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GLOBAL CHANGE STUDY OF THE CRYOSPHERE OF ANTARCTICA

Final Technical Report

by

Charles W Swithinbank
April 1995

United States Army

EUROPEAN RESEARCH OFFICE OF THE U.S.ARMY
London England

Contract No. DAJA45-91-C-0023

Contractor: Charles W Swithinbank

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REPORT DOCUMENTATION PAGE

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Global Change Study of the Cryosphere of Antarctica

Final Technical Report (No.5)

Period Covered: 1 October 1991 to 30 March 1995

Principal Investigator: Charles W Swithinbank

Abstract: Changes in the area and volume of polar ice sheets are intricately linked with changes in global climate and may severely impact the densely populated coastal regions on Earth. Melting of the West Antarctic part of the ice sheet alone could cause a sea-level rise of as much as 8 m. The potential sea level rise for the entire Antarctic ice sheet is estimated to be 73 m. Global climate is changing, and with it the volume of ice. The purpose of the work was to map recent changes in the coastline of Antarctica and to establish an accurate baseline series of 1:1,000,000-scale maps that define, from the analysis of Landsat images, the glaciological characteristics of the coastline of Antarctica during two time intervals (mid-1970's and late 1980's/early 1990's). A total of 240 separate map drawings have been completed—all of them based on interpretation of Landsat images. These form the basis for a series of 24 coastal maps being produced by the US Geological Survey.

Key words: Glaciology, Antarctica, maps.

Note: This report is not intended for publication. The final product of the study consists of maps based on my work—to be published by the US Geological Survey.

INTRODUCTION

Changes in the area and volume of polar ice sheets are intricately linked to changes in global climate and may severely impact the densely populated coastal regions on Earth. Melting of the West Antarctic part of the Antarctic ice sheet alone could cause a sea-level rise of as much as 8 m. The potential sea level rise for the entire Antarctic ice sheet is estimated to be 73 m (Williams and Hall, 1993). 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 (National Research Council, 1985). As a result, measurement of changes in the Antarctic ice sheet was given a very high priority in recommendations by the National Research Council (1986), the Scientific Committee on Antarctic Research (SCAR) (1989), and the National Science Foundation (1990). A set of mostly mid-1970's Landsat images of Antarctica formed the initial impetus for preparing a series of 24 1:1,000,000-scale maps of the coastal regions of Antarctica (Williams and Ferrigno, 1988), later modified to include Landsat 4 and 5 MSS and thematic mapper (TM) images to compare changes over a 15- to 20-year time interval (Fig.1).

OBJECTIVES

The Global Change Study of the Cryosphere of Antarctica has five objectives:

1. to determine coastline changes that have occurred during the past two decades;
2. to establish an accurate baseline series of 1:1,000,000-scale maps that defines, from the analysis of Landsat images, the glaciological characteristics of the coastline of Antarctica during two time intervals (mid-1970's and late 1980's/early 1990's);
3. to determine average velocity vectors on outlet glaciers, ice streams, and ice shelves from sequential Landsat images;
4. to compile a comprehensive inventory of named and unnamed outlet glaciers and ice streams mappable from Landsat images or derived from ancillary sources (e.g., maps, gazetteers, etc.) in

Antarctica (Swithinbank, 1980, 1985, 1988; National Science Foundation, 1989);

5. to compile a 1:5,000,000-scale map of Antarctica derived from the 24 1:1,000,000-scale maps.

SOURCES

Images used in the compilation were obtained from either the U.S. Geological Survey's EROS Data Center, Sioux Falls, SD 57198 or the Earth Observation Satellite (EOSAT) Corporation, 4300 Forbes Blvd., Lanham, MD 20706. The optimum Landsat 1, 2, and 3 MSS and Landsat 4 and 5 TM images were used. The 1:500,000-scale prints of Landsat images used in the analytical phase were enlarged from three types of source material: (1) 1:3,369,000-scale transparencies from the EROS Data Center, (2) 1:1,000,000-scale black-and-white or false-color-infrared prints from EOSAT, and (3) 1:500,000-scale black-and-white prints made from digitally enhanced images at the U.S. Geological Survey's Image Processing Facility, Flagstaff, AZ.

METHODOLOGY

The primary steps in the compilations were as follows:

1. Identification of optimum Landsat MSS or TM images for the two time intervals: mid-1970's and late 1980's/early 1990's and enlargement to a nominal scale of 1:500,000.

2. Identification and plotting of geodetic-control points on Landsat images from geodetic field-survey information (e.g., field notebooks, tables, vertical and trimetrogon aerial photographs, and maps) archived in the U.S. Geological Survey's SCAR Library (Reston, VA). Plotting of pass-points on overlapping Landsat images to provide ties between images in areas where geodetic ground control does not yet exist.

3. Annotation of glaciological features on 1:500,000-scale clear plastic overlays of each of the selected Landsat images for each time interval. A total of 240 separate map drawings were completed.

4. Transfer of geodetic control points and pass-points to annotated overlays.

5. Transfer of the mid-1970's annotated overlays to the late 1980's/early 1990's overlays derived from Landsat 4 or 5 TM images, because the TM images provide the most geometrically accurate base.

6. Tranfer of the combined annotated overlays to a series of 1:500,000 -scale oblique mercator map projections plotted on lightly frosted mylar.

7. Digitization, using the U.S. Geological Survey's MAPGEN/DIGIN software (Evenden and Botbol, 1985), of glaciological annotations and other related information on the oblique mercator projections by attribute code.

8. Transformation of digitized annotations to a 1:1,000,000-scale polar stereographic map base (standard parallel at 71°S. lat) using the U.S. Geological Survey's MAPGEN software (Evenden, 1990).

9. Addition of velocity vectors, geographic place-names, and selected topographic and bathymetric contours.

10. Analysis of coastal changes and glaciological features.

ANALYSIS

Coastal Change

As would be expected, the 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 of outlet glaciers, ice streams, and ice shelves, 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. Although calving does occur along ice walls, the magnitude of change on an annual to decadal basis is generally not discernible on Landsat 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

Velocities of glacier tongues, ice streams, and ice shelves were calculated by sequential tracking of crevasse patterns. Under optimum conditions, errors can be as small as ± 0.02 km a^{-1}, but for most Landsat image pairs, the accuracy of velocity vectors is ± 0.1 km a^{-1}. The larger glacier tongues and ice shelves have well-developed rift patterns that can be used for velocity measurements. From 10 to 50 measurement points were made for each glacier tongue or ice shelf. (Lucchitta and others, 1993). Fig.2 shows an extract from the Bakutis Coast map sheet, with velocity vectors.

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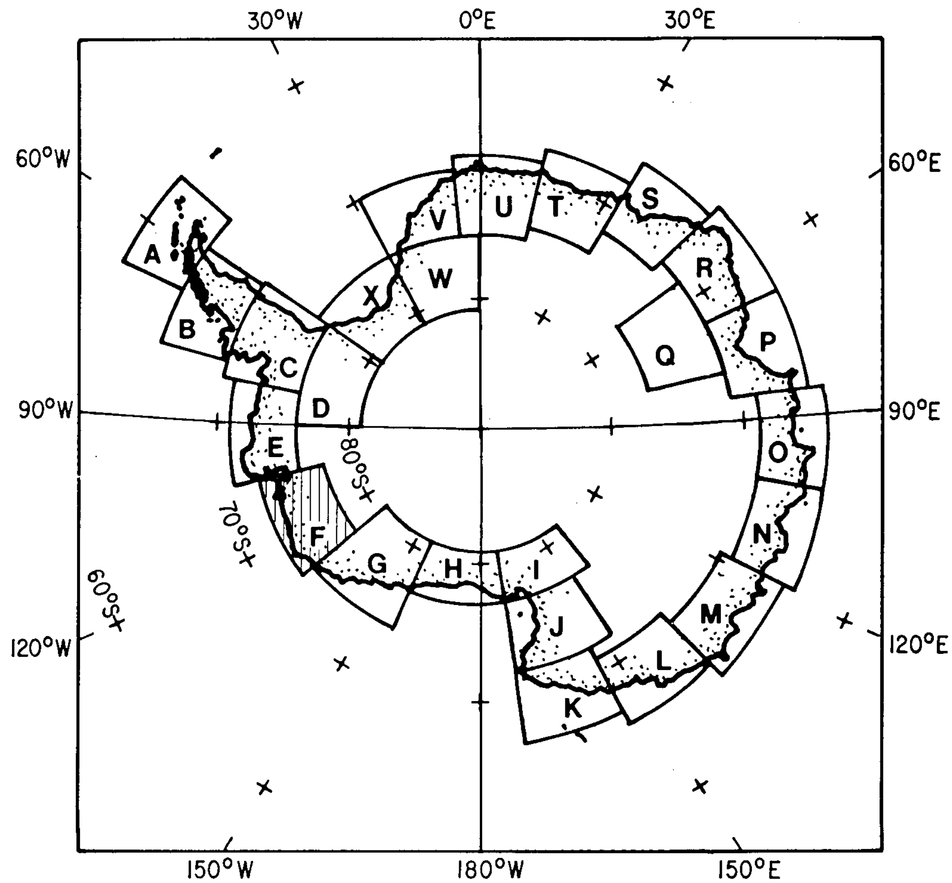

A – TRINITY PENINSULA
B – LARSEN ICE SHELF
C – PALMER LAND
D – RONNE ICE SHELF
E – EIGHTS COAST
F – BAKUTIS COAST
G – SAUNDERS COAST
H – ROSS ICE SHELF
I – ROSS ISLAND
J – DRYGALSKI ICE TONGUE
K – OATES COAST
L – GEORGE V COAST
M – BANZARE COAST
N – KNOX COAST
O – QUEEN MARY SHELF
P – AMERY ICE SHELF
Q – LAMBERT GLACIER
R – MAWSON COAST
S – PRINCE OLAV COAST
T – PRINCESS RAGNHILD COA
U – FIMBUL ICE SHELF
V – CAPE NORVEGIA
W – CAIRD COAST
X – BERKNER ISLAND

Fig.1 Antarctic coastal image maps at 1:1,000,000 scale

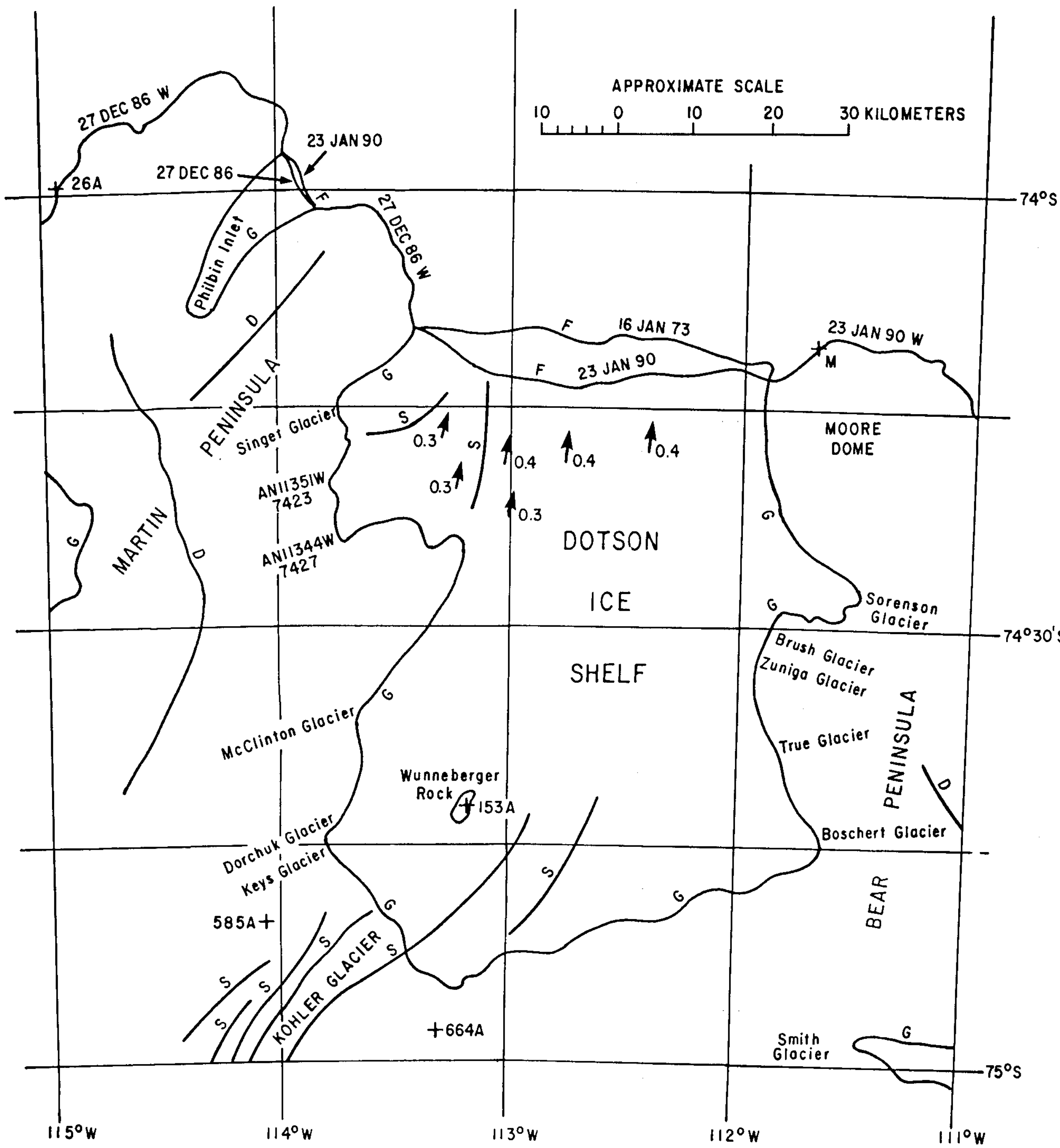

Fig.2 Sample from Sheet F of Antarctic coastal image maps