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Application of Artificial Satellites Data for Fisheries Studies in Japan

by

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1. Introduction:

The application of satellites data for fisheries studies can be considered from various points of view; the one being the application of remote sensed data and the other being that of DSC (Data Collection System) using satellites as communication measurements as in the case of the ARGOS Project. Although the latter may have many prospectful fields for fisheries oceanographic researches, and possibly for some biological surveys such as tracking of animals migration or transmitting acoustic data, the present report is confined to the application of remote sensed data.

The application of remote sensed data for fisheries stock assessment study can also be considered from many ways. As to the direct application to stock assessment the detection of fish schools or individual large animals like whales may be suggested. Detection of fishing vessels may be useful both for fishery surveillance and for collectiong data on fishing effort distribution which are most basic data for stock assessment. For the former however, we need an extremely highly sensible sensor by considering the size of fish schools. At present stage therefore it seems rather premature to expect too much for application of civil satellites for this purpose, eventhough there have been some experiences to locate fish schools by means of optical characteristics of ambient water such as glittering or water colour observed by naked eyes or colour films taken from aircraft flying in low altude as low as 100 to 300 meters. In South Africa there is a report detecting fish schools by means of bioluminescence measured by a

Low Light Level TV from an aircraft (Cram 1977). But no such experiments has been tried in Japan yet.

As to the latter kind of study, application of microwave sensors such as SAR (Synthetic Apperture Rador) has just been undertaken.

At present stage, therefore, the more prospectful application of remote sensed data for fisheries research is the oceanographic study which is applied to the stock assessment study in rather indirect way but nevertheless giving basic and important information on ambient environment in synoptic way.

2. Application of synoptic infra-red data:

Among many oceanographic parameters the most common and basic one is the temperature, in particular the surface temperature. (Tomczak 1977). It is not only because the temperature itself influences the behavior of fish schooling through "optimum temperature" (Hela and Laevastu 1961 etc.), but also because , rather to say, that the temperature pattern indicates the dynamic aspects of the ocean such as oceanic circulation, fronts, and upwellings etc. which has significancy in fisheries.

A regular service collecting surface temperature data, (and subsurface data to some extent) by commercial fishing vessels as well as national and prefectural research vessels, and disseminating them by radio facsimile has been for years operated in Japan.

For commercial fishermen in particular those dealing with tuna and skipjack in the Northwest Pacific such information is very valuable and is utilizes and welcome in order to locate fishing grounds, because the formation of fishing ground is shown to be associated with the front between the Kuroshio and Oyashio, and with the so-called middle sized "rings" along the front (Kawai 1979).

Another type of application of surface temperature information for fisheries is to utilize temperature pattern as the indicator of circulation, which gives information concerning transportation of eggs and larvae, and thus leading to the stock status of the future fishing season, for example, forecasting of the sardine fisheries based on the information of the occurence and variation of the meandering of the Kuroshio in relation of that of the cold water mass off southern Honshu (Watanabe et al. 1979 etc.). Adopting satellite data of NOAA-Series to obtain infra-red data has been undertaken for the fisheries servive which was mentioned before.

The main problems arising in practical application of infra-red data include besides the foundamental optimetric problems on the conversion from the radiance to temperatuae, (1) How to eliminate the hazardous effect of cloud and moisture, and (2) What kind of information does the skin temperature measured by a satellite sensor give for fisheries. The former concerns the data processing techniques, while the latter does the problem of fisheries oceanography.

As to the former problem, a number of picture elements, for example, ten times ten are clustered and histograms of radiance values are obtained both in open and cloud covered areas respectively, By comparing those of the mixed areas to them, the sea surface temperature in those mixed areas can be obtained. Furthermore the effect of cloud can be also diminished by overlapping a few number of consequent images of the same area unless cloud stands throughout the period of such overlapping.

Such synthesized picture was found very useful for locating oceanic fronts although this method cannot eliminate the staying cloud. At present the outstanding problem is how to develop an effective system acquiring, processing, and disseminating information as quick as possible in an adequate form so as to answer the requirement of both fishermen and scientists.

A regular service publishing surface temperature by using data of the Geostational Meteorological Satellite GMS-1 (Himawari) has been operated by Japan Meteorological Agency, which broadcast by radio facsimile the ten days average surface temperature map with 1°C interval. The time lag from the reception of the last data to broadcasting is five days. In this service the data are clustered for 1° x 1° grid, and all data for ten days are put together in order to eliminate the cloud cover. The size of the grid is somewhat too big to know the detailed pattern of oceanographic conditions in particular in coastal areas. But it is still very useful because it covers a very wide area, 100° in diameter in one picture. (Fig. 1)

3. Evaluation of infra-red data from viewpoint of fisheries oceanography:

(1) Comparison of synthesized GMS-1 data with in situ data:

Discrepancy of several degrees in Centigrade is usually inevitable in absolute value between the GMS-1 and the in situ data obtained by vessels so long as the surface temperature is concerned. One of the reasons for this discrepancy is the difference between the skin temperature measured by the satellite sensor and the surface temperature measured by thermometer dipped in the water; and moreover, the correction of vapor absorption is not sufficient enough. Notwithstanding such anomaly, the correlationship between the satellite-measured surface temperature and vessels data was found very high along meridional lines, and a good agreement was found in the location of fronts, and as well, that of warm and cold patches larger than about 100 km. in diameter (Yamanaka et al. 1980). (Fig. 2)

Accordingly it can be said that, putting aside the absolute temperature, the sea surface temperature map made by the GMS-1 infra-red data can well reflect the in situ surface temperature pattern. As to the fisheries, it is such temperature pattern as fronts, upwellings, warm and cold water masses rather than temperature itself which has more significance. Moreuver, because of the synopticity such maps give us some important information such as warm and cold water patches which are sometimes missed in vessels data which are sporadic both in time and space. Just like the case of the skipjack tuna in the Northwest Pacific which has been mentioned in the previous paragraph, the fishing ground of skipjack tuna in the tropical western Pacific was found also associated with the steep gradient of surface temperature seen in the GMS-1 map. (Fig. 3)

(2) Current pattern in the South Pacific:

By sesing such good coincidence of the ten days surface temperature maps of the North Pacific between satellite data and vessels data, it can be inferred similar coincidence will stand for the surface temperature pattern in the South Pacific likewise. An interesting finding is to have ascertained a southward warm current along the coast of Western Australia in addition to the well known another southward Eastern Australian

Current. The former is the recently named Leeuwin Current (Creswell et al. 1980) of which discovery can be traced back only to the last decade. As the waters off Northwest Australia is the spawning ground of the southern bluefin tuna (Thunnus maccoyii) , the tuna biologists had been supposing that there must be a southward current along the western coast of Australia because their larvae and juveniles occur in the offshore of the Southern Australia. The monitoring of this current by the satellite will therefore help us to increase our knowledge on transportation of eggs and larvae, and as well, fishing ground formation of the fish. (Fig. 4)

(3) Depicting oceanic fronts:

The pattern of surface fronts can be detected by the density of isothermal lines. But drawing of such lines is somewhat subjective in particular when they are drawn based on sporadic vessels data. Satellite data compiled on a CCT (convertible computor tape) can be effectively used as an alternative way by computing the vector pattern of the temperature gradient to produce better information of the front pattern. Examples are shown for the North Pacific. (Fig. 5) In the pictures the vector of temperature gradient is shown in the form of wedges

Two major zones are seen with steepest gradient. The one lies around 30°N, 130°-140°E and inclines northward with longotude reaching around 40°N at around 150°E. This zone corresponds in its location to that of the northern margin of the Kuroshio. In most cases, however, the area between 30°N and 40° N are apt to be covered by cloud; and therefore the pattern of the front off eastern Honshu is rather obscure. Another one lies between 20° to 30° N with some meandering. In the western part of the area dealt here, namely 130°-140°E it lies in rather lower latitude and also inclines somewhat northward up to about 28°N. The latter front is obvious in springtime from February to May particularly. The pattern of this front corresponds to the Subtropical Front Zone described by White et al.(1978).

In tropical area the direction of the gradient vector is somewhat unstable because of occurence of warm and cold patches.

The transpacific migration of the albacore tuna (Thunnus alalunga) in the north Pacific is considered to be affected by the pattern of the subtropical zone of the Central Pacific. That is, if the front is well developed the migration route of the fish is narrow and relatively well developed likewise, so the fish aggregate in their vicinity, thus resulting in a tendency for the fish to stay offshore waters for period of time , making delay in thier arrival to the nearshore fishing ground (Laurs et al. 1977).

Thus the monitoring of the subtropical front above Emperors Seamonuts (30°-50°,N, ca. 170°E) in the North Central Pacific was recommended among scientists of U.S.A. and Japan. As the area is too far away from both countries to carry out regular survey frequently, the application of satellite data has been taken up as a practical method.

Another example which GMS-1 data effectively have shown is the Subarctic Boundary in the Northwest Pacific which is located in middle forties degree north, and having to do with salmon distribution (Favorite et al. 1976). In this latitude GMS-1 data of springtime show a slowdown or inversion of the meridional temperature gradient, which indicates the influence of the warm Alaskan Stream. It is also the case which cannot always be seen from sporadic data collected by vessels.unless using subsurface data. (Fig. 6)

We may thus infer that eventhough the infra-red data collected by the satellite gives us only skin temperature distribution, their synopcity overcomes the defect in depicting the fronts and shows much information concerning the oceanic circulation pattern.

4. Comparison of synthesized infra-red data with a real time picture:

The processing of superimposing ten days successive data by clustering them into 1° x 1° grid may certainly give a synoptic pattern concerning the temperature distribution and fronts. But they picture thus made is too rough for studying fine structure of such fronts if they have short term variation of their pattern. In such case a real time picture is preferable to obtain better information even if it is likely that cloud causes much nuisance.

An example is shown on the front of the northern margin of the Kuroshio Extention area obtained by a single picture of GMS-1 on May 24, 1980 (Fig. 7). Compared it with the synthesized ten days data

(Fig.8) and a surface temperatue map obtained by vessels data (Fig.9) the former shows that the front is formed of a lot of tiny eddy-like meanderings. The comparison of two scenes, namely May 23 with May 24 1980 shows that the shape of the front changed even in 24 hours (Fig. 10).

Such microscopic eddies along the front can be detected by real time infra-red pictures made by other types of satellites too. (Fig. 11) In some fisheries it often occures that the school of fish makes patched and also planktonic animals such as Antarctic krill (Euphausia superba) behave likewise in such eddies. (Nasu 1979). Thus the shape of such microscopic eddies are of great value for understanding the fishing ground formation and distribution of eggs and larvae transported by the current.

As such eddies can hardly be found by conventional oceanographic survey by means of vessels, the remote sensing method is now , rather to say, one of the substantial method of oceanographic study rather than the auxiliary one which is only to supple the vessels data.

Some fishermen are anxious for such picture of real time image including the microspic eddies to be disseminated as quickly as possible and say that if they could obtain such picture it should be very useful for them even if no digital temperature could be available and even if no interpretation would have been made by professional fisheries oceanographers.

5. Application of ocean colour information:

Remote sensing of ocean colour by multiple spectrum scanner (MSS) sensor is another prospectful application for fisheries oceanography which is now being undertaken. Among satellites whose data are now available, LANDSAT series and NIMBUS-7 (CZCS) can afford such information.

(1) LANDSAT series:

The data of LANDSAT series are most widely applied for biological study on the land.

A very successful example showing the coastal current by water colour taken by the LANDSAT 3 is the picture of October 22, 1979 obtained above the central part of Japan. It shows a very clear eastward stream of the outflow of river water along the Kuroshio forming an eddy at the southern tip off the Izu Peninsula. It is indeed a kind of huge scale experiment to trace a current made by throwing pigment into the sea and monitoring from an aircraft. The pattern of the flow shows a high correlation with the in situ data obtained by the Prefectural Fisheries Experimental Station of Shizuoka. The area off the river mouth of the Tenryu is the spawning and nursary ground of the anchovy and mackerel, of which larvae are carried and are aggragated at offshore the Pensisula where the eddy is formed. Thus such information would be helpful for fisheries prediction. (Fig. 12)

Unfortunately however, it has been rather specially lucky case that such clear contrast could be observed in water colour. One reason of it is that the time interval of flights of the satellite above the same area is 18 days, too long for monitoring; and moreover, most range in the radiance histogram of a channel is occupied by land area leaving very few for the ocean. Therefore the application of the LANDSAT to detect fishing ground and fishing school from contrast of ocean colour can be expected only for some fortunate cases, an example being the report published in U.S.A.)Kemmerer et al. 1974).

(2) NIMBUS/CZCS:

The NIMBUS 7 has a more preferable sensor CZCS to detect the ocean colour pattern in relation to the distribution of biological productivity in relation with that of chlorophyll.

A study has been carried out as one of the projects under the framework of the US-Japan Cooperative Research and Developing Programme in the Field of Space Science and Technology. Unfortunately the supply of the CZCS data was not smooth enogh for the time being and the amount of data which has been analyzed hitherot is rather limitted. Nevertheless some prospectful result could be obtained .

The example shows the data of CZCS Orbit N. 1297, Jan. 26 1979. Originally it was planned to make the data correspond with the cruise to collect sea truth data in the East China Sea. The area was unfortunately covered by cloud, and only a few data were obtained offshore Honshu as sea truth data during January to March 1979. (Fig. 13) Among six channels of CZCS, Channel No. 6 is the infra-red of which image shows a clear meandering of the Kuroshio off South Honshu.

Trials were made to combine radiance velues of various channels in order to compare them with the chlorophyll-a data; for example;

log (C2/C1)	and Chl.-a	r=0.67
log (C5/C1)	and Chl.-a	r=0.68
log (C3/C4)	and Chl.-a	r=0.65
log (C3/C1+C4)	and Chl.-a	r=0.84

Here Ci means the value of the i-th channel, and r does the correlation coeficients.

A picture (Fig. 14) was made so as to show the ration C2/C1 in colour scale the higher value of the ratio, and the higher amount of chlorophyll shows the reddish colour.

The extremely high value is seen in Seto Inland Sea and in the Ise Bay. Although there were co corresponding in situ data, it conformed to our common knowledge.. It may be expected that if there had been good data for comparison, higher correlation might have been expected.

It is also interesting to see a rather clear boundary of water colour between the coastal and offshore waters along the north-eastern coast of Honshu, which usually is the fishing ground of purse seine boats.

A peculiarity is seen in the centeral part of the Japan Sea where the colour in the picture is shown red. Ohwada (1971) showed that the chlorophyll concentration in the northern part of the Japan Sea in the October 1969 was higher than that in the warm Tsushima Current. The pattern in the picture, however, was too much excessive. It seems this is due to the effect of cloud.

It may be a little premature to expect too much that the CZCS data will serve for stock assessment directly until more detailed study will be made both thesatellite and in situ data. At present such in situ data are too sparse. Another trouble is that the real time acquisition and processing of data by CZCS are not regularized. The frequency obtaining data of a specific target area by CZCS id three times as big as the LANDSAT. The area covered by a picture of the former is also about 30 times as big as the latter. At present, therefore , the application of this type of satellite for fisheries is rather expected in a rather indirect way, say, to know the synoptic pattern of the biological aspect of the ocean, -

which is very difficult to obtain by conventional method, in parelell to the temperature pattern, so as to give us foundamental information pertaining to fisheries and resources study.

6. Cost and benefit assessment of satellite application:

Application of sattelite data appears very expensive. To launch a satellite is of course tremendously expensive. The data processing is not a cheap task. But the amount of information obtained from a satellite is beyond comparison to that done by a research vessel.

Assuming that a research vessel can work for 20 years, 250 days a year, covering ten stations a day, each station having 10 items of observation, each having 10 bits (1052 scales) of information. Then the total amount of information obtained by a vessel is

$$20 \times 250 \times 10 \times 10 \times 10 = 5 \times 10^6 \text{ bits.}$$

While, assuming a satellite, taking NIMBUS 7 (CZCS) as example, can last three years, working 365 days a year, two hours a day, every scene lasting two minutes, (therefore obtaining 60 seenes a day), but 70% of them being cloudy, each scene including $1968 \times 970 \doteq 1.9 \times 10^6$ pixels, each pixcel having six channels, each having 16 bits of information.

Thus the total amount of information by a satellite is

$$3 \times 365 \times 60 \times (1-0.7) \times 1.9 \times 10^6 \times 6 \times 16 = 3.6 \times 10^{12}$$

Therefore a satellite can give us only considering a single mission, CZCS, information $(3.6 \times 10^{12}) / (1.9 \times 10^6) = 1.9 \times 10^6$ times as much as that of a vessel.

Of course it goes without saying many other factors should be taken into account. A vessel can obtain much important information which a setellite cannot and she can also concentrate her effort to a special target area and items. The bulky amount of information obtained by a satellite means at the same time processing of the data needs expenses.

Anyhow, however we may say that it is not correct to complain that the satellite application is prohibitingly costy method for fisheries and its research.

7. Acknowledgement:

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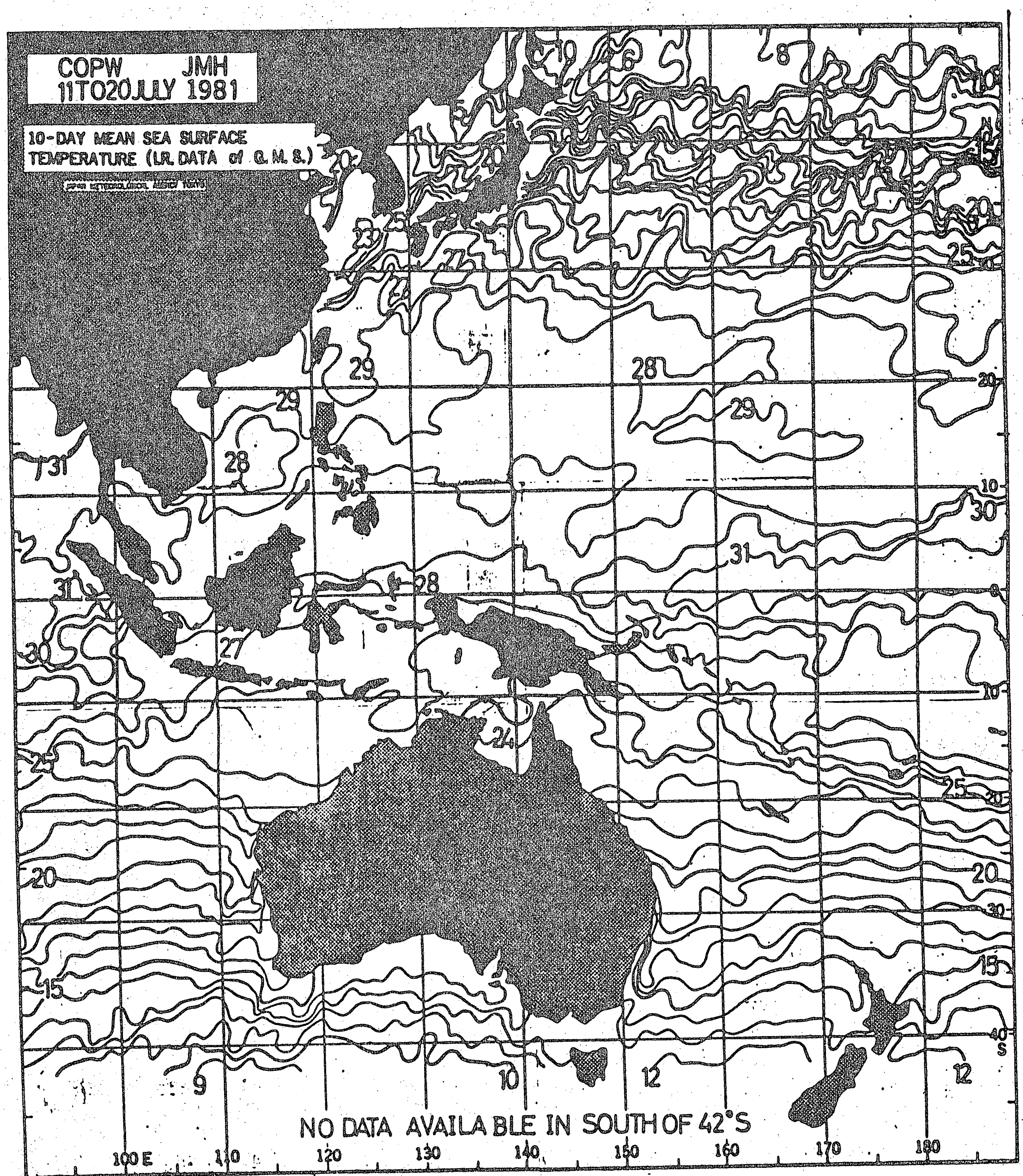


FIG. 1 GMS-1 TEN DAYS SST MAP BROADCAST BY FAX

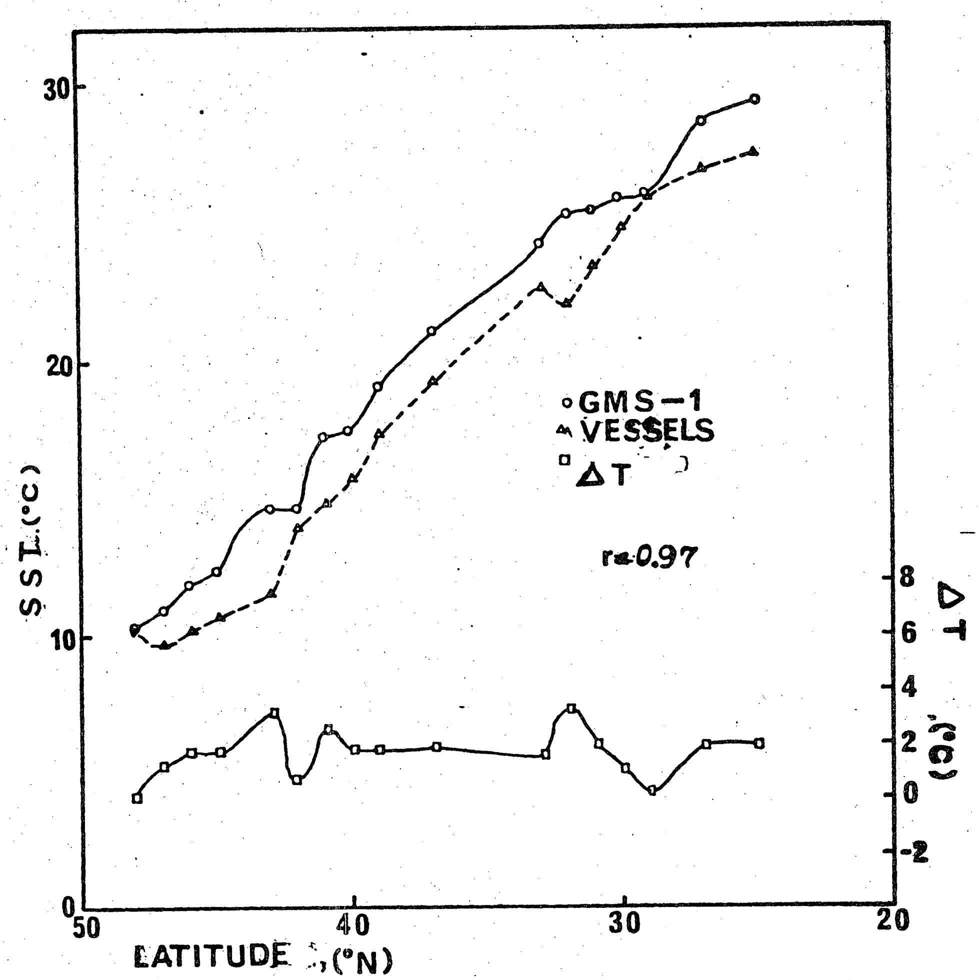


FIG. 2 COMPARISON OF SST MEASURED BY GMS-1 (BY TEN DAYS MAP)
AND VESSELS DATA AT 175°E
21 TO 31 OCTOBER 1978
(YAMANAKA AND FURUKAWA , 1980)

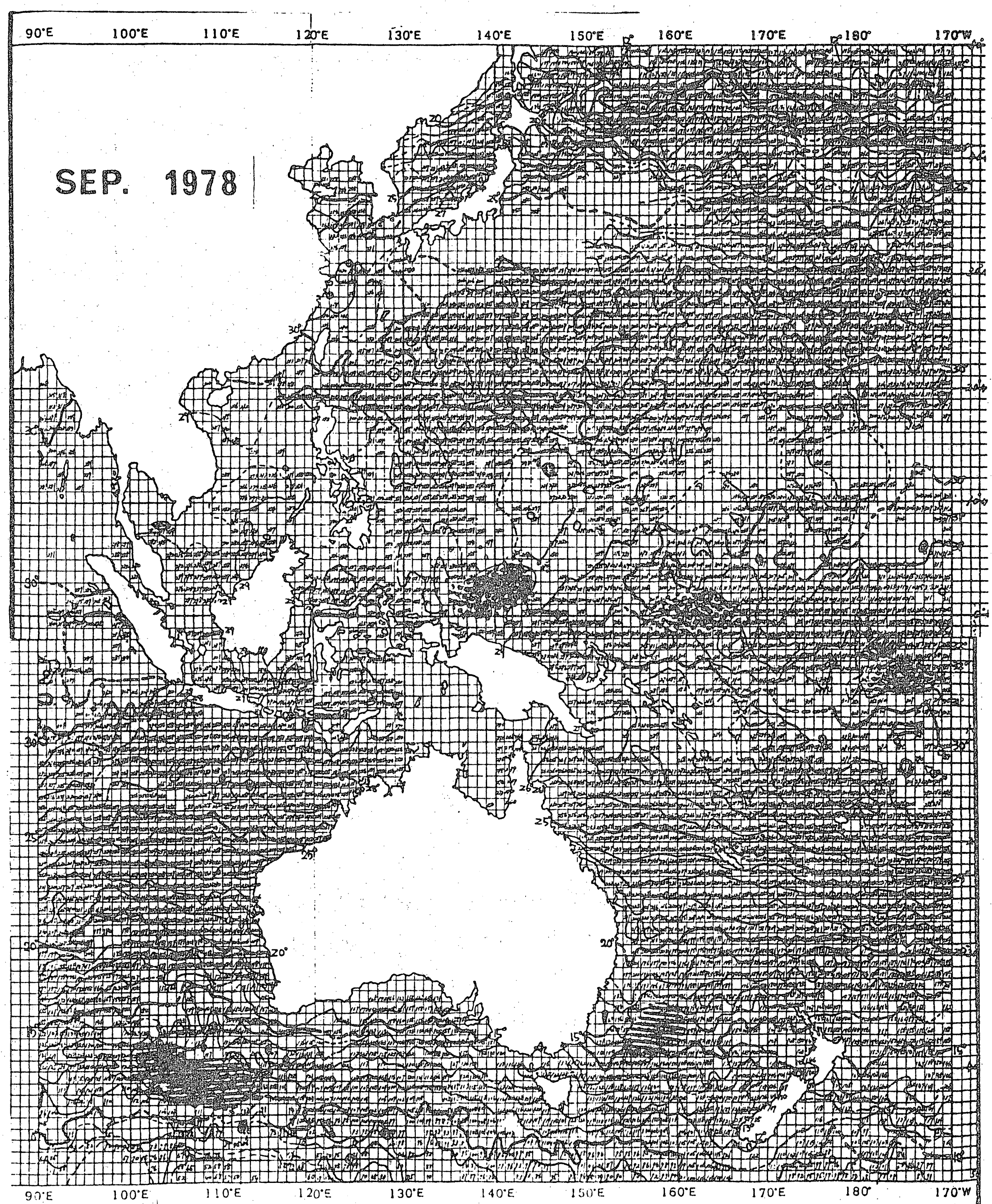


FIG. 3 FISHING GROUND FORMATION OF SKIPJACK IN THE TROPICAL PACIFIC (DOTTED AREA) AND THAT OF SOUTHERN BLUEFIN TUNA (HATCHED AREA)

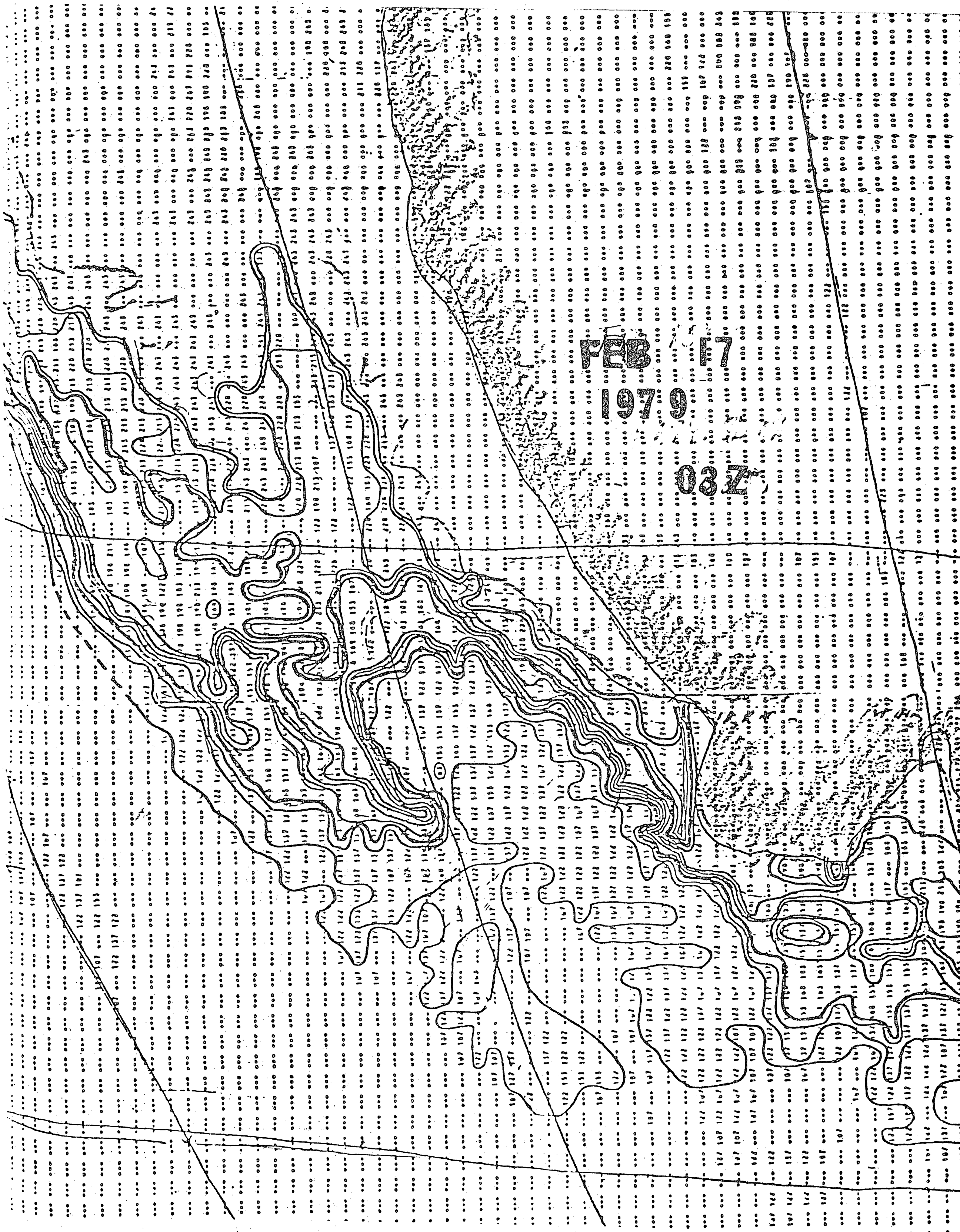


FIG. 4 SOUTH FLOWING LEEUWIN CURRENT SHOWN BY REAL TIME GMS-1 INFRA-RED DATA

(YAMANAKA MS)

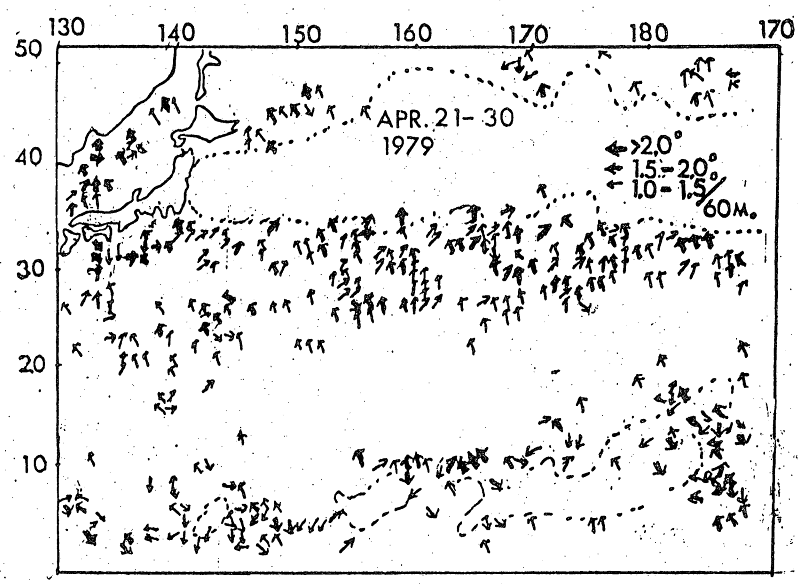


FIG. 5 TEMPERATURE GRADIENT IN THE NORTH PACIFIC COMPUTED FROM GMS-1 TEN DAYS DATA, APRIL 21-30, 1979 (Deg. C/ 60 Miles)

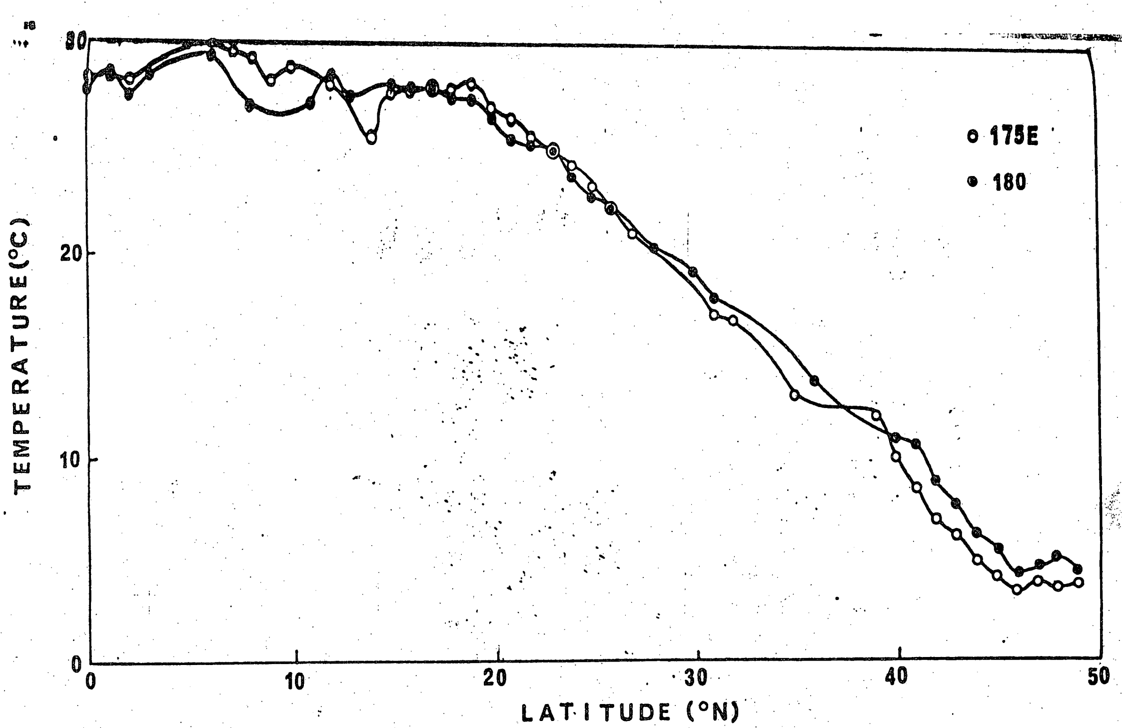


Fig. 6 MERIDIONAL CHANGE OF SEA SURFACE TEMPERATURE (MESURED BY GMS-1) MAR, 21-31 1979

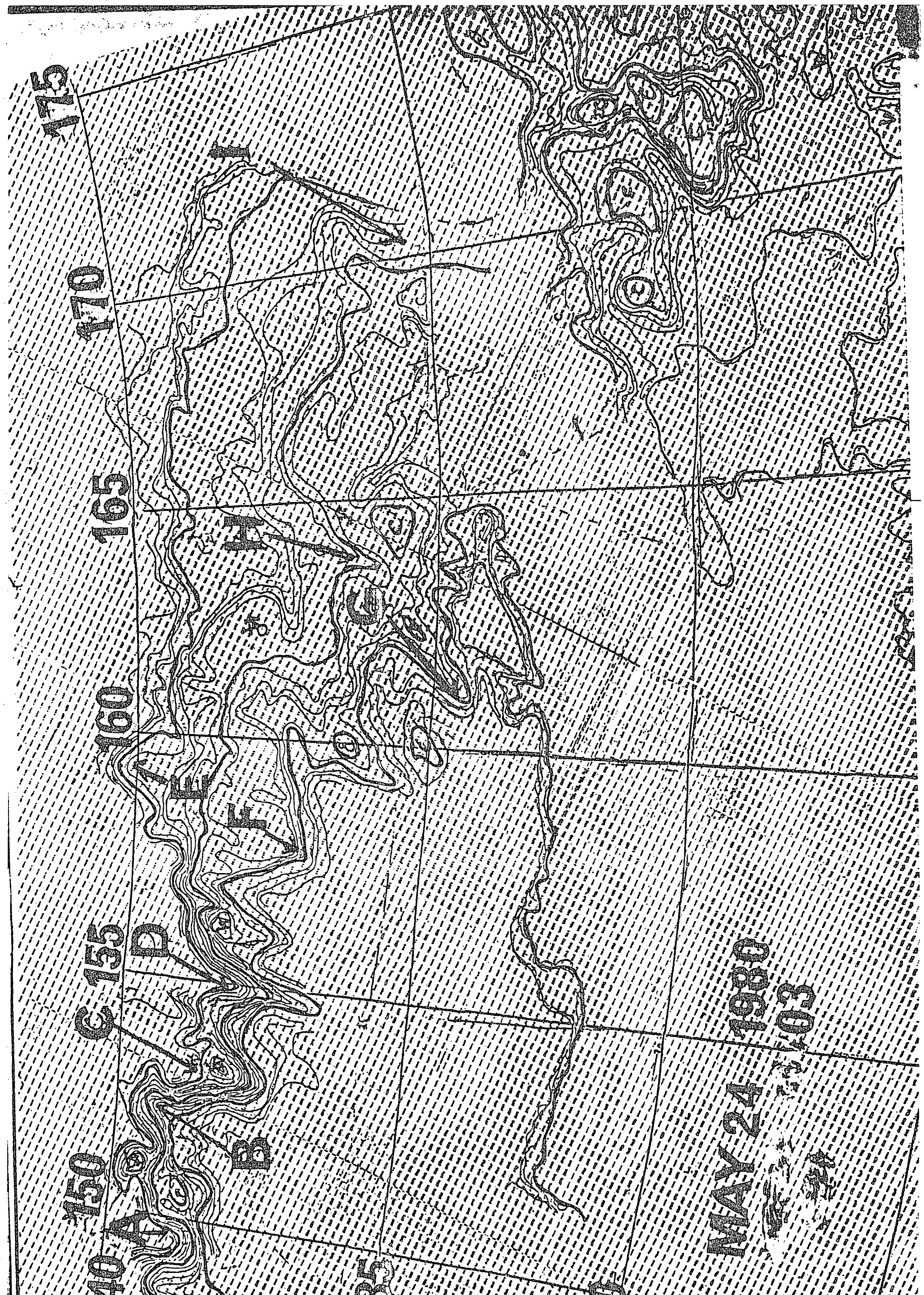


FIG. 7 FRONT PATTERN AT THE KUROSHIO EXTENTION AREA DRAWN BY GMS-1 ONE SCENE DATA

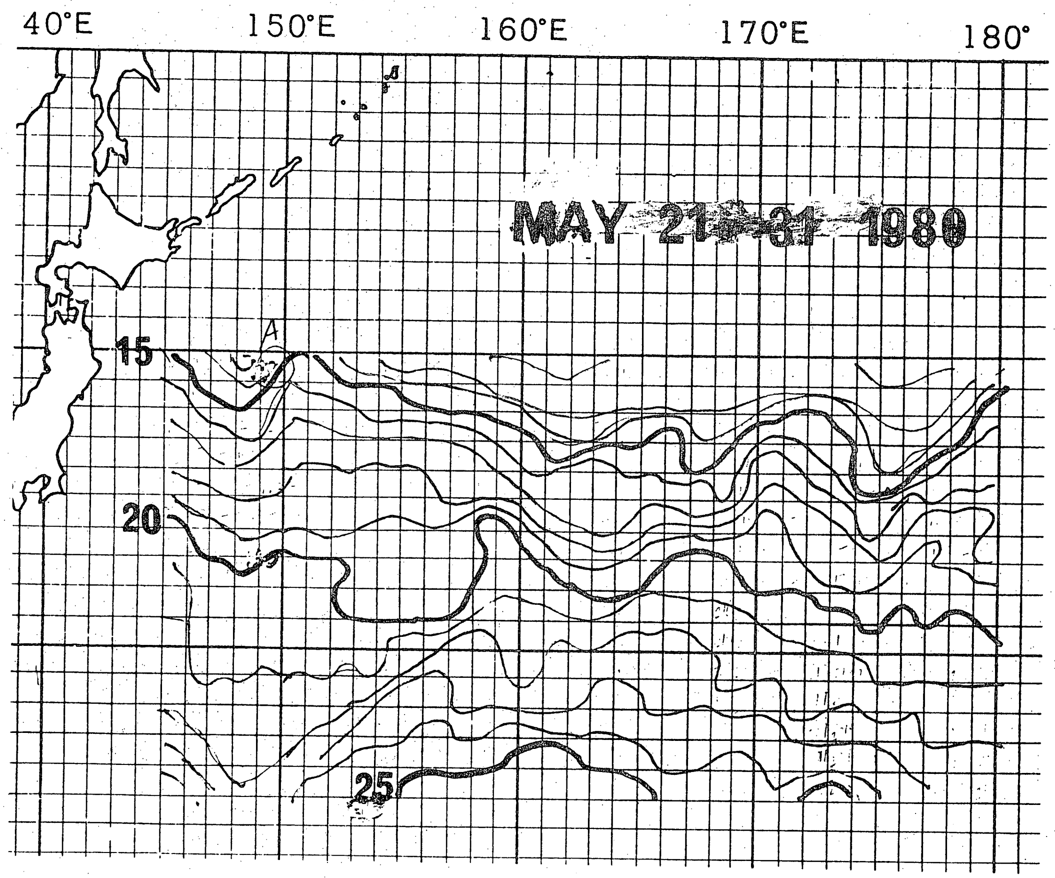


FIG. 8 FRONT PATTERN AT THE KUROSHIO EXTENTION AREA
MADE BY GMS-1 TEN DAYS DATA

5月21日〜5月25日　昭和55年5月26日発行　購読料　月額4,600円

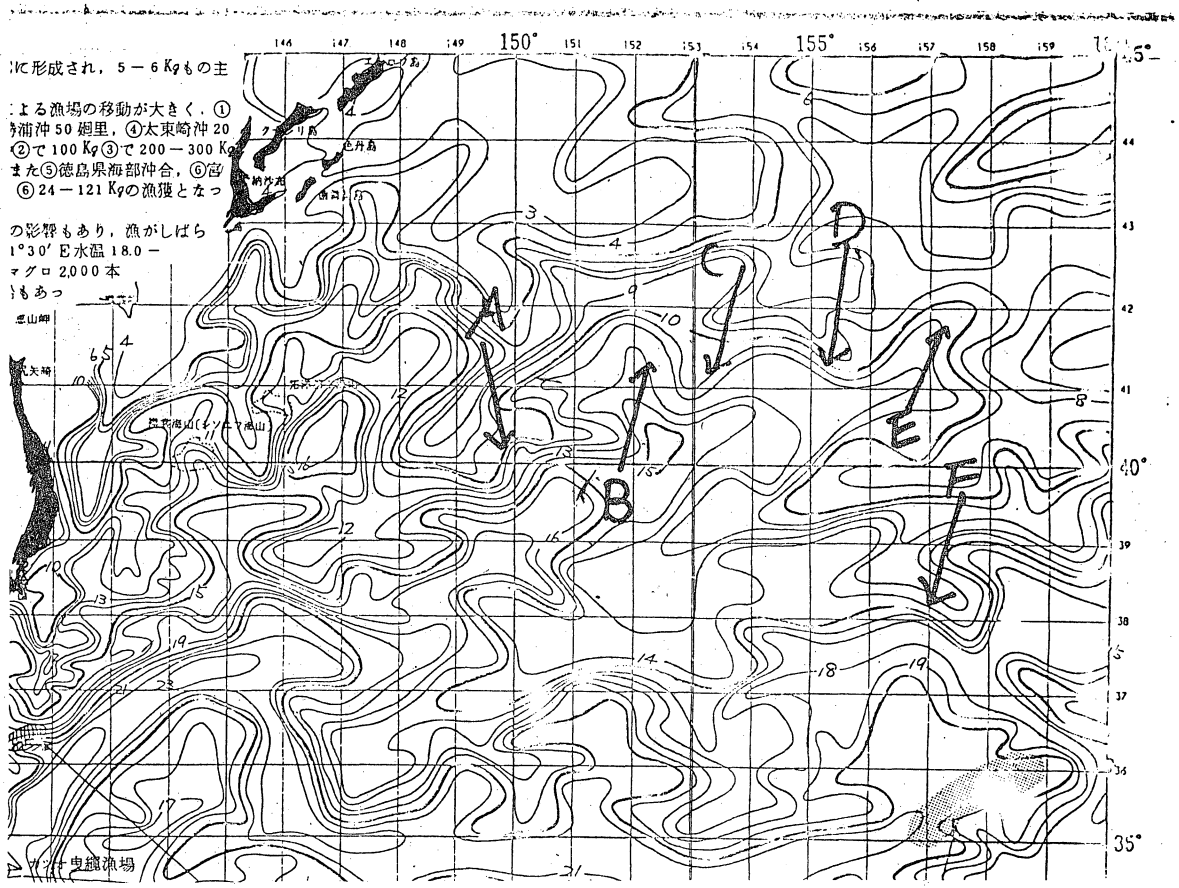


FIG. 9　FRONT PATTERN AT THE KUROSHIO EXTENTION AREA BY VESSELS
FIVE DAYS DATA, 21 - 25 MAY 1980
(PREPARED BY THE JAPAN FISHERIES INFORMATION CENTER)

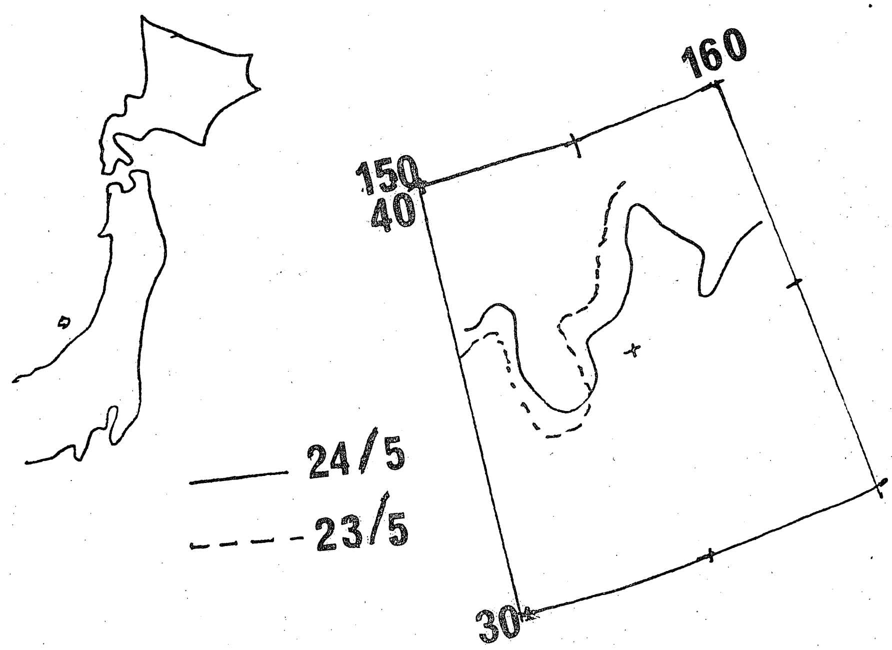


FIG. 10 SHIFT OF THE FRONT AT THE KUROSHIO EXTENTION AREA IN 24 HOURS, COMPARED BY GMS-1 REAL TIME PICTURES MAY 23 03Z TO MAY 24 03Z, 1980

FIG 11 EDDIES SHOWN BY NOAA-6 PICTURE
OCT. 24 1980

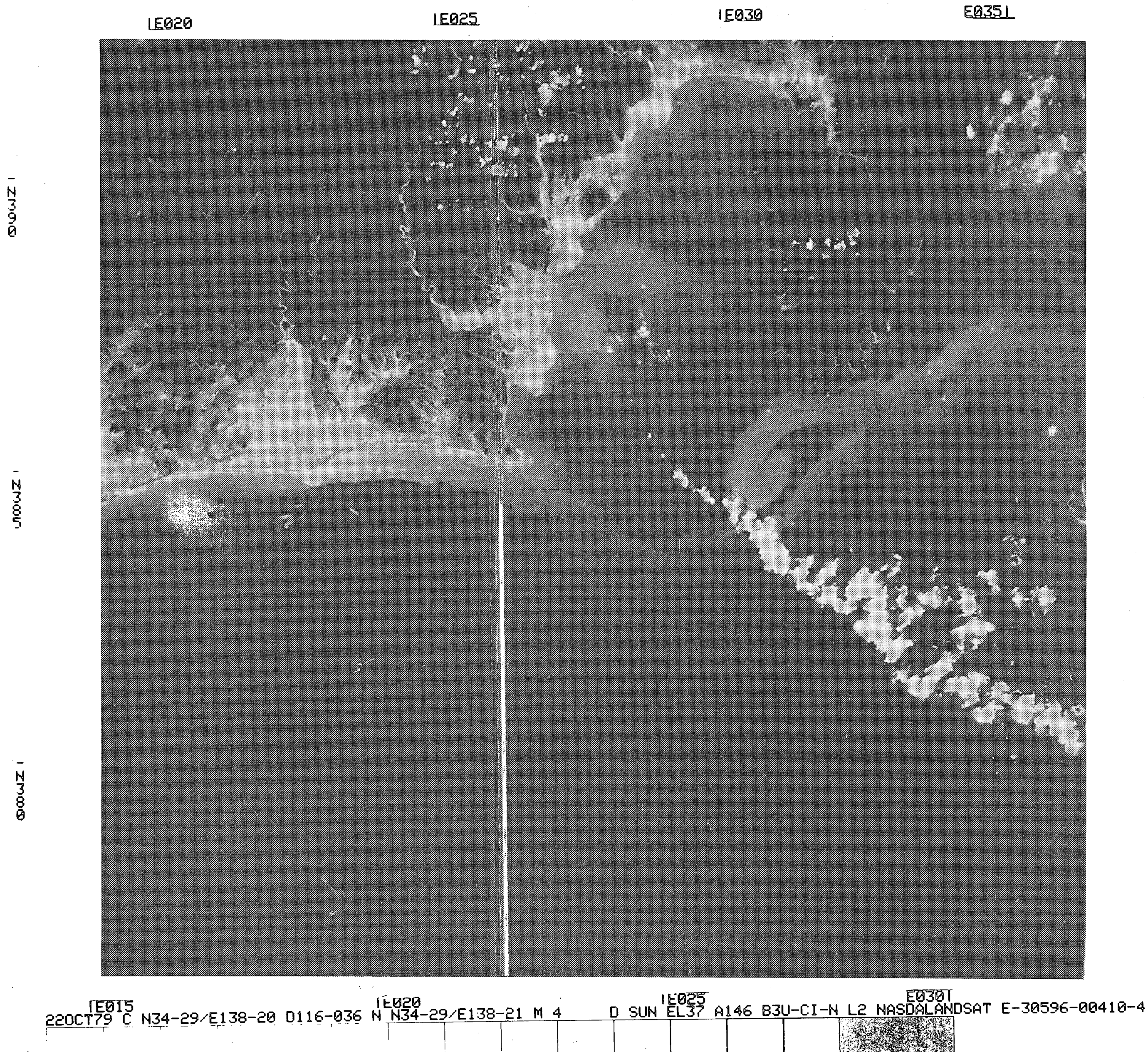
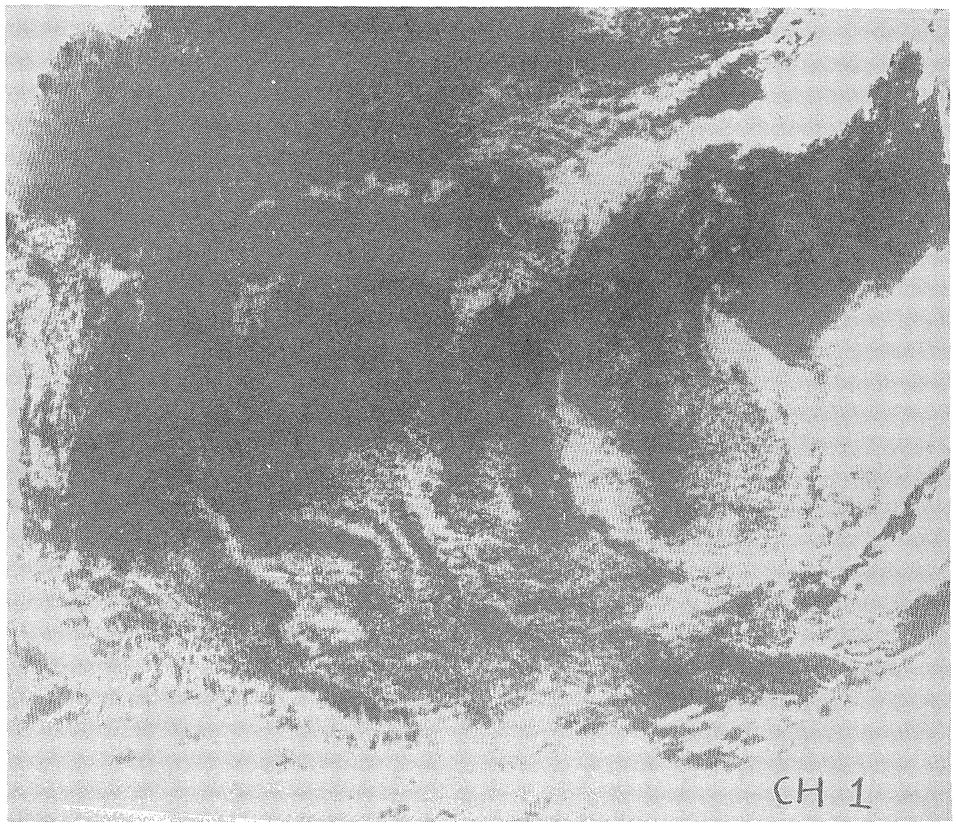


FIG. 12 COASTAL CURRENT AND EDDIES SHOWN BY LANDSAT-3
DEC. 14, 1979



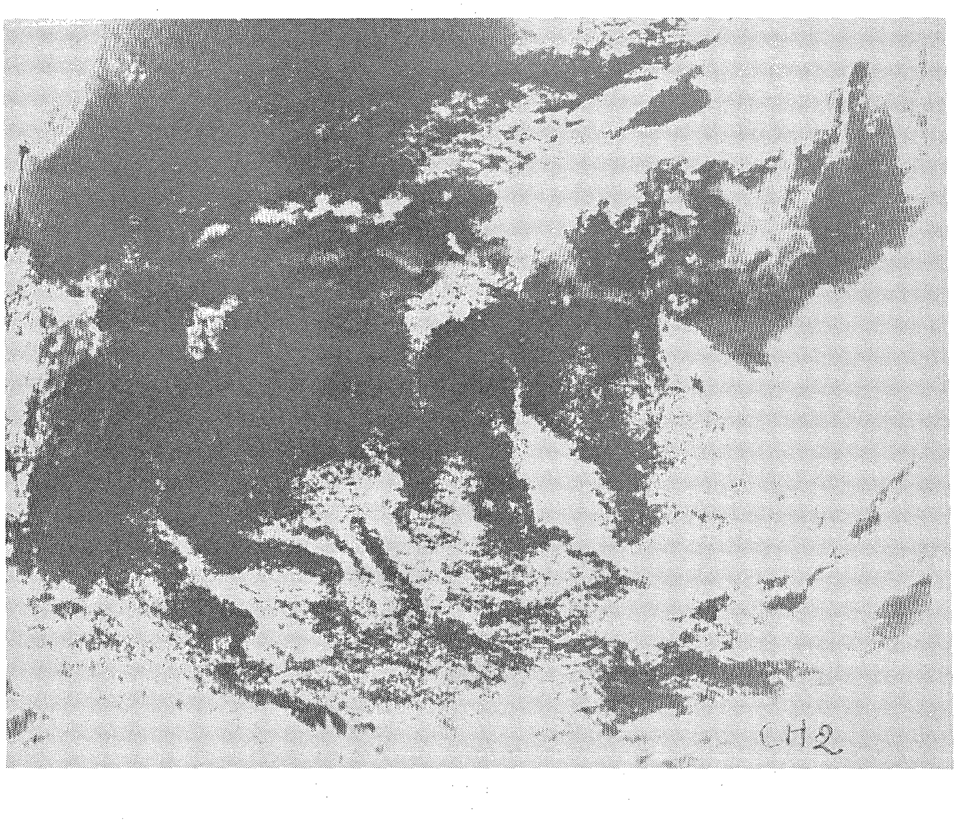


FIG. 13. NIMNUS -7 CZCS PICTURES AROUND JAPAN (JAN. 26 1979)

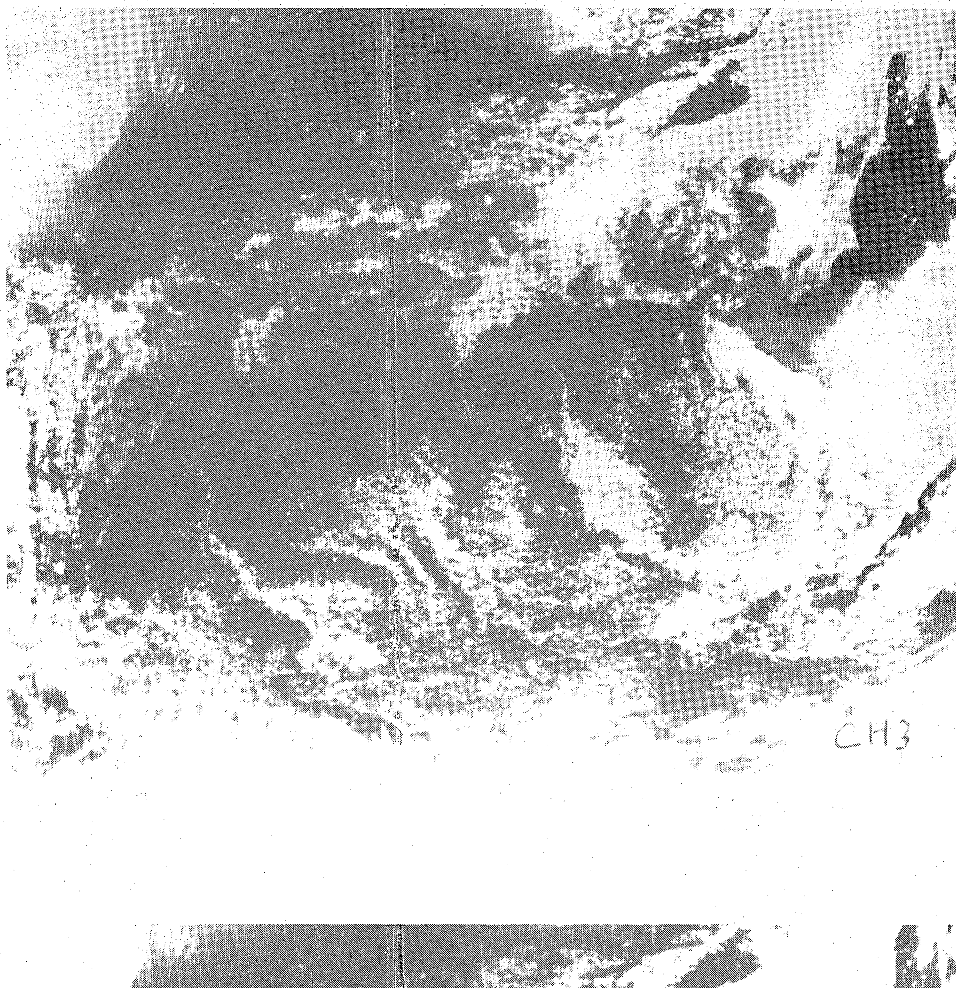


FIG. 13-2 NIMBUS-7 CZCS PICTURES AROUND JAPAN (JAN. 26 1979)

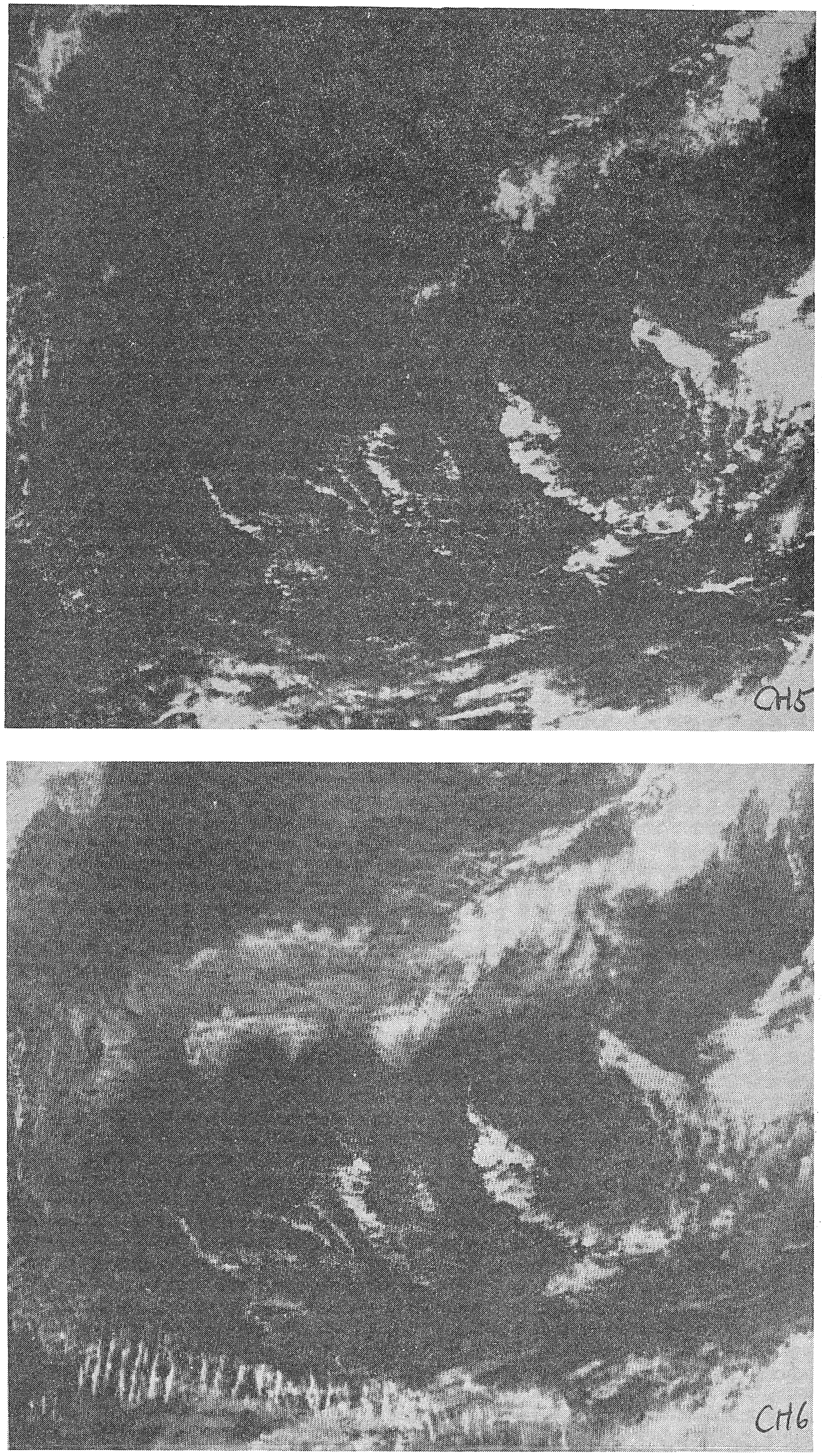


FIG. 13-3. NIMBUS-7 CZCS PICTURES AROUND JAPAN (JAN. 26, 1979)

(The NAFO Secretariat does not have facilities for for reproduction of color photographs, and consequently the color picture is not included).

Fig. 14. Color scale picture of NIMBUS-7 CZCS, January 26, 1979.