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Greenland Ice Mapping Project

by Ian Joughin, Ben Smith, Ian Howat, and Ted Scambos

Ice sheets were once thought to evolve slowly over centuries in response to climate change. Recent results by many authors, however, have shown that glaciers in both Greenland and Antarctica can alter their flow abruptly over periods of months or less. As an extreme example, Whillans Ice Stream, West Antarctica, remains stagnant most of each day, but slips forward by roughly half a meter over two relatively brief (<1 hour) periods each day. In Greenland, numerous glaciers have sped up over the last decade, contributing to a large portion of the overall mass loss from the ice sheet. The pattern of change is complicated. In some cases where two glaciers drain through the same fjord, presumably undergoing similar environmental forcing, one glacier may speed up remarkedly, while its neighboring glacier may remain unchanged, or even slow down. Across the overall population of outlet glaciers in Greenland, there is a trend toward speed up and increased discharge, but with a remarkable degree of variability. The fact that processes controlling such variability are poorly understood, forced the fourth Intergovernmental Panel on Climate Change (IPCC) to conclude that they could place no reasonable upper bound on the contribution to sea level from unstable ice dynamics in Greenland and Antarctica.

Ice-flow velocity remains one of the key observables for ice sheets and changes in speed are the direct response to shifts in the balance of driving- and resistive-stresses that control glacier flow. Velocity data are critical to understanding ice-sheet and outlet-glacier response to environmental forcing brought on by a changing climate. As a result, several years ago the Greenland Ice Mapping Project (GIMP) was started to begin building a consistent set of Earth Science Data Records (ESDR) under the National Aeronautics and Space Administration's (NASA) Making Earth System data records for Use in Research Environments (MEaSUREs) program. In addition to ice velocity, a number of georeferenced synthetic aperture radar (SAR) and optical-image data products are being produced for studying changes in glacier geometry. The large SAR mosaics will be archived and distributed through the Alaska Satellite Facility (ASF), while the other products are being archived and distributed through the National Snow and Ice Data Center (NSIDC). These datasets cover the 2000 to 2012 period and currently, it is being investigated to extend the record through 2017, via the next MEaSUREs solicitation.

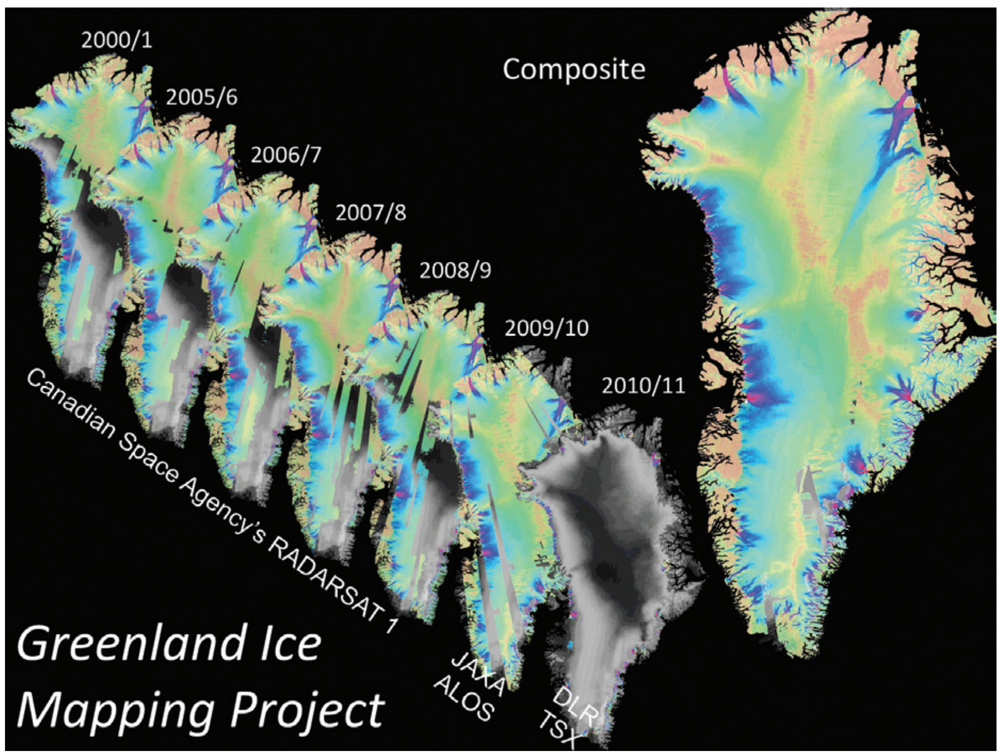

Figure 1: Time series of winter flow speed for Greenland, derived using the international constellation of SAR satellites.

One of the major products being generated is annual, ice-sheet-wide velocity maps for each winter when ice-flow velocities are relatively free from seasonal variation (e.g., meltwater lubrication in the summer). Figure 1 shows this time series, along with a composite map, representing the average of the results from

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every year. Because the time series spans a decade, multiple instruments were relied upon. The primary instrument utilized through winter 2008/9 was mainly on RADARSAT-1, C-band data acquired by the Canadian Space Agency. Once access to those data was lost, Advanced Land Observing Satellite (ALOS) L-band data from the Japan Aerospace Exploration Agency (JAXA) were used for the winter of 2009/10, just before that instrument reached its end of life. The raw SAR data that went into the production of these products were archived and distributed through ASF.

For the last two winters (11/12, not shown in Figure 1), X-band TerraSAR-X data was used directly, provided by the German Aero-Space Research Establishment (DLR). These data are of much higher resolution (0.9-m range, single-look-range resolution) than the earlier instruments, but coverage is much more limited. The broad coverage that was achieved with the other instruments could not be maintained (see Figure 1). Nonetheless, these data are tremendously valuable due to precise targeting of most of the major outlets, which represent the areas undergoing the most change. In addition, since 2009, TerraSAR-X was used to map a subset of the coastal outlets (20 supersites each with several glaciers) at much better temporal and spatial resolution (5 times/year or more) than was possible with earlier instruments. Figure 2 shows an example of such a supersite, revealing the rapidly evolving change in flow on the Uppernavik Istrom, to the north of Disko Bay, Greenland.

The first 3 years of velocity products have already been released through the NSIDC and the early TerraSAR-X supersite products have been delivered and will soon be online. The other maps are near the final stage of completion and will be undergoing final screening in preparation for delivery this summer through fall. A set of optically-derived coastal velocities for major outlets is soon to be released. The high-resolution SAR-image mosaics (i.e., grayscale mosaics shown under velocities in Figure 1) are awaiting final terrain-correction processing, using an ASTER-derived Digital-Elevation-Model (DEM) produced under this project, which will also be released through ASF in the coming months, along with a time series of full-Greenland Moderate Resolution Imaging Spectroradiometer (MODIS) mosaics at NSIDC. Collectively, these data show a striking degree of both temporal-and-spatial variability, characterizing change; the reasons for which are still poorly understood. As work begins with these and other data (e.g., IceBridge), glaciologists should develop a much-improved understanding of the processes governing fast glacial flow, leading eventually to improved projections of sea-level rise.

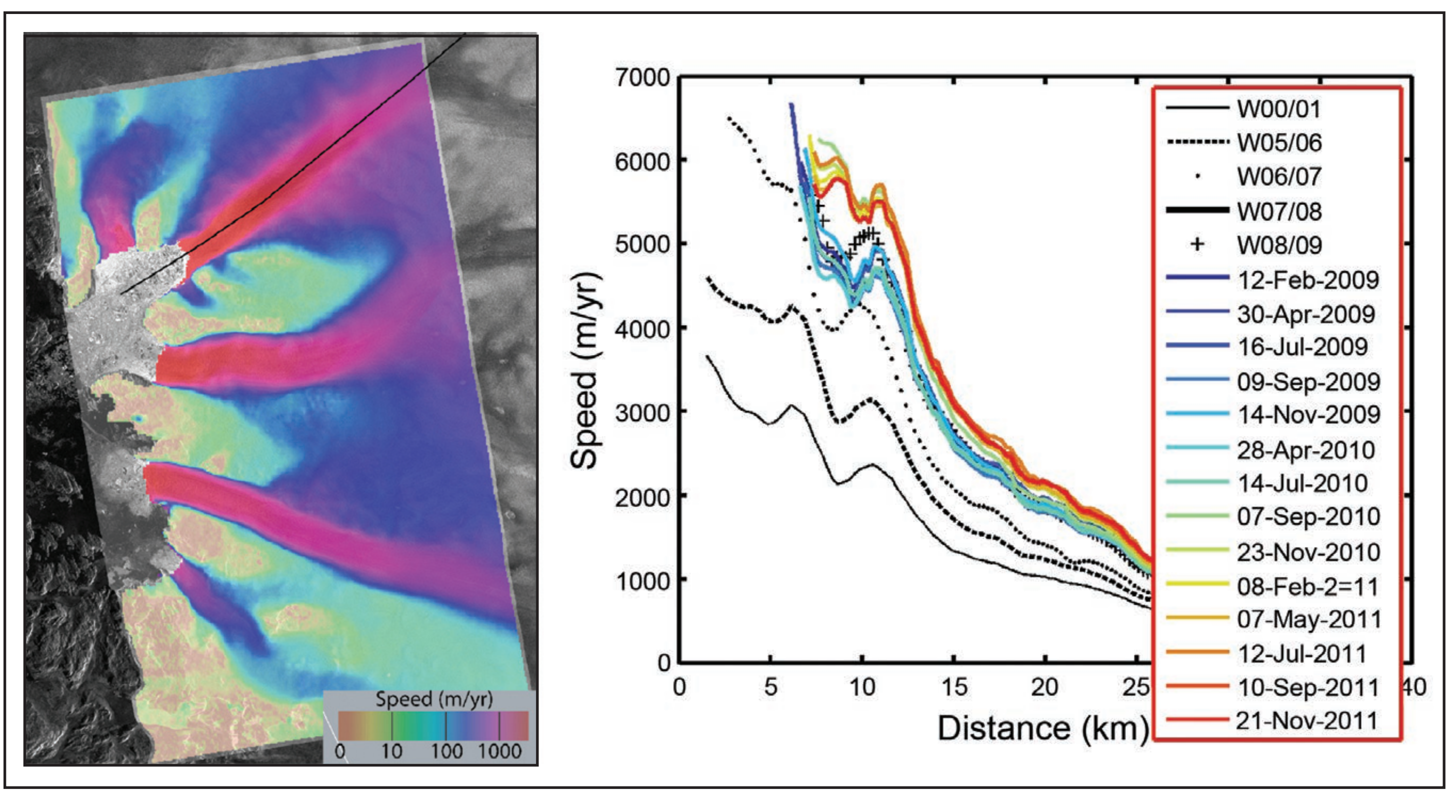

Figure 2: Velocity of Uppernavik Istrom, which is one of the 20 coastal supersites ASF frequently monitors.

Dr. Ian Joughin Receives 2012 Louis Agassiz Medal

by Angela R. Allen, Alaska Satellite Facility

ASF would like to recognize Dr. Ian Joughin (Figure 3), 2012 winner of the Louis Agassiz medal awarded by the European Geosciences Union (EGU). The Agassiz medal was established in 2005 by EGU's Division on Cryospheric Sciences to acknowledge the pioneering work of Louis Agassiz on ice ages and glaciers. It is reserved for outstanding individual scientific contributions to the study of the cryosphere on Earth or elsewhere in the solar system. Dr. Joughin was honored for his landmark research on the dynamics and mass balance of polar ice sheets using Differential Interferometry Synthetic Aperture Radar (DInSAR), empirical data, and modeling.

Dr. Joughin is a glaciologist at the University of Washington's Polar Science Center, with research focusing on Greenlandic and Antarctic ice sheet (e.g., Figure 4) contributions to current-and-future rates of sea-level change. Using DInSAR, Joughin has advanced polar glaciology from a field with sparse data owing to prohibitive logistics to one where satellite observations allow the study of continental-scale ice sheets. Specifically, his research involves satellite data analysis of ice-stream velocity and outlet glaciers augmented by ground- and airborne-based field work to obtain additional ice-flow measurements. By coupling these data with ice-sheet models, his work elucidates physical mechanisms controlling ice flow. His results

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Figure 3: Dr. Ian Joughin. Photo by Chris Linder, © Woods Hole Oceanographic Institution

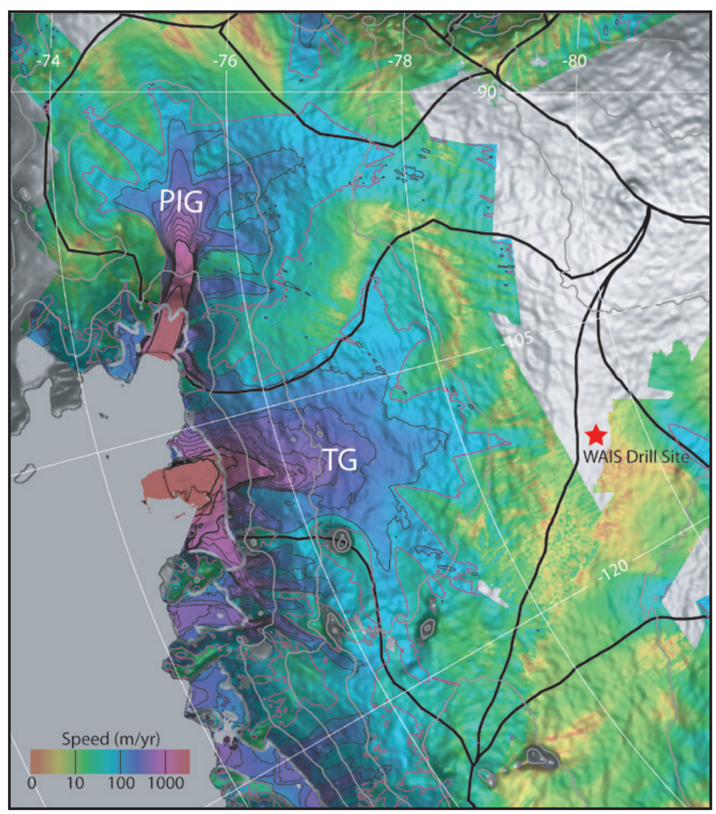

Figure 4: Total Antarctic Ice-Sheet Discharge: an International Polar Year Benchmark Dataset. Flow speed (color) over the artificially-shaded surface (grayscale) of a DEM produced from a combination of laser and radar altimetry (see text) for Pine Island (PIG) and Thwaites (TG) glaciers. Speed is also shown with a 50 m a-1 contour (purple), 100 m a-1 contours up to 900 m a-1 (thin black), and 1,000 m a-1 contours (thick black). Elevations are shown with 500-m contours (gray). Heavy black lines show the approximate locations of drainage divides.

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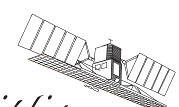
indicate that glacier and ice-stream dynamics occur on far shorter time scales than previously documented.

Dr. Joughin's current research has been lauded for both its scientific and societal relevance; most prominently, Dr. Joughin's effort to better understand the potential contribution of changes in the Greenland and Antarctic ice sheets to sea-level rise. His findings have filled key gaps in scientific knowledge highlighted in the 2007 Intergovernmental Panel on Climate Change (IPCC) report. The IPCC conclusion that it could not accurately predict an upper bound on the rate of sea-level rise due to glaciers and ice sheets has been addressed through Dr. Joughin's elucidation of the processes driving these changes. To that end, Dr. Joughin continues to refine his work, travelling to Greenland and Antarctica to study lake-drainage events and snowfall accumulation, and developing models to help predict how climate change will influence ice-sheet contributions to sea level. He is also widely considered as a generous collaborator and scholar who is excited to share his knowledge and insights. It is with great pleasure that ASF highlights Dr. Joughin's receipt of the 2012 Louis Agassiz medal.



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