Is The Number of Antarctic Icebergs Really Increasing?

Icebergs released from the ice shelves and glaciers of Antarctica account for the majority of the continent's freshwater flux into the ocean. It is estimated that an average of nearly 2000 km^3 [*Jacobs et al.*, 1992] of ice are released from continental ice shelves and glaciers each year. Much of this ice is released in the form of very large icebergs, some of which are as large as 295 km x 37 km.

A recent article by *Bindschadler and Rignot* [2001] notes that the number of icebergs around Antarctica appears to be on the rise, potentially heralding a climate trend. Examination of the National Ice Center (NIC) Antarctic iceberg data base tends to support the observation of an increase in the number of icebergs. Further driving the concern is the size of recently calves icebergs such as the largest ever observed, B15 measuring 295 km x 37 km, which calved from the Ross Ice Shelf in March 2000.

Does the increasing number of icebergs reported by the NIC reflect a climate trend or changes in the observation tools? To address this question, we used recently developed techniques that employ enhanced radar scatterometer data to observe icebergs to retrospectively analyze recent and historic scatterometer data sets. We found that the apparent trend in the NIC is primarily due to improved observation tools.

Iceberg Tracking

The U.S. NIC is a multi-agency operational center supported by the U.S. Navy, the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), and the U.S. Coast Guard. The NIC's mission is to provide high-quality sea-ice analysis and forecasts designed to meet the requirements of U.S. national interests (http://www.natice.noaa.gov/).

To qualify for NIC tracking, an Antarctic iceberg must be at least 10 nautical miles along the long axis, be located south of 60°S, and be observed within the past 30 calendar days. An exception to the latter requirement is made for icebergs that are thought to be grounded. Observations of iceberg positions are made by shipboard observers and through interpretation of visual, infrared, and microwave satellite imagery. The NIC generally tracks these large icebergs until fracturing results in individual bergs that no longer meet the tracking criteria.

Since ship observations are only occasionally available, the NIC relies primarily on satellite observations; visible and infrared images from the Operational Linescan System (OLS) aboard the Defense Meteorological Satellite Program satellite series are the most common source. Visible and infrared images from the Advanced Very High Resolution Radiometer aboard NOAA's meteorological satellites are also used. Cloud cover and poor solar illumination conditions during the polar winters adversely affect observation quality, resulting in observation gaps and occasional "lost" icebergs.

Microwave sensors, which can see through clouds and do not require solar illumination, have been used by the NIC to track icebergs in recent years. Synthetic Aperture Radar images from RADARSAT have a very high resolution of 100 m and better, but their availability is limited. Most recently, enhanced resolution wind scatterometer images generated from SeaWinds-on-QuikSCAT (QSCAT) data have been added to the NIC tracking suite (Figure 1). The MODIS (Moderate Resolution Imaging Spectroradiometer) imager is another potential new tool.

A plot of the number of icebergs tracked by the NIC from 1976 to 2001 is shown in Figure 2. A marked increase in the number of icebergs observed is evident. The time between reported iceberg sightings by the NIC typically varies from 15 to 20 days. This is generally adequate for slow-moving icebergs, but it can

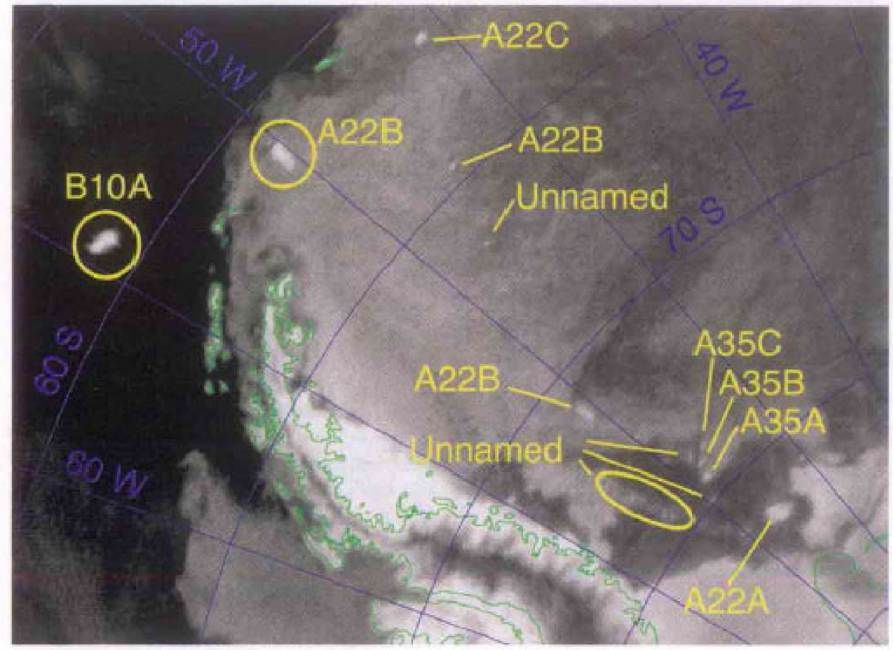

Fig. 1. This SeaWinds-on-QuikSCAT image shows icebergs in the Weddell Sea on 17 July 1999. The dark area to the left is open ocean while the gray-textured area is sea ice. The Antarctic Peninsula is generally bright with a dark band along its mountainous spine.

contribute to loss-of-track during periods of rapid motion.

Scatterometer Iceberg Tracking

Wind scatterometers are microwave radar instruments that were originally designed to measure oceanic surface winds, though their data have proven extremely useful in a broad variety of ice and land applications, including climate change studies [*Long et al.*, 2001]. Scatterometers have provided continuous synoptic microwave radar coverage of the Earth from space for a decade, with some earlier data collected nearly 30 years ago.

The SeaWinds scatterometer (QSCAT) is currently operating onboard QuikSCAT and was launched in 1999. The NASA scatterometer (NSCAT) operated for 9 months during 1996–1997, the Seasat-A scatterometer system (SASS) operated for 3 months in 1978, and the European Space Agency scatterometer (ESCAT) onboard the ERS-1 and ERS-2 satellites provided iceberg data from 1992 through early 2000.

In operation, a scatterometer transmits radar pulses and receives backscattered energy. The return energy depends on the roughness and dielectric properties of the surface. The wide swath of scatterometers provides frequent global coverage at intrinsic sensor resolutions of 25–50 km. By combining multiple passes in a resolution enhancement algorithm [*Early and Long*, 2001], an extensive time series of enhanced resolution radar backscatter imagery has been produced from data from these scatterometers. The time series is available from the Scatterometer Climate Record Pathfinder (SCP) project at http://www.scp.byu.edu/.

Icebergs (cont. on page 474)

Icebergs (cont. from page 469)

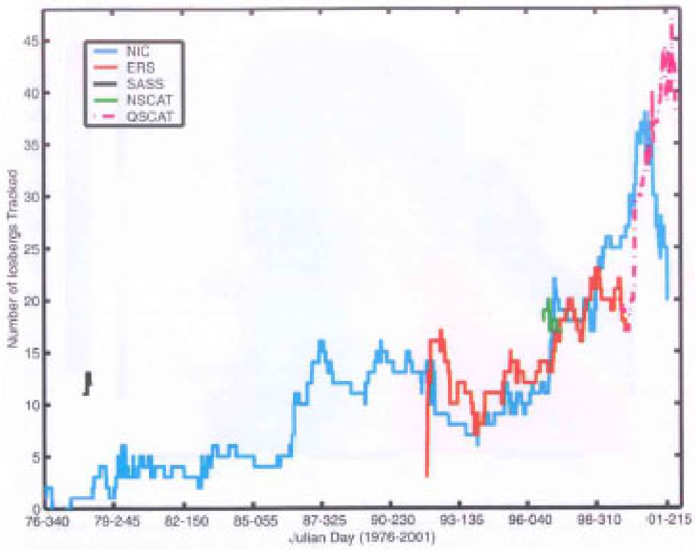

Fig. 2. This plot shows the number of icebergs versus time reported by the National Ice Center (NIC) and observed in enhanced resolution scatterometer images from various scatterometers. Images were obtained from the Scatterometer Climate Record Pathfinder (http://www.scp.byu.edu/).

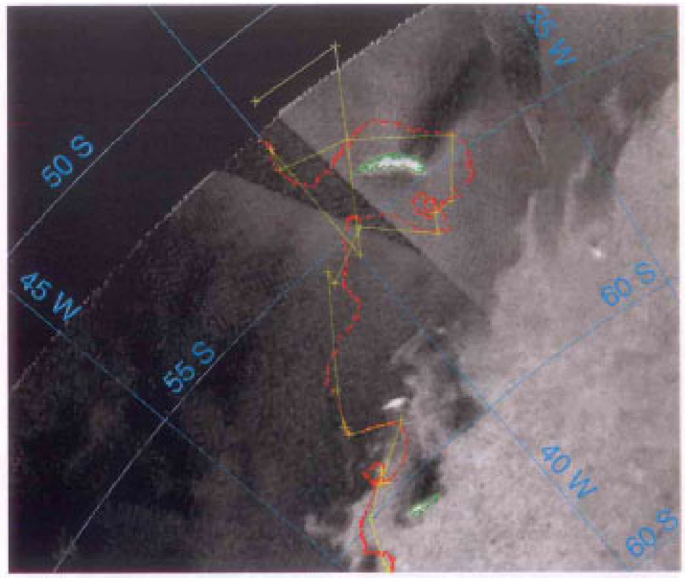

Fig. 3. Here a track of iceberg A22B overlays a 5 October 2000 SeaWinds-on-QuikSCAT image. The continuous blue curve shows Brigham Young University positions. The yellow line shows NIC reported positions and includes an erroneous position report. South Georgia Island is the bright arc in the upper center. The winter sea-ice pack is the light area to the right. Open ocean contains artifacts resulting from the combination of multiple passes. The black area is outside the polar stereographic project used for this image. The erroneous NIC position report is likely due to the limited availability of imagery at NIC for regions outside the ice pack.

Icebergs originate as glacial ice and typically exhibit very high radar backscatter values. Over sea ice, the backscatter is sensitive to roughness and physical properties that vary by ice type and season, but the backscatter from sea ice is much lower than that of glacial ice. This contrast in backscatter values makes icebergs readily visible in scatterometer images (Figure 1). Though the image resolution is relatively coarse-ranging from 2.225 to 8.9 km/pixel, depending on the sensor, larger tabular icebergs are readily visible in the scatterometer imagery. Surface melting can reduce the contrast during the summer months and complicate iceberg identification.

Separately examining the time series of scatterometer images for each sensor, the position of each visible iceberg was identified and tracked as a function of time. Icebergs were subjectively identified using either motion or as isolated, stationary high-backscatter ice masses. Motion was observed by animating sequences of images and played a key role in ensuring proper identification. Image resolution limits the minimum size of an iceberg that can be observed to a few pixels in extent, resulting in some variation in the number of concurrent icebergs visible in different sensors, for example, ESCAT and NSCAT. However, all icebergs of minimum size as identified by the NIC were observed in the scatterometer image data set, and additional icebergs were found in all sensor image sets, resulting in an extensive data base of iceberg positions as a function of time.

Approximately two-thirds of the icebergs observed exhibited no discernible movement for at least part of the observation period, with one-half of these never showing any discernible movement. Most of the latter category are listed in the NIC data base and are grounded. The retrospective tracking data base provides higher temporal resolution, with positions tracked every 1–5 days, than the NIC's 15–20 day positions and extends the range of iceberg tracking beyond the northern limit of 60°S used by the NIC. The data base also corrects some errors in the NIC data base such as inadvertent name changes, lost tracks, and reporting errors (Figure 3). This comprehensive data base is a recent addition to the Scatterometer Climate Record Pathfinder (SCP) data base and is now publicly available (http://www.scp.byu.edu/).

Observations

The icebergs tracked by the NIC in the late 1970s are sporadic and few, most likely due to the NIC's limited access to coarse resolution satellite imagery, primarily visible and IR sensors during this time period. However, in the austral winter of 1978, SASS observed 14 large icebergs versus NIC's two. During the early 1980s, the number of icebergs tracked at NIC was nearly constant, from 4 to 6, and these were mostly grounded . In 1986, the number of icebergs tracked by the NIC significantly increased to 10–15, coinciding with the introduction of the OLS to the tracking operations.

Between 1987 and 1996, the number of NIC icebergs fluctuated, but this corresponded to the somewhat higher ESCAT and NSCAT values. There was a jump in 1996 with additional jumps in 1999 and 2000. The latter two jumps are associated with very large iceberg calving events from the Ronne (1999) and Ross (1998, 2000) ice shelves, each of which released several very large icebergs, including B15, the largest ever observed [*Lazzara et al.*, 1999]. These large bergs have further fragmented, resulting in large numbers of icebergs that can be tracked. Such large calving events are not unexpected; major calvings occur every 50–100 years as an ice sheet advances into the ocean [*Jacobs et al.*, 1986]. Indeed, the recent 10 May 2002 calving of C19 along the edge of the Ross Ice Shelf was expected and probably finishes the Ross Ice Shelf reduction initiated by the 1998 and 2000 calvings.

The success of the scatterometer-based identification and tracking led the NIC to adopt the QSCAT tracking as a primary tracking data source to augment visible and infrared sensors. Since early 2000, QSCAT tracking information has been incorporated into the NIC data base with about 55% of all iceberg locations based on QSCAT data. This helps account for the fact that the number of NIC-tracked icebergs closely matches the scatterometer-based set after 2000.

Since earlier scatterometer data suggest more icebergs than are recorded in the early NIC data base and later scatterometer observations tend to agree with NIC observations, we conclude that technological advances in iceberg observation and tracking techniques explain much of the NIC's increasing iceberg count through 1999. We cannot conclude that the apparent increase in the number of icebergs represents a climate trend. Furthermore, while the recent Larsen Ice Shelf disintegration may be related to a warming trend, a relationship between the formation of large, tabular icebergs and climate trends has not been established [*Lazzara et al.*, 1999]. Thus, while the iceberg count has climbed significantly in recent years, the additional icebergs are clearly linked to episodic calving events, an expected phenomenon.

Authors

David G. Long, Jarom Ballantyne, and *Cheryl Bertoia*
For additional information, contact David G. Long, Brigham Young University, 459 Clyde Building, Provo UT 84601 USA; E-mail: long@ee.byu.edu

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