Thirteenth Workshop "Solar influence on the magnetosphere, ionosphere and atmosphere"

Several features of intense geomagnetic substorms (supersubstorms): a review

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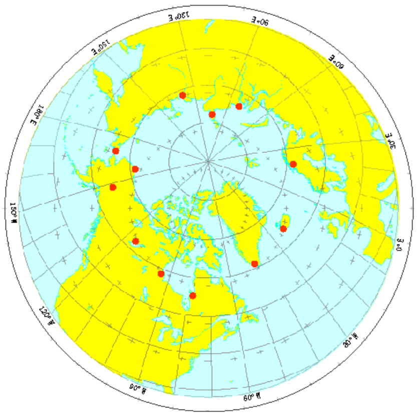
magnetic substorms

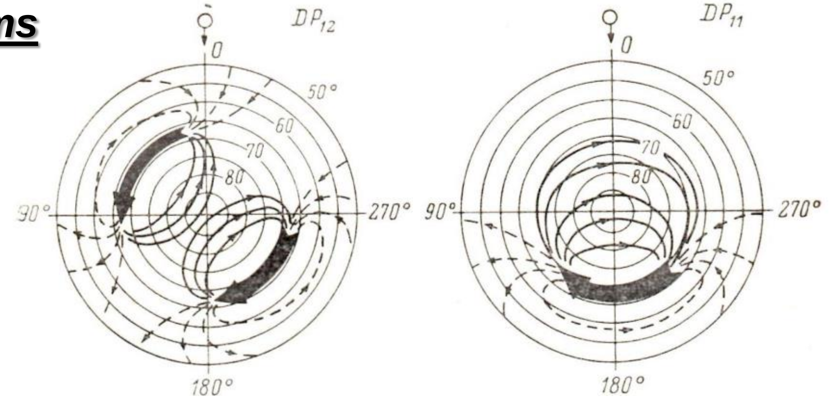
Typically, the intensity of substorms measured AE, AL, AU indices of geomagnetic activity.



Distribution of AE index stations

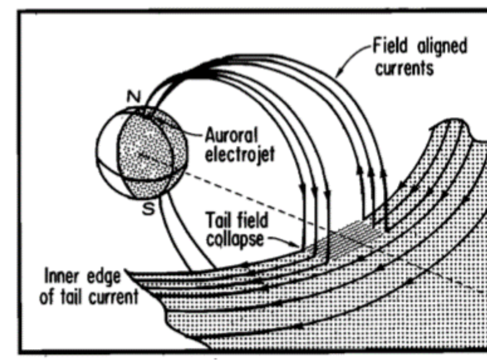
These indices are calculated according to the data from 12 ground-based auroral stations located at different longitudes.

However, these indices estimate the substorm activity too roughly because they do not reflect the substorm latitudinal features.



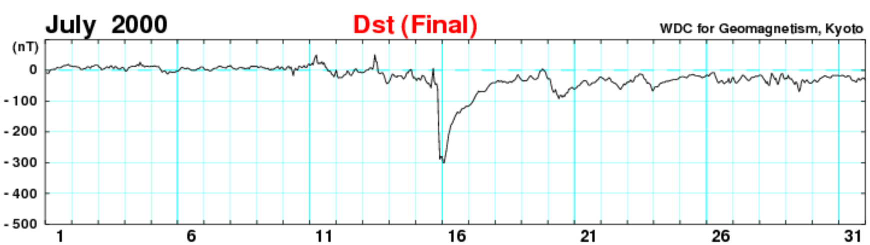
Equivalent current system DP12 and DP11

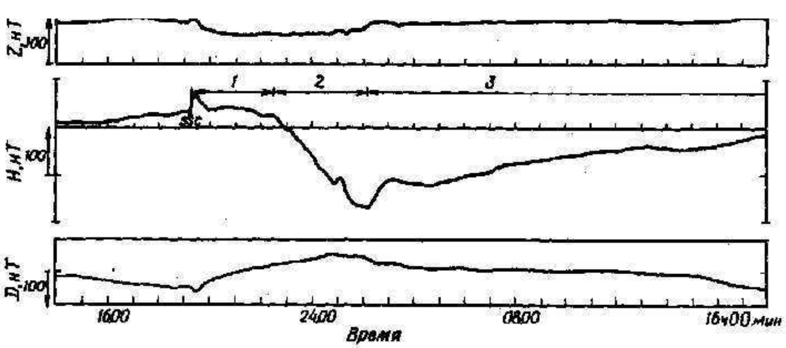
Substorm current wedge



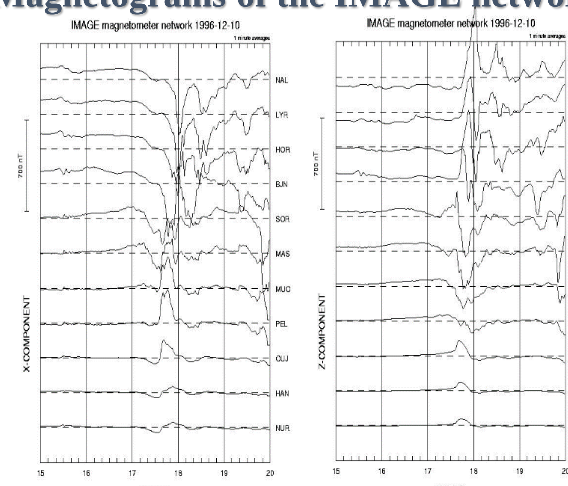
magnetic storm

Dst = DCF + DR + DP





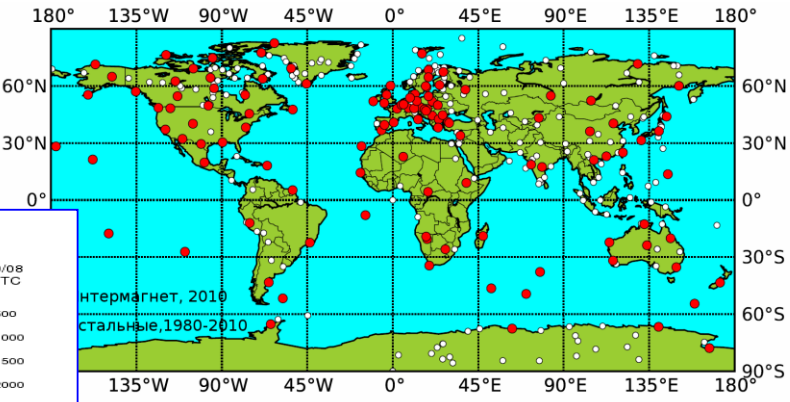
Magnetograms of the IMAGE network:

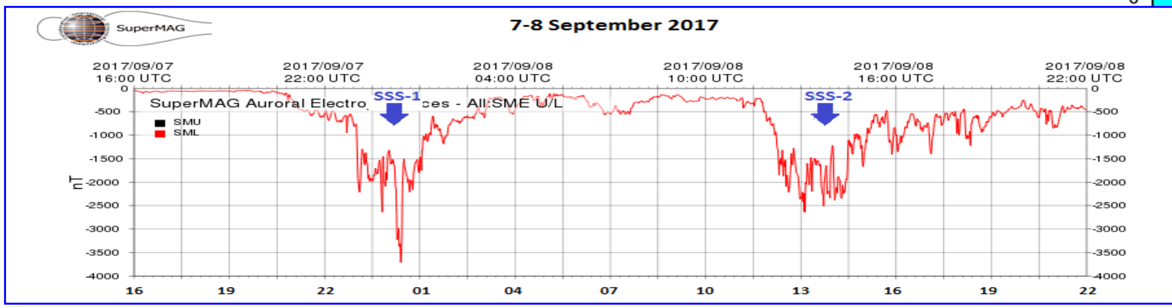


Supersubstorms (SSS) - determination

SML index < - 2500 nT

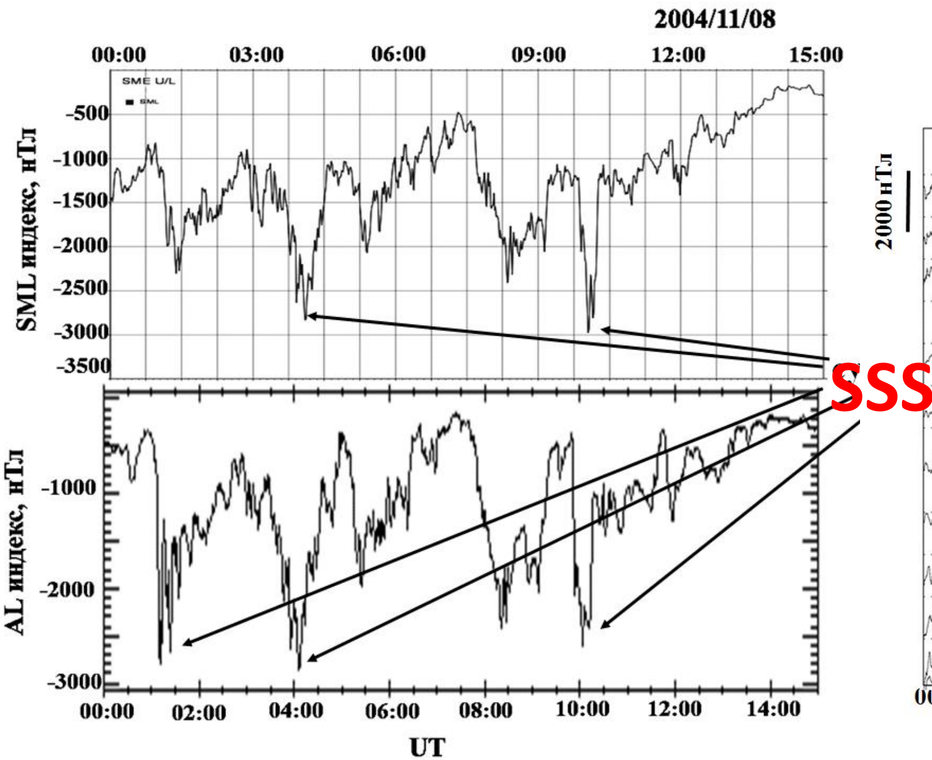
Tsurutani et al., 2015

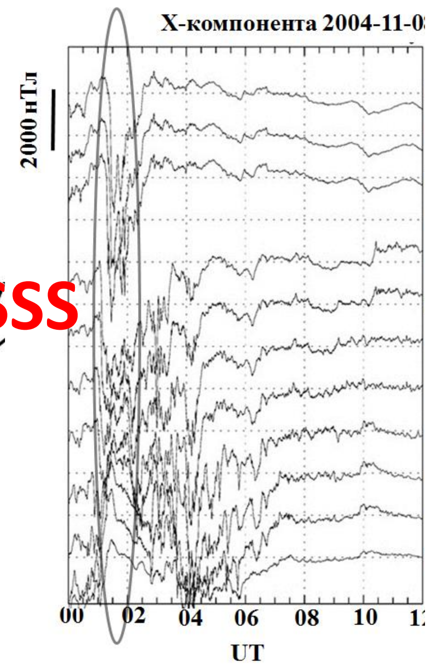


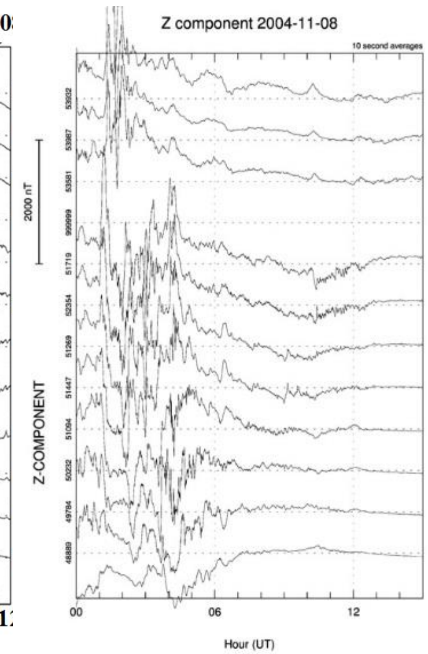


AL index < - 2500 nT

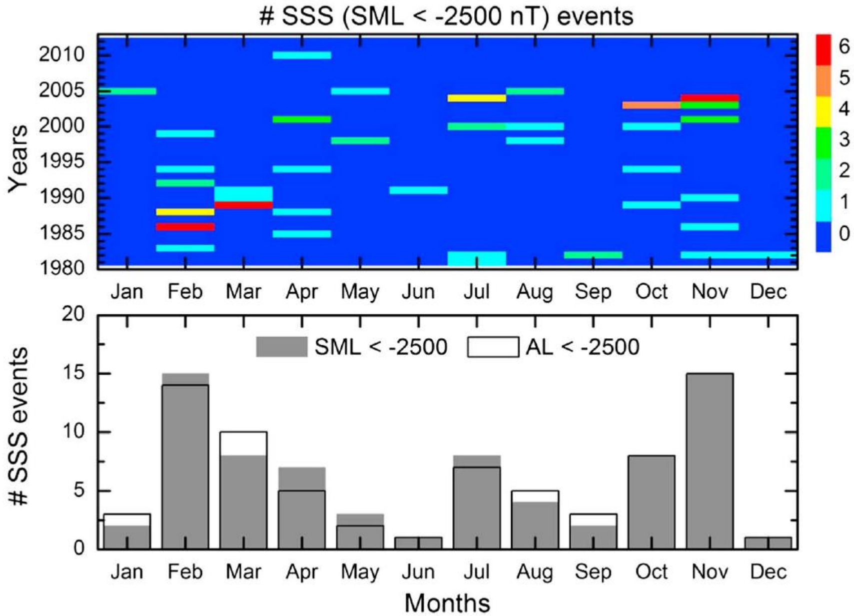
IMAGE magnetometers network:





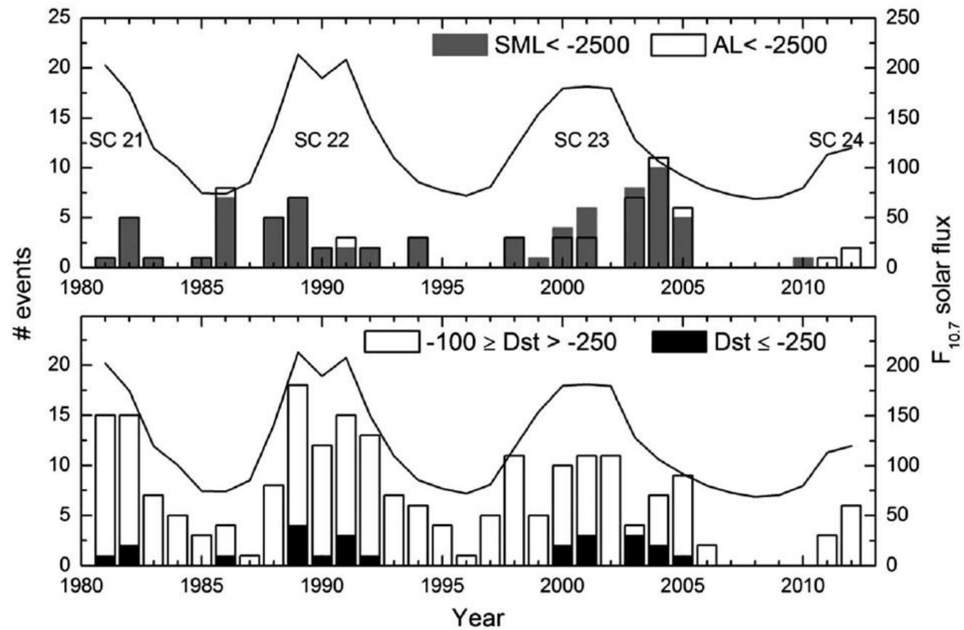


Seasonal distribution of SSS events detected during the interval 1981–2012:



SSS events exhibit an approximate "semiannual" variation with peak occurrences during February and November with a secondary peak during July.

Dependence on the solar activity:

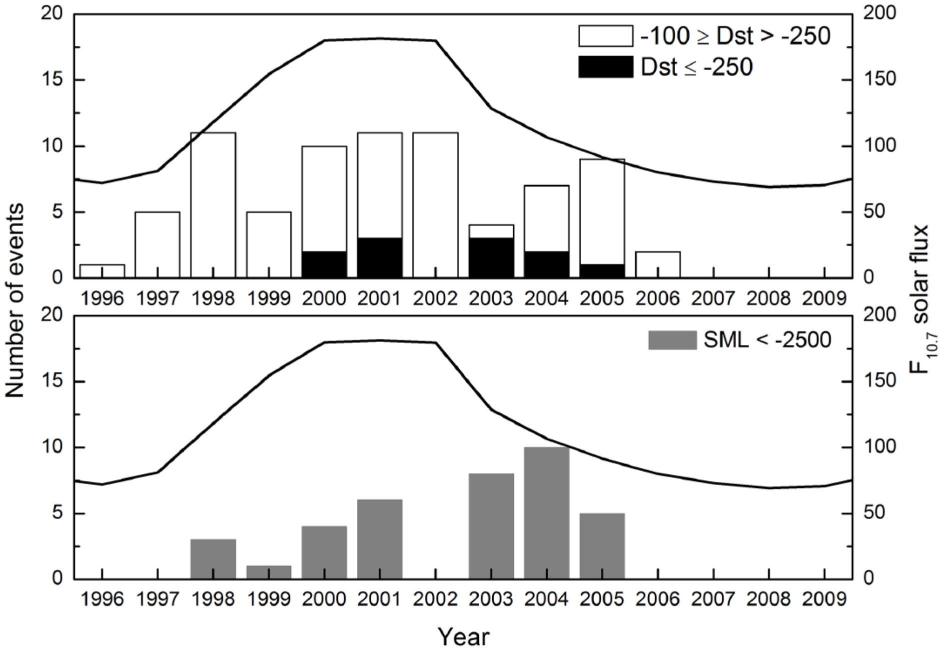


SSS events can be observed during any phase of the solar cycle, but their highest frequency falls in the declining phase of the cycle, the lowest occurs during the cycle minimum.

Haira et al., 2016

Relationship between SSS and geomagnetic storms

Tsurutani et al., 2015

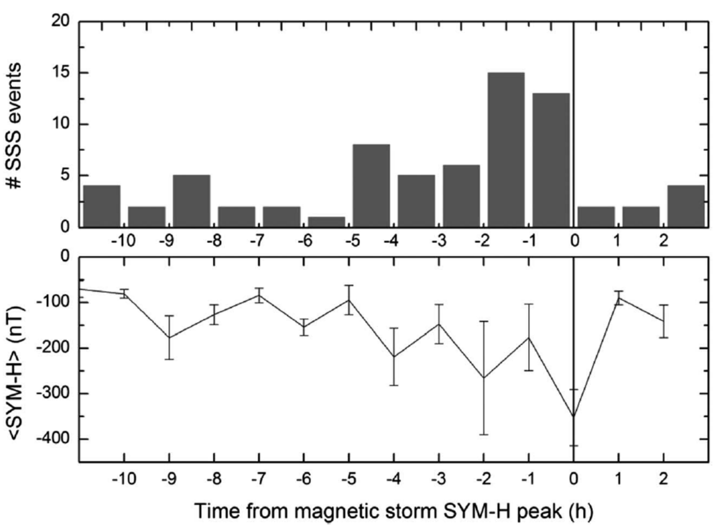


$$-50\ \mathrm{nT} \geq Dst > -100\ \mathrm{nT}$$ - moderate storm

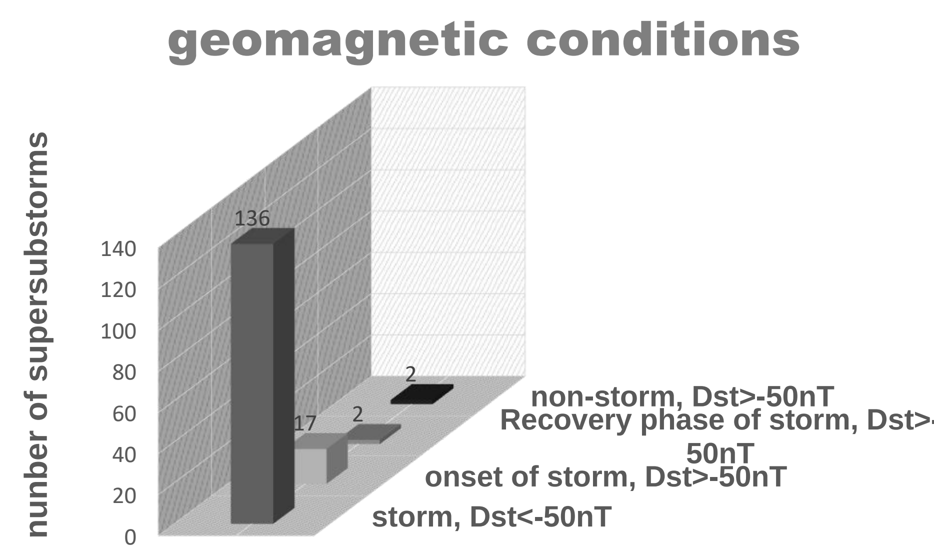
$$-100\ \mathrm{nT} \geq Dst > -250\ \mathrm{nT}$$ - intense storm

$$Dst \leq -250\ \mathrm{nT}$$ - superstorm

Haira et al., 2016

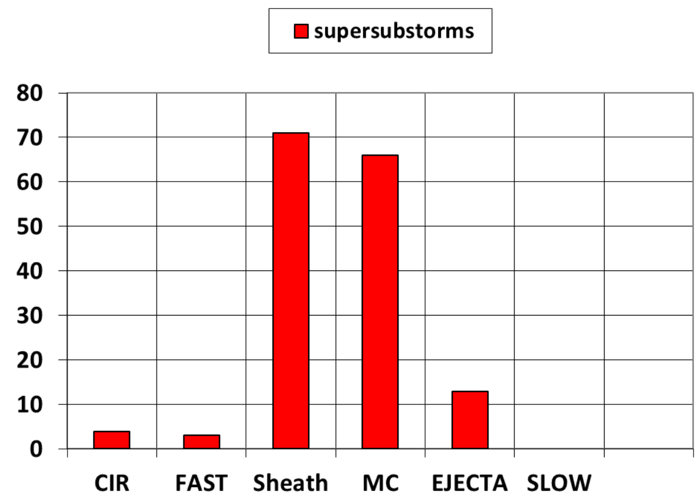


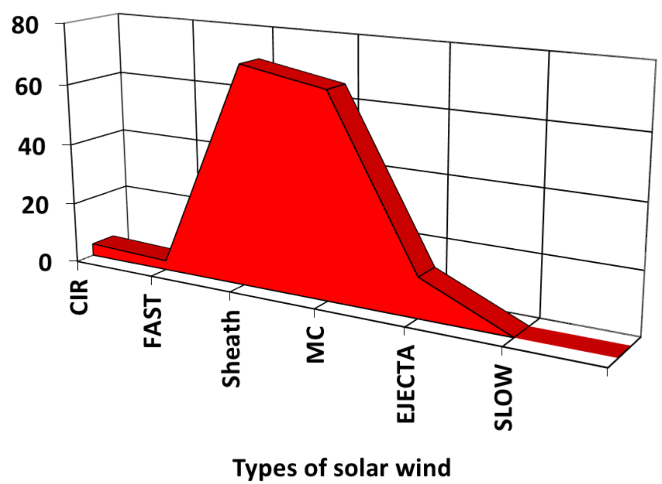
Despirak et al., 2019



Distribution of SSS on the solar wind types

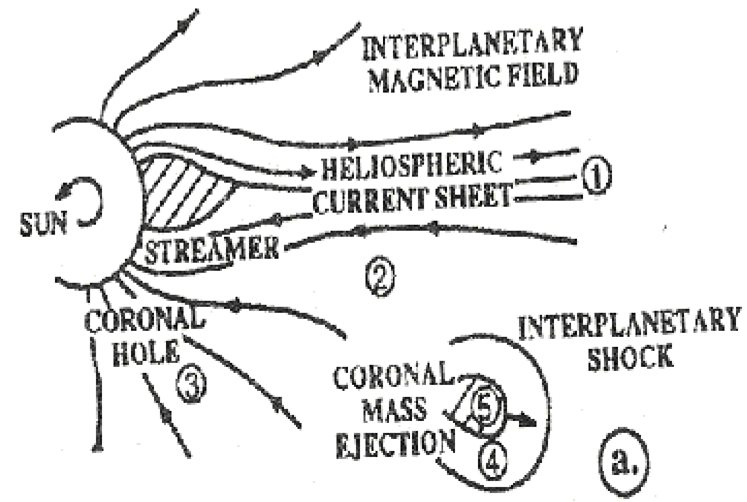
Histograms of the number of "supersubstorms" recorded under different types of the solar wind:





Despirak et al., 2019

Solar wind types according to the catalog of large-scale solar wind phenomena (ftp://ftp.iki.rssi.ru/pub/omni/catalog/) :

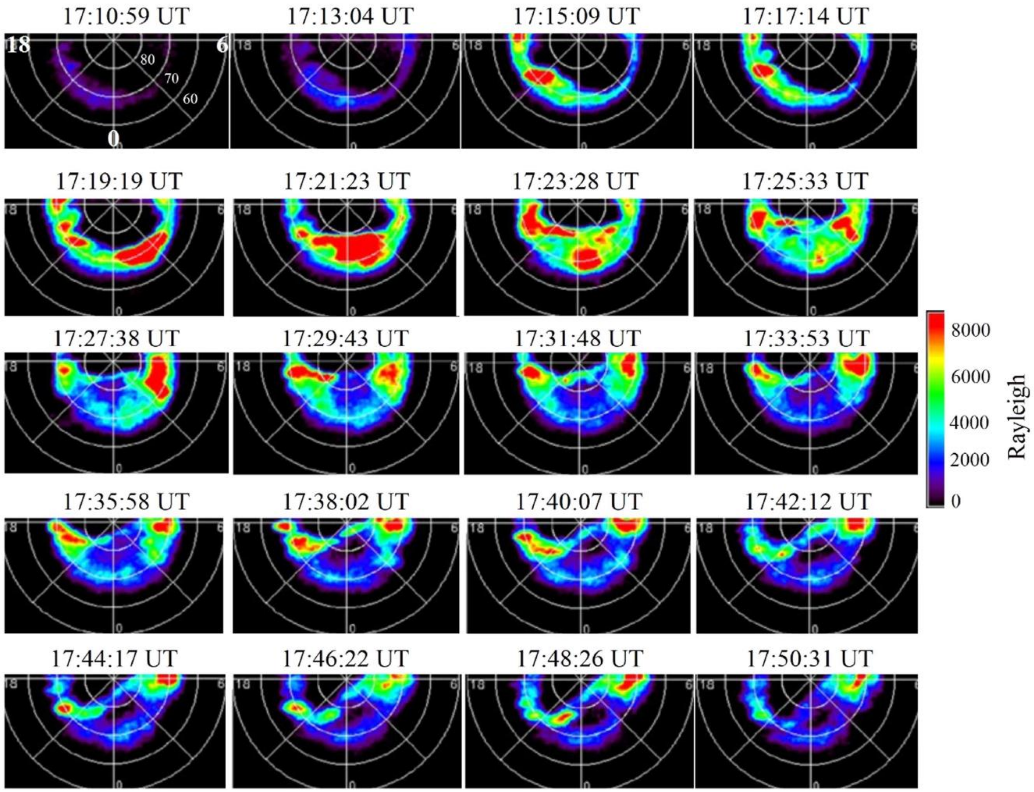


1) **Magnetic clouds (*MC*, 42%)**
2) **plasma compressed region before MC/EJECTA (*SHEATH*, 45.2%)**
3) **only sometimes during interplanetary displays of CME (*EJECTA*) (~13 %).**
4) **very seldom *SSS* can be observed during plasma compression region before high speed stream (*CIR*, 2.5%) and during high speed stream (*FAST*, 1.7%).**

Development of aurora during SSS

08 November 2004

IMAGE-FUV



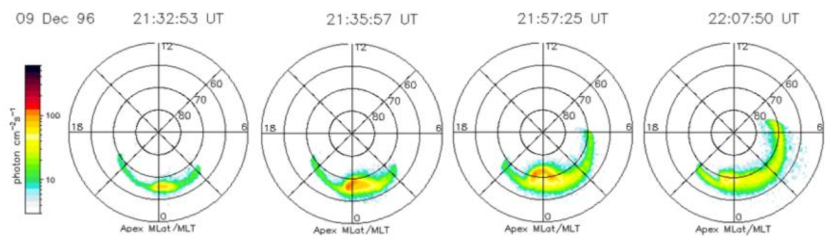
Haira et al., 2018

Auroral development during a supersubstorm is nonstandard:

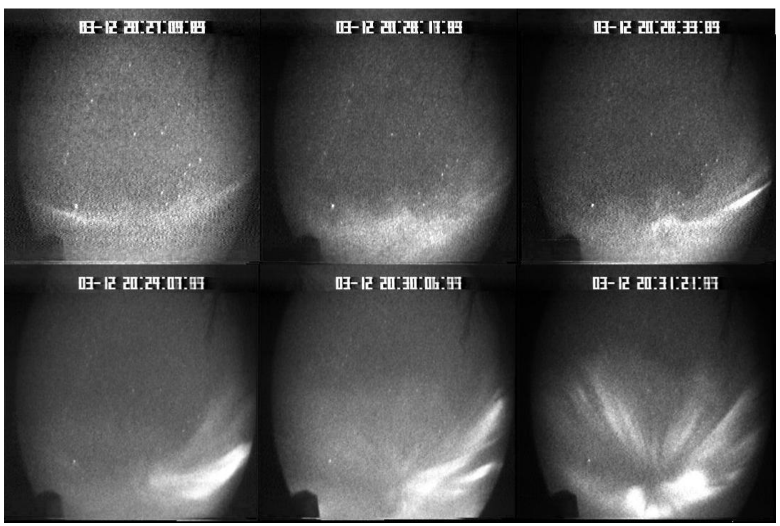
it is not seen the standard brightening of the equatorial arc in the midnight sector and breakup of auroras

However, there were intense auroras in the premidnight and morning sectors of magnetic local time (MLT).

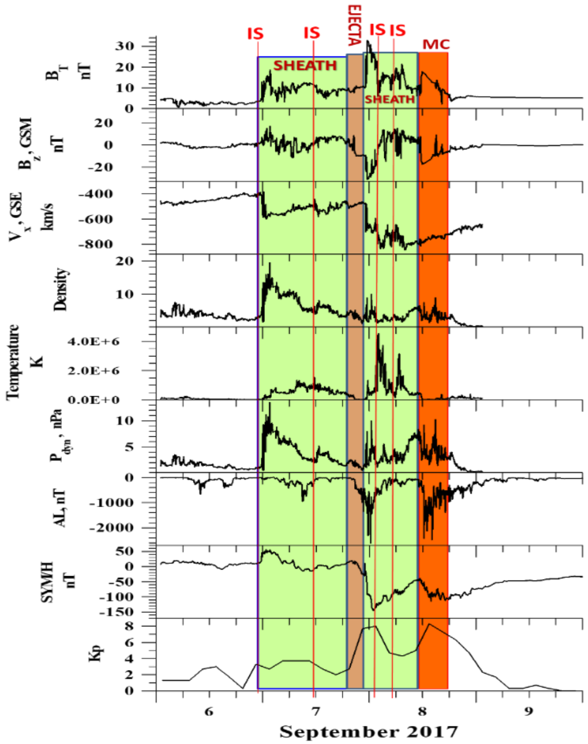
The example of substorm development by Polar UVI data

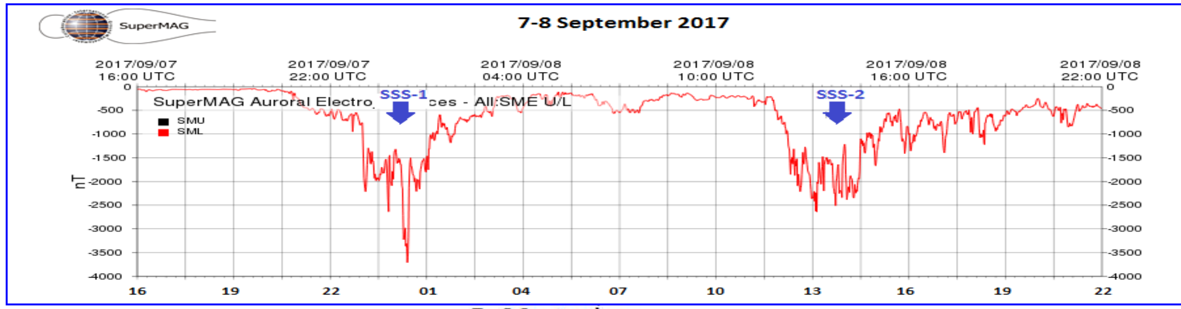


The example of substorm development by all-sky camera data



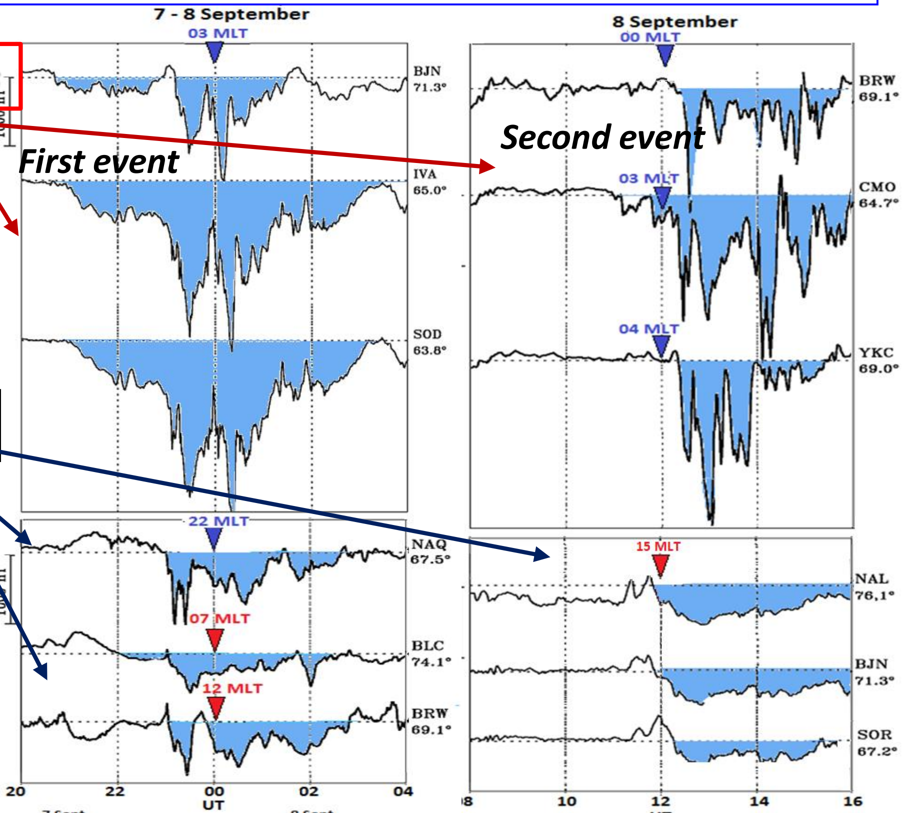
Supersubstorms on 7 - 8 September 2017



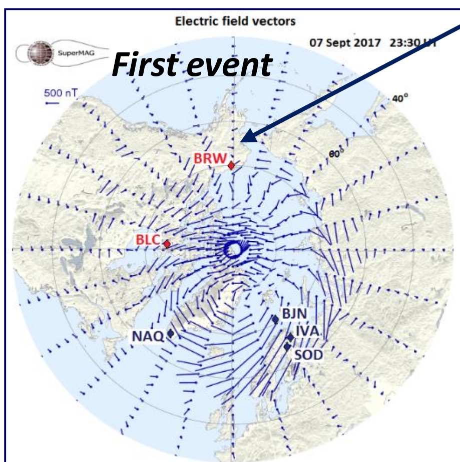


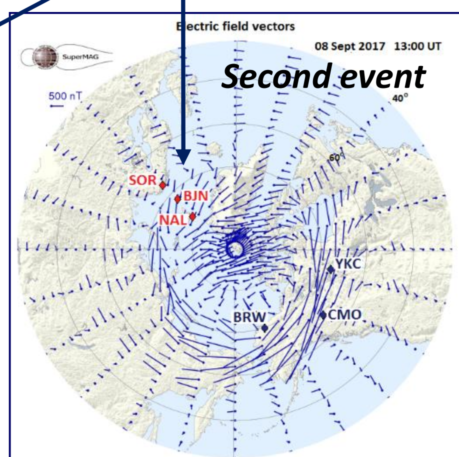
auroral latitudes

polar latitudes



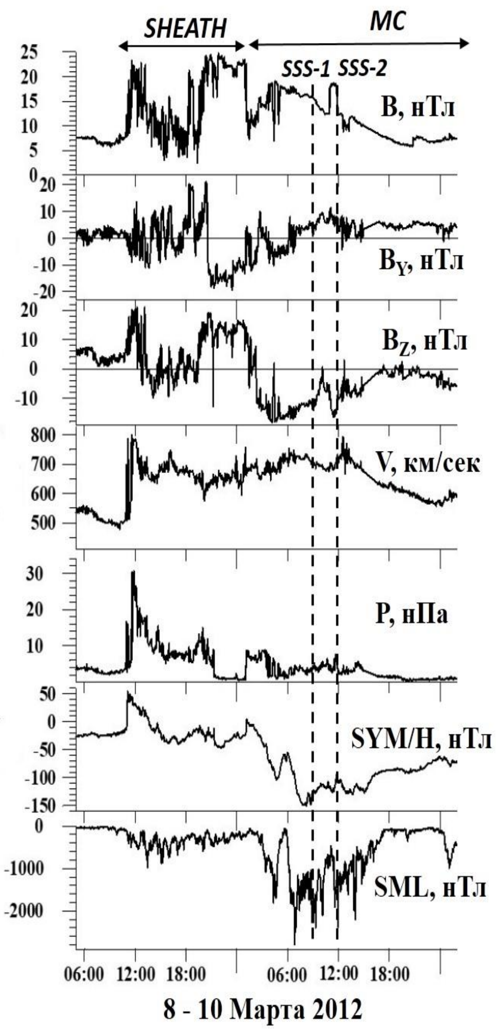
SuperMAG map of the magnetic field vectors

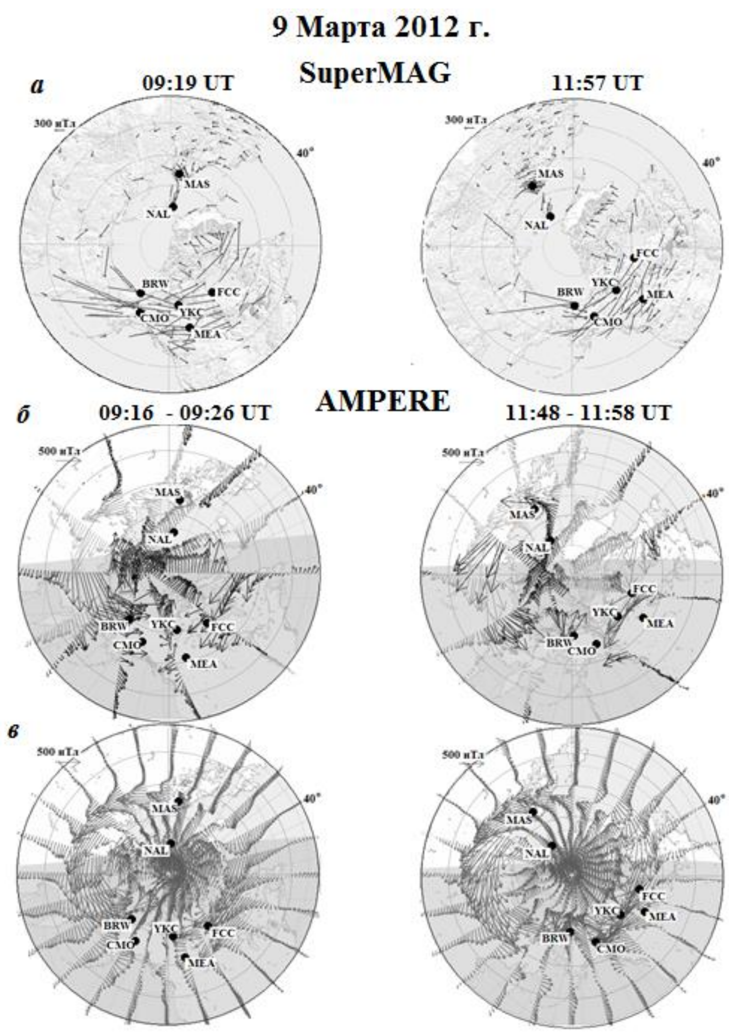


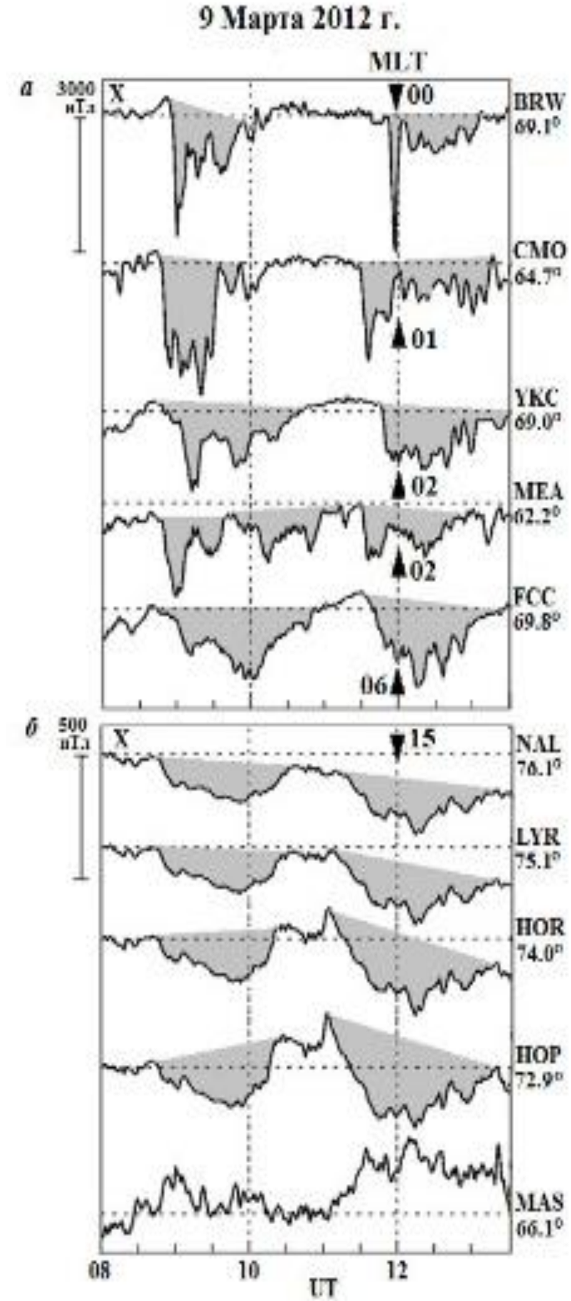


The strongest magnitude of both SSSs was observed at the post midnight auroral latitudes and was accompanied by the bay-like disturbances at day-side polar latitudes with significantly reduced intensity.

Supersubstorms during magnetic storm on 9 March 2012



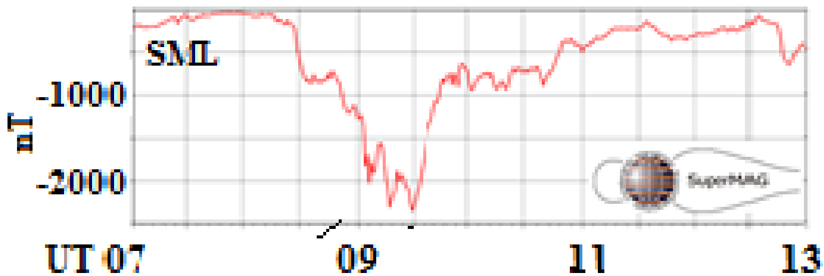


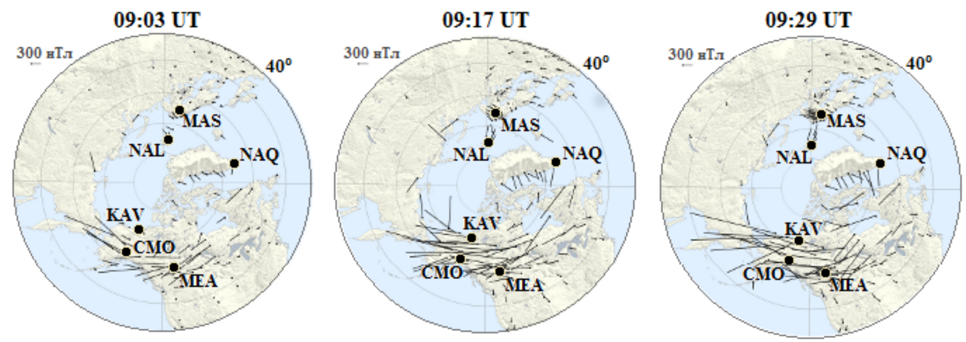


Despirak I.V., Lubchich A.A., Kleimenova N.G., Gromova L.I., Gromov S.V., Malysheva L.M. Longitude Geomagnetic Effects of the Supersubstorms during the Magnetic Storm of March 9, 2012. // Bulletin of the Russian Academy of Sciences: Physics, 2021, Vol. 85, No. 3, pp. 246–251

Supersubstorm on 5 April 2010

The SML index:

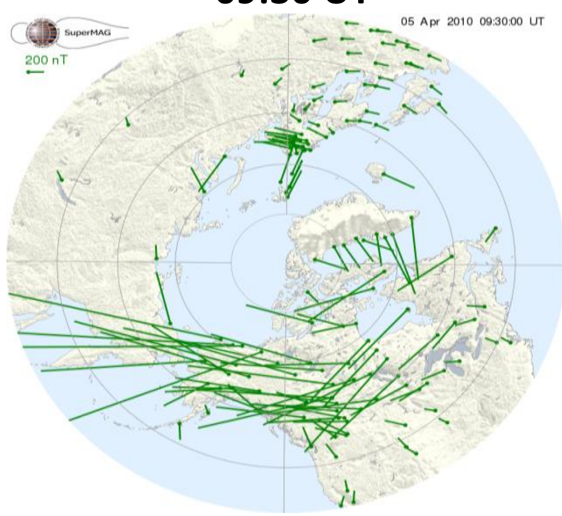


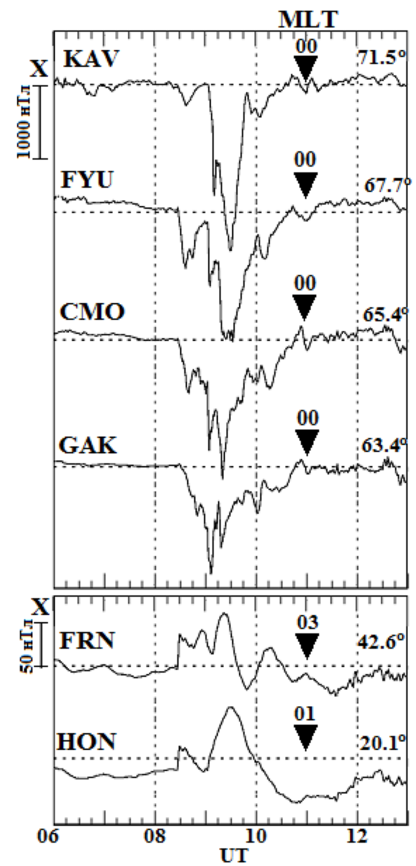


а)

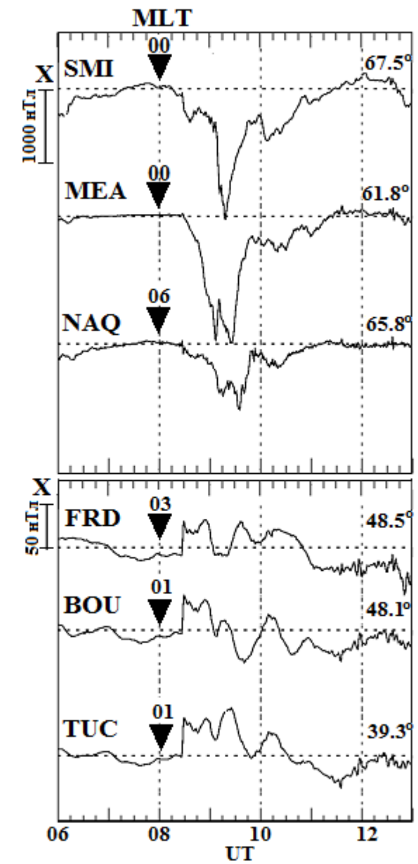
SuperMag *plots of magnetic vectors rotated 90° clockwise to indicate ionospheric equivalent current direction*

09:30 UT





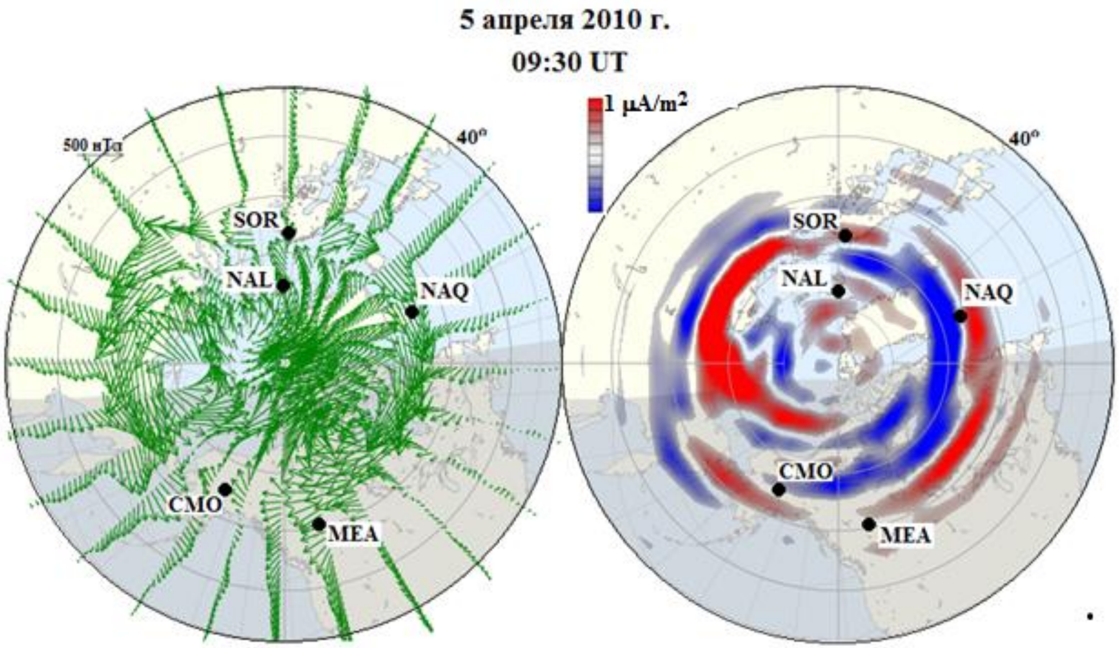
б)

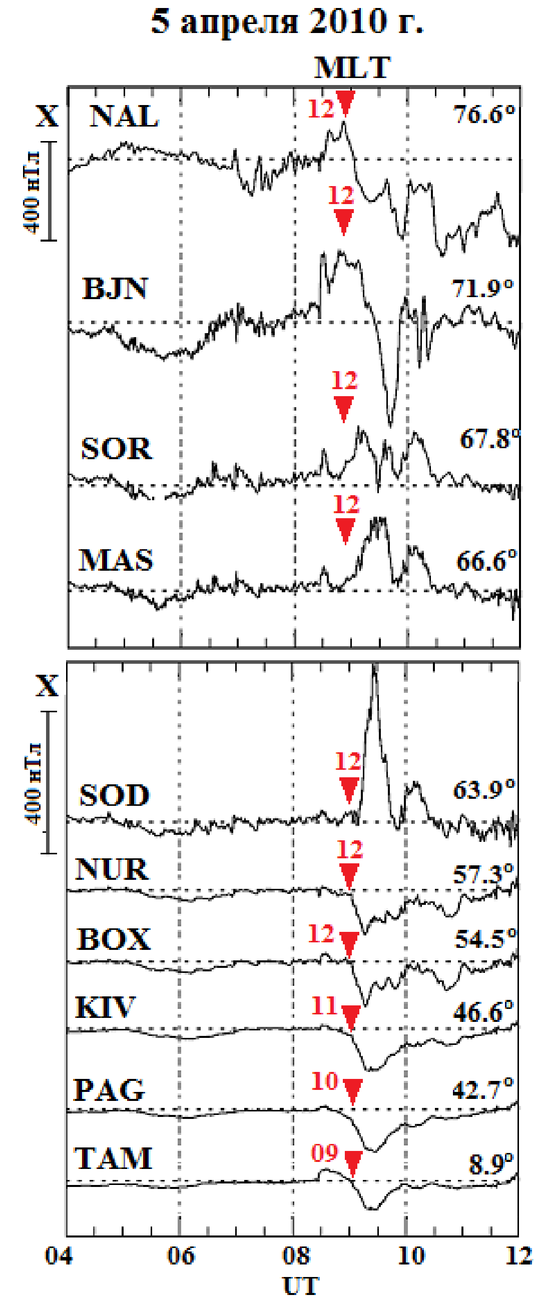


в)

It is seen the negative bay at auroral latitudes becomes the positive one at middle latitudes.

AMPERE maps





It is seen that in the evening sector (the North-East part of Siberia), the strong magnetic vortex was observed demonstrating the strong enhanced upward currents (red) associated with a huge particle precipitation.

After midnight the downward currents (blue) were located poleward of the upward ones (red), and westward current was located between the upward and downward FAC.

Hypothesis about the formation of an additional partial ring current during the SSS, closing to the eastern electrojet

Zong et al., 2021

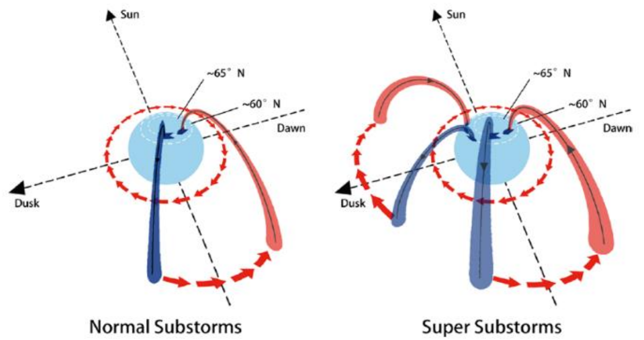
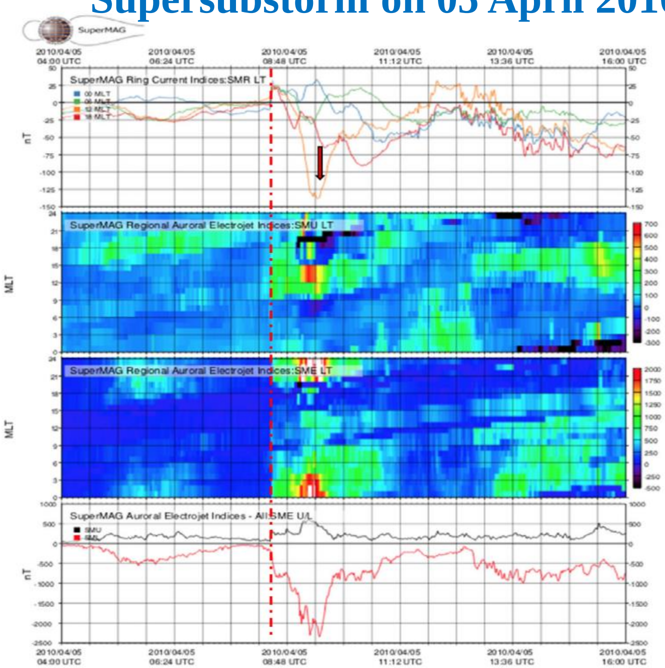


Fig. 10 The Substorm Current Wedge model. Almost 40 years ago the concept of the substorm current wedge (SCW) was developed to explain the pattern of magnetic signatures observed on the ground and in geosynchronous orbit during the substorm expansion phase. Left panel is the model for the normal substorms, right panel is the model for superstorms

In contrast to the typical scenario of the classical substorm, an intense eastward electrojet in the evening sector was detected, associated, probably, with an additional partial ring current which appear during SSS

Supersubstorm on 05 April 2010:



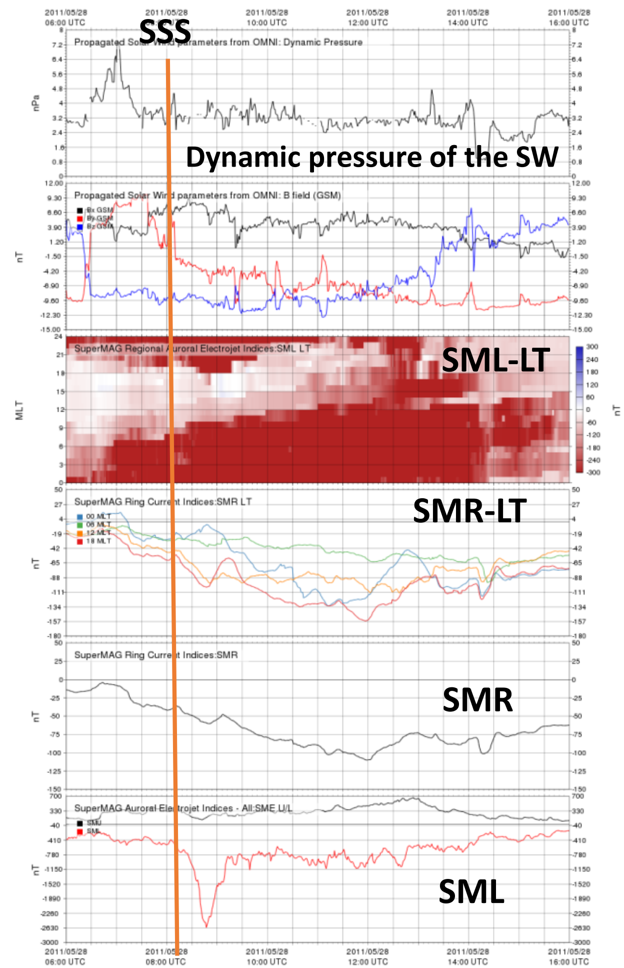
SML- maximum westward auroral electrojets strength. Lower envelope of N-component for stations between 40° and 80° magnetic north.

SML-LT- local time versions of electrojet indices.

SMR- symmetric ring current index.

SMR-LT - partial ring current indices partitioned by MLT

Supersubstorm on 28 May 2011:



Some features of supersubstorms

1) SSS appear mainly during interplanetary manifestations of coronal mass ejections (SHEATH, MC, EJECTA);

2) Jumps in the dynamic pressure of the solar wind were often noted before the appearance of the SSS.

3) the development of auroras is nonstandard: intense auroras were registered in the premidnight and morning sectors of magnetic local time (MLT).

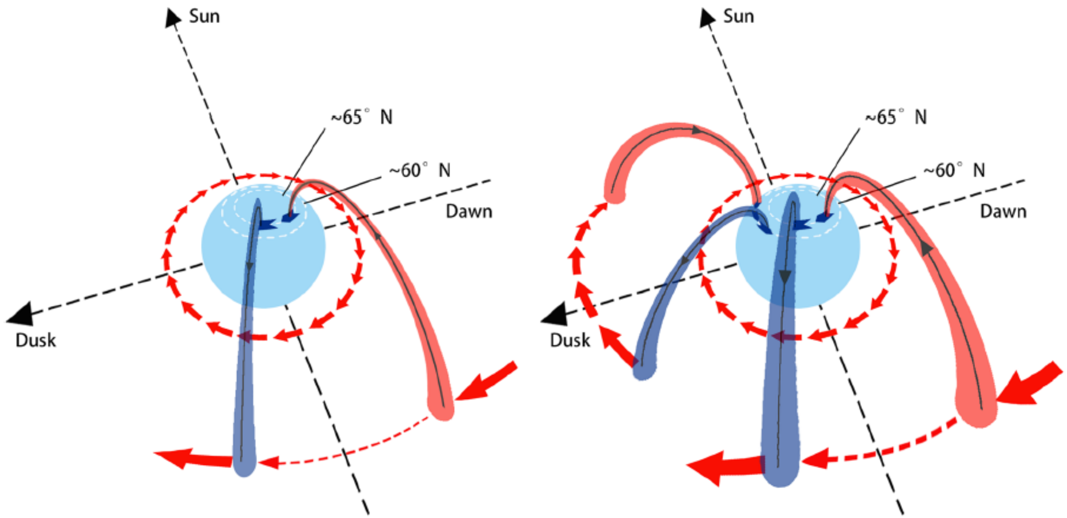
4) In the evening and night sectors, a strong westward electrojet was observed on a global scale - from the evening side at auroral latitudes to the dayside

5) an intense eastward electrojet in the evening sector was detected, which may be the result of the formation of an additional partial ring current during the supersubstorm.


Thank you for your attention !!

Fu et al., 2021

Statistical Characteristics of Substorms With Different Intensity



Normal Substorms

Intense Substorms

Substorm current wedges for normal substorms and intense substorms.
Left panel shows the substorm current wedge during normal substorms.
Right panel shows the substorm current wedge and the additional current wedge during intense substorms.
The red arrows stand for the magnetospheric currents
(e.g., ring current or cross-tail current sheet).

Unlike normal substorms, auroral electrojets during intense substorms show a bimodal distribution, indicating that eastward and westward electrojets are comparable during intense substorms.

As a result, authors suggest an additional substorm current wedge near the dusk side during intense substorms.

Auroral electrojets during the substorm expansion phase and the recovery phase show expansions.