Assimilating Earth System Observations at NASA:

MERRA and Beyond

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INTRODUCTION

This report provides an overview of the status and progress of the NASA/Global Modeling and Assimilation Office (GMAO) atmospheric global reanalysis project called the Modern Era Retrospective-Analysis for Research and Applications (MERRA). The report also includes a brief overview of NASA's emerging capabilities for assimilating a variety of other Earth Science observations of the land, ocean, and atmospheric constituents.

MERRA supports NASA Earth science by synthesizing the current suite of research satellite observations in a climate data context (covering the period 1979-present), and by providing the science and applications communities with of a broad range of weather and climate data with an emphasis on improved estimates of the hydrological cycle.

MERRA

MERRA is based on a major new version of the Goddard Earth Observing System Data Assimilation System (GEOS-5), that includes the Earth System Modeling Framework (ESMF)-based GEOS-5 AGCM (e.g., Collins et al., 2005) and the new NCEP unified grid-point statistical interpolation (GSI) analysis scheme (e.g., Derber et al., 2003) developed as a collaborative effort between NCEP and the GMAO. The MERRA system employs an incremental analysis update (IAU) procedure (Bloom et al., 1996) that eliminates the shocks that are otherwise associated with the insertion of the observations (see Fig. 1). The GEOS-5 AGCM includes a finite-volume dynamical core (Lin, 2004), model physics as described in Bacmeister et al. (2006) a new catchment land surface model (e.g., Koster et al., 2000), prescribed aerosols, and interactive ozone. The GSI assimilates radiances directly using the JCSDA community radiative transfer model, and includes a variational bias correction to the radiances. The native resolution of MERRA is 2⁄3 degree longitude by 1⁄2 degree latitude with 72 levels extending to 0.01 hPa. Further details are provided by Bosilovich et al. (2006).

MERRA products consist of a host of prognostic and diagnostic fields including comprehensive sets of cloud, radiation, hydrological cycle, ozone, and land surface diagnostics. A special collection of data files are designed to facilitate off-line forcing of chemistry/aerosol models. Analysis states and 2-dimensional diagnostics are made available hourly and at the native resolution, while many of the three-dimensional diagnostics are available 3 hourly on a coarser 1.25° latitude ×1.25° longitude grid. The MERRA data collections will be available from an online data server, the Modeling and Assimilation Data and Information Services Center (MDISC) at http://daac.gsfc.nasa.gov/MDISC/index.shtml.

MERRA processing consists of three streams that begin in 1979, 1989, and 1998. Each stream includes a spin-up period that starts three years prior to the start date, consisting of a two year coarse (2°) resolution spin-up period, followed by a one-year ½° spin-up period. Prior to the start of production, we have conducted a preliminary validation of the system by conducting analyses for 2004 and for some other selected periods to investigate issues associated with the changing observation data base. The 2° system is continuing as a data sweep to identify any issues associated with the staging of the input data stream. An initial pass through the data at the coarse resolution has also been used to initialize the satellite bias estimates for the ½° system. In the following, we show a few results from the ½° spin-up runs and from our 2004 validation runs.

Figure 2 compares the globally-averaged precipitation for the observations and the various reanalysis products. While the observations are fairly constant throughout the period, the analyses all show some tendency for a trend with increasing precipitation during the last decade. All the recent products (ERA40, NCEP/DOE R2 and JRA25) have global values considerably larger than the observed. MERRA is an exception, producing values very close to the observed products, although there is also an indication of a trend or shift towards larger values during the recent two decades. Figure 3 shows the seasonal evolution of the tropical precipitation during 2004. A comparison with the GPCP product shows that MERRA captures the seasonal evolution quite well, including such fine structure as the split in the ITCZ during Northern spring, and changing structure of the anomalies in the Pacific warm pool.

The above results are a small sample of an extensive validation effort that was carried out within the GMAO to ensure that the MERRA system was ready for production. These results, together with an evaluation carried out by an external user's group, showed that the MERRA product will be (in many aspects) a substantial improvement over existing products. The strengths of the MERRA product compared to the existing global reanalysis products include: increased horizontal resolution, a well-resolved stratosphere, improved precipitation and hydrological cycle, and exact (closed) vertically integrated budgets. Known problems include possible impacts of changes in the observing system (e.g., artificial trends in the precipitation), and deficiencies in the phasing of the diurnal cycle.

It is anticipated that the MERRA production will be completed in the middle of 2009. Further information about MERRA can be found at: http://gmao.gsfc.nasa.gov/research/merra/

EARTH SYSTEM ANALYSIS

In addition to MERRA, the GMAO has systems for ocean and land surface assimilation and is developing new capabilities in aerosol and constituent assimilation, and ocean biology assimilation (see Fig. 4). This includes the development of an assimilation capability for tropospheric air quality monitoring and prediction, the development of a carbon-cycle modeling and assimilation system, and an ocean data assimilation system for use in coupled short-term climate forecasting. The long-term goal of the GMAO is the development of a fully Integrated Earth System Analysis capability.

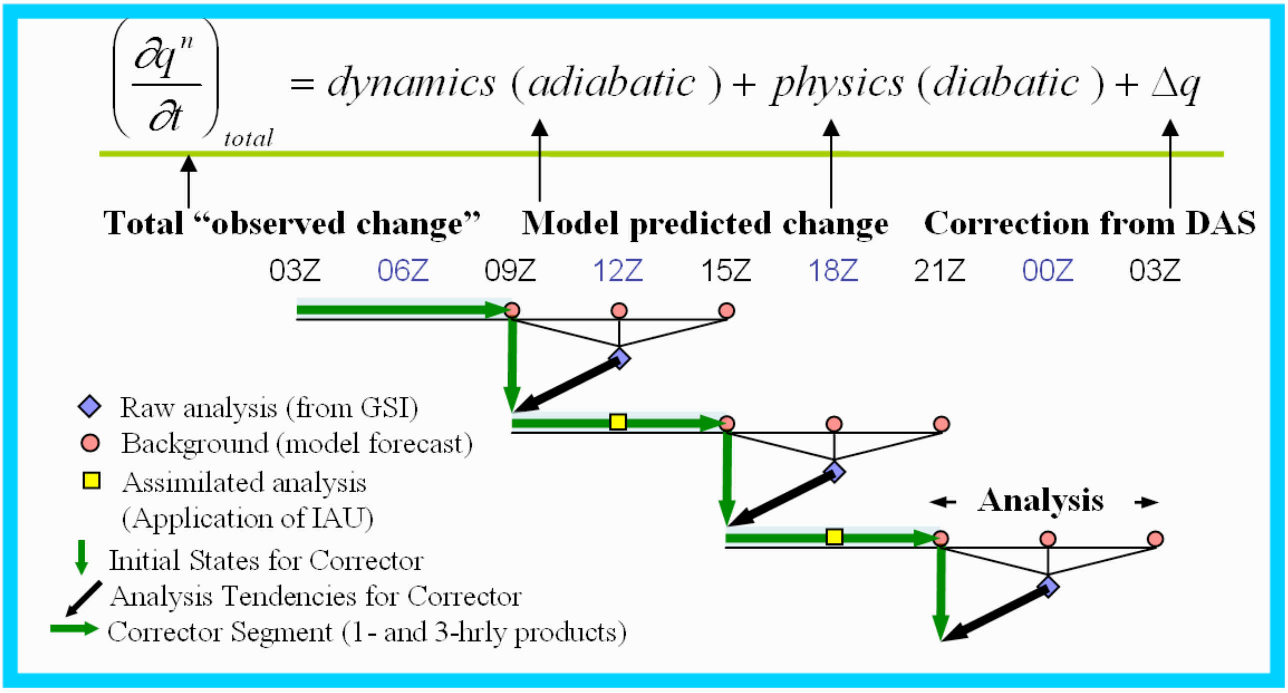

Figure 1: The incremental analysis update (IAU) procedure used in the GEOS-5 Data Assimilation System.

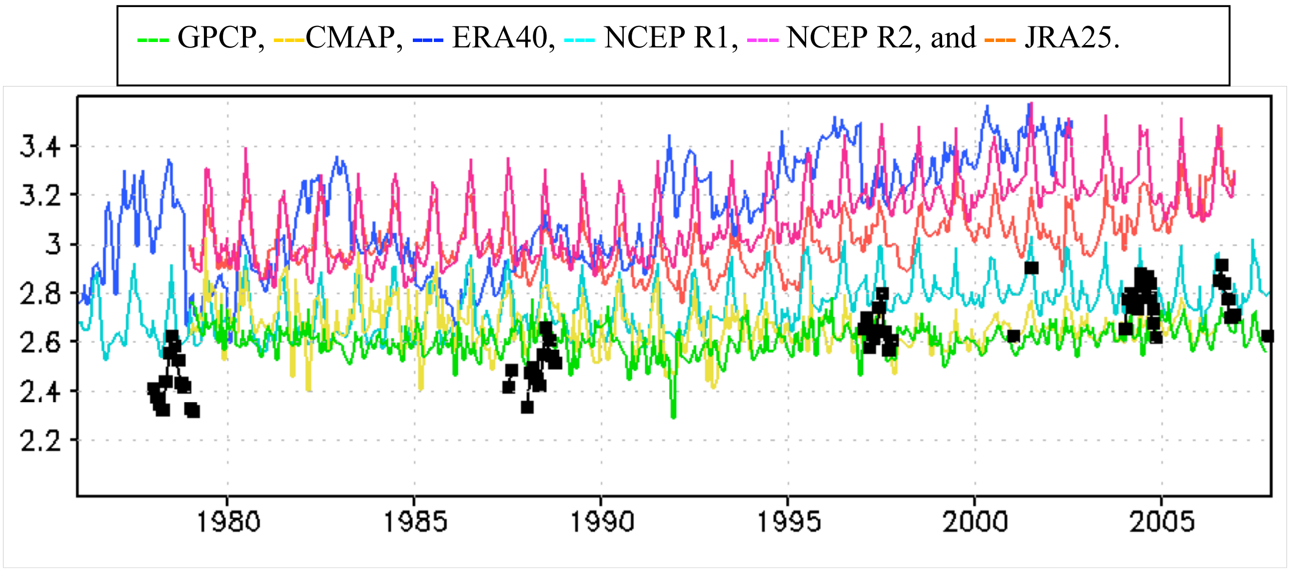

Figure 2: The globally-averaged precipitation from MERRA spin-up and validation runs (black squares), observations (GPCP, CMAP) and other reanalyses. Units: mm/day.

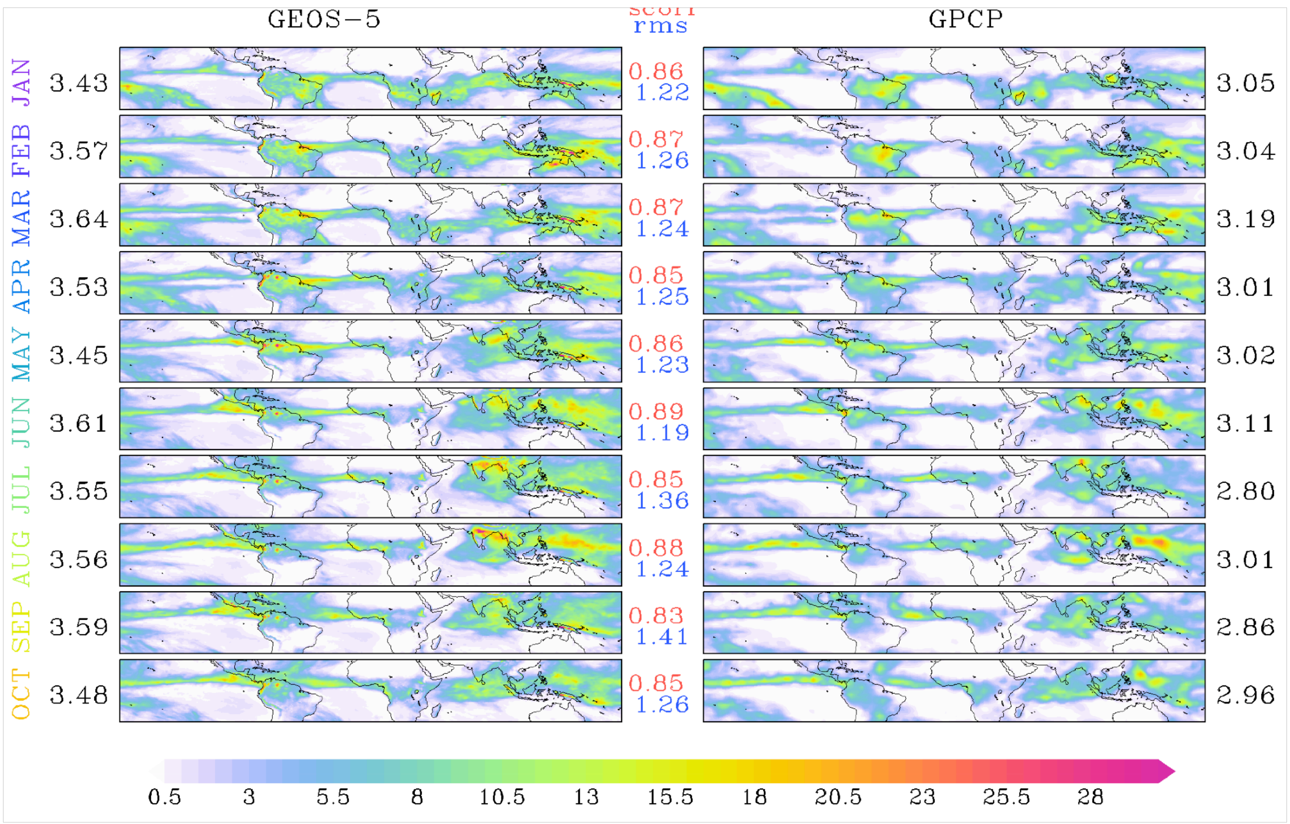

Figure 3: Distribution of the 2004 monthly mean tropical precipitation from the MERRA validation runs (left panel), and GPCP (right panel). The red (blue) numbers are the spatial correlations (rms) between the two products. The black numbers are the tropical mean values. Units: mm/day.

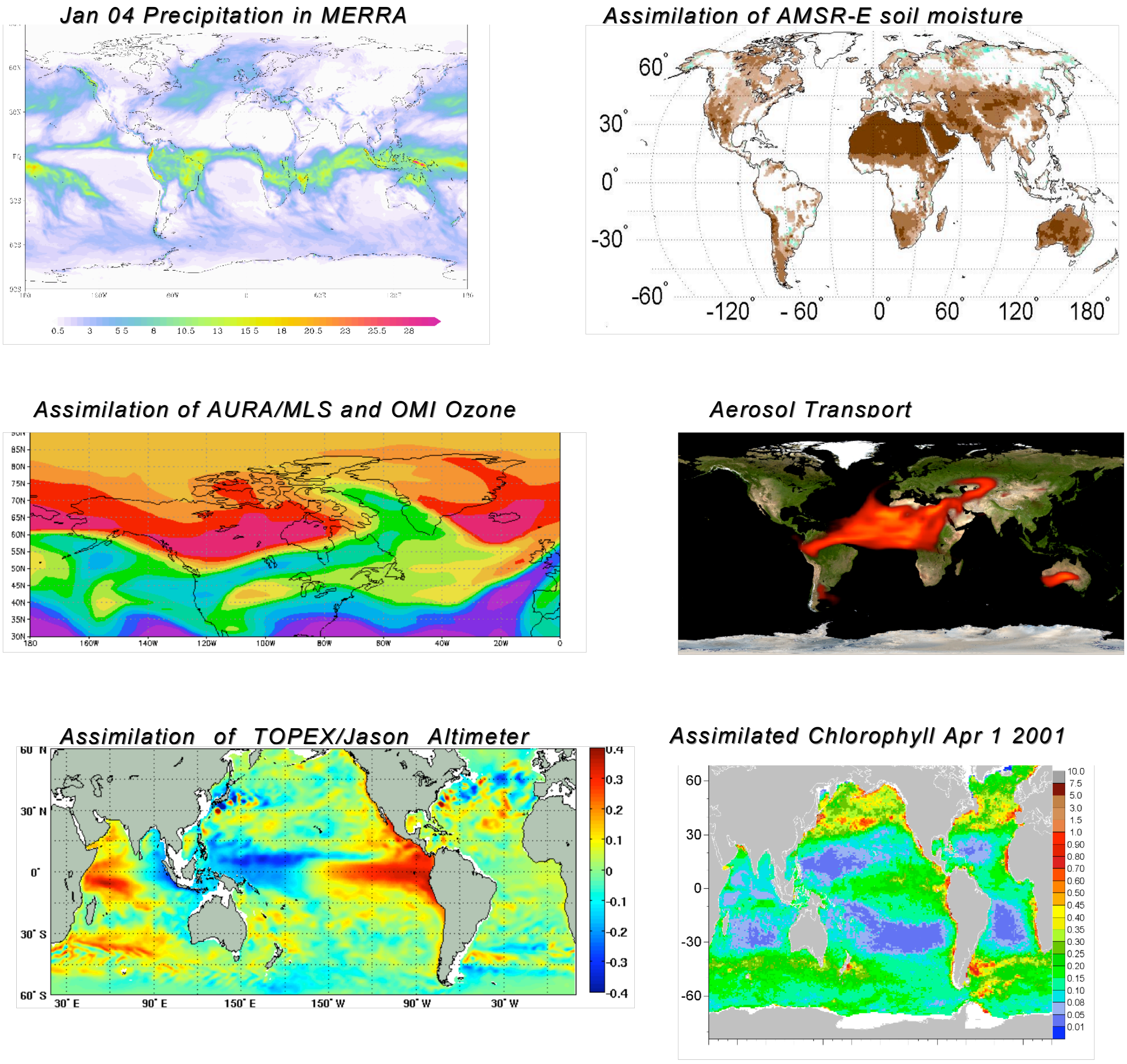

Figure 4: Moving towards an Integrated Earth System analysis at the GMAO. The individual panels highlight some of the other efforts within the GMAO (besides MERRA) to assimilate soil moisture, various constituents including ozone, aerosols, altimeter data, and chlorophyll.

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