

# GRACE data contributes to understanding of climate change

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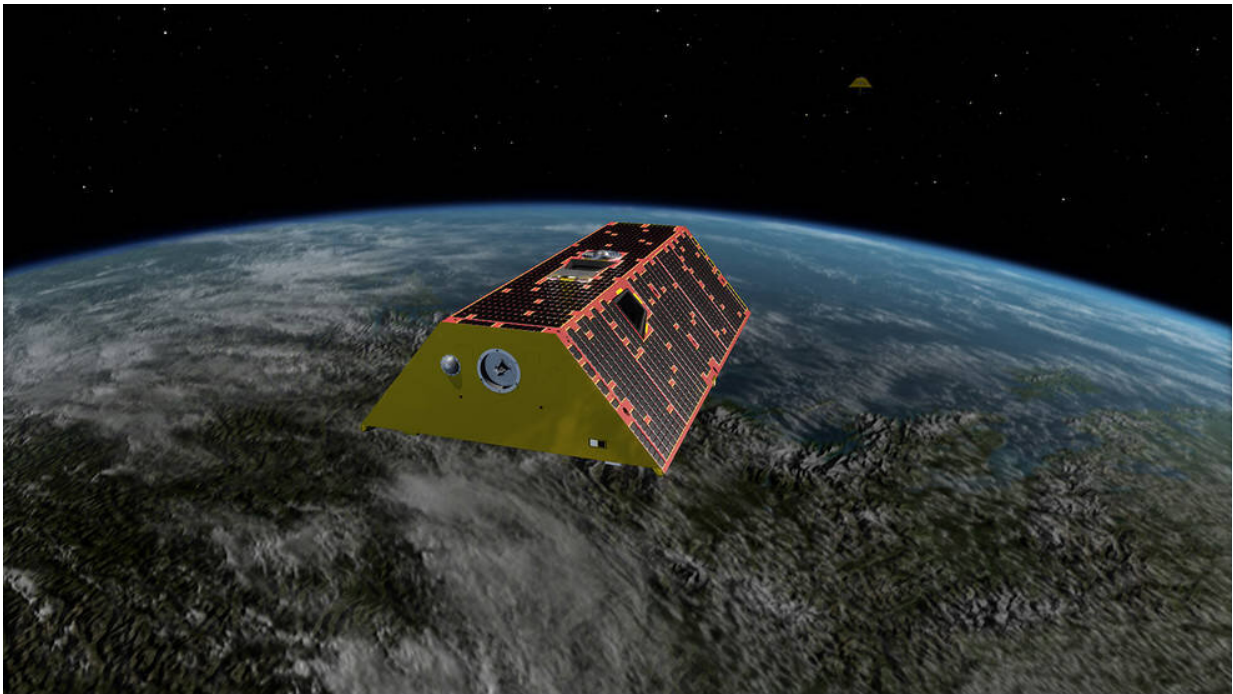


Illustration of the twin GRACE follow-on satellites. Credit: NASA/JPL-Caltech

The University of Texas at Austin team that led a twin satellite system launched in 2002 to take detailed measurements of the Earth, called the Gravity Recovery and Climate Experiment (GRACE), reports in the most recent issue of the journal *Nature Climate Change* on the contributions that their nearly two decades of data have made to our understanding of global climate patterns.

Among the many contributions that GRACE has made:

- GRACE recorded three times the mass of ice lost in the polar and mountainous regions since first beginning measurements—a consequence of global warming.
- GRACE enabled a measure of the quantity of heat added to the ocean and the location for said heat that remains stored in the ocean. GRACE has provided detailed observations, confirming that the majority of the warming occurs in the upper 2,000 meters of the oceans.
- GRACE has observed that of the 37 largest land-based aquifers, 13 have undergone critical mass loss. This loss, due to both a climate-related effect and an anthropogenic (human-induced) effect, documents the reduced availability of clean, fresh water supplies for human consumption.
- The information gathered from GRACE provides vital data for the federal agency United States Drought Monitor and has shed light on the causes of drought and aquifer depletion in places worldwide, from India to California.

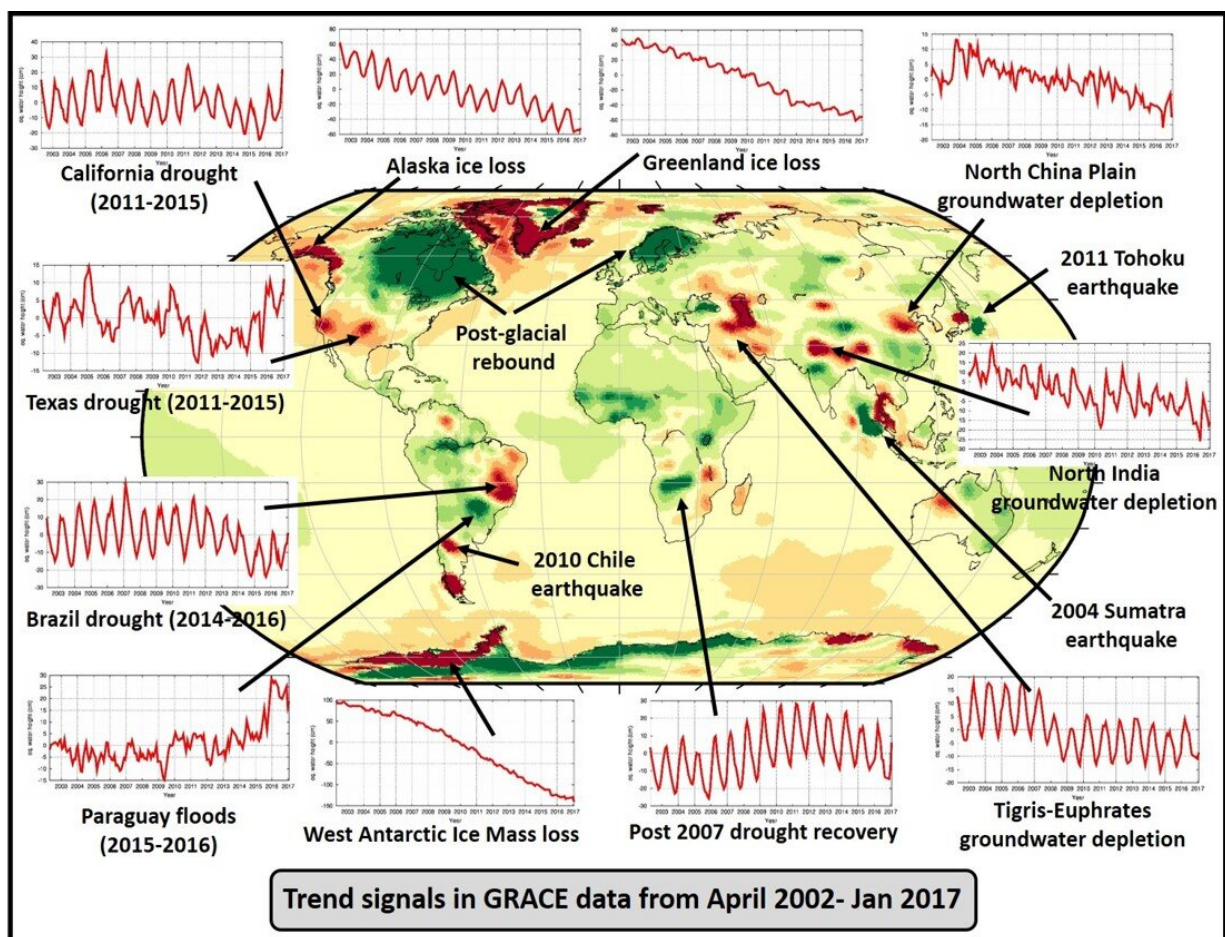
Intended to last just five years in orbit for a limited, experimental mission to measure small changes in the Earth's gravitational fields, GRACE operated for more than 15 years and has provided unprecedented insight into our global water resources, from more accurate measurements of polar ice loss to a better view of the ocean currents, and the rise in global sea levels. The mission was a collaboration between NASA and the German Aerospace Centre and was led by researchers in the Center for Space Research (CSR) in UT's Cockrell School of Engineering.

UT's Texas Advanced Computing Center (TACC) has played a critical role in this international project over the last 15 years, according to Byron Tapley, the Clare Cockrell Williams Centennial Chair Emeritus in

the Department of Aerospace Engineering and Engineering Mechanics who established the Center for Space Research at UT in 1981 and who served as principal investigator of the GRACE mission.

"As the demand for the GRACE science deliverables have grown, TACC's ability to support these demands have grown. It has been a seamless transition to a much richer reporting environment," he said.

By measuring changes in mass that cause deviations in the strength of gravity's pull on the Earth's various systems—water systems, ice sheets, atmosphere, land movements, and more—the satellites can measure [small changes](#) in the Earth system interactions.



Trend signals in GRACE data from April 2002-January 2017. Credit: Byron Tapley

"By monitoring the physical components of the Earth's dynamical system as a whole, GRACE provides a time variable and holistic overview of how our oceans, atmosphere and land surface topography interact," Tapley said.

The data system for the mission is highly distributed and requires significant data storage and computation through an internationally distributed network. Although the final data products for the CSR solutions are generated at TACC, there is considerable effort in Germany by the Geophysics Center in Potsdam and the NASA Jet Propulsion Laboratory (JPL) in Pasadena, California. The final CSR analysis at TACC starts with a data downlink from the satellites to a raw data collection center in Germany. The data is then transmitted to JPL where the primary measurements are converted into the geophysical measurements consisting of GPS, accelerometer, attitude quaternions, and the high accuracy intersatellite ranging measurements collected by each satellite during a month-long observation span.

"The collection of information from this international community are brought together by the fundamental computing capability and the operational philosophy at TACC to undergo the challenging data analysis required to obtain the paradigm-shifting view of the Earth's interactions," Tapley said.

Despite being a risky venture operating on minimal funding, the GRACE mission surpassed all expectations and continues to provide a critical set of measurements.



"The concept of using the changing gravimetric patterns on Earth as a means to understanding major changes in the Earth system interactions had been proposed before," Tapley said. "But we were the first to make it happen at a measurement level that supported the needs of the diverse Earth-science community."

One of the remarkable benefits of working with TACC, according to Tapley, is the ability to pose questions whose solutions would have not been feasible prior to TACC and to find the capability to answer the questions.

"As an example, when we began the GRACE mission, our capability was looking at gravity models that were characterized by approximately 5,000 model parameters, whose solution was obtained at approximately yearly analysis intervals. The satellite-only GRACE models today are based on approximately 33,000 parameters that we have the ability to determine at a daily interval. In the final re-analysis of the GRACE data, we're looking to expand this parameterization to 4,000,000 parameters for the mean model. The interaction with TACC has always been in the context of: 'If the answer to a meaningful question requires extensive computations, let's find a way to satisfy that requirement,'" Tapley said.

Now that the GRACE Follow-On mission, which the CSR will continue to play a role in, has launched successfully, the chance to continue the GRACE record for a second multi-decadal measurement of changes in mass across the Earth system is possible. Engineers and scientists anticipate that the longer data interval will allow them to see an even clearer picture of how the planet's climate patterns behave over time.

Provided by University of Texas at Austin

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