INSTITUTE OF SOLAR-TERRESTRIAL PHYSICS
OF SIBERIAN BRANCH OF THE RUSSIAN ACADEMY OF SCIENCES

How do substorms affect the storm-time magnetic variation

V.V. Mishin*, R.A. Marchuk, Yu.V. Penskikh

Institute of Solar-Terrestrial Physics of Siberian Branch of Russian Academy of Sciences, Irkutsk, Russia, 664033

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.

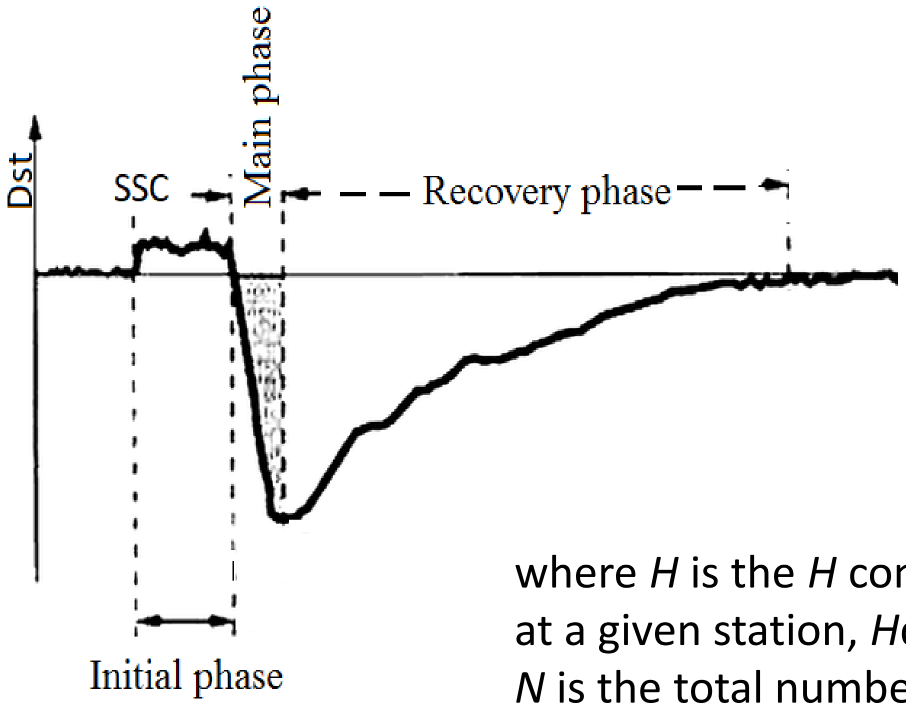
SUBSTORM EFFECTS ON THE STORM-TIME Dst VARIATION

V.V. Mishin*, R.A. Marchuk, Yu.V. Penskikh

Institute of Solar-Terrestrial Physics of Siberian Branch of Russian Academy of Sciences, Irkutsk, Russia, 664033

We present a comparative analysis of the dynamics of auroral electrojets, total and partial ring currents - by SuperMAG indices, field-aligned and ionospheric Hall currents (electrojets) - by maps obtained by the original magnetogram inversion technique, as well as geomagnetic pulsations - by observations at the observatories of ISTP SB RAS.

Magnetic storm and its indexes



Magnetic storm – specific Dst-variation, depression in H component of geomag. field – magnetic bay lasting for 1-3 days. It is mainly caused by the ring current (**RC**) flowing westward in the magnetosphere, and can be monitored by the *Dst* index

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

where *H* is the *H* component of the magnetic field disturbance at a given station, *H*q is the same component over the quietest days, *N* is the total number of the stations, and ϕ is the station latitude.

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

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

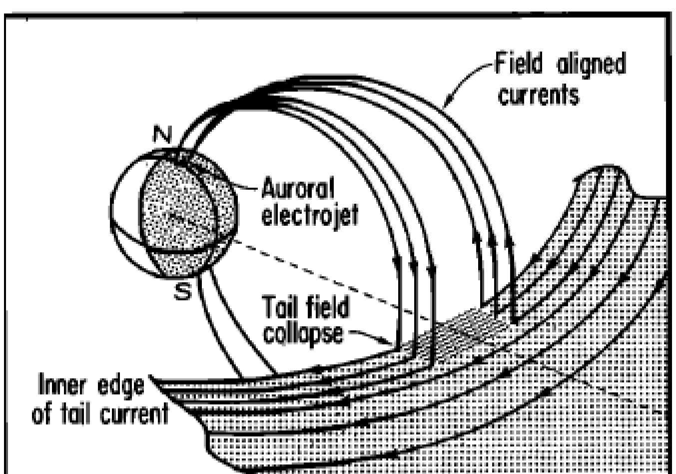
Dst has contributions from other currents in addition to RC: the magnetopause and cross-tail currents, as well as induced currents in the ground due to rapid temporal changes of ionospheric currents. During SSC large solar wind pressure compresses the magnetopause increasing the geomagnetic field , which is described by the DCF currents on the magnetopause .

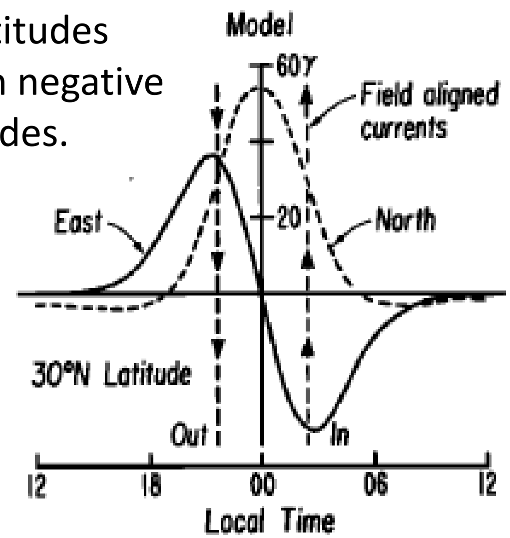
- The *pressure corrected Dst* index can be defined as $Dst* = Dst - b\ Pd + c$,
- where *Pd* is the solar wind dynamic pressure and *b* and *c* are empirical parameters,
- whose exact values depend on the used statistical analysis methods, e.g., *b* =
- 7.26 nT $nPa^{-1/2}$ and *c* = 11 nT as determined by O'Brien and McPherron (2000).
- The SSC is the effect of the magnetosphere compression by enhanced solar wind The magnetic field depression during the main phase is the effect of :
- 1) symmetric RC carried primarily by energetic ions lifting from the auroral ionosphere , 2) cross dawn-dusk magnetotail current, which can give ≤ ½ Dst (Alexeev et al., 199, 3) partial RC).
- During the substorm expansion phase 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 increases the H-geomagnetic field component at mid latitudes (McPherron, 1973) and its ionospheric part- westward electrojet decreases H at auroral latitudes. As the *auroral electrojets* flow at the altitude of about 100 km, their magnetic deviations on the ground are much larger than those caused by RC. During typical substorm activations *AE* is in the range 200–400nT and can during strong storms exceed 2000 nT, whereas the equatorial *Dst* perturbations exceed −200 nT only during the strongest storms. 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 auroral indices SME, SML and SMU from data of > 100 stations within more wide latitude band and also RC indices- 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?

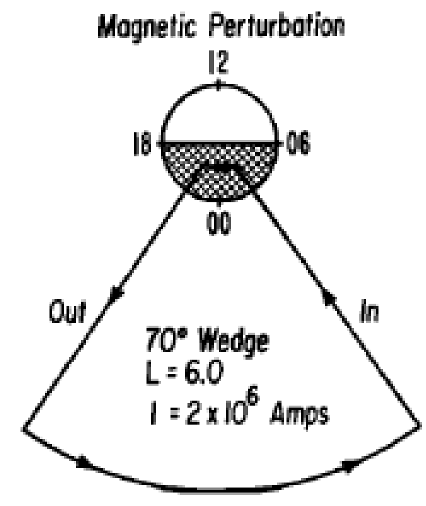
Iyemori & Rao, Ann. Geophys. 1996 used their modified indices SYM-H , ASY-H and noticed that stormtime substoms decrease the RC magnetic effect and supposed that Dst variation (make positive excursion in SYM-H index) is made not by substorms, but by southward IMF. However, their indices and ASY-H can't determine sector of RC intensification and they did not take into account RC increase in dusk sector by ionosphere ions in substorms. Last years people prefer to do statistical analysis, that's why they can miss fast changes such as current system rotation during substorm (Mishin et al., 2018. Here the give some examples of complex stormtime dynamics of RC, FACs and electrojets . We use time series of the ISTP magnetogram inversion FAC maps (1-min digitation) based on data of SUPERMAG worldwide net of magnetometers and PIBs from our induction magnetometers (20 -30 Hz) near Irkutsk and Norilsk.

McPherron et al., 1973. Substorm current wedge system gives positive H- variation at mid latitudes and westward Hall current –electrojet with negative H- variation (100-3000 nT) at auroral latitudes.





midlatitude magnetic signature



the expansion phase current system

Storm on 20 Dec 2015

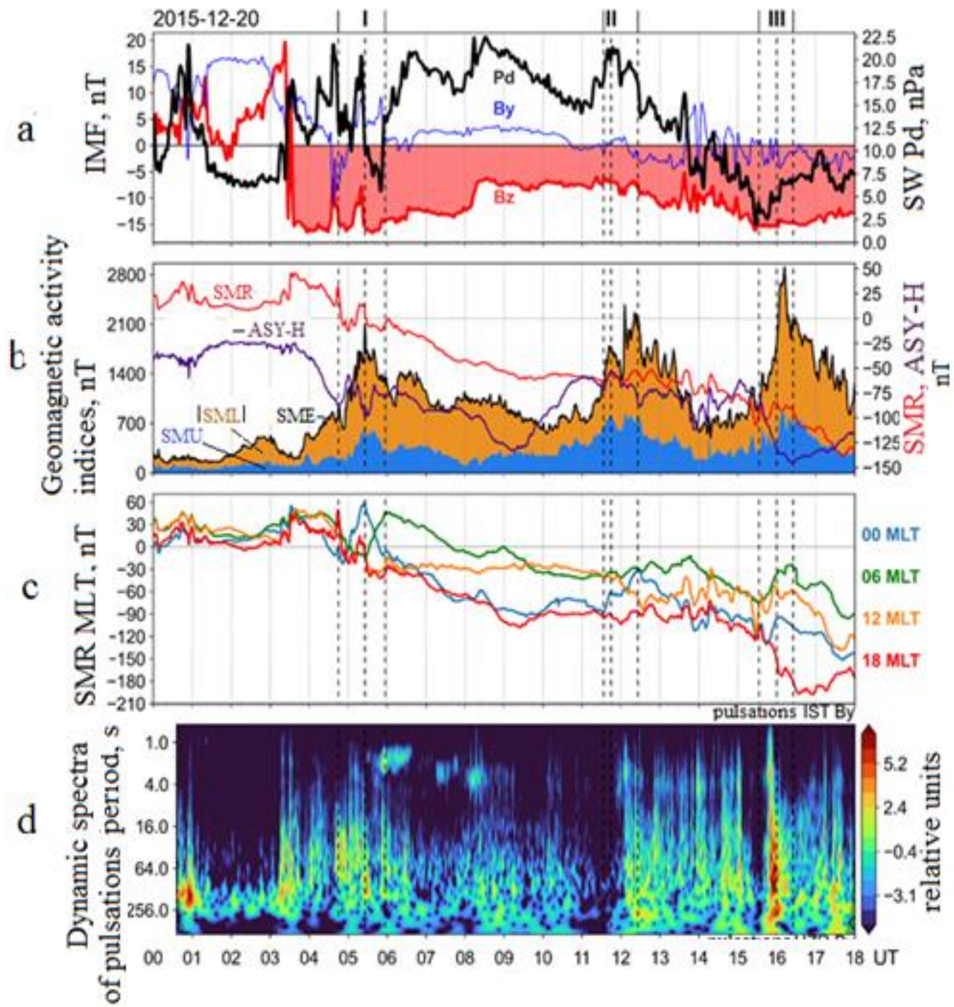
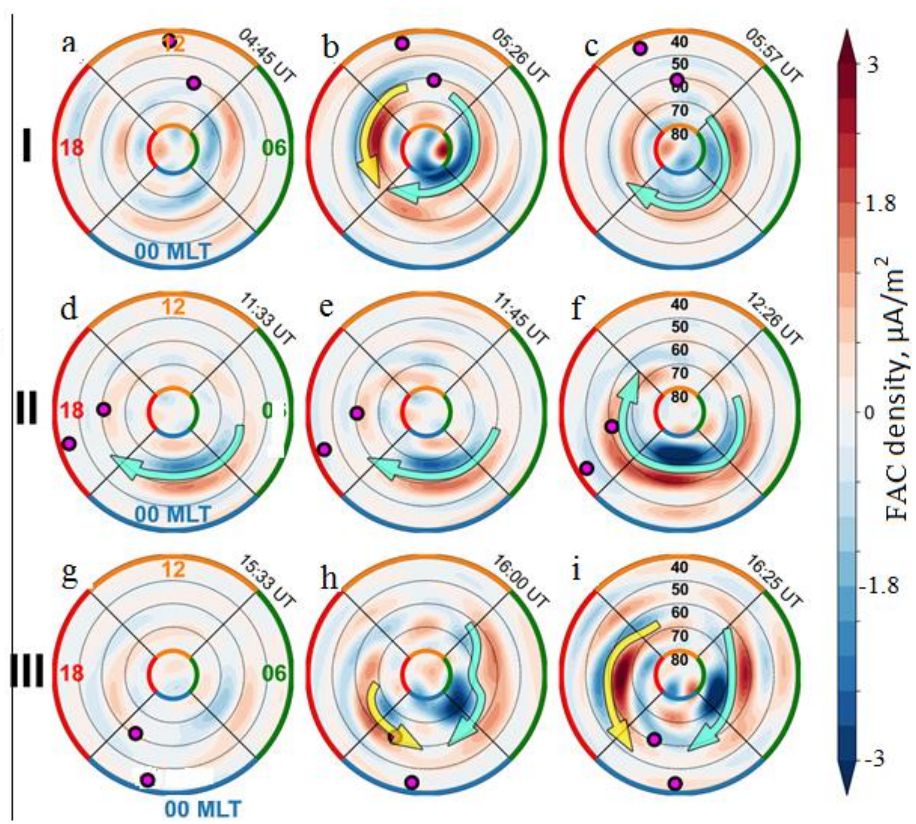


Fig. 2. a) IMF Bz & By, **Pd**; b) Stacked graph of **SME**, |SML|, SMU and RC (simmetric SMR and asymmetric – **ASY-H(with opposite sign)**); c) partial RC indices – SMR MLT; d- spectrograms of pulsations at st. IST (near Norilsk).



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

Results for low/mid latitudes

- 1. Positive (negative) SW pressure impulses without substorm activation (SI)– gives increase (decrease) in H-component synchronously at al了 latitudes and longitudes;
- 2. SW pressure 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: positive low/midlatitude variation $\Delta H > 0$ in the sector of substorm current disruption and westward electrojet amplification and increase Dst variation and negative in the duskward sector due to substorm/storm amplification of RC. Amplification of SMR
- 4. Substorm rotation of electric currents system and expansion of elecrojets in longitude can cause appearance of complex structure in SMR MLT indices . 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 are rather hard in stormtime substorms. We plan to add 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-dawn $\Delta H < 0$ (SMR 06 < 0 –green line) - it demands to be clear up. Possible reason – SMR net of stations can catch electrojet effects if it expand equatorward!
- Main problem of relationship storm and substorm is not clear up to date.