GRACE mission reaches five-year mark with reputation as leading global watchdog

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In the 1960s, astronauts provided the world with the first glimpses of Earth from afar. In those same years Aerospace Engineering Professor Byron Tapley nudged NASA to see more. He wanted to see beneath the Earth, to measure Earth's gravity from space.

Four decades later Tapley got his wish when NASA and the German Space Agency collaborated on the Gravity Recovery and Climate Experiment (GRACE), now completing its fifth year of doing far more than measuring the attractive pull of Earth on objects.

GRACE's twin satellites' indisputably precise measurements of mountain peaks and ocean depths, of underground watersheds and other hidden concentrations of mass offer a new understanding of changes in Earth's natural systems.

Orbiting 310 miles above Earth, the tandem satellites take advantage of Newton's law that objects receive a stronger gravitational tug from more massive objects. The satellites sense the slightest changes in gravitational pull from different planetary features, including craters deep below the Antarctic ice or the seafloor displacement that activated the Indian Ocean tsunami of 2004.

When warmer conditions melt Alaskan glaciers or major water shifts occur elsewhere, the water change registers as a minute, gravity related change in the distance between the tandem GRACE satellites. Researchers have used this satellite sensitivity since March 2002 to detect everything from the climate-related melting of Greenland's ice sheet, to water storage changes in the Amazon river basin.

"It's very interesting to get the whole Earth dynamic with GRACE and see a mass loss in one place, where elsewhere there's a mass gain," said Tapley, who directs the GRACE mission and the Center for Space Research at The University of Texas at Austin.

As the most precise mass-measuring system available, the satellites can indirectly detect a mass change that is a fraction of the Earth's standard gravitational pull on objects. Combine that sensitivity with GRACE's continually improving ability to pinpoint where mass shifts occur, and it becomes clear why the mission received NASA's "compelling" ranking during a 2005 review.

Just this month, Dr. Srinivas Bettadpur at the university's Center for Space Research announced that the Center has upgraded GRACE data to be about three times more accurate. Before GRACE, researchers could only assess the mass of an entire hemisphere. With this latest update, they can now estimate mass changes with a spatial resolution of less than 200 miles, an update partly made possible by the capabilities of the university's Texas Advanced Computing Center.

The scientific weight given to GRACE appears clear in the accelerating number of journal articles and meeting presentations based on GRACE data. Several of these, including findings of ice loss in Greenland's, have identified global warming's watermarks on the world in dramatic detail. In other instances, relatively small features have been the focus, such as the depletion of groundwater

Archives

- 2007
- 2006
- 2005
- 2004
- 2003
- 2002
- 2001
- 2000
- 1999
- 1998
- 1997
- 1996

in India, likely at the hands of farmers, and altered water storage caused by China's Three Gorges Dam.

"We've moved from a global approach to answering questions," Bettadpur said, "to one that can also address regional issues that involve real, hands-on science."

Michael Watkins, the GRACE Project Scientist at NASA's Jet Propulsion Laboratory, noted that even subtle changes, such as in oceans' circulation, are beginning to be monitored with GRACE along with water distribution changes at polar caps, river basins and elsewhere. "These small changes in ocean mass are almost impossible to detect from space with any technique but GRACE," the University of Texas at Austin alumnus said.

The highly successful mission has been possible through an outstanding international collaboration involving the Center for Space Research, the Jet Propulsion Laboratory that manages the mission, the German Space Agency (Deutsche Zentrum für Luft und Raumfahrt, or DLR), and Germany's National Research Centre for Geosciences (GeoForschungsZentrum Potsdam). The variety of scientific findings stemming from GRACE helped NASA decide to extend the initial five-year mission until fall 2009.

"GRACE data touch so many different parts of the globe and different areas of science, transcending the engineering domain into the natural sciences," Tapley said.

"GRACE is one of the best performing geo-research missions ever," said Dr. Christoph Reigber, director of GRACE satellite operations in Germany. "We're able to provide researchers with 98 percent of the satellites' data, and continue working daily with our U.S. partners to keep data flowing to researchers worldwide."

The GRACE measurements provide the added benefit of being comparable in cost to more involved approaches. For example, researchers have used GRACE to confirm that a change in water current direction on the Arctic Ocean floor affects other oceans. The findings have matched those obtained from hundreds of bottom-pressure gauges installed by extensive drilling through ice.

Among countries lacking extensive resources, the cost savings of GRACE measurements could become especially important. U.S. researchers have analyzed water levels in North American aquifers using the twin satellites. The satellite measurements matched those obtained with gauge measurements that do the same work, suggesting that resource-poor countries could use GRACE to evaluate water tables and prepare for impending shortages.

Researchers more often combine GRACE data with information from other projects to gain context. For instance, GRACE data and data from other satellites have helped identify global warming-related sea level rises in the Antarctic and elsewhere.

Dr. John Ries, another senior researcher with Bettadpur at the Center for Space Research, said, "It's important to understand what those sea levels will be in the future without having to put instruments throughout oceans."

Comparing GRACE data to data obtained with satellite interferometry also helped Center for Space Research researcher Jianli Chen, Geology Professor Clark Wilson and colleagues determine that Greenland's accelerated ice loss in recent years is occurring primarily along its southeastern edge.

That finding, published last August in the journal *Science*, has raised concerns since the added meltwater could change how much fresh water mixes with more buoyant salt water in a branch of the North Atlantic Current. The change could lower water and wind temperatures traveling past the west coast of Ireland and Great

Britain, potentially producing chillier winters.

Ultimately, Tapley measures GRACE's success by its relevance to vital issues such as the Earth's sensitivity to warmer climates and the affects of unrestricted farm irrigation on water tables.

"This gravity signal from GRACE is about mass movement around the Earth," Tapley said, "but its meaning extends far beyond that."

For photos of Dr. Tapley and researchers from the Center for Space Research, go to:
http://www.engr.utexas.edu/news/action_shots/pages/GRACE_Tapley_2007.cfm

For a list of major findings obtained using GRACE data, go to:
http://www.csr.utexas.edu/grace/timeline.html

To learn more about GRACE and the Center for Space Research, got to: http://www.csr.utexas.edu/grace/

To learn more about the Texas Advanced Computing Center, go to:
http://www.tacc.utexas.edu/general/overview/

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