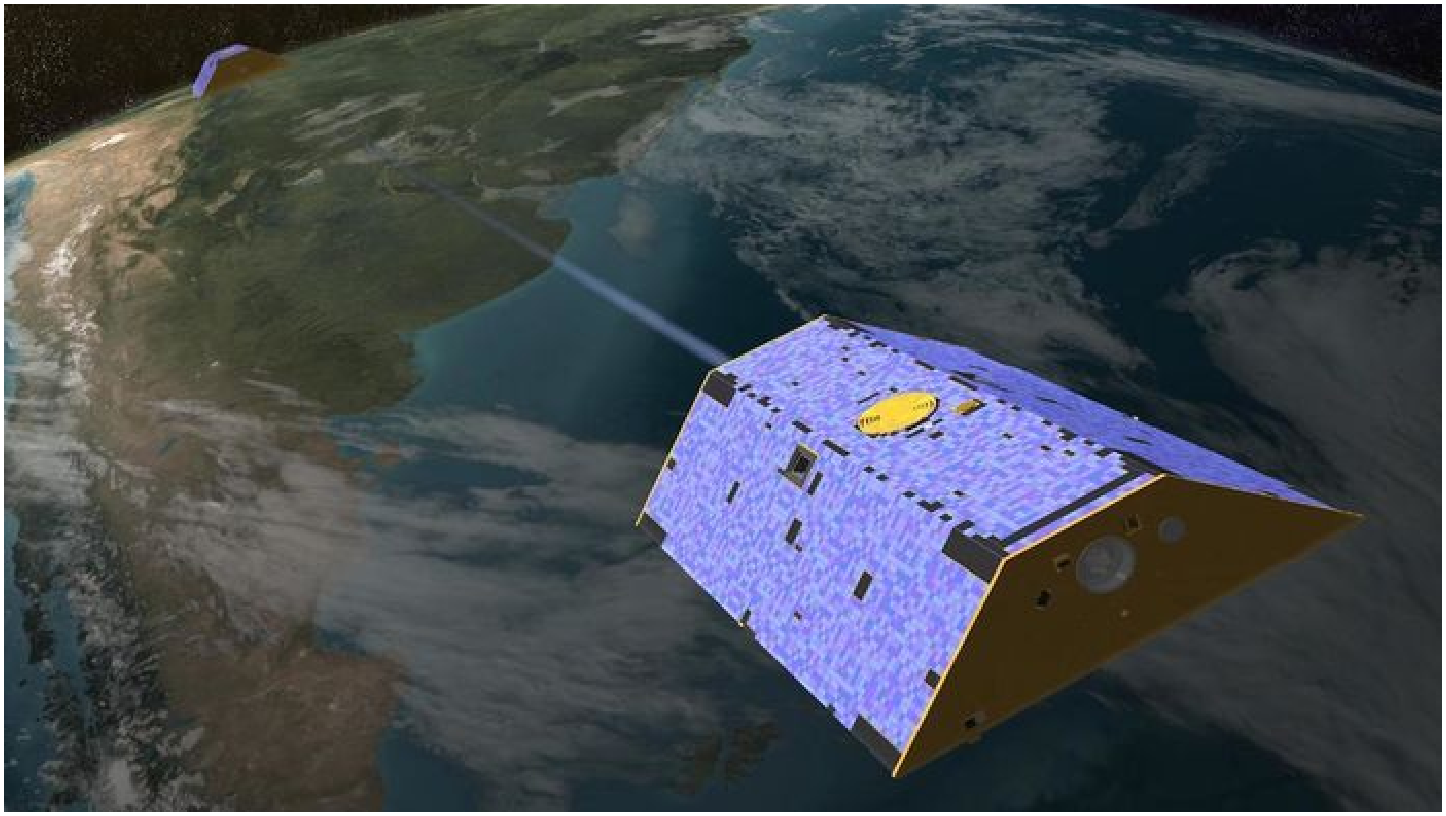

Artist's conception of the GRACE spacecraft orbiting Earth.

NASA/JPL

Satellites measuring Earth's melting ice sheets to go dark

By **Paul Voosen** | Sep. 15, 2017 , 11:30 AM

A sentinel of Earth's climate is going dark. After running for a decade beyond its planned life, the Gravity Recovery and Climate Experiment (GRACE) is nearly out of fuel and will soon make its final science run, NASA **announced** late yesterday. The tandem of satellites—called GRACE-1 and GRACE-2—measure minute shifts in Earth's gravity to chart flows of mass across the planet, such as the unexpectedly rapid melt of polar ice sheets and the drawdown of underground water reservoirs called aquifers.

Scientists had hoped GRACE would operate until its successor, the $550 million GRACE Follow-on (GRACE-FO) mission, reached orbit. But troubles securing a ride to space have delayed GRACE-FO's launch until early 2018. Meanwhile, the battery in GRACE-2 used to store solar power has been deteriorating rapidly, forcing the satellite to burn through fuel. Engineers turned off an accelerometer last year to keep it running, but the satellite's data have continued to degrade.

On 4 September, scientists lost contact with GRACE-2 after another of its battery cells stopped operating. Four days of feverish work followed, with scientists steeling themselves for the mission's end. But finally, engineers bypassed the satellite's flight software, successfully rebooting it. NASA has now put GRACE-2 on standby until mid-October, when it will run until early November in full sun on its final planned science collection.

However small, a gap between the missions will make it more challenging to stitch their records together into a seamless whole, says Eric Rignot, a glaciologist at NASA's Jet Propulsion Lab in Pasadena, California. There are alternative ways to calculate some of the measures GRACE provides, so stopgaps are possible. For example, changes in the mass of the ice sheets can be estimated by using other satellite data to compare discharges of peripheral ice to snowfall accumulations. But there is no comparable method to monitor changes in the mass of glaciers or ice caps, let alone the measures of Earth's groundwater and soil moisture that hydrologists derive from the satellites. "It would be an impossible task to fill the gap," Rignot says.

A dynamic duo

A joint U.S.-German effort, GRACE has provided an unprecedented view of the planet's water and ice since its launch in 2002. The experiment relies on measuring changes in the tug of gravity as the two satellites orbit the Earth. Flying 220 kilometers apart, the GRACE satellites constantly monitor their distance from each other with microwave pulses, down to microns. When the satellites approach a more massive feature, such as an ice sheet, the enhanced gravity of that region tugs a little bit more on the first satellite—briefly widening the distance between the pair—before the second satellite catches up. The changes in distance can be translated into mass.

This data revolutionized entire disciplines, such as hydrology, allowing scientists to document the loss of groundwater due to human exploitation. GRACE showed that the melting polar ice sheets are contributing more to sea level rise than the demise of mountain glaciers. Greenland, it found, is losing 280 gigatons of ice a year on average, while Antarctica is shedding 120 gigatons—rates that both seem to be accelerating. GRACE also inspired a similar mission, NASA's Gravity Recovery and Interior Laboratory, which probed the moon's interior.

There's much that can still be done with GRACE's archival data, says Isabella Velicogna, a geophysicist at the University of California, Irvine. For example, Velicogna and her colleagues **recently used GRACE data to observe for the first time a strange, counterintuitive effect**: Melting ice sheets in Greenland and Antarctica are pouring water into the oceans and adding to sea level rise. But the lost ice also means lost gravity—and so sea levels in the immediate vicinity of the ice sheets actually drop, while ocean levels half a world away are goosed. The dynamic, called sea level fingerprints, had wide acceptance in the field, but GRACE provided the first direct confirmation that it was happening.

Although the data gap is unfortunate, it was never a sure bet that GRACE would hold out, Velicogna says. And GRACE-FO, essentially a replication of the first mission, will provide finer mass resolutions by measuring the distance between the two satellites **not just with microwaves, but with an experimental laser ranging interferometer**. It's the same technology that could one day help a planned satellite constellation capture gravitational waves.

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