

for this region alone a total conduction current greater than the corpuscular current. In other words, there is a lower limit to the value which one may assume for the region of precipitation. Thus the avoidance of difficulties concerned with the failure to directly measure a corpuscular current, by relegating that current to regions where experiments have not been made, does not avoid what is perhaps one of the most serious difficulties confronting any corpuscular theory, that of reconciling the comparatively small ionization of the atmosphere with the passage through it of about 1500 high speed corpuscles per square centimeter per second.

THE CONDUCTIVITY OF THE UPPER ATMOSPHERE

The paper concluded with a reference to the importance of a knowledge of the conductivity of the upper atmosphere in relation to the origin of the earth's charge and allied phenomena, and the author described an experiment in progress at the University of Minnesota designed with the object of measuring the distance of the supposed conducting layer by measuring the time taken by wireless waves to reach that layer and return.

RECENT RESULTS DERIVED FROM THE DIURNAL-VARIATION OBSERVATIONS OF THE ATMOSPHERIC-ELECTRIC POTENTIAL-GRADIENT ON BOARD THE *CARNEGIE* ¹

By S. J. MAUCHLY

The Department of Terrestrial Magnetism, in accordance with its director's plans, has for many years been making not only magnetic but also atmospheric-electric observations aboard its survey vessel, the *Carnegie*. It is thus contributing the chief data for mapping both the earth's magnetic field and its electric field. Furthermore, since 1915 numerous observations have been made aboard the *Carnegie* to determine the nature and magnitude of the changes in the electric condition of the atmosphere which take place during a 24-hour cycle.

For the *potential-gradient* the general procedure in the diurnal-variation observations is to make a set of 20 observations during each of 24 consecutive hours. The observations for such a set require about 20 minutes and their mean value is referred to the mean time for the set. From deductions based on the observations made prior to April, 1916, it appeared that the diurnal variation of the potential-gradient over the oceans probably did not differ much from that which has been found at many land stations; that is, they indicated two rather pronounced maxima and two minima during a 24-hour period.² However, very few data were

¹ Preliminary report presented before the American Geophysical Union, with amplifications.

² "Researches of the Department of Terrestrial Magnetism," Vol. III, pp. 416-420, Washington (1917).

available from oceans other than the Pacific, and as pointed out in the report just cited, a large percentage was derived from series of observations which were terminated by the advent of unfavorable weather. It should also be noted in passing that Swann¹ a year later in discussing

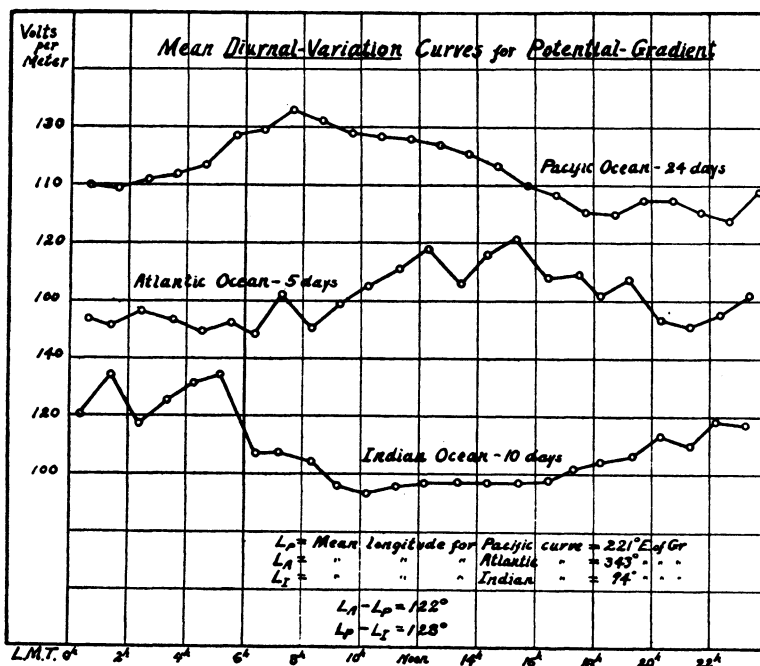


FIG. 3. Diurnal variation of electric potential-gradient on the oceans, plotted according to Local Mean Time.

the results of the observations for the year ending February 20, 1917, states that "the effect of the 12-hour Fourier wave is less important in the present curves than in those already published."

The largely increased amount of material which has accumulated since 1915 makes it now possible to reject nearly all data corresponding to less than a 24-hour series and still have 45 practically complete 24-hour series available. The data for each series, therefore, correspond to an actually occurring sequence of phenomena, and the mean results are free from the errors which would result from combining the results of partial series of observations.

Of the 45 diurnal-variation series referred to, 30 were made in the Pacific, 5 in the Atlantic, and 10 in the Indian Ocean; the combined data represent about half the earth's surface. The means corresponding to

¹ W. F. G. Swann. "Supplementary report on atmospheric-electric observations made aboard the *Carnegie* from May 17, 1916, to March 2, 1917," in "Annual Report of the Director of the Department of Terrestrial Magnetism" for the year 1917. Year Book of the Carnegie Institution of Washington, 1917, p. 282.

the separate oceans, as derived from 39 series, are represented in figure 3. They show: (1) That the mean diurnal-variation curves for the Pacific, Atlantic, and Indian oceans are similar in form; (2) that the principal component of the variation consists of a 24-hour wave, and (3) that the times of occurrence of the chief phases of this wave, when referred to

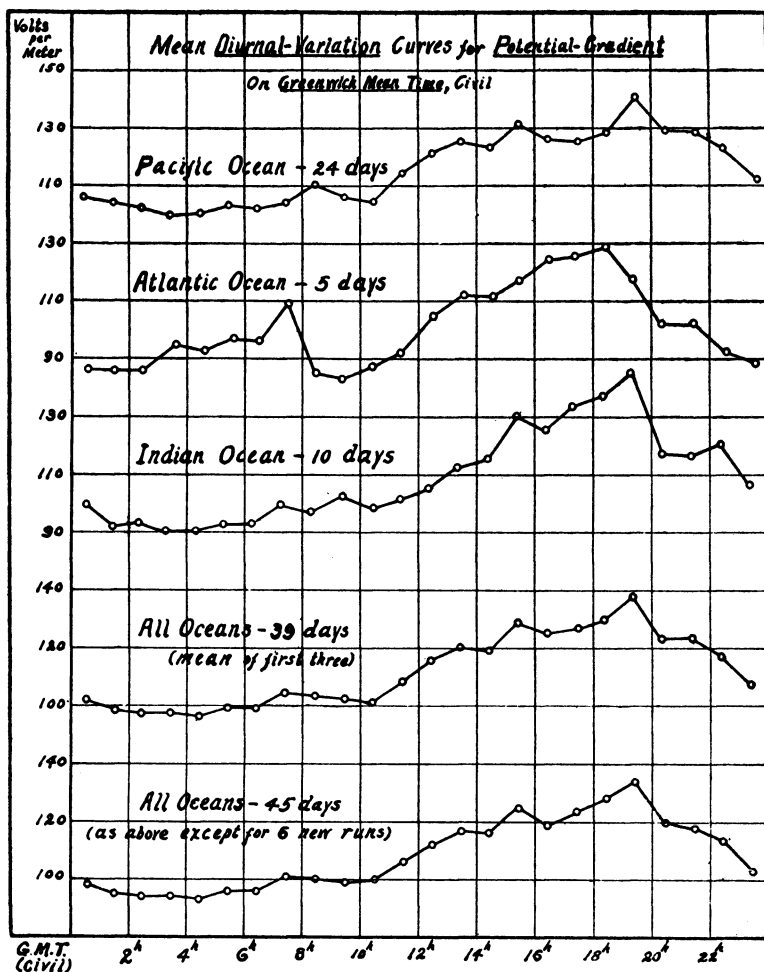


FIG. 4. Diurnal variation of electric potential-gradient on the oceans, plotted according to Greenwich Mean Time.

local time, differ for the several oceans by amounts which correspond approximately to the differences between the respective mean longitudes, for the several oceans, of all the points at which observations were made.

Since the curves of figure 3 suggest the simultaneous occurrence of maximum (or of minimum) phase over all three oceans, it was decided

to refer the results of each series of observations to Greenwich Mean Time (civil), and recompute the means for the separate oceans on this basis. The results are shown in figure 4, together with a curve which includes the data from 6 recent series received from the vessel after the curves in figure 3 had been prepared. The differences between the several curves of figure 4 are of course not to be thought of as representative of separate characteristics, since the smoothness of the respective curves is seen to be closely related to the number of component series.

The curves of figure 4 show a decided similarity to land results for high latitudes and also to many of the winter curves obtained in ordinary latitudes. Indeed, if differences in local mean time are taken into account, it appears that for many land stations at which the single diurnal wave predominates, there is approximate simultaneity as to the time of occurrence of maximum (likewise, of minimum), and this at a time which is in general agreement with what is indicated by the curves of figure 4. For the summer, however, as is well known, most land stations show, in addition to the 24-hour wave, a decided secondary wave which seems to occur in general at about the same local mean time at different stations.

The minimum value of the potential-gradient, according to figure 4, occurs at about 4^h A.M., G.M.T., and in view of the fact that for observatories in western and central Europe the difference between local and Greenwich time is not great, this may account for the fact that various authorities have assumed the occurrence of the principal minimum at about 4^h A.M., local time, to be a rather general characteristic for most stations. It is also significant to note that Mache and v. Schweidler¹ long ago pointed out that the phase angle of the 24-hour wave varied greatly from station to station while the phase angle of the 12-hour wave was approximately the same for nearly all stations. Although the phase angles of the 24-hour Fourier waves for the European stations show among themselves very much greater differences than can be accounted for by the rather small differences in longitude, it must be borne in mind that the results of harmonic analyses are dependent upon local meteorological and cultural, and sometimes topographical and instrumental, factors as well as upon any general characteristics which the potential-gradient may possess.

In the present investigation no account has been taken of possible changes in the characteristics of the diurnal variation with latitude and with time of year, except to ascertain that the preponderance of the 24-hour wave and the approximate progress on a universal-time basis seem to hold throughout the year and for wide ranges of latitude. The present results are, therefore, to be considered as provisional and representing only a general yearly average. In fact, investigations under way show that considerable modification in detail is to be expected as more observational material becomes available. The data from 45 practically

¹ H. Mache und E. v. Schweidler, "Die Atmosphärische Elektrizität," p. 27, Braunschweig, 1909.

complete series of diurnal-variation observations aboard the *Carnegie*, representing a general distribution over most of the accessible ocean-areas indicate, therefore, as a preliminary result, that *the chief component of the diurnal variation of the potential-gradient over the major portion of the earth (especially the oceans) is a wave of 24-hour period which occurs approximately simultaneously in all localities.*

A fact of considerable interest is that the diurnal-variation curves for the potential-gradient derived from the *Carnegie* observations are very similar to curves which represent the relative frequencies of the Aurora Borealis, as observed at several European stations, and also to curves representing the diurnal distribution of certain classes of magnetic disturbances, when all are referred to the same time-basis. It may also be pointed out that owing to the non-coincidence of the earth's magnetic axis with its axis of rotation, the time of daily potential-gradient maximum, as indicated by the ocean curves, corresponds approximately to the time when the earth's north magnetic pole, for example, is nearest to the sun, while the daily minimum occurs, in a general way, when this pole is farthest from the sun. The actual times of maximum and minimum, however, appear to depend upon the positions of *both* magnetic poles and the fact that their longitude difference is not 180°. These correlations appear to support the assumptions of various investigators that the earth's electric charge and resultant field may be very intimately related to an electric radiation from the sun. The best evidence as to the extent of this support will probably result from a study of the details of the diurnal-variation curves corresponding to various positions of the earth in its orbit. Reductions with this end in view are under way and it is hoped that sufficient data will soon be available to yield some information on this point.

The making of diurnal-variation observations in atmospheric electricity by eye readings is always a burdensome procedure; the carrying on of such work aboard a vessel is not only arduous but also difficult. In this connection the utmost credit is due the several commanders of the *Carnegie*, during her various cruises, and to all the observers who participated in the observational work.

I am indebted to the director, Dr. L. A. Bauer, for his constant interest in and encouragement of the work in hand, and for a suggestion of the possibility of finding in the asymmetry of the earth's magnetic field an explanation of the observed diurnal variation on a universal-time basis. I am also greatly under obligations to the members of the Department of Terrestrial Magnetism who assisted in the reduction of the observational data, especially to Dr. G. R. Wait, both for valuable assistance and helpful suggestions.

The full publication of the observational data and discussion of results will be deferred until after the completion of the present cruise of the *Carnegie*.

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