WORLD-WIDE PATTERN OF IONIZATION DRIFTS IN THE IONOSPHERE F REGION AS DEDUCED FROM GEOMAGNETIC VARIATIONS

BY

Hiroshi MAEDA

1. Introduction

It is now well known that the air movements in the ionosphere induce electric currents by dynamo action. Such currents flow mainly in the E region (usually called the dynamo region) and set up an electrostatic field there. This field seems to be communicated to the F region along highly conducting lines of geomagnetic force, as first suggested by Martyn (1955a) and later confirmed theoretically by Farley (1959, 1960) and Spreiter and Briggs (1961a, 1961b). The electrostatic field in the F region thus communicated would give rise to ionization drifts in that region under the influence of the geomagnetic field, and result a considerable distortion of the layer.

The purpose of this paper is to present a world-wide pattern of ionization drifts in the F region of the ionosphere, as deduced from geomagnetic variations during the Second Polar Year, 1932-33, and to discuss their effects on the distribution of the electron density in the ionosphere not only on quiet days but also on disturbed days.

2. Layer Drifts

The drift velocity, $\boldsymbol{V}_d$, of neutral ionization relative to an original air movement is given by

$$\boldsymbol{V}_d=\frac{\boldsymbol{J}\times\boldsymbol{H}}{\sum_r n_r m_r \nu_r}, \qquad (r=i,\ e) \qquad (1)$$

where $\boldsymbol{J}$ is the electric current density, $\boldsymbol{H}$ is the geomagnetic field intensity, and n_r, m_r and ν_r are respectively the number density, mass, and collision frequency for ions (i) and electrons (e).

If we assume that the vertical current component, J_z, vanishes exactly, the horizontal current density is given by

$$\left.\begin{aligned} J_x &= k_{xx}E_x + k_{xy}E_y \\ J_y &= -k_{xy}E_x + k_{yy}E_y, \end{aligned}\right\} \qquad (2)$$

where the subscripts x and y denote respectively the southward and eastward components, and k_{xx}, k_{xy} and k_{yy} denote the layer conductivities. Thus the components of $\boldsymbol{V}_d$ are expressed as follows:

$$\left.\begin{aligned} V_{d,x} &= -H_z(k_{xy}E_x - k_{yy}E_y)/\sum_r n_r m_r \nu_r \\ V_{d,y} &= -H_z(k_{xx}E_x + k_{xy}E_y)/\sum_r n_r m_r \nu_r \\ V_{d,z} &= H_x(k_{xy}E_x - k_{yy}E_y)/\sum_r n_r m_r \nu_r \,. \end{aligned}\right\} \qquad (3)$$

In the F region where ν_r is much smaller than ω_r, ω_r being the gyrofrequency, equation (3) is greatly simplified as follows:

$$\left.\begin{aligned} V_{d,x} &= (-E_y/H)\sin\phi \\ V_{d,y} &= (E_x/H)/\sin\phi \\ V_{d,z} &= (E_y/H)\cos\phi \,, \end{aligned}\right\} \qquad (4)$$

where ϕ is the geomagnetic dip measured positive in the northern hemisphere. If we suppose that the electric field in the F region is derived from a potential communicated from the E region along the lines of geomagnetic force, the electric field on a geomagnetic meridian plane must be perpendicular to the geomagnetic field, so that

$$E_z = -E_x\cot\phi \,. \qquad (5)$$

The second equation of (4) is, therefore, expressed as follows:

$$\begin{aligned} V_{d,y} &= E_x/H\sin\phi = E_x(\sin^2\phi + \cos^2\phi)/H\sin\phi \\ &= (E_x\sin\phi - E_z\cos\phi)/H \end{aligned} \qquad (6)$$

This expression may be useful on and near the magnetic equator.

3. Calculated Results

As first suggested by Martyn (1955a) and later confirmed by Weekes (1957) and Maeda (1959b), the ionization drift in the F region is mainly caused by an electrostatic field communicated from the dynamo region. On the other hand, according to the results of studies by Farley (1959, 1960) and Spreiter and Briggs (1961a, 1961b), the electrostatic coupling between the E and F regions is very good for a source of large scale. We here deal with the diurnal and semi-diurnal components of electrostatic field, so that the attenuation of the electrostatic field with height will be negligible.

The electrostatic field in the dynamo region may be estimated by the dynamo theory of geomagnetic variations. Maeda (1955, 1959a) has obtained the electrostatic field for *Sq* and for *Sd*, based on data during the Second Polar Year, 1932–33. By using his results, the electrostatic field in the F region is estimated on the assumption that the electrostatic field in the dynamo region is commuuicated to

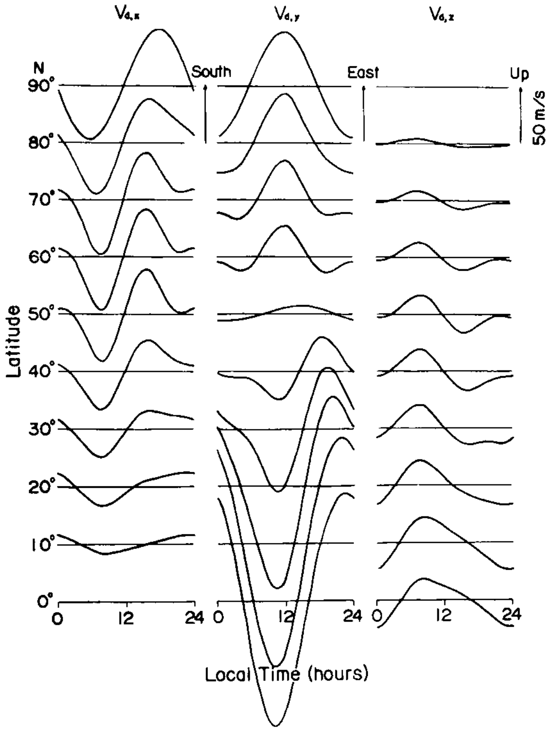

Fig. 1 *F*-region drifts due to *Sq*, where the length of arrows corresponds to 50 m/sec.

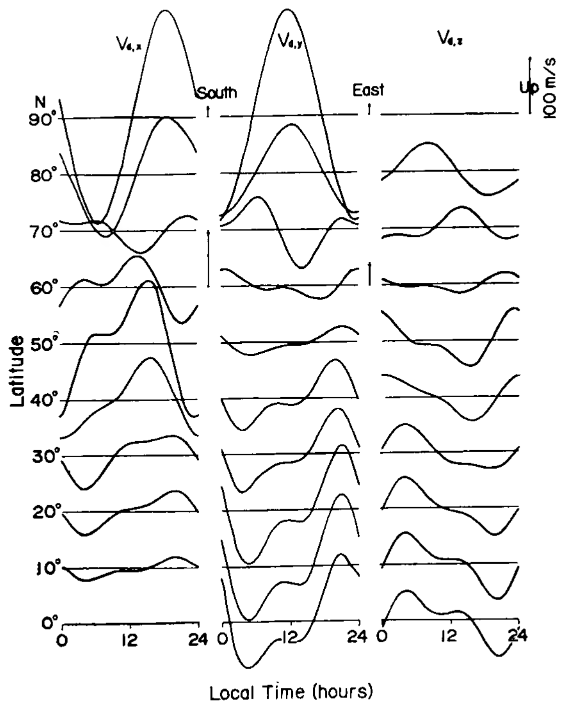

Fig. 2 *F*-region drifts due to *Sd*, where the length of arrows corresponds to 100 m/sec.

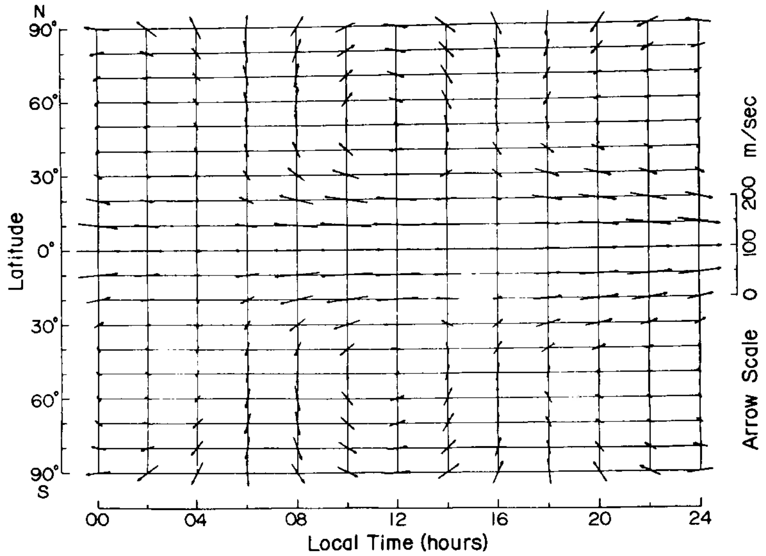

Fig. 3 World-wide pattern of horizontal *F*-region drifts due to *Sq*.

the *F* region along the lines of geomagnetic force without attenuation, and then the drift velocity in the *F* region is calculated from (4) and (6). The results are shown in Fig. 1 (for *Sq*) and Fig. 2 (for *Sd*). Moreover, in Fig. 3 is shown a world-wide pattern of horizontal *F*-region drifts due to *Sq*, by using the x and y componeuts shown in Fig. 1.

4. Discussion

It is clear that the calculated *F*-region drifts depend largely upon the electrostatic field in the dynamo region. The *Sq*- and *Sd*-electrostatic fields used here were estimated on some simplified assumptions, consequently the present results may be no more than an example.

It is, however, to be noted that the *EW* component of *F*-drifts is very large on and near the geomagnetic equator (this result has also been pointed out by Martyn (1955b)) and that the horizontal component is very large in high latitudes on disturbed days. These large horizontal drifts may play an important part in the distortion of the *F* layer, in addition to the vertical drifts.

On the other hand, direct measurements of *F*-region drift have recently been made at many stations over the world, especially during the IGY and IGC. We have made efforts to find a world-wide pattern of observed *F*-region drifts, using IGY and IGC data, and to compare with our calculated results, but the study is not completed yet. Such a comparison will, therefore, be made in a later paper.

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