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

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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


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


..BY NO MEANS A COMPREHENSIVE LIST!!
Motivation for understanding drivers of monsoon variability from stakeholders

- Severe weather
- Water supply and demand
- Wildfire
- Ranching and agriculture
Important motivational aside: Stakeholders **REALLY WANT** the “answer” of what happens with climate change!

Scientists predict Southwest mega-drought

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

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.

David Monroy / Getty Images
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

Tucson, AZ average daily surface dewpoints for 2006 monsoon (start date June 28)
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.
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
Subjectively determined presence of transient troughs in NARR data using methodology similar to Douglas and Englehart (2007).

Bieda et al. (2008, submitted)

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

- 18-21 UTC
- 21-00 UTC
- 00-03 UTC
- 03-06 UTC
- 06-09 UTC
- 09-12 UTC
Change in frequency of transient upper level troughs: negative minus positive CPVM years (1979-2003)

Late June, early July

August
Main conclusion: An MJO connection to monsoon precipitation in Arizona and northwest Mexico, but not New Mexico.

Hypothesis: 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?

**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 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.
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 variability—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