Final Technical Report on DOE DDEFG0208ER64548 (05/01/2008 – 04/30/2012)

Project Title: Atmosphere-Land-Surface Interaction over the Southern Great Plains: Diagnosis of Mechanisms from SGP ARM Data

Publications

1. Ruiz-Barradas, A, and S. Nigam, 2013: Atmosphere-Land-surface Interactions over the Southern Great Plains: Characterization from Pentad Analysis of DOE-ARM Field Observations and NARR Reanalysis. *J. Climate,* **26***,* No. 3 (1 February), 875-886.

The Department of Energy's Atmospheric Radiation Measurement (ARM) program's Southern Great Plains (SGP) site data is analyzed to provide insight into atmosphere –land-surface interactions generating summertime precipitation variability. Pentad (5-day) averaged data is analyzed; the average is long enough to suppress synoptic variability but sufficiently short to resolve atmosphere –land-surface interactions. Inter-comparison with the precipitation-assimilating North American Regional Reanalysis (NARR) helps with in-depth investigation of the processes. The analysis seeks to ascertain the process sequence, especially the role of evapotranspiration and soil-moisture – radiation feedbacks in the generation of regional precipitation variability at this temporal scale.

Transported moisture dominates over evapotranspiration in precipitation variability over the region, both from magnitude of the contribution to regional water-balance and its apparent temporal lead at pentad resolution. Antecedent and contemporaneous evapotranspiration are found to be *negatively* correlated with precipitation; only lagging correlations are positive, peaking at 2-pentad lag following precipitation, substantiating our characterization of the water-balance over SGP, and extending our previous findings at monthly resolution.

Precipitation episodes are linked with *net* negative surface radiation anomalies, i.e., with an energy-deprived land-surface state that cannot fuel evapotranspiration, ruling out radiatively-driven positive feedback on precipitation. Although the *net* longwave signal is positive due to a colder land-surface (less upward terrestrial radiation), it is more than offset by the cloudiness-related reduction in downward shortwave radiation. Thus, ARM (NARR) data does not support the soil-moisture–precipitation feedback hypothesis over the SGP at pentad time scales however it may be at work at sub-pentad resolution and over other regions.

2. Nigam, S., B. Guan, and A.Ruiz-Barradas (2011), Key role of theAtlanticMultidecadal Oscillation in 20th century drought and wet periods over the Great Plains, Geophys. Res. Lett., 38, L16713, doi:10.1029/2011GL048650.

The Great Plains of North America are susceptible to multi-year droughts, such as the 1930s 'Dust Bowl'. The droughts have been linked to SST variability in the Pacific and Atlantic basins. This observationally rooted analysis shows the SST influence in multi-year droughts and wet episodes over the Great Plains to be significantly more extensive than previously indicated. The remarkable statistical reconstruction of the major hydroclimate episodes attests to the extent of the SST influence in nature, and facilitated evaluation of the basin contributions. We find the Atlantic SSTs to be especially influential in forcing multi-year droughts; often, more than the Pacific ones. The Atlantic Multidecadal Oscillation (AMO), in particular, contributed the most in two of the four reconstructed episodes (Dust Bowl Spring, 1980s fall wetness), accounting for almost half the precipitation signal in each case. The AMO influence on continental precipitation was provided circulation context from analysis of NOAA's 20th Century Atmospheric Reanalysis.

A hypothesis for how the AMO atmospheric circulation anomalies are generated from AMO SSTs is proposed to advance discussion of the influence pathways of the mid-to-high latitude SST anomalies. Our analysis suggests that the La Nina–US Drought paradigm, operative on interannual timescales, has been conferred excessive relevance on decadal timescales in the recent literature.

3. Weaver, S.J., and S. Nigam, 2011: Recurrent Supersynoptic Evolution of the Great Plains Low-Level Jet. *J. Climate*, 24, 575-582.

The evolution of supersynoptic (i.e., pentad) Great Plains low-level jet (GPLLJ) variability, its precipitation impacts, and large-scale circulation context are analyzed in the North American Regional Reanalysis (NARR)—a high-resolution precipitation-assimilating dataset—and the NCEP–NCAR reanalysis. The analysis strategy leans on the extended EOF technique, which targets both spatial and temporal recurrence of a variability episode.

Pentad GPLLJ variability structures are found to be spatially similar to those in the monthly analysis. Thetemporal evolution of the supersynoptic GPLLJ-induced precipitation anomalies reveal interesting lead and lag relationships highlighted by GPLLJ variability-leading precipitation anomalies. Interestingly, similar temporal phasing of the GPLLJ and precipitation anomalies were operative during the 1993 (1988) floods (drought) over the Great Plains, indicating the importance of these submonthly GPLLJ variability modes in the instigation of extreme hydroclimatic episodes. The northward-shifted (dry) GPLLJ variability mode is linked to large-scale circulation variations emanating from remote regions that are modified by interaction with the Rocky Mountains, suggesting that the supersynoptic GPLLJ fluctuations may have their origin in orographic modulation of baroclinic development.

4. Weaver, S., A. Ruiz-Barradas, and S. Nigam, 2009: Pentad evolution of the 1988 drought and 1993 flood over the Great Plains: A NARR Perspective on the atmospheric and terrestrial water balance. *J. Climate*, 22, 5366-5384.

The evolution of the atmospheric and land-surface state during extreme hydroclimate episodes over North America is investigated using the North American Regional Reanalysis (NARR), which additionally, and successfully, assimilates precipitation. The pentad-resolution portrayals of atmospheric and terrestrial water-balance over the US Great Plains during the 1988summer drought and the July 1993 floods are analyzed to provide insight to the operative mechanisms including regional circulation (e.g., the Great Plains Low-Level Jet, or GPLLJ) and hydroclimate (precipitation, evaporation, soil-moisture recharge, runoff).

The sub-monthly (but super-synoptic time-scale) fluctuations of the GPLLJ are found to be very influential, through related moisture transport and kinematic convergence (e.g., $\partial v/\partial y$), with the jet anomalies in the southern Plains leading Northern precipitation and related moisture flux convergence, accounting for two-thirds of the dry and wet episode precipitation amplitude. The soil moisture influence on hydroclimate evolution is assessed to be marginal as evaporation anomalies are found to lag precipitation ones, a lead/lag not discernible at monthly resolution. The pentad analysis thus corroborates the authors' earlier findings on the importance of transported moisture over local evaporation in Great Plains' summer hydroclimate variability.

The regional water-budgets – atmospheric and terrestrial – are found to be substantially unbalanced, with the terrestrial imbalance being unacceptably large. Pentad analysis shows the atmospheric imbalance to arise from the sluggishness of the NARR evaporation, including its overestimation in wet periods. The larger terrestrial imbalance, on the other hand, has its origins in the striking unresponsiveness of the NARR's runoff, which is underestimated in wet episodes.

Finally, the influence of ENSO and NAO variability on the GPLLJ is quantified during the wet episode, in view of the importance of moisture transports. We show that a significant portion (~25%) of the GPLLJ anomaly (and downstream precipitation) is attributable to NAO and ENSO's influence, and that this combined influence prolongs the wet episode beyond the period of the instigating GPLLJ.

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