National Aeronautics
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FEATURE

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Measuring Gravity With GRACE **04.16.07**

It's an assumption that has made introductory physics just a little bit easier -- the acceleration of a body due to gravity is a constant 9.81 meters per second squared. Indeed, the assumption would be true if Earth were a smooth sphere made of uniform elements and materials.

Quite the opposite is true, however. Earth's diverse topography includes mountains, valleys, underground caverns, oceans and glaciers. Since gravity is directly related to mass, and different surface features contain more or less mass than others, slight variations in gravity exist across the surface of the planet.

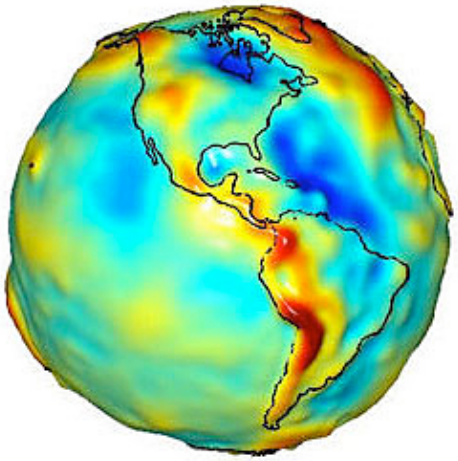

Image to right: A gravity model of the Earth constructed with data from GRACE. Credit: University of Texas Center for Space Research and NASA

While tiny changes in gravity may be negligible when solving a basic high school physics problem, they can be a critical clue to understanding the structure of the solid Earth, ocean circulation, sea ice and sea-level rise, and fluctuations in the amount of water stored above and below ground.

GRACE, short for Gravity Recovery and Climate Experiment, is a NASA mission consisting of twin satellites that were launched in 2002. The satellites are in the same orbit around Earth, one about 220 kilometers (137 miles) in front of the other at an altitude of 460 kilometers (286 miles) above the Earth's surface. Together, they measure Earth's gravity field with a precision greater than any previous instrument.

How does GRACE measure gravity?

As the lead satellite passes over an area on Earth of slightly stronger gravity, it detects an increased gravitational pull and speeds up ever so slightly, thus increasing its distance from the trailing satellite. Conversely, the lead satellite slows down when it passes over an area of slightly weaker gravity, decreasing the distance between the two satellites.

The changes in distance between the satellites are so minute -- about one-tenth the width of a human hair -- that they are undetectable by the human eye. GRACE measures these changes using an instrument that generates pulses of microwave energy -- a highly energetic form of electromagnetic radiation -- that bounce back and forth between the two satellites. The distance between the satellites is determined by the time a microwave pulse takes to travel from one satellite to the other and back.

GRACE maps the entire gravity field of Earth every 30 days. Changes in gravity over time can reveal important details about polar ice sheets, sea level, ocean currents, Earth's water cycle and the interior structure of the Earth.

In the Arctic, for example, GRACE has found that the ice sheet that covers most of Greenland is shrinking. Measurements of decreasing gravity over the ice sheet, thus indicating a decrease in the ice sheet's mass, showed a loss of about 150 billion tons of ice per year between 2003 and 2006. Melting ice sheets and glaciers contribute to rising sea level worldwide. The melting Greenland ice sheet contributes about 0.3 millimeters per year to a rising global sea level. GRACE continues its measurements to understand whether this rate of sea level rise is increasing or decreasing.

In Africa and Australia, decreases in gravity are evidence of drying river basins. GRACE not only measures changes in water above ground -- in rivers, lakes and reservoirs -- but also senses the amount of water stored in aquifers beneath the Earth's surface. This kind of information can enable better management of scarce water resources.

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GRACE can also detect changes in Earth's crust brought on by earthquakes, such as the 2004 tremor in the Indian Ocean that triggered the deadliest tsunami on record. The quake changed the density of the rock beneath the surrounding sea floor, which GRACE was able to see several months later as a change in gravity.

GRACE can also estimate differences in the mass or bottom pressure of the oceans. Taking a page from weather forecasting, which uses atmospheric pressure gradients to estimate wind velocities, GRACE measures ocean pressure gradients to estimate monthly changes in deep ocean currents such as the very important circum Antarctic current.

GRACE is a joint mission between NASA and the German Aerospace Center.

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