Observation Impact on the MERRA-2 Water Cycle

Michael Bosilovich, NASA GSFC GMAO

Franklin R. Robertson, NASA MSFC

Corresponding Author: Michael.Bosilovich@nasa.gov

1. Motivation

Improvements to the GEOS-5 Data Assimilation System since performing the MERRA reanalysis have dramatically changed the representation of the water cycle. A fundamental difference comes from the global mass balance constraint (Takacs et al. 2014). Here, we present and evaluate the MERRA-2 water cycle, and the implications of the constraint regarding the water cycle.

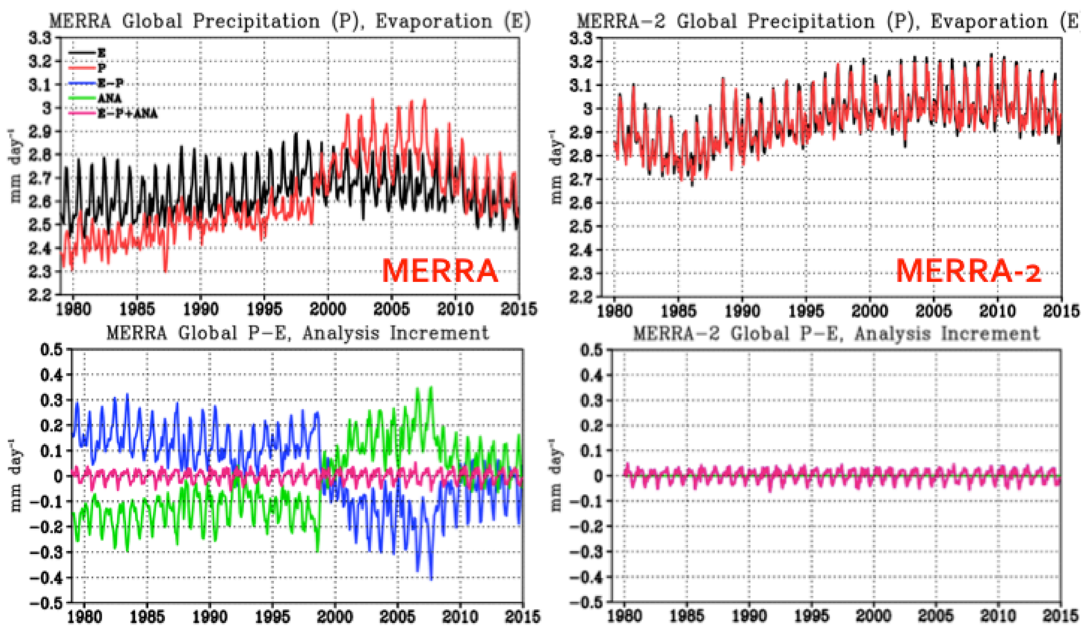

Figure 1 Time Series of MERRA and MERRA-2 P, E, P-E, water vapor analysis increment, and the total water change (magenta). In MERRA-2, P-E and the increment are so small that they do not register.

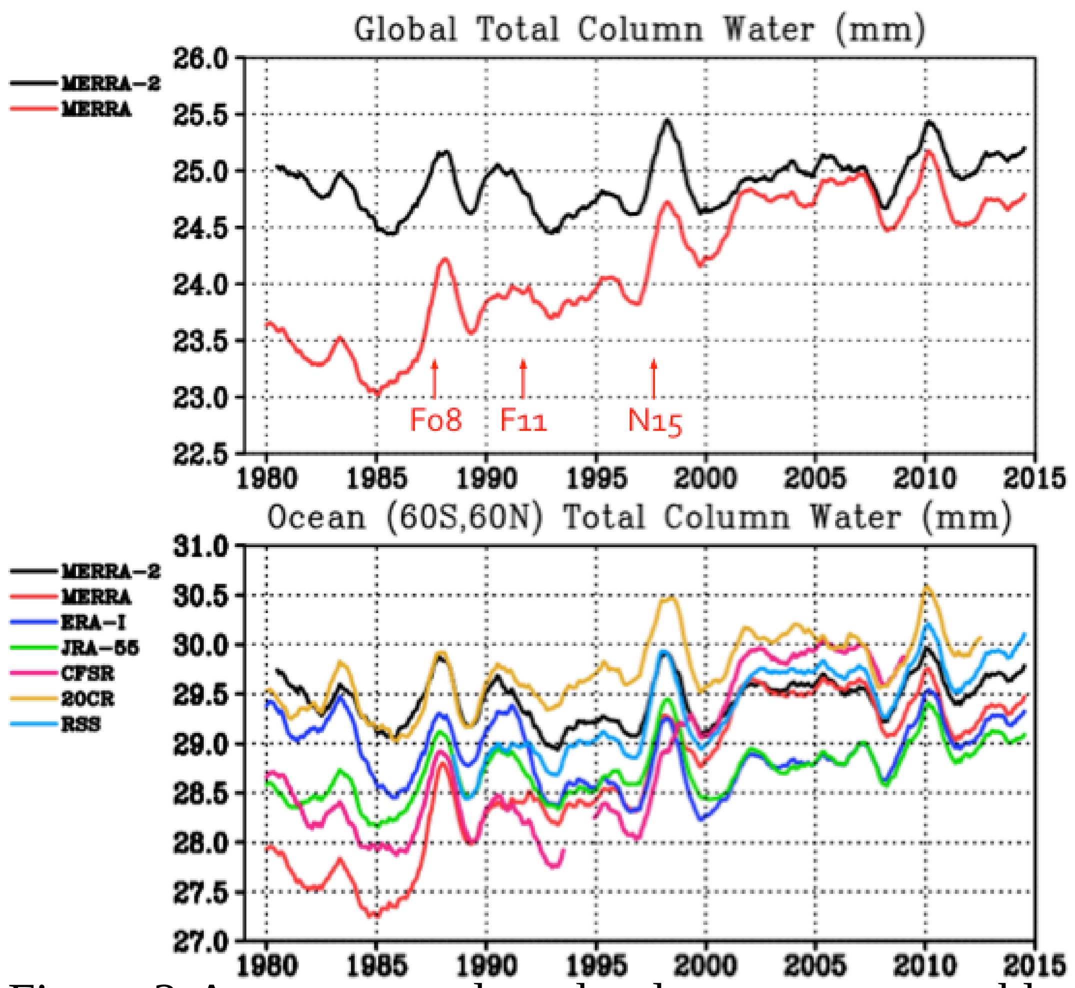

Figure 2 Area averaged total column water monthly means with a 12mon running mean.

2. Global Mass Conservation

Figure 1 shows MERRA and MERRA-2 monthly time series of global average water budget terms. In MERRA, observing system changes apparent in the water vapor analysis increment reflected into variations of the precipitation. In MERRA-2, the increments are penalized for global imbalances, and then scaled to maintain a mass balance, resulting in near-zero global mean increment. This allows P to balance E globally, and TCW to maintain a steady value near observations (Figure 2).

3. Land-Ocean Water Cycle

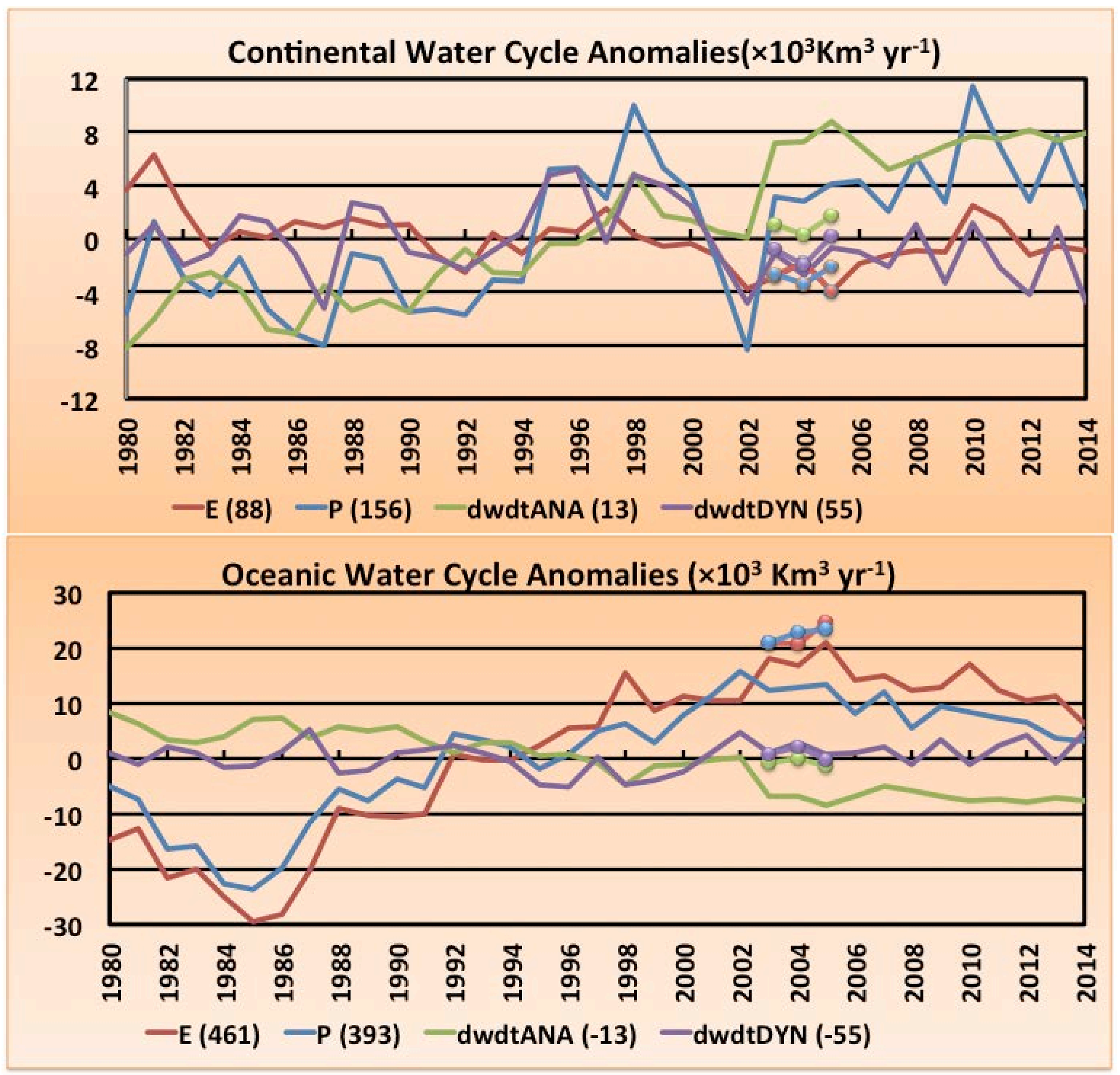

Figure 3 Annual mean water cycle terms area averaged for land and ocean areas. ANA and DYN represent the analysis increment and moisture transport tendencies respectively. Dotted lines represent an AIRS data withholding experiment.

Figure 3 separates the global water cycle into land and ocean area averages, where the water vapor increment (dwdtANA) and moisture transport (dwdtDYN) have non-zero tendencies. The transport term is remarkably stable, especially considering that reanalyses typically have low frequency trends (Robertson et al 2014). Over land, P tracks variations in increment (evaporation is partly disconnected, limited by the bias corrected precipitation), though there is some correlated interannual variability in between P and DYN. Over ocean, P and E generally track each other, with a decreasing trend of the increment, opposite the E trend.

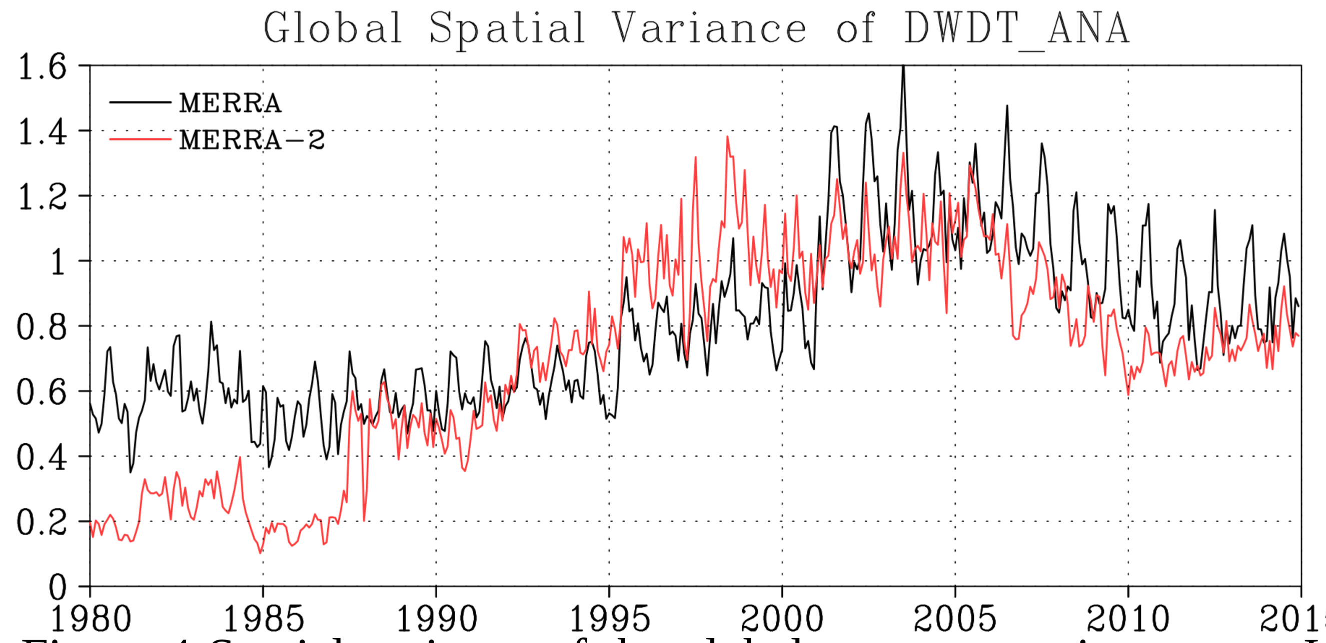

Figure 4 Spatial variance of the global water vapor increment. In units of $(mm/day)^2$. Observing system changes are apparent in MERRA-2's time series, similar to MERRA.

4. Analysis Increments

Regionally, water increments have values that contribute to the water cycle (Figure 4). Performing a data withholding experiment on AIRS shows that, over land AIRS increases the ANA and P, while over ocean it decreases the ANA and P (Figure 3, dotted lines are the AIRS withholding experiment).

5. Ocean Evaporation Controls

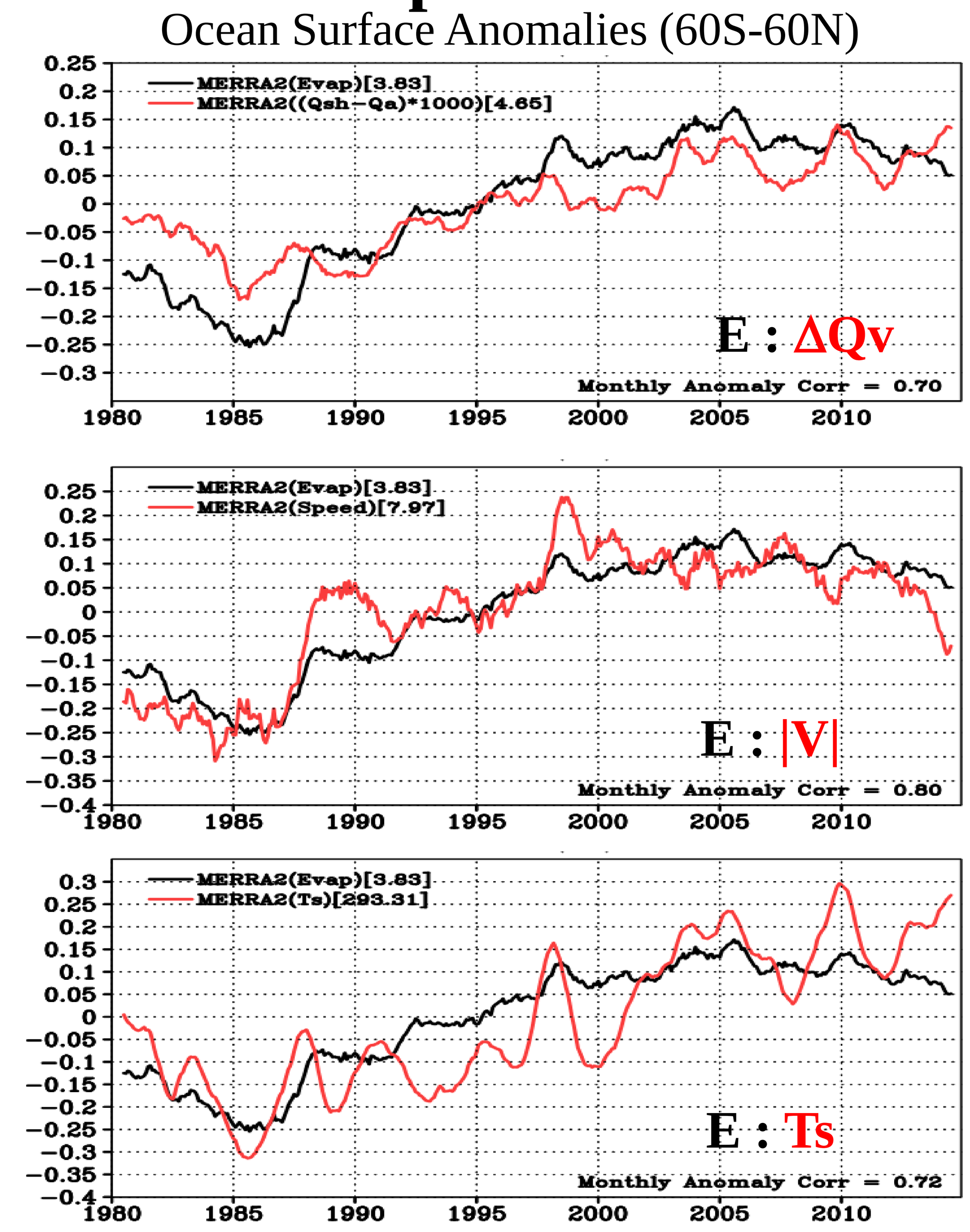

Figure 5. Anomalies of ocean evaporation and relevant parameters area averaged for ocean 60S-60N then averaged for a 12 month running mean. Evaporation (mm/day) compared to the vertical gradient of water vapor (top, g/kg), wind speed (middle, m/s) and surface temperature (bottom, K).

The drop in ocean E during the 80s leads to a concurrent drop of P (Figure 3), but what drives the E? Wind speed variations (Figure 5 middle) dominate thermodynamic forcing (Figure 5 lower) for global ocean evaporation changes. However, the SST (and ΔQv) supports low frequency variations and trends. Implementation of the global mass balance constraint leads to a significant connection between the surface observations and global water cycle (E, P).

6. Summary

Enforcing preservation of global mass has improved the stability of atmospheric water and balance over land and ocean. The resulting P variations are not apparent in global obs (GPCP and CMAP). More work is needed to better model evaporation at the surface.

7. References

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