Surface Water and Energy Budgets over the Northern Hemisphere in Three Data Assimilation Systems

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Surface water and energy budgets from the National Centers for Environmental Prediction-Department of Energy (NCEP-DOE) Global Reanalysis II (GR2; land-atmosphere reanalysis), the Global Land Data Assimilation System Version 2 (GLDAS2, offline land only analysis), and the NCEP Climate Forecast System Reanalysis (CFSR; fully coupled land-ocean-atmosphere reanalysis) are compared here with each other and with available observations over the Northern Hemisphere land mass. The comparisons in seasonal climatology, seasonal cycle and interannual variation over a 30-year period (1979 to 2008) show that there are a number of noticeable differences and similarities in the Northern Hemisphere averages.

Seasonal precipitation in both GR2 and CFSR are too large compared to the two observational precipitation datasets used to drive the offline GLDAS2 and the semi-coupled land analysis in the CFSR. The excessive precipitation yields higher evaporation with a small contribution to total runoff production in GR2, as the Oregon State University (OSU) land model in GR2 exerts less control on surface evaporation. In contrast, the high precipitation in CFSR is primarily removed from the system via the land analysis where soil moisture and soil temperature in the coupled run are replaced by their counterparts from the semi-coupled land analysis with virtually no impact on both surface evaporation and runoff as the Noah land model used in CFSR has more controls on the evaporative water loss. This leads to a lower runoff and a damped seasonal cycle in both GR2 and CFSR compared to the GLDAS2 where seasonal runoff and variability are much higher notwithstanding the low seasonal precipitation.

Seasonal variation of surface water in the GR2 has a similar phase and magnitude to that of GLDAS2, whereas surface water in the CFSR has a different seasonal cycle and seasonal variation is small. On average, the GR2 has a higher amount of surface water than both GLDAS2 and CFSR. The discrepancies between GR2 and GLDSA2 mainly come from the high bias in precipitation from the background atmospheric model and the nudging scheme used in assimilating observed precipitation, where the adjustments made to soil moisture are mostly applied to the top soil layer with the minimum impact on deep soil moisture. The difference in land model used is assumed to take the responsibility as well. The disagreement between GLDAS2 and CFSR is more reflective of the efforts made to correct surface water due to the high precipitation bias and the atmosphere model's responses to the correction in CFSR. The updates to soil moisture and snow water tend to lead to a smoother seasonal cycle when the precipitation bias is high. The use of observed meteorological forcing and no feedback between the atmosphere and underlying surface in GLDAS2 are also attributed to the differences among the three datasets.

Despite the discrepancies in seasonal water budget components, seasonal energy budget terms in the three data assimilation systems are close to each other and to available observations. Net shortwave flux in warm season from the three data assimilations is slightly higher than the satellite retrieval. The extra energy is consumed by higher longwave cooling and more evaporation in both GR2 and CFSR, whereas the energy in GLDAS2 goes to sensible heat with the minimum use of latent heat, which is consistent with its lower summertime evaporation. The slightly lower surface temperature in warm season is linked to ground heat flux where all the three datasets show a stronger ground heat cooling (non-zero annual mean); even its seasonal cycle and amplitude are close to each other. The interannual variations in both water and energy budgets are comparable.

This study shows that the surface meteorological forcing used in GLDAS2 and the data assimilation techniques used in both GR2 and CFSR are responsible for their differences, indicating that the nearsurface observation assimilation is essential to the data assimilation system success, and future improvements on data assimilation methodology is needed to depict a better water and energy climate.

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