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ALL-WEATHER ICE INFORMATION SYSTEM FOR ALASKAN ARCTIC COASTAL SHIPPING

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ABSTRACT

This paper describes a Coast Guard/NASA/NOAA/Navy demonstration of an all-weather, near real-time ice information system designed to aid arctic coast shipping along the Alaskan North Slope during August and September, 1976. The system utilizes a X-band Side Looking Airborne Radar (SLAR) mounted aboard a U.S. Coast Guard HC-130B aircraft. Radar mapping procedures showing the type, areal distribution and concentration of ice cover were originally developed by the NASA Lewis Research Center for aiding winter navigation in the Great Lakes. In order to guide vessel operational movements, near real-time SLAR image data were transmitted directly from the SLAR aircraft to Barrow, Alaska and the U.S. Coast Guard icebreaker Glacier. In addition, SLAR image data were transmitted in real time to Cleveland, Ohio via the NOAA-GOES Satellite. Radar images developed in Cleveland were subsequently facsimile transmitted to the U.S. Navy's Fleet Weather Facility in Suitland, Maryland for use in ice forecasting and also as a demonstration back to Barrow via the Communications Technology Satellite.

Results from the 1976 arctic ice information demonstration indicate the capability of this system to provide timely ice information on a routine basis. The entire north slope coastal shipping region regardless of the existing weather conditions was mapped at an appropriate image scale for operational use in directing vessel movements. The ice information transmitted to the U.S. icebreaker Glacier allowed it to continue operation in the Arctic three weeks longer than it had anticipated from earlier ice forecast.

I. INTRODUCTION

The need for an all-weather ice information system is established by the following description of the Alaskan resupply problem. Resupply of the various DEW line military sites, native villages and commercial oil and gas drilling bases along the North Slope of Alaska is generally accomplished by means of tug and barge convoys. Such sealift operations are not only the most economic mode of resupply but are the only means available for transporting large building units and modules used in the oil and gas development operations along the North Slope. Barge resupply operations for these northern bases are scheduled for the months of July, August and September when the arctic pack ice traditionally recedes and a navigable lead forms along the Alaskan coast. Oceanographic and meteorological influences maintain the arctic pack in a position offshore that almost continually threatens navigation. Shifting winds accompaning the passage of weather systems combine with surface currents to impart a dynamic movement to this pack ice. Leads and openings in the ice can be closed in a matter of hours.

The 1975 North Slope resupply sealift was a near disaster. Twenty-two (22) of the forty-seven (47) barges destined for the Prudhoe Bay oil fields as well as all of the barges destined for DEW Line resupply had to turn back from their scheduled destination because of the unseasonal arctic ice conditions found in the Point Barrow area. Easterly "summer" winds which normally create navigable leads along the North Slope did not materialize. Shifting winds and new ice build up made it extremely hazardous and difficult for those tugs and barges that did make it through. Some of the cargo was able to be shipped to its original destination by alternate means of transportation (airlift). The additional expense incurred however amounted to between 30 and 50 million dollars. Other types of cargo such as the large building modules, drill site skids, pumping plants and other large size units were not able to be shipped by alternate means due to their size alone. Such cargo had to wait for the 1976 summer arctic shipping season. Failure of the 1975 sealift to complete all of its scheduled deliveries had a severe impact on the scheduled completion of the Prudhoe Bay complex and its attendant 800 mile-long Alyeska pipeline to Valdez.

Ice information has traditionally been gathered for Alaska North Slope barge transportation via visual observation from either aircraft or satellite. In past years visual ice information for the North Slope has been obtained using (1) U.S. Navy P3 aircraft, (2) Canadian AES Lockheed Electra aircraft, (3) Crowley Maritime Corporation private light aircraft and (4) Landsat, NOAA-4VHRR and NOAA-GOES Satellites. Clouds and especially fog, which is prevalent in the

Arctic during the summer months, severely hampers such observations for days at a time. During the 1975 barge resupply efforts, decisions on barge movement were inhibited by lack of adequate ice information. As a result of the inability of traditional methods to obtain satisfactory ice information during the 1975 shipping season, requests were made by organizations associated with the shipping to the U.S. Coast Guard and NASA to demonstrate the all-weather near real-time microwave ice information system which had been developed for winter navigation in the Great Lakes. The near real-time requirement should be stressed because of the rapid change in ice conditions (within a few hours) which can occur along the North Slope of Alaska. The system uses a Side Looking Airborne Radar (SLAR) which has the ability to penetrate all but the most severe weather and to map broad areas. Thus it has the capability for monitoring sea ice in support of vessel operational movements. A number of previous investigations in the Arctic (references 1-4) have already demonstrated the ability of such radar systems to provide essentially all-weather ice information over a broad geographic area. However, only limited attempts have been made to provide an operational user with all-weather, near real-time ice information on a routine bases over an extended period of time.

As a result of the user initiative, a joint Coast Guard/NASA/NOAA/NAVY demonstration using the Great Lake Ice Information System was conducted during August and September of 1976 for the Alaskan North Slope barge shipping.

II. ALASKAN ICE INFORMATION DEMONSTRATION SYSTEM

The near real-time all-weather ice information system used in the North Slope demonstration was originally developed for the Great Lakes. A detailed description of its development and use in the Great Lakes can be found in reference 5.

A. Aircraft Sensor and Processing System

The system uses a Side Looking Airborne Radar (SLAR) mounted aboard a Coast Guard HC-130B aircraft. This SLAR was a real aperture X-band system which transmitted and received horizontally polarized radiation. For ice reconnaissance missions, the aircraft was flown at an altitude of 3.35 kilometers (11,000 feet) and at an average ground speed of 265 knots. A schematic of the radar system is presented in figure 1. A narrow 0.5 degree wide beam of pulsed microwave radiation was alternately radiated (every 16 pulses) from the left and right sides of the antenna at a rate (750 pps) that permits simultaneous mapping of the ice cover out to 50 kilometers on both sides of the aircraft. Backscattered radiation received by the antenna mounted beneath the tail of the aircraft is routed to the radar receiver where the signals are amplified and down-converted to video signals. These analog signals are used to produce an exposed only film negative. In addition, the signals are also sent to a digitizer signal encoder. The radar return signals were divided by the encoder into 400 equal right antenna and 400 equal left antenna time segments or range bin intervals. For each range bin, the radar video signal was sampled and digitized into a six-bit data word. The digitized video data from a radar pulse were accumulated in memory and averaged exponentially with the data from previous pulses from the same range. Auxiliary data including aircraft drift, ground speed, altitude and heading were multiplexed with the average video data every 806 ms to form a single radar scanline. The data are subsequently recorded on magnetic tape and at the same time decoded to display an image on both a cathode ray display tube and a CRT-Fiber Optics Recorder that employed dry-silver heat developed, photosensitive paper. The black and white print developed on the dry silver paper is of photographic quality with 9-12 gray levels at 200 lines/inch. The scale of the image was 1:500,000 with a swath width of 100 km. The advantage of the dry silver paper is that it is developed by a heater in the recorder avoiding wet processing. The radar signals were also simultaneously transmitted in real time to both the NOAA-GOES satellites as well as a ground station as described next.

B. Data Distribution System

The various elements associated with the Alaskan ice information system are depicted in figure 2. The Coast Guard SLAR aircraft routinely surveyed the ice conditions along the north coast of Alaska from Wainwright to Barter Island (see figure 3). The radar data were transmitted from the aircraft to (1) Barrow, Alaska by a continuous real-time downlink transmission, (2) the U.S. Coast Guard icebreaker Glacier and (3) the NASA Lewis Research Center in Cleveland, Ohio by a continuous real-time UHF uplink transmission to the NOAA-GOES Satellite in geosynchronous orbit and a subsequent S-band microwave downlink to Wallops Island, Virginia ground station and by special dedicated telephone lines to Cleveland, Ohio.

For the 1976 Arctic Sealift, Crowley Maritime Corporation controlled all vessel operations for both the military base and Prudhoe Bay resupply. Crowley established an operations center at the Naval Arctic Research Laboratory (NARL) in Barrow, Alaska. Since the primary objective of this demonstration was to provide all-weather, near real-time ice information for arctic coastal shipping, the downlink transmission to Barrow from the SLAR aircraft was the prime communications link. The ground station at Barrow could receive continuous real-time radar data transmissions from the aircraft out to range of 100-120 nautical miles. For those coastal areas of interest outside this range, the SLAR aircraft could re-transmit the data via a fast playback transmission from the tape recorders on-board the aircraft. Digital data were transmitted over a VHF channel at 217.55 MHz to Barrow, and recorded on magnetic tape. This signal was decoded to analog and used to generate a high quality image (109 lines/inch, 9-12 gray scale levels) by a Harris Laserfax Recorder using heat sensitive dry-silver paper at a scale of 1:500,000.

During the time period of this demonstration, scientists aboard the U.S. Coast Guard icebreaker Glacier were conducting a variety of experiments in both the Chukchi and Beaufort Seas. Radar ice information was also transmitted to the Glacier by means of a downlink facsimile transmission from the SLAR aircraft. Imagery generated in real time aboard the aircraft using the dry-silver paper image recorder was transmitted to the Glacier by means of a Harris Laserfax facsimile transmitter over a VHF-FM radio link. Aboard the Glacier, the radar image was received by an Alder recorder at a scale of 1:381,000.

At Cleveland, Ohio the real-time data were recorded on magnetic tape, decoded and used to generate a high quality image on dry silver paper by a recorder similar to the image recorder aboard the SLAR aircraft.

The radar image was subsequently facsimile transmitted from Cleveland to (1) the U.S. Navy Fleet Weather Facility in Suitland, Maryland over dedicated telephone lines and (2) to Barrow, Alaska via the Communications Technology Satellite (CTS)(reference 6). CTS was used as an alternate means of transmitting radar imagery to Barrow to demonstrate the capabilities of this communications satellite.

The CTS, a joint project between the United States and Canada, was launched in January, 1976. It is the first satellite to operate at a frequency of 12 GHz and incorporates new technology making possible new satellite telecommunications services. CTS has the capability of transmitting television video directly to small, inexpensive ground receivers in remote locations such as Barrow. For this demonstration a 0.6 meter dish antenna was used at Barrow to receive the facsimile transmissions from Cleveland.

III. SLAR Imagery of Arctic Sea Ice Along Alaska

The U.S. Coast Guard SLAR aircraft used in Project Icewarn has multiple mission assignments including Search and Rescue surveilance, International Ice Patrol and Great Lakes Ice Program. This aircraft could not be made available until the end of August, 1976 due to prior commitments. The aircraft arrived in Alaska on August 27, 1976. Operational radar flights were conducted almost daily from August 27 through September 17, 1976 along the North Slope. Figure 3 portrays the approximately 100 kilometer wide area surveyed by the SLAR aircraft along the west and north coastlines of Alaska from Cape Lisburne to Barter Island, east of Prudhoe Bay. Ice conditions during this August-September time period were such that the area between Wainwright and Cape Lisburne was ice free and therefore was not flown. The rest of this report will present examples of radar imagery generated during this time period, discuss the various aspects of the ice information communications network employed for this demonstration as well as the usefulness of near real-time ice information in support of shipping operations.

A radar image depicting typical ice conditions found along the northern Alaskan coast during this demonstration time period is presented in figure 4 from August 27, 1976. The image portrays the near shore ice conditions in the Beaufort Sea between the Colville River Delta to just east of Prudhoe Bay. The various shades of gray in the radar image correspond to the intensity of backscattered microwave radiation from within the antenna's field of view. Microwave backscattering from sea ice is a complicated phenomenon dependent on such parameters as microwave frequency, polarization, surface and bottom roughness, dielectric properties of the ice and the angle of incidence.

Light toned, white areas indicate high intensity backscattered radiation as might be expected from ice features exhibiting a high degree of surface roughness such as rafted and ridged areas as well as from features with multiple edges such as brash. Dark toned, black areas on the other hand represent areas of minimal backscattered radiation such as open water or smooth surfaced ice sheets from which the incident microwave pulse is specularly reflected away from the receiving antenna.

In the figure 4 imagery the coast line is readily discernable. The off shore barrier islands are easily identified. The oil field complex at Prudhoe Bay stands out as a interconnected web of white lines. The barges an tugs at anchor at Prudhoe Bay appear as elongated white dots. Within the ice field itself the various concentrations of ice can be distinguished. During this time of year, the ice in this area was broken into many small and medium size floes. Such ice floes provided a large amount of backscattering resulting in a very white toned area on the radar image. This is particularly evident in the pack ice area of 85% concentration. An altitude "hole" exists in the imagery along the aircraft flight track directly beneath the aircraft only as a display artifact.

Another example of the radar imagery collected during this time period is shown in figure 5. The figure portrays the ice condition in the Chukchi Sea in the vicinity of Barrow, Alaska on August 30, 1976. The horizontal striations evident in some of the light toned areas are interference patterns resulting from signal reflection from the aircraft horizontal stabilizer. Complex surface current patterns highlighted by varying concentrations of ice are readily discernable. Patterns such as these were evident in many of the radar images acquired during the time period of this demonstration. Such currents are one element responsible for rapid movement of the ice which necessitates the need for near real-time ice information.

A comparison between a Landsat visual image and a radar image of the ice conditions in the Beaufort Sea on September 7, 1976, is presented in figure 6. Landsat is the name given to two NASA satellites used for collecting earth resources data. Sensors in the current Landsat system employ four spectral bands in visible and near-infrared region of the spectrum. In figure 6, the Landsat image was from band 5 in the "red" region of the spectrum between 0.6 micrometers and 0.7 micrometers. During the time period of this demonstration the Landsat orbits were such as to repeat the same ground track every nine days. However, at these high latitudes, there is a large area of overlap in the daily ground coverage such that it is possible to image one area for a number of consecutive days. During the time period of this demonstration, persistent cloud cover and fog rendered most Landsat images useless for protraying ice conditions. The image from September 7 was the best available for displaying near shore ice condition. The SLAR image shown in this figure is a mosaic of two slightly offset flight lines so as to eliminate the altitude hole. In addition the Landsat image was taken approximately 5 hours prior to the radar image. A comparison between these images will reveal a high degree of correlation between the overall ice patterns. Closer examination will permit many individual ice floes to be identified in each image. In the areas of higher ice concentration, the Landsat image displays more detail than the radar image. This results from the difference in resolution capability of the two systems. Landsat has a resolution of 80 meters whereas the radar has a resolution of 80 meters in range but a varying azimuthal resolution between 80 meters at range of 10 kilometers from the aircraft flight track to 400 meters at a range of 50 kilometers.

IV. SUMMARY OF 1976 ALASKAN ICE INFORMATION DEMONSTRATION

During this Alaskan Demonstration, nineteen radar flights were conducted from August 27 to September 17,

1976. The SLAR aircraft was based at Eielson Air Force Base in Fairbanks, Alaska. Persistent fog in the Barrow area during this time period precluded operating the aircraft from Barrow. Due to favorable weather and ice conditions, the tugs and barges reached Prudhoe Bay prior to the deployment of the SLAR aircraft to Alaska. During the latter part of August and the early part of September, the unloaded barges made the return trip to southern Alaska. During this time period the ice remained in a continually threatening position a few miles offshore. Shifting winds frequently brought ice into the shipping lanes. Prior to this Demonstration, the weather had been unreasonably clear permitting visual ice observation as needed. The weather deteriorated in the latter part of August with fog preventing visual flights for days at a time. Crowley Maritime frequently conducted ice reconnaissance flights underneath the fog at altitudes below 100 meters. Of course, the effective field of view from such altitudes was limited to the immediate vicinity of the aircraft.

As previously mentioned the downlink transmission from the SLAR aircraft to Barrow was the primary communications channel to provide radar imagery for use in vessel operational movements. During the first few days of this demonstration, the SLAR aircraft was unable to land at Barrow, due to the poor weather, and deliver this receiving equipment. However, radar data were transmitted to Cleveland, Ohio via the GOES satellite link and a radar image was facsimile transmitted back to Barrow from Cleveland via the CTS satellite. This CTS link had been set-up and tested in early August.

Ice observers from the U.S. Navy and the Arctic Institute of North America, AINA, stationed at Barrow used this radar imagery and subsequent real-time imagery generated using the downlink recorder to develop interpretative ice charts. Figure 7 is an example of a SLAR Image/Ice Chart Product generated for August 27, 1976 in the Beaufort Sea between Smith Bay and Prudhoe Bay. The ice chart outlines the various ice concentration boundaries and identifies the open water areas. Ice concentrations are presented in eights, i.e. 3/8 indicates that the area is 37.5 percent covered by ice.

The downlink equipment was installed at Barrow on August 29 and provided real-time radar imagery on an almost daily basis in support of the tug and barge movements.

An example illustrating the dynamic movement of the ice as a function of time is presented in figure 8. Radar images of the ice cover in the Chukchi Sea in the vicinity of Barrow are presented for second, third and fourth of September 1976. The ice remained 2-3 nautical miles offshore at Barrow on the second of September and approximately 6 nautical miles offshore in the area of Peard Bay. On the third, the ice decreased in concentration around Barrow but still remained 2-3 nautical miles offshore. However at Peard Bay, the ice had moved to within 1.5 nautical miles of the coast. Radar imagery for the fourth of September showed that ice had continued to move toward the coast. The entire near shore area to within approximately 10 nautical miles of Peard Bay was ice covered with the heavest concentration in the vicinity of Barrow.

Operations at Barrow were continued through September 10 when barge movements were essentially completed along the north shore.

Radar flights were continued after September 10 to further support the operational activities of the U.S. Coast Guard icebreaker Glacier. Fog and persistent bad weather prevented the Glacier from launching her helicopters to obtain visual ice observations. The Glacier stated that the radar was the "consistent best source of ice info...." SLAR imagery was a basis for our extended north slope operation, and the continuing collection of valuable oceanographic and geologic information. "... daily SLAR data enabled us to recognize trends otherwise unavailable." (reference 7)

Daily radar flights were continued in support of the Glacier's operation until September 18 when the Glacier completed her mission in the ice pack.

Radar imagery from these demonstration flights were also relayed by facsimile transmission from Cleveland, Ohio to the ice observation unit of the Navy Fleet Weather Facility in Suitland, Maryland. The interpretation of this imagery was combined with ice information available from satellites, visual reconnaissance and any weather information to generate a comprehensive overview of the arctic ice conditions. This information was used by the Navy and AINA to make both short range and long term forecasts of the ice conditions along the North Slope.

V. CONCLUDING REMARKS

The demonstration was extremely useful in revealing the requirements that an ice information system must meet in order to provide direct support to vessel movement along the North Shore. The requirements for the ice information system are that it:

(1) Be all-weather

(2) Be capable of acquiring, processing, and distributing the ice information within 4 to 6 hours

(3) Be capable of acquiring the data at a frequency of up to at least once a day. There are periods when this frequency is not required.

(4) Be capable of providing the information along the entire coastal shipping lanes from Point Lay to Barter Island, a distance of some 500 nautical miles

(5) Present the information in great detail at a scale of at least 1:500,000

These quite stringent requirements could be eased by more adequate ice forecast models.

The demonstration verified that the Coast Guard/NASA/NOAA all-weather near real-time ice information system which was developed for the Great Lakes and used in the demonstration could meet these requirements. A most important feature of this Ice Information System is the communications system whereby real-time radar data can be transmitted to any number of remote ground locations. The ground station used at Barrow is portable and could be duplicated for use at other additional locations including aboard ship. Use of the NOAA-GOES satellite relay permits real-time radar data to be transmitted into any location that can establish a communications link with the Wallops Island, Virginia ground receiving station of NOAA.

Future operations can be envisioned whereby such radar data are transmitted to a joint Arctic Ice Center staffed by personnel from the Navy's FWF and NOAA. At such a center, ice information could be compiled from a variety of sources including NOAA weather satellites, NASA Landsat and upcoming Seasat satellites, among others, to develop a comprehensive overview of arctic ice conditions. The use of low cost portable transmitting and receiving stations being developed as part of the CTS Program would allow such an Ice Center to re-transmit both weather and ice information to remote field locations such as Barrow.

The side-looking radar system as currently used in the demonstration was mounted on a Coast Guard HC-130B aircraft. Future radars mounted aboard a satellite system could theoetically provide more frequent data more readily than possible by an aircraft system. For this reason, the upcoming launch of Seasat-A in 1978, with its own synthetic aperture SAR radar capable of providing 100 km wide images of the ice along the North Slope of Alaska is important. Test will be performed using Seasat-A SAR images to determine it's accuracy and capability for mapping the Arctic ice along the North Slope of Alaska.

REFERENCES

1. Anderson, V.H. 1966, "High Altitude, Side-Looking Radar Images of Sea Ice in the Arctic," Proceedings of the Fourth Symposium on Remote Sensing of Environment, University of Michigan, Ann Arbor, pp. 845-857.

2. Rouse, J.W., Jr. 1969, "Arctic Ice Type Identification by Radar," Proceedings IEEE, vol. 57 pp. 605-614.

3. Johnson, J.D., and L.D. Farmer, 1971, "Use of Side-Looking-Airborne-Radar for Sea Ice Identification," Journal of Geophysical Research, Vol 76, No. 9, pp. 2138-2155.

4. Loshchilov, V.S. and V.A. Voyevodin, 1972, "Determination of Elements of Ice Cover Drift and Ice Hummock Movement by Means of Toros Airborne Side Looking Radar Imagery Assembly." Problems of the Arctic and Antarctic, Gidrometeoizdat Press, Leningrad, 1972.

5. Schertler, R.J., et al., "Great Lakes All-Weather Ice Information System", Proceedings of the Symposium on Remote Sensing of Environment, University of Michigan, Ann Arbor, 1976. (NASA TM X-71815)

6. Robbins, W.H., and Donoughe, P.L., CTS United States Experiments - A Progress Report. NASA TM X-73510.

7. Coast Guard Communications from U.S. Coast Guard Icebreaker Glacier, 18 September 1976.

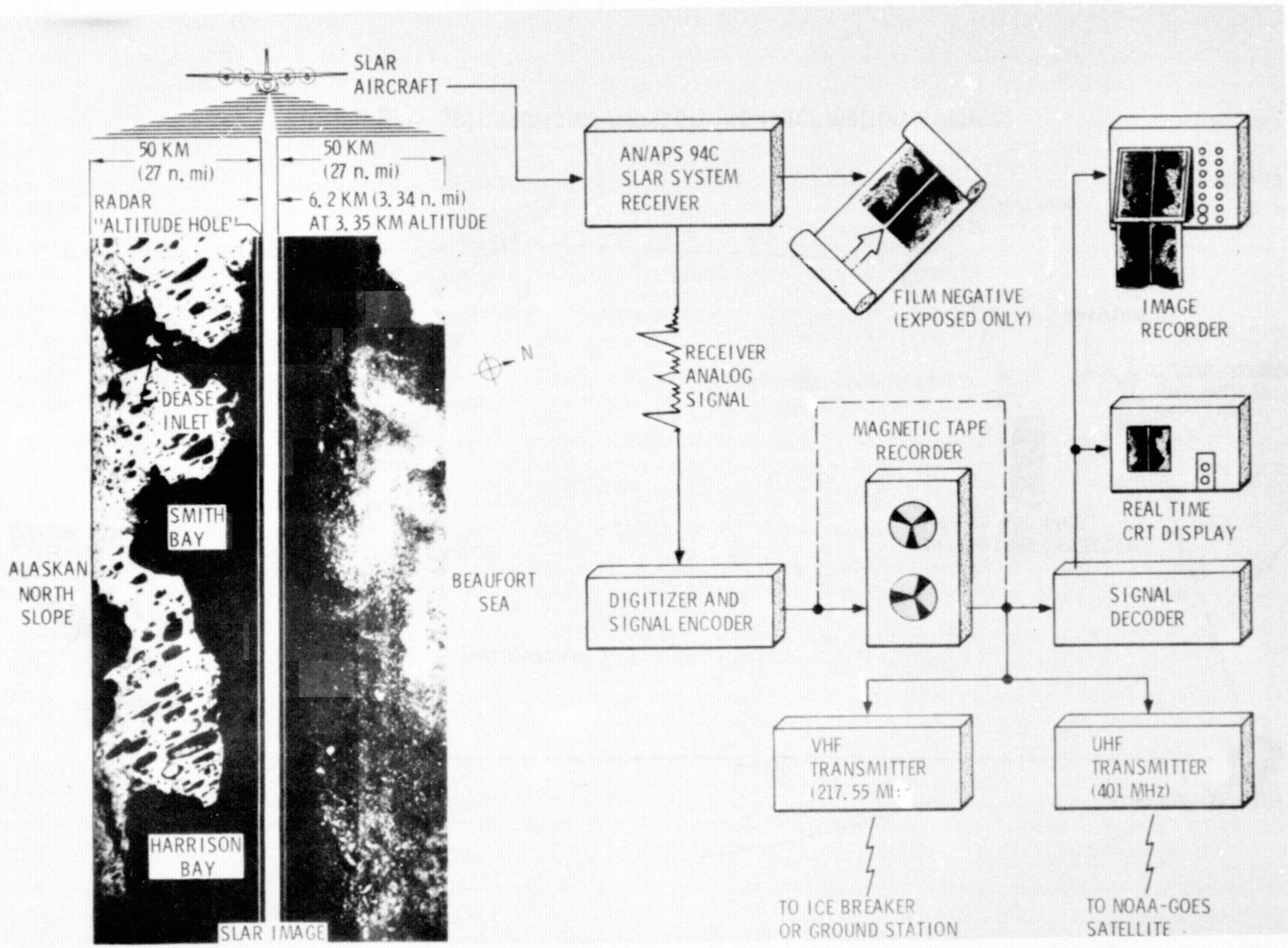

Figure 1. - Schematic of side-looking - airborne-radar system.

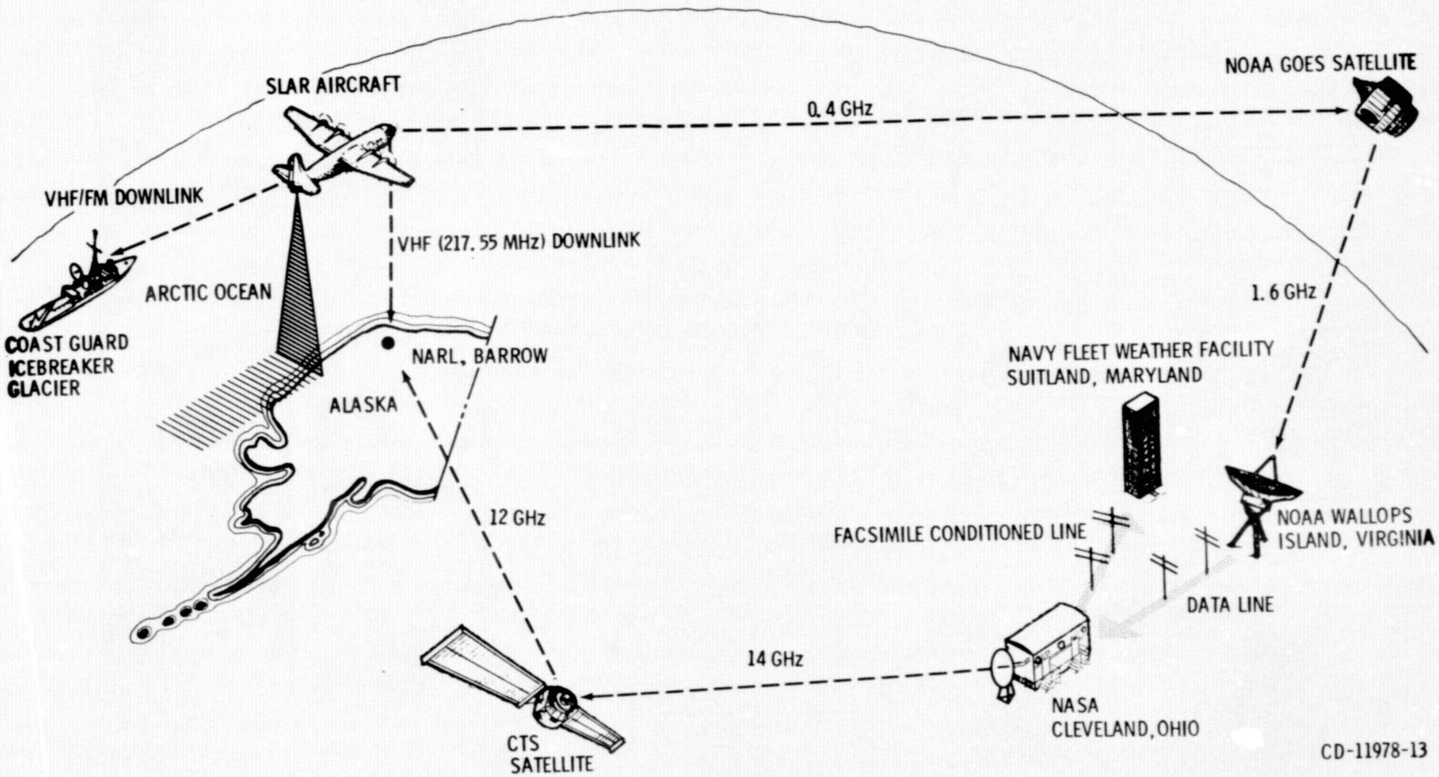

Figure 2. - Schematic of Alaskan ice information system.

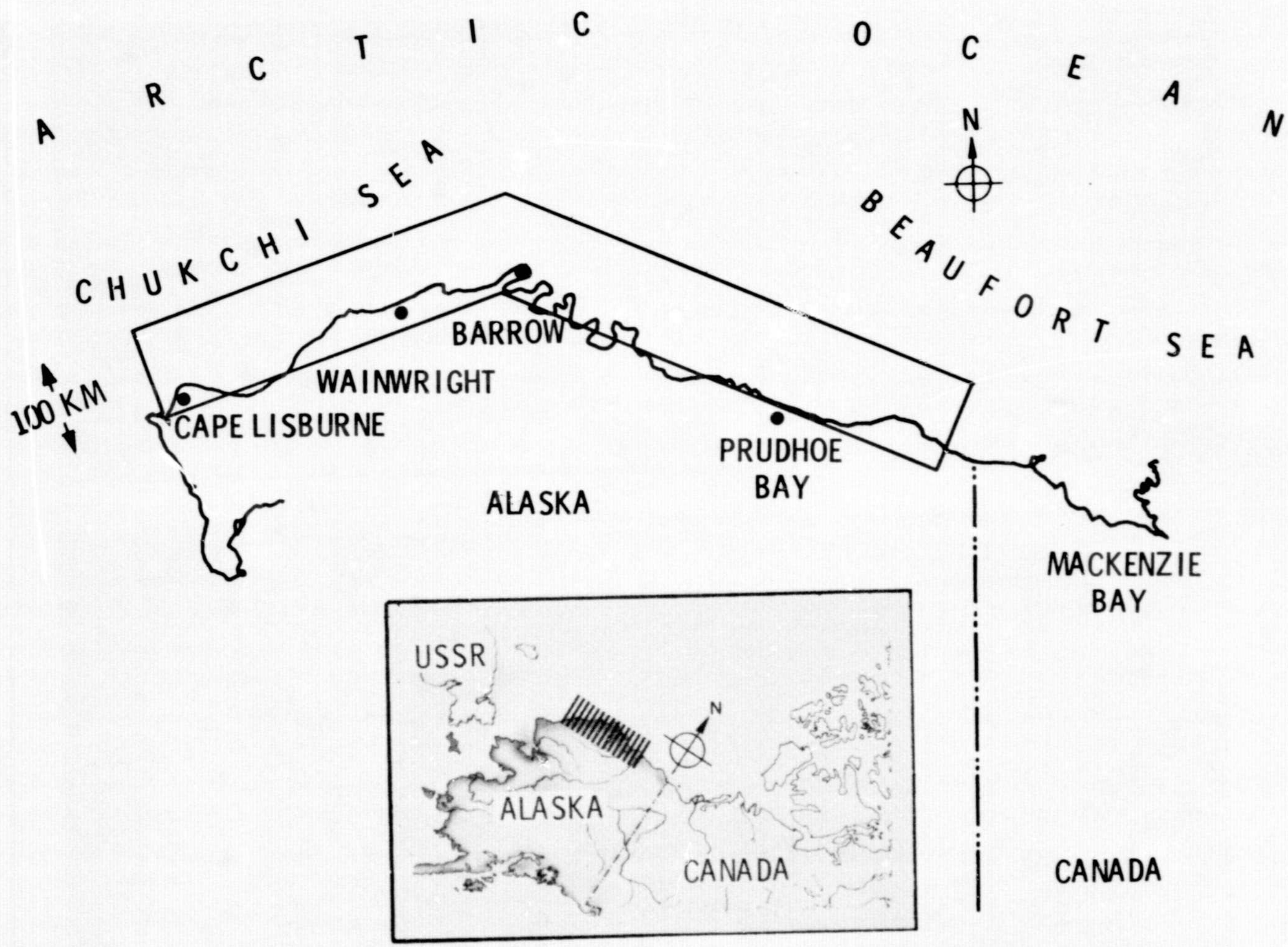

Figure 3. - Areas of radar coverage.

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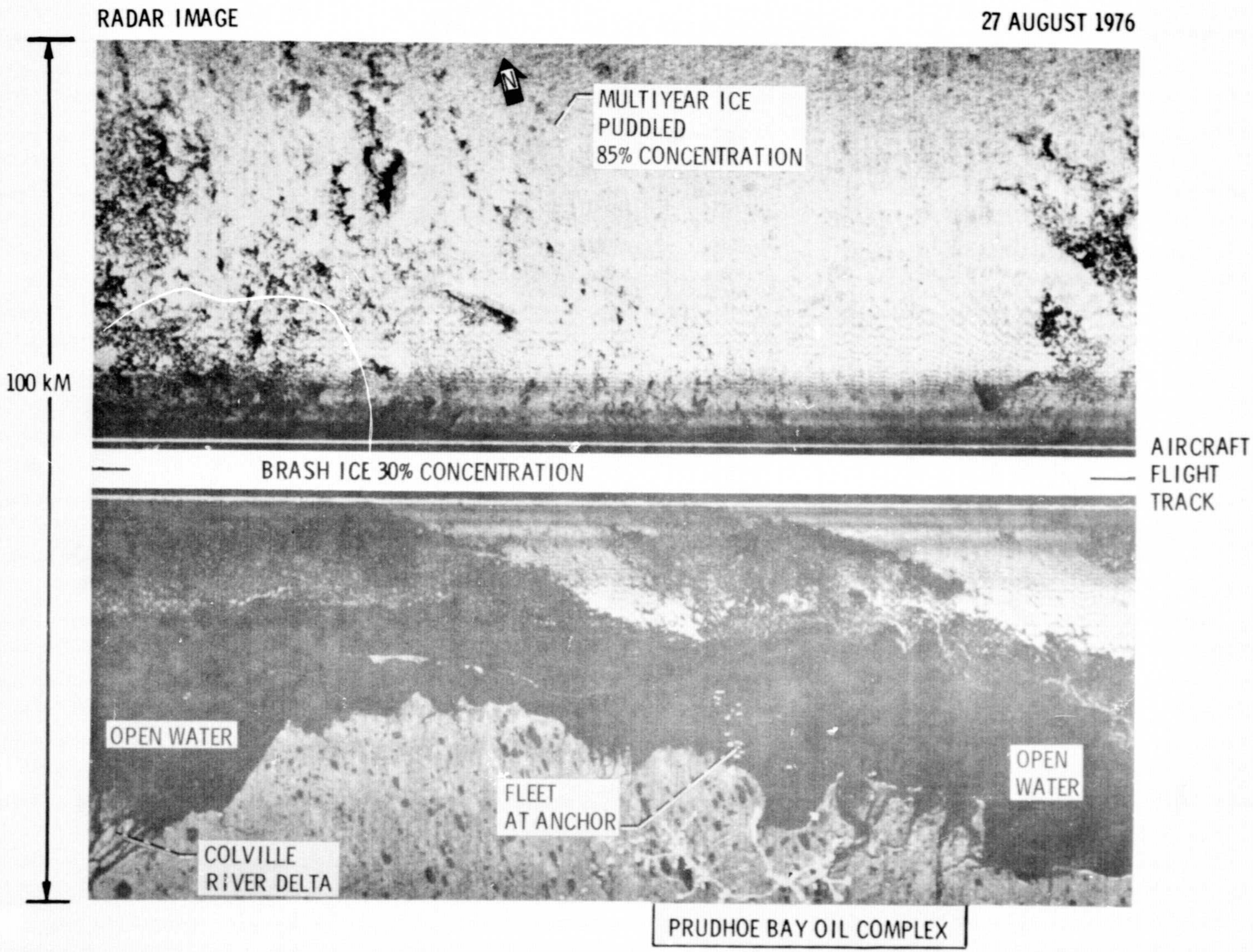


Figure 4. - Radar image of Beaufort Sea ice conditions on August 27, 1976.

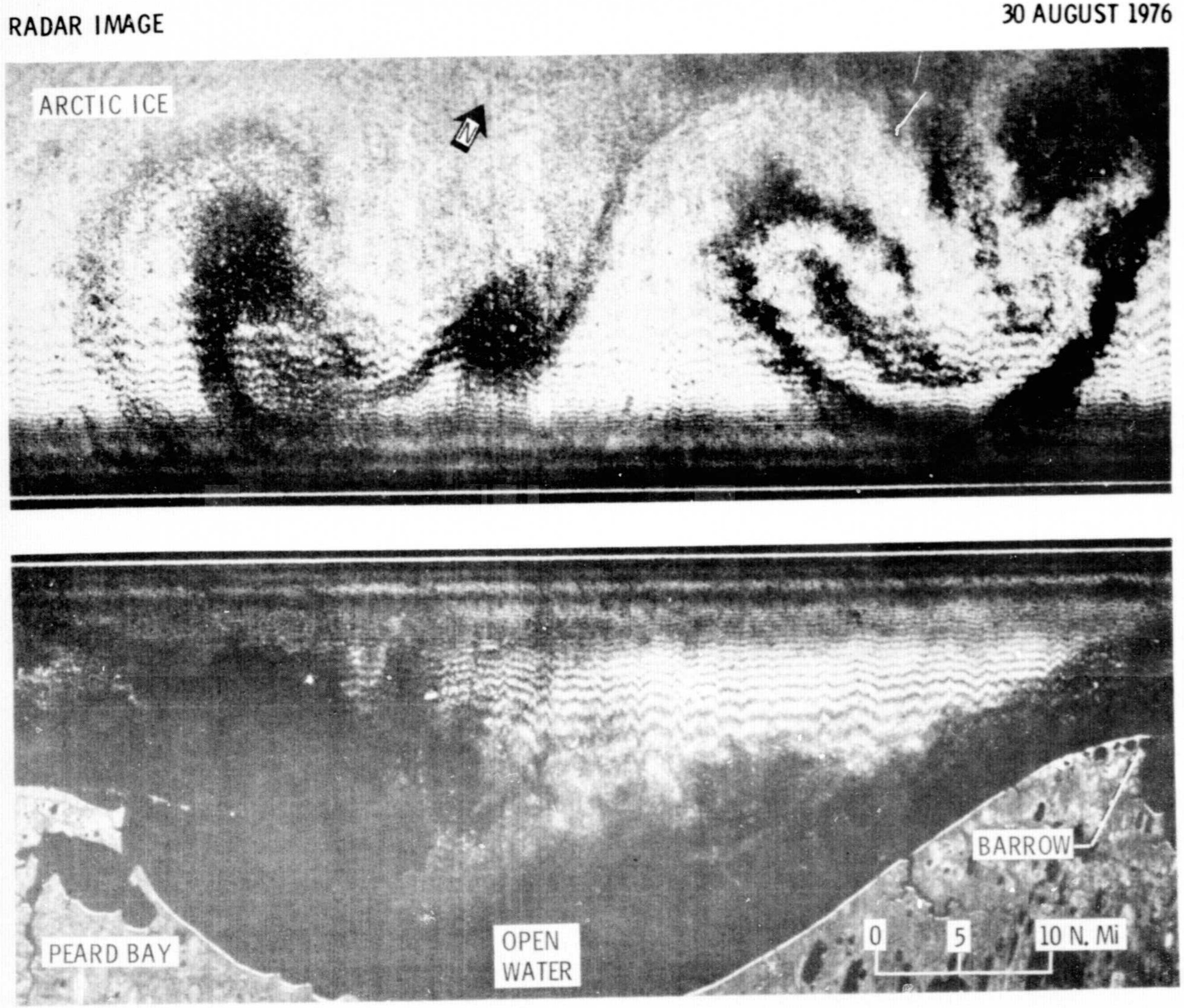
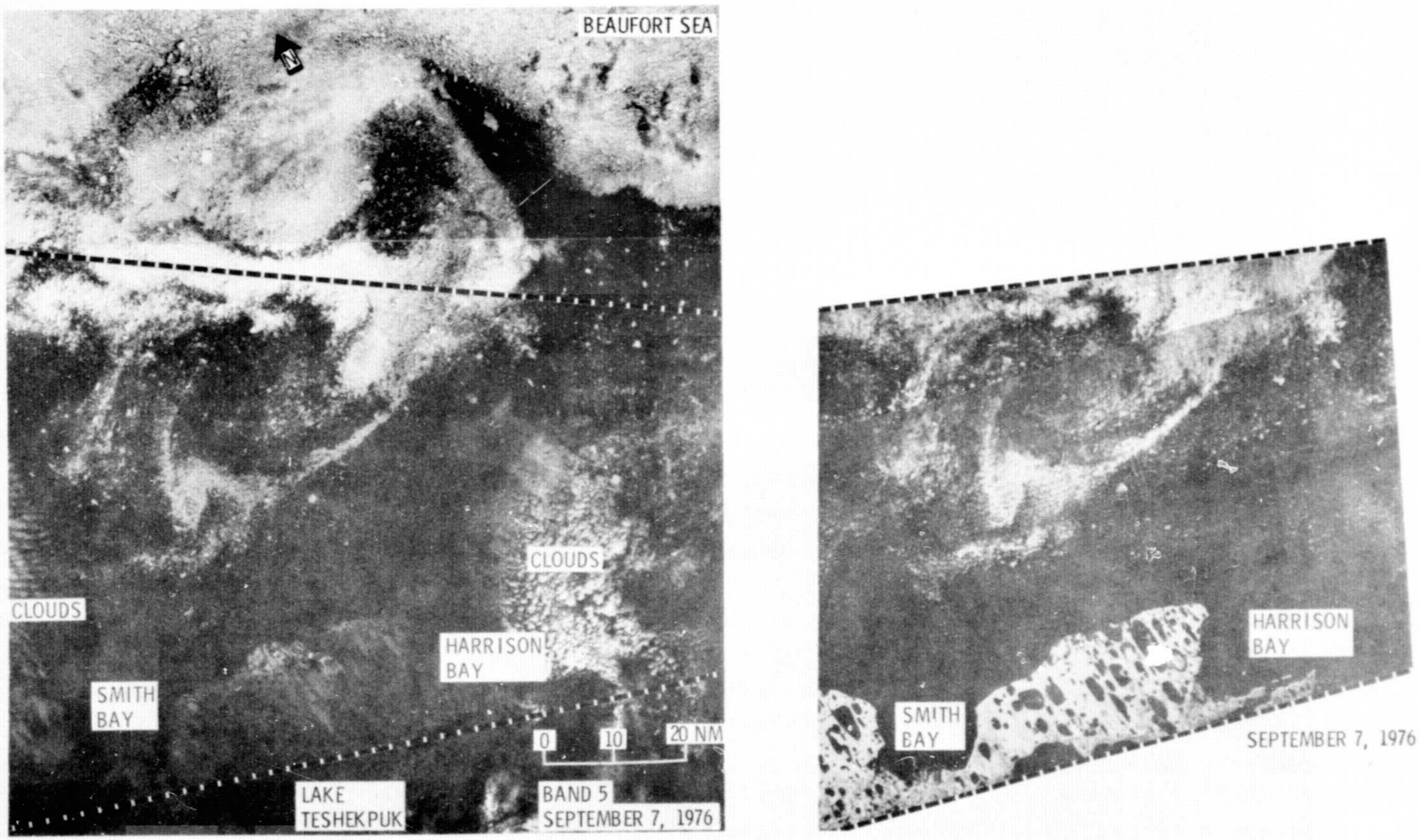


Figure 5. - Radar image of Chukchi Sea ice on August 30, 1976 displays complex current patterns.



LANDSAT VISUAL IMAGE

RADAR IMAGE MOSAIC

Figure 6. - Comparison between a Landsat visual and an aircraft radar image of Beaufort Sea ice conditions on September 7, 1976.

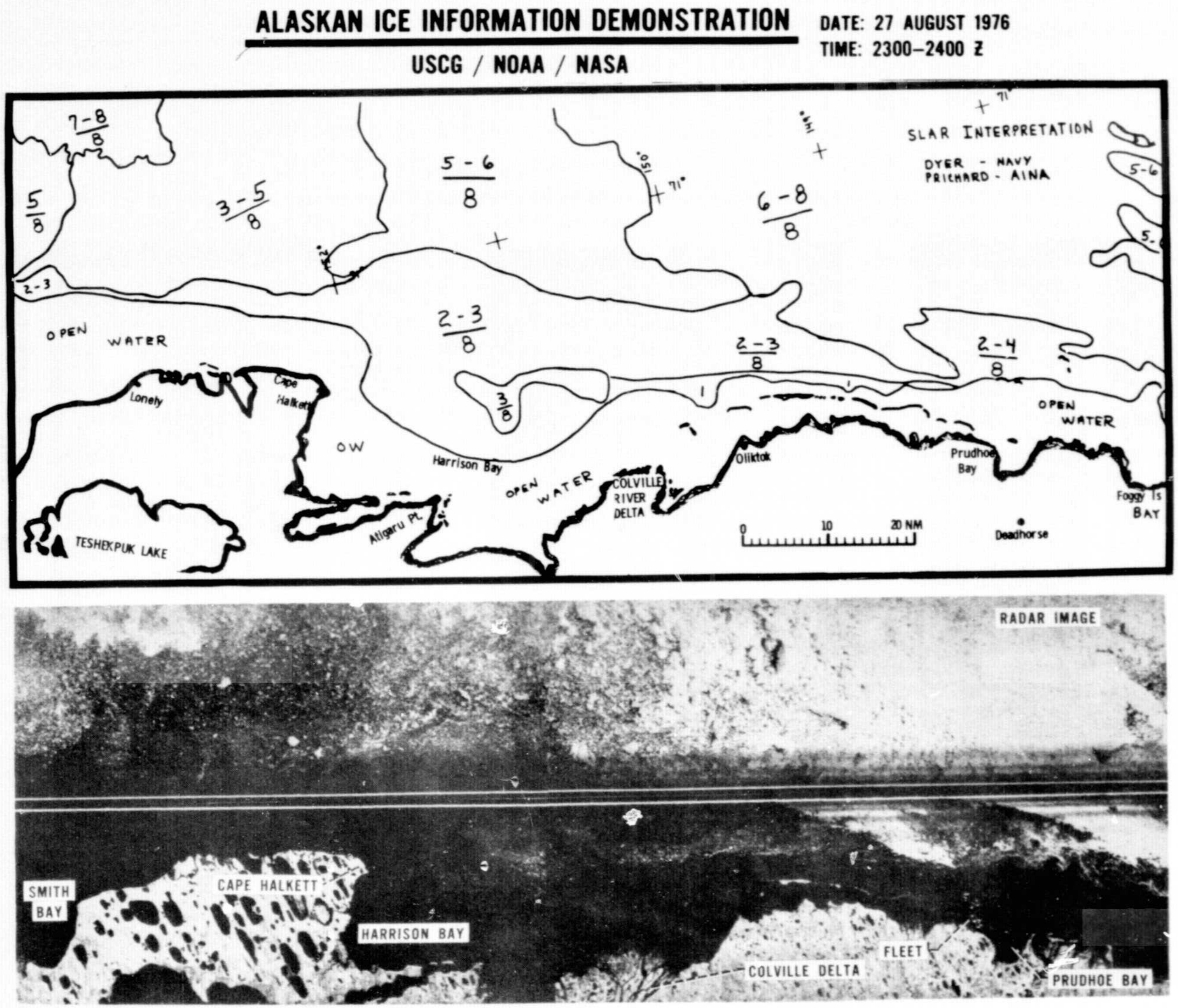


Figure 7. – SLAR Image/Ice Chart product of Alaskan north slope on August 27, 1976.

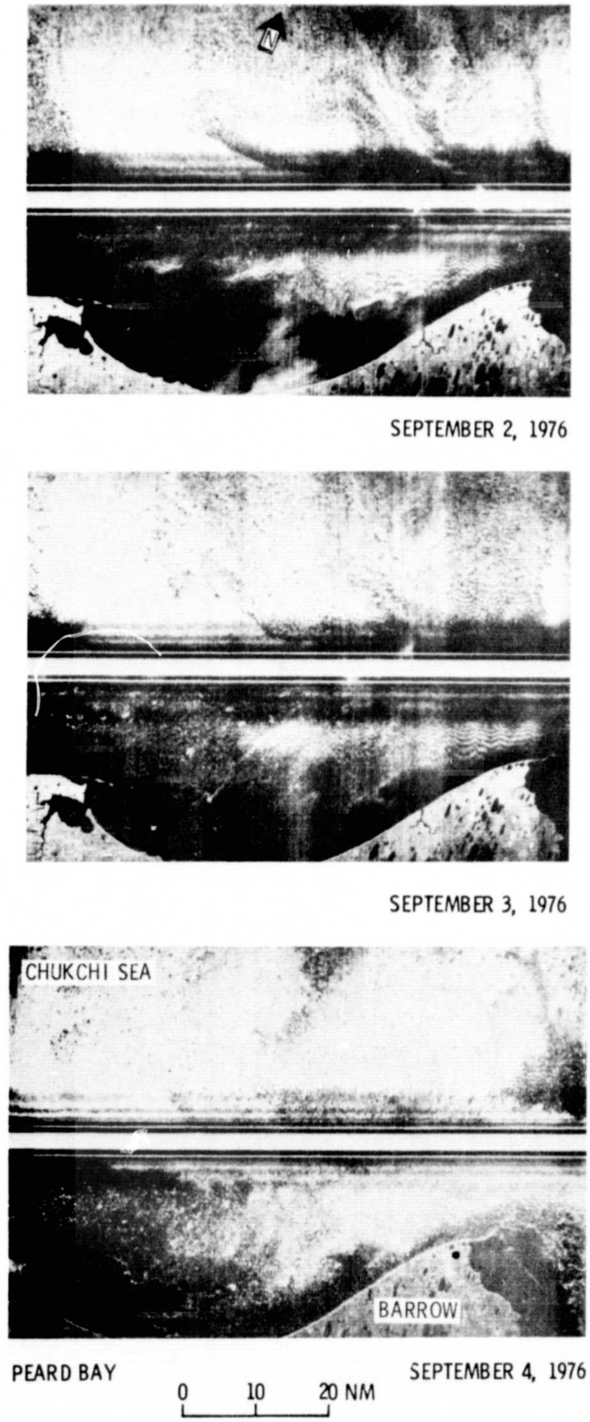


Figure 8. - Radar images of Chukchi Sea ice cover on September 2, 3, 4, 1976.