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Significant Applications of LANDSAT-2 MSS Data to Marine Environment

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Abstract

Remote sensed data obtained from LANDSAT-2 was confirmed that it is very useful for the monitoring of marine environment through the year around coastal area of Japan. Indeed more than one hundred scenes which contains various oceanic phenomenas were already produced from MSS data and analyzed during the LANDSAT-2 investigation term agreed with NASA.

In this report, the author described the significant applications of LANDSAT-2 MSS data acquired over Japan in nearly three years and revealed several coastal features including red tide, river effluent, coastal process and etc. with the supporting data obtained by air-born remote sensing using multispectral scanner.

Sea surface data observed by ship as routine work and special experiment were also used for data analysis as sea truth. In data analysis aspect, the author tried both analog processing and digital processing standing on application field.

1 Introduction

The objective of this LANDSAT-2 study is mainly inquiring the marine environment around Japan and monitoring of it. So, the author set up the test sites in Ise Bay, Kumanonada and Seto Inland Sea where various coastal features were experienced in recent year.

In this report, the author pointed out the few topics depend on the special experiment using aircraft and ship. One of the topics is the detection of the most effective wavelength for the monitoring of red tide in Ise Bay and Seto Inland Sea. And one more topic is the detection of characteristic of water mass from spectral distribution by digital analysis.

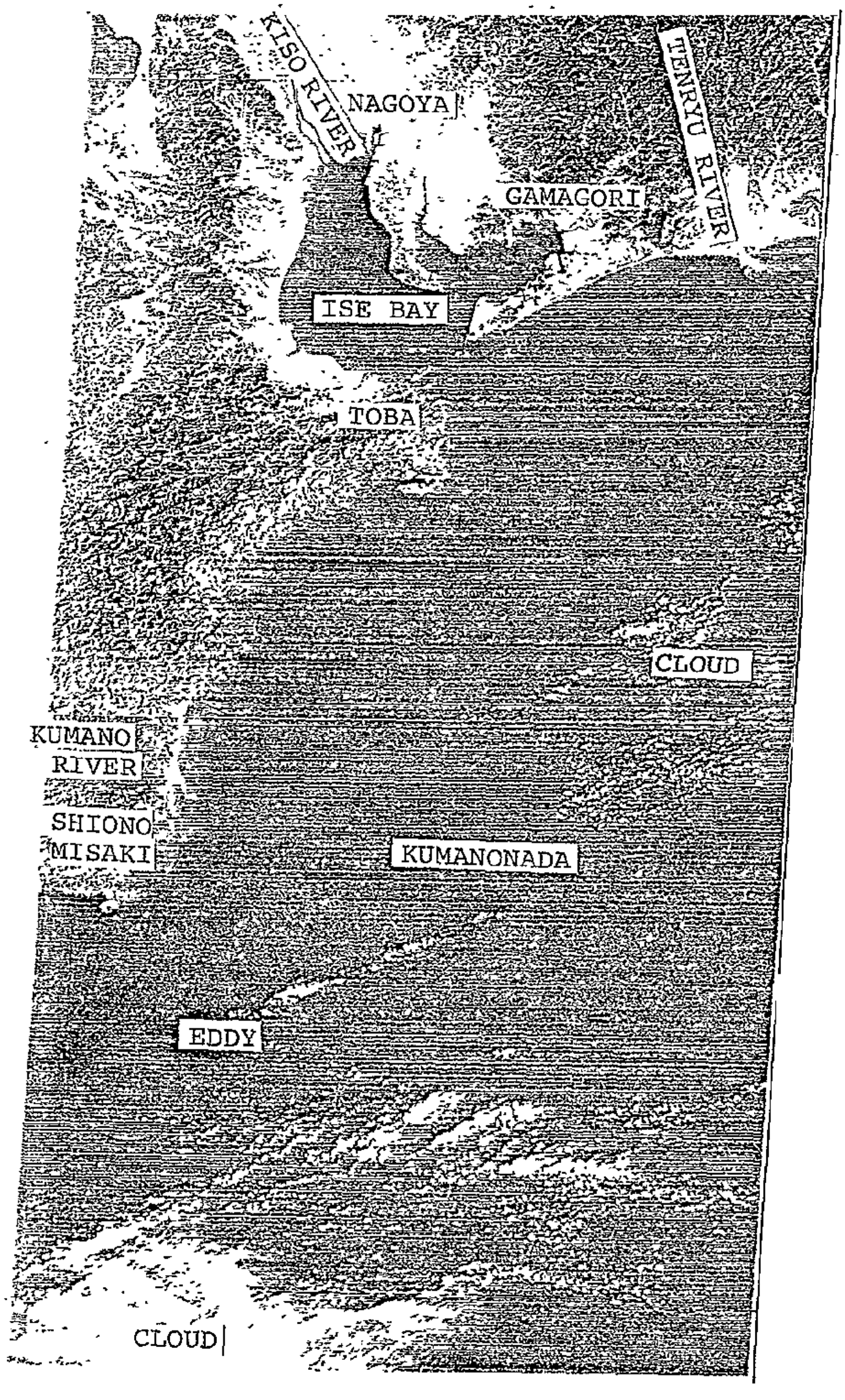

Figure 1 LANDSAT-2 MSS-4 imagery mosaic.
Sept. 11, 1975

2 Techniques

2-1 Aircraft and Instrument

Before the launching of LANDSAT-2, the author started the pre observation for collecting the foundamental sea surface data around Japan especially in Ise Bay and Seto Inland Sea. In these area, air-born remote sensing were experienced several times using three types aircraft. Cessna-402 was used for ordinary observation and YS-11 turbo jet plane was used for special flight like as long hour flight. And helicopter was used for low altitude observation around the boundary of water mass in the mouth of Ise Bay.

For the purpose of collecting the supporting data, three types air-born multispectral scanner were used. They were Daedlus-1250, JSCAN-AT-5M and JSCAN-AT-12M. Among the above mentioned three types multispectral scanner, JSCAN-AT-5M and JSCAN-AT-12M were developed by the author's study group in Japan.

After the successful launching of LANDSAT-2, the author tried several special experiments synchronized with the passing of LANDSAT -2 over the selected test sites in Ise Bay and Seto Inland Sea.

On September 11, 1975, a synchronized observation between aircraft and LANDSAT-2 was succeeded around Ise Bay and very good informations were carried out from both multispectral scanner data.

2-2 Sea truth data

Sea truth data were collected by observation ships. In Ise Bay, two types ship were used for observation. One of them was hydroboat equipped with data collecting system consisted with various sensors and she was used for daily observation between Toba and Gamagori Port acrossing Ise Bay four times for a day. So, sea surface data like as temperature profile or salinity profile were detected easily on data recorder as a pattern.

Each one time for a month, marine observation ships belong to the Fisheries Experiment Aichi and Mie Prefecture were used for special observation. In this case, almost environmental data were collected at more than fourty stationary points every time.

In Seto Inland Sea, data observed by passenger ships engaged to daily service were used for analysis as sea truth. And "Red tide report" by fishing boat to The Branch Office of Fishing Agency in Kobe were also used for analysis as sea truth.

3 Accomplishment

3-1 Ise Bay experiment

Ise Bay which is located in southern coast of central Japan is connected with Kumanonada:Pacific Ocean through the narrow water ways Irago and Momotori Channel. It has the total amount of water dimension 2.06 x $10^6 km^2$. As shown in Figure 1, Ise Bay is divided in two parts by Chita Peninsula and western half of it is called Ise Bay and eastern half of it is called as Mikawa Bay. Mikawa Bay is again divided in two parts by Shinojima located the mouth of Mikawa Bay. And small western half of it is called as Chita Bay and another half is called as Mikawa Bay.

Along the coast line of Ise Bay, several heavy industrial zones were located especially northern part of it like as Nagoya and Yokkaichi. Recently, almost area of Ise Bay including small bays were rapidly polluted with the increasing of industrial effluent from the industrial zone and social discharge through the river which flows into bays in surrounded area.

(A) Red tide

In recent year, we have experienced so many times red tide through the year and the total appearance of red tide in Ise Bay was exceeded one hundred in 1975. On January 29, we experienced a severe red tide around the mouth of Kiso River in spite of cold season once we have never experienced in winter around the bay.

As shown in Table 1, more than fourty five cases of notable red tide were reported in 1975 and some of them were not only very severe, the scale is also reportable.

Especially, red tide appeared on May 7-8 in Mikawa Bay, May 26-27 in Ise Bay, August 26-September 4 in Ise Bay and September 8-10 in Mikawa Baywere very notable cases. Because, on these days a large amount of fish and shell were diseased in almost area where red tide were reported. Red tide consisted by animal plankton was appeared as red color pattern usually. But borwn and black color

Table 1 Report of Red Tide Sighted in Ise Bay and Mikawa Bay (only notable case)

Date	Area	Color	Date	Area	Color
1975					
Jan. 29 ~ 30	Mouth of Kiso River	Brown	June 16	Western coast of central Ise Bay	Brown
March 26	Southwest part of Ise Bay	Yellow	June 19 ~	Gamagori Port	Brown
April 7	Along the western coast of centrak Ise Bay	Light brown	20	Eastern part of Mikawa Bay	Light brown
			June 25	Almost area of Mikawa Bay	Brown
April 9 ~ 11	Eastern part of Mikawa Bay	Brown	30	Toyohashi Port	Brown
			July 6	Mouth of Toyo River	Green
April 16 ~ 17	Northwest part of Ise Bay	Yellow	July 9 ~ 11	Western coast of central Ise Bay	Brown
May 1	Eastern part of Mikawa Bay	Pink	July 15	Eastern part of Mikawa Bay	Pink
May 7	Eastern part of Mikawa Bay	Light brown	16 17	Along the western coast of Chita Peninsula	Brown
8	Kinuura Port	Light brown			
May 21	Kinuura Port	Light brown	Aug. 11	Yokkaichi Port	Brown
			Aug. 20	Central part of Ise Bay	Pink
May 23	Western coast of central Ise Bay	Pink	Aug. 26	Southwest part of Ise Bay	Light brown
May 26	Western coast of northern Ise Bay	Brown	Aug. 27	Yokkaichi Port	Dark green
				Gamagori Port	Black
	Nagoya Port	Brown	Aug. 28 ~ 30	Matsuzaka Port	Brown
	Northern part of Ise Bay	Brown			
May 26 ~ May 27	Eastern part of Mikawa Bay	Brown	Sept. 1	Southwest coast of Ise Bay	Light brown
			Sept. 2	Kinuura Port	Brown
May 28	Northern coast of eastern Mikawa Bay	Brown	Sept. 2 ~ 4	Southwest coast of Ise Bay	Light brown
June 3	Western coast of central Ise Bay	Brown	Sept. 8 ~ 10	Northern part of Ise Bay	Light brown
				Eastern part of Mikawa Bay	Green
4	Eastern coast of Ise Bay	Pink		Almost area of Mikawa Bay	Brown
	Kinuura Port	Brown	Oct. 1	Almost area of Mikawa Bay	Brown
June 6	Western coast of Ise Bay	Brown	3	Kinuura Port	Brown
June 10 ~ 14	Eastern part of Mikawa Bay	Brown	Oct. 8 ~ 10	Eastern part Mikawa Bay	Brown

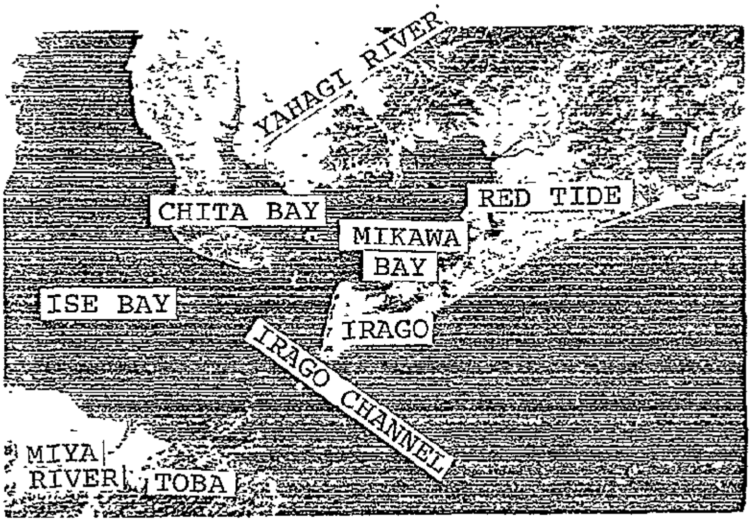

Figure 2 Enlarged MSS-4 imagery showed in Figure 1.

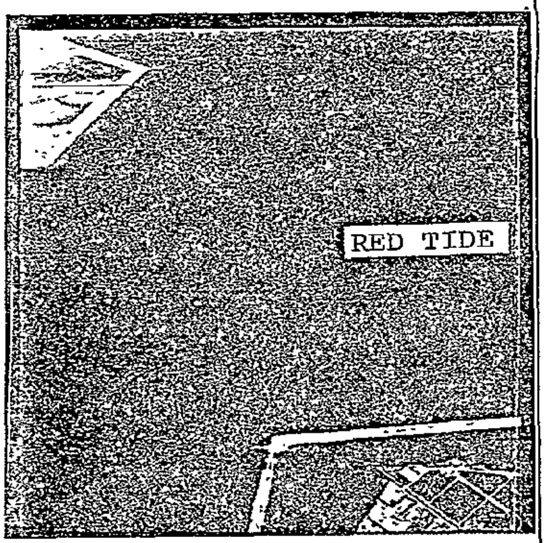

Figure 3 Aerial color photograph around red tide area in Mikawa Bay.
Sept. 11, 1975

were also experienced recently. On July 6 and early september of 1975, we experienced green color pattern in Mikawa Bay and it is called as "Nigashio" or "Green water" in this district.

From early April to late December in 1975, LANDSAT-2 passed over Ise Bay Fifteen times. But due to the weather, only few scenes were obtained in this term. If could we have more good weather condition on LANDSAT-2 passing day, we would be pleased to have another useful information concerned red tide around Ise Bay.

As noted before, LANDSAT-2 revealed very efficiency information around Ise Bay and Kumanonada on September 11, 1975. In MSS-4 imagery we could find out typical pattern in Mikawa Bay and this pattern was estimated as red tide compared with air-born remote sensing data. In eastern Mikawa Bay, very notable red tide was continued about ten days till September 10 by the report issued from Miya Fisheries Experiment. Although by the report, red tide was not identified in Mikawa Bay, as shown in Figure 3, we could recocognized it in aerial color photograph which obtained by the auther. Red tide pattern was detected in eastern Mikawa Bay around Toyohashi Port and this pattern was just the same color, brown reported on September 10, the day before in this area.

In thermal imagery obtained by air-born multispectral scanner, red tide pattern was detected distinctly in the area pointed out in Figure 2 and Figure 3.

Depend on the author's experience, the most effective wavelength for the monitoring of red tide consisted by Noctiluca was remarked as thermal channel of air-born multispectral scanner. Red tide consisted by Prorocentru was also recognized remarkablly in thermal channel too.

On present stage, we could not carry out the thermal pattern from MSS data obtained from LANDSAT-2. So, the most effective wavelength for the monitoring of red tide was considered as MSS-4 in analog processing. In another three channel we could not find out the pattern estimated as red tide in this case.

In digital analysis, the author tried enhancement of the data to produce a digital pattern of red tide distinctly in first step.

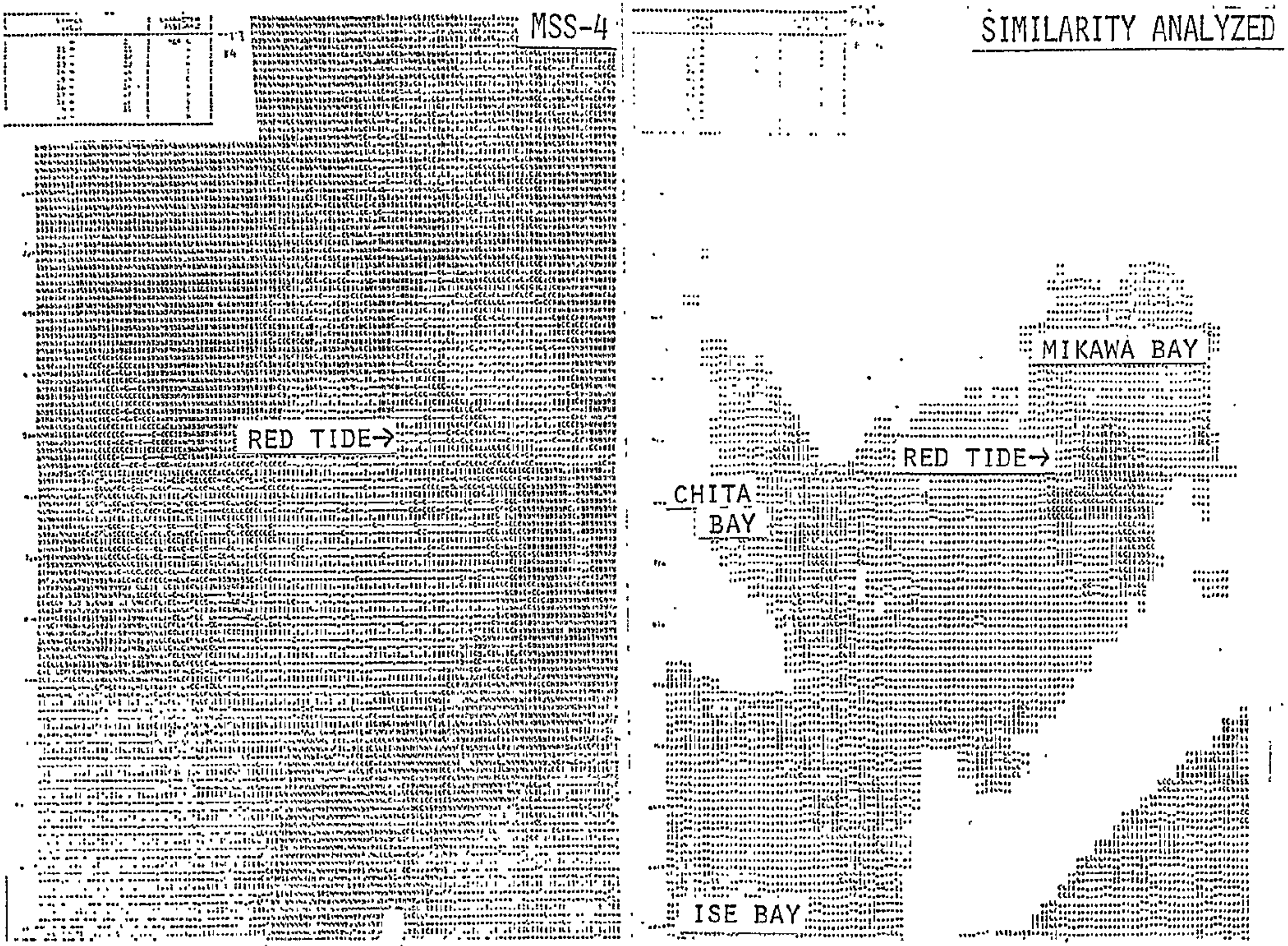

Figure 4 Print maps of LANDSAT-2 MSS data showed in Figure 1 and Figure 2.

and as shown in Figure 4, two print maps were printed out. Compared with two print maps, red tide pattern pointed out in Figure 2 and Figure 3 was produced more clearly in similarity analysis. Although red tide pattern was detected in enhanced MSS-4 print map, it was not so distinctly in eastern area of Mikawa Bay. But in similarity analyzed print map, we could recognized red tide pattern very clearlly.

(B) River effluent

In Figure.4, another pattern were recognized in Chita Bay and Ise Bay. And these patterns were estimated as influence of river effluent from surrounded bay. In Chita Bay, river water polluted by suspended substance from Yahagi River influence its environment very much. By the report of Environmental Department of Aichi Prefecture, the normal account of suspended substance at the mouth of Yahagi River was 45 in 1975. But after the heavy rainning, it exceeded more than 100. So, white-colored river water from Yahagi River influence near the mouth of Ise Bay.

In Ise Bay, a large amount of river water from Kiso River and Nagara River influence severely, especially after heavy rainning and anti-clockwise flow was recognized in past observation data. The normal account of suspended substance at the mouth of Kiso River was 39 and maximum account was 130 in 1975. On this point of view, we could recognized that Yahagi River was more polluted than Kiso River by suspended substance. Figure 5 is typical expanding pattern of river effluent from Yahagi River which obtained by air-born remote sensing after rainning.

In similarity analysis, analyzed data was displayed on color display system and classified by color code as shown in Figure 6. Namely, when standard point was set at red tide area in Mikawa Bay, similarity analyzed image would be display as right image and if standard point was set at the polluted area by suspended substance at the mouth of Yahagi River, color coded pattern would be display like as left pattern. In these imageries the most similarity area to standard point were showed in red color and color correlation was 1.0 in this stage. Between blue color and red color, the color correlation was set up five stages and the account of

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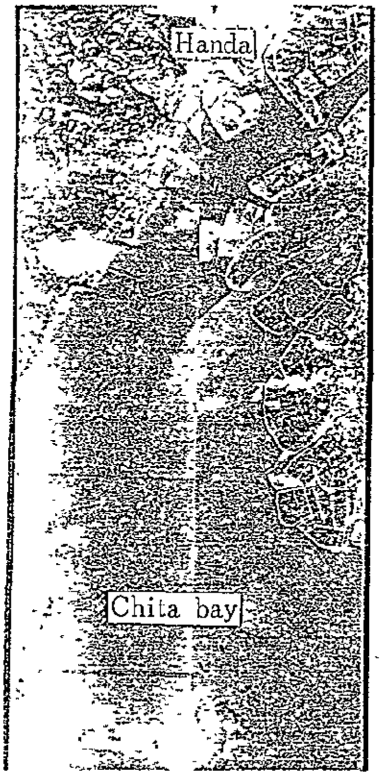


Figure 5 River effluent from Yahagi River in Chita Bay obtained by JSCAN-AT-12M multispectral scanner.

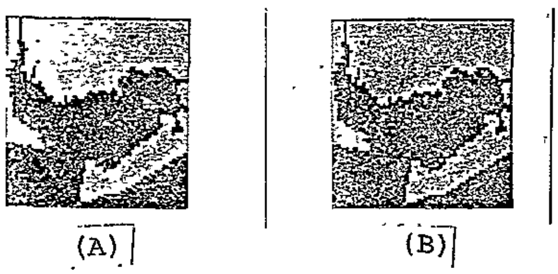


Figure 6 Similarity analysis for red tide in Mikawa Bay and river effluent from Yahagi River indicated in Figure 1 and Figure 2.
(A) Similarity to red tide.
(B) Similarity to mouth of Yahagi River.

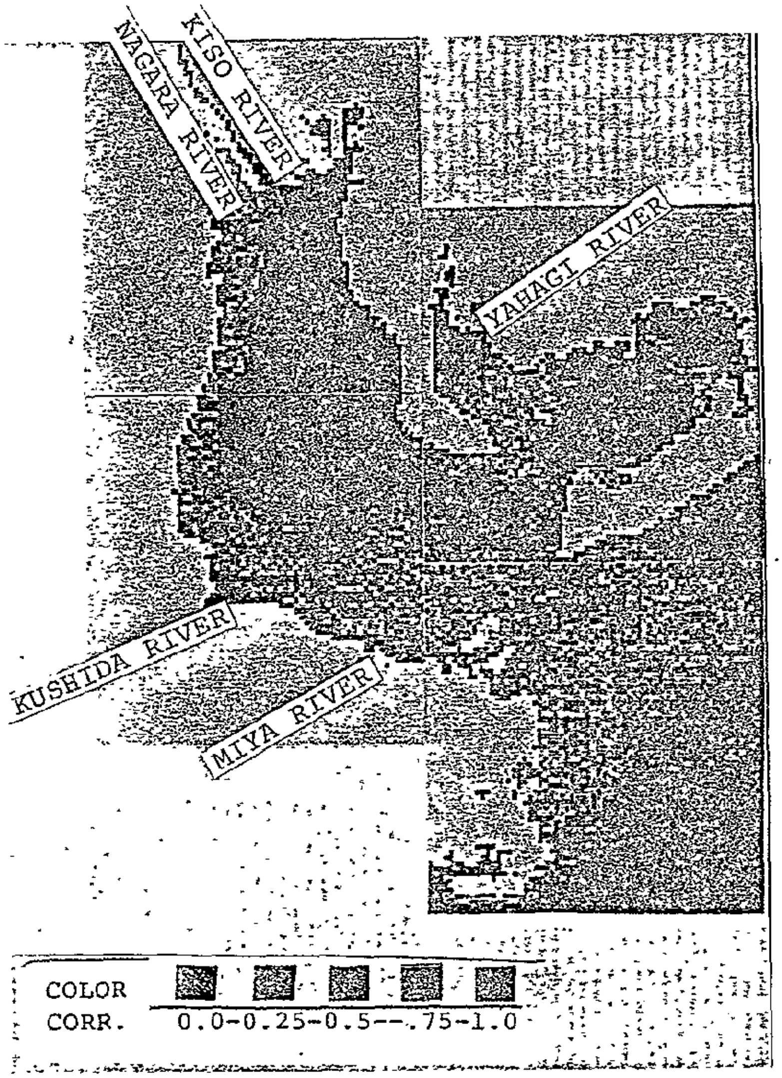


Figure 7 Similarity analysis for river effluent from Kiso River indicated in Figure 1.

correlation was divided to each stage 0.25. By the same technique, the author analyzed the MSS data and standard point of similarity was set up at the mouth of Kiso River. And as shown in Figure 7, typical correlation pattern was produced around whole Ise Bay and anti-clockwise flow of seawater in Ise Bay was recognized from the pattern. River water from the Kiso River and Nagara River flows along the west coast of Ise Bay towards south. In this case, the characteristic of sea water at the mouth of Ise Bay was estimated that just the same to river water from Kiso River in reflectance. So, it was considered that a large amount of river water from the norhern part of Ise Bay and western part of Ise Bay where Kushida River and Miya River flows into bay after rainning was transfered by current which flows along the western coast of Ise Bay towards the mouth of Ise Bay and also dam up against oceanic water from Kumanonada. The boundary of polluted water from Ise Bay was estimated as 15 km from the mouth of bay.

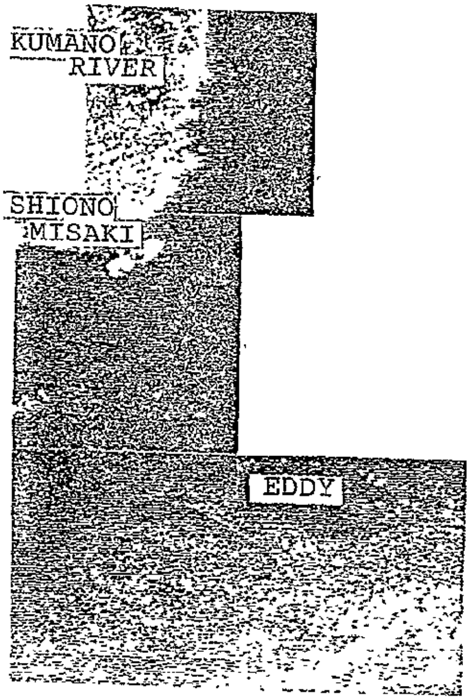
3-2 Kumanonada experiment

(A) River effluent

River effluent from Kumano River was noted as much polluted by suspended substance and it was caused by the construction of dam for power plant along the river side of connecting upper river. By the author's previous report (1), river effluent from Kumano River was recognized that it influenced more than 90km from the mouth and it extends to southern part of Kumanonada near Kuroshio Current. In Figure 1, river effluent from the Kumano River was well detected in MSS-4 imagery and it seem to be connected with big eddy located at about 180 km from Shionomisaki in southeast direction. So, it was the most expanded pattern we experienced through the LANDSAT-1 and LANDSAT-2 investigation.

In this experiment, the author tried enhancement of the data and displayed as composit false color imagery using two channels data. Figure 8 was a false color imagery consisted by MSS-4 in cyan color and MSS-6 in red color using digital processing.

Compared with analog processed imagery showed in Figure 1, the pattern of river water from the Kumano River and eddy considred



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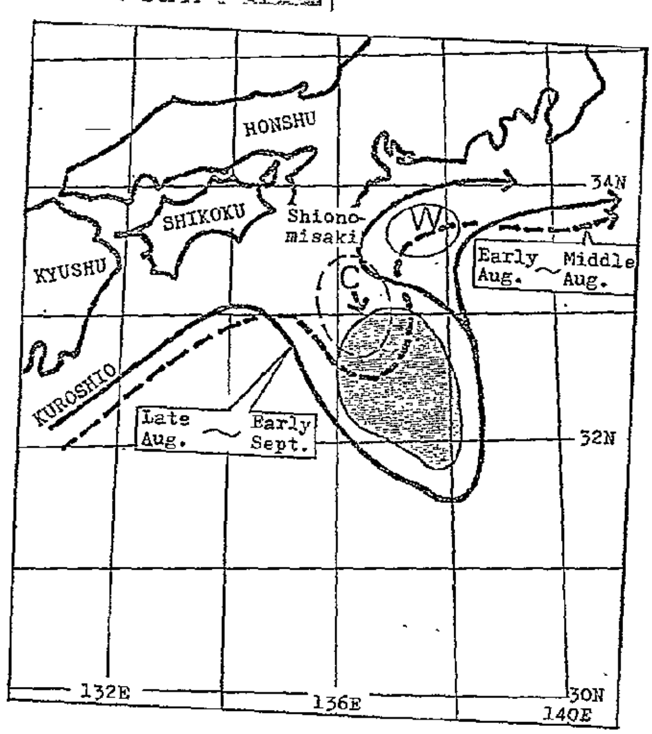

Figure 8 Color composit image by digital analysis for eddy indicated in Figure 1 and location of cold water mass in Kumanonada 1975.

as cold water mass caused by up welling.

(B) Cold water mass

In early June of 1975, a cold water mass in large scale was suddenly appeared off the southern coast of Kyushu and this cold water mass was considered as the effect of up welling. On the beginning of August, the cold water mass was shifted its position and located at the position of 90 km from Shionomisaki in southeast direction. Then the cold water mass changed its shifting course to southeast direction and the center position of it in early September was 180 km from Shionomisaki in southeast direction.

The boundary of the cold water mass was expanded as two times compared with the scale in August. The water temperature at the depth of 100 m was 16°c and at the depth of 200 m was 12°c in this time. These temperature were 5° or 6°c colder than at the same level in Kuroshio Current.

As shown in Figure 1 and Figure 8, a large scale of eddy was recognized distinctly and its scale was more than 30 km in major axis. The reason why this eddy was recognized in MSS-4 was estimated that depend on the spectral distribution in this area, the characteristic of water mass was identified as just the same to the water in Mikawa Bay where red tide was prevailed showed in Figure 2 and Figure 3. In the area where up welling was recognized, the distribution of plankton was normaly increased against to surrounded area. Indeed the characteristic of water consisted the eddy was carried out through the digital analysis as shown in Figure 9.

By the effect of similarity analysis in Kumanonada experiment, river effluent from Kumano River and eddy caused by cold water mass were well recognized more clearly in case of similarity point was set up in Mikawa Bay. Compared with two color coded similarity patterns, the one its similarity point was set at the mouth of Yahagi River in Chita Bay was not so distinctly against above mentioned another one. Namely, the pattern around eddy was more similar to color composit pattern showed in Figure 8. And river effluent pattern from Kumano River was also very similar to color composit imagery in the same analysis.

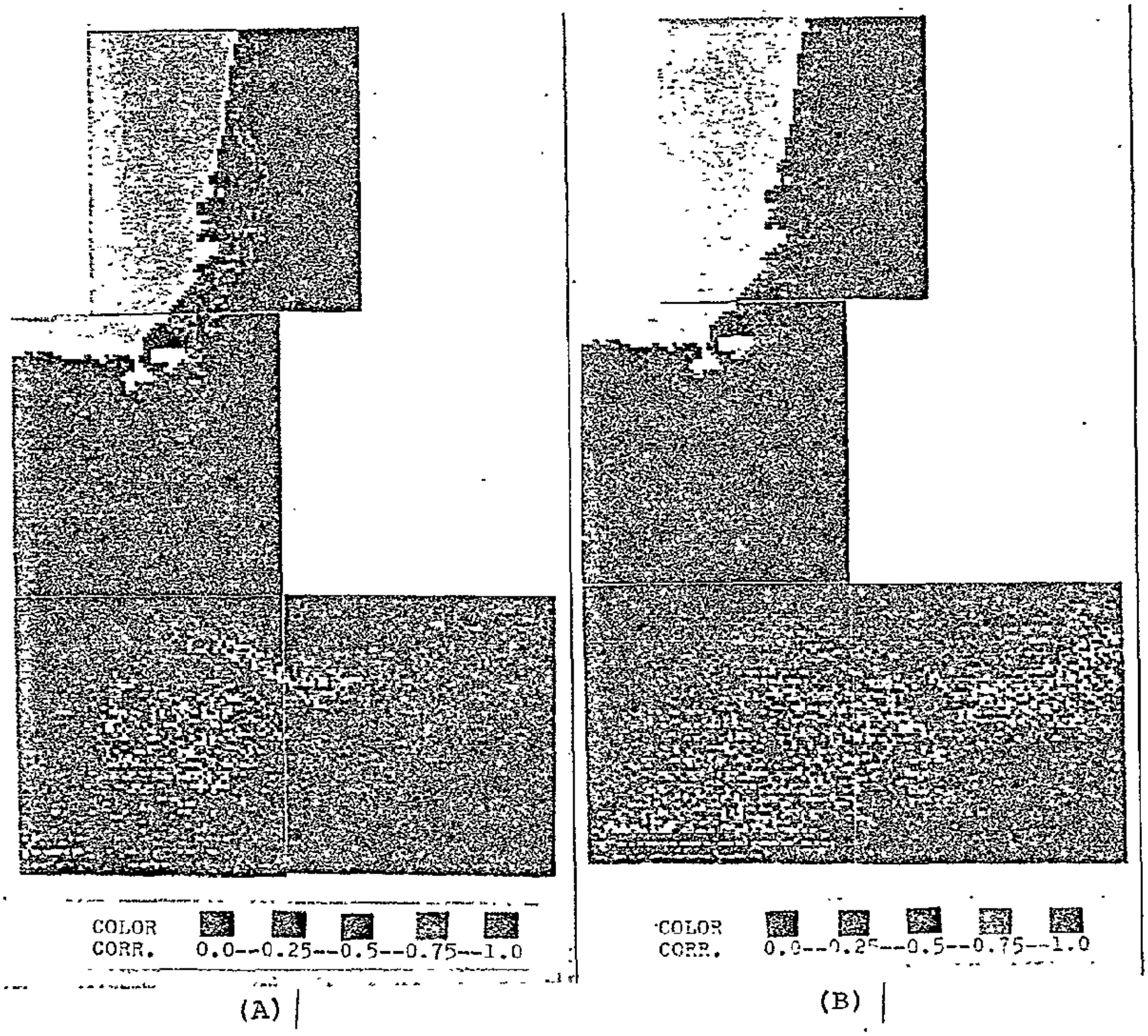

Figure 9 Similarity analysis for river water from Kumano River and eddy indicated in Figure 1 and Figure 8.
(A) Similarity to red tide in Mikawa Bay.
(B) Similarity to mouth of Yahagi River in Chita Bay.

From this point of view, the river effluent from Kumano River considered as much polluted by suspended substance in analog processed imagery was recognized as not so polluted by suspended substance against the author's estimation. The characteristic of water extended from the mouth of Kumano River was confirmed as very similar to the water in Mikawa Bay than to the water around the mouth of Yahagi River.

(C) Coastal current

Influenced by abnormal flow of Kuroshio Current, coastal current along the southern coast of Tokai District was considerably changed its flow pattern in 1975. As shown in Figure 8 meandered Kuroshio Current was closed to coast line against normal condition.when cold water mass was appeared in Kumanonada.

In Figure 1, we could recognized the expanding pattern of river effluent from Tenryu River which extended to southeast direction. Along the coast line of Enshunada, coastal current flows westwards as the countercurrent of Kuroshio Current when Kuroshio Current was not meandered at off Kumanonada. So, almost typical flow pattern of river effluent from Tenryu River obtained from LANDSAT-1 was extended to westwards.

But in this case, the expanding pattern of river effluent from Tenryu River was nearly opposite direction and the reason why coastal current changed its flow direction was estimated that due to the large scale meandering of Kuroshio Current, a warm core was consisted off the mouth of Ise Bay and influenced by it, Kuroshio Current was boosted up to shore line abnormally and coastal current as countercurrent was disappeared. The movement of coastal area of Enshunada was changed its direction towards east by strength of Kuroshio Current.

3-3 Seto Inland Sea experiment

Seto Inland Sea which has a total water dimension of 22,000 km^2 is located in wester Japan and it is the biggest inlet in Japan. Due to the increasing of industrial effluent from coastal industrial zone around the Kinki, Chugoku, Shikoku and Kyushu districts where newly developed kombinat like as Sakai Takasago, Mizushima, Ube, Sakaide, Niihama and Ooita were located, sea water in Seto Inland Sea was rapidly polluted and its environment was seriously bad condition.

(A) Red tide

According to the report announced by The Branch Office of Fishery Agency in Kobe, the total appearance of red tide was exceeded over three hundred times in 1975. By the progress of red tide appearance in Seto Inland Sea was very rapidly. in 1950, just one quater century ago, the total appearance of it was only few cases for a year and the appeared area were restricted in Osaka Bay and Harimanada only warm season. But recently, red tide appeared through the year and erea red tide appearance were reported expanded almost area of Seto Inland Sea.

In this experiment, MSS data acquired on December 30, 1975 was used for analysis both analog and digital processing. From late December of 1975 to early January of 1976, severe red tide consisted by Skeltonema were reported by fising boat around Harimanada. In Figure 10, several patterns indicated by black arrows were estimated as red tide patterns and a considerable big pattern was detected in MSS-4 imagery aound off eastern coast of Shodoshima. During the investigation term, the author tried air-born remote sensing for the purpose of monitoring of red tide using multispectral scanner around Harimanada and Osaka Bay.

Although the appearance mechanism of red tide was not yet analyzed clearly, the most effective wavelength for it was recognized as thermal channel in these area through the observation.

In digital analysis, the characteristic of water mass around Harimanada were carried out and similarity analysis was also investigated around the shodoshima area as shown in Figure 11. The characteristc of water mass was identified in data distribution patterns. Among the three channels, MSS-4 was recognized as the most effective wavelength for the monitoring of red tide in data distribution. The standard reflectance count for not polluted normal water in Seto Inland Sea in MSS-4 was 9.2 in this case and its deviation was each $\pm$ 2. But the center of data distribution of polluted water at the mouth of Kojima Bay and easterm area of

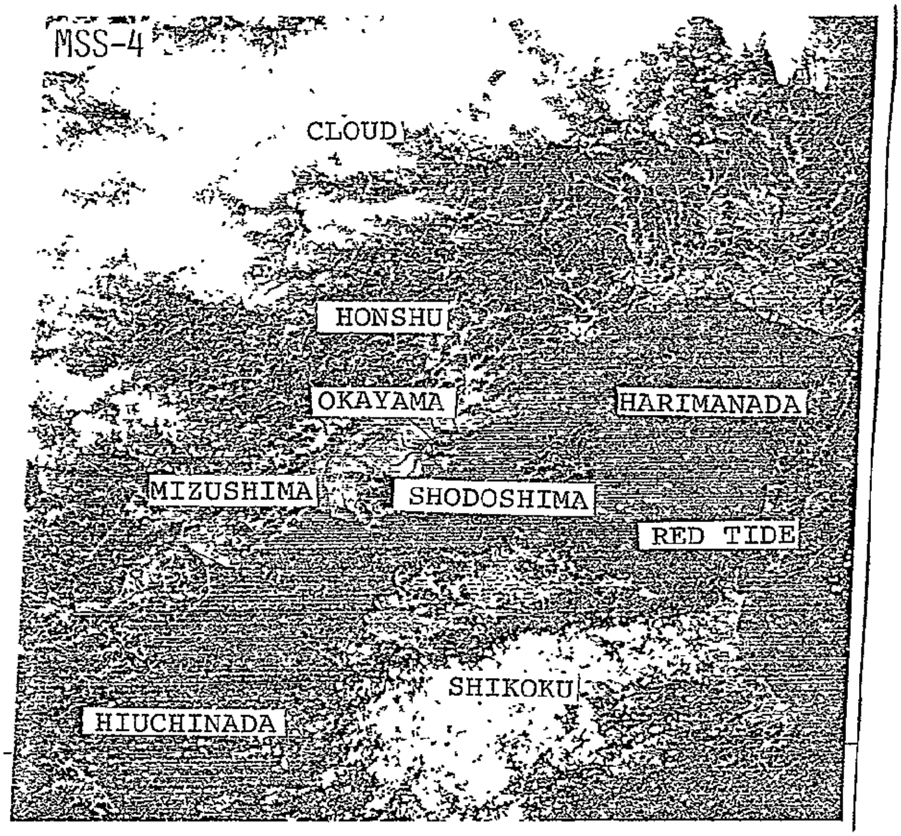

Figure 10 LANDSAT-2 MSS-4 imagery. Dec. 30, 1975

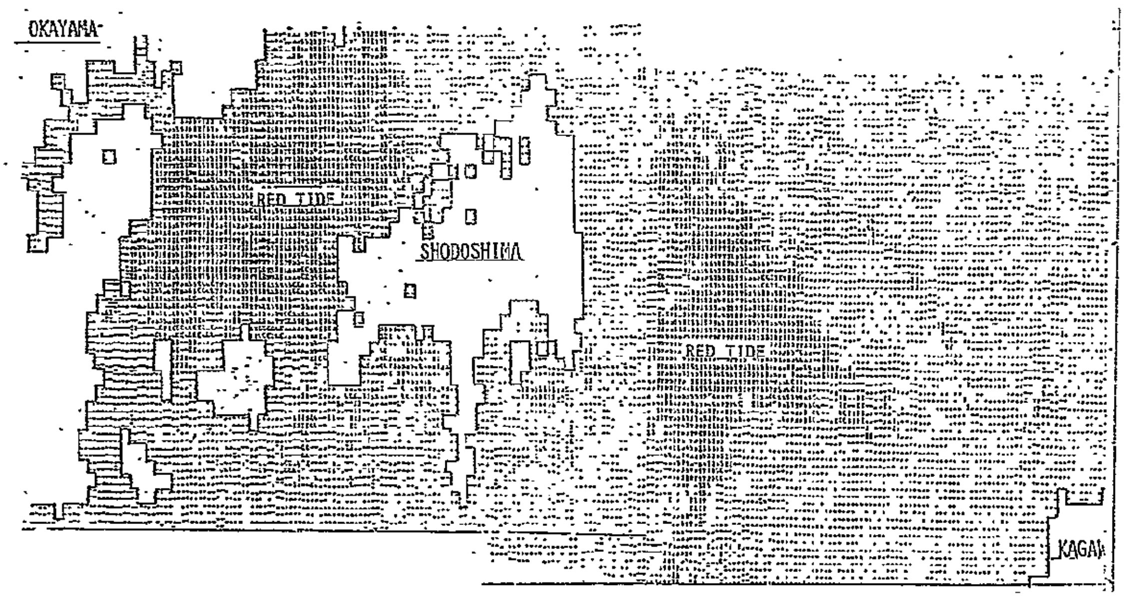

Figure 11 Print out of similarity analysis of red tide showed in Figure 10.

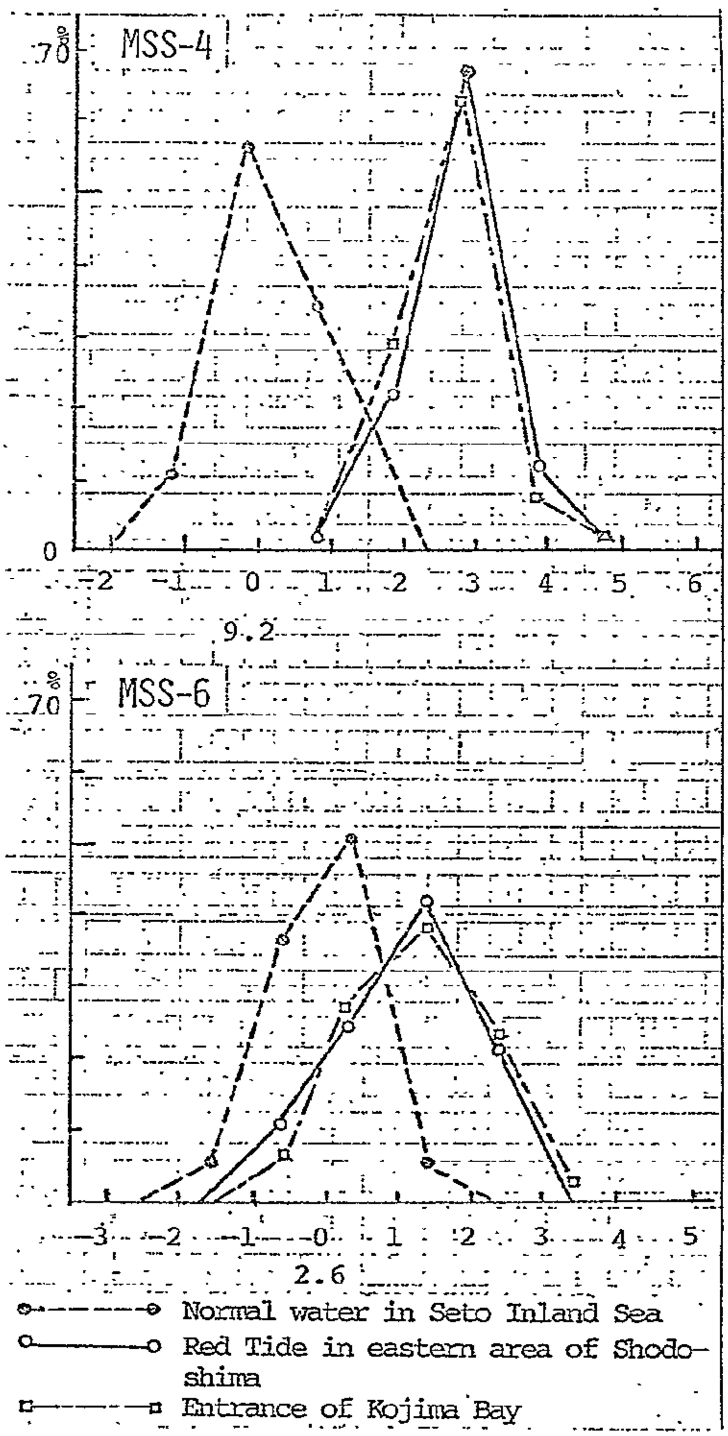

Figure 12 Spectral distritution of MSS data around Seto Inland Sea.

off Shodoshima were situated around 12 counts and these pattern were very similer to data distribution at red tide area in Mikawa Bay indicated in Figure 6. And the deviation of count were ± 2 and ust the same to not polluted water. In this point of view, the data distribution at red tide area showed in Figure 12 was recognized as typical distribution pattern and it was very effective to digital processing especially similarity analysis.

3-4 Hokkaido experiment

(A) Sedimentation

Along the southern coast of Hokkaido between Tomakomai and Urakawa, typical expanding pettern of sediment was detected in MSS-4 imagery as shown in Figure 12. As indicated in the author's report(2) MSS-4 imagery is very effective to detect the distribution of sediment, especially suspended sediment from the river. In Figure 13, expanding pattern from the mouth of Saru River was extended to southwest direction more than 15 km long. Saru River was noted as pollut-water with suspended substance and density of it is more concentrative compared with surrounding area. Namely, the river water contains so much suspended substance on normal condition, the river was named as Saru River. It means river which flows sand in Japanese.

Along the northeast coast of Hokkaido between Monbetsu and Abashiri, the distribution pattern of sediment was recognized in MSS-4 imagery as the index of shore current in this area. At the outside of Lake Saroma, a round-type pattern indicated black arrow was detected and it was estimated as sediment bulges out to the sea through sandy shoals which consist the outside bank of Lake Saroma.

4 Conclusion

The objective this study have been to analyze the marine environment in coastal area through the use of MSS data obtained by LANDSAT-2 2. During the LANDSAT-2 overpasses, air-born remotesensing and sea truth data have been collected for compairng and confirming of coastal phenomena around Japan. The major conclusions that have been described in this report were as follows:

(1) The most effective wavelength for the monitoring of red tide

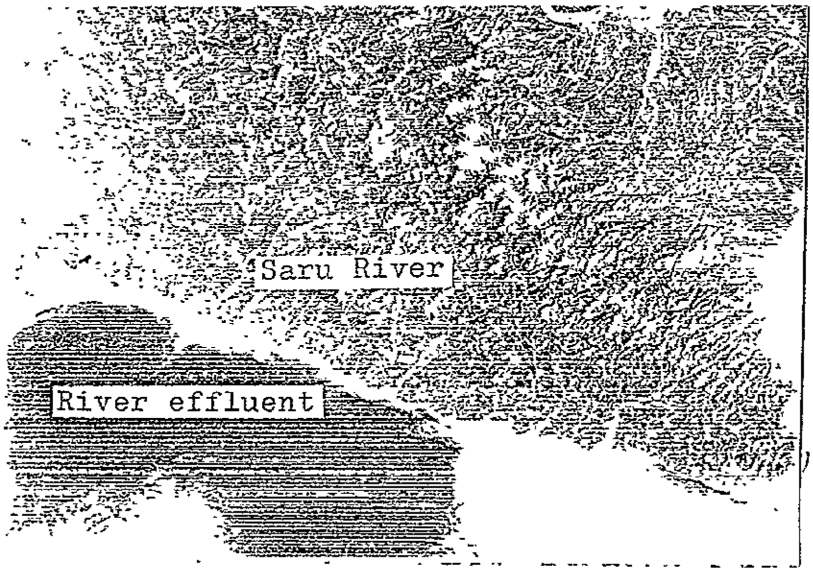

Figure 13 Distribution pattern of sedimentation. June 11, 1975

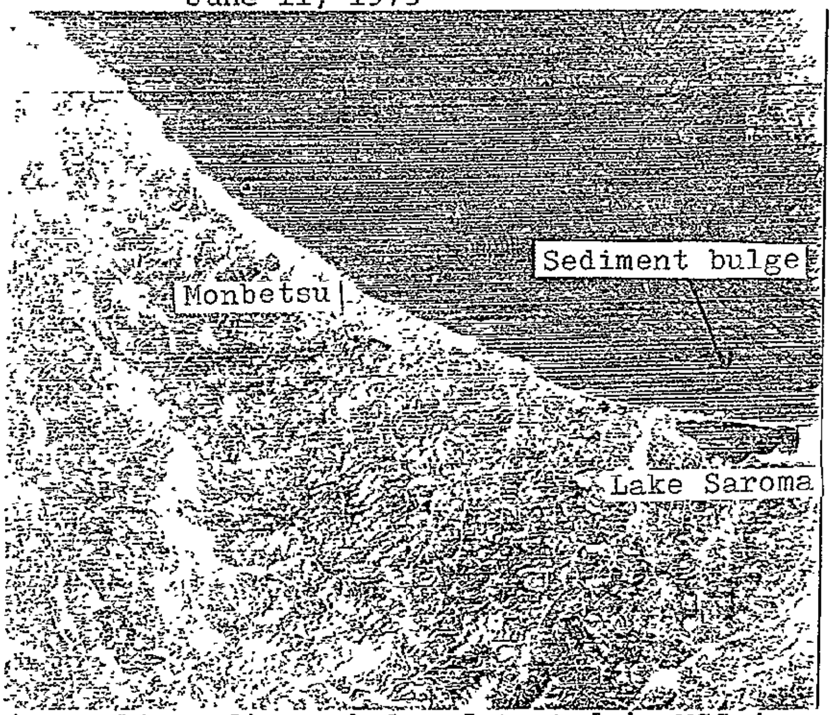

Figure 14 Sediment bulge detected in MSS-4 imagery. June 11, 1975

was recognized as MSS-4.

(2) In digital processing, similarity analysis was very effective to carry out the imformation for coastal phenomena like as red tide and suspended substance.

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