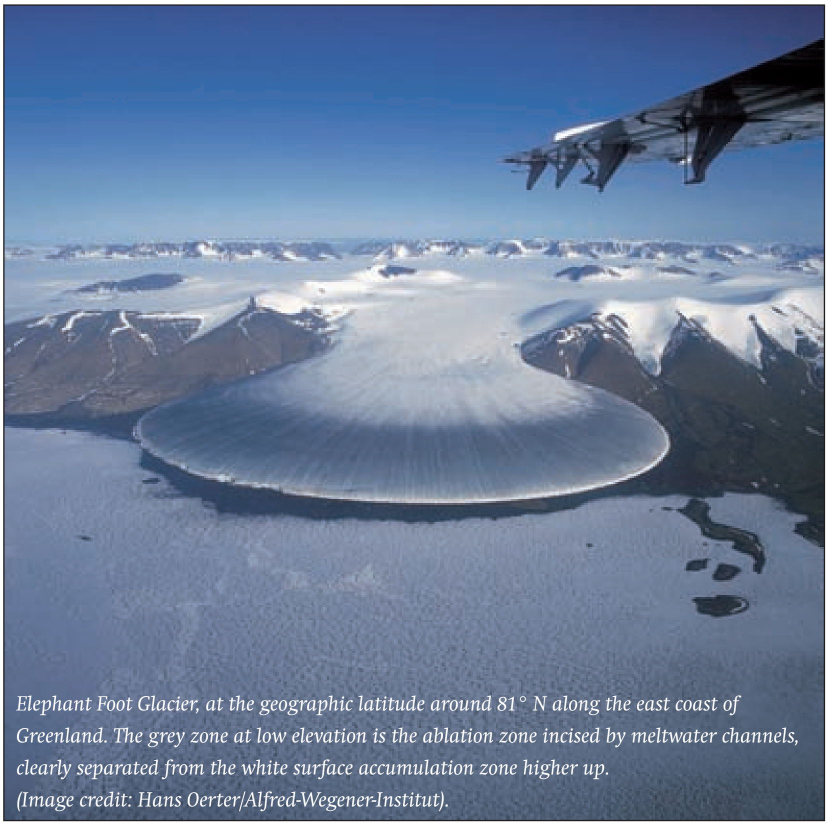
Ice Losses Now Far Surpass Ice Gains

Satellite Evidence of the Melting Gre

For the first time, NASA scientists have analyzed data from direct, detailed satellite measurements to show that ice losses now far surpass ice gains in the shrinking Greenland ice sheet. Will this trend continue? Today, thanks to modern satellite technology, the quickest and easiest way for scientists to survey the polar regions on a daily basis is from the unique vantage point of space. We compiled texts and images from various sources – mostly NASA – to bring you a short overview of this 'hot' subject.

By Joc Triglav



Elephant Foot Glacier, at the geographic latitude around 81° N along the east coast of Greenland. The grey zone at low elevation is the ablation zone incised by meltwater channels, clearly separated from the white surface accumulation zone higher up. (Image credit: Hans Oerter/Alfred-Wegener-Institut).

Fourth International Polar Year

Scientific research into polar regions is particularly relevant now that the Fourth IPY (International Polar Year) is underway (http://www.ipy.org/index.php?/ipy/ about/). March 1, 2007, marked the beginning of the IPY. The IPY actually spans two full years – from March 2007 through March 2009 – and includes more than 200 scientific research projects involving more than 10,000 scientists from 63 nations. The goal of the IPY is to increase international cooperation in polar exploration while advancing scientific understanding of these regions. One objective is to observe and measure the ways in which the polar regions affect, and are affected by, the global climate system. Naturally Greenland's ice sheet, as the largest remaining relic of the last ice age in the Northern Hemisphere, is the focus.

100 Billion Tons

Greenland, the world's largest island, contains the second-largest ice sheet on Earth, with a surface extent of approximately 1.75 million square kilometers and an average thickness of 2.3 kilometers. The ice sheet is so massive that it holds about seven percent of all the freshwater on Earth, enough water to elevate global sea levels by five meters if it melted completely. Scientists estimate it would take several centuries of global warming to melt all the ice on Greenland. Although they are not forecasting a sudden disastrous loss of Greenland's ice, they do observe considerable melting around the fringes of the sheet. This melting is only partly offset by the observed increase in the thickness of the ice sheet in the island's interior highland. A 2006 NASA study revealed that Greenland's ice mass decreased about 101 billion tons per year from 2003 to 2005. Using a novel technique that reveals regional changes in the weight of the massive ice sheet across the entire continent, scientists at NASA's Goddard Space Flight Center in Greenbelt, Maryland, reported recently that Greenland's low coastal regions lost 155 billion tons (170.8 cubic kilometers) of ice per year between 2003 and 2005 from excess melting and icebergs, while the high-elevation interior gained 54 billion tons (58.3 cubic kilometers) annually from excess snowfall. In this new analysis, dramatic ice mass losses were seen to be concentrated in the low-elevation coastal regions, with nearly half the loss coming from southeast Greenland.

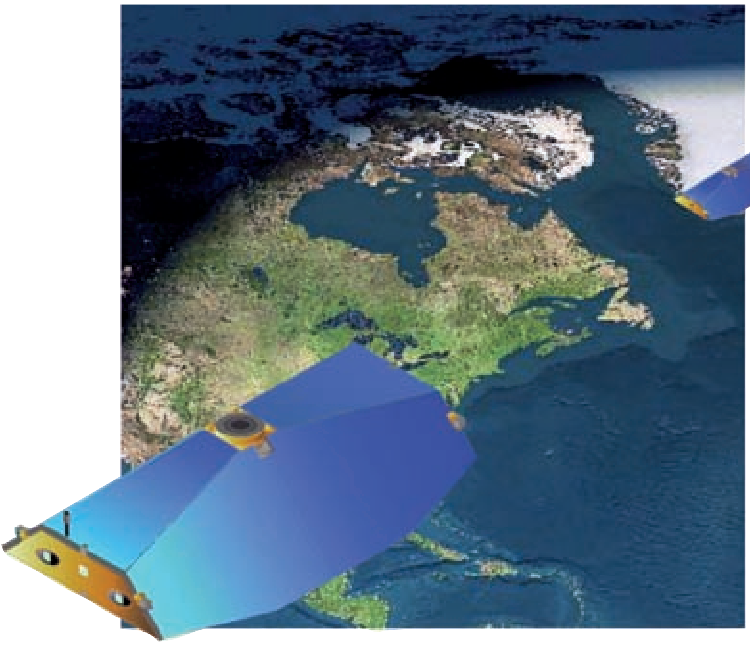
GRACE

Gravity Recovery and Climate Experiment (GRACE) is a joint partnership of NASA and the German Aerospace Center, Deutsches Zentrum für Luft und Raumfahrt. Its satellites, launched in 2002, are managed by the Jet Propulsion Laboratory. The pair of GRACE satellites orbiting in close formation detects changes in the Earth's mass directly below them by measuring changes in the distance between the two satellites as the gravitational force of the mass causes each to speed up or slow down.

The study is based on an innovative use of data from GRACE satellite observations that reveals detailed information about where and when the Greenland ice mass has changed. Other recent studies using GRACE observations have reported continent-wide ice mass declines, but none has shown these changes in enough detail for scientists to investigate the amount different areas of the ice sheet are losing.

To achieve this more detailed view of the ice sheet's behavior, a technique was used that brings GRACE's global view of the Earth down to a more frequent, more local view. The study was based on data collected over Greenland every 10 days. Scientists divided the island into

enland's Ice Cap



The changes in the ice sheet's mass were measured from space by the Gravity Recovery and Climate Experiment (GRACE) mission. GRACE is a pair of satellites orbiting in close formation that can detect changes in the Earth's mass directly below them by measuring changes in the distance between the two spacecraft as the gravitational force of the mass causes each to speed up or slow down. GRACE twin satellites celebrate their fifth anniversary on orbit this year, completing a successful primary mission that's improved our knowledge of Earth's gravity field by more than 100 times and is helping to revolutionize our understanding of Earth's climate. But GRACE's mission is far from being over. (Credit: NASA and GFZ).

separate drainage basins, based on which direction the ice sheet flows from the interior toward the coasts. They further divided the basins into high- and low-elevation terrain. While the two northernmost basins were in balance – snow accumulation equal to melting and iceberg loss – the southeastern basins experienced a rapid decline in ice mass, especially at low elevations. Overall, Greenland lost 20 percent more mass than it received in snowfall each year. These results are consistent with overall trends in ice loss that other types of observations of Greenland have documented, including radar-based estimates of accelerating glacier flow off the ice sheet.

Standard GRACE data products infer local mass changes from a global data set of these satellite measurements. The new study used only data from over the Greenland region. This new detailed view of the Greenland ice sheet goes a long way toward resolving the differences among recent observations and what we know about how the ice sheet behaves. A consistent picture from the different data sets is emerging. The seasonal cycle of increased mass loss during the summer melt season and growth during winter is captured clearly. The new results also capture more precisely where changes are taking place, showing that the loss of ice mass is occurring in the same three drainage systems where other studies have reported increased glacier flow and ice-quakes in outlet glaciers.

Faster Change

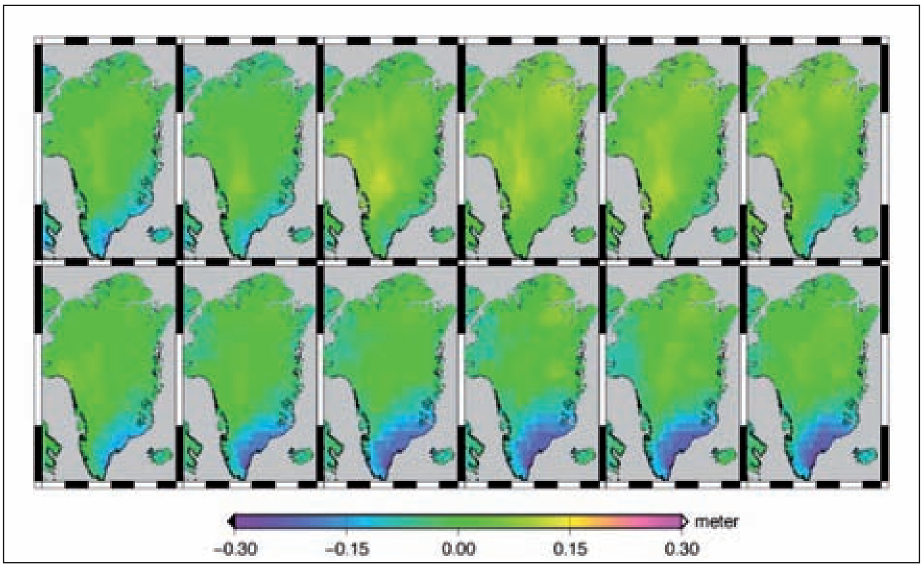
This is a very large change in a very short time. In the 1990s, the ice sheet was growing inland and shrinking significantly at the edges, which is what climate models predicted as a result of global warming. Now the processes of mass loss are clearly beginning to dominate inland growth, and we are only in the early stages of the climate warming predicted for this century.

While GRACE provides a new and independent way to study Earth's ice sheets, it will take a combination of different tools, including laser altimeters, radar, and field studies, to sort out more clearly what is happening. All technologies have different strengths and weaknesses. GRACE shows us the big picture, while other measurements look at a smaller scale. Scientists need to use them all together and they have to pay close attention, as these ice sheets are changing much faster than the scientists were expecting. Observations are the most powerful tool science has to know what is going on, especially when the changes - and what is causing them - are not obvious. Continued monitoring is needed, the authors of the NASA study point out, to determine whether this ice loss is a long-term trend.

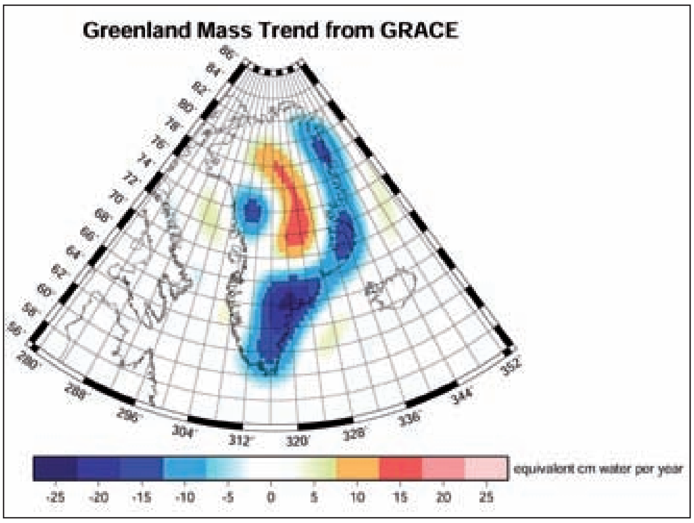
DMSP Special Sensor Microwave/Imager

The DMSP (Defense Meteorological Satellites Program) is a US Department of Defense program run by the Air Force Space and Missile Systems Center. The DMSP designs, builds, launches, and maintains satellites that monitor the meteorological, oceanographic, and solar-terrestrial physics environments. The DMSP-F13 SSM/I (Special Sensor Microwave/Imager) sensor measures microwave radiation emitted naturally from the surface of the Earth. Dry snow and liquid water behave differently in the microwave region of the spectrum, a fact that allows scientists to distinguish melting snow from dry snow in SSM/I data.

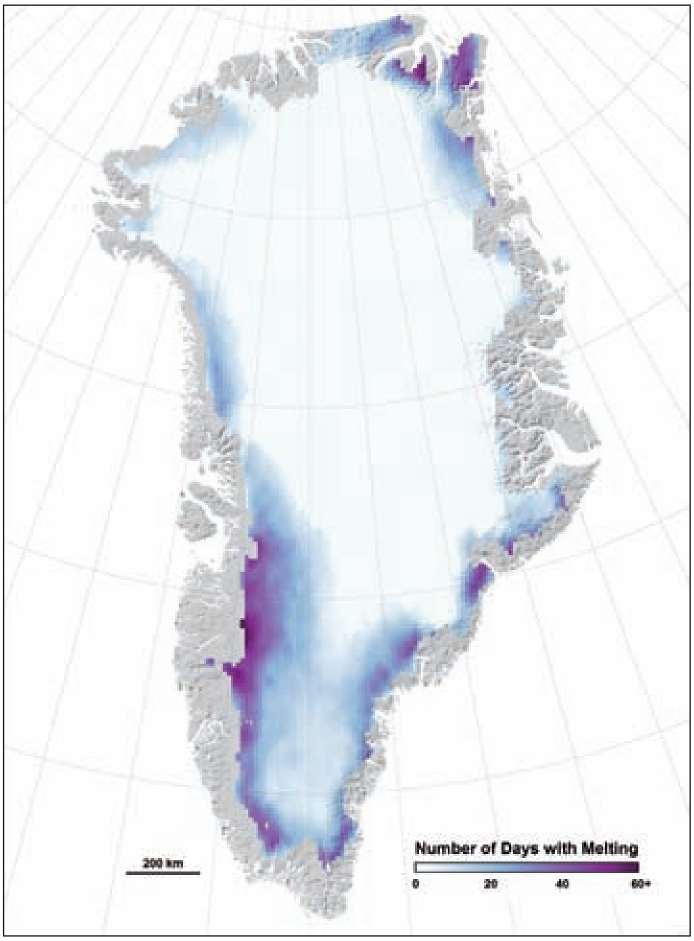
The number of days on which melting occurred



Monthly changes in the mass of Greenland's ice sheet coverage observed by the GRACE satellites during 2005. Purple and dark blue areas indicate areas of largest mass loss. (Credit: NASA/JPL).



The research, based on observations made by NASA's Gravity Recovery and Climate Experiment (GRACE) satellites, has revealed regional changes in the weight of the Greenland ice sheet between 2003 and 2005. This image illustrates where Greenland gained mass during the study period and where it lost mass. While the equivalent of 10 to 15 centimeters of water per year accumulated over the core of the island (red and orange areas), an even larger area experienced losses (blue) of between 5 and 25 centimeters per year. Losses were highest over southeastern Greenland. Low coastal regions (blue) lost three times as much ice per year from excess melting and icebergs than the high-elevation interior (orange/red) gained from excess snowfall. (Credit: Scott Luthcke, NASA Goddard).



The image above was made using data collected by the Defense Meteorological Satellites Program (DMSP-F13) Special Sensor Microwave/Imager (SSM/I) from April 1 to September 1, 2006. It shows the number of days snow was melting during that 5-month period. Darker blue shades show where there were more days of melting (up to 60 days or more), and lighter blue shades show fewer melting days (down to zero). The topographic shading along the coastlines is based on data collected by NASA's ICESat satellite. (Image by Robert Simmon, NASA's Earth Observatory, using data and analysis courtesy Marco Tedesco, University of Maryland-Baltimore County).

One of the largest Greenland's ice tongues belongs to Petermann glacier, which is the most influential outlet of ice in northern Greenland. Petermann's floating tongue is also the fastest flowing, moving between 950 to 1100 meters per year.
The 70-kilometer-long Petermann ice tongue drains a portion of the ice sheet about 71,500 square kilometers in area, pouring 12 cubic kilometers of ice per year into the Arctic Ocean. (Image credit: NASA/JPL).

on the surface of Greenland's ice sheet was determined by comparing SSM/I measurements taken both during the day and at night through most of the spring and summer of 2006. Specifically, by taking the difference of those measurements at frequencies of 19.35 gigahertz and 37 gigahertz each day, the SSM/I data was used to map where meltwater existed – even meltwater below the surface. Unlike existing techniques, a multi-frequency approach allows detection of wet snow at different depths and intensities, providing a tool for improving climatological and hydrological applications. Air temperature values, recorded either by ground-based stations or derived from models, were used for calibrating and validating the technique. Long-term results show that the extent of snowmelt has been increasing at a rate of approximately 40,000 square kilometers per year for the past 14 years.

Further reading

More information on the subject can be accessed at the following websites which were also used as a source for the compilation of texts, images and captions in this article:

- Gravity Measurements Help Melt Ice Mysteries www.nasa.gov/vision/earth/lookingatearth/grace20070320.html
- Greenland Ice Sheet on a Downward Slidewww.nasa.gov/vision/earth/lookingatearth/greenland_slide.html
- Images at NASA Earth Observatory http://earthobservatory.nasa.gov/
- NASA and IPY video http://ipy.nasa.gov/multimedia/ m000000/m000000/m000015/mv/index.html
- A Tour of the Cryosphere video http://learners.gsfc.nasa.gov/mediaviewer/Cryosphere/
- A series of GRACE videos www.csr.utexas.edu/grace/gallery/animations/
- GeoForschungsZentrum Potsdam (GFZ) GRACE website www.gfz-potsdam.de/grace/
- Tedesco, M. (2007). Snowmelt detection over the Greenland ice sheet from SSM/I brightness temperature daily variations, Geophysical Research Letters, 34, L02504, doi:10.1029/2006GL028466.
- National Geophysical Data Center (NGDC)-NOAA Satellite and Information Service-Earth Observation Group (EOG)-Defense Meteorological Satellite Program (DMSP) www.ngdc.noaa.gov/dmsp/

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