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A Comprehensive Ice Velocity Map of Greenland from RADARSAT-1 and Other Satellite Data

by Ian Joughin and Ted Scambos

The rate at which Greenland discharges ice to the ocean has accelerated dramatically over the last several years. These changes are significant and likely indicate a response to climate change (e.g., enhanced basal lubrication from surface melt draining to the bed or dynamic response due to the loss of resistance from grounded and floating ice as calving fronts retreat). With the near-doubling in speed of many of Greenland's outlet glaciers, the magnitude of the change is startling and has overturned the conventional wisdom that ice sheets respond sluggishly, with response times measured in centuries to millennia.

Field-based investigations can observe only a few locations on the ice sheet each year. Therefore, satellite remote sensing is essential both for detecting change and for understanding the physical processes that govern the ice sheet's response to climate change. Through its Program for Arctic Regional Climate Assessment, NASA in collaboration with NSF, has been investigating the ice sheet's mass balance for more than 15 years. As part of this effort, in late 2000, CSA and NASA conducted the Arctic Ice Mapping Mission at the same time as the Modified Antarctic Mapping Mission to collect multiple fine-beam mode acquisitions suitable for interferometry/speckle tracking over nearly the entire Greenland ice sheet. As rapid change began to unfold, the space agencies acquired four, back-to-back repeat mappings of the ice sheet during the winters of 2005-2006 and 2006-2007.

In March 2006, NASA funded a 2-year investigation at the Universities of Washington (I. Joughin, B. Smith, and I. Howat) and Colorado (T. Scambos and I. Howat) to process the 2000 and 2006 datasets. The main goal of this project is to produce comprehensive maps of velocity for the Greenland Ice Sheet. The project also is uses ASTER data (15 m) from NASA's Terra platform to determine summer velocities for many of Greenland's outlet glaciers. In addition, the project is producing high-resolution (20 and 100 m) SAR image mosaics of the ice sheet.

During the project's first year, the available data were processed and preliminary velocity maps were produced for both 2000 and 2006 (see Figure 1). Fine-beam mode data yielded velocity estimates for roughly two thirds of the ice sheet's nearly featureless interior. Coverage is even better

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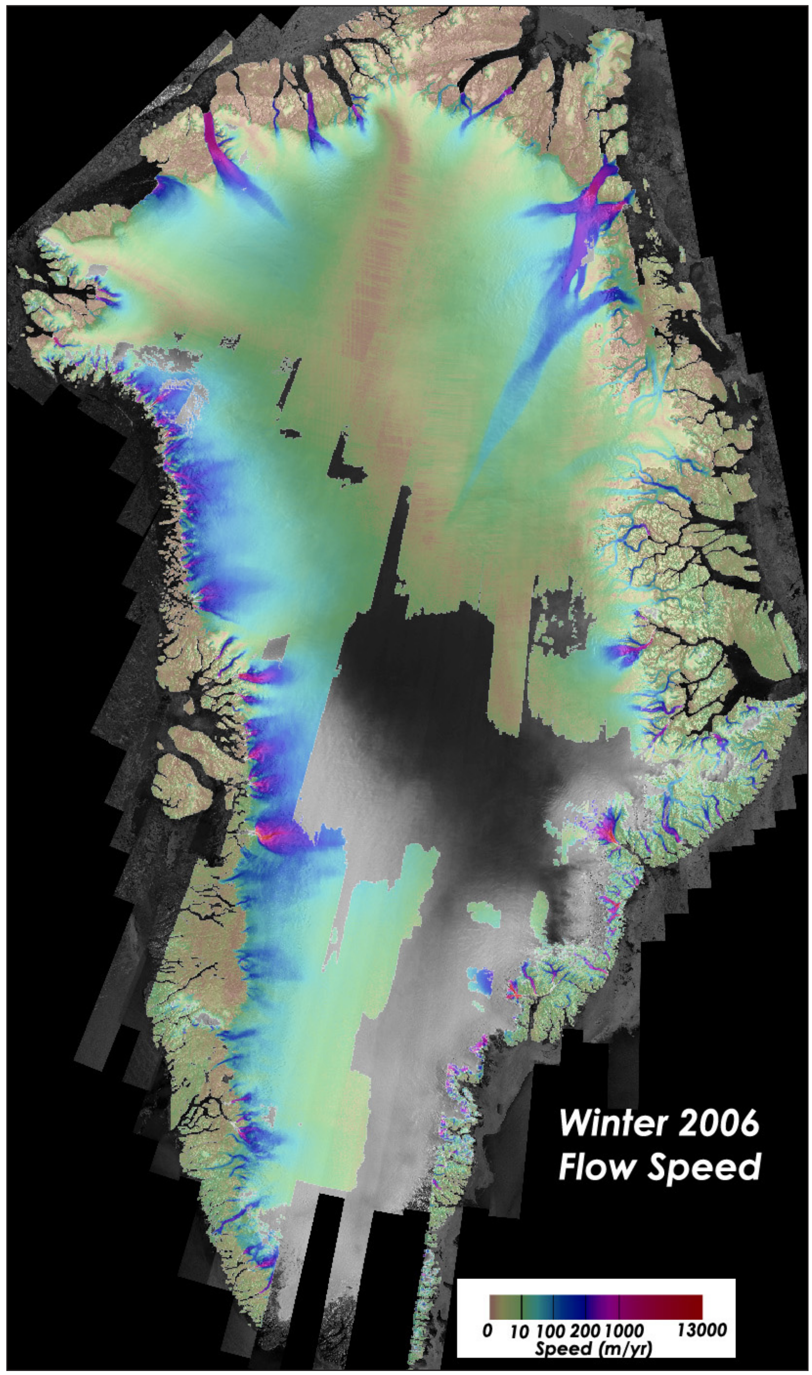

Figure 1: Velocity for winter 2006 derived from speckle tracking and Interferometric SAR applied to fine-beam RADARSAT-1 data overlaid over a SAR image mosaic for the same period. For the color version see http://www.asf.alaska.edu/publications/newsletter/ASFNNV.4No.3.pdf

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on outlet glaciers, where the presence of crevasses and other features improves the performance of the algorithms used for feature tracking. As a result, velocities are available on nearly all outlet glaciers where fine-beam mode coverage is available. Some large gaps in coverage occur along the southern portions of Greenland where ScanSAR commercial acquisitions have higher priority for acquisition. ASTER processing has largely focused on the southeast portion of the ice sheet, and time series of summer velocity now exist for many of the rapidly changing glaciers in this region.

Processing during the second year will focus on additional tracking in the fast moving regions, where the large displacements (>3 km per year) fall outside the window of the speckle-tracking algorithm. In addition, the interferometric phase data will be included in the velocity estimates to improve accuracy in the interior of the ice sheet.

The University of Colorado effort at the National Snow and Ice Data Center has focused on developing a Minnesota Map-Server based system for web-distribution of the data. Users will be able to browse the image and velocity data sets and select data for their regions of interest. The data can then be retrieved as GeoTiff products, which can be read by a number of packages (e.g., IDL-ENVI and ArcGIS). The data will also be available through direct ftp access.

The velocity and image mosaic products will be ready for release early in the summer of 2008. The high-resolution (20 m) image products will be subject to the same restrictions as those that apply to the high-resolution Antarctic Mapping Mission products, which require user approval from NASA.

ASF Provides Open Source Software for Increasing the Usability of SAR Data

by Patrick Denny, User Tool Development Lead, Alaska Satellite Facility

Synthetic Aperture Radar (SAR) technology has been around for quite some time now, but only in recent years has it become a common data type. The long path to popularity can most likely be attributed to a couple characteristics associated with SAR data. First, SAR data are typically provided in one of several CEOS formats. Since most image viewing software will not load such a format, many users are stopped here. Second, since SAR data are acquired from a side-looking geometry instead of the typical nadir geometry that most optical data are acquired from, it does not easily mesh with other data layers.

ASF has developed an open source tool, *Convert*, under a derivative of the BSD license, to help make SAR data more accessible to a wider variety of researchers. This software can ingest CEOS format data, process it to an orthorectified, map-projected state, and export it to several formats easily readable by imaging and GIS software.

The *Convert* package comes with a graphical user interface (GUI) and a set of command line tools. Both offer a means to the same end—SAR data to a more usable format for the user. The GUI provides an easy-to-use interface that can be learned in one sitting. The command line tools are available for more advanced users and provide the ability to add *Convert's* functionalities to a script.

Since it is common for scientists to want to process large quantities of data with similar parameters simultaneously, this tool was created with a batch processing concept. Users are able to select as many data sets as they like and load them into a queue that will be processed sequentially according to parameters setup by them in the *Convert* interface.

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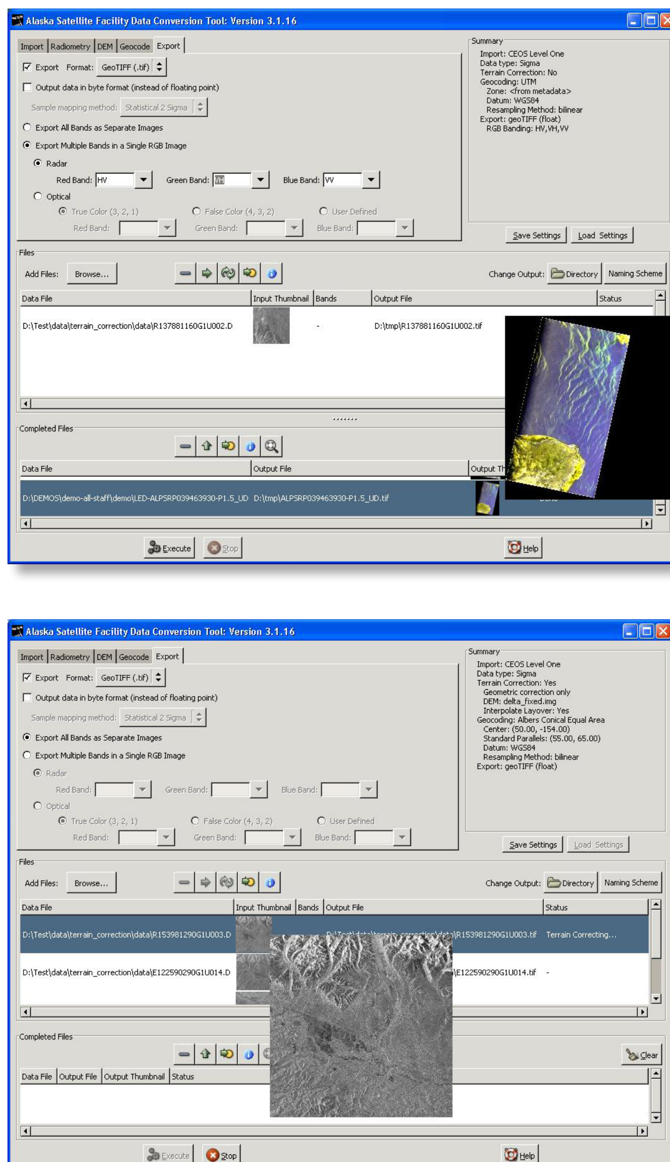


The GUI of the *Convert* tool provides users with a simple way to set-up processing of data and offers useful feedback while the processing takes place.

Convert's primary functions can be divided into four categories 1) data ingest, 2) digital terrain correction, 3) geocoding, and 4) export of finished products

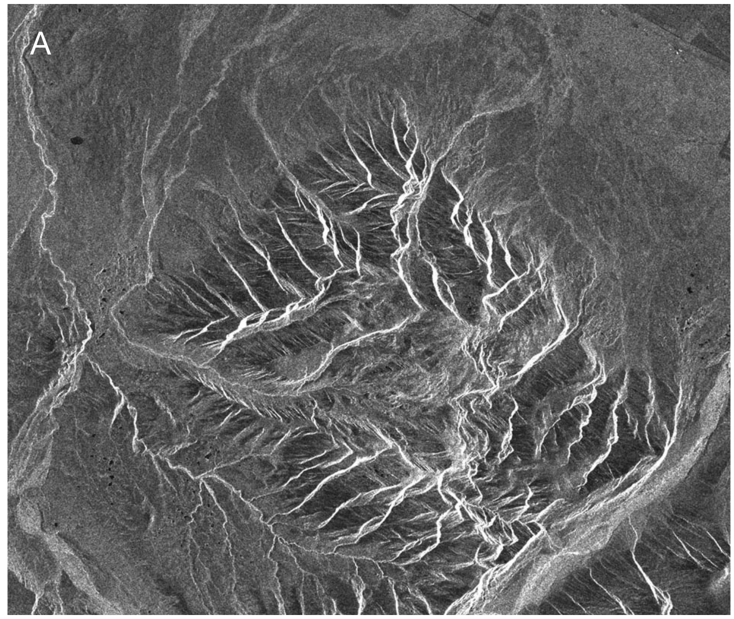
1. Data ingest: As CEOS data sets are selected and loaded into the *Convert* processing queue, a thumbnail of each scene is generated and the metadata is made viewable. Calibration parameters can be applied upon import in the sigma-, beta-, or gamma-naught projections in order to correct for the radar's antenna pattern. Users may choose to have the calibrated image in the power or decibel scale.

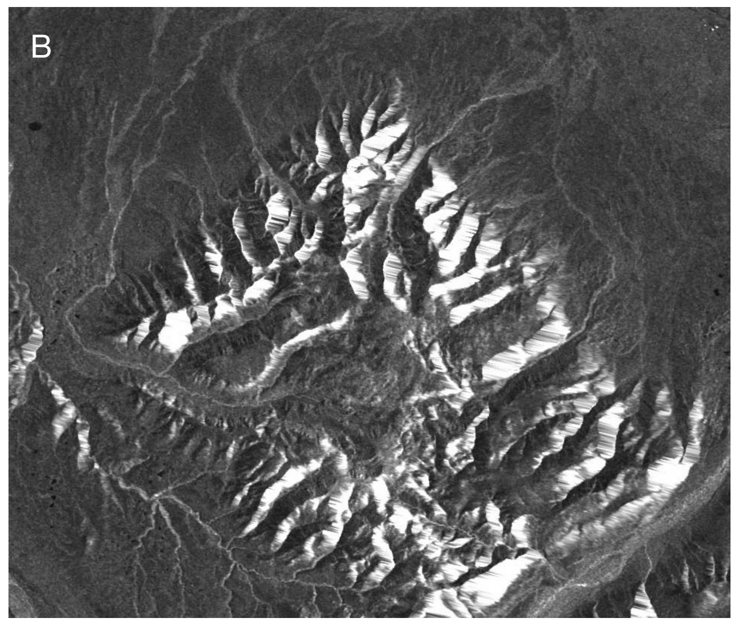
2. Digital terrain: The second facet of *Convert* is interaction with a user-provided digital elevation model (DEM). Due to the side-looking geometry of SAR, it is typically necessary to "terrain correct" or orthorectify the data in areas of high relief. This step removes distortions such as layover and shadow which characterize SAR data and is necessary when preparing SAR data for use with other data layers. The *Convert* software does an exceptional job at it. In addition to geometric terrain correction, radiometric terrain correction is available. This can be used to adjust the radiometric backscatter values so that the local topography is in effect removed.

In the case that the topography is somewhat flat, terrain correction may not be necessary; instead the accompanying DEM can be used to help refine the geolocation of the SAR data simply by matching the DEM and SAR and adjusting the metadata appropriately. This technique can correct for offsets such as those seen in JERS datasets, in which a clock error resulted in azimuthal offsets of up to 25 km.

3. Geocoding: Geocoding is transforming the SAR data into a map-projected state from its original slant-range geometry. There are three datums to choose from and five available map projections, each with several predefined parameter sets. The user may also define their own set of parameters for a map projection in order to attain minimal distortion. Splines are used to interpolate between a grid of precise projection points which results in fast processing and accurate results.

4. Export function: The final stage in the *Convert* processing stream is the export of data to a common imagery format. To preserve the full integrity of the data and geospatial metadata, the GeoTIFF format is available. Other available image types are generally used for display on posters or in image editing software. For ALOS PALSAR polarized data, the output image can be created in RGB color or each band can be exported as an individual grayscale image.





For scenes with notable topography *Convert* offers terrain correction functionality which corrects for SAR characteristics such as layover and shadow so that the SAR data will line up nicely with other orthorectified data sets. A) SAR image which has only been geocoded. B) Same SAR image A with terrain correction applied.

Once processing is complete, the item is moved from the processing queue to a list of completed processes, accompanied by an expandable thumbnail of the completed image. Users now have several options; the data can be moved back to the input queue for reprocessing, the ASF format metadata can be viewed, the processing log can be viewed, or if the output happens to be JPEG, there is a light weight image viewer built in for a quick inspection of the output.

The primary benefit of this software is the ability for remote-sensing and GIS professionals to easily use SAR data. The intuitive interface of this free, open-source software will enable users to convert ASF Level 1 SAR scenes into compatible GIS layers. Overlay with other data sets such as Landsat, MODIS, or commercial imagery is made feasible by the high geometric accuracy of *Convert's* GeoTIFF product.

New Pricing Structure and Order Interface for Level 1 Products

The ASF DAAC is pleased to announce a new, simplified pricing structure. Level 1 products now cost the same number of data credits regardless of processing type and level. The products may be ordered through the ASF DAAC URSA interface at https://ursa.asf.alaska.edu/cgi-bin/login/ or the EOS Data Gateway at http://edg.asf.alaska.edu:8000/%7Eimswww/pub/imswelcome/. We encourage you to try the URSA interface as an alternative to the EDG for ordering Level 1 processed SAR images from the ASF DAAC. Currently, the URSA interface can be used to order Level 1 products, except complex (SLC) frames and geocoded ScanSAR frames. Please continue to use the EDG to order these two products. In addition, GeoTIFF products are available only through the URSA interface. Your user id remains the same on both systems. The URSA password is the same as your V0 data access key used for ordering data through the EDG, unless otherwise indicated when we contacted you with your user id. If you have questions or problems, please contact ASF User Services at uso@asf.alaska.edu or (907) 474-6166.

- **2007 Arctic Science Conference**, September 24 to 26, 2007, Anchorage, Alaska. http://www.arcticaaas.org/meetings/2007/index.html,
- **American Geophysical Union fall meeting**, December 10 to 14, 2007, San Francisco, California. http://www.agu.org/meetings/fm07/. Abstracts due September 6, submission tool available July 20.
- **ASPRS**, April 28 to May 2, 2008, Portland, Oregon. http://www.asprs. org/portland08. Abstracts are due October 1, 2007.
- **EUSAR 2008**, June 2 to 5, 2008, Friedrichshafen, Germany. http://www.eusar.de/Conferences_en/Eusar+2008/About+EUSAR+2008.htm.
- **IGARSS**, July 6 to 11, 2008, Boston, Massachusetts. http://www.igarss08.org/. Abstracts are due January 7, 2008, submission tool available November 16, 2007.

Submissions and Subscriptions

This newsletter, published by ASF, was created to provide detailed information about special projects and noteworthy developments, as well as science articles highlighting the use of ASF data.

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Submissions to the *ASF News & Notes,* and suggestions about content are always welcome. If you are interested in contributing materials, please call or send an email to the editor:

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