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AURORAL DYNAMICS AT DIFFERENT STAGES OF STORM RECOVERY PHASE VERSUS THE STRENGTH OF THE MAIN PHASE

T.A. Kornilova, I.A. Kornilov *(Polar Geophysical Institute, Apatity, Russia)*

Introduction

Magnetic storms are induced by interaction of interplanetary solar plasma flows with the Earth’s magnetosphere. The strength of magnetic storm is determined by ring current development, which in turn, is characterized by the Dst-index. Storm recovery phase is traditionally considered to be connected with the ring current decay, which can be physically due to a combination of several different energetic particle loss processes (Coulomb collisions, charge exchange and wave-particle interactions). Usually two stages of storm recovery phases are observed: the early (fast) recovery phase and the late (slow) one. As known, the ring current consists of two different atomic ion components having different characteristic decay time that probably can be a reason for two-step storm recovery phase (Hamilton et al., 1988; Daglis, 1997). Contrary to this commonly accepted interpretation Feldstein and Dremukhina, (2000) suppose that the two-phase decay of the Dst variations during the magnetic storm recovery phase is controlled by the decay of a two current system: the ring current (DR) and the magnetospheric tail current (DT). Two types of magnetic storms, depending on their origins, take place: CME-driven storms and CIR-driven storms. Major/intense geomagnetic storms are mainly caused by coronal mass ejections (CME), while moderate and minor storms can be induced by both coronal mass ejections (CME) and corotating interaction region (CIR) associated with recurrent high-speed streams. CME and CIR events in the solar wind, the magnetosphere and the auroral zone are reviewed in (Borovsky J.E., and Denton M.H., 2006). Spectral characteristics of aurora and their connection with solar wind streams were investigated in (Hviyuzova, and Leontiev, 1997; 2001). Relationship between auroral bulge parameters and high-speed solar wind streams was studied in (Despirak et al., 2007).

Here we present a comparative analysis of spatio-temporal auroral dynamics in the dusk-midnight MLT sector during the early and late recovery phases of 10 magnetic storms of different intensity and driven by both CME and CIR geomagnetic events, considering Dst minimum value to be the energy characteristics of the storm main phase

Data

The main data used in our study were TV auroral observations of high-latitude observatory Barentsburg (BAB) (Φ’= 75.2° N, Λ’= 113.2° E) and of auroral zone observatories Loparskaya (LOP) (Φ’= 64.94° N, Λ’= 113.6° E) and Lovozero (LOZ) (Φ’= 64.2° N, Λ’= 115.3° E). High spatio-temporal permission of TV camera and using of optics with field of view ~ 180° allowed us to trace aurora dynamics in radius about 1000 km.

Dst-variations, Solar wind plasma and interplanetary magnetic field observations, IMAGE and POLAR spacecraft auroral images are taken from INTERNET site (http://cdaweb.gsfc.nasa.gov).

Zenith Scanning Photometer data of Lovozero observatory in 630.0 nm, 557.7nm and 427.8 nm emissions.

Geomagnetic activity was analyzed by using data of Scandinavian IMAGE Magnetometer Network.

Results and discussion

Fig.1 shows Dst-variation during isolated magnetic storm on December 14-18, 2006 occurred near the minimum of solar activity and aurora development at recovery phase of this storm. At the top panel the triangles denote onsets of the SC events, vertical lines mark the latitude range ($\Delta\Phi$’) occupied by auroras at specific time. At the beginning of recovery phase Dst value increases, while $\Delta\Phi$’decreases and shifts to higher latitudes. Nevertheless, at the end of recovery phase this tendency is violated. The second and fourth panels demonstrate auroral dynamic at Barentsburg and Lovozero during substorm on December 18. An aurora enhancement at the end of storm recovery phase on December 18 is most probably associated with SC events, which were more intensive than those on December 16. General features of the substorms occurred during this storm are: polar cap arc development (polar breakup) before and after the substorm, auroral bulge step-like spreading into polar cap latitudes and equatorward aurora movement inside the oval.

The Dst-variation for series of successive storms (number 1-4) on March 19 - April 04, 2001 during the maximum of solar activity is shown in Fig.2A. Figures 2B and 2C present magnetograms and fragments of aurora development in Lovozero for the late recovery phase of storm number 3 on March 27-30, and early recovery of storm number 4 on March 31-April 04, 2001, respectively. During substorm on March 30, the auroral activity was dominating in the South, as a series of pseudo-breakups and isolated long rayed structures in the northern part of the sky. The beginning of storm recovery phase (Fig.2C) is characterized by a step-like poleward auroral expansion (as in the case of classical breakup). Also, some features inherent to aurora during the main phase of this storm (Kornilova, and Kornilov, 2009) are observed, namely, simultaneous collocated existence of long rayed structures inside diffuse luminosity and very bright eastward moving pulsations (frame 20:48:50 in Fig.2C). Auroral configuration of the double oval type with polar boundary intensifications (PBIs) and streamers, black auroras are typical features of storm recovery phase aurora development.

Analysis of aurora dynamics for 10 storms of different intensity reveals the absence of clear relationship between storm intensity and spatio-temporal peculiarities of auroral dynamics. Unusual features (long-living stable rays, awfully bright auroral pulsations embedded in diffuse luminosity, simultaneously existing auroral forms inherent to different substorm phases) more frequently manifest during the early recovery of CME-driven storms and gradually disappear to the end of recovery phase. However, they can be seen during CIR-driven storms preceded by previous prolonged geomagnetic and auroral activity. For example, at non-storm substorm on November 19, 2001, occurred during HILDCAA (High Intensity Long-Duration Continuous AE Activity) events, unusual features were observed, as well as during storm-time substorm on November 24, 2001. It should be noted that the value of the emission intensity 630.0 nm during substorm on November 19, 2001 was factor 3 higher than that for the substorm on November 24, 2001. Hamilton et al., 1988 stated that the faster, early recovery stage from Dst minimum is dominated by the O^+ charge-exchange loss rate, while the slower, later recovery stage is governed by the H^+ charge-exchange loss rate. Daglis, 1997 also found observational evidence for this mechanism in CRESS measurements. Taking into account the their results of Hamilton et al. (1988) and Daglis (1997) we suppose that the appearance of unusual features mentioned above can be due to abnormally high oxygen content in the storm-time injections, which is higher during solar maximum than during solar minimum (Liemohn et al., 1999). However, prolonged previous non-storm activity can probably stimulate building-up of oxygen content resulting in the appearance of unusual auroral features similar to those observed during strong magnetic storms.

Conclusions

The results of our study are summarized as follows:

1. Peculiarities of auroral dynamics at different stages of magnetic storm recovery phase depend on combination of different factors: type of the solar source driving the storm, solar cycle phase, IMF and solar wind parameters, previous magnetic activity, etc.
2. At the early storm recovery phase, auroras occupy large latitudinal range (sometimes Φ'~56-80°). During the late recovery phase of the storm, substorms shift to higher latitudes.
3. An anticorrelation between the intensity of storm-time substorms and the intensity of the storm proper is observed when SC events occur in the course of storm recovery phase.
4. Substorms at the early storm recovery phase of CME-driven storms display specific features of substorms observed during the main storm phase (e.g., simultaneous collocated auroral forms inherent to different substorm phases, long-living stable rays and abnormally bright auroral pulsations embedded in diffuse luminosity). The double oval configuration, with its poleward boundary intensifying, and auroral streamers, separating from this boundary and drifting southward, are typical signatures of such events.

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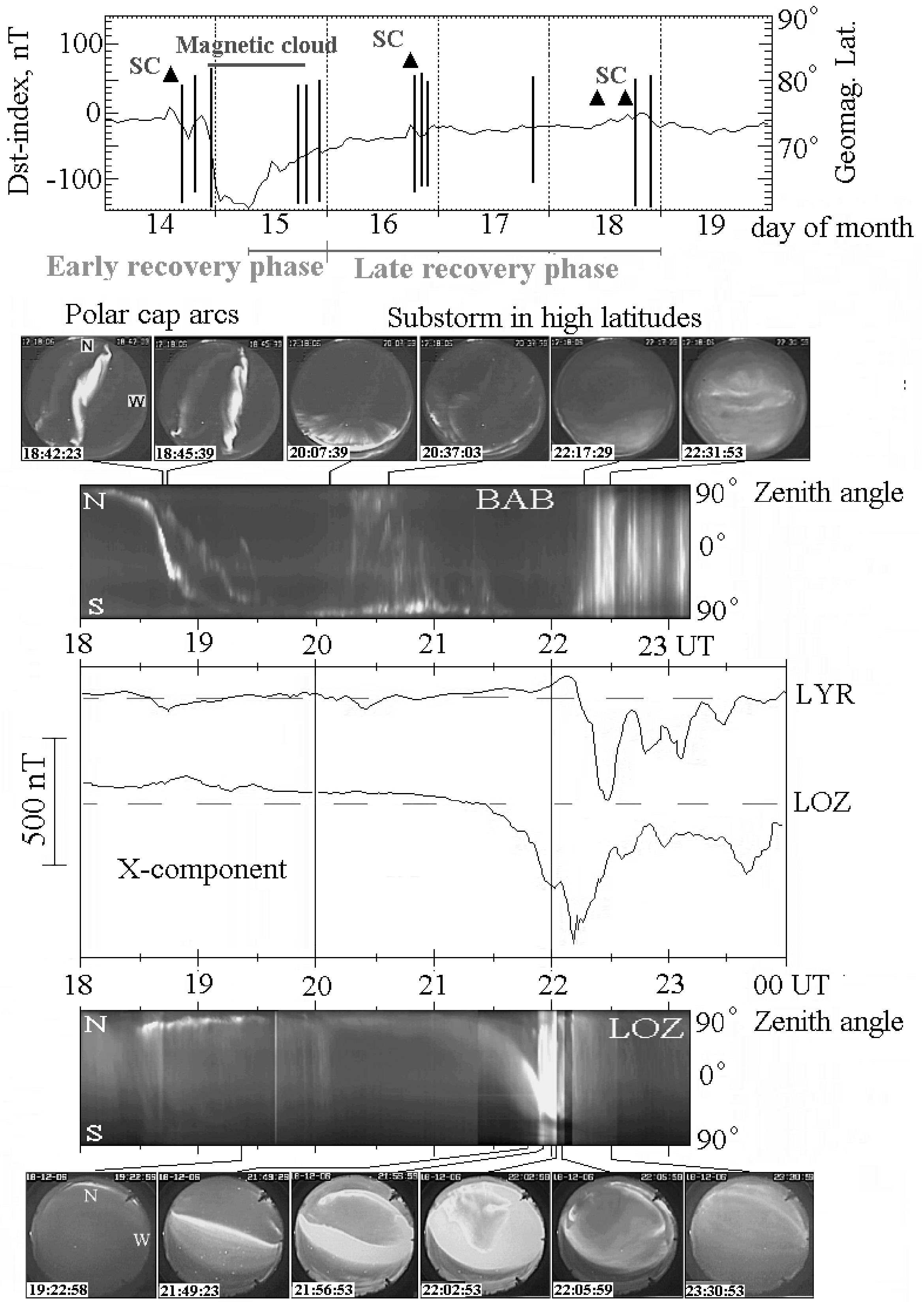

Figure 1. Example of aurora development in Barentsburg and Lovozero during late recovery stage of isolated magnetic storm on December 14-18, 2006.

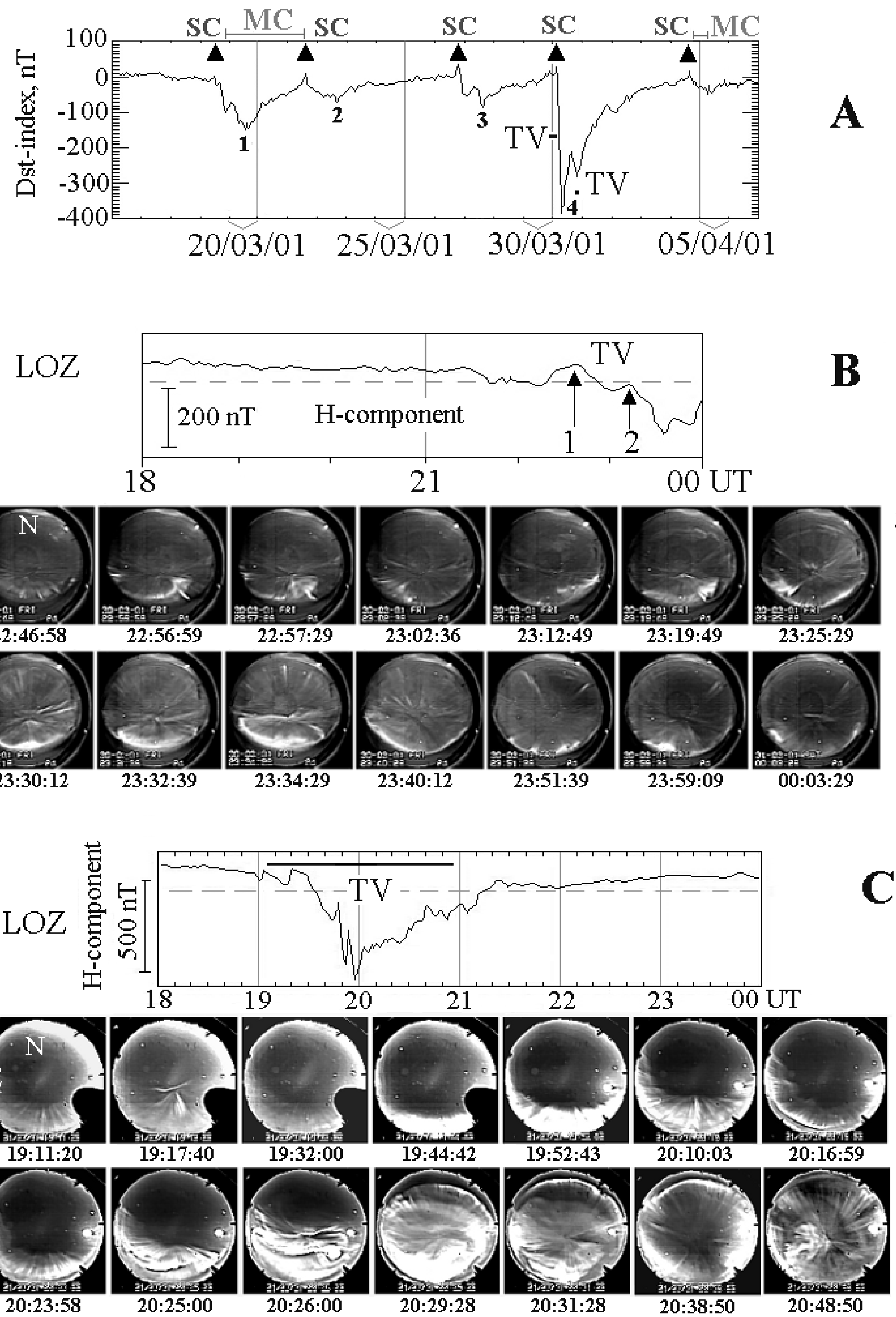

Figure 2. Aurora development in Lovozero for the late recovery phase of storm on 27-30 March, and early recovery of storm on March 31- April 04, 2001.