Satellite detection of volcanic aerosol at Miyakejima and Sakurajima

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Abstract: Ash-rich clouds at Sakurajima are well detected by the difference image of NOAA/A VHRR 5 and 4, while vapor clouds at Miyakejima are insensitive to the difference. Instead, the latter are detected by the difference of AVHRR 1 and 2, and discriminated well from meteorological clouds in many cases. Miyakejima plumes contain a lot of volcanic gas, and the daily monitoring of them by the NOAA satellites serves to understand high concentration events of sulfur dioxide at the downstream surfaces.

Keywords: NOAA/A VHRR, sulfur dioxide, satellite observation, aerosol

1. Introduction

Miyakejima volcano, about 160 km south of Tokyo as shown in Fig. 1, started eruptive activities at the summit Oyama (814 m) on 8 July 2000. Big eruptions were recorded on 10, 18 and 29 August with the altitudes of volcanic clouds about 8, 15 and 8 km, respectively. Since August 28, volcanic clouds and gas toward Main Island of Japan caused high concentration episodes of SO₂ at many ground stations 100-400 km leeward from Miyake-jima. Although big eruptions were not recorded since September, and plume heights were less than 3000 m above sea level, the estimated emission of SO₂ increased to 20-30 kt/day since mid-September. Southern and southwesterly winds brought the volcanic gas to the Main Island of Japan, where the smells of sulfur and/or H₂S were reported in various places. Since October, gray ash clouds are hardly seen, and the plumes turned out to be white with heights less than 1500 m above sea level after the middle of that month. Volcanic activities of Miyakejima have continued, with the emitted amount of SO₂ in volcanic gas about 10 times that of Sakurajima.

In previous studies, we have analyzed the air pollution at the foot of Miyakejima volcano, and the long-range advection of volcanic gas using various data such as satellite data, wind data, SO₂ concentration at the surface and the gas information [1-4]. The dispersion of SO₂ in Miyakejima plumes was detected by TERRA/ASTER sensor by Urai [5]. Thermal anomalies at Miyakejima crater were analyzed by Kaneko et al. using nighttime thermal images of NOAA/AVHRR [6].

In this study, we analyze NOAA/AVHRR images to detect the volcanic clouds from Miyakejima, and compare them with Sakurajima plumes. Furthermore, we discuss the SO₂ high concentration episodes recorded in the central part of Japan, by comparing the dispersion of volcanic clouds in the satellite images, gas information at the surface and the upper wind data.

Fig. 1. Location of Miyakejima in Izu Islands to the south of Tokyo. (2001/7/10 07:25JST NOAA15)
2. Methods of analyses

2-1. Satellite data analysis of Sakurajima plumes

In our previous studies, the split-window method taking the difference of AVHRR 4 and 5 (Aerosol Vapor Index: AVI = n (5) – n (4) + c) was very effective for the discrimination of the volcanic clouds at Mt. Sakurajima and Mt. Aso from the meteorological ones. This is due to the ash components with emissivity at 12 μm higher than at 11 μm. Fig. 2 shows wavelength of each band of NOAA/AVHRR and other satellites/sensors. This method can be also applied in monitoring large volcanic eruptions by GMS-5/VISSR.

2-2. Satellite data analysis of Miyakejima plumes

Volcanic clouds from Miyakejima were recognized as bright objects in visible and near infrared images as shown in Fig. 3 for 2001/7/12 13:27JST by NOAA16. Fig. 4 shows a profile of each band along the line AB indicated in Fig. 3. Volcanic cloud is not detected in band 4 and 5, but is detected in band 1, 2 and 3. We were able to distinguish volcanic cloud and meteorological ones from the difference of band 1 and 2. This may be due to the fact that volcanic cloud of Miyakejima is mainly white vapor with less ash since September 2000.

Band 3 is more sensitive to meteorological clouds compared with volcanic ones. We were able to distinguish volcanic clouds and meteorological ones by making color images of R:G:B=bands1:2:3. At the station in Kagoshima University, we receive data of NOAA12 at about 16:00, NOAA15 at about 7:00 and NOAA16 at about 13:00 in the daytime.

2-3. SO₂ concentration.
The estimates of total SO₂ emission by the correlation spectrometer (COSPEC) are shown in the homepages of GSJ (http://www.gsji.go.jp/~imiyagi/Works/Event/Miyake2000/geoI/000916cosepc/) and Japan Meteorological Agency (http://www.kishou.go.jp/miyake/jyoukyo/1116.pdf).

The Tokyo Metropolitan Government began continuous measurement of SO₂ and H₂S from November 2000 in Miyakejima, and also provides one-hour values of SO₂ concentrations in Tokyo, as analyzed in details in [2-4].

As the other sources of the information of SO₂ effect, there are the news of smell of sulfur, the notes of bulletin board in Internet, and Atmospheric Environmental Regional Observation System (AEROS) [7].

![Fig. 2. Wavelength of each band of satellites/sensors.](image)

![Fig. 3. Miyakejima plume, 2001/7/12 13:27JST NOAA16 R:G:B=1:2:3](image)

![Fig. 4. The data values of the bands1~5(left scale) and the difference band1 - band2(right scale) along a section in the NOAA16/AVHRR image on 2001/7/12 13:27JST](image)
2-4. Upper wind data

In this study, we assume that the volcanic gas behaves almost together with volcanic clouds, on the bases of previous analysis of Sakurajima volcano [8]. The nearest station of upper air observation by means of radio-sonde measurements is Hachijo-jima, which is to the south of Miyakejima as shown in Fig. 1. We confirmed that the wind field around Miyakejima is well approximated by the Hachijo-jima winds in most cases. Since the height of Miyakejima is 814m, we used the wind data obtained at 925hPa equivalent to about 830m above sea level at the Hachijo-jima station of the upper air observatory. The observation is performed 4 times / day at 03, 09, 15, 21JST.

To investigate the advection and dispersion of volcanic clouds and gas corresponding to SO$_2$ high concentration episodes in the Honshu area in conjunction with satellite images, we have performed the simulation of the dispersion of volcanic clouds based on a simple vertical shear model (VSM) using upper wind data [9].

Environment Scientific Research Part of Japan Atomic Energy Research Institute predicts diffusion behavior of volcanic gas at Miyakejima by the real-time simulation system SPEEDI (System for Prediction of Environmental Emergency Dose Information) which developed in order to predict radioactive material diffusion in atomic energy accident, and shows the results on the following homepage (in Japanese): http://des.tokai.jaeri.go.jp/incoming/.

3. Results and discussions

3-1. Volcanic clouds at Sakurajima

V-shaped long-range advection more than 300km is detected by AVHRR 4 as shown in Fig. 5.

White parts of AVI images in Figs. 6 - 8 are volcanic clouds at Sakurajima, and Karman Vortex is formed with Cheju Island in Fig. 7.

Fig. 8 demonstrates the dispersion of ash clouds from Sakurajima Volcano toward east over the Kuroshio Current in Pacific Ocean at 14:13JST on 28 January 1992. Thus, we see that the influence of volcanic clouds at Sakurajima extends occasionally to a long distance.

Volcanic clouds shown in Figs. 5-8 were the results of strong eruptions with much ash. They were drifted eastwards at high altitudes by the westerly winds, as their top heights were about 2000-4000 m from the summit crater (1040 m). There are many other scenes of small-scale clouds drifting toward different directions according to the weather conditions [8].

Fig. 5. AVHRR-4 at 07:26 on 20 October 1992

Fig. 6. NOAA14 AVI image at 07:16JST on 1996/12/14

Fig. 7. NOAA AVI image at 06:17 on 10 December 1999
3-2. Hotspots at Sakurajima, Aso and Swanose volcanoes

NOAA/AVHRR band 3 captures temperature anomaly of the crater. Hotspots of Sakurajima and Aso are shown as black points in Figs. 9 and 10. Hotspots of Sakurajima and Swanose-jima are seen in Fig. 11. In the same scene, they are not found at Aso and Unzen.
3-3. Volcanic clouds at Miyakejima

In Figs. 12-17, we show the NOAA/AVHRR images of Miyakejima plumes. The plumes are dark in Figs. 12 and 14, which represent the band difference 2 - 1, while they are white in Figs. 13 and 17 with the opposite difference. Figs. 3, 15 and 16 are monochrome version of color images with R:G:B = 1:2:3(or 4) which are useful to discriminate volcanic aerosol from meteorological clouds. Since lots of chemical substances in the gas are dissolved into the vapor clouds at Miyakejima, liquid aerosol with small diameters may be expected to remain after the dispersion in the dry air, resulting the above detection methods effective.

Typical patterns of Miyakejima plumes may be classified into two. When the winds are strong and collimated, we have linear type with narrow width such as shown in Figs. 3 and 13. On the other hand, we have dispersed type with rather wide width such as Figs. 12, 14, 16 and 17, when the winds are not so strong. It is not obvious to classify small-scale plumes such as Fig. 15. Volcanic gas from Miyakejima often arrived at the central part of Japan drifted by the southern wind especially in summer, while occasionally in other seasons owing to the change of wind-direction caused by the traveling of low/high pressure systems nearby. Other islands near Miyakejima may be affected by the gas, such as Hachijo-jima in Fig. 12. In the case of Fig. 14, the SO$_2$ concentration at the foot of Miyakejima stayed low, since the gas and plume were not blown down with the wind velocity 3-6m/s.

On the day of Fig.15, SO$_2$ of 158ppb was detected at 14:00 at Toba in Mie Prefecture (information of AEROS). About 5 hours earlier than the time of Fig. 16, SO$_2$ of 423ppb was detected at Oyasu also in Mie (11:00, information in AEROS). Fig. 16 indicates the change of the wind direction after affecting westwards.

On the same day as Fig. 17, SO$_2$ of 423ppb was detected at Sodegaura, Chiba Prefecture at 16:00 (information in AEROS). In the NOAA image received at 7:27, the plume had reached already Boso Peninsula. We suppose that the development of the convection mixing in the daytime brought down the gas to the surface, since the plume and gas drift at the altitudes about 1-2 km for medium and week winds otherwise.
4. Concluding remarks

We were able to detect the volcanic ash clouds at Sakurajima by the difference images of AVHRR 4 and 5. The same method did not work for the clouds at Miyakejima containing less silicate. The difference images of AVHRR 1 and 2 were found to be effective to discriminate Miyakejima plumes from meteorological clouds. The AVHRR images of them are consistent with the high concentration events of SO$_2$ at leeward directions. Many images that we analyzed here are shown in the following homepage. SiNG: http://www-sci.edu.kagoshima-u.ac.jp/sing/index-e.htm

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References


