Monitoring California Water Resources from Space

James Famiglietti
Department of Earth System Science
University of California, Irvine

The goal of this work is to use current and emerging capabilities of satellite remote sensing to develop a framework for monitoring California water resources from space.

A comprehensive monitoring system for California water resources would be greatly enhanced by the large-scale view afforded by satellite remote sensing. Several current and near-future satellite missions have now demonstrated the capability for monitoring soil moisture, snow water equivalent, heights of inland water bodies (e.g. rivers, lakes, reservoirs) and changes in total water storage (i.e. the aggregate of all of the snow, surface waters, soil moisture and groundwater). The goal of this work is to exploit these current and emerging capabilities to develop a framework for monitoring California water resources from space. The focus of our work is on statewide remote sensing of soil moisture, inland water bodies, changes in the mass of the snowpack, and changes in groundwater and total water storage. Specific objectives are to 1) prepare statewide maps of surface soil moisture using the AMSR-E satellite; 2) estimate monthly changes in the mass of the Sierra snowpack using data from the GRACE satellite; 3) estimate monthly changes in total water storage for the state's major watersheds using GRACE; 4) explore the performance of the current generation of ocean (e.g. TOPEX/Jason) and ice (e.g. ICESat) altimeters to monitor the heights of the state's major rivers, lakes and reservoirs; and 5) estimate changes in groundwater storage by combining GRACE water storage change estimates with AMSR-E soil moisture estimates and state-of-the-art land surface models. In this past year, we have focused on objective 3, and initiated new work on objectives 2 and 5.

Progress on Objective 3. The Gravity Recovery and Climate Experiment (GRACE) satellite mission provides monthly estimates of column integrated land water storage by observing variations of Earth's gravity field. This estimate includes a contribution from all the components of land water storage, both above and below ground.

Despite being in the midst of a significant multi-year drought, GRACE-derived water storage in two of the largest river basins in the western United States (San Joaquin and Sacramento) show a positive trend during the period of 2003-2006 (Figure 1). In this study we took a closer look into the apparent discrepancy by analyzing the consistency between GRACE data over the combined Sacramento-San Joaquin basin region, and those obtained from basin-scale water balance computations.

While GRACE-derived estimates of change in storage over time bear close correspondence with those obtained from terrestrial water balance using individual estimates of precipitation (P) and evaporation (E) (Figure 2, blue line), large discrepancies are noted, particularly during 2004, when compared to

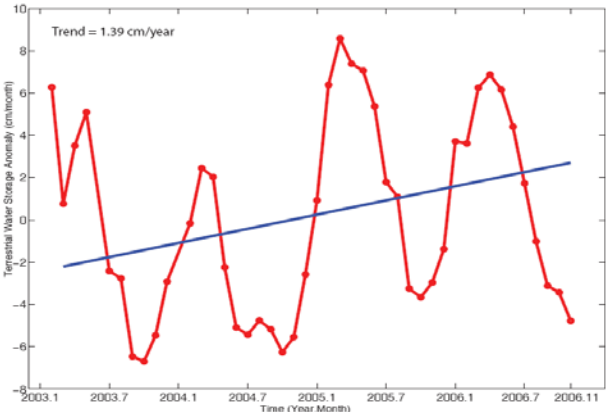

Figure 1. Water storage anomalies from GRACE for the Sacramento-San Joaquin drainage basin system.

those based on atmospheric moisture budget terms (Fig. 2, green line). For the purposes of this study, further analysis will utilize the terrestrial water balance computations. During the study time period, P has been increasing at a rate greater than that of evapotranspiration and streamflow.

When interpreting GRACE data, it is important to keep in mind that GRACE provides information on storage anomalies, relative to the average over the 2003-2006 time period. Although GRACE and the water balance data confirm that the increasing storage trend is real, the increase is relative to the average over that time period, and the average is low. Hence, the best explanation for the increasing storage documented by GRACE is that, as a result of a multi-year drought, storage levels became extremely low. In essence, increases in observed storage (GRACE) are only with respect to storage levels at the beginning of 2003 and can only contribute to reduce the storage deficit, based on severe drought conditions in place in early 2003.

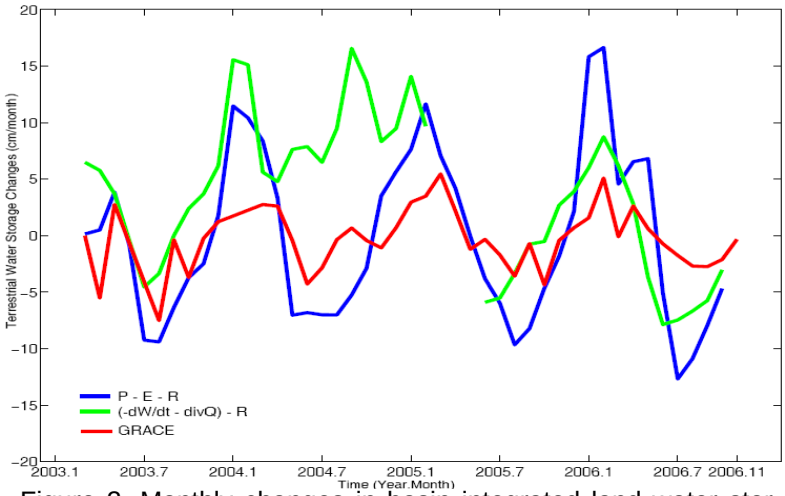

Figure 2. Monthly changes in basin integrated land water storage from GRACE (red), land-atmosphere water balance (green) and land water balance (blue).

While the WRC grant is modest, it has served an important purpose by giving our work focus on California and the west. It has allowed us to establish new collaborations and to make important progress towards our longer-term objectives to map the total water storage, snow water equivalent and soil moisture to the major drainage basins of the state, to explore the potential of satellite altimetry to monitor surface water variations, and to attempt to monitor groundwater storage variations using the methods of *Yeh et al*. [2006] in the Central Valley. An implicit goal is to demonstrate the utility of these data at spatial-temporal scales that are relevant to statewide water resources management.

Publications

Rodell, M., J. Chen, H. Kato, J. Famiglietti, J. Nigro and C. Wilson, Estimating ground water storage changes in the Mississippi river basin using GRACE, *Hydrogeology Journal*, doi 10.1007/s10040-006-0103-7

Swenson, S., J. Famiglietti J. Basara and J. Wahr, Estimating profile soil moisture and groundwater storage in the southern Great Plains using GRACE satellite gravimetric and Oklahoma mesonet soil moisture data, *Wat. Resour. Res.*, in press.

Yeh, P. J.-F., S. C. Swenson, J. S. Famiglietti and M. Rodell, Remote sensing of groundwater storage changes in Illinois using the Gravity Recovery and Climate Experiment (GRACE), *Water Resour. Res.*, 42, W12203, doi:10.1029/2006WR005374.

Professional Presentations

Dozier, J., J. Famiglietti, R. Rice. N. Molotch, T. Painter, and R. Bales, Analysis of the Sierra Nevada Snowpack in the 21st Century, AGU Fall Meeting, San Francisco, CA, December 10 - 14, 2007

Collaborative Efforts

We are working with Jeff Dozier from UCSB on GRACE-snow relationships. Work on objective 5, is just beginning in conjunction with Norm Miller at LLBL. With funding from LLBL, we will use GRACE for groundwater remote sensing of the Central Valley aquifer.

For further information please contact:

James Famiglietti
jfamigli@uci.edu
(949) 824-9434
http://www.ess.uci.edu/~famiglietti/