DEVELOPING METHOD FOR MONITORING RED-SOIL SEDIMENTATION IN CORAL REEFS OFF OKINAWA ISLAND, USING ALOS DATA

PI No. 366

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ABSTRACT

Red soil (local name: kunigami-maji) is a red to yellow soil that is easily washed away by rain when on a bare surface. Since the 1960s, a large amount of *red soil* in the northern part of Okinawa Island was washed out and deposited on the coral reefs as a result of land use changes. In this study, using the Advanced Land Observing Satellite (ALOS) Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) data for monitoring *red soil* sedimentation in the coral reefs were examined. In the Minna area, the ranges of green to near infrared bands of AVNIR-2 data were as same as or wider than those of TM data, but the range of blue band of AVNIR-2 data was narrower than that of TM data. These relations were also observed in the Katabaru area. The results suggest that the sensitivity of the blue band sensor of AVNIR-2 would differ from that of TM. However, it would not be fatal to monitoring *red soil* in the coral reefs.

1. INTRODUCTION

Red soil (local name: kunigami-maji) is a red to yellow soil that is easily washed away by rain when on a bare surface. Since the 1960s, a large amount of *red soil* in the northern part of Okinawa Island was washed out and deposited on the coral reefs as a result of land use changes. The coral reefs are sinks of greenhouse effect gas CO_2 and are important areas for ecosystems and global environment. In this study, using the Advanced Land Observing Satellite (ALOS) Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) data for monitoring *red soil* sedimentation in the coral reefs were examined. In this paper, the inner reef flats (*gamaku*), the shallow lagoons or moats of less than 3 m depth, and beaches inside reef crests (*pishi*) are generically referred to as coral reefs.

2. DATA AND METHOD

The study area is the whole Okinawa Island (Fig. 1). For a careful survey, Katabaru off the east coast of Okinawa Island was selected as a coral reef piled up by *red soil* and the coral reef off Minna Island as an area unpolluted by *red soil*. The method is based on the reflection spectral characteristics arising from the different mineral compositions of *red soil* and of the white sand of the coral reef [1]. The white sand of the coral reef consists of pieces of coral and shells; 98% of it is calcium carbonate ($CaCO_3$), and it contains a minute amount (0.03-0.10%) of iron oxide (Fe_2O_3). Conversely, 5-24% of the *red soil* of Okinawa Island is iron oxide [2]. The soil produced by the sedimentation of iron oxide absorbs blue to bluegreen spectra (400-500 nm wavelength) which corresponds to Landsat Thematic Mapper band 1 (TM1) and AVNIR-2 band 1 (AV1); the color in the region is yellow to reddish brown. Accordingly, the ratio of the brightness of the blue spectrum which is absorbed by iron oxide, to the brightness of unabsorbed red spectrum (630-690 nm) is negatively correlated with the amount of iron oxide in the soil (Fig. 2). Using this relationship, we can estimate the distribution of *red soil*.

The TM data acquired on 26 November 2000 on path-row=113-41&42 were used as reference one (Fig. 3). The AVNIR-2 data acquired on 16

November 2007, 15 December 2007, 3 July 2008, 1 October 2008, 18 October 2008 and 1 February 2009 on Path-Frame=85&86-3060&3070 (Table 1).
The reflection spectral characteristics for Katabaru area were compared with those of Minna area, taking into account the tide level at the observation time (Table 2). Sampling values of blue, green, red and near infrared bands at 15 m intervals, three spectral profiles in the Minna area were examined and a spectral profile in the Katabaru area was examined. Then, the concentrations of red soil were estimated, using the relationship shown in Fig. 2. after all TM and AVNIR-2 data were adjusted to the TM data acquired on 15 April 1988.

3. RESULTS AND DISCUSSION

The blue, green, red and near infrared brightness values of ALOS AVNIR-2 in coral reefs off Okinawa Island were compared with those of Landsat TM on the path-row=113-41 and 42, acquired on 26 November 2000.
In the Minna area, the ranges of green to near infrared bands of AVNIR-2 data were as same as or wider than those of TM data, but the range of blue band of AVNIR-2 data was narrower than that of TM data (Fig. 4, 5 and 6). These relations were also observed in the Katabaru area (Fig. 7 to 11).
Comparing the TM data acquired on 26 November 2000 with the AVNIR-2 acquired on 16 November 2007, the range of blue spectrum, which is absorbed by Fe_2O_3, of the TM data was larger than that of the AVNIR-2 data (Fig. 4). The range of red spectrum, which is reflected by Fe_2O_3, of the TM data was also larger than that of the AVNIR-2 data. The solar elevation at the observation time of TM data was 27.87° and smaller than that of the AVNIR-2 data (38.26°). The tide levels and DOY for both data were nearly equal. The results suggest that the sensitivity of the blue band sensor of AVNIR-2 would differ from that of TM.

4. CONCLUSIONS

In this study, using the ALOS AVNIR-2 data for monitoring *red soil* sedimentation in the coral reefs (inner reef flats, shallow lagoons and moats) were examined. In the Minna area, the ranges of green to near infrared bands of AVNIR-2 data were as same as or wider than those of TM data, but the range of blue band of AVNIR-2 data was narrower than that of TM data. These relations were also observed in the Katabaru area. The results suggest that the sensitivity of the blue band sensor of AVNIR-2 would differ from that of TM. However, it would not be fatal to monitoring *red soil* in the coral reefs (Fig. 12, 13 and 14).
In the future, making satellite data-based red-soil sedimentation map as a routine will be needed to monitor the land erosion and the coral reef pollution.

4. REFERENCES

[1] K. Okamoto, I. Yamada, T. Imagawa and M. Fukuhara, “Evaluation of the distribution of red soil outflow in the coral reefs off the northern part of Okinawa Island by using of the Landsat TM data,” *J. Geogr.*, **101**, pp. 107-116, 1992.
[2] T. Yamauchi, “*Special soil in Kyushu and Okinawa*,” Kyushu branch of the Society of Soil Engineering, Kyushu University Press, Fukuoka, 243p, 1983.

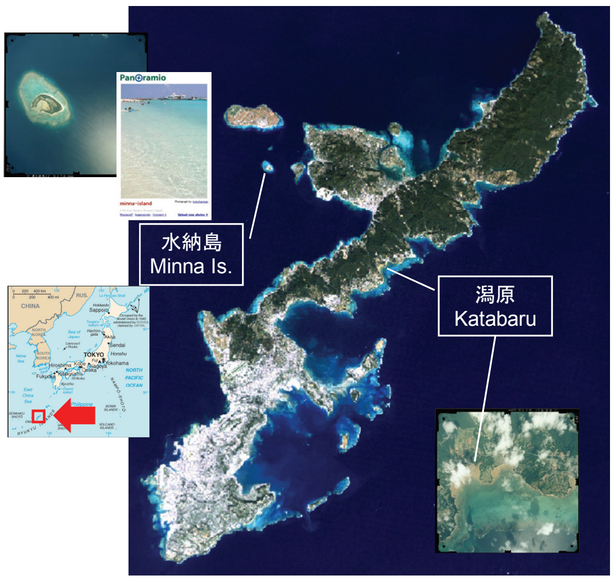

Fig. 1 Study area: Okinawa Island and coral reefs.

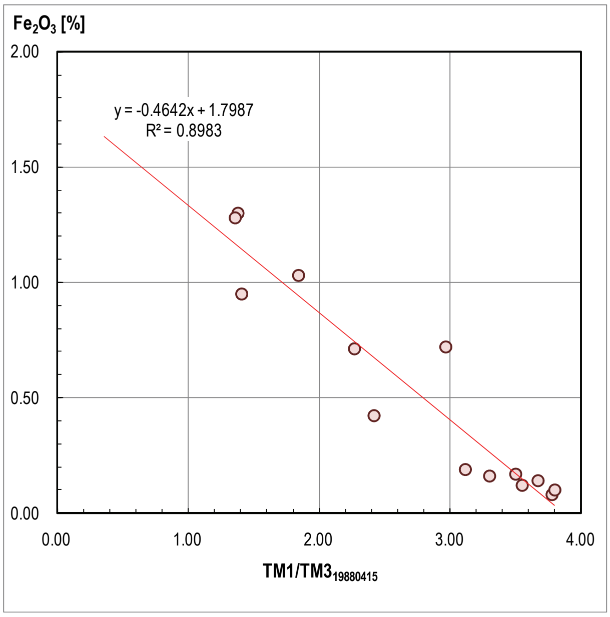

Fig. 2 Relation between ratio of blue-to-red (TM1/TM3) and Fe_2O_3 (%) of sediment in tideland and coral reef.

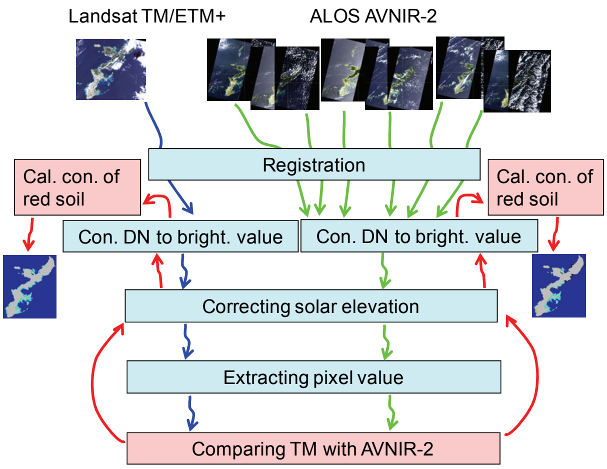

Fig. 3 Procedure of analysis.

Table 1 Landsat TM and ALOS AVNIR-2 used and solar elevation and azimuth at their observation time.

Data	Observation Time [year/month/day-hour:minute]	Solar Elevation [degree: average (North, South)]	Solar Azimuth [degree turning clockwise from North: average (North, South)]
Landsat TM	1988/04/15-09:30	44.78	103.25
Landsat TM	2000/11/26-09:30	27.87	135.79
ALOS AVNIR-2	2007/11/16-10:30	38.26 (38.08, 38.45)	148.13 (148.30, 147.96)
ALOS AVNIR-2	2007/12/15-10:30	33.32 (33.14, 33.50)	149.00 (149.14, 148.85)
ALOS AVNIR-2	2008/07/03-10:30	61.84 (61.89, 61.79)	90.71 (91.20, 90.21)
ALOS AVNIR-2	2008/08/01-10:30	60.25 (60.26, 60.24)	100.45 (100.92, 99.98)
ALOS AVNIR-2	2008/08/18-10:30	58.19 (58.16, 58.22)	109.24 (109.67, 108.80)
ALOS AVNIR-2	2009/02/01-10:30	36.03 (35.88, 36.19)	140.43 (140.61, 140.26)

Table 2 Tide level at observation time of Landsat TM and ALOS AVNIR-2: Minna Island (= Port of Toguchi) and Katabaru (= Port of Ishikawa).

Data	Observation Time [year/month/day-hour:minute]	Tide Level of Minna Island [cm]	Tide Level of Katabaru [cm]
Landsat TM	1988/04/15-09:30	96	77
Landsat TM	2000/11/26-09:30	153	137
ALOS AVNIR-2	2007/07/01-10:30	108	86
ALOS AVNIR-2	2007/11/16-10:30	146	153
ALOS AVNIR-2	2007/12/15-10:30	154	162
ALOS AVNIR-2	2008/07/03	81	72
ALOS AVNIR-2	2008/08/01-10:30	88	69
ALOS AVNIR-2	2008/08/18-10:30	148	120
ALOS AVNIR-2	2009/02/01-10:30	165	170

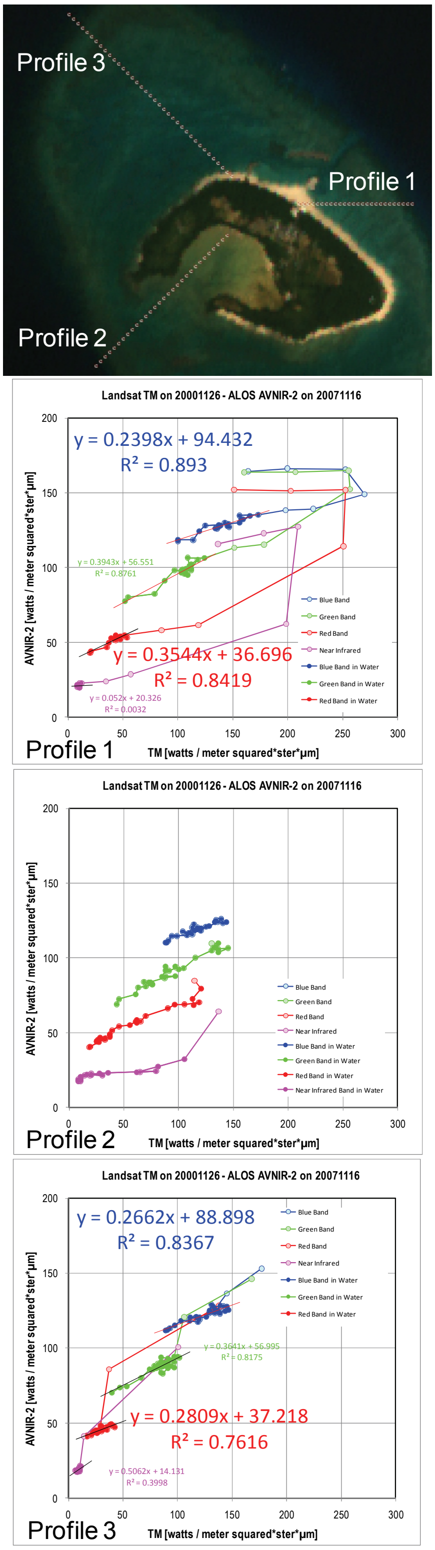

Fig. 4 Profile in Minna Island. ALOS AVNIR-2, Path-Frame: 86-3060&3070, 16 Nov. 2007, Profile 1: Points 1-4 are on land, others in water, 2: All points are in water, 3：Points 1-2 are on land, others in water.

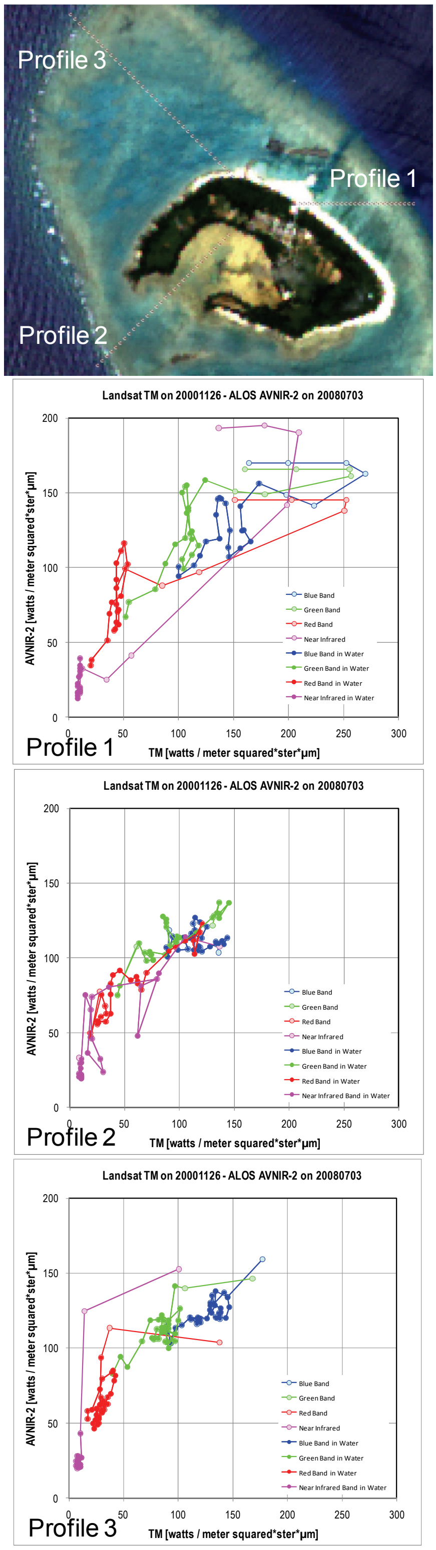

Fig. 5 Profile in Minna Island. ALOS AVNIR-2, Path-Frame: 86-3060&3070, 3 Jul. 2008, Profile 1: Points 1-4 are on land, others in water, 2: All points are in water, 3：Points 1-2 are on land, others in water.

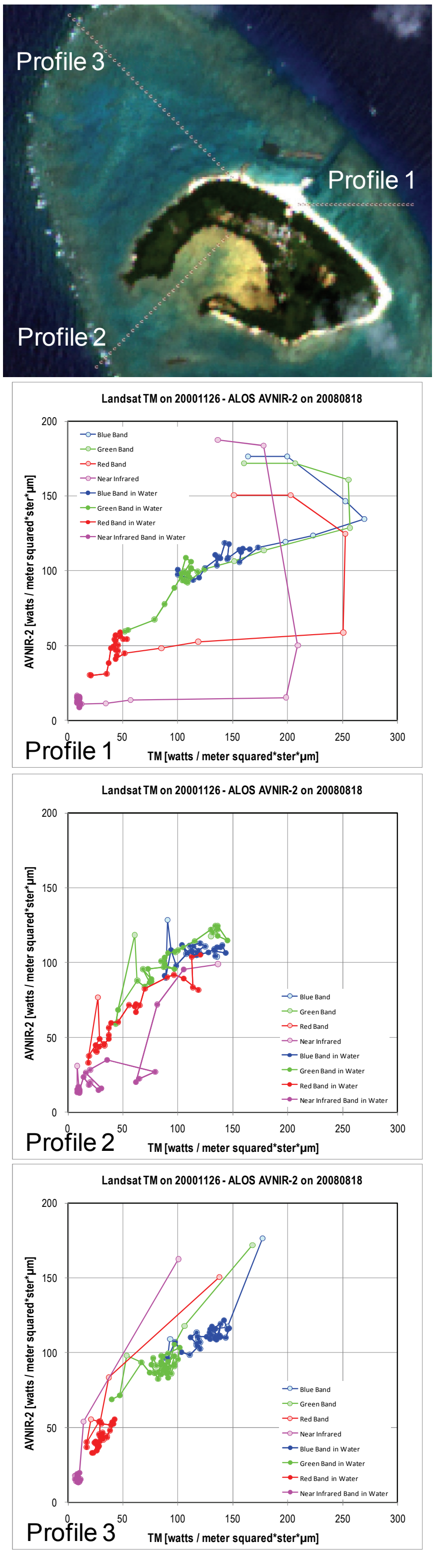

Fig. 6 Profile in Minna Island. ALOS AVNIR-2, Path-Frame: 86-3060&3070, 18 Aug. 2008, Profile 1: Points 1-4 are on land, others in water, 2: All points are in water, 3 : Points 1-2 are on land, others in water.

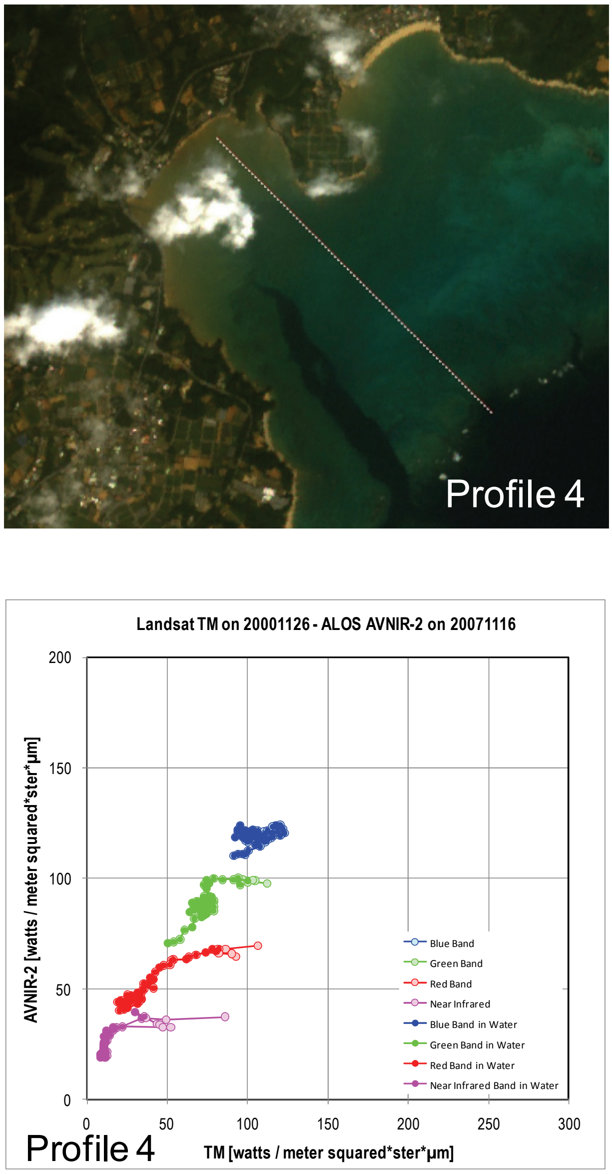

Fig. 7 Profile in Katabaru. ALOS AVNIR-2, Path-Frame: 86-3060&3070, 16 Nov. 2007, Profile 4: All points are in water.

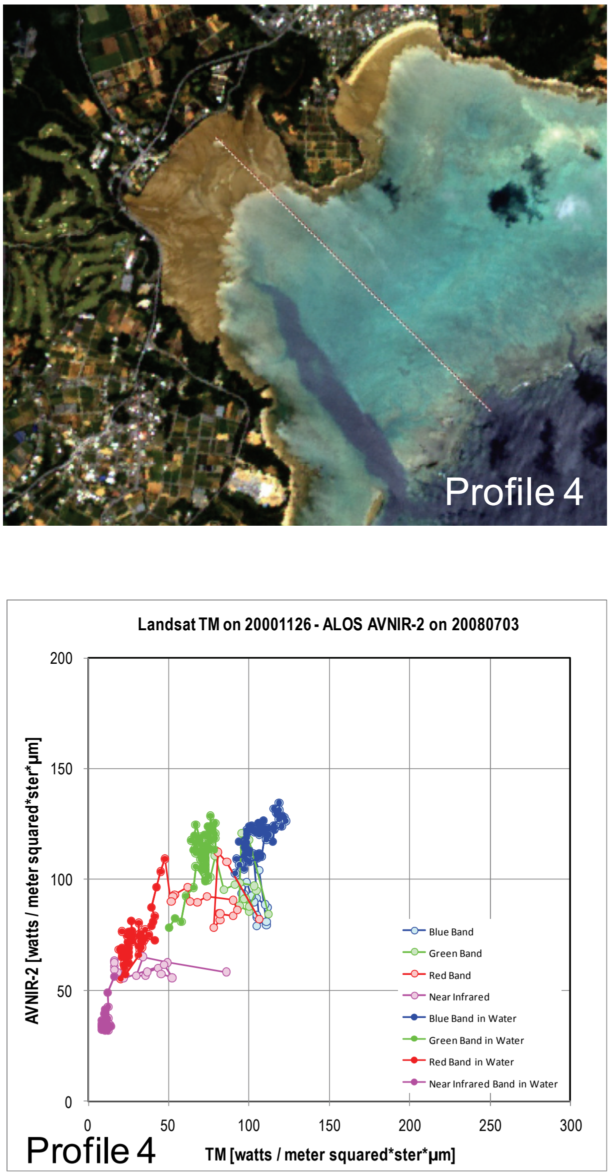

Fig. 8 Profile in Katabaru. ALOS AVNIR-2, Path-Frame: 86-3060&3070, 3 Jul. 2008, Profile 4: Points 1-17 are on land, others in water.

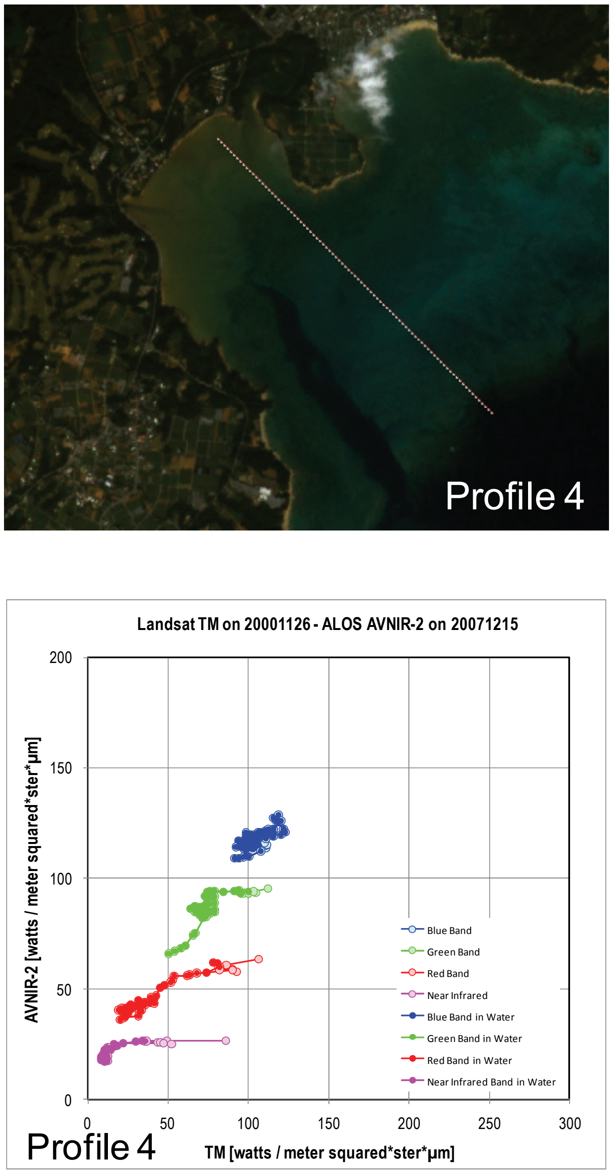

Fig. 9 Profile in Katabaru. ALOS AVNIR-2, Path-Frame: 85-3060&3070, 15 Dec. 2007, Profile 4: All points are in water.

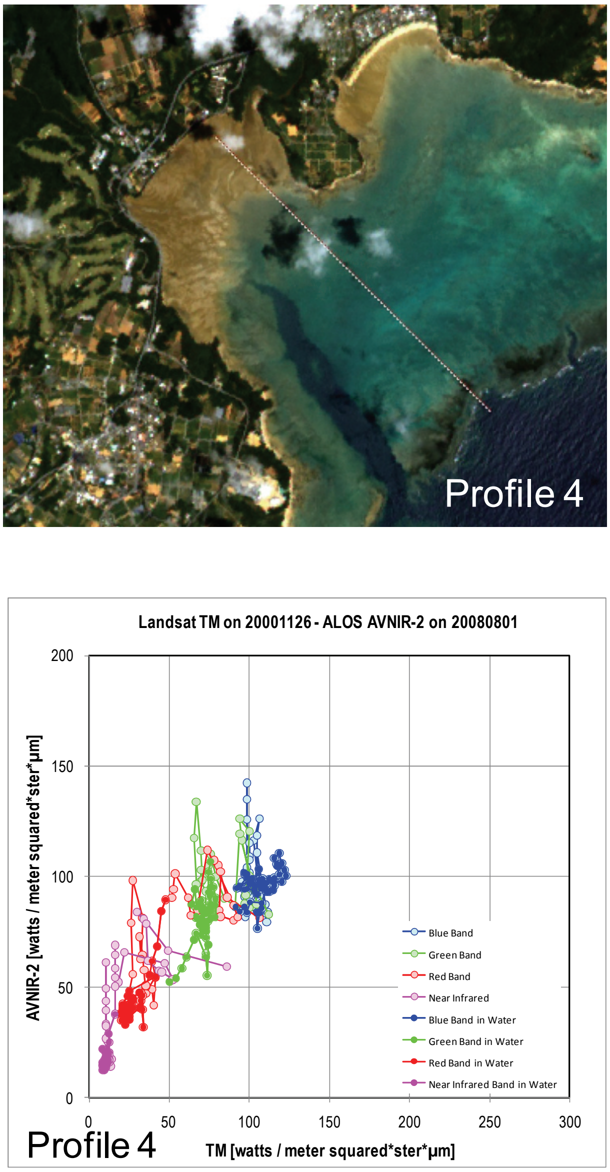

Fig. 10 Profile in Katabaru. ALOS AVNIR-2, Path-Frame: 85-3060&3070, 1 Aug. 2008, Profile 4: Points 1-17 are in land/cloud, 22-25 and 28-38 in cloud/shadow, others in water.

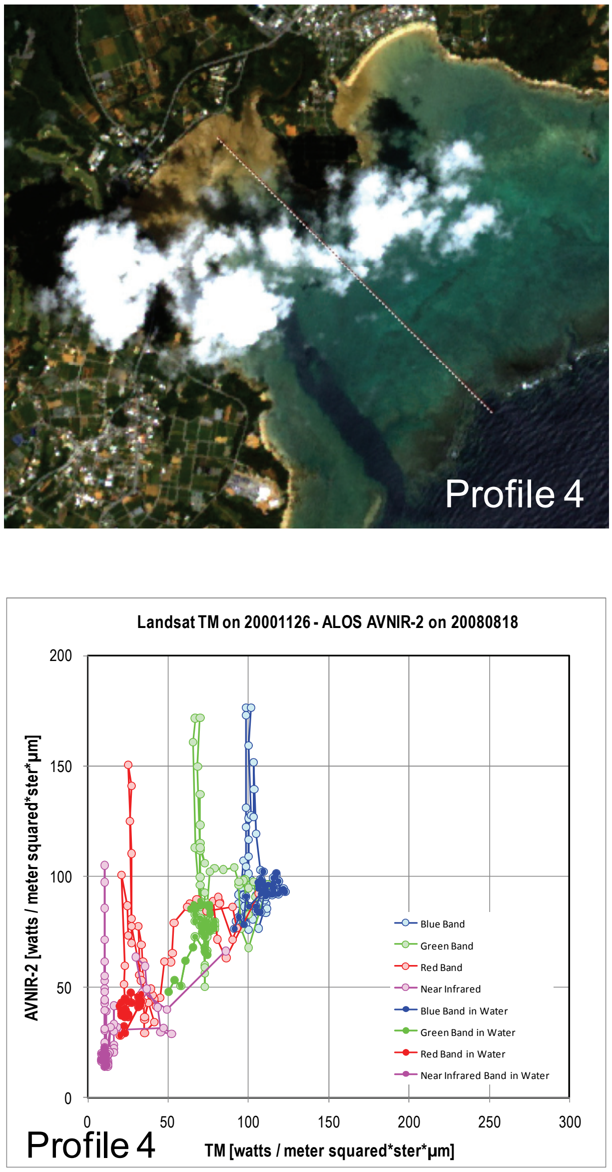

Fig. 11 Profile in Katabaru. ALOS AVNIR-2, Path-Frame: 86-3060&3070, 18 Aug. 2008, Profile 4: Point 1 and 4-10 are on land, 2-3 and 11-46 are in cloud/shadow, others in water.

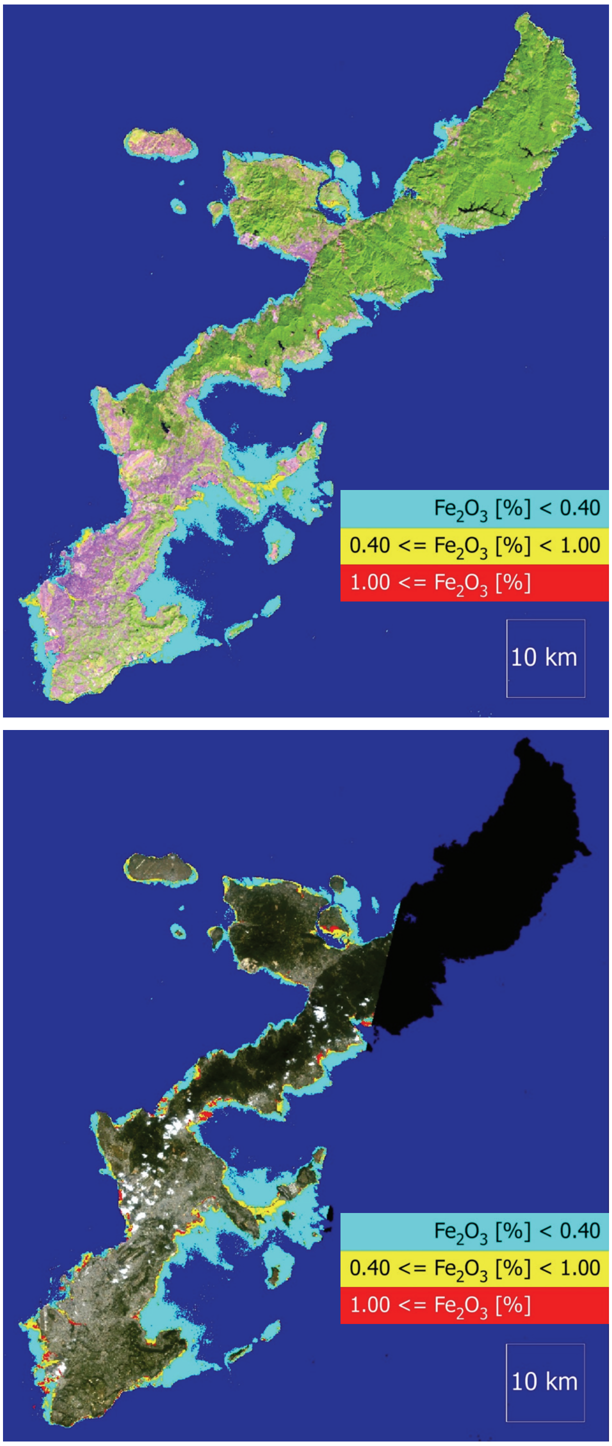

Fig. 12 Red soil maps. Top: Red soil map derived from Landsat TM data acquired on 26 November 2000, Bottom: Red soil map derived from ALOS AVNIR-2 data acquired on 16 November 2007.

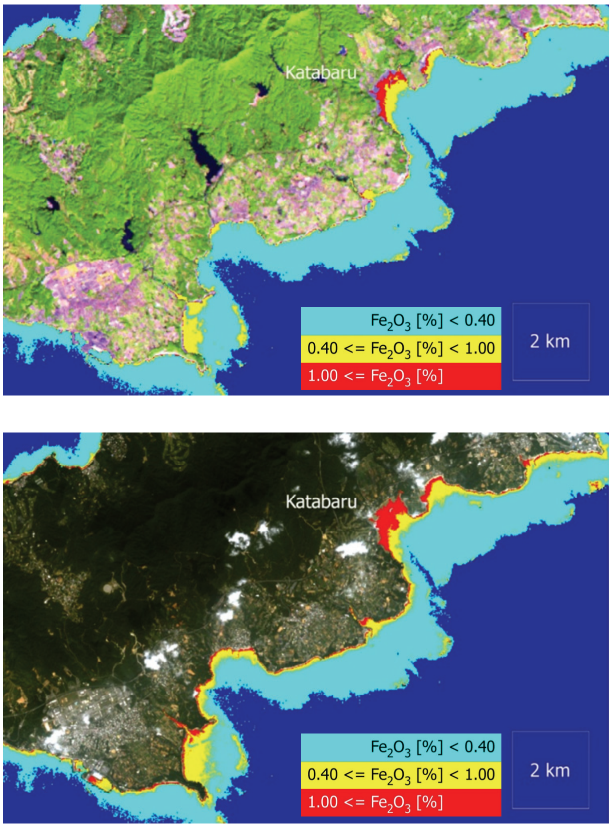

Fig. 13 Red soil maps. Top: Red soil map derived from Landsat TM data acquired on 26 November 2000, Bottom: Red soil map derived from ALOS AVNIR-2 data acquired on 16 November 2007.

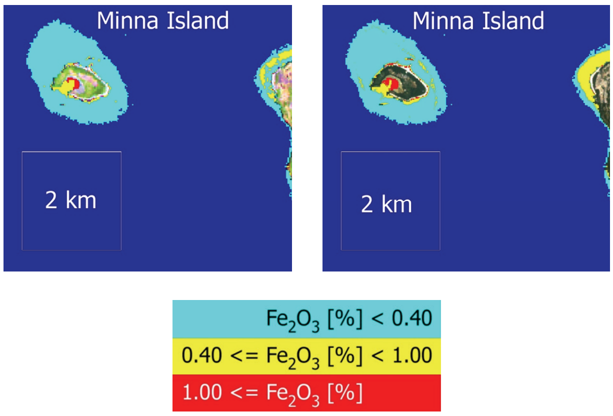

Fig. 14 Red soil maps. Left: Red soil map (part) derived from Landsat TM data acquired on 26 November 2000, Right: Red soil map (part) derived from ALOS AVNIR-2 data acquired on 16 November 2007.