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Some preliminary comments on the usefulness of satellite imagery for the Flemish Cap Area

by

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Introduction

The problem of synoptically mapping even relatively small areas of the ocean has never been satisfactorily resolved. For example, a program of mapping temperature and salinity conditions in the Flemish Cap area (within say the 1000m depth contour) on what most oceanographers would agree was excellent coverage might include 50-100 oceanographic stations. In terms of time it would probably take in the neighborhood of 10-15 days to be completed by one ship. Typically, one would try to analyze the data on the basis that a steady state existed during the survey and that the coverage could be considered synoptic. Sometimes one might moor a few self recording instruments at selected sites to determine just how variable the systems were, temporally, but even with these measurements, one might be quite unsure as to how representative of the whole were the sites selected for moored measurements.

A tool which provides synopticity over a wide area is remote sensing from satellites. Unfortunately, to date, it has suffered from a number of serious limitations. Firstly, in terms of quantitative oceanographic data, the list of parameters is short. The measurement of temperature using an infrared sensor is undoubtedly the most reliably developed; secondly, it is restricted to providing only surface or near surface data, while subsurface measurements are more important oceanographically; and thirdly, it acquires meaningful data only when the atmosphere is relatively cloud and fog free. While these limitations pose severe restrictions on its usefulness, nevertheless, even if one good infrared image can be obtained during the period of an oceanographic cruise of an area, it ought to provide an excellent aid to plotting and more realistically interpreting the data acquired onboard ship, and from moored instruments.

Satellite Data

In order to develop a feeling for the potential usefulness of satellite imagery for the Flemish Cap area, a request was made to the U.S. National Environmental Satellite Service (NOAA) for Very High Resolution Radiometer (VHRR) satellite data within the general area of 46° - 49°N, 43° - 47°W.

[1] Originally presented at the Symposium on the Role of Abiotic and Biotic Factors in the Reproduction of Fish Stocks in the Flemish Cap Area, 16-19 May 1977, Murmansk, USSR, as Working Paper 77/V/27.

The Environmental Data Service has all negatives of NOAA satellite imagery on file. Knowing that for the bulk of the pictures, the sea surface would be largely obscured by cloud, and hence of no use for estimating sea surface temperatures, it was requested that a suite of 20 photographs taken during 1976 be selected from their files, for which the area of interest was relatively cloud-free. Table I lists the dates and includes a comment on the usefulness of each. Additionally and specifically it was requested to select all photographs commencing with May 1, 1976, that were relatively clear, until a total of 10 were selected. It is noted that this covered a period of 69 days.

The Environmental Products Group of NOAA were asked to estimate what percentage of imagery for the Flemish Cap area would be cloud-free over a one year period. They estimated that it would be no more than 15 to 20%. Based on the photographs extracted for Table I, it appears that this estimate may be somewhat on the high side and that perhaps one should not rely on more than about one good image in any 15 day interval.

Perusal of the 20 VHRR pictures, along with normal visual photographs taken simultaneously in order to distinguish cloud features, shows some remarkable oceanographic structure particularly in frontal zones. Although instruments exist for translating these VHRR images into equivalent temperature maps, none were available to the author. Thus the comments made herein are based on visual estimates from the VHRR images.

Comparison of Satellite Imagery with Data Acquired by Ships

Sea surface temperatures recorded by ships traversing the northwest Atlantic Ocean, and reported to the Canadian Forces Base, Halifax, are routinely plotted to give a "synoptic" picture. Charts are prepared utilizing all sea surface temperature (SST) data received during a one week period. An abstract of the chart for the Grand Banks-Flemish Cap area for the period May 3-10, 1976, is shown in Fig. 1. The chart shows, as might be expected, two main temperature regimes, with a temperature ranging from $< 0°C$ in the northwestern portion to $> 18°C$ in the southeastern area. The frontal zone separating these two regions is depicted as being very sinuous, but essentially continuous.

A particularly good sequence of VHRR satellite photographs are available for the corresponding period as can be surmised from Table I. One of these has been selected (May 6, 1976) and abstracted visually. The data from Fig. 1 was used to "calibrate" the photograph for total temperature range. The warmest water observed during the week was over 18°C while the coldest was less than 0°C. Thus the grey scale was arbitrarily broken visually into 5 bands and assigned the following temperatures: $< 2°C$, 2-7°C, 7-12°C, 12-17°C, and $> 17°C$. These have been sketched in Fig. 2. A comparison with the map drawn from shipboard observations (Figs. 1 and 3) indicates that while both maps are consistent in terms of revealing two basic temperature regimes, there is really very little similarity in terms of the more detailed structures, particularly in the frontal zone. The suggestion of eddies and long thin "streaks" of water at a given temperature is very prominent in the satellite image. In an area in the central part of the picture, there is the suggestion of two large eddies, approaching 100 miles in diameter. In one of them (the more easterly one) the interior is comprised of cold and relatively uniform water, whereas the second one consists of a series of long thin curved tear-drop shaped masses of water, some "warm" and some "cold". It very much has the appearance of the early stirring stage, when one introduces say some black paint into a can of white paint.

If we examine the sequence of photographs over the period from April 30 to May 8, one can see features developing or dissapating. For example, a small gyre of perhaps 20 miles in diameter, developed in the southerly area. The commencement of this development was apparent on May 2nd, when cold water (estimated to be between 2-7°C) extended in the form of a long thin crescent-shaped tongue into a water mass with temperatures estimated to be in the 12-17°C range. By May 6th (Fig. 2), the ring had closed, but was still attached to the larger cold water mass. The imagery of May 8th shows the ring completely separated from its cold water source.

A closer examination of the data input to Fig. 1 reveals some of the problems faced by the person preparing the chart. Widely varying temperatures may have been reported (often on different days) in close proximity to one another and yet some distance away from the front as depicted. Although precise positioning was not possible for the satellite imagery, it seems clear that some of these "discrepancies" can be reconciled, when one realizes that the actual thermal distribution as portrayed by the average SST map never actually occurred at any given time. Indeed it is not at all obvious that it even represents a very good average picture. What is probably more useful is to portray a picture of temperature distribution on one particular day, noting that in the frontal region the pattern will have coherence over a good portion of a week, even though at any one geographic site temperatures may vary widely over the period as gyres and tongues develop and move through a region.

Projected Satellite Coverage

No attempt has been made to survey the entire satellite field. In terms of the NOAA series referred to here, the frequency of passes over the Flemish Cap area is reported to be usually two daytime orbits every three days. In 1978, a new series of NOAA satellites is to be launched, the Tiros-N series. Sensors on board will include an IR channel in the spectral region 3.55-3.93 microns in addition to the regular band of 10.5-11.5 microns. This could yield some new useful oceanographic imagery data.

Additionally a SEASAT satellite series slated to commence with SEASAT-A in autumn of 1978 promises to partially overcome the problem of cloud cover. In addition to the normal infrared sensors it will have a sensor in the microwave band that will give essentially a sea surface thermal map even when cloud is present. Although its resolution will not match that of the sensors in the infrared band, it should enable one to go a considerable way in aleviating the problem of acquiring useful thermal data in areas like the Northwest Atlantic. The satellite should make two passes every three days. One of the receiving stations will be sited on the east coast of Newfoundland.

Summary and Conclusions

Evaluation of selected infrared photographs taken by NOAA satellites gives one a very different impression of likely oceanographic events from that acquired by shipborne methods alone. For the area south and east of the Grand Banks, the satellite data does not suggest a long, sinuous and continuous front, but rather one fragmented, and frequently consisting of long (several hundred miles) narrow crescent shaped bands, often with remarkably sharp horizontal gradients. A spectrum of eddies, both in size and structure, can be discerned from the satellite imagery which is almost totally missing from the sea surface temperature map constructed from shipborne observations.

Although the amount of useful satellite sensed infrared data acquired for the Flemish Cap area is limited, the addition of microwave band sensors on SEASAT should markedly upgrade its usefulness oceanographically. Certainly any oceanographic program that may be developed for the Flemish Cap area will find the satellite sensed data a valuable adjunct.

Table I. Comments on VHRR satellite photographs provided by NOAA for selected periods in 1976.

Date (1976)	Comments
9 Mar	Flemish Cap (F.C.) too cloud covered to see surface. Some structure can be seen well south of F.C.
22 Mar	F.C. partly cloudy, but area south of Cap is clear and good structural detail apparent.
26 Mar	Area in immediate vicinity of Cap is clear.
28 Mar	F.C. cloudy but areas to northwest and south are clear.
12 Apr	F.C. clear, as well as small area to the northwest, west and southwest of Cap.
22 Apr	Predominantly cloud covered - some structure discernible but only of limited usefulness.
30 Apr	F.C. and area to the south and southwest is clear.
2 May	F.C. cloud covered, but area south of Cap is clear.
6 May	Cloud in northwest extends nearly to the Cap. Otherwise, excellent detail of entire region.
8 May	F.C. cloud covered, but area north and northwest of Cap is clear, also area well south from the Cap.
9 May	F.C. cloudy, but area to the south has useful data.
13 May	F.C. is clear, including area to north and to the south.
17 May	F.C. cloudy. Limited information for area north and northwest of Cap.
27 May	Mostly cloudy, very limited usefulness.
5 June	Most of area is clear and contains excellent detail.
28 June	Only I.R. photo available, making it difficult to judge usefulness.
8 July	Only I.R. photo available, but it appears to have useful data.
8 Aug.	Only I.R. photo available. Area fairly obscured with cloud.
14 Aug	Cap is cloudy. Only a small area east and south of Cap is clear.
7 Oct	Entire area is mostly clear, and shows marked structures.

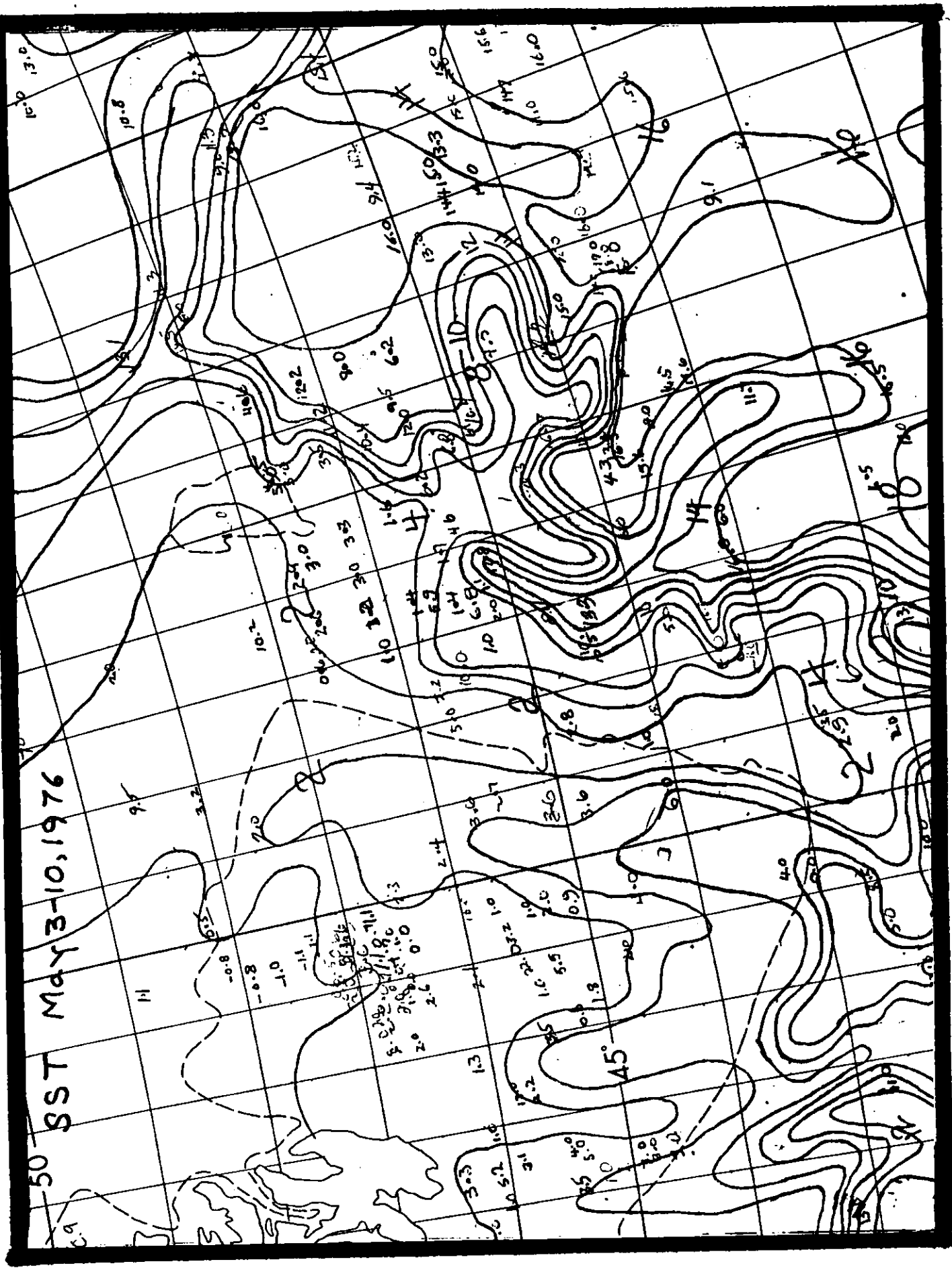


Figure 1: Extract from sea surface temperature plotting sheet produced by METOC, Canadian Forces Base, Halifax, Canada, for period May 3-10, 1976.

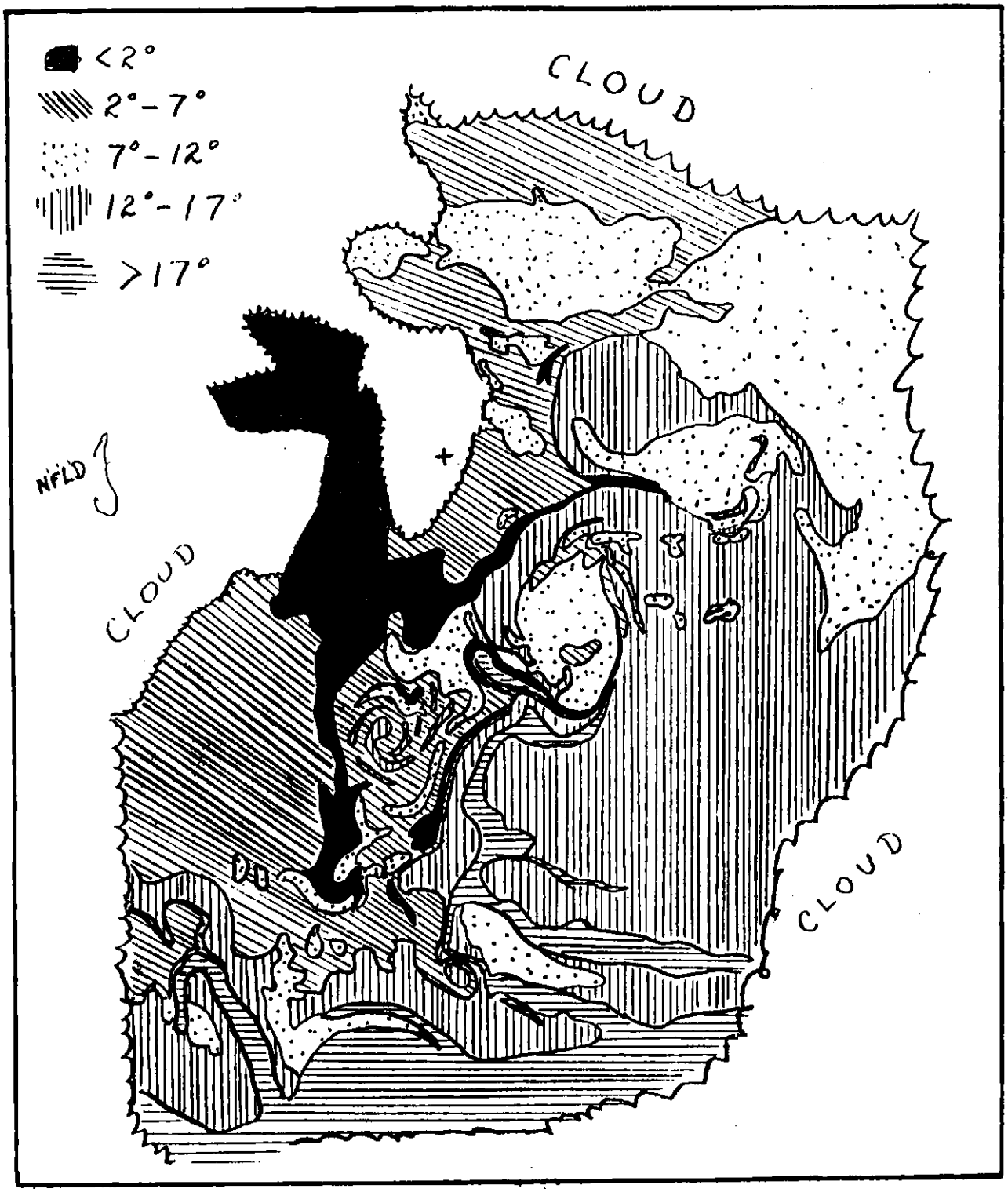


Figure 2: Sketch of sea surface temperature distribution as estimated visually from VHRR, NOAA satellite image taken May 6, 1976. Approximate position 47°N, 45°W is shown as "+".

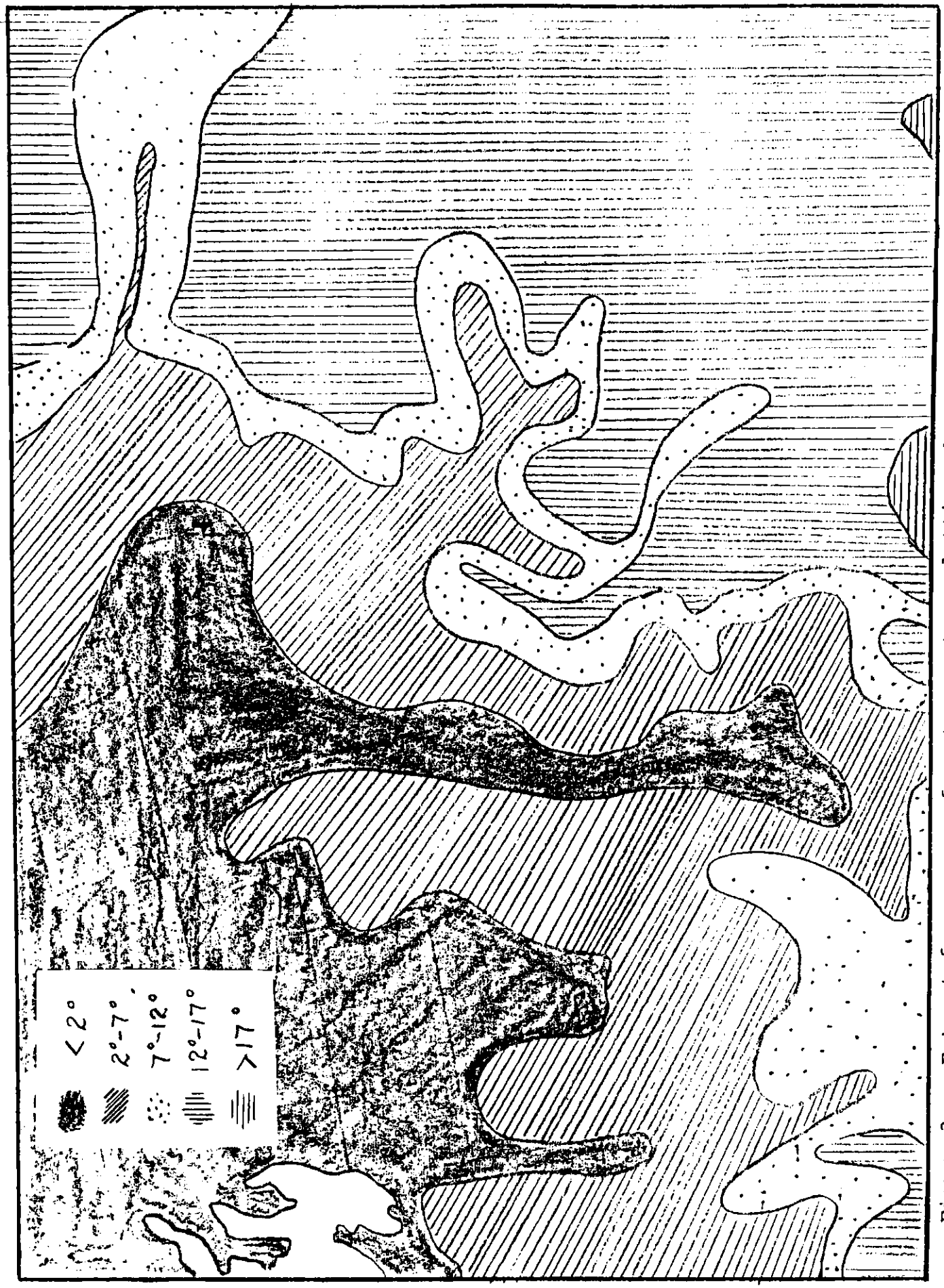
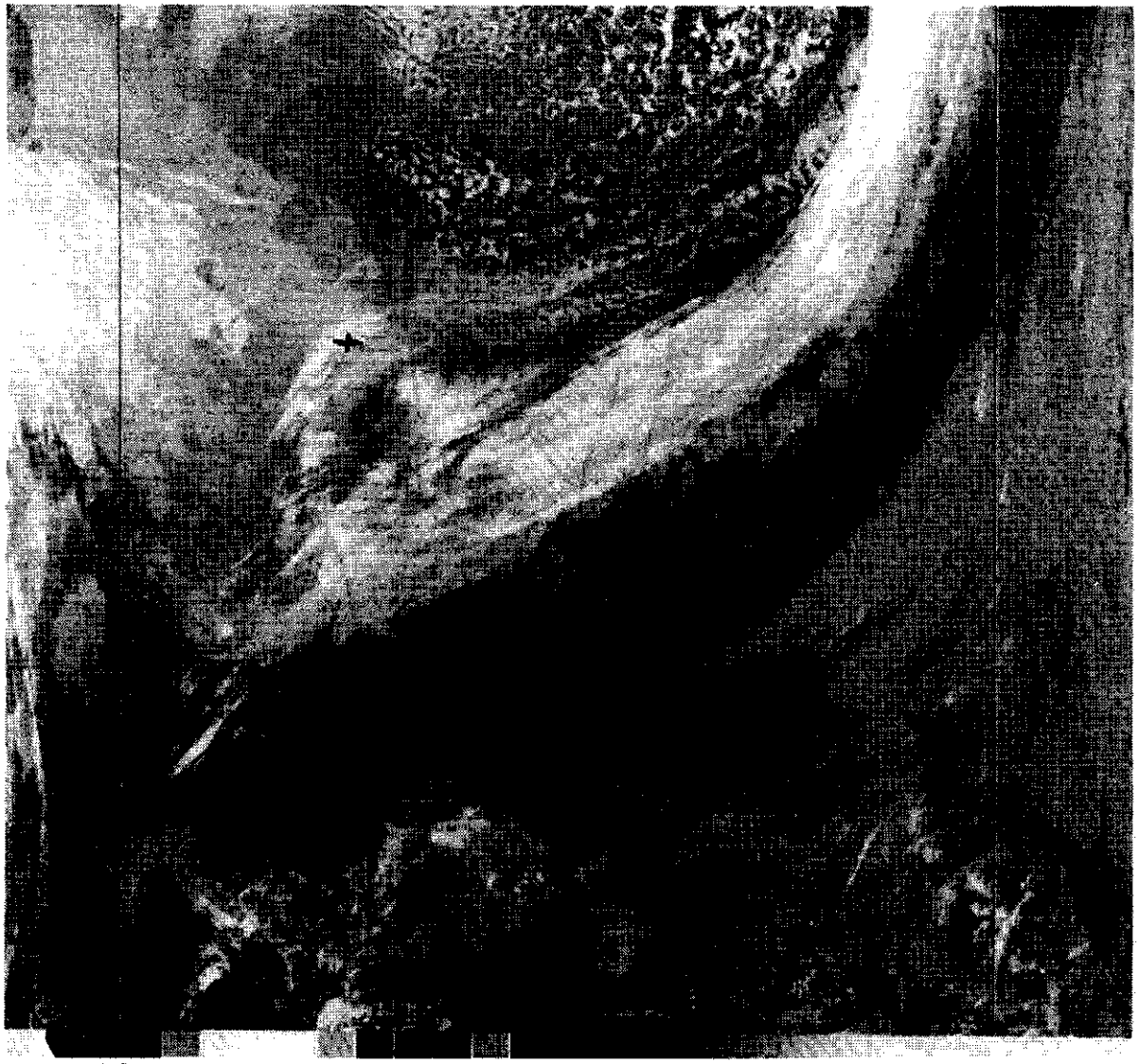


Figure 3: Extract from sea surface temperature plotting sheet produced by METOC, Canadian Forces Base, Halifax, Canada, for period May 3-10, 1976 (as shown in Fig. 1) with temperature ranges delineated similarly as for satellite data in Figure 2



129:12:01:03 6759 I1F0001 08MAY76 N4 8S 139E


L 123:12:14:06 6684 I1F0001 02MAY76 N4 8S 136E


L 127:12:05:59 6734 I1F0001 06MAY76 N4 8S 138E