

# DIAGNOSIS AND VALIDATION OF LAND-ATMOSPHERE FEEDBACKS IN TWO GLOBAL MODELS

## **Year 1 Progress Report**

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Paul A. Dirmeyer (PI)

George Mason University

4400 University Drive, Mail Stop 6C5

Fairfax, Virginia 22030

Co-PIs: Joseph A. Santanello, Hydrologic Sciences Laboratory, NASA/GSFC Code 617

Michael G. Bosilovich, GMAO, NASA/GSFC Code 610.1

Michael B. Ek, NOAA/NWS/NCEP/EMC

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Year one of our research plan has focused on the first phase of the work plan, but we are happy to report progress on all phases.. Results from this research have been presented at multiple venues as published, as indicated at the end of the report.

## **Students**

Two PhD students in the Climate Dynamics Program within the Atmospheric, Oceanic and Earth Sciences (AOES) Department at George Mason University are currently supported on this grant. Holly Norton has a background in Atmospheric Sciences (SUNY Oswego) and Geology (Temple) and completed the second year of her graduate studies during the period of this report. This summer she is examining characteristics of soil moisture memory in GEOS5 and CFSv2 as manifested in each models' most recent re-analyses, including validation against in situ soil moisture data from the USDA Soil Climate Analysis Network (SCAN) over the United States. We are pursuing the idea that soil moisture memory may be significantly tied to underlying geology, namely the presence or absence of karst, which may significantly affect land-atmosphere interactions through the hydrologic cycle. This is not accounted for presently in any land surface models.

Jiexia Wu began PhD studies at GMU in January after completing MS degrees in Earth System Science (U. North Dakota) and Water Resources (U. Twente, Netherlands). This summer she is examining correlation-based metrics of land-atmosphere coupling in GEOS5 and CFSv2 as manifested in each models' most recent reanalyses. These will be validated against in situ based estimates from FluxNET observations around the globe, and to other previous model-based global assessments. Both students' current work address Phase 1 of the workplan.

### **MERRA and CFSR local metrics**

A range of diagnostics exploring the links between soil moisture, evaporation, PBL height, temperature, humidity, and precipitation are applied to the summertime monthly mean diurnal cycles of the North American Regional Reanalysis (NARR), Modern-Era Retrospective analysis for Research and Applications (MERRA), and Climate Forecast System Reanalysis (CFSR). Results show that CFSR is the driest and MERRA the wettest of the three RAs in terms of overall surface-PBL coupling. When compared against observations, CFSR has a significant dry bias that impacts all components of the land-PBL system. CFSR and NARR are more similar in terms of PBL dynamics and response to dry and wet extremes, while MERRA is more constrained in terms of evaporation and PBL variability. The implications for moist processes are also discussed, which warrants further investigation into the potential downstream impacts of land-PBL coupling on the diurnal cycle of clouds, convection, and precipitation. Lastly, the results are put into context of community investigations into drought assessment and predictability over the region and underscore that caution should be used when treating RAs as truth, as the coupled water and energy cycle representation in each can vary considerably.

For Phase 1 of the workplan, validation of several reanalyses including CFSR and MERRA against the thorough observational data during a 17-year period from the DOE Southern Great Plains (SGP) in situ measurement facilities has been conducted (Santanello and Roundy 2014). A range of diagnostics exploring the links between soil moisture, evaporation, PBL height, temperature, humidity, and precipitation have been applied to the summertime monthly mean diurnal cycles of the North American Regional Reanalysis (NARR) as well as MERRA and CFSR. Results show that CFSR is the driest and MERRA the wettest of the three reanalyses in terms of overall surface-PBL coupling. CFSR and NARR are most similar in terms of PBL dynamics and response to dry and wet extreme years, while MERRA is more constrained in terms of evaporation and PBL variability. When compared against observations, CFSR has a significant dry bias that impacts all components of the land-PBL system, and the results are put into context of community investigations into drought assessment and predictability over SGP. The implications for moist processes is also discussed, and warrants further investigation into the potential downstream impacts of land-PBL coupling on the diurnal cycle of clouds, convection, and precipitation. Overall, caution should be used when treating RAs as truth, as the coupled water and energy cycle representation in each can vary considerably.

### **MERRA and CFSR global metrics**

As mentioned in the Students section, this summer analyses of land-atmosphere coupling metrics and behavior of CFSR and MERRA are underway. We anticipate completion and first draft of a manuscript in fall 2014.

### **CFSRR global metrics**

Pursuant to Phase 2a of the workplan, assessments of the *reforecasts* from CFSv2 (Dirmeyer 2013) have revealed that precipitation biases are evident in both reanalysis and reforecasts, while biases in soil moisture grow throughout the duration of the forecasts.

Locally, the soil moisture biases may shrink or reverse sign. These biases are reflected in evaporation and runoff. The Noah land surface scheme shows the necessary relationships between evaporation and soil moisture for land-driven climate predictability. There is evidence that the atmospheric model cannot maintain the link between precipitation and antecedent soil moisture as strongly as in the real atmosphere, potentially hampering prediction skill, although there is better precipitation forecast skill over most locations when initial soil moisture anomalies are large. Bias change with lead-time, measured as the variance across ten monthly forecast leads, is often comparable to or larger than the inter-annual variance. Skill scores when forecast anomalies are calculated relative to reanalysis are seriously reduced over most locations when compared to validation against anomalies based on the forecast model climate at the corresponding lead-time. When all anomalies are calculated relative to the 0-month forecast, some skill is recovered over some regions, but the complex manner in which biases evolve indicates that a complete suite of reforecasts would be necessary whenever a new version of a climate model is implemented. The utility of reforecast programs is evident for operational forecast systems.

### **CFSv2 Hindcast Simulations**

We have had the opportunity to begin on Phase 2b ahead of schedule, starting to run hindcasts of CFSv2 in spring 2014. One 28-year set of simulations with 1 May initial conditions and large initial land surface state perturbations (ensemble size of 28) has been completed. Simulations for other forecast start dates and with small initial perturbations are ongoing.

### **Publications:**

Dirmeyer, P. A., 2013: Characteristics of the water cycle and land-atmosphere interactions from a comprehensive reforecast and reanalysis data set: CFSv2. *Climate Dyn.*, **41**, 1083-1097, doi: 10.1007/s00382-013-1866-x.

Santanello, J. A., and J. Roundy, 2014: Quantifying the land-atmosphere coupling behavior in modern reanalysis products over the U.S. Southern Great Plains. *J. Climate*, (in preparation).

### **Presentations:**

Dirmeyer, P. A., and A. Tawfik, 2014: Validation of CFSv2 model behavior – Land-atmosphere interactions and the hydrologic cycle. NOAA Climate Prediction Science and Technology Digest, Feb 2014, 75-79.

Dirmeyer, P. A., 2014: Does the NOAA global model take full benefit of land state information for subseasonal forecasts? WMO WWRP/THORPEX-WCRP International Conference on Subseasonal to Seasonal Prediction, College Park, Maryland, USA

Dirmeyer, P. A., 2013: Land Surface Processes and Drought Forecast Skill over North America (Invited). American Geophysical Union Fall Meeting, San Francisco, CA, USA, H12B-06.

- Dirmeyer, P. A., 2013: "Drought forecasts and land-atmosphere interactions in the NOAA climate model" AOES Climate Dynamics seminar, George Mason University, 6 November 2013.
- Dirmeyer, P. A. and A. Tawfik, 2013: Validation of CFSv2 model behavior – land-atmosphere interactions and the hydrologic cycle. 38th Climate Diagnostics and Prediction Workshop, College Park, Maryland, USA.
- Shrestha, R. K., H. Wei, J. Dong, P. A. Dirmeyer, and M. B. Ek , 2014: Sensitivity of albedo and greenness fraction parameters in surface fluxes estimated from Noah land surface models in the FLUXNET sites. American Meteorological Society, 28th Conference on Hydrology, 49.
- Shrestha, R. K., J. Dong, P. A. Dirmeyer, M. B. Ek, and G. Abramowitz, 2013: Evaluation of Noah land surface models in the FLUXNET sites using the Land Information System. American Geophysical Union Fall Meeting, San Francisco, CA, USA, H32G-07.
- Tawfik, A. B., and P. A. Dirmeyer, 2014: Isolating the Impact of Local and Large-Scale Forcings on Surface Triggered Convection. American Meteorological Society, 28th Conference on Hydrology, J1.1.