

INVENTORY OF ARCTIC LASER TERRAIN PROFILES

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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.

RÉSUMÉ. *Inventaire des profils au laser dans l'Arctique.* Dix cartes montrent où et quand ont été relevés 90 000 km de profils aériens au laser de la glace de mer Arctique. On décrit brièvement le système de mesures des profils au laser. On décrit aussi brièvement les méthodes de réduction des données.

ZUSAMMENFASSUNG. *Inventar arktischer Laser-Geländeprofile.* In 10 Karten wird dargestellt, wo und wann Laser-Geländeprofile von 90 000 km Länge über arktischem Meereis gewonnen wurden. Das Laser-Aufnahmesystem wird kurz beschrieben, ebenso wie das Verfahren zur Daten-Reduktion.

1. 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 are available.

The data on file have been collected on an opportunity basis since 1970 and are 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 a HP2240A (analog/digital converter). The analog voltages are then digitized to make them compatible for reading by the HP9845B (table-top computer). The data are stored on flexible discs driven by a 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 by Holyer and others (1977) must be removed to obtain a precise description of the terrain. Computer programs designed to automatically remove some discontinuities in the data have been written but the process was unsatisfactory since the profiles had to be examined afterwards 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, the data being addressed on the flexible disc and processed by the computer.

The final 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 and others, 1977; Lohanick, 1979). However, on a table-top computer (HP9845B) the amount of time required to complete this procedure is a reduction ratio in excess of 700:1; requiring approximately 60 h of computer time to extract the aircraft motion present in 5 min of laser data. The procedure being utilized at present is a three step active filtering scheme discussed by 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.

2. 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 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 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 2π which corresponds to a range height of 3.05 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.

3. APPLICATION

The sea-ice terrain profiles produced when the raw laser data are 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, for input to and for 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 and others, 1977; Lowry and Brochu, 1978; 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 the amount of time and labor previously required for reduction of long tracks of laser data. Applying the reduction scheme used at NORDA a minimum of 10 min of real time data can be completely reduced in a single day. This time segment spans a track line of 65 km with sampled points spaced approximately 1 m apart. Thus, the quantity of information yielded from this resource is extremely large. The 10 000 km of data coverage presented in this note has been reduced and is 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.

The potential contribution of this very large data set is directed toward understanding the dynamics of sea ice in the polar seas.

4. THE MAPS

The maps (Figs 1–10) 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.

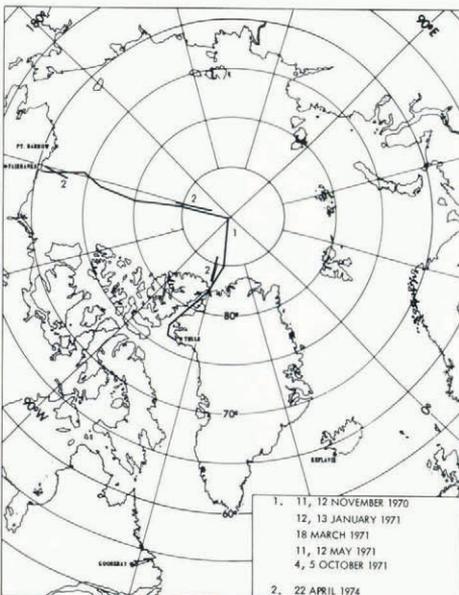


Fig. 1. Arctic basin, November 1970 to April 1974.

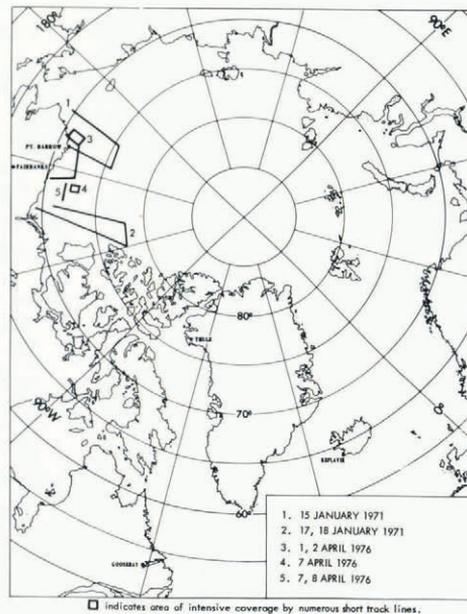


Fig. 2. Beaufort Sea, January 1971 to April 1976.

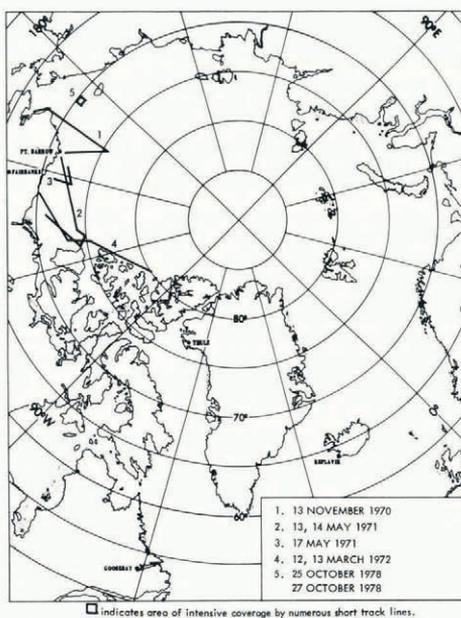


Fig. 3. Beaufort Sea, November 1970 to October 1978.

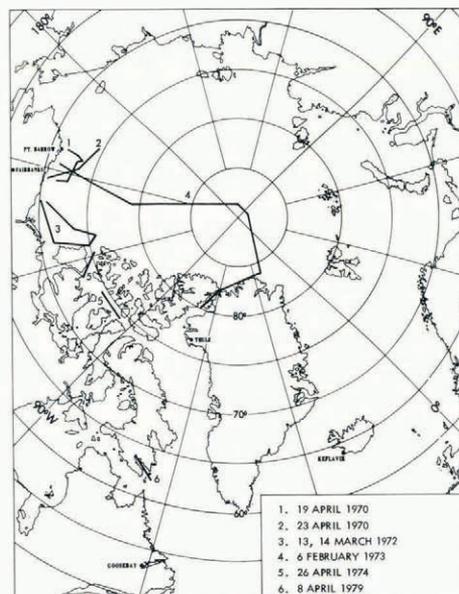


Fig. 4. Beaufort Sea, Canadian Archipelago, and Central Arctic, April 1970 to April 1979.

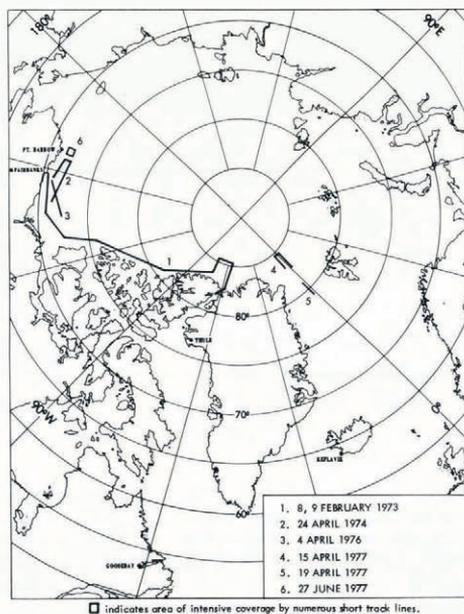


Fig. 5. Beaufort Sea, Canadian Archipelago, and Greenland Sea, February 1973 to June 1977.

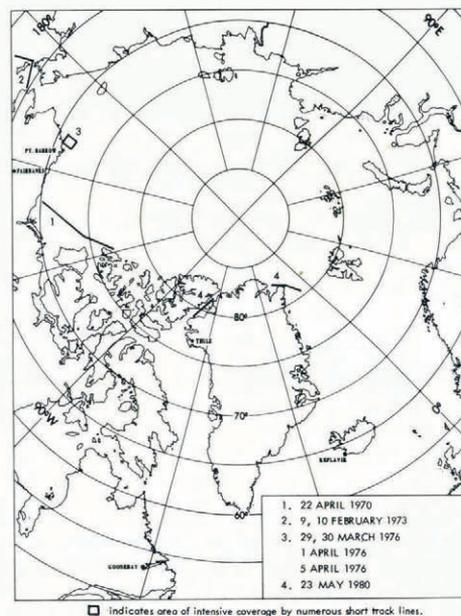


Fig. 6. Bering Strait, Beaufort Sea, Kennedy Channel, and Greenland Sea April 1970 to May 1980.

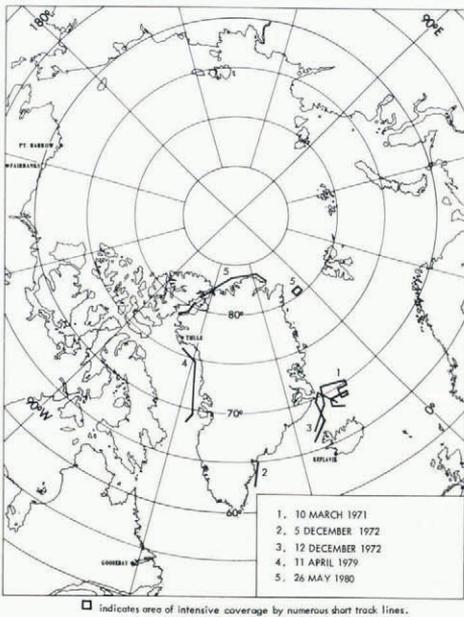


Fig. 7. Eastern Arctic, March 1971 to May 1980.

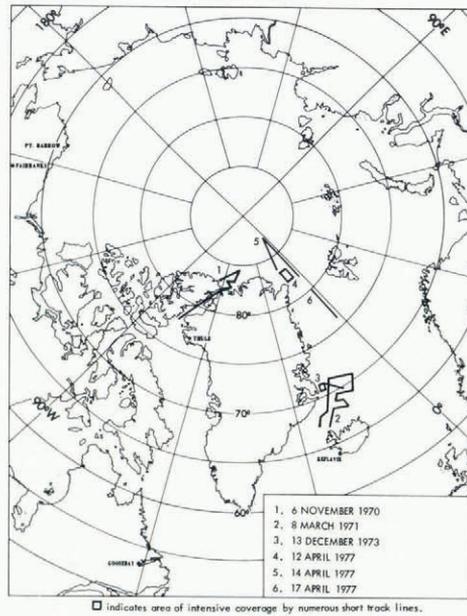


Fig. 8. Eastern Arctic, November 1970 to April 1977.

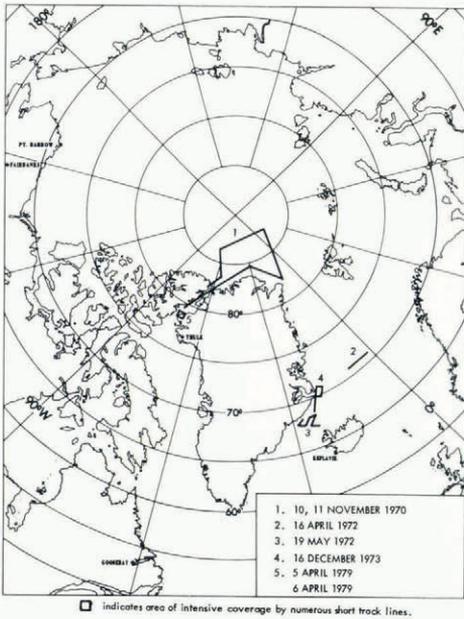


Fig. 9. Lincoln Sea, Kennedy Channel, Norwegian Sea, and Denmark Strait, November 1970 to April 1979.

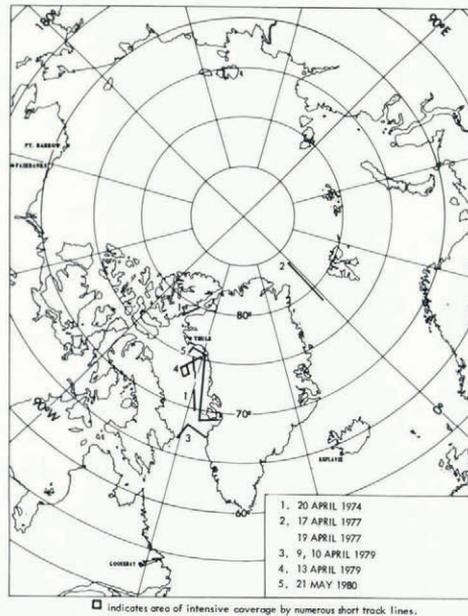


Fig. 10. Baffin Bay, Davis Strait, Smith Sound, and Greenland Sea, April 1974 to May 1980.

Each map shows the aircraft track for the month and year the laser terrain profile data were obtained. There are ten maps in all which show approximately 90 000 km of track lines from November 1970 to May 1980.

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