NEWS Progress Report, April 2008

Title: Evaluation of NASA's Global Water Cycle Data: Interannual Variability, Inter-decadal Changes and Trends

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We have one paper accepted for publication, "Evaluation of Precipitation in Reanalyses" (http://ams.allenpress.com/perlserv/?request=get-abstract&doi=10.1175%2F2008JAMC1921.1). The objective of the paper was to test metrics for explaining the quality of reanalysis data relative to observed data sets. 25 years of ERA40, NCEP R1, NCEP R2 and the JRA25 were compared against GPCP precipitation for the globe and major continental and oceanic basins. CMAP precipitation was used as a check on the uncertainty in the observed data product. After evaluating the long term precipitation time series, we applied the same method to short analyses of the GEOS5 data assimilation system (experiments leading up to the production of a new reanalysis). The results quantitatively show that, while GEOS5 still has some regional biases compared to GPCP, relative to existing long reanalyses the spatial distribution of total precipitation is much better represented.

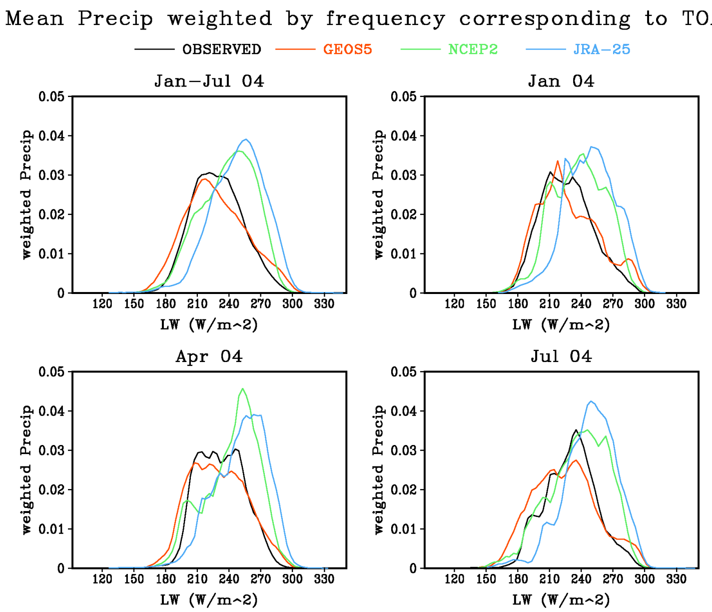

Figure 1 Precipitation weighted by the frequency of occurrence in TOA Longwave conditions.

Dr. Chen's analysis of the water and energy cycles in reanalyses has progressed significantly. He is investigating in the frequency distribution domain so to better evaluate the conditions under which biases and anomalies form in reanalyses, compared to satellite measurements of the water and energy cycle components. Figure 1 compares the frequency weighted precipitation occurring at various longwave radiation conditions for each of NCEP R2, JRA25 and MERRA validation experiments with GEOS5 data assimilation system. The Observations are CERES TOA longwave radiation and GPCP total precipitation. The distributions for three individual months are presented (except the top left panel which is the distribution of January through July 2004 average, the longest GEOS5 validation experiment). The obvious result of Figure 1 is that GEOS5 is much more comparable to the observations in the functional relationship of precipitation and longwave radiation than NCER R2 and JRA25. This is an encouraging result for NEWS and using MERRA in NEWS Integration efforts. NCEP and JRA have too much precipitation in the occurrences of high TOA OLR (which should be related to warm temperatures closer to the surface). In July, GOES5 overestimates precipitation in the presence of low OLR, but in general is still much closer to the observations than JRA and NCEP. This is one way we can link the evaluation and processes of the water and energy cycles.

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Comment: This panel is also based on monthly data.

Dr. Chen presented his work about the water and energy cycles in reanalyses at the AMS annual meeting (January 2008), and also at an invited seminar at CPC (April 10, 2008). This work is currently being prepared for publication.

Our work within the NEWS Project #3 has resulted in new insights regarding interannual to decadal variations in tropical precipitation, sea-surface temperature, and latent heat flux. Using the statistical tool of *singular value decomposition* (SVD) analysis we have identified coupled modes of variability between GPCP precipitation and tropical SST (see Mar 4, 2008 slide forwarded to HQ). This analysis showed two distinct ENSO-related modes and a third longer term trend mode. The first mode is a well-known eastward shift of precipitation into the central equatorial Pacific. The second mode couples an E-W dipole structure in equatorial SST to precipitation anomalies not only in the Pacific Ocean, but stretching into the Indian Ocean. The third mode is actually a manifestation of the precipitation trend identified by Gu and Adler (2007 JClim), and couples to SST warming in the Indian Ocean and subtropical western Pacific. These results also offer a target that models (and reanalyses) have to hit in order to verify that convective parameterizations and moist physics are realistic in producing interannual variability.

Identifying this decadal scale signal related to SST variations has led us to examine two recently published data sets for global ocean latent heat flux, those created by Remote Sensing Systems (RSS) and the OAFlux data set by the Woods Hole Oceanographic Institution (WHOI). Our goal was to determine the realism of decadal LHF trends and variability in response to SST changes over the past 20 years. We note that this work represents collaboration between this investigation and RSS scientists also funded by NEWS. Time series of the fluxes, the near-surface moisture deficit, qs-qa, and wind speed are shown in Figure 2. Our analysis of these data sets in detail has led to the following conclusions:

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(1) Despite significant differences in their incorporation of satellite wind speed data, valuation of reanalysis data, and approach to deriving Δq=qs-qa, RSS and WHOI data sets each indicate that tropically averaged LHF increases during the 1990s and then becomes quasi-steady thereafter. However, the difference between these LHF trends is significant with the upward trend in latent heat flux over the tropical oceans at nearly 4.4 % per decade WHOI compared to a values of about half that for RSS.
(2) These differences are readily explained by two aspects of the methodology used in the flux estimates: Incorporation into the OAFlux data set of QuikSCAT and AMSR-E

winds speeds starting in 1999 and 2002, respectively, and the end of ERA-40 in 2002 produces an artificial high bias in the OAFlux winds of order 0.15 ms^{-1}. QuikSCAT and AMSR-E winds are biased high relative to the intercalibrated SSM/I winds while ERA-40 wind speeds are biased low. We conclude that the RSS intercalibrated SSM/I wind speeds more accurately represent interannual and decadal variations. Regional aspects of these biases are likely to be very small. Conversely, the RSS formulation of $\Delta q = q_s - q_a$ admits only variations related directly to SST, not the atmosphere. This weakens regional patterns of LHF variability and results in a trend pattern whose spatial structure is too strongly influences by wind speed variations.

(3) The overall tropical mean upward trend in LHF is consistent with evidence of an increased meridional overturning circulation in the tropical Pacific Ocean during the 1990s and a likely reversal of that trend at turn of the century.

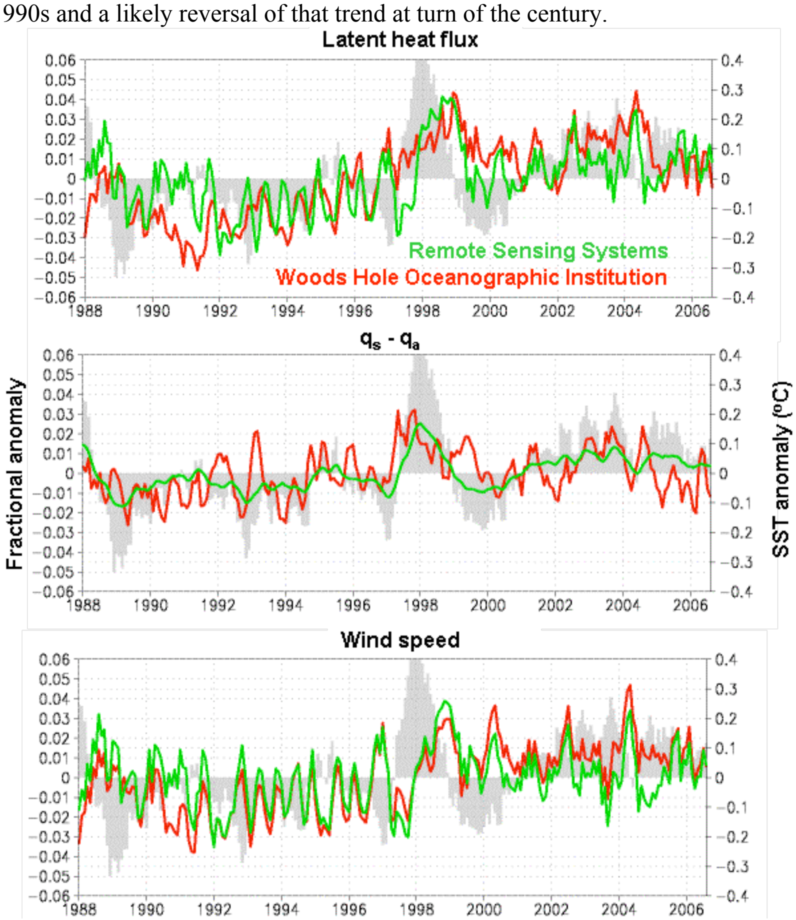

Figure 2 Time series of de-seasonalized latent heat flux and near surface qs-qa and wind speed for the RSS and WHOI ocean flux data sets. Quantities are fractional departures from climatological values. SST anomalies are in °C.

The significance of these results is that we now have much tighter uncertainties on ocean latent heat flux variations than when NEWS started—we understand WHY LHF estimates differ. We can also relate these flux changes changes to recent studies that detect decadal signals of variation in sea-surface height from TOPEX / POSEIDON and wind stress from ERS-1, 2 and QuikSCAT scatterometry. We find that the wind and moisture variations that drive the RSS and WHOI LHF variations are consistent with those findings. We now are in a position within NEWS to evaluate the hypothesis that global tropical oceanic precipitation and latent heat flux variability over the last 20 years is relatable to ocean dynamical changes associated with meridional overturning cells (MOCs) and consequent changes in equatorial Ekman pumping in the Pacific and Indian Oceans. These natural modes of variability are superimposed on, and likely mask, any anthropogenic water / energy cycle signals. This work will be presented at Spring AGU and is to be submitted to GRL by the end of April.

We have also contributed to the documents and formulation of the other two NEWS Working Group projects. In addition, M. Bosilovich coordinated the transfer of GEOS5 data for 2006-2007 to the CREW-NDIC site. Also, we just completed a new ensemble of analyses data set (funded by MAP) called the Multi-model Analysis for CEOP (MAC). This could be useful to the NEWS integration teams.

Upcoming tasks

In early March 2008, MERRA began production and moving data to the Data Information Services Center (DISC). We will begin to use the MERRA data in the context of the NEWS Integration activities. While the validation of any given month of GEOS5 or MERRA seems to indicate that it shall be a useful tool for the study of the atmospheric water and energy cycles, the next challenge will be in the interannual variability and low frequency trends. Figure 3 shows the time series of global average P, E and P-E from existing long reanalyses (and GPCP and CMAP precipitation) along with the small number of GEOS5 validation experiments (each red dot represents a monthly average in 1987, 2001, 2004 and 2006). These experiments indicate that GEOS5 precipitation is the closest to the observation of all reanalyses, and that P-E is generally small (analysis increments affect the long term balance of P-E). As MERRA is produced we will be evaluating its water cycle data. In addition, we plan to test the MERRA systems response to water vapor increments in the water cycle. We will use MERRA as a focal point of intercomparing the uncertainties of all the observed components of the water cycle.

Presentations at AGU:

(1) Dominance of ENSO-Like Variability in Controlling Tropical Ocean Surface Energy Fluxes in the Satellite Era; Franklin R. Robertson, Tim Miller, Mike Bosilovich
(2) Validation of NASA's Modern Era Retrospective-analysis for Research and Applications (MERRA), Michael Bosilovich and the GMAO Validation team
(3) Evaluation of the GEOS5 reanalysis system with a Multi-model Analysis for CEOP, Michael Bosilovich, David Mocko, John Roads and Alan Betts
(4) The water and energy cycles in an upcoming NASA reanalysis, Junye Chen

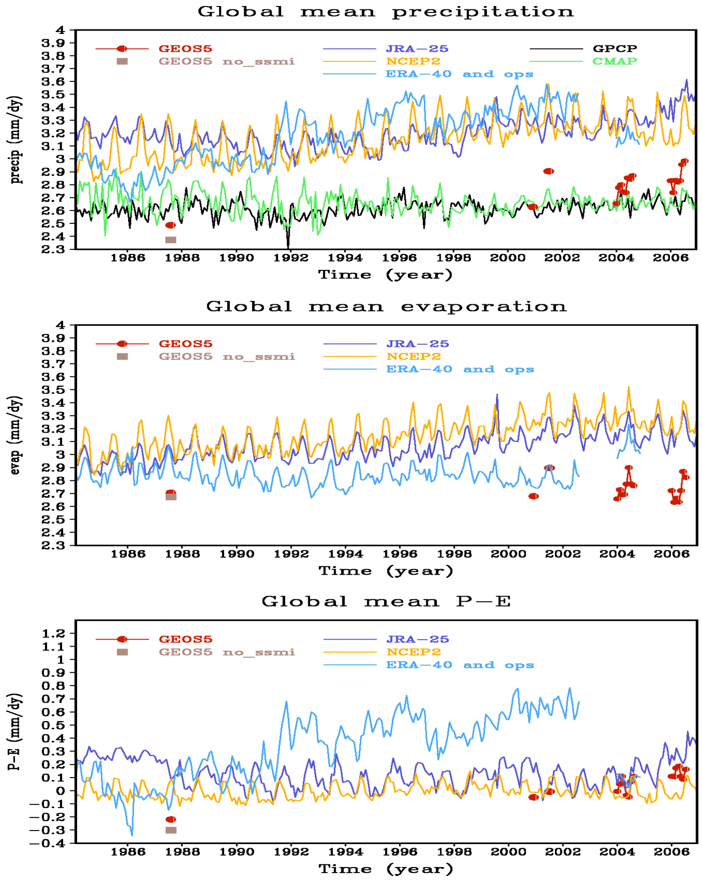

Figure 3 Global average monthly time series of precipitation, evaporation and precipitation minus evaporation for existing reanalyses (NCERP R2, JRA25, ERA40) and the GEOS5/MERRA validation experiments.