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Coastal-Change and Glaciological Maps of Antarctica

Changes in the area and volume of the two polar ice sheets in Antarctica (fig. 1) and Greenland are intricately linked to changes in global climate and could result in sea-level changes that would severely affect the densely populated coastal regions on Earth. Melting of the West Antarctica part of the Antarctic ice sheet alone could cause a worldwide sea-level rise of approximately 6 m. The potential sea-level rise after melting of the entire Antarctic ice sheet is estimated to be 73 m. In spite of its importance, the mass balance (the net volumetric gain or loss) of the Antarctic ice sheet is poorly known; it is not known whether the ice sheet is growing or shrinking. As a result, measurement of changes in the Antarctic ice sheet has been given a very high priority in recommendations by the Polar Research Board of the National Research Council, by the Scientific Committee on Antarctic Research (SCAR), and by the National Science Foundation's Office of Polar Programs.

An extensive archive of early 1970's Landsat 1, 2, and 3 Multispectral Scanner (MSS) images of Antarctica was the impetus for the U.S. Geological Survey (USGS), in cooperation with Scott Polar Research Institute (Cambridge, U.K.), to carry out a comprehensive analysis of the glaciological features of the coastal regions of Antarctica. The project was later modified to include analysis of coastal change using Landsat 4 and 5 MSS and Thematic Mapper (TM) images from the late 1980's/early 1990's, declassified 1963 Argon (Corona Program) images, and 1992 and 1995 European Space Agency (ESA) Remote-Sensing Satellite (ERS) radar images. The different data sets allow determination of coastal change in Antarctica over 15–20 years for the MSS and TM images and over as much as 32 years where Argon and ERS images exist, such as the Antarctic Peninsula. Coastal change has been most pronounced in the Antarctic Peninsula in the last few decades, where the Wordie Ice Shelf has practically disappeared, the northern part of the Larsen Ice Shelf has disintegrated, and other ice shelves are also changing. Cooperation with other Antarctic mapping groups now includes scientists from Italy, Russia, Norway, Canada, Australia, Argentina, and Germany.

The coastal-change and glaciological mapping task, an element of the Glacier Studies Project, has five objectives:

- To determine coastline changes in Antarctica that have occurred between the mid-1970's and the late 1980's/early 1990's (Landsat 1–5 MSS and Landsat 4 and 5 TM) and between 1963 and 1995 where the data are available.
- To establish an accurate baseline series of 1:1,000,000-scale maps (fig. 2) that defines, from the analysis of remotely sensed data, the glaciological characteristics (for example, floating ice, grounded ice) of the coastline of Antarctica and the location of floating ice fronts during the time periods represented by the imagery.
- To determine velocities of outlet glaciers, ice streams, and ice shelves from comparison of Landsat images of the same areas taken over time.
- To compile a comprehensive inventory of named (from published maps, gazetteers, and compact discs) and unnamed (from analysis of Landsat

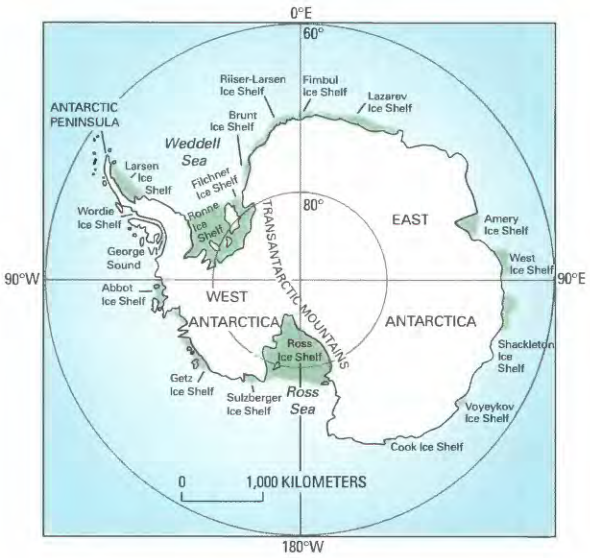
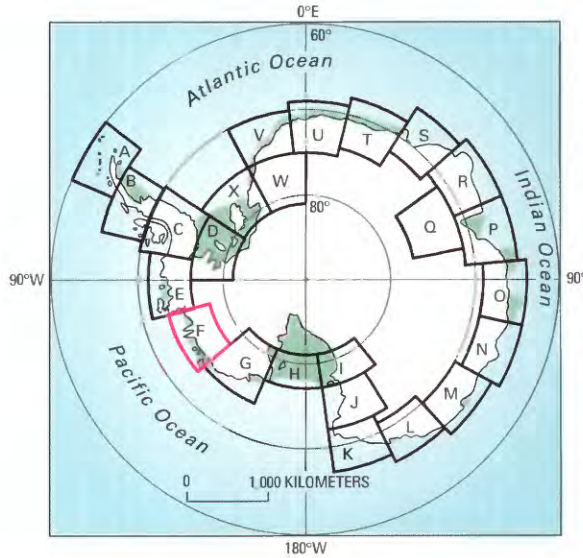


Figure 1. Index map to the principal geographic features of Antarctica, including the ice shelves where large coastal-change events commonly occur.



Planned USGS I-2600 Maps:

A–Trinity Peninsula
B–Larsen Ice Shelf
C–Palmer Land
D–Ronne Ice Shelf
E–Eights Coast
F–Bakutis Coast (1997)
G–Saunders Coast
H–Ross Ice Shelf
I–Ross Island
J–Drygalski Ice Tongue
K–Oates Coast
L–George V Coast
M–Banzare Coast
N–Knox Coast
O–Queen Mary Coast
P–Amery Ice Shelf
Q–Lambert Glacier
R–Mawson Coast
S–Prince Olav Coast
T–Princess Ragnhild Coast
U–Fimbul Ice Shelf
V–Cape Norvegia
W–Caird Coast
X–Berkner Island

Figure 2. Index map showing the locations and names of the 24 planned 1:1,000,000-scale coastal-change and glaciological maps of Antarctica. The first (prototype) map, I–2600–F, "Coastal-Change and Glaciological Map of the Bakutis Coast, Antarctica: 1972–1990," was published by the U.S. Geological Survey in 1997.

images) outlet glaciers and ice streams in Antarctica that are mappable from Landsat and other satellite images.

- To publish the results of the analyses in 24 maps as I–2600–A–X of the USGS Geologic Investigations Series (I-Maps) (fig. 2). Each 1:1,000,000-scale map extends to the southernmost nunatak within each map area or to the southernmost extent of Landsat images (about 81.5°S. lat.). The 1:1,000,000-scale maps will be combined to produce a 1:5,000,000-scale map of Antarctica.

Ice fronts, iceberg tongues, and glacier tongues are the most dynamic and changeable features in the coastal regions of Antarctica. Seaward of the grounding line, the floating ice margin is subject to frequent and large calving events or rapid flow. Both of these situations lead to annual and decadal changes in the position of ice fronts on the order of several kilometers, even tens of kilometers in extreme cases of major calving events (fig. 3).

On the coastal-change and glaciological maps, the positions of the dynamic ice fronts as observed on remotely sensed data have been mapped and annotated with the date of each position. This record makes it possible to analyze changes that have occurred. Although calving does occur along ice walls, the magnitude of the change on an annual to decadal basis is generally not discernible on the images; therefore, ice walls can be used as relatively stable reference features against which to measure other changes along the coast. Only a single observation date is given for the position of ice walls.

Velocities of floating glaciers (such as glacier tongues, ice streams, ice shelves) are determined by two methods: (1) an interactive one in which crevasse patterns are traced visually on images and (2) an autocorrelation program developed by the U.S. National Aeronautics and Space Administration (NASA). The larger glacier tongues and ice shelves have well-developed rift patterns that can be used for velocity measurements. Under optimum conditions, errors can be as small as ±0.02 km per year, but for most Landsat image pairs, where registration of features is not as accurate, the accuracy of velocity vectors is ±0.1 km per year. A third method for calculating ice surface velocity using satellite radar interferometry has been developed by scientists at the California Institute of Technology (Jet Propulsion Laboratory) and NASA and offers promise in some areas.

Producing a sophisticated glacier inventory of Antarctica according to the requirements of the World Glacier Monitoring Service, as part of its ongoing "World Glacier Inventory" program, is impossible with the present state of glaciological knowledge about Antarctica. Landsat and other images and available maps are used in the compilation of the coastal-change and glaciological maps to produce a reasonably complete preliminary inventory of named and unnamed outlet glaciers and ice streams and also to define, more accurately, related glaciological features such as ice domes, ice piedmonts, ice shelves, ice rises, ice rumples, glacier tongues, and iceberg tongues.

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The Coastal-Change and Glaciological Maps of Antarctica effort is being done under the Glacier Studies Project of the Processes and Regional Impacts component of the Global Change and Climate History Program, USGS Global Change Research Program. For more information, visit the World Wide Web site at http://geochange.er.usgs.gov

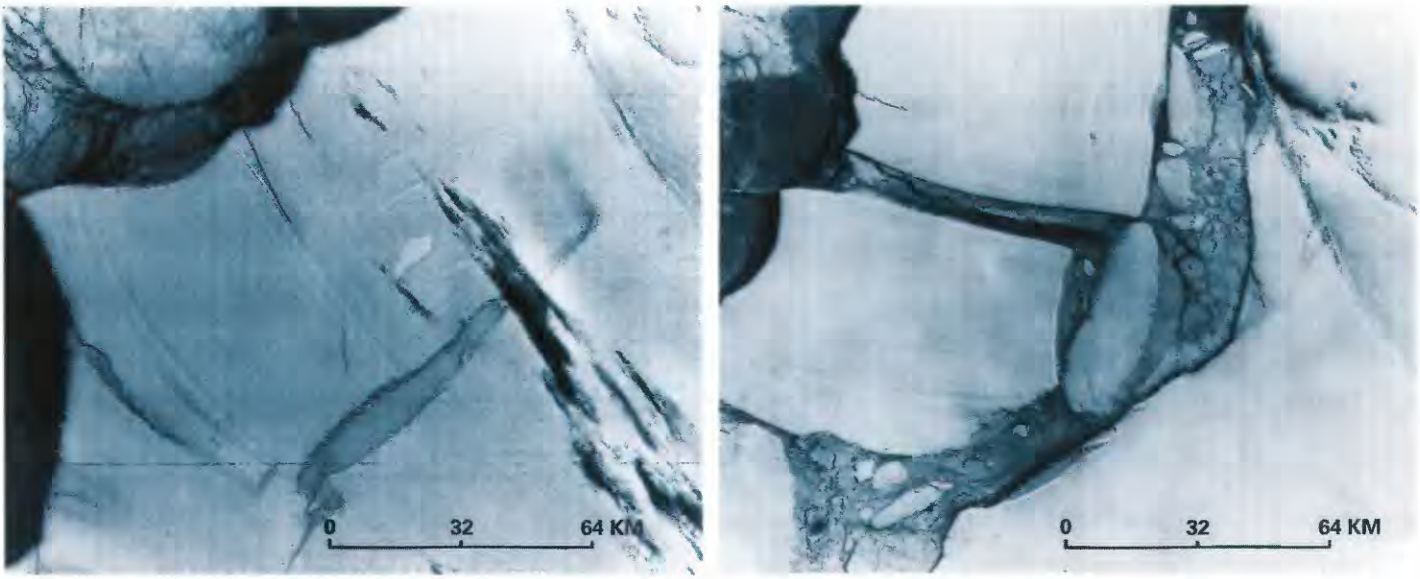

Figure 3. Left, Landsat MSS image of margin of the Filchner Ice Shelf, Weddell Sea, West Antarctica, on 11 November 1973. Right, Landsat MSS image of the same area on 18 October 1986 after a major calving event.