ALASKA SATELLITE FACILITY
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Mapping Glacier Flow Speeds Throughout Alaska With ALOS PALSAR

by Evan Burgess, UAF Geophysical Institute and the USGS Alaska Science Center

Improving projections of future sea-level rise will require a much better understanding of how climate change affects glacier flow speeds. Although close monitoring of flow speeds of ocean-calving glaciers originating from ice sheets has led to better understanding of ocean-ice sheet interactions, flow velocities of mountain glaciers have not been as widely monitored.

Data for Mass-Loss Projections

Alaska is losing about 50 cubic km of ice per year, contributing to 20 percent of global new-water sea-level rise—but much of the new-water sea-level rise expected over the next 100 years may come from changes in ice flow and calving from glaciers originating in mountains. These changes have not been incorporated into mass-loss projections.

In collaboration with the Alaska Satellite Facility (ASF) and the University of Alaska Fairbanks (UAF), the University of Utah has generated the first near-comprehensive map of glacier flow speeds throughout Alaska, using synthetic-aperture-radar (SAR) data. The dataset is hosted on the ASF website (Figure 1). The team derived glacier-surface velocities using Advanced Land Observing Satellite (ALOS) Phased Array type L-band SAR (PALSAR), fine-beam data (HH polarization, 46-day orbit interval) provided by ASF.

Repeat image pairs, acquired within one to two orbit intervals, were used to measure the ground displacement of features on glacier surfaces, such as crevasses or SAR speckle. Ground displacement was measured using image cross correlation, which provides estimates of flow speed both in azimuth and range directions, rather than using interferometry. Raw [L0 (level zero)] data from ASF were processed to single-look complex (SLC) images using GAMMA software. Using intensity cross-correlation optimization offset tracking, ground offsets were calculated from slant-range SLCs. After offsets were calculated, they were geocoded, topographically corrected, and corrected for image coregistration.

This final data product provides highly accurate estimates of flow speeds; uncertainties are generally below 2 cm/day and overall biases are less than 3 mm/day. While the data product available is provided at 90-m gridded resolution, the method's true spatial resolution is about three times larger due to the size of correlation windows. Nonetheless, these data are still capable of resolving velocities on glaciers of all sizes and speeds in Alaska.

A total of 624 frames were processed into 344 image pairs that encompass the Wrangell-St. Elias Mountains, the Chugach, Kenai Peninsula, Alaska Range and Tordrillo/Neacola Ranges, the Fairweather Range, Glacier Bay, and the Coast Mountains in Southeast Alaska. Then, custom software was used to identify which frames best represent each glacier and to mosaic the frames together for a seamless dataset. Temporal changes in flow velocity require caution when mosaicking; continuity within each glacier basin was prioritized above optimal spatial coverage. In total, 60 frames, all acquired in the winters between 2006 and 2011, were chosen to produce the final maps.

The dataset represents the first regional map of mountain-glacier flow speeds in Alaska. Surface velocities are available for 47,880 km^2 of glacier ice, which includes almost all major glaciers in Alaska. An example from the

Figure 1: The Burgess, et al., Glacier Flow Speed dataset is available in GeoTIFF and kml formats at https://www.asf.alaska.edu/other-data/glacier-speed/.

Wrangell-St. Elias Mountains is shown in Figure 2. We emphasize caution when using this map to look at trends in velocity through time, as inter-annual changes in velocity were found to be common throughout the image pairs processed.

Flow Dynamics

The spatial structure of flow velocity conforms to our understanding of glacier flow velocity and climate. Flow speeds generally increase from continental climes toward the maritime coast. Over half of the downstream ice flux from more than 20,000 glaciers throughout Alaska comes from fewer than 20 coastal glaciers.

The flow dynamics on these rapid-flow systems will operate differently than other glaciers, because they are capable of maintaining higher flow speeds without losing mass. Understanding the dynamics of these glaciers is critical for future efforts to estimate flow-speed-related mass loss in Alaska. This map also helps quantify the volume of ice lost to iceberg calving, as the ice flux through each glacier terminus can be measured with these data. Results showed that approximately 17 km^3 of ice are lost annually in Alaska due to calving alone. This number is equivalent to about 40 percent of the net mass lost in Alaska each year. These data are revolutionary for advancing our understanding of the mechanisms responsible for the rapid glacier mass loss occurring in Alaska.

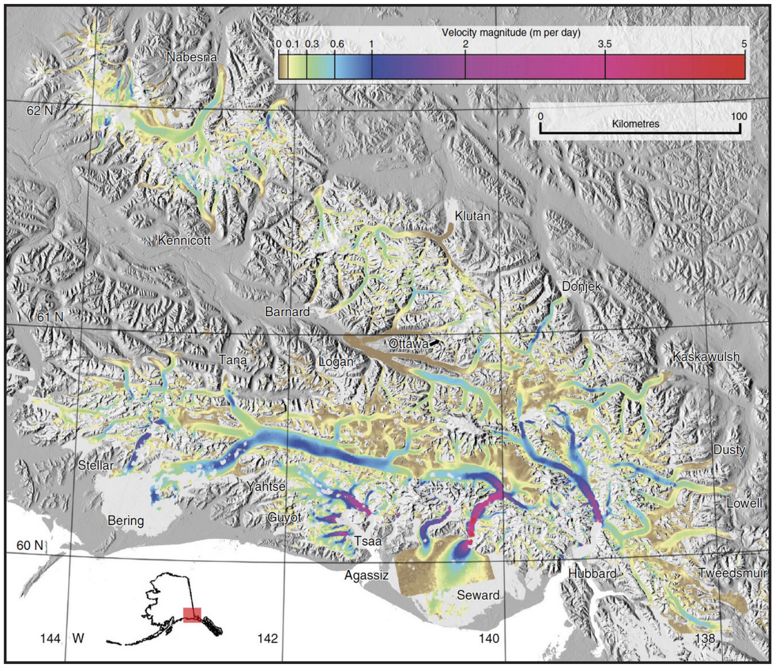


Figure 2: Glacier flow speeds in the Wrangell-St. Elias Mountains are represented in this portion of a colorized Google Earth™ map of glacier speeds throughout Alaska. Credit: Evan Burgess, 2013.

More information on this dataset[1] can be found through the metadata available with the dataset hosted at ASF and through the *Nature Communications*[2] paper cited below.

[1] Burgess, et al., "Glacier Flow Speed Dataset," hosted by ASF; http://www.asf.alaska.edu/other-data/glacier-speed, 2014

[2] Burgess, E. W., R. R. Forster, and C. F. Larsen (2013), "Flow velocities of Alaska glaciers," Nat. Commun., 4, DOI:10.1038/ncomms3146.

Radar Reveals Thinning Arctic Lake Ice

by Lisa W. Drew, ASF

Over the last 20 years, Arctic lakes have been freezing later in the year and thawing earlier – and fewer of them freeze solidly to lake bottoms. Those are among the findings from a recent study of shallow lakes on Alaska's North Slope led by University of Waterloo researcher Cristina Surdu. The team examined SAR images from 1991 to 2011 and also used climate data to model ice thickness and duration from 1950 to 2011.

Changes in ice cover on Arctic lakes, which cover up to 40 percent of the North Slope, are strong indicators of climate change. Dwindling ice and an increasing proportion of water under the ice may affect a complex web of physical, chemical, and ecological relationships, such as energy exchanges between the lakes and the atmosphere, shifts in lake-algal productivity, thawing of permafrost under lake beds, and methane releases to the atmosphere.

Dramatic Changes

"The changes in ice and the shortened winter affect northern communities that depend on ice roads to transport goods," said Surdu. "The dramatic changes in lake ice may also contribute to further warming of the entire region because open water on lakes contribute to warmer air temperatures, albeit to a lesser extent than open sea water." The researchers analyzed a time series of 79 SAR images of over 400 lakes taken by the European Remote Sensing Satellite-1 (ERS-1) and ERS-2, available through ASF. They then used MapReady software available from ASF to radiometrically calibrate and geocode the SAR images, each of which was segmented to derive ice-cover fractions for floating and grounded (bedfast) ice.

In 1992, 62 percent of the lakes in the region were grounded; by 2011, that percentage had dropped to 26 percent (Figure 3). Overall, there was a 22 percent reduction in grounded ice. "When we saw the actual numbers, we were shocked at how dramatic the change has been," said Surdu.

Detecting Water Under Lake Ice

The researchers were able to discern the difference between a fully frozen and floating lake ice because radar signals are absorbed into the sediment under the lake when it is frozen to the bottom. When there is water under the ice, the beam bounces back strongly toward the radar system (Figure 4). Lakes that are completely frozen show up on satellite images as very dark; those with water under the ice are bright. Using the Canadian Lake Ice Model (CLIMo), the researchers found that in 2011, Arctic lake ice was up to 38 cm thinner than in 1950, and the winter ice season was about 24 days shorter. The study was published in *The Cryosphere*[3] in January 2014.

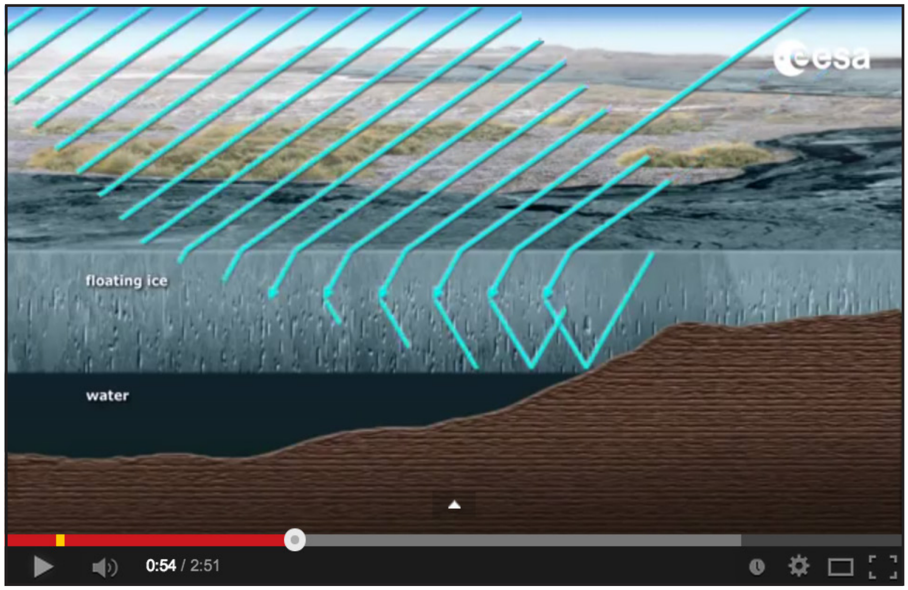


Figure 4: The Surdu, et al., research findings and the use of SAR to detect lake ice are explained in a video at https://www.youtube.com/watch?v=pyOLYYaT9Tw. Credit: ESA.

[3] C. M. Surdu, et al., "Response of ice cover on shallow lakes of the North Slope of Alaska to contemporary climate conditions (1950–2011): radar remote-sensing and numerical modeling data analysis." The Cryosphere, 2014; 8 (1): 167 DOI: 10.5194/tc-8-167-2014.

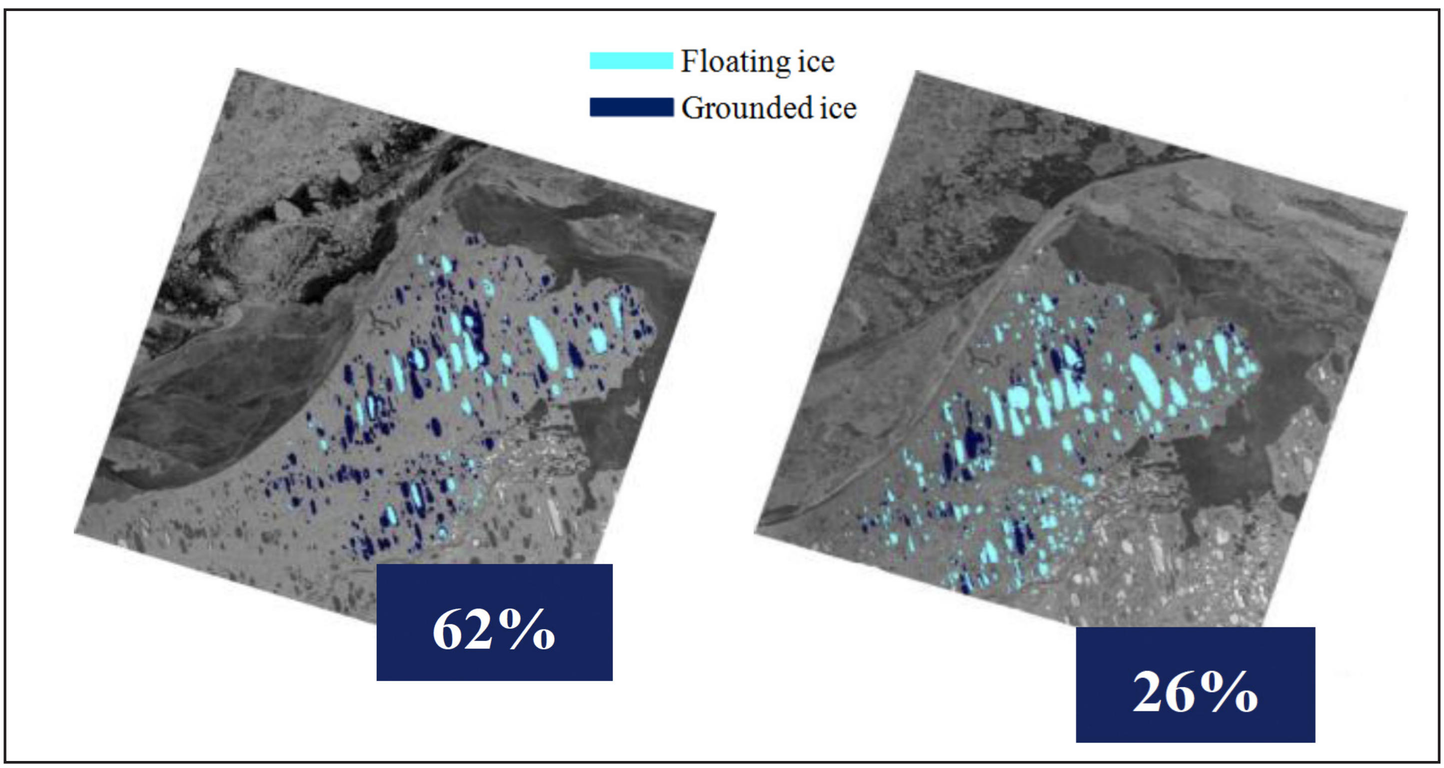
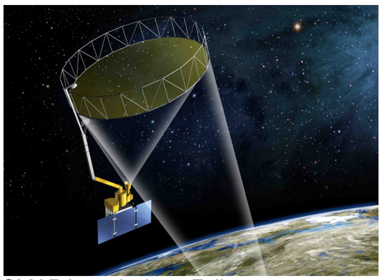


Figure 3: Image segmentation of SAR images, taken on 20 April 1992 (left) and 16 April 2011 (right), reveals dramatic decrease in grounded ice in shallow lakes on Alaska's North Slope from 62 percent to 26 percent. Data from ASF, © ESA (1992-2011).

ASF News Granules

Spotlight on SMAP

Highlighting the global significance of the upcoming Soil Moisture Active Passive (SMAP) mission, ASF has developed a website (https://www.asf.alaska.edu/smap) for SMAP information ranging from applications to multimedia. SMAP is a National Aeronautics and Space Administration (NASA) mission. Active and passive refer to the mission's SAR and radiometer.



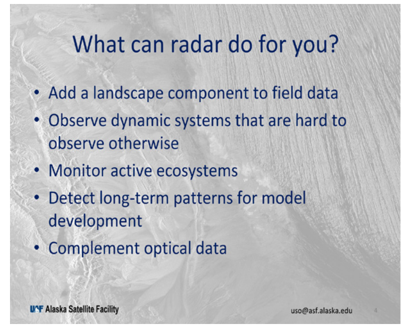
SMAP launch date: Fall 2014

SMAP will collect data on the entire planet's soil moisture every three days for three years. From mud, to permafrost, to drought-stricken cropland, the Earth's soil holds vital information about the planet's water. Understanding where water is stored, where it is going, and how fast it is moving is critical as the human population grows, demand for water increases, the climate changes, and weather patterns shift.

As NASA's SAR Distributed Active Archive Center (DAAC), ASF will distribute SMAP data products starting in spring 2015. Data products also will be available through the National Snow and Ice Data Center (NSIDC) DAAC.

Radar for Real-Life Scientists

Now available online, an ASF-produced, NASA Earthdata Webinar titled "Real-Life Uses of Radar for Real-Life Scientists" features the increasingly varied ways scientists are using radar. After presenting radar basics and showing several examples of recent research, ASF Senior Science Consultant Michelle Harbin also walks users through a search for data on Vertex, ASF's data portal. Users can access the Webinar at http://www.youtube.com/watch?v=ph00QUwlj18.



Website Redesign

ASF's Mission Support welcomes feedback on the redesigned ASF website (https://www.asf.alaska.edu), launched this past winter. Users are encouraged to suggest content, citations, or any other improvements. Fill out the feedback form on the website or email uso@asf.alaska.edu.

Archive Exceeds 1.5 Petabytes

The ASF SAR DAAC data archive now exceeds 1.5 petabytes: 961.02 terabytes of SAR products are on spinning disk storage, and 561 terabytes of SAR raw data are stored on LTO-4 tapes.

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