# Application of Landsat MSS Data to the Study of Oceanographical Environment

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ABSTRACT

Based on Landsat MSS data of three years time lapse, the change of sea surface condition in Seto Inland Sea and coastal region is studied. It is found that red tide popularly called after its apparent color expanded. It is also found that red tide which used to concentrate in the bay or inland sea extends into an open sea. A small ocean vortex similar to mesoscale atmospheric vortex is revealed by the Band 4 image of Landsat MSS data.

A simple manual photographic method, "Equi Density Slicing Method", is applied to a single band image of MSS which indicates this method is effective to detect sea surface pollution.

## 1. Introduction

Recently the coastal region is suffering from red tide popularly called after its apparent color. Red tide is caused by unusually abundant generation of plankton which is caused by nutrification of water. When red tide appears, fish is killed resulting in damage to coastal fishing industry.

Maruyasu and Ochiai (1976) pointed out that Bands 4 and 6 data of Landsat MSS are useful for the detection of red tide. Although visual analysis can distinguish polluted sea surface from clean area it is hard to distinguish red tide from other pollutants such as oil slick. An attempt is made to apply numerical analysis for the detection of red tide. In addition a simple photographical method which is useful for the study of sea surface pollution detection will be stated.

2. Occurrence of red tide in Seto Inland Sea

The name of red tide has become very popular recently, however this phenomenon is not recent finding. In Table 1 is shown annual frequency of red tide in Seto Inland Sea which the authors have collected from all available sauces at present. Seto Inland Sea, located between western mainland of Japan and Shikoku has been noted for its beautiful scenery and clean water. This Inland Sea is also very important place for coastal fishing industry ( as to the location see Fig., 1).

Table 1 Annual occurrence of red tide in Seto Inland Sea

| Year | Number of appearance case | Number of damaged case |
|---|---|---|
| 1967 | 48 | 8 |
| 1968 | 61 | 12 |
| 1969 | 67 | 18 |
| 1970 | 79 | 35 |
| 1971 | 136 | 39 |
| 1972 | 164 | 23 |
| 1973 | 210 | 18 |
| 1974 | 298 | 17 |
| 1975 | 300 | 29 |
| 1976 | 326 | 18 |

It can be seen that the number of observation increased from 48 in 1967 to 326 in 1976 or 7 times as many as that in 1967.. In spite of rapid increase of occurrence, the increase of damaged cases is not so large as the total occurrence case.

In order to see an effect of season on the occurrence; monthly frequency of recent two years is plotted and shown in Fig. 2, which clearly indicates seasonal effect on its occurrence. High frequency of occurrence is limited in the warm season between April and September.

3. Landsat MSS images showing the sea surface pollution

In Fig. 2 is shown Landsat MSS images of Seto Inland Sea taken

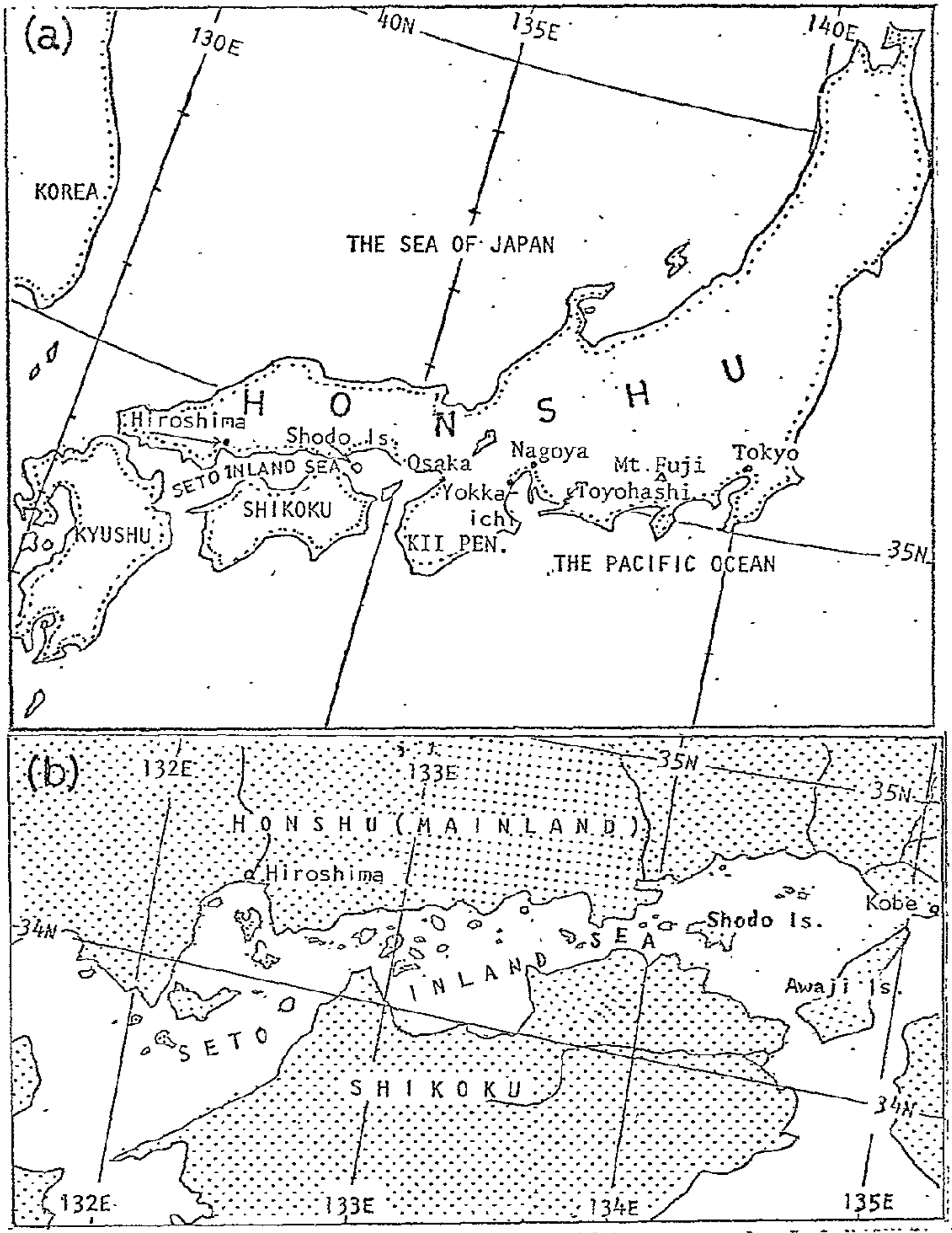


Fig. I (a) Map of Japan showing approximate position of cities.
(b) Map of Seto Inland Sea.

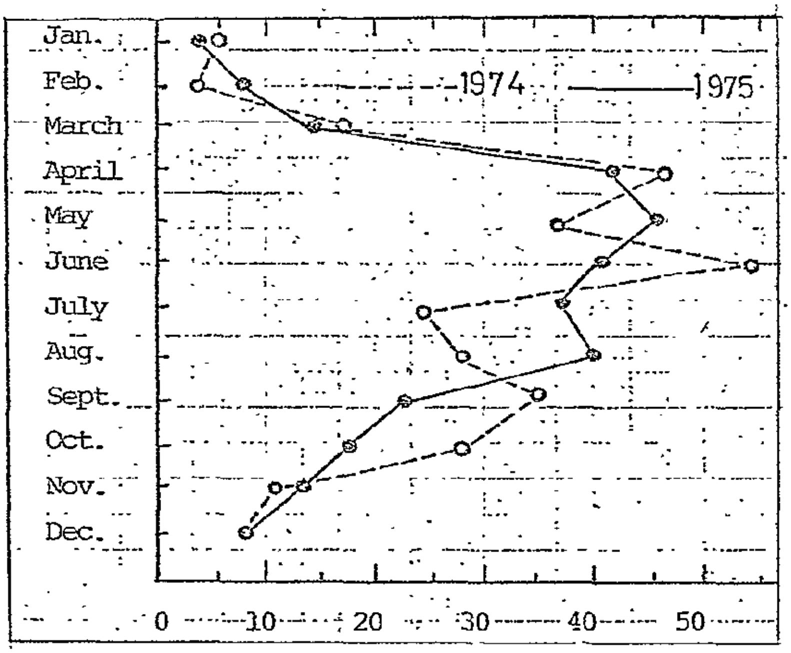


Fig. 2 Monthly frequency of red tide in Seto Inland Sea in 1974 and 1975.

three years time lapse. In Fig. 3 are shown Landsat MSS images of Seto Inland Sea taken on Nov. 12 1972, Jan. 23 1973 and Dec. 30 1975 respectively.

Comparing the last image with those taken nearly three years before, one spectacular difference is recognized in the area to the east of Shodo Island where a fairly large white area is recognized. There is no sea truth information in this area and it is hard to know the source of this high reflectance. There was an report of red tide observation at the mouth of Kojima Bay (A in Fig. 4) in Seto Inland Sea. Making use of this area as sea truth, an analysis of similarity to red tide is made and the result of which is shown in Fig. 4 in 5 categories ranging from 1 to 5. The number 5 means similarity to red tide at the mouth of Kojima Bay is 100 %, while number 1 means the probability of red tide is zero. Generally speaking the area with the values above 4 has very high probability of red tide. Since sea surface condition is influenced by various factors and

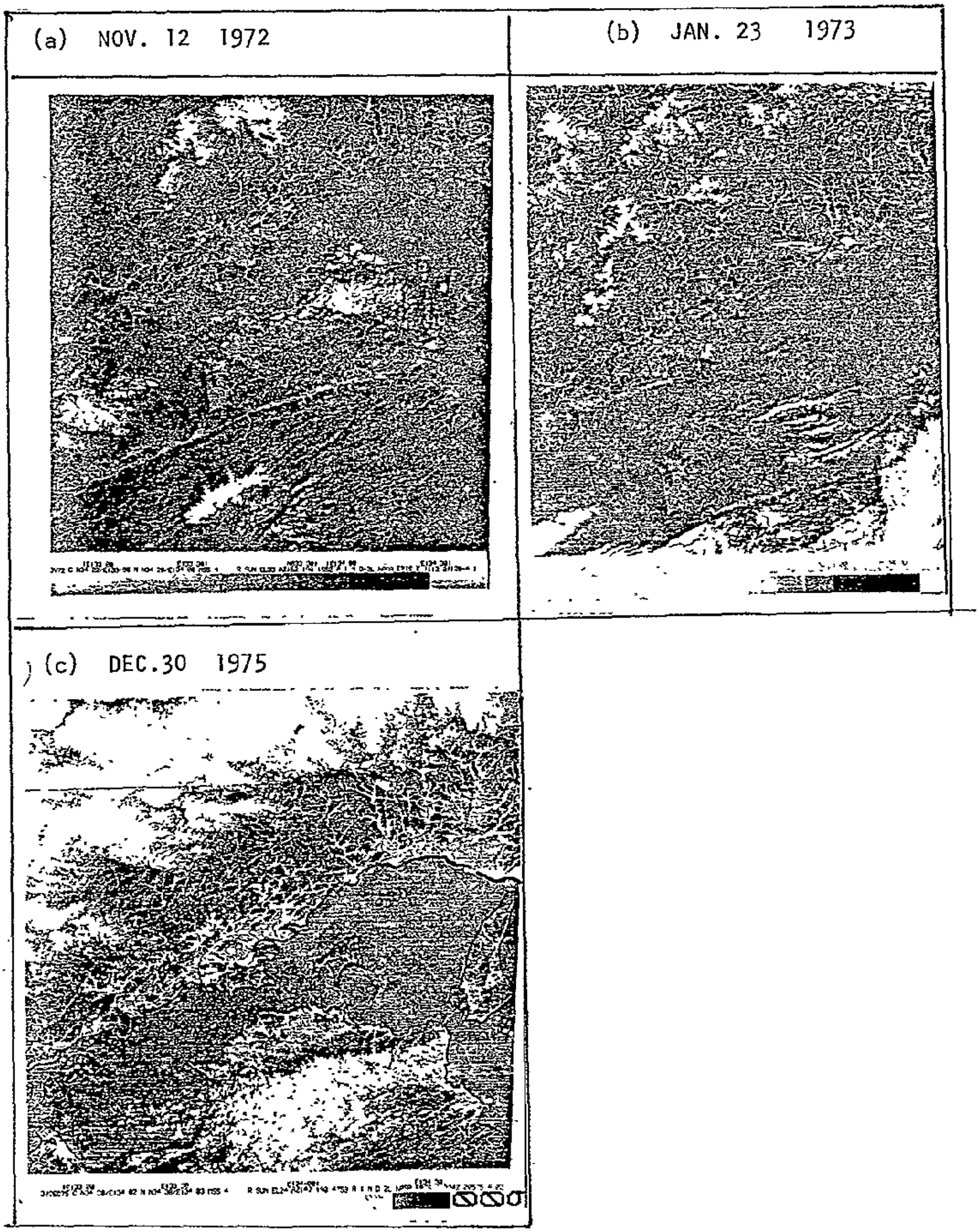


Fig. 3 Landsat MSS images. (a) Nov. 12 1972, (b) Jan. 23 1973, (c) Dec. 30 1975. All the images and Band-4.

the speed of variation is rather fast, it does not mean that red tide exists always in the same place, however the result of the analysis indicates that the surface of Seto Inland Sea to the east of Shodo Island has chnaged during the past three years.

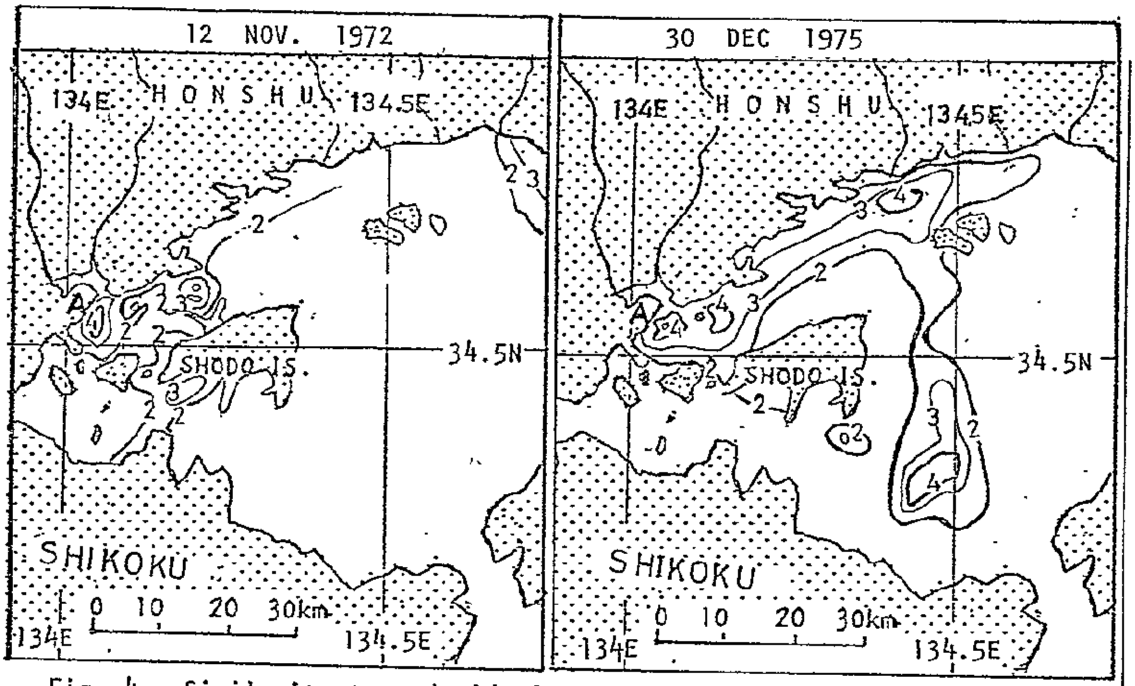


Fig. 4 Similarity to red tide in eastern Seto Inland Sea around Shodo Island. The degree of similarity is shown in 5 categories ranging from 1 to 5 with 5 the highest similarity.

3. A small ocean vortex as revealed by Landsat MSS image

In the image of September 11 1975 covering the coastal area of central Japan, a small ocean vortex is found off the tip of Kii Peninsula in the periphery of the Kuroshio, one of the largest warm ocean current in the world which is flowing along Japanese Islands. The whole image of which is shown in Fig. 5. An attempt is made to interpret the phenomenon.

i) A synoptic·oceanographical condition

Detailed analysis of all available data indicates the existence of a

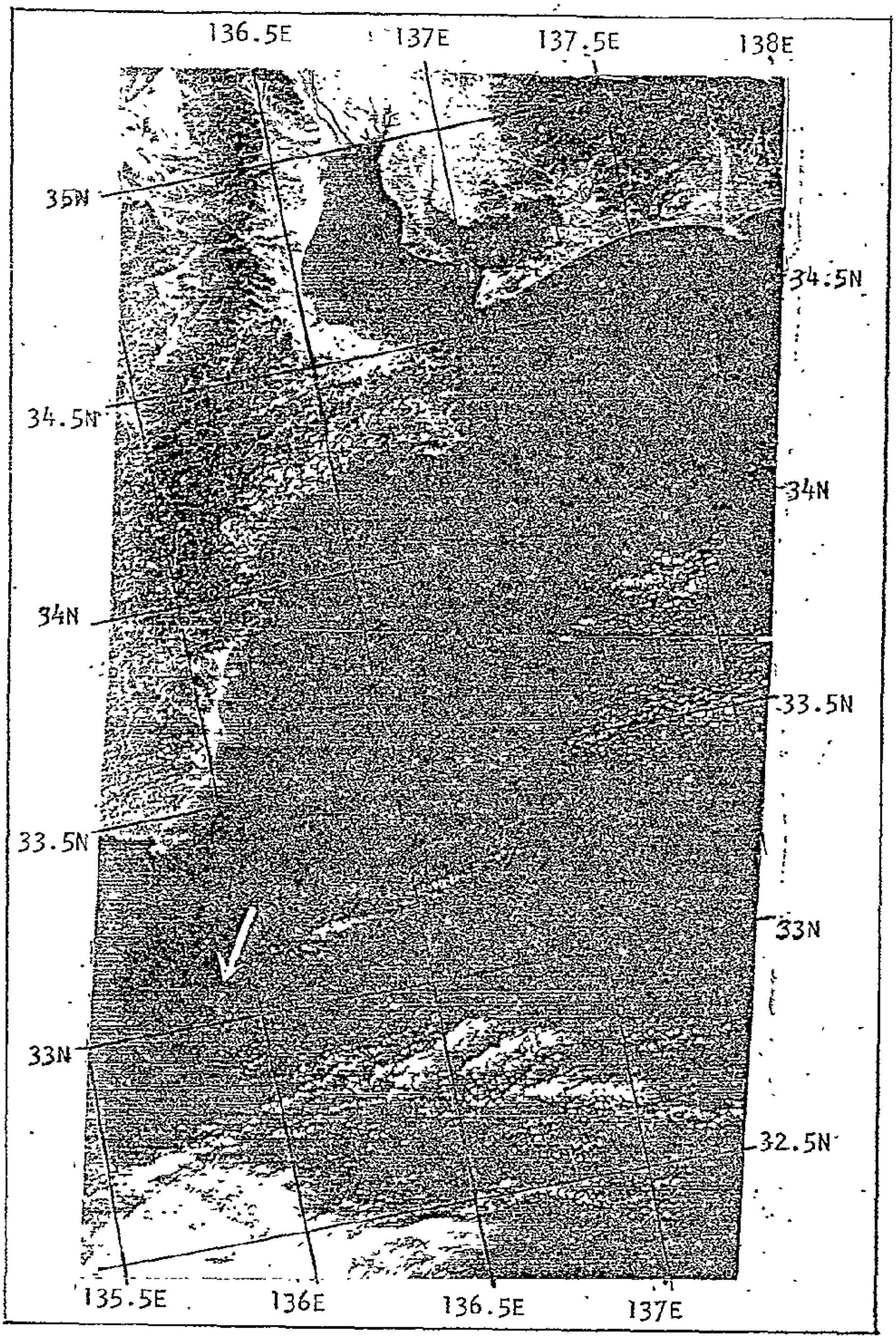


Fig.5 The image of Landsat-2 showing turbid coastal water and small ocean vortex. 0048 GMT September 11 1975

fairly large scale cold water mass to the south-eastern tip of Kii Peninsula where a large meandering of the Kuroshio was taking place as is indicated in Fig. 6. The large meandering of the Kuroshio was first found by Japanese Navy in 1934 during the maneuver. Through their large scale survey, they found a large cold water mass blocking the Kuroshio. The Kuroshio was detouring the cold water mass resulting in a large meandering. Later it was found that the cold water mass influences fishing grounds a great deal. Since then this cold water mass has been observed five times as is indicated in Table 2.

Table 2 Observation of cold water mass to the south-east of Kii Peninsula

| Year of first obs. | Duration |
|---|---|
| 1934 | 9.5 years |
| 1953 | 2.5 |
| 1959 | 4 |
| 1969 | 1 |
| 1975 | Still existing |

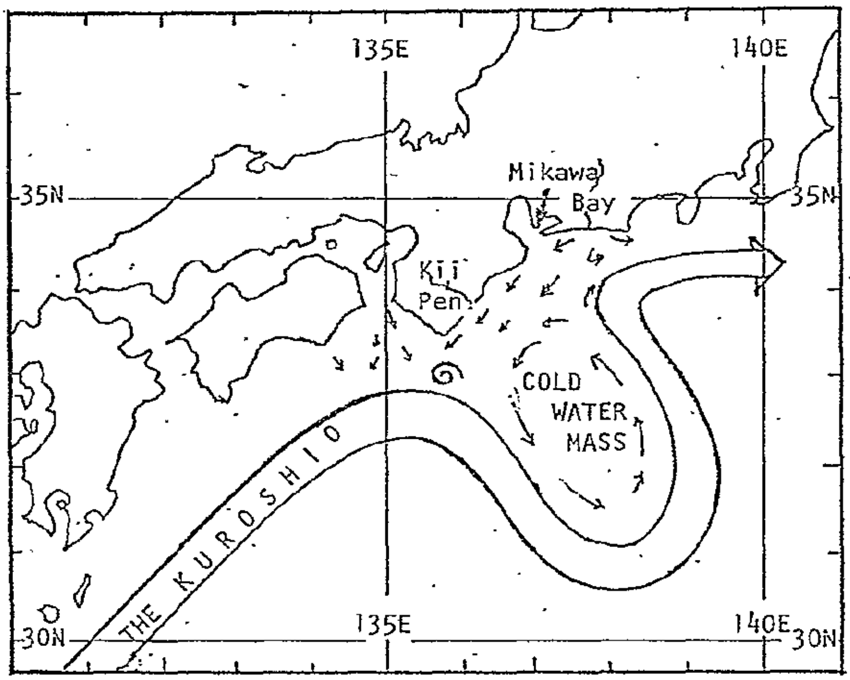


Fig. 6 Schematic representation of the synoptic condition of the Kuroshio, coastal current and cold water mass on September 11 1975.

The present cold water mass was first observed in August 1975. Its spatial dimension is oscillating. At its maximum size, the major and minor axes were as large as 280 and 220 kms respextively while at its minimum it shrinked to a circular shape of approximately 90 kms diameter. The cold water mass split into two parts in May 1977 and the meandering of the Kuroshio stoped for a while then again the meandering has started due to reformation of large cold water mass in the previous place.

At the time of observation by Landsat, on September 11 1975 it is considered that the axis of the Kuroshio was slowly moving toward north or approacing Kii Peninsula. There were south-west and south-south-east ward coastal current to the east and west of Kii Peninsula respectively. It is considered that the present vortex was formed in the place where turbid coastal flows on both sides of the peninsula and the Kuroshio converge. The strong cyclonic shear may have triggered its formation and maintained it. It has a certain similarity to the plume like pattern of suspended sediments in Calorina's continental shelf revealed by Apollo pictures and studied by Mairs (1971). Both phenomena were formed on the left hand periphery of large warm ocean currents.

ii) Similarity analysis

A similar analysis to the one made in the Seto Inland Sea is applied to the small ocean vortex using the red tide observed in Mikawa Bay (as to location see Fig. 6) the result of which is shown in Fig. 7 (a). It was found that the spiral part of the vortex has a high degree of similarity to the red tide of Mikawa Bay. Using CCT of MSS data the classification is also made with the red tide of Mikawa Bay, the water at the mouth of River Yahagi flowing into the western edge of Mikawa Bay and the water of the open sea as the sea truth. The result of analysis is shown in Fig. 7 (b).

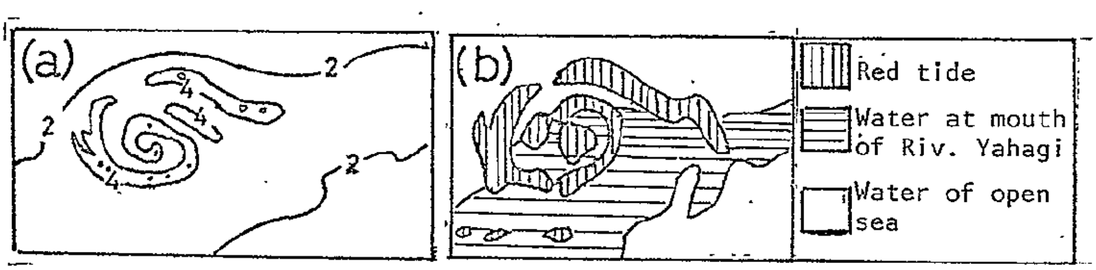


Fig. 7 (a) Similarity analysis applied to the small ocean vortex. Symbols are same as those in Fig. 4. (b) Classification of water involved in the small ocean vortex.

It is interesting to notice that the radiation characteristics of the water involved in the vortex have strong similarity to that of red tide in the spiral part and the rest of the part to the water in the mouth of the River Yahagi. There are no enough data to discuss the mechanism of the formation of the vortex in detail, however, the result of the present analysis indicates that the vortex is revealed by the water drawn into the vortex. If there is an upward motion in the spiral part like an atmospheric vortex, an upwelling nutricious water may have contributed to the generation of plankton with the result of contribution of the formation of the red tide in the spiral part.

## 4. A simple method of photographic processing for equi-density extraction

Recently it has become easy to use false color representation method by specially made apparatus, however it is not all who can use it. The method described below may be of use who are trying to analyze a single MSS band image using only photographic processing facilities. Fig. 8 is a schematic representation of the method, the detail of which will be explained below.

i) From an original positive film make proper number of negative films giving different exposure time for simplicity make it four in this case. Assume the density of the films are: $N1 < N2 < N3 < N4$.

ii) Make four positive films from the four previously made negative films and name them as P1, P2, P3 and P4 respectively(same exposure time).

iii) Superpose the negative films on the positive films in such a manner: P1+N2, P2+N3 and P3+N4 then due to the difference in density of each film, equi-density part appears. In the figure, the white part conrresponds to this equi-density region.

iv) Make positive films out of the superposed films. Name them as equi-density positive films; Q1, Q2 and Q3 respectively. Stippled areas in the figure correspond to them. It should be understood that three different densities are extracted.

v) Make negative films out of the previously made three positive films and call them Q1', Q2' and Q3' respectively. Using

vi) Using the three negative films make positive color film in such a manner: first take Q1' and expose it on a color paper through a blue filter, then take Q2' and expose it through a green filter on the same paper and finally taking Q3' expose it through a red filter on the same paper then

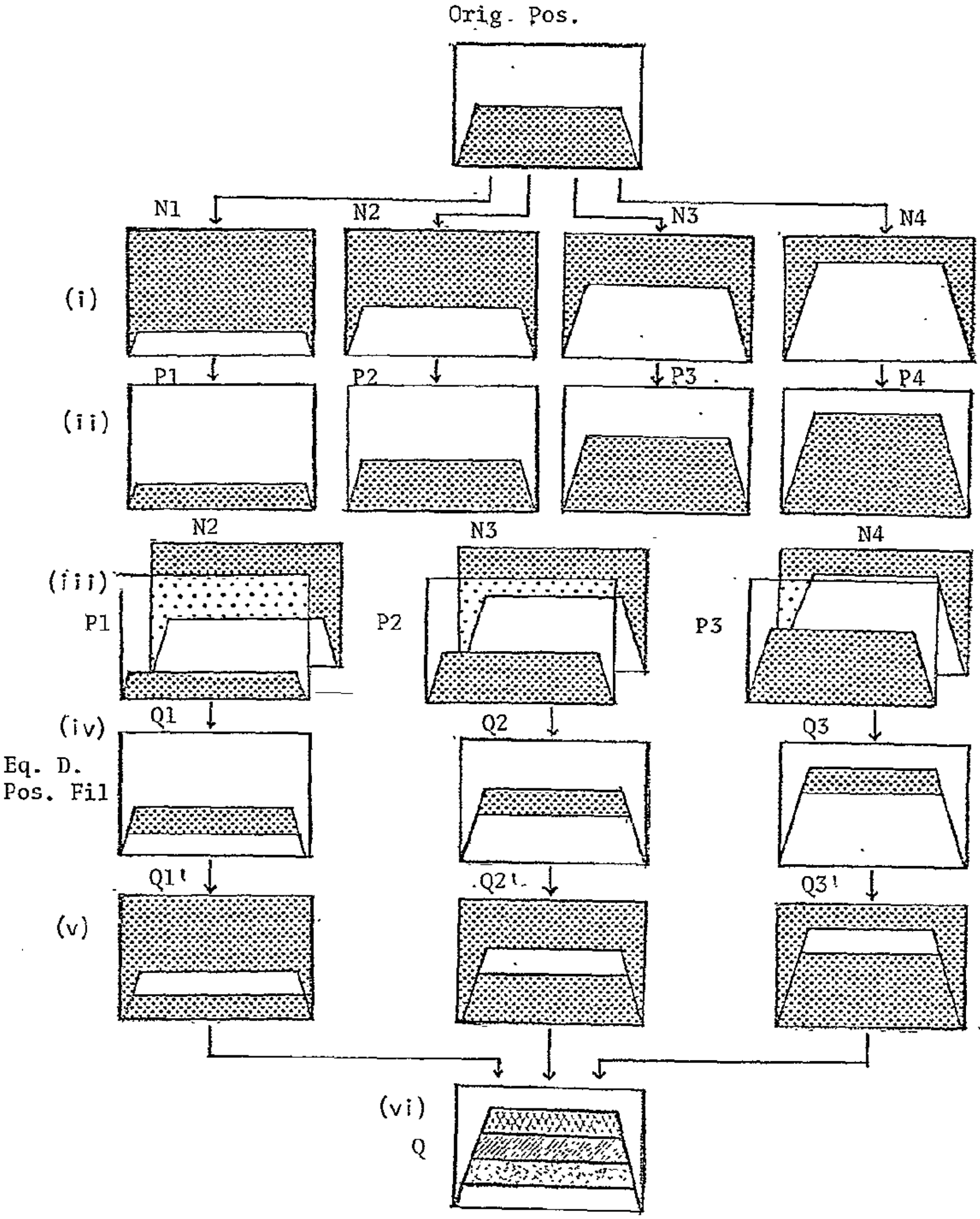


Fig. 8 Schematic representation of equi-density extraction method through manual photographic processing.

a color positive print is completed. It is not necessary to follow the combination of the color filters described above. The positive color print thus made is shown in Fig. 9 in which the turbid sea surface is well indicated.

Fig. 9 A color positive print made out of Band-4 of Landsat Mss image alone through manual photographic pcoessing method. Dec. 30 1975.

The above described method is a standard procedure. Generally speaking a certain amount of information is lost in going through one processing therefore if it is possible less processing step is desirable. In this sense the step (v) may be omitted in certain field such as in the study of oceanography in which a small difference of reflectance must be treated. Fig. 10 is an example of the image made through omitting the step (v) in which a small density difference is better indicated than Fig. 9.

Fig. 10 A color negative print made out of Band-4 of Landsat MSS image alone through manual photographic processing method. Dec. 30 '75.

5. Concluding-remark

Landsat MSS data are especially useful to get a most-up-to-date information on the se surface condition. In spite of a great effort to keep the sea surface clean, it seems that the pollution is still going on. Red tide in the Seto Inland Sea is becoming a great problem in a fishing industry there. The spatial extension as revealed by Landsat image is of great use in the study of the mechanism of this phenomenon.

Just like atmospheric vortices of various scales have been found by meteorological satellites, vortices of various scales of the ocean will be found if a proper observation tool is invented. Equi-density extraction method developed by the present authors will be of help to those who have only photographic facilities.

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