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AEROSOL OBSERVATION AT HACHIJO-JIMA IN EARLY WINTER

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Abstract

Observations, made at Hachijo-Jima in the early winter, of atmospheric electrical conductivity, aerosol number densities in Aitken- and Mie-size ranges, and concentrations of radon, ozone, and nitrogen oxides are described. The representative values of the above items were 10.0×10^{-15} S/m, 1.47×10^{3} cm^{-3}, 39.4 cm^{-3}, 28 pCi/m^3, 71 ppb, and 3.0 ppb, respectively. These values and the ranges of distribution show that the atmosphere on Hachijo-Jima is in an intermediate state between the coastal area of the mainland Japan and the mid-ocean. The values observed in the air, which blows in from the sea and probably not much disturbed by pollution of island origin, are near the mid-ocean values. The highest conductivity and the lowest aerosol density were observed in the rain in the sea wind. A few items observed some days showed remarkable daily variations which possibly correspond to weather conditions.

1. Introduction

Atmospheric pollutants are continually dispersing from industrial areas onto the oceans. If the pollutants are progressively accumulated in the ocean atmosphere and enhance their global background, it will be a crucial problem for the future environment. In fact, it has been reported that the electrical conductivity of the atmosphere on the North Atlantic has decreased by at least 20 % in this half century. The secular conductivity decrease is attributed to an increase in fine aerosol particles (Cobb and Wells, 1970). It is very important to know the actual state of oceanic atmosphere, which is controlled by a balance between the pollutants supply mainly from industrial regions and the decay rate in the natural atmosphere. In recent years there have been several observational studies made over the sea near Japan on aerosols and related parameters using vessels and island stations isolated far from the mainland (e.g., Misaki et al., 1975; Mochizuki, 1978; Morita, 1973). Through these studies it has been pointed out that the transport time of air after leaving the coast of the mainland may first control the decay of pollution but that such meteorological processes as turbulence and precipitating phenomena with which the pollutants have met during transport are important factors determining the response of pollutants scavenging from the atmosphere. An approach to a general understanding of the atmospheric pollution diffusing over wide areas will be to accumulate and analyze more data in various geographical and meteorological conditions. This paper deals with observations made in the early winter at an isolated island, Hachijo-Jima, located in the East Pacific about 200 km south-east from the nearest coast of the mainland of Japan. In the winter north-westerly monsoon season, the island is just under the influence of airflow which has passed through industrial regions extending over the coastal zone of the mainland of Japan. Various observed data are given in this paper, and the analyses taking account of detailed meteorological factors will be separately discussed.

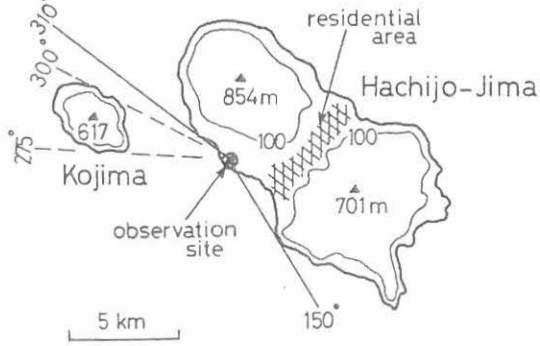

Fig. 1. Location of the observation site at Hachijo-Jima.

2. Observation

The observation at Hachijo-Jima was carried out from 25 November to 4 December, 1979. An aircraft survey of the vertical structure of aerosols up to 3 km altitude was made above the sea of westward side of the island on 24 November just before the island station observation; a part of the results of the aircraft survey has been already reported (Takagi et al., 1981). The site of observation was chosen on the west coast of the island (33°05'N, 139°44'E) to observe the air coming directly from the sea in the westerly wind. The location of the site is shown in Fig. 1. The directions between 150° and 310° are the seaward side. Uninhabited Hachijo-Kojima, which lies between 275° and 300° at a distance of about 7 km, is not considered to be a source of serious disturbances. The main residential district in the island is in a narrow lowland between two peaks with heights of 854 and 701 m;

Table 1. Observation items and instruments

Item	Type of instrument	Effective limit of accuracy*
Conductivity positive & negative polarities	Gerdien coaxial cylinder	10^{-15} S/m
Aerosol	Pollak type CN counter	200 cm^{-3}
	Electrostatic analyzer (size divisible 0.01-1 μm)	5 cm^{-3} #
	Light-scatter analyzer (size divisible 0.3-10 μm)	0.5 cm^{-3} #
Radon	Membrane air filter and scintillator	10^{-12} Ci/m^3
Ozone	Chemiluminescent detector for the reaction between O_3 and supplied ethylene	5 ppb
Nitrogen oxides	Chemiluminescent detector for the reaction between NO and supplied O_3, & NO_2-NO converter	1 ppb

* for the time sequence and sensitivity range adopted in the observation
# for the largest size range

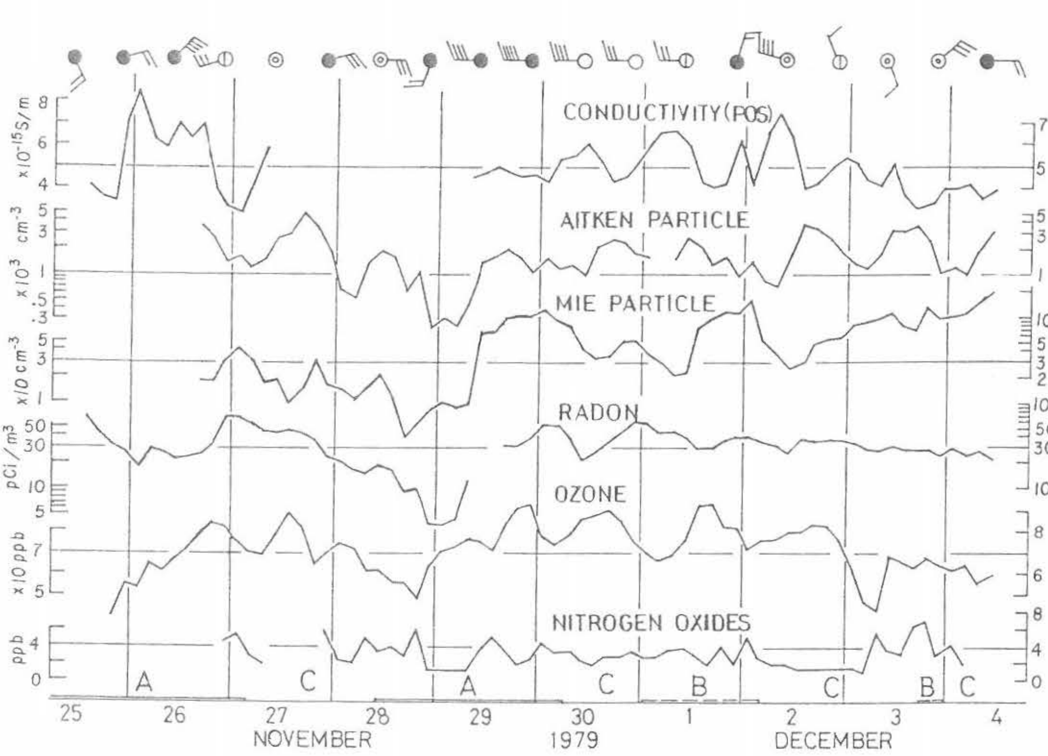

Fig. 2. Variations of positive polar conductivity, aerosol densities in Aitken- and Mie-size ranges, concentrations of radon, ozone, and nitrogen oxides in the observation period from 25 November to 4 December, 1979. Uppermost are weather and wind at 900 and 2100 JST at Hachijo-Jima Weather Station about 2 km east from our site. The three periods A, B, and C are classified according to 850 mb wind trajectories.

the direction of the district from the observation site is roughly between 60° and 120°.

The items measured were atmospheric electrical conductivity of both polarities, aerosol densities in the size range from 0.01 to 10 μm, and concentrations of some gaseous substances which have some relationships to the ion and aerosol formation. The items and the instruments used are listed in Table 1.

To survey the general trends during the observation period, the variations of 3-hourly mean values for positive polar conductivity, aerosol densities in Aitken- and Mie-size ranges, and concentrations of radon, ozone, and nitrogen oxides are shown in Fig. 2. The weather and wind at Hachijo-Jima Weather Station at 900 and 2100 JST are also shown. The weather in the former half of the observation period was not good, and low pressures and fronts passed over the island one after another. In the latter half high pressures generally covered the island. The air which seemed to be cleanest was observed during the period from 28 to 29 November when it rained. Negative correlations between conductivity and aerosol density, and between ozone and nitrogen oxides were sometimes found.

3. Observed values

3-1. Atmospheric electrical conductivity (λ)

The mean and the standard deviation of hourly values of the total conductivity ($\lambda_+ + \lambda_-$) for the observation period are $10.0 \pm 2.7 \times 10^{-15}$ S/m. The mean value is less than half of the conductivities $25.4 \pm 0.4 \times 10^{-15}$ S/m observed on the Pacific near Marcus Island (Misaki et al., 1972) and $20.6 \pm 2.0 \times 10^{-15}$ S/m at Ogasawara (Ishikawa et al., 1973). The highest value of conductivity at Hachijo-Jima during the observation period was 19.0×10^{-15} S/m observed in the rain at midnight of 25 November; the value is close to but slightly less than that usually observed in much more distant regions of the ocean.

In the same period as this observation, the conductivity at Sakushima Observatory (34°43'N, 137°03'E), located in the coastal zone of the mainland but more than 10 km away from severe sources of pollution, was $9.9 \pm 4.6 \times 10^{-15}$ S/m; this is characterized by a mean similar to and a deviation much larger than that at Hachijo-Jima.

Compared these values at various stations, the conductivity at Hachijo-Jima is, in a favorite condition, sometimes as high as the values on the ocean. However, the deviation of conductivity values is larger at the stations located in poorer environments because the air circumstances are variously affected by weather and the pollution sources arranged just around the site.

The ratio of positive to negative polar conductivities (λ_+ / λ_-) is very close to 1 throughout the observation period. The overall ratio of hourly values is 0.97 ± 0.07. There is a trend that the ratio is higher in the case of lower conductivity than in the case of higher conductivity.

3-2. Aitken particles (AP)

The density measured with a Pollak counter is described here. The size spectrum obtained with an electrostatic analyzer will be discussed separately. The number density of aerosols is dispersed as widely as expressed in a logarithmic scale shown in the ordinate in Fig. 2. Thus it is proper to take the logarithmic mean as a representative value of the distribution. The overall average is 1.47×10^3 cm^{-3}, and the range of standard deviation in logarithmic scale is 0.72 to 3.07×10^3 cm^{-3}. The lowest value 0.17×10^3 cm^{-3}, which is almost the limit of measurement accuracy, was observed in the rain in the early morning of 29 November. It was unfortunate that at the time of the highest conductivity the aerosol instrument was not yet operational and at the time of the lowest aerosol density the conductivity recorder was out of order.

The number density usually observed in the urban atmosphere is the order of 10^4 to 10^5 cm^{-3}. The density at Sakushima in the same season ranges from 0.5 to 8×10^3 cm^{-3}, which is still somewhat higher than on Hachijo-Jima.

The density value in the atmosphere of the central Pacific are almost always less than 500 cm^{-3} (Takagi and Toriyama, 1972; Sekikawa et al., 1972). Thus Hachijo-Jima can be said to occupy an intermediate state between the coastal area and the mid-ocean.

The conductivity is combined with the aerosols through the attachment process of small ions to aerosol particles. Therefore the reversal relationship between the conductivity and the aerosol density, especially that in the Aitken-size range, is often found in the natural atmosphere. This situation was seen from 30 November to 4 December in the later half of the observation for the variations of period 6 to 24 hours. However, the correlation between the respective overall observed absolute values is not as good as expected from the above general tendency. The correlation coefficient between hourly values of positive polar conductivity (λ_+) and logarithmic density of Aitken particles (log AP) is only -0.30. This suggests that the factors contributing to the attachment process such as ionization and aerosol size spectrum are different from one case to another according to weather conditions.

3-3. Mie particles (MP)

Aerosol particles with radii larger than 0.1 μm cause intense Mie-scattering for visible light. The designation of Mie particle which has recently been in general use is favorable for use in comparison with Aitken particles, because both are named after the respective investigators. In this respect we use here this designation for aerosols which are detectable by the light-scattering method.

The density of Mie particles in this observation on Hachijo-Jima has the logarithmic mean of 39.4 cm^{-3} and the range of deviation of

15.0 to 103.8 cm^{-3} which is 1.6 times larger than that of Aitken particles. The lowest hourly value 2.9 cm^{-3} was observed in the evening hours of 28 November.

The ratio of (AP)/(MP) distributes roughly between 10 and 300; the range is considerably wider than 40 to 250 in aircraft observations in altitudes 0.5 to 3 km (Takagi et al., 1981). The correlation coefficient between all corresponding values of log(AP) and log(MP) is 0.34. The correlation is worse for the variations of shorter period.

Compared with the value 1.0 to 5.7 cm^{-3} in the middle of the Pacific (Sekikawa et al., 1972), the density here is rather near the coast value.

3-4. Radon (Rn)

Radon-222 is a non-activated gas with the half-life of 3.8 days and α-particles emitted from the radon nucleus ionize the atmosphere. The rate of ionization is estimated to be 1.40 J for radon concentration of 100 pCi/m^3 (Ikebe, 1970). In the oceanic atmosphere, radon with comparatively long life is a main source of ionization other than cosmic rays which have the rate of about 2.0 J.

The source of radon is restricted to land surfaces and its generation is not expected on the sea. Radon concentration only decays during transport over the sea by diffusion due to air turbulence and by radioactive disintegration. Hence it is a good tracer for studying the history of airmass departing away from the land.

The value of radon concentration, like that of aerosol density, distributes as widely as expressed in a logarithmic scale. Here also the means are logarithmically taken. The overall mean in the observation period is 28 pCi/m^3 and the range of deviation is 15 to 53 pCi/m^3. The lowest value 3.0 pCi/m^3 was observed from the late night of 28 to the early morning of 29 November at the same time as in the low phase of aerosol density. The correlation between (Rn) and (MP) is found to be good for the variations of period 0.5 to 2 days.

Coinciding with our observations, Mochizuki and Tanji (1981) made radon measurements on board a vessel cruising between Tokyo and Hachijo-Jima from 28 to 30 November. Radon observed at sea between Oshima and Hachijo-Jima ranges from 10 to 70 pCi/m^3, and the low values of less than 10 pCi/m^3 were also obtained in the early morning of 29 November.

Radon was measured at the same site as our observation in the early spring of 1974 and 1975 by Mochizuki (1978); the values distributed in the range of 15 to 150 pCi/m^3 which were higher than those observed this time. The difference may be due to the observation seasons because in the period of our observation the north-westerly monsoon was not so violent as in the late winter or in the early spring.

Radon measurements at Ogasawara showed low values of less than 10 to 60 pCi/m^3 (Iwata and Sekigawa, 1980); this again shows the intermediate state of the atmosphere on Hachijo-Jima.

3-5. Ozone (O_3) and nitrogen oxides (NO_x)

In the urban atmosphere the conversion to particulate matters from gaseous substances such as nitrogen oxides and sulphur oxides is a phenomenon frequently seen as a photochemical reaction in strong sunlight. Ozone is a principal constituent of so-called oxidants. Our main purpose in observing ozone and nitrogen oxides together with aerosols is to know how these gaseous substances behave in a comparatively clean atmosphere far from industrially active regions.

Densities of O_3 and NO_x ($= NO + NO_2$) in this observation on Hachijo-Jima are 71 ± 12 ppb and 3.0 ± 1.8 ppb, respectively. For nitrogen oxides it is desirable to measure NO and NO_2 separately, but the concentration observed is sometimes so low and close to the limit of accuracy that it is difficult to describe the difference of variations in NO and NO_2. Anyway these values are quite low compared with those in urban districts.

A negative correlation of between O_3 and NO_x is sometimes found for the variations of period 6 to 24 hours. This may correspond to the alteration that the peaks of NO, NO_2, and O_3 appear alternately in order.

4. Effect of wind

The airmass trajectories are of basic importance to the analysis of aerosols which have been transported above the ocean for a long time (Morita, 1973). As the surface wind is much influenced by the geographical features of the station, it is reasonable to follow the wind stream at somewhat higher levels. Thus trajectories are calculated by adopting a temporal and spatial linear interpolation from the 850 mb data obtained twice a day at aerological observatories. Fig. 3 shows the trajectories which arrive at our observation site at 900 JST every day; the dates are shown at the ends of respective trajectories. Small numerals affixed to the trajectory curves are hours required to reach the observation site from those points. The trajectories are

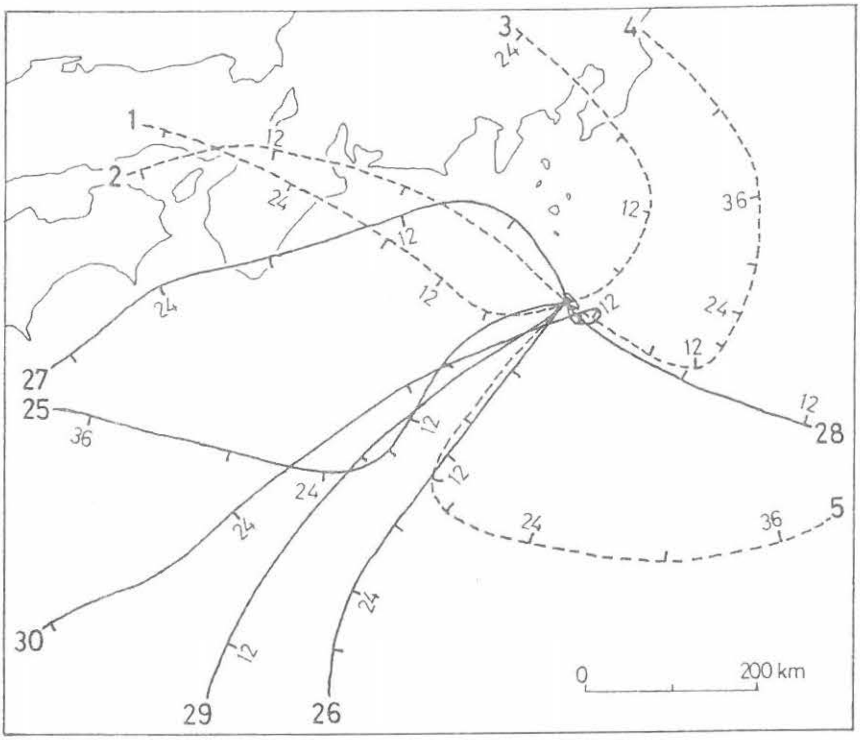

Fig. 3. Airmass trajectories calculated by a temporal and spatial interpolation from 850 mb wind data at aerological stations. Trajectories plotted are those arriving at the site on 900 JST every day. The dates of arrival are shown at the ends of the respective curves; full lines are in November and dashed lines are in December. Numerals along trjectory curves are hours to reach the site from those points.

divided into three groups from their course figures: A) 25, 26, and 29 November, the trajectories passed over the ocean more than 2 days and approached the site from the sea. B) 1 December, left the mainland 10 to 40 hours prior to the arriving time and approached the site from the sea. C) 27, 28, 30 November, 2, 3, and 4 December, approached the site from the landward side after more or less passing over Hachijo-Jima. Further temporal estimation gives the times belonging to the above trajectory groups as follows, during the period from noon, 25 November through noon, 4 December.

A) 1200, 25 Nov. - 0400, 27 Nov.
   1000, 28 Nov. - 0700, 30 Nov. (85 hrs)

B) 0100, 1 Dec. - 0500, 2 Dec.
   1800, 3 Dec. - 2400, 3 Dec. (34 hrs)

C) 0400, 27 Nov. - 1000, 28 Nov.
   0700, 30 Nov. - 0100, 1 Dec.

0500, 2 Dec. - 1800, 3 Dec.
0000, 4 Dec. - 1200, 4 Dec. (97 hrs)

The three periods A, B, and C are also shown lowermost in Fig. 2. Mean values of the observed items in the respective periods are given in Table 2. Aerosols and radon concentrations are definitely low in the period A.

To study the wind effect in more detail, the data are divided into 16 wind directions at the site. We could not prepare any wind meter at our site, and there are probably some differences in surface winds at the weather station 2 km away and at our site. Therefore, we estimate the 850 mb wind every hour by vectorially dividing the 850 mb wind data measured twice a day at the weather station. The results are shown in Fig. 4. Due to the shortage of data the trajectory groups A and B are not distinguished. The directions SSE and S are based on the group B, the directions SSW, SW, and WSW on the group A, and the directions W and WNW are on both groups. To minimize the fluctuation 3-directions binomial running means are taken. The ordinates show the deviations from the overall mean values. For AP, MP, and Rn, the deviations are represented for their logarithmic concentrations (for example, + 20 % means 1.58 times larger than the mean value). In the directions from 180° to 240° facing the sea, Aitken and Mie particles

Table 2. Mean values of observed items in three airmass trajectory conditions

Trajectory conditions		A	B	C	all periods	
Time over the sea		more than 2 days	10-40 hours			
side of approach		sea	sea	land		
conductivity	(λ)	10.1	10.4	9.8	10.0×10^{-15}	S/m
Aitken particles	(AP)	1.07	1.51	1.76	1.47×10^{3}	$/cm^3$
Mie particles	(MP)	26.4	66.3	41.3	39.4	$/cm^3$
radon	(Rn)	21	36	31	28	pCi/m^3
ozone	(O_3)	69	76	72	71	ppb
nitrogen oxides	(NO_x)	3.4	3.3	2.6	3.0	ppb

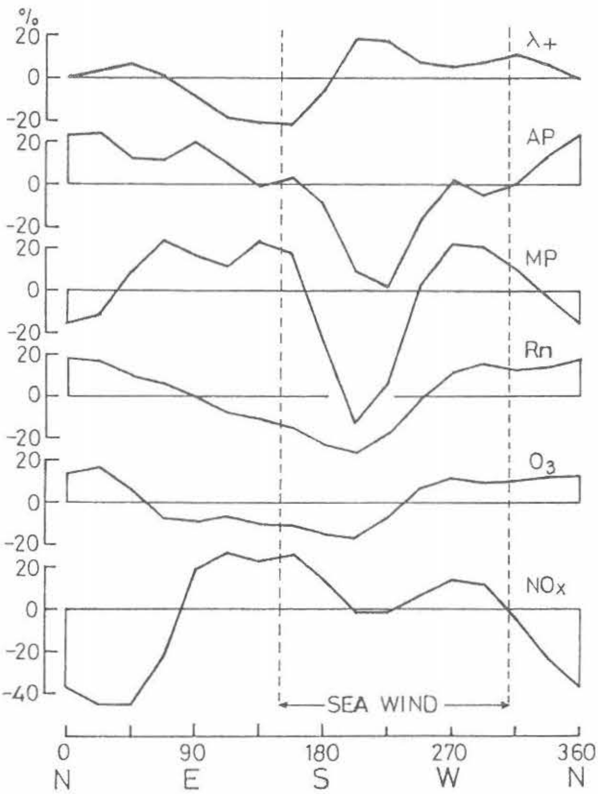

Fig. 4. Characteristics with respect to 850 mb wind directions. The ordinates are given by deviations from the means of the respective items.

show extremely low density values and the conductivity is very high. Rn, O_3, and NO_x also show their minima in these directions. For the maxima appeared at around 270° to 300° there may be some influences from Hachijo-Kojima. The full explanation on the wind direction effect, however, will require analyses taking more information on meteorological states along airmass trajectories into account.

5. Diurnal variations

In Fig. 2, a few items observed show similar respective diurnal variations for some days. For example, the conductivity on 30 November, 1, and 2 December, Aitken particles on almost all days, and ozone density on 27, 29, and 30 November, 1, and 2 December seem to involve 24-hour diurnal variations. Nitrogen oxides on 28 November, 1, and 3 December show 12-hour semi-diurnal variation. The results of evalua-

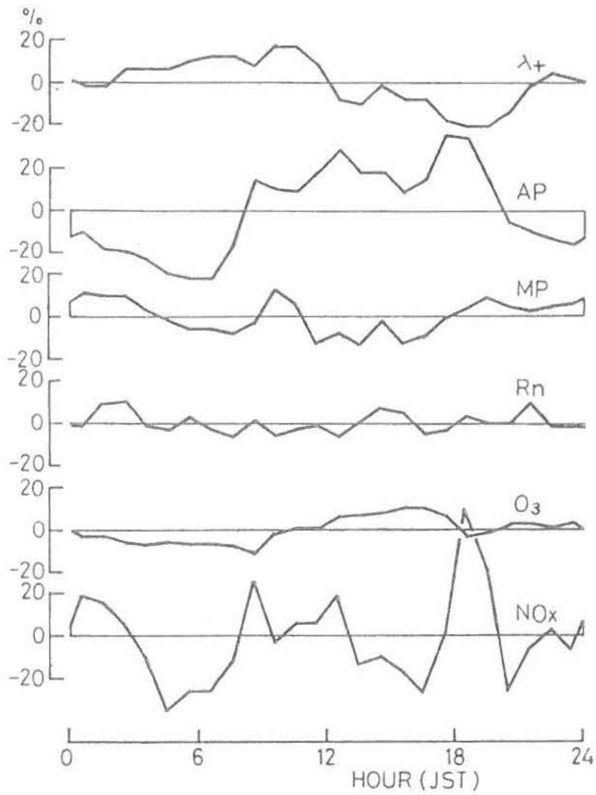

Fig. 5. Diurnal variations. The ordinates are given by deviations from the means of the respective items.

tion, without any data selection, for diurnal variations are shown in Fig. 5. The ordinates are represented, similarly to those in Fig. 4, by the deviations from the overall means of the respective items.

The daily tendencies recognized in Fig. 2 are distinct from Fig. 5. The conductivity is high in the morning hours and low in the afternoon. Contrary to this, Aitken particles are at their lowest in the morning and their highest in the evening hours. The reversal relationship of conductivity and Aitken particles is again significant in their diurnal variations. On the other hand, Mie particles seem to have a semi-diurnal variation though with a slight amplitude. The comparison of density variations of Aitken and Mie particles suggests that the aerosol size distribution is quite different between daytime and nighttime.

For radon there is no significant variation. Ozone density has a diurnal variation similar to Aitken particles, but the minima at 800 and 1800 JST is associated with the remarkable peaks of nitrogen oxides density; these peaks at 800, 1200, and 1800 JST coincide roughly with the daily human life cycle and suggest a contribution from the residential area on the island because these variations are not seen in the westerly wind.

At present it is difficult to offer more reasonable explanations for all the causes and effects represented in diurnal variations of the respective items.

6. Concluding remarks

It is confirmed for all items observed that the atmosphere on Hachijo-Jima is in an intermediate stage between the coastal area of the mainland Japan and the mid-ocean. On the occasion of direct sea wind and possibly scarce disturbance from island sources, the values of the observed parameters become close to those in the mid-ocean though still there remain some differences. On the occasion of land wind, the effect from the residential area on the island pushes up the levels of aerosols and radon, and gives rise to characteristic peaks in NO_x density due to the daily human life cycle. It may be notable that the highest conductivity and the lowest aerosol density was found in the rain; this fact probably shows the scavenging effect of rain on aerosols, which is well known as the washout.

It is very hard at present to obtain from these observation results a conclusion as can describe the whole story of atmospheric state on Hachijo-Jima. The analyses here have to persistently remain in the phenomenological realm.

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References

Cobb, W.E. and H.J. Wells, The electrical conductivity of oceanic air and its correlation to global atmospheric pollution, J. Atm. Sci., 27, 814-819 (1970)

Ikebe, Y., Evaluation of the total ionization in the lower atmosphere, J. Earth Sci., Nagoya Univ., 18, 85-121 (1970)

Ishikawa, H., Y. Morita, and M. Kanada, Observation of ion and aerosols at Chichi-Jima, Ogasawara, Proc. Soc. Atm. Elect. Japan, 9, 42-45 (1973)

Iwata, A. and K. Sekigawa, Measurement of aerosols at Bonin Islands, Proc. Soc. Atm. Elect. Japan, 23, 52-55 (1980)

Misaki, M., M. Ikegami, and I. Kanazawa, Atmospheric electrical conductivity measurement in the Pacific Ocean, exploring the background level of global pollution, J. Met. Soc. Japan, 50, 497-500 (1972)

Misaki, M., M. Ikegami, and I. Kanazawa, Deformation of the size distribution of aerosol particles dispersing from land to ocean, J. Met. Soc. Japan, 53, 111-120 (1975)

Mochizuki, S., Comparison of natural atmospheric radioactivity appeared over Hachijo Island and Miyake Island in the early spring, J. Met. Soc. Japan, 56, 52-56 (1978)

Mochizuki, S. and T. Tanji, Radioactive aerosols in the atmosphere over ocean near Japan Islands, Res. Lett. Atm. Elect., 1, 9-14 (1981)

Morita, Y., Studies on the temporal and spatial variation of atmospheric electric parameters and their relation to atmospheric pollution, Proc. Res. Inst. Atmosp., Nagoya Univ., 20A, 1-152 (1973)

Sekikawa, T., H. Kojima, and F. Tanaka, On aerosols in the oceanic atmosphere, Proc. Soc. Atm. Elect. Japan, 7, 36-39 (1972)

Takagi, M., Y. Morita, M. Kanada, and N. Toriyama, Some examples of vertical distribution of aerosols in 3 km altitude, Res. Lett. Atm. Elect., 1, 5-8 (1981)

Takagi, M. and N. Toriyama, Report on Hakuho-Maru observations of electric field, conductivity, space charge, and condensation nuclei on the Pacific Ocean, Proc. Soc. Atm. Elect. Japan, 7, 32-35 (1972)