# Satellite Observations of Water Mass Changes in New Mexico

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## Introduction

In February 2014, the USDA announced 7 regional climate hubs to assist farmers, ranchers and forest landowners in adapting to the effects of climate change. In the Southwestern US, one of the projected impacts is a decrease in water availability and an increase in drought (Southwest Climate Alliance, 2013). This projection reinforces the need for methods to measure changes in total water mass over large areas of the southwest. NASA's Gravity Recovery and Climate Experiment (GRACE) data can be used to measure changes in total water of a relatively large area. GRACE satellite data provide the basis for recent articles depicting change in water movement in various regions of the United States (Famiglietti and Rodell, 2013).

## Methods

GRACE consists of twin satellites at an initial altitude of 500 km (current altitude 412 km) that trail one another at a distance of ~200 km. The satellites and other onboard instruments can detect change rates in the distance between the satellites. Changes in mass redistribution causes slight variations in the orbits of the satellites, which are detected via highly precise intersatellite range measurements. We use 130 months (2002-2013) of GRACE gravity coefficients to estimate changes in water mass (mm) from the NASA GRACE dataset. Data were obtained from the University of Colorado GRACE Data Analysis Website – http://geoid.Colorado.edu/grace/ (Swenson and Wahr, 2006) The GRACE footprint for this analysis covers a circular area (~196,000 km$^2$) over central New Mexico (Figure 1). Changes in equivalent water height over the 2002-2013 and the 2006-2013 time periods are used to estimate the change in total water mass in the region. One cm of loss over the GRACE footprint equates to a decline of ~1.6 million acre-feet of water (1.97 km$^3$).

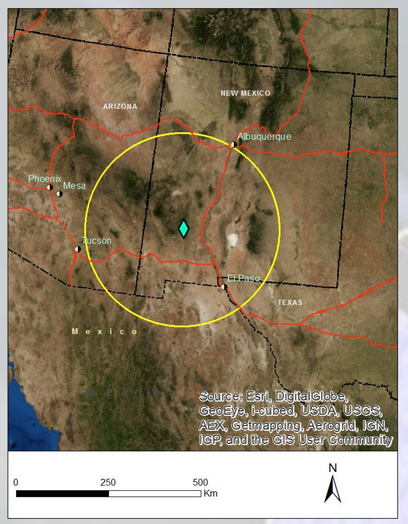



Figure 1. GRACE footprint depicting the study region of monthly total water mass changes (measurement center: 33.06 N, -107.83 W (DD).

## Recent GRACE water mass measurements

GRACE data have been used to develop drought indicators (Houborg et al., 2012), and estimate changes in regional and national water mass (Famiglietti and Rodell, 2013).

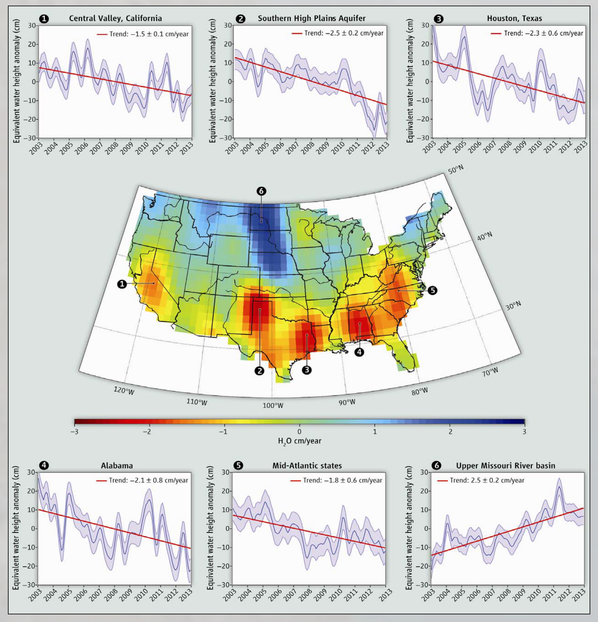
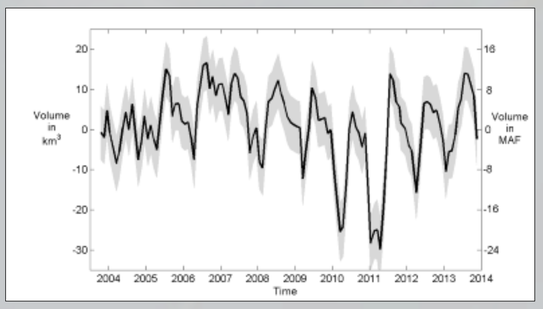



Figure 2. Regional change in groundwater levels measured in cm/year, (Famiglietti and Rodell, 2013). Groundwater levels increase in some regions and decrease in others. We followed similar methodology to focus on water in southern NM.


Figure 3. Monthly groundwater storage anomalies for California's Central Valley, derived from the NASA GRACE satellite mission and other ground-based data and model simulations. Updated from Famiglietti et al., (2011).




## Results from Southern New Mexico

For the area shown in Figure 1 from 2002-2013, total water mass decreased by -0.73 cm per year (Figure 4). Most of this decline occurs in the latter half of the study period. From 2006-2013 total water mass decreased by -1.27 cm per year, equating to ~2 million acre-feet per year (2.47 km$^3$ per year) or slightly less than the storage volume of Elephant Butte Reservoir (Figure 5).

On an annual basis, GRACE total water change ranges from an increase of 109 km$^3$ in 2005 to a decrease of -132 km$^3$ in 2013. On average, total water storage from 2002-2013 (130 months) decreased by -21.4 km$^3$ over the satellite footprint.

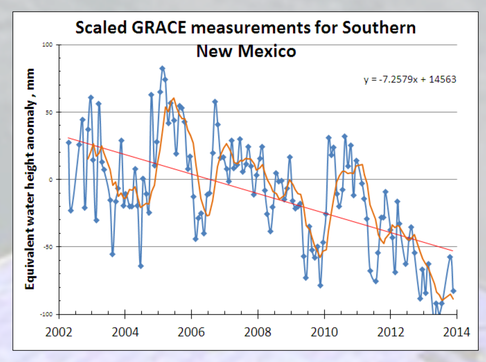



Figure 4. Equivalent water height anomaly (mm) with decreasing trend of – 0.73 cm per year, 2002-2013.

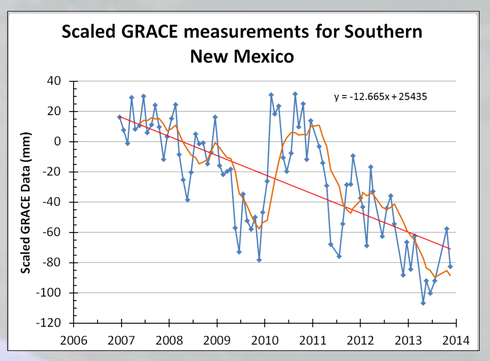



Figure 5. Equivalent water height anomaly with decreasing trend of – 1.27 cm per year, 2006-2013.

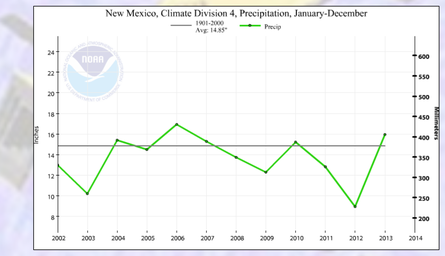



Figure 6 (left). Annual precipitation for the Southwestern Mountain Region of New Mexico, 2002-2013 as compared with the 1901-2000 average (NOAA NCDC: http://www.ncdc.noaa.gov/cag/time-series)

The reduction in water mass over the area reflects a decline in total water storage. The period 2007-2013 was below average precipitation in the region. The average precipitation decline for the southwestern NM mountains between 2002-2013 was -2.9 cm per year below the 1901-2000 average (37.7 cm) for the region (NOAA time series; http://www.ncdc.noaa.gov/cag/time-series; Figure 6).

In the Colorado Basin from 2004-2013 groundwater accounted for 50.1 km$^3$ of the total 64.8 km$^3$ of freshwater loss (Castle et al., 2014). The reduction of 200,000 acre-feet per year in the study area from 2006-2013 likely reflects a reduction in groundwater storage similar to the reduction reported for the Colorado Basin. Future efforts will estimate the regional groundwater change.

## Future Work in the Southwest

Here we use gridded GRACE hydrology dataset to derive the terrestrial water storage anomaly time series. Next we will acquire NASA soil moisture (SM) and snow water equivalent (SWE) data to calculate the total SM and SWE. The change in regional groundwater is equivalent to the terrestrial water storage less the regional soil moisture and snow water equivalent: *[GW = TWS – (SM+SWE)]* This change estimated by GRACE satellites will be compared with groundwater measurements, where possible. The GRACE follow-on mission, will be launched in 2017. Due to technological improvements it will have roughly 30% better spatial resolution.

References and data sources:

NASA GRACE dataset (http://grace.jpl.nasa.gov/data/gracemonthlymassgridsland/); NOAA time series (http://www.ncdc.noaa.gov/cag/time-series);

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Houborg, R., M. Rodell, B. Li, R. Reichle, and B. F. Zaitchik (2012), Drought indicators based on model-assimilated Gravity Recovery and Climate Experiment (GRACE) terrestrial water storage observations, Water Resour. Res. 48, W07525, doi:10.1029/ 2011WR011291.

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Acknowledgements: Thanks to Peg Gronemeyer and Ryann Smith for technical support.