Evaluation of variations in the late-80s observing system on the GEOS-5 data assimilation system

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INTRODUCTION

The impact of observing system changes on retrospective-analyses (or reanalyses) has been known for some time (e.g. Chen et al. 2008), and continues to be an issue in recent reanalyses. For example, Onogi et al (2007) show the spatial correlation of Japanese 25 Year Reanalysis (JRA-25) precipitation to the Global Precipitation Climatology Project (GPCP) merged satellite/gauge observations. The result shows that the JRA-25 produces very good spatial patterns of precipitation. However, there is a distinct change (improvement) when SSMI total column water retrievals become available (their Figure 5). Variations in the total column water, evaporation and precipitation time series' are also apparent (figures not shown).

The Global Modeling and Assimilation Office (GMAO) has developed the GEOS5 data assimilation system to support NASA instrument teams, field experiments and scientific priorities. In preparing to begin a retrospective analysis of the satellite era (called the Modern Era Retrospective-analysis for Research and Applications, MERRA), the GMAO has performed several validation experiments to evaluate the GEOS5 system.

Briefly, the GEOS5 data assimilation system includes NASA modeling components, coupled with the NCEP Gridpoint Statitical Interpolation (GSI) for data assimilation. The GSI allows for radiance assimilation of the operational NOAA instruments, SSMI and AIRS. While analysis and forecast cycles are run every 6 hours, an additional segment uses the analysis tendencies to update the model state equations at every time step (called Incremental Analyiss Update, IAU, Bloom et al. 1996). The IAU segment produces the research diagnostics evaluated here. Rienecker et al. (2008) discusses the development of the GEOS5 data assimilation system.

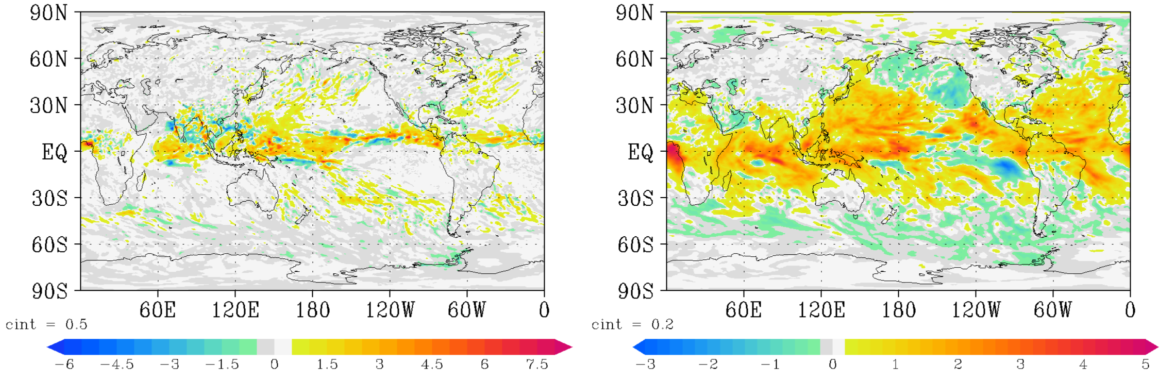
To evaluate the impact of SSMI on the GEOS5 data assimilation system, as it pertains to reanalysis, we have conducted a short sensitivity experiment at the native MERRA spatial resolution (1/2°×2/3°), and also a long coarse spatial resolution experiment (2°×2.5°, Jan1979-Dec1990, call the Scout experiment). In the short sensitivity experiment, a control experiment was run from July through August of 1987, with the full observing system available at the time, except that SSMI is not included. In the SSMI experiment, SSMI (Version 6 from Wentz, RSS) retrievals of rain rate and surface wind are assimilated starting on July 11. The radiances are analyzed in passive mode for two weeks, building the adaptive bias corrections, and begin to be assimilated on July 25. In the Scout experiment, all observations that would be used for MERRA are used. The Scout system is a fundamentally identical configuration of the short sensitivity test and the data assimilation system that will be used for MERRA, with the primary difference being the spatial resolution.

SENSITIVITY EXPERIMENT

After SSMI radiances are assimilated, the analysis increments generally add more water (add more in the lower troposphere, take away less in the mid-troposphere) to the system (figure in the presentation available from the WCRP Reanalysis Conference WWW site). Figure 1 shows the difference of the sensitivity experiment and the control for the monthly mean of August 1987 (the first full month when SSMI is available).

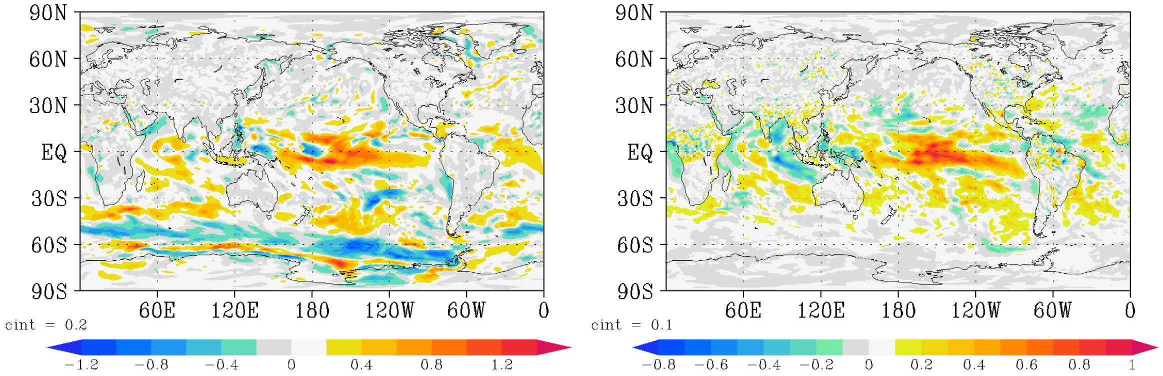
a) Precipitation (mm day^{-1})

b) Total Column Water (mm)



c) 10m Wind Speed (m s^{-1})

d) Evaporation (mm day^{-1})



e) Outgoing Longwave Radiation (W m^{-2})

f) Cloud Fraction

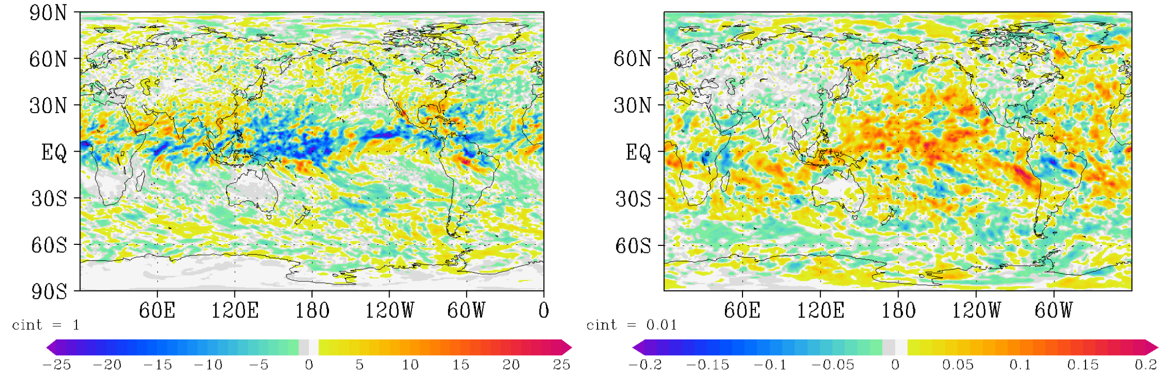


Figure 1 Monthly mean differences (August 1987) of several quantities for the SSMI experiment minus the control (not assimilating SSMI retrievals or radiances).

Large scale increases in total column water occur (Figure 1 b), predominantly focused on the tropics. Precipitation generally increases, where precipitation occurs, with the largest increases are in the ITCZ. The strongest tropical wind speed increases contribute to increases in surface evaporation. There are significant changes to the wind speed outside of the tropics (primarily decreases of the wind speed in the 40-60S latitude band), likely from the assimilation of SSMI retrieved winds. Additionally, the cloud fraction increases, while OLR decreases. While there are some intermittent regions that do not follow the generality, it is reasonably consistent across the tropics. Away from the tropics, the differences between the experiments tend to be small.

Table 1 GEOS5 experiment Tropics area averages.

Tropics Average (15°S-15°N)		
August 1987	No SSMI	GEOS5
|**V**| 10m (m s^{-1})	4.98	5.17
P (mm day^{-1})	3.70	4.04
E (mm day^{-1})	3.99	4.06
TPW (mm)	41.3	42.2
CLDFRC	0.64	0.66
OLR (W m^{-2})	256	254

Table 1 summarizes the differences across the tropics. Precipitation increases in the SSMI experiment by ~10% of the Control experiment precipitation. There is also a robust response to the increasing water vapor, where cloud fraction increases, and the outgoing longwave radiation decreases. While the changes are apparently robust, they are only a few percent of the control experiment. In the following experiment, we evaluate the long time series compared to existing reanalyses.

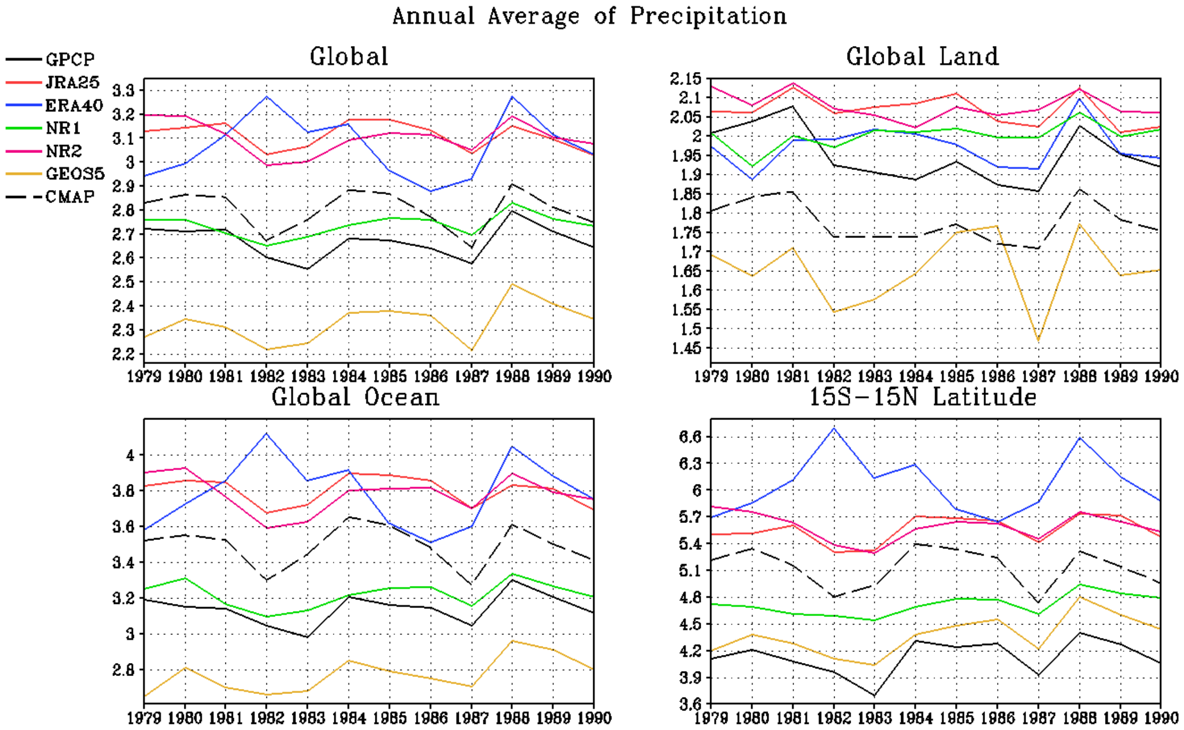


Figure 2 Annual mean precipitation (mm day-1) for GPCP (Adler et al 2003), CMAP (Xie and Arkin, 1996) and reanalyses data.

CLIMATE EXPERIMENT

A coarse resolution (Scout) experiment has been run for the period Jan 1979 – Dec 1990 to test the variations of satellite data in the 1980s for this system. The settings for the data assimilation are identical to what would be used for MERRA, with the exception that the model and data assimilation are run at 2° latitude × 2.5° longitude spatial resolution. Schubert et al (2008) presented some results from the GEOS5 validation at the WCRP Reanalysis Conference. Bosilovich et al (2008) evaluate precipitation among the existing long reanalyses and also the GEOS5 validation experiments. GEOS5 has a smaller tropical precipitation bias compared to reanalyses, regardless of the resolution (Figure 2). However at 2 degrees resolution, low oceanic precipitation occurs off the east coast of the Northern hemisphere continents. At ½ degree resolution, dynamically driven precipitation in these regions increases substantially.

In spatial correlation (as in Onogi et al 2007, their Figure 5), the coarse version of the GEOS5 reproduces the spatial distribution of the precipitation very well, compared to previous reanalyses for the early satellite period discussed here (Figure 3). There is a slight decline in the GEOS5 correlations after 1987, but without data beyond 1990, it is not clear if that continues or ameliorates. Even with this, the temporal variability of the GOES5 spatial correlations are generally smaller than that of the previous reanalyses. In Figure 3, the increasing correlations of JRA-25 are apparent, but across the GOES5 Scout experiment, the change is smaller.

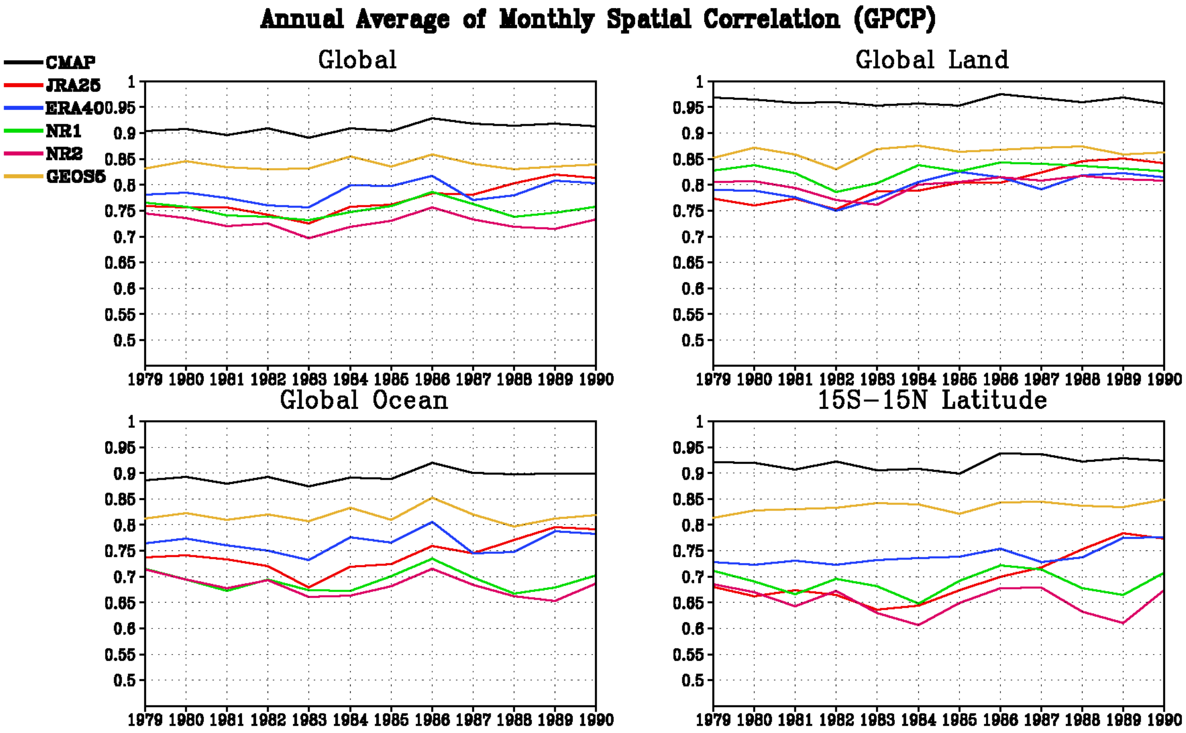


Figure 3 Annual average of the area weighted spatial correlation of monthly GPCP precipitation to CMAP and the reanalyses.

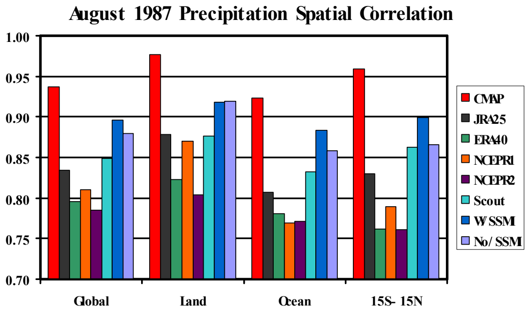


Figure 4 Spatial correltion for August 1987 monthly mean fields of GPCP to CMAP, existing satellite era reanalyses, and the GEOS5 Scout and SSMI experiments.

In the validation of the GEOS5 system for MERRA, there is only the ½ degree analysis for August 1987 to compare to the 2 degree system. Figure 4 shows spatial correlations for the long reanalyses and the GEOS5 experiments. While the 2 degree system (including SSMI) is good, oceanic precipitation correlations are improved both by including SSMI and by increasing spatial resolution. While this is a limited comparison for the purposes here, Bosilovich et al (2008) discuss further statistics of the GOES5 precipitation for experiments when AIRS is also assimilated, where the spatial correlations are also high.

SUMMARY

Sensitivity tests of the initial weeks of SSMI availability show that there is a systematic response of the analysis diagnostics and state variables. Tropical precipitation shows some of the largest response, at ~10% increase of the control precipitation without SSMI assimilation. Other variables have a smaller percent change. In the coarse resolution Scout experiment, the change of correlation in time, is less dramatic than the JRA-25, and the interannual variability of spatial correlation is smaller. These statistics will be monitored during the production of MERRA data. MERRA data production began in February 2008, and should be completed by Mid-2009. Status and information on GEOS5 MERRA data production can be found at http://gmao.gsfc.nasa.gov/merra/.

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