

PECULIARITIES OF TRAVELING CONVECTION VORTICES PROPAGATION: COMPARISON WITH SUDDEN GEOMAGNETIC IMPULSE

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1. Introduction

Among the high-latitude magnetic impulsive events it can be identified as two basic types: traveling convection vortices (TCV) and the geomagnetic sudden impulses (SI). Unlike SI, TCV is registered only in the daytime high-latitude ionosphere, while the SI is observed globally. Unlike SI, the source of TCV in interplanetary space is still under discussion. Some of the possible TCV sources are: abrupt solar wind dynamic pressure (Pd) variations [Kivelson and Southwood, 1991], pulsed reconnection [Konik et al., 1994], sharp IMF orientation changes [Sibeck and Korotova, 1996]. TCV like SI are propagated both in azimuthal and in the meridional direction. Most morning TCV events move westward and afternoon events eastward, that is away from local noon, but there are exceptions, especially near noon [Korotova et al., 1997; Vorobjev et al., 1999]. Zesta et al. [2002] found that TCV is not stationary phenomena it is decelerated during the propagation from the noon meridian. In opposite the Luhr et al. [1996] found the acceleration in his event. In spite of the lot of work devoted to the TCV nobody investigated how the TCV propagated on different latitudes.

The purpose of this work is to investigate the nature of the azimuth and meridional propagation of TCV of the different origin and to compare with propagation peculiarities observed during the SI.

2. Data sources and methodology

In present study we have used the magnetic data of Greenland coast chain stations. The location of the stations (west and east Greenland coast) allowed us to study the meridional and azimuthal propagation on different latitudes. The conditions in the solar wind were analyzed using the data of the WIND satellite.

TCV events were taken to satisfy the following criteria: in ground signatures must be a 90 deg phase shift between the H and D components, the vertical (Z) component must have monopolar or bipolar signature as it is specified in the works [Lanzerotti et al., 1986; Glassmeier et al., 1989]. Figure 1 presents the geomagnetic field variations recorded during the TCV in all field components.

For the analysis two groups of the TCV events (12 events) were selected: 1) TCV stimulated by Pd variations; 2)

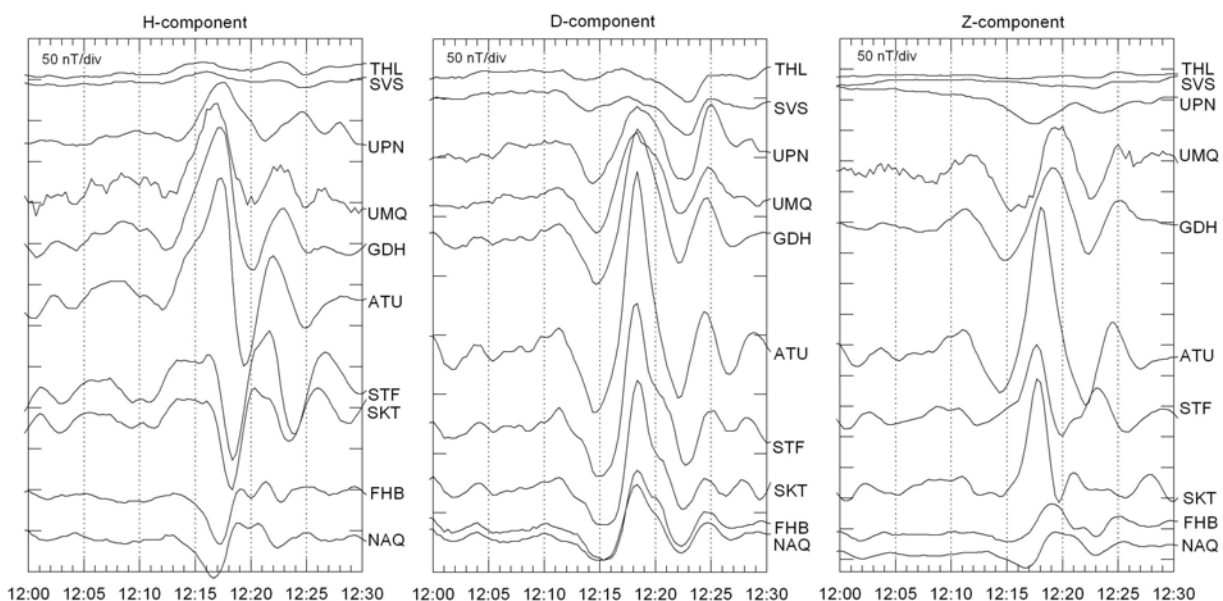


Fig. 1 Geomagnetic field H, D, Z-components variations by west Greenland Coast stations data during the TCV event on March 14, 1996.

TCV which is not related to Pd variations i.e. having other sources than Pd variations. Figure 2 illustrates the interplanetary medium variations recorded during the 1st group TCV event on March 14, 1996 (Figure 2a) and the

2nd group TCV event on June 22, 1996 (Figure 2b) with onsets by ground data at 1212 UT and 1735 UT, correspondingly. As can be seen the event on the Figure 2a clearly was caused by Pd variations and there are no discernible Pd variations during the event on Figure 2b.

3. Experimental results

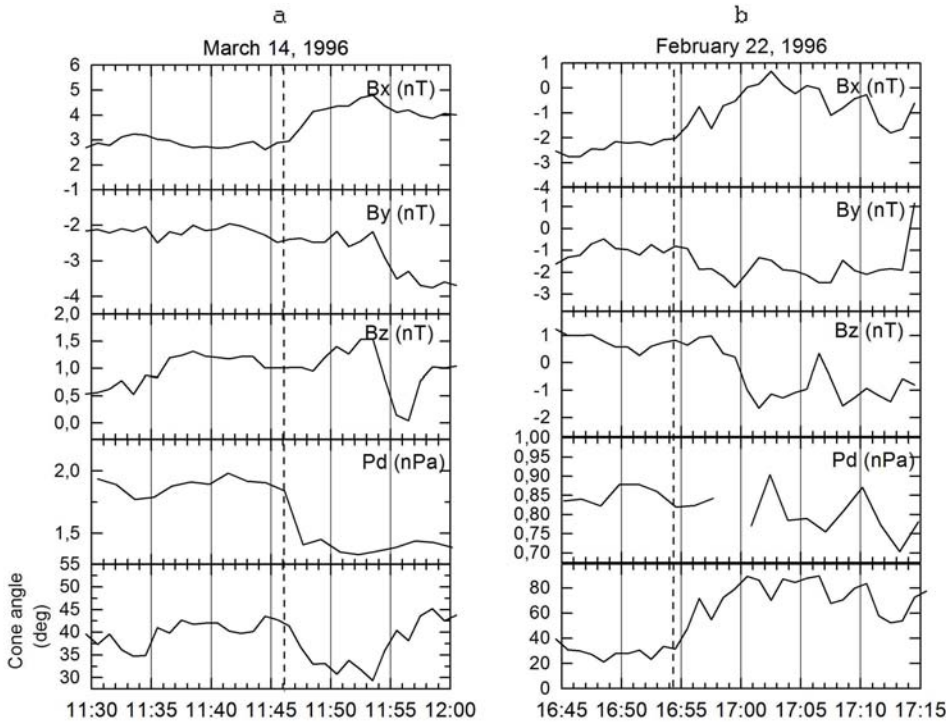


Fig. 2 B_x , B_y , and B_z components of the IMF, dynamic solar wind pressure (Pd) and cone angle variations as measured onboard the WIND satellite during the TCV events on March 14, 1996 (a) and June 22, 1996 (b) with onsets at 1212 UT and 1735 UT, correspondingly. The corresponding changes in solar wind and IMF parameters denoted by dash line.

noon and morning sector. In TCV registered in evening sector the eastward propagation is observed. The observed azimuthal propagation velocity values lies in 5-25 km/s range. Figure 4 illustrates the character of meridional propagation in TCV events. The following characteristics of meridional propagation are observed: in all of the events the poleward propagation is predominated with velocity decreasing in value with increasing of the latitude. So, at the latitude of $\Phi'=70^\circ$ the TCV velocity was about 5 km/s, at the latitude of $\Phi'=74^\circ$ the velocity was 1.2 km/s. At the polar cap latitudes ($\Phi'=78^\circ$) the TCV velocity increased up to 3 km/s.

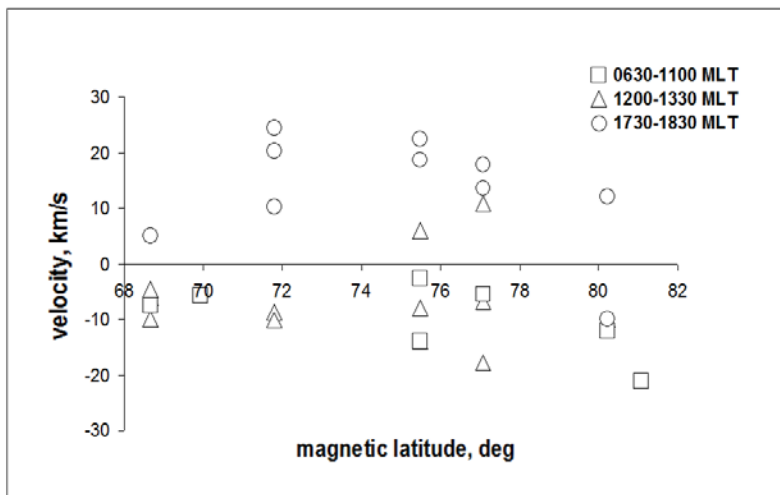


Fig. 3 The latitudinal profile of azimuthal TCV propagation velocity. Positive velocity values correspond to the eastward propagation; negative values correspond to the westward propagation. Propagation in different MLT denoted by different symbols: **square** in morning MLT, **triangle** in noon MLT, **circle** in evening sector.

The propagation of TCV events analyzed by phase delay of the corresponded maxima (minima) in the geomagnetic H-component variations of the stations distributed by longitude in the case of azimuthal propagation or by latitude in the case of meridional propagation. The time delay of the impulse minima with increasing of the station latitude as illustrated by Fig. 1 corresponds to meridional poleward propagation of the TCV. On Figure 3 the latitudinal profile of azimuthal TCV propagation velocity is presented. As seen from the figure in general the westward propagation predominate in TCV events registered both at

It will be interesting to compare the TCV propagation velocities distribution with such which is registered in the sudden impulse (SI) events. The next figure (Figure 5) illustrates the meridional propagation characteristics for both positive and negative sudden impulse events. The comparison of the latitudinal profiles reveals their similarity as like as in direction of the propagation as in values of the meridional propagation velocities at corresponding latitudes. The longitudinal velocities distributions for the both type of events (TCV and SI) are also similar.

4. Discussion

4.1. The source of the TCV

As was mentioned above there were two types of TCV events: the TCV clearly related to the Pd variations and the TCV having another source (see as an example the February 22, 1996 event). This TCV was registered in the evening sector. There were no registered pronounce Pd variations in all evening events. We suggest that such events can be driven by abrupt changes in the foreshock configuration in connection with cone angle changes from 35 to 70 deg during the event on the Fig. 2b. The similar mechanism was suggested by Vorobjev et al., [2001] for their post noon transients. Impulsive reconnection mechanism is also not excluded.

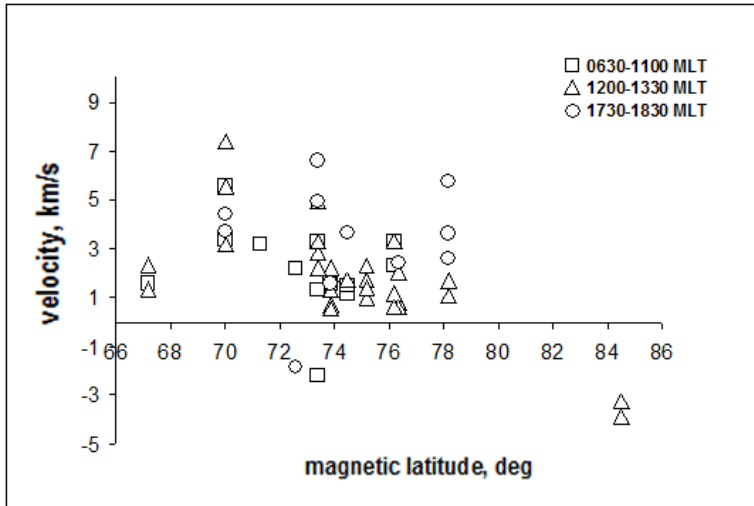


Fig. 4 The latitudinal profile of meridional TCV propagation velocity. Positive velocity values correspond to the poleward propagation; negative values correspond to the equatorward propagation. Propagation in different MLT denoted by different symbols: **square** in morning MLT, **triangle** in noon MLT, **circle** in evening sector.

study velocities are greater than azimuthal propagation velocities in the events reported in previous studies. In the case of TCV stimulated by Pd variations these velocities can reflect the fast magnetosonic wave propagation in the magnetosphere, in the case of TCV which have another source than the Pd variations these velocities can be the phase velocities. The observed azimuthal velocity distribution is similar to observed in SI events (not shown).

Meridional propagation

According to the numerical simulation in the work [Chi et al., 2006] the convection vortices after the formation at $L=6.3$ propagate to the pole. The examination of meridional propagation revealed the following characteristics: in

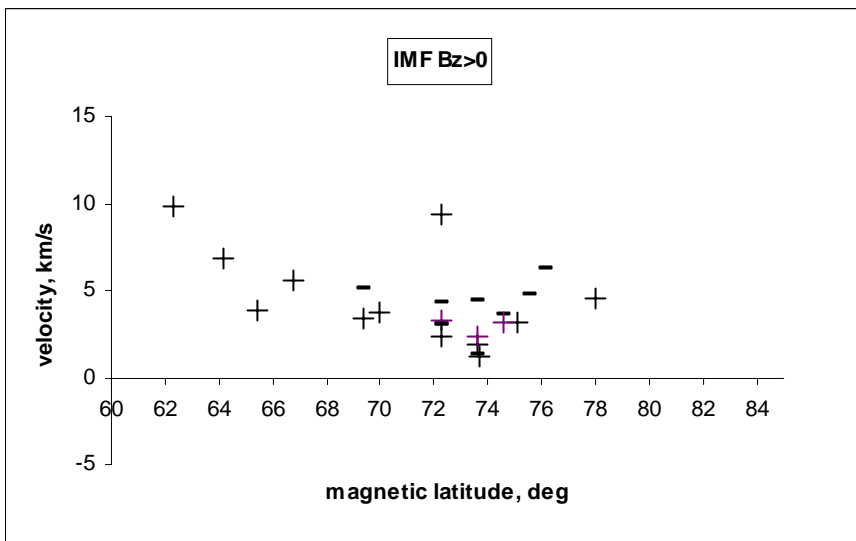


Fig. 5 The latitudinal profile of meridional sudden impulse (SI) propagation velocity during the IMF $B_z > 0$ periods. Positive velocity values correspond to the poleward propagation; negative values correspond to the equatorward propagation. Propagation of positive SI events denoted by “plus”, propagation of negative SI events denoted by “minus”.

4.2. TCV propagation peculiarities

Azimuthal propagation

In general the westward propagation predominate in TCV events registered both at noon and morning sector. In TCV registered in evening sector the eastward propagation is observed.

The observed velocity values lies in 5-25 km/s range. The observed velocities in the evening sector are greater than in morning and noon sector. It can be the result of accelerating of TCV movement away of the noon meridian. As Luhr et al. [1996] point out, the TCVs are not stationary during their antisunward movement, a considerable increase of their propagation velocity has been observed from 2.5 km/s at 1045 MLT to 7.4 km/s at 0650 MLT. Observed in our

all of the events the poleward propagation is predominated with velocity decreasing in value with increasing of the latitude. So, at the latitude of $\Phi'=70^\circ$ the TCV velocity was about 5 km/s, at the latitude of $\Phi'=74^\circ$ the velocity was 1.2 km/s. At the polar cap latitudes ($\Phi'=78^\circ$) the TCV velocity increased up to 3 km/s. Such a distribution of the meridional propagation velocity, depending on latitude is registered in the SI events [Makarov et al, 2001] and similar to the distribution for the positive and negative SI events (see Fig. 5) registered during quiet periods (IMF $B_z > 0$).

One could assume that in our events such a character of

meridional propagation will be observed only for the first group of TCV events (since the events of the first group like the SI excited by variations of Pd), but it is observed for the second group of events also.

Such similarity of the characteristics of different phenomena (TCV and SI) allows us to apply to the TCV the Tamao's model describing SI [Tamao, 1964a, 1964b]. Strong evidence has been found that SI propagate from the subsolar magnetopause to the ground in a fashion consistent with Tamao's model that predicts how a pressure impulse propagates in the three-dimensional space and what travel time and polarization properties are expected on the ground. There are two key concepts in Tamao's model. The first concept is the propagation of fast magnetosonic wave. The second concept is the field-aligned currents (Alfvén mode) generation that correspond to the twin ionospheric convection vortices formation. Probably in the case of TCV events which have another source than the Pd variations, Tamao's two pictures, one for travel time and the other for twin ionospheric convection vortices, tend to be mentioned as two independent concepts.

It is suggested that the obtained meridional velocity distributions in a greater extent reflects the movement of the Hall vortex currents of the field-aligned currents in the TCV and SI events, then the processes of fast magnetosonic wave propagation.

Conclusion

On the base of ground magnetic observations the nature of the azimuth and meridional propagation of TCV is investigated. The following results were obtained:

1. There were no registered pronounce Pd variations in all evening TCV events. We suggest that such events can be driven by abrupt changes in the foreshock configuration. Dayside reconnection mechanism is also not excluded.
2. In general the azimuthal westward propagation predominate in TCV events registered both at noon and morning sector. In TCV registered in evening sector the eastward propagation is observed.
3. The examination of meridional propagation revealed the following peculiarities: in all of the events the poleward propagation is predominated. The velocity of poleward propagation decreases in value with increase of the latitude.

It is suggested that the obtained latitudinal velocity distributions in a greater extent reflects the movement of the Hall vortex currents of the field-aligned currents in the TCV and SI events, then the processes of fast magnetosonic wave propagation.

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