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SUBSTORM EFFECTS ON THE STORM-TIME Dst VARIATION

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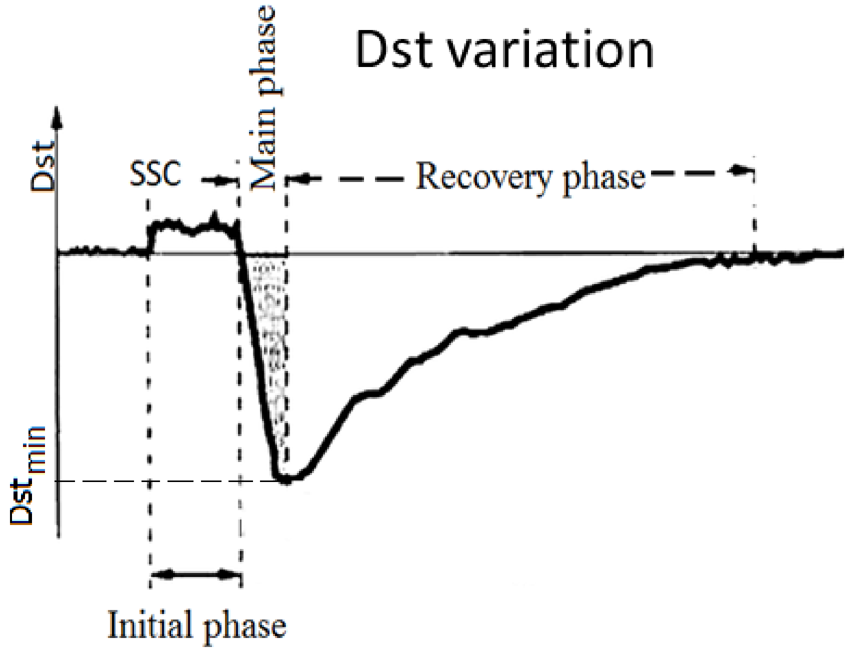
We present a comparative analysis of the dynamics of SuperMAG indices of: auroral electrojets, total and partial ring currents, and also maps of distribution of field-aligned and ionospheric currents obtained by the original magnetogram inversion technique, as well as geomagnetic pulsations – from data of observatories of ISTP SB RAS.

Magnetic storm and its indices



In narrow sense a magnetic storm – negative storm-time disturbance (Dst) in H component of geomag. field lasting from 3 Hours to 1-3 days. It is monitored by the *Dst* index

$$Dst = \frac{1}{N}\sum_{n=1}^{N}\frac{H - H_q}{\cos\phi}$$

here *H- H*q is the disturbance of *H* component of the magnetic field at a given station, *N =4* is the number of the stations, and ϕ is the station latitude.

$$\Delta B \approx -\frac{2W}{B_0 R_E^3}$$

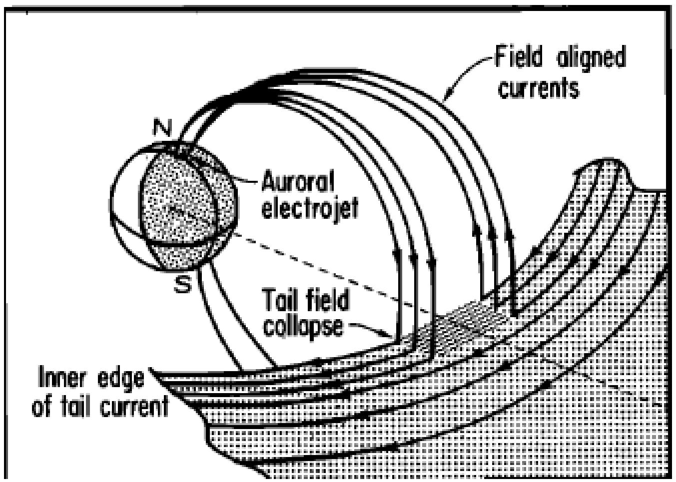
Dstmin: from – 25 to – 50 nT – weak storms
from –50 to –100 nT - moderate storms
from –100 to –200 nT - intense storms
Dstmin < –200 nT - big storms

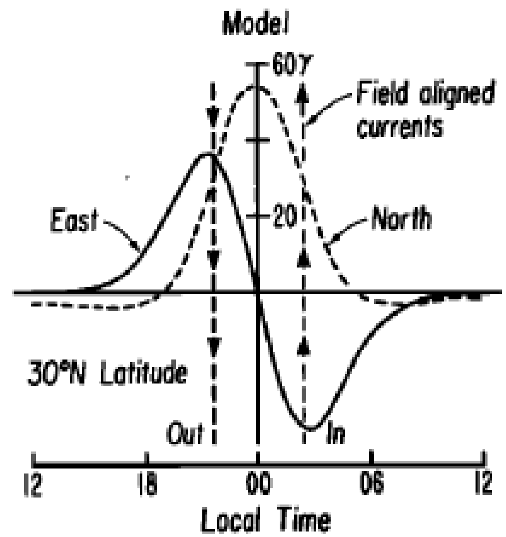
Dst has contributions from ring current (RC), the magnetopause and cross-tail currents. During SSC dense solar wind compresses the magnetopause increasing the geomagnetic field , which is described by the Chapman-Ferraro (DCF) currents at the magnetopause .

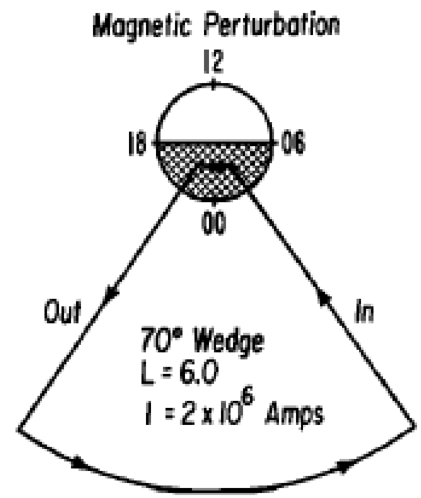
- The *pressure corrected Dst* index can be defined as $Dst* = Dst - b\,Pd + c$,
- where *Pd* is the solar wind dynamic pressure and *b* and *c* are empirical parameters,
- whose exact values depend on the used statistical analysis methods, e.g., $b =$
- 7.26 nT $nPa^{-1/2}$ and $c = 11$ nT as determined by O'Brien and McPherron (2000).

- The magnetic field depression during the main phase is the effect of:
- 1) symmetric RC, 2) dawn-dusk magnetotail current, which can give ≤ ½ Dst (Alexeev et al., 1996), 3) partial RC.
- During a storm, a complex of processes occurs in the magnetosphere-ionosphere-atmosphere system. Therefore, it is more correct to speak not about magnetic storm, but about a magnetospheric storm as well as a magnetospheric substorm.

During the substorm expansion phase in the near midnight sector the common dawn-dusk (cross-tail+partial RC) current is dusrupted and the substorm current wedge current system forms. Its magnetospheric part gives positive variation in the H-geomagnetic field component at mid latitudes (ΔH ≈ +50 nT, McPherron, 1973), which is much less of negative one (ΔH≈ -1000 nT) caused by its ionosphere part- westward electrojet at auroral latitudes).







Usual auroral electrojet indices AL, AU and AE=AL-AU are determined every min from 12 stations located under the average auroral oval in the northern hemisphere.

Now project SUPERMAG gives its own modified indices:

1) auroral SME, SML and SMU from data of > 100 stations within more wide latitude band

and 2) RC indices from 98 low /mid latitude stations- symmetric SMR and partial SMR MLT in four MLT sectors (*00±3 MLT, 06±3 MLT ,12±3 MLT, 18±3 MLT).*

Why do we need to look magnetic variations in limited MLT sectors?

Iyemori & Rao, Ann. Geophys. 1996 used their modified indices SYM-H , ASY-H from 6 low-latitude stations and declaired that storm-time substorms can cause only little decrease the RC magnetic effect (positive excursions in the negative SYM-H bay with ASY-H> SYM -H and supposed that that the only southward IMF defines RC through magnetospheric convection, not a substorm. However, their indices can't determine sector of RC intensification and they did not take into account RC increase in dusk sector by ionosphere ions in substorms (Kamide& Maltsev, 2007). Later statistically from many events it was found: RC independence from magnetospheric convection (Dubyagin et al., 2015), and existence of second maximum in the dusk sector of substorm distribution in MLT(Fu et al., Pekin University, 2021). However, fast changes of electric current system such during substorm (Mishin et al., 2018) can disappear in such analysis. Here the give some examples of complex storm-time dynamics of RC, FACs and electrojets. We use time series of the ISTP magnetogram inversion technique (MIT) FAC maps based on 1-min data of SUPERMAG worldwide net of magnetometers and PIBs from our induction magnetometers (20 -30 Hz) near Irkutsk and Norilsk. 1-min time resolution of MIT allows to follow fast substorm dynamics that is impossible from AMPERE FAC maps with 10 min resolution.

Storm on 20 Dec 2015

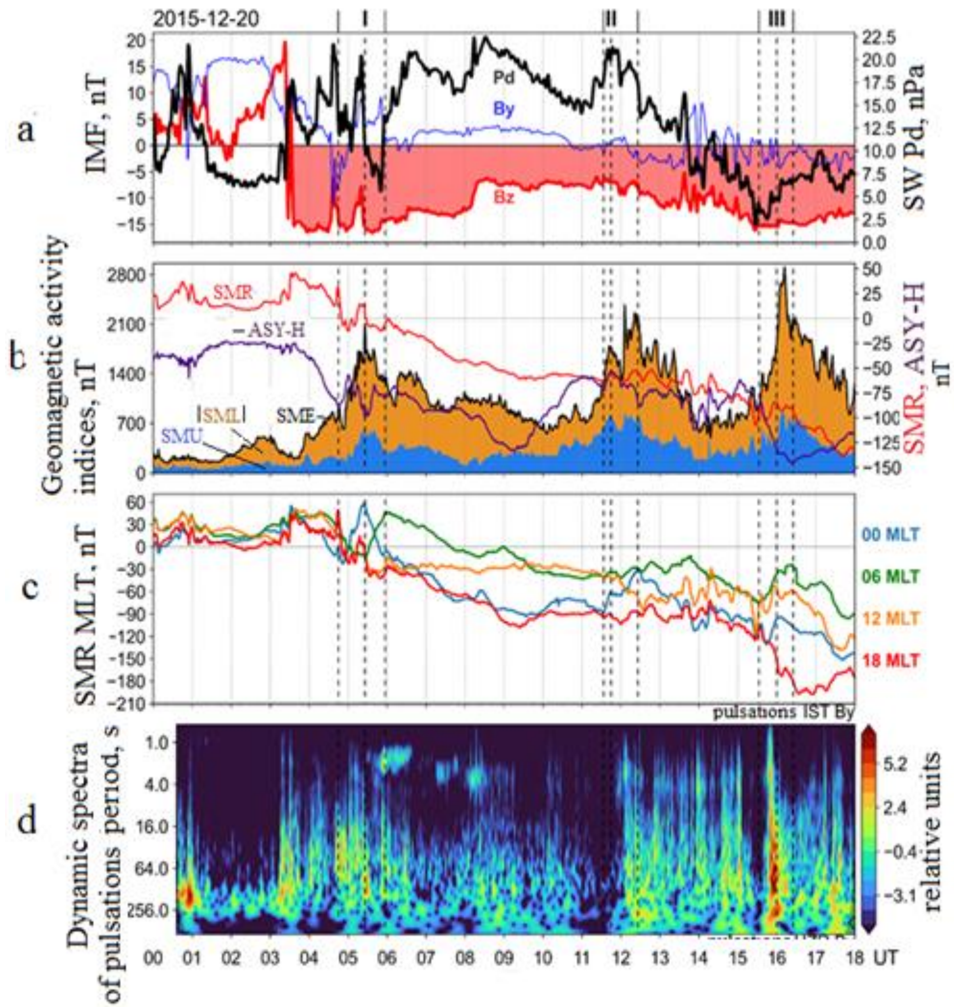
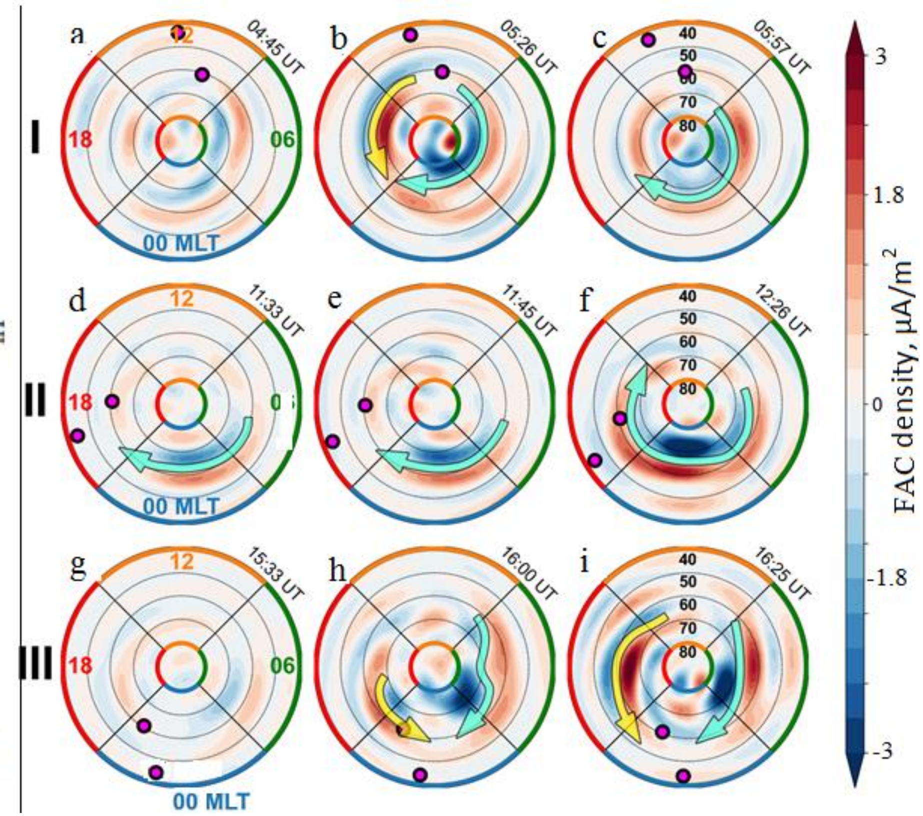


Fig. 2. a) IMF Bz & By, **Pd**; b) Stacked graph of **SME**, |SML|, SMU and RC (simmetric SMR and asymmetric – **ASY-H(with opposite sign)**); c) partial RC indices – SMR MLT; d- spectrograms of pulsations at st. IST (near Norilsk).



MIT FAC maps for I, II and III substorm periods in dipole geomagnetic coordinates latitude – MLT. Red color – upward FACs, blue – downward FACs. Thick arrowed lines **yellow** (cyan) - **eastward** (westward) electrojet

Results for low/mid latitudes

- 1. SW dynamic pressure Pd impulses without substorm activation (SI)– gives synchronous global response in H-component (at al latitudes and longitudes);
- 2. Pd impulses with substorm activation – the same at low/mid latitudes except near-electrojet latitudes, where westward (eastward) electrojet gives the negative (positive) H-variation (Mishin et al., 2022).
- 3. Substorms without Pd changes: 1) positive low/midlatitude variation ΔH >0 in the sector of substorm current disruption and westward electrojet amplification, and 2) increase of negative Dst variation in the dusk sector due to amplification of RC by acceleration of quasi-trapped heavy ions.
- 4. Substorm rotation of electric currents system and expansion of elecrojets in longitude can cause appearance of complex structure in SMR MLT indices. Special complex situation is for Dp-2 current system: if edges of both electrojets are in one MLT sector they can compensate their input in SMR of this MLT sector.
- 5. To clear up such fast SMR MLT dynamics without using FAC maps is rather hard in storm-time substorms. We plan to use in analysis the Hall current distribution maps and also SME LT index with 1 hour MLT resolution
- Example of unclear moments: the 05:26 UT, Pd impulse at substorm expansion phase- SMR 06 <0 (green line) - it demands to be clear up. Possible reason – SMR net of stations can catch electrojet effects if it expands to the south!
- Search of the problem of the storm - substorm relationship is to be continued!
- **Спасибо! Thanks for attention!**