South Pacific Studies Vol. 25, No.1, 2004

Ground Observation of Volcanic Plumes and High Sulphur-Dioxide Concentrations around Sakurajima Volcano

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Abstract

Surface SO_2 concentrations at the foot of Mt. Sakurajima are discussed in conjunction with ground observation videos and upper wind data. It is found that the main cause of high concentrations is downdraft due to fresh wind blowing the volcanic plume and gases from the summit crater down to a monitoring station downstream, often forming a mountain lee wave. Convective mixing on warm and sunny days is found to be the secondary cause, bringing the SO_2 back to the ground level from the plume which rises and flows at high altitudes in light winds.
Key words: high concentration event, mountain lee wave, SO_2, volcanic gas

Introduction

Sakurajima volcano in Kyushu, Japan, has been continuously active since 1972, ejecting ash or vaporous plumes almost daily from the summit crater Minamidake at 1040 m above sea level, mixed with occasional big eruptions. The volcanic gases strongly affect the surrounding air quality, and acidic substances are sometimes transported a considerable distance (Kinoshita et al. 2001). In this note, we discuss the short distance behaviour of the gas around the volcano, which has been reported in English in conference abstracts only up to now (Kinoshita et al. 2000, 2003a,b). More detailed reports in Japanese have been made in the context of understanding the situation in Miyakejima (see Kinoshita et al. 2003c and papers cited therein).

At Sakurajima, there are four gas observation stations, and several plume observation points at a distance of about 10 km from the volcano, with archived continuous data (Fig. 1).

Received June 3, 2004
Accepted Aug. 9, 2004

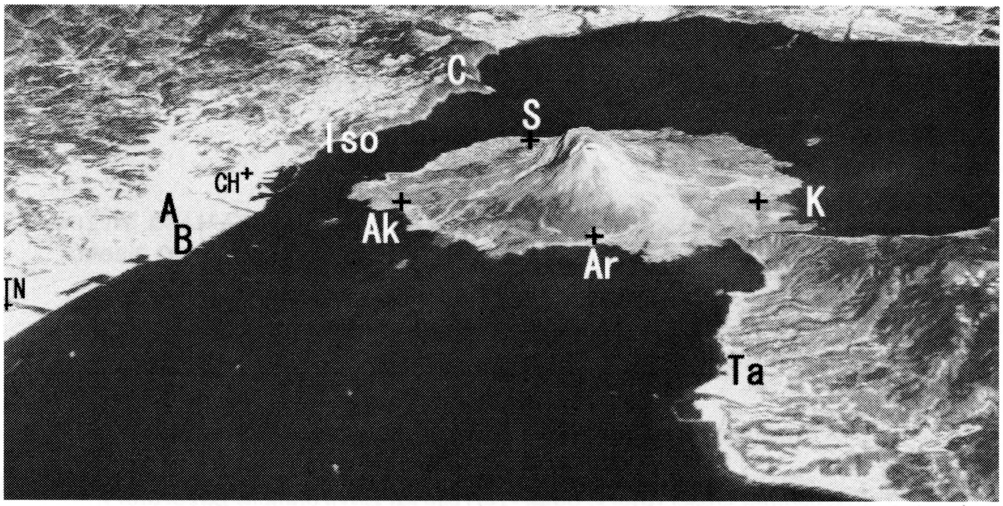


Fig. 1. Locations of gas-monitoring stations (+) and plume observation points viewed from southern sky. Gas-monitoring stations at Sakurajima; Ar: Arimura, Ak: Akamizu, K: Kurokami, and S: Sakurajima town office. Gas-monitoring stations in Kagoshima City; CH: City Hall and TN: Taniyama. Plume observation points : A: Kagoshima University main campus, B: Kamoike port, C: Nansei-Toko Observatory, Iso: seashore at Iso, and Ta: Tarumizu. The background image was made by the SiPSE system.

High sulphur-dioxide (SO_2) concentrations at the ground level are highly dependent on the meteorological conditions. The main cause of the high concentrations at the foot of volcano was found to be fresh wind blowing the volcanic plume and gases from the crater height around 1000 m down to a measuring station downstream at the ground level, often forming a mountain lee wave (Fig. 2a). Light winds allow the plume to rise, with little effect on residents. However, high SO_2 concentrations at the ground may also happen in light winds when convective mixing on warm and sunny days brings the SO_2 back to the ground level (Fig. 2b).

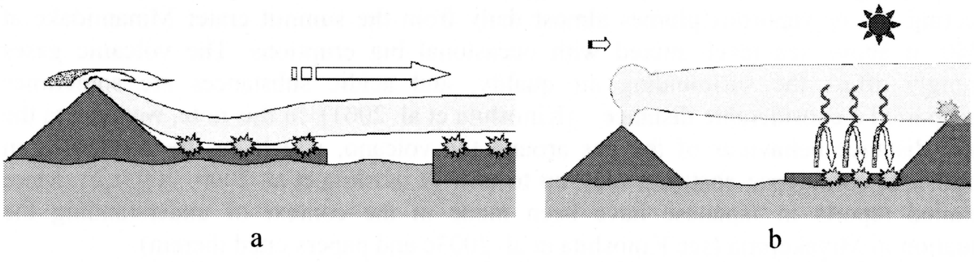


Fig. 2. Schematic diagrams. (a) Main cause of high concentration: Downdraft in mountain lee wave. (b) Secondarily cause: Convective mixing on sunny days.

Seasonal characteristics

Fig. 3 shows the number of hours of high SO_2 concentrations each month, defined as the hourly value exceeding 100 ppb which is the public standard of warning in Japan, at four gas-monitoring stations around the crater at Sakurajima in 1999. We may see the seasonal characteristics of each station as summarized in Table 1, which is understood in terms of the meteorological condition to cause the fresh wind with its direction determined by the location of the low pressure system near southern Kyushu. This is also in agreement with the results in 2000 mentioned later, and many other studies reported in Japanese.

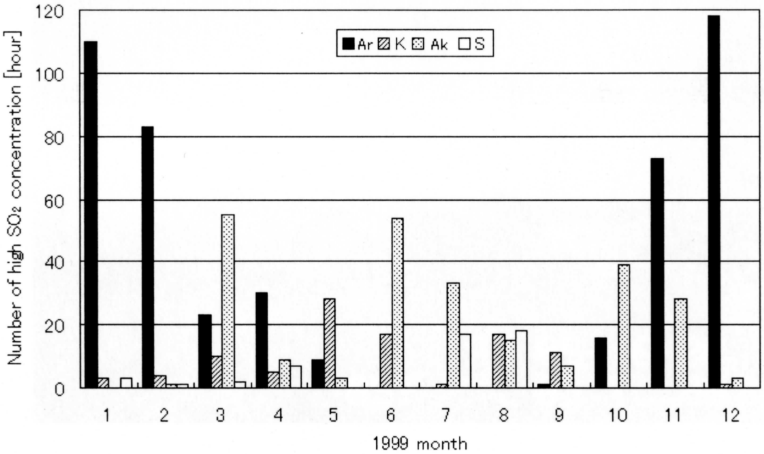


Fig. 3. Hours of high SO_2 concentrations, defined as the one-hour value$\geqq$100 ppb in 1999 at each gas-monitoring station at Sakurajima volcano.

Table 1. Seasonal characteristics of high SO_2 concentrations at Sakurajima in 1999.

gas-monitoring points	direction from the crater	type	location of low presure system from Sakurajima
Ar : Arimura	south	Winter: January, February, November, and December	east
S: Sakurajima Town Office	north	Summer: July and August	west
K: Kurokami	east-northeast	May, June and August	north
Ak : Akamizu	west	March, November	south

Typical results

Typical video images when high SO_2 concentrations occurred at the stations in Sakurajima are shown in Figs. 4-6, together with temporal variations of SO_2 concentrations in respective months.

There are seasonal variations at four stations for the times when the SO_2 concentration exceeds 100 ppb. Arimura station (Ar), situated on the southern flank of the volcano close to the seashore and 2.7 km from the crater, is the worst point for air quality among the four stations around the crater. There, high concentration events are frequently seen in winter, when strong northerly winds prevail owing to low-pressure systems to the east. Fig. 4(a) shows a video image of a downdraft of the plume toward the south, which indicates that the SO_2 gas may affect the station Ar. This is confirmed by Fig .4(b), which shows the hourly values of SO_2 in January 1999 at four stations. We see that the most of high concentration events occur at Arimura, except for the afternoon on 5 January at Kurokami.

a

b

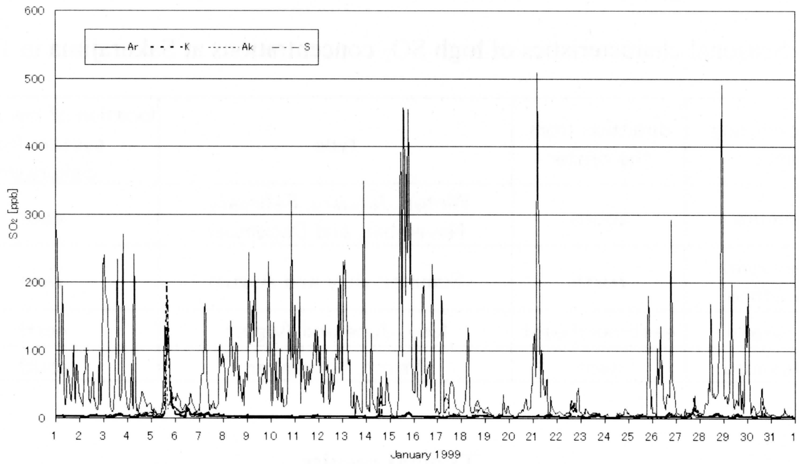


Fig. 4. High SO_2 concentrations at Arimura. (a) A video image from point B at 6:57 JST on 29 January 1999. (b) Hourly values of SO_2 in January 1999 at four stations in Sakurajima.

Conversely, at the Sakurajima town office station (S) 4 km NNW from the crater, the events are occasionally seen in summer with strong southerly winds. Fig. 5(a) shows an image when a typhoon passed west of Kyushu. Mandarin orange farms on the northern flank of the mountain were heavily damaged by the wind, ash and gas in those days. In the hourly values of SO_2 in August 1999 shown in Fig. 5(b), we see that the high concentration events at the station S are limited to the days 2-3 and 16. We note that similar events are also seen in the other stations at east and west sides of Sakurajima, but not at Arimura.

a

b

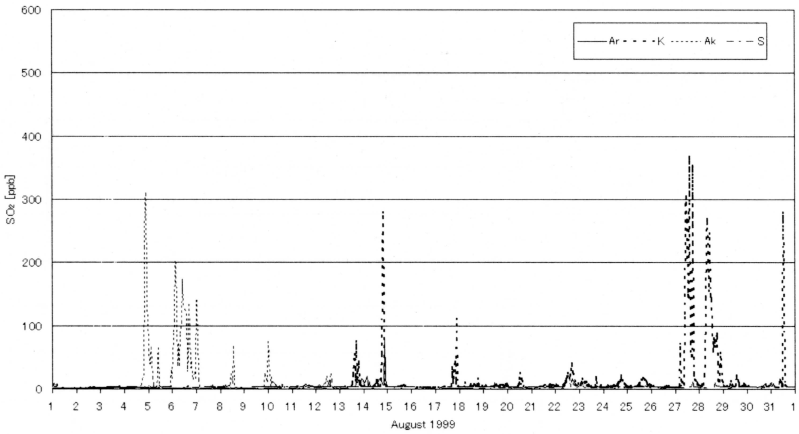
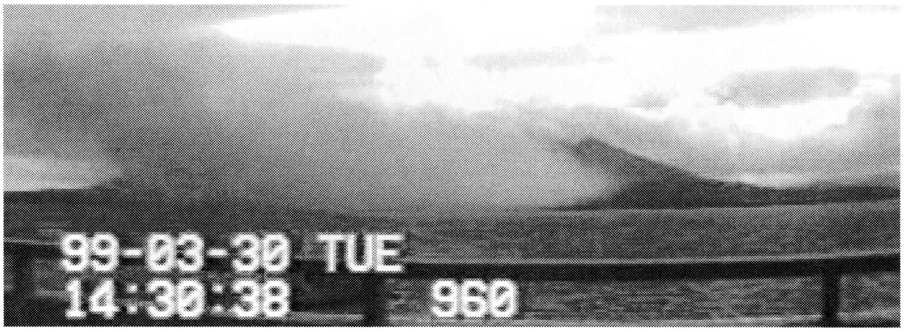


Fig. 5. High SO_2 concentrations at Sakurajima Town Office. (a) A video image from point B at 14:16 JST on 3 August 1999. (b) Hourly values of SO_2 in August 1999 at four stations in Sakurajima.

At Akamizu station (Ak) 5 km west from the crater in March, October and November, while at Kurokami station (K), 5 km ENE from the crater, the events are seen in May, June and August due to anti-clockwise winds around a low pressure system near the north or south of southern Kyushu. In most cases with video observation, volcanic plumes were blown down towards the station, often with an evident mountain lee wave. The temporal variation of the SO_2 concentrations is rather strong, following changes of the wind direction with the migration of low-pressure systems. Fig. 6(a) is a video image when the concentration at Ak recorded 1640 ppb. Ash clouds were coming from the crater along the western flank down to the sea surface, and then rising gently forming a lee wave structure. The down-up motion can be confirmed in the mpeg file converted from time-lapse video record. High concentration events are seen at Ak on 10, 12-14, 29 and 30 in March, while at K on 15 as seen in Fig. 6(b). We also see high concentrations exceeding 100 ppb at Ar on many days; i.e., 2, 7, 11, 16, 21, 22, and 28, though not so dominant over other stations as in January (Fig. 4b).

a



b

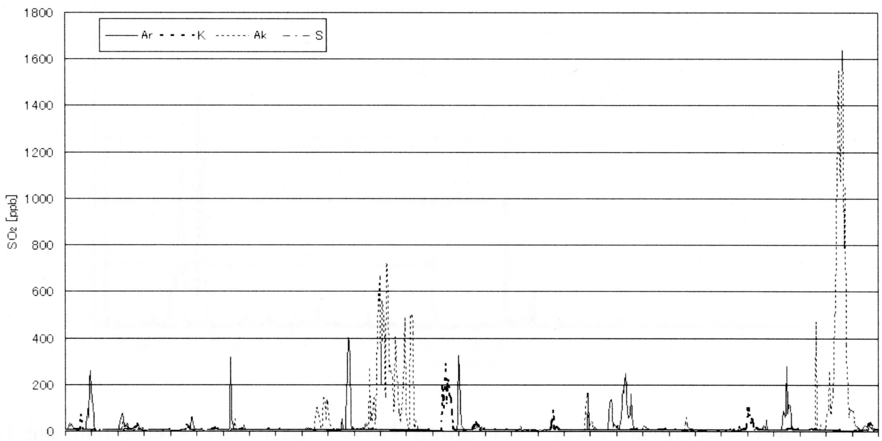


Fig. 6. High SO_2 concentrations at Akamizu. (a) A video image from point B at 14:30 JST on 30 March 1999. (b) Hourly values of SO_2 in March 1999 at four stations in Sakurajima.

Concluding remarks

We have seen highlight scenes exhibiting the main cause of the high concentrations. All of the video and photo images in 1999, taken at the plume observation points around Sakurajima shown in Fig. 1, were studied together with the SO_2 concentration data at four stations and the upper wind data at Kagoshima. The main cause of high concentrations at these stations was confirmed to be fresh wind blowing the volcanic gases down to a station downstream. Convective mixing on warm and sunny days as described in Fig. 2b was found to be the secondary cause, with relatively high concentrations in light winds. Suspended particulate matter (SPM) data were found to exhibit a strong correlation with the increase of the SO_2 concentration in some cases, while in some cases without correlation. There are other causes of high concentration events of SPM, such as Asian dust, characterized by a universal rise in different stations in Kagoshima.

The above results were further confirmed studying the data in 2000 as summarized in Table 2, where the results at Kagoshima City Hall (CH) and Taniyama (TN) outside Sakurajima are also included noticing the concentration over 40 ppb. At the latter stations, the convective mixing is as important as fresh wind. There are some unclassified events lacking image and/or wind data, or to be studied further.

Table 2. Summary of high SO_2 concentrations in 2000.

	Ar	K	S	Ak	CH	TN
total number of high SO_2 concentrations * [hour]	527	102	30	274	24	22
event number of high SO2 concentrations [event]	38/(58)**	11/(13)**	4/(4)**	29/(40)**	10	13
lee wave	28	9	3	15	5	1
%	73.7	81.8	75.0	51.7	50.0	7.7
covective mixing	6	1	1	2	3	6
%	15.8	9.1	25.0	6.9	30.0	46.2
others	4	1	0	10	2	6
%	10.5	9.1	0.0	34.5	20.0	46.2
rate of Sakurajima causing	89	91	100	59	80	54

* high SO_2 concentration level: ≧100ppb at Sakurajima, ≧40ppb at CH and TN

** event number/(number of high concentrations at wind observation time; 3 9 15 21 JST)

Surface concentration monitoring of volcanic gas at the foot of Mt. Sakurajima started in 1980's by Kagoshima City and Kagoshima Prefectural Goverments. Continuous observation of volcanic clouds at the point B started in September 1987. The observation points have increased since then, including real-time monitoring with web-camera systems (Kinoshita et al. 2003c). Detailed analyses of them have been reported in Japanese, and utilized to understand the volcanic gas in Miyakejima, where the number of surface monitoring stations increased from three in January 2001 to fourteen in April 2004. Thus, Sakurajima and Miyakejima are unique volcanoes in the world with continuous surface gas concentration monitoring, providing precious data of atmospheric dispersion of air pollutants from fixed sources.

Acknowledgements

We thank very much Mr. J. Ushirogata for providing pictures taken from Iso. We are grateful to the Kagoshima Prefecture and City offices for providing the SO_2 data.

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