More Science news

Appraising GRACE

Twin satellites provide a new way to track changes in the Earth

By Richard A. Lovett
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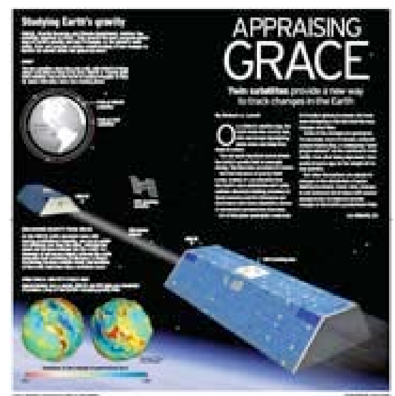

Studying Earth's gravity (PDF)

All of this gives geologists a new way to visualize global processes. But even more intriguing is the fact that the map changes over time.

Some of the changes are geological. For example, much of Canada, centered around Hudson Bay, is undergoing “post-glacial rebound” as the continental crust slowly rises after being depressed, thousands of years ago, by the weight of Ice Age glaciers.

But other fluctuations are related to changes in the distribution of water. Melting ice sheets, heavy rains, changes in soil moisture: All of these shift around enough water to make discernible changes in the Earth's gravitational field.

Some of these changes are signs of global warming. Others can provide early warning of floods, crop failures, poor snowpack for irrigation water, and aquifer depletion in remote corners of the globe.

“Water has weight,” said project scientist Michael Watkins of NASA's Jet Propulsion Laboratory in Pasadena. “Therefore, it has gravitational attraction, and GRACE can detect it.”

GRACE is a satellite launched in 2002. Or, more precisely, it's a pair of satellites. The name itself – Gravity Recovery and Climate Experiment – indicates the major role water was expected to play in its findings.

The concept is simple. The two satellites, each about 10 feet long, follow each other in identical orbits roughly 250 miles above the Earth, approximately 130 miles apart. Microwave instruments measure the distance between them precisely enough to detect variations smaller than 1 percent of the width of a human hair.

It's as though “you have two automobile-sized things, one in Los Angeles and one in San Diego, and you're measuring the distance between them to the size of a red blood cell," Watkins said last fall at a meeting of the American Geophysical Union.

As one satellite and then the other passes through wrinkles in the Earth's gravity field, they speed up or slow down slightly, shifting the distance between them. By measuring these tiny yo-yo effects, scientists can calculate the gravity field that produced them, mapping the entire Earth about once a month.

Already there have been some dramatic findings. In late 2005, GRACE was instrumental in determining that the Greenland ice sheet was melting much faster than previously anticipated – enough to be contributing 0.016 inches per year to the rise in the global sea level.

But long-term changes aren't the only ones that GRACE can detect. For example, it's possible to spot the difference between the tropical monsoon season and the dry season. "It's a big signal," Watkins said.

One of the advantages of using gravity to monitor changes in wetness is that GRACE measures changes not just in surface water, but also in hidden water, such as soil moisture or groundwater.

"It has been difficult to measure (that) without an army of grad students or people monitoring a well all the time," Watkins said. But it's important to get these measurements because there are parts of the world where many people rely entirely on such water supplies.

Nor can normal satellite instruments see this deep moisture, said James Famiglietti a hydrologist at UC Irvine, because they are simply taking pictures of the surface.

"GRACE is giving us a first-ever look at how water storage on the continents is changing," he said.

Not all of the changes are due to climate. Like the seasonal pattern of the monsoon moisture, some are natural. Others could be due to agricultural practices, wetland drainage or river diversions.

Offbeat observations

Because GRACE has only been in orbit for five years, the research is just beginning, but already interesting results are coming in. At the geophysics meeting, John Wahr of the Cooperative Institute for Research in Environmental Sciences at the University of Colorado ran through a list of "offbeat anomalies" that GRACE appeared to have found in Central Asia.

One of these, he speculated, might be from the impoundment of water in the mammoth Three Gorges Reservoir, which began filling in June 2003 and had reached a depth of 300 feet.

A bigger anomaly, he said, is southeast of the Aral Sea, which lies between Kazakhstan and Uzbekistan. The Aral Sea is fed by snowmelt from big mountain ranges to the south and southeast. Since the 1930s, local farmers have been diverting large amounts of water from the incoming rivers for use in cotton farming. That has led to a crisis in the Aral Sea itself, which is drying up.

But some of the diverted water is accumulating in the desert soil, creating a man-made aquifer. GRACE can't reveal how polluted that aquifer might be, but it can indicate the rate at which water is accumulating in it.

All told, Wahr said, gravity is increasing in the surrounding desert fast enough to indicate that about 25 cubic kilometers of water – a volume one-sixth that of Lake Tahoe – is percolating into the ground each year.

Northern India, on the other hand, shows a declining gravitational field. Again, the cause is irrigation, but in this case, water is being pumped out of the ground. Overall, about 150 cubic kilometers per year is being drawn out of wells, Wahr said, but some of that water presumably percolates back into the ground to recharge the aquifer. The question is, how much?

In the Aral Sea region, only about 20 percent to 25 percent of the irrigation water is making its way into the ground. In India, Wahr's calculations show that the fraction is much higher, but that 35 to 40 cubic

kilometers per year is still being lost.

The same calculation, of course, could have been done by monitoring water levels in wells. But with GRACE, the observation could be made cheaply, by one man thousands of miles away.

“GRACE is a new technique for hydrology,” Watkins said.

“Water can't hide from GRACE,” added Matt Rodell, a hydrologist at NASA's Goddard Space Flight Center in Greenbelt, Md.

GRACE also turns out to be a new technique for geology. Another of Wahr's “offbeat anomalies” was in Tibet, where he saw an odd increase in gravity that he can only explain as post-glacial rebound, similar to what is seen in Canada.

There's only one hitch: Geologists aren't convinced there ever was an ice sheet in Tibet, and the question is the subject of a long-standing debate. It would be ironic if the dispute were resolved in this manner, via a satellite designed to track climate change.

Other scientists are looking at trends in water supplies at the national or regional level. With GRACE, Famiglietti says, it's possible to see which parts of the world are getting wetter, and which are getting drier.

With only a few years of data, he adds, there's no reason to get alarmed about the trends, because everyone knows that climates run in cycles. But the results could reveal much about the workings of region-wide climate.

“If you start checking something frequently, like your blood pressure,” he said, “you realize that it goes up and down. This is the first time we've been able to track these variations at this scale.”

Climate baseline

GRACE is also giving the first-ever baseline measurements of important climate variables. One of these is the flow of water into the Arctic Ocean.

Several big rivers drain into the Arctic, and changes in their flow are likely to occur as glaciers retreat and the rate of snowmelt changes. This is important because the rate at which fresh water is flowing into the Arctic Ocean is believed to play a major role in ocean circulation and therefore in overall global climate.

Traditionally, it requires river gauges to measure the rate of discharge from a watershed.

“Before GRACE, if we wanted to estimate fresh-water discharge from an ungauged basin, it was simply not possible,” Famiglietti said.

But now, he said, GRACE allows scientist to measure all such flows and to confirm estimates that the rate of fresh-water discharge into the Arctic has been increasing.

On a seasonal basis, hydrologists are also looking for ways to use GRACE data to issue water reports that might be useful to farmers.

“Our hope is that water resource managers can integrate this into their reservoir allocations,” Famiglietti said.

And in an application familiar to Californians, Rodell said it's possible to use GRACE to monitor mountain snowpack.

“If you know there's a lot of snow up there, you can tell that this year is going to be a good year for crops,” he said.

Because GRACE sees only at a regional scale, it can't substitute for the drainage figures obtained by conventional on-the-ground snowpack measurements, but it can certainly reveal overall snowpack in entire mountain ranges, such as the Rockies, the Sierra Nevada or remote sections of countries where the snowpack has not been well monitored.

It can also help determine the risk of springtime floods in places like the Midwest, where heavy, late snowpack poses a risk downstream.

"Grace won't replace ground-based observations," Rodell said. But it "gives another piece of the puzzle, so you get a better prediction."

▪Richard A. Lovett is a freelance writer in Oregon and a frequent contributor to Quest.

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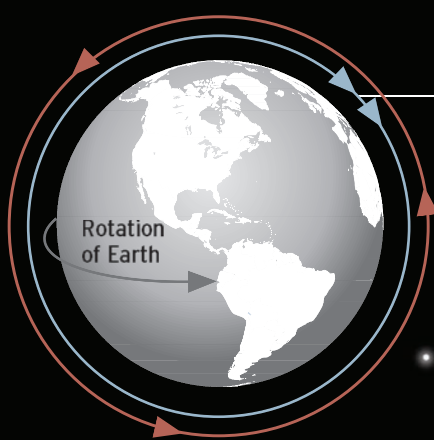
SEE **GRACE, E3**

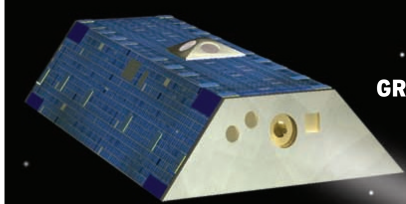
Studying Earth's gravity

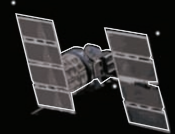
GRACE, Gravity Recovery and Climate Experiment, involves two satellites launched in 2002. They provide the most accurate global map of Earth's gravity and how it changes as the planet's mass shifts. Data also provide a better understanding of how changes in Earth's ice sheets affect the global sea level.

ORBIT

The two satellites share the same orbit, with GRACE B flying about 130 miles in front of its twin, GRACE A. Gravity pulls both satellites toward the Earth at varying strengths as they fly about 300 miles above the rotating planet.

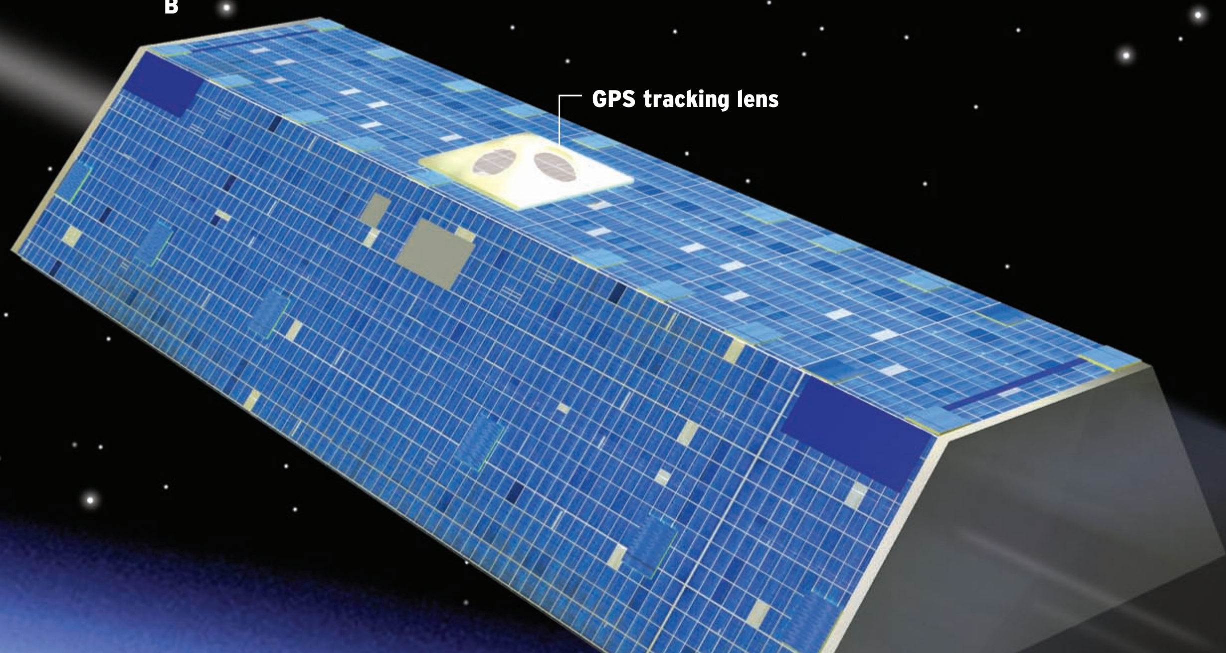






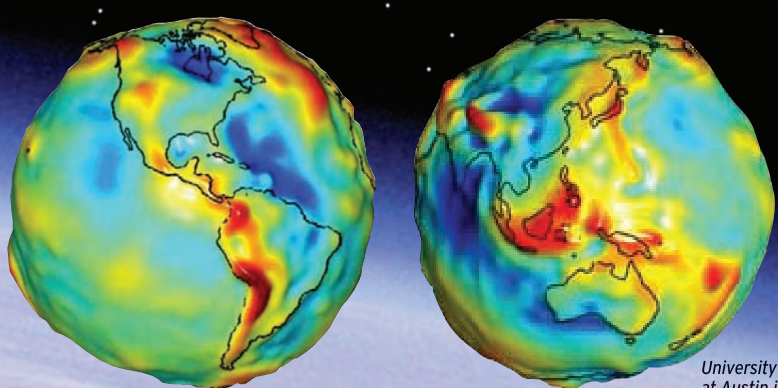
MEASURING GRAVITY FROM SPACE

As the GRACE crafts encounter areas with varying gravitational intensity, one can be pulled at a different rate than the other, affecting the speed and distance between the two crafts. An exchange of microwave signals between the crafts measures their variations in distance. A Global Positioning System satellite tracks the locations of the crafts and where these variations occur.



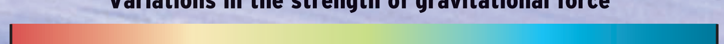
CREATING A GRAVITY-FIELD MAP

Approximately once a month, GRACE and GPS data are calculated to produce a map of the Earth's changing gravity field.



University of Texas at Austin images

Variations in the strength of gravitational force



SOURCE: University of Texas at Austin Center for Space Research

DANIEL WIEGAND / Union-Tribune