Assimilation of Terrestrial Water Storage from GRACE in a Snow-dominated Basin

Barton Forman, Rolf Reichle, and Matthew Rodell (Code 614.3)

Overview: Passive microwave (e.g. AMSR-E) and visible spectrum (e.g. MODIS) measurements of snow states have been used in conjunction with land surface models to better characterize snow pack states, most notably snow water equivalent (SWE). However, both types of measurements have limitations. AMSR-E, for example, suffers a loss of information in deep/wet snow packs. Similarly, MODIS suffers a loss of temporal correlation information beyond the initial accumulation and final ablation phases of the snow season. Gravimetric measurements, on the other hand, do not suffer from these limitations. In this study, gravimetric measurements from the Gravity Recovery and Climate Experiment (GRACE) mission are used in a land surface model data assimilation (DA) framework to better characterize SWE in the Mackenzie River basin located in northern Canada. Comparisons are made against independent, ground-based SWE observations, state-of-the-art modeled SWE estimates, and independent, ground-based river discharge observations. Results suggest improved SWE estimates, including improved timing of the subsequent ablation and runoff of the snow pack. Additionally, use of the DA procedure has the potential to add vertical and horizontal resolution to the coarse-scale GRACE measurements as well as downscale the measurements in time. Such findings offer better understanding of the hydrologic cycle in snow-dominated basins located in remote regions of the globe where ground-based observation collection is difficult, if not impossible. This information could ultimately lead to improved freshwater resource management in communities dependent on snow melt as well as a reduction in the uncertainty of river discharge into the Arctic Ocean.

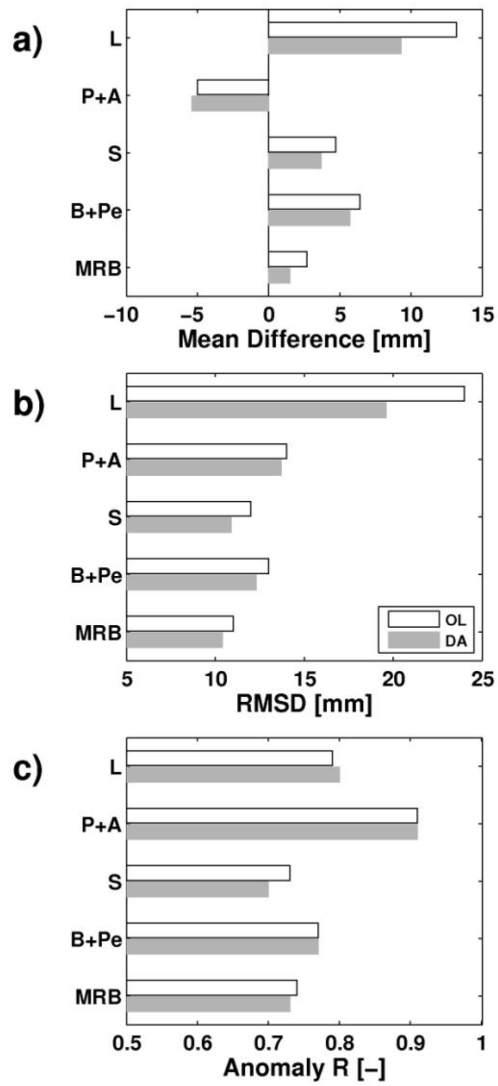

Figure 1: SWE statistics of a) Mean difference, b) RMSD, and c) anomaly R for open-loop (OL; white) and data assimilation (DA; light gray) results relative to Canadian Meteorological Centre SWE estimates via Sturm el al. [2010]. Differences in anomaly R are not statistically different.

Results: Figure 1 shows the improvements in SWE estimation in the Goddard Earth Observing System (GEOS-5) Catchment land surface model resulting from the assimilation of GRACE terrestrial water storage information. The white bars represent model results without assimilation whereas the gray bars represent results with assimilation. Each of the labels on the y-axis of each subplot represent a different studied sub-basin. As shown in Figure 1a, the assimilation of GRACE measurements significantly reduce the mean difference (MD) between the model and independent observations, particularly in the Liard basin (labeled L in Figure 1) where the greatest amount of snow accumulation occurs. The MD is improved in the majority of the sub-basins. Similarly, the root mean squared difference (RMSD) shown in Figure 1b is reduced as a result of the DA framework. The greatest reduction occurs in the Liard basin with smaller reductions occurring in the other sub-basins. The correlation coefficient of the SWE anomalies (i.e., the average seasonal cycle has been removed to better highlight interannual variability) suggest a slight degree of degradation resulting from assimilation, but further analysis shows there is no statistically significant difference on a 5% confidence interval. That is, one must conclude that there is no difference in the anomaly correlations between results with or without assimilation. In summary, the assimilation of GRACE terrestrial water storage information into the Catchment land surface model reduces the MD and RMSD in SWE estimates without adversely impacting its ability to estimate interannual variability.

Additional work was conducted to analyze modeled river discharge estimates against ground-based gauging stations. The findings (results not shown) suggested the assimilation of GRACE observations causes little of no change in the MD and RMSD of modeled river discharge, but that small, statistically significant improvements in the anomaly correlations were found. Improvements in the modeled river runoff anomalies are attributed to a redistribution of the water mass from the snow pack during the accumulation phase into the subsurface during the subsequent ablation and runoff phase. This redistribution of water mass by the DA framework effectively retains water mass within the hydrologic basin for a longer period of time, which results in small but statistically significant improvements in modeled estimates of river discharge.

The results presented here are a first step in GMAO towards utilizing space-based gravimetric measurements for the purpose of improved freshwater resource characterization where snow is a significant contributor to the hydrologic cycle. Future experiments could include visible and passive microwave measurements from existing instruments such as MODIS and AMSR-E to further downscale the GRACE observations in time and space while simultaneously disaggregating the GRACE observations into individual, vertical components of TWS. Finally, additional improvements could be achieved through refining the GRACE measurement error model, investigating the effects of different horizontal error correlation lengths within the land surface model forcings, determining a more optimal GRACE measurement scale, utilizing a more optimal GRACE averaging kernel, and enhanced constraining of post-glacial rebound model estimates used during GRACE preprocessing.

URL: http://gmao.gsfc.nasa.gov/research/landsurface/tws.php

Publications:

Forman, B.A., R.H. Reichle, and M. Rodell, 2011: Assimilation of Terrestrial Water Storage from GRACE in a Snow-dominated Basin, *Water Resources Research,* submitted.

References:

Sturm, M., B. Taras, G.E. Liston, C. Derksen, T. Jonas, and J. Lea, 2010: Estimating Snow Water Equivalent Using Snow Depth Data and Climate Classes, *J. of Hydrometeorol.,* **11**, 1380-1394.