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ENVIRONMENTAL CHANGE PATTERN IN CENTRAL JAPAN AS REVEALED BY LANDSAT DATA

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ABSTRACT

Based on the MSS data taken in early Autumn by Landsat-1 and 2 of three years time lapse, intensive studies on environmental change pattern in Central Japan including Nagoya City, the 4th largest city of the country is made.

It is found that a patched cirrus reported by weather stations over the land which is hardly recognizable by eyes in the images of MSS affects radiance values significantly in Band 4 while its effect is little in Bands 6 and 7 (Near infrared spectra). The cross correlation coefficient analysis between two images indicates the highest value of 0.96 is obtained for a peninsula with a smooth shoreline followed by a small island with the value of 0.95 while the lowest value is 0.68 for a mountainous area with a river. The analysis of land use in Nagoya area shows there is little change in the metropolitan area while fairly large change took place in the northern periphery of the city where large housing projects are going on.

1. Intruduction

Due to the fact that the radiance values obtained at the Landsat level is the energy of reflected solar radiation by earth's surface and scattered in the atmosphere, the effect of the atmosphere is doubled. Theoretical studies of atmospheric effects on solar radiation has been made by many investigators, among them are Elterman(1968), Tanaka(1971) and Turner(1974) Rogers(1973) tried to evaluate atmospheric effect on the observed value of Landsat data, while Tsuchiya(1973, 1976) and Tschiya, Nakamura, Iwata and Ochiai(1975) discussed the effect of thin cirrus on the radiance value of Landsat MSS data.

Among a few good images taken over Japan during Landsat-2 Follow-on Project is the one covering central Japan including Nagoya City taken on Sept. 11 1975.

From the view point of season this image can be said that it was taken 20 days before the Landsat-1 image which was taken on Oct. 5 1972 in spite of the fact that there is three years time lapse. Making use of these two images data an attempt is made to find out environmental change in Nagoya area.

The first subject discussed is the comparison of radiance values of four selected areas in reference with the meteorological conditions. The numerical analysis on the environmental change through computation of cross correlation coefficient between the two images described before is the second subject. The third subject is the change of land use in Nagoya city and its suburbs.

2. The image of central Japan taken by Landsat-1 and 2

In Fig. 1 (a - d) are shown the images of central Japan including Nagoya city, the fourth largest city of Japan with 2 million population. The images were taken by Landsat 1 and 2 on Oct. 5 1972 and Sep. 11 1975 respectively. Throughout the study the former is called the old while the latter is called the new for short. Comparing the new and old images a large difference in the appearance is recognized over the ocean where clouds are visible in the old image while not in the new. As far as a part of the image over the land, no significant difference is recognized.

3. Atmospheric condition

In an attempt to see the actual atmospheric condition, weather map analysis is made and shown in Fig. 2. The area corresponding to the Landsat image is indicated by broken line. In the figure the weather, clouds and winds are plotted in standard WMO code. Numerals in the figure are visibility in the unit of km.

On Oct. 5 1972 most of the stations reported patched thin cirrus and smog was observed at Nagoya. General cloud distribution was such that the clouds were thicker towards east, west and south. On Sep. 11 1975 no cloud was observed at the weather stations within the image boundary. The distribution of visibility on both days is similar except eastern part where that of Oct. 5 1972 showed a poor visibility. The poor visibility of Nagoya is due to smog which is caused by dusts and smoke from the factories and heavy traffics. It is interesting to see that the visibility at Nagoya is same on both days. In order to see the vertical atmospheric condition, radio sounding at Hamamatsu (as to location see Fig. 2. (b)) are plotted and shown in Fig. 3.

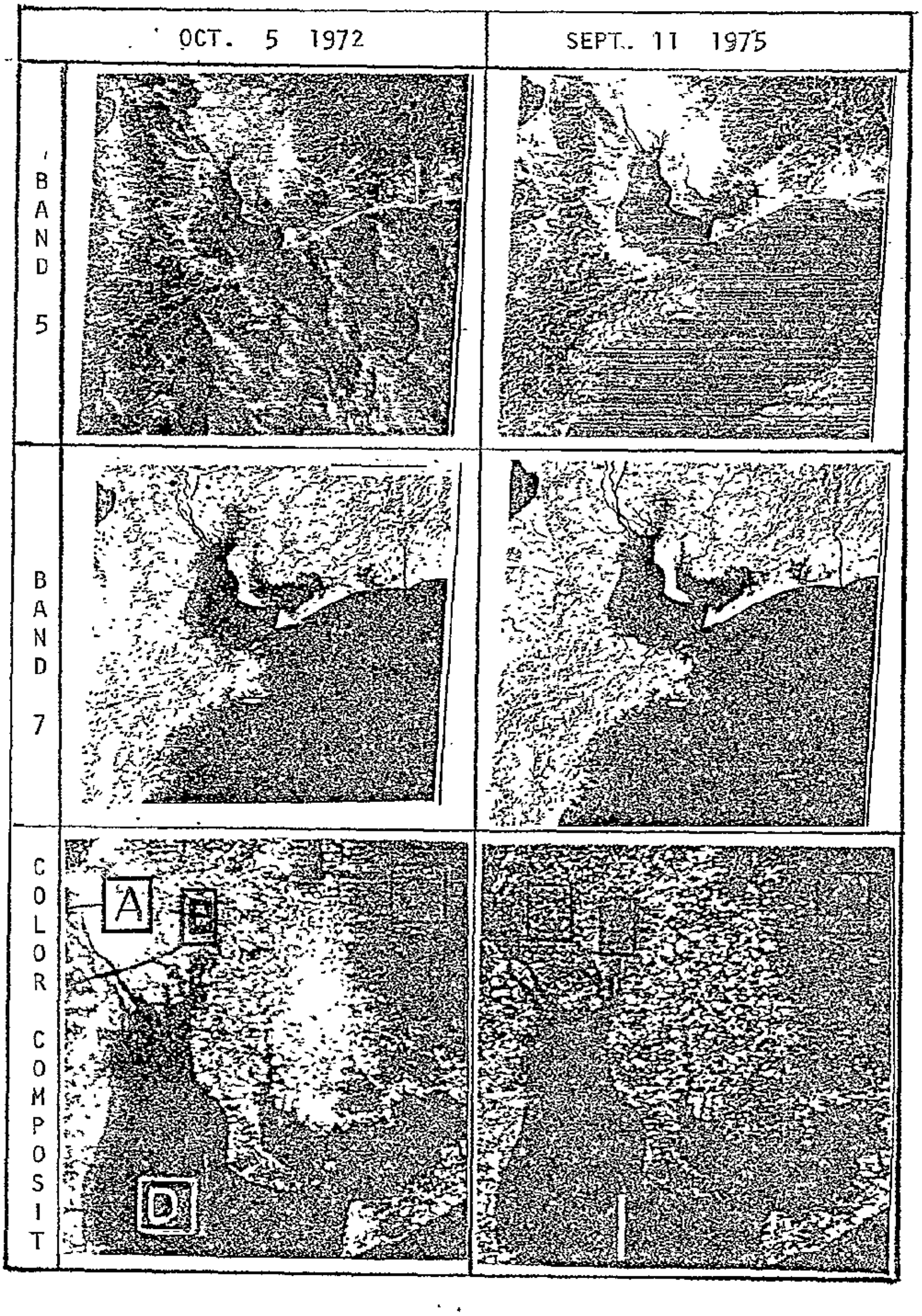

Fig. 1 Landsat MSS images taken on Oct. 5 1972 by Landsat-1 and on Sept. 11 1975 by Landsat-2 respectively. The areas indicated by letters A, B, C and D are the areas over which digital analysis is made in section 4.

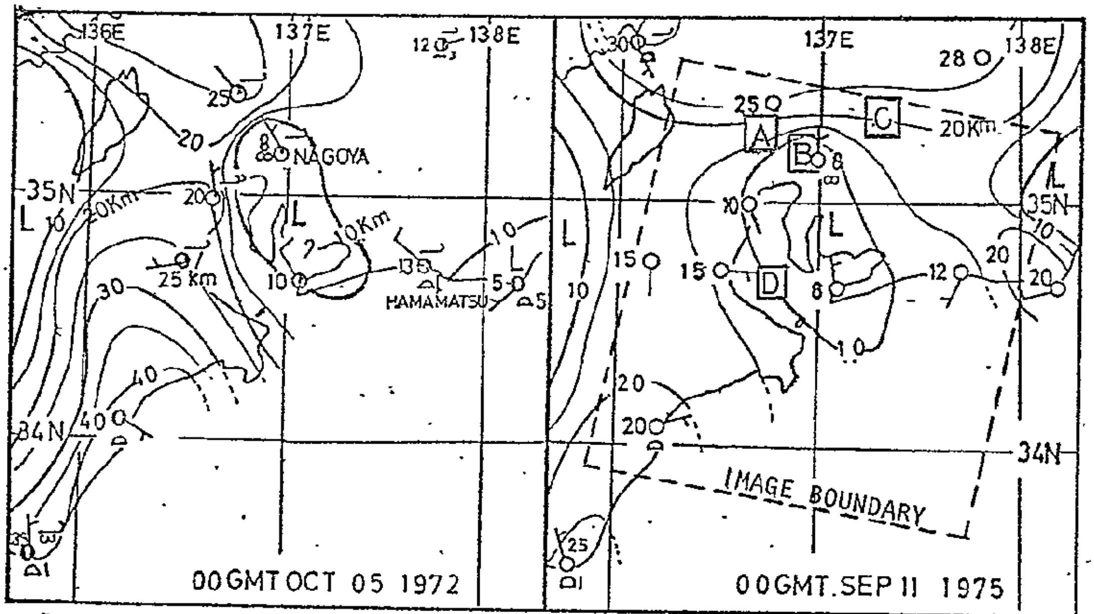

Fig. 2 Weather map at 00 GMT on Oct. 5 1972 and Sep. 11 1975. Numerals are visibility in kms and solid line is iso-visibility line.

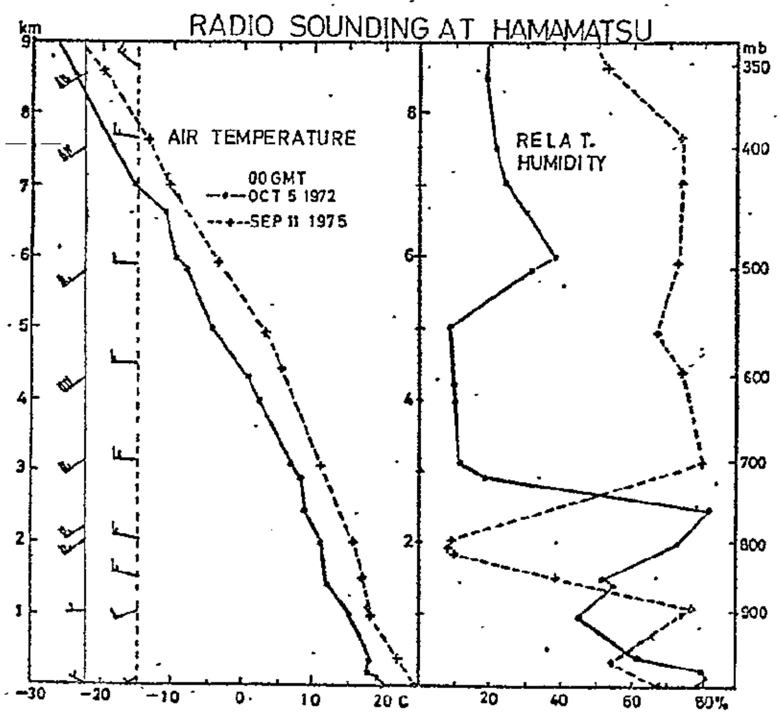

Fig. 3 Radio sounding at Hamamatsu at 00 GMT on Oct. 5 1972 and Sep. 11 1975 respectively showing vertical distribution of air temperature and relative humidity. Winds are also shown in standard WMO Code.

The vertical distribution of air temperature on both days is similar except a very slight inversion in the lower layer close to the ground level observed on Oct. 5 1972, however there is a fairly large difference in the distribution of relative humidity which is shown in the right hand side of the figure. The phase of vertical distribution is somehow opposite. There is an extremely dry layer at 800-mb level on September 11 1975 while on Oct. 5 1975 above 700-mb level it is very dry except at 500-mb. On Sep. 11 1975 a fairly thick wet layer exists between 400 and 700-mb levels.

If aerosols in the upper layer is assumed same, the main factors contributing to solar radiation reaching the ground is smog and water vapor. Since water vapor is a unique function of air timperature, it is considered that total amount of water vapor or precipitable water in the air column on both days is not much different in spite of the difference in vertical distribution pattern of relative humidity.

4. Radiance values of four selected areas.

Making use of the CCT's supplied from NASA the mean values and standard deviations of digital numbers corresponding to radiance over four selected areas, i. e. a farming area, Nagoya City, a mountain area with thick ever green trees and sea surface of Ise Bay are computed and shown in Table 1. The locations of the areas are shown in Fig. 1 and 2.

Table 1 Mean and standard deviation of digital number of four selected areas. A: Farming area, B: Nagoya City, C: Mountain area with thick evergreen trees, D: Sea surface.

		.00 GMT OCT 5 1972				0048 GMT SEP 11 1975			
		B4	B5	B6	B7	B4	B5	B6	B7
A	M	39.3	32.0	43.5	21.5	22.8	22.9	47.1	21.7
	S. D.	7.0	3.2	4.7	3.0	3.1	4.8	6.9	4.5
B	M	37.8	31.7	29.1	12.1	27.7	30.5	31.1	10.9
	S.D.	6.3	3.0	2.9	1.6	2.8	4.5	5.4	2.6
C	M	23.1	14.5	33.3	19.5	12.5	10.7	38.1	19.8
	S.D.	8.3	3.2	6.7	4.5	2.0	2.9	8.4	5.0
D	M	25.7	15.5	11.3	3.4	13.3	9.5	4.0	0.3
	S.D.	1.4	1.3	1.4	0.8	0.8	0.8	0.9	0.0

Over the land areas, there is a certain similarity, i. e. the digital numbers of Bands-4 and 5 of Oct. 5 1975 are systematically larger than those of Sep. 11 1975 even if the incoming solar radiation is a little smaller. On the other hand at Band 6 the value of the latter is larger and at Band 7 the value is nearly equal. Apparently the effect of thin cirrus and atmospheric condition are well reflected in the values of Bands-4 and 5 while the contribution of them is not so large in Bands-6 and 7 or it can be concluded that the effect is negligible.

The global albedo defined as the ratio of outgoing and incoming solar radiation at the outside of the atmosphere is computed and shown in Table 2. In the conversion of digital number into radiance, the values in Landsat User's Handbook(1972) is used.

Table 2 Global albedo for the four selected areas (%)

	OCT. 5 1972				SEPT. 11 1975			
	B4	B5	B6	B7	B4	B5	B6	B7
A	45.4	36.0	49.0	49.1	24.3	23.9	49.0	45.5
B	43.6	35.8	32.9	27.6	29.5	31.6	32.2	22.9
C	26.8	16.4	37.5	44.5	13.4	11.1	39.5	41.6
D	12.0	17.5	12.6	7.7	14.2	9.8	4.1	0.0

In average over the land the value of Band 4 of the old is larger than that of the new by 16 % while the difference becomes -0.6 % and 3.7 % in Bands- 6 and 7 respectively. The larger value of the old in Bands- 6 and 7 can be attributed to the effect of vegetation since the leaves of vegetation are more green with larger reflectance in near-infrared spectra.

5. Numerical analysis of environmental change during the three years

In order to find out the degree of environmental change, a cross correlation analysis is made using the values of Band 7 data. Since the radiance value has the least atmospheric effect as is indicated in the previous analysis. In the computation of cross correlation coefficient, the following procedures are taken. First, reference areas are selected from the old image the location of which is indicated in Fig. 4.

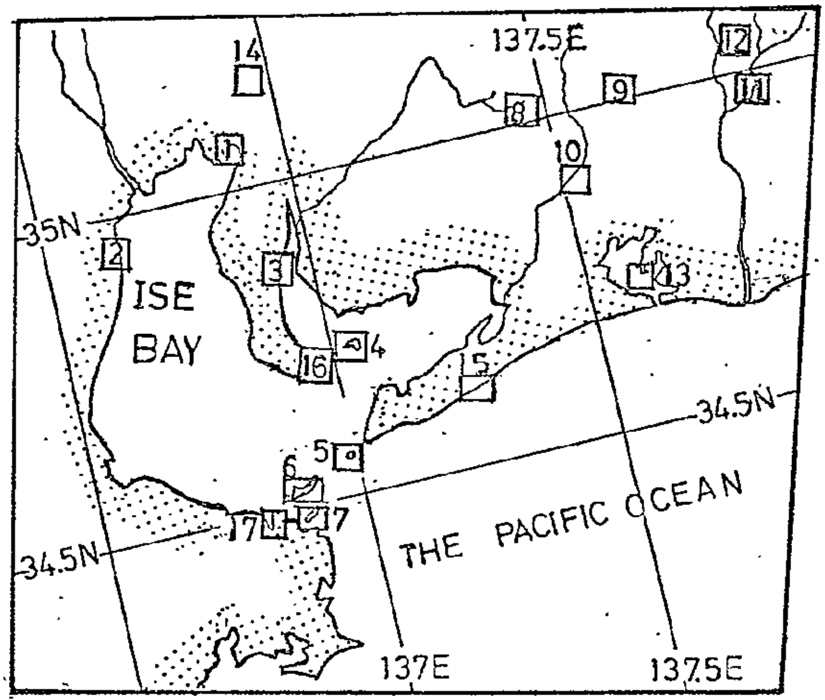

Fig. 4 A map showing the the locations where reference templates were taken.

From each reference area a template composed of 64x64 picture elements (pixels) is made. Then cross correlation coefficients are computed between the template and the corresponding areas in the new image. In order to avoid mis-registration, the computation is made by Eq. (1).

$$C(m,n) = \frac{\sum_{i=1}^{M}\sum_{j=1}^{M}[X(i+m, j+n) - \overline{X}(m,n)][Y(i,j) - \overline{Y}]}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{M}[X(i+m, j+n) - \overline{X}(m,n)]^2}\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{M}[Y(i,j) - \overline{Y}]^2}} \qquad (1)$$

where, X and Y denote radiance values of each pixel in the new and the old images respectively and M is fixed as 64. The size of the areas in the new image is fixed to be 4 times as large as a template with the template approximately in the center. Then computation is made by changing 1 and m then the largest value of cross correlation coefficients is selected. The result of computation is indicated in Table 3.

Table 3 The cross correlation coefficient between the old and the new images for selected areas

Number	Geographical feature	Cr. Cor. Coeff.
	Harbor	
1	of Large city	0.840
2	of Oil industry	0.888
3	of Small city	0.887
	Island	
4	Small	0.928
5	Very small	0.928
6	Large	0.935
7	Small	0.946
8	Mountain area with	0.789
9	a small lake	0.811
10	Mountain area with	0.801
11	a river	0.684
12	Summit with trees	0.809
13	Lake with a bridge	0.935
14	Large city	0.762
	Peninsula	
15	with smooth shore line	0.963
16	Same as above	0.955
17	with Complicated shore line	0.938

The best fit is a peninsula with a smooth shore line (No 15) with the value of 0.963 while the poorest value is 0.684 for a mountain area with a river. This poor value is considered due to the amount of water in the river since the amount of water gives significant effect on the distribution of radiance especially in the near-infrared spectrum.

As far as the numerical values are concerned, the areas with the values above 0.85 may be defined as the area with little environmental change. It should be also added that the area named as a city (No 14) is picked up from eastern part of Nagoya city where land use change took place during the three years.

6. Land-use analysis in Nagoya City

Further land use classification is made for Nagoya area. The area analyzed is approximately 15x15 km^2. Classification is made into 6 categories, i. e. forest, agricultural, open, urban, suburban, water, new urban areas and others. The result of analysis is indicated in Fig.5 in which original 16 pixels are combined into one pixel therefore pixel in the figure corresponds to the area of 316x316 km^2. In the figure a large area of blue color in the center is urban area and denotes the metropolitan area of Nagoya City. Comparing two images it can easily be recognized that very little change took place in metropolitan area while changes took place in the periphery of the city.

To show more clearly the land use change, based on the two classified images, a land use change analysis is made and shown in Fig. 6 which shows large change in the areas to the north of metropolitan area. Ground surveys indicate that a number of large scale housing projects were going on at the observation time. It is also seen a fairly large variation of land use in the south-eastern area, however, here individual size is not so large.

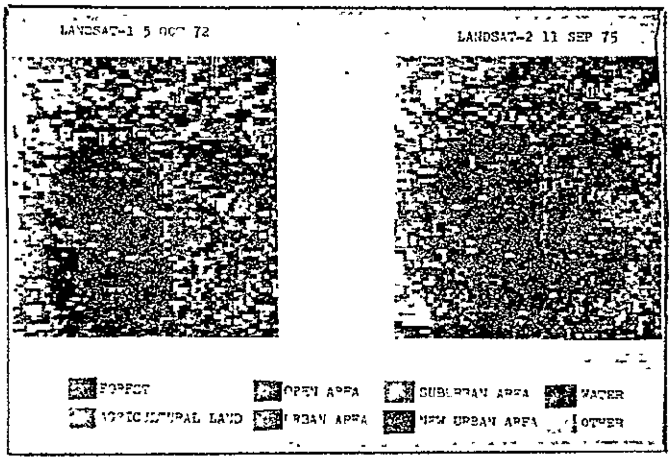

Fig. 5 Land use classification of Nagoya City and its suburbs.
Left hand: Oct. 5 1972, Right hand: Sep. 11 1975

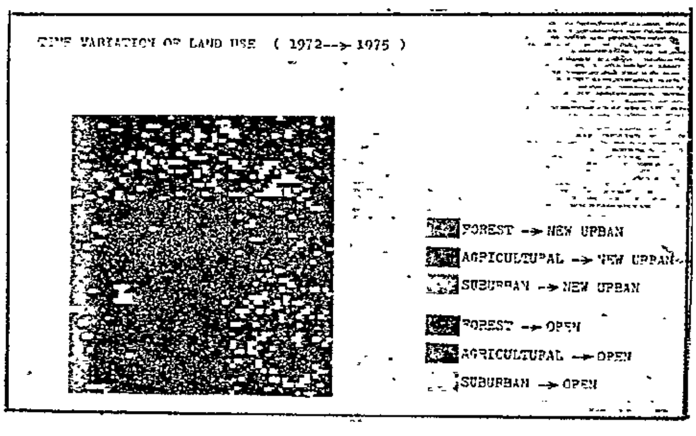

Fig. 6 Land use change in Nagoya City and its suburbs during 3 years between Oct. 5 1972 and Sep. 11 1975.

7. Concluding Remark

The foregoing analyses lead to the following conclusion. In the digital analysis of Landsat data, care must be taken for thin cirrus which often is hard to recognize visually. At the same time MSS data can be effectively used for the study of atmospheric radiation. Cross correlation analysis indicates the highest value obtained in central Japan is 0.963 for the area where little change occurred in land use. This suggests that a certain care must be taken in applying GCP matching method in precision processing of landsat raw data. Landsat MSS data are extremely useful for making land use map for a large area.

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