A Multidecadal Study of the Number of Antarctic Icebergs Using Scatterometer Data

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Abstract— Tabular Antarctic icebergs are regularly formed by the separation of massive sections of ice from ice shelves and glaciers. The National Ice Center (NIC) uses a variety of satellite sensors to track large Antarctic icebergs and reports iceberg positions. According to the NIC database, the number of large Antarctic icebergs has been increasing in recent years. A long term analysis of Antarctic iceberg activity based on scatterometer and radiometer data is presented. Our analysis suggests this increase is largely due to improved resources and technological advancements for iceberg tracking. Recent calving events may represent natural variability in iceberg activity. This study identifies some of the advantages and limitations of tracking icebergs using scatterometer data.

I. INTRODUCTION

The National Ice Center (NIC) is using a variety of satellite sensors to track and monitor Antarctic icebergs depending on their size and position. The instruments used by the NIC include an infrared imager, a radiometer, SAR, and most recently, scatterometers. Significant increases in the number of icebergs are reported by the NIC over the last 25 years. The increase is partly due to large iceberg calving events that have taken place in recent years. In order to evaluate the NIC's data and independently monitor iceberg activity, we use scatterometer and radiometer data to track Antarctic icebergs for segments of time over the last 25 years. Image data sets from the Scatterometer Climate Record Pathfinder (SCP) [1], [2] for five different spaceborne scatterometer and radiometer instruments are used in the study. The images provide coverage of the entire Antarctic continent and allow iceberg positions to be recorded every 1-5 days. These results are analyzed to determine the validity of the reported trend in the number of icebergs over the last 25 years. This study also identifies some of the relative merits of tracking and monitoring icebergs with methods used at the NIC and methods used at BYU.

II. NATIONAL ICE CENTER TRACKS ICEBERGS

The NIC uses a variety of methods for tracking and monitoring Antarctic icebergs. The most commonly used instrument is the Operational Linescan System (OLS) which provides global coverage at 2.7 km resolution. A key limitation to using OLS is the obstruction in visibility due to cloud cover. For example, due to this limitation, iceberg B10A was lost to the NIC and later located using scatterometer images. The OLS images offer relatively high resolution but limited coverage area due to swath and image processing limitation. Other sensors include the Advanced Very High Resolution Radiometer (AVHRR) and Radarsat SAR. The limitations of using AVHRR images to track Antarctic icebergs are similar to OLS. SAR images see thru clouds but have limited coverage. The NIC also currently obtains iceberg positions provided by BYU who use SCP enhanced resolution images derived from the SeaWinds scatterometer on board the satellite QuikSCAT.

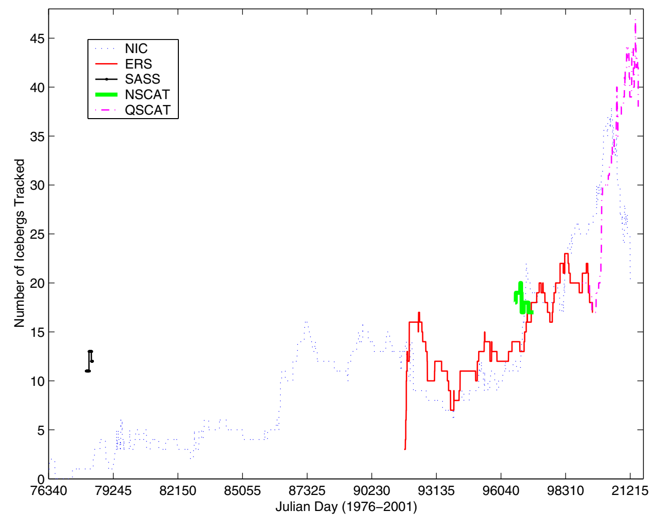

Fig. 1. *Number of icebergs tracked over time.*

Figure 1 shows the number of icebergs tracked by the NIC from 1976 to 2001. This figure also shows the number of icebergs tracked by BYU using various sensors. The icebergs tracked by the NIC in the late 1970's are sporadic and few, most likely due to the NIC's limited resources during this time period. During the early 1980's the number of icebergs tracked remains relatively constant (from 4 to 6). During 1986-1987, the number of icebergs tracked by the NIC increases to between 10-15.

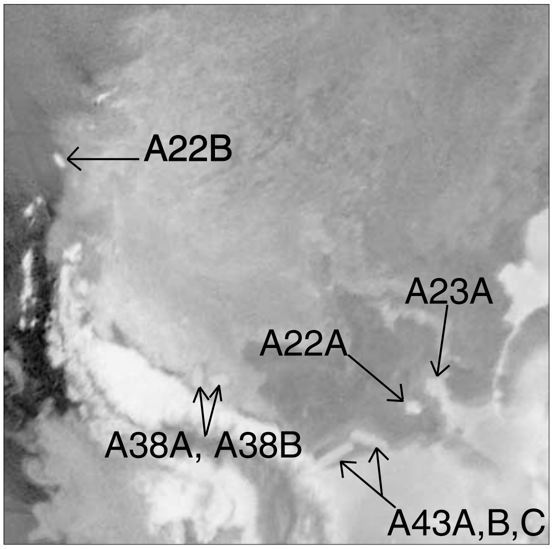

Fig. 2. *Enhanced resolution scatterometer image of the Weddell Sea.*

Between 1987-1999 the number of icebergs fluctuate, followed by significant jumps in early 1999 and 2000. These jumps in the number of icebergs are associated with large iceberg calving events from the Ronne and Ross ice shelves.

The largest cluster of icebergs reported by the NIC have come from the Weddell Sea seen in Figure 2. These icebergs calved from either the Ronne or Filchner Ice Shelves and then travel north between 20 degrees to 50 degrees west longitude along what has been named 'Iceberg Alley'. The second largest group of icebergs is located in the Ross Sea. These icebergs calve from the Ross Ice Shelf and typically travel west along the Antarctic coast being carried by an Antarctic coastal current. Most of the recent icebergs in the Ross Sea were first reported in 2000 due to several large calving events (e.g. B15). Many of these icebergs eventually reach the Weddell Sea and then travel north through the 'Iceberg Alley'. A few icebergs traveling west with the Antarctic coastal current turn north near 90 degrees east longitude, getting caught in the Antarctic Circumpolar Current (ACC) and travel northeast e.g. B10A [3]. Other icebergs in the Ross Sea travel north until they are caught in the ACC and move east through the Drake Passage. Icebergs are also formed from glacier tongues [4].

III. TRACKING ICEBERGS AT BYU

As shown in Figure 1, the number of icebergs reported by the NIC has gradually been increasing for the last 25 years. However, this rise in the number of icebergs is primarily an artifact of increasing iceberg-identification and tracking techniques. In order to evaluate the NIC's data and independently monitor iceberg activity, we use scatterometer and radiometer data to track Antarctic icebergs.

Enhanced resolution images from five different spaceborne scatterometer and radiometer instruments are used in the study and include the Seasat-A Satellite Scatterometer (SASS), the European Space Agency's Remote Sensing Satellite 1(2) (ERS1(2)), the NASA Scatterometer (NSCAT), and the QuikSCAT/SeaWinds scatterometer (QSCAT). Data from the Special Sensor Microwave/Imager (SSM/I) is also utilized. Although the images are "enhanced resolution", varying from 8-25 km, they have lower resolution than many of the other instruments used by the NIC but have broader coverage.

Distinct features of the Antarctic continent can be seen with resolution-enhanced images (see Fig. 2). Sea ice, ice shelves, and land features can be clearly distinguished. Large Antarctic icebergs are identified as objects of contrasting backscatter values against the surrounding ocean or sea ice.

Icebergs are independently tracked with each data set for various time periods from 1976 to the present. An iceberg is identified if it is clearly distinguishable from land or ice shelves and if it passes either of two criteria. First, if it is located in the same position as indicated by the NIC. Second, an iceberg is identified when clearly distinguishable and motion is detected. A few icebergs are additionally identified where they were not reported by the NIC and motion was not detected. In these cases the icebergs were clearly not a part of any land feature or ice shelf. Only very large icebergs were tracked to be consistent with the NIC's 10 mile size tracking limit.

A. THE BYU ICEBERG DATABASE

Using five different satellite instruments, we have produced an Antarctic iceberg tracking database. The BYU database includes icebergs identified during 1978 and icebergs from 1992 to the present. Many icebergs that were not tracked by the NIC are included in this database. For example, the NIC recorded only two icebergs in the Antarctic region in 1978 while BYU tracked 13 icebergs during this time.

Icebergs are reported every 1 to 5 days in BYU's iceberg database versus every 15 to 20 days in the NIC's database. While generally visible, summer melt can adversely affect iceberg contrast and some iceberg tracks exhibit short summer gaps. Figure 3 shows the detailed path of iceberg A22C tracked by BYU (shown in black) and tracked by the NIC (shown in grey). This figure displays the complicated motion of the iceberg not evidenced in the NIC data. The higher temporal resolution provides information about the ocean currents that are primarily responsible for the iceberg's motion. It also gives more accurate position measurements for mariners operating in the Antarctic regions. In addition, the database extends the tracking of several icebergs beyond the NIC's range. Reported positions for all icebergs at BYU are shown in Figure 4.

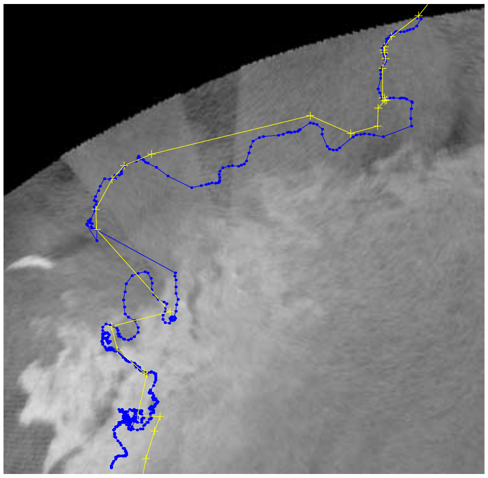

Fig. 3. *Track of iceberg A22C overlaying QSCAT σ^0 image. NIC positions (white), BYU positions (black).*

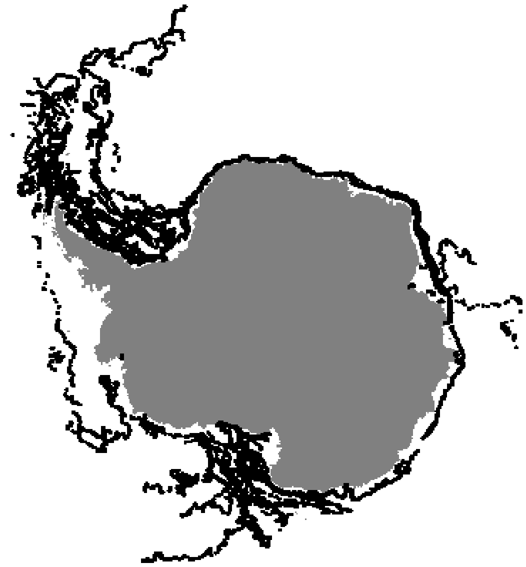

Fig. 4. *Reported positions for all icebergs in the BYU database (1978,1992-2001).*

B. NIC vs. BYU

The higher resolution images used by the NIC allow traking of smaller icebergs than the limited resolution scatterometer and radiometer images. Most of the icebergs detected by the NIC and not by BYU are of relatively small size. However, because of low coverage the NIC generally only tracks icebergs in specific Antarctic regions. The scatterometer and radiometer images have lower resolution but broader coverage area. Images by SSM/I and QSCAT provide daily coverage of the entire Antarctic continent and surrounding oceans allowing monitoring over a wide coverage area with frequent (daily) coverage.

Are the numbers of Antarctic icebergs increasing? While Figure 1 shows the number of icebergs increasing for both the NIC and for BYU. It is interesting to note the difference in tracking numbers for BYU and the NIC. In 1978 the NIC tracked two icebergs while 13 icebergs were tracked by BYU. This difference may be due to the limited amount of resources available to the NIC at the time. During 1992, there is also a significant difference in the number of icebergs tracked. This may be due to the improved coverage capabilities of the sensors used at BYU versus the NIC. Since 1995 the number of icebergs tracked for both the NIC and BYU are very similar. This is due in part to BYU supplying iceberg tracking information to the NIC. The main increase in the number of icebergs from 1999 to 2001 is largely due to several large calving events from the Ronne and Ross Ice Shelves. Also, a greater number of icebergs are identified due to the improved resolution of images used and due to improved tracking techniques. Based on BYU's tracking, the number of icebergs did not change significantly from 1978-1999. The number of icebergs being tracked has increased since 1999 due to major calving. Such major calvings are expected every 50 to 60 years. However, the data is insufficient to determine whether this is a cyclic event or a long term increase.

IV. Conclusions

The number of icebergs tracked by the NIC has risen over the last 25 years. This increase is largely due to improved resources for iceberg tracking and to several major iceberg calving events that have taken place in recent years.

To evaluate the NIC's results and monitor iceberg activity, we used scatterometer and radiometer data to identify and track Antarctic icebergs for different segments of time over the last 25 years. Five data sets from various instruments were used in the study. Icebergs were tracked independently with each data set for time periods between 1976 to 2001. We report an increasing trend in the number of visible icebergs over the last 20-25 years. However, this trend is only significant from 1999 to 2001 due to several major calving events during these years. Whether this recent increasing trend represents a natural variability in the number of icebergs or a long term increase is unknown.

References

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