Is the Number of Icebergs Around Antarctica Really Increasing?

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Introduction

Icebergs released from the ice shelves and glaciers of Antarctica represent this most remote of continent's major 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 as large as 295 X 37 km. In addition to fresh water, icebergs transport important nutrients far from the coast. Large icebergs move independently of the wind-driven sea ice pack due to their deep keels and as a result often cause the formation of large open water areas or polynyas of import in ocean/atmosphere heat flux. Additionally, icebergs represent a well-known hazard for shipping.

A recent article Bindschadler and Rignot (2001) note 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 database tends to support the observation of an increase in the number of icebergs. Further fueling the controversy are the largest icebergs ever observed (e.g., B15 at 295 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 utilize recently developed techniques for enhancing radar scatterometer data for observing icebergs to retrospectively analyze recent and historic scatterometer datasets. We found that the apparent trend in the NIC is primarily due to improved observation tools.

Iceberg Tracking at the NIC

The U.S. (NIC) is a multi-agency operational center supported by the Navy (Department of Defense), the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), and the Department of Transportation'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 believed 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 which no longer meet the tracking criteria.

As ship observations are only occasionally available, the NIC relies primarily on satellite observations, with visible and infrared images from the Operational Linescan System (OLS) aboard the Defense Meteorological Satellite Program (DMSP) satellite series as the most common source. Visible and infrared images from the Advanced Very High Resolution Radiometer (AVHRR), aboard NOAA 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 added to the NIC tracking sources in recent years. Synthetic Aperture Radar (SAR) images from RADARSAT have very high resolution (100 m and better), but limited availability. Most recently, enhanced resolution wind scatterometer images generated from SeaWinds-on-QuikSCAT (QSCAT) data have been added to the NIC tracking suite. The MODIS imager is another potential tool.

A plot of the number of icebergs tracked by the NIC from 1976 to 2001 is shown in Fig. 1. 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 slowing moving icebergs but can contribute to loss-of-track during periods of rapid motion.

Scatterometer Iceberg Tracking

Wind scatterometers are microwave radar instruments originally designed to measure oceanic surface winds; however, 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 been providing continuous synoptic microwave radar coverage of the Earth from space for a decade with some prior data collected nearly two and a half decades ago. The SeaWinds scatterometer (QSCAT) is currently operating onboard

QuikSCAT and was launched in 1999. Prior scatterometers include the NASA scatterometer (NSCAT) which operated for 9 months during 1996-97; the Seasat-A scatterometer system (SASS) which operated for 3 months in 1978; and the European Space Agency (ESA) scatterometer (ESCAT) onboard the ERS-1 and ERS-2 satellites. ESCAT data spans 1992 through early 2000. In operation, a scatterometer transmits radar pulses and receives backscattered energy. The return energy is dependent 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 combing multiple passes in a resolution enhancement algorithm (Early and Long, 2000) an extensive time series of enhanced resolution radar backscatter imagery has been produced from data from these scatterometers (available from the Scatterometer Climate Record Pathfinder (SCP) project (http://www.scp.byu.edu/).

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 is much lower than glacial ice. This contrast in backscatter values makes icebergs readily visible in scatterometer images as illustrated in Fig. 2. Though the image resolution is relatively coarse (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, e.g. ESCAT and NSCAT. However, all icebergs of minimum size as identified by the NIC were observed in the scatterometer image dataset and additional icebergs were found in all sensor image sets, resulting in an extensive database of iceberg positions as a function of time.

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

Observations

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

Between 1987-1996 the number of NIC icebergs fluctuates but tracks the somewhat higher ESCAT and NSCAT values. There is 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 the largest (B15) ever observed (Lazzara et al. 1999). These large bergs have further fragmented, resulting in large numbers of trackable icebergs. Such large calving events are not unexpected, with major calvings occurring very 50-100 years as an ice sheet advances into the ocean (Jacobs et al., 1986). Indeed, the recent (May 10, 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 database 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.

Noting that earlier scatterometer data suggests more icebergs than recorded in the early NIC database 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 though 1999. We cannot conclude that the apparent increase in the number of icebergs represents a climate trend. Further, 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.

References

Bindschadler, R.A., and E. Rignot, "Crack!" in the polar night, *EOS, Transactions, AGU*, 82(43), 497-505, 2001.

Early, D. S., and D. G. Long, Image reconstruction and enhanced resolution imaging from irregular samples, *IEEE Trans. Geosci. Remote Sens., 39*, 291-302, 2001.

Jacobs, S.S., D.R. MacAyeal, and J.L. Ardai, Jr., The recent advance of the Ross Ice Shelf, *J. Glaciol.*, 32, 464-474, 1986.

Jacobs, S.S., H. Hellmer, C. Doake, and R., Frolich, Melting of ice shelves and the mass balance of Antarctica, *J. Glaciol.,* 38, 375-387, 1992.

Lazzara, M.A., K.C. Jezek, T.A. Scambos, D.R. MacAyeal, and C.J. van der Veen, On the Recent Calving of Icebergs from the Ross Ice Shelf, *Polar Geography*, 23(3), 201-212, 1999.

Long, D. G., M. R. Drinkwater, B. Holt, S. Saatchi, and C. Bertoia, Global ice and land climate studies using scatterometer image data, *EOS Transactions, AGU*, 82(43), 503, 2001.

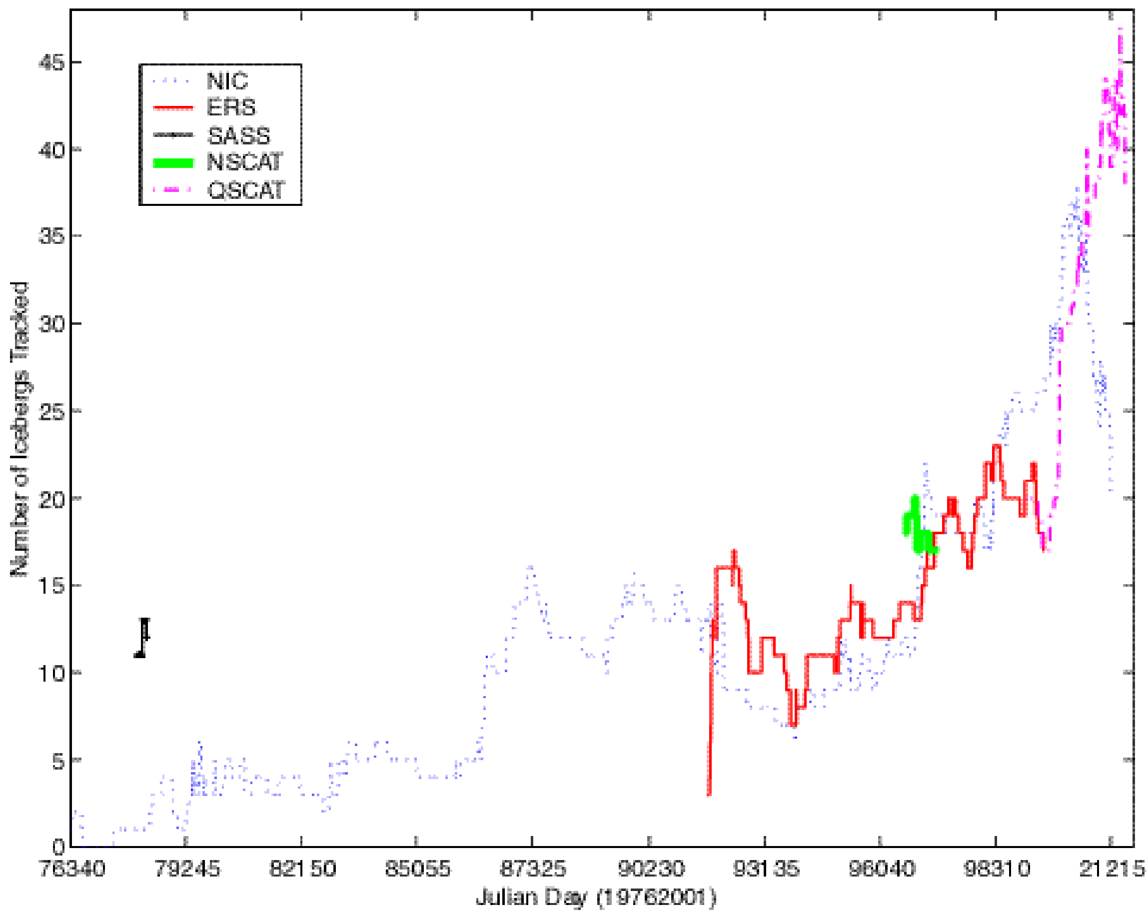

Figure 1. Plot of the number of icebergs versus time reported by the National Ice Center (NIC) and observed in enhanced resolution scatterometer images from various scatterometers. Images were obtained from the Scatterometer Climate Record Pathfinder (http://www.scp.byu.edu/).

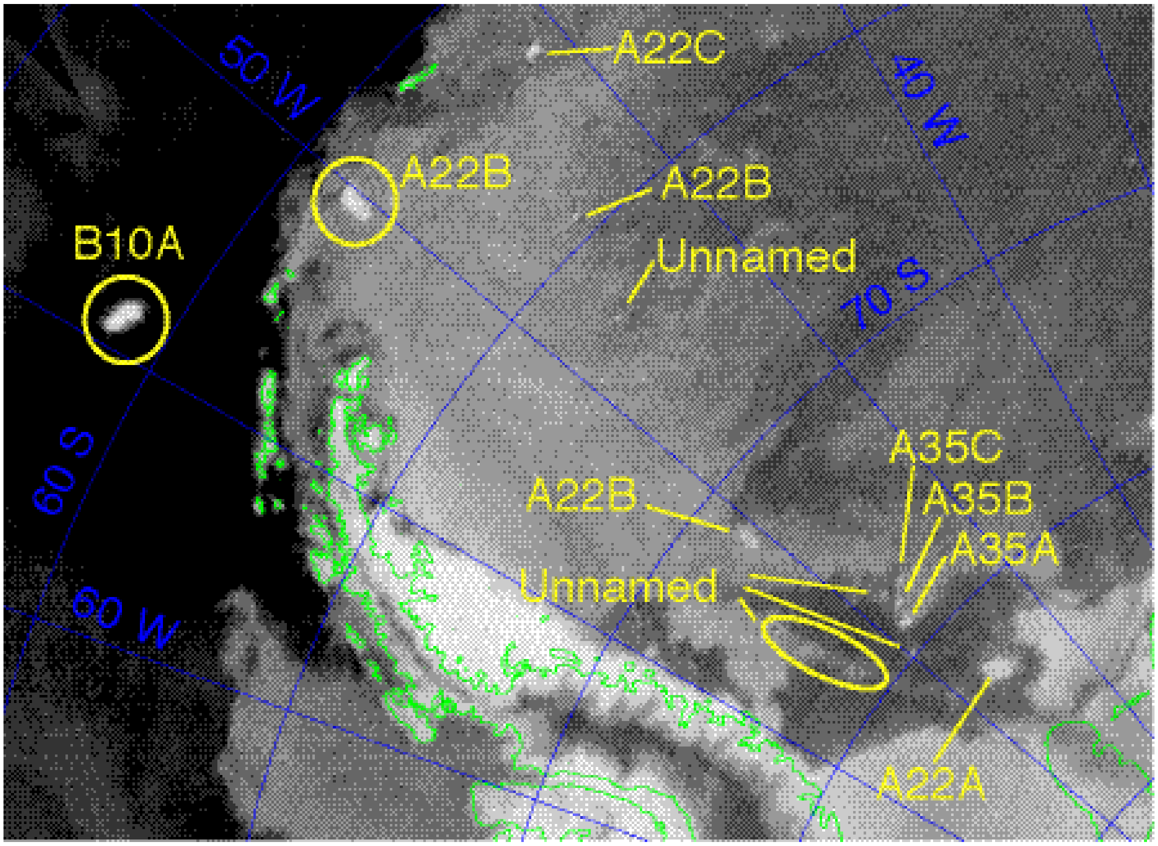

Figure 2. SeaWinds-on-QuikSCAT image showing icebergs in the Weddell Sea on JD 201 (July), 1999. The dark area to the left is open ocean while the gray textured area is sea ice. The Antarctic Peninsula is generally bright with a dark band along its mountainous spine.

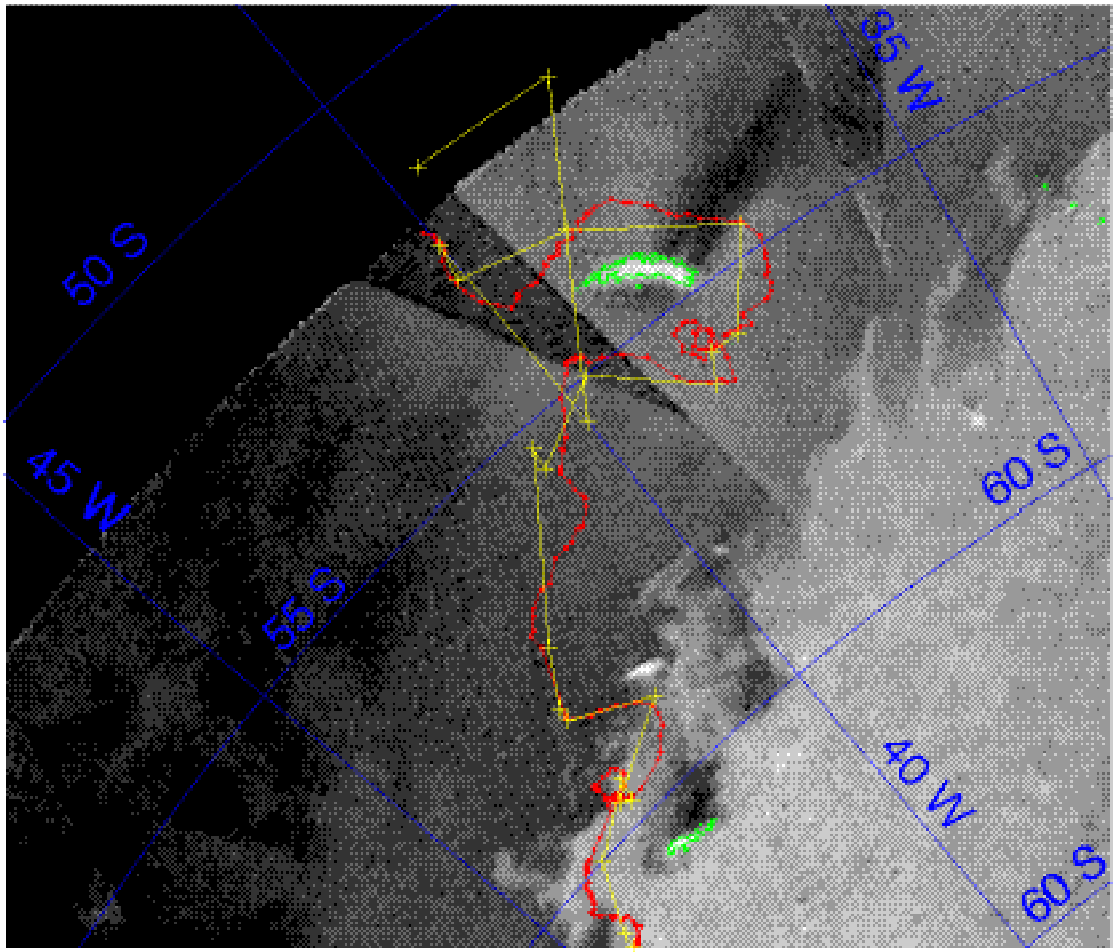

Figure 3. Track of A22B overlaying a JD 278 (Oct.) 2000 SeaWinds-on-QuikSCAT image. The continuous blue curve shows BYU positions. The yellow line shows NIC reported positions, and includes an erroneous position report. South Georgia Island is the bright arc in the upper center. The winter sea-ice pack 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 of the ice pack.