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Coastal-Change and Glaciological Map of the Northern Ross Ice Shelf Area, Antarctica: 1962–2004

By Jane G. Ferrigno, Kevin M. Foley, Charles Swithinbank, and Richard S. Williams, Jr.

Pamphlet to accompany
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Conversion Factors

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)

Coastal-Change and Glaciological Map of the Northern Ross Ice Shelf Area, Antarctica: 1962–2004

By Jane G. Ferrigno,[1] Kevin M. Foley,[1] Charles Swithinbank,[2] and Richard S. Williams, Jr.[3]

Introduction

Background

Changes in the area and volume of polar ice sheets are intricately linked to changes in global climate, and the resulting changes in sea level could severely impact the densely populated coastal regions on Earth. Melting of the West Antarctic part alone of the Antarctic ice sheet would cause a sea-level rise of approximately 6 meters (m). The potential sea-level rise after melting of the entire Antarctic ice sheet is estimated to be 65 m (Lythe and others, 2001) to 73 m (Williams and Hall, 1993). The mass balance (the net volumetric gain or loss) of the Antarctic ice sheet is highly complex, responding differently to different conditions in each region (Vaughan, 2005). In a review paper, Rignot and Thomas (2002) concluded that the West Antarctic ice sheet is probably becoming thinner overall; although it is thickening in the west, it is thinning in the north. Thomas and others (2004), on the basis of aircraft and satellite laser altimetry surveys, believe the thinning may be accelerating. Joughin and Tulaczyk (2002), on the basis of analysis of ice-flow velocities derived from synthetic aperture radar, concluded that most of the Ross ice streams (ice streams on the east side of the Ross Ice Shelf) have a positive mass balance, whereas Rignot and others (2004) infer even larger negative mass balance for glaciers flowing northward into the Amundsen Sea, a trend suggested by Swithinbank and others (2003a,b; 2004). The mass balance of the East Antarctic ice sheet is thought by Davis and others (2005) to be strongly positive on the basis of the change in satellite altimetry measurements made between 1992 and 2003.

Measurement of changes in area and mass balance of the Antarctic ice sheet was given a very high priority in recommendations by the Polar Research Board of the National Research Council (1986), in subsequent recommendations by the Scientific Committee on Antarctic Research (SCAR) (1989, 1993), and by the National Science Foundation's (1990) Division of Polar Programs. On the basis of these recommendations, the U.S. Geological Survey (USGS) decided that the archive of early 1970s Landsat 1, 2, and 3 Multispectral Scanner (MSS) images of Antarctica and the subsequent repeat coverage made possible with Landsat and other satellite images provided an excellent means of documenting changes in the coastline of Antarctica (Ferrigno and Gould, 1987). The availability of this information provided the impetus for carrying out a comprehensive analysis of the glaciological features of the coastal regions and changes in ice fronts of Antarctica (Swithinbank, 1988; Williams and Ferrigno, 1988). The project was later modified to include Landsat 4 and 5 MSS and Thematic Mapper (TM) images (and in some areas Landsat 7 Enhanced Thematic Mapper Plus [ETM+] images), RADARSAT images, and other data where available, in order to compare changes that occurred during a 20- to 25- or 30-year time interval (or longer where data were available, as in the Antarctic Peninsula). The results of the analysis are being used to produce a digital database and a series of USGS Geologic Investigations Series Maps (I–2600) (Williams and others, 1995; Williams and Ferrigno, 1998; Ferrigno and others, 2002) (available online at http://www.glaciers.er.usgs.gov).

Objectives

The coastal-change and glaciological mapping project has five primary objectives, listed as follows:

1. to determine coastline changes that have occurred during the past three decades, or longer where additional information exists;

2. to establish an accurate baseline series of 23 individual maps (fig. 1) that defines, from the analysis of Landsat and other satellite images, the glaciological characteristics (for example, floating ice and grounded ice) of the coastline of Antarctica during three main time intervals: (1) early 1970s (Landsat 1, 2, or 3), (2) middle 1980s to early 1990s (Landsat 4 or 5), and (3) late 1990s to early 2000s (RADARSAT or Landsat 7 ETM+);

[1]U.S. Geological Survey, 926A National Center, Reston, VA 20192-0002.
[2]Scott Polar Research Institute, University of Cambridge, Lensfield Road, Cambridge CB2 1ER, United Kingdom.
[3]U.S. Geological Survey, 384 Woods Hole Road, Woods Hole, MA 02543-1598.

3. to determine velocities of outlet glaciers, ice streams, and ice shelves, and the position of the grounding line from analysis of Landsat images and other sources;

4. to compile a comprehensive inventory of named (from published maps) and unnamed (from analysis of Landsat images) outlet glaciers and ice streams in Antarctica that are mappable from Landsat and other satellite images or from ancillary sources (for example, maps, gazetteers, and digital databases) (Swithinbank, 1980, 1985; Alberts, 1981, 1995; National Science Foundation, 1989; British Antarctic Survey and others, 1993);

5. to compile a 1:5,000,000-scale map of Antarctica derived from the 23 individual maps. Each individual map extends to the southernmost nunatak within each map area or to the southernmost extent of Landsat images (about lat 81.5° S.). The coverage area of some maps (for example, those covering the Ronne and Filchner Ice Shelves) was extended farther south to encompass the entire ice shelf.

Sources

Landsat images used in the compilation of the northern Ross Ice Shelf area map were obtained from either the EROS Data Center, now the Center for Earth Resources Observation and Science (EROS)[4], or the former Earth Observation Satellite (EOSAT) Corporation, now Space Imaging LLC[5]. The coverage areas of the Landsat 1 and 2 MSS, Landsat 5 TM, and Landsat 7 ETM+ images used in the compilation are shown in the index maps on the accompanying map. Below the index maps, information about each image is listed. The Landsat 7 data were received in digital form, and the Landsat 1, 2, and 5 images were received as photographic negatives. The 1:500,000-scale photographic prints of Landsat images used in the analytical phase were derived from two types of source material: (1) 1:1,000,000-scale film transparencies from EROS and (2) 1:1,000,000-scale black-and-white or false-color-infrared prints from EOSAT. The early Landsat scenes cover the years 1973 and 1975; the later Landsat images are from 1986 and 2001. National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) data from 2000 and 2001 and Moderate Resolution Imaging Spectroradiometer (MODIS) images from 3 February 2004 were used to track icebergs calved from the Ross Ice Shelf. Two maps were used for ice-front positions: a U.S. Defense Mapping Agency Hydrographic Center 1966 map (revised 1972) of the McMurdo Sound area at 1:1,500,000 scale portraying a 1962 coastline, and a USGS 1980 map of the Ross Ice Shelf at 1:2,188,800 scale portraying the ice edge in 1971. A Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) image was used to map the ice front of 2 November 2004.

The 125-meter picture-element (pixel)-resolution 1997 RADARSAT image mosaic of Antarctica, compiled by The Ohio State University's Byrd Polar Research Center (BPRC), was used both as a base for correct geographic position and geometric rectification of digitized Landsat imagery and as an additional source of coastal-change data. The RADARSAT image mosaic is composed of data recorded from 9 September 1997 to 20 October 1997 (Jezek, 1998).

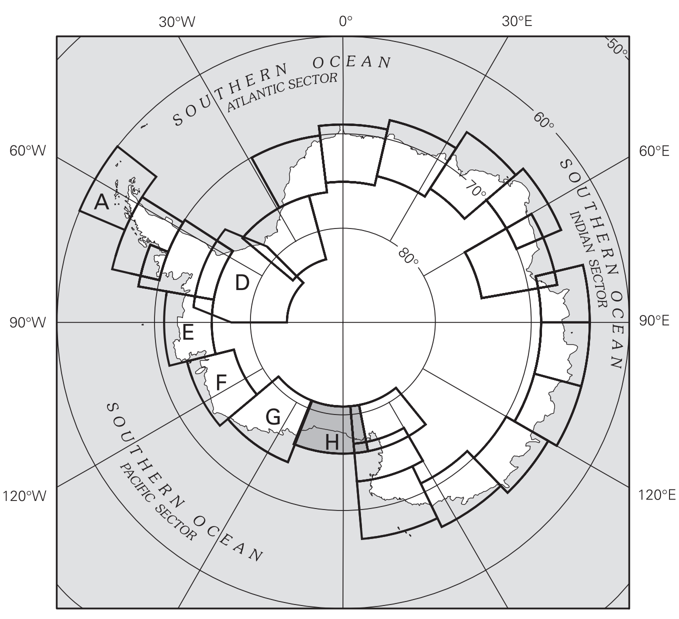

Figure 1. Index map of the planned 23 coastal-change and glaciological maps of Antarctica. The northern Ross Ice Shelf map area is shaded. Maps published to date are indicated by letter and are described in table 1.

Methodology

The primary steps in the compilation of the northern Ross Ice Shelf area map are listed and discussed below:

1. Identification of optimum Landsat MSS, TM, or ETM+ images for three time intervals used for the map series (early 1970s, middle 1980s to early 1990s, and early 2000s) and enlargement to a nominal scale of 1:500,000;

2. Manual annotation of glaciological features by SCAR Code (Scientific Committee on Antarctic Research, 1980) or Antarctic Digital Database (ADD) Geocode (British Antarctic Survey and others, 1993) on 1:500,000-scale transparent overlays of earlier Landsat images for both earlier time intervals and directly on the computer workstation monitor for the 1997 RADARSAT image mosaic and Landsat ETM+;

3. Positional control of mapped features. Because our goal is to produce the most accurate, high-resolution printed

[4]Center for Earth Resources Observation and Science (EROS), U.S. Geological Survey, 47914 252d Street, Sioux Falls, SD 57198-0001.

[5]Space Imaging LLC, 12076 Grant Street, Thornton, CO 80241.

maps and digital databases of the coastal regions of Antarctica, we expended considerable thought and research on choosing the optimum method of geolocating mapped features. The decision was made to georegister the imagery and annotations to the 1997 RADARSAT image mosaic of Antarctica produced by the BPRC in order to give the most geometrically accurate base. An added benefit was that the RADARSAT mosaic was compiled in polar stereographic projection having a standard parallel at lat 71° S.—the projection selected for the map series—with due consideration given to scale distortion on map coverage north and south of lat 71° S. (Sievers and Bennat, 1989). The primary benefit of the polar stereographic projection is cartographic continuity between adjacent maps in the coverage provided of the coastal regions of Antarctica.

The RADARSAT image mosaic of Antarctica was generated from Synthetic Aperture Radar (SAR) data collected by the Canadian Space Agency's RADARSAT-1 satellite. Geodetic ground-control points (GCPs) supplied by the National Imagery and Mapping Agency (NIMA), now the National Geospatial-Intelligence Agency (NGA), and the Environmental Research Institute of Michigan (ERIM) were used in conjunction with a calibration transponder located at the South Pole in the processing of data in order to improve the accuracy of geolocation from what is possible from use of satellite ephemeris data alone (Jezek, 1998, p. 15). Most of the 231 GCPs chosen (clustered at 91 locations) were located on nunataks in coastal regions; others were distributed along the Transantarctic Mountains. The geodetic accuracy of the RADARSAT image mosaic is cited as ±150 m (Noltimier and others, 1999). Orthorectification of the mosaic was accomplished using a Digital Elevation Model (DEM) generated by the BPRC specifically for the production of the mosaic. Data used in construction of the DEM were obtained from multiple sources. Types of data include ground-leveling and Global Positioning System (GPS) surveys, radar and laser altimeter data, optical and SAR stereographic image pairs and spot-elevation points, and contours and form lines digitized from map sheets (Liu, 1999, p. 15);

4. Scanning hard-copy images to produce 400 dots-per-inch (dpi), 256-shade, gray-scale digitized satellite images. The digitized satellite images, and those already in digital form, were coregistered and geometrically corrected to the RADARSAT image mosaic by using ERDAS Imagine software. Features from corrected image data were digitized to ARC/INFO vector coverages by using the digital overlay images as guides;

5. Addition of velocity contours and geographic place-names; and addition of topographic contours at selected intervals, generated from the BPRC DEM data and modified where necessary to be congruent with surface features;

6. Description of glaciological features (including the position of the grounding line) and analysis of ice-surface velocities of selected outlet glaciers, ice streams, and the Ross Ice Shelf.

Geodetic Accuracy of the RADARSAT Image Mosaic of Antarctica[6]

Introduction

The RADARSAT image mosaic of Antarctica was selected as the most accurate base available for geolocating the Landsat imagery; therefore, it was considered essential to confirm the published geodetic accuracy of the mosaic (±150 m; Noltimier and others, 1999).

BPRC's Procedure

With the assistance of BPRC personnel, the procedure for constructing the RADARSAT image mosaic was comprehensively reviewed. BPRC used custom software from Vexcel, a contractor on the project (Norikane and others, 1998). Described simply, long radar data strips were mosaicked into 24 blocks. These blocks were first rectified by using a generated digital terrain model to remove relief distortion and then mosaicked together to form the RADARSAT mosaic. Of the original 164 proposed sites for GCPs, 91 sites containing 231 high-quality GCPs were supplied by NIMA and identified on the RADARSAT imagery by ERIM. These were used in the block construction and the mosaic construction in conjunction with a calibration transponder located at the South Pole (K.F. Noltimier, BPRC, written commun., Oct. 9, 2001). The GCPs used were not evenly distributed over the continent, however, but tended to be in the flat coastal areas, with few in the mountainous regions. Some GCPs were withheld as a check of the overall accuracy. Unfortunately, the BPRC overall-accuracy check of the mosaic construction was not available for analysis. Large amounts of intermediate data were reviewed, basically the residuals for each tie point and control point used in each of the 24 blocks, but the overall results of the final block adjustments were not available. On the basis of a study of the data, the following analysis was made and conclusions reached.

USGS Analysis

Each block had three sets of errors called Block Overall, GCPs Overall, and Tie Points Overall. Each error set had both an average and a root mean square (RMS). Both the average and the RMS had separate values for x, y, and z, but no vector sum. In the sense used, it appears that "average" is really a measure of bias (shift); the RMS is essentially the

[6]Geodetic accuracy determined by J. William Schoonmaker, research geodesist, U.S. Geological Survey (retired).

Glaciological Studies

The Ross Ice Shelf is probably the ice shelf that has the longest history of scientific studies, beginning with the earliest exploration. Both Robert Falcon Scott and Roald Amundsen made measurements of surface heights on the ice shelf along their routes to the South Pole in 1911–12, and extensive glaciological studies of the ice shelf resulted from Scott's expedition (Wright and Priestley, 1922). Glaciological and geophysical observations were carried out during the First (1928–30), Second (1933–35), and Third (1939–41) Byrd Antarctic Expeditions (Bentley, 1984). During the International Geophysical Year (IGY) (1957–58) and the following International Geophysical Cooperation (IGC) (1958–59), the first general geophysical and glaciological survey of the Ross Ice Shelf was carried out (Crary and others, 1962). The next important program, the Ross Ice Shelf Survey (RISS) (1962–63 and 1965–66), measured ice-surface velocity and snow accumulation along its traverse (Bentley and Jezek, 1981). Throughout the 1960s, airborne radar techniques for measuring ice thickness were developed and used to measure the ice shelf. The 1970s was the decade of the Ross Ice Shelf Project (RISP), which had a goal of drilling through the ice shelf. Under that project, the Ross Ice Shelf Geophysical and Glaciological Survey (RIGGS) (1973–78) was formulated to study comprehensively the entire Ross Ice Shelf, as well as the subglacier terrain (Bentley, 1984). The studies included surface-velocity, mass-balance, temperature, and ice-thickness measurements (Thomas and others, 1984; Bentley, 1984). The thickness measurements ranged from less than 300 m at the ice front to greater than 800 m at the mouth of Whillans Ice Stream (formerly named Ice Stream B) southeast of the map area (Bentley and others, 1979). When RISP was completed, attention shifted across the grounding line of the Ross Ice Shelf and onto the West Antarctic ice sheet to continue similar measurements in the area of the West Antarctic ice streams, the glaciers that feed into the Ross Ice Shelf from the east and most strongly affect its flow. The work was done under the umbrella of the Siple Coast Project (SCP) in the 1980s, which became the West Antarctic Ice Sheet (WAIS) Project in the l990s, largely under the direction of Robert A. Bindschadler at the NASA/Goddard Space Flight Center (Bindschadler, written commun., 2003). The numerous results of this later research are found throughout the scientific literature and in the agenda of the annual WAIS workshops (1994–2006) (http://igloo.gsfc.nasa.gov/wais).

Remote-Sensing Studies

Since the 1960s, remote-sensing studies have become more numerous with the advent of a multitude of satellite sensors and, in fact, have become a part of most glaciological studies of the Antarctic. During the last 30 years, data from imaging and (or) other sensors on NOAA, Landsat, European Remote Sensing (ERS), RADARSAT, DMSP, and other satellites have been used extensively, in addition to information from ground and airborne remote-sensing instruments, and all have contributed greatly to the advance of knowledge of the Ross Ice Shelf area. Some of the image data have been used to make image and image mosaic maps (Ferrigno and others, 1996; Swithinbank and others, 2003a). Radar studies were carried out by Jezek (1980). Radio-echosounding has been used by the Scott Polar Research Institute for thickness determinations (Drewry, 1983) and for ice-dynamics investigations by Neal (1979), among others. Bamber and Bentley (1994) used ERS-1 altimetry data to create a DEM of the Ross Ice Shelf north of lat 81.5° S. that has a cell size of 10 km and an elevation estimate error of about 2 m. They also compared the altimetry with ice-thickness data from RIGGS to show areas of agreement and disagreement.

One of the most interesting topics of study of the Ross Ice Shelf using remotely sensed data has involved the delineation and analysis of surface features, including those caused by differential flow, in order to determine the ice dynamics and glaciological history of the ice shelf. The flow features, variously called flow lines, plumes, or flow stripes, can best be seen on images acquired under low solar-angle conditions or that have been enhanced using special digital techniques. Two of the earliest scientists to examine this application of remotely sensed data in the Ronne-Filchner Ice Shelf area were Crabtree and Doake (1980). Among others who studied surface features with reference to the Ross Ice Shelf were MacAyeal and others (1988), Bindschadler and Vornberger (1990), Casassa and Turner (1991), Casassa and others (1991), and Casassa (1993). A comprehensive paper analyzing flow features of the Ross Ice Shelf, including an excellent bibliography, was published by Fahnestock and others (2000). They used an enhanced composite NOAA AVHRR image to map flow stripes and rifts and to determine a history of discharge variation of the West Antarctic ice streams that feed the ice shelf.

Outlet-Glacier, Ice-Stream, and Ice-Shelf Velocities

Ice-velocity information is important for determining ice flow, coastal change, and mass balance of the ice, as well as for testing ice-shelf models. Prior to RIGGS (1973–78), movement of the Ross Ice Shelf had been measured in localized areas near Ross Island (Stuart and Heine, 1961; Swithinbank, 1970), near the Transantarctic Mountains (Swithinbank, 1964), near the ice front, and south of Roosevelt Island (Dorrer and others, 1969), according to Thomas and others (1984). These measurements were combined with ice-shelf strain rates and a few velocity measurements made during RIGGS that used Doppler (Geoceiver) satellite-tracking equipment to infer ice velocities over the entire ice shelf, flow lines across the ice shelf, and velocity contours (Thomas and others, 1984). The velocities, ranging from <300 to >1,000 meters per year (m a^{-1}), have been contoured and the data made available on the

National Snow and Ice Data Center (NSIDC) Web site (http://nsidc.org/data/velmap/index.html). In addition, ice velocities have been calculated by using feature-tracking methods on Landsat images in the vicinity of Ross Island where the RIGGS measurements are sparse. These velocities range from <100 to ~700 m a^{-1} and are also available at the NSIDC Web site. Contoured ice-velocity information from the NSIDC Web site is shown on the map.

Information from both velocity determinations and from the flow regime has been incorporated into ice-shelf models in order to test and refine interpretations of the discharge history. Some of the flow studies and modeling work on the Ross Ice Shelf have been done by MacAyeal (1989), MacAyeal and others (1996), Hulbe and others (1999), Kenneally and Hughes (2004), and Humbert and others (2005).

Coastal Change

As can be seen on the map, the ice front has changed considerably between 1962 and 2004. Most of the change has been the result of the calving of massive tabular icebergs. The normal behavior of an ice shelf (the floating extension of an ice sheet) is to move seaward, pushed by ice from the grounded ice sheet flowing toward the sea in response to gravity. Generally, ice-shelf velocities increase seaward because the ice is able to spread over its frictionless bed. When the extended ice shelf reaches an unstable position, stresses cause icebergs to calve, often along previously formed rifts. The National Ice Center (NIC), a cooperative endeavor of NOAA, the U.S. Navy Naval Ice Center, and the U.S. Coast Guard, established to provide global ice information for the U.S. national need, identifies and tracks, by using remotely sensed data, all Antarctic icebergs longer than 10 nautical miles that are deemed to be a hazard to navigation. The icebergs are named by a letter based on the Antarctic quadrant where they were originally sighted, followed by a sequential number. For example, B-15 is the fifteenth tabular iceberg to be identified and tracked from the eastern Ross Ice Shelf. The quadrants are bounded by the 0°, 90° W., 180°, and 90° E. longitudes; the eastern Ross Ice Shelf is in quadrant B (90° W. to 180°), and the western Ross Ice Shelf is in quadrant C (180° to 90° E.).

Calving of large tabular icebergs and their subsequent drift patterns have been topics of scientific interest for many years. Swithinbank and others (1977) and Shabtaie and Bentley (1982) carried out some of the first studies. Jacobs and others (1986) and Keys and others (1998) plotted the northward expansion of the Ross Ice Shelf front, starting with its position in 1841, by using data derived from historical accounts and maps, shipboard surveys, and satellite images. They concluded that the ice front is relatively stable and has periods of several decades to more than a century between major calving events. Jacobs and others (1986) compared ice velocities with ice advance between 1962 and 1985, and they determined that little recent iceberg calving had taken place and that west of long 178° E., the 1985 ice front was at its most northerly position in about 145 years.

In October 1987, an iceberg named B-9 calved from the ice front between Roosevelt Island and Edward VII Peninsula. It was 154 by 35 km in size and had an area of about 5,100 km^2 (Keys and others, 1990, 1998). The iceberg removed the equivalent of about 100 years' worth of ice advance in this area. Monitoring the drift of the iceberg greatly increased the knowledge of ocean circulation in the Ross Sea (Keys and others, 1990).

In the last few years, several very large icebergs have calved from other parts of the ice front. On 17 March 2000, one of the largest tabular icebergs ever recorded was seen and named B-15. It calved from west of Roosevelt Island along rifts that had been observed on satellite imagery for several years (Lazzara and others, 1999). It was about 295 km long and 37 km wide, and it had an area of about 10,000 km^2 according to the NIC. Soon afterward, several new icebergs were formed both by the breaking of B-15 into smaller pieces (B-15A, B, C, and D) and by the interaction of B-15 with the ice shelf (B-16, -17, -18, and -19, and C-16). B-15A, the largest remnant of the original B-15, and C-16 drifted west until they collided with Ross Island by December 2001 and December 2000, respectively, where they remained until at least October 2003. In 2006, C-16 drifted north and collided with the Drygalski Ice Tongue, breaking off some of the end of the tongue and creating a new, relatively small (7 × 6 nautical miles) iceberg that was named C-25 according to the NIC. The icebergs disrupted ocean circulation, shipping, and marine life. MacAyeal and others (2003) placed automatic weather stations, ice-sounding radar, seismometers, and tracking devices on B-15A and C-16 for detailed monitoring and to model the effects of future climate change on the ice shelves of Antarctica. Some of the results of six years of observations are given by Kim and MacAyeal (2006) and Okal and MacAyeal (2006). Joughin and MacAyeal (2005) used Interferometric Synthetic Aperture Radar to study the detachment process of icebergs from the Ross Ice Shelf. Their observations and modeling suggested that the tabular iceberg calving was a result of glaciological stresses rather than a result of stresses introduced by ocean or atmosphere.

In May 2002, two additional icebergs, C-18 and C-19, calved from the ice front east of Ross Island. C-19 was another large iceberg with dimensions of 200 km by 35 km. The calving of C-19 returned the Ross Ice Shelf to the size it was in 1911, when first mapped by Scott's expedition (Charles Stearns, University of Wisconsin, written commun., 2002). C-19 drifted west and, by June 2002, collided with B-15A just north of Ross Island, where it created additional disruption to the area (Arrigo and van Dijken, 2003). C-19 then drifted north, rotated, and eventually broke into several pieces. Following the collision of C-19 and B-15A, and maybe because of it, B-15A broke into two large pieces in October 2003 (B-15A and B-15J). These glaciological events are ones for which remotely sensed data and Internet technology played key roles. The dramatic iceberg-calving events from the Ross

Ice Shelf have been monitored since 2000, and the information has been disseminated to the public by the use of numerous different satellite sensors and hundreds of Internet sites. See the Web sites maintained by the University of Wisconsin (http://uwamrc.ssec.wisc.edu/iceberg.html) and NSIDC (http://nsidc.org/iceshelves/index.html) for information about current and historic icebergs.

Map Improvements

One of the earliest uses of Landsat imagery was to make image mosaics to study visually the glaciological features and to map the Ross Ice Shelf, an area that had not been possible to examine previously from the vantage point of regional coverage.

The Ross Ice Shelf has been mapped in whole or in part many times since 1911, including two USGS maps: Ross Ice Shelf, 1972, 1:1,000,000 scale, and McMurdo Sound, 1976, 1:1,000,000 scale. As described in the Sources and Methodology sections, the northern Ross Ice Shelf area map presented here was compiled from annotations of geographic and glaciological features on Landsat 1, 2, 5, and 7 and other imagery that have been georegistered to the RADARSAT image mosaic, so this is geodetically the most accurate map of the northern part of the ice shelf currently available.

The analysis of Landsat imagery for this map series has shown that, in some cases, geographic place-names do not accurately describe geographic and glaciological features. Ice rises, islands, peninsulas, and inlets in Antarctica were often incorrectly identified on earlier maps because of the lack of sufficient information. For example, Roosevelt Island would be named *Roosevelt Ice Rise* on the basis of its glaciologic characteristics.

Summary

The northern Ross Ice Shelf area map covers that part of Antarctica bounded by long 158° W. and 169° E. and by lat 76° and 81° S. The Ross Ice Shelf is the world's largest body of floating ice, and estimates of its size range from 496,000 to 540,000 km^2. The area of the ice shelf digitally measured on this map is 225,044 km^2. The Ross Ice Shelf is probably the ice shelf that has the longest history of scientific studies, beginning with the earliest exploration of the area and followed by many scientific studies such as those included in the IGY, IGC, RISS, RISP, RIGGS, SCP, and WAIS. Velocities determined as part of RIGGS range from <300 to >1,000 m a^{-1}. Other velocities calculated using feature-tracking methods on Landsat images in the vicinity of Ross Island, where the RIGGS measurements are sparse, range from <100 to ~700 m a^{-1}. The majority of the ice shelf, probably about 75 percent, originates from the West Antarctic ice streams. Since 1987, several very large tabular icebergs have calved from the ice shelf. On 17 March 2000, one of the largest icebergs ever recorded was noted and named B-15. It was about 295 km long and 37 km wide, and it had an area of about 10,000 km^2. In May 2002, two additional icebergs, C-18 and C-19, calved from the ice front east of Ross Island. C-19 was another large iceberg, measuring 200 km by 35 km. The calving of C-19 returned the Ross Ice Shelf to the size it was in 1911, when first mapped by Scott's expedition. The northern Ross Ice Shelf area map presented here, compiled from annotations of geographic and glaciological features on Landsat images and georegistered to the RADARSAT image mosaic, is geodetically the most accurate map of the area currently available.

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Table 1. Coastal-change and glaciological maps of Antarctica at 1:1,000,000 scale, published to date.

[Information on ordering published maps can be obtained by calling the U.S. Geological Survey at 1-888-ASK-USGS or by visiting the USGS online at http://www.usgs.gov/pubprod]

As shown on index map	Map number	Map name	Reference (see References Cited)
A	I–2600–A	Trinity Peninsula and So. Shetland Islands	Ferrigno and others (2006)
D	I–2600–D	Ronne Ice Shelf	Ferrigno and others (2005)
E	I–2600–E	Eights Coast	Swithinbank and others (2004)
F	I–2600–F (2d ed.)	Bakutis Coast	Swithinbank and others (2003b)
G	I–2600–G	Saunders Coast	Swithinbank and others (2003a)
H	I–2600–H	Northern Ross Ice Shelf	This report