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INVENTORY OF ARCTIC LASER TERRAIN PROFILES.(U)  
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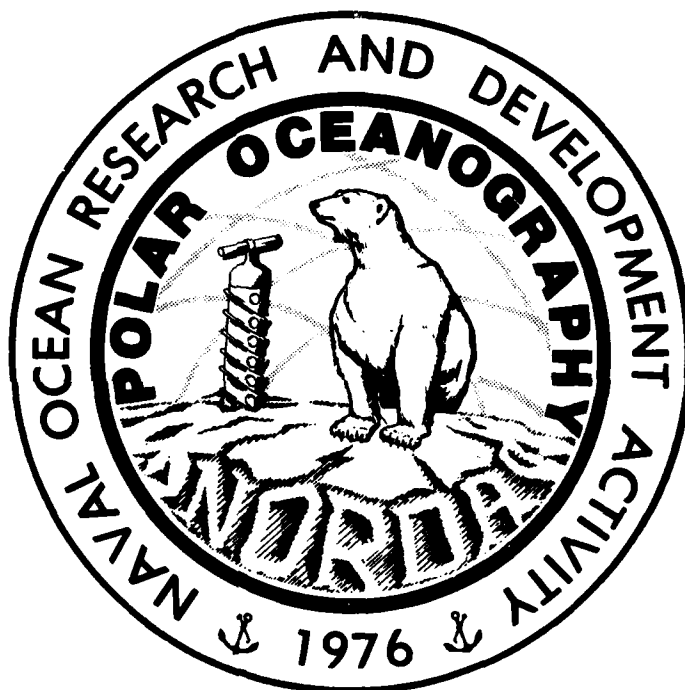
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NORDA Technical Note 136

Naval Ocean Research  
and Development Activity  
NSTL Station, Mississippi 39529



# Inventory of Arctic Laser Terrain Profiles



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January 1982

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ABSTRACT

Ten maps show where and when 90,000 km of airborne laser terrain profiles of Arctic sea ice have been obtained. The laser terrain profiling system is briefly described. The data reduction procedure is also briefly described.

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## I. INTRODUCTION

The purpose of this note is to describe the inventory of collection time and geographical location of historical laser terrain profile data obtained over Arctic sea ice. Track lines on the included maps show areas of recorded laser altimeter and reflectometer data held in the NORDA magnetic tape library. These maps are not meant to be cartographic plots but rather indicators of when and where data is available.

The data on file has been collected on an opportunity basis since 1970 and is stored on 193 magnetic tapes, which contain approximately 180,000 km of track lines. Approximately 90,000 km of track lines are shown on the maps. These tracks were plotted from navigation and laser data logs and contain the longest segments of continuous data. Many shorter runs (<40 km) also exist in the records for specific geographical locations.

The detailed description of the data reduction method written and used at NORDA can be found in Lohanick (1981). In brief, the selected tape containing the chosen data track is played on an Ampex FR-1300 tape recorder through an HP2240A (analog/digital converter). The analog voltages are then digitized to make them compatible for reading by the HP9845B (tabletop computer). The data is stored on flexible discs driven by an HP9885M (flexible disc drive) for manipulation, and a plot of the data is generated on a CRT display to be analyzed. Discontinuities present in raw laser data such as phase shifts, drop outs, noise spikes and other peculiarities discussed in Holyer, et al., 1977, must be removed to obtain a precise description of the terrain. Computer programs have been written and designed to automatically remove some discontinuities in the data, but the process was unsatisfactory since the profiles had to be examined

afterward and edit errors had to be discarded or further treated. The most efficient editing procedure thus far involves a trained analyst with recognition and alteration exchange capabilities with the data being addressed on the flexible disc and processed by the computer.

The final sequential procedure of data reduction to recover a terrain profile is the removal of aircraft motion. These long wavelength undulations in the data are the result of aircraft variation in pitch and roll during normal flight. Aircraft motion removal has been performed previously by numerical Hamming filters (Hibler, 1972; Holyer, *et al.*, 1977; and Lohanick, 1979). However, on a tabletop computer (HP9845B) the amount of time required to complete this procedure is a reduction ratio in excess of 700:1, requiring approximately 60 hours of computer time to extract the aircraft motion present in five minutes of laser data. The present procedure utilized is a three step active filtering scheme discussed in Hibler (1972) and Lohanick (1981).

The final product stored on the disc represents a precise profile of the ice/snow surface directly below the aircraft along the track lines indicated on the maps.

## II. BACKGROUND

Airborne experiments over the Arctic Pack Ice were conducted from 1962 to 1975 by the Naval Oceanographic Office (NAVOCEANO). From 1975 to the present the program has been conducted by the Naval Ocean Research and Development Activity (NORDA). The purpose is to obtain data pertaining to the Arctic environment as well as to explore the feasibility and limitations of remote sensing of sea ice

using infrared scanners, side-looking radar, passive microwave imagers, aerial photography, and the principal subject of this note: the laser altimeter terrain profiling system.

The laser profilometer functions as a very precise altimeter, with a very rapid response time. The system used extensively in the Arctic is a Spectra Physics Geodolite 3A, which uses a modulated CW laser to obtain a continuous measurement of instrument height above the surface. A detailed description of the system can be found in Ketchum (1971). In brief, the transmitted signal is amplitude-modulated at selected frequencies producing 25 milliwatts (mW) of red light at 632.8 nm. The outgoing beam is about 20 mm in diameter and illuminates a spot on the surface about 30.5 mm in diameter from an altitude of 300 m. A receiving telescope 20.3 cm in diameter collects a fraction of the reflected light and brings it to focus on the cathode of a photomultiplier tube where the light is converted into an electrical signal and amplified. The phase shift between the modulations on the transmitted and received beams is measured, giving a precise distance from the aircraft to the ice surface. The highest modulation frequency produces a phase shift of  $2\pi$ , which corresponds to a range height of 3.05 m; the vertical precision is about 20 mm, and the vertical resolution is greater over a limited height differential. The magnitude of the continuous electrical signal is recorded on FM analog tape with a coincident time code channel. The correlation of the time code record with navigation logs yields the geographical sequence of recorded events.

### III. APPLICATION

The sea ice terrain profiles produced when the raw laser data is reduced can be directly applied to a variety of Arctic investigations. Statistical data

analysis can yield information regarding the overall and regional distribution of various sea ice features and conditions such as "roughness," ridge height distribution and frequency, power spectral density, and for input to and refinement of various ice prediction models. The laser profiling system is not restricted by Arctic darkness, and it eliminates inherent human limitations for objectively and quantitatively estimating vertical magnitudes of ice canopy features. Historical trends and alterations along with future predictive changes will become more apparent and precise as the data collection process is continued and repeated for various times and locations.

Transforming the data collected by this system to a reasonable format for manipulation has been the subject of various authors (Hibler, 1972; Holyer, et al., 1977; and Lohanick, 1981). However, the application of laser altimeter data has been limited to local areas viewing short track lines (the exception is Wadhams, 1975). The main reason for this lack of application has been due to the amount of time and labor previously required for reduction of long tracks of laser data. Applying the reduction scheme used at NORDA 10 minutes of real time data or more can be completely reduced in a single day. This time segment spans a track line 65 km with sampled point spacing approximately one meter apart. Thus, the quantity of information yielded from this resource is extremely large. Approximately 10,000 km of the data presented in this note have been reduced and are presently being analyzed to obtain the population density function for "roughness" of the Arctic ice cover. The 10,000 km data set will serve as the data base to which future reduced laser profiles can be added. Data reduction will proceed at NORDA according to geographic priority, seasonal priority, and funding.

#### IV. THE MAPS

The maps have been arranged to allow the least confused and uncluttered appearance. Clearly, more information could have been placed on each map; however, the ability to distinguish time and position would be greatly reduced at the necessary scale.

Each map shows the aircraft track for the month and year the laser terrain profile data was obtained. There are 10 maps showing approximately 90,000 km of track lines from November 1970 to May 1980.

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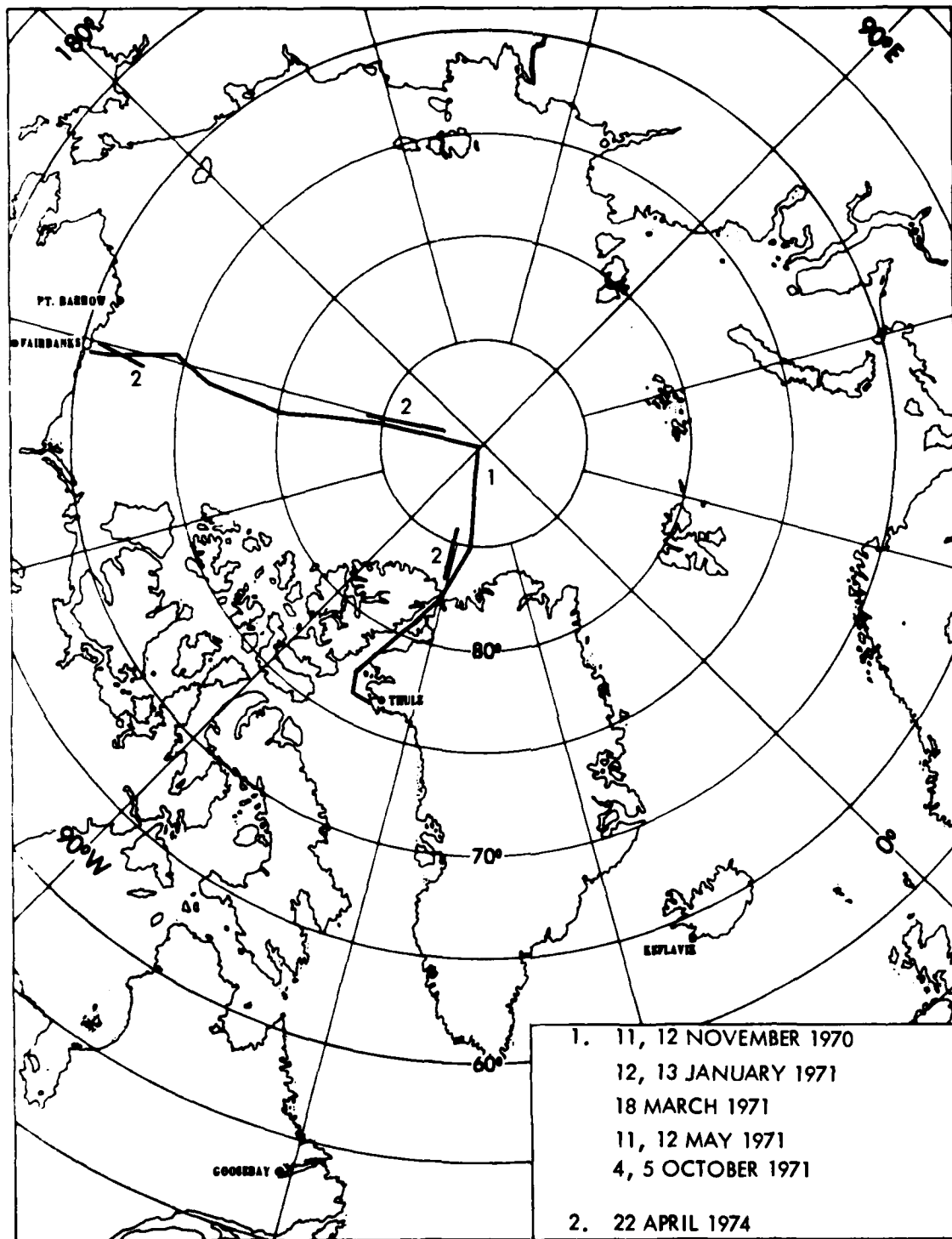
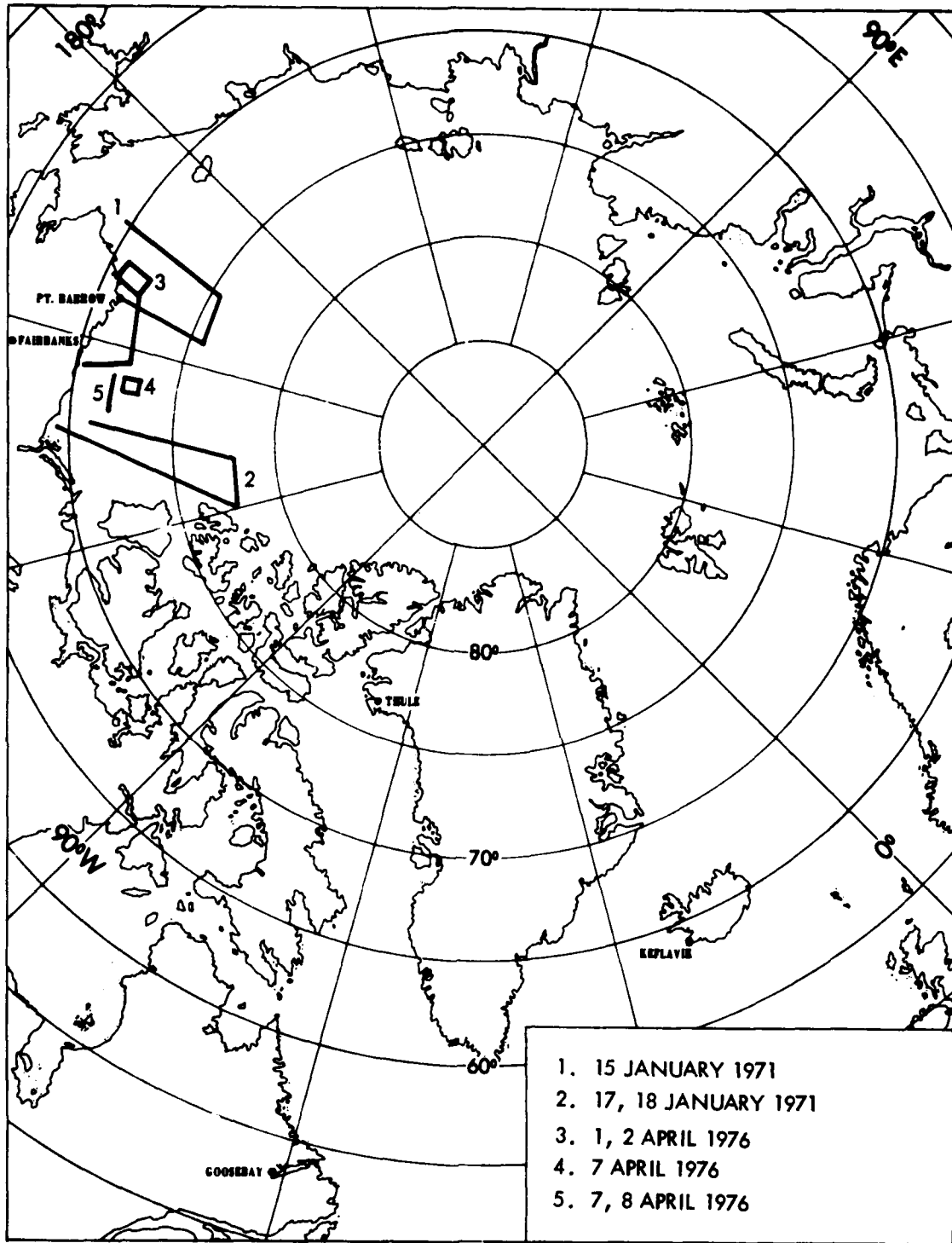
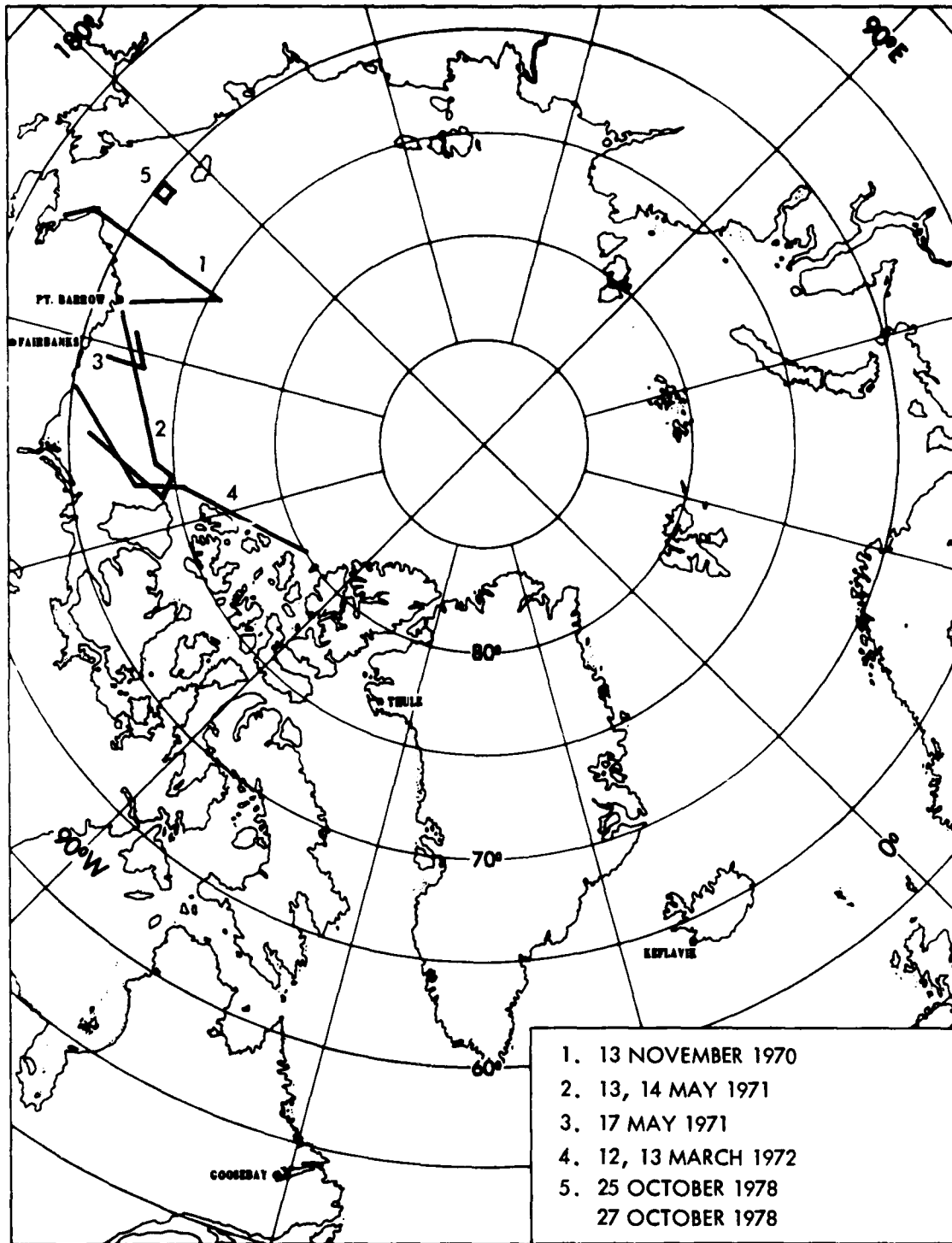


Figure 1. Arctic Basin, November 1970 to April 1974



□ indicates area of intensive coverage by numerous short track lines.

Figure 2. Beaufort Sea, January 1971 to April 1976



□ indicates area of intensive coverage by numerous short track lines.

Figure 3. Beaufort Sea, November 1970 to October 1978

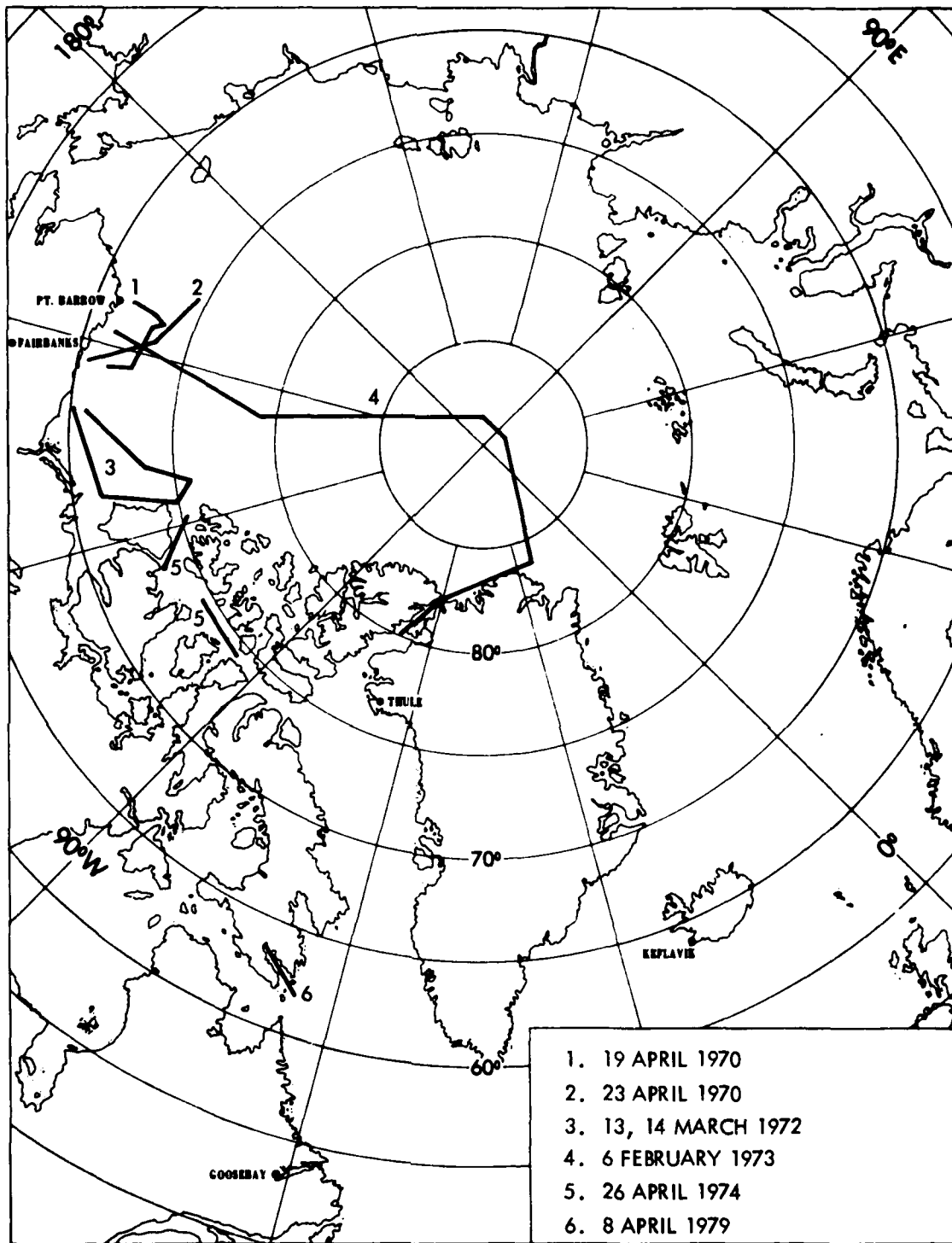
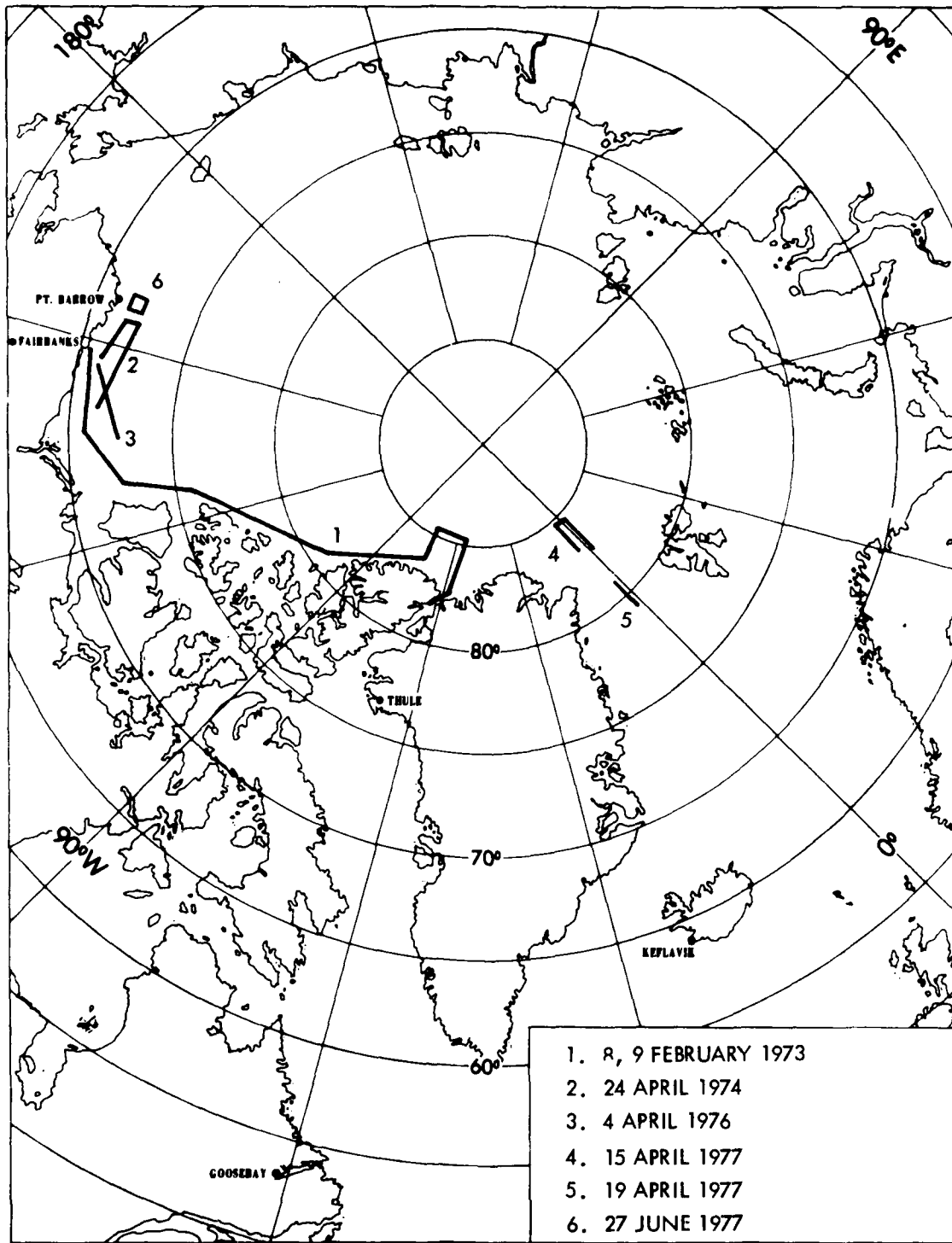
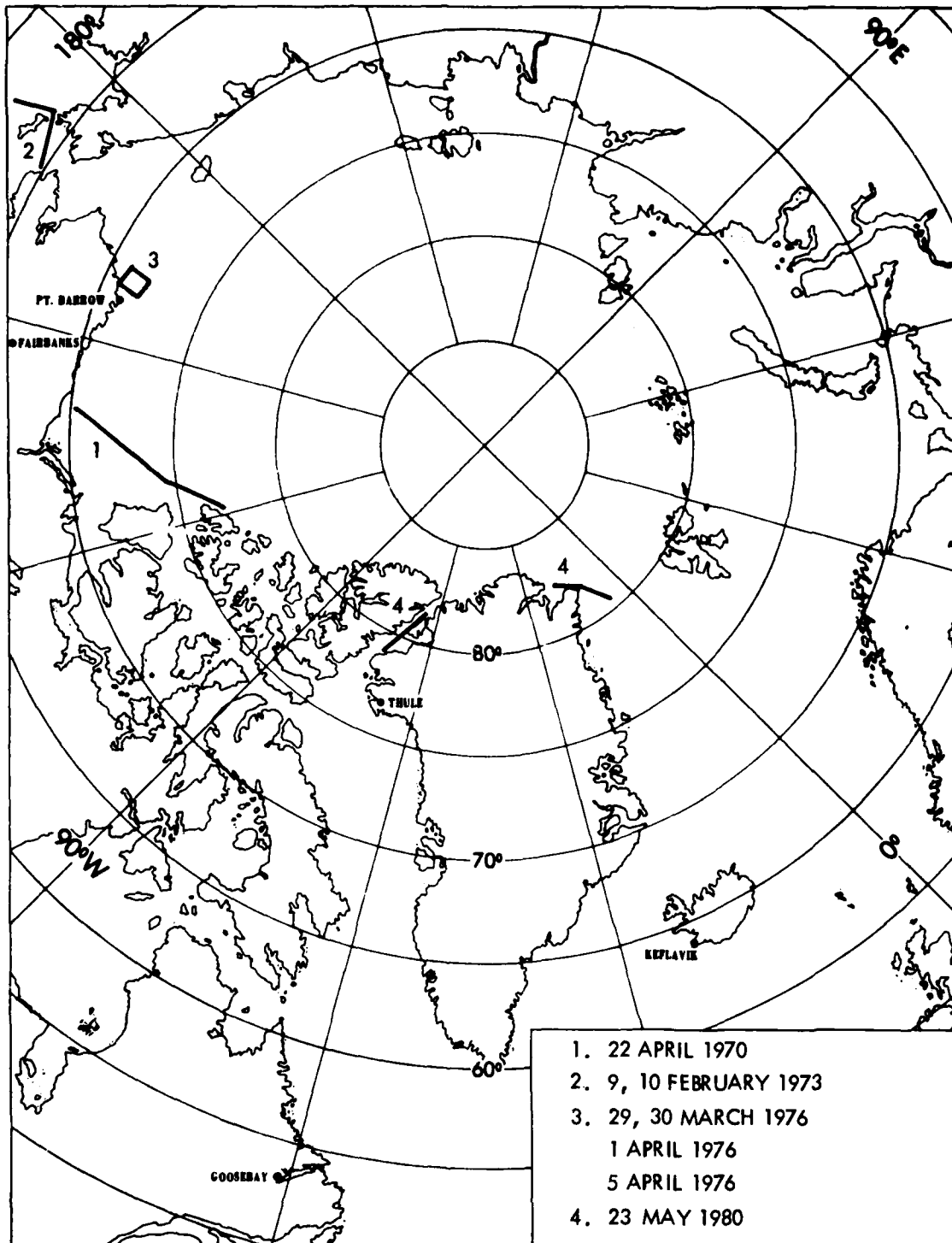


Figure 4. Beaufort Sea, Canadian Archipelago and Central Arctic, April 1970 to April 1979



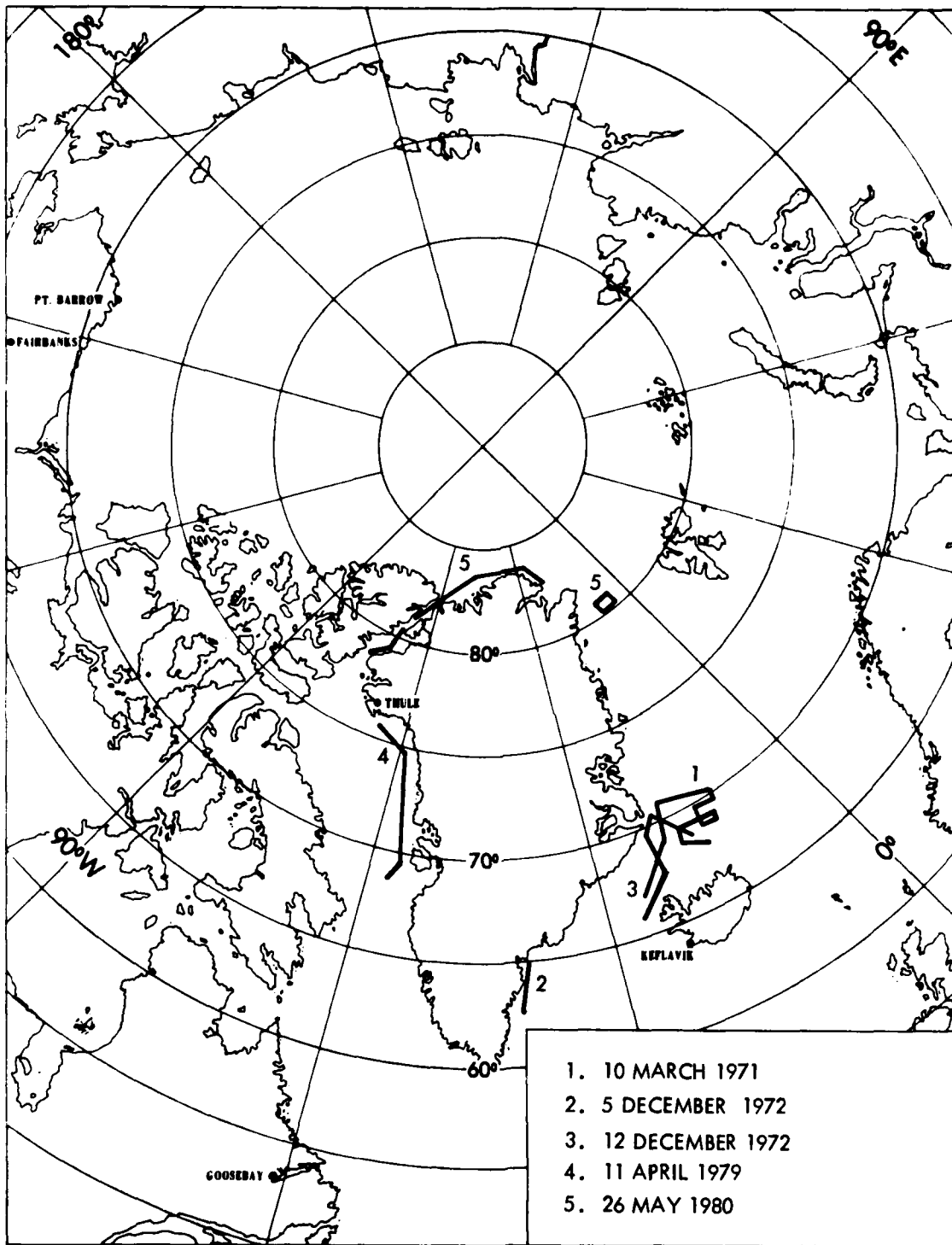
□ indicates area of intensive coverage by numerous short track lines.

Figure 5. Beaufort Sea, Canadian Archipelago and Greenland Sea, February 1973 to June 1977



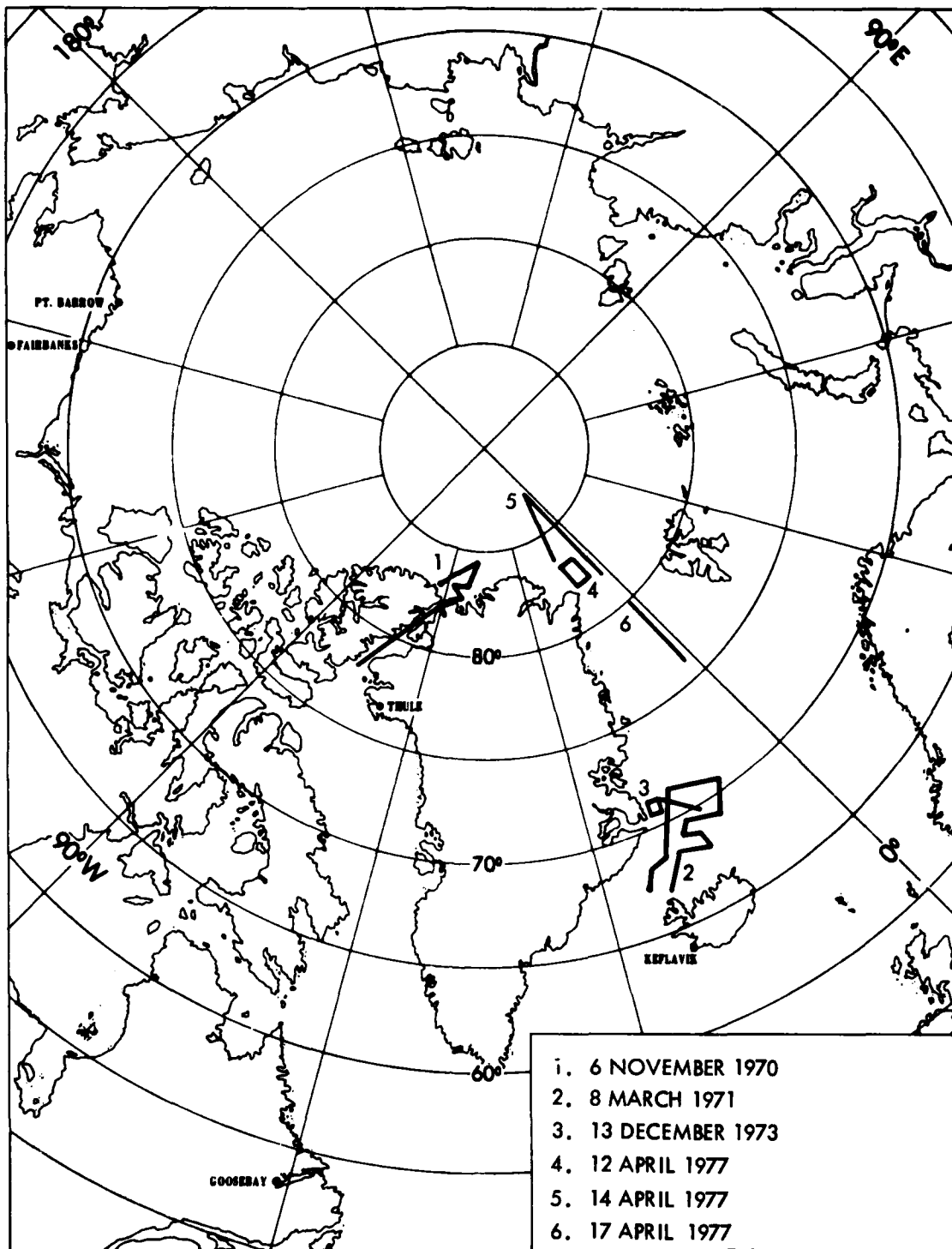
□ indicates area of intensive coverage by numerous short track lines.

Figure 6. Bering Strait, Beaufort Sea, Kennedy channel and Greenland Sea, April 1970 to May 1980



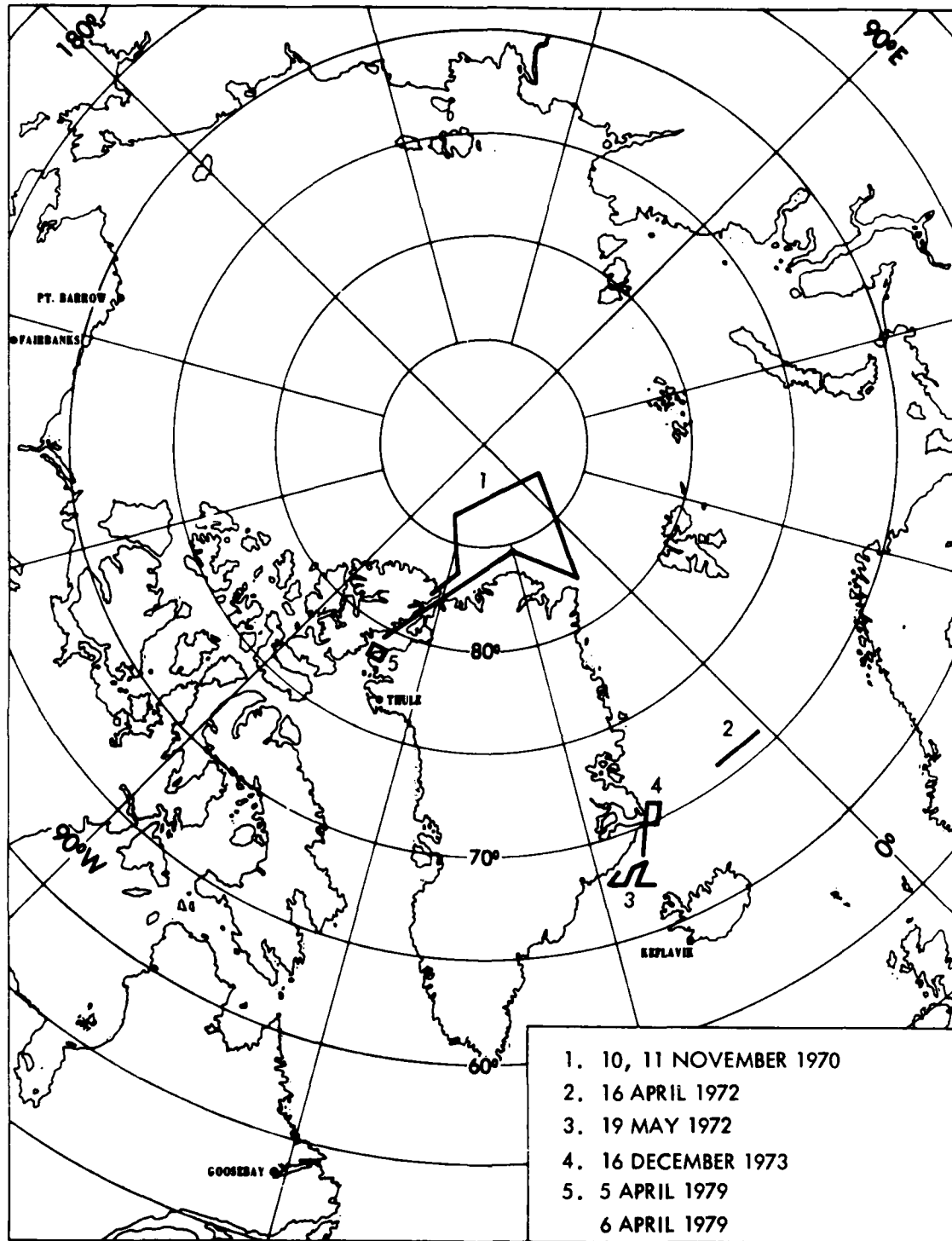
□ indicates area of intensive coverage by numerous short track lines.

Figure 7. Eastern Arctic, March 1971 to May 1980



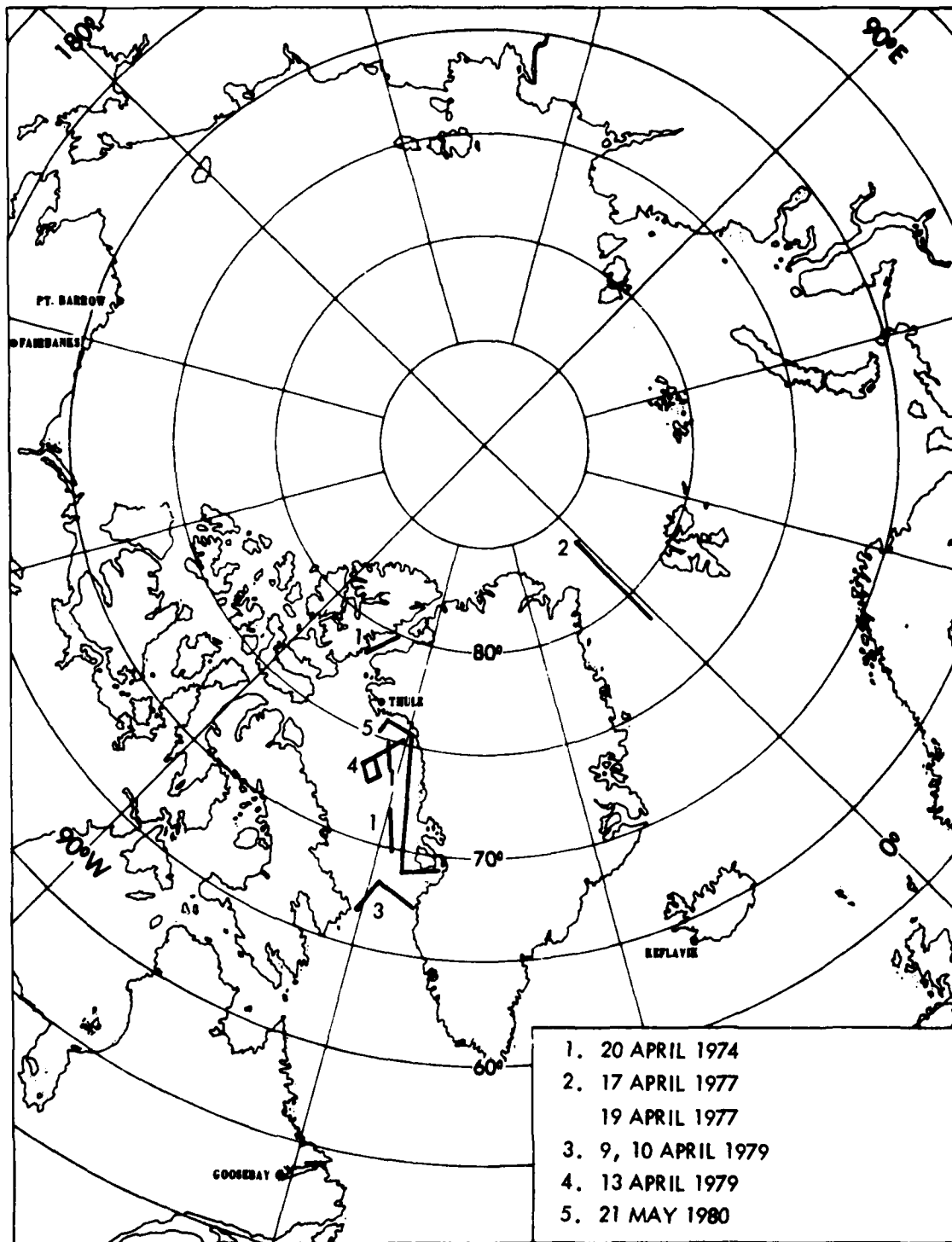
□ indicates area of intensive coverage by numerous short track lines.

Figure 8. Eastern Arctic, November 1970 to April 1977



□ indicates area of intensive coverage by numerous short track lines.

Figure 9. Lincoln Sea, Kennedy channel Norwegian Sea and Denmark Strait, November 1970 to April 1979



□ indicates area of intensive coverage by numerous short track lines.

Figure 10. Baffin Bay, Davis Strait Smith Sound and Greenland Sea, April 1974 to May 1980

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