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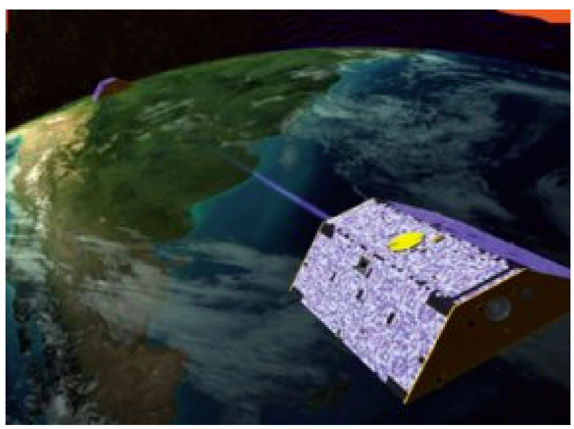
Mapping with GRACE

Twin satellites chart changes in Earth's gravitational field

Sid Perkins

Concerned about your weight? Don't go to the North Pole, where you're about 20 km closer to the center of Earth—and therefore a pound or so heavier—than at the equator. Head, instead, for India. There, you'd be standing over a less-dense landscape with a gentler gravitational pull. Yes, what you weigh depends on where you are. Your body doesn't change from place to place, but the gravitational field does. Topography, crust composition, and the planet's rotation-induced equatorial bulging are among the factors that influence Earth's gravitational pull at different locations. Furthermore, this uneven gravitational field changes slightly with the seasons, as precipitation carries moisture's mass from the oceans onto the continents.



ORBITING TWINS. A microwave relay between the GRACE satellites measures their separation, which varies as the craft pass over gravitational anomalies on Earth's surface.
NASA

For more than 30 years, scientists have been monitoring the planet's tug with several dozen satellites and sensitive instruments carried into the field. But the global gravitational model that they've compiled from that data has just been rendered obsolete by a pair of satellites that were launched last March.

Over their 5-year lifespan, the two spacecraft—dubbed the Gravity Recovery and Climate Experiment, or GRACE—will produce gravity maps more than 1,000 times as accurate as those currently in use. With this enhanced accuracy, scientists will monitor subtle seasonal shifts in ocean currents, the changing mass of ice sheets, and the movement of water over and beneath Earth's surface.

Orbit for two

The twin GRACE craft—each about the size of a car and weighing half a ton—will orbit Earth at an altitude of nearly 500 kilometers, says Michael M. Watkins, a project scientist at NASA's Jet Propulsion Laboratory in Pasadena, Calif. They'll zip along a single trajectory, with one satellite leading the other by about 200 km. A microwave relay between the two craft will enable scientists to measure the distance between the satellites within a few millionths of a meter—about the width of a red blood cell or a particle of smoke. That accuracy is the key to constructing detailed maps of the planet's gravitational field, says Watkins.

Here's how the process works: As the first GRACE craft approaches a massive object on Earth's surface—a mountain, for example—it's pulled slightly forward in its orbit, away from its partner. After it passes over the mountain, it's pulled backward while the second satellite is pulled ahead, thus decreasing the distance between the two craft. Finally, after the second satellite crosses the mountain, it's pulled backward. Eventually, the distance between the two craft returns to normal. The changes in separation between the two satellites indicate the size of the gravitational anomaly that the mountain creates.

Those anomalies, representing local distributions of mass, are then used to map Earth's so-called geoid—the height that sea level would be at any point on the planet without the effects of ocean currents, weather, or tides.

Better by far

The first geoid maps derived from GRACE data were unveiled last month at the American Geophysical Union's fall meeting in San Francisco. Even though those maps were compiled from data garnered during the satellites' calibration period, they're "already a step forward," says Byron D. Tapley, director of the Center for Space Research at the University of Texas at Austin.

Updates to old gravity maps are largest in South America, Africa, the Himalayas, and other areas where scientists had previously collected only limited field data. In some places, errors in geoid height on the old maps were as much as 2 meters, says Watkins. GRACE data has reduced that error to less than 1 centimeter. "Now, we're ready to look at how the geoid varies over short periods of time," he adds.

What scientists hope to see in GRACE data are month-to-month changes in Earth's geoid, says John M. Wahr of the

University of Colorado at Boulder. For example, GRACE will soon detect to accuracies of about 4 mm any rises or falls in water stored in a snow pack or in soil over areas about the size of the Mississippi River basin, an area of 3.2 million square km. When the satellites are fully operational in a few months, GRACE will detect monthly changes of 4 mm or more in water level over areas as small as 250,000 square km.

That sort of accuracy could help scientists watching arctic ice sheets determine whether the ice masses are shrinking and enable farmers to monitor soil-moisture levels, says Wahr. Monthly updates to Earth's geoid should be available beginning in about a year.

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References and sources for this article

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Further Readings:

For more information on the GRACE mission go to http://www.csr.utexas.edu/grace/.

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