ASTER time series image database dedicated to volcanoes

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Abstract
The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), which was launched on Terra platform in 1999, has a high spatial resolution imaging spectro-radiometer in the visible to near-infrared, shortwave-infrared and thermal infrared regions. A global volcano monitoring plan by using ASTER data has started, in which over 900 volcanoes are monitored periodically. A web-based ASTER image database dedicated to volcanoes is developed and opened to the public (http://www.gsj.jp/database/vsidb/image/index-E.html). The database consists of Official Version and Prototype Version. The Official Version contains all ASTER images of 49 most active volcanoes that are mainly in East Asia. The Prototype Version contains a part of ASTER images over 900 active volcanoes.

1. Introduction

Satellite remote sensing is a powerful tool for volcano monitoring. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), which was launched on Terra platform in 1999, is a high spatial resolution imaging spectro-radiometer (Yamaguchi et al., 1998). The ASTER can be used for volcano observations in the context of 1) topographic and geologic analysis, 2) mapping volcanic products, 3) eruption plume analysis, 4) discolored sea water and crater lake monitoring, 5) generating digital elevation models, 6) surface temperature mapping and 7) sulfur dioxide emission analysis (Urai et al., 1999). The unique features of the ASTER instrument such as along track stereo imaging and multispectral thermal infrared radiometry allow additional information about volcanoes to be acquired.
The ASTER Science Team proposed the global volcano observation plan with ASTER (Urai et al., 1999) and a large number of volcanic ASTER scenes were acquired since June 2000 when the ASTER normal operation was started. We can retrieve ASTER data from the ASTER Ground Data System (GDS) by geographic location. However, we often do not know the exact geographic location of the volcano. The Geological Survey of Japan, AIST developed a prototype image database for volcanoes that we can retrieve ASTER data by the volcano name. In this paper, the author describes the global volcano observation plan with ASTER and the ASTER image database dedicated to volcanoes.

2. Overview of ASTER instruments

The ASTER consists of three separate optical subsystems: visible and near-infrared (VNIR) radiometer, shortwave-infrared (SWIR) radiometer, and thermal infrared (TIR) radiometer, as described in Table 1. The VNIR subsystem has four bands similar to JERS-1 OPS including along-track stereo capability with nadir (band 3N) and backward (band 3B) views. The SWIR subsystem has a band centered at 1.65 μm and five bands from 2.1 μm to 2.5 μm mainly for soil and mineral mapping. The Low Gain 2, which is the special gain setting available only for SWIR, is used for observation of high temperature targets such as lava flows and fumaroles. The TIR subsystem has five bands in the thermal infrared region mainly for precise temperature measurements and rock type discrimination. Further details can be found in Yamaguchi et al. (1998) and Fujisada et al. (1998).

3. Volcano monitoring with ASTER

Volcanic features such as craters, lava flows and faults can be interpreted from an ASTER image, particularly a VNIR image with a 15 m ground resolution for a 60 km swath. The acquisition of a stereo image pair makes geologic interpretation easier. The areas covered by fresh volcanic ash and pyroclastic flow deposits are observed as bright colors in the VNIR images. Lava flows are represented by dark colors in the VNIR and bright colors in the SWIR images.
Eruption plumes are observed by the ASTER as well as Landsat TM, SPOT HRV, JERS-1 OPS, MOS 1/2 MESSR and NOAA AVHRR (Kinoshita, 1996). Drift velocity and altitude of volcanic plumes can be obtained using an image pair taken by the ASTER VNIR along track stereo function (Urai, 2004). Discolored sea water, which is generated above a submarine volcano or along the shoreline of a volcano, are observed by the VNIR bands (Urai and Machida, 2005). Temperature changes of crater lakes are observed in the TIR bands. Digital elevation models generated by ASTER stereo image pairs have the accuracy better than 20 m and 50 m in the vertical and horizontal directions, respectively, without GCP correction (Fujisada et al., 2005). The ASTER GDS provides digital elevation models as one of the standard data products. The TIR instrument is designed for surface temperature and emissivity mapping. Surface temperature up to 300 K are observed by the TIR. Pieri and Abrams (2005) found pre-eruption thermal anomalies at Chikurachki volcano, Russia, using TIR.
Radiance from active lava flows, lava lakes, pyroclastic flows and high temperature fumaroles may saturate the TIR detectors. These high temperature targets are observed by the SWIR bands, which have a special gain mode : Low Gain 2. The ASTER allows continuous temperature measurements ranging from the prevailing temperature to 460 °C and

from 670 °C to 910 °C.
Sulfur dioxide is one of the major constituents of volcanic gases. Sulfur dioxide has a strong absorption spectrum in the thermal infrared region, where the ASTER TIR has five bands. Realmuto et al. (1994) pointed out that the ASTER TIR could be used to make an estimation of the sulfur dioxide content of a volcanic plume. Urai (2004) estimated the sulfur dioxide flux from the Oyama volcano in Miyakejima, Japan using ASTER.

Subsystem	Band no.	Spectral range(μm)	Spatial resolution
VNIR	1	0.52-0.60	15m
	2	0.63-0.69	
	3N, 3B	0.78-0.86	
SWIR	4	1.600-1.700	30m
	5	2.145-2.185	
	6	2.185-2.225	
	7	2.235-2.285	
	8	2.295-2.365	
	9	2.360-2.430	
TIR	10	8.125-8.475	90m
	11	8.475-8.825	
	12	8.925-9.275	
	13	10.25-10.95	
	14	10.95-11.65	

Stereo Base-to-Height ratio	0.6
Swath width	60km
Total Coverage in Cross-Track Direction by Pointing	232km
Distance between adjacent orbit	172km
Repeat cycle	16days

Table 1 ASTER base line performance requirements (modified from Yamaguchi et al., 1998)

4. Global volcano monitoring plan with ASTER
Urai et al. (1999) proposed a global volcano monitoring plan using ASTER data. Over 900 volcanoes are monitored periodically (Figure 1). Observing strategies for individual volcanoes will vary according to their volcanic activity. The volcanoes to be monitored are selected from Simkin and Siebert (1994) and the Japan Meteorological Agency (1991). They are divided into three classes, A, B and C as shown in Table 2. Volcanoes of Class A, which have several eruption records during the last 10 years, are observed every 48 days in the daytime and every 32 days at night. Volcanoes of Class B have several eruption records during the last 100 years and are observed every three months in the daytime and at night. The other volcanoes classified as Class C are observed every six months in the daytime and at night.

Class	Number of volcano	Observation interval in day time (day)	Observation interval in night time (day)
A	102	48	32
B	222	91	91
C	182	182	182

Table 2 Observation intervals for the Global Volcano Monitoring (Urai et al., 1999).

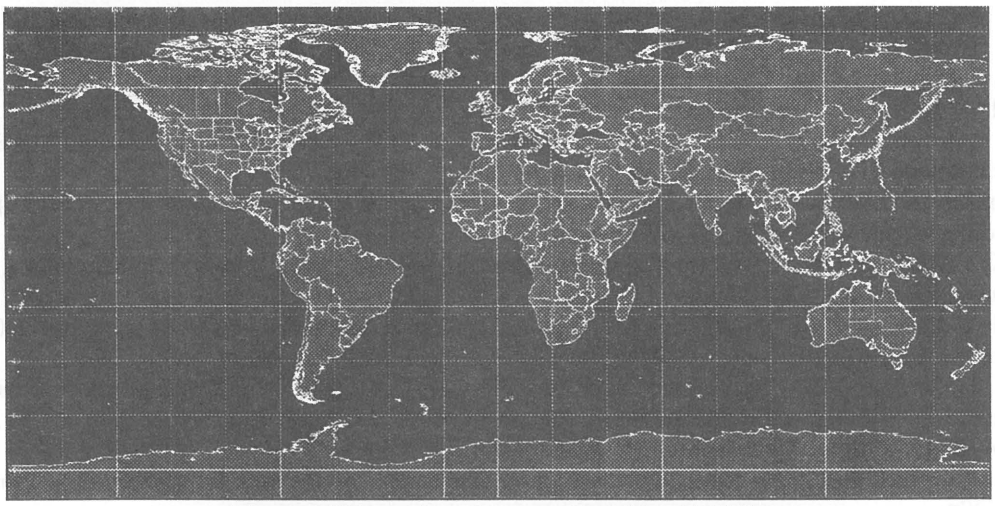
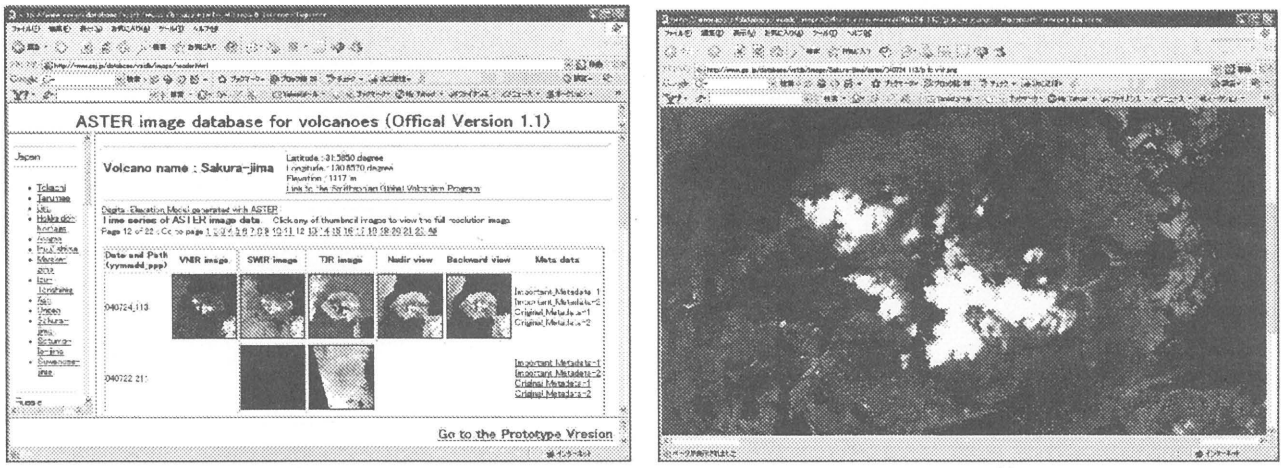


Figure 1 Volcano locations monitored by ASTER.

5. ASTER image database dedicated to volcanoes

A web-based ASTER image database dedicated to volcanoes is developed and opened to the public (http://www.gsj.jp/database/vsidb/image/index-E.html). The database consists of Official Version and Prototype Version. The Official Version contains all ASTER images of 49 most active volcanoes that are mainly in East Asia. The Prototype Version contains a part of ASTER images over 900 active volcanoes. All newly acquired ASTER images of the volcanoes in the Official Version are added to the database every month. However, some ASTER images of the volcanoes in the Prototype Version may not be added to the database. About 60 most active volcanoes other than in East Asia will be added to the Official Version within several months.

Figure 2a shows the web-based image database dedicated to volcanoes. You can choose a volcano from the menu displayed on the left hand side. Clicking a volcano name, you can see thumbnail ASTER images that are sorted by the data acquisition date. You can get a full resolution image by clicking a thumbnail as shown in Figure 2b.



(a) (b)

Figure 2 Web based ASTER image database dedicated to volcanoes.
(a) : Initial menu of the Official Version. (b) : Full resolution image display.

6. Conclusions

The ASTER can be used for volcano observations in the context of 1) topographic and geologic analysis, 2) mapping volcanic products, 3) eruption plume analysis, 4) discolored sea water and crater lake monitoring, 5) generating digital elevation models, 6) surface temperature mapping and 7) sulfur dioxide emission analysis. The ASTER observation is complementary to those from existing satellite sensors as well as with the MODIS instrument that is flying on the same platform. The global volcano monitoring has started using the ASTER. Over 900 volcanoes are monitored periodically according to the level of their volcanic activity. A web-based ASTER image database dedicated to volcanoes is developed and opened to the public. ASTER instrument is a powerful tool for monitoring of active volcanoes because ASTER has a wide spectral range, stereo imaging allowing DEM generation, thermal anomaly detection capability and the ability to classify land cover characteristics.

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References

Fujisada, H., Sakuma, F., Ono, A. and Kudoh, M. (1998) Design and Preflight Performance of ASTER Instrument Protoflight Model. IEEE Transactions on Geoscience and Remote Sensing, 36, no.4, 1152-1160.

Fujisada, H., Bailey, G. B., Kelly, G., Hara, S. and Abrams, M. J. (2005). ASTER DEM Performance. IEEE Transactions on Geoscience and Remote Sensing, 43, no.12, 2707-2714.

Japan Meteorological Agency (1991) National catalogue of the active volcanoes in Japan (Second edition). Japan Meteorological Agency, Tokyo, p.483. (in Japanese)

Kinoshita, K. (1996) Observation of flow and dispersion of volcanic clouds from Mt. Sakurajima. Atmospheric Environment, 30, no.16, 2831-2837.

Pieri, D. and Abrams, M. J. (2005) ASTER observations of thermal anomalies preceding the April 2003 eruption of Chikurachki volcano, Kurile Islands, Russia. Remote Sensing of Environment, 99, no.1/2, 84-94.

Realmuto, V. J., Abrams, M. J., Buongiorno, M. F. and Pieri, D. C. (1994) The use of multispectral thermal infrared image data to estimate the sulfur dioxide flux from volcanoes: A case study from Mount Etna, Sicily, July 29, 1986. Journal of Geophysical Research, 99, no.B1, 481-488.

Simkin, T. and Siebert, L. (1994) Smithonian Institution Volcanoes of the world (2nd edition). Geoscience Press, Tucson, 349p.

Urai, M. (2004) Sulfur dioxide flux estimation from volcanoes using Advanced Spaceborne Thermal Emission and Reflection Radiometer - A case study of Miyakejima volcano, Japan. Journal of Volcanology and Geothermal Research, 134, no.1-2, 1-13.

Urai, M. and Machida, S. (2005) Discolored seawater detection using ASTER Reflectance Products: a case study of Satsuma-Iwojima, Japan. Remote Sensing of Environment, 99, 95-104.

Urai, M., Fukui, K., Yamaguchi, Y. and Pieri, D. C. (1999) Volcano Observation Potential and Global Volcano Monitoring Plan with ASTER (in Japanese with Eng lish abstract). Bulletin of the Volcanological Society of Japan, 44, no.3, 131-141.

Yamaguchi, Y., Kahle, A. B., Tsu, H., Kawakami, T. and Pniel, M. (1998) Overview of Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). IEEE Transactions on Geoscience and Remote Sensing, 36, no.4, 1062-1071.