MERRA and Beyond - Towards the Development of Integrated Earth System Analysis (IESA) at NASA/GMAO

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The Modern-Era Retrospective analysis for Research and Applications (MERRA) was undertaken by NASA's Global Modeling and Assimilation Office with two primary objectives: to place observations from NASA's Earth Observing System satellites in a climate context, and to improve upon the hydrologic cycle represented in earlier generations of reanalyses. Focusing on the satellite era, from 1979 to the present, MERRA has achieved its goals with significant improvements in precipitation and water vapor climatology. Here, we give a brief overview of the MERRA system, some aspects of its performance, issues that have been identified for attention in the next generation of reanalysis, and the GMAO's plans for the next phases beyond MERRA.

Significant improvements have come from each generation of reanalyses – model biases and assimilation increments have been reduced, and so have the differences in the climate variability from different reanalyses. However, there are still substantial differences between the existing reanalyses in poorly constrained quantities such as precipitation and surface fluxes due to differences in the assimilating models and in how the models interact with the assimilated data. These differences are an important measure of the uncertainty in reanalysis products.

The high quality of today's models and assimilation systems, together with the recognition that improvements in modeling and prediction require attention to the interactions of the different components of the Earth system, have led the drive towards Integrated Earth System Model and Analysis (IESM, IESA). The goal of an IESA is to provide a scientifically based, internally consistent description of the state of the Earth system and how it is evolving over time. The GMAO is undertaking an incremental, phased approach toward building an IESA, gradually coupling different components to increase system complexity. This phased effort builds upon MERRA and upon the current GEOS-5 atmospheric data assimilation system used for near-real-time analysis and forecasting.

In the early phase, MERRA-driven component reanalyses are conducted, focused on carbon species, aerosols, ocean biology and land surface fields, with the goal of producing "consistent" simulations and analyses of the various components of the Earth system. The ocean data assimilation system implemented in the GEOS-5 AOGCM, constrained by MERRA, has been used to generate an ocean reanalysis and initial conditions for short-term climate predictions for 1981 to the present. It and the offline MERRA-Land analysis are other steps towards an IESA. Later phases will include more interactions that capture two-way exchanges between Earth system components. As an early step towards this phase, the most recent version of GEOS-5 is coupled with an aerosol assimilation system and with chemistry modules.

Our initial attempts at an integrated Earth system *reanalysis* will focus on the EOS era where we have more consistently available data in all components. The presentation will include some results from these initial steps towards an IESA.

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