NOTES AND CORRESPONDENCE

Effect of Land on Aerosols in Oceanic Atmosphere under the Westerly Monsoon

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1. Introduction

For the study of the air pollution of global scale, measurements of aerosols in the oceanic atmosphere are very important and were already carried out by several authors (Cobb *et al.* 1970, Junge *et al.* 1971, Misaki *et al.* 1972, Kojima *et al.* 1974, Elliot 1976).

Hogan *et al.* (1973) made a map of aerosols through the measurements in different parts of oceanic atmosphere.

Some authors (Sagalin *et al.* 1956, Misaki *et al.* 1970, Morita *et al.* 1973) measured aerosols in the oceanic atmosphere from the origin on land to mid-ocean and tried to find out the general tendency of the change of particle size as well as particle concentration along the route of their travel from land to ocean.

In order to investigate the transport behavior of aerosol from land to ocean more effectively, we took the following procedures.

- (1) As the observing place, we selected two islands (Miyake and Hachijyo) in the Pacific Ocean (Fig. 4); Miyake is of about 170 km and Hachijyo of about 290 km off-shore southward from Tokyo.
- (2) As the time of observation, we selected the days in February 1974; in this month the westerly monsoon prevails in this region of the Pacific Ocean.

From Fig. 4, we see easily that the air masses, fully contaminated by aerosols during the time of passage over the Japan proper, will arrive at these islands under the westerly monsoon. Therefore we may expect to find some important clues to clarify the transport behavior by analyzing our data.

2. Observation

The observations were made on the total particle concentration using Pollack counters during the period 2 to 17 February 1974.

Since we should have the data which are completely free from the contamination arising from the islands, we paid adequate attention to the location of the setting of the measuring apparatus. At Miyake, they were set at the northern fringe of the island and the sample air was introduced at 10 m above the sea surface; at Hachijyo, they were set at the north-western fringe and at about 50 m apart from sea shore.

With these arrangements we may say safely, as long as westerly monsoon is blowing, that the air at the both locations will not be influenced by the contaminations of local origins.

Data at the two islands were obtained every five minutes using two Pollack counters of the same type. The Pollack counters we used had been carefully calibrated in our laboratory. At Miyake, we also used an absolute counter (Kojima *et al.* 1973) regularly (three times a day) to calibrate our Pollack counter further.

3. Results and data analysis

In Fig. 1, we show two typical examples of hourly variation of aerosol concentration: one for the day of westerly monsoon (Feb. 11, 1974) and the other for the day of other wind direction (Feb. 4, 1974).

We see clearly in this figure the following two facts.

- (1) On the day of westerly monsoon, aerosol concentration shows pronounced diurnal variation with a maximum. On the day of other wind direction, however, it does not show such regular pattern of diurnal variation. But as our data might be influenced by local contaminations on the day of other wind direction, we can not draw any conclusions from the apparent change of these data.
- (2) The patterns of diurnal variation on the day of westerly monsoon are nearly the same except in their phases. From our data (Fig.

1), the increase of aerosol concentration begins at about 10 h and a maximum appears at about 18 h or 19 h at Miyake; at Hachijyo the increase at about noon and a maximum at about 20 h or 21 h.

In Fig. 2 we show the patterns of the average diurnal variation of 6 days observations under westerly monsoon for each island. From this figure, we can show that the phase difference in the diurnal variations between Hachijyo and Miyake is about two hours.

In order to obtain the most probable value of the above time-lag between Hachijyo and Miyake, we calculated a cross correlation; the correlation coefficient γ_{MH} between N_H at Hachijyo and N_M at Miyake is calculated from the following formula using hourly data of 24 hours.

$$r_{MH}(L) = \frac{\sum N'_M(t) \cdot N'_H(t+L)}{\sqrt{\sum N'^2_M(t)} \cdot \sqrt{\sum N'^2_H(t)}}$$

where (') denotes deviation from the mean value, and L denotes the adopted time-lag in the calculation. The result is shown in Fig. 3. From this, we conclude that the time-lag or the phase difference in the diurnal variations is 2 or 3 hours.

This time-lag can be explained by the transport of air masses. Air mass trajectories for 850 mb level have frequently been used for transport of aerosols (e.g. Reiquam 1970). Accordingly we calculated air mass trajectories of 12 hours length which passed through Hachijyo at 9 h and 21 h J.S.T. of days restricted to westerly monsoon,

using upper air charts of 850 mb level (Fig. 4). From these trajectories the amount of time spent over ocean prior to Hachijyo was interpolated.

As there were no data on upper wind at Miyake, we can not obtain such trajectories with the same method described above. So, it was assumed that the direction and length of air mass trajectories for Miyake were equal to those for Hachijyo. We believe that this assumption does not lead to much errors of the air mass trajectories because the distance between the two islands is short compared with the scale of pressure pattern on air charts.

In this way, we obtain the following average values for the elapse time since air mass has left on land.

$$\begin{aligned} 4.8 \pm 0.3 \text{ hours} & \quad \text{for Hachijyo,} \\ 2.1 \pm 0.2 \text{ hours} & \quad \text{for Miyake.} \end{aligned}$$

Fig. 2 Average diurnal variation of aerosols under westerly monsoon.

Fig. 1 Time variation of total aerosol concentration under westerly monsoon (on 11 Feb.) and other wind direction (on 4 Feb.). The wind direction and velocity are indicated by Beaufort wind scale for each point in the figure.

Fig. 3 The relation between the correlation coefficient and the time-lag.

Fig. 4 The original points on the trajectories of 12 hours length which passed through Hachijyo. Data are abbreviated in the four-digit number. The first two digits give the day and the second two the hour.

We see that the time difference of about 2.7 hours between both islands is nearly equal to the time-lag between diurnal variations shown in Fig. 3. If we assume that the phase of diurnal variation on land is the same at every part of Japan proper, this coincidence of two time differences indicates that the tendency of diurnal variation of aerosols on land are transported to the distance of about 200 km in oceanic atmosphere under westerly monsoon.

4. Conclusion

From the observation on two small islands (one about 170 km and the other about 290 km from Tokyo) in the Pacific Ocean, we obtained the following two results.

- (1) Aerosol concentrations on two islands show pronounced diurnal variation with a maximum, on days of westerly monsoon.
- (2) The time-lag between diurnal variations of two islands was 2 or 3 hours.

These two results can be explained by the transport of contaminated air over Japan proper at 850 mb level.

There are few papers which report the existence of such a diurnal variation of the aerosol concentration in the oceanic atmosphere. The reasons why we found pronounced diurnal variation are as follows: (1) Japan proper is a long island

and can be considered as a kind of long line source of aerosols under westerly monsoon, (2) the distances of both islands from Japan proper are short compared with the length of this line source and (3) the air masses which passed through the two islands under westerly monsoon are those which had been contaminated by aerosols over Japan proper several hours before.

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