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IONOSPHERIC DISTURBANCES GENERATED IN THE AURORAL ZONE DURING MAGNETIC STORMS

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Abstract. Deviation of large-scale traveling ionospheric disturbances (LS TIDs) from the equatorward propagation direction is discussed. These LS TIDs are registered in the auroral zone during magnetic storms. The deviation is a well-known phenomenon, but its causes are still unclear. The LS TID motion along the geomagnetic meridian may be a possible cause. In order to check this hypothesis, we simulated motion of the points in the geographic and geomagnetic coordinate systems. If a point travels along the geomagnetic meridian, its velocity has two components in the geographical coordinate system: along the geographical meridian (meridional component) and along the geographical parallel (zonal component). The values of meridional and zonal components vary with longitude and latitude.

1. Introduction

When studying the ionospheric response to magnetic storms, special attention is given to large-scale traveling ionospheric disturbances (LS TIDs) with characteristic time periods of 1-2 hours and wavelengths of 1000-2000 km [Maeda and Handa, 1980; Balthazor and Moffett, 1999; Afraimovich and Perevalova, 2006; Ding et al., 2007; Ding et al., 2008]. These LS TIDs are generated at the southern boundary of the auroral oval and propagate from high to middle and low latitudes with phase velocities of 600-900 m/s [Hajkowicz, 1991; Perevalova et al., 2008; Ding et al., 2007; Ding et al., 2008].

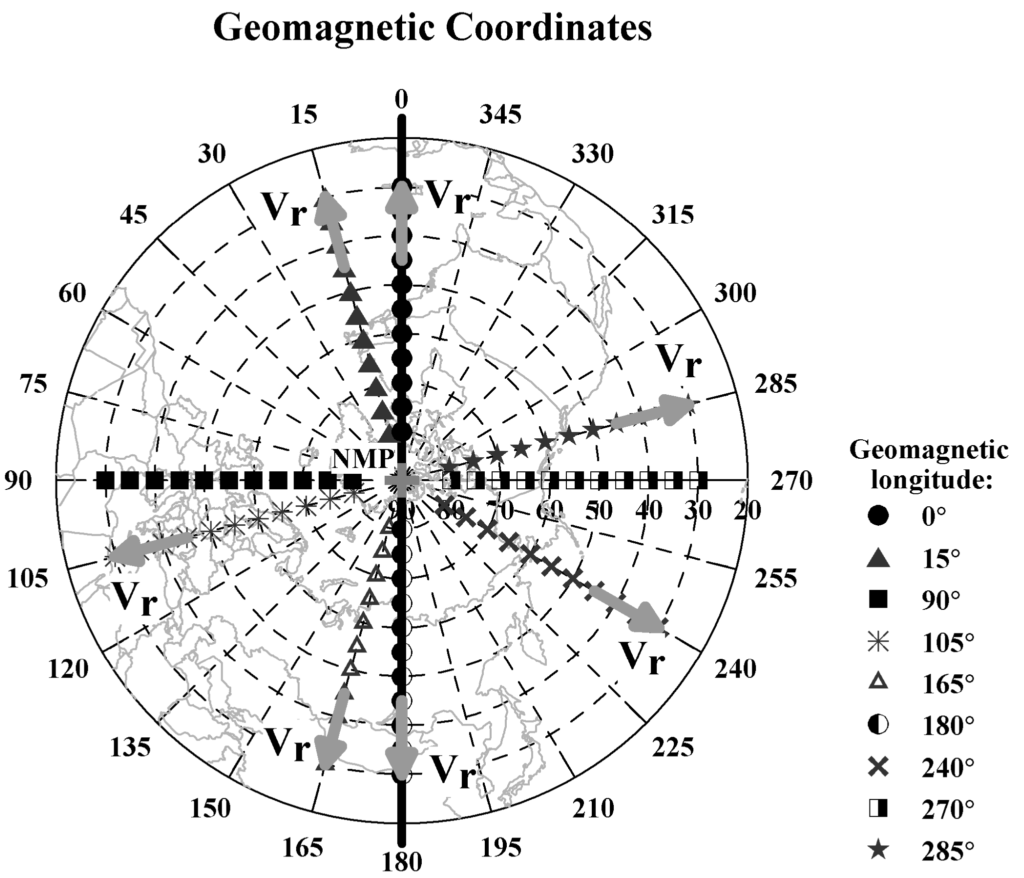

Fig. 1. Simulation of motion of points along nine geomagnetic meridians (0°, 15°, 90°, 105°, 165°, 180°, 240°, 270°, 285°) in the geomagnetic coordinate system.

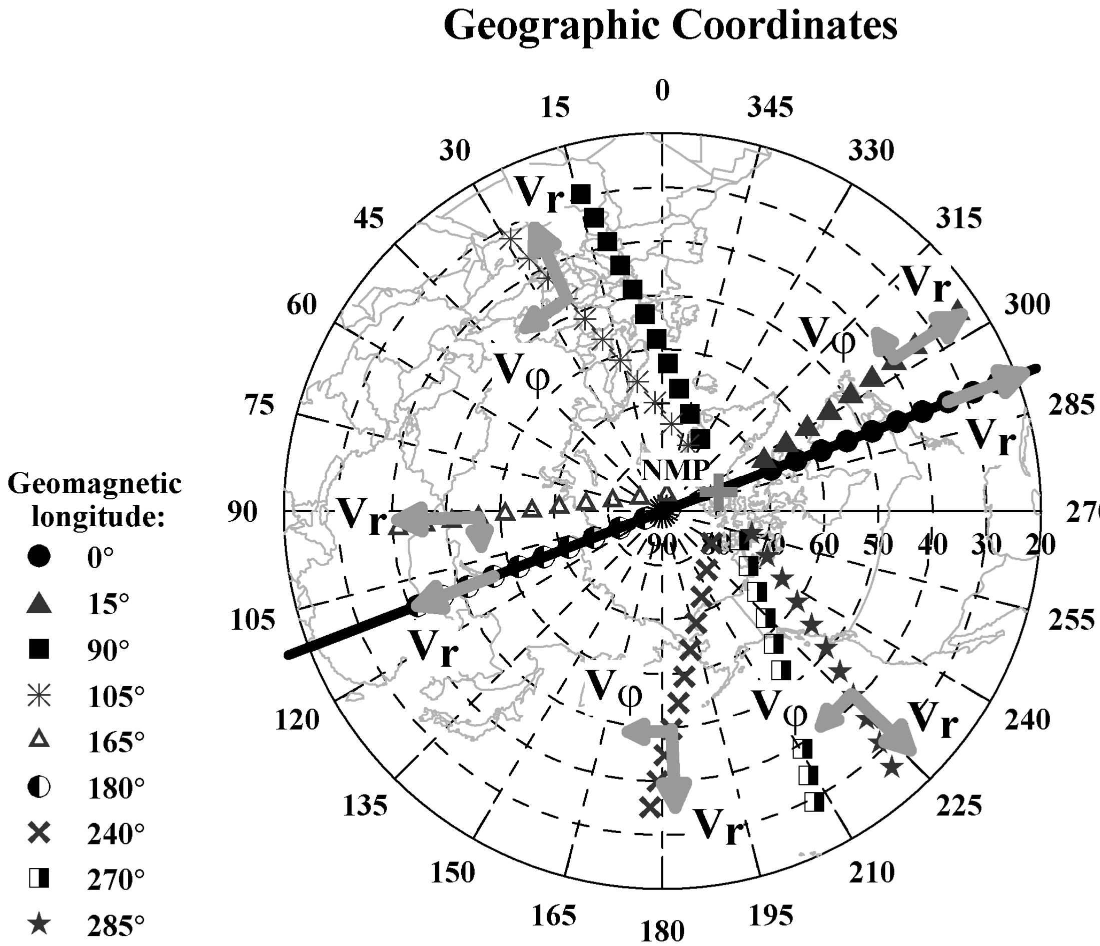

Fig. 2. Travel of points moving along nine geomagnetic meridians (0°, 15°, 90°, 105°, 165°, 180°, 240°, 270°, 285°) in the geographic coordinate system

Calculation of the velocity and travel direction of the LS TIDs during different magnetic storms have repeatedly been made by the Institute of Solar-Terrestrial Physics SB RAS (Irkutsk, Russia). It was shown that in the Northern Hemisphere LS TIDs do not travel strictly southwards, but south-westwards as a rule, or south-eastwards in certain cases [Leonovich et al., 2004; Perevalova et al., 2008]. The velocity and travel direction of the LS TIDs exhibit a strongly pronounced longitudinal dependence, which is usually related with the local time (LT). During the 29 October 2003 magnetic storm [Perevalova et al., 2008] the LS TID propagation direction in the night and day sectors was close to meridional; in the morning and evening sectors the zonal component of LS TID velocity exceeded the meridional one. The smallest LS TID velocity (700 m/s) was detected in the night region, the highest (1600 m/s) on the day side. During a strong magnetic storm on 25 September 1998 [Afraimovich et al., 2000] the azimuth of the LS TID wave vector varied in North America along the wavefront from 245º at the longitude corresponding to 1600 LT to 177 º at the longitude corresponding to 1900 LT. Toward the local nighttime, the propagation direction was nearly equatorward. Analysis of LS TID propagation directions during five magnetic storms of 1998-2001 [Leonovich et al., 2004] showed that south-westward direction (198±25°) predominated on the Earth dayside with a south-eastward (169±20°) prevailing on the night side. The LS TID propagation velocities on the night side (970±300 m/s) were higher then those on the dayside (660±200 m/s). Many other authors also mentioned the westward displacement (by 10–20° on average) of the LS TID propagation direction [Maeda and Handa, 1980; Balthazor and Moffett, 1999; Hall et al., 1999; Foster et al., 1989].

The causes of the LS TID deviation from the equatorward propagation direction are not exactly known. Possible causes include Coriolis force effect, thermospheric winds, a powerful stream of plasma ejected from polar cap. However, one of the causes may lie in the calculation technique involved. One can expect that in the absence of deviating factors wave LS TID generated at the southern boundary of the auroral oval should propagate radially from a source, i.e. along the geomagnetic meridian. Calculating the LS TID velocity in geographic coordinate systems, can lead to certain distortions. The purpose of this paper is to conduct comparative analysis of the motion parameters (travel direction and velocity) of auroral LS TIDs in the geomagnetic and geographic coordinate systems. The analysis is based on a simulation of the point motion in these coordinate systems.

2. Simulation of the motion of points in the geomagnetic and geographic coordinate systems

We carried out the simulation to find out how a point (having certain velocity components in latitude and longitude in the geomagnetic coordinate system) moves in the geographic coordinate system. It was suggested that the point moved along the geomagnetic meridian with velocity Vr = 617 m/s. The chosen value Vr corresponded to the average velocity of travel of LS TIDs during magnetic storms. We simulated the motion of nine points along meridians with longitudinal values of 0°, 15°, 90°, 105°, 165°, 180°, 240°, 270°, 285°. Fig. 1 presents the successive positions of points that moved along geomagnetic meridians. The distance between the successive positions was 5°. At velocity Vr = 617 m/s, the point travelled this distance in about 15 minutes. Grey arrows in Fig. 1 indicate the directions of velocity Vr for some magnetic meridian. The Zero Magnetic Meridian is marked by thick black line.

The geomagnetic coordinates of the point successive positions were converted to their geographic coordinates, thus obtaining a visible motion of points in geographic coordinate systems. Fig. 2 shows the derived position of the same points in the geographic coordinate system. According to calculations, the velocity of the point in the geographic system has two components: along the geographic meridian (meridional component, Vr) and geographic parallel (zonal component, Vφ). The meridional component reflects changes in latitude of the travelling point; the zonal component, changes in its longitude. The directions of Vr and Vφ are shown by grey arrows. A thick black line in Fig. 2 marks the positions of the Zero Magnetic Meridian.

At meridians with a geomagnetic longitude of 0° and 180°, the zonal velocity component Vφ in geographic coordinates is equal to zero. This is a result of the Geographic North Pole been located at the Zero Magnetic Meridian. At meridians with the geomagnetic longitude of 90° and 270°, Vφ reaches its maximum value. At geomagnetic longitudes 0° to 180°, the zonal velocity component Vφ is eastward. At geomagnetic longitudes 180° to 360°, the zonal velocity component is westward.

The values of meridional Vr and zonal Vφ components at the various geographic latitudes are displayed in Fig. 3. The symbols designate latitude variations of Vr and Vφ at geomagnetic meridians 0° and 180° (dots), 90° and 270° (squares), 15° and 240° (triangles). The positive values correspond to eastward Vφ. A solid black line in the left side of Fig. 3 marks the meridional velocity Vr = 617 m/s in the geomagnetic coordinate system. The zonal

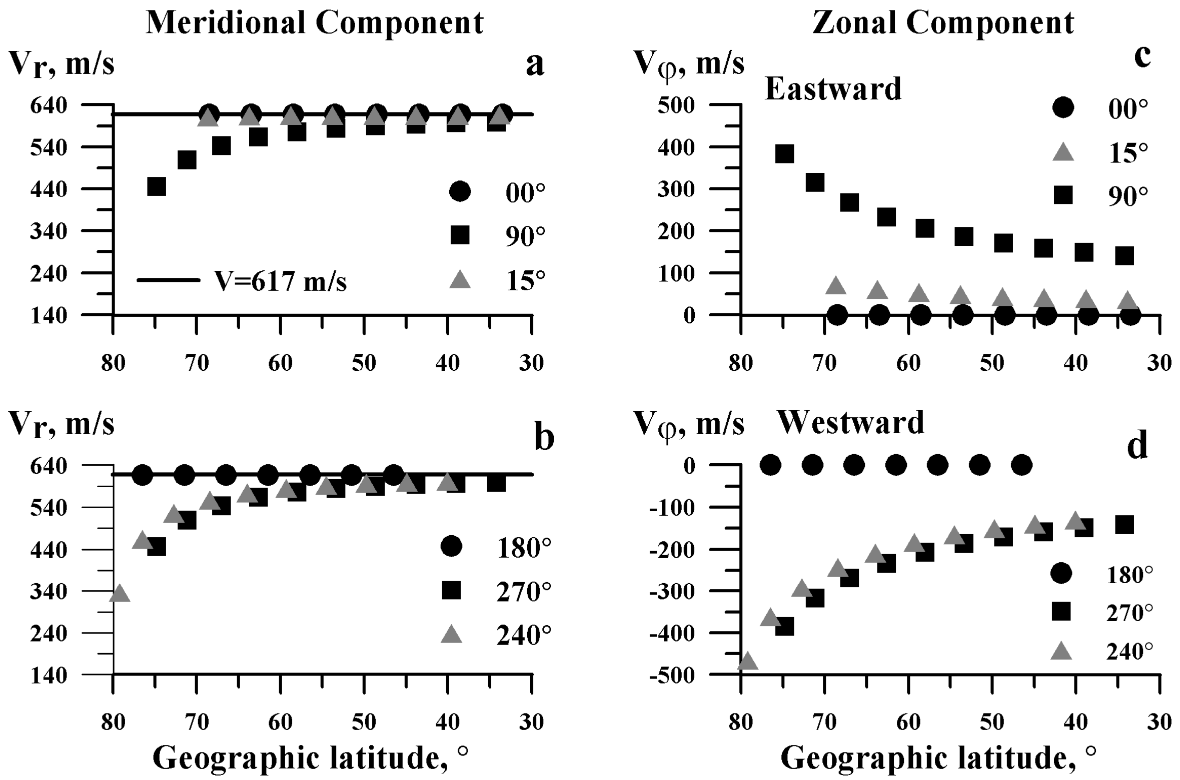

Fig. 3. Values of meridional Vr (at the left) and zonal Vφ (at the right) components of point velocity in the geographical coordinate system at the geomagnetic meridians with longitudes: 0° and 180° (dots), 90° and 270° (squares), 15° and 240° (triangles). Positive values correspond to eastward Vφ.

velocity component Vφ decreases from polar latitudes to the equator. The effect is more evident at the geomagnetic longitudes near 90° and 270°. The meridional velocity component Vr in the geomagnetic longitudes near 0° and 180° slightly varies with latitude and is close to the meridional velocity in the geomagnetic coordinate system. At other longitudes, the meridional component Vr tends to increase (from ~250 to ~617 m/s) as the latitude decreases.

3. Discussion

If LS TIDs (occurring in the auroral zone during magnetic storms) travel along geomagnetic meridians, it is reasonable to expect that the propagation velocity of these disturbances (calculated in the geographic coordinate system) has the above peculiarities.

We compared the simulation results with data on LS TID motions obtained in [Afraimovich et al., 2000; Leonovich et al., 2004, Perevalova et al., 2008]. The condition of LS TID propagation along the geomagnetic meridian is satisfied in the American and Far Eastern regions: Vφ is small near the Zero Magnetic Meridian increasing with distance away from it [Afraimovich et al., 2000; Perevalova et al., 2008]. The statistics for five magnetic storms [Leonovich et al., 2004] supports the assumption of the meridional propagation too. An analysis of the table in [Leonovich et al., 2004] shows that westward deviations on the dayside were obtained in the American region; eastward deviations on the night side, in the European and Asian regions. However, a westward deviation was registered in the European and Asian sectors during the 29 October 2003 storm [Perevalova et al., 2008]. This contradicts the above assumption, requiring further study.

4. Conclusion

We simulated the motion of points in the geomagnetic and geographic coordinate systems. In the geographic coordinate system, the point moving along the geomagnetic meridian is shown to have two components (the meridional Vr and the zonal Vφ ones). The value of Vφ decreases from polar latitudes to the equator. At meridians with a geomagnetic longitude of 0° and 180°, Vφ is 0. At geomagnetic longitudes from 0° to 180°, Vφ is eastward; at geomagnetic longitudes from 180° to 360° it is westward.

If LS TIDs travel along geomagnetic meridians, their propagation velocity (calculated in the geographic coordinate system) should have the above-mentioned peculiarities. Experimental data on direction of auroral LS TIDs travel suggest that these disturbances propagate along magnetic meridians in the American and Far Eastern longitudinal sectors.

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