Chapter 2 General view of eruption clouds detected by GMS images

2.1 Volcanic eruptions reported during 1977 - 1985

According to the reports in the Bulletin of Volcanic Eruptions (1979 - 1986) and the SEAN (Scientific Event Alert Network, Smithsonian Institution) Bulletin (1977 - 1985), 75 volcanoes erupted in the field of view of GMS (inside the bold line in Fig. 2-1) during the period from 1977 through 1985. The number, however, does not include submarine volcanic activities which showed only discolorations of sea-water. It includes only those eruptive activities which ejected volcanic eruption clouds. The locations of the volcanoes that erupted are plotted in Fig. 2-1 with solid circles.

A summary of the annual volcanic eruptions is given in Table 2-1. Observational data of the maximum heights of eruption clouds above the craters are given in numerals in the table. In cases where there is no numeral data of eruption cloud heights, the approximate intensities of the eruptions are divided into three grades of large (L), medium (M) and small (L) on the basis of descriptions in the reports. Eruption clouds which rose higher than 4 km above the crater may be detected by GMS, and those eruptions took place at 31 volcanoes as shown by larger solid circles in Fig. 2-1.

There were 12 big eruptions of which the eruption clouds rose higher than 10 km during 1977 - 1985. Their ejecta ranged wide both horizontally and vertically, and caused damage not only on dwelling ground / arable land but also on commercial air lanes. The mean annual frequency of occurrence of such big eruptions is about 1.3 events a year.

The annual frequency of occurrence of volcanic eruption in the field of view of GMS during 1977 - 1985 ranges from 20 in 1983 to 36 in 1980 and the total of the annual frequency is 234 at 75 volcanoes with a mean frequency of 26 events at about 8.3 volcanoes a year.

From the summary of volcanic activities in Table 2-1, we notice that almost incessant eruptive activities are taking place at ten-odd volcanoes such as Sakurajima, Suwanosejima, Marapi, Merapi, Semeru, Manam, Langila, Bagana, Yasur and White Island, and also that the intensity of their explosion is not so remarkably great as to be accompanied by big and high eruption columns. Big eruptions with large eruption columns which went to altitudes higher than 10 km took place at ten-odd volcanoes such as Bezymianny, Usu, Dukono, Gareloi, Ulawun, Alaid, Pagan, Soputan, Galunggung, Miyakejima, Una Una and Mayon. However, these big eruptions were not frequent compared with those of the volcanoes which showed almost continual occurrences of eruption. When big eruptions took place, eruptive activity continued for more than several months at some volcanoes such as Galunggung, but in many cases it decayed or ended within a short term after the occurrence of big eruptions.

2.2 Volcanoes for which eruption clouds were detected by GMS

The first GMS was launched in the summer of 1977 and the image data have been provided since November of the year. A careful examination of the image data returned from GMS during the period from November 1977 through December 1985 detected eruption clouds from 23 volcanoes in the images (Yasoshina et al., 1982, Sawada, 1981, 1983 a, 1983 b and 1985). The locations and names of these volcanoes are shown in Fig. 2-2, where the larger solid circles indicate that the eruption clouds were well detected without being seriously hampered by surrounding atmospheric clouds, and the smaller ones that the eruption clouds were hampered, sometimes severely, by the presence of atmospheric clouds around the volcanoes.

The results of measurement of respective eruption cloud images from the 23 volcanoes are compiled in Table 2-2, which contains the maximum width (W in km), the maximum horizontal length (L in km) of eruption clouds, its drifting direction (DIR.), the lowest temperature in the surface of the eruption cloud (T in °C) and its highest altitude (H in km) estimated from T and air-temperature profile by radio-sounding data or based on the atmosphere model. In the table, "UP" in "DIR." column means that an eruption cloud existed just above the location of the volcano in GMS image and had at that time, an almost circular shape, suggesting that the eruption cloud image was taken within a very short time after the volcanic eruption. All the observation or image-taking times are in GMT (JST - 9). Parentheses in this table denote that the eruption cloud has left the location of the volcano, which means that the eruption activity has already decayed or ended at that time of image returning. In cases where the eruption cloud was seriously hampered by surrounding atmospheric cloud, the observation time of the image is marked by * in the table. Data with the mark of " ? " mean that there is uncertainty whether they are actual volcanic clouds or not, though the images were obtained during considerably big eruptions according to the reports.

Throughout these examinations, it was noticed that although eruption clouds change their extent in a short time, they could be tracked in GMS images for more than several hours after the occurrence of volcanic eruption in many cases of successive eruptions as well as of single ones. Brightness of eruption cloud in photograph image is important information by which to judge that the eruption has decayed or resumed its activity, because we can consider that the eruption cloud becomes thinner after the decay of eruption activities, lessening the brightness of the eruption cloud in GMS image. At the same time, it is also important information for monitoring volcanic eruptions to know whether the eruption cloud has detached itself from the site of the volcano or not, for the eruption cloud leaves the crater with the prevailing wind over it when the eruption stops.

To determine the occurrence time of an eruption by finding out its eruption cloud was very difficult because the IFOV of GMS's sensor, VISSR and the intervals of image returning are not yet sufficient to catch a small-scale and low-altitude eruption cloud at the initial stage of an eruption, and also because of the difficulty of distinguishing an eruption cloud among the atmospheric clouds with only VISSR data.

Usually, eruption clouds are driven in a single direction by the prevailing wind, but sometimes in two or three directions when the wind direction is different at various altitudes above the volcanoes. Some eruption clouds continue to stay above the volcanoes under conditions of low wind velocities.

When an eruption cloud has penetrated the tropopause, the surface temperature at the top of the eruption cloud at the first stage will show a higher temperature domain than the surrounding lower temperature domain which corresponds to the temperature of the tropopause. Therefore, it should be possible to judge whether the eruption cloud has penetrated the tropopause or not by processing the surface temperature distribution of eruption clouds. Some eruption clouds from the 1985 Soputan Eruption and the 1983 Una Una Eruption showed such a surface temperature distribution and are supposed to have penetrated the tropopause. But it is concluded that most of the eruption clouds detected by GMS images during late 1977 - 1985 did not penetrate the tropopause.

In Table 2-2, the eruption clouds of the 1981 Sheveluch Eruption, the 1985 Soputan Eruption, the 1979 Karkar Eruption and the 1984 Home Reef Eruption are listed with marks of ? , because their eruption cloud data were not completely separated from the surrounding atmospheric clouds in GMS images. In the case of the Sheveluch eruption cloud data listed in Table 2-2, the eruption cloud-like images were found out in GMS images although no eruption was reported at this volcano at their respective image-taking times.

Some eruption clouds dispersed horizontally to a distance of 1,300 - 1,500 km from the volcano, even as far as 3,000 km in the case the 1981 Alaid Eruption. It is deduced that there must be ash falls in the areas where eruption clouds were detected by GMS images, but this is not certain because visual observations of ash falls are lacking over such wide and especially ocean regions. It is certain that GMS images are useful for detecting eruption clouds and tracking their movement.

2.3 Detection rate of eruptions with eruption clouds by GMS

The annual frequency of volcanic eruptions and the ratio of volcanic eruptions for which eruption clouds were detected in GMS image during the period from November 1977, when GMS's images were first obtained to the end of 1985 are shown in Table 2-3. Numerals in parentheses mean the annual numbers of volcanic eruptions that sent eruption clouds higher than 4 km above the craters. "All" and "GOOD" mean the total frequency of eruption clouds detected in GMS images and the frequency of good image data without being seriously hampered by the surrounding atmospheric clouds, respectively. Each annual frequency and annual rate normalized by the total number of eruptions are also shown in this table.

As shown in Table 2-3, the total annual frequency of volcanic eruptions throughout the above-mentioned period was 227 from 75 volcanoes and the total annual frequency of eruption clouds higher than 4 km which correspond to occurrences of relatively strong eruptions was 51 at 30 volcanoes. The total annual frequency of "ALL" and "GOOD" were 31 events at 23 volcanoes and 15 at 12 volcanoes, respectively. The arithmetic mean of the annual values of the ratio was 13.7 % for ALL and 6.6 % for GOOD. The maximum values of ratios for ALL and GOOD were 28.6 % and 23.8 % in 1982, respectively.

Examinations of GMS images revealed that eruption clouds reported to have risen higher than 4 km above the craters did not appear clearly in GMS images. The major reasons are insufficiency of IFOV of GMS's sensor or ground resolution of GMS photograph images in the case of the whole globe, long intervals of GMS image returning and the difficulty of distinguishing eruption clouds from atmospheric clouds. Errors of the maximum height of eruption clouds by ground observation is also a possible reason for the low detection rate. As described in Chapter 1, detection of eruption clouds was conducted mainly on photograph image data, and the detection rate of eruption clouds might increase by the data-processing of GMS digital image data, because of the higher precision of ground resolutions compared to that of photograph images. Analyses of digital image data, however, need much time for their data processing. It is very convenient to search for eruption clouds by using photograph images.

Basides the whole glove photograph images, we have two kinds of magnified photograph images. The first is one of high magnification covering around Japan including the region of the Kurile Islands and Kamchatka. The second is one of lower magnification covering the region ranging from Kamchatka through Japan and the Mariana Islands to the Philippines. However, these magnified images are available only for a limited number of routine observation times. By inspecting these two kinds of magnified photograph images, small eruption clouds which are about 10 km in horizontal dimensions and around 2 km in height above the craters could be detected at several volcanoes in the above-mentioned region.

According to the results in Table 2-3, the lowest limits of the horizontal domain and the height above the crater were 10 km and 1.7 km, respectively. However, the smallest and the lowest eruption clouds are the ones detected by using the above-mentioned magnified photograph images and partly by the aid of analyses of digital data. As long as we use the GMS photograph images of the whole globe as shown in Fig. 1-1, the lowest limits of detectable eruption clouds are 20 - 30 km in horizontal dimensions and 4 - 5 km in height.

According to the summary on volcanic activities in Table 2-1, eruption clouds reaching higher than 10 km are reported in 19 eruptions at 12 volcanoes in total during late 1977 - 1985, and in 17 of them at 11 volcanoes the eruption clouds were detected in GMS images. The exception was the 1983 Miyakejima Eruption. Most of these large eruption clouds were well traced in successive images for more than several hours. The reason why the large eruption clouds of the 1983 Miyakejima Eruption were not detected is that the thick surrounding atmospheric clouds above the volcano interfered. In cases of volcanoes located near the edge of the globe in GMS images, since the ground resolution or IFOV of GMS images extremely decreases, detection and observation of eruption clouds in GMS images are rather difficult even for big eruptions. However, large and widespread eruption clouds produced by big eruptions which generate ash falls over a broad region and affect the navigation of aircraft could be mostly detected in GMS images, and it was confirmed that we can well track the dispersion processes of eruption clouds as described in the following chapter.