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SEASONAL VARIATION IN THE D-COMPONENT OF Sq NEAR THE DIP-EQUATOR

By

Hiroo MURATA[1]

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Abstract

The purpose of the present paper is to analyse the seasonal variation of the geomagnetic D-component of Sq at five selected magnetic observatories nea rthe dip-equator, by using data on magnetically quiet days during the IGY. The result shows a persistent winter-summer symmetry in such a way that its variation has a maximum value at about 0.7 L.T. ($\simeq 15\gamma$) and 18 L.T. ($\simeq 5\gamma$) and a minimum value at about 12 L.T. ($\simeq -15\gamma$) for summer, and the sign of its variation is inversed for winter. It will be discussed as to why these variations of the D-component occurred.

1. Introduction

In reference to the well-known method of Chapman and Bartels [1940], the geomagnetic Sq field is represented in terms of the ionospheric current system which is derived from observations. The pattern of this current system cannot, in general, be regarded as a real current flow in the ionosphere, because the two dimensional treatment of the dynamo theory may not be applicable, especially in solstice, i.e. the vertical current can flow along the magnetic lines of force, which tends to balance the potential at conjugate points in the northern and southern hemispheres (Hines [1963], Dougherty [1963]). The potential differences are produced by the different dynamo action in the both hemispheres in solstice, because the neutral wind in the ionosphere which causes the dynamo action, is not symmetrical about the equator. As the current flow along the magnetic lines of force, its magnetic effect at the earth's surface may be seen in the D- and Z-component of the geomagnetic variation, and this current will flow in opposite directions in different solstices. This means that the current may produce the seasonal variation in the D- and Z-components. The purpose of this paper is to investigate the net effect of such a field aligned current on the observed geomagnetic variations at the equator. The present investigation

[1] Now at the Department of Applied Mathematics, Faculty of Engineering, Gifu University.

is limited to the D-component, because the Z-component is greatly influenced by subterranean structure.

2. Seasonal variation of the D-component

Five observatories are situated near the magnetic equator (dip-equator). There are Huancayo (dip latitude 1.0°), Koror (−0.04°), Jarvis Island (1.1°), Trivandrum (−0.3°) and Addis Ababa (−0.5°). The data used here was obtained from these five station during IGY and also from Huancayo in 1963 only. These enable us to investigate the influence of the solar activity. To minimize the disturbance effects, undisturbed days ($\sum K_p \leqslant 15$) are selected and also the non-cyclic changes are eliminated by equalization of the consecutive two midnight values.

In order to obtain the seasonal variation, the daily variation in the solstitial seasons (deviated from its datum line) is subtracted from those in the equinoxial one (deviation from its datum line) which is shown in Fig. 1. The seasonal

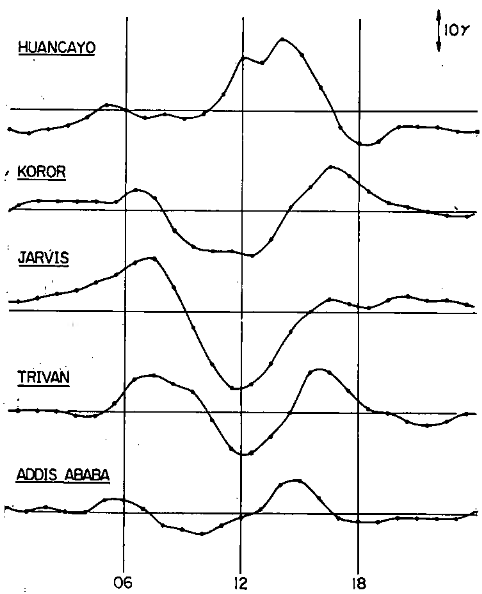

Fig. 1. The equinoxial daily variations (IGY) of D-component for five stations, Huancayo, Koror, Jarvis Island, Trivandrum and Addis Ababa.

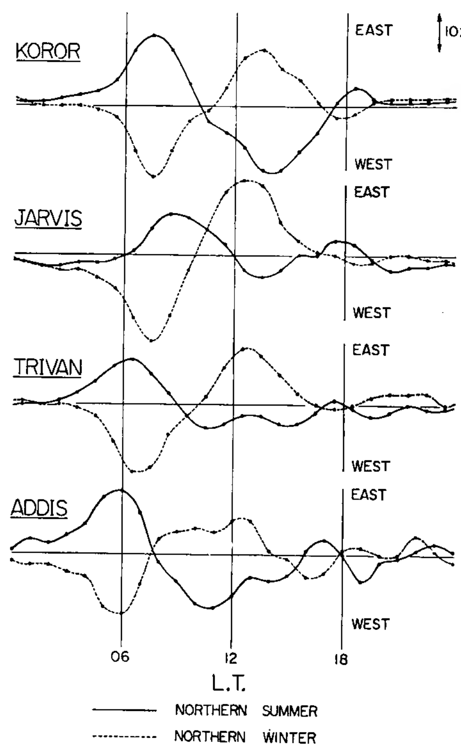

Fig. 2. The solstitial daily variations (IGY) of D-component deviated from the equinoxial daily one for four stations, Koror, Jarvis Island, Trivandrum and Addis Ababa.

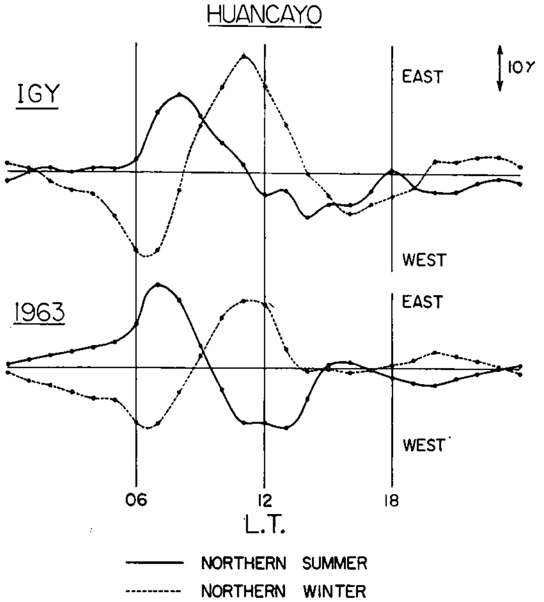

Fig. 3. The solstitial daily variations of D-component deviated from the equinoxial daily one for IGY and 1963 at Huancayo.

variations thus obtained are shown in Fig. 2 and Fig. 3. In Fig. 2, it may be said that the daily changes in summer and winter are antisymmetric. To examine the effect of solar activity, the variations at Huancayo during the IGY and in 1963 are shown in Fig. 3. The effect of the solar activity during the period of sunspot minimum is remarkably weaker than during the period of maximum. The variation at Huancayo during the period of sunspot minimum shows a similar variation to that in Fig. 2. It can be seen from these figures that the daily variations for all stations show similar tendency in each season ; i.e., maximum or minimum values at about 07 L.T., 12 L.T. and 18 L.T. The amplitude of the first two is about 15γ and the last one is several gammas.

3. Discussion

Most investigations of equatorial electrojet current have been made on the basis of observed values of the H- and Z-components measured on the surface of the earth near the equatorial zone. Recently, Ogbuehi and Onwumechilli [1965] have concluded that the position of the equatorial electrojet does not show any seasonal change, i.e., the axis of equatorial electrojet is exactly coincident with the dip-equator and the electrojet is most intense in equinox. On the other hand, the ionospheric current system which is derived from the geomagnetic Sq variation using the well-known method of Chapman and Bartels [1940] has the south-north component of the current on the dip-equator (Fig. 4) and recently Matsushita and Maeda, H. [1965) also obtained the same results. It is shown in these calculations, that the position of the equatorial electrojet moves across the dip-equator southward in northern summer and northward in northern winter. This discrepancy results from the observed fact which is seen to be due to the adoption of non-vertical current model.

Various researchers have investigated the ionospheric current systems taking

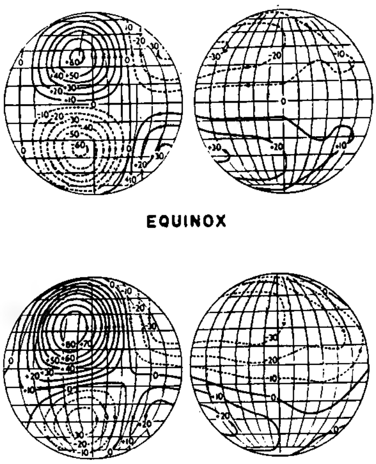

Fig. 4. Ionospheric current system calculated by Chapman and Bartels [1940]. Between consecutive stream-lines, 10,000 Amperes flow in the direction of the arrows.

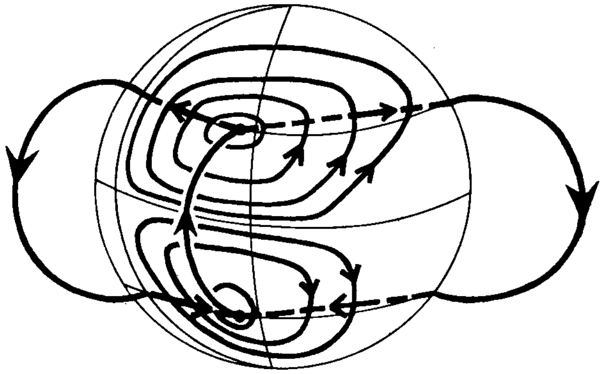

Fig. 5. The schematic figure of the northern summer Sq current system. It has two current loops, one is the ionospheric current loop and the other is a sample of the magnetospheric current loops derived by the different order of polarizations of the center of the current vortex in both hemispheres. The meridian which is drawn in the center of the figure represents 12 L.T. The left side in this figure is about 07 L.T. and the right side is about 18 L.T.

the vertical current into account. Maeda, K. and Murata [1965] showed from a simple calculation that the current flow across the equator in the ionosphere in solstice becomes negligibly small as compared with the non-vertical model. Since the geomagnetic field has only the N-S component on the dip-equator and the conductivity along the field lines is higher than that in the other direction, it is thought that the electrostatic field along the field lines is too small to permit appreciable currents in the N-S direction. The field aligned current in this case was found to be 10^{-10} Amp/m^2 in order of magnitude and that its magnetic effect on the earth's surface attaines a maximum of several gammas at the equatorial zone. The effect of the field aligned current for the variation of the D-component of the Sq variation is, therefore, negligible. The seasonal variation of the D-component of the Sq variation is produced by the ionospheric currents which flow in both the northern and southern hemispheres independently, without crossing the dip-equator. Bacause the ionospheric current is, in general, not symmetrical about the dip-equator it can be produced by the northern and southern ionospheric currents.

A charge separation and resultant polarization between the center and the outer regions of the Sq current vortex in the ionosphere would be produced by Hall effect (Hirono [1950]), that is, negative charges are set up at the center of the vortex, and positive charges are set up at the sunrise and sunset zone where the conductivity is smaller than that at noon by factor 10 in magnitude.

In northern summer, the dynamo action in the northern hemisphere is larger than in the southern hemisphere. The accumulation of charge in the former may, therefore, be greater than that in the latter. The electrical linkage between the magnetically conjugate points makes the production of a divergence-free current flow (Fig. 5) possible. This magnetospheric current also produces the change of D-component of the geomagnetic field in the same sense as the effect of the ionospheric current (Fig. 2). It seems, therefore, to be very hard to separate these two effects from the observed D-component. If this magnetospheric current produces some contribution to the D-component observed on the dip-equator near sunset, a variation of the same order should be produced near the time of sunrise because of the possibility of the same charge accumulation on the sunrise and sunset ionospheric zones. Since the variation of D-component near sunset time is about 5γ (Fig. 2), the effect of the magnetospheric current would be equal to or less than 5γ.

It might be thought that no daily variations of D-component is seen in equinox on the dip-equator. But, for all five stations these daily variations are always seen as shown in Fig. 1. This fact means that the current system is not asymmetrical about the dip-equator even at the equinox. This asymmetry may be related to the fact that the positions of the foci of the Sq current vortices are not located on magnetically conjugate points, which has already been pointed out by Ota [1948], and Price and Wilkins [1963] using the data of the International Polar Year 1932-33 and van Sabben [1964] using the data of IGY. From the theoretical point of view this asymmetry might be affected by the fact that the ionospheric wind is dependent on the geographic coordinates, but the dip-equator, of course, conforms more to the geomagnetic equator than the geographic one. Actually, Nagata [1948] already showed in consideration of the disagreement of these axeses that this asymmetry can be produced sufficiently. On the other hand, van Sabben [1966] attributed this north-south asymmetry to the field aligned currents in the magnetosphere. We cannot, however, accept his theory as well as Mishin's one [1966] on the following two points: (1) The effect of the disagreement of geographic and geomagnetic axses is neglected, and (2) there is no reason that the whole field aligned currents flow into the ionosphere to close ionospheric current circuits, as van Sabben considered in the elementary region of the ionosphre. His work is no more than the calculation of ionospheric currents and field aligned currents in the magnetosphere to satisfy div $J=0$ (J is current density) based on the particular given current system.

4. Conclusion

The present analysis shows that D-component of Sq on the dip-equatorial zone has a seasonal variation as well as a daily variation in the equinox. The daily variation in the equinox is due to the effect of the disagreement of geographic and geomagnetic axses.

The tendency of the seasonal variation is antisymmetrical with respect to the equator in summer and winter. Its absolute maxima reaches to about 07 L.T., 12 L.T. and 18 L.T. with the order of 15γ for the former two and 5γ for the latter. This variation of D-component in solstice seems to be produced mainly by the ionospheric currents flowing in the northern and southern hemispheres independently, without crossing the dip-equator. It seems that the magnetospheric current has a smaller effect on Sq at the earth's surface than the ionospheric current. The effect of the magnetospheric current may be several gamma, at most.

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