International Council for
the Exploration of the Sea

C.M. 1975/C:25
Hydrography Committee

Some Oceanographic Service Products Derived from Satellite Data

by

F. E. Kniskern

National Environmental Satellite Service

and

B. J. Thompson

National Weather Service

1. Introduction

With the advent of the Improved TIROS Operational Satellite (National Oceanic and Atmospheric Administration (NOAA) series) and the Synchronous Meteorological Satellite (SMS-1), great quantities of meteorological data and potential resources of oceanographic data became available. Imagery of tropical storms, cyclones and severe thunderstorms have added accuracy to the positioning of these storms especially over the oceans where ground truth is scarce. Temperatures of cloud tops derived from satellite imagery plus moisture and temperature inputs at various levels of the atmosphere have recently given meteorologists a greater data set on which to base their forecasts. These are just a few examples of the use of satellites for meteorological purposes.

The oceanographic data base has also been greatly increased due to the launch of recent high resolution satellites. Oceanographers now find they can accurately determine thermal gradients in the ocean such as along the Gulf Stream and warm and cold eddies. Ice edges and even individual ice floes can be readily detected in both the Arctic and Antarctic using the new polar orbiting satellites.

The purpose of this paper is to describe some of the new oceanographic products which are derived using high resolution satellite data. Before this task is undertaken, a brief description of the two main data sources, namely the NOAA and SMS satellites will be given.

2. Satellite Systems

An Improved TIROS Operational Satellite (ITOS D) was launched in October 1972 by the National Aeronautical and Space Administration (NASA). When the satellite and sensors aboard proved functional, the polar orbiter satellite became the responsibility of the National Environmental Satellite Service (NESS) and was named NOAA-2. This same procedure has been followed with the launch of ITOS F and G which have been designated NOAA-3 and NOAA-4 respectively. NOAA-4 is presently the operational satellite. Each of the ITOS spacecraft were launched into a sun synchronous,1450 Km orbit with an ortibal passage time of approximately 0900 local time southbound and 2100 local time northbound over a given area.

These sun synchronous, polar orbiting satellites all carry three primary, earth oriented, environmental sensors. The first sensor is the Scanning Radiometer (SR) which is essentially the same sensor that was aboard earlier spacecraft. One channel of the SR senses energy in the visible spectrum with a resolution of 4 Km and the other channel of the SR senses energy in the infrared "window" with a resolution of 7.5 Km. The SR is valuable to meteorologists because of its global coverage of storms, clouds, and fronts and to oceanographers because of its global water temperature coverage. The second sensor aboard is the Vertical Temperature Profile Radiometer (VTPR) designed to measure the vertical temperature structure of the atmosphere. This sensor again is used mostly by meteorologists. The third sensor is the Very High Resolution Radiometer (VHRR) which has provided the oceanographers with a tremendous amount of useful data since its inception. The VHRR instrument is sensitive to energy in the visible spectrum 0.6 to 0.7 um and the infrared (IR) window 10.5 to 12.5 um. The resolution of 0.9 Km in both the visible and IR sensors of the VHRR allow observation of oceanographic features never before discernible by satellite remote sensing. Data coverage is limited to approximately 3600 Km of a readout station. NOAA/NESS operates three such sites; The Wallops Island, Virginia Command and Data Acquisition (CDA), the Gilmore Creek CDA near Fairbanks, Alaska and the San Francisco Field Station at Redwood City, California. VHRR data from areas outside the range of these CDA stations must be recorded and stored on the spacecraft and played back when the satellite passes over a CDA station. Recorded data are limited to approximately 8-1/2 minutes per orbit. It is from this VHRR instrument that most of the oceanographic examples are given for this paper.

The SMS satellites were launched by NASA in May 1974 and February 1975 and are designated SMS-1 and SMS-2 respectively. These are the first spacecraft in NOAA's Geostationary Operational Environmental Satellite (GOES) program. Both spacecraft, orbit at a geostationary altitude of approximately 36,000 Km with SMS-1 located at 75°West longitude and SMS-2 located at 135°West longitude. Both satellites carry the Visible and Infrared Spin Scan Radiometer (VISSR) which provide continuous day and night imaging of much of the Western Hemisphere between the 60° latitude lines. The visible sensors responds to energy in the 0.55 to 0.75 um range with a resolution of 1 Km. The IR senses energy in the 10.5 to 12.5 um wavelength region with a resolution of 7.5 Km. Although the IR resolution of the SMS satellites are not as good as the VHRR, oceanographers have found the data very useful because of its continuity (pictures every half hour). Larger oceanographic features that might be missed because of cloud cover using the VHRR, may be observed during a break in the clouds for any given day using the SMS data. Utilizing a combination of VHRR and SMS data seems to give the oceanographer the best operational results in most cases.

3. Products

3.1 Frontal System and Water Mass Analyses

The large variation in temperatures between water masses is the characteristic of the Northwest Atlantic which enables the mapping and, to some degree, the following of discrete ocean features for extended periods of time; even when using conventional shipboard sensors. Our ability to map and follow features has been greatly enhanced through the use of satellite imagery as we are now able to obtain synoptic pictures in which frontal systems and the water masses they delineate are clearly depicted. Figure 1, a NOAA-3 imagery, which shows the Gulf Stream and many fronts in the surrounding waters, is a good example of the type of information that is now being made available. The two factors which hinder the obtaining of daily, or twice daily, photos of this nature are the presence of clouds, particularly in the late spring and early summer and the weakening of gradients between water masses during summer. With such information now available, service organizations have been able to issue operational products for specialized and general user groups which are direct derivations of the satellite data.

Before discussing specific products, a few comments are warranted on the use of satellite data in oceanographic research, particularly the study of the Gulf Stream and its associated cyclonic and anticyclonic eddies. The life cycles of eddies have been a curious phenomena to oceanographers for a long time and they have made great efforts to obtain observations from time to time during a particular eddies' life span: Now we literally watch eddies develop, break away from the stream, then drift independently until recaptured by the Gulf Stream or destroyed through another process. The entire cycle can take up to a year or more while near by the Gulf Stream is going through large short term variations. The point that we wish to make is that these processes can now be monitored over long periods and, furthermore, we can see how they are interrelated. In the past, researchers had to make certain assumptions for extended periods between observations of a phenomena. These assumptions often led to misleading conclusions. Thus, satellite data is helping to eliminate the doubt that often existed about the evolution of Gulf Stream meanders and eddies. Satellites can greatly extend the boundaries of ocean studies as well by giving researchers some knowledge of the forces that impact on a particular area or phenomena of interest. Upwelling studies, for example, can be easily extended and refined as the sensors can detect the instant of on-set and the boundaries of the upwelling almost continuously. Thus, satellites have extended our data bases, eliminated some of the unknowns, and assisted in defining the variability of certain parameters.

The ocean features of the Northwest Atlantic clearly visible from satellites are the North and South Walls of the Gulf Stream, the front between shelf and slope water, and warm and cold eddies. River discharges are often visible as well. All of these features, except the latter, are visible in figure 1 and shown, as interpreted by subjective inspection, in figure 2. Once the features have been outlined as in figure 2, the next step in generating a product, other than the picture itself, is to apply known relationship between these surface features and other parameters, such as ocean currents. Three Northwest Atlantic products will be described in this section: Gulf Stream Analyses prepared by NOAA/NESS; Gulf Stream Wall Analyses prepared by NOAA/National Weather Service (NWS) and Current Analyses prepared by the U.S. Coast Guard Oceanographic Unit.

3.1.1 NOAA/NESS Gulf Stream Analyses (Figure 3, 18-22 April 1975)

By inspection of figure 3, one can see that this product is a depiction of all the water masses and their associated fronts off the east coast of the U.S. It is usually a composite obtained from several satellite photos as the entire area is seldom cloud free at one time. The prominent features of this product are the Gulf Stream, the front between slope and shelf water and eddies. The product is used by, amongst others, fisheries, maritime transportation, recreation (Bermuda Yacht race for example) and is, in general, applicable to most problems requiring water mass delineations. It does not present the absolute temperature of the water masses represented as does a similar product produced by the U.S. Naval Oceanographic Office. The NOAA/NESS Gulf Stream Analysis is issued weekly by National Facsimile and mail.

3.1.2 NOAA/NWS Gulf Stream Wall Analysis

The NWS has initiated an experimental project for locating the Gulf Stream off the U.S. east coast from Florida to the mid-Atlantic states (38°N). The aim of this project is to develop a capability for providing mariners with routine depictions of the Gulf Stream from which they may estimate current velocities for routing purposes. Through analysis of satellite, ship sea-surface temperatures (SST), and bathythermograph data, the Weather Service provides all-weather analyses of the location of the Inner Wall of the Gulf Stream. Once informed of the location of the Inner Wall, mariners can approximate the band of high-speed currents which parallels the Wall and from which he can expect significant following currents when running northward. Likewise, the mariner can also determine the speed minimum, perhaps even a countercurrent, for use when running southward. Until satellites began producing photos of the Gulf Stream routinely, a project of this nature was not possible. Surface and subsurface water temperature observations from conventional platforms, primarily ships, were just too scarce for the detailed analysis needed.

The National Meteorological Center (NMC) assisted by the NESS, produces an analysis of the Inner Wall twice weekly. A daily watch is kept on the incoming data and, if warranted, supplemental analyses are prepared and issued. The analyses are encoded in alphanumeric message format for dissemination to the shipping fleet.

Using the general rule that significant northerly currents can be found 12 to 25 mi east of the line indicated in the message, a mariner can plot a band of maximum current and determine his best time and fuel track, taking currents, as one of several factors, into account. Heading south, a master should remain west of the Wall or 50 mi or more to the east of it to reduce the opposing current, hopefully to zero, and even possibly to pick up a countercurrent. Evaluations have been conducted of this product to determine: (1) the accuracy of the analyses; and (2) its usefulness to tankers transiting from Texas to New England. The following data were provided by a Northbound vessel during February 1975.

Wall Position Latitude	Forecast Longitude	Ships Longitude @ Latitude in Col. (1)	Ship Speed (Kts)	Revs (Min)	SST (°F)	
(1)	(2)	(3)	(4)	(5)	(6)	
36	74.2	74.9	10.5	59.1	67	
35	75.3	75.2	19.2	79.1	76)	Gulf Stream
34	76.0	76.7	17.0	79.0	75)	
33	77.0	78.1	16.2	79.1	69	
32	77.9	79.4	15.5	73.4	70	
31	79.7	80.0	17.1	73.0	72	
30	80.3	80.1	18.7	72.3	82)	
29	80.2	80.1	19.3	71.6	80)	Gulf Stream
28	80.1	79.9	19.5	72.0	81)	
27	80.0	79.8	18.7	73.6	82)	

This vessel did not use the Wall forecast given in columns 1&2 entirely, thus the time and fuel saving were not as great as they could have been. However, the statistics contain some very interesting information. For example, while the ship remained east of the wall (compare columns 2&3) she was experiencing Gulf Stream temperatures and moved north at a good rate. When the ship went west of the wall, the temperature dropped over 10°F and her speed decreased significantly, even while increasing revolutions (column 5). If the ship had followed the slight meander at 32°N, high speeds would certainly have been maintained. As this is only one factor in determining the ships track, the captain may have decided to deviate from the forecast track for other reasons. Winds and waves were not a factor during the period of this transit. The overall evaluation has demonstrated that this is a useful application of satellite data to ship routing.

3.1.3 USCG Current Analysis (Figure 4, 26 June 1975)

The USCG has taken the surface temperature and feature information obtained from the satellite one step further to produce a current analyses. Their need is for drift information that can be used in Search and Rescue (SAR) operations. Because the ocean off the U.S. coast is highly variable, accurate trajectories cannot be computed from mean currents and the synoptic wind field. Eddies which maintain circular current patterns such as is shown in figure 4 can completely reverse the flow in a given area. Without knowledge of this, SAR patterns employed could be erroneous. All available data; bathythermographs, sea surface temperatures from ships, airborne radiation thermometer data, etc., are used to supplement the satellite data in preparing these analyses. The current analyses are telecopied to Rescue Control Centers and mailed to other users.

3.2 Sea Surface Temperature

The NESS has developed a sea surface temperature (SST) observation system to support operational, research, and developmental needs of environmental scientists. The system provides daily global surveillance of the ocean's surface temperature structure. Temperature values are derived from Scanning Radiometer infrared data from the NOAA series satellites. The technique used to obtain these temperatures is the fully automated computer procedure Global Operational Sea Surface Temperature Computation (GOSSTCOMP). Temperature retrievals are derived by statistical analysis and quality control techniques applied to instrument measurements covering roughly a 100 Km square area. Retrieval temperatures are corrected for the effects of atmospheric attenuation by using time coincident measurements derived from the VTPR.

The basic product obtained from the model is a daily set of 5000 to 6000 observations of SST covering both hemispheres. In addition to individual observations, derived products are generated. These include: (1) global analyzed SST field accessible on computer disk storage, (2) hard copy displays of portions of this analyzed field, and (3) a permanent archive of the analyzed field and observations. The GOSSTCOMP procedure has produced a high level of dependability of product delivery. During the second half of 1974, an operational success rate of 97% was maintained. During 1974, 1,640,654 observations were produced with a global daily mean difference from ship reports ranging from - .9°C to + .39°C with an RMS deviation varying between 1.67°C and 2.23°C.

The current version of the GOSSTCOMP Model uses only the recorded infrared data received from the scanning radiometer. The processing flow for this model is deeply integrated with the total scanning radiometer data processing system to achieve a most efficient combination of shared functions with other products.

The total system data flow path from the spacecraft to output product is lengthy with several complex component functions. In general, data from the scanning radiometer sensor (Infrared and Visible) are recorded on the spacecraft analog tape recorders. The recorders are read out at a rate of 40:1 at the CDA stations located at Gilmore Creek, Alaska and Wallops Station, Virginia. Orbital data on readout are re-recorded in analog form at the CDA stations. The data are then transmitted to the NESS, via microwave and ground lines at a 2:1 rate where the signal is converted into digital format and stored on magnetic tape. The orbital data are next assembled onto NOAA's central processing computer storage for automated processing.

Surface temperature values are derived by a statistical histogram analysis technique applied to 1024 instrument measurements arranged in roughly a 100 Km square area surrounding the retrieval point. The detection of cloud free areas from which measurement are to be made, and a determination of the quality of the measurements are incorporated in a set of pre-retrieval and post-retrieval decision making tests. Accepted retrievals are assigned a geographical location and calibrated.

The validity of each retrieval temperature is determined in a final quality control comparative analysis against the previous day's temperature field. This procedure establishes separate boundary values of allowable temperature change for each retrieval. The boundary threshold is determined from a combination of (1) the age in days of the observed temperature values surrounding the retrieval point, (2) the temperature gradient, and (3) the magnitude of the atmospheric attenuation compensation. Those retrievals meeting these quality control criteria are designated as valid temperature observations.

The SST programs run daily on all data gathered in the previous 24 hours. Since the ITOS satellite covers every area of the earth at least twice each day (up to 25 times at the poles), there are two chances to retrieve an SST measurement over any given region, which is cloud free. This translates to 40,007 retrieval histograms before quality control, and after all data rejection tests are complete 6,291 remain. The figures are from a representative day. One observation will effect more than its immediate area, thus extending the region changed for a particular analysis run. No attempt is made to determine SST above the 70° parallel due to the continuing ice coverage in that region.

Satellite SST's are available to users in two forms: (1) observations and (2) analyzed fields. These two products are available from NOAA's Environmental Data Service (EDS) in the form of magnetic tape. In addition, users with NOAA IBM 360/195 terminals can obtain SST data directly from disk. Satellite SST observations are presently available in three forms: (1) Archive Tape, (2) Observation Transmission Tape, and (3) Observation Disk Data Set. All three forms consist of a collection of individual SST observations. Each observation contains the latitude, longitude, time, source (satellite and sensor number), and magnitude of the satellite SST.

(1) Archive Tape

All SST observations for one month are collected, written to tape, and archived by EDS. The EDS Archive Tape series begins with December 1972 and continues uninterrupted to the present.

(2) Observation Transmission Tape

Each morning all the observations for the previous day are archived to a tape for transmission purposes. The content of this tape is similar to the EDS Archive Tape although the format is different.

(3) Observation Disk Data Set

This is the master file of observations from which the above two tapes are created. It can be accessed by terminal users at any time, although it is updated only once a day.

Once per day all the satellite SST observations are merged into a polar stereographic field. This "Analyzed Field" contains, in addition to the SST, land-sea tags, climatology temperatures, SST gradients, data age information, and verification temperatures. The latest field is accessible to terminal users at any time on disk. With a few exceptions every day since May 10, 1973, is available. Examples of the analyzed fields are shown in figures 5, 6, and 7. These same fields are also available in digital form.

3.3 Great Lakes Surface Temperature

Qualitative and quantitative surface water temperature data derived from satellites are not limited to the oceans; other large bodies of water, namely the Great Lakes, are also excellent targets for satellite sensing. This fall (1975) the NESS is starting a surface water temperature anlaysis of the Great Lakes using data derived from VHRR and VISSR sensors. Imagery sensed from the satellite is digitized and computer analyzed for every 2°C for each of the five Great Lakes. The computer product is then hand adjusted for accuracy and continuity and mailed biweekly to various customers. These analyses will likely be utilized as input for the freeze-up forecasts of the Great Lakes. Surface water temperature is an important indicator on how rapidly or slowly certain areas of the lakes will freeze. Scientists interested in upwelling should also find this chart beneficial. Preliminary analyses have already shown upwelling changing from one side of both Lake Michigan and Lake Huron to the other sides depending on wind conditions. If these charts prove useful, more frequent analyses will likely be attempted, especially in the spring and fall when water surface temperatures change abruptly.

4. Ice Analyses

Two types of ice analysis will be considered in this paper; sea ice analysis which covers most of the Arctic and Antarctic and fresh water ice analysis with the Great Lakes as the prime example.

4.1 Sea Ice Analyses

The inaccessability of the Arctic and Antarctic has made sea ice observation not only difficult but expensive. Throughout the 1950's and most of the 1960's, aerial reconnaissance was the major source of ice information. However, several days were often required to reconnoiter an area the size of the Beaufort and Chukchi Seas. With the advent of the TIROS satellite in the early 1960's, a new potential for ice observing was possible. Satellite photographs could now be used to supplement aerial ice information. In the late 1960's the Advanced Vidicon Camera System (AVCS) aboard ESSA 7 greatly improved the ice observing from satellite imagery. It was now possible to depict an ice edge if the transition between ice and water was distinct. Concentrations could also be estimated with fairly good accuracy and large leads and polynas could be observed. However, it was generally felt by most ice experts that satellite imagery should still be used as a supplement to aerial reconnaissance, even though it was utilized in the Antarctic as the primary data source.

The launch of NOAA-2 in October 1972 with its VHRR sensor of 1 Km resolution brought a much greater quality of ice imagery. Small leads could now be easily observed. Individual ice floes could be detected and a diffuse ice edge (i.e., poorly defined area of dispersed ice) could easily be seen. Thus, in early 1973, the NESS initiated an experimental composite ice analysis of the seas surrounding Alaska using only VHRR data. These ice analyses are sent via National Facsimile weekly and also distributed via a mailing list to private companies, government agencies and universities. An example of a typical VHRR photograph and the corresponding ice analyses are shown in Figures 8A and 8B. Figure 8A is a NOAA-2 visible recorded VHRR picture of spring break-up of ice in the Bering Sea and Bering Strait. Leads can be seen along both the Alaskan and Russian coasts with a large lead evident in Norton Sound. Individual ice floes are observed North and West of Nunivak Island. The diffuse ice edge is easily distinguishable from the main pack ice. Another interesting feature is the line of demarcation in the Bering Strait between the broken ice to the south and the solid pack ice with no openings to the north. Although the ice thickness cannot be directly measured using satellite imagery, the gray tones of the picture combined with the analyst's experience can provide a fairly good estimate of the age and thickness of the ice. For example, ice in the Chukchi Sea appears very white and thus one would expect older and thicker ice, while ice further south in the Bering Sea has a slightly grayer hue and one would expect younger and thinner ice.

Prior to February 1974, imagery such as figure 8A of the Alaskan area was only received three or four times weekly. The imagery was recorded and dumped at the Wallops Island CDA station. In February 1974 the CDA station at Gilmore Creek, Alaska was opened. Since that time period, daily VHRR pictures have been available of the Alaska area, Canadian Archipelago, and Northern Baffin Bay. Thus, the quantity of high resolution imagery has increased over the past couple of years especially in the northern hemisphere.

From the above discussion the operational uses of the VHRR ice imagery seem apparent. The greatest use is providing the largest amount of data for sea ice forecasting. In other words, the satellite has now become the observational tool of the ice forecaster. With much more detailed ice imagery available, more detailed ice forecasts can be provided, especially in the short-range category. However, a word of caution must be stated; ice formation, disintegration and movement depend on atmospheric conditions such as temperature and wind, therefore, ice forecasts especially in the long-range category will only be as good as the weather forecasts.

Another use of satellite imagery which approximates ice forecasting is ship routing. The ship router or ice forecaster now has near real-time ice information at his disposal to supply ships with the best possible route while transiting the Arctic or Antarctic. Depending on ice conditions, ship routers may be able to steer ships completely outside the ice pack in their transit or at least route them through the least and easiest amount of ice. For example, Prudhoe Bay, Alaska must be resupplied during the summer in support of the Alaskan Pipeline Project. Routing ships from the Chukchi Sea around Point Barrow through the southern Beaufort Sea to Prudhoe Bay requires real-time ice information. The lead that forms in late August and September along the north coast of Alaska varies yearly from almost non-existent to 200 miles wide. This lead usually refreezes or the pack ice retreats southward in early October (Figure 9). Thus, during a rough ice year, timely ice information, good ice forecasts, and ship routes are needed for a safe transit to and from Prudhoe Bay.

The VHRR imagery are also used for the Antarctic where ice forecasts and ship routes are given to vessels resupplying various ports. Figure 10 shows ice conditions in the Ross Sea and McMardo Sound area of Antarctica. This particular picture in late November 1974 shows open water already forming along the Ross Ice Shelf. The pack ice gradually recedes so that by late January or February ships can transit the Ross Sea encountering very little ice. Research groups also use satellite ice data for various projects. Scientists participation in the Arctic Ice Dynamic Joint Experiment (AIDJEX) are conducting ice dynamic and drift studies on floes in the eastern Beaufort Sea. VHRR ice data has been distributed to aid them in their studies. So far the VHRR data examples have been visual pictures. However, IR imagery can also be utilized for ice observations. During the 1974-75 winter, a special cold temperature IR enhanced image was produced at Gilmore Creek. As shown in Figure 11, this imagery is excellent in quality and compares very favorably with the visual pictures. Of particular interest are the leads in Kotzebue Sound and Cape Lisburne areas. Good quality ice imagery can be produced during the wintertime to provide continuity of ice conditions to support operational users.

In the discussion of sea ice analyses and the operational uses of satellite ice data, clouds have not been mentioned. However, clouds do interfere with the detection of ice on satellite imagery. On the average, clouds are present more often than shown in the above examples. Ice edges and leads can be observed through thin clouds on many occasions by receiving high resolution data daily over a given area.

4.2 Fresh Water Ice

The VHRR and VISSR sensors now allow us to observe ice in smaller bodies of water such as the fresh water of the Great Lakes. During the winters of 1974 and 1975, the NESS provided a twice weekly, composite, satellite analysis of ice conditions in the Great Lakes. The chart was transmitted via National Facsimile. Figures 12A and 12B show a typical VHRR picture of the Great Lakes with its corresponding analysis. Figure 13 is a visible picture of the Great Lakes taken from the SMS-1 satellite on March 17, 1975.

Figure 12A was taken by the visible VHRR sensor aboard NOAA-2 on February 21, 1974. The three main ice parameters observed from the imagery are ice concentration, fast ice and leads. In this photograph, Lake Superior has the greatest variety of ice phenomena. Fast ice is evident in the northwestern part of the lake north of Isle Royale. A lead can be observed several miles along the coast northeast of Duluth. The western part of Lake Superior appears to have fairly heavy ice concentration while the central portion of the lake which shows a gray appearance has thinner ice and is less concentrated. Much of the eastern portion of the lake is ice free.

The NESS analyses were used by the National Weather Service (NWS) as a supplement to their Great Lakes ice analyses and forecasts which were issued to ships transiting the lakes. The NWS utilized aerial reconnaissance,side looking airborne radar (SLAR), coastal station reports and satellite imagery for their analyses and forecasts. Generally the satellite ice analyses were in close agreement with analyses based on aerial and ground observations.

As in the case of sea ice, satellite imagery of the Great Lakes is used for forecasting and ship routing. Lately an effort has been made to keep the Great Lakes open to navigation for the entire winter. Only with close surveillance and accurate ice forecasts can this endeavor be possible. Satellite ice information certainly aids in this surveillance.

5. Concluding Remarks

This paper is not presented as a comprehensive review nor an in-depth study of all satellite derived oceanographic products but has been compiled to demonstrate that the use of satellite data in the preparation of oceanographic service products has become an operational and indispensible practice. The scope of these particular products is admittedly regional, however, the same techniques could be applied on a hemispheric or global basis, provided that the essential communications and data processing facilities are available. The GOSSTCOMP SST product is ideally suited for use in global atmospheric prediction models and could serve as an input to the SST analyses that will be utilized during the First GARP Global Experiment (FGGE). The ocean service products to be provided through the Integrated Global Ocean Station System (IGOSS), which will be for regional and ocean basin applications, should certainly have had the benefit of satellite data in their preparation. It is our opinion that satellites are now primary rather than experimental ocean data acquisition systems.

The authors wish to thank the USCG Oceanographic Unit for permitting the inclusion of their current analyses in this paper and Messrs. R. Brower, W. Pickel, T. Sigmore, and C. Walton of the NESS for providing the samples and general description of GOSSTGOMP. A full description of GOSSTCOMP is presented in their paper, "Satellite Derived Sea Surface Temperature from NOAA Spacecraft."

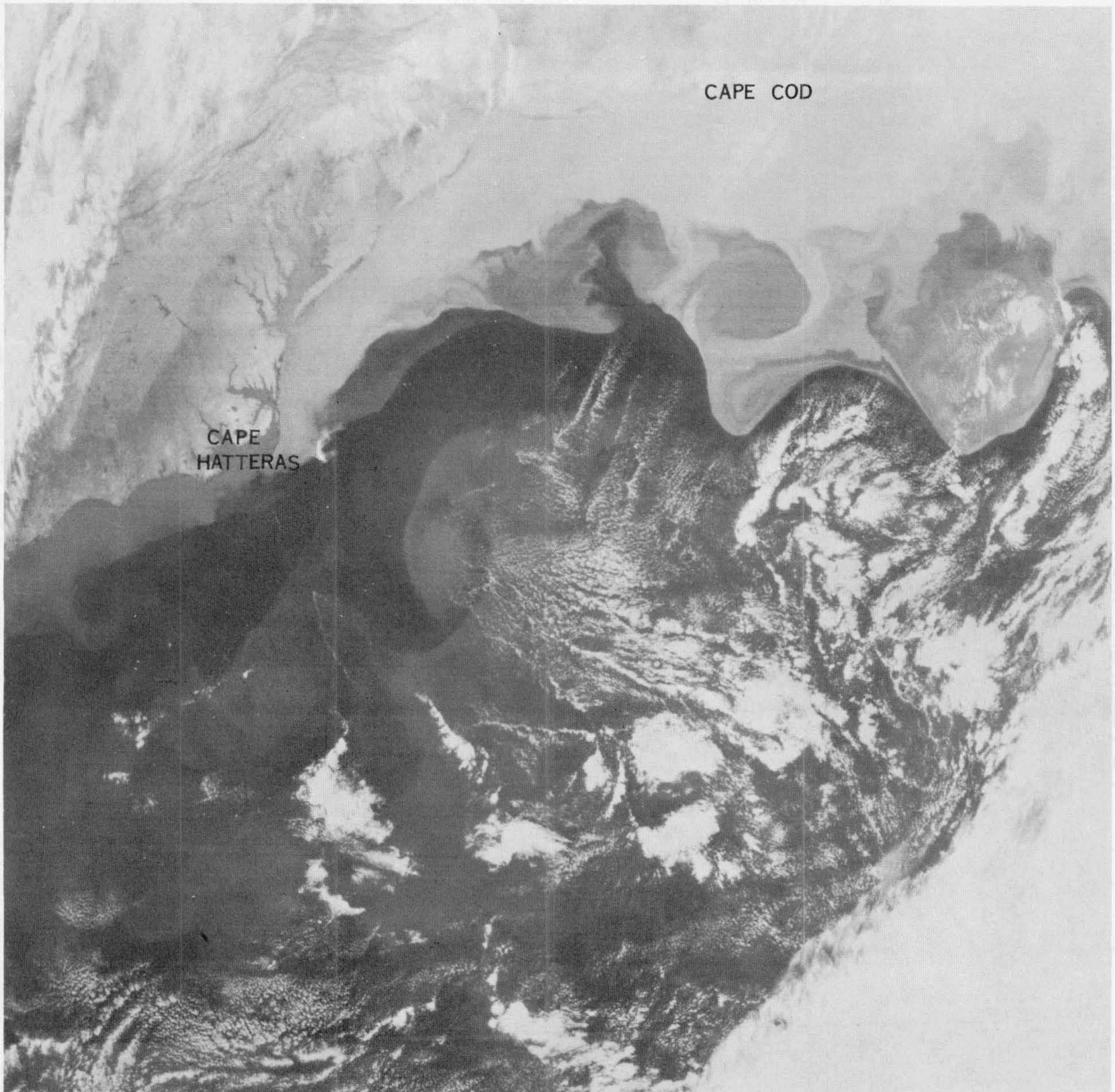


Figure 1. -- NOAA - 3 VHRR IR image of water structure off the Eastern Coast of the United States, April 28, 1974.

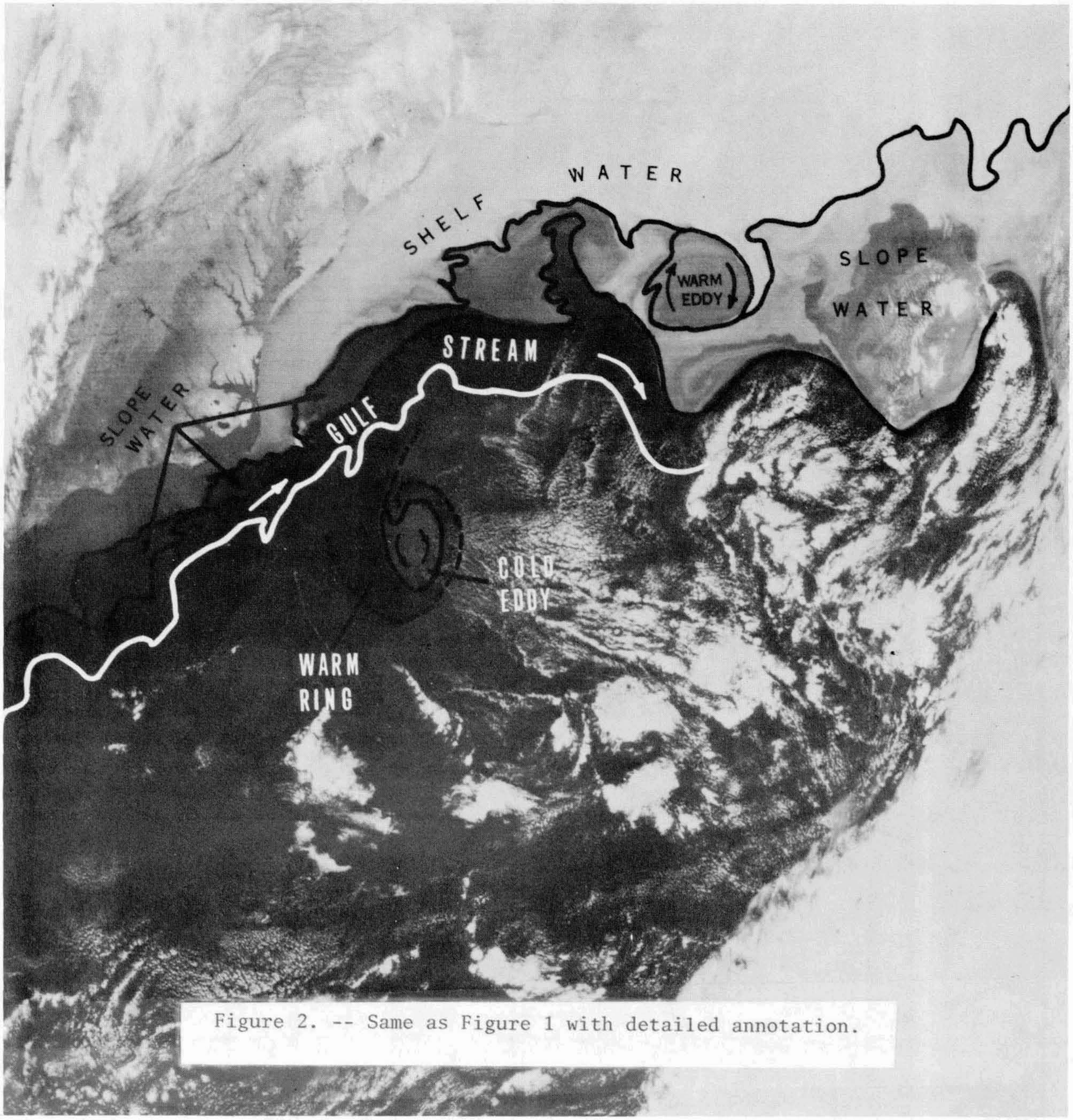


Figure 2. -- Same as Figure 1 with detailed annotation.

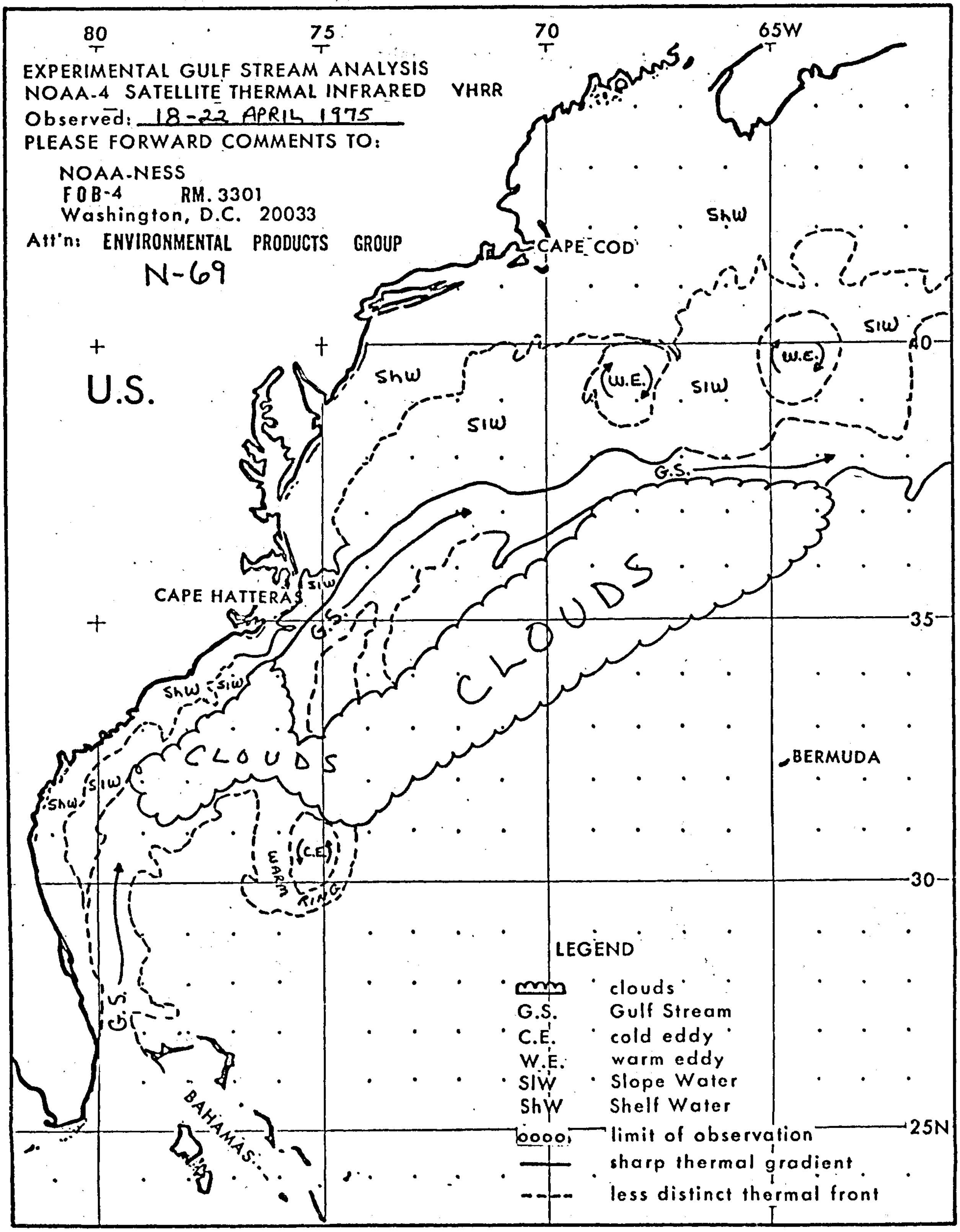

80
75
70
65W
EXPERIMENTAL GULF STREAM ANALYSIS
NOAA-4 SATELLITE THERMAL INFRARED VHRR
Observed: 18-22 APRIL 1975
PLEASE FORWARD COMMENTS TO:
NOAA-NESS
FOB-4 RM. 3301
Washington, D.C. 20033
Att'n: ENVIRONMENTAL PRODUCTS GROUP
N-69
U.S.
CAPE COD
CAPE HATTERAS
BERMUDA
BAHAMAS
ShW
SlW
W.E.
G.S.
CLOUDS
C.E.
WARM RING
40
35
30
25N
LEGEND
clouds
G.S. Gulf Stream
C.E. cold eddy
W.E. warm eddy
SlW Slope Water
ShW Shelf Water
limit of observation
sharp thermal gradient
less distinct thermal front

Figure 3

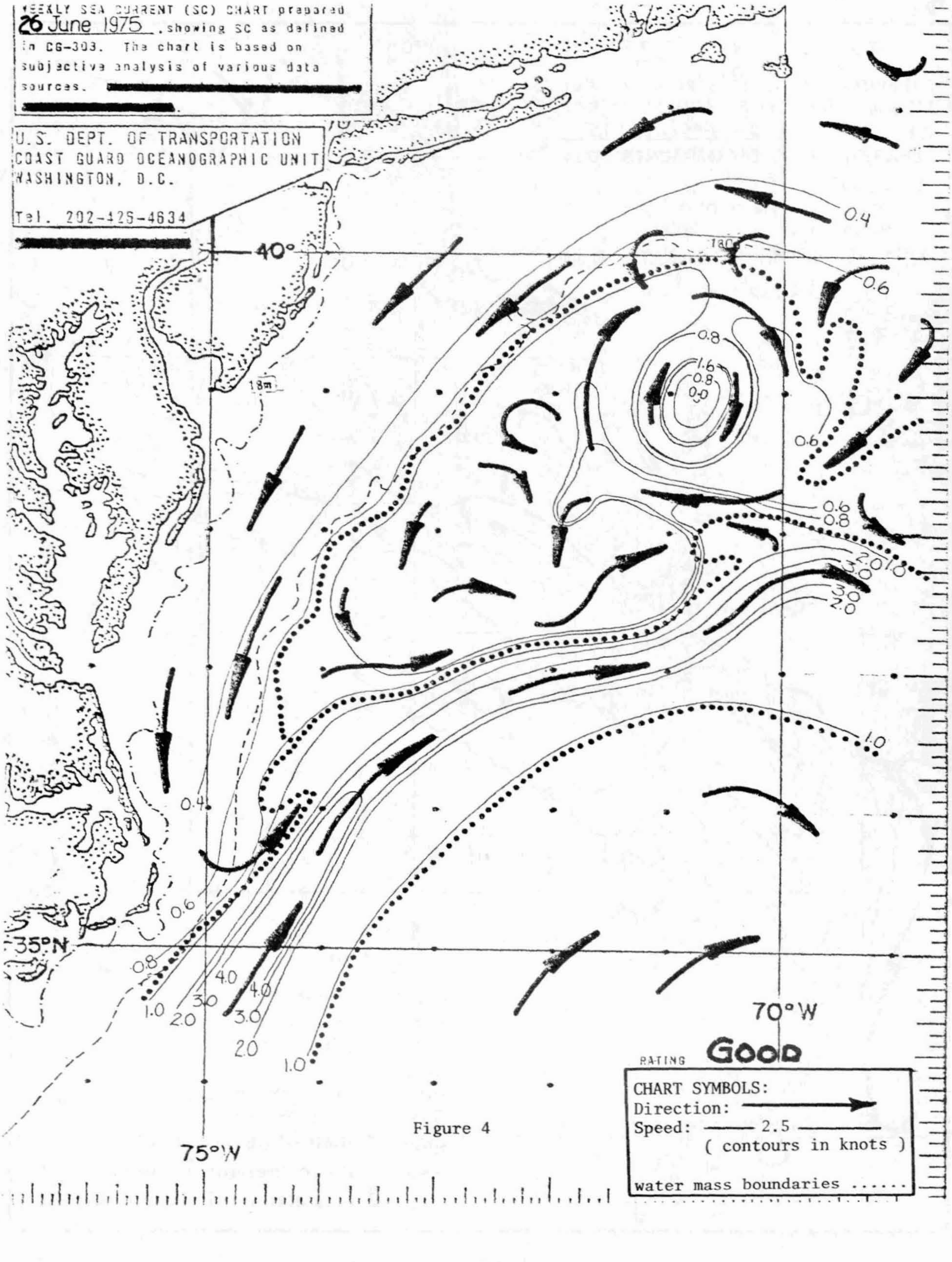
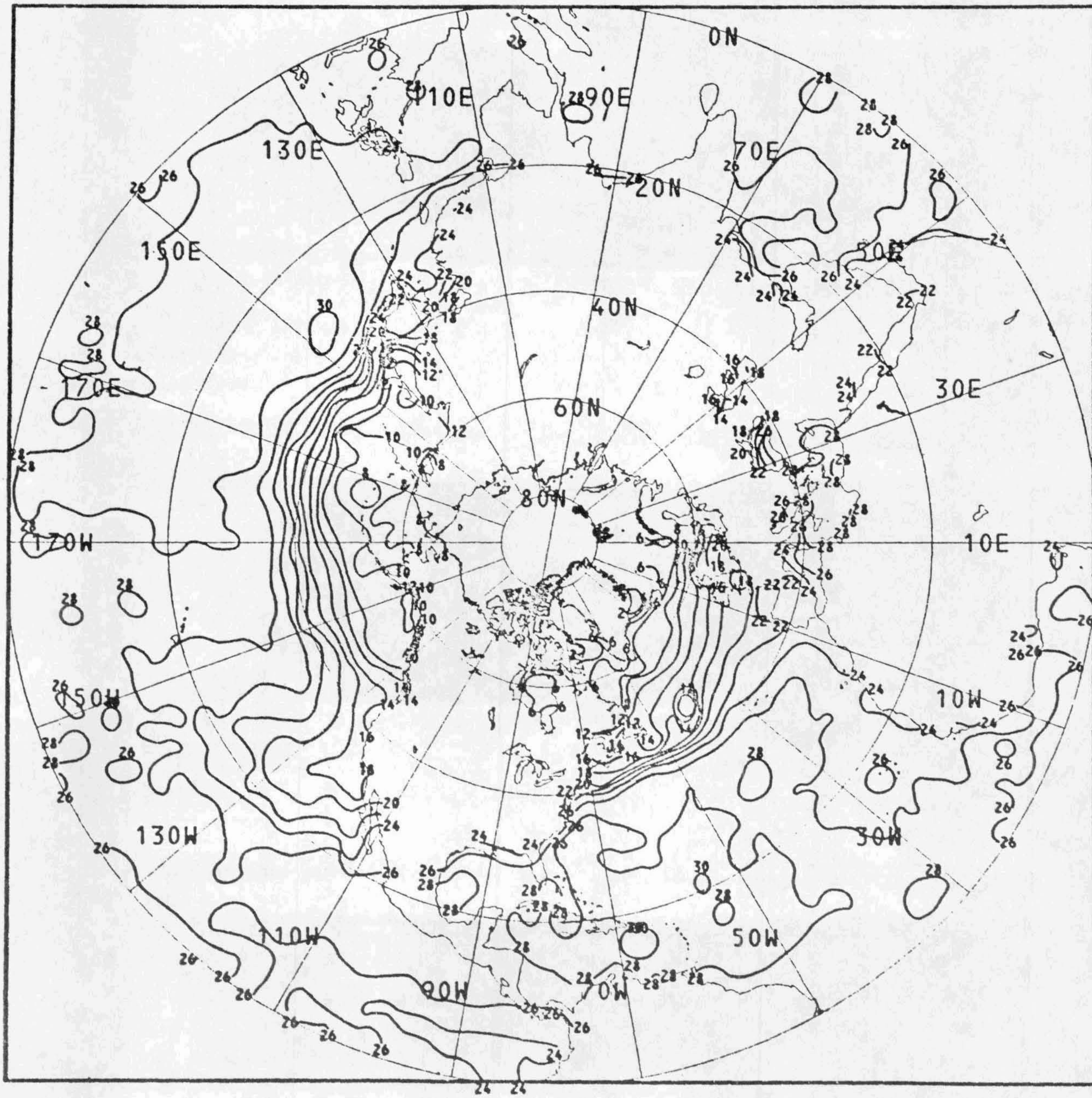

WEEKLY SEA CURRENT (SC) CHART prepared 26 June 1975, showing SC as defined in CG-303. The chart is based on subjective analysis of various data sources. [redacted]
U.S. DEPT. OF TRANSPORTATION
COAST GUARD OCEANOGRAPHIC UNIT
WASHINGTON, D.C.
Tel. 202-426-4634
[redacted]
40°
35°N
75°W
70°W
18m
0.4
0.6
0.8
1.0
1.6
0.0
2.0
3.0
4.0
RATING GOOD
CHART SYMBOLS:
Direction:
Speed: 2.5
(contours in knots)
water mass boundaries

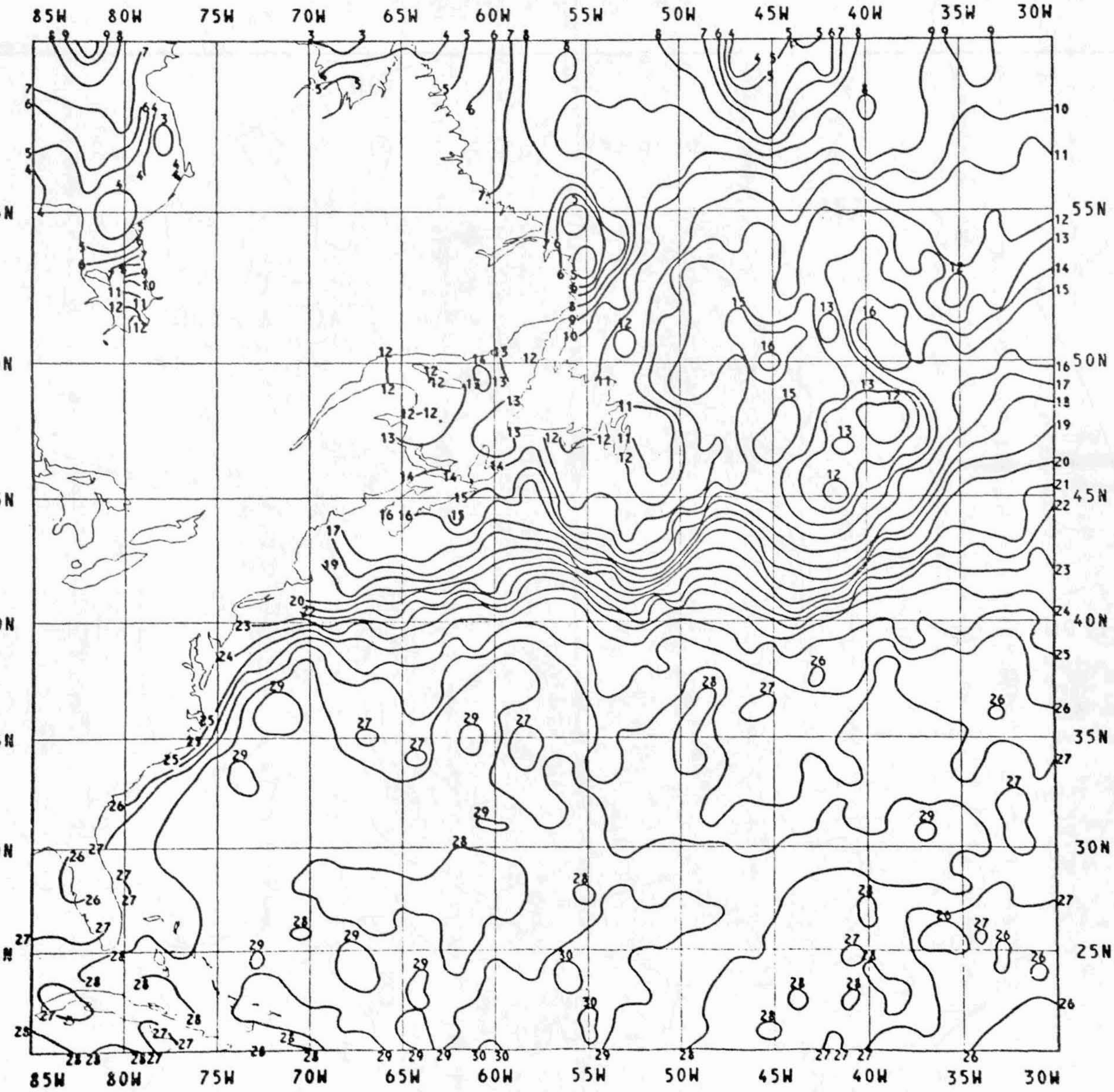
Figure 4

GOSSTCOMP SEA SURFACE TEMPERATURE



NOAA-NESS Figure 5. -- August 6,1975

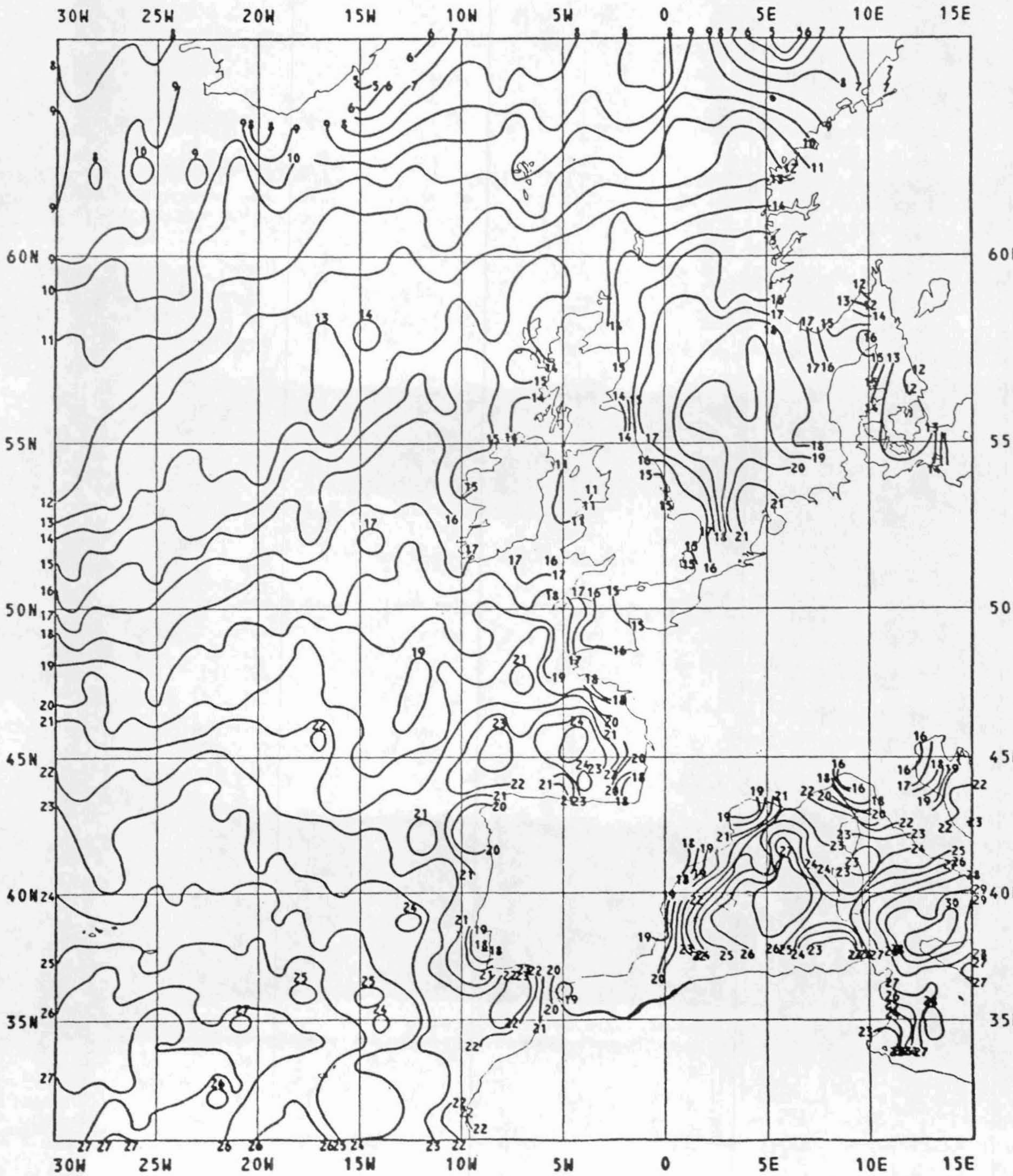
GOSSTCOMP SEA SURFACE TEMPERATURE



NOAA - NESS

Figure 6. -- August 6,1975

GOSSTCOMP SEA SURFACE TEMPERATURE



NOAA - NESS

Figure 7. -- August 6,1975

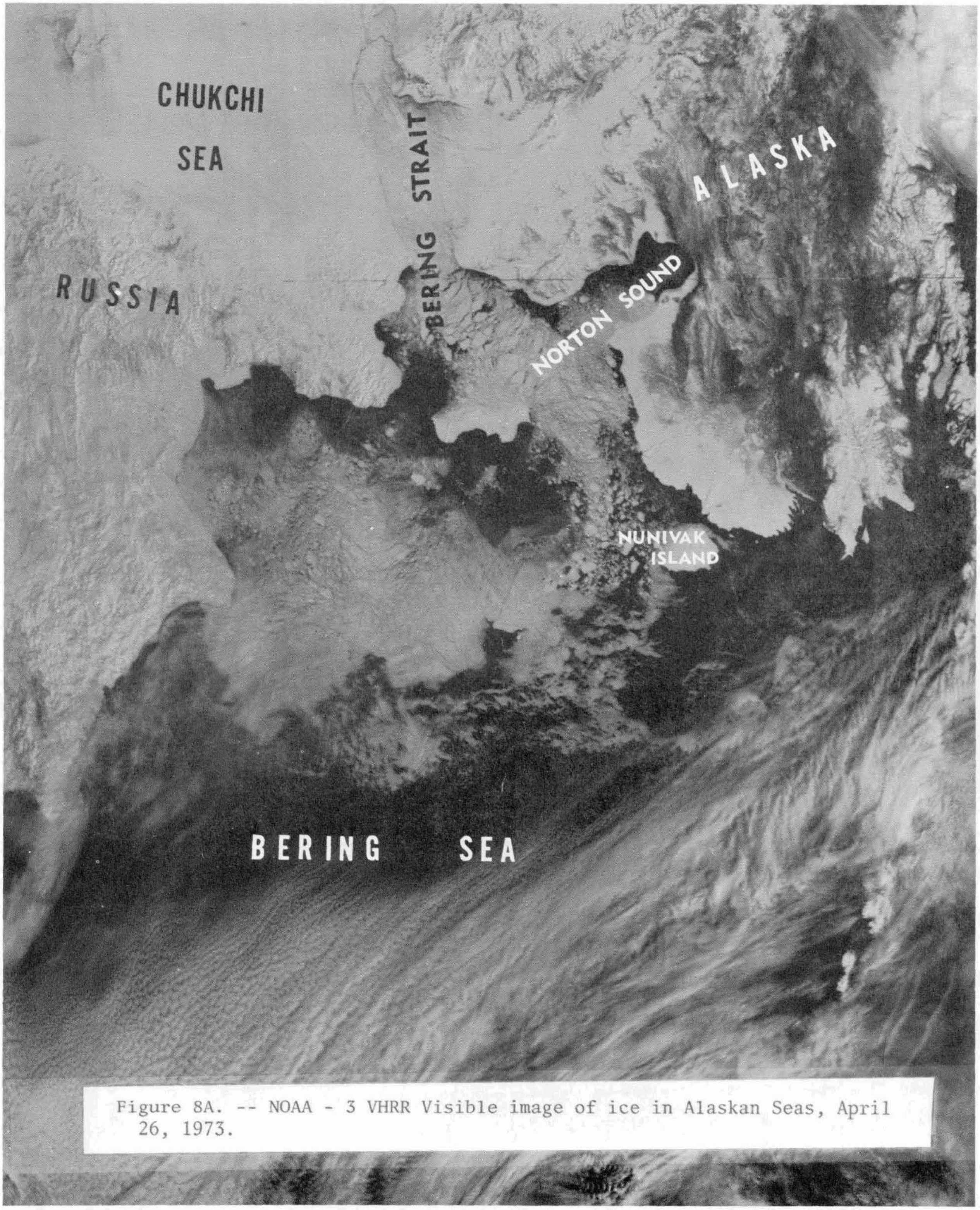


Figure 8A. -- NOAA - 3 VHRR Visible image of ice in Alaskan Seas, April 26, 1973.

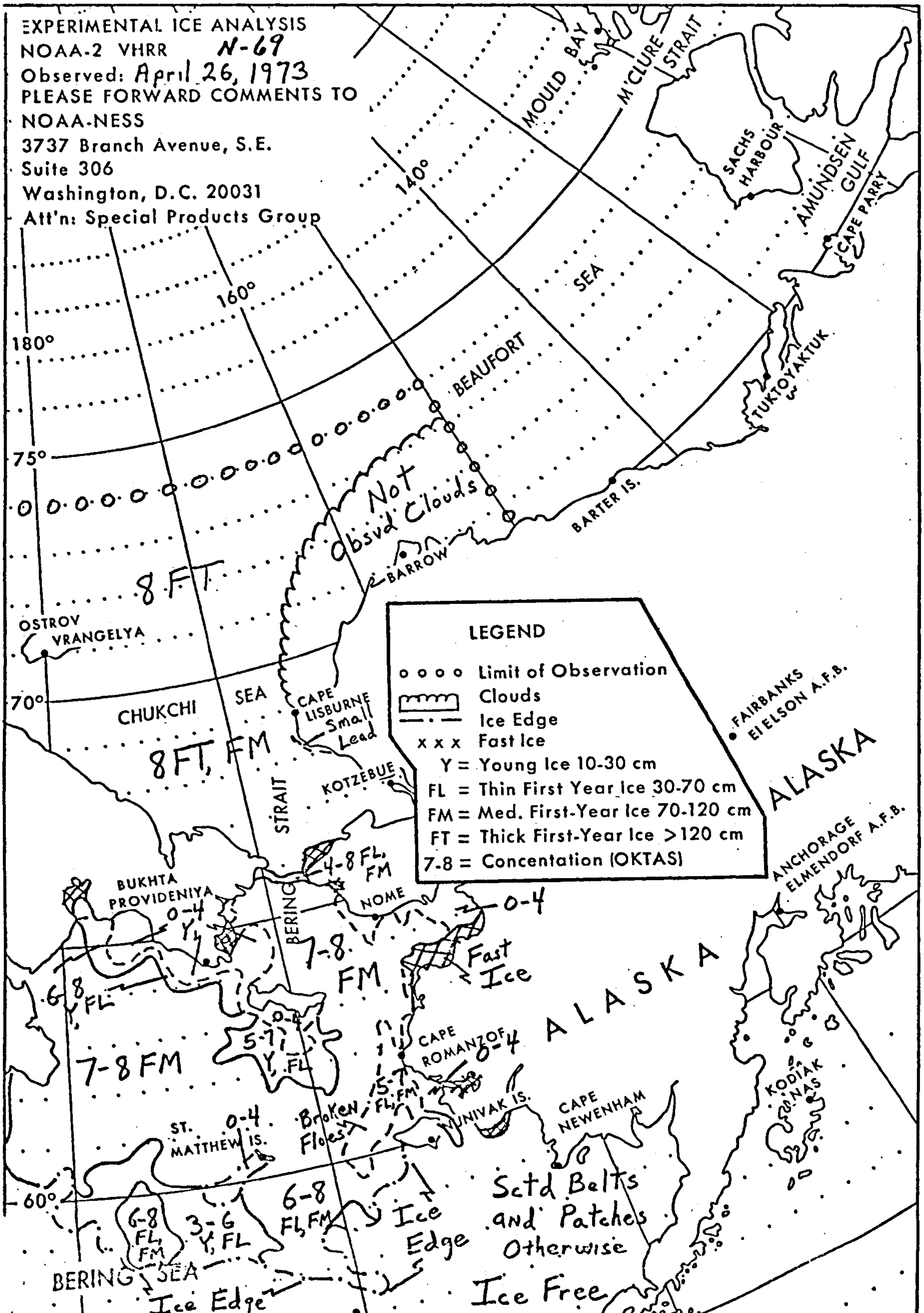


Figure 8B. -- Ice analysis corresponding to Figure 8A

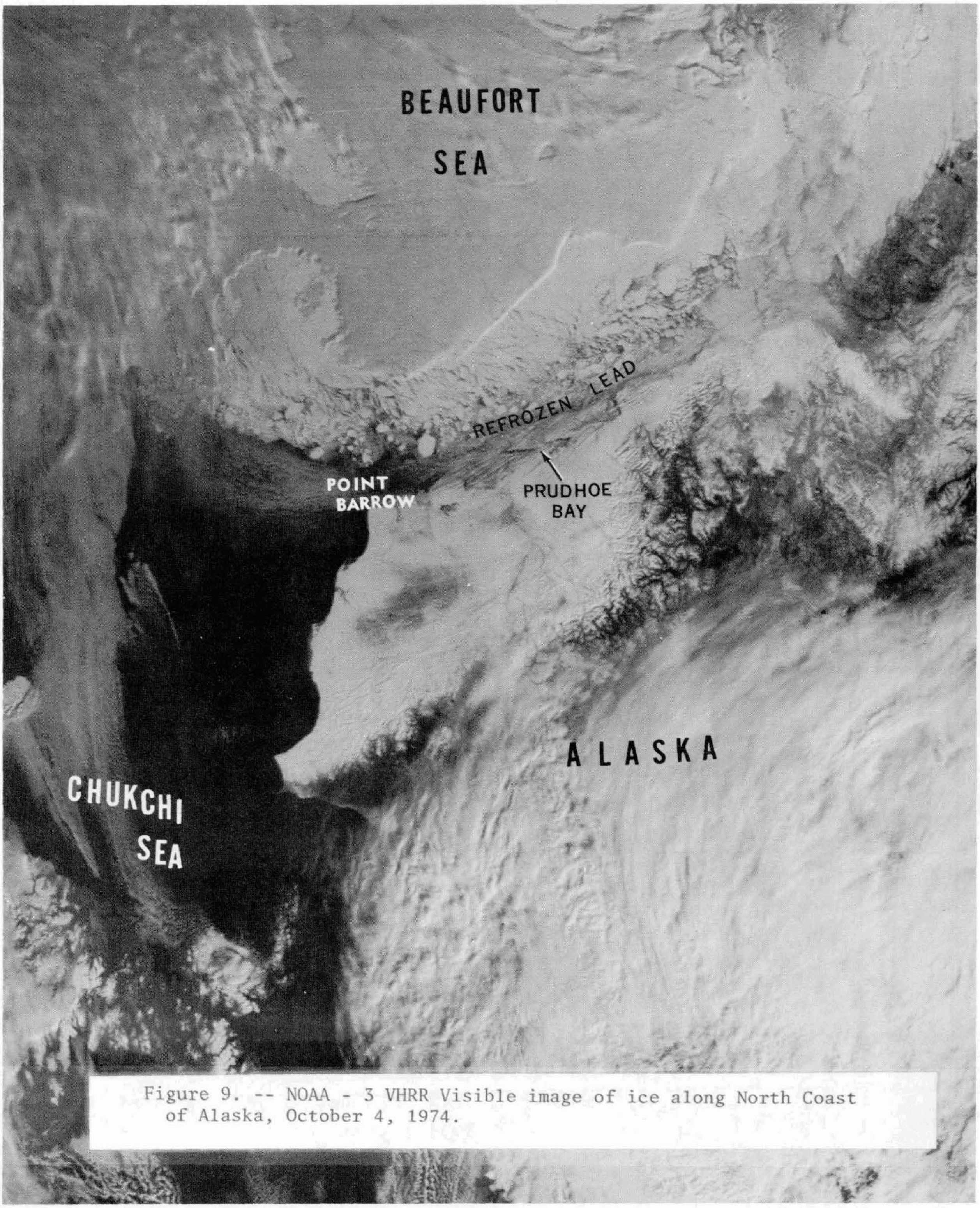


Figure 9. -- NOAA - 3 VHRR Visible image of ice along North Coast of Alaska, October 4, 1974.

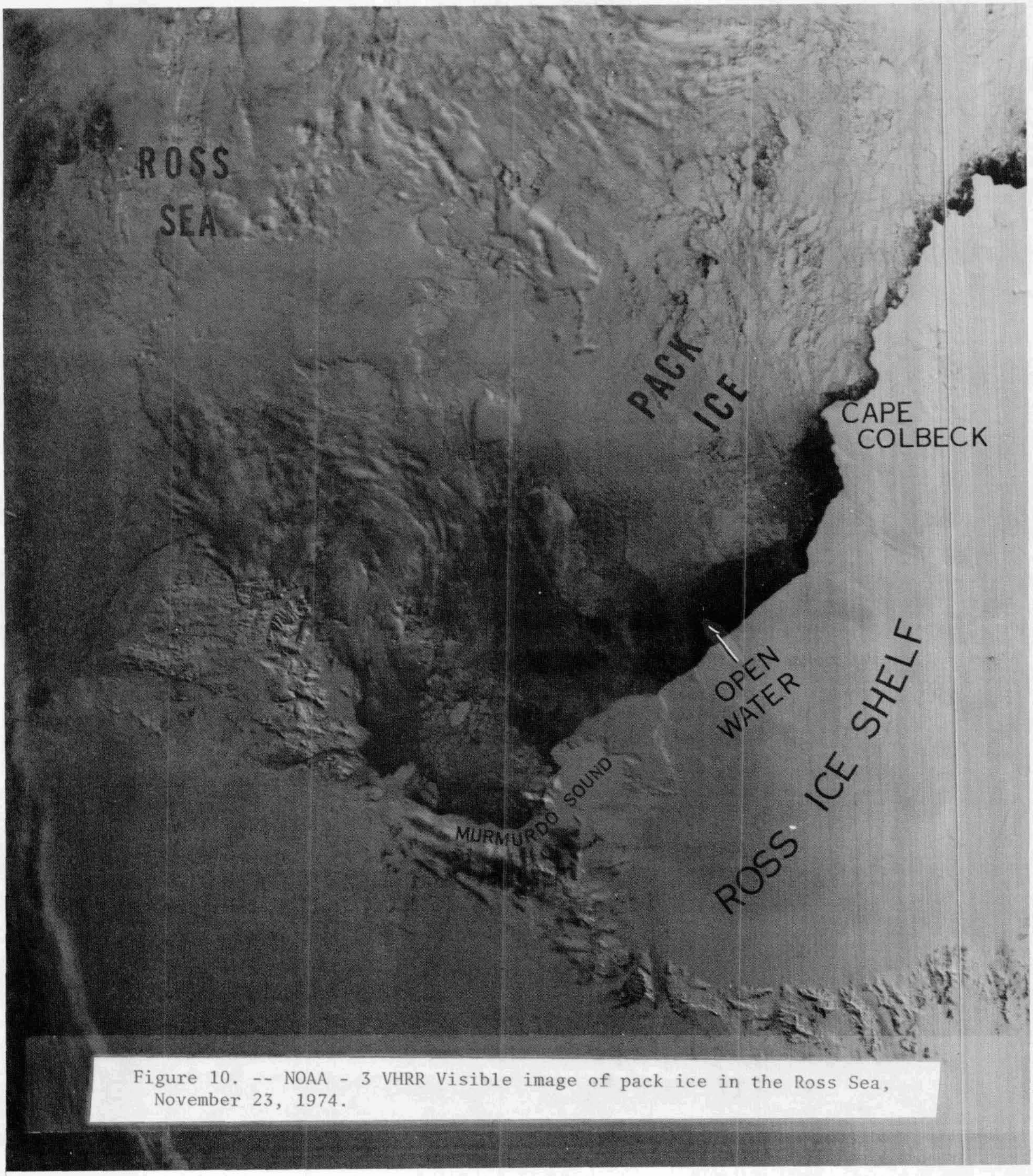


Figure 10. -- NOAA - 3 VHRR Visible image of pack ice in the Ross Sea, November 23, 1974.

Figure 11. -- NOAA - 4 VHRR IR image of ice conditions in the Alaskan Seas, January 3, 1975.

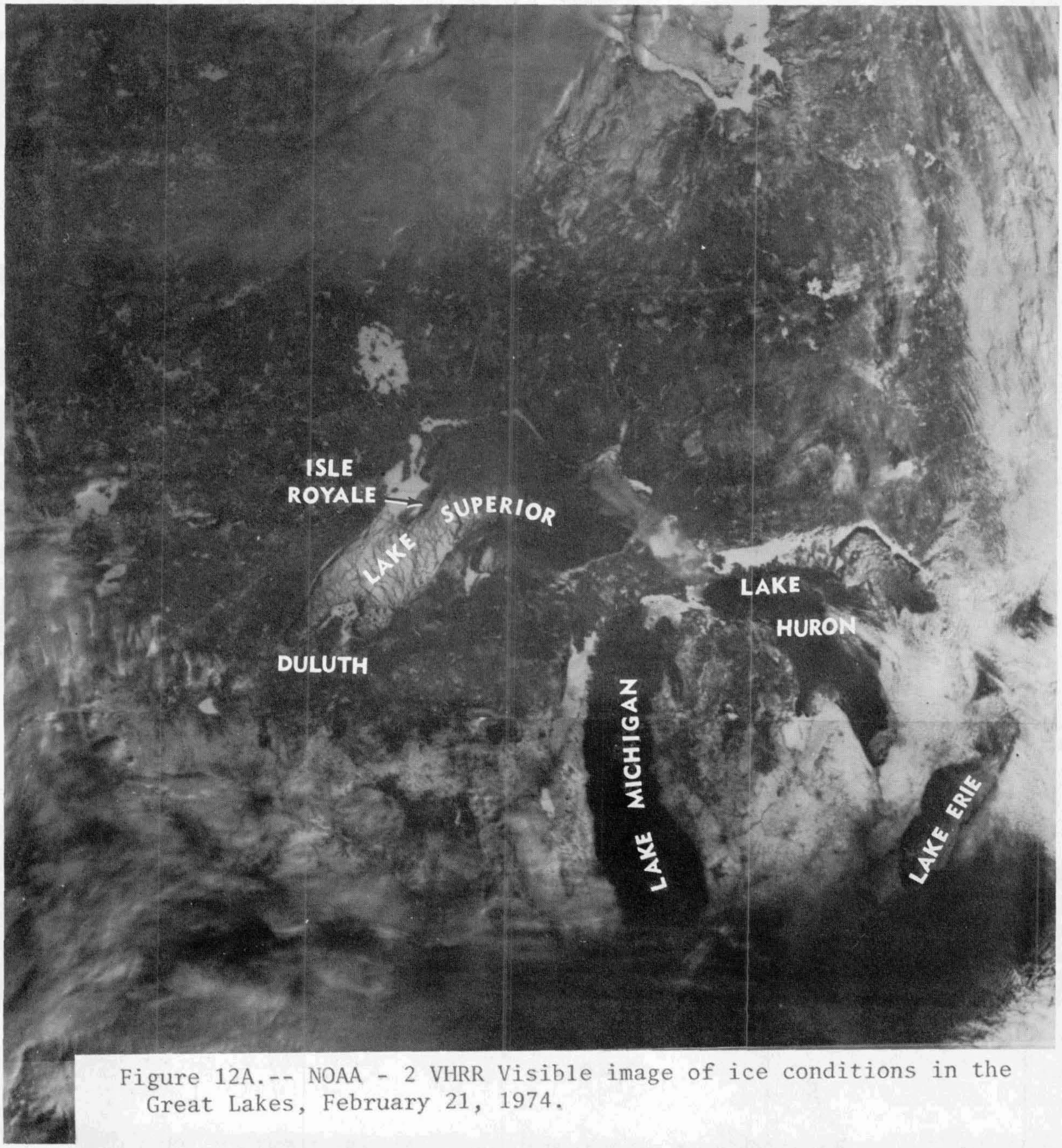


Figure 12A.-- NOAA - 2 VHRR Visible image of ice conditions in the Great Lakes, February 21, 1974.

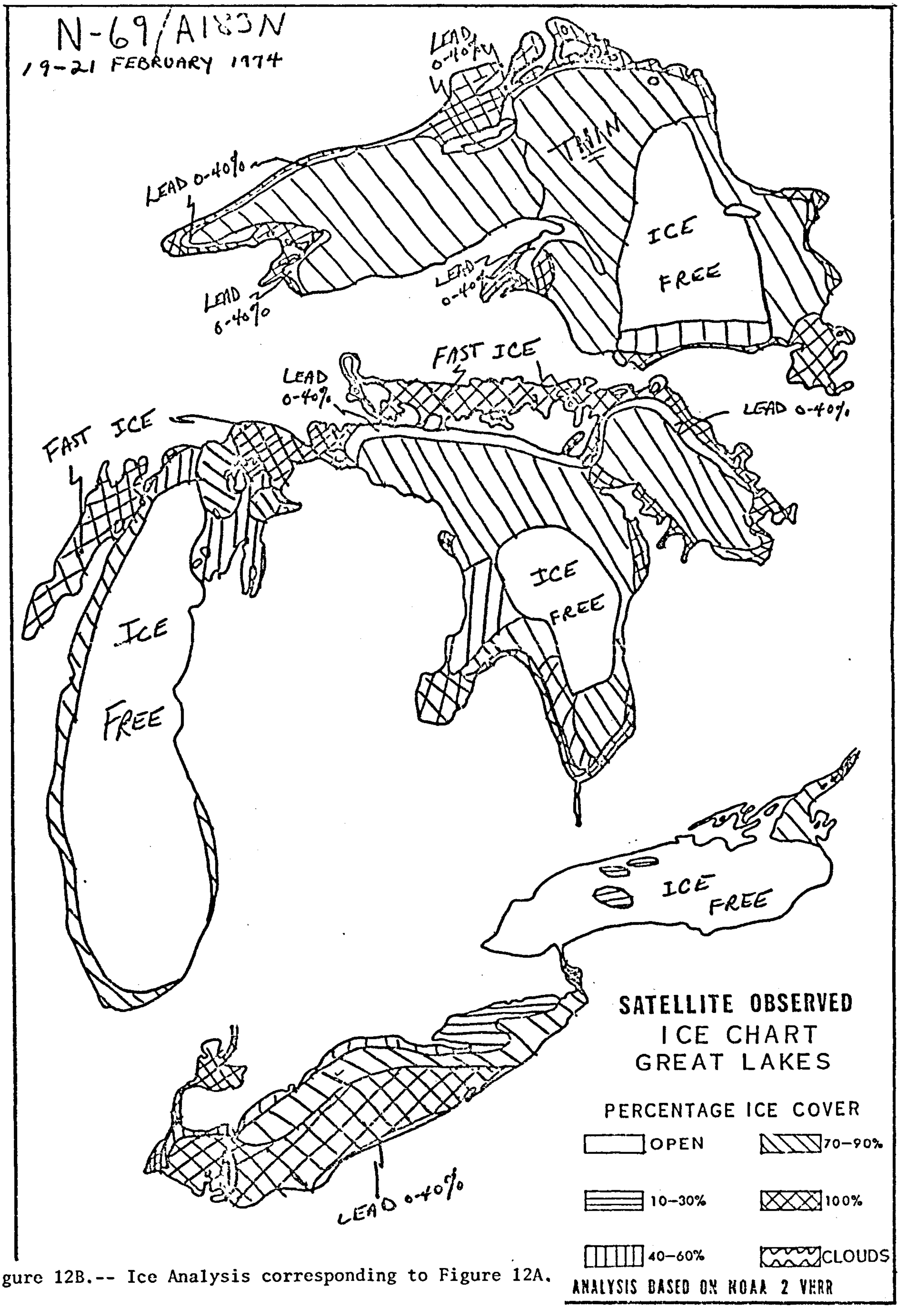


Figure 12B.-- Ice Analysis corresponding to Figure 12A.

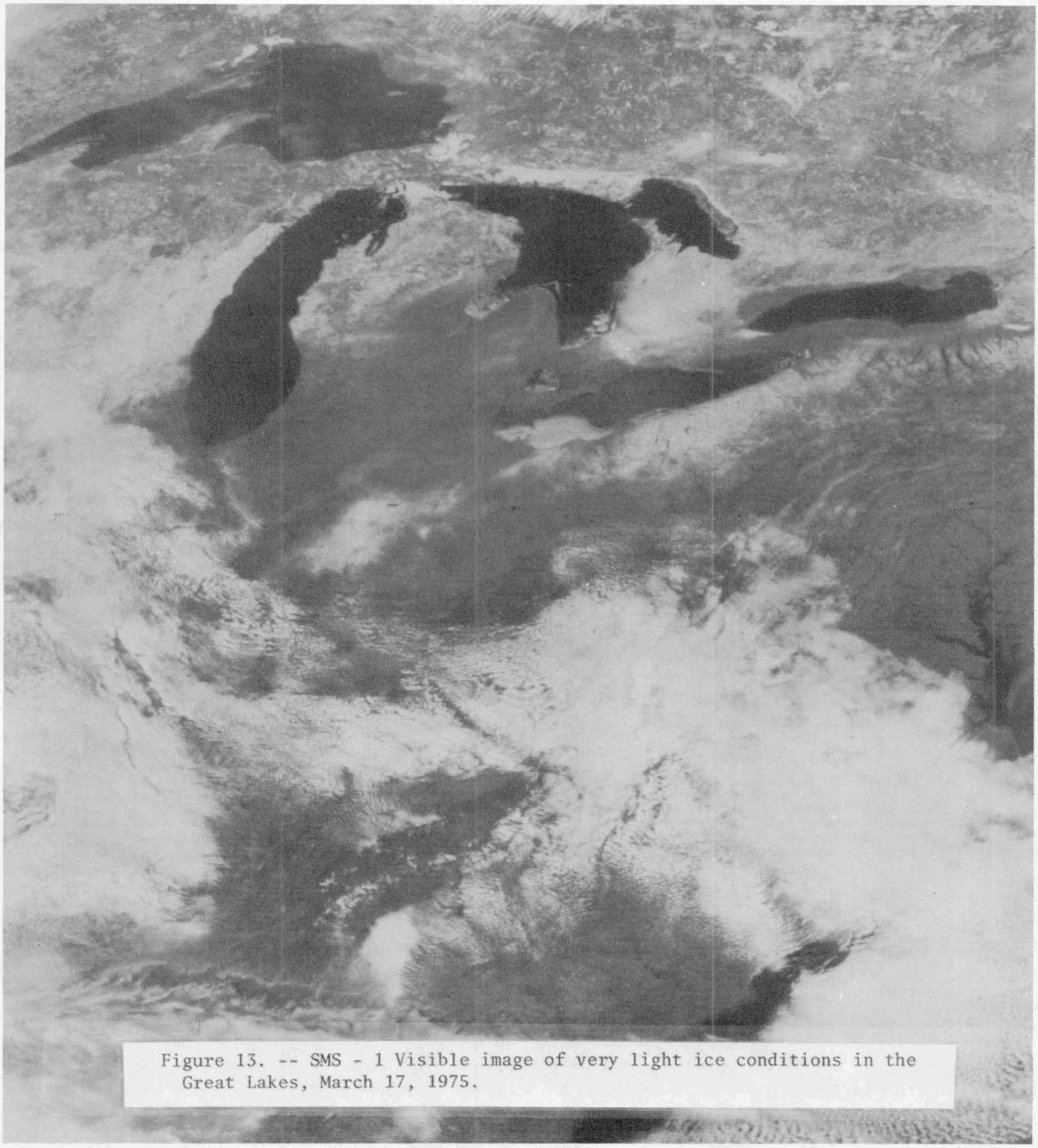


Figure 13. -- SMS - 1 Visible image of very light ice conditions in the Great Lakes, March 17, 1975.