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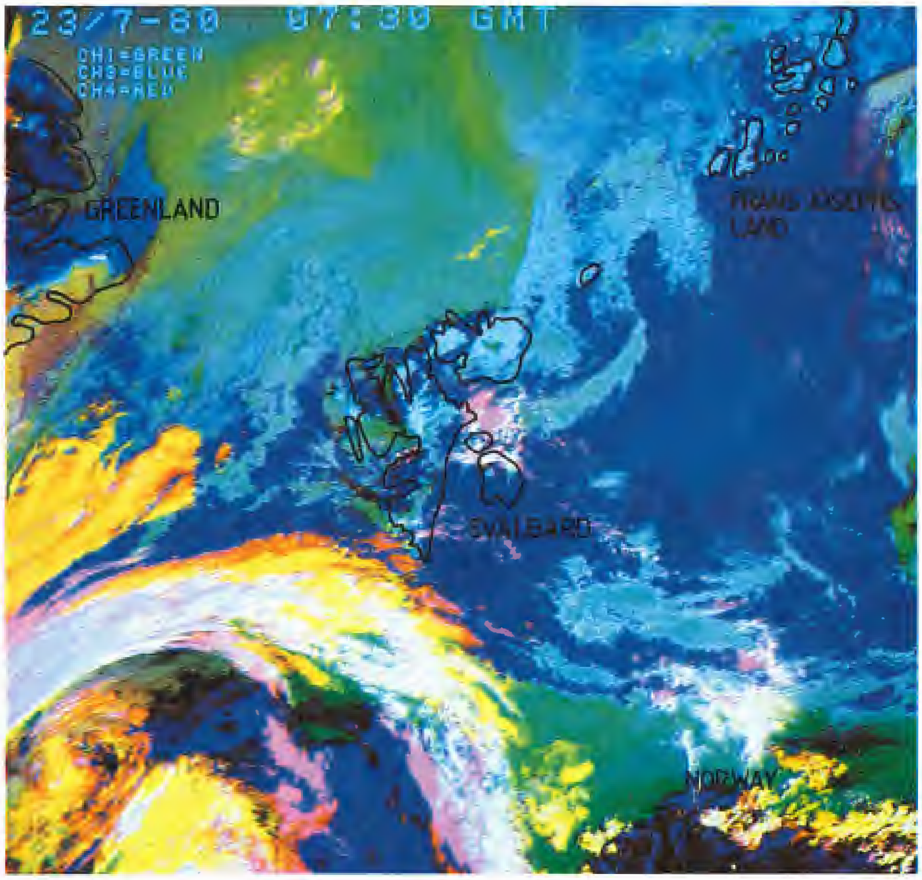

YMER–80, SATELLITES, ARCTIC SEA ICE AND WEATHER

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ABSTRACT

During the arctic expedition YMER-80 which took place in the area north of Svalbard between northeast Greenland and Frans Josephs Land satellite information was received onboard as an important aid in weather and sea ice surveillance. A satellite receiving station made it possible to receive images directly onboard from the NOAA weather satellites. These APT images proved to be very valuable for the weather analyses but for sea ice mapping the resolution, geometrically as well as radiometrically, proved to be a little to coarce to be of real use in the the daily operations planning. High resolution LANDSAT images were received by radio from the receiving station in Kiruna but the limited areal coverage if these images together with the quality degradation in the transmission limited their operational usefullness.
Multispectral processing of the full resolution NOAA, AVHRR data proved however that such data can give considerable details about the ice and therefore be of great value for the daily operetions of an expedition like YMER-80. The report shows examples of NOAA and LANDSAT images received onboard as well as full resolution images processed after the the expedition was completed.
In summing up the report includs conclusions and recommendations as to how remote sensing techniques best could be used for operational support in arctic expeditions.

Key words
ARCTIC SEA ICE, ARCTIC WEATHER, YMER-80, SATELLITE REMOTE SENSING

Supplementary notes

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ABREVIATIONS AND ACROMYMS

AMI	Active Microwave Instrument (ERS-1)
APT	Automatic Picture Transmission (continous, analogue transmission of image data from the NOAA satellites
ARGOS	Date collection and platform positioning system. (France and USA)
AVHRR	Advanced Very High Resolution Radiometer (digital image data from the NOAA satellites)
ESA	European Space Agency
LANDSAT	Land resources satellite system, operated by USA
METEOR	USSR operated weather satellite system with APT transmission
MSS	Multifrequency Scanning Radiometer (LANDSAT)
NOAA	National Oceanographic and Atmospheric Administration (USA)
SAR	Syntetic Aperture Radar (aircraft and satellite)
SEASAT	Active microwave satellite, operated by USA July- October 1978
SLAR	Side-Looking Airborne Radar. (aircraft only)

TABLE OF CONTENTS

FOREWORD

The arctic expedition YMER-80 which took place in the area north of Svalbard between northeast Greenland and Frans Josephs Land in the period July - September 1980 gave the opportunity for close to 100 scientists to carry out a vast number of scientific experiments in a virgin area.The scientific work required carefull tactical support and daily decissions on eg. the best route to take and which experiments or combinations of experiments to carry out in the light of actual and expected ice and weather conditions.
To assist in this task the operational leader of the YMER-80 expedition, admiral Bengt Lundvall decided that a meteorologist/ice expert should participate in each of the two legs of the expedition. In consultation with the Swedish Space Corporation arrangements were also made for satellite information to be received onboard directly from the NOAA as well as indirectly from the LANDSAT satellites via the receiving station in Kiruna.
Meteorologists onboard were, during the first leg of the expedition, Thomas Thompson from the Swedish Meteorological Institute (SMHI), and during the second, Erling Småland from the Norwegian Meteorological Institute. They received, in addition to the satellite information,weather observations by radio from about 35 stations in the arctic area, 4 times daily. These observations formed the backbone for the weather analyses produced 4 times a day which again formed the basis for the twice daily weather forecasts. The satellite information provided a very substansial support to the weather/ice analyses and also gave the impetus to the post- analysis presented in this report, encouraged by the chairman of the Remote Sensing Committee of the Swedish Board for Space Activities, professor Gunnar Hoppe.

1. BACKGROUND

During the period 24 june -24 september 1980 a Svedish expedition was took place in the ara north of Svalbard-Frans Josephs Land-north east Greenland. The route of the first leg of the expedition is shown in Figure1. The base for the expedition was the Svedish icebreaker YMER, specially built for assisting ships in the Gulf of Bothnia and the Baltic Sea. Ymer has an overall length of 124 meters, a beam of 24 and is equipped with a dieselelectric machinery of 22000 horsepovers. It has two stern and two bow propellers which is ideal for operation in first year ice with thicknesses upp to 1m but it also proved to work well in ice thicknesses upp to 3m.

***Figure 1** - The route of YMER-80, leg one*

Ymer had crew of 50 and accomodated a scientific staff of the same size. A large number of containers, mainly accomodating laboratories were mounted on deck. Vinches for oceanographic instruments and for taking bottom samples down to 4000m as well as cranes and skylifts had been installed. For transportation and ice recognoissance the icebreaker carried 2 helikopters. Ymer was equipped with a modern satellite navigation system, satellite communications as well as short and long wave radio communication systems.

Weather observations were transmitted by radio and via satellite through the ARGOS system. The ARGOS system also had the capability of calculating the position of the ship with an accuracy of 500 meters or better. Satellite images could be received by radio from a station in Sweden and directly from the NOAA polar orbiting weather satellites by a receiving station onboard. These capabilities will be described in more detail later in the report.

The scientific programme was multidiciplinary and included, to mention some of the diciplins:

-oceanography
-biology
-geology,land as well as marine
-glaciology
-meteorology
-air chemestry
-sea ice

The scientists came from 11 countries and the expedition was thus truly international. In order to accomodate as many projects as possible the expedition was divided in two legs, the first from 2 July to 6 August and the second from 9 August to 24 September The expedition started from Tromsoe in northern Norway. It was also in Tromsoe the scientific staff and some of the crew was exchanged between leg one and two. Figure 2 shows Ymer in the ice.

Figure 2 *- The icebreaker* ***HMS YMER*** *in the ice*

This report will concentrate on the first leg. It will give a brief overview of the ice and weather situation and will describe how satellite information was used operationally during the expedition and how more advanced processing could improve the usefullness of satellite data.

2. REMOTE SENSING TECHNIQUES, A BRIEF OVERWIEV

With remote sensing we mean thechnical methods by which we, from distance can register, processe and present information from the earths surface, the ocean and the atmosphere. To register a the signals from a given surface we need **sensors** and we need **platforms** to carry the sensors. The signals registered by the sensor can be processad directly onboard the platform or they can be transmitted to a receiving station and processed after reception. The platforms used for weather and ice surveillance are normally aircraft or satellites.

For the arctic regions aircraft surveillance becomes very expensive in particular as large areas normally needs to be surveilled. Satellites on the other hand offers repeted and, over the arctic, overlapping information covering large areas. For arctic sea ice surveillance satellite information is therefore of very great importance and this report will therefore concentrate on satellite techniques.

Sensors carried by satellites are of two major types; passive and active.
The passive sensors register the natural energy that is emitted or reflected from the earths surface or the clouds. The active sensors transmitt energy towards the surface and register the energy that is reflected back.

The sensors can operate in a wide range of intervalls within the electromagnetic spectrum, from the ultraviolet, via the visual and the infrared to micro- and radio waves The absorbtion in the atmosphere poses however a serious problem. Within the visual and infrared the atmosphere is only transparent within some spectral intervall called **windows** and the sensors have therefore been constructed to operate within these windows. The atmospheric absorbtion in the electromagnetic spectrum is shaded in figure 3 and the so called windows can be cleary seen.

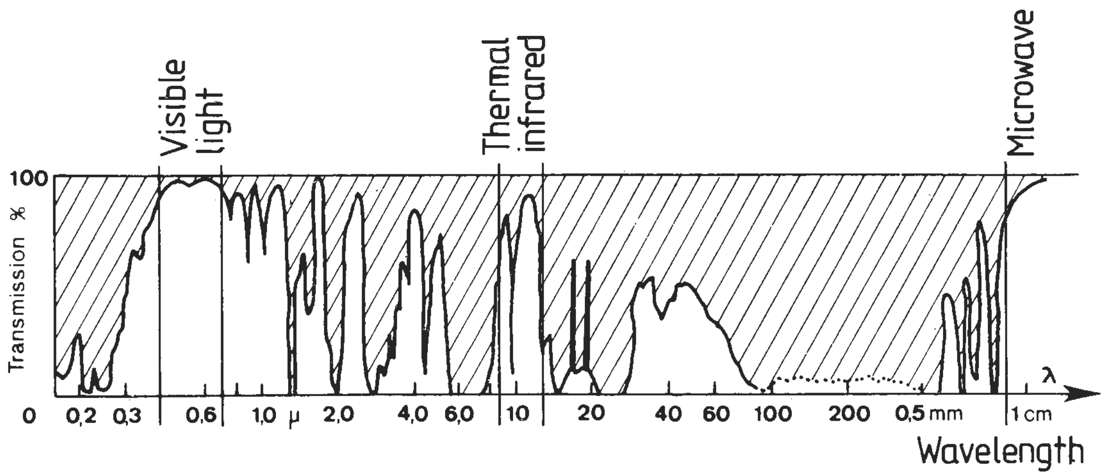


Figure 3 *- The electromagnetic spectrum*

In the microwave range the atmosphere is however totally transparent and the earths surface can there be mapped independant of cloud and weather conditions. Only heavy precipitation will effect the "visibility" within the lover frequency ranges. The use of microwaves would therefore seem quite obvious but the application of the technique is unfortunately restricted due to a number of tehnical difficulties:

a. The energy emitted from the earths surface in the microwave range is very low and with todays technology the resolution with the passive technique is limited to 20-30 km for space applications. To improve the resolution much larger antennas would be required and these would be difficult to mount on spacecrafts.

b. The active technique requires much energy in the image mode and the very high information rate and complicated processing poses problems which are intricate and expensive to solve.

Passive microwave satellites have been operational since many years but not very extencively used for operational sea ice mapping. Also an active microwave satellite has been sucessfully tested. SEASAT,launched by USA and operated during 3 months in 1978 and provided an overwhelming amount of interesting and usefull data. The next generation microwave satellites are planned for launch in 1989 and 1991 by ESA and Canada.

The operational weather satellites operated by USA and by USSR have proved to be the best tools for day to day operational sea ice surveillance. This applies in particular to the NOAA satellites which transmits data to earth in digital as well as analogue form, data that can be freely received by anyone and anywhere in the world.
Also data from the LANDSAT satellites have proved usefull for sea ice mapping but due to restricted coverage and high costs they are nearly exclusively used for research purposes.

In addition to the satellites mentioned above, which are all polar orbiting, there ara a number of geostationary satellites but these cannot be used for sea ice mapping north or south of 55 deg. due to decreasing resolution with increasing latitudes.

The data from the NOAA satellites can be received in two modes:

- in analogue form transmitting one image in the visual range and one in the infrared. This mode is called (APT).The resolution is 4 km and the possibilities for further processing are rather limited.

- in digital form including data from 5 different spectral channels within the visual and infrared. (AVHRR). The resolution is 1.1 km and the data is ready for digital processing by computer.

The sensor AVHRR is a scanning radiometer which covers a swath of ab.2800 km. Each pixel (1.1x1.1 km) contains radiation information ranging from 0 to 1023 in each of the 5 spectral channels.

The spectral intervalls of the 5 channels are:

- **CH1** 0.58 - 0.68 um ; visual, can penetrate thin clouds and low fog

- **CH2** 0.725 - 1.0 um, infrared near visual, very like CH1

- **CH3** 3.55 - 3.93 um; infrared, register thermal as well as reflected light. Usefull for night mapping, diskriminats fog and low clouds.

- **CH4** 10.3 - 11.3 um; thermal infrared, usefull for nigh and temperature mapping

- **CH 5** 11,5 - 12,5 um; as ch4

The different channels will give different signatures for one and the same object, such as water, clouds, ice types etc. By combining the information from two or more channels channel it is therefore possible to discriminate eg. ice from clouds, which in individual channels may not be possible. This is called multispectral processing and is used extensively for weather and sea ice surveillance.

3. SATELLITE RECEIVING FACILITIES ONBOARD

3.1 APT image reception

For the expedition YMER was equipped with an APT receiver which could receive NOAA as well as METEOR (USSR) images. The image recorder was a film type with a liquid processor, which created some difficulties in open water when the icebreaker at times rolled heavily. The equipment would at such cases spill develloping liquid on the floor which was quite damaging to the rugs. This problem was solved by placing the APT equipment on a tray.

Figure 4 *- The APT receiver onboard YMER*

Apart from this initial inconveniance the APT equipment functioned without failures during the whole expedition. It was placed on the bridge (see figure 4) where also the meteorologist/ice forecaster had his "office". The antanna was a simple rod mounted on the roof of the bridge.

The physical size of the images received were 14.8 cm across track and 16.4 along track. Each passage gave two images that had to be taped or glued together. The geographical area covered across-track was appr. 2600 km and 5000 km along-track. At low elevations various types of interfearences would normally degrade the quality of the images and the usefull part would be of the size of 2400 by 3200 km.

The reception was also effected by radio transmitters and various other types of electronic equipment onboard. A typical good quality image from the visual channel is shown on figure 5.

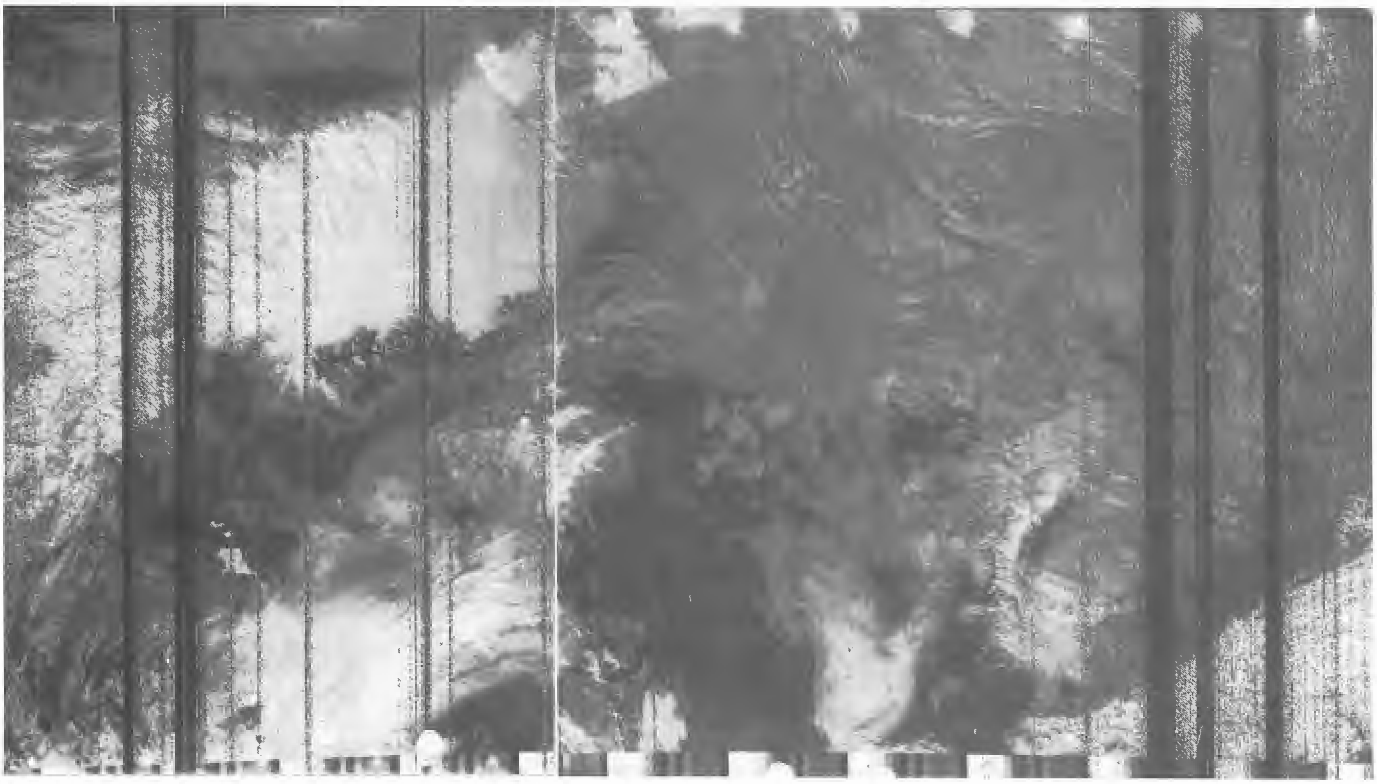


Figure 5 *- NOAA APT image received onboard YMER*

On this simple equipment it was impossible to tune the gray scale to give optimal resolution for both clouds and ice and it was therefore difficult to identify any detailes in the heavier ice and even a thin cloud layer would totally obscure the ice.

Despite the shortcomings of the APT system of which the most restricting were the small physical size of the images and the coarce geometric and radiometric resolution the satellite information proved to be very great value under conditions as very little other information was available

An advantage was the large geographical coverage of the APT image. This gave information, several times a day, not only over the total expedition area but also surrounding areas which was very important for the weather analyses.

3.2 LANDSAT image reception

Through the Swedish Space Corporation an arrangement was made for special real-time processing of LANDSAT data at the Esrange receiving station i Kiruna in northern Sweden. The processing produced an image, 17.5 by 25 cm on which position and orientation information was written before transmitted to YMER via Aelvsborg radio. The images were received onboard YMER on an image recorder. The LANDSAT images had a geographical coverage of 100 x 100 nm. and a resolution of 60 x 80 meters.

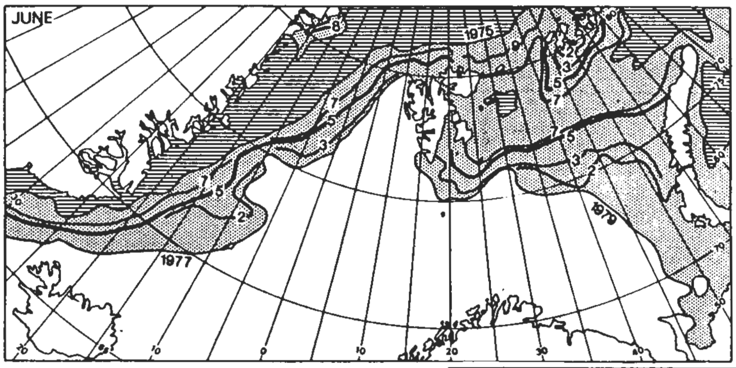
On lower latitudes LANDSAT is scheduled to cover the same area every 16 day. On the latitudes on which this expedition took place, 78 - 83^{0} N, there is a conciderable overlapping and images were received from some part of the expedition area nearly every day. With the limited area of coverage it could however last several days, and even weeks, between the the occations when the actual operations area was covered.

The LANDSAT images as produced in Kiruna was of a very high quality. Most of this quality was however lost in the transmission. The images received onboard YMER were therefore in most cases difficult to use. So despite the outstanding geometric resolution of the LANDSAT images were they of less value for real time use and operation planning than the NOAA 4 km resolution images received directly from the satellites 6 -8 times a day.

4. THE SEA ICE AND WEATHER SITUATION (FIRST LEG)

4.1 The ice situation

The ice extention in the Svalbard area varies considerably from year to year. Figure 6 shows the frequency distribution, in tenths, of ice concentrations above 4/10 at the end of June and July for the period 1971 to 1980 . The information is taken from a work of Torgny Vinje from the Norwegian Polar Institut. Note the greate variation between the years 1975 and 1979. By the end of June 1975 the limit for 4/10 ice concentration lay as far north as 82^{o} to 83^{o}N and the ice conditions in the expedition area would have been very light. In 1979 the situation war reversed, the western part of Barents Sea was ice covered down to 75^{o} N and in the eastern part even to south of 70^{o}N. In a normal year the 4/10 ice concentration limit lays at 76^{o} N by the end of June and at around 80^{o} by the end of July and this was also the case in 1980.



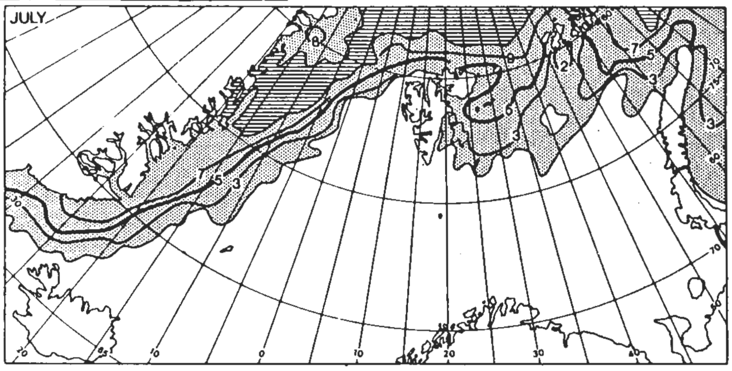


***Figure 6** - Frequency distribution, in tenths of ice concentrations above 4/10 at the end of month*

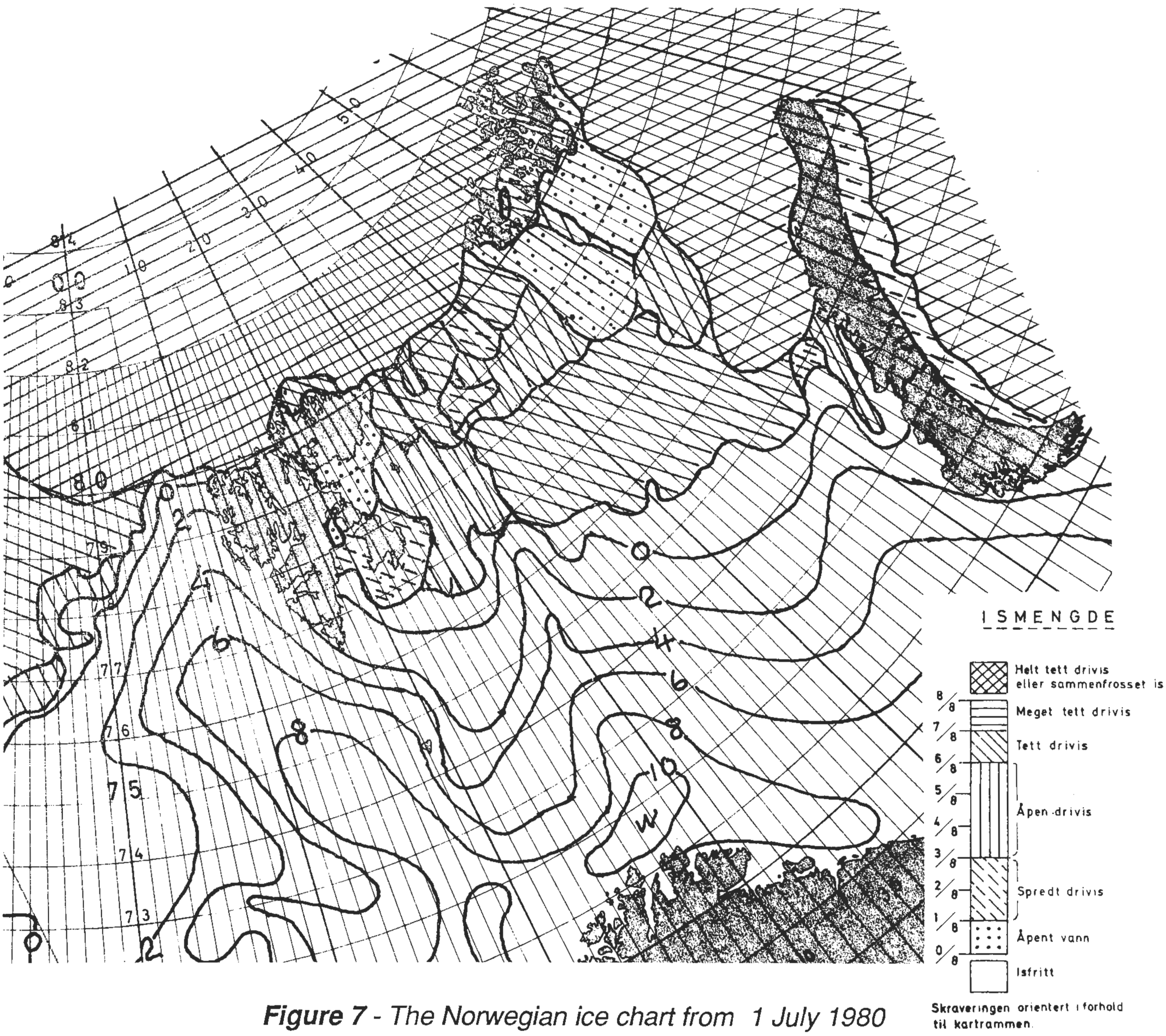


***Figure 7** - The Norwegian ice chart from 1 July 1980*

The Norwegian ice chart from 1 July 1980 (fig. 7) gives an overall view of the ice situation at the beginning of the YMER-80 expedition and shows an ice situation close to normal. A NOAA, AVHRR quick-look image received by the telemetry station in Tromsoe 29 June (fig. 8) givs a more detailed picture of the ice condition and indicates a situatuon slightly lighter than normal. The northern limit of the the heavier ice with concentrations higher than 7-8/10 lies north of 80^{O} N and presses towards the northern coasts of Svalbard and Frans Josephs Land. Ice is drifting southward in 3 distintive toungs between the two groups of islands into the Barents Sea where it slowly disintegrats. A larger field of ice lies west of Novaja Semlja south to 75^{O}N. This ice is slowly melting and has totally disapeared by 20 June.

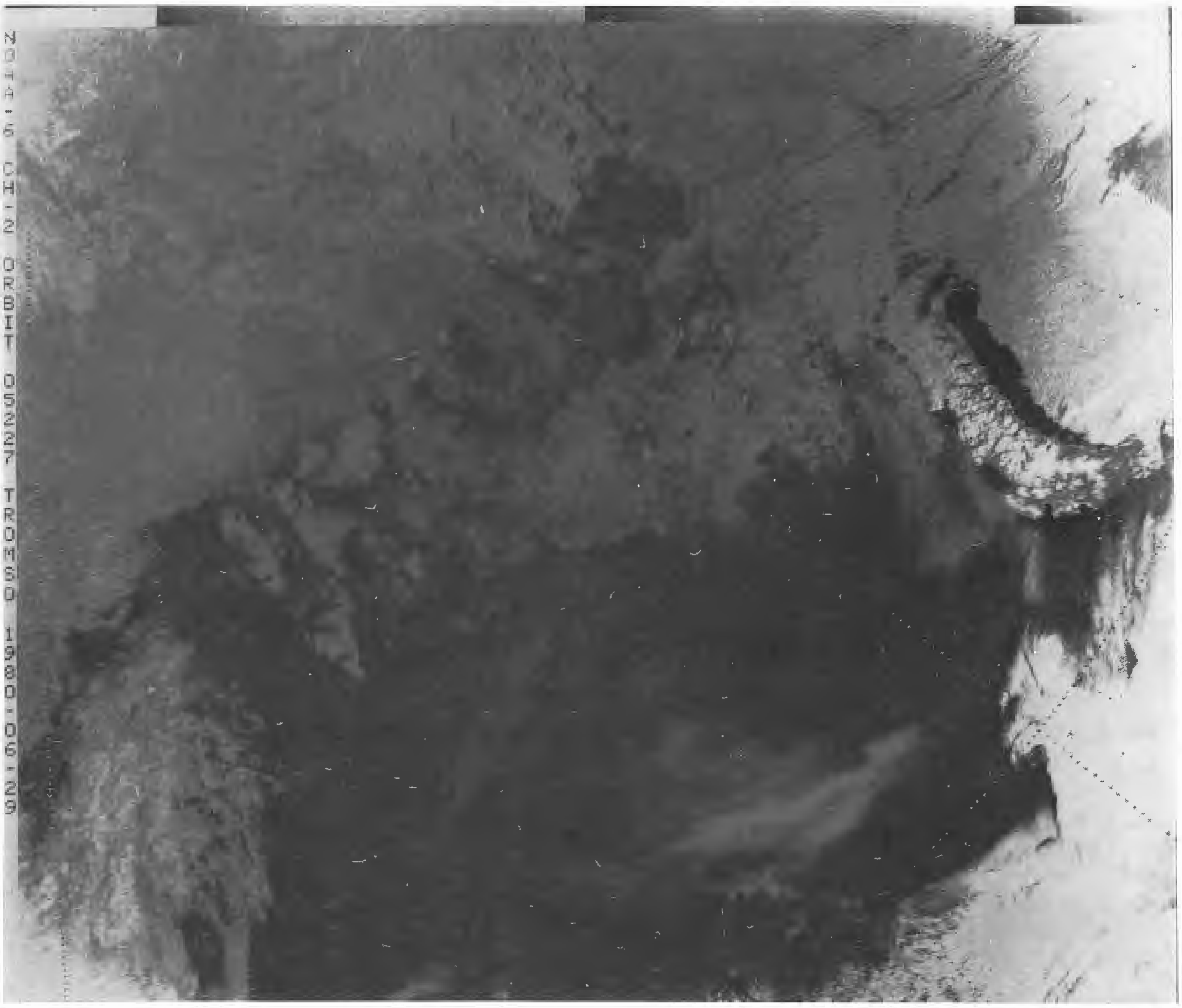


Figure 8 *- Satellite AVHRR quick-look image from 29 June 1980. Received by Tromsoe telemetry station*

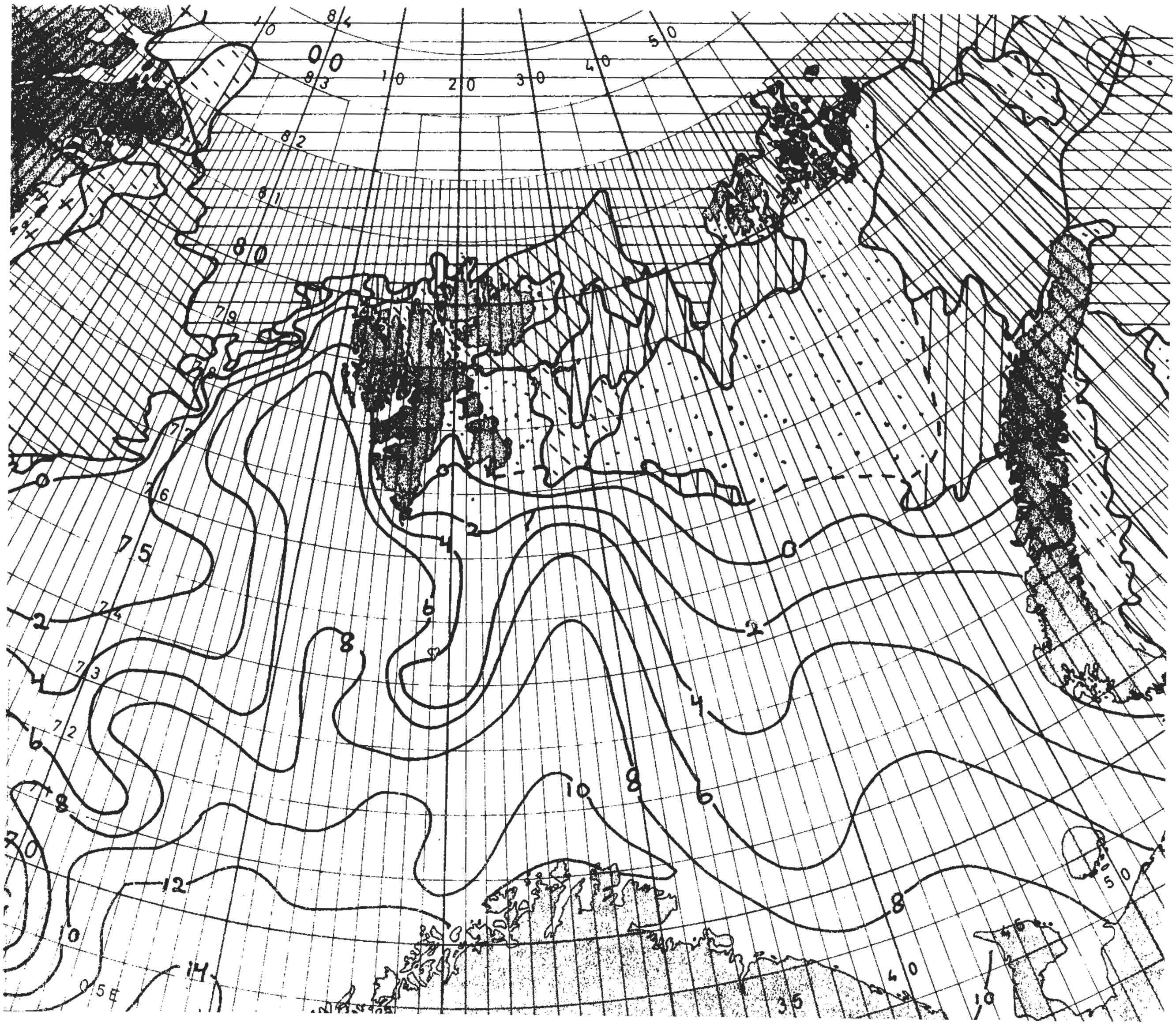


Figure 9 *- The Norwegian ice chart from 31 July 1980*

Otherwise the situation remained virtually unchanged during leg 1 as can bee seen from the ice chart in figure 8 which is from 31 July 1980. The southward ice drift continued and only after 28 June there were some open water at the northern coast of Svalbard. The area between 80^{O}N and 83^{O}N consisted mainly of first year ice and only 1-2/10 of multiyear ice occured. The thickness of the first year ice was 120 cm in the southern part, increasing to 180- 200 cm at 82^{O}30' N. The multiyear ice was 250 - 300 cm but rather rotten in the upper and lower 50-100 cm. Most of the ice was snow covered with melt ponds and thaw holes. In the area around 80^{O}N the melt ponds increased during the expedition and covered 30% of the surface at the end of leg 1. Between 82^{O} and 83^{O}N the melt pond concentration was lower or about 15-20%.

4.2 The weather

During the first part of the period a high pressure remained stationary over the northern part of the Norwegian sea while depressions moved from the south from Finland over Novaja Semlja to Frans Josephs Land. This gave north to northwesterly winds in the area north of Svalbard. From 15 July the situation reversed as a high pressure parked in the area south of Frans Josephs Land and lows started moving northward over the Norwegian Sea towards Svalbard. This gave mainly southerly winds in the expedition area.

The winds were mainly light to moderate. The most frequent wind speed lay in the intervall 4-6 m/s . Only in a few cases was the wind speed above 10 m/s. The frequencies of different wind directions and wind speeds are given in figure 10.

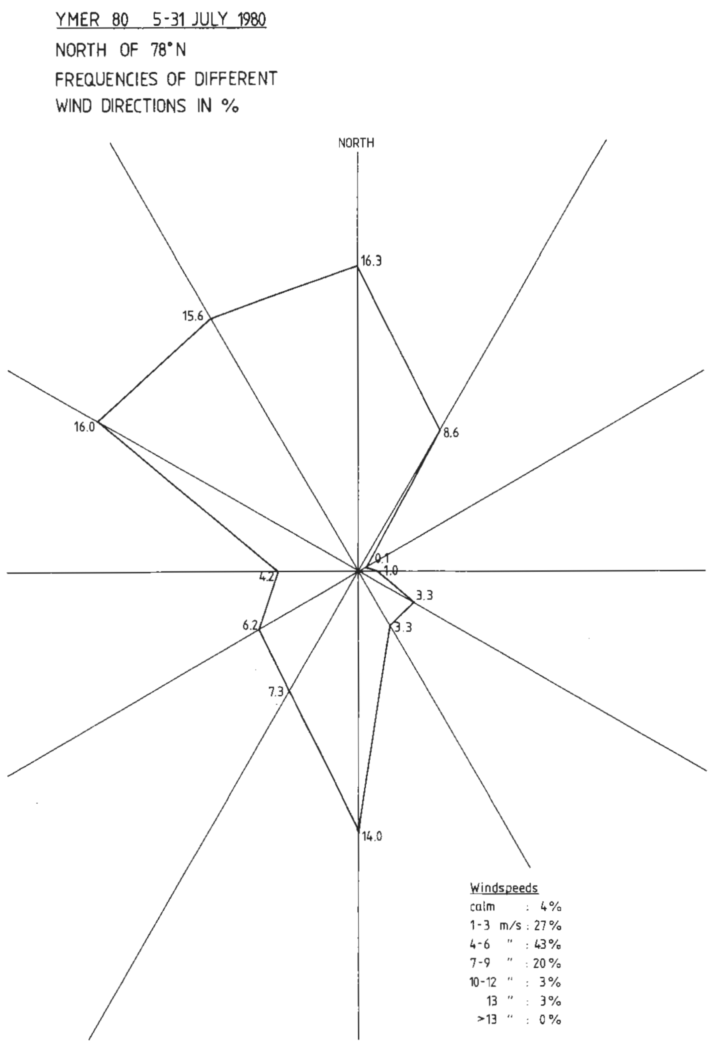


Figure 10 *- Frequencies of different wind directions and wind speeds for the period 5 - 31 July 1980 (north of78^{O}N)*

The temperature varied between -3.6°C and +3.4°C which were the lowest and highest temperatures measured. The mean temperature for the period was -0.45°C. Figure 11 shows the daily mean temperature as well as the maximum and minimum temperature during the period 5 to 31 July 1980.

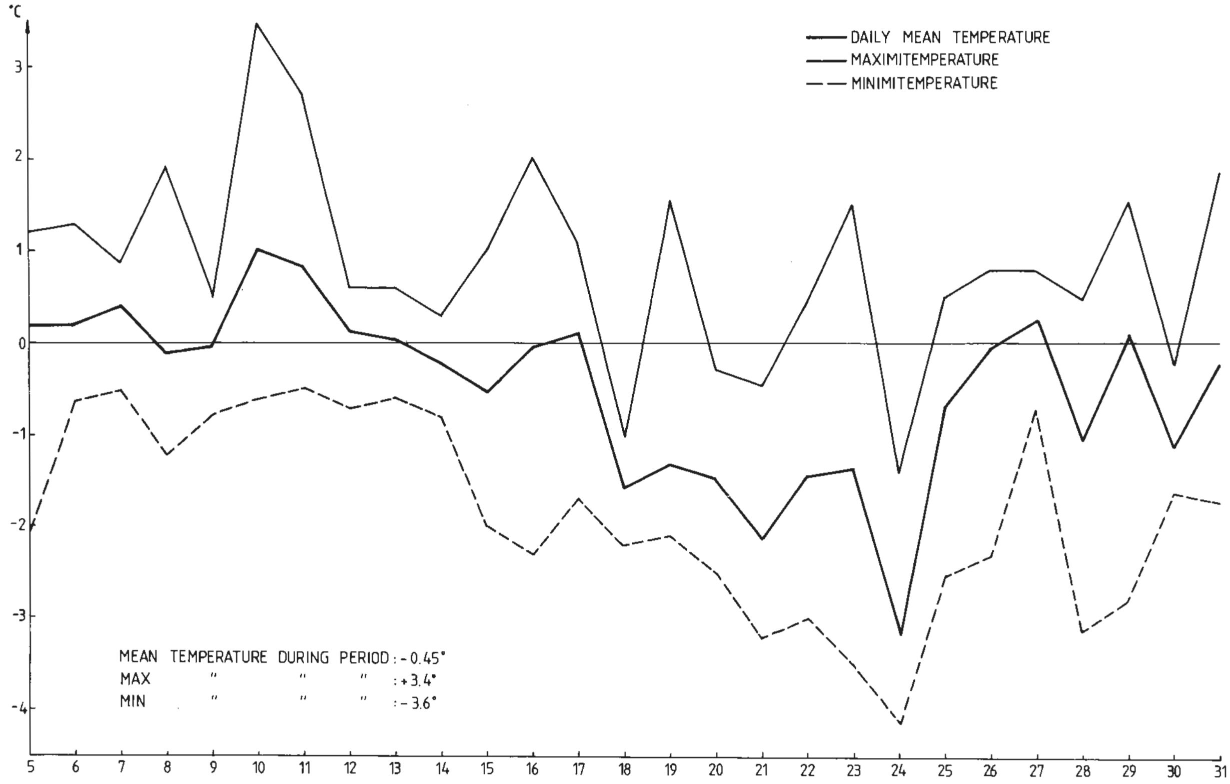


Figure 11 *- Daily mean temperature variations during period 5-31 July*

Cloud and fog conditions were also quite stable. The frequency of both was very high. Fog occured during 23 of the 27 days of the period. A total of 201 hours of fog was observed which means fog 31% of the time. In mean fog occured during 7 hours per day. The mean cloud cover was 6.8 eights or 85%. The variation in fog and cloud cover is given in figure 12.

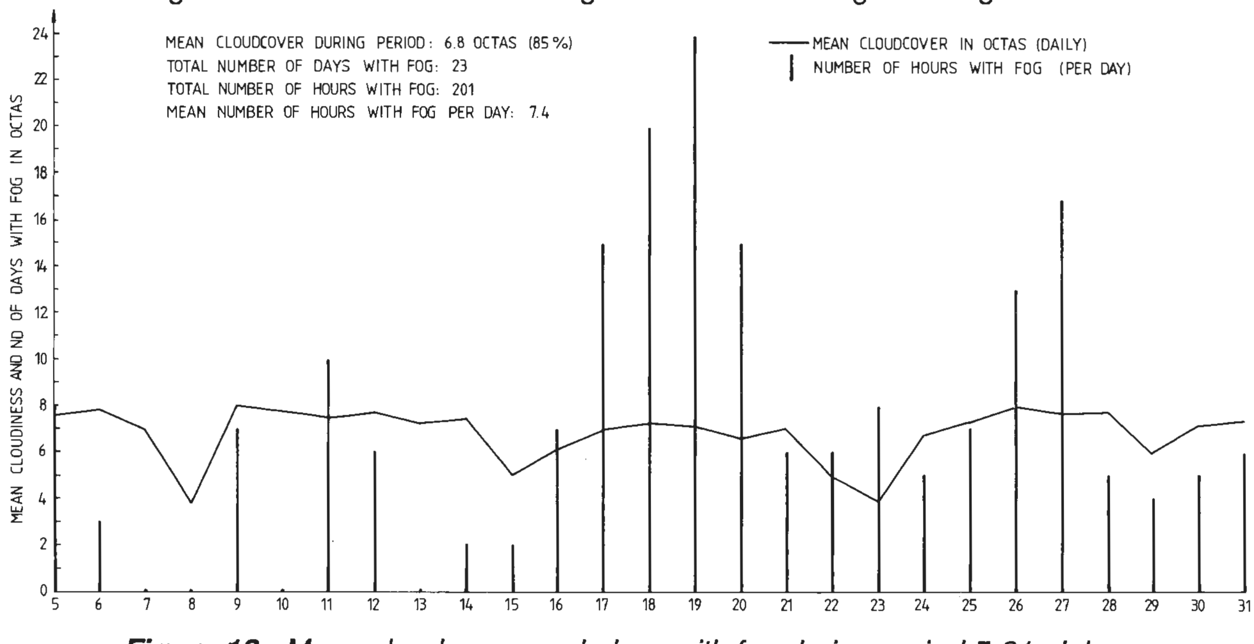


Figure 12 *- Mean cloud cover and days with fog during period 5-31 July*

5. OPERATIONAL USE OF SATELLITE DATA

5.1 LANDSAT data

Altogether were 57 LANDSAT images received onboard YMER during the whole expedition from 1 July to 11 September. Of these were 39 received during the first leg and 18 during the second. Some of the images,12 altogether, were produced in a smaller scale, 12,5 by 18 cm while the rest were of the size 17,5 by 25 cm. In some cases, particularly during the second leg, repeted transmissions were made, mainly due to unfavorable radio conditions.

ANNEX 1 contains a listing of LANDSAT images received on YMER. It includs the date of the image, the position (lat. and long.) of the centre of the image, the size, the quality, and cloud cover. The quality scale goes from 0 to 10 where 0 means totally unidentifiable and 10 the quality of the original. The highest quality mark given is 6 and the lowest 2. The mean quality was significantly better during the second leg, 4.9 against 3.8 for the first leg. The quality for the whole period was 4.2. Mark 3 is about the limit where any usefull information at all can be deduced from the image.

Fog and clouds were naturally severe limitations for the use of the LANDSAT images for ice mapping. Also in this respect the second leg proved better than the first. The mean cloud cover in images from the first leg was 55% and for the second 29% and for the whole period 45%. The cloud cover is estimated from the original images as it in most cases was impossible to distinguish clouds from ice on the images received onboard.

Figure 13 shows a, slightly reduced, original of a LANDSAT MSS image,(channel 7) from 23 July 1980. The island in the middle is Nordaustlandet in northern Svalbard. The small island to the NE is Storoeya. This was during the period YMER was in the area north of Frans Josephs Land. The ice can here be viewed in grete detail in the cloud free areas and it is easy to distinguish ice from clouds. Figure 14 shows the same image as received onboard YMER. This is of quality 5 and thus one of the better received. The glaciers and the land-ice boundaries can still be clearty seen but most of the details in the ice are lost and it is difficult to distinguish clouds and ice.

Figure 15 shows a sligtly reduced original image from 21 July 1980 from the area NE of Kvitoeja. The northern part of Kvitoeya can be seen in the lower central part of the figure and Victoria island in the open water area to the NE. Figure 16 shows the same image as received onboard YMER. This is of quality 3 and again demonstrates the difficulties in the interpretation of the information received.

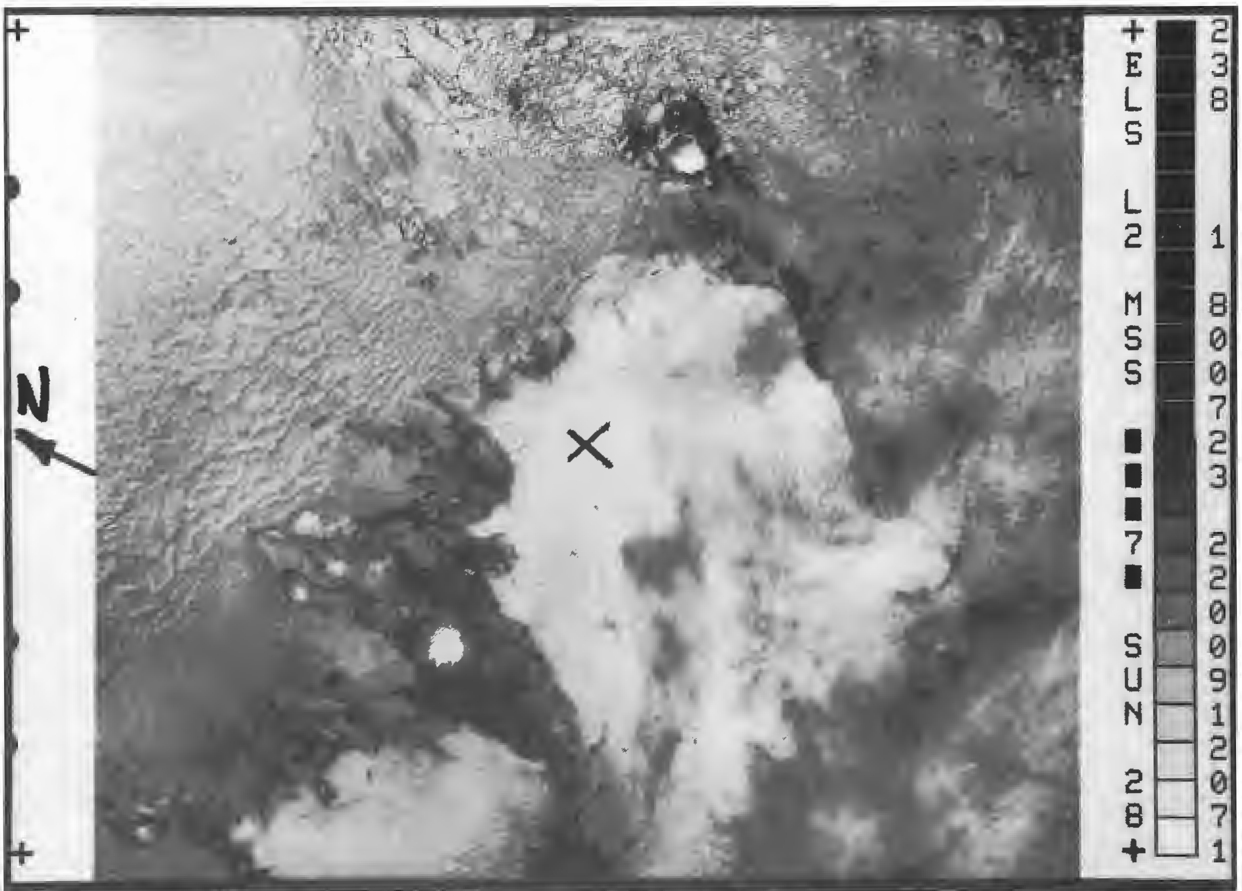
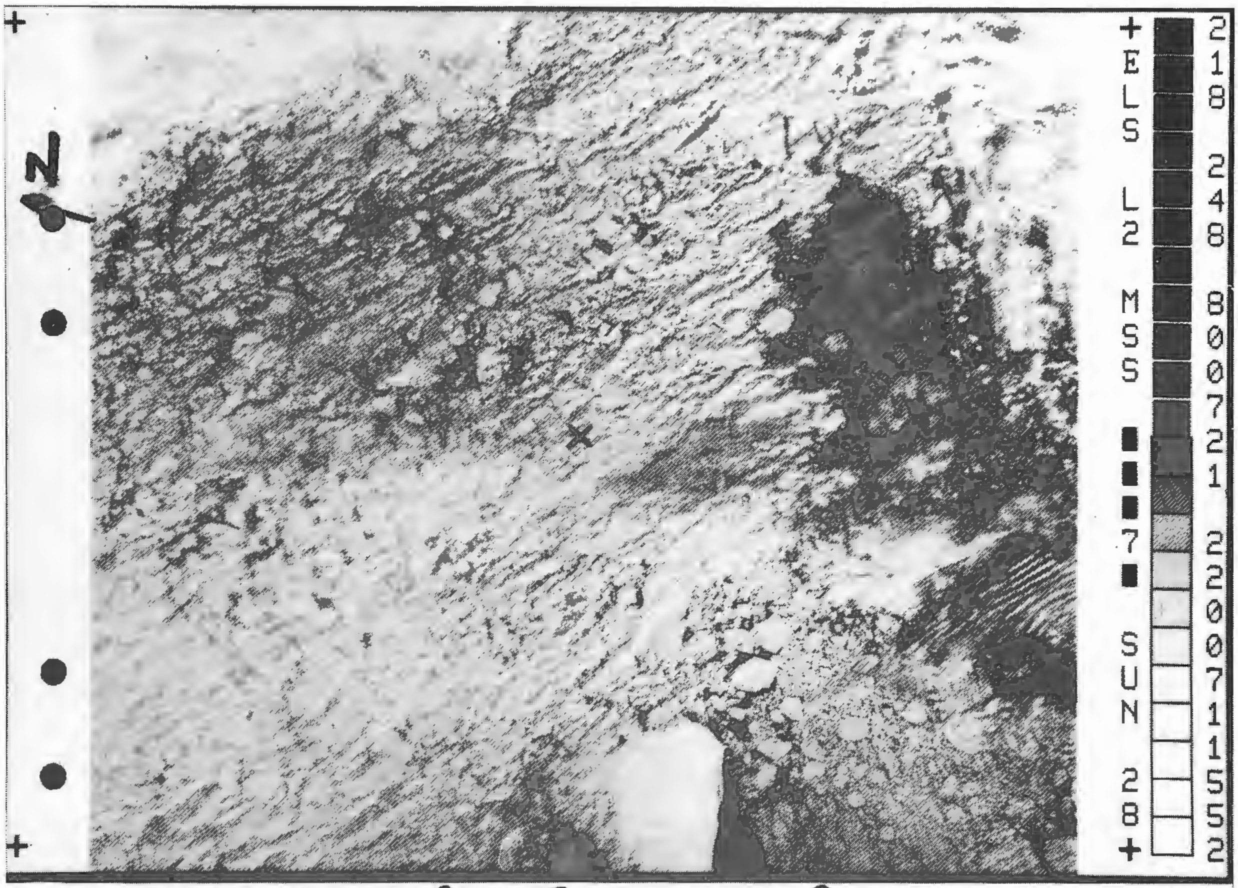


Figure 13 - *Copy of original LANDSAT MSS image (channel 7) from 23 July1980 1000 GMT before transmission to YMER.*

Figure 14 - *Copy of LANDSAT MSS image (channel 7) in Fig 13 as received onboard YMER from Kiruna via Aelvsborg radio.*



N80.55° E 36.10°

Figure 15 *- Copy of origional LANDSAT MSS image (channel 7) from 21 July 1980 1000 GMT before transmission to YMER.*

N80.55° E 36.10°

Figure 16 *- Copy of LANDSAT MSS image (channel 7) in Fig. 15 as received onboard YMER from Kiruna via Aelvsborg radio.*

5.2 NOAA APT data

The APT images were, as already described in chapter 4 , received regularely, several times a day directly from the NOAA satellites. Due to some technical difficulties no METEOR images were received. The meteorologist onboard was responsible for the station and it was he who calculated and decided which passages to take and used the images in his daily operational work. The use was twofold;

1. as an input to the weather analyses which were made 4 times a day and
2. as the basis for daily ice analyses.

Based on these analyses forecasts were made twice daily for the operations planning. At briefings, held twice daily at 0900 am and 0900 pm with the expedition leaders (operations and scientific) the weather and ice situation was presented together with forecasts. Based on these forecasts the work programme for the next 12 to 24 hours was decided. General outlooks for the period up to 48 hours were also made and used in the more general planning.

The usefullness of the NOAA APT images for weather analyses is illustrated by figures 17 and 18 which shows the satellite image received 8 July at 0939 GMT and the weather map from the same day at1800 GMT. The cloud system associated with a low pressure NE of Frans Josephs Land can be clearly seen on the satellite image and the movemen in a SSW direction can be followed. The same is the case with the low pressure SW of Novaja Semlja moving slowly SSE and filling.

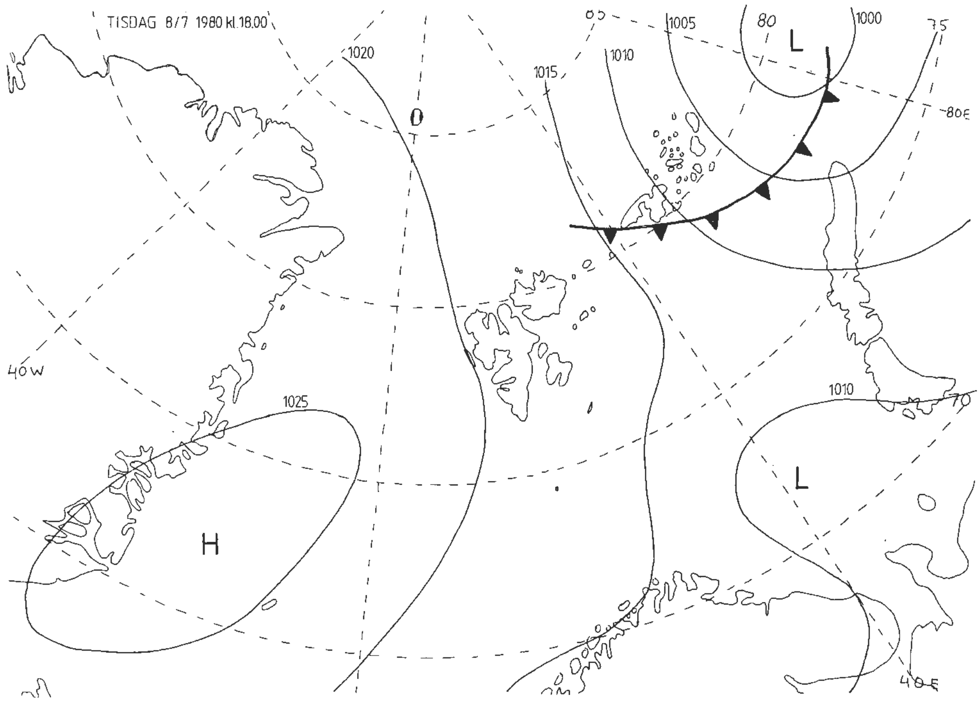


Figure 17 *- The weather map from 8 July 1980 1800 GMT. To be compared with the satellite image in figure 18.*

This satellite image givs very little information about the ice. It can however be seen that the ice lies against the northern coast of Nordaustlandet and is still drifting southward into the Barents Sea between Svalbard and Frans Josephs Land.

Figure 19 shows an APT image from 22 July at 1120 GMT and is from the infrared channel. Here is weather situation is favorable in the expedition area and again it can be seen that the ice is pressing against the northern coasts of the arctic islands and drifting southward into Barents Sea. At this time YMER is slowly heading NE off the coast of Semlja Alexandra at about 81^{O}N and 47^{O}E. The ice is becoming heavier and in this situation one is in desperate need of more detailed ice information for decissions on the best route to follow in penetrating the ice further NE. This information cannot be given by the APT images, partly due to the low resolution, both geometrically and radiometrically, and partly to the thin arctic fog covering most of the area. The fog is however so shallow that it is penetrated by some of the channels of the NOAA satellites but it requires carefull multispectral processing to enhance the details of the ice surface through the fog. This technique will be demonstrated later in the report.

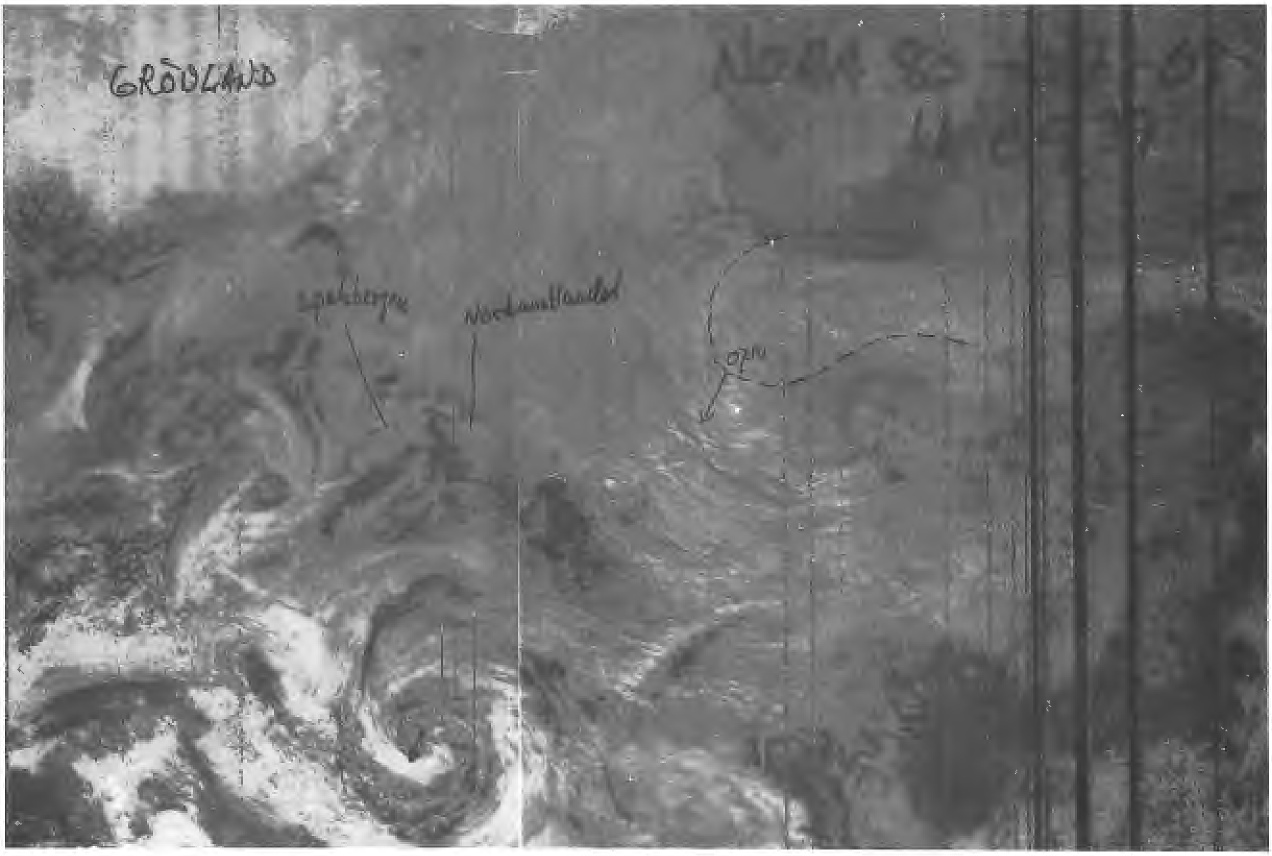


Figure 18 *- NOAA, APT satellite image received onboard YMER 8 July 1980.*
Note the cloud system associated with the low pressures
NE of Frans Josephs Land and southern Barents Sea.

Figure 19 *- NOAA; APT infrared ,satellite image received onboard YMER 22 July 1980, 1110 GMT*

As to the expedition it had to give up the plans to reach further NE and at 50°N turn arround in a wide sling towards N and W to return to the easier ice at about 80°N. Figure 20 shows the ice as seen from the deck of YMER at about 81°30'N 50°00'E when the decision to return was taken. The mean speed of the ship was then down to less than 2 knots.

The next example of an APT image is given in figure 21 showing the situation 28 July 1980 at 1040 GMT. It is from the visual channel. Low pressures are now moving from the Norwegian Sea over Barents Sea toward Frans Josephs Land and clouds are covering most of the area south of 80°N. The area north of Kvitoeya and Svalbard is however mostly cloudfree and it can be seen that the ice situation has improved over the last few days.

***Figure 20** - The ice at $81^{o}30'N$, $50^{o}E$ as seen from the deck of YMER.*

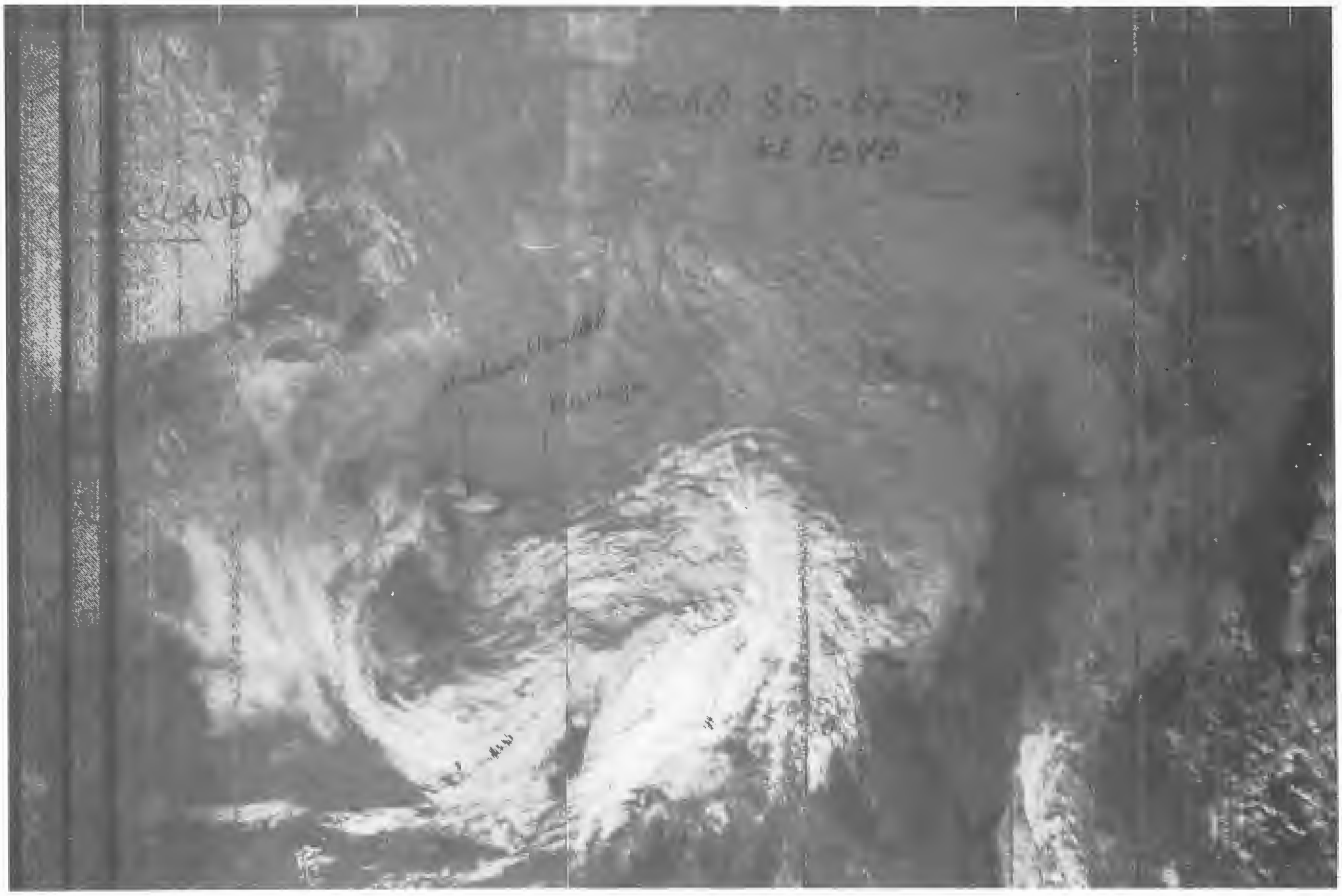


***Figure 21** - NOAA, APT image ,visual channel, received onboard YMER 28 July 1980 ,1040 GMT.*

6. POST-PROCESSING OF NOAA AVHRR DATA

The NOAA satellites provides, as described in chapter 2 information in 5 spectrel intervalls, here called channels, ranging from the visual through near infrared to thermal infrared. The underlaying surface have different signatures in each of these channels and by combining them in different ways it is possible to distinguish features which in one single channel would have had the same signature and therefore look the same. This is in particular the case with snowcovered ice and low clouds and fog. The arctic fog will, in most cases be so shallow that the ice can be seen through it in the visual channels. In the infrared channels however, only the upper surface of the fog will be registered by the satellite. The same is the case with thin clouds, in particular high level cirrus clouds and low stratus. Other types of clouds will in most cases be obscuring the underlaying surface totally. Over ice the clouds will in many cases be difficult to distinguish from the ice itself in the visual channels but in the infrared the temperature difference will be significant enough to give a clear distinction. By combining several channels it is therefore possible to visualize the different features.

A very usefull technique is to assign the colours green, blue and red to three selected channels and to project these into one composite colour image. The colour composite shown in figure 22 is from 23 July 1980 at 0730 GMT and is obtained by projecting channel 1 in green, channel 3 in blue and channel 4 in red. By carefull monitoring of the colour intensity of each of the 3 channels it has been possible to obtaine a composite that in a illustrative way shows various features of interest. The image gives an overall view of the area between northern Norway, northeast Greenland and Frans Josephs Land. Svalbard is situated in the centre of the image. The blue is open water, the blue-white is sea ice and glaciers, yellow is fog or low stratus over ice, red is fog or low stratus over open water while dark yellow,pink and white represents medium and high level clouds.

YMER was at that time in the position 82^{o}10'N 50^{o}00'E, 75 nautical miles north of Semlja Georga in Frans Josphs Land.

Figure 23 shows the area between Svalbard and Frans Josephs Land on 23 July 1980 at 0908 GMT. It is a colour composite from NOAA 6 with ch 1 = green, ch 3 = blue and ch 4 = red. The approximate track of YMER from 21 July at1200 GMT to 23 July 0900 GMT is also shown. In this image more details in the ice can be seen and it can be noted that the route taken by YMER is not the optimum one. Further to the north the ice concentration was lower and it would have been easier to take the route indicated by the broken line. Also in this image water comes out as blue, ice as blue-white and fog and low stratus as yellow over ice and red over water.

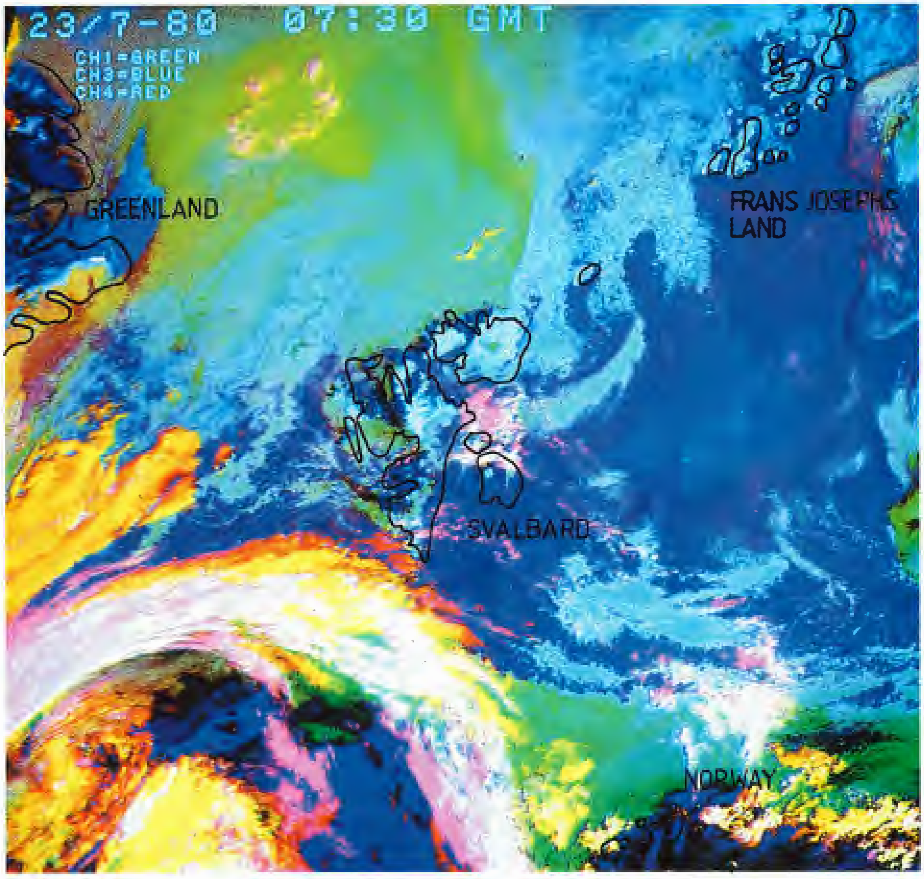


Figure 22 *- Multispectral AVHRR image from NOAA-6, 23 July 1980 0730 GMT. Ch1 = green, Ch 3 = blue, Ch 4 = red.*

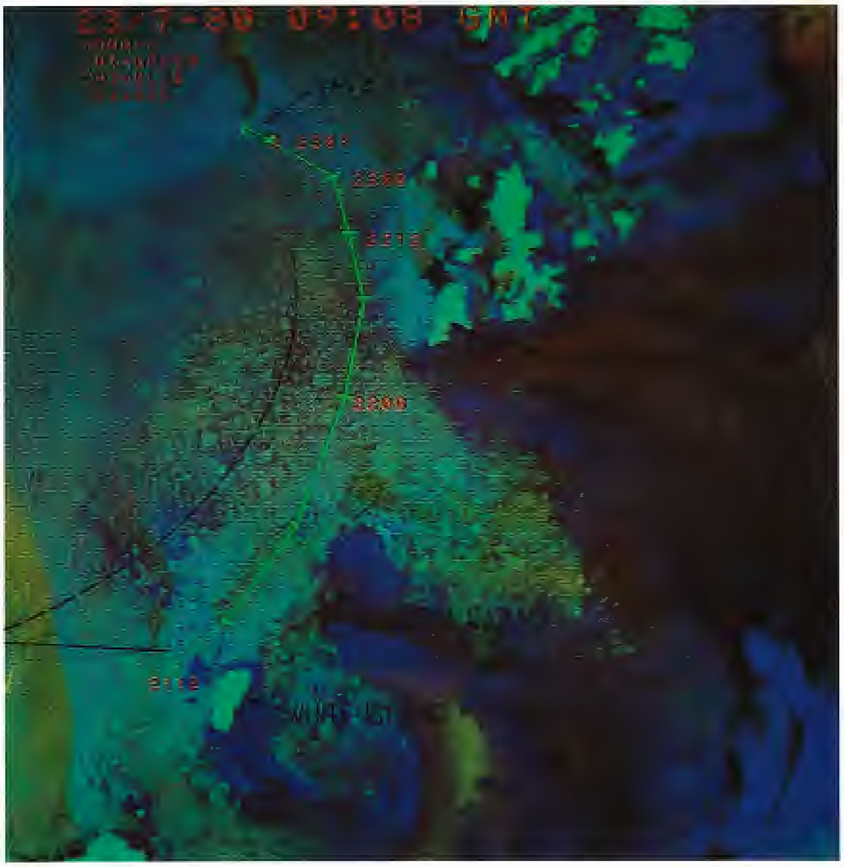


Figure 23 *- Multispectral AVHRR image from NOAA-6 , 23 July 1980 0908 GMT. Figures along Ymers route give day and hour.*

Note the increase in ice concentration from the position at 2212 to 2300 when the decission was taken to change heading from NE to N. This can be still better seen from figure 24 which is a close-up of the area north of Frans Josephs Land. The ice between 2300 and 2309 was in fact the heaviest and most difficult encountered during the first leg of the expedition. From the position at 2300 it would have been fairly easy to continue further east following the stippled line to point **A** but from there it would have been impossible to continue as the satellite image shows an ice concentration very close or equal to 100% in the area north of the island Rudolfa. With the westherly ice drift there is obviously also a conciderable ice pressure in the area north and east of O.Rudolfa. The only possibility of reaching the area east of 60^{O}E would be to follow a more norherly route between 82^{O} and 83^{O}N but even here carefull navigation and access to high quality and specially processed satellite images would be required.

The intensity level in each of the 5 AVHRR channels lays within the range 0 to 255. By selecting characteristic test areas and print out statististical histograms it is possible to find out the intensity intervalls within which given parameters lay. Such statistics for channel 2 shows that water has intensities ranging from 13 to 25 and ice from 38 to 48. The histograms are shown in figure 26 a. and b.

By giving all pixels with an intensity value lower than 38 a blue colour and pixels with value 38 and higher white an ice concentration map can be constructed. Figure 25 shows the distribution ice/water from channel 2 on 23 July at 0908 GMT.

Apart from the left part if the image which is outside the area of interest for the YMER expedition two areas with very high ice concentrations stands out. The one marked **A** on the figure YMER managed to navigate through with difficulties. The one marked **B** would have made it close to impossible fo YMER to go further east. With this type of information onboard it is however clear that it would have been possible to find a navigable way eastward and one which seems possible is indicated by the dotted line in figure 25.

The NOAA, AVHRR images with their wide coverage and high repetitivity can be of greate value in ice mapping. One major drawback is the sensibility to clouds and fog but as the fog in the arctic normally is fairly shallow it is still possible to map the ice even under fog conditions. The resolution is also sufficient for a general mapping but if information is required about details in the ice or surface conditions of individual floes other sources of information are required.

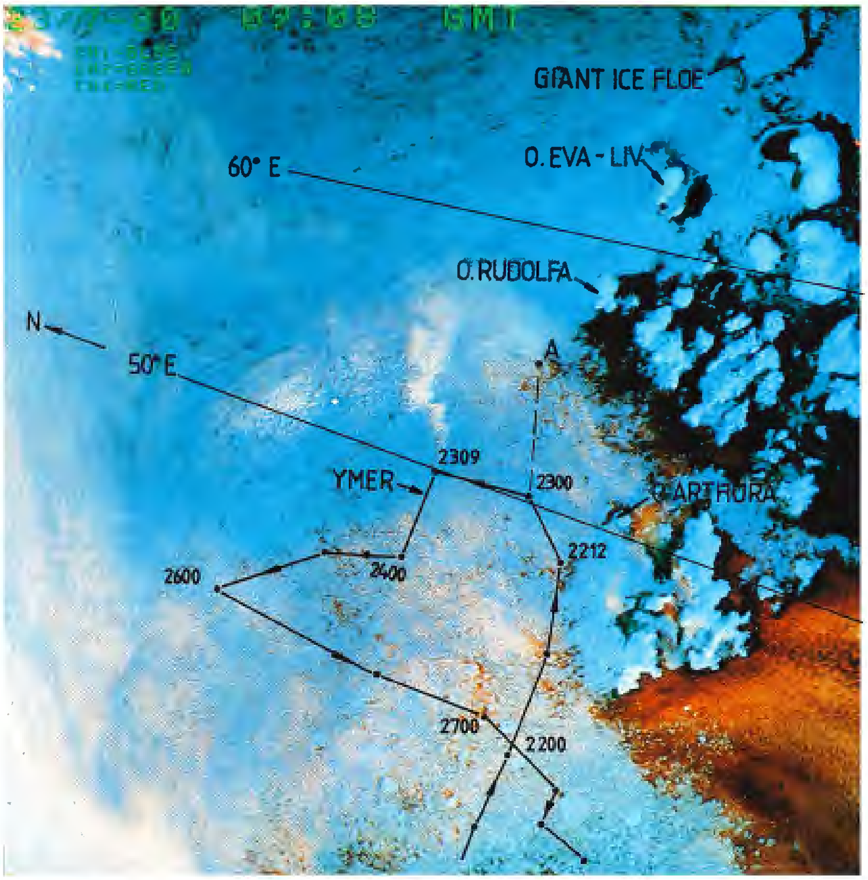


Figure 24 *- Multispectral AVHRR image from NOAA-6, 23 July 1980 0908 GMT. Ch 1 = blue, Ch 2 = green, Ch 4 = red.*

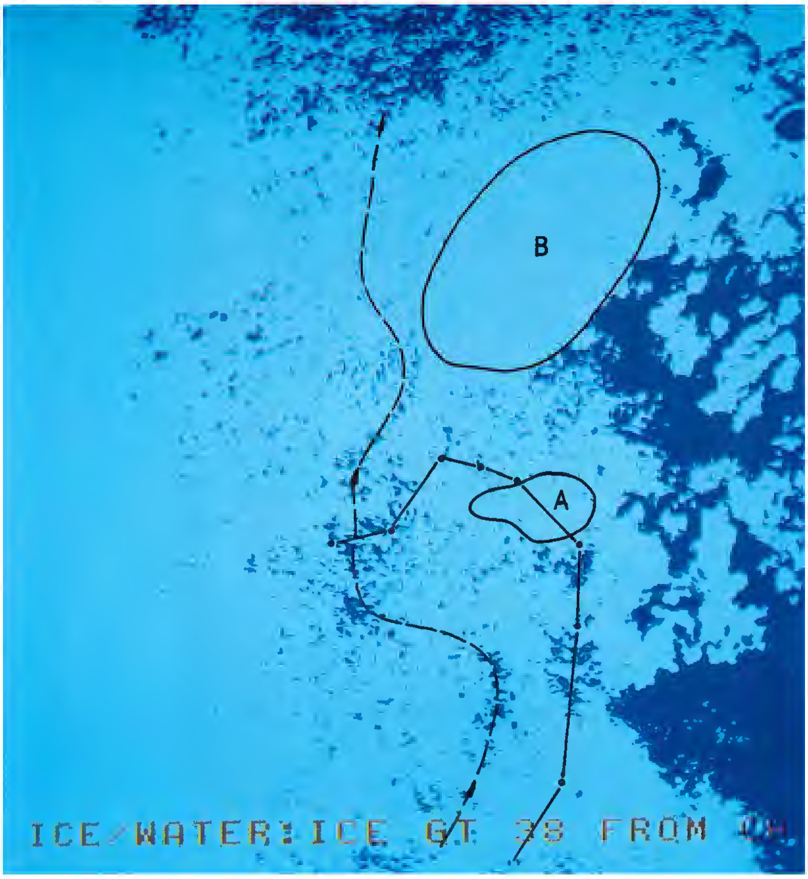


Figure 25 *- AVHRR image from NOAA-6 23 July 0908 GMT. Masked to show only water (blue) and ice (white).*

Figure 26- *Histogram showing the intensity distribution of areas with water (a.) and with sea ice (b.)*

Figure 28 shows a blow-up of the area between Svalbard and Frans Josephs Land and it illustrates how ice features can be seen through the fog which shows up as yellow on the image. On the far left side a band of low stratus is nearly totally obscuring the ice surface. Figure 29 shows a LANDSAT image for the same day. The image has a resolution of 180 by 160 meters. Here individual floes can be clearly identified though fog but clouds are obscuring more of the ice than the corresponding AVHRR image. Figure 27 shows a detail of figure 29. The resolution is 60 by 80 metres. Note the details of this multiyear icefloe and surrounding ice. The dark spots are melt ponds or thaw holes which covers about 30% of the surface.

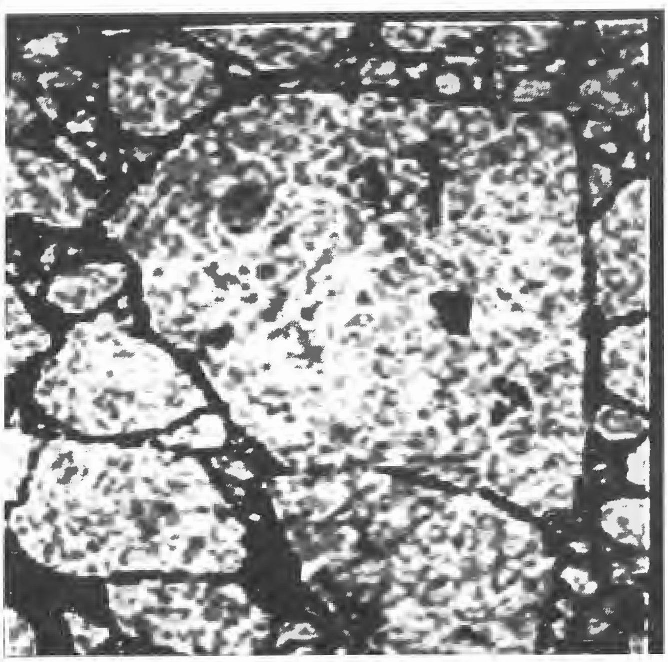


Figure 27 - *LANDSAT image showing a multiyear icefloe some 20 nm. north of Kvitoeya. Note the many melt ponds and thaw holes.*

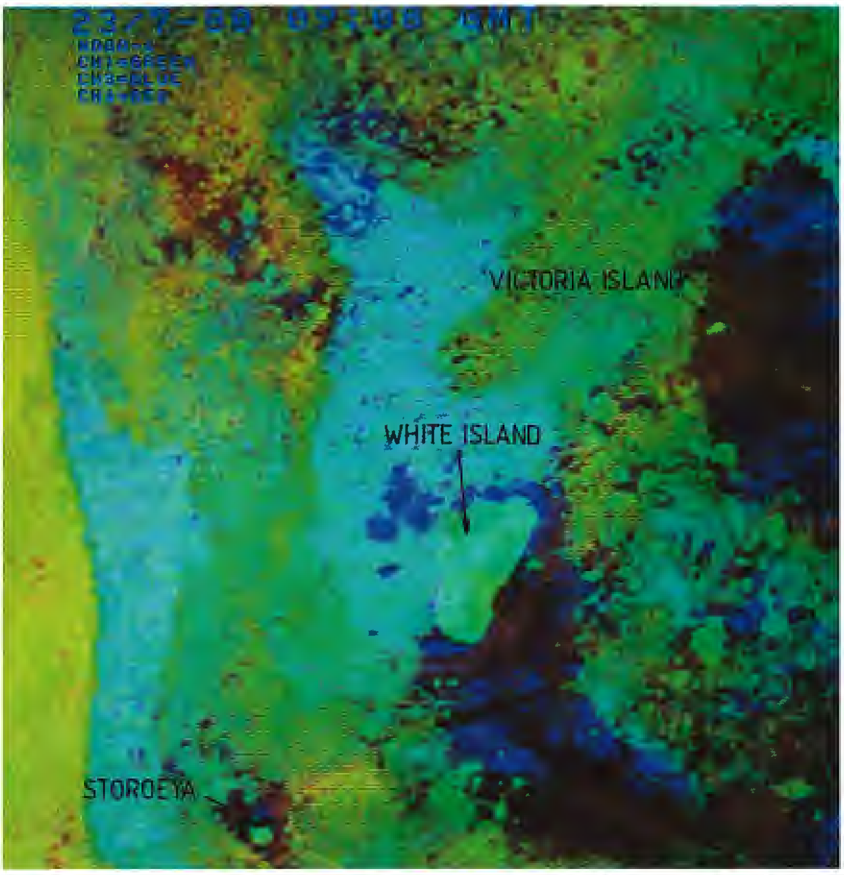


Figure 28 *- Multispectral AVHRR image from 23 June 1980 , 0900 GMT Ch 1 = green, Ch 3 = blue, Ch 4 = red. Shows water (blue), sea ice and glaciers (white), fog and stratus (yellow)*

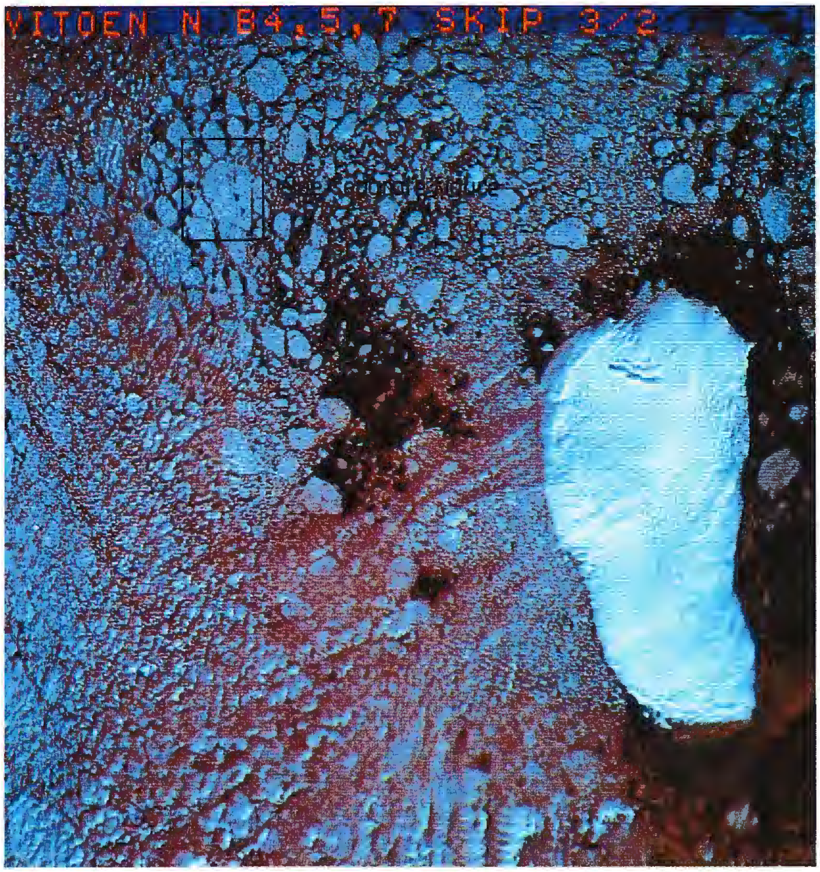


Figure 29 *- Multispectral LANDSAT image from 22 July 1000 GMT, showing Kvitoeya and surrounding areas.*

7. CONCLUSIONS

The experiment shows that APT images received directly onboard are of great value for the weather analyses. With the the very limited number of observations in the area it would have been difficult to prepare reliable weather analyses without the satellite information. For ice mapping the APT images proved to be of less value. It was possible to determine the major ice boundaries but within the ice only very major differences in ice concentration could be seen. For the routing of the ship through the ice the APT images were of little or no value.

The LANDSAT images received from Kiruna via Aelvsborgs radio were also of limited value for ice mapping partly due to the loss of quality in the transmission and partly due to the limited geographical coverage.

The AVHRR images proved, after an interactive processing, to be capable of providing information which would have been very usefull, not only for the weather analyses but also for ice mapping and thereby also for the day to day operations and navigation of the icebreaker.

The main drawback is however that the antenna requirements makes it very difficult and expensive to receive AVHRR data directly from the satellite on the icebreaker. One solution would be to receive the data and process them on a suitable land station and transmitt the analysed data eg. in the form of an ice map to the ship by radio facsimile or other means.

8. RECOMMENDATIONS

For future expeditions of this kind it is recommended:

1.<u>That better use be made of the data available from the NOAA weather satellites:</u>

a. By equipping the ship with a "digital" APT receiving station. Such a station will automatically convert the analogue signal received from the satellite to to digital form and allow image processing such as colour coding, enhancement and zooming of interesting areas, mixing of the two available channels (1 and 4) and temperature coding. Even if the resolution is still only 4 km. this type of processing will certainly bring out a lot of information making the APT images comparable with the AVHRR images shown in this report.

b. By arranging with a suitable land station to receive and process AVHRR data along the lines described in this report and for this station to transmitt the information to the ship in a suitable form,eg as an enhanced black and white image on which an analysis is superimposed.

2. That aircraft support be arranged:

By installing equipment for the reception of SLAR or SAR information from aircraft detailed ice information could be received onboard. As SLAR/SAR is independant of cloud and fog conditions such overflights could be arranged under weather conditions when the satellites give unsufficient information.

3. Future use of satellite microwave data

In the beginning of the 90-ties the first European active microwave satellite (ERS-1) will be in orbit. This satellite will carry an active microwave instrument (AMI) including an imaging SAR which will make available high resolution (25m), weather independant, ice information for large areas in the arctic. Preparations for the processing and use of these data have already been started but should to be intensified.

9. ACKNOWLEDGEMENTS

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ANNEX 1

LANDSAT MSS IMAGES RECEIVED ONBOARD YMER

DATE	POSITION		SIZE	QUAL	CL %	REMARKS
LEG 1						
80-07-01	77.53 N	24.89 E	S	4	30	
80-07-03	78.48	27.41 E	S	4	10	
80-07-07	80.55	69.09 E	S	3	50	
80-07-07	80.02	35.15 E	S	4	40	
80-07-08	80.02	33.71 E	S	2	-	
80-07-09	79.32	25.07 E	S	6	10	2 copies
80-07-09	78.48	18.80 E	S	6	10	
80-07-10	79.32	23.63 E	S	5	30	
80-07-10	80.02	30.84 E	S	5	98	
80-07-12	78.48	14.50 E	L	4	90	
80-07-12	79.32	20.77 E	L	3	40	
80-07-13	80.02	20.80 E	L	4	40	
80-07-13	80.02	26.54 E	L	3	90	
80-07-13	79.32	19.33 E	L	2	95	
80-07-14	79.32	17.90 E	L	4	80	
80-07-14	78.48	11.63 E	L	5	50	3 copies received
80-07-14	80.02	25.11 E	L	?	95	
80-07-14	80.02	19.37 E	S	2	80	
80-07-15	80.55	57.62 E	L	3	90	
80-07-15	78.48	10.20 E	L	3	75	
80-07-15	79.32	16.46 E	L	4	30	
80-07-16	79.32	15.03 E	L	4	60	
80-07-16	80.02	22.24 E	L	3	70	
80-07-17	80.55	28.93 E	S	5	75	
80-07-19	80.05	26.06 E	L	5	50	
80-07-19	80.55	27.50 E	L	4	60	
80-07-19	80.88	34,95 E	L	4	80	
80-07-20	80.02	16.50 E	L	5	10	
80-07-21	80.02	27.97 E	L	2	90	
80-07-21	80.55	36.10 E	L	3	80	
80-07-23	80.02	25.11 E	L	5	50	2 copies
80-07-24	80.55	31.80 E	L	4	50	
80-07-25	80.55	30.37 E	L	5	60	
80-07-29	80.55	50.45 W	L	4	40	
80-07-29	80.02	16.50 E	L	5	60	
80-07-30	78.48	21.41 E	L	4	10	
80-07-30	80.02	40.88 E	L	5	20	2 copies
80-07-31	78.48	25.98 E	L	5	10	
80-08-04	80.02	33.xx E	L	4	60	
<u>Mean values leg 1</u>						
<u>Number of images: 39</u>				<u>3.8</u>	<u>53</u>	<u>9 copies</u>

DATE	POSITION		SIZE	QUAL	CL %	REMARKS
LEG 2						
80-08-13	79.32	13.59 E	L	4	60	
80-08-13	80.55	28.93 E	L	5	60	
80-08-14	80.55	27.55 E	S	4	40	
80-08-22	80.02	07.89 E	L	4	50	
80-08-23	80.02	19.36 E	L	6	10	3 copies
80-08-23	80.55	11.23 E	L	5	20	
80-08-24	77.53	13.83 E	L	6	10	
80-08-24	78.48	08.45 E	L	6	20	
80-08-24	79.32	02.18 E	L	6	30	2 copies received
80-07-25	80.55	30.37 E	L	4	70	
80-08-27	80.55	08.85 W	L	5	10	
80-08-28	79.32	07.92 W	L	6	0	3 copies
80-08-28	78.48	14.14 W	L	6	10	3 copies received
80-08-30	78.48	17.05 E	L	5	30	2 copies
80-09-01	80.55	01.68 E	L	4	20	
80-09-02	80.02	07.88 W	L	5	00	2 copies
80-09-02	80.55	00.25 W	L	4	00	2 copies
80-09-11	80.02	56.66 E	L	4	20	2 copies

Mean values leg 2

Number of images: 18	**4.9**	**29**	**19 copies**

Mean values leg 1 and 2

Number of images: 57	**4.2**	**45**	**28 copies**

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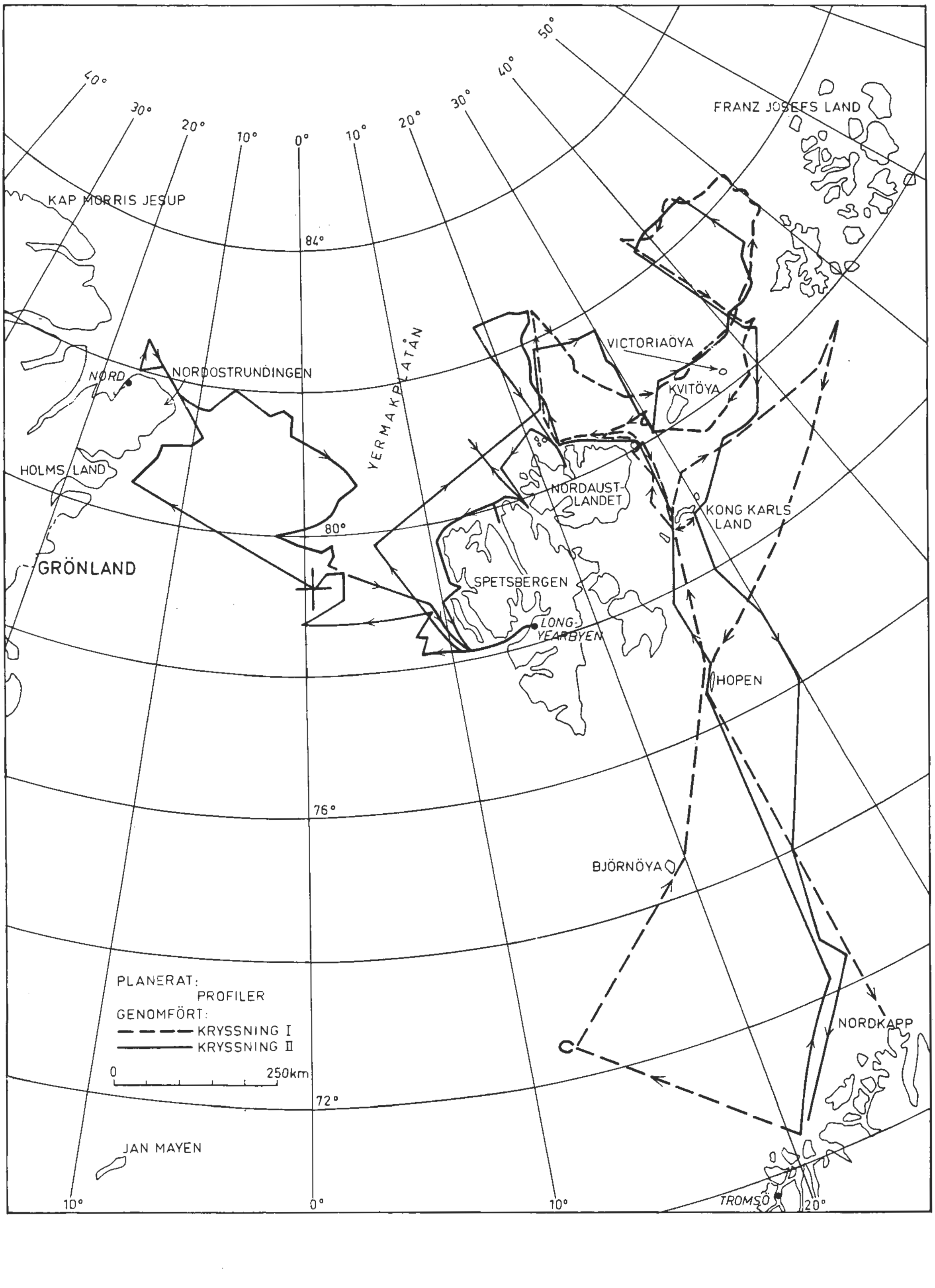

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