Program Work Statements

Environmental Assessment of the Alaskan Continental Shelf

8 - Sea Ice

U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

U. S. DEPARTMENT OF INTERIOR
Bureau of Land Management

CONTENTS - SEA ICE

Research Unit #87

Work Statement for the Alaskan Marine Environmental Assessment Program, Bureau of Land Management and National Oceanic and Atmospheric Administration, 18 April 1975

I. TITLE: The interaction of oil with sea ice in the Beaufort Sea

II. PRINCIPAL INVESTIGATOR:

Seelye Martin
Research Associate Professor
Department of Oceanography WB-10
University of Washington
Seattle, Washington 98195
(206) 543-6438
(206) LA 3-2863 (home)

III. GEOGRAPHICAL AREA AND INCLUSIVE DATES: Beaufort Sea, 1 July 1975 - 30 September 1976

IV. COST SUMMARY:

FY 1975 through June 30, 1975	FY 1976 July 1, 1975 - Sept. 30, 1976
$0.00	$42,590.00

V. PROPOSED RESEARCH:

A. Background and Objectives

We propose a two part study on the absorption and spread of oil by sea ice in the shear zone north of Alaska. This study directly relates to task B-14, "the development of means to predict possible interactions between ice and oil," and indirectly relates to task B-12, "the description of pack ice motions in the shear zone."

The proposed study consists of the following elements: (1) a laboratory experiment on the growth of frazil ice in a wind and wave field and on oil absorption by this ice; (2) a cooperative field study, our part of which is a coring program with Knut Aagaard on the small properties of sea ice within the shear zone. The data from these two studies will be combined with remote sensing and ice movement data to estimate how an oil spill will both spread and be absorbed within the shear zone.

This proposal relates directly to the Canadian Beaufort Sea Project (BSP), part of which is an experimental field study of the effects on columnar sea ice of a series of controlled oil spills. At the present time, I am participating with the Canadians in both the field work and data analysis of this experiment, which will be complete by 30 September 1975. The BSP experiments are only concerned about oil absorption by columnar sea ice, which is sea ice with a vertical crystal orientation. In contrast, field observations in the open ocean such as Ramseier's (R.O. Ramseier *et al.*, "Mesoscale description for the principal Bering Sea Experiment," paper number 2 of the *U.S. Results of the Bering Sea Experiment*, June, 1974, Goddard Space Flight Center, Greenbelt, Maryland) show from a systematic ice coring program that during the Bering Sea Experiment (BESEX) that 10 to 30% of the ice in the Bering Sea is frazil ice, which has a horizontal platelet structure.

At the present time, there have been no laboratory or field studies on oil entrainment by frazil ice; further, the details of the ice consistency in the Alaskan shear zone, namely the relative amounts of frazil, columnar, rafted, or pressure-ridged ice are not known. To address these questions, our proposal consists of a laboratory study of the kinds of ice within the Alaskan shear zone. Our proposed laboratory study will complement the BSP study by showing how frazil ice absorbs oil, and the field study will allow us to estimate the relative amounts of frazil and columnar ice in the Alaskan shear zone. From these parameters, we should be able to estimate roughly how an oil spill would spread and be absorbed within the shear zone. As presently planned, our results will be available in report form by 30 September 1976.

B. Methods

1. The Laboratory Program:

Using our existing cold rooms, the largest of which measures 6 m in length by 3 m in width, we will build a wind-wave facility for the study of ice growth in a wind and wave field. We already possess a wave generator from an earlier experiment, the wind source will be a simple fan, and the tank will be constructed from plywood and Plexiglas, so that we will be able to observe the ice growth from both the top and sides.

Within this apparatus we will do several experiments on sea ice growth in both a wave field and a wind-plus-wave field with the purpose of observing the growth of grease and hopefully pancake ice. Having observed the ice growth in un-oiled sea water, we will next run two additional experiments, one studying the absorption of oil by grease ice, the other studying the absorption of oil by a field of pancake ice. The results of this experiment will permit us to estimate the extent of an oil spill under grease and pancake ice. Then given both our own and other field observations on the relative amount of frazil and columnar ice within the shear zone, we can estimate the extent of a hypothetical spill.

2. The Field Program:

In order to obtain information about the kinds of ice in the shear zone north of Alaska, the author will cooperate with Knut Aagaard in his proposal "STD measurements of the Beaufort Sea Shelf."

This experiment involves 3 eight day helicopter traverses over the ice in three straight line segments at 142°W, 147°W, and 153°W respectively, of 100 km lengths during October-November 1975, February-March 1976, and May 1976. There will be eight stations occupied on each traverse, at space intervals of approximately 12 kilometers and at a rate of 3 per day.

Our experiment, which involves two people, has the following field procedure, based on Ramseier's BESEX observations. Once we select a landing site for the helicopter, we will photograph the site from the air for later comparison with remote sensing data. Then, on the ice, we will carry out the following program.

First, we will pull an ice core from the ice floe and measure its length. To determine the temperature profile within the ice, we will immediately drill several small holes at intervals along the core. We then will record the temperature by inserting a fast response silicone-coated thermister into the holes, and reading the resultant signal on a digital multimeter.

Second, the salinity and crystal structure of the ice determine the way in which oil will be absorbed by the ice. The salinity in combination with the temperature gives the brine volume, or the amount of liquid content; and the brine entrained within the ice core during the fall also determines the ice porosity during the spring-summer melt. To measure the salinity profile of an ice core, we will pull an additional core, then immediately cut the core up into 2-4 cm sections, using a wooden jig to hold the core and a handsaw. We will then package the sections into individual numbered plastic bags for shipment back to camp.

Third, to determine the crystal structure of the ice, we will use our jig to cut a second core into a longitudinal section with a thickness of 2 cm. We will then polish the resulting core and both sketch the crystal structure and photograph the core against a black velvet background. We will also do both a rubbing and a photograph of the bottom of the core. Finally, if the experiment is carried out simultaneously with remote sensing flights, we will remove the upper part of an ice core for subsequent analysis of air volume.

At the field camp, we will allow the packaged salinity samples to melt; then with an optical refractometer we will measure the individual sample salinities. We will also check the ice samples for any evidence of algae growth. To simplify our transport problems, we plan to do all of our water and ice sample analysis in the field camps.

Upon our return to Seattle, we will analyze the data to determine the brine volume, crystal structure, and occurrence of rafting for each core as a function of position within the shear zone. After completion of both the field and laboratory studies, we will combine our data with that of the BSP and any remote sensing observations to estimate how an oil spill would spread within the shear zone at the times of year of the field traverses.

VI. INFORMATION PRODUCTS:

The data gathered by our observations, experiments and analysis will be available as technical reports.

VII. DATA OR SAMPLE EXCHANGE INTERFACES:

To estimate the spread of oil within the shear zone, we need the remote sensing data on the motion of the Alaskan shear zone by no later than 1 August 1976.

Preliminary field reports on our coring data will be available within 90 days of acquisition. Our laboratory results will be available in report form on 30 September 1976. Our estimates on the possible interaction of oil with the ice in the shear zone will be available in report form by 30 September 1976.

VIII. SAMPLE ARCHIVAL REQUIREMENTS: None

IX. SCHEDULE:

1 October 1975:	Laboratory apparatus constructed.
1 December 1975:	First field experiment completed.
1 March 1976:	Field report on our first field experiment submitted.
1 April 1976:	Second field experiment completed.
1 June 1976:	Laboratory studies completed.
20 June 1976:	Third field experiment completed.
1 July 1976:	Field report on second field experiment submitted.
1 September 1976:	Field report on third field experiment submitted.
30 September 1976:	Report on laboratory studies submitted; report on how oil and ice might interact within the shear zone during the periods covered by the three field studies submitted.

X: EQUIPMENT REQUIREMENTS:

Our equipment consists of a corer, a digital thermometer, an optical refractometer, a density balance, and our cameras plus assorted small tools. This equipment will be either shipped or hand carried to Point Barrow, Alaska for deployment.

XI: LOGISTIC REQUIREMENTS:

A. Logistics arranged by the University of Washington: flights and shipping to and from point Barrow, Alaska

B. Logistics arranged by BLM/NOAA:

1. Transportation:

We will share helicopter space with Knut Aagaard in his BLM/NOAA proposal "STD measurements." The experiments involve 3 helicopter traverses for eight days of field time each during October-November 1975, February-March 1976, and May 1976. Our proposal requires two people and about 500 pounds of gear.

2. Housing and Board:

During the time periods described in "Transportation" above, we will require housing and board for two people for 15 days. This will involve two days preceding the helicopter traverses and five days following for sample analysis.

3. Laboratory Space:

During the time periods described above, we will need access to one 8' x 10' laboratory space with running water and electricity for our water analysis.

4. Storage:

Between 1 October 1975 and 20 June 1976, we will need storage space for about 400 pounds of gear at Point Barrow.

WORK STATEMENT (Research Unit #88)

I. TITLE: Dynamics of Near-Shore Ice (Near shore radar transponder and fast ice studies)

II. PRINCIPAL INVESTIGATORS:

Dr. W. F. Weeks (603) 643-3200 Ext. 261
and A. Kovacs (603) 643-3200 Ext. 211
USACRREL
Hanover, NH 03755

III. GEOGRAPHIC AREA AND INCLUSIVE DATES: Coastal fast and pack ice zones of the Beaufort Sea; FY 1975 through June 30, 1975 and FY 1976 July 1 1975 through September 30 1976.

IV. COST SUMMARY:

FY1975	FY1976
$168,002	$184,198

V. PROPOSED RESEARCH:

A. Background and objectives

A1. This project will provide fundamental data for the following tasks:

Primary--A30, B12, B13, D11, D12, D13
Secondary--A29, A31, B3, B5

A2. Very little quantitative information is available on the motion of either the fast ice or the near shore pack ice in the Beaufort Sea. The information that is available is limited by the range and accuracy of the system that was used (U. of Alaska radar studies from Point Barrow), the short time period of the observations (CRREL ERTS studies in the vicinity of Point Barrow) and the non-typical nature of the research sites (Barrow is an undesirable site for coastal ice work). The most comparable data for near-shore pack ice motion has been obtained on the northeast coast of Hokkaido where the ice conditions are very different. The limited information on the motion of the fast ice along the Beaufort Sea coast has been collected for private companies and is not available for examination. These fast ice motion studies are also reported to be for only very limited periods of time.

A3. The basic experimental goal of this program is to collect detailed quantitative information on the movements (rates, directions, accellerations) and deformation rates (spatial variations in the ice velocity field) of both the near shore pack ice and the fast ice along the southern coast of the Beaufort Sea. Data will also be collected on the ice deformation features that form near the fast ice-pack ice boundary and presumably serve to fix the location of the boundary. Bottom scoring will also be examined in these same areas. It is also planned to make observations on ice growth, brine drainage, and the internal structure of both undeformed and deformed sea ice. These data will also serve as ground truth for the USGS-CRREL remote sensing program.

A4. By 30 September 1976 we anticipate that we will have four continuous months of pack ice motion data collected and partially analyzed. We also should have fast ice motion data covering a whole ice season (one month in the fall and four months in the late winter and spring) that has been partially analyzed. In addition, we will have started to examine the interrelations between these two time series and the local meteorological conditions. We will also have collected a variety of information on the local ice characteristics north of Prudhoe Bay including general observations on the types of ridging in both 1975 and 1976.

A5. The related research programs are the data buoy and modeling efforts that have been proposed by AIDJEX and the joint USGS-CRREL "Remote Sensing Program for the Arctic Offshore." Considerable coordination between these projects was carried out during the time that these programs were being formulated. This is expected to continue in the future as we enter into the data collection phase. Coordination between the present program and the remote sensing effort has been particularly close inasmuch as several CRREL investigators are involved in both programs. The method of coordination will be by informal meetings and discussions.

B. Methods

B1. We will not need to make use of archived data with the exception of the gridded atmospheric pressure information that is available from the NWS and the LANDSAT, U-2 and Convair 990 imagery that will be available from NASA. The data collected by the USGS-CRREL remote sensing program and the AIDJEX data buoy program will presumably be made directly available to us. Inasmuch as CRREL has done most of the published mesoscale ice deformation studies, we obviously already have that data available.

B2. To make the proposed measurements, two basically different systems will be used. The motion of the pack ice will be determined by a precision tracking radar transponder system will all weather capability and 1 meter resolution. The anticipated range of the system is 35 km and the azimuth and distance to each target with respect to true north will be determined automatically at least as often as every three hours and possibly as often as every five minutes. Because of the drift of the pack parallel to the coastline, the transponders will be repositioned by helicopter as required. Approximately ten targets will be used at any given time.

A laser ranging system will be employed to look at the movement and deformation in the shore fast ice within a radius of up to 15 km from Cross and Narwhal Islands. The basic approach will be to put corner reflectors along lines oriented at approximately 40° angles. The repeated measurement of this array will specify strains caused by thermal and tidal effects as well as coupling effects between the shore fast ice and the pack ice. The laser targets will be measured every three hours. Between these spot measurements the lasers will be locked on one target and a continuous digital record will be made to resolve any high frequency motions of the fast ice. An array of markers will also be set out during the fall of 1975 on the fast ice south of the islands. This array will be resurveyed in early March 1976 and at monthly intervals thereafter. This data will allow us to monitor the broad-scale motion of the fast ice.

The observations of ice properties and of ridging and bottom scoring will be made at irregular times as ice conditions and the press of other work permits.

The temporal sampling scheme in the strain measurements is based on our previous experience with such observations. Our main concern is the range limitations of our radar system caused by the curvature of the earth. We will, of course, attempt to minimize this problem by using very high (>30m) radar towers located on the coastal islands. Measures of sampling variance will be obtained by replicate readings on a transponder located on a nearby island. Previous programs we have used for the analysis of such data include variance transformation from measurement errors to strain rates and velocity estimates using maximum likelihood methods.

B3. Not applicable.

B4. An analysis of the observed pack ice motions will allow comparisons to be made between these results and the predictions of a variety of different theoretical ice drift models. Here particular attention will be paid to changes in the constitutive law parameters that characterize the response of the pack versus the distance from the fast ice edge. Time series analysis of the data using a number of spectral and filtering techniques including maximum entropy will be made to determine coupling effects between the shore fast ice and the moving pack and to develop predictive schemes for such motions. The analysis will also give a measure of periodicities in the motion and deformation records.

With regard to pack ice modelling we will also attempt to develop a predictive model for fast ice motions based on quanititative measures of the degree of coupling with the pack ice and the variations in the local meteorological conditions. A description of the general analysis scheme that will be used for the ice motion studies can be found in Hibler, Weeks, Kovacs and Ackley (1974), in Hibler (1974) and in Coon, Maykut, Rothrock, and Thorndike (1974). Other useful information on observed variations in ice drift characteristics as a function of distance from shore can be found in Hibler, Ackley, Crowder, McKim and Anderson (1974).

Descriptions of the general techniques that will be used in the pressure ridge, ice property and ice scoring investigations can be found in Weeks and Assur (1968, 1972) Weeks, Kovacs, and Hibler (1971) Kovacs (1972) and Kovacs and Mellor (1974).

VI. INFORMATION PRODUCTS

The prime data produced by this project will be the coordinates of the radar transponder and the laser ranging targets with time. This can be provided to NOAA in a magnetic tape format. Other data on ice properties will be provided as a data tabulation. The main results and interpretations of these investigations will be published as a series of reports in appropriate technical journals and supplied to NOAA/BLM.

VII. DATA OR SAMPLE EXCHANGE INTERFACES

We will require SLAR, IR and laser profilometry that will be collected by the USGS-CRREL remote sensing program and LANDSAT imagery that will be obtained by NASA. This data will, hopefully, be available in a "raw" unanalyzed form within one month of the time of data collection. We also will require the atmospheric pressure, wind, temperature and location information collected by the AIDJEX data buoy program within the same general time frame.

VIII. SAMPLE ARCHIVAL REQUIREMENTS

There are no significant requirements in this area.

IX. SCHEDULE

(a) April 1975--Make preliminary visit to vicinity of Cross Island for purposes of examining its suitability as a research site. Results of this trip suggest that Narwhal Island should be used as the main camp site with a second tower placed upon Cross Island. During this visit the general morphology of the ridged ice north of Cross Island was examined, the water depth at the edge of the outer grounded shear ridge was determined to be 20 meters and observations were made of a large grounded multiyear pressure ridge resting in 14 meters of water. A visit was also made to a grounded floeberg located roughly 160 km NNW of Barrow to examine its potential as a research site.

(b) September 1975--The camp will be installed on Narwhal Island, the large radar towers will be erected, and the radar system will be run through a series of preliminary field checks. In addition, a series of ice motion points will be laid out by laser triangulation on the fast ice south of the islands; it will probably be too dangerous to lay out markers on the ice north of the islands.

(c) October 1975--The radar transponder system will be operated for one month on the AIDJEX drift station Big Bear. Inasmuch as Big Bear drifts with the ice surrounding it, the dangerous problem of continually retreiving and moving the transponders in the shear zone in the dark will be avoided. This test will allow us to investigate the operation of our system under periods of long cold-soaking and also to obtain valuable data on floe-floe interactions which will assist in our later analysis of the near-shore data.

(d) March 1976-June 1976--The radar transponder array will be operated from Narwhal and Cross Islands, the fast ice motion studies will be made, and observations of ice growth and ice properties will be undertaken.

(e) July-August 1976--Data analysis will proceed and report writing will continue.

The radar transponder data will initially be available on standard ASC II paper tape. The final ice deformation data that is calculated from the transponder information will be on 7 track magnetic tape in BCD format. All time references will be in Julian hours. The data will be brought back to CRREL monthly with the rotation of personnel and it will be edited and examined within two months.

The most important interface between our program and other OCS observations will be with the USGS-CRREL remote sensing program. It is presumed that this exchange of information will proceed directly on a project to project basis inasmuch as the contacts between these projects are obviously excellent.

X. EQUIPMENT REQUIREMENTS

The principal item of special equipment that is required for the above program is a radar ranging system that has been developed by Del Norte Electronics. This system is currently on order with delivery anticipated in June.

XI. LOGISTICS REQUIREMENTS

The following logistics support will be required from NOAA and is not included in the present budget:

1. Helicopter support*

   a. April 1975--Cross Island, 10 hours
   b. September 1975--Cross and Narwhal Islands, 20 hours
   c. March-June 1976--Cross and Narwhal Islands, 80 hours
   [We would prefer to charter commercial helicopters based at the Prudhoe/Deadhorse airports.]

2. Operational staging area at Point McIntyre open in September 1975

and March-June 1976.

*(If it is decided not to open Point McIntyre but to base out of Prudhoe Bay instead, we will need more helicopter time--5 additional hours in September 1975 and 25 additional hours during March-June 1976).

3. Equipment storage and ground transportation (truck) available in the Prudhoe Bay area during August-September 1975 and March-June 1976.

4. Establishment of a 4-man camp on Narwhal (or possibly Cross Island). The camp should be at Prudhoe (or Pt. McIntyre) by 1 September 1975 ready for helicopter airlift to the islands. The camp should include three buildings (sleeping quarters, instrument hut, generator-tool storage hut), four beds, three tables, six chairs, four mattresses, propane cook stove and cooking gear, fuel to operate camp and food. Four barrels of mogas will also be needed to operate the vehicles at the camp.

5. Propane to operate the thermoelectric cells (1000 lbs/month for five months). This should also be ready for transport to Cross Island in September.

XIII. REFERENCES

Coon, M. D., Maykut, G. A., Pritchard, R. S., Rothrock, D. A. and Thorndike, A. S. (1974) Modeling the pack ice as an elastic-plastic material. AIDJEX Bulletin 24, 1-105.

Hibler, W. D. III (1974) Differential sea-ice drift: II. Comparison of mesoscale strain measurements to linear drift theory predictions. Journal of Glaciology 13 (69), 457-471.

Hibler, W. D. III, Ackley, S. F., Crowder, W. K., McKim, H. L., and Anderson, D. M. (1974) Analysis of shear zone ice deformation in the Beaufort Sea using satellite imagery. In "Coast and Shelf of the Beaufort Sea" (J. C. Reed and J. E. Sater, eds.), p. 285-300, Arctic Institute of North America.

Hibler, W. D. III, Weeks, W. F., Kovacs, A. and Ackley, S. F. (1974) Differential sea-ice drift: I. Spatial and temporal variations in sea ice deformation. Journal of Glaciology 13 (69), 437-455.

Kovacs, A. (1972) On pressured sea ice. In "Sea Ice, Proceedings of an International Conference" (T. Karlsson, ed.), p. 276-295, National Research Council of Iceland, Reykjavik.

Kovacs, A. and Mellor, M. (1974) Sea ice morphology and ice as a geologic agent in the southern Beaufort Sea. In "Coast and Shelf of the Beaufort Sea" (J. C. Reed and J. E. Sater eds.), p. 113-161, Arctic Institute of North America.

Weeks, W. F. and Assur A. (1968) The mechanical properties of sea ice. In "Proceedings Conference on Ice Pressures against Structures," National Research Council of Canada, Assoc. Committee on Geotechnical Research, Tech. Memo. No. 92, 25-78.

Weeks, W. F., and Assur, A. (1972) Fracture of lake and sea ice. In "Fracture, An Advanced Treatise." Volume 7; Fracture of nonmetals and composites (H. Liebowitz, ed.), p. 879-978, Academic Press.

Weeks, W. F., Kovacs, A. and Hibler, W. D. III (1971) Pressure ridge characteristics in the Arctic coastal environment. In "Proceedings First International Conference on Port and Ocean Engineering under Arctic Conditioning" Vol. I, p. 152-183, Technical University of Norway.

I. TITLE: A Remote Sensing Program for the Arctic Offshore

II. PRINCIPAL INVESTIGATORS:

Dr. W.J. Campbell
Ice Dynamics Project
US Geological Survey
113 Thompson Hall
University of Puget Sound
Tacoma, Washington 98416
(206) 593-6517

and

Dr. W.F. Weeks
USA CRREL
Hanover, New Hampshire 03755
(603) 643-3200, ext. 261

III. GEOGRAPHIC AREA AND INCLUSIVE DATES: Beaufort and Northern Bering Seas; FY 1975 - through June 30, 1975 and FY 1976 July 1, 1975 - September 30, 1976

IV. COST SUMMARY: FY 1975 - $25,000
FY 1976 - $263,500

V. PROPOSED RESEARCH:

A. Background and objectives

A.1. The following tasks are ones for which this project will provide fundamental data:

A-29, A-30, B-11, B-12, B-13, B-14, D-4, D-12

The elements which are of primary interest to this project are:

A-29, A-30, B-12, B-13

A.2. Essentially nothing is known about the time-dependent ice distribution of sea ice and its dynamics in the shear zone of the Alaskan Arctic offshore. The only data we have is fragmented and piecemeal and of very limited range, i.e., a given bay or a given point.

A.3. The information needed to meet the task objective is to acquire photography and imagery of the sea ice in the Alaskan Arctic offshore at reasonably frequent time intervals over the whole year. In other words, what we need is large space-scale coverage at reasonably short time-scales.

A.4. As was clearly stated in all previous documents for this project, the sequential large-scale remote sensing of the Alaskan Arctic offshore is something that will have to continue for a number of years, something in the order of 5-10, before we have an accurate idea of the monthly, seasonal, and annual variations of the sea ice dynamics and morphology of the region. Within the scope of this proposal, therefore, we will acquire what can be considered the initial set of data for a longer term project. Data collected through FY76 will be reported on by September 30, 1976, with the full understanding that future work will be necessary to achieve the above given state of knowledge.

B. Methods

B.1. Since very little data of the kind we wish to obtain has been obtained in the past, we plan essentially no time hunting for archived, published, or unpublished materials. The exception to this is the satellite coverage of the region which has been collected in some detail in the last few years. Other projects are going through this data and therefore we see no sense in our duplicating this effort.

B.2. We must consider the use of the SLAR sensing equipment aboard the Mohawk aircraft as the prime aircraft for this study. We have modified the SLAR so that it can scan on either side of the aircraft to a range of 100 km, but will have a dead band from nadir out to 10 km both left and right. Therefore, it should be possible to image with SLAR the entire shear zone from Barter Island to Cape Lisborne at an interval of one-two weeks for the entire time of this study. We are going to attempt a sampling time of one week, but this will probably have to be modified for aircraft maintainance, crew availability, etc. We fully intend to cover this entire area with SLAR at least once every two weeks.

The use of the infrared scanner, laser profilometer, and cameras on board the Cessna 310 will be used for targets-of-opportunity. By this we mean that for specific areas, such as Prodhoe Bay and Point Barrow, where detailed studies are being carried out on the surface, we will perform CESSNA 310 missions at times of interest.

The use of both of these aircraft for non-ice studies, such as mammals and geology, will be determined in June when the Principal Investigators meet with Dr. Gunther Weller to review the requests which he has distributed.

The prime task of analysis is to learn to properly interpret the SLAR imagery. Essentially nothing on this had been published, therefore we can give no reference. However, we did acquire the first sequential SLAR coverage of sea ice during the USGS-CRREL Shear Zone Study of 1974, and we feel that further analysis of these data will help us in our task. NSF has agreed to pick up ice related data analysis in FY75 and perhaps FY76.

VI. INFORMATION PRODUCTS:

Since this project is basically involved in starting a historical sample of the ice in the Alaskan Arctic offshore, the prime information contents will be SLAR, IR, laser profilometer charts, and photography of the region.

The analysis of some of the above data will be published in scientific journals and submitted in quarterly and annual reports to NOAA/BLM.

VII. DATA OR SAMPLE EXCHANGE INTERFACES:

The main data interface is with the NASA CV990 "Galileo II" investigation. Within one month following each flight sequence, we should have most of that data in hand, except for the microwave imagery which will take approximately three months. To our knowledge, some of the products of this project will be required by other investigators of the Alaskan Marine Environment Assessment Program, for example, the mammal, geology, and limnology investigations. It is assumed that these investigators will acquire the needed data from the Environmental Data Service/National Oceanographic Data Center.

We are not aware of where this Center will be. Discussions with various officials of the Office of Polar Programs of NSF lead us to conclude that there is a good possibility that an NSF office will be established in Seattle for the purpose of overseeing the NSF-funded investigations in the Arctic. Since this project is jointly funded by NSF, and since both Principal Investigators of this project spend considerable time in Seattle through their AIDJEX committments, we feel that if this Seattle NSF office is established, either the original or a copy of all data collected under this project be archived in this office. These data then could also be used by the number of investigators at the University of Washington who are involved in research in this area, such as AIDJEX, Oceanography, Geophysics.

VIII. SAMPLE ARCHIVAL REQUIREMENTS:

None of the data to be presented to the NOAA or NSF data centers will be in form that requires special storage conditions. However, a substantial amount of data will be generated, therefore both centers should make allowance for at least one normal-sized room to store these data.

IX. SCHEDULE:

Mohawk aircraft - approximately onemission per week to image the entire Alaskan Arctic offshore from Barter Island to Cape Lisborne with SLAR (with strip chart photography along the center of the track).

Cessna 310 aircraft - targets-of-opportunity for infrared and photography and laser profilometer data.

Beaver aircraft - targets-of-opportunity for infrared and photographic data.

The fuel requirements for these aircraft have been submitted tentatively for approximately 760 flying hours. The scheduling of these flight hours will be detailed in late June as stated earlier, and at that time allocated by discipline.

X. EQUIPMENT REQUIREMENTS:

No special equipment, other than that onthe aircraft, will be required for this study.

XI. LOGISTICS REQUIREMENTS:

The most important logistics requirement is hangar space for the two USGS aircraft - Mohawk and CESSNA 310. The instrumentation on board these aircraft is such that none of them can be kept outside for any long periods during cold weather. Dr. Gunther Weller is looking into the possibility of leaving these aircraft in the Air Force DEW Line hangar. If this does not work out, arrangements will be made to hangar them in the NARL hangar.

A room will have to be made available at Barrow to serve as an electronics lab for these aircraft.

Also another room will have to be made available at Barrow to serve as a photo lab.

Food and lodging for approximately four people over the entire length of the project will have to be provided. It should be understood that at times six people will be in residence and at times two people, but four people is the average number.

The fuel requirements for the aircraft have already been submitted to Dr. Weller, and his personnel are acting to ship the fuel there by barge.

All of the above logistics requirements are being arranged by NOAA.

WORK STATEMENT (Research Unit #98)

I. TITLE: Dynamics of Near-Shore Sea Ice (Data Buoys)

II. PRINCIPAL INVESTIGATOR: Norbert Untersteiner, Coordinator AIDJEX Program
Professor, Atmospheric Sciences and Geophysics,
University of Washington
4059 Roosevelt Way N.E., Seattle, Washington 98105
Telephone: (206) 543-6613

III. GEOGRAPHIC AREA AND INCLUSIVE DATES: 1 May 1975 to 30 September 1976

IV. COST SUMMARY:

FY 1975	FY 1976
through June 30, 1975 - $18,531	July 1, 1975 - September 30, 1976 - $53,9

V. PROPOSED RESEARCH

A. Background and objectives

Primary emphasis on Task B-12 with secondary emphasis on Tasks B-13 and D-11.

This proposal outlines a research program directed at providing an understanding of the dynamics of near shore sea ice in the southern Beaufort and Chukchi Seas. The circulation of ice within the essentially land-locked Arctic Ocean is dominated by two main features: the Beaufort Sea gyre and the transpolar drift stream. The ice in the Beaufort Sea gyre, a region of clockwise ice circulation located north of Alaska and west of the Canadian Archipelago, is the oldest and thickest in the Arctic, with multiyear ice thickness in undeformed ice of 3-4 meters. The transpolar drift stream transports ice from the Siberian shelf over the pole and out of the Arctic Basin into the east Greenland current. The Arctic Ice Dynamics Joint Experiment (AIDJEX), a joint U.S.-Canadian research program, is studying the problem of understanding the drift of the heavy multiyear ice in the central ocean, away from the complicating edge effects of land. By acquiring new data and developing new ice modeling concepts and techniques, the AIDJEX program addresses the problem of dynamics and thermodynamics in the interior of large fields of sea ice. This is the first step in understanding the overall sea ice problem. The next step (originally included in the AIDJEX program and later dropped for fiscal reasons) must be a research program directed at understanding the processes controlling the behavior of ice in the marginal, near-shore zone, where the ice undergoes seasonal variations and interacts strongly with the solid coastal boundaries. The marginal or near-shore zone is comparable in extent to the continental shelf in the Beaufort and Chukchi Seas.

In the past few years, it has become recognized that the safe development and economic extraction and transportation of natural resources that are believed to lie within the offshore sediments of this region require a thorough understanding of the geophysics of ice behavior. Without this understanding it will be impossible to make an adequate assessment of the environmental hazards involved in developmental activities. Such an understanding is necessary to permit the development of adequate methods for forecasting ice conditions and designing operational systems that minimize undesirable effects of sea ice. The research outlined here proposes to study the overall deformation patterns on the near-shore regions of the Beaufort and Chukchi Seas by observing the drift of an array of data buoys which will also collect oceanographic information. This data buoy program will be integrated closely with the AIDJEX main experiment scheduled to commence on 1 March 1975 and continue for approximately 14 months. The scheduled data collection period proposed here should provide the required information during one season which will coincide with the data taken by the AIDJEX program. In addition, the data buoy program will be complemented by a detailed study of near-shore ice deformation and motion using radar transponders and lasers in a 35 kilometer radius north of Prudhoe Bay and detailed studies of coastal ice properties and processes such as the formation of shear ridges in the area near the radar transponder sites. This study is to be undertaken by scientists from the Cold Regions Research and Engineering Laboratory (CRREL). Both data buoy and radar transponder programs will also provide the ground truth data required for interpretation and verification of information collected by a remote sensing program which will utilize aircraft and satellite platforms, to document ice behavior along the coastal zone between the Bering Strait and Demarcation Point. All of the field studies will be complemented by an effort at the University of Washington to model the behavior of the dynamics and thermodynamics of the near shore ice cover using the data collected in the field program. These efforts are the first step toward developing forecasting procedures that will be of direct use to arctic operators.

Each of these complementary studies is the subject of proposals prepared at the respective institutions and are based upon a program prepared jointly by CRREL and the University entitled, "Dynamics of Near-Shore Sea Ice: A Research Program," dated 10 January 1975.

B. Methods

Specifically our proposal is to develop, build, and deploy a number of buoys to measure position, atmospheric pressure, temperature, and ocean currents. It is planned that 12 buoys will be deployed in an initial array, as shown in Figure 1. Four of them will be instrumented with atmospheric pressure and temperature sensors, two current meters and a Random Access Measurement System (RAMS) platform to permit tracking by satellite. The RAMS platforms should provide a positioning accuracy of at least five kilometers, sufficient to study the behavior of the ice in the shear zone. The other eight buoys in the initial array will provide tracking information only. An additional eight tracking buoys will be procured for deployment in the following spring. Four of these eight additional buoys will be deployed as shown in Figure 1 to compensate for the expected drift pattern of the original array, and the other four will be used to improve the distribution of the array caused by irregular drift patterns and to replace buoys which may have failed. The data thus obtained will yield for the first time a synoptic picture of the kinematics of near-shore sea ice. In addition, the data will be used together with other AIDJEX data to drive and check the AIDJEX ice model.

It is proposed that the buoys equipped with tracking devices only be developed in a configuration which would permit them to be air-dropped, an important advantage in a region where thin ice or heavily ridged ice frequently poses severe deployment problems. It is planned that the buoys instrumented with sensors will be put in place by helicopter.

VI. INFORMATION PRODUCTS

The information product from this program will be the data described under V-B, above. It will be placed in the AIDJEX Data Bank and such other data archiving systems as may be prescribed.

The air droppable buoys will provide position only to an accuracy of ± 5 km by means of the RAMS system. The environmental sensing buoys will provide the following data:

data sampling:	synoptic every 3 hours
current measurements:	5 m and 20 m depth
current speed:	range 0 to 50 cm/s
	accuracy ± 0.2 cm/s
current direction:	accuracy ± 5°
atmospheric pressure:	10 minute average
	accuracy ± 0.1 mb
air temperature:	accuracy ± 2°C

VII. DATA EXCHANGE INTERFACES

As described above, the data taken in this experiment will provide ground truth information for a remote sensing program designed to document ice behavior along the coastal zone between the Bering Straits and Demarcation Point. This data will be provided through the AIDJEX data bank as it becomes available.

VIII. SAMPLE ARCHIVAL REQUIREMENTS

None

IX. SCHEDULE

Data collection described in VI above will commence upon installation of the buoys about 15 October to 5 November 1975. The proposed schedule is as follows:

1 October 1975	Delivery of buoys to NARL, Barrow, Alaska
1-15 October 1975	Equipment assembly and check out
15 Oct. - 5 Nov. 1975	Deploy buoys
15 Oct. - 1 March 1976	Monitor buoys
1 March - 15 March 1976	Deploy remaining buoys
1 March - 30 June 1976	Monitor buoys

X. EQUIPMENT REQUIREMENTS

The buoys will be provided through the NOAA Data Buoy Office. Deployment will be in accordance with IX above.

XI. LOGISTICS REQUIREMENTS

The principal logistics requirements are for fixed and rotary wing aircraft services to deploy the buoys.

Fixed wing aircraft services will be required for deployment of the air droppable buoys. Twelve of these buoys will be deployed in October 1976. Each buoy will weigh about 100 pounds and the most easterly will be deployed off Prince Patrick Island in the Canadian Archipelago, about 700 miles from Barrow, Alaska. (The proposed initial array is shown in Figure 1). If refueling can be arranged at a Canadian field it should be possible to deploy the buoys in three flights, though the actual requirement will depend on the aircraft characteristics. An aircraft with a tail door drop capability is preferred. Deployment of buoys in March 1976 should require no more than one long range flight and a shorter flight from Barrow.

The four meteorological and oceanographic buoys will require a helicopter to deploy. We have estimated a three week period for helicopter installation to allow for weather, and anticipate that each installation will require about 10 hours of flying in addition to the time required to ferry the helicopter to an advanced base for each deployment. Since these buoys will be entirely deployed in October, the primary requirement for helicopter services in March would be to service and maintain an additional three weeks of helicopter availability at that time. As was the case with fixed wing aircraft the requirements will be modified slightly by the type of helicopter available.

Aside from the aircraft support the principal logistics requirement will be for lodging at coastal stations for the aircraft and deployment crews during the operation. The deployment crew will consist of two persons. Lodging at NARL will be available to the deployment crew through the AIDJEX program. It is assumed that NOAA will provide all aircraft services and lodging arrangements outside Barrow.

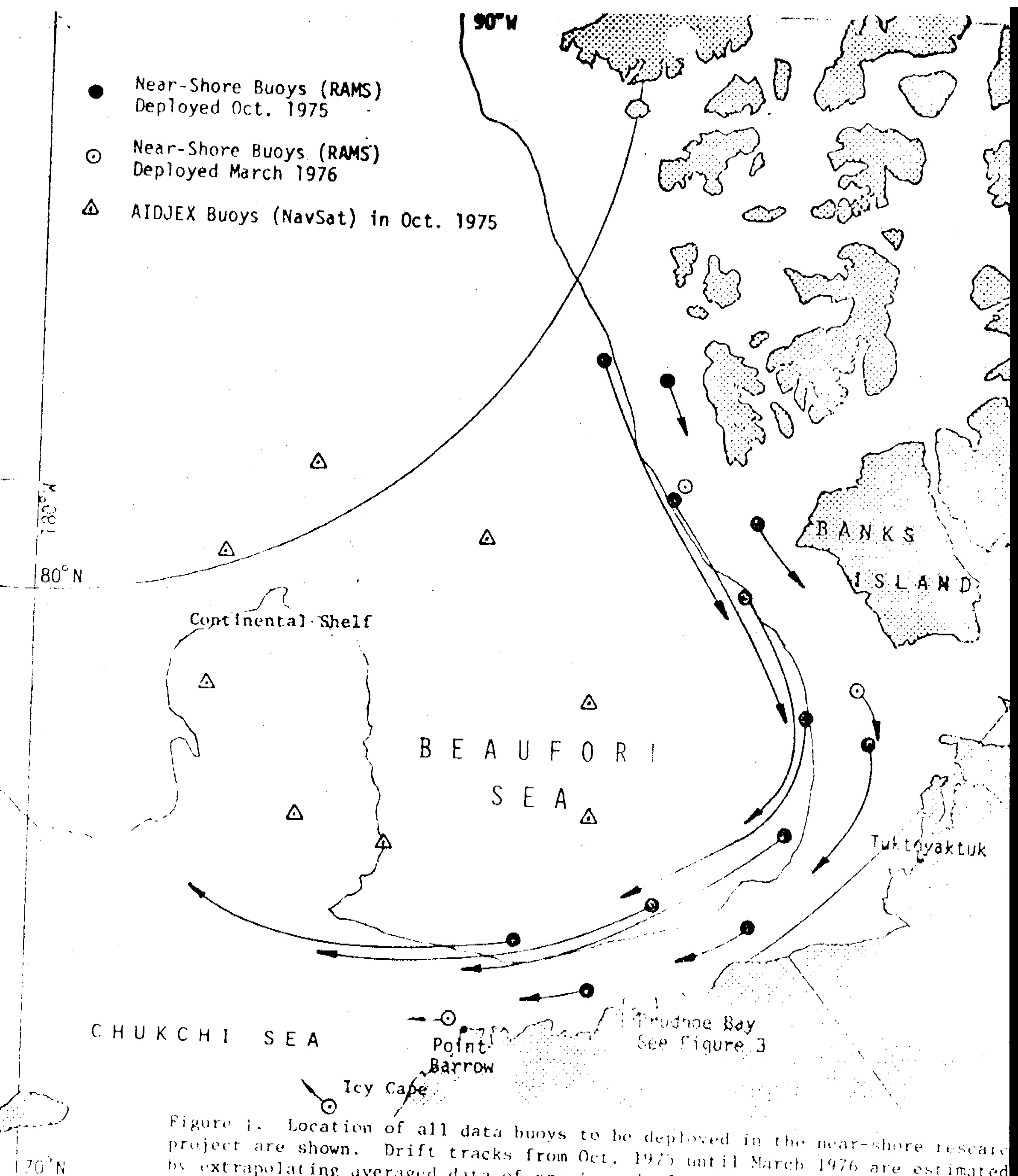


Figure 1. Location of all data buoys to be deployed in the near-shore researc project are shown. Drift tracks from Oct. 1975 until March 1976 are estimated by extrapolating averaged data of previous drift track data (Figure 1). Two lines of buoys, equally spaced, are set out 75 km and 150 km from shore. Near Banks Island, these distances are increased to 100 km and 200 km. The con- tinental shelf lies between these lines near the outer one. Extra buoys are deployed in March 1976 to fill out the array at that time. Gaps are expected due to anticipated drift over the fall and winter months in addition to mal- function. Chukchi Sea coverage is anticipated beginning spring 1976 (March) due to buoys drifting into this area. AIDJEX buoys are also shown in the Oct. 1975 configuration. Shaded region at Prudhoe Bay shows where radar transponder are used for small-scale mechanics studies.

WORK STATEMENT RESEARCH UNIT #244

I. Title: STUDY OF CLIMATIC EFFECTS ON FAST ICE EXTENT AND ITS SEASONAL DECAY ALONG THE BEAUFORT SEA COAST.

II. Principal Investigator: Roger G. Barry

III. Geographic Area and Dates: BEAUFORT SEA COAST OF ALASKA, EAST OF 160°W. 4/15/75 - 9/30/76.

IV. Cost Summary:

	FY 1975	FY 1976
	through 30 June 1975	1 July 1975 - 30 September 1976
	$14,030	$44,635

V. Proposed Research:

A. Background and Objectives

The primary focus of the work is to assess the role of climatic factors in determining the extent and seasonal decay of fast ice along the Beaufort Sea coast. The spatial and inter-annual variability of the seasonal progression of fast ice decay from its maximum extent will be analyzed with particular attention to synoptic meteorological events during critical phases of the seasonal cycle. A subsidiary objective, to be carried out in conjunction with University of Purdue, Laboratory for the Application of Remote Sensing (LARS), is to explore the application of the LARSYS classification and mapping system to ice conditions. This Institute has collaborated previously with LARS on ERTS and Skylab research programs.

The P.I. and colleagues have been involved in similar work on fast ice and climate in eastern Baffin Island, N.W.T., since 1971 (Jacobs et al., 1974; Barry et al., in press; Jacobs et al., in press). Some basic information on fast ice on the Beaufort Sea coast, mainly at Barrow and Barter Is., has been provided by Lieske (1963), Bilello (1964), Bilello and Bates (1966, 1971) and Stringer (1974a,b).

The information required to meet this objective will include (1) maps of seasonal extent of fast ice to be prepared by W.J. Stringer (Univ. of Alaska) under the OCS program, (2) USGS aircraft underflight and ERTS imagery for selected, more detailed, analysis of ice parameters, and (3) synoptic weather maps and weather data; coordination in this respect is planned with Mr. H.W. Searly (NOAA, Anchorage).

Items (2) and (3) should be available within about 4 weeks and hence will allow full reporting by September 1976. However, for item (1) we will be dependent on Dr. Stringer's data products. The 1975 data will be fully analyzed during the project period, but it is likely that only preliminary findings for the 1976 decay season could be documented.

Coordination with planned Alaskan studies under the OCS program and with USGS aircraft flights will be facilitated by a proposed visit to Anchorage, Fairbanks and Barrow by Mr. R. Moritz from about 15 May-10 June 1975. Similar coordination with aircraft flights would be carried out in Spring 1976.

B. Methods

1. Existing Data: Historical records of ice conditions, which are to be reviewed by Professors Hunt and Naske (Univ. of Alaska), may provide some indication of the frequency of severe ice years. Quantitative materials, however, will derive only from the ice records at Barrow and Barter Is. (referred to above) and Stringer's analyses of 2½ years of ERTS imagery based on the University of Alaska's ERTS archives.

Meteorological data for Barrow include, in addition to the routine US Weather Service records (which are also available for Barter Island), measurements of radiation components (Maykut and Church, 1973; Weller and Hohmgren, 1974; LeDrew and Weller, in press). Much of this information can be usefully extrapolated to estimate conditions on the fast ice.

2. Remote Sensing Data: Using Stringer's maps of seasonal ice morphology as a basis and working with appropriate morphological categories, developed by Weaver (1975) from LANDSAT band 6 MSS imagery, we will examine the extent and summer decay of fast ice along the entire Beaufort Sea coast from 160°W to the Canadian border. Sectors with different temporal morphological characteristics will be distinguished. In view of the location of existing weather stations, special attention will be concentrated on the sectors outlined in Figure 1. The analysis procedures are outlined below.

The temporal sampling is determined in part by the availability of LANDSAT imagery. Past data are available on an 18-day cycle, with imagery on about 4 successive days (depending on cloud cover). At present, greater frequency of coverage is feasible due to the simultaneous operation of LANDSAT 1 and 2. Daily coverage with coarser resolution (∿3.5 km compared with <100 m for LANDSAT) is available from the DMSP visible and IR imagery.

From the point of view of year-to-year variation, the few available years of quantitative information from the ERTS imagery will all be used. It is uncertain as to the long-term representativeness of conditions during this period. We can perhaps approach this problem from climatological evidence when the role of the major climatic determinants of ice conditions have been identified.

3. Underflight Data: Imagery is required for control on the satellite interpretation and mapping. We propose 1 flight in spring and 3 in the summer phase. A further 1-2 flights in the freeze-up period may be desirable also. Flights at ca. 1000 ft. (or below cloud) should be in a parallel transect pattern from pre-determined coastal features along a coastal strip of approximately 30 km long and ca. 10 km wide. Instrumentation requested is:

- visual multiband photography (spectral ranges similar to Landsat)
- IR imagery (preferably 8-14 μm)
- albedometer
- PRT-5 (we have available if needed)

Recording systems for albedo and surface radiation temperature should have time-mark system for matching with imagery. Selected SLAR coverage as also requested by Dr. Stringer would be valuable during the period of maximum extent in spring (mid-late May) to differentiate ice morphological characteristics.

R. Moritz will be at Barrow in the spring-early summer phase to coordinate with the USGS aircrew. He will also take surface photographs and collect data on snow cover and ice thickness along a transect off Barrow.

4. Analysis Procedures: The organization of the analysis is outlined in Figure 2. The major tasks are as follows:

a. Mapping of fast ice extent and characteristics, as described in B., using conventional photo interpretation techniques on the satellite imagery supplemented by use of color enhancer system (Spatial Data Systems) available in the Institute. The underflight imagery, plus ground observations of ice characteristics (B.4.), will be used as control data for establishing classification categories based on the state of surface, degree of puddling, etc., and for validation of satellite imagery interpretation.

An attempt will be made to evaluate the feasibility of using the LARSYS system (Baumgardner et al. 1973) for automatic classification and mapping of ice types. This is applied to gray-scale LANDSAT data tapes and will be tested for 1 or 2 selected quarter-frames for nearly cloud-free early-mid-summer conditions (see Appendix 1).

b. Reduction of meteorological data, using existing routines for the CDC-6400 computer, to calculate synoptic parameters (wind velocity, components, radiative inputs) during the decay season along the lines of Jacobs et al. (1972). Data sources and procedures are outlined in Table 1.

c. Synoptic climatological analysis of daily MSL atmospheric circulation patterns and associated daily climatic data at Barrow, Prudhoe and Barter Island for selected periods (see Barry and Perry, 1973), relating to:

(1) the seasonal course of the regional circulation regime. The synoptic classification procedures have been established for the eastern Canadian Arctic (Barry, 1974) and work is well advanced on objective procedures using grid-point pressure data. The work would focus initially on seasons with significant positive and negative departures in ice extent as determined from our mapping and other sources, and in climatic conditions. Long-term records for Barrow have been analyzed under IBP Tundra Biome abiotic studies (Barry et al. 1975). Climatic data of particular importance are temperature, precipitation, wind velocity and cloudiness.

(2) specific events of significance to the decay process, such as early-mid-summer snowfall, major warm air advection (cf. Jacobs et al. 1974; Fahl, 1973). Synoptic situations giving rise to storm winds and high waves will probably be examined by other groups (Searby and Quinlan). Their information will undoubtedly be useful to this project as input to assessment of factors affecting break-up, although some additional synoptic climatological analysis may be required for our purposes.

VI. Information Products:

A. Maps of fast ice extent and surface morphological characteristics, by month in the decay seasons since 1973, for the 3 sectors delineated in figure 1 on a scale of ca. 1:500,000. The specific products will be coordinated with those seasonal ice conditions to be prepared by W. Stringer.

B. Daily catalog of mean sea-level pressure pattern types since 1973. This may be expanded to cover a longer time period if useful earlier records of ice conditions can be obtained.

C. Classification of synoptic pressure patterns according to their significance in terms of accelerated or retarded break-up of fast ice (radiation budget parameters, temperature, wind velocity).

D. Computer-aided analysis map products of 2 sample test frames (1/4 ERTS frames) of ice surface morphology.

VII. Data Exchange Interfaces:

Our primary dependence will be on EROS Data Center LANDSAT imagery, University of Wisconsin DMSP Data Center imagery, and USGS underflight imagery. Underflight imagery are requested within 10-16 days of the flights; the other imagery should be available within ca. 4 weeks.

Requirements for our products have not yet been identified to us, but the ice maps and climatic data are likely to be requested by groups involved in the marine ecology baseline characterization and in the ice force studies by Barnes/Reimnitz, USGS.

VIII. Sample Archival Requirements:

Not applicable.

IX. Schedule:

1975

15 May - 15 June	Ground-truth data collection at Barrow (R. Moritz), and USGS aircraft underflights. Project coordination and planning; ordering weather data, imagery products.
15 - 30 June	Literature review, analysis of ground-truth data on snow and ice conditions.
10 July	Preliminary report FY 1975 of previous items; revision as needed of planned field checking program in light of experience.
July - August	Examination of fast-ice maps generated by W. Stringer under previous grants. Qualitative assessment of significant synoptic meteorological events. Analysis of May-June underflight imagery.

September	Development of synoptic classification categories; program testing.
10 October	Quarterly report.
October - December	Generation of synoptic catalog for the Beaufort seacoast region; calculation of daily geostrophic wind indices. Analysis of summer-fall underflight data. Review of Stringer's map products, modification as needed, development of categories of ice surface morphology for production of sector maps.
	<u>1976</u>
10 January	Quarterly report.
January - March	Selection of LANDSAT frames for supply of data tapes to LARS; LARS computer-aided mapping. Imagery interpretation and synoptic map analysis for determination of meteorological parameters (see Table 1). Preparation of maps of ice extent and morphology.
10 April	Quarterly report.
April - 15 May	Case studies of significant break-up related weather events; evaluation of LARSYS map-classification products.
15 May - 15 June	Ground-truth data collection at Barrow and USGS aircraft underflights.
15 - 30 June	Analysis of field data on snow and ice conditions.
10 July	Quarterly report.
July - August	Continued analysis of imagery and meteorological data; continuation of preparation of ice maps incorporating field data and underflight products. Identification of major controls of climate regime and synoptic events on fast ice extent and seasonal decay.
September	Writing final report, which will include map products, synoptic catalog, analysis of climatic factors influencing fast ice extent and seasonal decay.

TABLE 1

PROCEDURES FOR REGIONAL SYNOPTIC ENERGY BUDGET ANALYSES

1. Mapping significant features from imagery
   a. Cloud cover--visual and IR (DMSP, NOAA)
   b. Ice and snow cover--visual and IR (DMSP, NOAA, ERTS)
   c. Surface temperatures--IR (DMSP, NOAA)

2. Calculation of the radiation budget components
   a. Global solar radiation (function of clouds, declination, latitude, time)
   b. Absorbed solar radiation (from reflectance assigned to 1.b categories and incoming total from 2.a)
   c. IR surface emittance (Stefan-Boltzmann approximation from 1.c, or 273 K assumption for melting ice)
   d. Atmospheric emittance (analyzed from Sasamori program routine applied to Barrow soundings and/or empirical approximations based on Maykut/Church for synoptic data)

3. Turbulent energy budget
   a. Ten meter wind (extrapolated from geostrophic)
   b. Temperature, vapor profiles empirically approximated for synoptic types from Barrow weather station data.

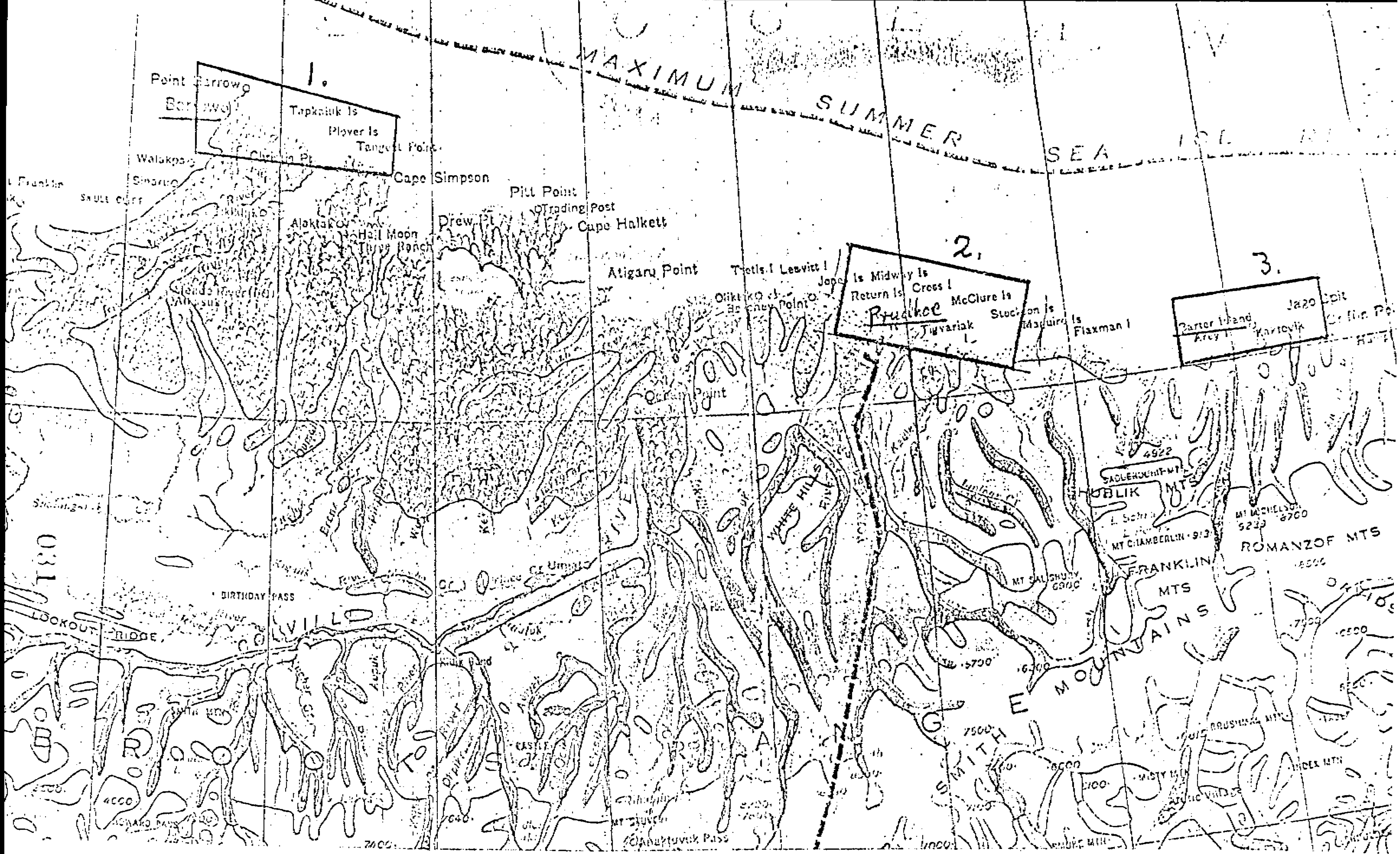


Fig. 1. Location map outlining 3 sectors for mapping
Weather stations underlined

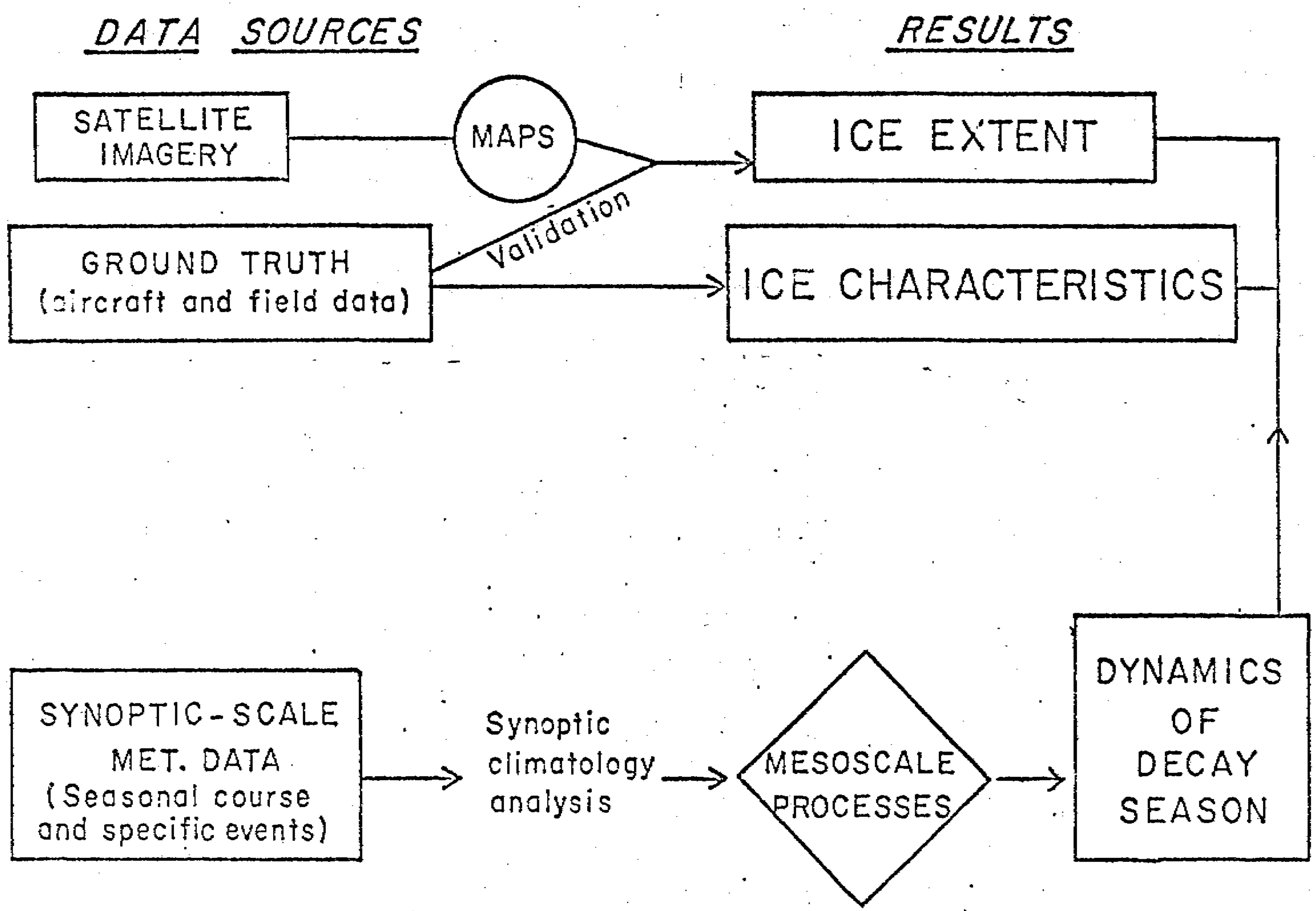


Fig. 2. Organization of data analysis

X. Equipment Requirements:

None.

XI. Logistics Requirements:

1. USGS Mohawk and Cessna 310.

1975 and 1976

ca. 12 hours low-level (below cloud) flights over the fast ice zone from Barrow eastward to Prudhoe in the period 16 May - 15 June 1975.

It would be desirable to have 5-6 flights of ca. 2-hour duration at approximately 5-day intervals during this period. Flight pattern in transect approximately parallel to coast, from predetermined coastal features, covering strips ca. 10 km wide. Full coverage of Barrow and Prudhoe sectors on Fig. 1 is essential. Similar coverage is requested at approximately 10-15 day intervals in the periods 15 June - 15 July, freeze-up (ca. 15 September - 31 October), maximum extent (March).

Instrumentation requested is:
- visual multiband photography (spectral ranges similar to LANDSAT; ·5-·6, ·6-·7, ·7-·8, ·8-1.1 μm)
- IR imagery (preferably 8-14 μm)
- albedometer
- PRT-5 (we have available if needed)

Recording systems for albedo and surface radiation temperature should have time-mark system for matching with imagery.

SLAR images would also be especially valuable during the period of maximum extent, if SLAR is available.

Requested format of products:

visual and IR	black and white transparencies preferred, rectified if possible, 9" x 9" frames.
albedo and PRT records	time-marked trace to match with photographic products.
SLAR	black and white opaque prints (9" x 9")

2. NARL (Requested arrangements of NOAA).

Accomodation and meals for one man (R. Moritz) ca. 16 May - 15 June 1975 and 1976.

Surface transportation - 4-wheel drive and/or over-snow vehicle for access onto coastal ice in vicinity off Barrow. Approximately seven (7) days during this period.

Notes on Indirect Costs

These are divided between on-campus and off-campus categories by calculating that Mr. Clark will be in the field June 1975 and June 1976. All other salries and wages represent work done on the Boulder campus.

APPENDIX 1

As outlines in section VB4(a), an additional analysis is proposed relating to the LARSYS numerical classification and mapping system of the Laboratory for the Application of Remote Sensing (LARS), Purdue University. This analysis requires a subcontract to LARS, as outlines below. The Institute has collaborated on ERTS and SKYLAB contracts previously with LARS.

LARS will analyze 1 or 2 quarter frames of Landsat-2 data (in tape format) under the LARSYS system in a "supervised" (i.e. with training data on ice surface types obtained by our field program) and an "unsupervised" mode. The system provides a machine clustering of similar spectral signatures and the classification categories are output in map form.

The cost for this sub-project under Dr. R. M. Hoffer is itemized below.

Subcontract from the University of Colorado
to LARS, Purdue University

Estimated Budget	July 1, 1975 - September 30, 1976
Systems programmer consultant	$ 1,500
Computer time (LARSYS analysis):	
reformatting Landsat-2 tapes (2 quarter frames)	2,000
supervised/unsupervised LARSYS	1,800
Landsat data tapes, computer tapes	350
Mailing, telephone	200
TOTAL	$ 5,850

References

Barry, R. G., 1974. Further climatological studies of Baffin Island, Northwest Territories. Inland Waters Branch, Tech. Bull. 65 (Ottawa), 54 pp.

Barry, R. G., Bradley, R. S. and Jacobs, J. D., 1975. Synoptic climatological studies of the Baffin Island area. Climate of the Arctic (24th Alaska Sci. Conf.), Fairbanks, p. 82-90.

Barry, R. G., Perry, A. H., 1974. Synoptic Climatology: Methods and application. Methuen, London, 555 pp.

Barry, R. G., Benson, C. S., Kelley, J. J., Outcalt, S. I. and Weller, G., 1975. Tundra climate, Abstracts. AAAS Meeting, New York.

Baumgardner, M. A., Kristof, S. J. and Henderson, J. A., 1973. Identification and mapping of soils, vegetation, and water resources of Lynn County, Texas, by computer analysis of ERTS MSS data. Sympos. on Significant Results obtained from the ERTS-1 NASA SP-327, Vol. 1, p. 213-221.

Bilello, M. A., 1964. Ice thickness observations, North American Arctic and Subarctic. U.S. Army CRREL Special Rep. 43, Parts 1 and 2.

Bilello, M. and Bates, R. E., 1966, 1968, 1971. Ice thickness observations, North American Arctic and Subarctic. U.S. Army CRREL Special Report 43, Parts 3, 4 and 5.

Jacobs, J. D. et al. Short-term air-sea interactions and surface effects in the Baffin Bay - Davis Strait region from satellite observations. Inst. Arct. Alp. Res., Occas. Pap. No. 9, 78 pp.

Jacobs, J. D., Barry, R. G., Bradley, R. S. and Weaver, R. L., 1974. Studies of climate and ice conditions in eastern Baffin Island, 1971-1973. Inst. Arct. Alp. Res., Occas. Pap. No. 9, 78 pp.

Jacobs, J. D., Barry, R. G. and Weaver, R. L., in press. Fast Ice characteristics in the eastern Canadian Arctic. Polar Record.

LeDrew, E. and Weller, G., in press. The radiation and energy balances. The Structure and Function of the Tundra Ecosystem, Vol. 1, U. S. Tundra Biome.

Lieske, B. J., 1964. Net radiation over fast sea ice during spring break-up at Barrow, Alaska. Proc. 15th Alaskan Sci. Conf., p. 52-60.

Maykut, G. A. and Church, P. E., 1973. Radiation climate of Barrow, Alaska, 1962-66. J. Appl. Met., 12, 620-628.

Stringer, W. J., 1974a. Shore-fast ice in vicinity of Harrison Bay. Northern Engineer, 5, 36-39.

Stringer, W. J., 1974b. The morphology of Beaufort Sea-shorefast ice. In: Beaufort Sea Symposium, Arct. Inst. North America.

Weller, G. and Holmgren, B., 1974a. The microclimates of the arctic tundra. J. Appl. Met., 13, 854-62.

Weller, G. E. and Holmgren, B., 1974b. Summer global radiation and albedo--data for 3 stations in the Arctic basin. Tech. Rep. No. 2, Univ. of Alaska USGR-229.

RESEARCH UNIT #250

Final

WORK STATEMENT

JUN 30 1975

I. TITLE: Mechanics of Origin of Pressure Ridges, Shear Ridges, and Hummock Fields in Landfast Ice

II. PRINCIPAL INVESTIGATORS: Lewis H. Shapiro SS# 117-26-5144
Assistant Professor of Geology

William D. Harrison SS# 554-70-4301
Assistant Professor of Physics
University of Alaska

III. GEOGRAPHIC DATA AND INCLUSIVE DATES: Beaufort Sea OCS Area
April 1, 1975 - September 30, 1976

IV. COST SUMMARY:

FY 1975 through June 30, 1975	FY 1976 July 1, 1975 - Sept. 30, 1976
$10,976	$63,324

V. PROPOSED RESEARCH

A. Background and Objectives

This research falls within the general task heading "Transport Processes", and specifically within the category "Ice Dynamics".

The problem of the origin and growth of pressure ridges in the open ocean has been treated in the model of Parmenter and Coon (1973), but no similar analysis has been done for ridging in the near shore zone. Descriptions of grounded ridges, and some possible mechanisms of origin have been given by Kovacs (1972), Kovacs and Mellor (1974) and Weeks et al. (1971). In addition, Bruun and Johannesson (1971), Zubov (1943) and Allen (1970) have considered the problem of piling of ice in shallow water or against an obstruction, a problem which we consider to be closely related to the ridging problem. Finally, in previous work by one of the Principal Investigators (Shapiro, 1975), the importance of the use of radar data to determine the movement vector of the pack ice during ridging has been demonstrated. The results of this work, along with supplemental field studies, provides the basis for much of the work proposed here.

Following the work of Parmenter and Coon (1973) we have tentatively identified the pattern of energy partition during the formation of pressure and shear ridges and hummocks (Shapiro, 1975). These fall into the following categories: (1) gravitational potential energy, (2) formation of new surface energy by fracture, (3) friction, which may enter the problem in several ways, and (4) energy loss due to gouging of the sea floor. In the process of ridging in the open sea, (4) does not enter, while, from the Parmenter and Coon model, (2) and (3) are of much lower magnitude than (1) and may therefore be ignored. However, our results for the near shore zone suggest that friction and the formation of new surface energy taken together may be of the same order of magnitude as the gravitational potential energy when grounding occurs. Further, this is certainly the case for shear ridges, in which large masses of ice are crushed and fragmented (Weeks et al., 1971; Shapiro, 1975), so that virtually all of the energy is absorbed as surface energy associated with fracture. Finally, it has not yet been possible to consider the contribution of gouging of the sea floor during grounding to the total energy balance. The recent work of Kovacs and Mellor (1974) may provide the basis through which this can be done. At present, however, it is apparent that better estimates of the importance of these processes are needed, and we believe that some progress can be made towards this goal through the study proposed here.

Movement data from the radar imagery enters the analysis in several important aspects, including providing a means of determining the temporal relationship between the formation of various features of the landfast ice. As an example, during the winter of 1973-74, the radar imagery permitted recognition of a transition, in time, from pressure ridging to shear ridging along the same line, and with no change in the velocity or direction of movement of the pack ice. This process has not previously been reported in the literature, and a preliminary analysis of the role of friction in the transition has been prepared by one of the Principal Investigators (W. D. Harrison). Further, following formation of the shear ridge, the pack ice was rafted over the adjacent shear zone and pressure ridging occurred, again with no change in the drift vector of the pack ice. The entire process took less than 4 hours and occurred during a heavy storm on January 1, when visibility was limited by the absence of daylight and the storm conditions. This illustrates the importance of the continuous, all-weather information provided by the radar system.

Analysis of movement data also provides a method for estimating the energy available during the ridging process, through measurement of the velocity of the ice (supplemented by measurement of the thickness of the ice in the resulting ridges) and the distance through which the ice moved during the formation of the ridges. Finally, there are some preliminary results suggesting that the limiting heights of grounded pressure ridges are at least partly dependent upon both the velocity of the pack ice, and its angle of approach to the growing ridge.

The objectives, as stated in the original letter proposal, are:

(1) To develop an understanding of the environmental parameters which localize pressure ridges, shear ridges (and related shear zones) and hummock fields within the landfast ice zone of the Arctic Coast.

(2) To gather field data regarding the mechanisms by which these structures form.

(3) To prepare a semi-quantitative model of the processes involved in the formation of these features, in order to test the validity of the concepts developed in (1) and (2) above.

(4) To use these results to develop a procedure for estimating average and worst possible occurrences of heavily deformed ice within the landfast ice zone in terms of environmental parameters (such as water depth, bottom configuration, shoreline geography), ice thickness, and prevailing and unusual meteorological events.

The information required to meet these objectives falls into three categories:

(1) Bathymetry and side-scan sonar data of the area within the radar field-of-view at Barrow. At present, we have arranged with the U.S. Geological Survey to acquire this data during the summer of 1975. It would be desirable to repeat the side-scan sonar survey in 1976 in order to estimate the extent of gouging which occurs during the winter of 1975-1976.

(2) Continuous radar coverage of the study area at a suitable scale, during the time of ridge formation. The radar system is currently operated under the University of Alaska Sea Grant Project,

and data from this source is expected to be available during the project proposed here.

(3) Field studies including mapping, profiling and sampling of typical shear and pressure ridges within the radar field-of-view, to determine the geometry of these features, and, in the case of shear ridges, their internal structure. The distribution of features, their time of formation, and the direction and velocity of the pack ice at those times will be mapped from a combination of air photos and radar data. Finally, field measurements will be made of the thickness of the ice involved in the ridges, and the size and shape of blocks, for information regarding failure mechanisms of the ice which operated during the ridging process.

It is anticipated that, barring an unusually smooth ice year at Barrow during the winter of 1975-76, sufficient information will be available by June 1976 to meet all of the objectives of this project except the last. This will depend, to some extent, on the results of other projects, notably that of Stringer and Hunt and Naske, regarding the occurrences of pressured ice in areas other than Barrow. This information is necessary to test the ideas developed in the last objective.

In addition to Stringer, and Hunt and Naske, the work of Weeks and Kovacs on ridges in the Prudhoe Bay-Cross Island area will be of interest to us. We anticipate no difficulties in communication with these workers. We have daily contact with Stringer and Hunt and Naske, and will be in contact with Weeks and Kovacs by telephone, letter or at meetings. We do not consider that formal arrangements for communication with any of these people are necessary.

B. Methods

The approach to gathering the information needed for this study is outlined in the discussion above regarding data requirements.

At the start of this project, two full years of photo imagery from the Barrow radar will be available, along with supplemental field information. This data will be analyzed for relevant information. In addition, we will continue the work reported in Shapiro (1975), and the investigation of the role of friction in the transition from pressure ridging to shearing which was begun by W. D. Harrison (see above). Finally, a search of the published literature, in addition to that already done, will be made.

The method of sampling depends upon the manner in which the ice forms. The intention is to survey and map as many ridges as time permits, and to include, within the sample, examples of ridges formed under different conditions of ice drift, and in different water depths.

We do not intend to develop a computer model of the growth of ridges in shallow water analogous to that of Parmenter and Coon (1973) for ridging in the open sea. Instead, we anticipate calculating semi-quantitative physical models which are designed to test ideas developed during the study. As an example, we hope to analyze the problem of the limiting height of grounded pressure ridges as a function of fracture mechanisms, ice thickness, angle and velocity of approach of the pack ice, water depth, and any other parameters which we believe might be relevant.

REFERENCES CITED

JUN 30 1975

Allen, J. L., 1970. Analysis of forces in a pile-up of ice, in Ice Engineering and Avalanche Forcasting and Control, Proc. Calgary Conf., 1969, Nat'l. Res. Council of Canada, Com. on Geotech. Res., Tech. Mem. 98, p. 49-56.

Bruun, P. M. and P. Johannesson, 1971. The interaction between ice and coastal structures: Proc. 1st Int. Conf. on Port and Ocean Eng. Under Arctic Conditions, Trondheim, Norway, p. 152-183.

Kovacs, A., 1972. Pressured sea ice, in Sea Ice, Proc. of an Int. Conf., Reykjavik, Iceland, May 10-13, 1971, p. 276-295.

Kovacs, A. and M. Mellor, 1974. Sea ice morphology and ice as a geologic agent in the southern Beaufort Sea, in The Coast and Shelf of the Beaufort Sea, J. C. Reed and J. E. Sater, editors, p. 113-161.

Parmenter, R. R. and M. D. Coon, 1973. Mechanical models of ridging in Arctic sea ice cover, AIDJEX Bull. 19, p. 59-112.

Shapiro, L. H., 1975. Preliminary report on the formation of landfast ice at Barrow, Alaska, Winter 1973-74, University of Alaska Sea Grant Report, 45 p.

Weeks, W. F., A. Kovacs and W. D. Hibler III, 1971. Pressure ridge characteristics in the Arctic coastal environment, 1st Int. Conf. on Port and Ocean Engineering under Arctic Conditions, Trondheim, Norway, p. 152-183.

Zubov, N. N., 1943. Arctic Ice, Izdatel'stvo Glavsevmorputi, Moscow (Translation AD426972, NTIS, Springfield, Va.), 491 p.

VI. INFORMATION PRODUCTS

Information products will include a final report describing observations, methods of study, and results If objective (4) can be attained, then a series of maps depicting areas where severe ice conditions may occur in the near shore zone will also be included. Finally, a motion picture of the relevant parts of the radar imagery will be prepared.

VII. DATA OR SAMPLE EXCHANGE INTERFACES

No other data are routinely required from other investigators. However, we will be interested in the location of severe ice conditions during the coming year from Stringer, and in the results from Hunt and Naske toward the conclusion of their project. These data will aid us in meeting objective (4). In addition, as noted above, we will be interested in the results of the work by Weeks and Kovacs, but no special time limit is placed upon acquisition of this information. We anticipate that these investigators will be interested in our results, but are not aware of any specific time requirement. However, we believe that communication is more than adequate to insure that information needed will be readily available.

VIII. SAMPLE ARCHIVAL REQUIREMENTS

No sample archiving will be required.

IX. SCHEDULE

The available radar data will be completely analyzed and a preliminary report prepared using existing data by December 1975. The major field effort will be in the Barrow area at selected times between January and late May 1976. Analysis of field and radar data will be completed by July of 1976, and a final report prepared by September 30, 1976.

X. EQUIPMENT REQUIREMENTS

A steam drill for ice ridge characterization will be required.

XI. LOGISTICS REQUIREMENTS

The only logistics requirements are for a total of 90 days lodging at NARL, during field trips, and for up to 10 hours of dedicated flight time by a Cessna 180 in the Barrow area during field trips in the field season, for the purpose of acquiring air photos of the study area, and general observations of ice conditions.

It is anticipated that remote sensing photographic and SLAR imagery taken by the OCS program throughout the ice season in the vicinity of Barrow will supplement the specific flights mentioned above.

JUN 30 1975

RESEARCH UNIT #257

WORK STATEMENT

I. TITLE: Morphology of Beaufort Near Shore Ice Conditions by Means of Satellite and Aerial Remote Sensing

II. PRINCIPAL INVESTIGATOR: W. J. Stringer SS# 530-24-3717
Research Associate
University of Alaska

III. GEOGRAPHIC AREA AND INCLUSIVE DATES: Beaufort Sea
May 1, 1975 - September 30, 1976

IV. COST SUMMARY:

FY 1975 through June 30, 1975	FY 1976 July 1, 1975 - Sept. 30, 1976
$22,000	$35,200

V. PROPOSED RESEARCH

A. Background and Objectives

1. State of Knowledge

The general description of ice in near shore areas has been investigated and reported. For instance, Zubov (1943) discusses a variety of near shore ice conditions. Most recently, Kovacs and Mellor (1973) have given a review of the state of knowledge of sea ice including near shore ice. The principal near shore ice, fast ice, has been investigated to the point that several general parameters have been accepted -- at least in terms of Beaufort Sea shore fast ice. Briefly these are:

a) Sometime around midwinter, the ice along the shoreline is no longer subject to breaking free and having open water except under the most unusual circumstances.

b) This "shorefast" ice sheet may contain many pressure ridges. Its seaward edge is defined by the most seaward grounded pressure ridge.

c) Bottom sediments appearing in the piled ice are generally taken to be evidence that a pressure ridge is grounded.

d) The most seaward grounded pressure ridge is characteristically near the 18-m contour.

e) From time to time, a floating sheet of ice can be attached to the shorefast sheet and extend many kilometers farther seaward.

f) The grounded pressure ridge system endures into summer, sometimes as late as mid-July.

Virtually nothing is known about the dynamic morphology of shorefast ice; formation processes, stress-induced changes, year-to-year variations in location of its edge and locations of hummock fields, stability and other parameters related to specific weather patterns or geomorphological features.

2. Objectives

The objective of this proposed study is to develop a comprehensive morphology of near shore ice conditions in the Beaufort Sea. This morphology would include a synoptic picture of the development and decay of fast ice and related features along the Beaufort Sea coast, and in the absence of fast ice, the nature of other ice (pack ice, ice islands, hummock fields, etc.) which may occasion the near shore areas in other seasons. Special emphasis would be given to consideration of potential hazards to offshore facilities and operations created by near shore ice dynamics. A historical perspective of near shore ice dynamics will be developed to aid in determining the statistical rate of occurrence of ice hazards.

The data gathered here would be provided on a timely basis to other investigators performing related tasks (detailed later).

3. Expected Results and Results Related to Other Studies

There are two categories of results to be anticipated. The first category consists of direct data products while the second consists of indirect data produc..., which will be combined with s..dies performed by others within the study program.

a) DIRECT DATA PRODUCTS: These products would consist of a morphology of Beaufort Sea near shore ice and a series of maps showing persistent locations of major ice features including ice hazards within the near shore zone. These include the locations of large grounded pressure ridge systems, the location of summertime pack ice visits to the near shore areas and the drift pattern of ice islands. The morphology developed will provide a comprehensive picture of the development and decay of fast ice and the description of the sea ice cover on the Alaskan Continental Shelf.

b) INDIRECT DATA PRODUCTS: The morphology developed would yield information toward the determination of ice movement and deformation mechanism in the coastal fast ice zone. The ice type maps will indicate where to apply data relating stress-strain relationships to man-made and natural structures. The mapped pressure ridge locations and sites of ice island groundings will provide data toward a predictive technique for ice scoring processes. The assembled data will be of use to the study of the relationship of living resources to the ice environment.

4. Relationship of This Study to Defined Tasks

The objective of this proposed study is to develop a comprehensive morphology of near shore ice conditions in the Beaufort Sea. This objective can be related in a primary way to three NOAA-identified tasks: A-29, A-30 and B-13. Task A-29 calls for the "assemblege and analysis of historical records and remote sensing data to provide a comprehensive picture of the development and decay of the fast ice along the Beaufort Sea coast". This task then considers the near shore areas in fall, winter and spring months. The primary data source for this project will be ERTS and NOAA satellite imagery and aircraft photography. Historical data will be assembled by another project (Hunt and Naske) and incorporated here.

Task A-30 calls for "using remote sensing methods, quantitatively describe the sea ice cover on the Alaskan continental shelf including the temporal and spatial description of the extent, location, type and state of the pack ice in the Beaufort and Bering seas". This task is concerned primarily with summer months as far as the near shore areas are concerned. However, summer pack ice behavior is still a major part of the morphology of near shore ice.

Task B-13 is to "determine deformation mechanisms in the coastal fast-ice zone". Although a study to specifically analyze the mechanics of origin of pressure ridges, shear ridges and hummock fields in land-fast ice will take place, other deformations of much larger size also occur which must be considered a part of the general morphology. Analysis of these deformations will be made as part of this study.

The objectives of this study can be secondarily related to the following tasks which are the primary responsibility of others: Tasks A-31, B-12, B-13, D-11.

Task A-31 asks for the "determination of the relationship of living resources to the ice environment". The results of the near shore ice study would yield comprehensive maps for the application of results of this task in a general sense to the entire coast.

Task B-12 is the "description and analysis of the large scale motions and deformation mechanisms of the primarily first-year ice in the region of strong shear, that separates the coastal fast-ice zone from the multi-year pack ice zone". Much of the morphology of the shore-fast ice is determined by the large scale motions of the ice in the region of strong shear. Hence, there will, of necessity, be a relationship between the near shore ice study and the study(ies) related to Task B-12.

Task B-13 has already been regarded to be, in part, a primary responsibility of this study in terms of large scale ice deformations. This study is also related to the analysis of smaller deformations in a secondary sense in that those results must be taken into account when developing a comprehensive morphology.

Task D-11 calls for "determination of the stress-strain relationships of various types of sea ice encountered in the Beaufort, Chukchi and Bering seas in order to permit calculation of ice forces and loads transmitted from the ice to man-made and natural structures". The near shore ice maps should supply sites for tests of stress-strain laws for sea ice against large natural structures.

5. Information Needed to Meet Task Objectives

The information needed to meet these objectives was not available until the construction and launch of the ERTS-I satellite. The imagery from this system, now covering three freeze-thaw cycles, combined with imagery with NOAA satellites should provide a good data base. This comprehensive data should be sufficient to give a reasonable perspective to the one year's research based on concurrent satellite and aircraft data. This information, combined with field reports from other investigations, should be sufficient to meet the task objectives.

6. The Extent of Completion by September 30, 1976

A morphology of near shore ice conditions based on 4 years' data can be presented by September 30, 1976.

7. Related Research

All research related to this study is being carried out by other OCS investigators and has been described above and elsewhere in this work statement. There is no need for detailed coordination between this study and any other in terms of input to this study. It is anticipated that other investigators with first-hand field information will contribute verbal reports on ice conditions they encounter. In terms of output, a number of other projects are anticipating some usefulness from the various products produced. These investigators include Barry, Shapiro, Sackinger, Nelson and Weeks. Here, no coordination is needed other than perhaps some early agreement on product format. Some of the above subjects are discussed in more detail later.

B. Methods

Data from all seasons, past and historical data will be used to compile a series of maps of the Beaufort Sea near shore areas denoting summer and fall pack ice behavior, fall freezing characteristics and growth and decay of the fast ice zone. Particular attention will be paid to the behavior of ice islands and other large free ice features, hummock fields, pressure and shear ridges, open and refrozen leads, etc. A written morphology associating ice behavior patterns with winds, storms, currents, temperature and bathymetric data will be developed (see, for instance, Stringer, 1974a).

1. Sampling Strategy

a) REMOTE PAST (preERTS): Data gathered by investigators analyzing historical records will be incorporated into the morphology, generally to confirm persistent locations of major ice features or determine patterns of extreme behavior. This investigator anticipates continuous interaction with the investigators researching historical ice records. In conjunction with them, a map of historical ice behavior can be developed. Historical information can be utilized to determine locations to give particular attention at present. Similarly, present data may give them additional information toward interpretation of historical data.

b) IMMEDIATE PAST: ERTS imagery will be combined with aerial photographic surveys performed in the past by the author and others (NASA, USGS) to perform a detailed and comprehensive study of near shore ice previous to this time. Thus maximum utilization will be made of the 2-1/2 years of ERTS data which have been collected and archived at the University of Alaska ERTS archives. It is anticipated that this data can be nearly as valuable as ERTS data taken during this study. However, the project airborne remote sensing activities are anticipated to enhance the utility of present ERTS data over past ERTS data.

c) PRESENT: ERTS imagery combined with data from project remote sensing aircraft will be used to monitor the behavior of shore-fast and other ice within the near-shore zone. It is anticipated that interaction will take place with many other investigators studying related subjects (shear zone ice dynamics, pressure ridge modeling, sea mammal habitat, etc.) to yield additional information for incorporation into development of a coastal ice morphology.

REFERENCES

Colvocresses, A. P. and Robert B. McEwen, 1973. Progress in cartography, EROS Program. Printed in Proceedings of NASA Symposium on Significant Results Obtained from the Earth Resources Technology Satellite-I, Published by the National Aeronautics and Space Administration, 1973.

Kovacs, A. and M. Mellor, 1974. Sea ice morphology and ice as a geologic agent in the southern Beaufort sea. Printed in the Proceedings of the Symposium on Beaufort Sea Coast and Shelf Research, Published by the Arctic Institute of North America, December 1974.

Stringer, W. J., 1974a. Shore-fast ice in vicinity of Harrison Bay, Printed in the Northern Engineer, Vol. 5, No. 4, Winter 1973/74.

Stringer, W. J., 1974b. The morphology of Beaufort Sea shorefast ice. Presented at the Beaufort Sea Symposium, January 1974, and published in the Proceedings of the Arctic Institute of North America, December 1974.

Zubov, N. N., 1944. Arctic Ice. U. S. Navy Translation from Russian, 112-15.

VI. INFORMATION PRODUCTS

A. Routine Data Products

Maps of near shore ice conditions for each 18-day LANDSAT cycle with low cloud cover will be prepared at 1:500,000 scale showing locations of major ice features as determined from LANDSAT and NOAA satellite imagery. At this scale, the estimated LANDSAT mapping errors are of the same magnitude as the finest detail which can be drawn. [At 1:500,000 scale, the estimated uncertainty of LANDSAT positional accuracy, 200 m (see Colvocoresses, 1973), is .4 mm.] These maps will be anotated with dates of ice events, ground truth information and any other data which becomes available. These maps will fall in two categories: "on schedule" and "retroactive".

1. The "on schedule" maps will be available as soon as the satellite data become available, interpreted and maps drawn. It is anticipated that this product will be available 90 days after data acquisition (see Section IX).
2. The "retroactive" maps will be compiled based on existing satellite data for those years previous to funding as soon as the required data products can be identified and acquired. These maps will be produced starting with the earliest data first and will be completed by June 1976.

B. Non-Routine Data Products

1. "Epoch Summary Maps". Whenever it appears that a major epoch has taken place (over a period of several LANDSAT cycles), an epoch composite map will be prepared at 1:500,000 scale with accompanying text incorporating other data (e.g., winds, currents, insolation, aircraft data not available when "on schedule" maps are made, etc.). Epoch maps will include a yearly summary map.
2. "Special Event Maps". Occasionally, ice features like the grounded floeberg at 72°N, 162°W develop which show particularly well behavior patterns which illustrate general morphology or

characteristics relevant to a single location. These events will be analyzed in whatever combination of temporal or spatial resolution seems appropriate. (For instance, it is possible to perform digital analysis of LANDSAT data at 1:20,000 scale.)

C. Final Data Products

The final data product of this study will be a written morphology of near shore ice conditions in the Beaufort Sea, illustrated by a series of maps at 1:500,000 scale and special event maps. The morphology will describe persistent near shore ice features and behavioral patterns as well as an analysis of general behaviorial patterns.

The range of subjects will include: (1) Summertime visits of pack ice to the near shore areas and note of locations where pack ice has been grounded or driven onshore. (2) Summertime ice island visits to the near shore areas. (3) Fall freeze-up characteristics in the near shore areas. (4) Development of shorefast ice. (5) Mid-winter modifications and changes within shorefast ice. (6) Interaction of shorefast ice with shear zone ice. (7) Motions of and within shorefast ice. (8) Springtime decay of the shorefast ice.

VII. DATA OR SAMPLE EXCHANGE INTERFACES

This project does not require data from other investigators. (Remote sensing aircraft data is considered to be logistics.) However, we will seek first-hand observations from investigators doing field work.

To my knowledge, only two projects require results from this project and those are Roger G. Barry's study of climate effects on shorefast ice and Sackinger and Nelson's study of the grounded floeberg. It is very possible that much informal exchange will take place among the ice investigators. For instance, Shapiro has indicated an interest in some of the data produced by this project.

VIII. SAMPLE ARCHIVAL REQUIREMENTS

There will be no samples which require archiving.

IX. SCHEDULE

A. Sample Acquisition

1. Satellite Data. LANDSAT and NOAA II data are acquired on a fixed schedule and will be archived as part of another project. Generally speaking, the sample acquisition is continuous.

2. Aircraft Data. The schedule for aircraft data acquisition is not yet known. My request will be found under "Logistics Requirements".

B. Analysis and Information Delivery Milestones

This topic has already been partly covered under Section VI, Information Products, and will be reviewed here.

1. "On schedule" maps of shorefast ice will be produced within 90 days of LANDSAT data acquisition provided that NASA/EROS schedules remain as they are at present.

2. "Retroactive" maps will be generated starting within 60 days of funding. This lag is largely due to the time required to obtain 1:500,000 scale LANDSAT imagery from the EROS data center. It is anticipated that all retroactive maps will be completed by June 1976.

3. "Epoch summary" maps will be produced whenever an epoch has been identified. Since the depth of analysis is much greater than for "on schedule" maps, and can only come after either "on schedule" or "retroactive" maps have been compiled, they will most likely follow the last of these maps in the epoch by at least 30 days but not more than 60 days.
4. "Special event" maps are, in terms of scheduling, identical to epoch summary maps.
5. Final Data Product. It is anticipated that the final data product, a morphology of Beaufort Sea shorefast ice, including all LANDSAT data up to June 30, 1976, will be available September 30, 1976.

C. Interfaces with Other Projects

Several points of interface with other projects were discussed in Section V. All of these involve rather continuous communication among investigators, but no specific dates for exchange of data products. However, there are two points of interface I am currently aware of where timely interface is required:

1. Identification of useful LANDSAT scenes as provided by the remote sensing project. At this time the University of Alaska data archivist receives a printout of available LANDSAT images approximately 42 days after the scenes are obtained. The locations of the scenes are plotted on a map overlay from which data selection can be made. We anticipate the ability to submit our data product requests to the EROS data facility within five days of the receipt of the available data printout by the remote sensing project.

2. Delivery of "on schedule" shorefast ice maps to project entitled "Study of climatic effects on fast ice extent and its seasonal decay along the Beaufort Sea coast". I estimate that the time required for delivery of these maps is 90 days after the data is taken. This lag is based on the following: 42 days between data acquisition and receipt of printout, 5 days for identification of useful scenes and submission of order, 21 days for delivery of data products from Sioux Falls, 14 days for preparation of maps (average). "Retroactive" maps for data already in existence will be prepared on a production basis starting within 60 days of funding (see item 2 under B above). It is anticipated that these will be made for the earliest LANDSAT coverage first and work will proceed toward the data obtained just before the start-up date of this project. It is anticipated that this data will be complete by June 1976. These will be supplied to the study on climatic effects on fast ice as soon as they were prepared.

I am willing to include on these "on schedule" and "retroactive" maps additional information which may be required by other studies, and allow other investigators to impose threshold criteria for determination of certain conditions. For example, Roger Barry may determine the criteria for identification of puddling during the decay of fast ice. In this way, my data products will be most useful to others along the analysis chain.

X. EQUIPMENT REQUIREMENTS

Miscellaneous drafting equipment will be purchased.

JUN 30 1975

XI. LOGISTICS REQUIREMENTS

Logistics requirements for this project are limited to airborne photo and SLAR reconnaissance missions performed by the project Mohawk aircraft. Below are listed the desired flight lines, dates and data requirements:

1. Spring/Summer 1975. Ten transects perpendicular to the coast to a distance of 50 km at equally spaced intervals from Barrow east to the Canadian border yielding stereo pair photography by the RC-8 mapping camera at 1000 m altitude and wide field photography at 5000 m altitude, SLAR at 25 km range.
2. November 1975. Same as 1.
3. December 1975. Same flight lines as 1 but flown with SLAR only. In addition, a flight line from Barrow to Alaska/Canada border with SLAR at 25 km range and return at 100 km range.
4. January 1976. Same as 3.
5. February 1976. Same as 3 with addition of RC-8.
6. March 1976. Same as 1.
7. April 1976. Same as 1.
8. May 1976. Same as 1.
9. June 1976. Same as 1.

JUN 30 1975

WORK STATEMENT

I. TITLE: Morphology of Bering Near Shore Ice Conditions by Means of Satellite and Aerial Remote Sensing

II. PRINCIPAL INVESTIGATOR: W. J. Stringer SS# 530-24-3717
Research Associate
University of Alaska

III. GEOGRAPHIC AREA AND INCLUSIVE DATES: Bering Sea
May 1, 1975 - September 30, 1976

IV. COST SUMMARY:

FY 1975 through June 30, 1975	FY 1976 July 1, 1975 - Sept. 30, 1976
$18,000	$23,700

V. PROPOSED RESEARCH

A. Background and Objectives

1. State of Knowledge

The general description of ice in near shore areas has been investigated and reported. For instance, Zubov (1943) discusses a variety of near shore ice conditions. Most recently, Kovacs and Mellor (1973) have given a review of the state of knowledge of sea ice including near shore ice. The principal near shore ice, fast ice, has been investigated to the point that several general parameters have been accepted -- at least in terms of Bering Sea shore fast ice. Briefly these are:

a) Sometime around midwinter, the ice along the shoreline is no longer subject to breaking free and having open water except under the most unusual circumstances.

b) This "shorefast" ice sheet may contain many pressure ridges. Its seaward edge is defined by the most seaward grounded pressure ridge.

c) Bottom sediments appearing in the piled ice are generally taken to be evidence that a pressure ridge is grounded.

d) The most seaward grounded pressure ridge is characteristically near the 18-m contour.

e) From time to time, a floating sheet of ice can be attached to the shorefast sheet and extend many kilometers farther seaward.

f) The grounded pressure ridge system endures into summer, sometimes as late as mid-July.

It is expected that tidal effects will play a strong role in the behavior of Bering Sea near shore ice, modifying the above list.

Virtually nothing is known about the dynamic morphology of shorefast ice; formation processes, stress-induced changes, year-to-year variations in location of its edge and locations of hummock fields, stability and other parameters related to specific weather patterns or geomorphological features.

2. Objectives

The objective of this proposed study is to develop a comprehensive morphology of near shore ice conditions in the Bering Sea. This morphology would include a synoptic picture of the development and decay of fast ice and related features along the Bering Sea coast, and in the absence of fast ice, the nature of other ice (pack ice, ice islands, hummock fields, etc.) which may occasion the near shore areas in other seasons. Special emphasis would be given to consideration of potential hazards to offshore facilities and operations created by near shore ice dynamics. A historical perspective of near shore ice dynamics will be developed to aid in determining the statistical rate of occurrence of ice hazards.

The data gathered here would be provided on a timely basis to other investigators performing related tasks (detailed later).

3. Expected Results and Results Related to Other Studies JUN 3 0 1975

There are two categories of results to be anticipated. The first category consists of direct data products while the second consists of indirect data products, which will be combined with studies performed by others within the study program.

a) DIRECT DATA PRODUCTS: These products would consist of a morphology of **Bering Sea** near shore ice and a series of maps showing persistent locations of major ice features including ice hazards within the near shore zone. These include the locations of large grounded pressure ridge systems, the location of summertime pack ice visits to the near shore areas and the drift pattern of ice islands. The morphology developed will provide a comprehensive picture of the development and decay of fast ice and the description of the sea ice cover on the Alaskan Continental Shelf.

b) INDIRECT DATA PRODUCTS: The morphology developed would yield information toward the determination of ice movement and deformation mechanism in the coastal fast ice zone. The ice type maps will indicate where to apply data relating stress-strain relationships to man-made and natural structures. The mapped pressure ridge locations and sites of ice groundings will provide data toward a predictive technique for ice scoring processes. The assembled data will be of use to the study of the relationship of living resources to the ice environment.

4. Relationship of This Study to Defined Tasks

The objective of this proposed study is to develop a comprehensive morphology of near shore ice conditions in the Bering Sea. This objective can be related in a primary way to three NOAA-identified tasks: A-29, A-30 and B-13. Task A-29 calls for the "assemblege and analysis of historical records and remote sensing data to provide a comprehensive picture of the development and decay of the fast ice .. ..." This task then considers the near shore areas in fall, winter and spring months. The primary data source for this project will be ERTS and NOAA satellite imagery and aircraft photography. Historical data will be assembled by another project (Hunt and Naske) and incorporated here.

Task A-30 calls for "using remote sensing methods, quantitatively describe the sea ice cover on the Alaskan continental shelf including the temporal and spatial description of the extent, location, type and state of the pack ice in the Beaufort and Bering seas". This task is concerned primarily with summer months as far as the near shore areas are concerned. However, summer pack ice behavior is still a major part of the morphology of near shore ice.

Task B-13 is to "determine deformation mechanisms in the coastal fast-ice zone". Although a study to specifically analyze the mechanics of origin of pressure ridges, shear ridges and hummock fields in land-fast ice will take place, other deformations of much larger size also occur which must be considered a part of the general morphology. Analysis of these deformations will be made as part of this study.

The objectives of this study can be secondarily related to the following tasks which are the primary responsibility of others: Tasks A-31, B-12, B-13 and D-11.

Task A-31 asks for the "determination of the relationship of living resources to the ice environment". The results of the near shore ice study would yield comprehensive maps for the application of results of this task in a general sense to the entire coast.

Task B-12 is the "description and analysis of the large scale motions and deformation mechanisms of the primarily first-year ice in the region of strong shear, that separates the coastal fast-ice zone from the multi-year pack ice zone". Much of the morphology of the shore-fast ice is determined by the large scale motions of the ice in the region of strong shear. Hence, there will, of necessity, be a relationship between the near shore ice study and the study(ies) related to Task B-12.

Task B-13 has already been regarded to be, in part, a primary responsibility of this study in terms of large scale ice deformations. This study is also related to the analysis of smaller deformations in a secondary sense in that those results must be taken into account when developing a comprehensive morphology.

Task D-11 calls for "determination of the stress-strain relationships of various types of sea ice encountered in the Beaufort, Chukchi and Bering seas in order to permit calculation of ice forces and loads transmitted from the ice to man-made and natural structures". The near shore ice maps should supply sites for tests of stress-strain laws for sea ice against large natural structures.

5. Information Needed to Meet Task Objectives

The information needed to meet these objectives are not available until the construction and launch of the ERTS-1 satellite. The imagery from this system, now covering three freeze-thaw cycles, combined with imagery with NOAA satellites should provide a good data base. This comprehensive data should be sufficient to give a reasonable perspective to the one year's research based on concurrent satellite and aircraft data. This information, combined with field reports from other investigations, should be sufficient to meet the task objectives.

6. The Extent of Completion by September 30, 1976

A morphology of near shore ice conditions based on 4 years' data can be presented by September 30, 1976.

7. Related Research

All research related to this study is being carried out by other OCS investigators and has been described above and elsewhere in this work statement. There is no need for detailed coordination between this study and any other in terms of input to this study. It is anticipated that other investigators with first-hand field information will contribute verbal reports on ice conditions they encounter. In terms of output, a number of other projects are anticipating some usefulness from the various products produced. These investigators include Barry, Shapiro, Sackinger, Nelson and Weeks. Here, no coordination is needed other than perhaps some early agreement on product format. Some of the above subjects are discussed in more detail later.

JUN 3 0 1975

B. Methods

Data from all seasons, past and historical data will be used to compile a series of maps of the Bering Sea near shore areas denoting summer and fall pack ice behavior, fall freezing characteristics and growth and decay of the fast ice zone. Particular attention will be paid to the behavior of large free ice features, hummock fields, pressure and shear ridges, open and refrozen leads, etc. A written morphology associating ice behavior patterns with winds, storms, currents, temperature and bathymetric data will be developed (see, for instance, Stringer, 1974a).

1. Sampling Strategy

a) REMOTE PAST (preERTS): Data gathered by investigators analyzing historical records will be incorporated into the morphology, generally to confirm persistent locations of major ice features or determine patterns of extreme behavior. This investigator anticipates continuous interaction with the investigators researching historical ice records. In conjunction with them, a map of historical ice behavior will be developed. Historical information can be utilized to determine locations to give particular attention at present. Similarly, present data may give them additional information toward interpretation of historical data.

b) IMMEDIATE PAST: ERTS imagery will be combined with aerial photographic surveys performed in the past by the author and others (NASA, USGS) to perform a detailed and comprehensive study of near shore ice previous to this time. Thus maximum utilization will be made of the 2-1/2 years of ERTS data which have been collected and archived at the University of Alaska ERTS archives. It is anticipated that this data can be nearly as valuable as ERTS data taken during this study. However, the project airborne remote sensing activities are anticipated to enhance the utility of present ERTS data over past ERTS data.

c) PRESENT: ERTS imagery combined with data from project remote sensing aircraft will be used to monitor the behavior of shore-fast and other ice within the near-shore zone. It is anticipated that interaction will take place with many other investigators studying related subjects (shear zone ice dynamics, pressure ridge modeling, sea mammal habitat, etc.) to yield additional information for incorporation into development of a coastal ice morphology.

REFERENCES

Colvocresses, A. P. and Robert B. McEwen, 1973. Progress in cartography, EROS Program. Printed in Proceedings of NASA Symposium on Significant Results Obtained from the Earth Resources Technology Satellite-I, Published by the National Aeronautics and Space Administration, 1973.

Kovacs, A. and M. Mellor, 1974. Sea ice morphology and ice as a geologic agent in the southern Beaufort sea. Printed in the Proceedings of the Symposium on Beaufort Sea Coast and Shelf Research, Published by the Arctic Institute of North America, December 1974.

Stringer, W. J., 1974a. Shore-fast ice in vicinity of Harrison Bay, Printed in the Northern Engineer, Vol. 5, No. 4, Winter 1973/74.

Stringer, W. J., 1974b. The morphology of Beaufort Sea shorefast ice. Presented at the Beaufort Sea Symposium, January 1974, and published in the Proceedings of the Arctic Institute of North America, December 1974.

Zubov, N.N., 1944. Arctic Ice. U.S. Navy Translation from Russian, 112-15.

IV. INFORMATION PRODUCTS

A. Routine Data Products

Maps of near shore ice conditions for each 18-day LANDSAT cycle with low cloud cover will be prepared at 1:500,000 scale showing locations of major ice features as determined from LANDSAT and NOAA satellite imagery. At this scale, the estimated LANDSAT mapping errors are of the same magnitude as the finest detail which can be drawn. (At 1:500,000 scale, the estimated uncertainty of LANDSAT positional accuracy, 200 m -- see Colvocoresses, 1973 --, is .4 mm.) These maps will be annotated with dates of ice events, ground truth information and any other data which becomes available. These maps will fall in two categories: "on schedule" and "retroactive".

1. The "on schedule" maps will be available as soon as the satellite data become available, interpreted and maps drawn. It is anticipated that this product will be available 90 days after data acquisition (see Section IX).
2. The "retroactive" maps will be compiled based on existing satellite data for those years previous to funding as soon as the required data products can be identified and acquired. These maps will be produced starting with the earliest data first and will be completed by June 1976.

B. Non-Routine Data Products

1. "Epoch Summary Maps". Whenever it appears that a major epoch has taken place (over a period of several LANDSAT cycles), an

epoch composite map will be prepared at 1:500,000 scale with accompanying text incorporating other data (e.g., winds, currents, isolation, aircraft data not available when "on schedule" maps are made, etc.). Epoch maps will include a yearly summary map.

2. "Special Event Maps". Occasionally, ice features like the grounded floeberg at 72°N, 162°W develop which show particularly well some behavioral pattern which illustrates general morphology or characteristics relevant to a single location. These events will be analyzed in whatever combination of temporal or spatial resolution that seems appropriate. (For instance, it is possible to perform digital analysis of LANDSAT data at 1:20,000 scale.)

C. Final Data Products

The final data product of this study will be a written morphology of near shore ice conditions in the Beaufort Sea, illustrated by a series of maps at 1:500,000 scale and special event maps. The morphology will describe persistent near shore ice features and behavioral patterns as well as an analysis of general behaviorial patterns.

The range of subjects will include: (1) Summertime visits of pack ice to the near shore areas and note of locations where pack ice has been grounded or driven onshore. (2) Summertime ice island visits to the near shore areas. (3) Fall freeze-up characteristics in the near shore areas. (4) Development of shorefast ice. (5) Mid-winter modifications and changes within shorefast ice. (6) Interaction of shorefast ice with shear zone ice. (7) Motions of and within shorefast ice. (8) Springtime decay of the shorefast ice.

VII. DATA OR SAMPLE EXCHANGE INTERFACES

This project does not require data from other investigators. (Remote sensing aircraft data is considered to be logistics.) However, we will seek first-hand observations from investigators doing field work.

To my knowledge, only two projects require results from this project and those are Roger G. Barry's study of climate effects on shorefast ice and Sackinger and Nelson's study of the grounded floeberg. It is very possible that much informal exchange will take place among the ice investigators. For instance, Shapiro has indicated an interest in some of the data produced by this project.

VIII. SAMPLE ARCHIVAL REQUIREMENTS

There will be no samples which require archiving.

IX. SCHEDULE

A. Sample Acquisition

1. Satellite Data. LANDSAT and NOAA II data are acquired on a fixed schedule and will be archived as part of another project. Generally speaking, the sample acquisition is continuous.
2. Aircraft Data. The schedule for aircraft data acquisition is not yet known. My request will be found under "Logistics Requirements".

B. Analysis and Information Delivery Milestones

This topic has already been partly covered under Section VI, Information Products, and will be reviewed here.

1. "On schedule" maps of shorefast ice will be produced within 90 days of LANDSAT data acquisition provided that NASA/EROS schedules remain as they are at present.
2. "Retroactive" maps will be generated starting within 60 days of funding. This lag is largely due to the time required to obtain 1:500,000 scale LANDSAT imagery from the EROS data center. It is anticipated that all retroactive maps will be completed by June 1976.
3. "Epoch summary" maps will be produced whenever an epoch has been identified. Since the depth of analysis is much greater than for "on schedule" maps, and can only come after either "on schedule" or "retroactive" maps have been compiled, they will most likely follow the last of these maps in the epoch by at least 30 days but not more than 60 days.
4. "Special event" maps are, in terms of scheduling, identical to epoch summary maps.
5. Final Data Product. It is anticipated that the final data product, a morphology of Bering Sea shorefast ice, including all LANDSAT data received up to June 30, 1976, will be available September 30, 1976.

C. Interfaces with Other Projects

Several points of interface with other projects were discussed in Section V. All of these involve rather continuous communication among investigators, but no specific dates for exchange of data products. However, there are two points of interface I am currently aware of where timely interface is required:

1. Identification of useful LANDSAT scenes as provided by the remote sensing project. At this time the University of Alaska data archivist receives a printout of available LANDSAT images approximately 42 days after the scenes are obtained. The locations of the scenes are plotted on a map overlay from which data selection can be made. We anticipate the ability to submit our data product requests to the EROS data facility within five days of the receipt of the available data printout by the remote sensing project.
2. Delivery of "on schedule" shorefast ice maps to project entitled "Study of climatic effects on fast ice extent and its seasonal decay along the Beaufort Sea coast". We anticipate that their interest will also extend to the Bering Sea. I estimate that the time required for delivery of these maps is 90 days after the data is taken. This lag is based on the following: A lag of 42 days between data acquisition and receipt of printout; 5 days for identification of useful scenes and submission of order; 21 days for delivery of data products from Sioux Falls; and 14 days for preparation of maps (average). "Retroactive" maps for data already in existence will be prepared on a production basis starting within 60 days of funding (see item 2 under B above). It is anticipated that these will be made for the earliest LANDSAT coverage first and

work will proceed toward the data obtained just before the start-up date of this project. It is anticipated that this data will be complete by June 1976. These will be supplied to the study on climatic effects on fast ice as soon as they were prepared.

I am willing to include on these "on schedule" and "retroactive" maps additional information which may be required by other studies, and allow other investigators to impose threshold criteria for determination of certain conditions. For example, Roger Barry may determine the criteria for identification of puddling during the decay of fast ice. In this way, my data products will be most useful to others along the analysis chain.

X. EQUIPMENT REQUIREMENTS

As listed in XII Cost.

XI. LOGISTICS REQUIREMENTS

Logistics requirements for this project are limited to airborne photo and SLAR reconnaissance missions performed by the project Mohawk aircraft. Below are listed the desired flight lines, dates and data requirements:

1. Spring/Summer 1975. Ten transects perpendicular to the coast to a distance of 50 km at equally spaced intervals from Wales south to Dillingham yielding stereo pair photography by the RC-8 mapping camera at 1000 m altitude and wide field photography at 5000 m altitude, SLAR at 25 km range.
2. November 1975. Same as 1.

3. December 1975. Same flight lines as 1. In addition, a flight line from Wales to Dillingham with SLAR at 25 km range and return at 100 km range.
4. January 1976. Same as 3.
5. February 1976. Same as 3.
6. March 1976. Same as 1.
7. April 1976. Same as 1.
8. May 1976. Same as 1.
9. June 1976. Same as 1.

Final
JUN 30 1975

WORK STATEMENT

I. TITLE: Experimental Measurements of Sea Ice Failure Stresses Near Grounded Structures

II. PRINCIPAL INVESTIGATOR: Richard D. Nelson SS# 342-30-8946
Associate Professor of Mechanical Engineering
University of Alaska
William M. Sackinger SS# 084-30-8305
Associate Professor of Electrical Engineering
University of Alaska

III. GEOGRAPHIC AREA AND INCLUSIVE DATES: Beaufort Sea
1 May 1975 - 30 September 1976

IV. COST SUMMARY

FY 1975 through June 30, 1975	FY 1976 July 1, 1975 - Sept. 30, 1976
$26,402	$37,798

V. PROPOSED RESEARCH

A. Background and Objectives

Offshore structures for oil exploration and development in the Beaufort Sea are likely to be attached firmly to the sea floor, either by pilings driven into the sediments, or by virtue of their own weight. They must be strong enough to withstand the forces of moving ice, and must neither move nor break during periods of intense ice activity. This proposal addresses Objective D11 listed in the April 11, 1975 memo from John H. Robinson, Deputy Director, NOAA Marine Environmental Assessment Program. Objective D11 aims at information required for the direct or indirect calculation of ice forces which may be transmitted to man-made or natural structures in arctic waters. This program proposes a direct measurement of the stresses on an ice sheet impinging on a fixed obstacle by taking advantage of a naturally-occurring grounded ice floeberg, located about 100 miles northwest of Barrow, as a convenient and inexpensive alternative to a multi-million dollar man-made test structure. This grounded ice feature consists of ridges of multi-year pack ice which have grounded on a shoal in about 25 to 40 meters of water depth, producing intense ridging and ice lead activity around the feature, which tends to build and reinforce it.

Approaches to ice load estimation in the Arctic have been primarily based upon theoretical calculations assuming continuous, homogeneous sheets of ice. It is generally assumed that the forces on a single piling would be limited by the crushing strength of the ice while the forces on a group of pilings or an extended structure would be limited by buckling of the ice during pressure ridge generation. Neither mechanism is well understood because most ice strength tests to date have been limited to small samples which do not incorporate the inhomogeneities present in full size floes of sea ice. Also there is the possibility of large average compressive stresses during buckling for which no experimental data is presently available.

In order to establish design criteria for loading of offshore structure by ice motions, it would be necessary to fully understand the stress and strain behavior of an ice block of the order of a 1 meter cube, including its failure criteria. It would also be necessary to extend these properties to full size sheets of ice several kilometers in extent and to understand the mechanics of buckling which govern pressure ridge formation. Finally, it would be necessary to know the mechanisms of ice sheet loading due to wind or pack ice motion and typical rates of advance of the ice sheet.

An alternative approach is to measure the loads actually induced on a fixed structure or the stresses in the surrounding ice during typical events of ice motion. This approach is more direct, but requires a body of data sufficiently large to form a statistical basis for prediction. In fact, both approaches are necessary and complementary.

Research related to this proposal has been carried out by the present authors in the NOAA Sea Grant Program at the University of Alaska since 1973. In that program, stresses in landfast ice have been measured extensively. However, due to ice conditions and logistics problems, no measurements have been accomplished in regions of intense ice activity. The authors of this proposal have also measured stresses in active ice near an artificial island in McKenzie Bay in a proprietary program funded by Imperial Oil Limited.

The results of this proposal should provide, by September 30, 1976, several measurements of the maximum stresses generated during pressure ridge formation at a fixed obstacle. This data will provide the kernal of a statistical basis for predicting ice loading.

B. Methods

At the University of Alaska an ice stress transducer system has been developed which has been used successfully for 3 years to measure in situ the internal stresses of an ice sheet. It is proposed that several of these systems can be imbedded in the ice sheet adjacent to the floeberg, with data transmitted by cable or telemetry to a central site on the floeberg. As the pack crushes against the floeberg, ice stress buildup would be recorded until the point of final destruction of the gauge at the floeberg. Concurrent measurements of ice motion will also be obtained. From these measurements it should be possible to evaluate the fracture strength of full scale ice sheets when driven against a large bottom founded structure at naturally-occurring velocities.

This data will place lower limits on the required strength of man-made structures to be placed in ice bound waters.

The stress gauges which will be used in this program are essentially stiff load cells which are embedded in the ice. As discussed by Nelson et al. (1972) and by Nelson (1975), the transducer is capable of measuring stress in the ice, regardless of the ensueing strain, only if it is stiffer than the surrounding medium. These transducers were developed by Nelson et al. (1972) specifically for stress analysis in sea ice and they have shown experimentally that the load measured by the transducer is directly proportional to the stress in the surrounding ice. A single proportionality factor has been found which applied for both short duration quasi-elastic tests and creep tests of several days duration, and which also applied when the ice was stressed to over 80% of its ultimate crushing strength. The transducers are 1-1/2" diameter by 6" brass cylinders with 1/4" diameter by 3/4" long studs at each end. Steel washers welded to the studs provide a grip for measuring tensile stress. The transducers are sensitive only to axial loads and hence measure the stress tensor component along their axis. A moderate transverse sensitivity has been noted by Nelson et al. and can be accounted for in calculations; thus, an array of 6 transducers can be used to evaluate the entire stress tensor in a region. However, the transducers must be separated by at least 12 inches to avoid influencing one another. It may be desirable to design smaller transducers or a multi-axial transducer to evaluate the stress in the region of a single point. If so, Nelson (1975) has given a technique to facilitate numerical analysis of the behavior of transducers embedded in a visco-elastic medium.

The stress transducers and their associated electronic equipment have been used in the field to measure stresses in shore fast sea ice at Point Barrow (Nelson, 1974), around artificial islands in the McKenzie Delta (Nelson and Sackinger, 1974, 1975a), in fresh water ice being crushed by a 12-foot wide indenter (Nelson and Sackinger, 1974, 1975a), and in large scale bending tests of sea ice at Resolute Bay (Nelson and Sackinger, 1975b).

Activities - April 1, 1975 to June 31, 1975

The first three months of this program have two objectives:

1. To perform a preliminary reconnaissance of the floeberg to assess the rate at which ice activity occurs and any environmental factors which would influence the instrumentation selected for further work.

2. To purchase or construct the required instrumentation and equipment.

An aerial reconnaissance of the floeberg will be made during the week of May 12-16, flying from the Naval Arctic Research Laboratory at Barrow, Alaska. The results of this flight, together with information from Austin Kovacs of the U. S. Army Cold Regions Research Laboratory, who has landed on the ice at the floeberg, along with such information on ice velocities in the region as may be gained from satellite photography, will be used to select between telemetered and cabled data acquisition systems. The budget for this period includes 10 transducers cable-connected to 10 amplifiers and chart recorders. Ten spare transducers are also included. If telemetry links are required, fewer transducers will be constructed so as to stay within the budget.

Activities - July 1, 1975 to September 30, 1976

The experiment will be conducted several times during the year, since the temperature and salinity distribution in the ice are functions of the season. Furthermore, the open leads on the lee side of the floeberg refreeze in winter, giving thin, weaker ice which fails more readily than the multi-year ice sheet. Experimental periods will probably occur in October, March and May. In each experiment three or more transducers will be placed near the floeberg and monitored continuously as the ice advances. The exact number and placement of transducers depends upon the experience gained during the first trip in May 1975. If there is the possibility of recovering instruments from the ice after failure, more transducers can be committed during each test. Actual placement of the transducers and activation of the equipment will take 2 to 3 days for each test. Data gathering will continue over at least another 5 days, although it will not be necessary for the crew to be present during this time. Salinity profiles and ice temperature measurements will be obtained for each test period.

During the time that the experimental site is occupied it will be possible to measure the rate of advance of the ice sheet by means of interferometric surveying equipment which will be supplied by the University of Alaska. During other times, time-lapse photography will be used to monitor the positions of several targets placed on the ice and this data will be used to evaluate ice velocities. In addition, experimental periods will be selected to correspond to the times of ERTS satellite coverage to provide some knowledge of the overall ice motion in the region.

Nelson, R. D., M. Tauriainen and J. Borghorst, 1972. Techniques for measuring stress in sea ice. University of Alaska, Institute of Arctic Environmental Engineering.

Nelson, R. D., 1974. Measurements of tide and temperature generated stresses in shorefast sea ice. In The Coast and Shelf of the Beaufort Sea, Arctic Institute of North America, Arlington, Virginia.

Nelson, R. D. and W. Sackinger, 1974. Final report on ice stress measurements at Adgo Island. Presented to Imperial Oil Ltd., Calgary, Alberta, University of Alaska, Geophysical Institute, Confidential.

Nelson, R. D., 1975. Internal stress measurements in ice sheets using embedded load cells. To be presented at POAC '75 conference to be held at the University of Alaska, August 11-15, 1975.

Nelson, R. D. and W. Sackinger, 1975a. Work in progress, University of Alaska, Geophysical Institute.

Nelson, R. D. and W. Sackinger, 1975b. Work in progress, University of Alaska, Geophysical Institute.

VI. INFORMATION PRODUCTS

The data obtained will be directly interpretable as stress at the location of the transducer. The data from the several transducers in each test will be correlated with observed ice motion and failure modes to establish minimum values for stresses in moving ice near a large static obstacle. A report including data and analysis will be provided NOAA prior to September 30, 1976.

VII. DATA OR SAMPLE EXCHANGE INTERFACES

A complete library of ERTS satellite imagery of Alaska is available through the University of Alaska Geophysical Institute. In addition, Dr. William Stringer, at the University of Alaska, is working with ice velocity information obtained from ERTS imagery of the area of the floeberg and these data will be available for use in this proposed project.

VIII. SAMPLE ARCHIVAL REQUIREMENTS

JUN 30 1975

N/A

IX. SCHEDULE

NOTE: Exact dates of experiments in October 1975, March and May 1976 depend on dates of ERTS fly-by which are as yet unannounced.

May 12-17, 1975	Reconnaissance of experimental area
May 20-Oct. 1, 1975	Purchase, manufacture, test and calibrate experimental equipment
October 1975	Experiment I at floeberg
February 15, 1976	Data reduction from Experiment I complete
March 1976	Experiment II at floeberg
May 1976	Experiment III at floeberg
September 30, 1976	Final Report

X. EQUIPMENT REQUIREMENTS

All special experimental equipment will be assembled at the University of Alaska and is included in the budget for this project. Equipment for subsistence and survival is included in logistics requested from NOAA. **A time-lapse camera will be purchased.**

XI. LOGISTICS REQUIREMENTS

All to be supplied by NOAA.

Transportation

May 1975 - One round trip to floeberg (approx. 3 hours) by fixed wing aircraft. Two people, no equipment.

October 1975 - Two round trips to floeberg, approximately 10 days apart, 3 persons, with 200 pounds baggage. Also one round trip to bring in hut and supplies, approximately 4000 lb. Depending on conditions of the ice, fixed wing aircraft may be acceptable. Helicopter must be available for instrument deployment during experimental period. 100 to 150 miles from Barrow, Alaska.

March 1976 - Two round trips, approximately 10 days apart, 3 persons, 500 pounds supplies. Fixed wing or helicopter. Helicopter must be available for instrument deployment.

May 1976 - Two round trips, approximately 10 days apart, 3 persons, 500 pounds supplies. One round trip to remove hut and other equipment, 4000 lb. Fixed wing or helicopter depending on ice conditions. Helicopter available for instrument deployment

Lodging

Due to the possibility of bad weather preventing immediate transportation from Barrow to floeberg, 12 man-days lodging are requested at the Naval Arctic Research Laboratory at Barrow, Alaska, during each experimental period: May and October 1975 and March and May 1976.

Food and Shelter

A wood or metal building will be required at the floeberg for shelter due to the presence of polar bears. The shelter should be heated, sleep 3 and have gasoline or kerosene stove and lights. Food for 30 man-days will be required during each experiment, and food for another 30 man-days should be on hand for emergency. Sleeping bags for 3 men will be required. A two-way radio capable of communicating with Barrow will be required as well as three personnel locator beacons to be carried by crew members.

JUN 3 0 1975

RESEARCH UNIT #261/262
WORK STATEMENT

I. Title: Beaufort Sea Historical Baseline Ice Study Proposal

II. Principal Investigators: Dr. William R. Hunt,
Professor of History
SS#: 532-22-1162

Dr. Claus-M. Naske,
Associate Professor of History
SS#: 574-12-5479

University of Alaska
Fairbanks, Alaska 99701

III. Geographic Area and Inclusive Dates: Beaufort Sea
June 2, 1975-Sept 30, 1976

IV. Cost Summary

FY 1975	FY 1976
through June 30, 1975	July 1, 1975-Sept 30, 1976
$26,340	$21,660

V. Proposed Research

The investigators will search, evaluate and synthesize the historial literature relating to ice conditions and movements in the Beaufort Sea. Data on the past location and behavior of the coastal fast ice and shear zone ice movements, leads, and thickness will supplement satellite studies.

The investigators also expect to find data relating to ice islands, large ice rubble piles, ice buildup on offshore islands and unusual pressuring. Archival work so far indicates that recorded observations of the sea ice environment made over the last 125 years includes considerable data on wildfowl and marine mammal populations, locations, and movements.

The historical data accumulated will be reported quarterly, in a form which can be utilized as the basis for cartographic representation if so desired. An atlas that combines historical data with satellite observations could be the ultimate product.

No historical data relating to Beaufort Sea ice phenomena has been systematically gathered nor interpreted. The investigators have corresponded with the National Archives, Canadian Archives and appropriate whaling museums and shipping companies. One of the investigators spent a week in Washington, D.C. and made a survey of available materials. Dr. William R. Hunt, the other investigator, at this writing is working at the National Archives in Washington, D.C. gathering data from amongst the records of the U.S. Hydrographic Service and from the logs of the U.S. Revenue Cutter Service in the Old War Records section.

Correspondence with archival personnel and personal visits made so far indicate that the investigators will be able to gather, compile, analyze and report the information sought by September 30, 1976.

Methods

Historical research involves scanning large volumes of written records for the desired data. Once found it has to be verified and then copied in abbreviated fashion. We are planning to record several kinds of data separately, such as observations on shore erosion, large ice rubble piles, unusual pressuring and observations on the populations, locations and movements of marine mammal populations.

VI. Information Products

The investigators will write a narrative report quarterly describing the progress of work. At the end of the contract, copies of data collected in various categories will be submitted and a final narrative report describing average and extreme conditions will be indicated.

VII. Data or Sample Exchange

The investigators have contacted researchers involved in OCS projects in the Geophysical Institute and the Institute of Marine Science at the University of Alaska and asked if there is any information we might find in the course of our research which might be useful to the other projects and which we should collect. We anticipate working closely with remote satellite sensing and ice physics projects.

At this point we are unable to say exactly which data resulting from our research will be required by other principal investigators.

VIII. Sample Archival Requirements

Archival requirements will be simple since the information will be on index cards classified according to subject matter and should be easily accessible.

IX. Schedule

William R. Hunt, two trips of two weeks duration each, one to the National Archives in Washington, D.C. and the Canadian Archives in Ottawa, Canada. Research will be conducted in the Old War and Navy records, Hydrographic Office materials and Department of the Interior documents. In the Canadian Archives the logs of Arctic traders will be researched.

Claus-M. Naske, two trips of two weeks duration each, one to the National Archives in Washington, D.C. and to a whaling museum in

New Bedford, Massachusetts. Research will be conducted in the Polar Archives at the National Archives and in logs of whaling ships in New Bedford, Massachusetts.

William R. Hunt will spend two months in the Archives of the University of Alaska researching published and unpublished materials.

Claus-M. Naske will spend one and three-quarters months in the Archives of the University of Alaska researching published and unpublished materials.

X. Equipment Requirements

Not applicable. Historians need paper, pen and typewriter and index cards as well as patience and ability to unearth the material.

XI. Logistics Requirements

None required

Final

RESEARCH UNIT #265

JUN 30 1975

ALASKA MARINE ENVIRONMENTAL ASSESSMENT PROGRAM
WORK STATEMENT

I. Title: Development of hardware and procedures for in situ measurement of creep in sea ice

II. Principal Investigators:

Lewis H. Shapiro, Assistant Professor of Geology
SS#: 117-26-5144

William M. Sackinger, Associate Professor and Head, Department of Electrical Engineering
SS#: 084-30-8305

Richard D. Nelson, Associate Professor of Mechanical Engineering
SS#: 342-30-8946

University of Alaska
Fairbanks, Alaska 99701

III. Geographic Data and Inclusive Dates: Beaufort Sea OCS Area, Apr 1, 1975 to Sept 30, 1976

IV Cost Summary:

FY 1975	FY 1976
through June 30, 1975	July 1, 1975-Sept 30, 1976
$4,345	$111.855

V. Proposed Research

A. Background and Objectives

This research falls within the general task heading "Hazards" and specifically within the category "Ice Forces".

Studies of creep in fresh ice have been conducted for many years, often with the objective of examining the long term flow of glaciers. In this case stresses remain relatively constant and the secondary creep stage is of prime interest. For sea ice in its natural setting however, stresses are seldom constant for more than short periods of time, but instead, change rapidly with variations in wind directions, currents, or internal stresses induced by motion of the pack under forces applied at a distance. Thus, the entire creep curve, including both primary and secondary creep, is of interest, as well as the transition from creep to fracture. The ultimate objective of this project is to generate the data necessary for establishing the creep properties of sea ice through in situ testing. The objective of the work proposed here is to conduct the necessary hardware development for these measurements to be made.

Previous work on the determination of creep properties of sea ice was reviewed by Weeks and Assur (1967). The work of most direct interest to us is that of Tabata (1958) who performed a series of in situ tests using cantilever and fixed end beams. In these tests, a constant load was applied to the beam and the deflection at that point was measured as a function of time. The resulting curve of deflection vs. time has the form of a creep curve, and the constants for a 4-parameter, linear viscoelastic model were derived from it.

Peyton (1966) conducted a laboratory study in which cylinders of natural sea ice were subjected to constant tensile or compressive loads of different magnitudes to generate creep curves. Loads were removed after the creep curves were established, and the elastic components of the deformation were recovered. Unfortunately, for all but a very few of the tests, no information is given regarding the temperature, salinity, or crystal orientation of the test specimens. These parameters can be expected to influence the behavior of the specimens, so that interpretation of the results, for the purpose of determining the parameters of a stress-strain law, is likely to lead to a broad distribution of results. Peyton did not include any analysis of the results of these tests in his final report. However, most of his unpublished notes and laboratory records are archived at the University of Alaska, and it is possible that some of the information needed to fully characterize the test samples is included with them.

Creep curves for fresh ice show a pronounced increase in strain rate following the initial decrease leading to the secondary creep stage, for the case of loads above some threshold value (about 4 kg/cm^2). For sea ice, Peyton's (1966) data show a similar effect, but with the increase in strain rate restricted to a short time period, after which the rate decreases again. This introduces an obvious "kink" into the curve. Karlsson (1972) interpreted this effect as an example of strain rate-dependent yield, and developed a three-dimensional viscoelastic-plastic stress-strain law from which good approximations to some of Peyton's one-dimensional, experimental curves have been calculated. Note, however, that the effects of salinity, temperature and mechanical anisotropy are not included in the law.

Finally, a detailed laboratory investigation of the viscoelastic properties of sea ice has been outlined by Katona and Vaudry (1973), but there is no indication as yet that the work is being carried out.

The problem of translating results from laboratory tests to field conditions is well known in many branches of science, and is likely to be an important aspect of studies of the creep behavior of sea ice. It is difficult in the laboratory to simulate the effects of strong temperature and salinity gradients, variations in grain size and ice fabric, and the presence of inhomogeneities on scales larger than laboratory samples. Further, in nature, these properties vary continuously in space and time through a growing ice sheet which may reach two meters in thickness. A program of determining the creep properties of sea ice <u>in situ</u> is thus needed to supplement and verify laboratory results.

The major problems to be solved in this study are: 1) howe can a dominant horizontal stress field of known magnitude and geometry be generated in an ice sheet on scales up to 1-2 times the ice thickness and, 2) how can stresses and strains within that stress field be measured with minimal disturbance to the field. Further, the equipment used must be simple enough so that a large number of tests can be run in a relatively short time. Long term tests (i.e. in excess of several days) are probably not required, because loads of constant direction of durations greater than this will probably not be encountered in nature.

In order to meet these objectives, three types of instrumentation are needed; a loading device, a stress sensor, and a strain sensor.

Most of the loading stresses will be generated with flat-jacks. The use of these instruments for measuring stresses or mechanical properties of rock in situ is well established (Jaeger and Cook, 1969; Hoskins, 1966). Briefly, flat-jacks consist of two plates of any suitable material fastened together along their edges to form an envelope. They are loaded by pumping a fluid between the plates which causes an expansion of the envelope. The geometry of the expanding plates is such that a uniform load is achieved over about 90% of the jack face. Loads will be generated by freezing the flat-jacks into slits cut vertically into the ice sheet, and then expanding the flat-jacks using a suitable fluid. Both uniaxial and biaxial stress fields can be generated in this manner.

The nature of the stress and strain sensors is undecided at present, and their design and fabrication is an important part of this project. However, we have designed, built and employed transducers for measuring stress in sea ice (Nelson et al., 1972.; Nelson, 1975) and are familiar with the requirements of such systems. In general, in order for a transducer to measure stress, it must be stiffer than the medium in which it is embedded. The systems developed by Nelson et al. (1972) have been experiementally shown to measure loads which are directly propertional to the stress in the surrounding ice. A single proportionality constant has been found which applies for both short duration, quasi-elastic tests, as well as creep tests of several days duration. Further, this factor also applies when the ice is stressed to over 80% of its crushing strength. The experience gained in the design of this system will be valuable in developing the modified stress transducers which will be required to obtain multi-axial data to meet the ultimate objective of this project. The technique to be used for measuring strain are modifications of those commonly used in other fields of engineering and rock mechanics. Surface strains can be measured with dial gauges and with L.V.D.T. continuous reading extensometers. Strains internal to the ice sheet will be measured with embedded strain transducers which will be designed especially for this project. The requirements demanded of these instruments are that they must be capable of sustaining large strains associated with creep, and their effective compliance must be low so that they readily deform with the moving ice, rather than respond in the manner of stiff stress transducers.

When the instrumentation is developed and tested, it will be possible to load a given volume of ice in situ, and then record the stress and strain simultaneously at various points within that volume. By controlling the loading through the flat-jacks, creep and relaxation tests can both be run, and the data obtained can be multi-dimensional.

As noted above, the first step toward development of a three-dimensional, visoelastic-plastic stress-strain law for sea ice has been given by Karlsson (1972). The data obtained from the experiments which we intend to do, following development of the instrumentation, will provide the parameters which are presently missing from the law, and allow its evaluation and modification if necessary.

We anticipate that the development, testing, and modification of the requisite equipment can be completed by September 30, 1976.

We are not aware of any related work being conducted under the OCS Program, although related studies are in progress within the oil industry.

References Cites

Hoskins, E.R., 1966, An investigation of the flatjack method of measuring rock stress; Int. J. Rock, Mech. Min. Sci., vol. 3, p. 249-64.

Jaeger, J.C., and N. G. W. Cook, 1969, Fundamentals of Rock Mechanics: Methuen & Co. Ltd., London, 513 p.

Karlsson, T., 1972, A viscoelastic-plastic material model for drifting sea ice; in Sea Ice, Proc. Conf., Reykjavik, Iceland, May 10-13, 1971; p. 188-195.

Katona, M.G. and K. D. Vaudrey, 1973, Ice engineering -- summary of elastic properties research and introduction to viscoelastic and non-linear analysis of saline ice; Tech Rpt. R797, Naval Civ. Eng. Lab., Port Hueneme, Cal., 67 p.

Nelson, R.D., 1975, Internal stress measurements in ice sheets using embedded load cells; to be presented at P.O.A.C. 1975 Conf. U. of Alaska Aug. 11-15 1975.

Nelson, R.D., Taurianen, M., and Borghorst, J., 1972, Techniques for measuring stress in sea ice; Inst. of Arctic Environ. Eng. Rpt., U of Alaska.

Peyton, H.R., 1966, Sea ice strength, Geophysical Inst. U. of Alaska, Rept. UAG R-182, 273 p.

Tabata, T., 1958, Studies on visco-elastic properties of sea ice; in Arctic Sea Ice, U.S. NAS-NRC pub. 598, p. 39-147.

Weeks, W.F., and A. Assur, 1967, The Mechanical Properties of Sea Ice; CRREL Monograph 11-C3, 94 p.

B. Methods

A review of published data was given above. The unpublished laboratory notes relating to Peyton's (1966) work are available to us and will be examined to determine whether the necessary temperature, salinity and grain orientation data are available. If they are, then the creep curves will be analyzed to develop a one-dimensional form of Karlsson's (1972) viscoelastic-plastic stress-strain law for comparison with the <u>in situ</u> test results.

Tests of various transducers and loading configurations will be conducted in the field during the time interval January-May 1976. Laboratory work associated with the initial design of the transducers will be conducted prior to the field season, and any necessary modifications will be made and tested in the laboratory following the field study.

VI. Information Products

The results of this work will be presented in a final report, detailing the design of the instrumentation, equipment testing procedures used both in the laboratory and in the field program, and evaluation of the equipment test results.

VII. Data or Sample Exchange Interfaces

We are not aware of any other OCS investigators who will routinely require the results of this work, not do we require data from other studies.

VIII. Archival Requirements

None

IX. Schedule

1) April-May 1975-Preliminary field work to include an experiment to evaluate the disturbance to the temperature field of the ice sheet caused by introduction of a flat-jack, and emplacement and loading of several flat-jacks to determine design parameters.

2) June-December 1975-Design, laboratory testing, and construction of stress and strain sensors and modified flat-jacks.

3) January-May 1976-Field testing program to be conducted at NARL, Barrow, Ak.

4) June-August 1976-Evaluation of equipment tests in the field will be conducted, and any modifications in the instrumentation will be tested in the laboratory.

5) September, 1976-Preparation of final report.

X. Equipment Requirements

Fabrication of customized stress and strain measuring equipment is detailed in the budget.

JUN 30 1975

XI Logistics Requirements

Approximately 200 days lodging at NARL, Barrow for Principal Investigators and Design Engineer (who will be stationed at NARL for approximately 5 months). Assuming that ice conditions near the radar site are suitable for our purpose, a small building will be required at the site for 5 months as a temporary laboratory. If ice conditions there are not suitable, the work will be done in Elson Lagoon and two field wanagans, with power, will be required at that test site.

RESEARCH UNIT #267

Final

WORK STATEMENT

JUN 30 1975

I. TITLE: Operation of an Alaskan Facility for Applications of Remote-Sensing Data of Outer Continental Shelf Studies

II. PRINCIPAL INVESTIGATOR: Albert E. Belon SS# 574-09-9574
Professor of Physics
University of Alaska

III. GEOGRAPHIC AREA AND INCLUSIVE DATES: Beaufort Sea, Chukchi Sea
Bering Sea, Gulf of Alaska

May 1, 1975 to September 30, 1976

IV. COST SUMMARY:

FY 1975 through June 30, 1975	FY 1976 July 1, 1975 - Sept. 30, 1976
$26,331	$85,669

V. PROPOSED RESEARCH

A. Background and Objectives

1. Task Identification

This project is identified with task A-29. Its primary objective is to assemble and to assist in the analysis of remote-sensing data to provide a comprehensive assessment of the development and decay of fast ice, sediment plumes and offshore suspended sediment patterns along the Alaskan coast from Yakutak to Demarcation Bay.

2. State of Knowledge

The utilization of remote-sensing techniques in environmental surveys and resource inventories has made great strides during the last few years with the development of advanced instruments carried by aircraft and satellites. A remote-sensing library and data processing facility has evolved on the Fairbanks campus of the University of Alaska as a result of a NASA-funded program entitled "An interdisciplinary feasibility study of the applications of ERTS-1 data to a survey of the Alaskan environment". This experimental program, which covered ten environmental disciplines and involved eight research institutes and academic departments of the University, has now terminated; but the facility which it established has proved to be so useful to state-wide university and government agencies that it has continued to operate on a minimal basis with partial funding from a NASA grant and a USGS/EROS contract.

As a result of the NASA-funded program, the remote-sensing data library has total cloud-free and repetitive coverage of Alaska by the ERTS - now LANDSAT - satellite up to May 1974 (about 30,000 data products), 60 rolls of imagery acquired by NASA aircraft (NP3A and U-2) some of which includes coverage of the Beaufort Sea, Cook Inlet and Prince William Sound, and substantial facilities for optical and digital processing of these data. In preparation for the OCS program, we have requested NASA to provide U-2 aerial photographic coverage of the entire Alaskan coastal zone during a scheduled mission in June 1975. This request has been tentatively approved. Through a NOAA-funded pilot project, which studies the applications of NOAA satellite data in meteorology, hydrology and oceanography, the remote-sensing data library also has complete coverage of Alaska by the NOAA satellite since February 1974.

As part of the NASA-supported LANDSAT program the University of Alaska demonstrated the feasibility of deriving, from LANDSAT imagery, substantially new information on suspended sediment transport and deposition in Alaskan coastal waters (1),on the morphology of shorefast ice in the Beaufort Sea (2),and on sea-ice dymanics in the Bering Sea region (3). The data interpretation techniques developed for the University of

Alaska LANDSAT program have been described by Belon and Miller (4) and Miller and Belon (5). Briefly, the data interpretation techniques which have proven most useful for outer continental shelf studies are color-coded density slicing of LANDSAT transparencies for mapping sediment plumes and sedimentation patterns (using a VP-8 image analyzer), visual photointerpretation for studying the morphology of sea-ice, and multi-date analysis using a color-additive viewer for measuring sea-ice movement and the resultant fracture patterns. Recently we have used an automatic (computer) unsupervised classification technique which offers great promise for mapping sea-ice types from LANDSAT imagery with high ground resolution (80 meters) over limited areas (185 x 185 km).

References

(1) Burbank, D. C., Suspended Sediment Transport and Deposition in Alaskan Coastal Waters with Special Emphasis on Remote Sensing by the ERTS-1 Satellite, M.S. Dissertation, University of Alaska, December 1974.

(2) Stringer, W. J., Morphology of the Beaufort Sea Shorefast Ice, Proceedings of Symposium on the Coast and Shelf of the Beaufort Sea, Arctic Institute of North America, 1974.

(3) Shapiro, L. H. and J. J. Burns, Satellite Observations of Sea-Ice Movement in the Bering Strait Region, Climate of the Arctic, University of Alaska Press, 1975.

(4) Belon, A. E. and J. M. Miller, Application of ERTS Data to Resources Surveys of Alaska, Proceedings of the Third ERTS-1 Symposium, Vol. I, 1899-1907, NASA/GSFC, 1974.

(5) Miller, J. M. and A. E. Belon, A Summary of ERTS Data Application in Alaska, Proceedings of the Ninth International Symposium on Remote Sensing of Environment, Vol. I, 2118-2138, University of Michigan, 1974.

3. Information Required to Meet the Task Objective

Repetitive, low-cloud-cover LANDSAT imagery of the Alaskan coastal zone for the period August 1, 1972 to May 1, 1974, NOAA-2, -3 and -4 satellite im ry of Alaska acquired since Fe ary 1974, and aerial photography of parts of the Beaufort Sea, Cook Inlet and Prince William Sound, acquired in July 1972 and June 1974, are presently available in the University of Alaska remote-sensing data library.

LANDSAT imagery of the Alaskan coastal zone acquired since May 1, 1974 is available at the EROS Data Center (EDC) in Sioux Falls, South Dakota. We have obtained computer listings of these data and propose to purchase low-cloud-cover LANDSAT images from EDC under this project. We have requested NASA to provide U-2 aerial photographic coverage of the entire Alaskan coastal zone. The U-2 mission is scheduled for June 1975 and we will probably receive the imagery (presumably at no charge) in September 1975. We are also requesting that copies of remote-sensing data acquired by U.S.G.S. aircraft for the OCS program be provided to our remote-sensing data library. Other existing imagery will be purchased on a selected basis from EDC and other agencies.

4. Time Schedule

The satellite and aircraft imagery which we propose to assemble, the data processing facilities and the data interpretation techniques already exist, for the most part; therefore, we do not anticipate any problems in meeting the proposed objectives and reporting the results quarterly from the start of the contract to September 30, 1976.

6. Related Research and Coordination

This project proposes that the existing University of Alaska remote-sensing facility be upgraded to serve all the OCS investigators with available remote-sensing data of the Alaskan coastal zone, data processing facilities and image interpretation assistance using facilities and proven techniques developed for previous research programs. We expect that most investigators concerned with sea-ice morphology and dynamics, physical oceanography and marine geology will utilize our facilities and services. Several U of A investigators have already expressed their intent to do so. We will coordinate our activities with all OCS investigators by periodic remote-sensing data catalogs and bulletins, and by personal visits and training workshops.

B. Methods

Three complementary approaches will be used to achieve the project's objective:

1. Operation of the Remote-Sensing Data Library

   a) Search our existing data base and the EROS Data Center data bank for all low-cloud-cover LANDSAT data acquired since launch of the satellite (July 23, 1972) and aerial photography of the Alaskan coastal zone acquired since 1950. We are in a good position to perform this task because we have direct access to the EROS Data bank and we are thoroughly familiar with the EDC capabilities through our USGS/EROS contract. In addition, we soon will have microform copies of all Alaska data available at EDC.

   b) Prepare periodic catalogs and maps of available satellite and aircraft imagery of the Alaskan coastal zone.

   c) Purchase from EDC selected satellite and aircraft data of the Alaskan coastal zone to update the data available in our remote-sensing data library, and purchase on a standing order basis the data which will be required in 1975 and 1976.

d) Obtain from government and industrial agencies in Alaska listings of aircraft data of the Alaskan coastal zone available in their files, and purchase selected data.

e) Obtain copies of aircraft remote-sensing data obtained for the OCS program.

f) Assist OCS investigators in searching for remote-sensing data applicable to their investigations.

2. Operation and Maintenance of Remote-Sensing Data Processing Facilities

The existing remote-sensing data processing facilities and the associated data processing techniques are shown in Figures 1 and 2.

a) The existing data processing facilities will be maintained in good operating condition for the use of the OCS investigators. We expect, based on discussions with potential OCS investigators, that the equipment most heavily used will be the color-additive viewer, the zoom transfer scope, the stereo light table, the VP-8 image analyzer, and darkroom photographic equipment.

b) Send our color-additive viewer to the manufacturer (I^2S) to be retrofitted with a viewing-tracing-projection attachment which will permit a 6.7X enlarged projection on a ground-glass tracing table and an enlarged projection up to 20X on a wall screen. At present, the viewer provides only a 3.35X enlargement (1:1,000,000

JUN 3 0 1975

scale _ LANDSAT data). The proposed _tachment has been specifically requested by several OCS investigators concerned with sea-ice investigations, but will be used by others as well.

3. Assistance to OCS Investigators in Data Processing and Interpretation. Development of New Techniques for OCS Purposes.

   a) Training of OCS investigators in the use of the various remote-sensing data processing instruments.

   b) Provide remote-sensing specialists to assist OCS investigators in the operation of some of the most sophisticated instruments (e.g., VP-8 image analyzer and CDU digital color display system).

   c) Perform remote-sensing data processing for OCS investigators on the basis of work orders. Since this task could rapidly consume the financial resources of the contract, if many investigators utilize this service, we will place a limit of $50 per month per project for "free" data orders and work orders performed by our project. The investigator's project will be billed for costs in excess of the $50 limit.

   d) Develop techniques for multidate analysis of remote-sensing data. At least three areas of research where multidate analysis techniques need to be further developed are sea-ice dynamics, shoreline erosion, and sea-surface sediment transport.

   e) Participate in various OCS investigations from the remote-sensing point of view.

f) Assist and consult on the formulation of aircraft data acquisition program.

VI. INFORMATION PRODUCTS

The primary objective of the project is to provide a service to the OCS investigators in the acquisition and processing of remote-sensing data. Therefore, it is expected that most of the disciplinary information products will be reported by the individual user projects. These products are expected to be primarily thematic maps and photographs showing sea-ice conditions, sediment plumes and suspended sediment concentrations.

The project itself will prepare periodic remote-sensing data catalogs, including lists and maps, and bulletins describing the facilities and data processing techniques which have been developed and are available for use by the OCS projects. A sample data map and list are illustrated in Figures 3 and 4. We will also calculate predicted LANDSAT orbits (Figure 5) to assist OCS investigators in coordinating field measurements and aircraft data flights with overhead passage of the LANDSAT satellites.

VII. DATA OR SAMPLE EXCHANGE INTERFACES

Although satellite and aircraft data can be acquired and analyzed independently of other data, the accuracy and quantification of these analyses are very dependent on the availability of concurrent field data. For instance, satellite and aircraft imagery can be density-sliced to produce maps of relative suspended sediment concentrations; however, calibrating these maps in terms of absolute concentrations of suspended sediments, in milligrams per liter, requires water samples obtained concurrently over a portion of the study area. Once this calibration is made, it can be applied confidently over the entire area covered by the remotely sensed image. Similarly, satellite or aircraft data analysis can identify different types of sea-ice (new ice, year-old ice, and multi-year ice), but the accurate identification of these types is dependent on the availability of field data over a portion of the image. In effect, these field data over limited areas are used as training sets for the interpretation of remotely-sensed data.

We anticipate no problems in exchanging data from other investigators because the analyses we undertake will be performed for and in cooperation with them.

VIII. SAMPLE ARCHIVAL REQUIREMENTS

We propose to archive all remote-sensing data acquired under this project in the University of Alaska remote-sensing data library. It presently contains some 30,000 satellite images, 60 rolls of aerial photography and 150 digital magnetic tapes in temperature and humidity controlled storage. We expect that the amount of data stored in the library will nearly double, from the OCS project and other sources, over the next two years.

IX. SCHEDULE

May 1, 1975 - All remote-sensing data currently stored in the remote-sensing data library, and adjoining data processing facilities, will be available to OCS investigators.

June 15, 1975 - All available satellite and NASA aircraft data previously acquired will be catalogued and mapped. Data not available in remote-sensing data library will be ordered from the EROS Data Center.

July 1, 1975 - A catalog of remote-sensing data of the Alaskan coastal zone will be distributed to OCS investigators along with a bulletin describing the facilities and techniques available for processing the data and providing sample data products.

October 1, 1975, January 1, 1976, April 1, 1976, July 1, 1976 - The catalog and bulletin previously mailed on July 1, 1975 will be updated and distributed to OCS investigators.

September 30, 1976 - A final report describing the activities of the project and its users will be prepared and submitted to NOAA.

X. EQUIPMENT REQUIREMENTS

Nearly all the equipment required for the project is presently available at the Geophysical Institute of the University of Alaska. The only exception, requested by several OCS investigators, is a modification of our I^2S Model 6040 color-additive viewer to provide for a viewing-tracing-projection attachment which will permit a 6.7X enlarged projection on a ground-glass tracing table and an enlarged projection up to 20X on a wall screen. At present the viewer provides only a 3.35X enlargement (1:1,000,000 scale for LANDSAT data). The modification must be retrofitted in our viewer by the manufacturer at his plant in Mountain View, California. The manufacturer's bid for this modification if $4761 with a delivery of 60 days. We plan to send our equipment to the manufacturer as soon as a contract is awarded or before, if the appropriate arrangements can be made with NOAA and the manufacturer.

XI.. LOGISTICS REQUIREMENTS

None. However, we would like to participate in the planning of the U.S.G.S. aircraft data acquisition and in some of the data flights.

FIGURE CAPTIONS

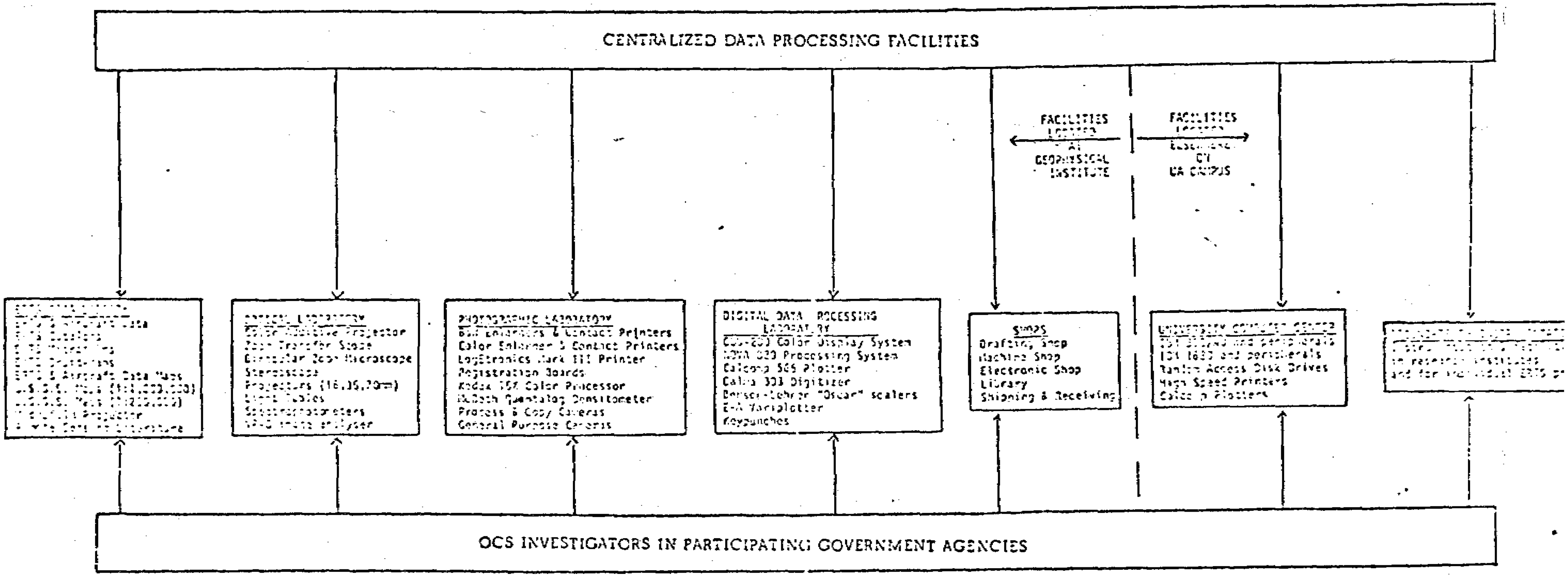


Figure 1 - Centralized Data Processing Facilities

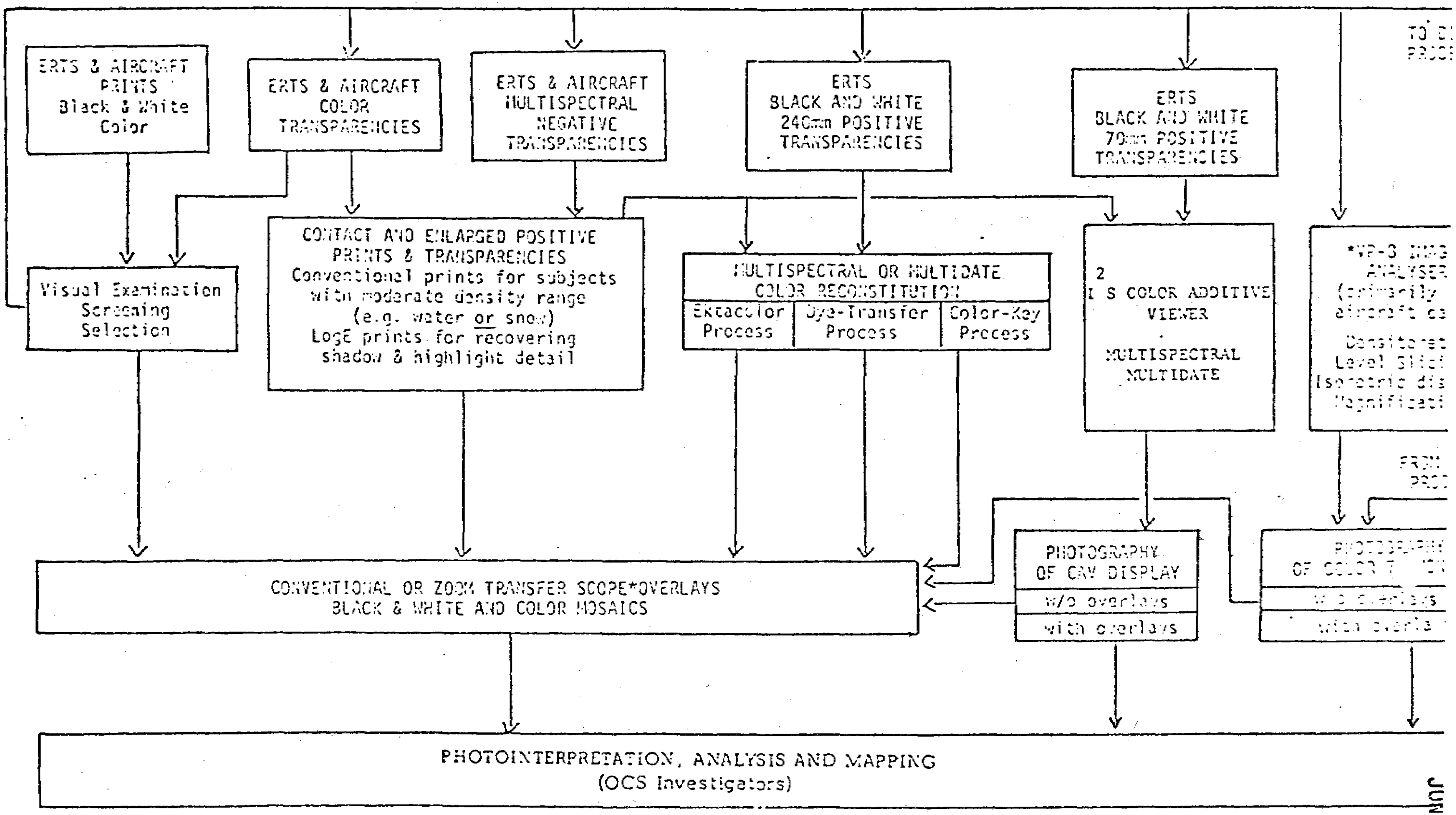
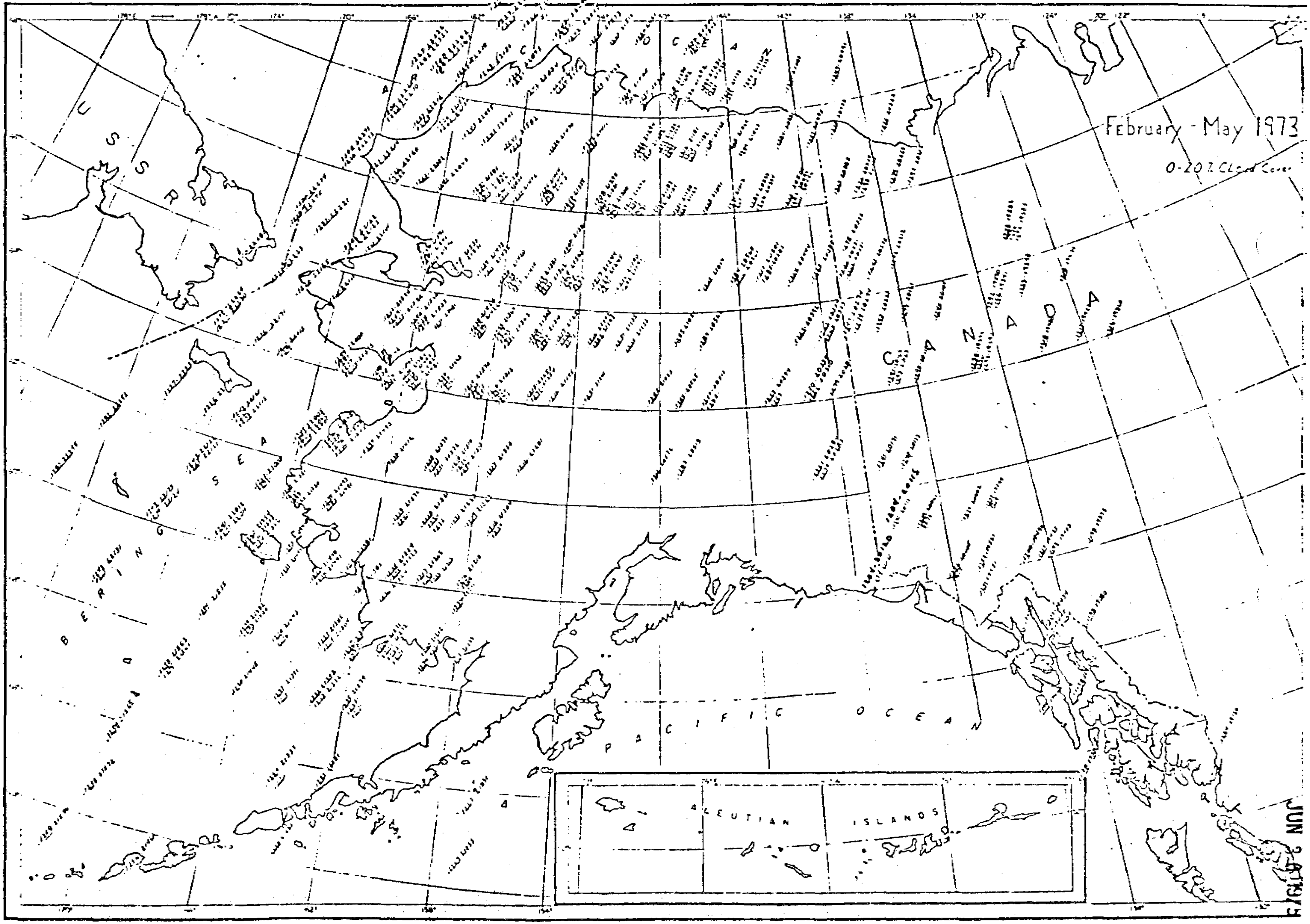


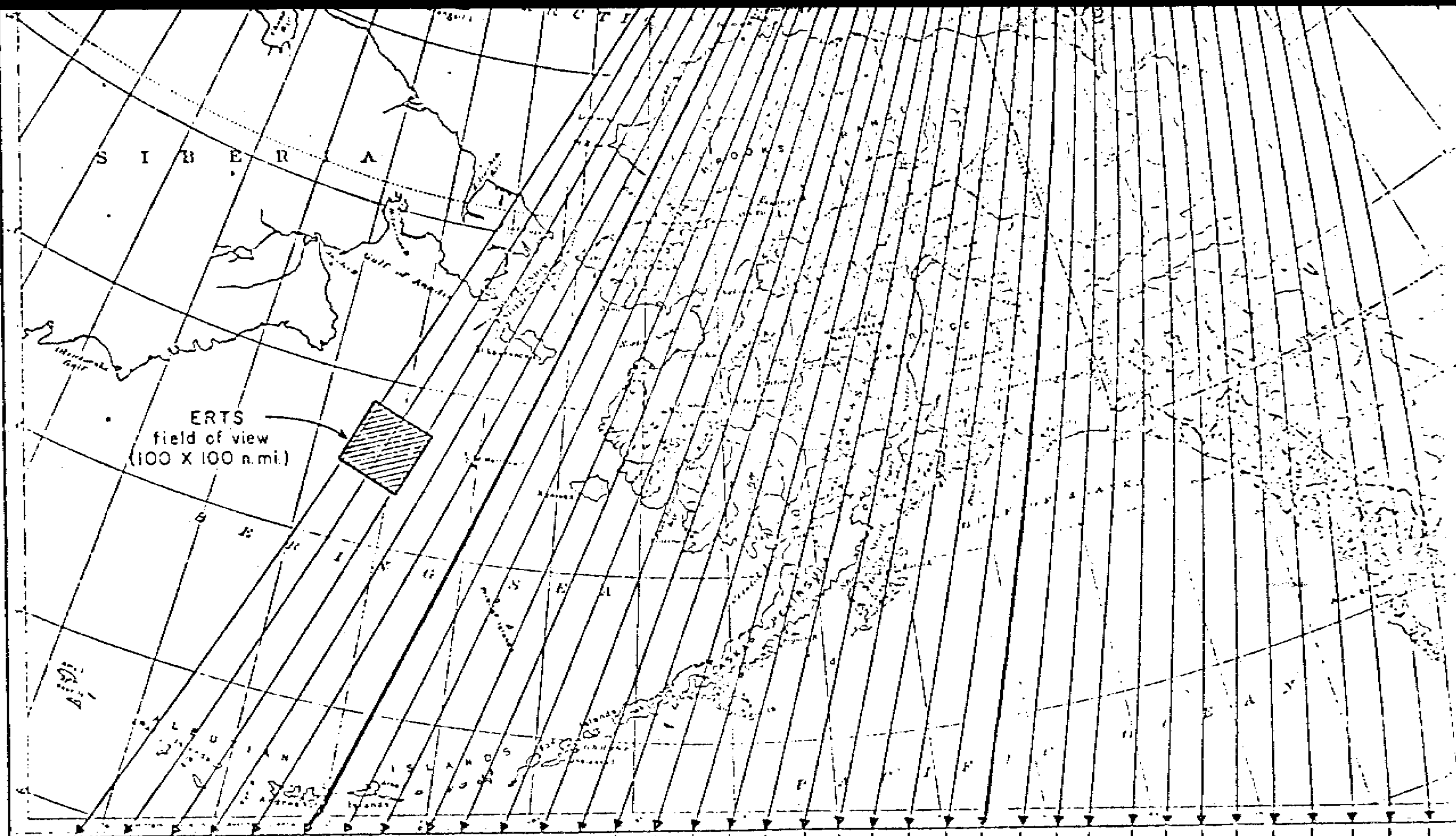
Figure 2 - Optical and Photographic Processing

Prepared by:
Geophysical Institute
University of Alaska



Scene ID No.	Date	Cloud Cover	Lat. Center	Long. Center Pt.	Sun El.	Sun Az.	Map Description	Color C Digital Tape D
1002-21310	July 25, 1972	15	67.25N	154.43W	41	162	Walker Lake	D
1002-21312	July 25, 1972	15	66.06N	156.16W	42	160	Hughes	D
1002-21315	July 25, 1972	10	64.45N	157.42W	43	158	Nulato	C + D
1002-21324	July 25, 1972	15	62.02N	160.09W	45	154	Holy Cross	
1006-21510	July 29, 1972	5	60.32N	155.26W	37	168	Barrow	C
1009-22083	August 1, 1972	5	69.25N	161.30W	37	166	Point Lay	
1009-22090	August 1, 1972	2	68.07N	163.21W	39	164	Point Hope	C
1009-22092	August 1, 1972	0	66.48N	165.00W	40	162	Kotzebue	
1009-22095	August 1, 1972	0	65.27N	166.30W	41	160	Seward Peninsula	C + D
1009-22101	August 1, 1972	20	64.07N	167.51W	42	158	Nome	
1009-22110	August 1, 1972	10	61.23N	170.14W	44	154	Bering Sea	
1010-20313	August 2, 1972	10	67.56N	139.29W	39	164	Old Crow	
1010-22133	August 2, 1972	10	71.53N	159.04W	35	171	Sea Ice Off Barrow	
1010-22135	August 2, 1972	0	70.37N	161.21W	36	169	Wainwright, Point Lay	
1010-22142	August 2, 1972	2	69.20N	163.22W	37	166	Point Lay	C
1010-22144	August 2, 1972	2	68.02N	165.09W	38	164	Point Hope	C + D
1010-22145	August 2, 1972	5	67.37N	165.26W	39	163	Point Hope	
1010-22151	August 2, 1972	5	66.42N	166.47W	40	162	Shishmaref	C
1010-22153	August 2, 1972	2	65.21N	168.19W	41	160	Teller	C
1010-22160	August 2, 1972	0	64.01N	169.39W	42	158	St. Lawrence Island	C
1010-22162	August 2, 1972	10	62.39N	170.53W	43	156	St. Lawrence Island	
1016-21045	August 8, 1972	10	71.20N	142.35W	34	171	Arctic Ocean, sea ice	
1018-21191	August 10, 1972	5	62.40N	156.24W	41	157	Iditarod	C + D
1018-21193	August 10, 1972	0	61.19N	157.32W	42	155	Sleetmute	C
1018-21200	August 10, 1972	5	59.57N	158.36W	43	153	Dillingham	C
1019-19423	August 11, 1972	20	59.30N	134.23W	43	153	Atlin	
1019-19430	August 11, 1972	20	58.07N	135.20W	44	151	Juneau	C
1019-21234	August 11, 1972	15	66.24N	153.59W	37	162	Hughes, Bettles	C
1020-19480	August 12, 1972	0	60.32N	135.04W	42	154	Whitehorse	
1026-20211	August 18, 1972	10	64.28N	140.25W	37	160	Eagle	C
1026-20214	August 18, 1972	10	63.06N	141.40W	38	158	Tanacross	C
1026-20220	August 18, 1972	5	61.45N	142.50W	39	156	McCarthy	C
1027-20255	August 19, 1972	10	68.14N	137.29W	33	166	East of Table Mts	
1027-20261	August 19, 1972	20	66.55N	139.08W	34	164	East of BlackRiver	C
1027-22074	August 19, 1972	5	72.26N	156.23W	30	174	Sea Ice north of Barrow	
1028-20324	August 20, 1972	20	64.37N	143.08W	36	160	Eagle	
1029-20365	August 21, 1972	20	69.32N	138.38W	32	168	Herschel Island	
1029-20381	August 21, 1972	2	65.33N	143.38W	35	162	Charlie River	D
1029-20383	August 21, 1972	0	64.12N	145.00W	36	160	Big Delta	C + D
1030-20424	August 22, 1972	20	69.27N	139.54W	31	168	Demarcation Point	C
1030-20430	August 22, 1972	10	68.09N	141.45W	32	166	Table Mountains	C
1030-20433	August 22, 1972	5	66.50N	143.24W	34	164	Black River	C
1030-20435	August 22, 1972	15	65.29N	144.55W	35	162	Circle	
1030-20442	August 22, 1972	10	64.08N	146.17W	36	160	Fairbanks, Delta	C
1030-22270	August 22, 1972	15	65.52N	170.20W	34	162	Chukotsk Penn., Siberia	C
1030-22273	August 22, 1972	20	64.31N	171.44W	35	161	Siberia, St. Lawrence Is.	
1033-21020	August 25, 1972	20	62.43N	151.52W	36	159	McKinley	C + D
1033-21022	August 25, 1972	10	61.20N	153.01W	37	157	Lime Hills, Tyonek	C
1033-21025	August 25, 1972	10	59.57N	154.04	38	156	Lake Clark, Iliamna	
1034-21095	August 26, 1972	10	55.46N	158.28W	41	151	Stepovak Bay	C
1037-21231	August 29, 1972	5	68.08N	152.01W	30	167	Chandler Lake, Wiseman	C
1037-21234	August 29, 1972	2	66.49N	153.40W	31	165	Hughes, Bettles	C + D
1037-21240	August 29, 1972	5	65.28N	155.09W	32	163	Melozitna	C + D
1037-21243	August 29, 1972	5	64.07N	156.30W	33	161	Nulato, Ruby	C
1037-21245	August 29, 1972	5	62.45N	157.44W	35	159	Ophir, Iditarod	C
1037-21252	August 29, 1972	20	61.23N	158.53W	36	158	Russian Mission, Sleetmute	
1038-21295	August 30, 1972	5	65.29N	156.35W	32	163	Koteel River	C
1038-21301	August 30, 1972	0	64.06N	157.57W	33	161	Nulato	C + D
1038-21304	August 30, 1972	0	62.46N	159.11W	34	160	Holy Cross, Iditarod	C + D
1038-21310	August 30, 1972	20	61.24N	160.19W	35	158	Russian Mission	C + D
1039-21371	August 31, 1972	10	60.00N	162.48W	36	157	Kuskokwim Bay	
1039-21374	August 31, 1972	5	58.37N	163.48W	37	155	Kuskokwim Bay	
1043-20161	September 4, 1972	15	62.42N	140.34W	33	160	Nabesna & east	
1043-20163	September 4, 1972	0	61.19N	141.42W	34	159	McCarthy	C
1044-20201	September 5, 1972	2	68.05N	136.15W	28	167	Aklavik, NWT	
1044-20212	September 5, 1972	2	64.01N	140.44W	31	162	Eagle, Tanacross	C
1044-20215	September 5, 1972	10	62.42N	141.57W	32	161	Tanacross, Nabesna	C
1044-22024	September 5, 1972	0	70.40N	150.09W	25	172	Meade River	
1045-20255	September 6, 1972	0	68.05N	137.39W	27	168	East of Table Mountains	
1045-22091	September 6, 1972	10	68.05N	163.30W	27	168	Noatak	
1046-20343	September 7, 1972	5	58.31N	148.04W	35	156	Gulf of Alaska	
1046-20350	September 7, 1972	10	57.08N	148.58W	36	155	Pacific Ocean	
1046-22143	September 7, 1972	20	69.20N	163.12W	26	170	Point Lay	

Figure 4 - List of available LANDSAT scenes, July-September 1972



DATES IN JUNE	3 21	2 20	1 19	18	17	16	15	14	13	12 30	11 29	10 28	9 27	8 26	7 25	6 24	5 23	4 22	3 21
DATES IN JULY	9 27	8 26	7 25	6 24	5 23	4 22	3 21	2 20	1 19	18	17	16	15	14	13 31	12 30	11 29	10 28	9 27
DATES IN AUGUST	14	13 31	12 30	11 29	10 28	9 27	8 26	7 25	6 24	5 23	4 22	3 21	2 20	1 19	18	17	16	15	14
DATES IN SEPTEMBER	1 19	18	17	16	15	14	13	12 30	11 29	10 28	9 27	8 26	7 25	6 24	5 23	4 22	3 21	2 20	1 19
DATES IN OCTOBER	7 25	6 24	5 23	4 22	3 21	2 20	1 19	18	17	16	15	14	13 31	12 30	11 29	10 28	9 27	8 26	7 25

DATES IN JUNE	2 20	1 19	18	17	16	15	14	13	12 30	11 29	10 28	9 27	8 26	7 25	6 24	5 23	4 22	3 21
DATES IN JULY	8 26	7 25	6 24	5 23	4 22	3 21	2 20	1 19	18	17	16	15	14	13 31	12 30	11 29	10 28	9 27
DATES IN AUGUST	13 31	12 30	11 29	10 28	9 27	8 26	7 25	6 24	5 23	4 22	3 21	2 20	1 19	18	17	16	15	14
DATES IN SEPTEMBER	18	17	16	15	14	13	12 30	11 29	10 28	9 27	8 26	7 25	6 24	5 23	4 22	3 21	2 20	1 19
DATES IN OCTOBER	6 24	5 23	4 22	3 21	2 20	1 19	18	17	16	15	14	13 31	12 30	11 29	10 28	9 27	8 26	7 25

Figure 5 - Predicted LANDSAT orbits over Alaska, June - October 1974

Prepared by: GEOPHYSICAL INSTITUTE, UNIVERSITY OF ALASKA