ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.

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N73-11297

10 November 1972

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Attention: Mr. James R. Greaves
ERTS Scientific Monitor, Code 651

Subject: ERTS-A Proposal No. SR126: Evaluate the Application of ERTS-A Data for Detecting and Mapping Sea Ice

Principal Investigator: James C. Barnes, PR525

Gentlemen:

This is the second bimonthly Type I Progress Report describing work performed by Environmental Research & Technology, Inc. (ERT), for the National Aeronautics and Space Administration under Contract No. NAS 5-21802. This report covers the period from 31 August to 31 October 1972.

The purpose of this investigation is to evaluate the application of imagery from the ERTS-A RBV and MSS sensors for surveillance of sea ice. The objectives are: to determine the spectral interval most suitable for ice survey; to measure the scale and types of ice features that can be detected; and to develop simplified interpretive techniques for differentiating ice from cloud and for mapping ice features. The results will enable the maximum use of data from ERTS and future spacecraft systems for operational ship routing, compilation of ice charts, and scientific research.

A. ACCOMPLISHMENTS DURING REPORTING PERIOD

1. Data Collection

Data have been received for nearly 100 ERTS-1 passes over the Arctic during the period from 25 July to 7 October 1972. Using the techniques described in the first progress report (6 September) to identify sea ice, this data sample has been screened to select suitable passes for further analysis. The screening has revealed that approximately two-thirds of the original passes are not usable either because of cloud observation or because of the lack of visible ice. The 32 passes in which ice can be identified are in the areas listed on the following page:

(E72-10199) EVALUATE THE APPLICATION OF ERTS-A DATA FOR DETECTING AND MAPPING SEA ICE Bimonthly Progress J.C. Barnes (Environmental Research and Technology, Inc.) 10 Nov. 1972 12 p CSCL 08L G3/13
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Mid-Beaufort Sea	-	11 passes
Prince Patrick Is., Banks Is.		
Amundsen Gulf	-	10 passes
Hudson Bay	-	2 passes
East Coast of Greenland	-	4 passes
West Coast of Greenland	-	2 passes
Baffin Is., Baffin Bay, and Ellesmere Is.	-	3 passes

Through review of the 16 mm microfilm covering the first 18-day observation cycle, as well as data in the NASA-GSFC ERTS-1 browse facility, 10 additional passes depicting sea ice have been selected. Most of these passes are in the region of Devon Island, Somerset Island and Prince of Wales Island, an area that was not included in the initial standing order request. These passes have been ordered through the retrospective data request procedure.

2. Initial Analysis Procedures

The 9.5 inch positive prints containing identifiable sea ice are in the process of being assembled and analyzed. Where more than one frame on a pass has been received, the frames are being mosaiced and mounted on cardboard backing. Acetate overlays are being used for mapping features from the images. Identification of land areas is being made through reference to ONC maps (Scale: 1:1 million). The principal source of ground truth has been aerial ice observation charts obtained from the Canadian Ice Central in Ottawa.

The initial data analysis is being directed toward the following: (a) verification of the geographic coordinates indicated on the images; (b) identification of ice boundaries, concentrations, and types; (c) measurement of the scales of detectable ice features; (d) mapping of the movement and deformation of ice features identifiable on two or more consecutive days; and (e) investigation of differences in the various spectral bands.

3. Preliminary Results

3.1 Northern Hudson Bay

The initial analysis of two passes crossing Hudson Bay in in the area south of Coats and Southampton Islands during late July has been completed (Pass 41, 26 July 1972, identifiers 1003-16273 through 1003-16282 (all bands)); Pass 55, 27 July 1972, identifiers 1004-16322 bands) and 1004-16324 (MSS only)). These data show a well-defined ice boundary southwest of Coats Island, with several bights and tongues apparently caused by a westerly surface wind flow (ice terminology is from the WMO Sea Ice Nomenclature, WMO Pub. No. 259, TP.145). The ice along the immediate ice edge appears to consist mostly of brash or rotten ice, whereas the ice east of the edge consists of close or open pack ice. The majority of ice floes visible in these passes are vast, big, or medium sizes, although one giant ice floe is located near 61.7°N latitude and 85.6°W longitude. An ice belt is visible off the south coast of Southampton Island and some fast ice is apparent along the north coast of Coats Island. Four vast ice floes are also located just off the north coast of Coats Island. (NOTE: Ice floes are defined in the WMO sea-ice nomenclature as follows: Giant Floe - over 10 km across; Vast Floe - 2 to 10 km across; Big Floe - 500 to 2000 m across; Medium Floe - 100 to 500 m across; Small Flow - 20 to 100 m across.

The ice features mapped from the ERTS data are in good agreement with the conditions reported on the Canadian ice charts for the last week in July. These charts indicate: (a) A sharp, irregular (bights) ice edge extending southwest of Coats Island with ice-free water to the west; (b) an ice belt south of Southampton Island composed of 3/10's of first year ice of which 1/10 is medium or larger size floes; (c) an area of open water with less than 1 okta (1/8) ice concentration south of the ice belt and extending to the ice edge southwest of Coats Island; and (4) an area northwest of Coats Island in Fisher Strait comprised of 5/10's of first year ice of which 2/10's is medium or larger size floes with ridges and hummocks.

3.2 Banks Island - Amundsen Gulf

Initial analysis of four passes crossing the Banks Island, Amundsen Gulf, and Franklin Bay area during late July has also been completed (Pass 43, 26 July, identifiers 1003-19513 and 19511 (RBV); Pass 71, 28 July, identifiers 1005-20014 and 20012 (RBV); Pass 85, 29 July, identifiers 1006-20074 and 20071 (RBV); Pass 98, 30 July, identifiers 1007-20123 through 20132 (RBV)). Although much of Amundsen Gulf is open water in these passes, several isolated vast ice floes are located off the west coast of Banks Island, south of a giant ice flow (about 12 km x 50 km). A field of very close and close pack ice is located to the southeast of Banks Island and areas of close, open, and very open pack ice are located in Amundsen Gulf; these ice areas consist mostly of giant, vast, big and medium ice floes.

Ice in Franklin Bay is composed of close, open and very open pack ice. Although one giant floe and several vast ice floes are observed in this region, the majority of the ice consists of big, medium and small, ice floes.

Aerial ice observation charts for the period 25-30 July indicate the following ice conditions in this region: (a) a giant ice flow off the southwest coast of Banks Island north of 72°N latitude composed entirely of first year ice with ridges 1 meter high and some puddles; (b) a small area south of this giant ice floe indicated as 4/10's of first year ice of which 2/10's is comprised of medium or larger size floes; (c) the region of the Amundsen Gulf south of Banks Island to about 70.5°N is indicated as open water with some loose ice strips (total concentration of ice is indicated as less than 1 okta); and (d) several small areas of first year ice indicated south of 71°N into Franklin Bay with the majority of floes of the medium size category.

With the repetitive coverage of the Admundsen Gulf area, preliminary measurements of ice motion have also been made. Measurements of the motion of ice floes off the west coast of Banks Island during the 24-hour periods indicated a mean direction of motion toward the west-southwest at about 8 kts. The smaller floes nearer the coast appear to be moving more south-southwest at 8 to 11 kts, while in the area of 10 to 20 n.mi. offshore, larger floes moved toward the west to southwest at 5 to 8 kts. Little or no movement was observed in the giant floe to the north, although some deterioration (breaking off of smaller floes) did occur. Measurements of 24-hour motions of ice floes in western Franklin Bay in the area 10 to 20 miles off the coast of Cape Bathurst showed a mean direction toward the northwest at 7 to 15 kts into the Amundsen Gulf and Beaufort Sea. Two floes closer to the coast (7 miles offshore) moved southwest toward the coast of Cape Bathurst at about 6 kts.

3.3 Scale of Identifiable Ice Features

Preliminary analyses indicate that the limit of floe size which can actually be measured on the ERTS-1 imagery is the small floe (60 to 300 ft) category. Ice cakes and brash ice which exist in relatively high concentrations over large enough areas can usually be determined in the MSS-4 spectral band by brightness and texture. Icebergs and bergy bits in fiords or bays close to observed glaciers can also be determined in the MSS-4 spectral band by their extremely bright white characteristics, and by their isolated concentrations.

Types of ice which have not been observed and which are considered more difficult to determine upon viewing the ERTS-1 imagery are the categories of new ice, including: frazil ice, grease ice, slush, and shuga.

Light and dark nilas ice may be visible at times in the MSS-4 spectral band. Other features which have been observed include fractures, cracks, leads, ridges, hummocks, puddles, floebergs, grounded ice, fast ice, ice foot, compact pack ice, consolidated pack ice, ice patches, tongues, and rotten ice.

3.4 Other Terrestrial Features

Several features of interest have been noted in the ERTS imagery over land areas. These include: (a) glaciers along the east and west coasts of Greenland which show imbedded sediment trails leading to ends of mountain ranges, end moraines, areas of cracks and crevices caused by sudden changes in elevation, and apparent limits of new ice or snow over old glacier ice; (b) mountain shadows that in some instances could be confused as open water in ice-covered bays or sharp breaks in glaciers; and (c) Jan Mayan Island located near 8^{o}W 71^{o}N latitude (observed in Pass 168, 15 October 1972, identifier 1084-12061). This image clearly shows the 7500 ft volcano with apparent steam cloud located at the eastern-most end of the island.

3.5 Cloud Features

Many of the passes over the Arctic contain thin cirrus, cirro-stratus, or stratus cloud cover. In many instances the clouds are thin or transparent enough so as not to obscure limits of ice pack, ice floes, or even leads. Small scale surface features such as ridges, hummocks, thaw holes, puddles, and cracks are, however, not discernible. Also, because of the very low sun angle, isolated small cloud shadows have been observed over ice areas, where the clouds themselves are difficult to distinguish. These shadows are generally lighter in tone than shadows cast by elevated surface ice features or by coastal mountain peaks; they are also lighter in tone than flooded ice, leads, or fracture zones, at least in the MSS-4 and MSS-5 imagery.

3.6 Differences in Appearance of Sea Ice and Other Features at the Various Spectral Bands

The initial investigation of the multispectral characteristics of sea ice and other features has concentrated on a comparison between the MSS-4 (0.5 to 0.6 μm) and MSS-7 (0.8 to 1.1 μm) bands. Examination of these spectral bands in passes over the Beaufort Sea (1053-22503-4 and -7), Banks Island (1043-20120-4 and -7), the Thule, Greenland area (1062-16504-4 and -7), and the east coast of Greenland (1064-13354-4 and -7) indicate the following:

(a) Overall contrast is greater at MSS-7 with open water and mountain shadows being blacker than at MSS-4.

(b) Some areas of sea ice that appear uniformly bright at MSS-4 are very dark at MSS-7; these are believed to be areas of melt-water on top of the ice surface. Other features that appear dark in both bands are believed to be cracks through the ice. Thus, through use of both spectral bands, puddles can be distinguished from cracks.

(c) Areas of apparent brash ice appear darker than areas of thicker ice at MSS-4, but can still be easily detected; these areas are difficult to distinguish from open water at MSS-7. However, ice floes that are difficult to distinguish from surrounding ice at MSS-4 because of similar reflectances, appear distinctly brighter than the surrounding ice at MSS-7.

(d) In areas of nearly solid ice cover, greater detail is evident at MSS-7. This is primarily because tonal differences between ice floes, brash ice, and cracks and openings are greater at MSS-7 than at MSS-4. Also, tonal variations within some ice floes are evident at MSS-7; these variations may be associated with hummocks, ridges, or refrozen cracks.

(e) Broken cloud fields over ice are more easily distinguishable at MSS-7 because of more distinct shadows, both on the ice surface and within the cloud field itself. However, the most reliable method to distinguish between clouds and ice is to use both the MSS-4 and MSS-7; at MSS-7 cracks in the ice and cloud shadows have similar reflectances, whereas at MSS-4 the cracks appear significantly darker than do the cloud shadows.

(f) Glaciers on the coasts of Greenland generally have a uniform reflectance throughout their extents at the MSS-4 spectral band. The lower extents of several of these glaciers, however, appear much darker at the MSS-7 band. This difference may be due to sediment or melt water covering the lower portion of the glacier as opposed to snow covering the higher elevation part.

A separate discussion of significant results and their relationship to practical applications or operational problems, including estimates of the cost benefits of any significant results, is attached to this progress report.

B. PLANS FOR NEXT REPORTING PERIOD

During the next reporting period, analysis of the data sample collected to date will be continued. Any additional data received will be screened to select frames containing ice features suitable for further analysis. It is anticipated, however, that because of the approach of the winter dark period, data from the originally designated geographic areas will not be available for several months. As suggested in the proposal (SR126), data from areas such as southern Hudson Bay and the Gulf of St. Lawrence can be acquired during the winter season.

The analyses to be conducted will include more precise measuring of the scales of detectable ice features, development of keys to identify ice types, measurement of ice movement over 24-hour periods when repetitive coverage is available and mapping of ice changes over longer periods, and continued investigation of differences in the various sensor bands. Additional ground-truth data will be sought. In this regard, a meeting was held on 18 October 1972 with the U.S.Navy Ice-Forecast Personnel at Fleet Weather Central. Suitland, Maryland, for purposes of discussing acquisition of their aerial ice observation data and other operational ice data for correlation with ERTS-1 ice imagery; the Navy has agreed to cooperate and has consented to supply all data available to them upon receipt of specified dates and coordinates.

C. PROBLEMS

In an attempt to have portions of selected ERTS frames enlarged to permit more detailed mapping of certain ice features, one unanticipated problem has arisen, which may impede the desired progress at the investigation. Examination of the quality of the corresponding 70 mm negatives has revealed that a high-intensity light source is required for reproduction from these negatives. We understand that NASA has realized this problem and is currently formulating a list of suggestions to allow users a suitable reproduction with more conventional photographic equipment.

D. ERTS IMAGE DESCRPTOR FORMS

Image Descriptor Forms are attached to this progress report.

E. FUNDS

It is anticipated that the remaining funds will be adequate for successful completion of the investigation.

Very truly yours,

James C. Barnes

James C. Barnes
Principal Investigator

JCB:jm
Enclosure

ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

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ID ________

DATE 8 November 1972

PRINCIPAL INVESTIGATOR Mr. James C. Barnes

USER ID (GSFC) P 525

ORGANIZATION Environmental Research & Technology, Inc.

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Ice	Snow	Glacier	
1016 21045 MP	X			Ice Floes, Ice Pack
1027 20241 MP	X			Ice Floes
1030 20401 MP	X			Ice Floes
1030 20410 MP	X			Ice Floes
1030 20412 MP	X			Ice Floes
1035 21095 MP	X			Ice Floes
1046 22120 MP	X			Ice Pack
1043 20120 MP	X	X		Ice Floes, Bay Ice, Islands, Mountains
1043 20122 MP	X	X		Ice Floes
1046 20284 MP	X			Ice Floes, Ice Pack, Bay Ice
1060 20063 MP	X	X		Ice Floes, Island
1060 20070 MP	X	X		Ice Floes, Island, Frozen Lakes
1061 20115 MP	X	X		Ice Floes, Bay Ice, Island
1061 20122 MP	X	X		Ice Floes, Island
1042 13142 MP	X	X	X	Fiords, Ice Bergs, Snow Pack, Moraines, Mountains
1042 13145 MP	X	X	X	Fiords, Ice Bergs, Snow Pack, Moraines, Mountains
1042 13133 MP	X	X	X	Fiords, Ice Bergs, Snow Pack, Ice Floes, Eddies, Moraine, Islands

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Ice	Snow	Glacier	
1042 13131 MP	X			Ice Floes, Bay Ice, Ice Pack
1042 13124 MP	X			Ice Floes
1047 13421 MP	X	X	X	Ice Bergs, Fiords, Snow Pack, Moraines, Mountains
1047 13424 MP	X	X	X	Fiords, Ice Bergs, Snow Pack, Mountains, Moraines
1064 13342 MP	X			Ice Floes, Pack Ice
1064 13351 MP	X			Ice Floes, Pack Ice
1064 13360 MP	X	X	X	Ice Floes, Pack Ice, Ice Bergs, Fiords, Snow Pack, Mountains, Islands
1064 13363 MP	X	X	X	Ice Floes, Ice Bergs, Fiords, Snow Pack, Mountains
1064 13365 MP	X	X	X	Ice Floes, Ice Bergs, Fiords, Snow Pack, Mountains
1064 13354 MP	X	X		Ice Floes, Pack Ice, Islands, Snow Pack, Mountains
1077 13084 MP	X	X	X	Ice Floes, Ice Pack, Ice Bergs, Fiords, Snow Pack, Mountains
1077 13091 MP	X	X	X	Ice Pack, Ice Bergs, Snow Pack, Fiords, Mountains

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Ice	Snow	Glacier	
1077 13093 MP	X	X	X	Fiords, Ice Bergs, Snow Pack, Mountains
1005 18162 MP	X	X	X	Pack Ice, Bay Ice, Ice Floes, Moraines, Mountains, Fiords, Snow Pack

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GSFC 37-2 (7/72)

DISCIPLINE: MARINE RESOURCES AND OCEAN SURVEYS, SEA ICE MONITORING

TITLE: EVALUATE THE APPLICATION OF ERTS-A DATA FOR DETECTING AND MAPPING SEA ICE (SR NO. 126)

PRINCIPAL INVESTIGATOR: James C. Barnes (PR525)
Environmental Research & Technology, Inc.
429 Marrett Road, Lexington, Massachusetts 02173

DISCUSSION OF SIGNIFICANT RESULTS:

Some 30 ERTS-1 passes over the Arctic in which sea ice features have been identified are in the process of being analyzed. Sea ice can be identified in the ERTS data because ice often has a higher reflectance than clouds, ice edges are usually more sharply defined than cloud edges, ice fits coastlines and islands, spatial frequencies of ice features are often different from clouds, and ice features can be identified from one day to the next when repetitive coverage is available. The analysis of RBV and MSS data from two passes crossing northern Hudson Bay in late July (Pass 41, 26 July, and Pass 55, 27 July) reveals well-defined ice features that are in good agreement with aerial ice observation charts for the same period. Similarly, ice features mapped from RBV imagery on four passes crossing the Banks Island-Amundsen Gulf area (Passes 43, 71, 85, and 98 on 26, 28, 29, and 30 July) agree well with ice conditions depicted on concurrent ice charts. Because of the repetitive coverage over this area, it has been possible to obtain measurements of the 24-hour movements of ice floes.

The preliminary results indicate that the following ice features can probably be identified in ERTS imagery: floes, fractures, cracks, leads, ridges, hummocks, puddles, floebergs, grounded ice, fast ice, ice foot, compact pack ice, consolidated pack ice, ice patches, tongues, and rotten ice. Ice floes as small as the "small floe (20 to 100 m)" can be detected; ice cakes and brash ice can usually be distinguished from ice floes because of differences in reflectance and texture. In addition, icebergs in fiords and bays near glaciers can be identified by their high reflectance and isolated concentrations. Several features of interest have also been noted over land areas, including glaciers on the east and west coasts of Greenland, which show imbedded sediment trails, end moraines, areas of cracks and crevices caused by sudden changes in elevation, and apparent limits of new ice or snow over old glacier ice. A volcano on Jan Mayan Island with an apparent steam cloud has also been detected (Pass 168, 15 October).

The initial investigation of the multispectral characteristics of sea ice and other features has concentrated on a comparison between the MSS-4 (0.5 to 0.6 m) and MSS-7 (0.8 to 1.1 m) bands. Examination of these spectral bands in passes crossing the Beaufort Sea-Banks Island area and the Greenland Coast indicate that multispectral analysis is useful for distinguishing ice floes from surrounding brash ice and ice cakes, for detecting puddling on the ice surface as opposed to cracks or fractures through the ice, and for identifying broken cloud fields over ice surfaces.

Discipline: Marine Resources and Ocean Surveys, Sea Ice Monitoring

In areas of nearly solid ice cover, greater detail is evident at the MSS-7 spectral band primarily because differences in reflectance between ice floes, brash ice, and cracks and openings are greater. Also, reflectance variations within some ice floes, which are evident at MSS-7, may be associated with hummocks, ridges, or refrozen cracks. Additionally, glaciers on the coasts of Greenland generally have a uniform reflectance at the MSS-4 spectral band. The lower extents of several of these glaciers, however, appear much darker at the MSS-7 band. This difference may be due to sediment or melt water covering the lower portion of the glacier as opposed to snow covering the higher elevation part.