GRACE Groundwater

Monitoring water storage with GLDAS and GRACE

The Global Land Data Assimilation System (GLDAS) produces global, continuous fields of surface states and fluxes, as derived from the most complete combination of advanced land surface models (LSMs), reliable observations, and statistical assimilation techniques available. These fields provide important information on terrestrial water storage (TWS). In many regions, total TWS variability can be approximated as the sum of changes in snow, soil moisture, and ground water. All GLDAS LSMs provide estimates of snow and soil moisture.

The Gravity Recovery and Climate Experiment (GRACE) is a joint satellite mission of NASA and the DLR that can measure changes in total, column-integrated TWS from space. However, GRACE has no vertical resolution—it cannot distinguish between water stored as snow, soil moisture, and ground water. The difference between TWS anomalies observed by GRACE and changes in water storage determined by GLDAS, then, can be used as an estimate of variability. That is:

\[
\Delta \text{Groundwater} = \Delta \text{TWS}_{\text{GRACE}} - (\Delta \text{Soil Moisture}_{\text{GLDAS}} + \Delta \text{Snow Water Equivalent}_{\text{GLDAS}})
\]

[Eq. 1]

The combination of GLDAS and GRACE thus allows for near real-time estimates of all three of the major components of TWS.

Groundwater, in particular, is a notoriously difficult quantity to monitor over large spatial scales. The ability to produce global estimates at reasonably high frequency (monthly or better) using GLDAS with GRACE constitutes a significant step forward in our ability to understand and, ultimately, to manage variability in this invaluable hydrologic resource.
Sample Application

Researchers at the University of California, Irvine, the University of Texas, and the Hydrological Sciences Branch at NASA GSFC have worked in partnership to apply GRACE and GLDAS to TWS monitoring. In a study of the Mississippi River basin, they found that the two data sources could be combined to provide estimates of seasonal groundwater variability. First, GRACE estimates of TWS were compared with GLDAS water storage (Figure 1). Next, differences between GRACE observations and summed GLDAS storage were assessed against in situ groundwater observations from the region (Figure 2). Finally, these groundwater estimates were analyzed in combination with GLDAS simulations of snow and soil moisture to give a full account of TWS variability. In subsequent work, this approach has been extended geographically and in time, providing insights on groundwater dynamics and trends over much of the globe.

Figure 1: GRACE derived terrestrial water storage (black bars), and the means from three GLDAS land surface models of soil moisture (brown dots) and snow (blue line), as deviations from their means, presented as equivalent layers of water (cm) averaged over the Mississippi River basin. The length of each black bar represents the extent of the GRACE averaging period. The tan shaded area depicts the range of the modeled soil moisture values. [From Rodell et al. (2006)]
Figure 2: Groundwater storage estimated from GRACE and land surface models using Eq. 1 (dark blue bars), and based on monitoring well observations (black line), as deviations from their GRACE-period means, presented as equivalent layers of water (cm) averaged over the Mississippi River basin. The length of the dark blue bars represents the extent of the GRACE averaging period. The light blue shaded area depicts computed uncertainty in the GRACE-GLDAS estimates. [From Rodell et al. (2006)]

Data Used

GLDAS has the capability of simulating soil moisture and snow water equivalent using several different LSMs. In this application, the Noah LSM, Mosaic LSM, and Community Land Model, available at GES DISC, were used to provide a range of water storage estimates. GRACE terrestrial water storage anomalies are derived from detected gravitational anomalies. In this study, TWS anomalies were estimated from the first 22 near-monthly (13–31 day) GRACE gravity solutions, covering the period April 2002 to July 2004. An optimized smoothing technique was applied which suppressed the noise that exists in the spherical harmonic solutions at high degrees and orders.
References