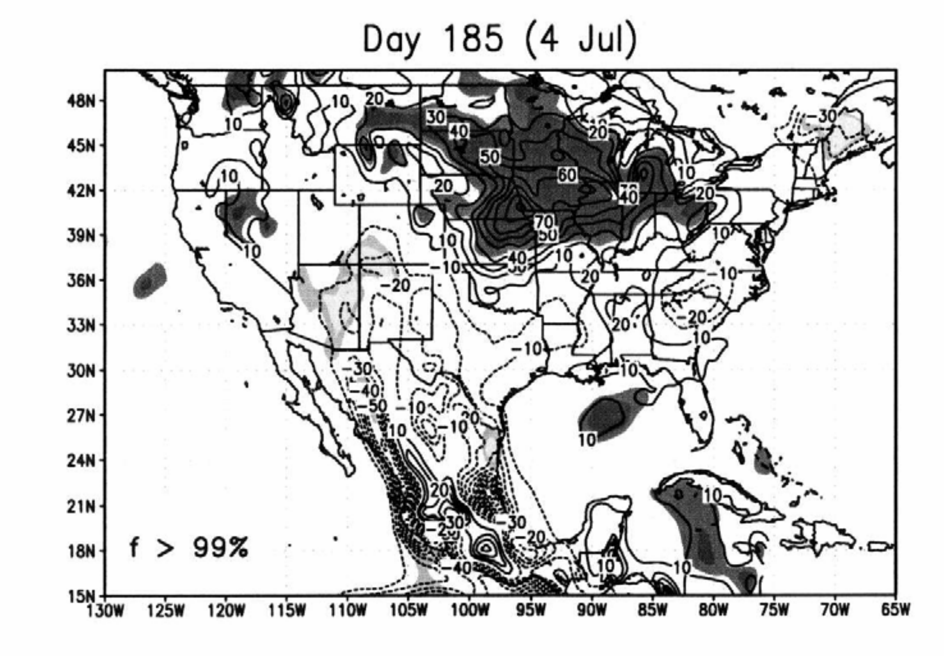


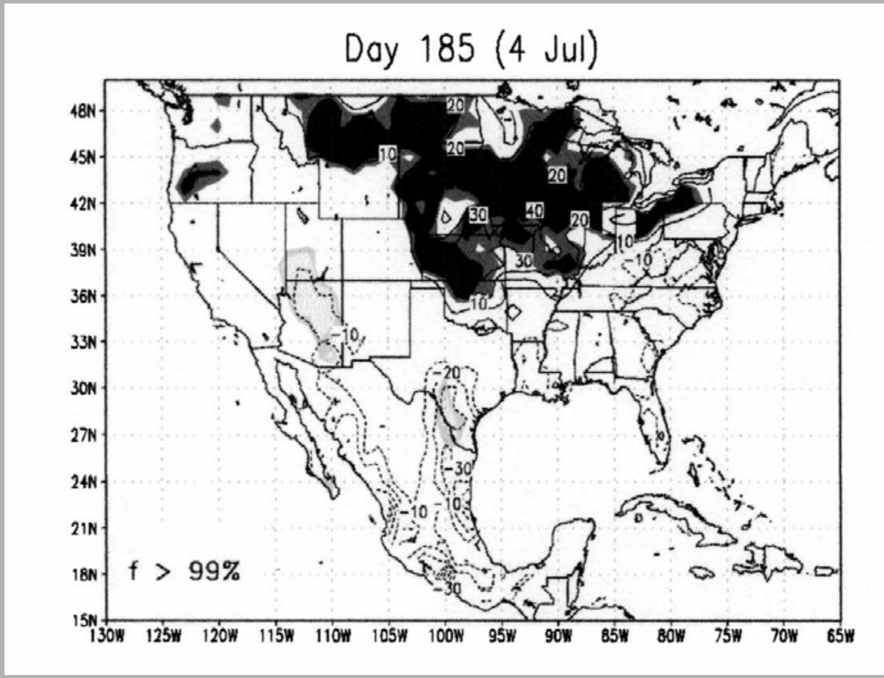
FIG. 8. Time evolution of 30-day average RAMS precipitation anomalies (mm) centered on the date for the combined Pacific variability mode composites in Table 4. Contour interval is 10 mm. Shading indicates local statistical significance at the 90% and 95% levels. Significant positive (negative) areas are shaded dark (light). Field significance (f) of shaded areas is indicated on each plot.

Focus to monsoon onset period

RCM Simulated



NCEP Obs. Precipitation



Similarity to Mo and Paegle (2000)

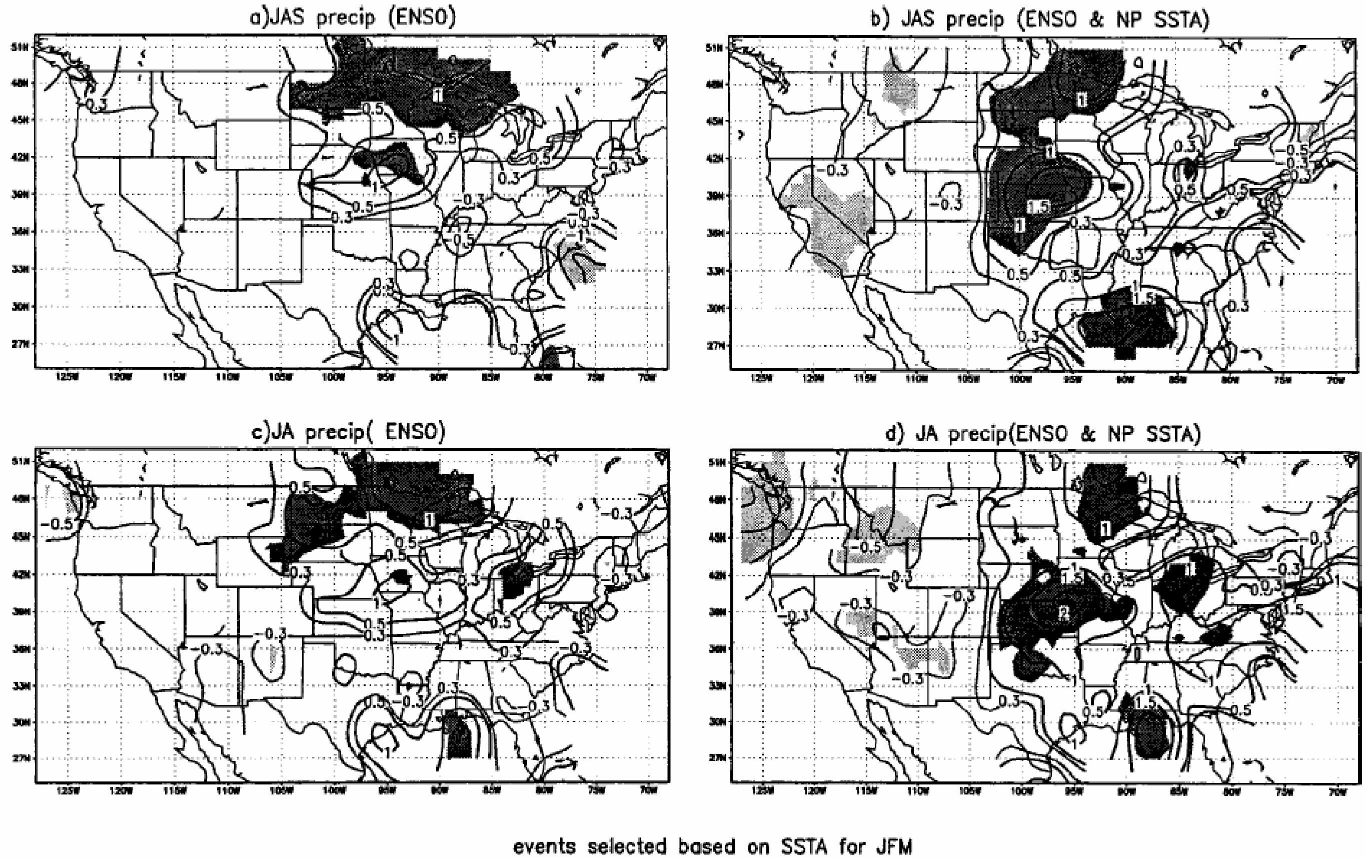
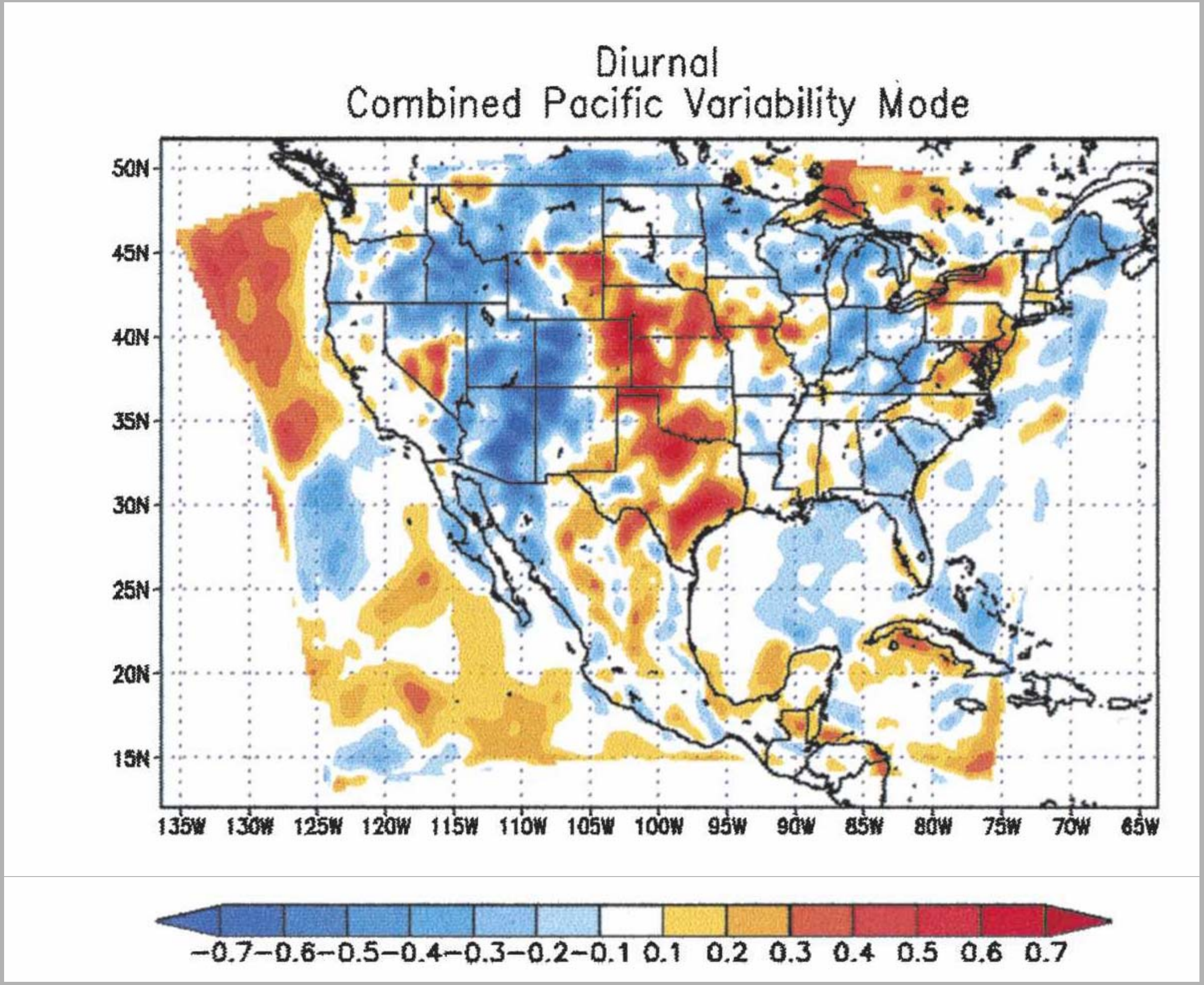


FIG. 9. (a) Precipitation composite difference between warm and cold ENSO events determined according to SSTA in the central Pacific for JAS (Fig. 4c). Contour interval is 0.5 mm day⁻¹. Zero contours are omitted. Contours −0.3 and 0.3 mm day⁻¹ are added. Areas, where positive (negative) values are statistically significant at the 95% levels are shaded dark (light), and (b) same as (a), but events are selected according to both SSTA in the central Pacific and the NP SSTA index, (c) same as (a), but for Jul and Aug and (d) same as (b), but for Jul and Aug.

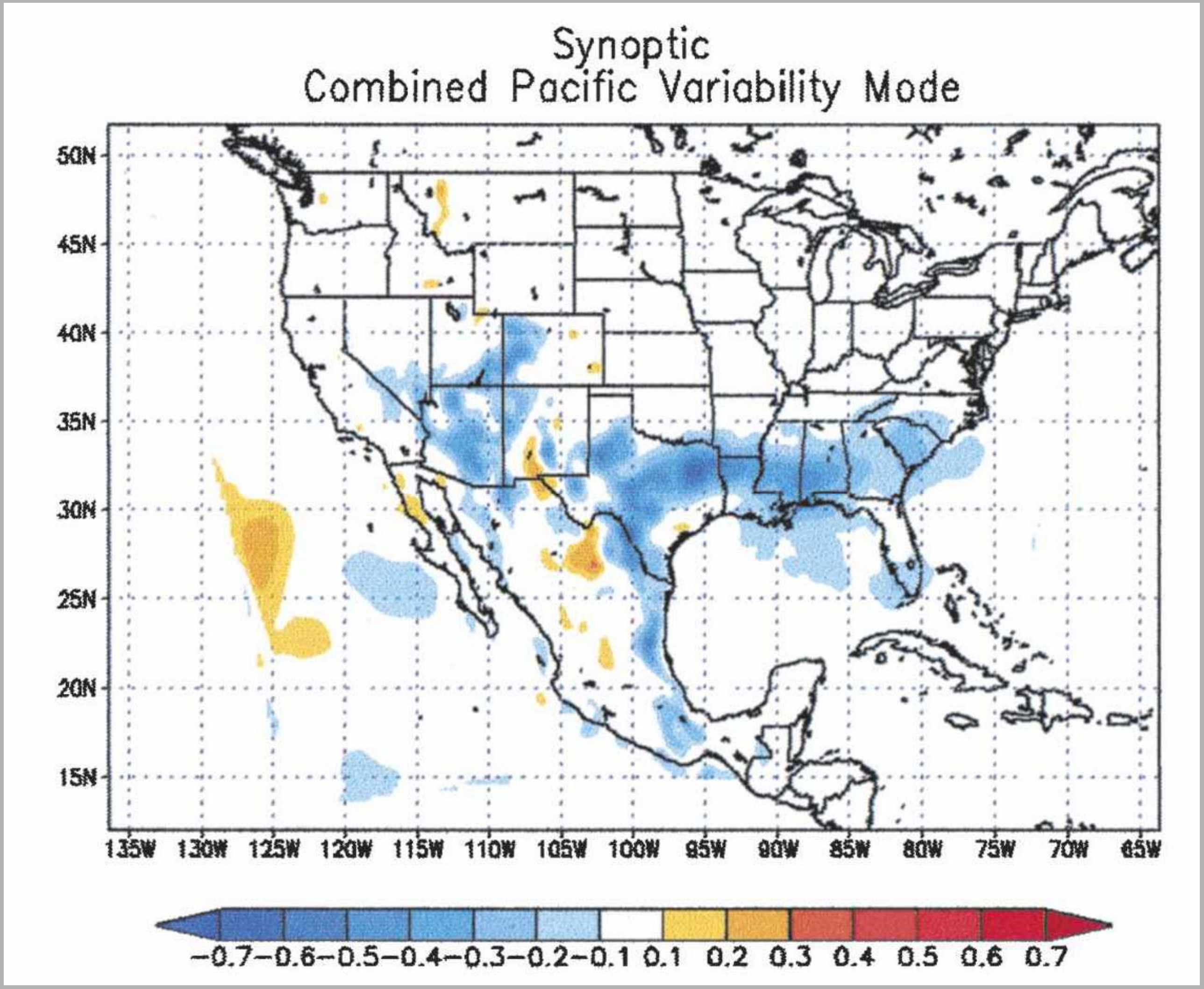
RCM-simulated change in diurnal moisture flux convergence associated with CPVM



Note:

Occurs during time of maximum teleconnectivity at monsoon onset

RCM simulated change in "synoptic" MFC (4-15 days) associated with CPVM



Similarly at time of maximum teleconnectivity

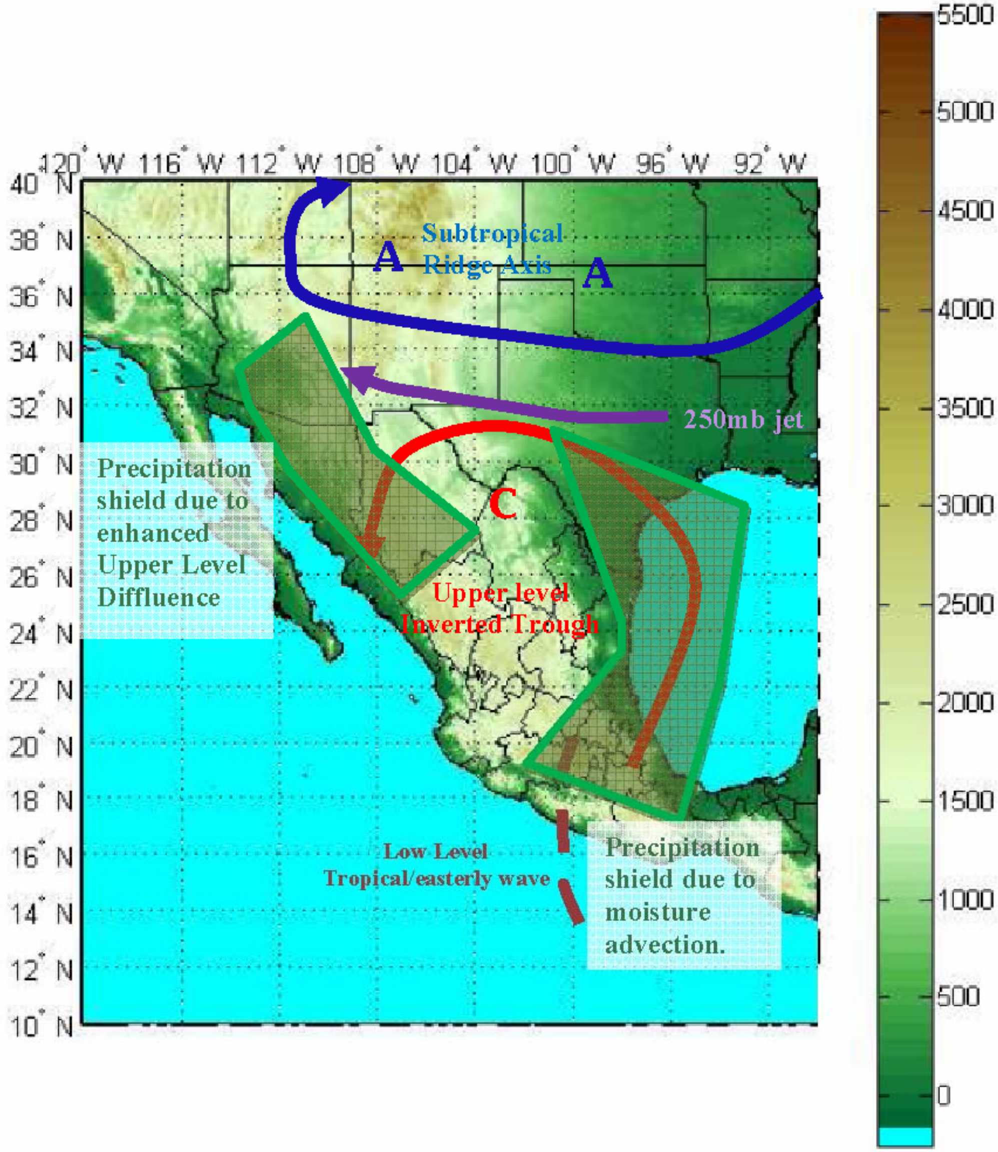
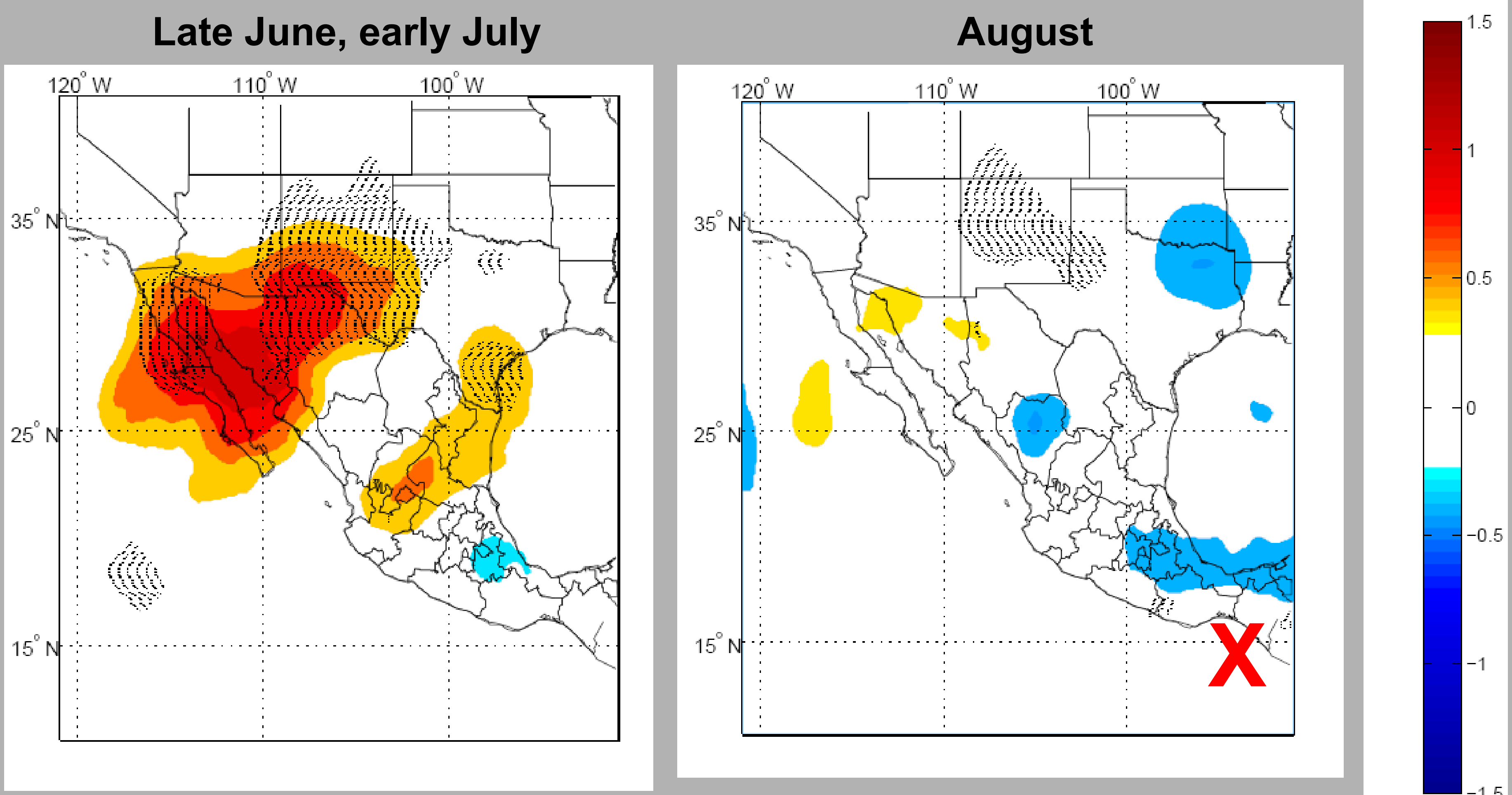


Figure 2: Conceptual Model of Inverted Troughs/Subtropical Ridge interaction, as presented in Pytlak et al. (2005), overlaid on topography of study region (terrain height in meters).

Subjectively determined presence of transient troughs in NARR data using methodology similar to Douglas and Englehart (2007).

Bieda et al. (2008, submitted)

Change in frequency of transient upper level troughs: negative minus positive CPVM years (1979-2003)



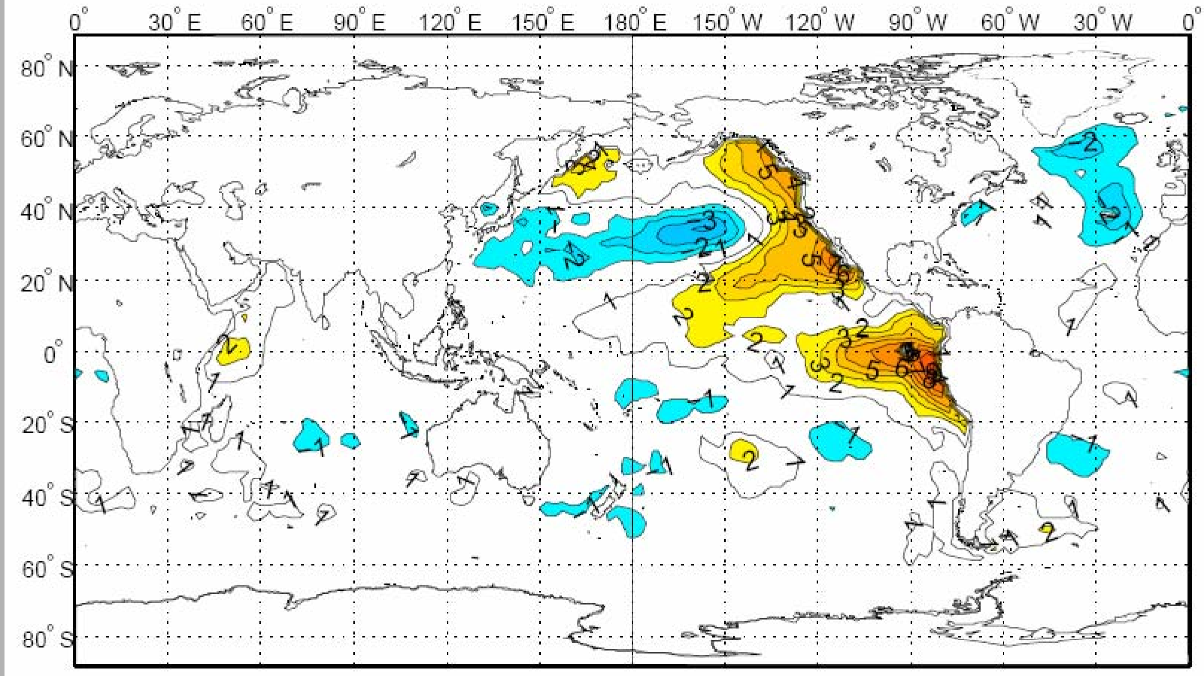
Is there a potential for more skillful NAMS prediction?

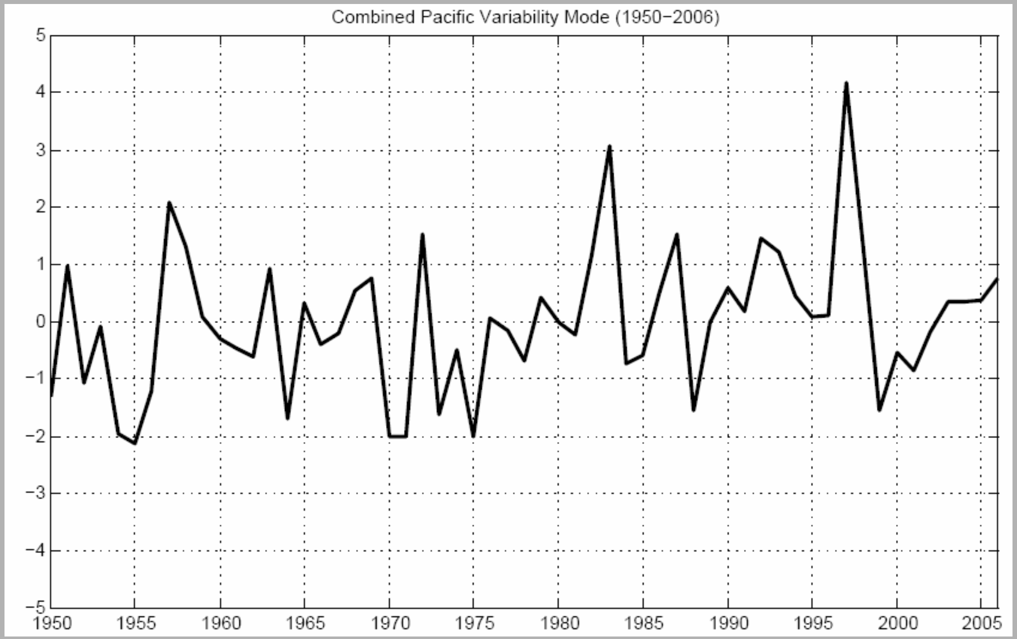
Statistical prediction: requires persistence of SST modes from antecedent winter and spring

Dynamical prediction: requires the above +

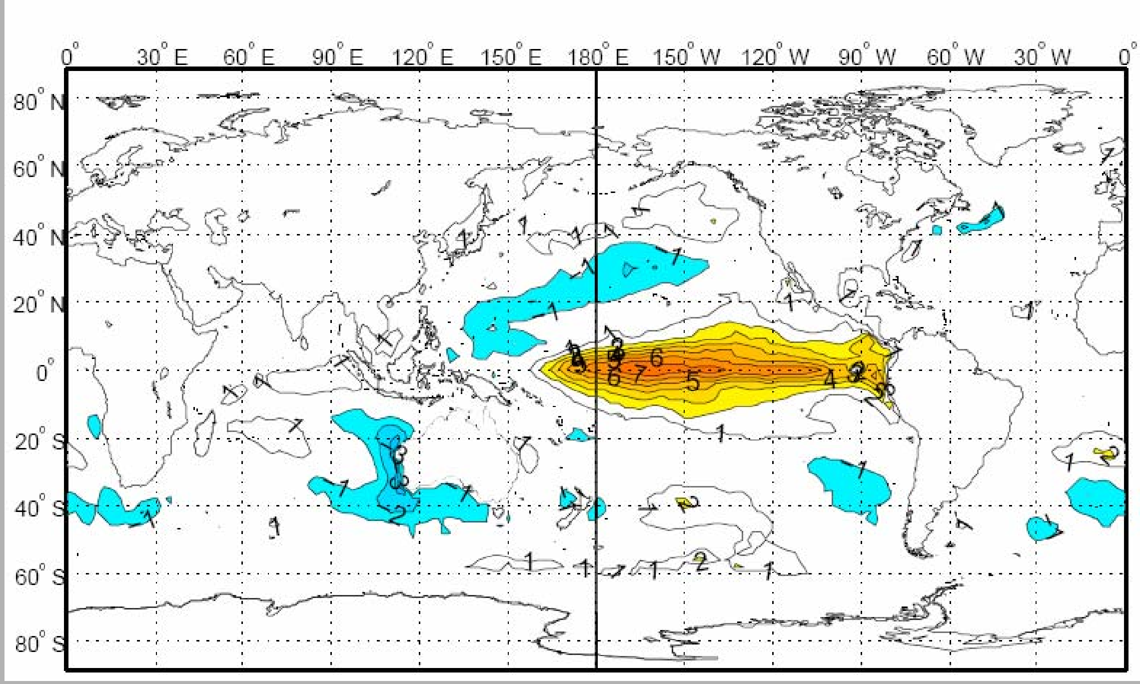
- •representation of summer teleconnections (+MJO??) in a GCM ensemble (e.g. in NCEP CFS model)
- •use of RCM or high resolution GCM to resolve summer rainfall processes

Summer CPVM: 1950-2006

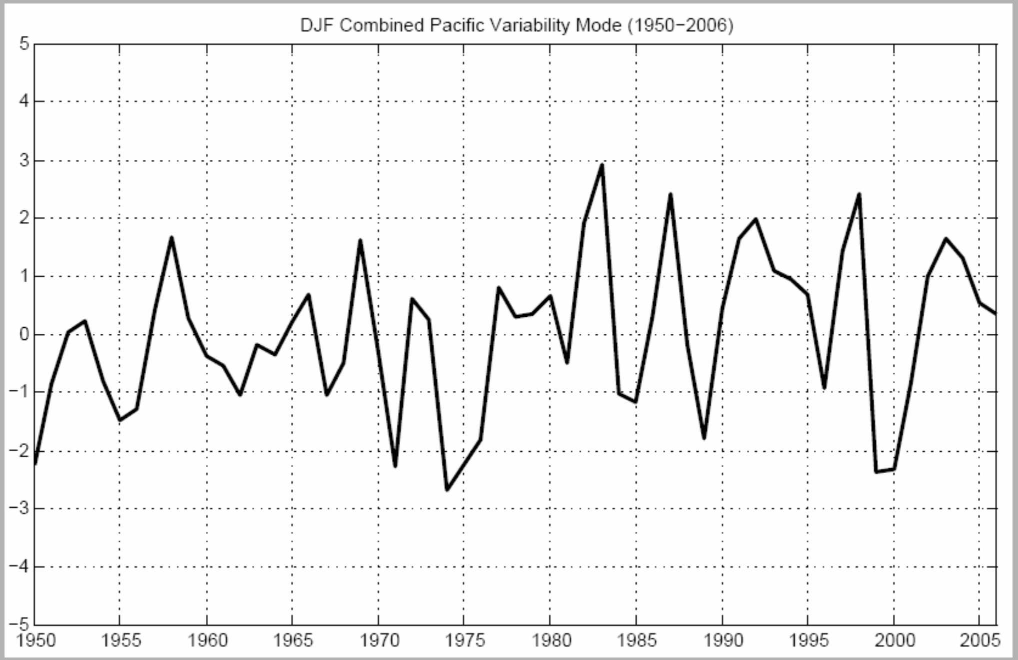




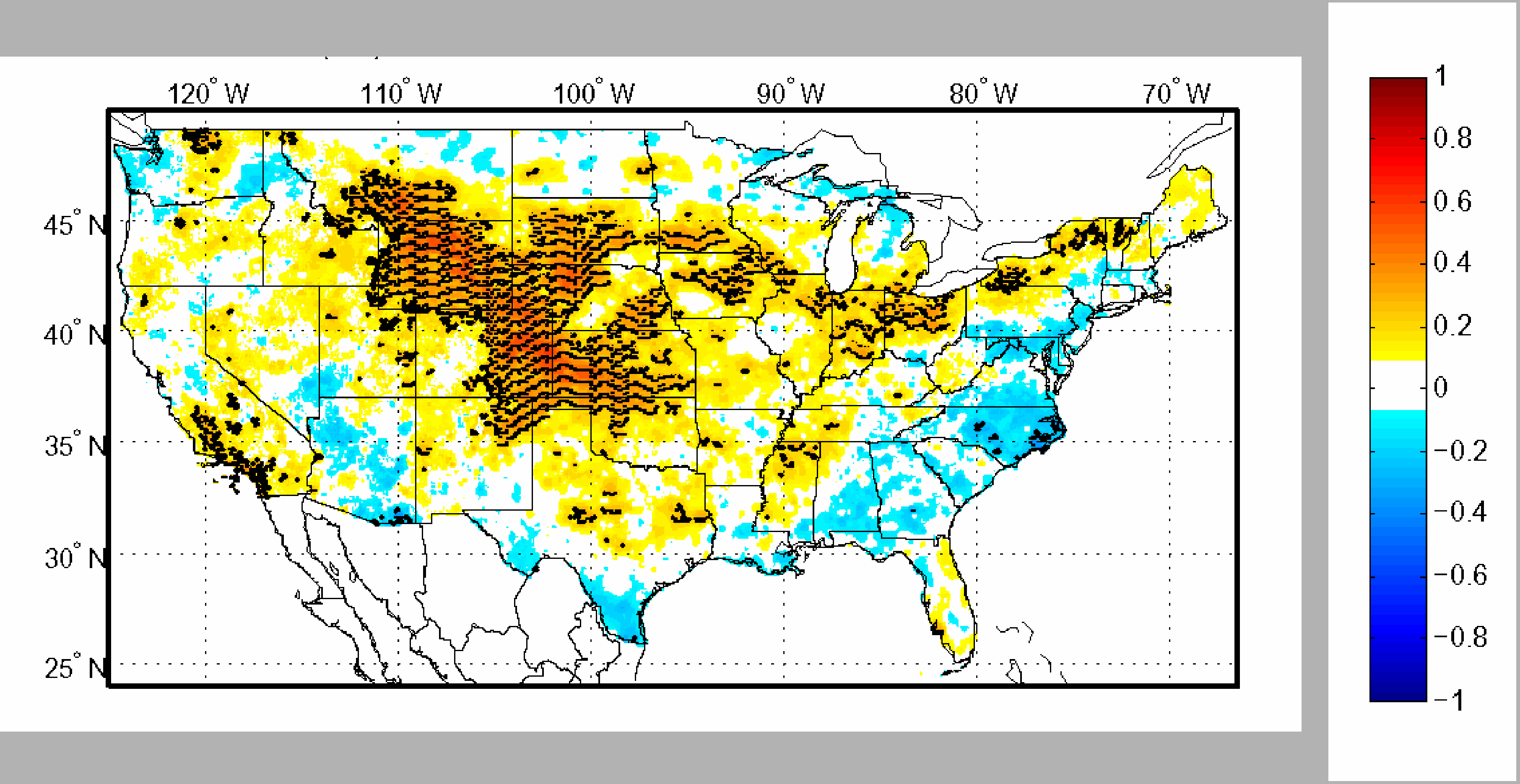
Antecedent winter CPVM



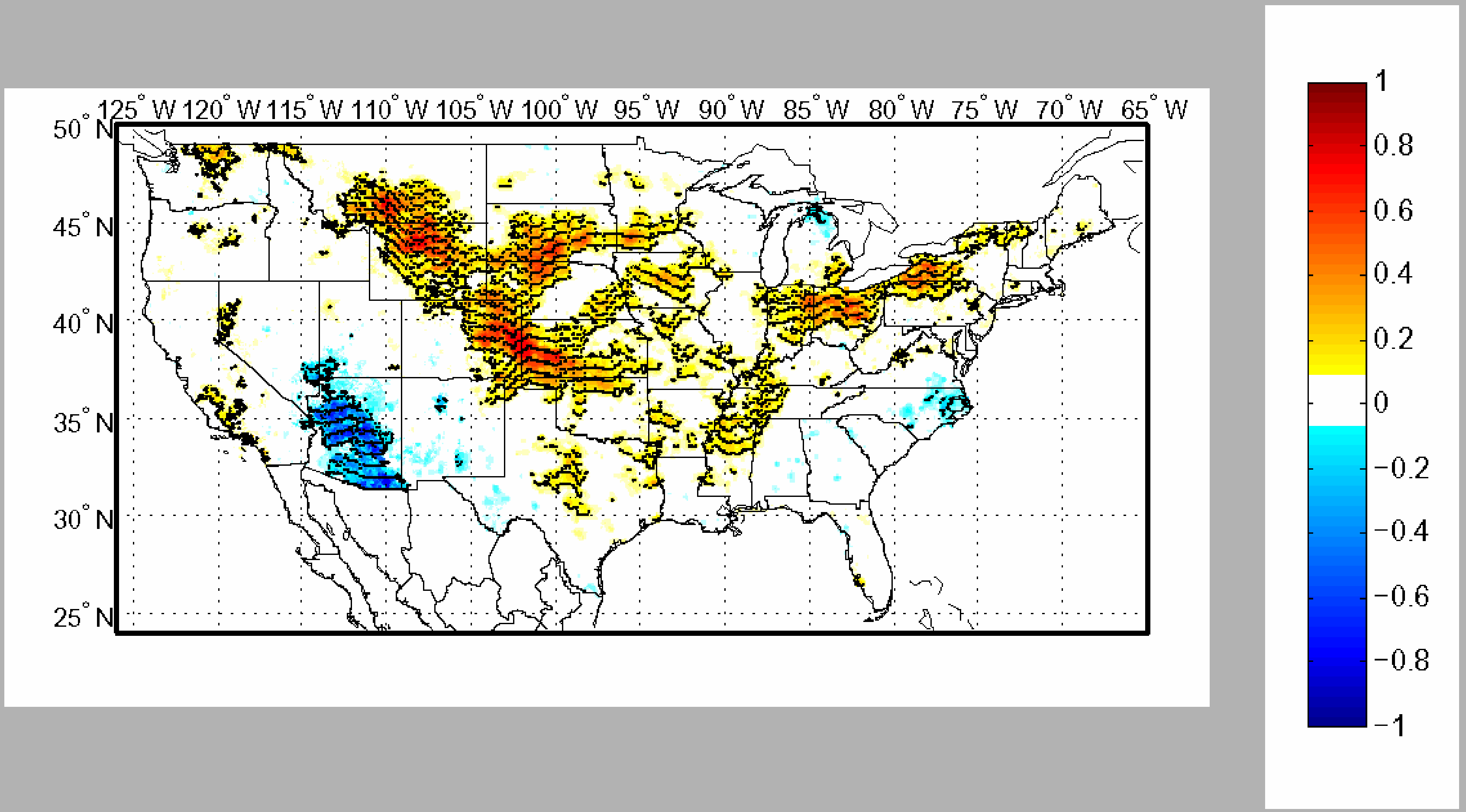
The CPVM is still pretty coherent through the antecedent winter season, though the exact ranking of its component REOFs may change.



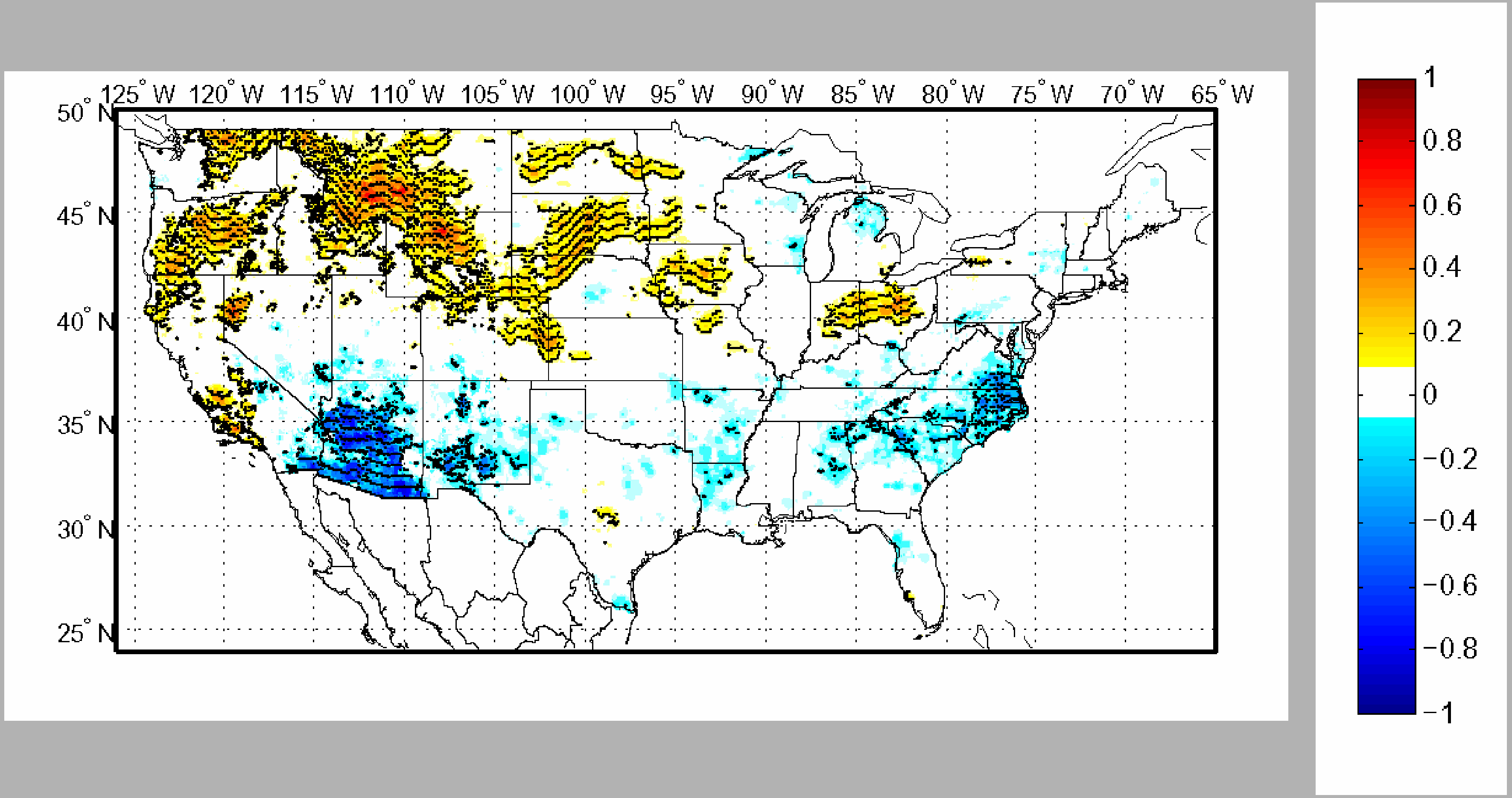
Correlation of JJA 3 mo. PRISM-derived SPI with concurrent CPVM



Correlation of JJ 2mo. PRISM-derived SPI with concurrent CPVM (onset period)

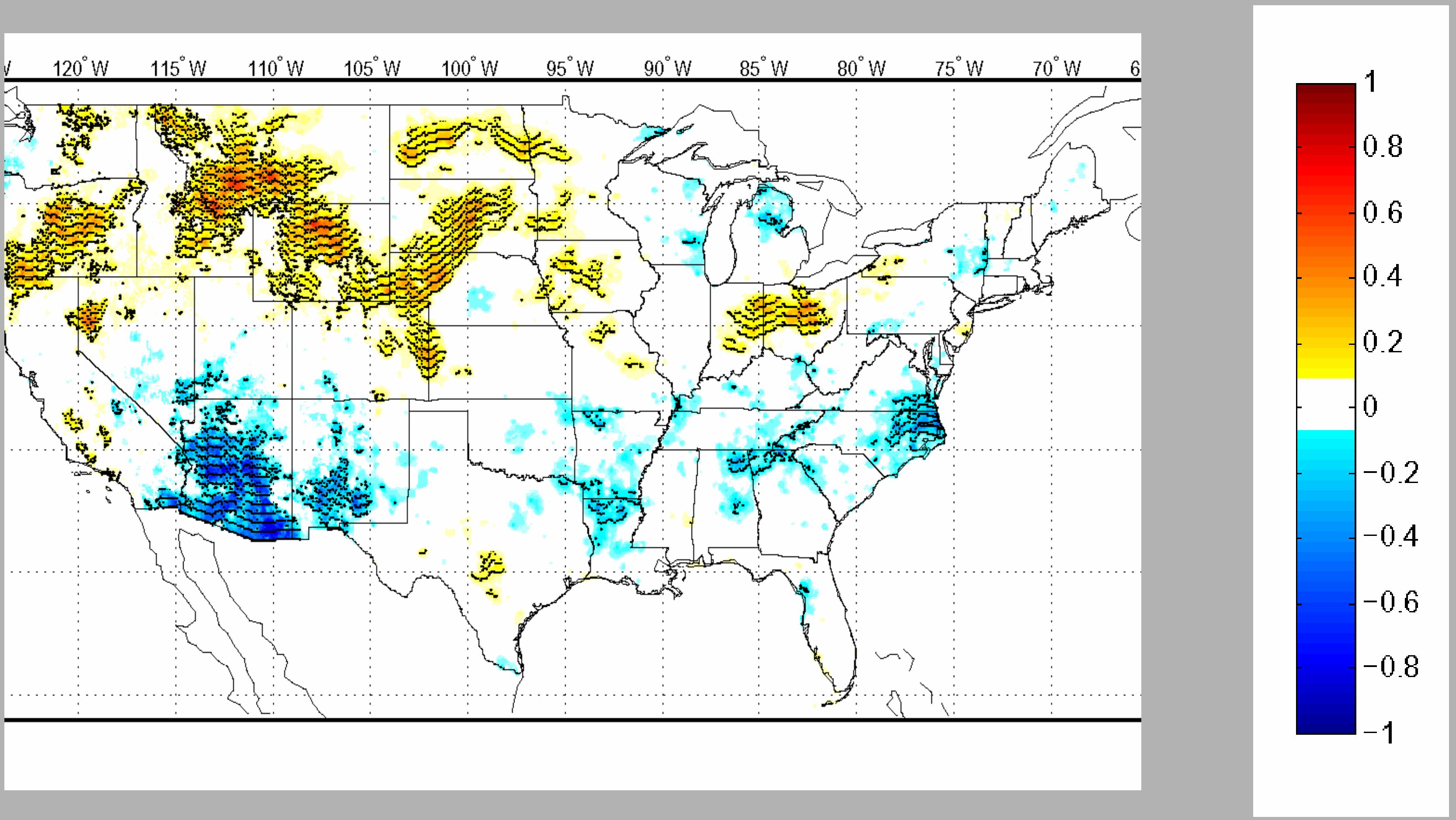


Correlation of JJ 2mo. PRISM-derived SPI with antecedent MAM CPVM (onset period)



MOST CRITICAL TIME FOR DECISION MAKING!

Correlation of JJ 2mo. PRISM-derived SPI with antecedent DJF CPVM (onset period)



Could RCM dynamical downscaling of GCM seasonal forecasts work as well?

Probably—if the driving GCM ensemble has the time evolving teleconnections and a "reasonable" climatology

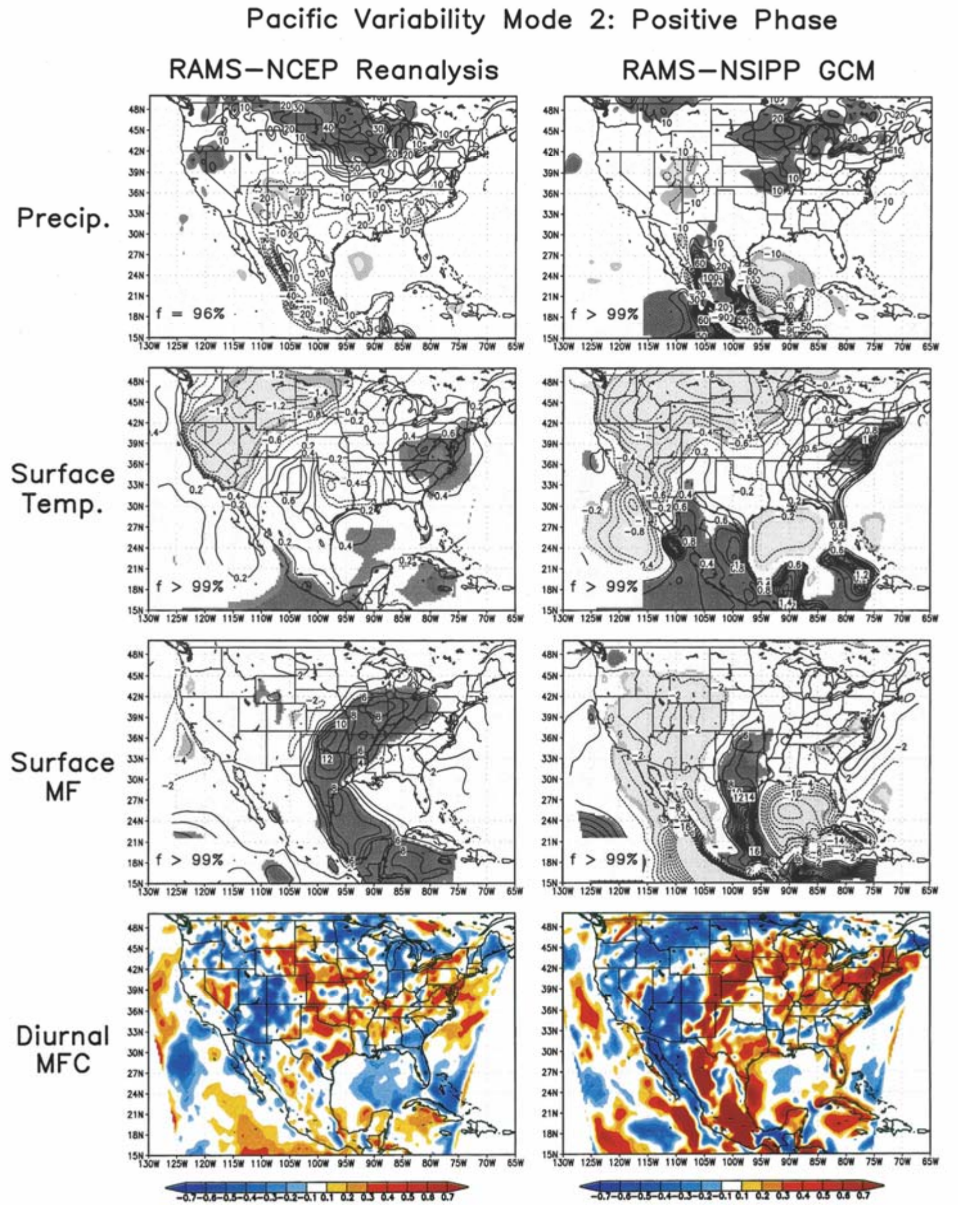
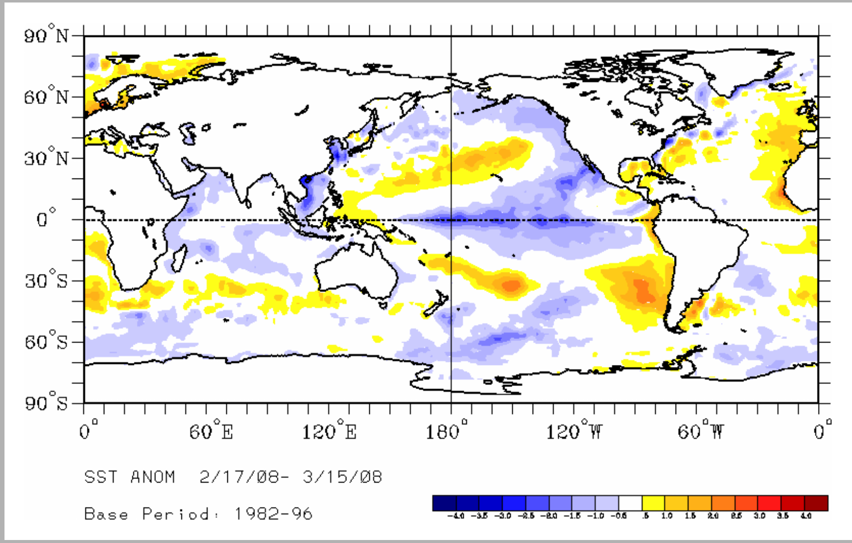


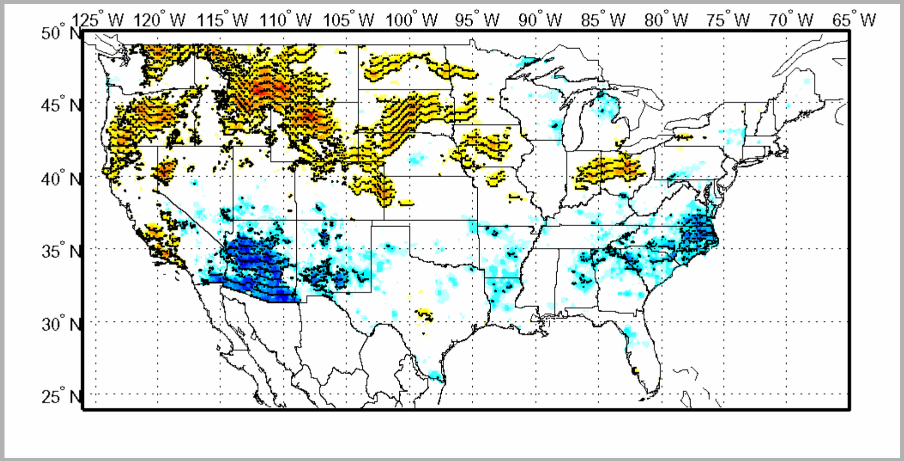
FIG. 14. Comparison of Pacific variability mode-2 positive phase at the period of maximum teleconnectivity for RAMS–NCEP composite (30-day average centered on 15 Jul) and RAMS–NSIPP ensembles (30-day average centered on 20 Jul). RAMS–NCEP composite years are defined in Table 1. Anomalies of precipitation, surface temperature, surface moisture flux (MF), and diurnal MFC are considered the same as in previous figures in section 4. RAMS–NSIPP simulations are described in Castro (2005).

Currently working on updating CPVM in real time for monsoon forecasting purposes...

Probably has good potential for a monsoon forecast index.

What happens this summer, according to CPVM?





Antecedent spring CPVM relationship to monsoon onset SPI

Current SSTA pattern projects <u>negatively</u> on the combined Pacific variability mode.

↓

A stronger, more north to northeastward positioning of monsoon ridge during onset period.

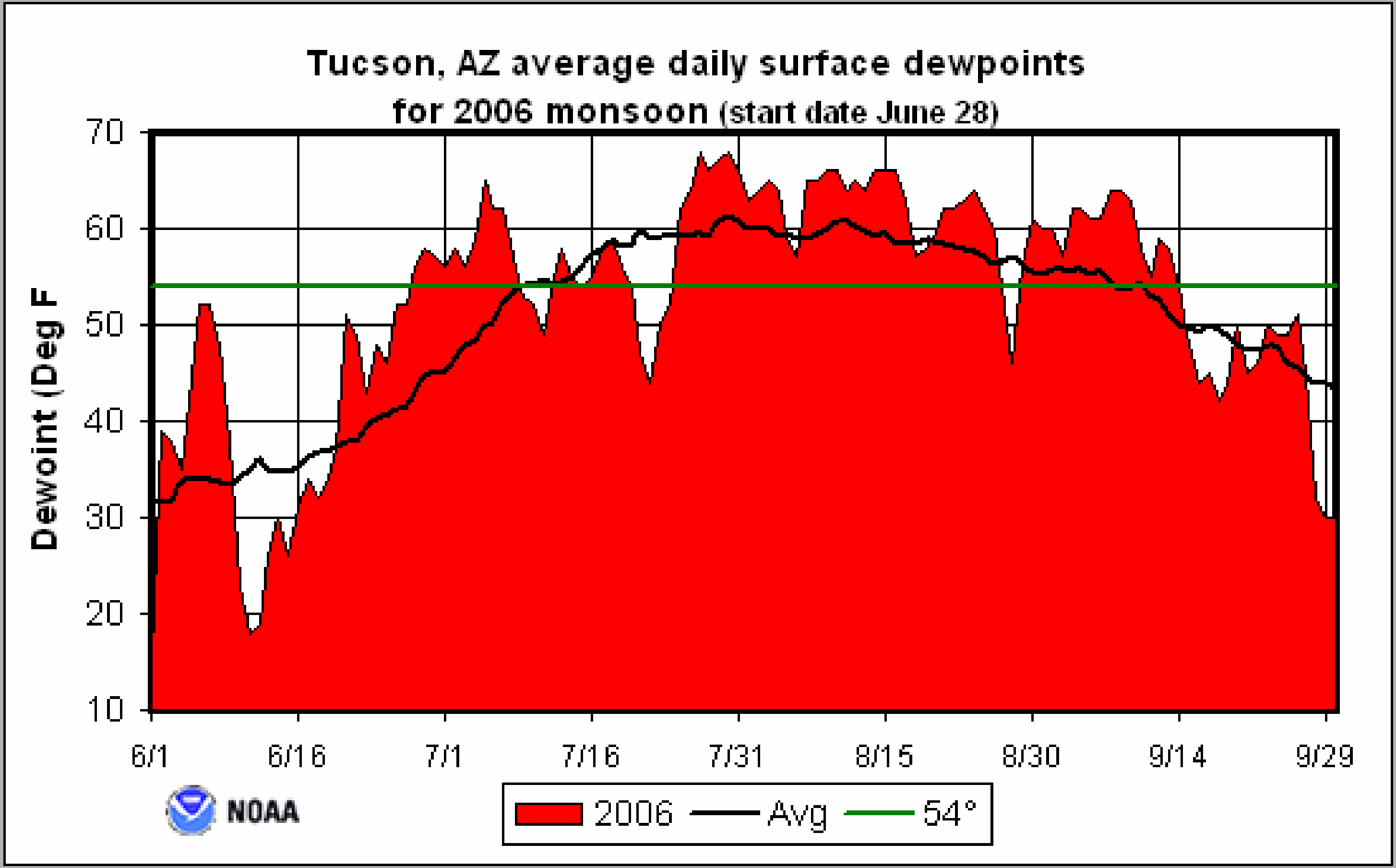
↓

A greater frequency of synoptic transients (e.g. inverted troughs) and stronger diurnal cycle of convection.

↓

<u>BOTTOM LINE</u>: Above average rainfall in Arizona during June to July period, below normal rainfall in Great Plains.

Will it be like the monsoon of 2006?



6th wettest monsoon on record!

Concluding points

Pacific SSTs serve as one of the main "orchestrators" of long-term climate variabilility in our region—*in <u>both</u> cool and warm seasons.*

Pacific SSTs are statistically significantly related to the monsoon ridge position and frequency of synoptic transients during the onset period (late June, early July). Modeling studies also suggest physical causality, but more research is needed.

The antecedent CPVM appears to be a good predictive gauge of North American monsoon onset and strength.

RCMs, or more highly resolved GCMs, are necessary to resolve the physical processes which lead to summer rainfall, particularly the diurnal cycle. This may improve on the typical "equal chances" forecasts for North American monsoon rainfall in Arizona, for example.

Future directions toward improving seasonal forecasts and climate change projections

Real-time updating of the CPVM for the NAME community as a forecast index.

Development of real-time, statistically based summer precipitation forecasts based on the CPVM and high resolution precipitation data, like PRISM.

Dynamical downscaling of archived CFS ensembles from CPC with WRF for the summer season (about 1980-present).

Dynamical downscaling of several “reasonable” IPCC GCM simulations for climate change projection purposes.