PRELIMINARY OBSERVATION OF ATMOSPHERIC ELECTRIC FIELD ON THE SEA SURFACE

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As emphasized in the "Atmospheric Electricity Ten-Year Program" (Resolution of Joint Committee on Atmospheric Electricity, 1963), a basic requirement of the fair-weather measurement is to differentiate between the effect of global electric circuit and of disturbance locally caused by meteorological and industrial conditions around the observation point. As to the meteorological effect, we could keep it out by selecting the so-called fair-weather records from the others, though the definition of fair-weather still involves some ambiguities, especially at land stations. Disturbance due to human existence, however, would be unavoidable so far as we would stay on the land, where industries pollute circumferences day and night. Atmosphere on the sea surface could be thought to be much clean compared with that on land, when one would leave anywhere the sea coast several tens of kilometers apart. Since the first observation of atmospheric electrical elements on the ocean by "Carnegie", several investigators reported that the electric field on the ocean surface was of the order of 100 to 200 v/m and that the diurnal variation of it was independent of local time and in phase with thunderstorm activity accumulated all over the world. The present observation also aims at investigating the global effect besides the atmospheric electric natures characteristic on the sea.

We have had opportunities of measuring the atmospheric electric elements on two research vessels: Ryofu-Maru of Japan Meteorological Agency, April 1967 and Tansei-Maru of Ocean Research Institute, University of Tokyo, November 1967. The field meter used was of mill type, which was mounted on the upper deck of them. Although the weather was not always fair during both cruises, especially on the fall cruise, we could get the data that could be regarded as fair-weather type for three days in spring and one day in fall. The courses of the two cruises are shown in the map, Fig. 1. The spring cruise included two periods of long drifting without engine drive, where we obtained reliable results in the analysis because of little vibration of ship and little spray of sea water. In the fall cruise we could get to be no farther than 50 km apart from the land because of bad weather. The north-east wind of 2 to 8 m/sec would effectively have enhanced the influence of land, yet the values of field displayed the tipical diurnal variation on the ocean.

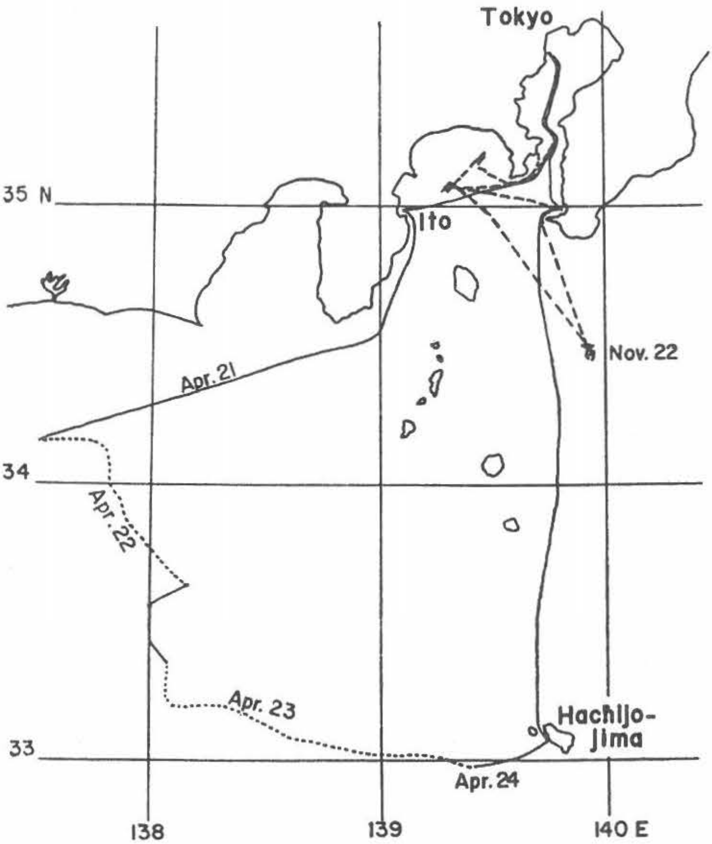

Fig. 1. Courses of spring (solid line) and fall (broken line) cruises in 1967.
Dotted line in the spring course shows drifting.

Figs. 2 (a), (b) and (c) tell us the difference in the diurnal variations, which are depicted by connecting the values averaged for every 30 minutes, between ocean and coast. Fig. (a) is the record obtained for nearly three days of drifting on the ocean. Figs. (b) and (c) are the records obtained while the ship was anchored at a harbor of Hachijo-jima, a small island on the Pacific Ocean, and at Ito harbor where the ship stayed close to a rather densely populated district. The curve pattern in (b) is similar to that in (a), except for the changes around local noon and sunset, which seem to be originated in local pollution flowing out with the east wind from the island. On the other hand, Fig. (c) is completely influenced by dusty atmosphere brought from the land.

Fig. 3 (a) and Fig. 4 (a) are representative fair weather variations on both cruises, in which dots are the mean levels for every 30 minutes and each solid line is calculated out from these dots with harmonic analysis including up to the component of half day period. Table 1 is the results of calculation on daily mean values and on amplitudes and phases of diurnal and semi-diurnal variations in respective dates. It includes, for the

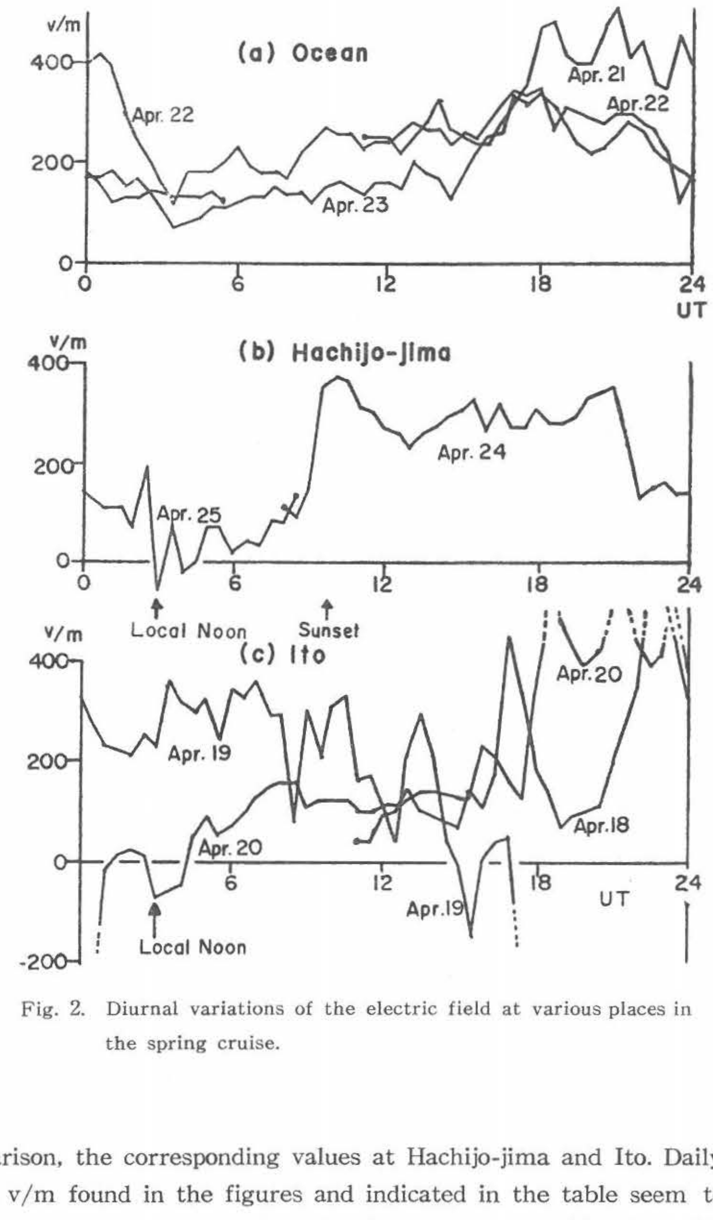

Fig. 2. Diurnal variations of the electric field at various places in the spring cruise.

sake of comparison, the corresponding values at Hachijo-jima and Ito. Daily mean values exceeding 200 v/m found in the figures and indicated in the table seem to be too high compared with measurements done by other investigators to this time. But it is to be noted that these absolute values here are not always reliable, because the estimate of reduction factor to the horizontal plane field is based on the potential measurement of a long horizontal wire with a smoke collector done at a pier aside the vessel, on which the field mill operated, in Tokyo Port. The atmosphere there were far from normal and values of the field were so altered in time as well as in space that the reduction to plane field was difficult to be done with a wanted accuracy.

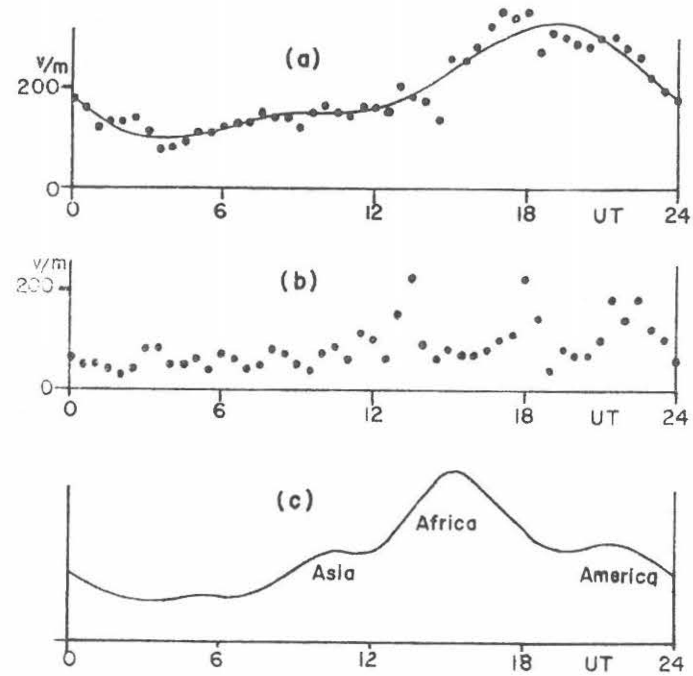

Fig. 3. Representative diurnal variations in the spring cruise, April 22-23.
(a) Electric field.
(b) Peak to peak value of rapid change of the field.
(c) Thunderstorm activity.

Table 1. Result of harmonic analysis.

Date	Observation place	Daily mean value v/m	Diurnal variation		Semi-diurnal variation	
			Amplitude v/m	Time of max. U. T.	Amplitude v/m	Time of max. U. T.
Apr. 22-23	150 km south from Omae-zaki	193	101	18.3	36	7.5, 19.5
Nov. 22	50 km south from Nojima-zaki	252	55	13.1	4	8.2, 20.2
Apr. 24-25	Hachijo-jima	201	139	15.9	47	10.2, 22.2
Apr. 18-19	Ito	245	83	2.3	28	10.2 22.2

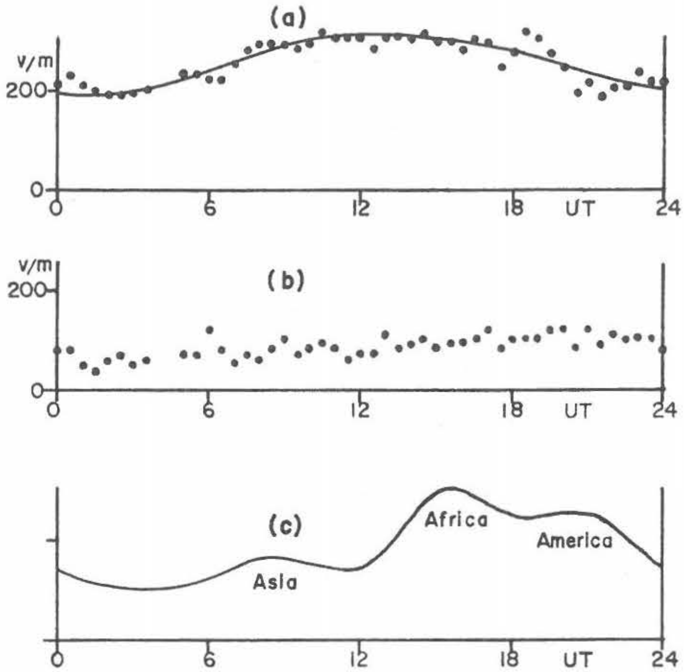

Fig. 4. Representative diurnal variations in the fall cruise, November 22.

(a) Electric field.

(b) Peak to peak value of rapid change of the field.

(c) Thunderstorm activity.

Fig. 3 (c) and Fig. 4 (c) are respectively the diurnal variations of the world-wide thunderstorm activity in April and in November. They are estimated from the world contour maps of storm days in Handbook of Geophysics (1961) under the assumptions that the daily storm activity is proportional to the number of storm days there and that the storm occurrence depends only on local time, the maximum of which appears between 16 and 18 hours local time. Therefore, the peaks of activity curve around 10, 15 and 21 U. T. correspond to thunderstorms in South-East Asia, Africa and South/North America, respectively. We confirm the evidence that the electric field and the world-wide thunderstorm activity very roughly vary in phase with each other, but with an exception of unusually low field intensity in the hours of African storm maximum in the spring result. The effect of thunderstorm activity integrated all over the world at any moment could be thought to contribute to the main part of source in the global atmospheric electric current system, yet the activity, though integrated, would be very changeable from a day to another. In this respect, the variations of three successive days in the spring cruise actually show the occurrence hour of maximum field to fluctuate as much as 2 to 4 hours as can be found in Fig. 2 (a). Then the comparison between the field and the storm activity, not on monthly, seasonal or annual average, but on the record of a specified day, will become very important. But an accurate estimation of diurnal variation of the world-wide storm activity on a specified day seems impossible at the present, where we have no perfectly dense networks of thunderstorm observation on the globe or on satellites yet. Another way to settle the above argument is to compare two or more independent electric element observations simultaneously done at a few quite distant places on the globe where the effect of local disturbances could be kept quite low. An international cooperative work on atmospheric electricity is going to be done simultaneously in the Pacific and in the Atlantic to promote the study.

Another notable feature of the field on the sea surface is the rapid change up to 100 v/m in magnitude and 3 to 9 minutes in period. Peak to peak values of the change are averaged for every 30 minutes and then plotted in Fig. 3 (b) and Fig. 4 (b) on the respective dates. They vary in a similar way with the field strength. The ratio of the rapid change to the mean field ranges roughly 1/2 to 1/3: this is somewhat larger than that recently reported by Mühleisen (1968). The rapid change may probably depend on space charge originating from the sea surface, while the electrical conductivity on the sea, according to the measurement by Misaki (1968), did not give such rapid change that presumes the presence of space charge. Anyhow, the relation between the electrical natures of oceanic atmosphere and the condition of sea surface is an important problem to be solved hereafter.

Acknowledgement——We are grateful to the members of Meteorological Agency and Ocean Research Institute, who have arranged for us to investigate on the vessels.

References

Misaki, M. : Private communication (1968)

Mühleisen, R. P. : Recent potential gradient and ion measurements on the Atlantic Ocean in 1965, Short paper presented at the Fourth International Conference on the Universal Aspects of Atmospheric Electricity (1968)

U. S. Air Force : Handbook of Geophysics, the Macmillan Company, New York (1961)