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CORRELATION BETWEEN THE ATMOSPHERIC ELECTRIC FIELD MEASURED ON THE PACIFIC AND ATLANTIC OCEANS AND ANTARCTICA

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Abstract

The atmospheric electric field measured on the research vessel, "Hakuho-Maru", on the Mid- and South-Pacific Ocean was compared with that measured at Syowa Station in Antarctica and on two vessels on the Mid-Atlantic ocean. The ratio of daily averages on Hakuho-Maru and at Syowa Station alters in accordance with the advance of Hakuho-Maru, and it suggests the latitude effect characterized by the gradual decrease toward the antarctic region. The correlation of the diurnal course of the electric field among these globally representative stations is much higher than that among the land stations. This indicates the influence of the atmospheric electrical generator extends over the entire globe without significant attenuation.

1. Introduction

Since the observation of atmospheric electrical elements during the cruise of "Carnegie" almost half a century ago, a well-recognized result is that the averaged diurnal variation in the atmospheric electric field or the potential gradient on the ocean surface under fair weather conditions is dependent only on universal time and roughly similar to the variation in world-wide thunderstorm activity. This has been regarded as evidence for the hypothetical concept of the global circuit. We also could confirm the above result by analyzing our measurement of atmospheric electric field on vessels (Takagi and Kanada, 1969 and 1970). It is still true, however, that the diurnal course of the electric field significantly alters its form from one day to another. We sometimes found exceptionally large variations and sometimes field values remained almost invariable throughout a day or more even under completely

undisturbed dis weather. It is not clear whether or not these observational facts could be explained by only occasional abnormality in thunderstorm activity accumulated over the entire globe. We now have no useful data of storm activity mapped in full for the days in question. Coincident measurement of the electric field at some globally representative stations located on oceans, in polar regions or on high mountain tops, where the electrical condition in the atmosphere is considered to be little influenced by local pollution, would be an important way to approach the general solution of the problems on global circuit.

We had a chance to measure the atmospheric electric parameters over the Pacific Ocean on a cruise of "Hakuho-Maru", the research vessel of the Ocean Research Institute, University of Tokoy, which covered the period from mid-November, 1968 through the end of February, 1969. Fortunately, the Japanese Antarctic Research Expedition had been carrying out the measurement of the atmospheric electric field at Syowa Station. Moreover, the later half of the present cruise coincided with the Atlantic Expedition 1969 by German and American research vessels, the period of which was assigned for the First Intensification Interval of the Atmospheric Electricity Ten-Year Program by the IAMAP/IAGA Joint Committee on Atmospheric Electricity, IUGG. This paper discusses the comparison between these coincident measurements of the atmospheric electric field.

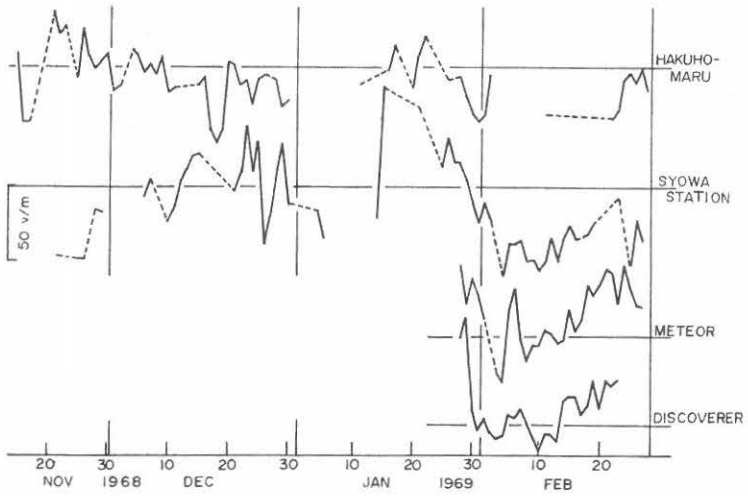

Fig. 1. Daily averages at four stations. Full lines connect continuing daily averages and dashed lines mean the lack of successive data. Horizontal lines attached to the names of stations are the level of 100 V/m of respective curves. Left-hand scale of 50 V/m is applicable to all curves.

2. Comparison of Daily Averages

The atmospheric electric field observed on Hakuho-Maru was analyzed and already reported in the previous issue of our Proceedings. The definition of undisturbed period was regulated by the following two conditions. One was so-called fair-weather, which included blue sky and clouds covering less than half of the whole sky and, of course, no precipitation within sight. The other was the location of the vessel relative to any land. The data obtained when the vessel was within 100 km from any land including comparatively small islands were not taken into account because of possible influence of land pollution. The measurement of electric conductivity on the same vessel showed the possibility of the extension of land pollution over the ocean, though gradually diminishing, up to a few hundred kilometers. (Morita et al. 1971). Daily averages were taken for days that held the above conditions for at least 12 hours. The hourly values and daily averages on Hakuho-Maru were listed in the previous issue (Takagi and Kanada, 1970).

Fig. 1 shows the progress of daily averages with the lapse of days at the four stations; Hakuho-Maru on the Mid- and south-Pacific Ocean, Syowa Station (69°S, 40°E) in the Antarctica, Meteor, the German research vessel, and Discoverer, the American research vessel, both on the Mid-Atlantic Ocean (around 5-15°N, 30-40°W). In Fig. 1, horizontal straight lines accompanying the respective curves represent the level of 100 V/m and the left-hand scale of 50 V/m is applicable to all curves. The correlation between daily averages on Hakuho-Maru and at Syowa Station is not very high. That is shown more clearly in Fig. 2, in which the points are scattered over a wide range. But the distribution for each 20 degrees latitude section, especially for the sections near Syowa Station in latitude, is brought comparatively in order. Then we find low correlation to be dependent on the latitude effect, which will be discussed in the next section. In the interval after the end of January, 1969, the curves of daily averages at three stations excepting Hakuho-Maru are quite well correlated with each other, although the absolute values are much higher on the Atlantic Ocean than at Syowa Station. We regret to say that the interval was the

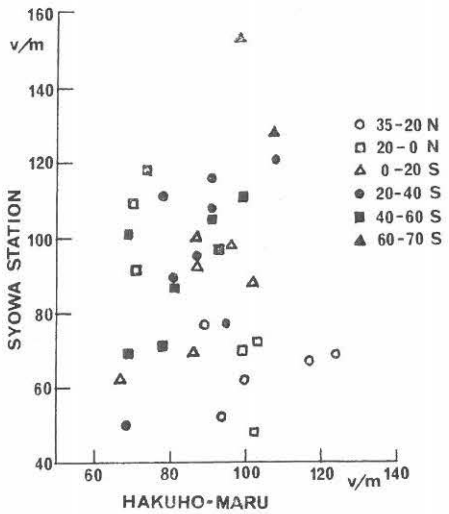

Fig. 2. Correlaton of daily averages between Hakuho-Maru and Syowa Station. Different marks correspond to the different latitudinal position of Hakuho-Maru.

worst for Hakuho-Maru to get undisturbed data because of unwanted weather and the route of vessel.

3. Latitude Effect

We reported in the previous paper that the daily averages measured on Hakuho-Maru were lowest at about 20°S and increased with increasing latitude both in the northern and southern hemispheres. This is similar to the rather old results by Rough (1941) and Gish (1942). The conclusion assumes that the diurnal course of the global thunderstorm activity would be regarded stable enough as the generator of global circuit if it is averaged for at least several days. Now we have coincident measurements at two representative stations during the whole period of the present cruise. The above assumption will be needless, if the condition of global circuit connecting the stations to the generator area is kept almost constant throughout the period, therefore if the values of the electric field at a fixed station is nothing other than the reflection of world-wide storm activity. Viewed in this way, Fig. 3, in which the ratios of daily averages at Hakuho-Maru to those at Syowa Station are plotted with respect to the latitude of Hakuho-Maru, will be a more reasonable indication of latitude effect than the results obtained from the statistics at a single moving station. We see here a different type of latitude effect. The normalized electric field tends to decrease monotonously as the observation point goes down toward the southern polar region. The similarity of the distribution of black circles and white ones in Fig. 3 seems to suggest that the effect is not accidental, because the route of Hakuho-Maru going down to the southern polar region and then back to Japan were separated by a distance of several thousand kilometers and by about a month interval. This latitude effect could not be explained by the latitude dependence of cosmic rays that are the main ionization source on the ocean. We shall have to search for other reasons; for example, the seasonal alteration of electric field; or the differences in background pollution, still existing even in the middle of the ocean, in the northern and southern hemispheres. Anyway it would be meaningless to go further into discussion based on these insufficient data.

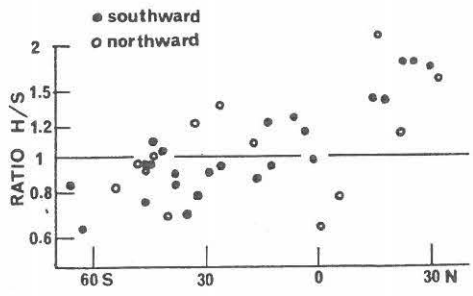

Fig. 3. Latittude effect of the ratio of electric field daily average at Hakuho-Maru to that at Syowa Station. Black and white circles correspond to the southward and northward period during the cruise of Hakuho-Maru,

4. Correlation of Diurnal Variations

One of the ways of investigating the propagation of global influence from the generator area is to compare the diurnal variations at two or more stations on the same day. Fig. 4 shows examples of diurnal course of the electric field recorded on Hakuho-Maru and at Syowa Station. Curves in full line are of Hakuho-Maru, and curves in dashed line are of Syowa Station. Just as in Fig. 1, the level of 100 V/m is on each respective horizontal line, while the time 00 UT falls on each vertical line. The number written at the upper right-hand side of the correlated two curves in each day is the value of the correlation coefficient of hourly values.

In the uppermost example, Nov. 28 and 29, 1968, the amplitude of variation is extremely small both on Hakuho-Maru and at Syowa Station. Kikuchi (1970) often observed at Syowa Station that the fair-weather elecric field was almost invariable for continuing several tens of hours. The example seems to correspond to this observation. It is notable that the field on the ocean surface also displays rather invariable course synchronizing with the antarctic region. The correlation coefficients are of negative values for both days, but we have to note the correlation coefficient is useful to only the variable component after removing the basic component. It is not

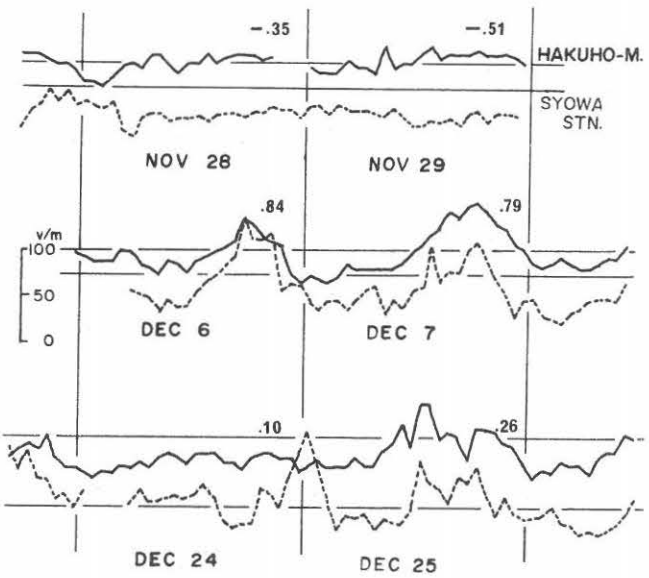

Fig. 4. Comparison of diurnal variations on Hakuho-Maru and at Syowa Station.[1] Horizontal lines are the level of 100 V/m. Left-hand scale of 100 V/m is applicable to all curves.

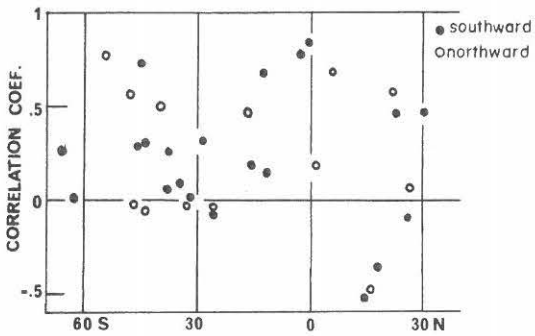

Fig. 5. Correlation coefficient of hourly values between Hakuho-Maru and Syowa Station with respect to the position of Hakuho-Maru.

always a good indication of the degree of mutual relation in these cases, because it is reasonable to consider that the small variable component is rather locally generated and that the large basic part is of global origination.

The second example, Dec. 6 and 7, 1968, displays typical diurnal variations of quite high correlation between both curves. The example, Dec. 24 to 25, 1968, is of rather low correlation. A large peak around 00 UT on Dec. 25 at Syowa Station is probably due to local effect.

Although the correlation coefficient is not always a pertinent indication of the mutual relation as seen in the first example, it is useful to represent some relationship. Therefore, we calculated the correlation coefficient of hourly values for every day that holds at least twelve undisturbed correlated hourly values. Fig. 5 is the result of this calculation plotted with respect to the position of Hakuho-Maru. The days of correlation coefficient higher than 0.5 are 26 % of all data. Better correlation is found when both stations are in the same hemisphere.

In the end of January and February, 1969, coincident records were obtained at four stations. Fig. 6 shows four curves representing the field variations on Hakuho-Maru, Meteor, Discoverer and at Syowa Station respectively from top to bottom. Horizontal and vertical lines mean the same as in Fig. 4 and the numbers are correlation coefficients of hourly values between Hakuho-Maru and the respective three stations. Comparatively good correlation is seen, especially in the lower example, Feb. 22 to 24, 1969.

Fig. 7 is the distribution of correlation coefficients of hourly values for every day between the respective stations. Let us denote the four stations with their initials H, S, M and D, respectively. The rate of days having correlation coefficient higher than 0.5 are 26, 43, 64 and 64 % respectively for the combinations H-S, H-M, H-D and M-D. If we take the correlation coefficient of hourly values in the diurnal

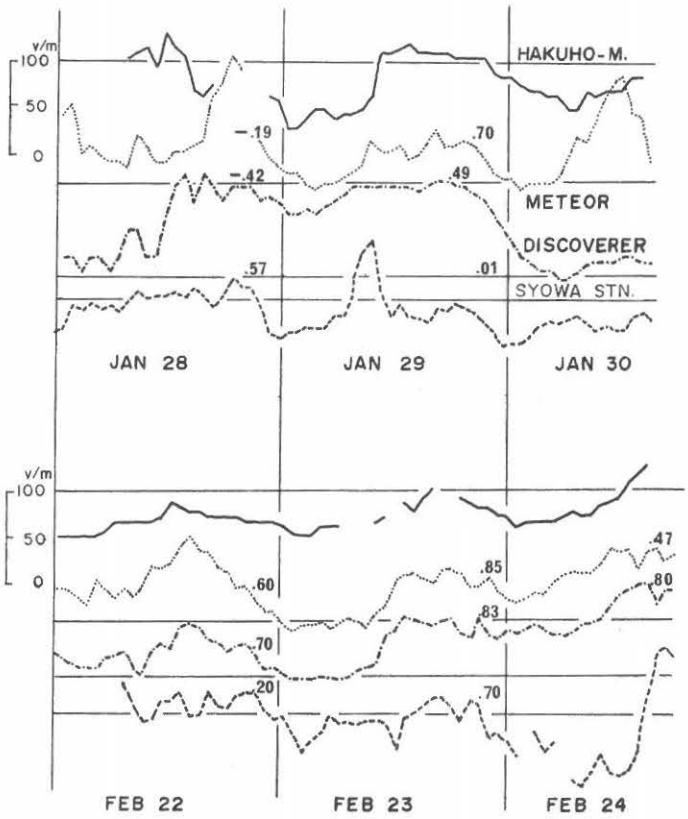

Fig. 6. Comparison of diurnal variations at four stations. Horizontal lines are the level of 100 V/m. The absolute values on two vessels on the Atlantic Ocean are comparatively higher than those at the other two stations.

variation averaged for a long period, it is expected the coefficient would much improve compared with that for a specific day. Actually, the values of coefficient thus calculated for a whole correlated period are .80, .75, .97 and .82, for H-S, H-M, H-D and M-D combinations, respectively.

Recently Bhartendu (1969) gave correlation coefficients of hourly values in the monthly averaged diurnal course between a number of land stations for the period of two years. According to his result, the greater part of the coefficient values lie between 0 and 0.5, and values more than 0.5 occupy only 12 % of all combinations of stations. Israel (1968) showed in his circular letter that the correlation of hourly averages was usually low even between two stations on land separated by only a few hundred kilometers. Compared with these reports, the correlation between the respective stations on oceans or in polar regions is concluded to be much higher than that between land stations.

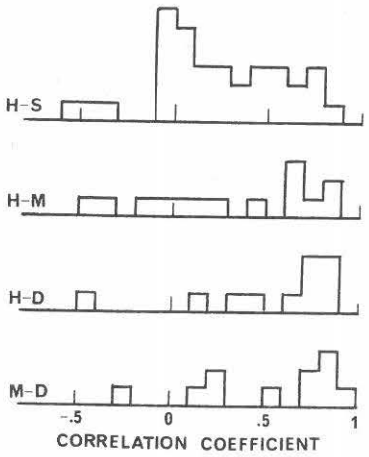

Fig. 7. Distribution of correlation coefficient of hourly values for each day between Hakuho-Maru and the other stations. For reference the combination Meteor-Discoverer, both located close to each other, is shown to have better correlation.

5. Concluding Remarks

The similarity of fair weather diurnal curves of the atmospheric electric field on the same day at a few stations in the ocean and the polar region indicates unquestionably the existence of a global generator for the electric field. However, we need further investigation to confirm whether the generator is usually composed of only thunderstorms globally distributed. For example, it is doubtful whether the diurnal course of an almost invariant nature means that meteorological conditions have kept the globally accumulated storm activity almost constant throughout a day or more. The comparison of daily averages at two stations, one fixed and the other moved over a wide latitudinal range, suggests a new type of latitude effect of the electric field, which is characterized by gradual monotonous decrease toward the antarctic region. Its explanation is left as a future problem.

Acknowledgements

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