Large Scale Influences on the North American Monsoon Variability and Potential for Improved Seasonal Predictability

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THE UNIVERSITY OF ARIZONA.

Presentation Outline

Recent literature on the subject

Motivation for understanding what drives North American Monsoon variability

Current state of seasonal monitoring and prediction

Development of Pacific SST-based indices for NAMS monitoring and prediction

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

Some thoughts on the climate change question (if time)

Concluding points and future directions

Our work in this area

Bieda III, S.W., C.L. Castro, S.L. Mullen, A. Comrie, and E. Pytlak, 2008. Transient Upper Level Troughs and their relationship to intraseasonal and interannual variability of the North American Monsoon. *J. Climate*, submitted.

Castro, C.L., T.B. McKee, and R.A. Pielke Sr., 2001: The Relationship of the North American Monsoon to Tropical and North Pacific Sea Surface Temperatures as Revealed by Observational Analyses. *J. Climate*, **14**, 4449-4473.

Castro, C.L., R.A. Pielke, Sr., J.O. Adegoke, S.D Schubert, and P.J. Pegion, 2007. Investigation of the Summer Climate of the Contiguous U.S. and Mexico Using the Regional Atmospheric Modeling System (RAMS). Part II: Model Climate Variability. *J. Climate*, **20**, 3888-3901.

Castro, C.L., A. Beltrán-Przekurat, and R.A. Pielke Sr., 2007. Spatiotemporal Variability and Covariability of Temperature, Precipitation, Soil Moisture, and Vegetation for Regional Climate Model Applications, *Eos. Trans. AGU*, 88(23), Jt. Assem. Suppl., Abstract A33B-08.

Dominguez, F., P. Kumar, and E.R. Vivoni, 2007. Precipitation recycling as a mechanism for ecoclimatological stability through local and non-local interactions. Part II: North American Monsoon Region. *J. Climate* (submitted).

Some other studies which document NAMS connections to large-scale variability

Cavazos, T., A.C. Comrie, and D.M. Liverman, 2002: Intraseasonal variability associated with wet monsoons in southeast Arizona. *J. Climate*, **15**, 2477-2490.

Grantz, K., B. Rajagopalan, M. Clark, and E. Zogona, 2007. Seasonal Shifts in the North American Monsoon. *J. Climate*, **20**, 1923-1935.

Hu, Q., and S. Feng, 2002. Interannual rainfall variations in the North American monsoon region: 1900-98. J. Climate, 17, 4473-4480

Lorenz, D.J., and D.L. Hartmann, 2006. The Effect of the MJO on the North American Monsoon. J. Climate, 19, 333-343.

Mo, K.C., and J.N. Paegle, 2000: Influence of Sea Surface Temperature Anomalies on the Precipitation Regimes over the Southwest United States. *J. Climate*, **13**, 3588-3598.

..BY NO MEANS A COMPREHENSIVE LIST!!

Motivation for understanding drivers of monsoon variability from stakeholders

Severe weather

Wildfire

Water supply and demand

Ranching and agriculture

Important motivational aside: Stakeholders REALLY WANT the “answer” of what happens with climate change!

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- Health
- Tech / Science

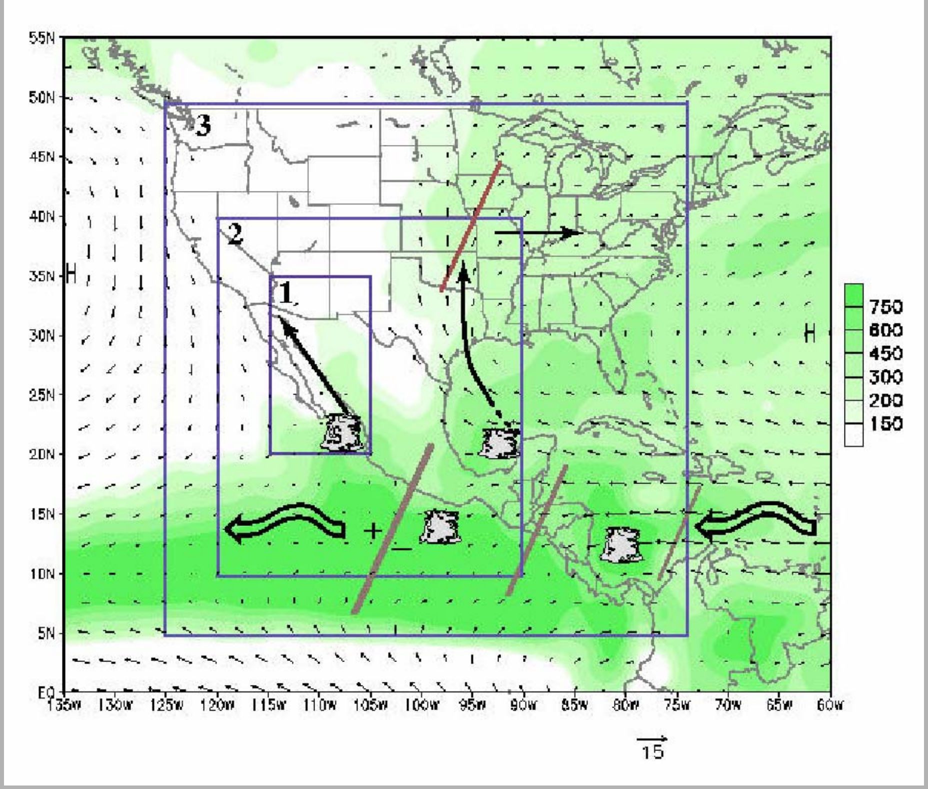
Scientists predict Southwest mega-drought

Climate models indicate region will be as dry as Dust Bowl for decades

David Mcnew / Getty Images

A bleached "bathtub ring," the result of a six-year drought that has dramatically dropped the level of the reservoir, shows on red Navajo sandstone formations near Last Chance Bay at Lake Powell near Page, Ariz. Lake Powell and the next biggest Colorado River reservoir, the nearly 100-year-old Lake Mead, are at the lowest levels ever recorded.

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

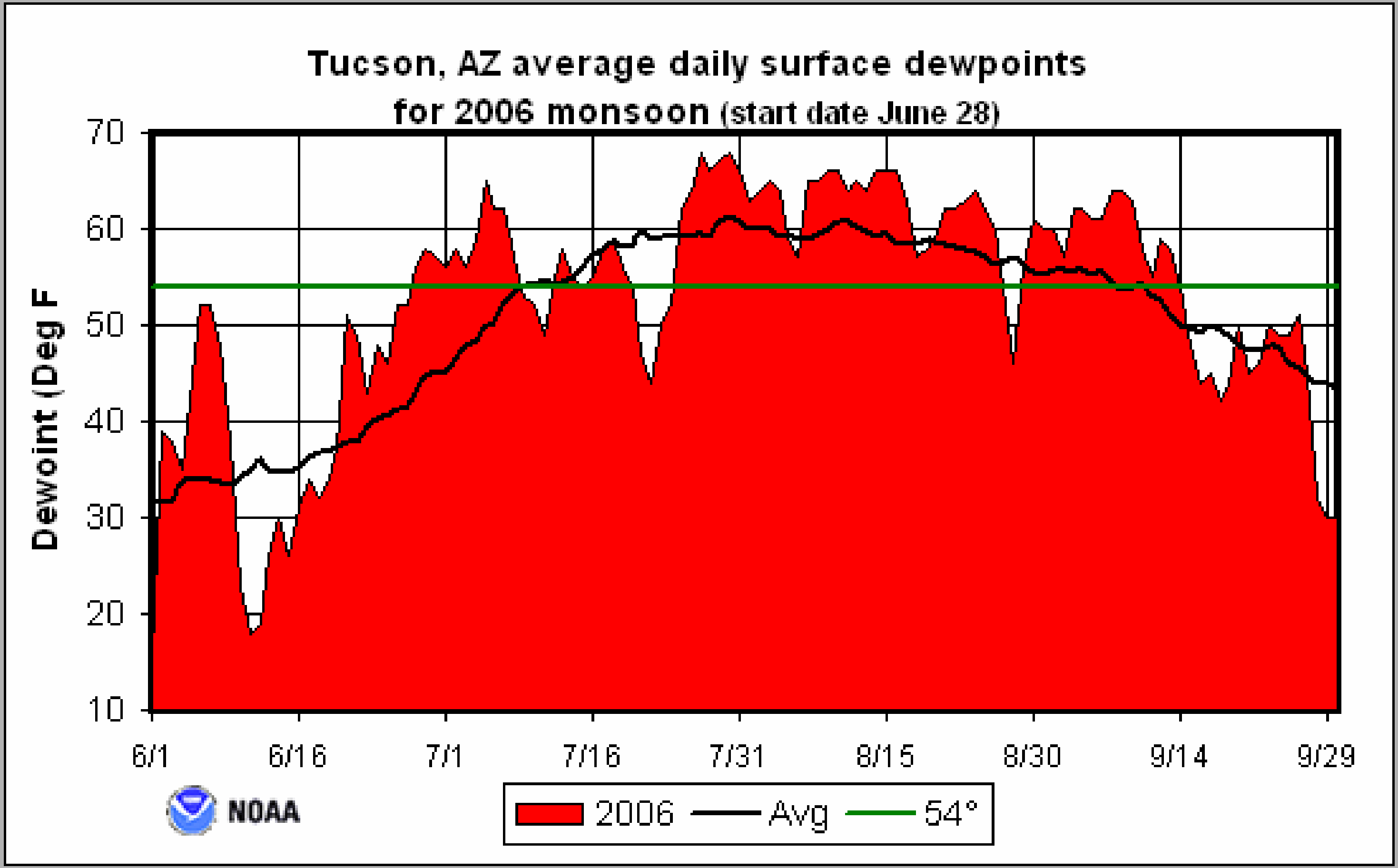
Moisture transport and possible teleconnections from Atlantic and inter-American seas

Land surface feedback processes

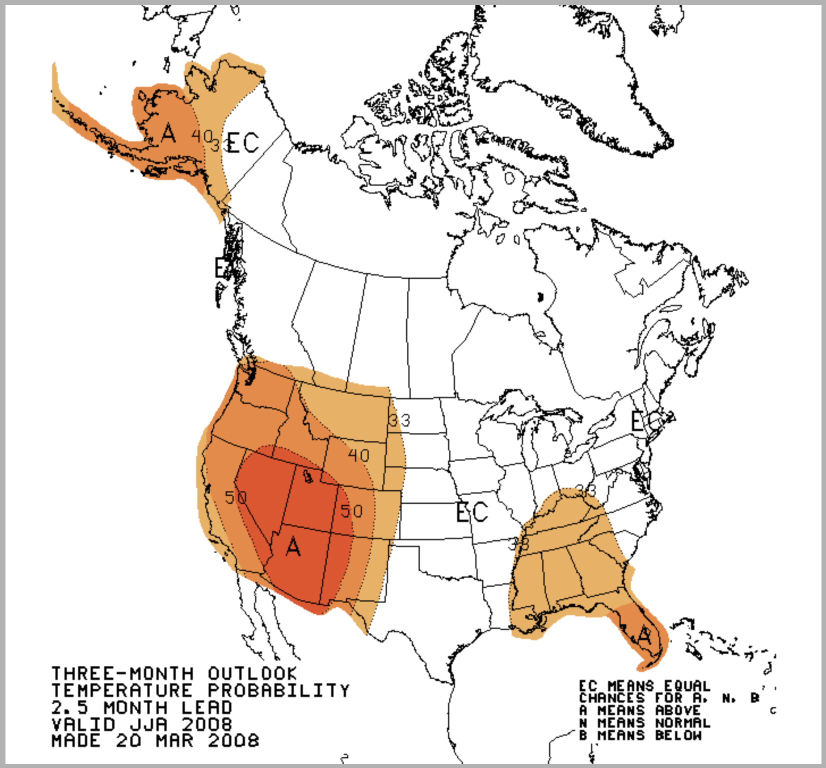
Anthropogenic climate change

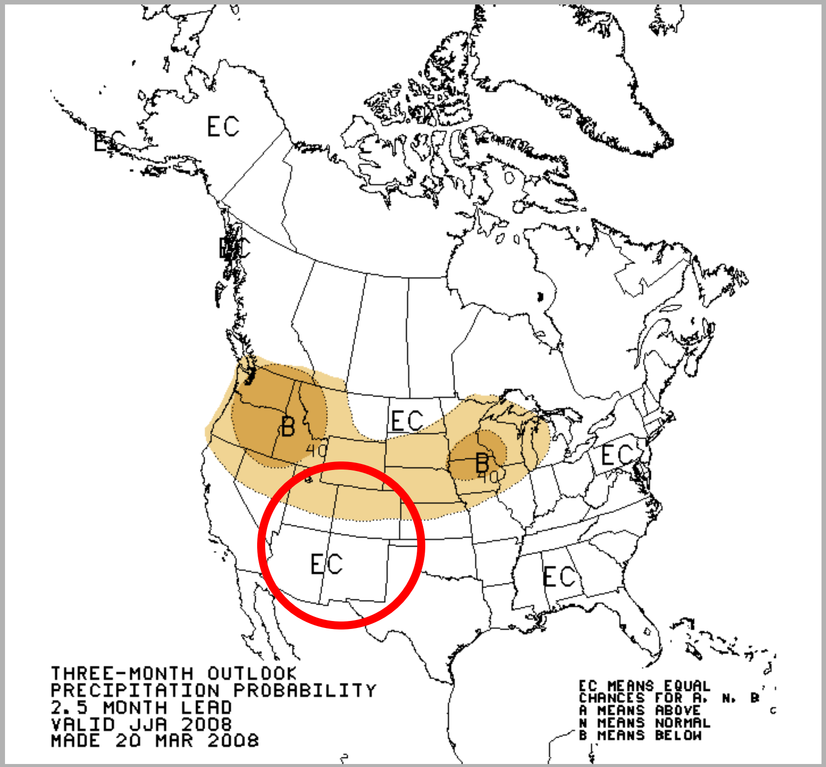
THESE ARE LIKELY NOT INDEPENDENT OF EACH OTHER!

Monsoon monitoring by Tucson NWS



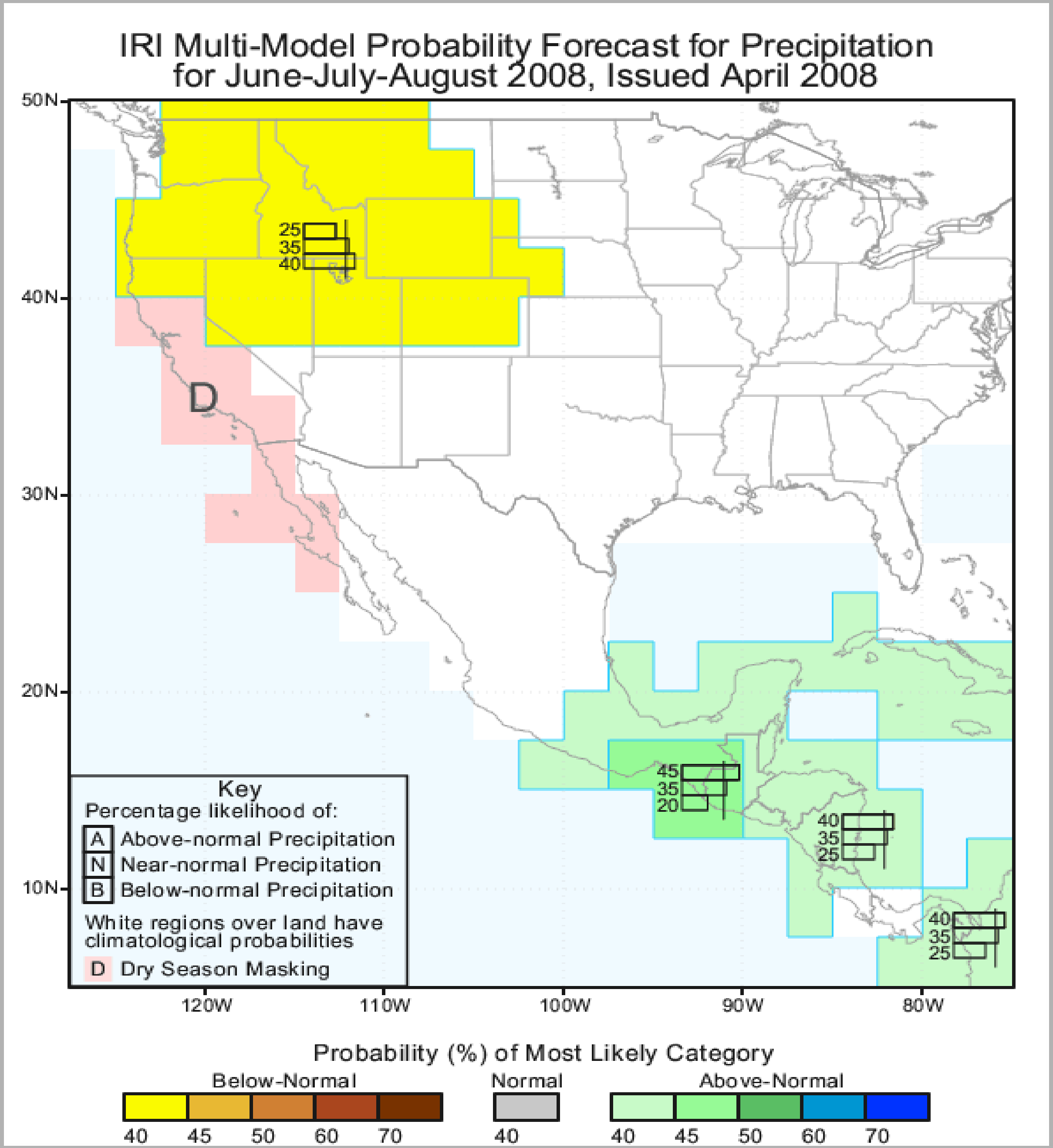
Current state of seasonal prediction: CPC Forecasts





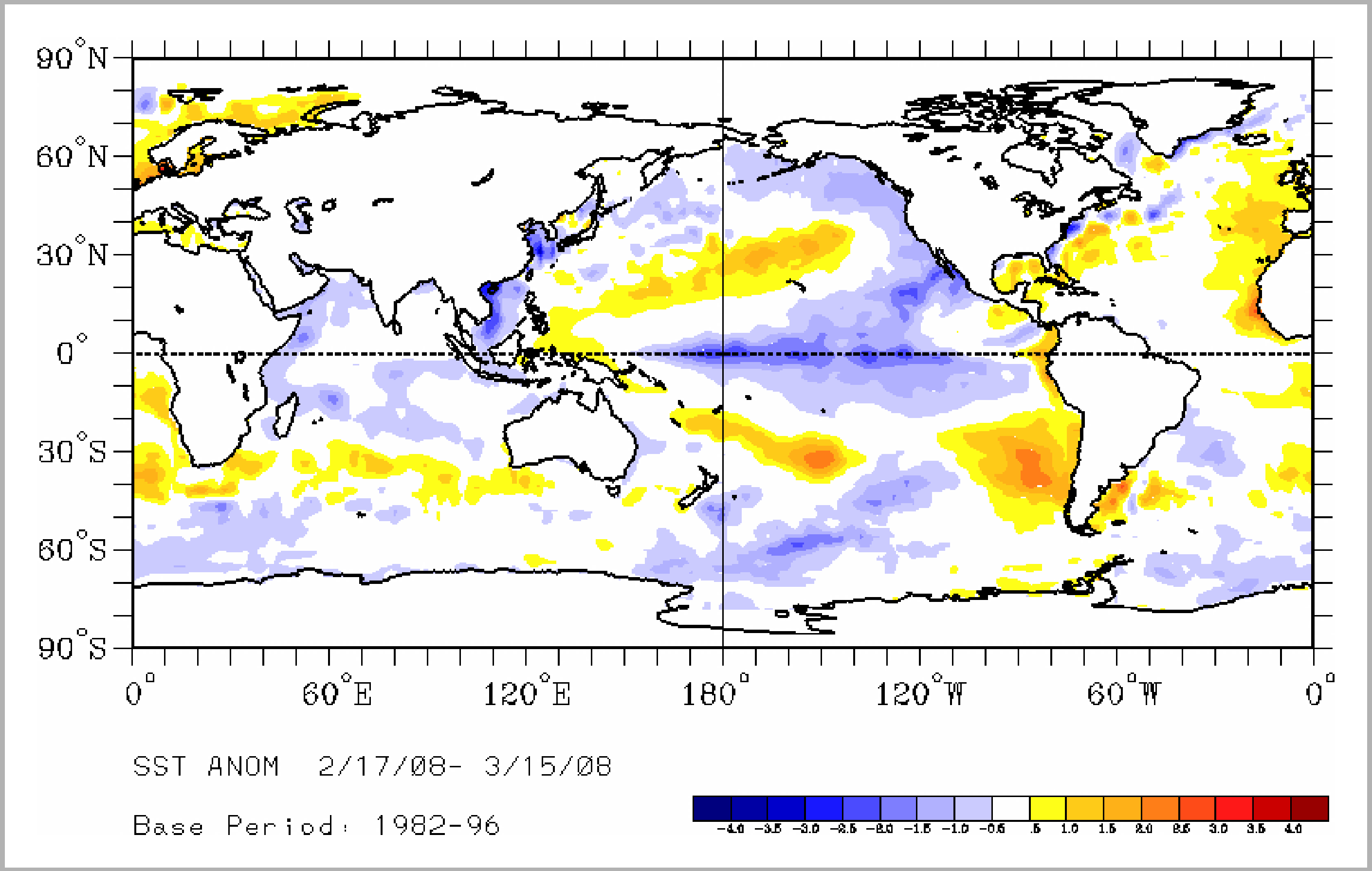
Temperature forecasts are becoming more dominated by long-term trends, probably due to climate change.

"Equal chances" for monsoon precipitation in the Southwest.



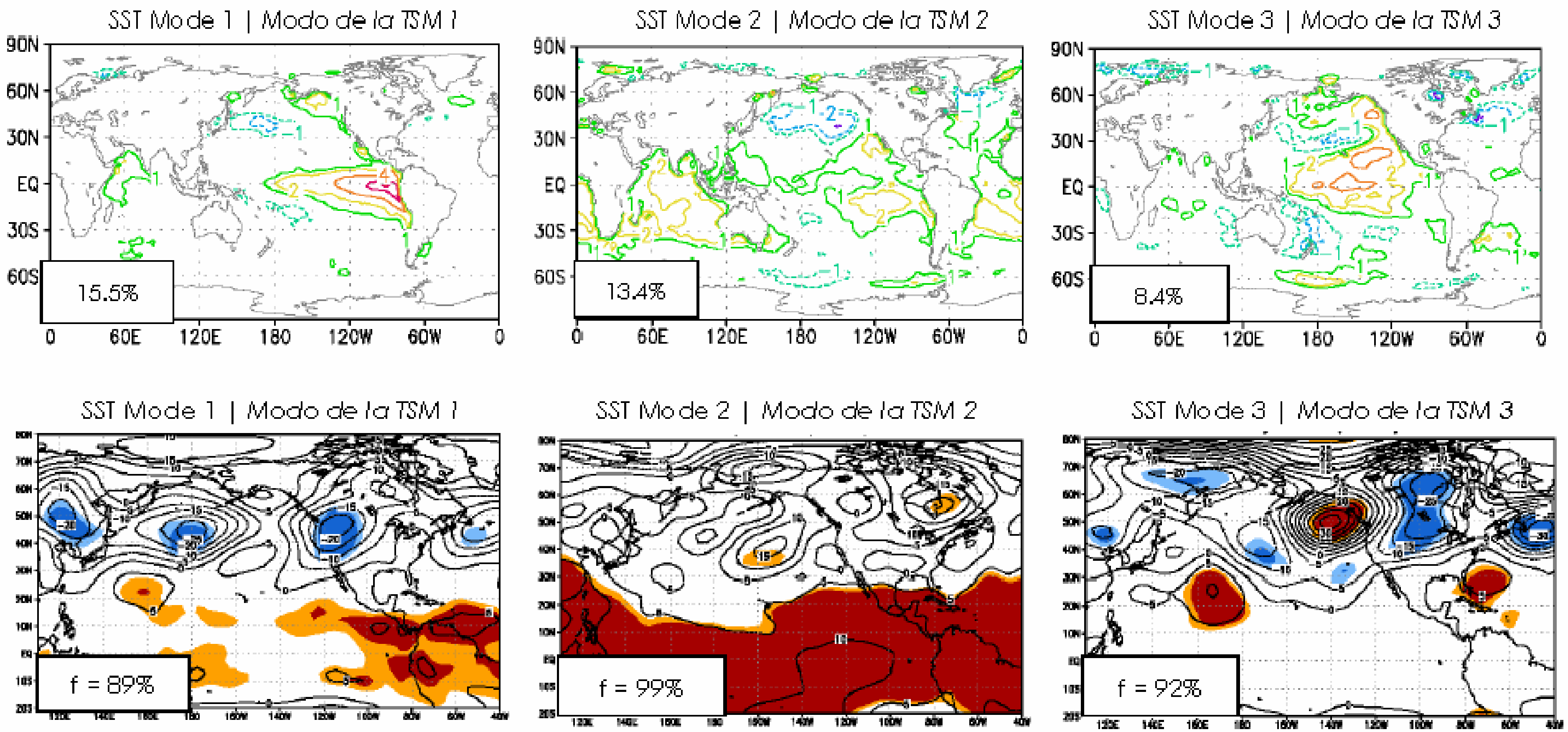
Again, basically a forecast for near normal precipitation in the core monsoon region

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)

Combined Pacific Variability Mode (CPVM)

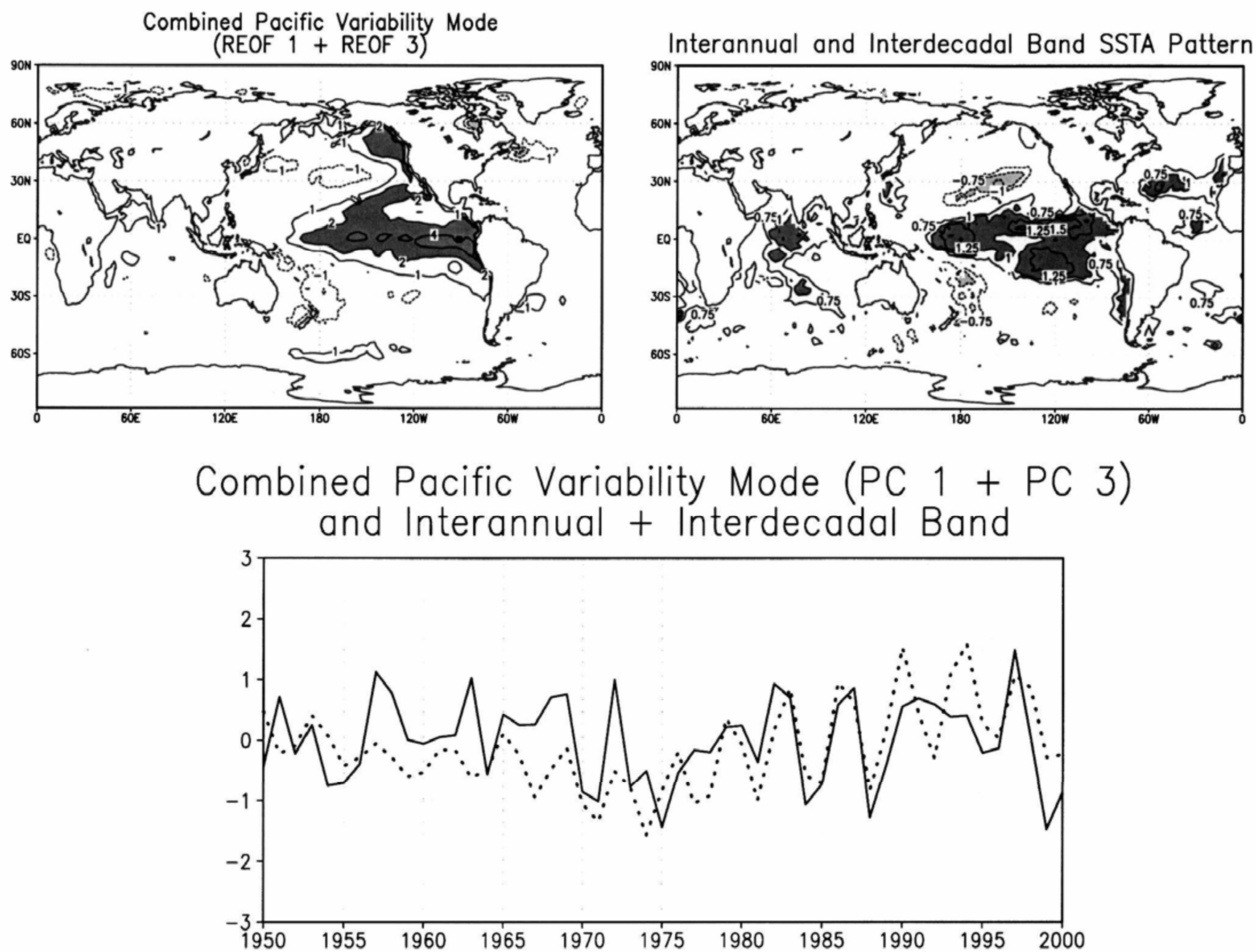


FIG. 4. As in Figs. 1 and 2 but for the combined Pacific variability mode and the combination of interannual and interdecadal band SSTA.

(Castro et al. 2007)

Similar looking SSTA patterns from other referenced studies: Grantz et al. (2007)

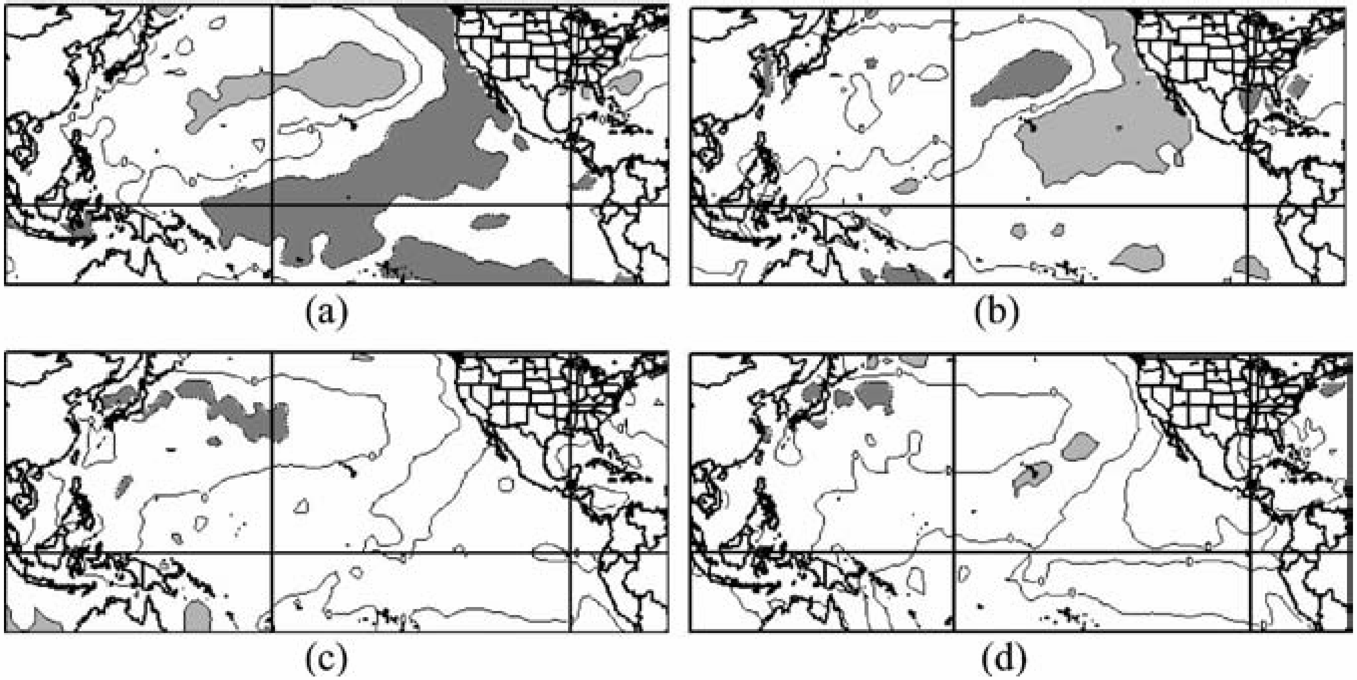


FIG. 10. Same as in Fig. 9 except for correlations between the winter–spring (December–May) SSTs and the first PC of the (a) July, (b) August, (c) September, and (d) July–September monsoon rainfall.

SSTA pattern in Hu et al. (2002)

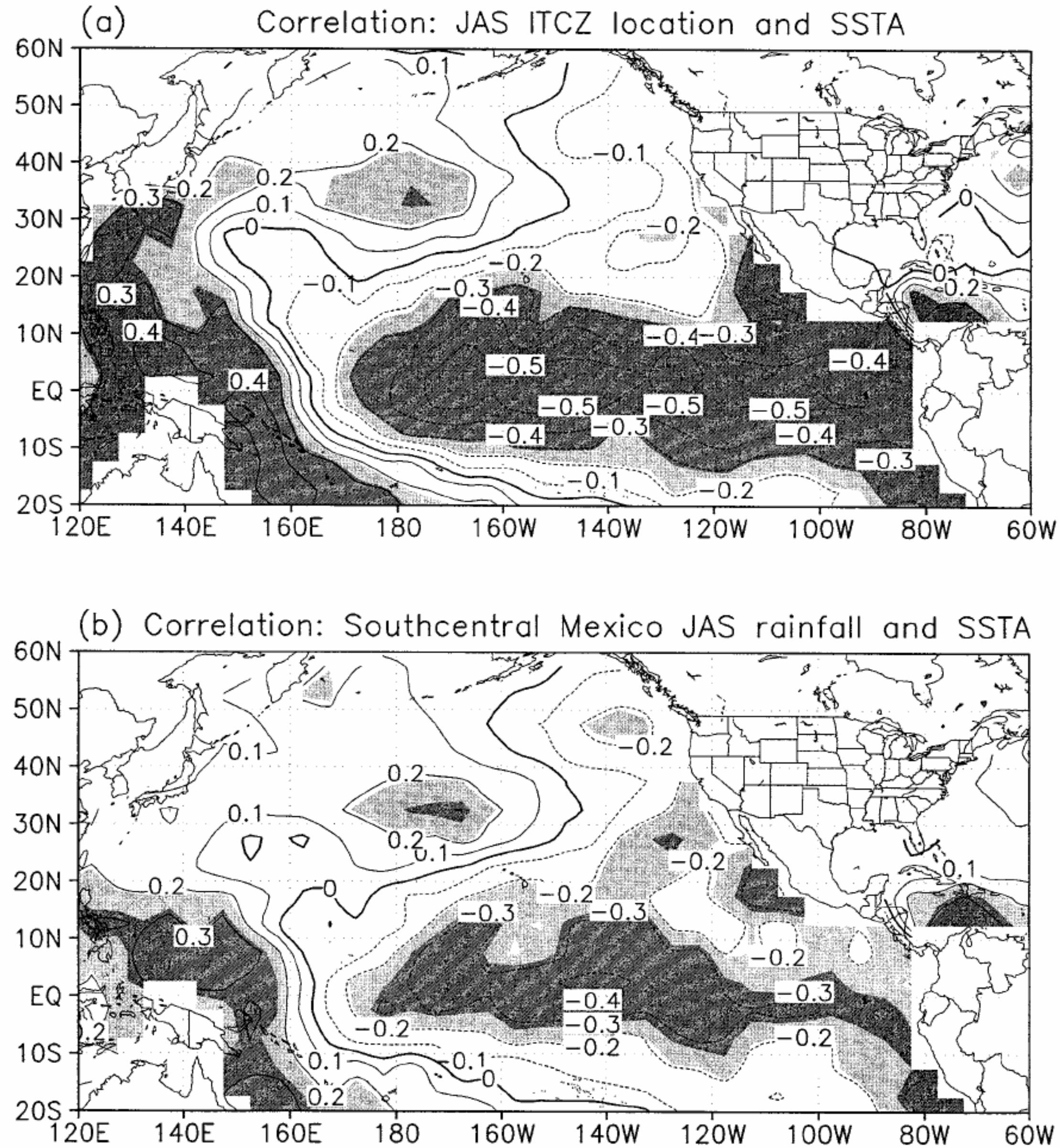
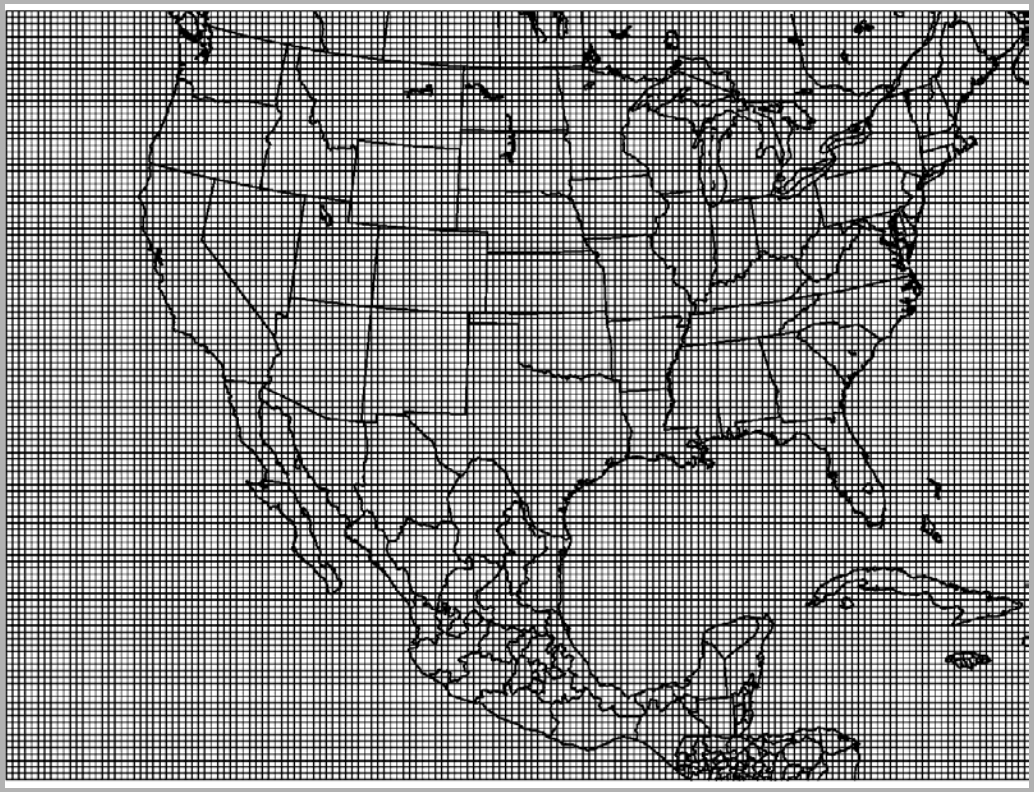


FIG. 4. (a) Distribution of the correlation of the JAS average ITCZ location vs the same-time SSTA in the North Pacific Ocean, and (b) distribution of the correlation of south-central Mexico JAS rainfall vs the same-time SSTA in the North Pacific Ocean (contour interval is 0.1, solid line for positive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

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

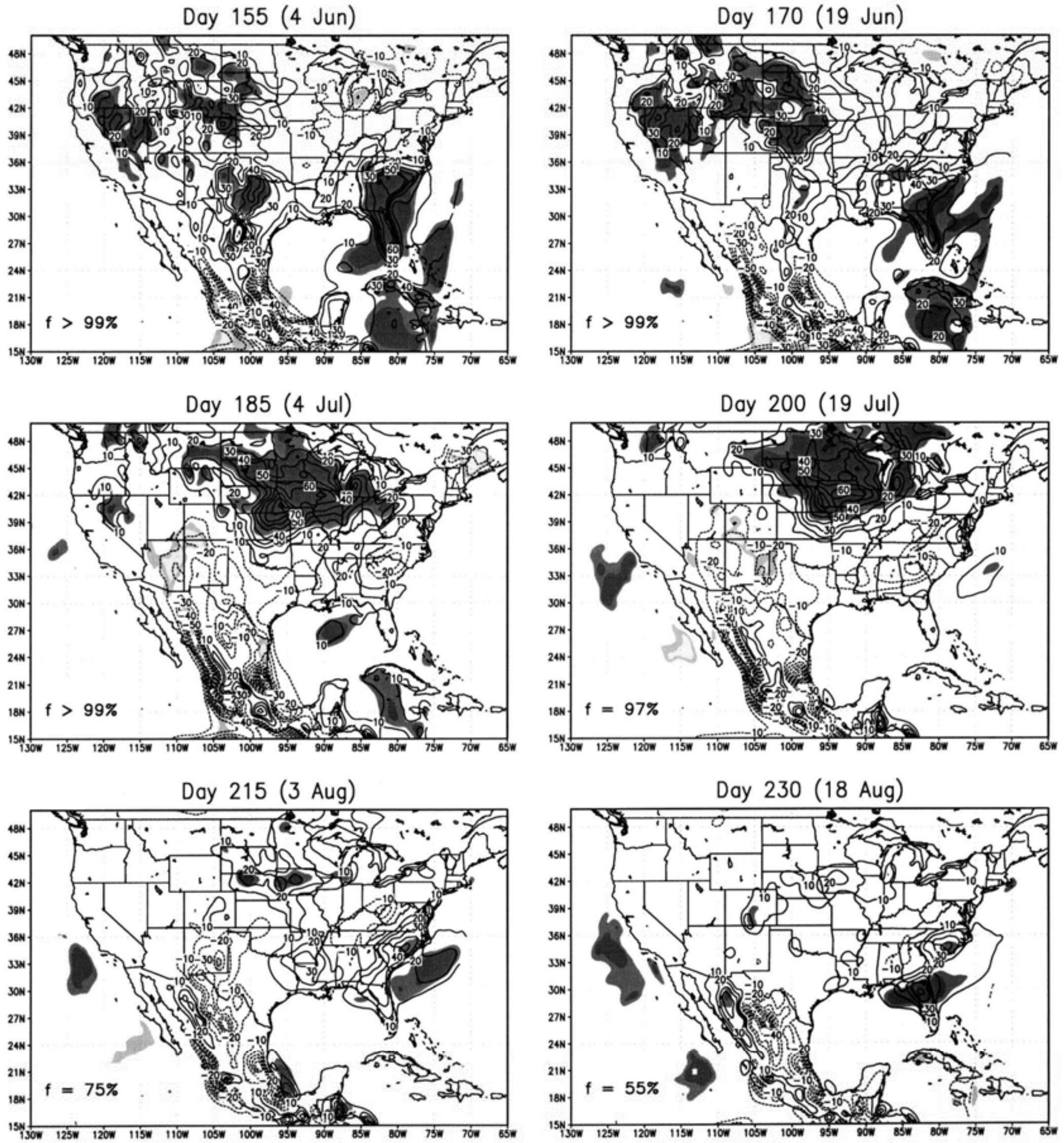
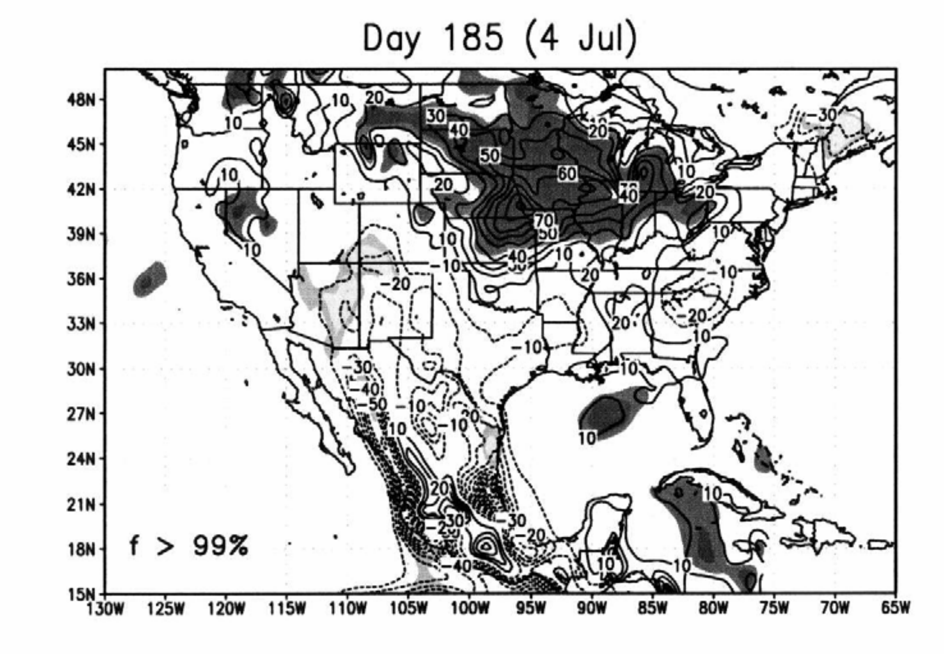


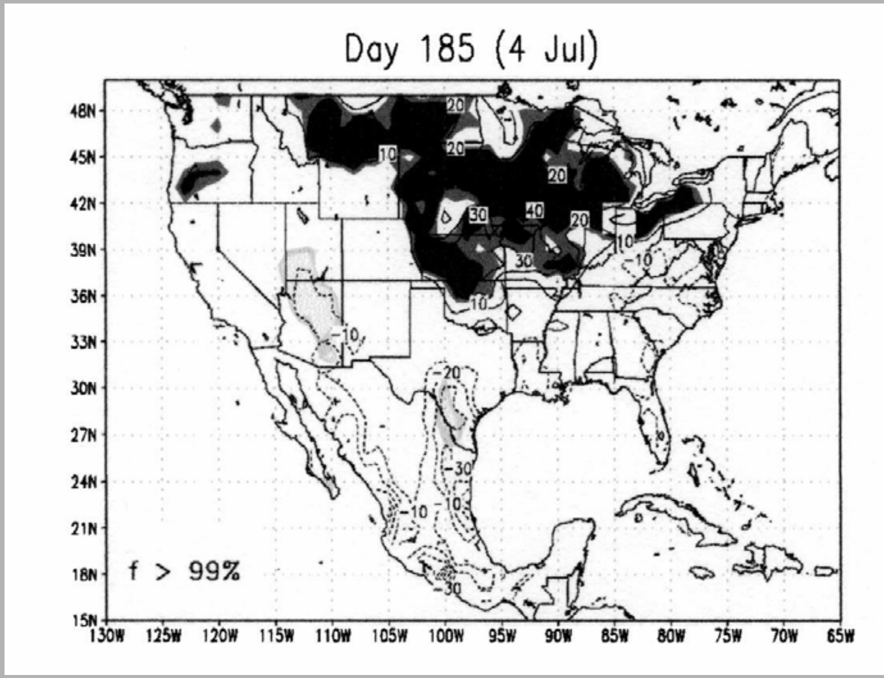
FIG. 8. Time evolution of 30-day average RAMS precipitation anomalies (mm) centered on the date for the combined Pacific variability mode composites in Table 4. Contour interval is 10 mm. Shading indicates local statistical significance at the 90% and 95% levels. Significant positive (negative) areas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

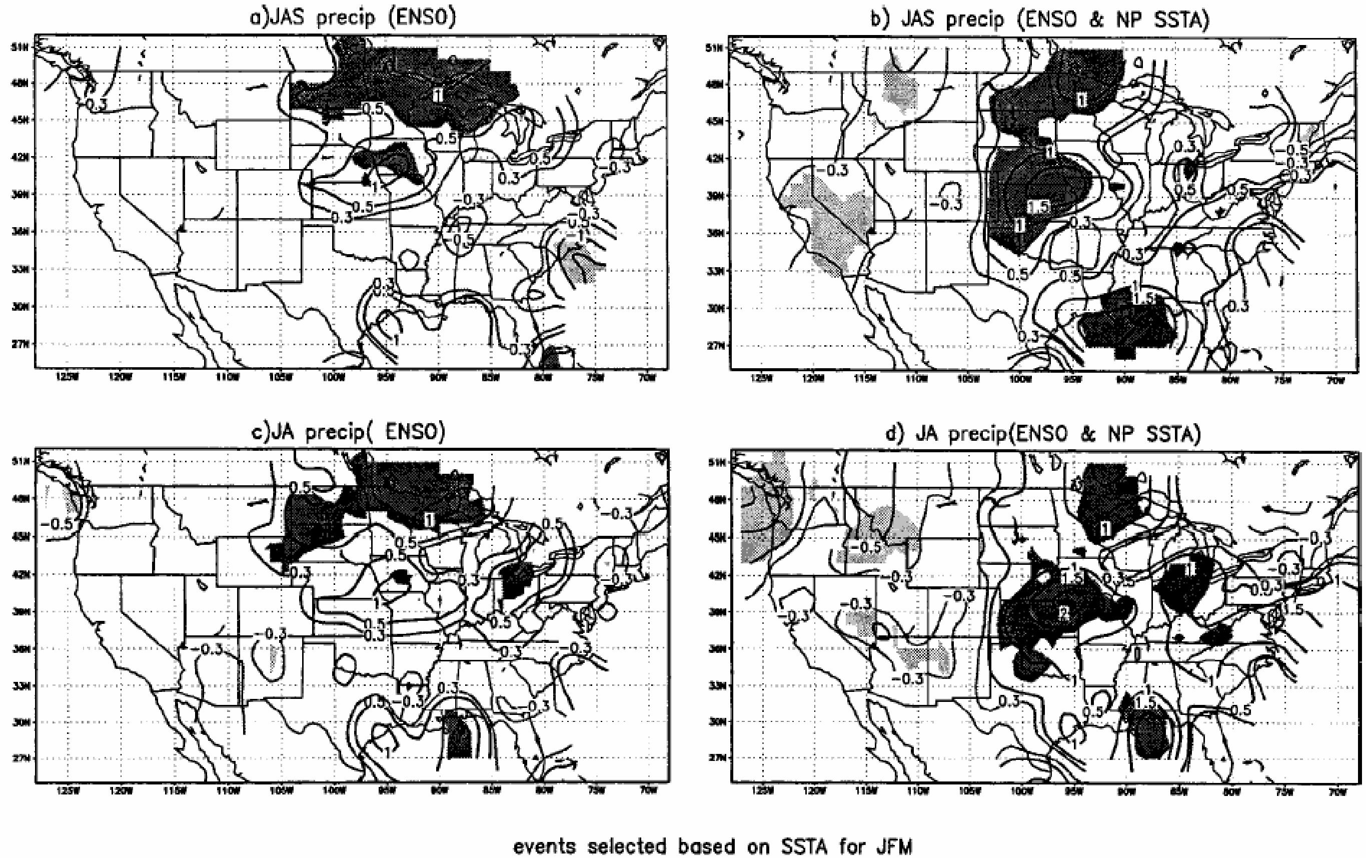
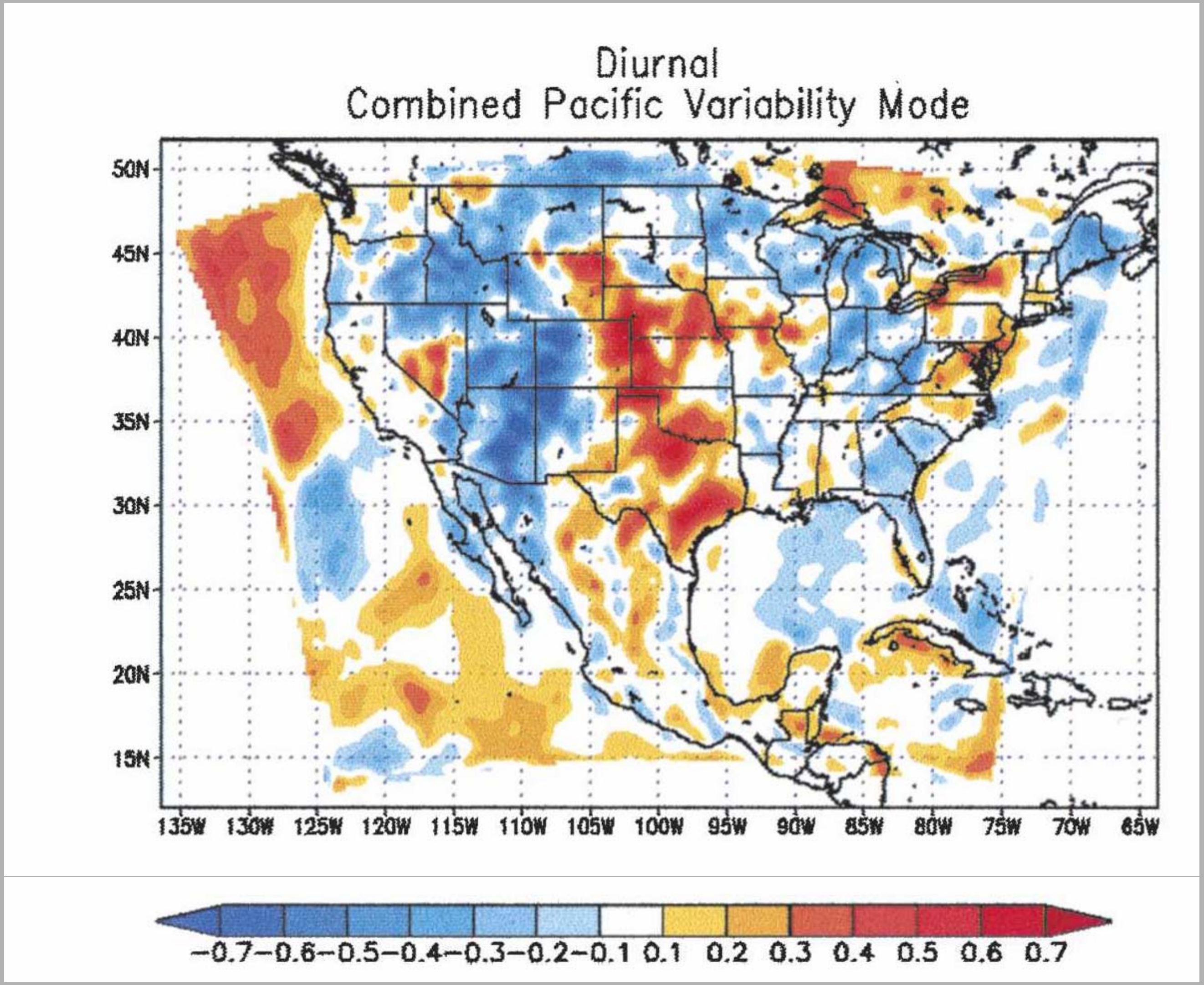


FIG. 9. (a) Precipitation composite difference between warm and cold ENSO events determined according to SSTA in the central Pacific for JAS (Fig. 4c). Contour interval is 0.5 mm day^{-1}. Zero contours are omitted. Contours −0.3 and 0.3 mm day^{-1} are added. Areas, where positive (negative) values 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.

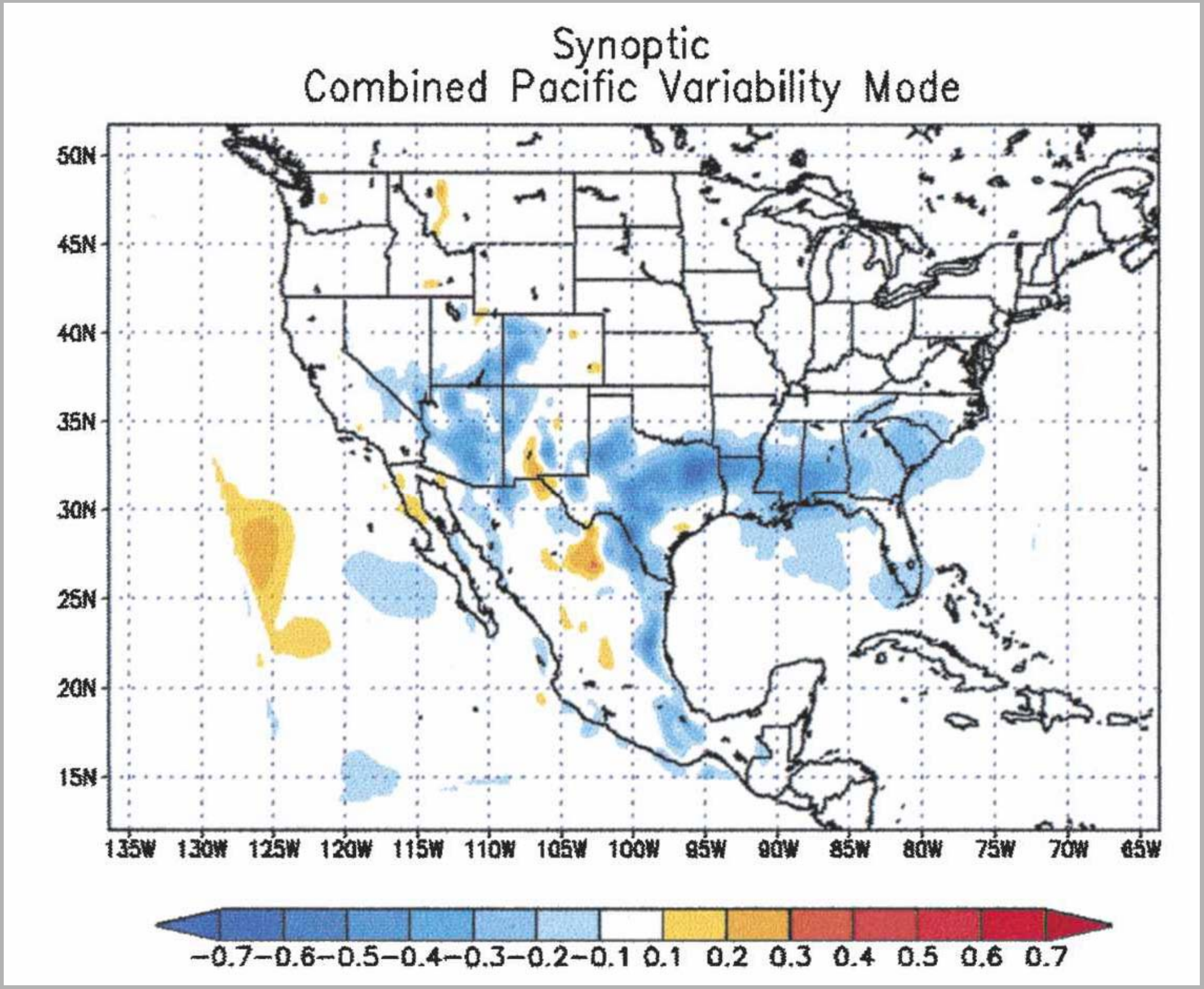
RCM-simulated change in diurnal moisture flux convergence associated with CPVM



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

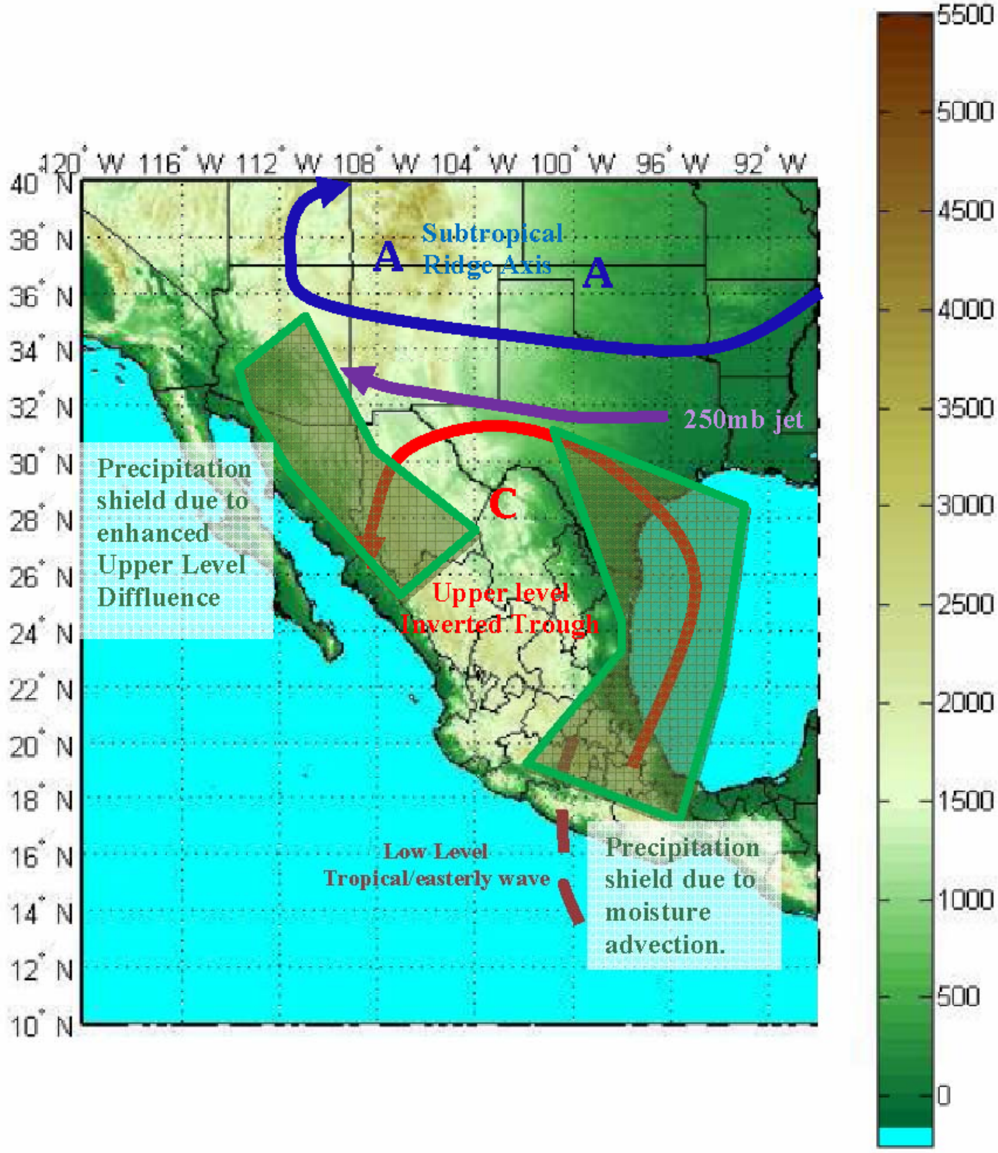
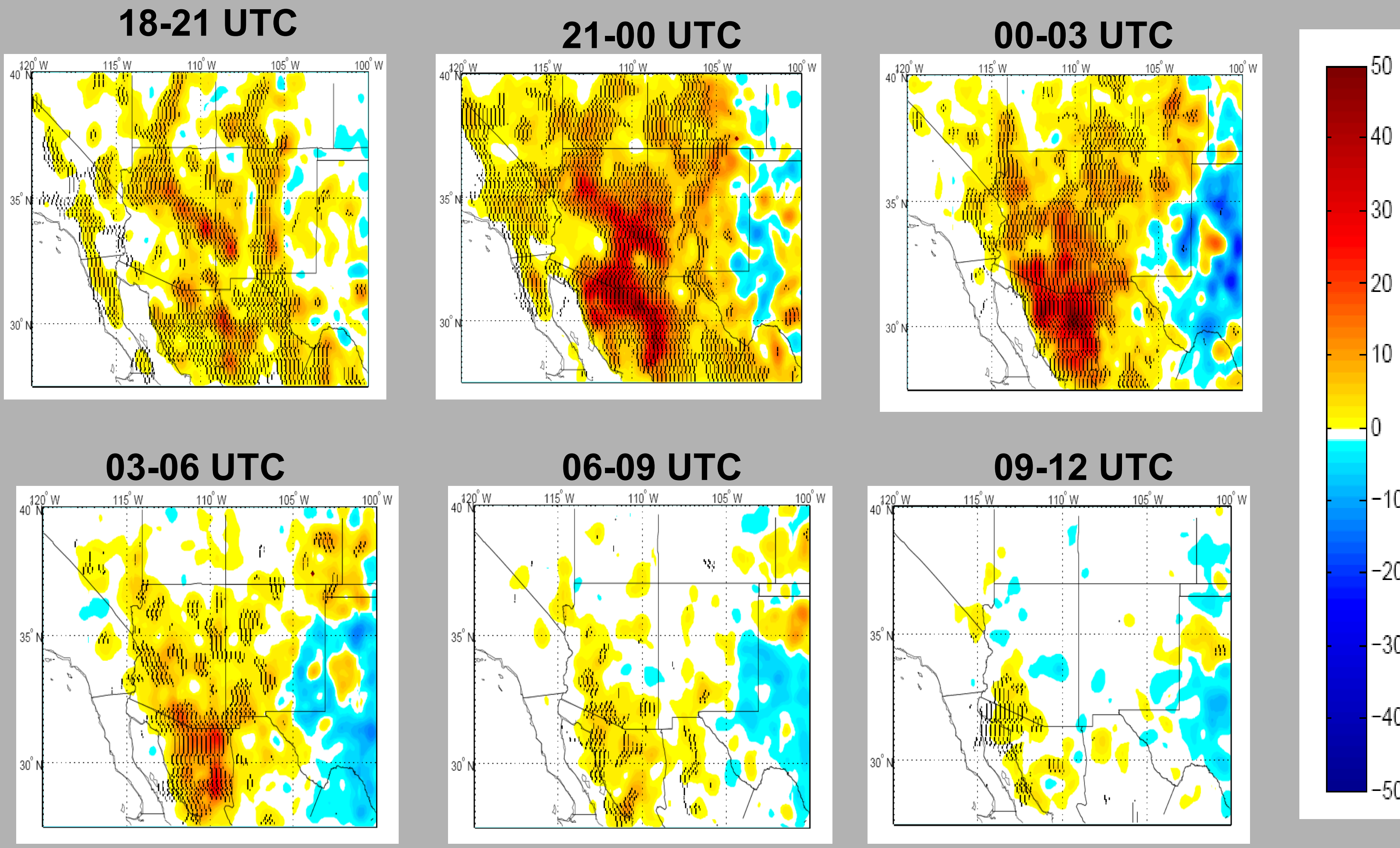


Figure 2: Conceptual Model of Inverted Troughs/Subtropical Ridge interaction, as presented in Pytlak et al. (2005), overlaid on topography of study region (terrain height in meters).

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

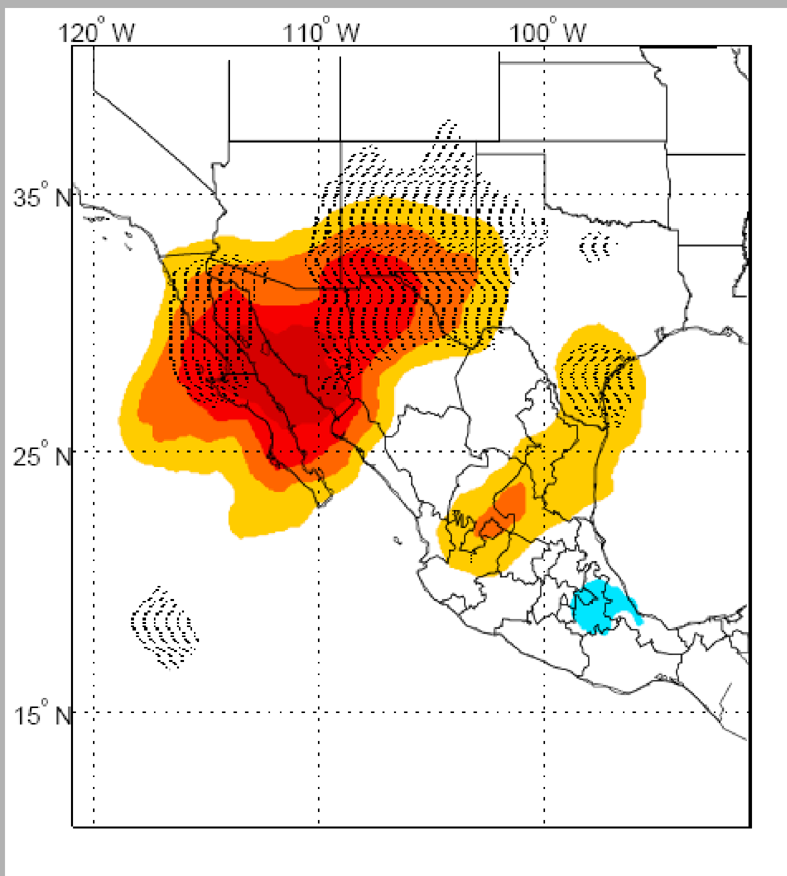
Bieda et al. (2008, submitted)

Change in lightning counts (per 10 km^{-2}) associated with transient upper-level troughs

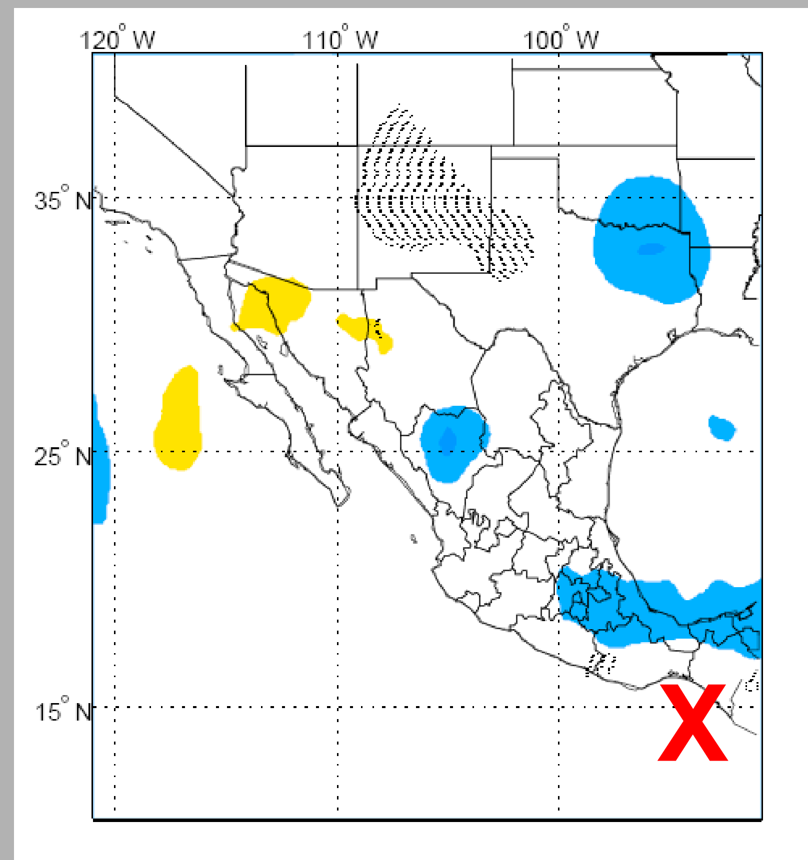


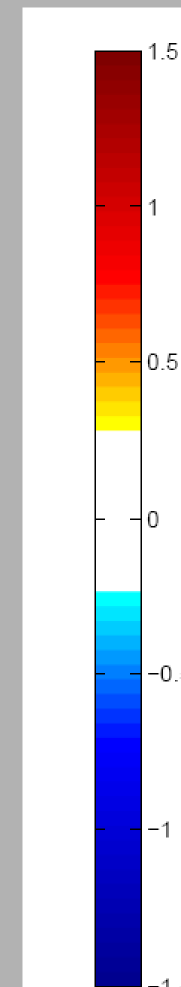
Change in frequency of transient upper level troughs: negative minus positive CPVM years (1979-2003)

Late June, early July

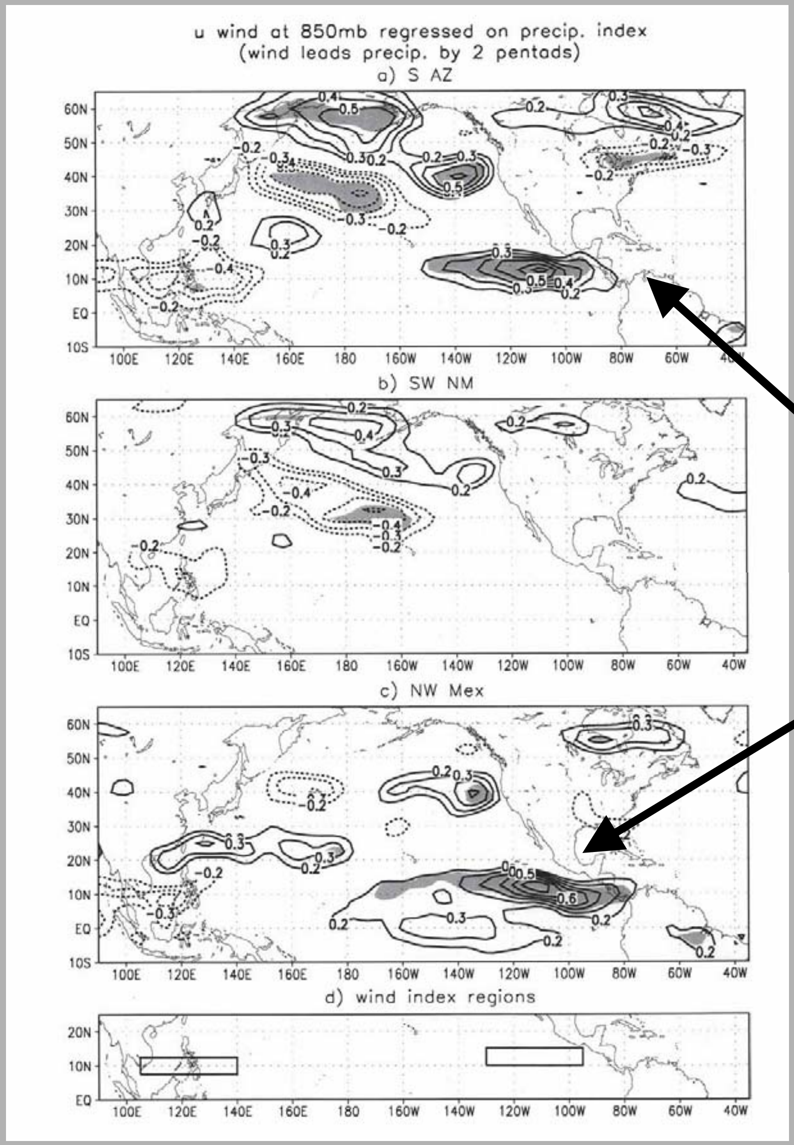


August





NAMS-MJO Connection (Lorenz and Hartmann, 2006)



<u>Main conclusion</u>: An MJO connection to monsoon precipitation in Arizona and northwest Mexico, but not New Mexico.

<u>Hypothesis</u>: a connection of the MJO to gulf surge mechanisms?

Probably need a regional model to fully investigate.

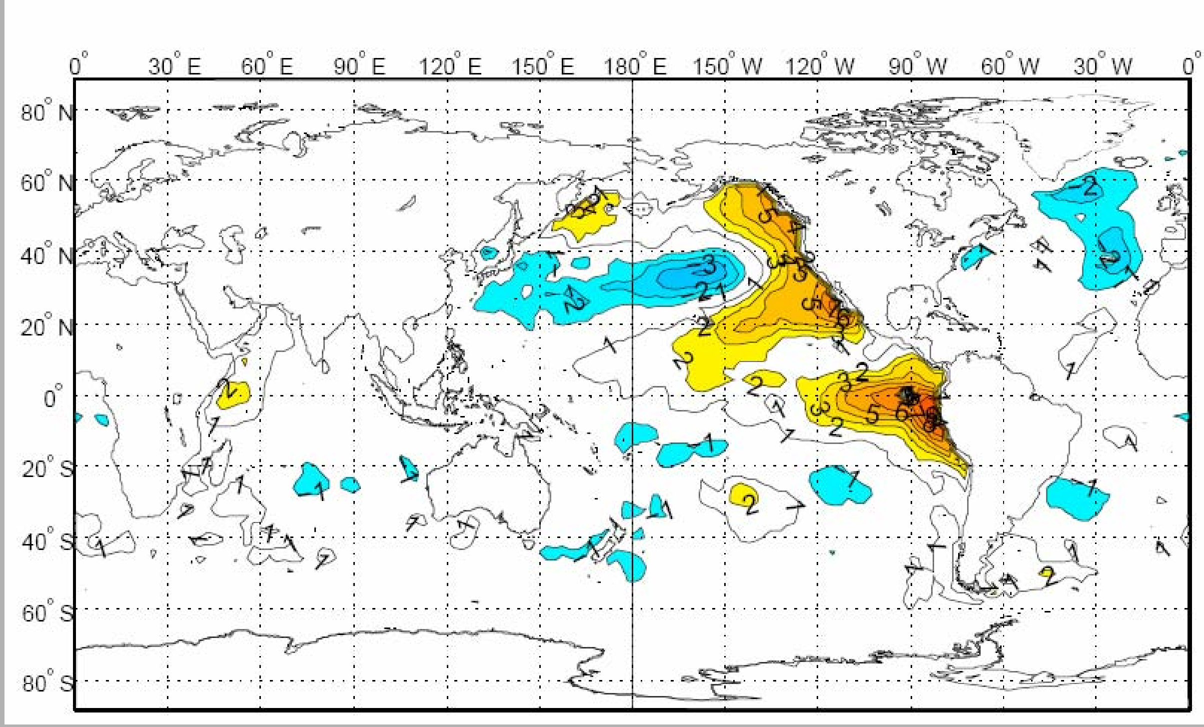
Is there a potential for more skillful NAMS prediction?

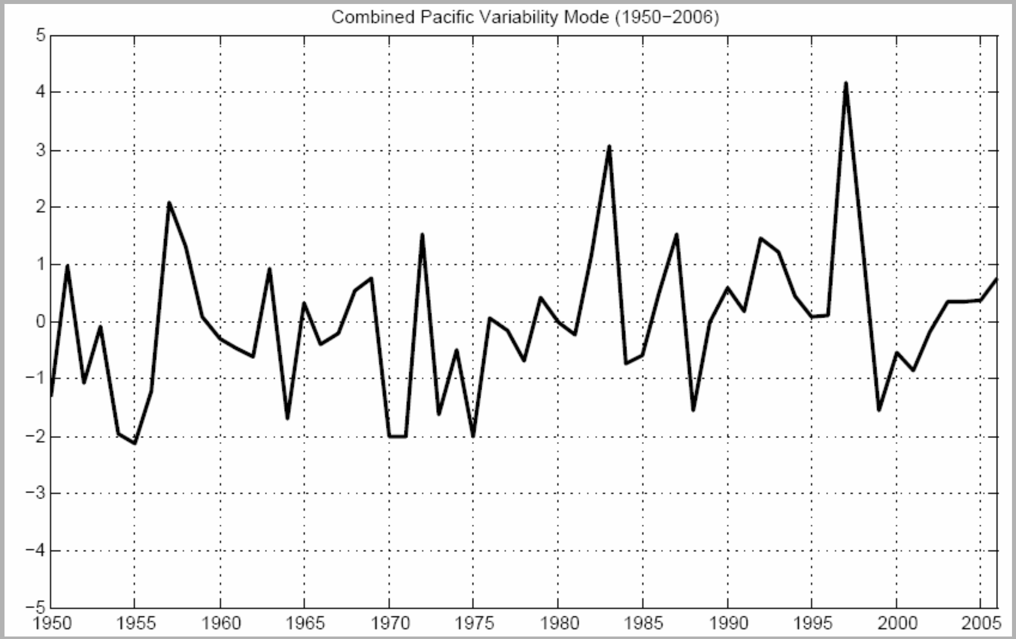
<u>Statistical prediction</u>: requires persistence of SST modes from antecedent winter and spring

<u>Dynamical prediction</u>: requires the above +

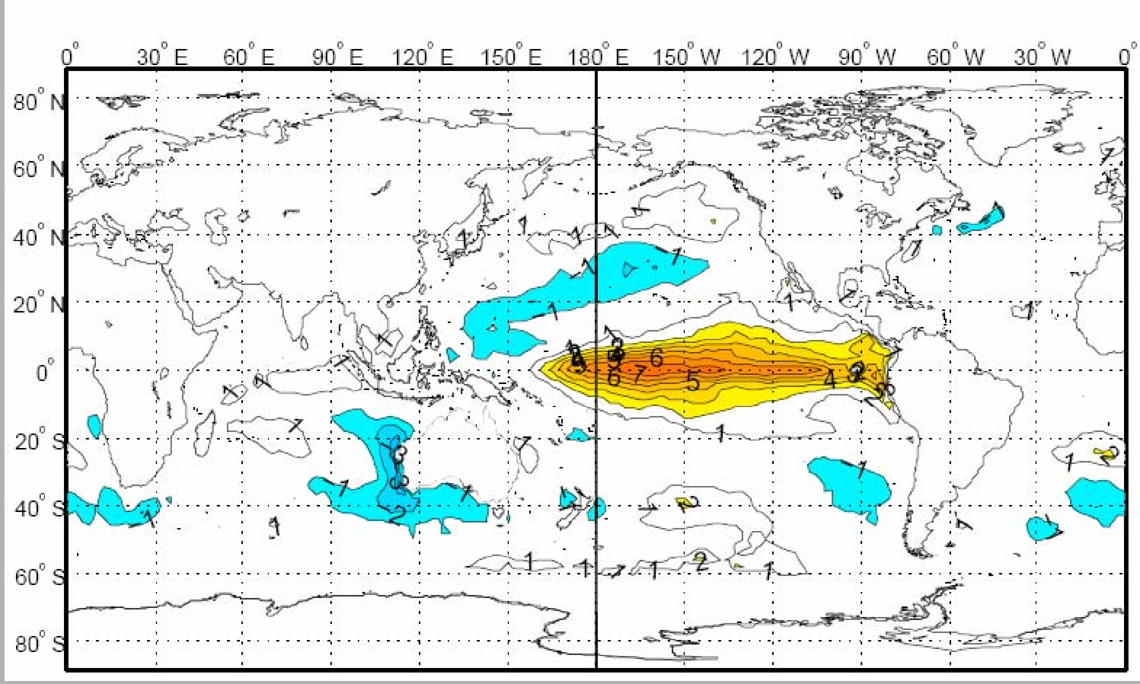
- representation of summer teleconnections (+MJO??) in a GCM ensemble (e.g. in NCEP CFS model)
- use of RCM or high resolution GCM to resolve summer rainfall processes

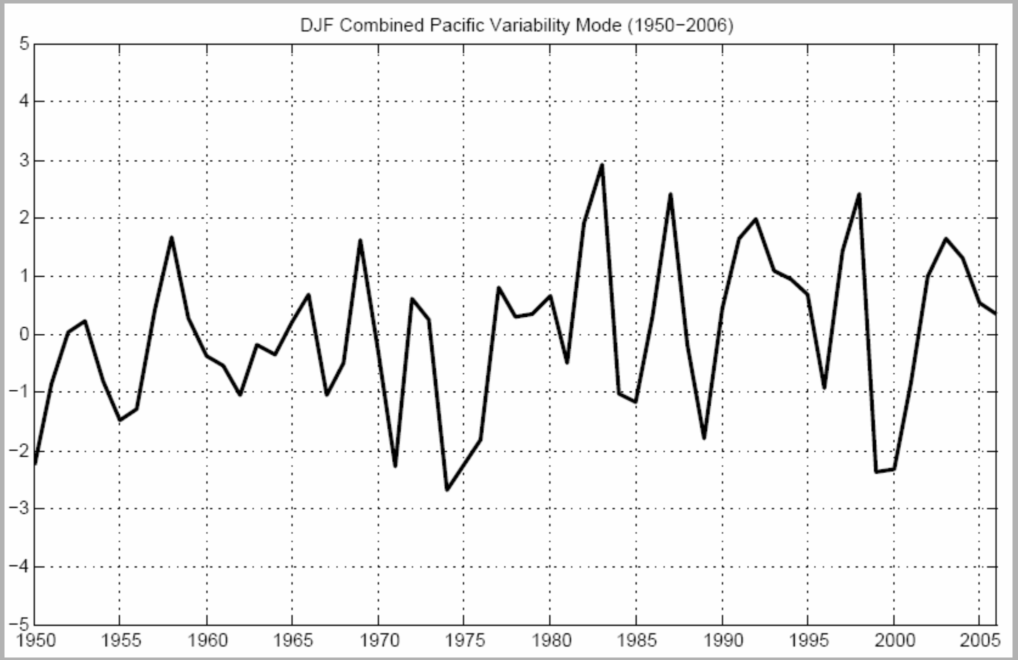
Summer CPVM: 1950-2006





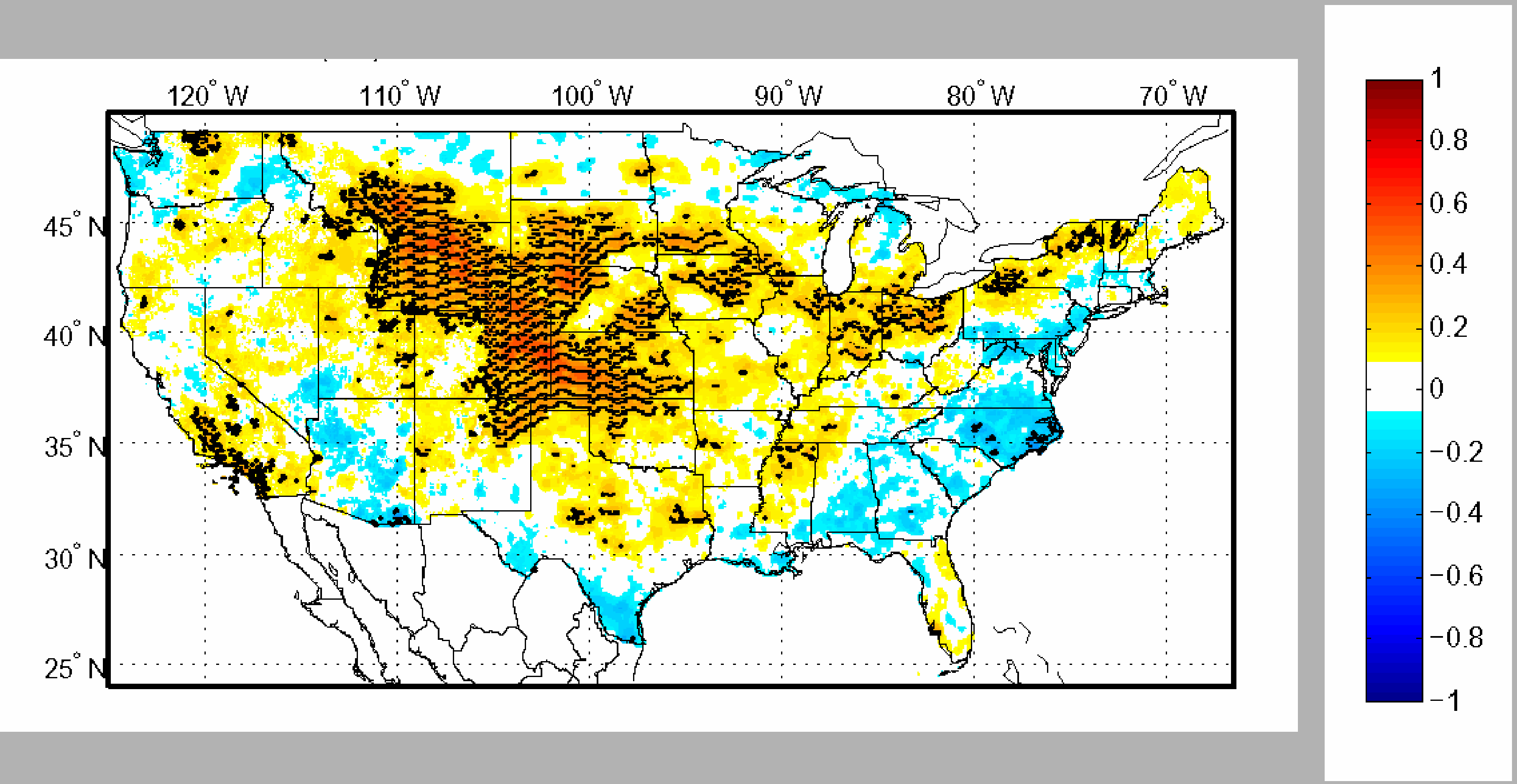
Antecedent winter CPVM



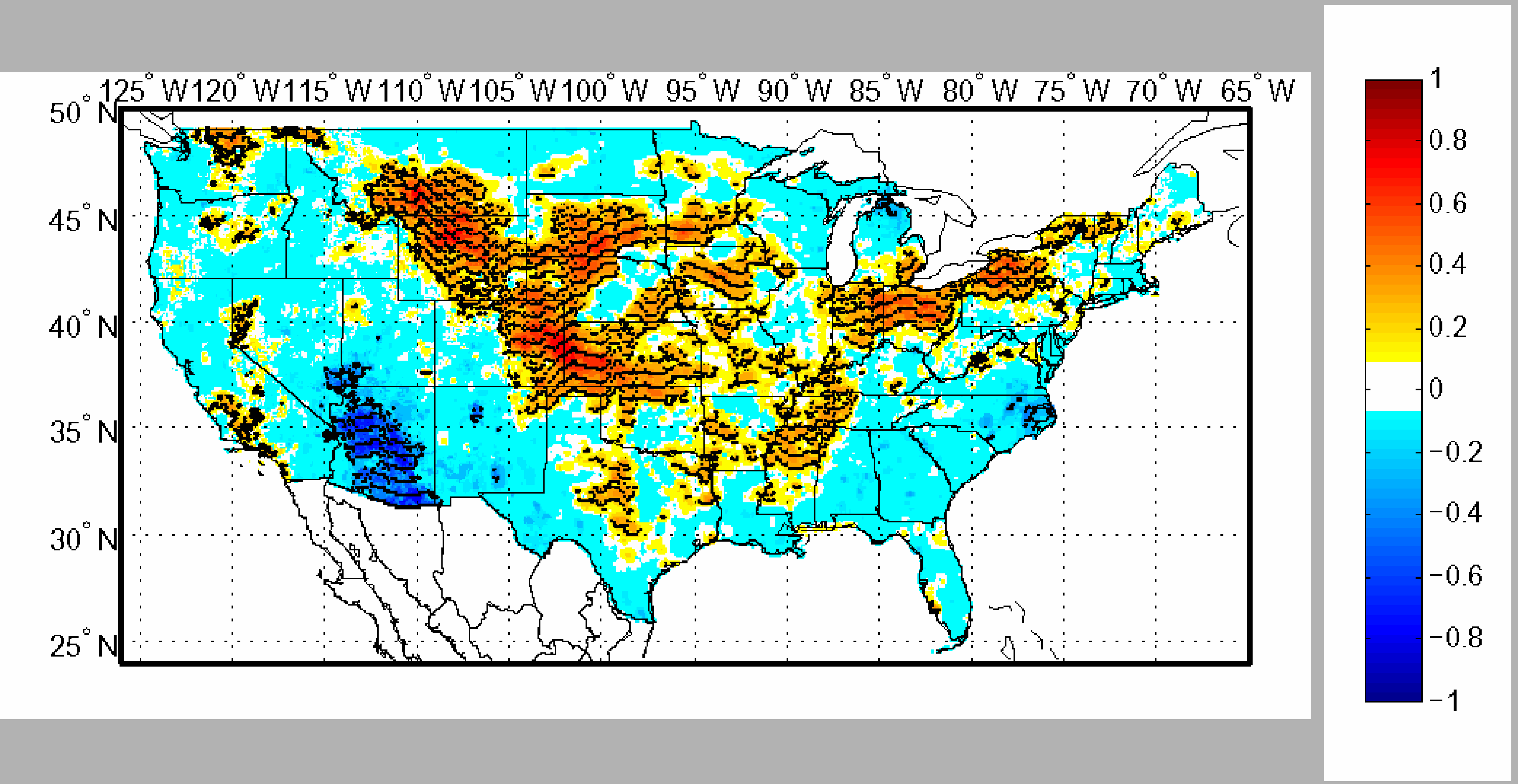


The CPVM is still pretty coherent through the antecedent winter season, though the exact ranking of its component REOFs may change.

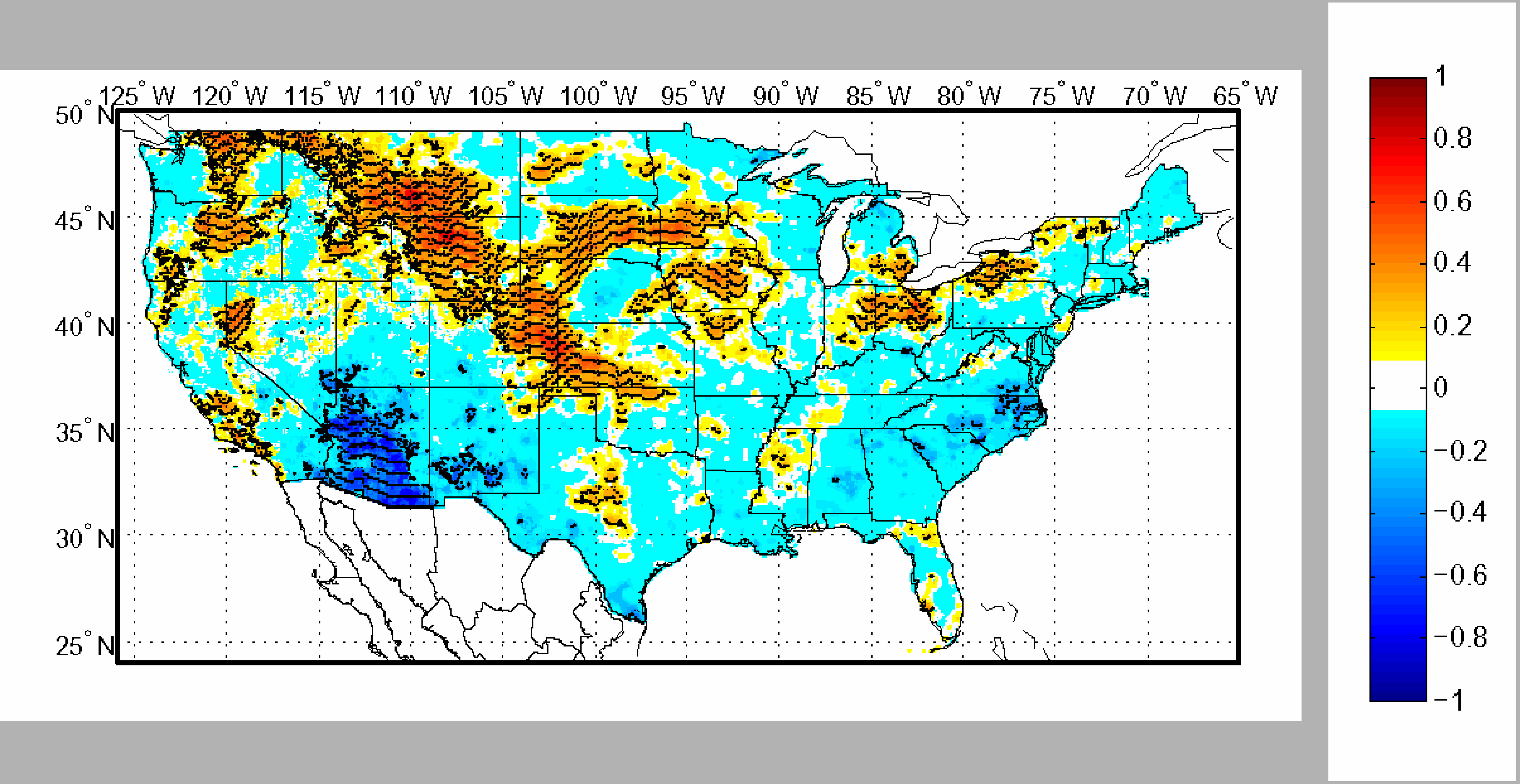
Correlation of JJA 3 mo. PRISM-derived SPI with concurrent CPVM



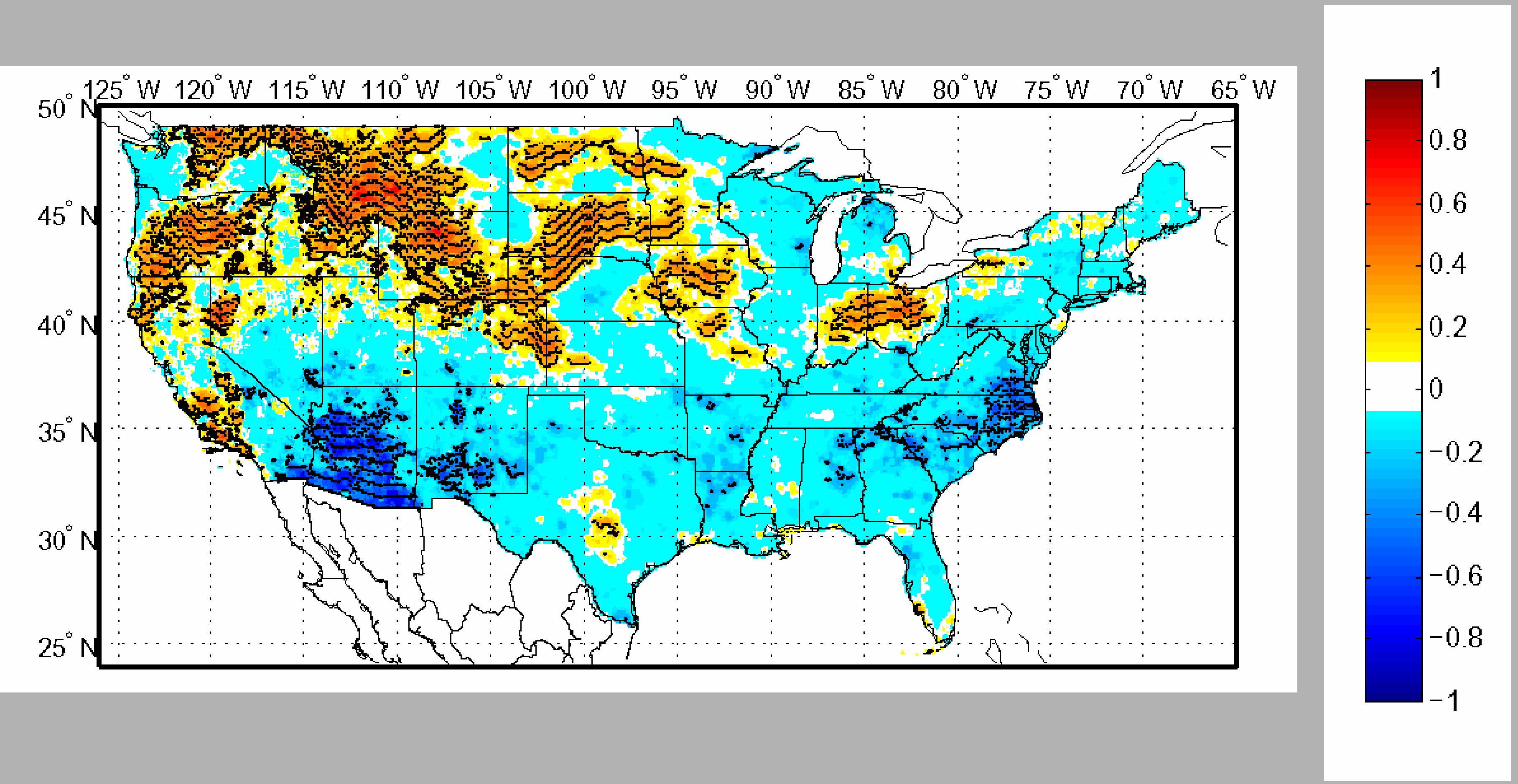
Correlation of JJ 2mo. PRISM-derived SPI with concurrent CPVM (onset period)



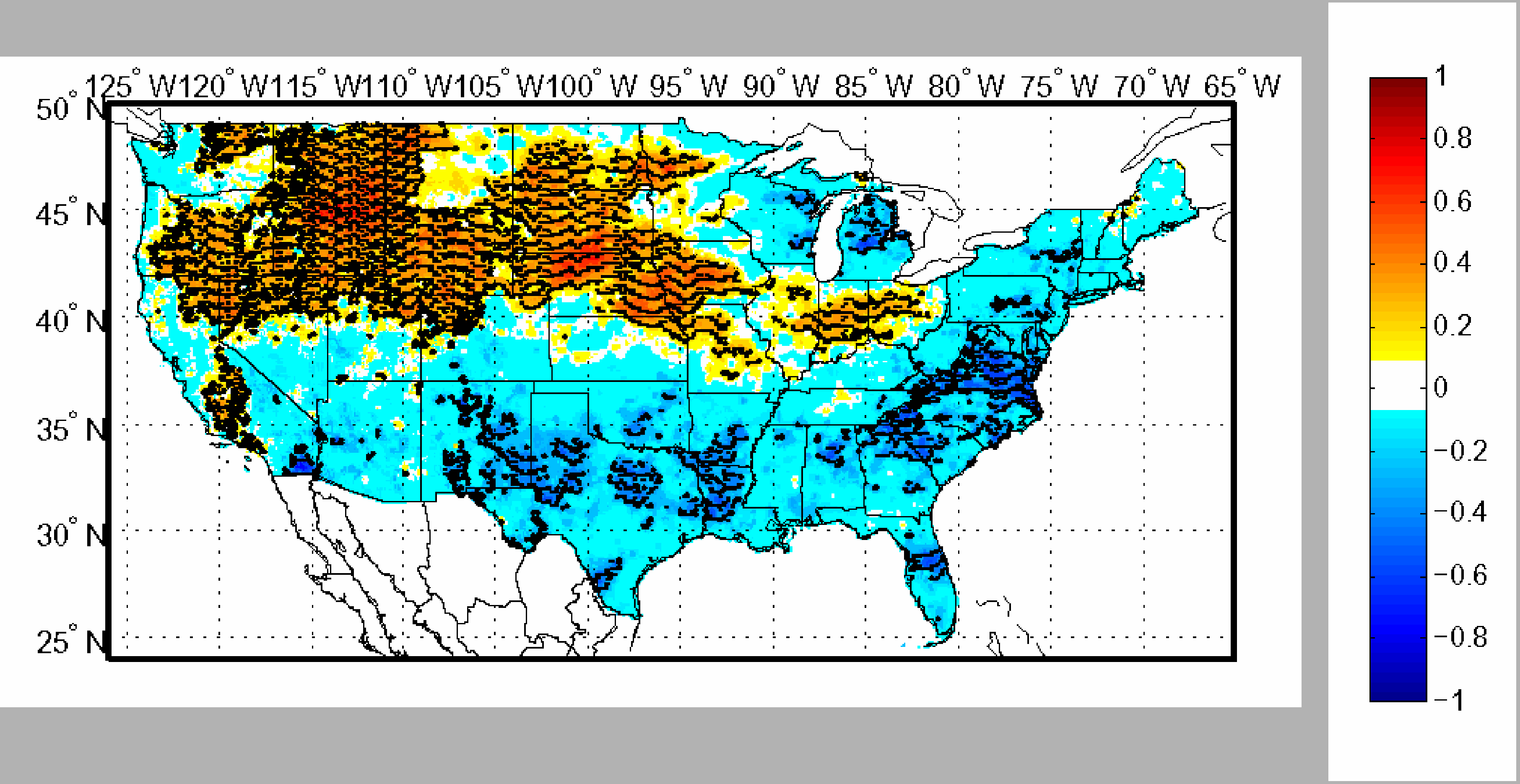
Correlation of JJ 2mo. PRISM-derived SPI with antecedent AMJ CPVM (onset period)



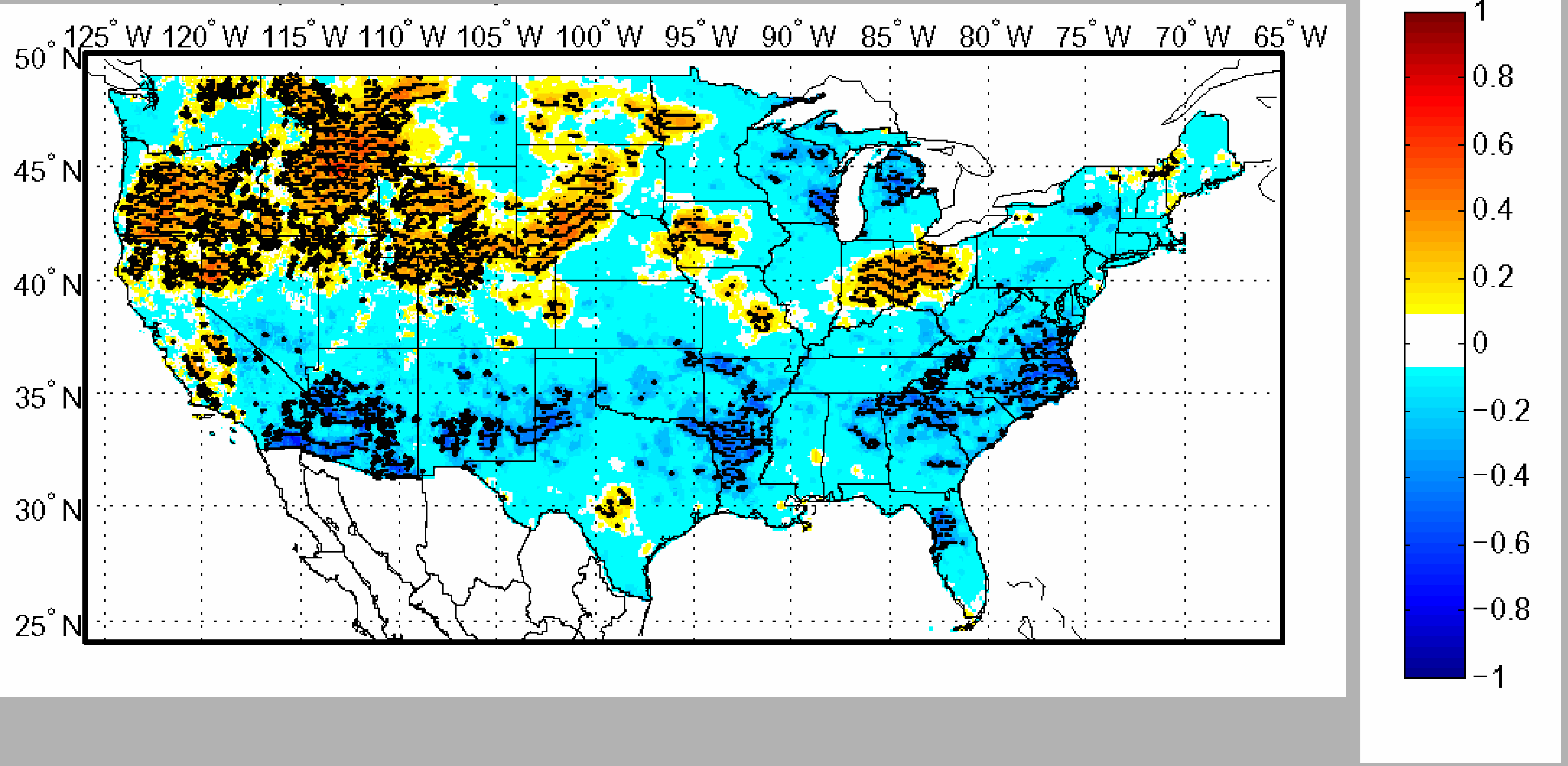
Correlation of JJ 2mo. PRISM-derived SPI with antecedent MAM CPVM (onset period)



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



Correlation of JJ 2mo. PRISM-derived SPI with antecedent JFM 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

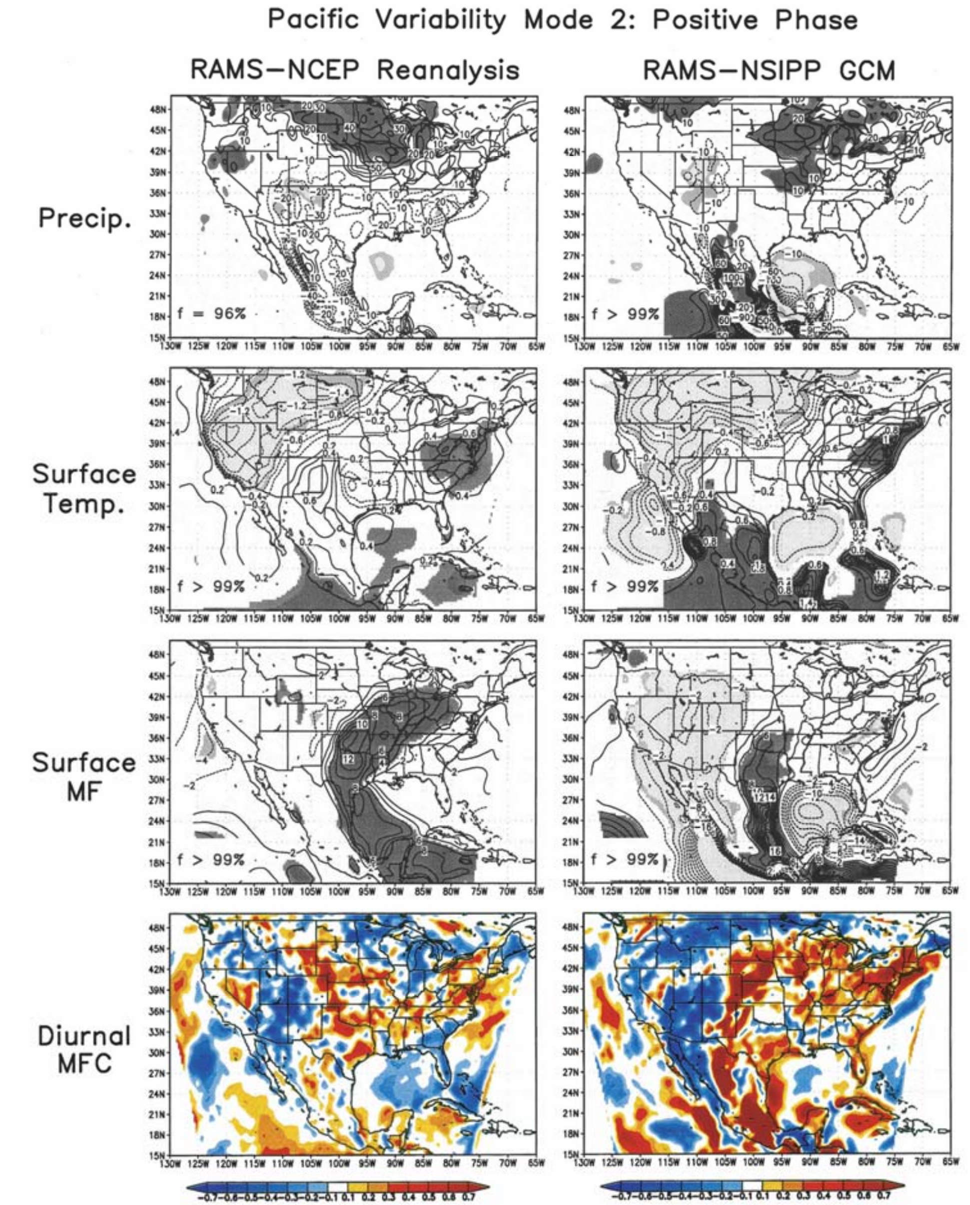


FIG. 14. Comparison of Pacific variability mode-2 positive phase at the period of maximum teleconnectivity for RAMS–NCEP composite (30-day average centered on 15 Jul) and RAMS–NSIPP ensembles (30-day average centered on 20 Jul). RAMS–NCEP composite years are defined in Table 1. Anomalies of precipitation, 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).

Concluding points

There is an order of importance of NAMS predictability factors. The one which I've heavily emphasized is the teleconnectivity to the Pacific. It serves as one of the main "orchestrators" of interannual variabilility—and may be the most important one.

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 state of Pacific SSTs in late winter and spring appears to be a good predictive gauge of NAMS onset and strength.

RCMs, or more highly resolved GCMs, are necessary to resolve the physical processes which lead to monsoon rainfall, particularly the diurnal cycle. A grid spacing roughly equivalent to NARR is probably okay.

Climate change has probably affected the monsoon during the past fifty years, increasing the intensity of synoptic rainfall events and decreasing rainfall in parts of western Mexico.

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.

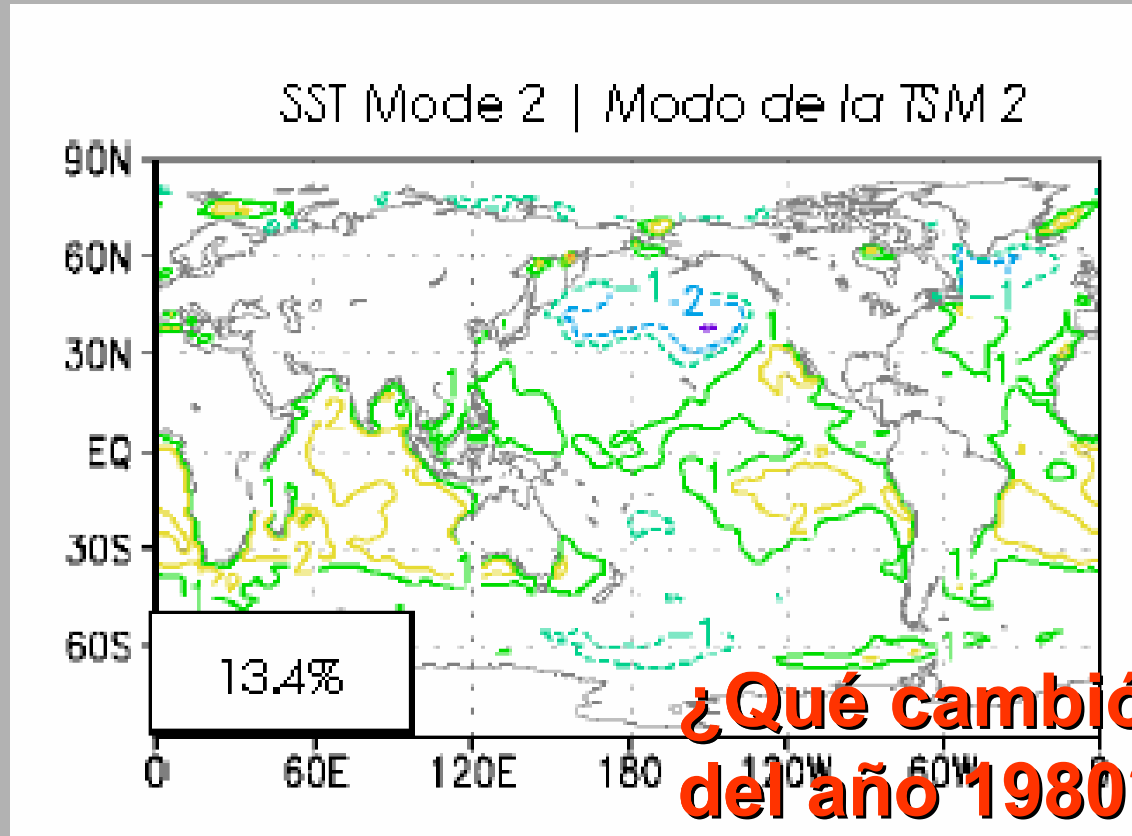
Dynamical downscaling of archived CFS ensembles from CPC with WRF for the summer season (about 1980-present). Working with Jae Schemm on this...

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

What about the climate change question?

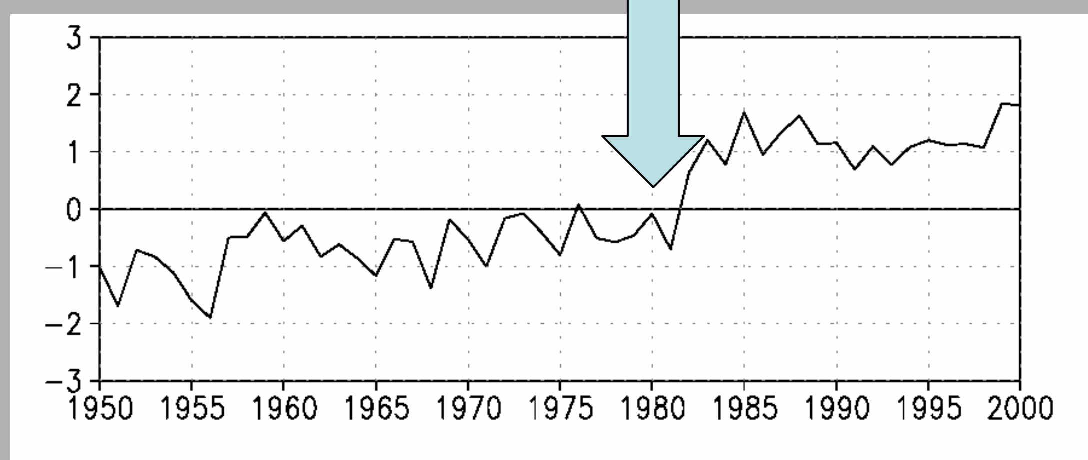
...Will keep it brief because Tereza Cavazos will speak more on this.

El modo del aumento global de la TSM en los trópicos

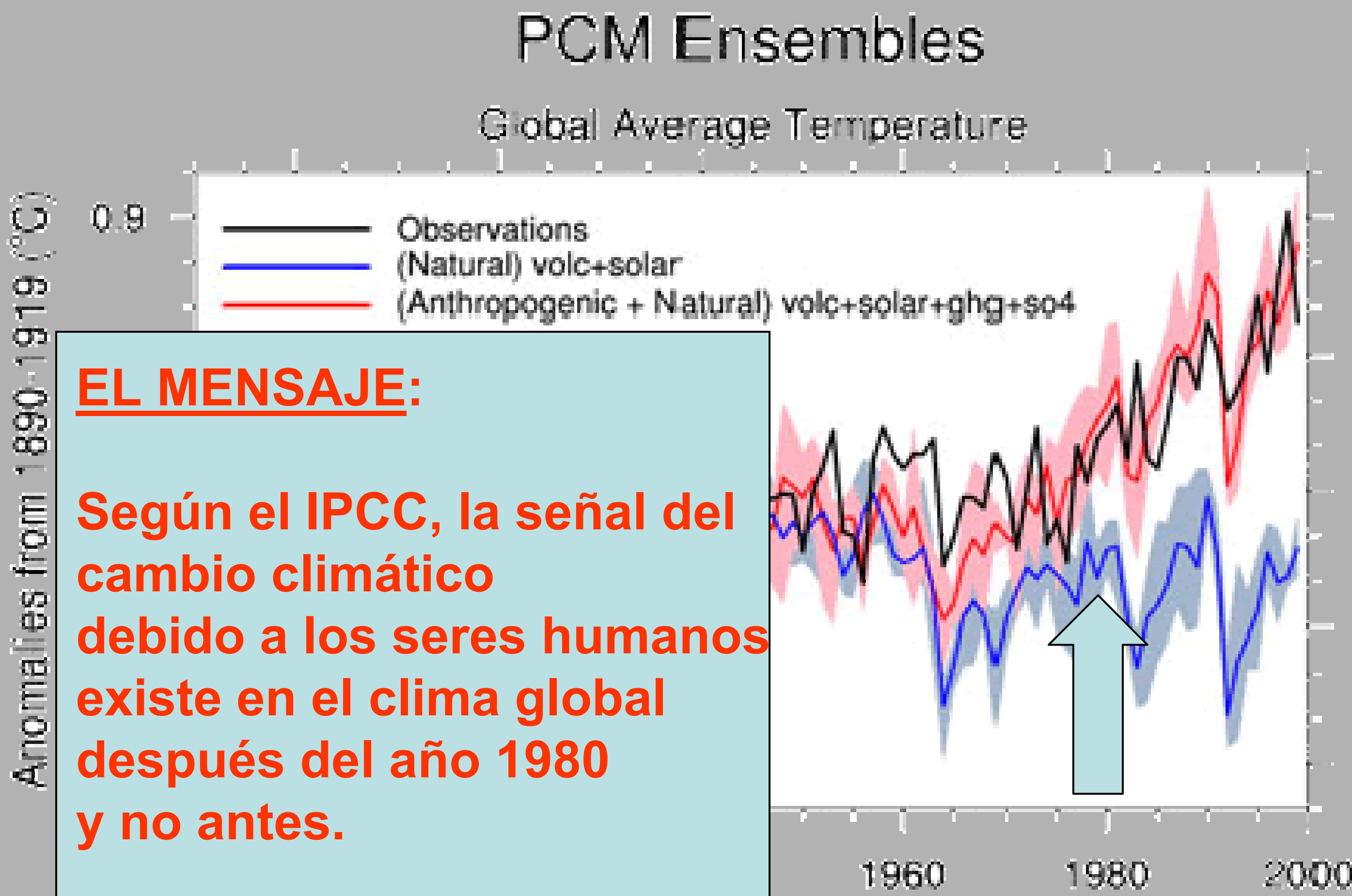


¿Qué cambió cerca del año 1980?

Serie del tiempo (Componente principal)



Los experimentos de atribución del cambio climático (de IPCC)

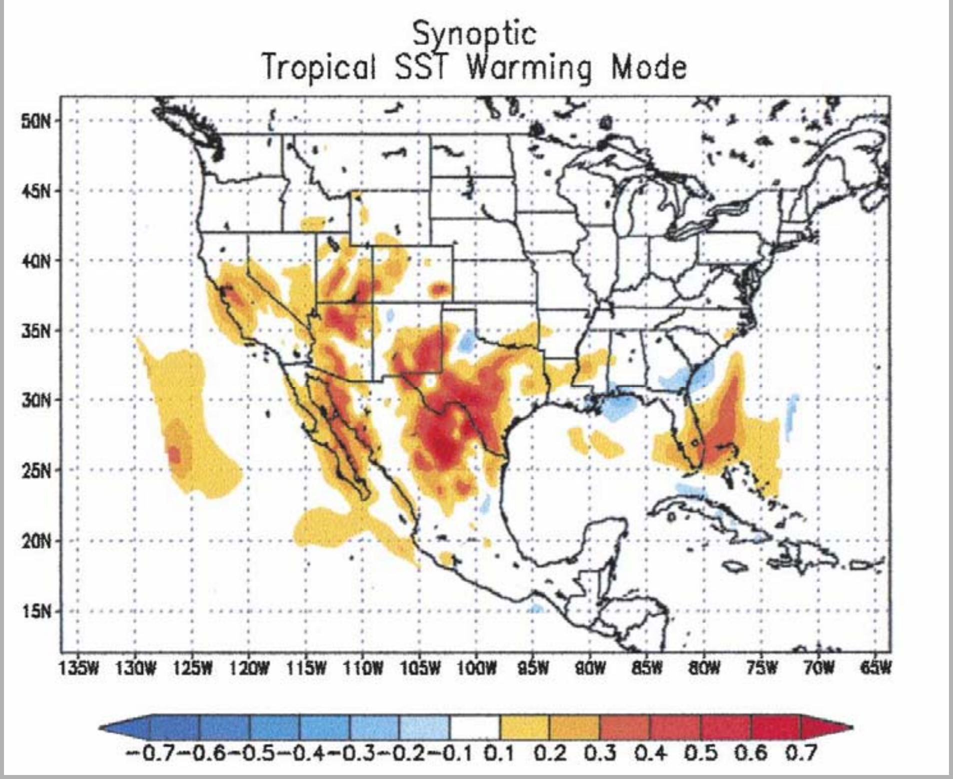


EL MENSAJE:

Según el IPCC, la señal del cambio climático debido a los seres humanos existe en el clima global después del año 1980 y no antes.

(Meehl et al., National Center for Atmospheric Research)

El cambio de CFH debido a los eventos sinópticos asociado con el aumento de la TSM en los trópicos

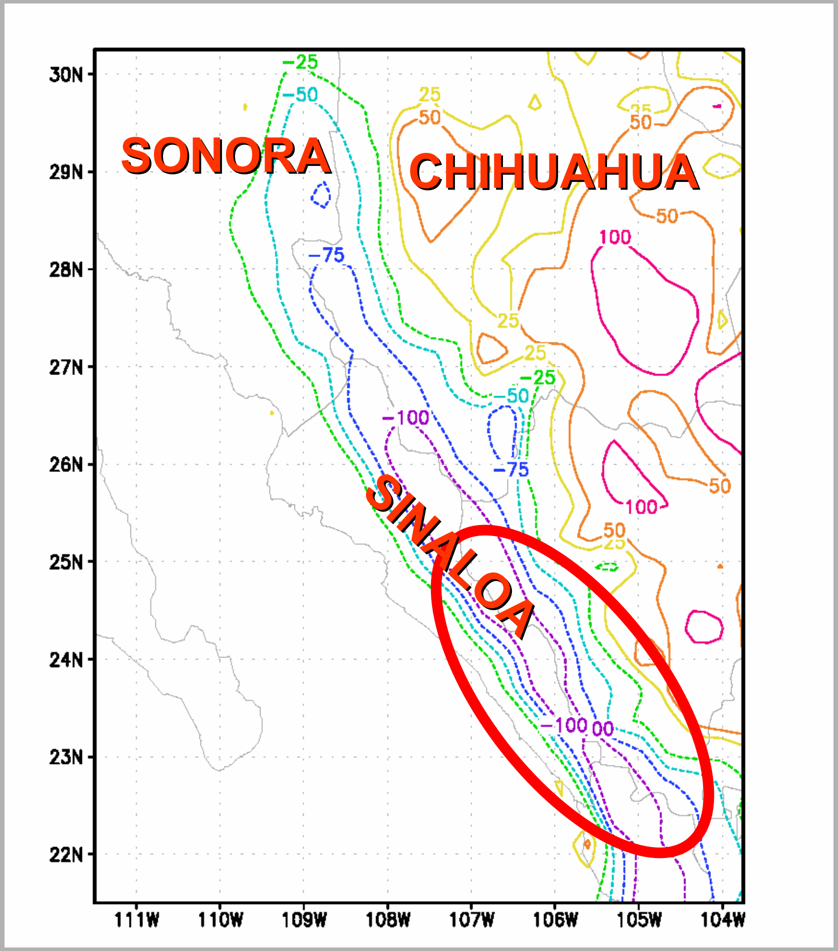


Las simulaciones sugieren que la precipitación del monzón que viene de la convección más organizada está creciendo.

¿Qué significa para Sonora y Arizona?

Tal vez no ha cambiado la cantidad de lluvia del monzón, *pero es más intensa que hace cincuenta años*.

El cambio correspondiente de la precipitación del modelo regional durante el mes de julio asociado con el modo 2 de la TSM global



Las observaciones del flujo de agua en los ríos en el sur de Sinaloa generalmente están de acuerdo con los resultados del modelo regional.

El porcentaje de la disminución de la precipitación es cerca de 30%.

Unidades: mm