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

Year 2 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 continues to focus 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

Jiexia Wu passed her qualifier exams earlier this month. Both she and Holly Norton, supported on this grant, are assembling advisory committees this summer and plan to take their specialty exams before fall semester starts. That will place each fully into the research phases of their PhD programs.

Norton's dissertation topic is tending toward 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. Wu is interested in drought and the role of land-atmosphere feedbacks therein. Both topics fit well within the scope of the proposed research in this project, and each will contribute significantly. In fact, both Wu and Norton have already contributed essential analysis of observational and model data as described below.

Observational data acquisition and evaluation

We have been working with W. Dorigo of the International Soil Moisture Network (ISWN) at T.U. Vienna, and Stephen Quiring of the North American Soil Moisture Data Bank (NASMDB) at Texas A&M to apply a wide range of in situ and near-field remotely sensed soil moisture observations to the task of validation in land surface models and coupled land-atmosphere models. This is resulting in a first-of-its-kind wide ranging comparison of observational soil moisture data, and broad validation of gridded model output that can contribute to significant model development (Dirmeyer 2014). We are extending the theoretical work of K. Vinnikov from the 1990s regarding error estimation in observational soil moisture data sets based on lagged autocorrelation statistics to a wide range of station data. We are also exploring its application to error estimation of

remotely-sensed soil moisture (with S. Kumar and C. Draper, NASA/GSFC). Issues of scaling, variability and memory of soil moisture and their validation in models are being addressed in what is becoming a major paper (Dirmeyer et al. 2015, in prep.) that should be submitted later this summer.

We also have submitted a proposal to the management of the FluxNET La Thuile data which has been accepted (including an enthusiastic direct email from Markus Reichstein, co-director of MPI-Jena) that grants us access to the complete quality-controlled La Thuile data set of surface fluxes, soil moisture, near surface meteorology and other data from well over 100 sites around the world. This will provide an unprecedented capability to quantify broadly over the globe from observations many land-atmosphere coupling metrics, and perform a similar validation exercise of "confronting" models with reality.

Coupling metrics

We have compiled a "cheat sheet" of land-atmosphere coupling metrics that is making the rounds among the GEWEX community, which has championed efforts for local coupled evaluation (e.g., Best et al. 2015). It brings together the theory, formulations and references for various published metrics of land-atmosphere feedbacks over the past 20 years in one place, with strengths and weaknesses of each listed.

Interest in the metrics we are applying to NASA/GSFC and NCEP models has caused us to expand our analysis to include ECMWF (via G. Balsamo) and NCAR (via D. Lawrence) models (it is almost trivial to extend our analysis to data from additional models once the observational data has been processed and scripts for calculating metrics are written). Additionally, G. Campo at NOASS/ESRL expressed interest in applying our metrics to the 20th Century Reanalysis (20CR) version 2 output, which uses the same atmospheric and land models from NCEP in a different data assimilation framework. We are happy to see our efforts garnering such interest elsewhere in the US and abroad.

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 et al. 2015). 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.

Lo-Co Downscaling

Leveraging off of the NU-WRF downscaling project, which will have 24, 12, and 4km simulations with and without nudging and non-nudging, as well as MERRA-2 and high-resolution GEOS-5 simulations, we will assess coupling metrics in this suite of NASA model simulations in the same manner that we are doing with older NASA products, NCEP and other model output. J. Roundy is currently coding scripts to produce the coupling analysis on these runs and comparing them to default reanalysis products and to the AIRS/AMSR-e based product. We will assess other coupling metrics and land-surface validation. We are finding for soil moisture that global models do a good job representing the variability that the regional-national scale soil moisture networks show, but do poorly on smaller state-level networks where the spatial variations have more to do with land surface properties than climate. Comparison to NU-WRF simulations can validate the value and impact of high-resolution land surface data.

Betts Collaboration

COLA has supported Alan Betts to collaborate on issues of land-atmosphere coupling and feedbacks highly germane to this project. We had a project group meeting on 7 November 2014 to discuss collaboration options. Betts has been working with former COLA post-doc (now at NCAR) A. Tawfik on some analysis, We will be applying some of Betts analysis techniques from the Canadian Prairies observations to data from the US Great Plains, particularly the ARM Best Estimate (ARMBE) data set.

Publications:

Best, M. J., G. Abramowitz, H. R. Johnson, A. J. Pitman, G. Balsamo, A. Boone, M. Cuntz, B. Decharme, P. A. Dirmeyer, J. Dong, M. Ek, Z. Guo, V. Haverd, B. J. J. van den Hurk, G. S. Nearing, B. Pak, C. Peters-Lidard, J. A. Santanello Jr., L. Stevens, and N. Vuichard, 2015: The plumbing of land surface models: benchmarking model performance. *J. Hydrometeor.*, **16**, 1425-1442, doi: 10.1175/JHM-D-14-0158.1.

Dirmeyer, P. A., 2014: The cusp of major progress in predicting land-atmosphere interactions. *GEWEX News*, **24**(1-2), 15-18.

Dirmeyer, P. A., C. Peters-Lidard, and G. Balsamo, 2015: Land-Atmosphere Interactions and the Water Cycle. [Chapter 8 in: Seamless Prediction of the Earth System: from Minutes to Months, (G Brunet, S Jones, PM Ruti Eds.)], World Meteorological Organization (WMO-No. 1156), Geneva.

Dirmeyer, P. A., J. Wu, H. Norton, W. Dorigo, S. Quiring; J. A. Santanello, M. G. Bosilovich, M. B. Ek, G. Balsamo, D. Lawrence, and G. Campo, 2015: Confronting weather and climate models with observational data from soil moisture networks over the United States. (in preparation).

Santanello, J. A., J. Roundy, and P. A. Dirmeyer, 2015: Quantifying the land-atmosphere coupling behavior in modern reanalysis products over the U.S. Southern Great Plains. *J. Climate*, (early release), doi: 10.1175/JCLI-D-14-00680.1.

Presentations:

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Dirmeyer, P. A., Z. Guo, S. Halder, H. Norton, and J. Wu, 2014: An initial assessment of coupled land-atmosphere memory in (and beyond) reanalysis. 39th Climate Diagnostics and Prediction Workshop, St. Louis, Missouri, USA.

Dirmeyer, P. A., A. Tawfik, H. Norton, and J. Wu, 2014: Land-atmosphere feedbacks over North America: How well do weather and climate models represent reality? World Weather Open Sci. Conf. (WWOSC), Montréal, Canada, SCI-PS101.02.

Meng, J., Y. Xia, J. Dong, P. Dirmeyer, M. Ek, R. Shrestha, Preliminary investigations on high resolution land data assimilation over CONUS region. WWOSC, Montréal, Canada, SCI-POW1049.

Santanello, J. and A., J. Roundy, 2014: Quantifying the land-atmosphere coupling behavior in modern reanalysis products over the U.S. Southern Great Plains. American Geophysical Union Fall Meeting, San Francisco, CA, USA, H11J-05.

Shrestha, R. K., J. Meng, P. Xie, P. A. Dirmeyer, M. B. Ek, and K. Mo, 2015: Evaluation of OLR-based CPC high-resolution precipitation in GLDAS re-run experiment. American Meteorological Society, 29th Conference on Hydrology, Phoenix, Arizona, USA, 511.

Shrestha, R., H. Wei, J. Dong, P. A. Dirmeyer, and M. B. Ek, 2014: Introducing an automated Gap-Filling method to use CEOP data in land surface model evaluation and benchmarking experiment. 7th Intl. GEWEX Sci. Conf., The Hague, The Netherlands.

White Papers:

Dirmeyer, P. A., D. J. Gochis, T. S. Hogue, A. Barros, C. J. Duffy, K. Friedrich, M. Hughes, W. Krajewski, and N. P. Molotch, 2014: Advancing Hydrometeorological-Hydroclimatic-Ecohydrological Process Understanding and Predictions. White Paper: Hydrologic-Atmospheric Community Workshop, Golden, Colorado, 12pp [Available at: http://inside.mines.edu/~thogue/nsf-hydro-atmo-workshop/NSFHydroAtmosWorkshopWhitePaper120314FINAL.pdf.

Dirmeyer, P. A., E. K. Jin, J. L. Kinter III and J. Shukla, 2014: Land Surface Modeling in Support of Numerical Weather Prediction and Sub-Seasonal Climate Prediction. White Paper: Workshop on Land Surface Modeling in Support of NWP and Sub-Seasonal Climate Prediction, 17pp [Available at: http://www.iges.org/lsm/GMU_KIAPS_White_Paper.pdf].