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Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	1419445
Project Title:	EaSM-3: Land Use Change and Land Atmosphere Feedback Processes as Regulators of Regional Climate Change
PD/PI Name:	Paul A Dirmeyer, Principal Investigator
Recipient Organization:	George Mason University
Project/Grant Period:	08/01/2014 - 07/31/2018
Reporting Period:	08/01/2014 - 07/31/2015
Submitting Official (if other than PD\PI):	N/A
Submission Date:	N/A
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	N/A

Accomplishments

*** What are the major goals of the project?**

Goals for the project are:

1. Examine the coupled feedback processes between land and atmosphere in CESM. This includes the relationships between soil moisture and surface fluxes, and the connection between surface fluxes and the development of the atmospheric boundary layer, clouds and precipitation, and the role of the biogeophysical elements of CLM in these processes.
2. Develop and refine metrics for (a) quantifying land-atmosphere coupling in models and observations for purposes

of model validation and the quantification of important climate processes over land; (b) land use changes in the context of their effects on, and response to, climate variations and change.

3. Investigate the evolution of coupled land-atmosphere climate processes in CESM under the dual axes of a changing climate and regional land use change.

These are to be executed in the following tasks:

- Task 1: Develop analysis tools for offline and coupled models
- a: Land-atmosphere interaction diagnostics
- b: Metrics for assessment of modeled terrestrial response to land use
- Task 2: Assess land-atmosphere coupling under varying land uses in CAM-CLM
- a: Land-atmosphere coupling assessment across CAM-CLM configurations
- b: Analysis of offline CLM simulation across a variety of land covers and land uses
- c: Analysis of land-atmosphere coupling across range of land cover / land use
- Task 3: Decadal-timescale evolution of land-atmosphere feedbacks due to dual axes of climate and land use change
- a: Assess changes in land-atmosphere feedback due to climate change and land use change separately
- b: Land-atmosphere feedbacks and impact on extremes under scenarios with both climate change and land use change

*** What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?**

Major Activities:

The Land-Use Model Inter-comparison Project (LUMIP) is a major international project that will be closely tied to CMIP6 and the climate modeling efforts for the next IPCC Assessment. LUMIP is targeted to sort-out and compare the specific climate change responses that result from land use change and land management practices on a large scale. Assessment of the realism of current models and the degree to which climate response to land use change may itself vary in a changing climate are the key elements for LUMIP, and this project is designed to develop and test metrics and methods that will then be applied widely in the international climate modeling community.

Fundamental to such assessments is the coupled behavior of climate models in a stable land use scenario. PI Dirmeyer has led efforts in this area within the World Climate Research Programme (WCRP) Global Energy and Water Exchanges (GEWEX) Global Land-Atmosphere System Study (GLASS), of which the PI was a co-founder 16 years ago, and which is concerned with modeling and understanding the coupled land-climate system. This is pertinent to sub-seasonal predictability and prediction, as well as longer-scale climate aspects. The first step is to assess the character and strength of coupled land-atmosphere variablity from the growing pool of observational data and *confront* models with these multi-variate metrics in ways that have not been done before, exposing heretofore undiagnosed problems in Earth system model coupled behavior.

Specific Objectives:

Under Task 1a, we have begun developing a Land–Atmosphere Coupling Toolkit (details under "Products") based on ongoing evaluation of land-atmosphere coupling metrics from observations, and the *confrontation* of models with these multi-variate validation statistics.

Work under Task 1b is proceeding under co-I Lawrence's co-leadership of LUMIP (Land-Use Model Inter-comparison Project), which is one of the proposed MIPs for CMIP6 and the 6th IPCC Assessment.

Significant Results:

Key outcomes or

In this early stage, no manuscripts directly supported by this grant have yet been submitted for publication, but we expect the first will be drafted at the end of summer and submitted in the fall.

Other achievements: Two relevant related publications supported by National Science Foundation grant 0947837 for Earth System Modeling post-doctoral fellows at George Mason University have been revised and we expect to be accepted for publication shortly:

Tawfik, A. B., P. A. Dirmeyer, and J. A. Santanello, 2015: The heated condensation framework. Part I: Description and Southern Great Plains case study. *J. Hydrometeor*., (in review).

Tawfik, A. B., P. A. Dirmeyer, and J. A. Santanello, 2015: The heated condensation framework. Part II: Climatological behavior of convective initiation and land-atmosphere coupling over the continental United States. *J. Hydrometeor*., (in review).

*** What opportunities for training and professional development has the project provided?**

This project is supporting PhD student Ako Heidari for Spring and Summer 2015 – he is a graduate student in the Department of Geography and GeoInformation Science at George Mason University now working collaboratively with the PI.

We are happy to announce the hire of Liang Chen (Texas A&M Ph.D. May 2015) as a post-doctoral fellow on the project, after an open search that produced 25 applicants, 6 viable candidates and 3 interviews. He will start in August 2015.

Supported on collaborative grant to co-I D. Lawrence funded by USDA, Ahmed Tawfik was hired as a Scientist I at NCAR for this project in January 2015.

*** How have the results been disseminated to communities of interest?**

Preliminary results, largely focused on the evaluation of metrics in observations and reanalysis products in preparation for evaluation of NCAR CESM, have been presented at the World Weather Open Science Conference in Montreal in August 2014, the Climate Diagnostics and Prediction Workshop in St. Louis in October, the AGU Fall Meeting in December, and the AMS Annual Meeting in January 2015:

Dirmeyer, P. A., A. Tawfik, S. Halder, H. Norton, J. Wu, M. G. Bosilovich, J. A. Santanello Jr., and M. B. Ek, 2015: Confronting global land-atmosphere models with coupled process metrics. American Meteorological Society, 29th Conference on Hydrology, Phoenix, Arizona, USA, J1.2.

Tawfik, A. B., and P. A. Dirmeyer, 2015: A New Explicit and Computationally Efficient Sub-grid Convective Initiation Scheme. American Meteorological Society, 27th Conference on Climate Variability and Change, Phoenix, Arizona, USA, 12A.2.

Dirmeyer, P. A., A. Tawfik, Confronting CLM with land surface observations, NCAR Land Model Working Group (LMWG) Meeting, Boulder, Colorado, 3 March 2015.

Tawfik, A. B., and P. A. Dirmeyer, 2014: Evolution of Soil Moisture-Convection Interactions against the Backdrop of Global Oscillations. American Geophysical Union Fall Meeting, San Francisco, CA, USA, H11J-05.

Dirmeyer, P. A., Z. Guo, S. Halder, H. Norton, and J. Wu, 2014: An initial assessment of coupled landatmosphere 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.

*** What do you plan to do during the next reporting period to accomplish the goals?**

Work so far has focused on Task 1. With the new personnel beginning research work this summer and the

acquisition of computer time to begin model simulations, we will be able to begin work on Task 2 during year 2 while completing the development of metrics under Task 1, including publication on those accomplishments.

Products

Books

Book Chapters

Conference Papers and Presentations

Tawfik, A. B., and P. A. Dirmeyer (2015). *A New Explicit and Computationally Efficient Sub-grid Convective Initiation Scheme.*. American Meteorological Society, 27th Conference on Climate Variability and Change. Phoenix, Arizona, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Dirmeyer, P. A., Z. Guo, S. Halder, H. Norton, and J. Wu (2014). *An initial assessment of coupled landatmosphere memory in (and beyond) reanalysis.*. 39th Climate Diagnostics and Prediction Workshop. St. Louis, Missouri, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Dirmeyer, P. A., A. Tawfik (2015). *Confronting CLM with land surface observations*. NCAR Land Model Working Group (LMWG) Meeting. Boulder, Colorado, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Dirmeyer, P. A., A. Tawfik, S. Halder, H. Norton, J. Wu, M. G. Bosilovich, J. A. Santanello Jr., and M. B. Ek (2015). *Confronting global land-atmosphere models with coupled process metrics.*. American Meteorological Society, 29th Conference on Hydrology. Phoenix, Arizona, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Tawfik, A. B., and P. A. Dirmeyer (2014). *Evolution of Soil Moisture-Convection Interactions against the Backdrop of Global Oscillations.*. American Geophysical Union Fall Meeting. San Francisco, CA, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

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, Quebec, Canada. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Inventions

Journals

Licenses

Other Products

Software or Netware.

To help streamline the model evaluation process, a Land–Atmosphere Coupling Toolkit is being developed. A suite of land-atmosphere coupling metrics from current literature is being coded and documented in standardized Fortran 90. These portable modules will enable rapid evaluation of models and observations. In total there will be 8 different metrics providing a holistic overview of land, atmosphere, and coupled land-atmosphere behavior. Three out of four preliminary metrics are currently ready to be used, and the code can be easily expanded to include more metrics. This will be shared with the broader scientific community through the World Climate Research Programme (WCRP) Global Energy and Water Exchanges (GEWEX) Global Land-Atmosphere System Study (GLASS), of which the PI was a co-founder 16 years ago, and which is concerned with modeling and understanding the coupled land-climate system.

Other Publications

Patents

Technologies or Techniques

Thesis/Dissertations

Websites

Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Dirmeyer, Paul	PD/PI	1
Heidari, Ako	Graduate Student (research assistant)	1

Full details of individuals who have worked on the project:

Paul A Dirmeyer
Email: pdirmeye@gmu.edu
Most Senior Project Role: PD/PI
Nearest Person Month Worked: 1

Contribution to the Project: Leadership as PI, observational data analysis per Task 1.

Funding Support: N/A

International Collaboration: No
International Travel: No

Ako Heidari
Email: aheidari@masonlive.gmu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1

Contribution to the Project: Graduate student support started January 2015. Academic support for Spring semester. Will be support for research during summer term at 20 hour/week rate to perform observational and model data analysis.

Funding Support: N/A

International Collaboration: No
International Travel: No

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
NCAR	Academic Institution	Boulder, CO

Full details of organizations that have been involved as partners:

NCAR

Organization Type: Academic Institution
Organization Location: Boulder, CO

Partner's Contribution to the Project:
Collaborative Research

More Detail on Partner and Contribution: Part of this Collaborative Research project - grant support provided by USDA; David Lawrence is NCAR PI, Rich Neale is NCAR co-PI.

What other collaborators or contacts have been involved?

Leveraging expertise from collaborators on a NASA-funded project “Diagnosis and Validation of Land-Atmosphere Feedback in Two Global Models” (NNX13AQ21G) with Co-Is: Joseph Santanello (NASA/GSFC), Michael Bosilovich (NASA/GSFC), and Michael Ek (NOAA/NCEP/EMC). That project is focused on evaluation of NOAA/NCEP and NASA/GSFC Earth system models, and lessons learned there are being brought to bear on the NCAR Earth System Model. Evaluation work by two supported graduate students (H. Norton, J. Wu) is useful and transferable to this project.

Additionally, COLA has recently supported collaboration with Alan Betts whose expertise will also be applicable and invaluable for this project.

Impacts

What is the impact on the development of the principal discipline(s) of the project?

Basic land-atmosphere metrics development will be shared with the broader scientific community through the World Climate Research Programme (WCRP) Global Energy and Water Exchanges (GEWEX) Global Land-Atmosphere System Study (GLASS), of which the PI was a co-founder 16 years ago, and which is concerned with modeling and understanding the coupled land-climate system. The Land Surface, Snow and Soil Moisture Model Inter-comparison Project (LS3MIP); a CMIP6-endorsed project (cf. http://www.wcrp-climate.org/modelling-wgcm-mip-catalogue/modelling-wgcm-cmip6-endorsed-mips) will also be a beneficiary of this work.

Land use change-climate metrics development will be shared with the broader scientific community through the Land Use Model Inter-comparison Project (LUMIP); a CMIP6-endorsed project (cf. http://www.wcrp-climate.org/modelling-wgcm-mip-catalogue/modelling-wgcm-cmip6-endorsed-mips), of which co-PI Lawrence is co-chair.

What is the impact on other disciplines?
Nothing to report.

What is the impact on the development of human resources?

The GMU faculty have established a unique PhD program in Climate Dynamics, which is based on theory, observations and, importantly, modeling, using numerical experiments as a fundamental tool to teach both basic and advanced graduate courses in climate and to serve as the basis for dissertation research. The project graduate student will contribute directly to the tasks and goals of this project. However, the student will also be encouraged to formulate his/her own hypotheses and approaches to the research relevant to the topics of this project, commensurate with development of independent research skills needed to earn a PhD degree.

The NCAR project scientist (supported on the collaborative grant) will be able to develop leadership skills within this project, as well as assist NCAR in terms of accomplishing its strategic goals through contributions to basic science, climate model development.

The post-doc on this project will continue to develop independent research skills and expand professional contacts and experience. The PIs on this project have interacted with many post-docs over the course of their careers. We recognize that such appointments are a significant step in the training of young scientists. Our general philosophy is that the goals of a post-doctoral appointment should be to help the young scientist broaden his or her academic skills by working on new problems or new approaches in the fields of interest, to gain research independence which will prepare them for future academic and research careers, and to develop an ethical sense of their responsibilities to society as a climate scientist. We believe that the most important elements of such appointments should therefore be:

1) A focus on high quality publications – specifically, those that make a real impact on the field, and are published in high-impact journals. It is desirable that the post-doc be the lead author on a substantial number of publications during the course of his/her appointment, commensurate with leadership in specific project research tasks. However, we also recognize the increasingly collaborative nature of academic research, and therefore we expect post-docs to interact with colleagues both within and among the multiple participating institutions. These interactions in many cases may lead to involvement in publications with relatively long author lists;

2) Maximize the visibility of the post-doc in the research community. This results from our encouragement through active participation in conferences such as the annual meetings of the American Geophysical Union and American Meteorological Society, and other more focused workshops and conferences. We also encourage our post-docs to participate in the organization of special sessions at such meetings, and/or participation in journal special issues and other activities that prepare them to take a leadership role in the profession;

3) Assist as appropriate in project management and outreach. As research has become more interdisciplinary in nature, and has tended toward larger projects, project management skills have become increasingly important. Involving post-docs in activities such as planning of periodic project meetings conference calls and project outreach activities helps them to understand how their own research fits both into this project and into the needs of our global society. This will help them both in the development of their own research proposals, and in the management of research projects later in their careers. Post-docs are also encouraged to be at the forefront when public attention and educational opportunities arise in association with the research project, contributing to the broader impacts of the supported research.

We encourage post-docs to be proactive in addressing the research problems with which they are charged. This may include refining the science questions underlying the research; preparing drafts of research progress reports; inclusion in research meetings with graduate students so they learn about advising; and participation in relevant community science programs and projects at national and international levels.

Beyond this, we will encourage the post-docs on this project to interact with colleagues outside the funded project in his/her host institution. For example, this is already the procedure within the Climate Dynamics Program and the Center for Ocean-Land-Atmosphere Studies at GMU, where there is a very large team of senior and associate scientists, post-docs and students who are engaged in a range of group and individual research projects. Furthermore, we will insist that the post-doc make extended visits to our collaborating institution (NCAR) to enhance the cross-fertilization of the interdisciplinary research activities and to give the post-docs a taste of the type of work that is being done across the climate variability and change research enterprise.

A large number of post-docs have worked with the PIs over the last 20 years, and two have been working recently with both PIs via NSF-sponsored Earth System Modeling Fellowships through COLA. Many of our post-docs have gone on to faculty positions at major universities, which we believe is the ultimate measure of success in the mentoring we have provided.

What is the impact on physical resources that form infrastructure?
Nothing to report.

What is the impact on institutional resources that form infrastructure?
Nothing to report.

What is the impact on information resources that form infrastructure?

A university computing proposal has been submitted to NCAR/CISL in March 2015 for 4.2M core supercomputing hours to conduct the necessary CESM simulations and analysis of the model output under this project. 75TB of project space and 215TB of HPSS storage have also been requested.

A significant portion of this project involves new simulations with the CESM-CLM model framework. Due to the exploratory and investigative nature of the proposed model work, we do not anticipate that there will be a large demand from the broader scientific community for model data generated during the course of this project. Consequently, we have not budgeted any costs into this proposal for data dissemination. Naturally, if there are specific requests for data that arise through interactions with current or future collaborators who are external to this project, we will be happy to share the data with them. The data volume is not expected to be large by today's standards so we will be able to transfer this data via normal data transfer methods (e.g., through anonymous ftp site or the Earth System Grid). Results from the model integrations will be reported through conferences and in the peer-reviewed literature. Storage costs for any data that needs to be archived for the lifetime of this project have been folded into the Yellowstone request for computing allocations to support the work outlined in this proposal.

What is the impact on technology transfer?
Nothing to report.

What is the impact on society beyond science and technology?
Nothing to report.

Changes/Problems

Changes in approach and reason for change
Nothing to report.

Actual or Anticipated problems or delays and actions or plans to resolve them

Given the grant start date and some confusion with co-sponsor USDA-NIFA regarding who would be supporting the GMU portion of the project, it was not possible to support a student in fall 2014, so student support is shifted 1 semester later than anticipated.

Delays in funding of the collaborative portion of the project at NCAR caused us to hold back on advertising the search for the post-doc until January 2015. That position has been filled and will begin this summer.

This will not ultimately affect project goals, but may shift completion of certain tasks back 3-6 months from original project management timelines.

Changes that have a significant impact on expenditures

See above.

Significant changes in use or care of human subjects
Nothing to report.

Significant changes in use or care of vertebrate animals
Nothing to report.

Significant changes in use or care of biohazards
Nothing to report.

Special Requirements

Responses to any special reporting requirements specified in the award terms and conditions, as well

as any award specific reporting requirements.

Task 1a "Development of L-A diagnostics" should be completed in 2015 per proposed project milestones.