Chapter 4 Some analyses of the behavior of dispersing eruption clouds

4.1 Horizontal moving velocity and ascending velocity

Horizontally spreading velocity of the eruption cloud was analyzed on the eruption cloud of the 1981 May Pagan Eruption. The velocity was obtained as the difference of the distances of downwind edges of isothermal domains in successive images taken every 3 hours. The result is shown in Fig. 4-1. A mean horizontal velocity of 21 - 30 m/s was obtained for domains warmer than - 67 °C which correspond to altitudes lower than about 14.2 km. On the other hand, mean horizontal velocities under 3 - 15 m/s were obtained for domains colder than - 71 °C. When we compare the horizontal moving velocities of eruption clouds with the ambient wind speeds at respective altitudes deduced from radio-sounding data at Guam station, it is noticed that horizontal moving velocities of the upper portion near the top of the Pagan eruption cloud were similar to or smaller than those of the ambient wind velocities, but those of the lower portions were almost 20 m/s faster than the ambient wind velocities. It is not certain at this moment whether or not the above-mentioned results are phenomena common to all eruption clouds. At least, we may expect that the spreading rate of the eruption cloud which rose to a high altitude within a short time of the occurrence of an eruption will show a large value during or immediately after its active rise compared with that of a dispersing cloud long after the occurrence of an eruption. The horizontal moving velocity of the Pagan eruption cloud warmer than - 60 °C during 06 GMT - 09 GMT and 09 GMT - 12 GMT on May 15 was about 17 - 24 m/s and 10 - 18 m/s, respectively. These values were about 15 m/s and 4 - 8 m/s faster than those of the ambient wind velocity, respectively. In cases of the Alaid eruption clouds during April 27 - 30, 1981, the mean horizontal moving velocity of 19 - 32 m/s was obtained for domains of - 30 °C - - 40 °C, which correspond to altitudes of about 5.5 - 9 km, respectively. The wind velocity at respective altitudes ranged from 10 to 30 m/s, and this value was about 4 - 6 m/s faster than the ambient wind speed.

The horizontal velocity at the upper portion of the Pagan eruption cloud was around or under the ambient wind speed as shown in Fig. 4-1, and the same result was also obtained in the case of the Alaid eruption cloud. This result may lead us to consider that the main spreading and expanding portion of an eruption cloud which rose to high altitudes should be located at about 2 km lower than the top of an eruption cloud.

The ascending velocity of the eruption cloud at the initial stage of the occurrence of the

1981 May Pagan Eruption was tentatively analyzed using GMS image data. The ascending velocity was obtained by measurement of difference between the top altitude of an eruption cloud in successive images taken at intervals of 30 minutes - 4 hours. The maximum ascending velocity of the Pagan eruption cloud was about 5.6 m/s as shown in Fig. 4-2 together with several results from other volcanic eruption clouds. However, other results from the eruption clouds from Galunggung, Alaid, Soputan and Una Una eruptions did not exceed even 1 m/s. These results seem too low. The main reason for these low values is the difficulty of detecting the very active stage of an ascending eruption cloud with GMS image owing to limitations in the time intervals of GMS image taking. This is a common problem throughout the measurements not only of the ascending velocity, but also of the horizontal moving velocity of eruption clouds based on GMS image data.

4.2 Estimation of the horizontal diffusion rate

Horizontal eddy diffusivity of eruption clouds was obtained using the maximum width and the longest horizontal length in the downwind direction following the formula (1,4) given in Chapter 1. The estimated results are compiled in Table 4-1. All of the results on horizontal eddy diffusivities showed large-values than 10^9 cm^2/s, some larger than 10^{10} cm^2/s. These values coincide well with such large values as are frequently obtained for active atmospheric clouds during typhoons. Such high horizontal eddy diffusivity may be a common feature of eruption clouds spreading in the atmosphere, though there still remains some uncertainty in determining the margins of eruption clouds in GMS images.

4.3 Time variations of profiles of eruption clouds

Cross sections of the upper surfaces of eruption clouds from Pagan and Una Una volcanoes during the May 1981 and the August 1982 Eruptions are shown in Fig. 4-3 (a) - (b). The first eruption cloud from Pagan volcano, A in Fig. 4-3 (a), quickly expanded to B and then spread to a distance of more than 500 km. The highest altitude of the eruption cloud decreased with time, but there was a temporary increase of its top altitude at D, at a distance of about 300 km from the volcano. In the case of the Una Una eruption cloud, the first eruption cloud detected, A in Fig. 4-3 (b), expanded and spread to D and finally dispersed to F, which is more than 400 km away from the location of the volcano. There was also a temporary increase of the top altitude and the vertical domain of the eruption cloud at F. These phenomena took place after the end of eruptive activity and may indicate that the eruption cloud keeps expanding during its dispersion, even after the supply of ascending eruption cloud ceased to come out of the crater. However, at the same time, it will also be possible to consider that the eruption cloud might join the growing atmospheric clouds during its dispersion.

4.4 Time variations of isothermal domains on the surface of eruption clouds

The surface temperature distribution of an eruption cloud usually shows a complicated pattern like the Pagan eruption cloud shown in Fig. 4-4. We can consider that the time variation of altitude distribution on the surface of an eruption cloud reflects the time sequence of spreading or dispersion of the eruption cloud. However, it is very difficult to pursue the time variation of individual temperature distribution on the surface of an eruption cloud. Therefore, the time variation of the total square encircled with an isothermal contour at the interval of - 10 °C which is called in this paper an "isothermal domain" is investigated.

The time variations of regions colder than - 10 °C on the surfaces of the Pagan, Soputan and Una Una eruption clouds are shown in Fig. 4-5 (a) - (b), Fig. 4-6 (a) - (b) and Fig. 4-7, respectively. The extent steadily enlarged with time, and the temporary expansion of eruption clouds after the cessation of eruptions was not well detected.

The time variations of isothermal domains every - 10 °C on the eruption clouds of the May 1981 Pagan, the August 1982 Soputan and the August 1983 Una Una Eruptions are shown in Fig. 4-8 (a) - (c). Rectangles in these figures denote the duration periods of individual explosive activities. In the case of the Pagan eruption cloud, the expansion after the end of the eruption was not clear except for the isothermal domain of - 20 °C. The lower part of the eruption cloud having isothermal domains of - 10 °C — - 20 °C quickly decreased after the end of the eruption. The higher portion of the eruption cloud having isothermal domains of - 30 °C — - 50 °C decreased their areas corresponding to the decrease of the maximum intensity of eruption. The Soputan eruption cloud showed a steady decrease of isothermal domains after the end of the eruption, especially after the peak activity at around 09 GMT. But slight increases of isothermal domains of - 20 °C — - 60 °C were noticed at 21 GMT, about 9 hours after the end of the eruption. The Una Una eruption cloud, however, showed a more complicated pattern as shown in Fig. 4-8 (c). There were two eruptions which took place at a short interval till 01 GMT on August 2, and both eruption clouds quickly expanded into one. A slight decrease of an isothermal domain of - 70 °C was noticed at the end of the former eruption, while every isothermal domain kept expanding after the end of the latter eruption. In the higher portion near the top of the eruption cloud, isothermal domains under - 50 °C — - 70 °C decreased their extent about two hours after the end of the latter eruption, and the other portion of isothermal domains warmer than - 40 °C finally decreased their areas about 5 hours later.