PROCESS-BASED AND OBJECT-BASED INVESTIGATION OF BIAS IN THE SIMULATIONS OF THE PHYSICAL CLIMATE

Richard B. Rood, Principal Investigator (PI)

Progress Report: January 8, 2010

FY09 PROGRESS:

FY08 was the initial year of this new project. FY09 has seen substantial progress. The focus of the work is to pursue new methods of diagnosing climate models based on the definition of like "objects" in both observations and models. The proposed strategy follows from the notion that while models might not produce features, for example hurricanes, on an event by event basis, there are similar features in both observations and models. It is asserted that there are underlying physical principles that lead to the organization of the objects in the model. The object could be related to something as direct as topography, for example, a rain shadow. An object could also be related to a complex interaction between dynamical scales and physical processes. The proposal will, ultimately, focus on the cloud-object data set from the Clouds and the Earth Radiant Energy System (CERES) Instrument. Basic information for this proposal can be obtained here.

Northwest U.S., Wintertime Precipitation and Meteorological Realism:

The initial research followed from studies of precipitation regimes initiated by the PI, Rood. A second year graduate student, Soner Yorgun, is fully supported by this grant. Yorgun's focus has been on topographically forced, wintertime precipitation in the Northwest United States. This focus was chosen because it is reasonable to assume that underlying physics is known; namely, there is moisture flux from the Pacific Ocean associated with resolved-scale dynamics. At the mountains on the West Coast the air is lifted and there is rain. Furthermore, there are obvious differences between models that use spectral methods and finite volume methods as their dynamical cores. If there is a signal to be obtained by our methods, then this is a situation where it will work. We pose that we are looking for "meteorological realism," trying to quantify the geospatial structure of features (objects), and determining sensitivity of "realism" to model formulation and resolution. First results rely on simulations of the Community Atmosphere Model, and follow from the work reported in Bala *et al.* (2008). They were reported at the 2009 Community Climate System Model Workshop in Breckenridge.

Methods of geospatial statistics have been used to define spatial variance. These include variograms and principal component decomposition. These approaches are able to represent quantitative differences of the two numerical methods, spectral and finite volume dynamical cores, at comparable resolution. As resolution is increased, differences remain in the basic underlying structure; that is, the relationship of the precipitation to the topography is different. However, the increased resolution brings the solutions closer together. (Link to poster.) There will be a presentation at the Annual Meeting of the American Meteorological Society (abstract).

CERES Cloud Objects:

The original proposal focused on the cloud object data sets produced by the CERES science team. The original strategy relied on the availability of high resolution runs from NASA's GOES-5 atmospheric models. These runs were not available, and using the Community Atmosphere Model simulations referenced in the previous section was not possible due to unavailability of simulated cloud fields at adequate time resolution. Therefore, the focus was changed from the GEOS5 model to the MERRA reanalysis. Under the direction of Co-PI Derek Posselt, an undergraduate student, Andrew Jongeward, has extracted pseudo cloud objects from the MERRA data. Results of comparisons between MERRA and CERES deep convective cloud objects will be a presented at the 2010 Annual Meeting of the American Meteorological Society (abstract). The comparison method developed for the MERRA reanalysis will be immediately adapted to GOES-5 output as it becomes available.

Eastern U.S., Summertime Precipitation and the Bermuda High:
This line of work focuses on quantifying the variability of summertime precipitation over the Southern and Eastern U.S., and on understanding its relationship to the position and properties of the Bermuda High. This research is scientifically interesting from both a numerical and geophysical point of view. Directly relevant to this proposal, this research will allow the development of object definition and analysis strategies with an intuitively accessible problem. Also, the data sets to be used in this study are the same as those for the cloud-object work. Initial studies will focus on both the dynamical formulation of the model and the impact of resolution. A poster describing results of this work will be presented by Laura Bell (supported by non-NASA funds) at the 2010 Annual Meeting of the American Meteorological Society (abstract).

Deep Convection and the Walker Circulation
This work has been proceeding on two fronts. One component has focused on how mid-tropospheric stable layers interact with, and potentially modulate the relationship between deep convection and the large scale circulation in the equatorial tropics. Atmospheric Radiation Measurement (ARM) and Atmospheric Infrared Sounder (AIRS) data have been used to examine the interaction between mid-tropospheric stable layers and tropical deep convection over the tropical western Pacific ocean. This work will transition from observation analysis to model evaluation in FY10. First results from this work will be presented at the 2010 Annual Meeting of the American Meteorological Society (abstract). The second component examines changes in the Walker circulation during the 1998 El Nino – La Nina transition. The collapse of the Walker circulation during El Nino was well observed and the relationship to changes in the location and properties of deep convection should be reflected in the cloud object data. The goal of this work is to develop methods of quantifying the relationship between the Walker circulation and cloud properties then to use these relationships to assess the fidelity of dynamics-cloud connections in the GEOS-5 model. A conceptual overview of this work will be presented at the 2010 Annual Meeting of the American Meteorological Society (abstract).

Programmatic points

In addition to the scientific progress documented above, this team has made a commitment to work with programs at NASA Goddard to develop tools and capabilities for NASA's GEOS-5 atmospheric model so that it can better serve as an asset for NASA. This has consumed a significant amount of time.

The above work that makes use of the NCAR CAM data was originally intended to be applied to NASA's GEOS-5 atmospheric model, however, this model has been largely unavailable. Therefore, the work of Yorgun and Bell has by necessity employed output from the Community Atmosphere Model. Yorgun was accepted into a 2009 summer tutorial at the National Center for Atmospheric Research, where he learned to modify and run the model. He also obtained access to output data sets of archived simulations.

Initial efforts by Co-I Jerry Potter to work with Goddard in the development of a workflow tool to allow configuring and running GEOS-5 ended without a functional tool. This activity appears to have become of low priority to NASA. Regular meetings with the Global Modeling and Assimilation Office were initiated in Summer 2009. These meetings have been highly productive and have resulted in improved communication with GMAO and the GEOS-5 developers. Potter and Posselt have both attended these meetings regularly, and have visited Goddard. Recently, October 2009, a stable version of GEOS-5 was provided, and we have run our first test experiments on computational resources at NASA Goddard. Potter has extended his work with NASA to help develop an Earth System Grid portal, and we are trying to use the work in this proposal to advance the development of this community infrastructure. Initial results indicate that the GEOS-5 is configurable in multiple resolutions, and we plan to proceed with additional scientific experiments involving the GEOS-5 model as described below.

Personnel

Co-PI Derek Posselt has been working with both PI Rood and Mr. Yorgun to define both the short-term and long-term research plan. Dr. Posselt has a background in statistical-physical approaches to model analysis, and has been leading the effort to compare CERES cloud objects with MERRA data. He has been working with Dr. Potter on object-based methods for evaluating GEOS-5 simulations of the effect of El Nino on the properties of deep convective clouds and the large-scale atmospheric overturning (Walker) circulation. He has also been exploring ways to quantitatively assess model uncertainty using observations. Results from this work have been presented in a seminar at NASA Goddard Space Flight center and in talks at the 2009 AGU Joint Assembly, the 5th WMO Data Assimilation Symposium, and the 2010 Annual Meeting of the American Meteorological Society. Dr. Posselt's model error quantification work is now in press in Monthly Weather Review; two additional manuscripts in preparation, listed below, are also being supported by this proposal.

Jerry Potter retired from the Program for Climate Diagnosis and Intercomparison. Dr. Potter was originally an unfunded co-investigator; the funding profile was amended to provide support for Dr Potter. Dr. Potter is now in the process of transitioning from his position at the University of California at Davis to a visiting scientist position at the University of Michigan. This move will facilitate continued collaboration with University of Michigan personnel. Dr. Potter is developing expertise in configuring and running the GEOS-5 model. He has acquired and continues to acquire CAM and GEOS-5 model simulations at multiple resolutions for this proposal. He also has been involved in the testing of the workflow tool developed at NASA Goddard to allow NASA's GEOS-5 model to be configured and run on NASA computers. These tests have shown that the model can be run and output can be accessed. Performance and the ability to configure the code require more development. The future development path is being discussed with NASA managers.

Dr. Natasha Andronova is working with Dr. Potter to develop ways to represent the Walker circulation as an object in the MERRA analyses and GEOS-5 simulations. The intent is to investigate the cloud variability in comparison with the cloud-object data set. Given the challenges with the model simulations, the use of the MERRA analysis now has priority.

Dr. William Collins has obtained a graduate student to work on this proposal.

FY10 PLAN

In the next year the research for this effort will be started in earnest; it will move past the initial and planning phases. Specifically, we will pursue the precipitation – topography research (Yorgan, Posselt and Rood). This work will lead to the development of tools and techniques for the longer-term cloud-object proposal. Rood and Bell will apply object based evaluation techniques to the Bermuda High – North American monsoon relationship and a manuscript will be submitted for publication. Potter will develop documentation on how to configure and run the GEOS-5 and will instruct other members of the team in the use of the model and interpretation of the output. His research will focus on the model representation of cloud organization during the 1997-98 El Nino. Posselt, Potter and Andronova will conduct object-based analysis of the relationship between dynamics and cloud systems for the 1998 El Nino-La Nina transition. Posselt and Jongeward will complete the cloud object – MERRA comparison and transition to an object-based assessment of GEOS-5 output. The team will acquire the remaining (non-deep convective) cloud-object data and will develop techniques to extract comparable objects from model simulations at multiple resolutions.

Publications

G. Bala, R. B. Rood, D. Bader, A. Mirin, D. Ivanova, and Cedric Drui, 2008: Simulated Climate near Steep Topography: Sensitivity to Dynamical Methods for Atmospheric Transport, *Geophys. Res. Lett.,* **35**, L14807, doi:10.1029/2008GL033204.

Manuscripts in press

Posselt, D. J., and T. Vukicevic, 2009: Robust Characterization of Model Physics Uncertainty for Simulations of Deep Moist Convection. Mon. Wea. Rev., In Press.

Manuscripts in preparation

Posselt, D. J., T. S. L'Ecuyer, S. Lang, and W.-K. Tao: Objective Assessment of Model Sensitivity to Changes in Cloud Microphysical Parameters, In Preparation.

Posselt, D. J., T. S. L'Ecuyer, S. Saleeby, and W.-K. Tao: Object-Based Evaluation of Single- and Double-Moment Bulk Microphysics Schemes in a Cloud Resolving Model using TRMM Observations, In Preparation.

Submitted (8 January 2010)
NASA Grant Officer / email: NSSC-grant-report@mail.nasa.gov
DAVID CONSIDINE / david.b.considine@nasa.gov