Improving Global Analysis and Forecast Using Microwave-based Rain and Moisture Data

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Analyses produced by global data assimilation systems currently contain significant errors in primary hydrological fields such as precipitation and evaporation, especially in the tropics. Rainfall estimates derived from space-borne passive microwave sensors can provide valuable pattern and intensity information on precipitation for improving global analysis and forecast. At the Data Assimilation Office at NASA Goddard Space Flight Center, we have been exploring the use of innovative techniques to assimilate rainfall and total precipitable water (TPW) data provided by the TRMM Microwave Imager (TMI) and Special Sensor Microwave/Imager (SSM/I) instruments. Results show that variational assimilation of 6-h averaged surface rain rate and TPW using the moisture tendency of the forecast model as a control variable significantly improves not only the hydrological fields but also key climate parameters such as clouds, radiation, and tropospheric moisture in the analysis produced by the Goddard Earth Observing System (GEOS) Data Assimilation System. The improved analysis also yields improved short-range forecasts in the tropics.

Figure 1 shows the impact of assimilating 6-hour averaged TMI and SSM/I rainfall and TPW on GEOS analysis at 1^{o} x 1^{o} horizontal resolution for January 1998. The improved precipitation in the tropics effectively reduces the monthly-mean bias and standard deviation errors in the outgoing longwave radiation (OLR), which was not assimilated but used for independent verification. Since current global analyses contain significant errors in hydrological parameters, the result that rainfall assimilation improves not only precipitation but also related fields such as cloud and radiation has important implications. It identifies precipitation as a key observation type for improving the quality and usefulness of global analyses for understanding the earth's water and energy cycles.

The improved analysis with rainfall data also provides better initial conditions for storm-track and quantitative precipitation forecasts (QPF), as shown in Fig. 2 for Hurricane Bonnie. Results from 5-day ensemble forecasts show systematic improvements in precipitation, divergent winds and geopotential heights in the tropics. These results suggest that rainfall assimilation has the potential to significantly improve weather forecasting skills.

Reference:

Hou, A. Y., S. Zhang, A. da Silva, W. Olson, C. Kummerow, J. Simpson, 2001: Improving global analysis and short-range forecast using rainfall and moisture observations derived from TRMM and SSM/I passive microwave instruments. *Bulletin of Amer. Meteor. Soc.*, **82**, 659-679.

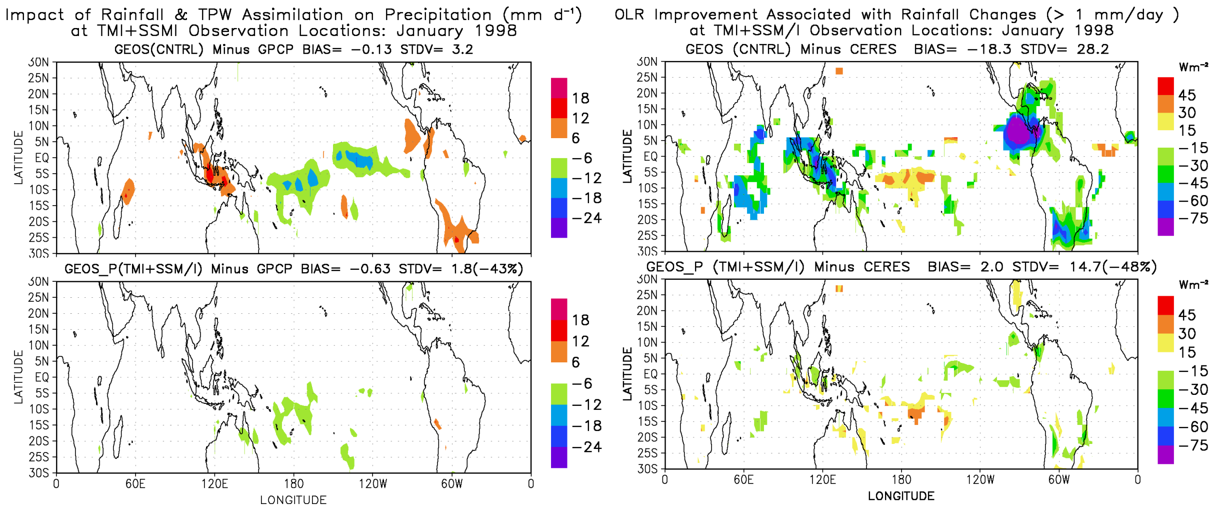

Figure 1. GEOS assimilation results with and without TMI and SSM/I observations for January 1998. Left panels show errors in the monthly-mean tropical precipitation fields verified against GPCP combined Satellite-gauge estimate: Top is the difference between the GEOS control (without rainfall and TPW data) and GPCP. Bottom is the corresponding error in GEOS assimilation with rainfall and TPW data. Right panels show the impact on the outgoing longwave radiation (OLR) verified against CERES/TRMM measurements. Percentage changes in the tropical-mean error standard deviation relative to the GEOS control are given in parentheses.

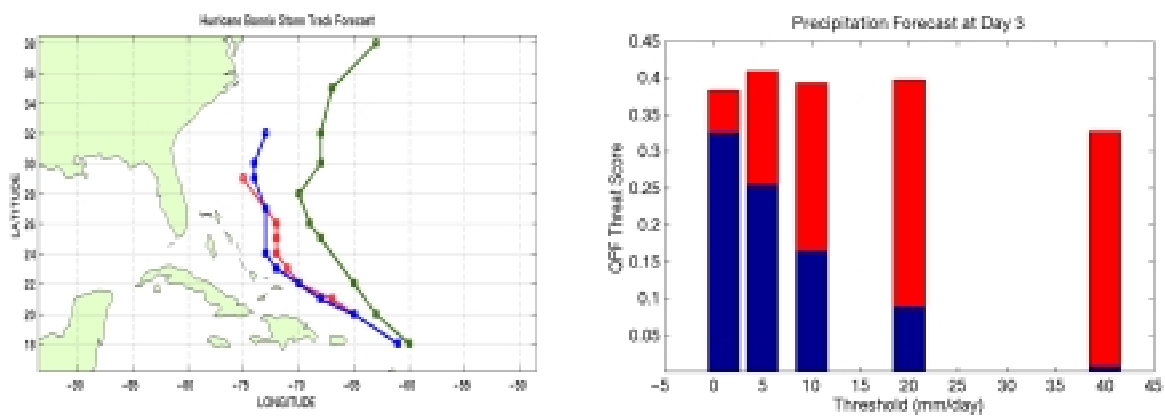

Figure 2. Improved storm track forecasts and QPF Equitable Threat Scores for Hurricane Bonnie. The left panel shows that the 5-day storm track forecast initialized with 1^o x 1^o GEOS analysis containing TMI and SSM/I rainfall data (blue) is in close agreement with the best track analysis from NOAA. The track from the control experiment is shown in green. The forecasts are initialized at 12:00 on 20 August 1998. The right panel shows the consistently higher Equitable Threat Scores for Day 3 precipitation forecast (red) initialized by the analysis with rainfall data. Results for the control experiment are shown in blue. A higher Threat Score corresponds to greater forecast skills.