High-latitude substorms, supersubstorms and space weather conditions

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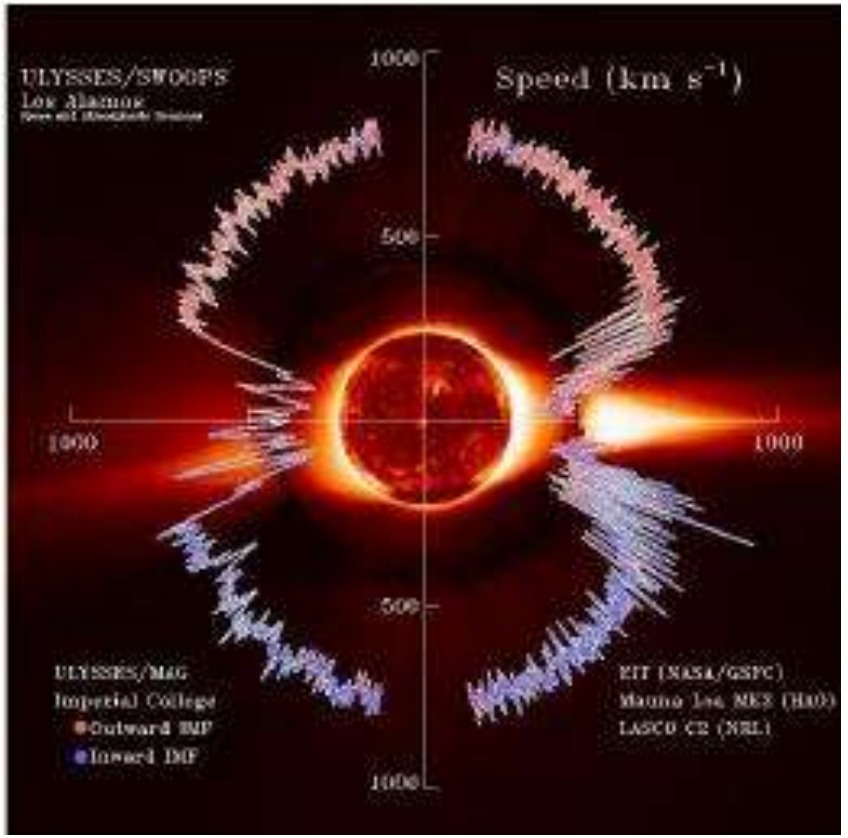


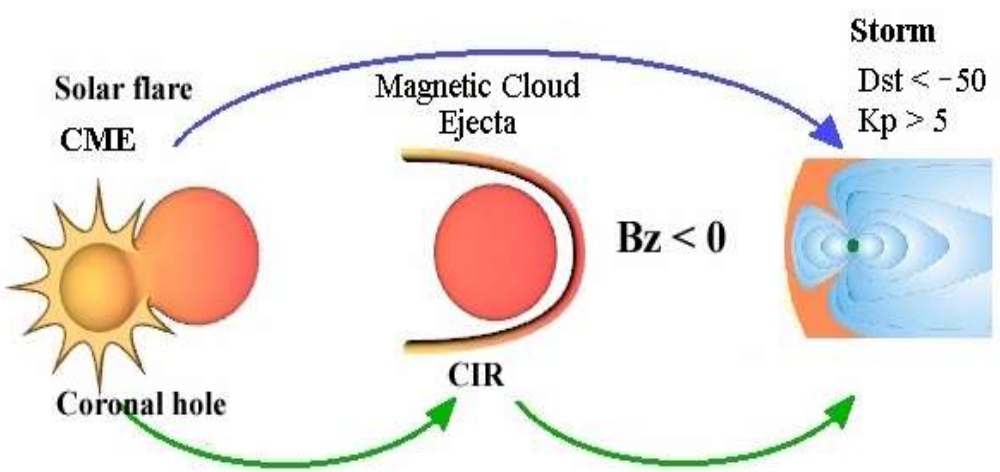
Solar wind is not inhomogeneous, there are different streams and structures :

1) *ICME- interplanetary coronal mass ejection*

2) *HSS- high speed streams from coronal holes*

3) *SSW - slow solar wind*

These large-scale types of solar wind vary with their sources on the Sun and are characterized by different plasma and field parameters. [Klein and Burlaga, 1982; Schwenn, 2006; Sheeley and Harvey, 1981; Cane and Richardson, 2003; Gopalswamy, 2006].

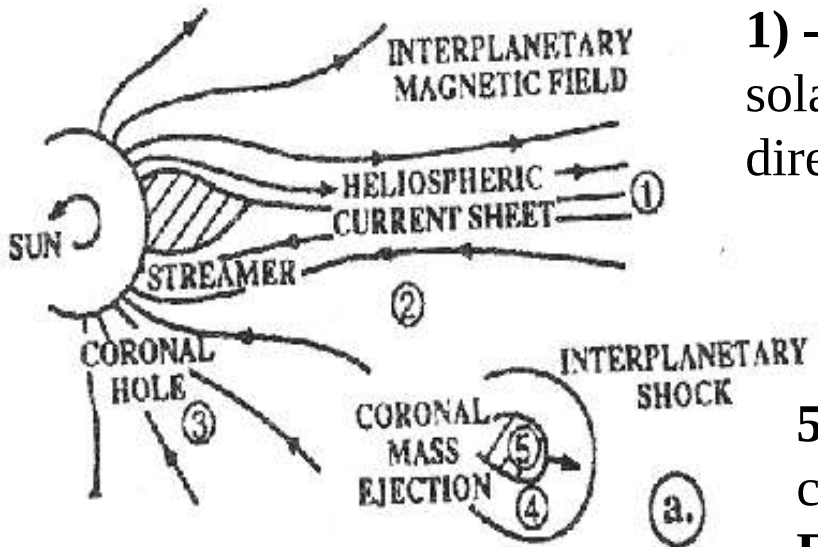


It should be noted what within a certain type of the solar wind , the values of the plasma and field parameters vary only slightly.
Different classifications of the solar wind types were developed [eg. Ivanov, 1996; Yermolaev et al., 2009].

The purpose of our work:

Space weather conditions for the magnetic substorms appearance depending on the large-scale structure of the solar wind.

Solar wind types we determined according to the catalog of large-scale solar wind phenomena (ftp://ftp.iki.rssi.ru/pub/omni/catalog/) (Yermolaev et al., 2009):



1) - HCS – a heliospheric current sheet associated with the solar wind sector structure and dividing the regions with the direction of the IMF toward the Sun and from the Sun

2) - SLOW – slow plasma flows observed above the equatorial streamer belt, ***V*<450 km/s**; the dense and cold solar wind

3) - FAST- fast stream of plasma over polar coronal holes; ***V*>450 km/s**; the hot, rarefied high speed stream

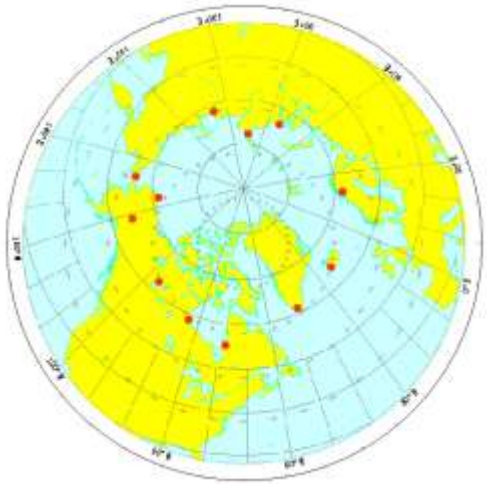
4) - SHEATH - plasma compression region before MC / EJECTA, the plasma has increased values of density, temperature and field magnitude, and $\beta > 1$; High values of the pressure, high variability of the magnetic field

5) - EJECTA - or Interplanetary CME ; **MC –** Magnetic cloud**,** the manifestation of ICME (is a subclass of **EJECTA** but differs by a higher and more regular magnetic field); magnetic field in the form of a bundle, the magnetic pressure prevails over the thermal pressure ($\beta << 1$)

6) - CIR - a plasma compression region before the fast stream (**FAST**)

“classical” magnetic substorms

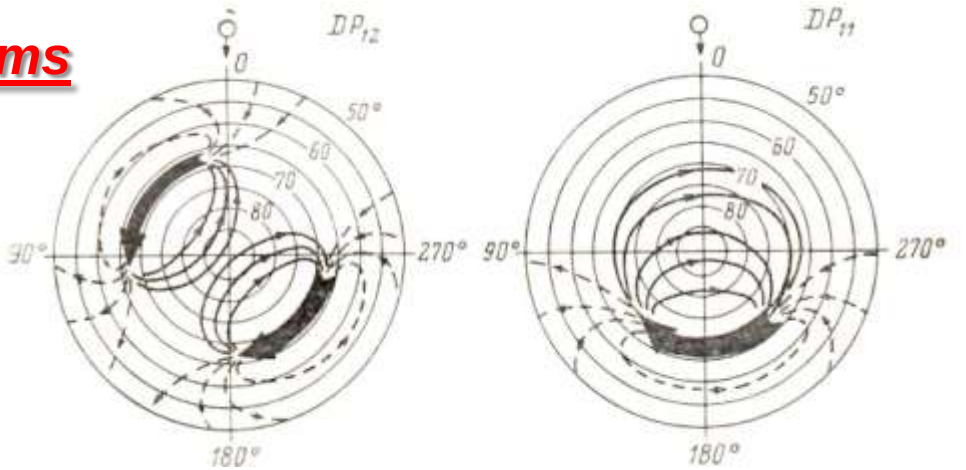
Typically, the intensity of substorms measured AE, AL, AU indices of geomagnetic activity.



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

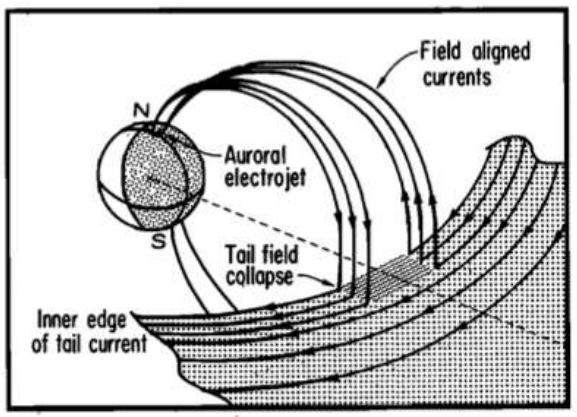
However, these indices estimate the substorm activity too roughly because they do not reflect the substorm latitudinal features.

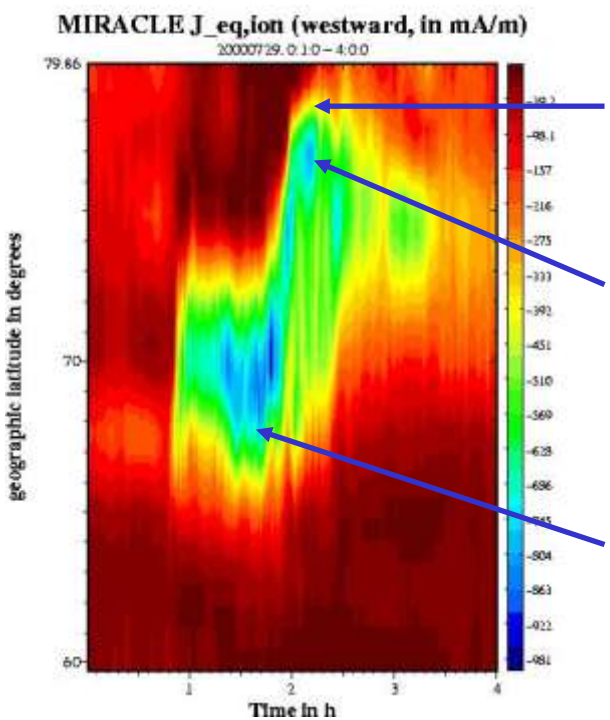
Distribution of AE index stations



Equivalent current system DP12 and DP11

Substorm current wedge



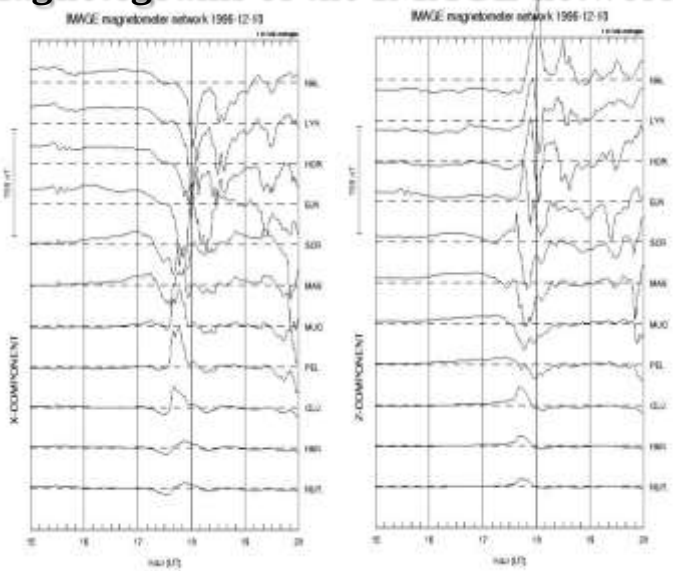


Fpk - latitude of the westward electojet poleward edge

F_m -maximum latitude of the center of the westward electrojet

F_o- onset latitude of the center of the westward electojet

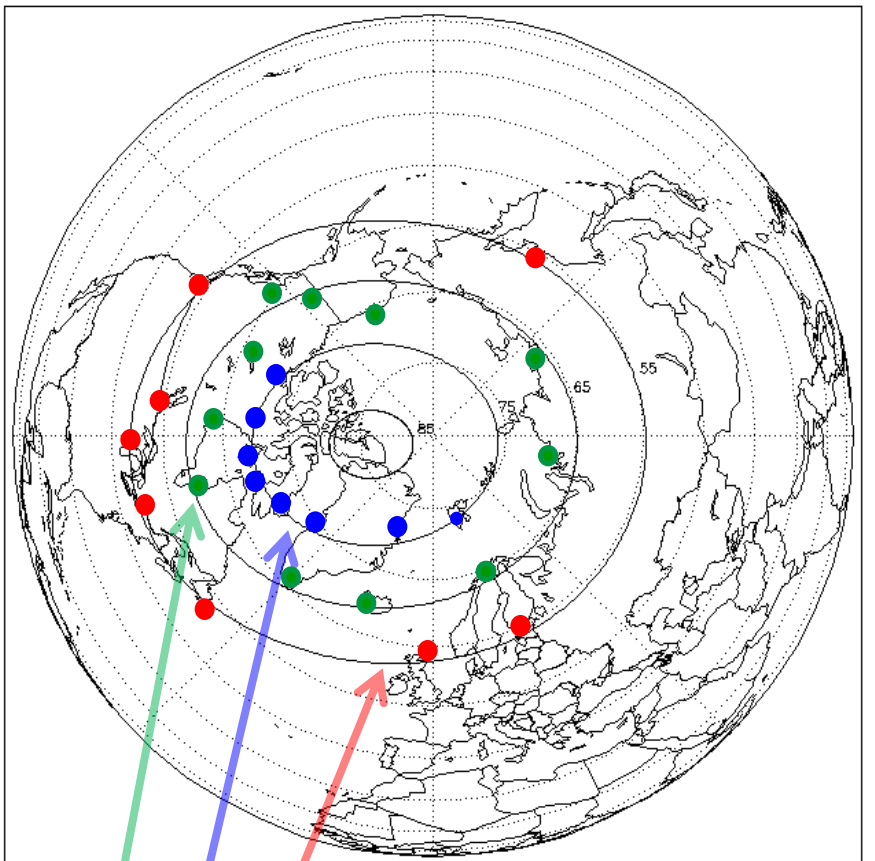
Magnetograms of the IMAGE network:



Three types of substorms:

1) «supersubstorms» (SSS)
are particularly intense substorms
(**SML <- 2500 nT or AL <-2500 nT**)

Auroral oval :



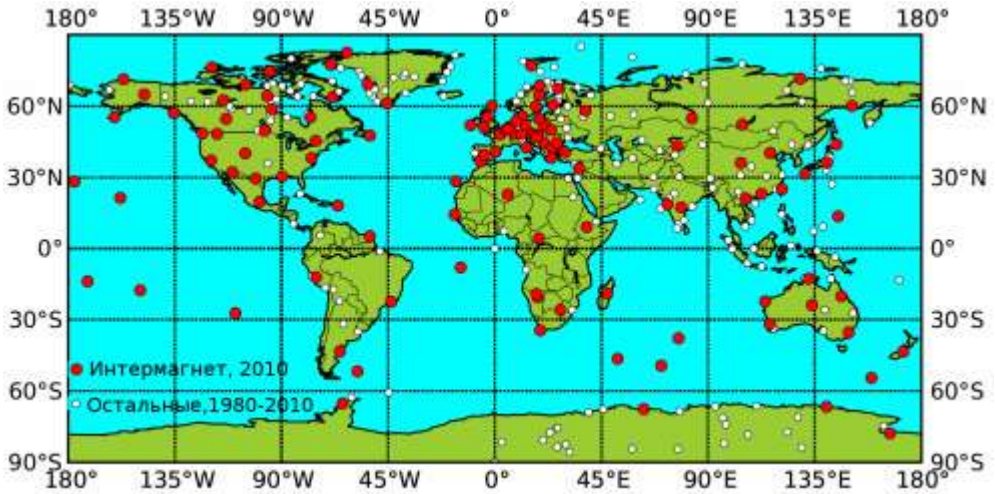
Blue points – stations on contracted oval
Green points – stations on auroral oval (normal)
Red points – station of extended auroral oval

Two types of high-latitudes substorm disturbances:

2) substorms, which observed during quit conditions, when the auroral oval is compressed and shifted to high latitudes (substorms on the contracted oval or **"polar"** substorms);

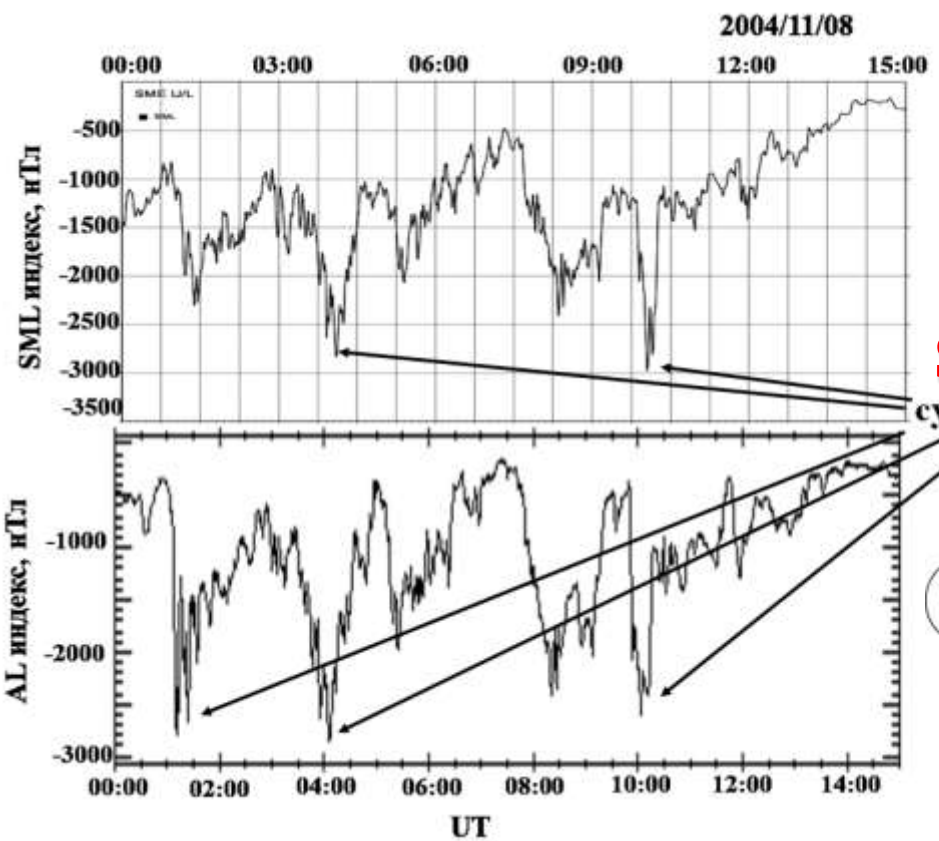
3) substorms, which observed during the disturbed conditions, when auroral oval is expanded (substorms on the extended oval or **"expanded"** substorms)

Supersubstorms (SSS) by data of the SuperMAG network



SML index < - 2500 nT

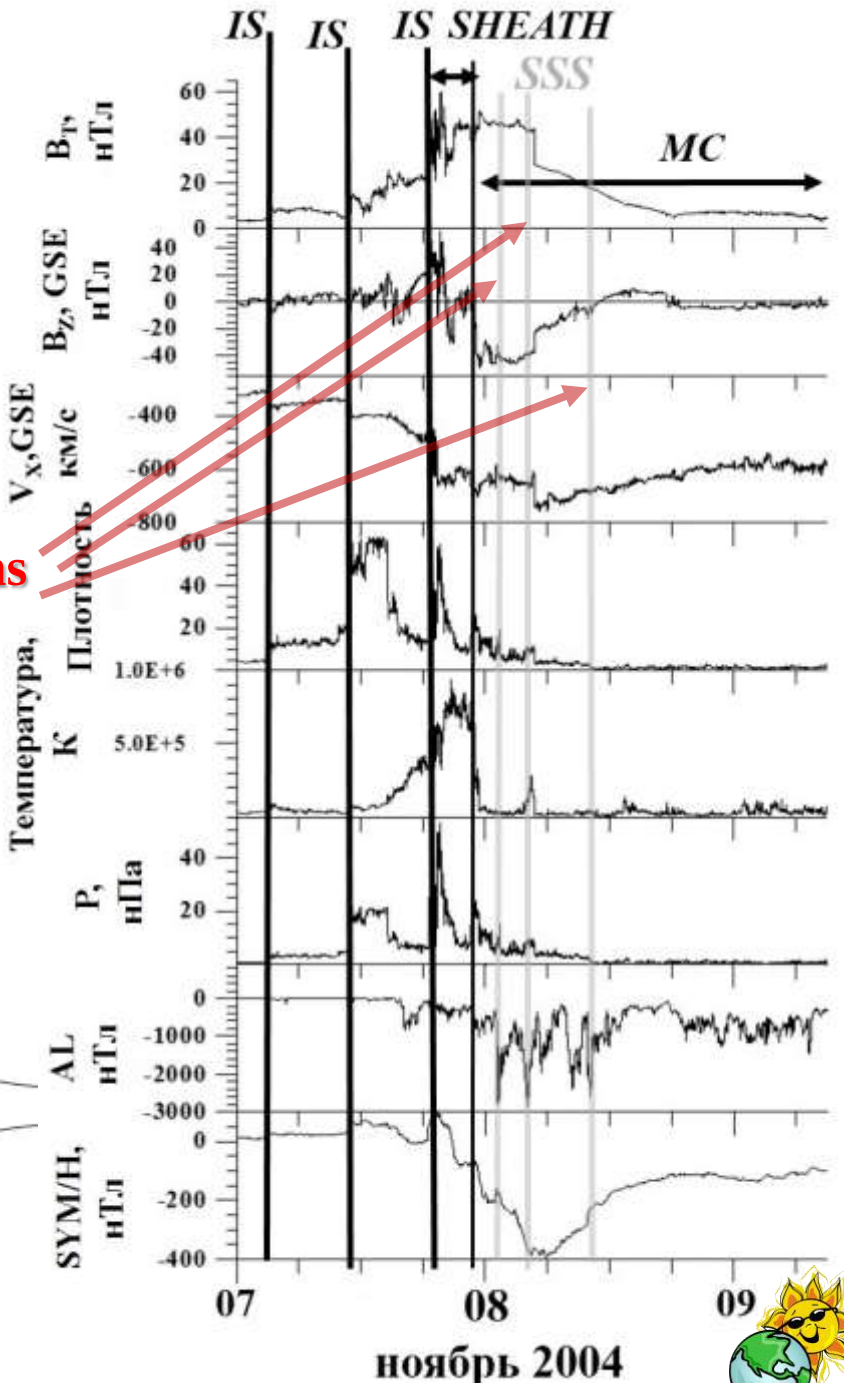
Solar wind data:



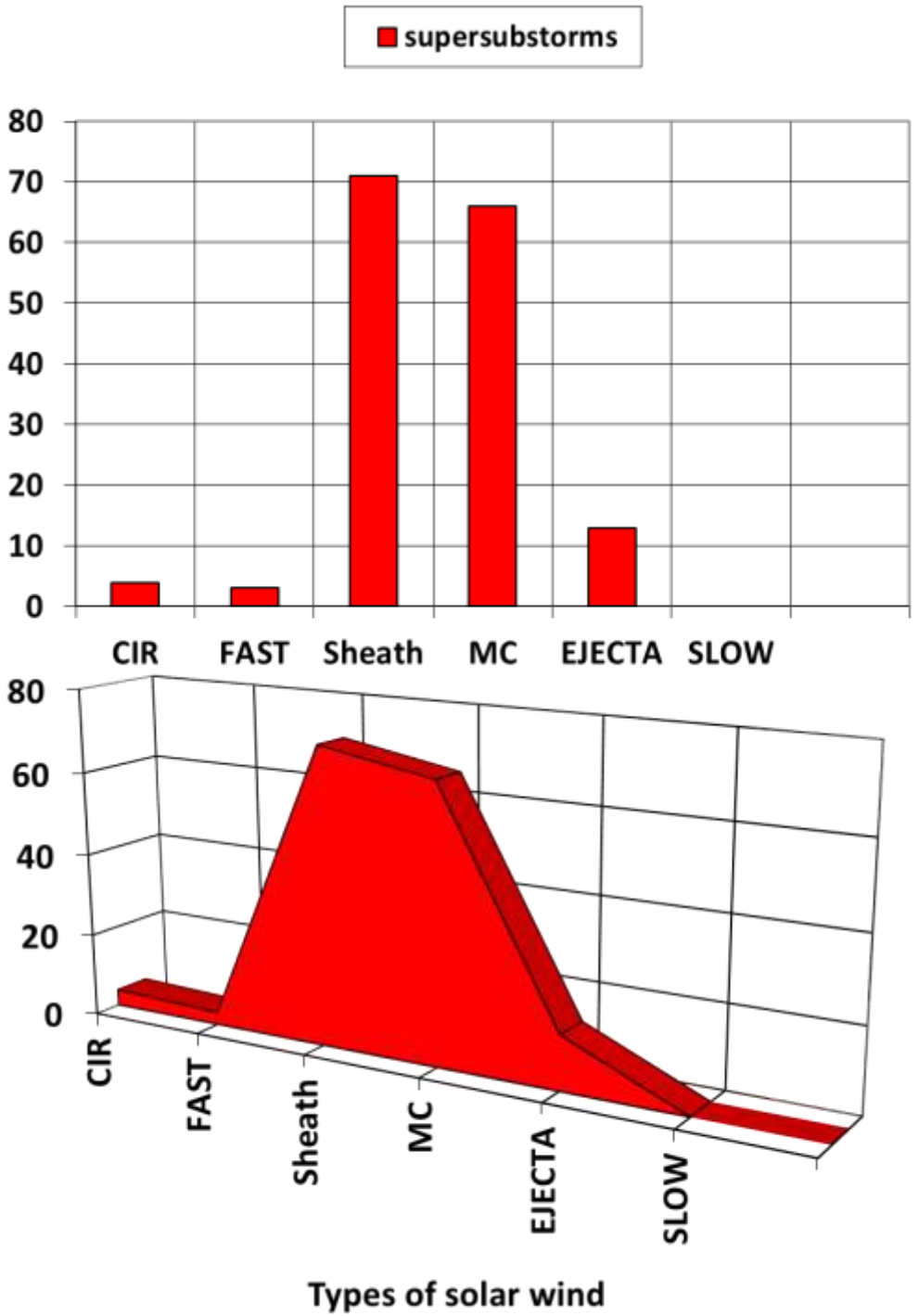
Supersubstorms

SSS

суперсуббури



Histograms of the number of "supersubstorm" recorded under different types of the solar wind



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%)**

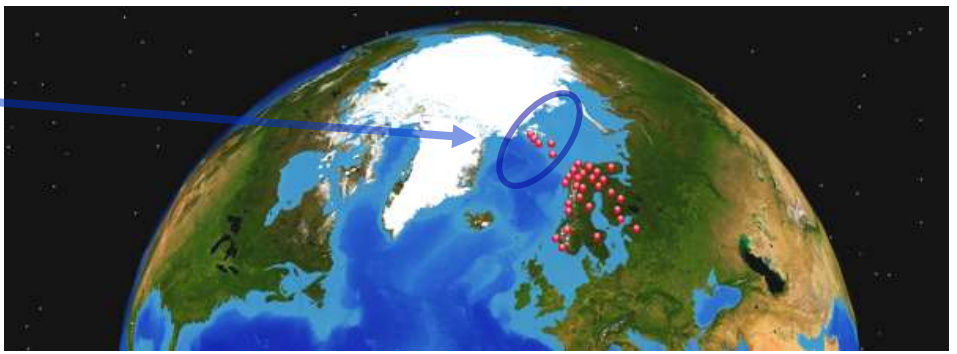
5) **very seldom during high speed stream (*FAST*, 1.7%).**

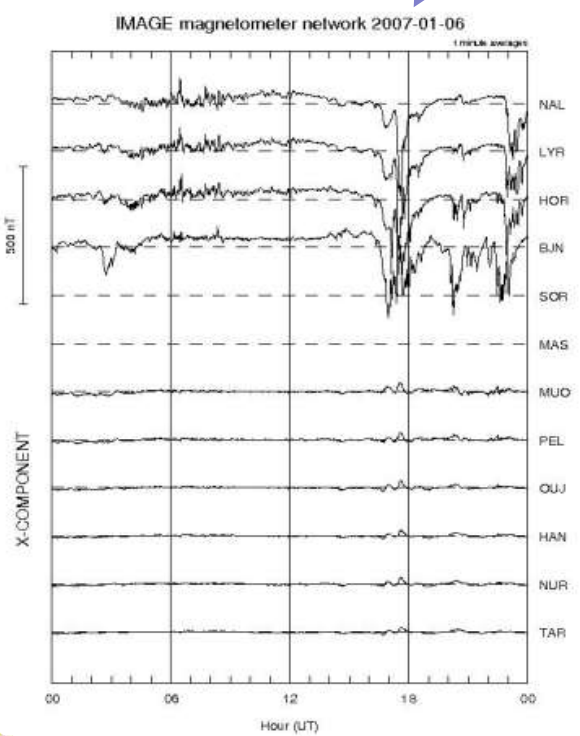
In addition, often before the SSS appearance, there were strong jumps in the dynamic pressure and density of the solar wind, which were observed against on the background of its high speed.

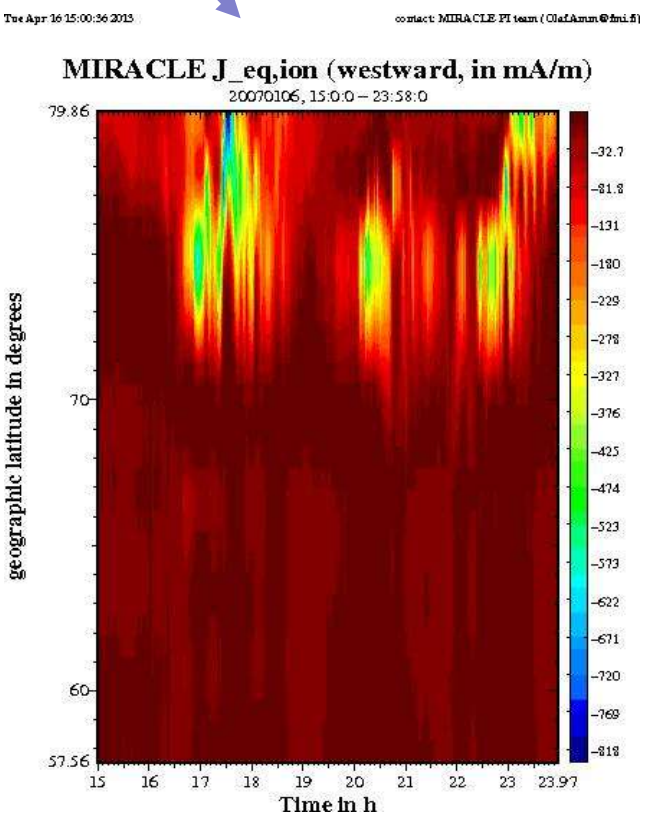
«Polar» substorms

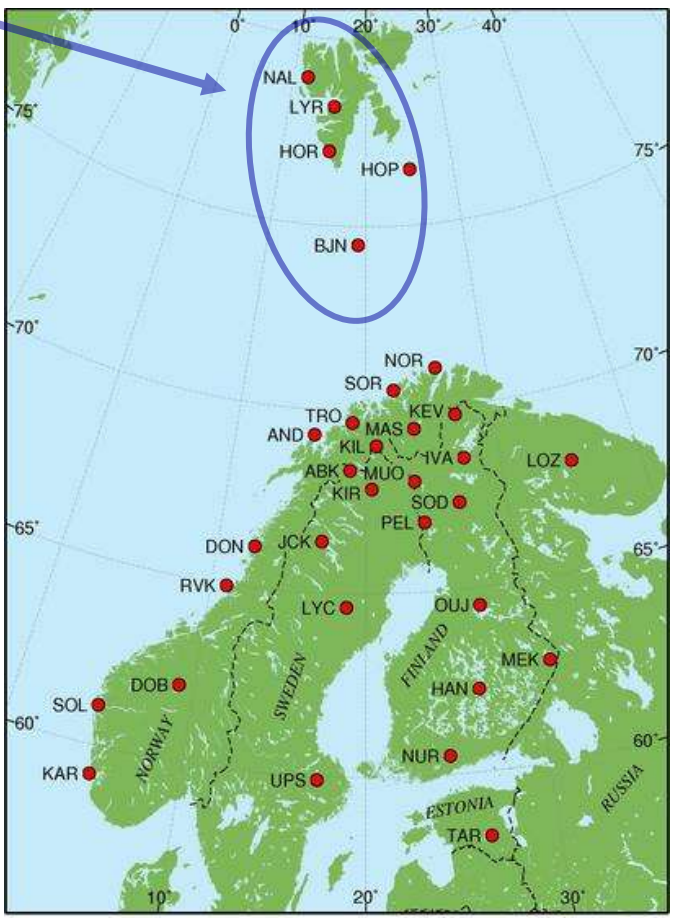
Substorms,
which registered only at geomagnetic latitudes over ~70º in the absence of simultaneous geomagnetic disturbances at latitudes below ~ 70º.

IMAGE magnetometers network:

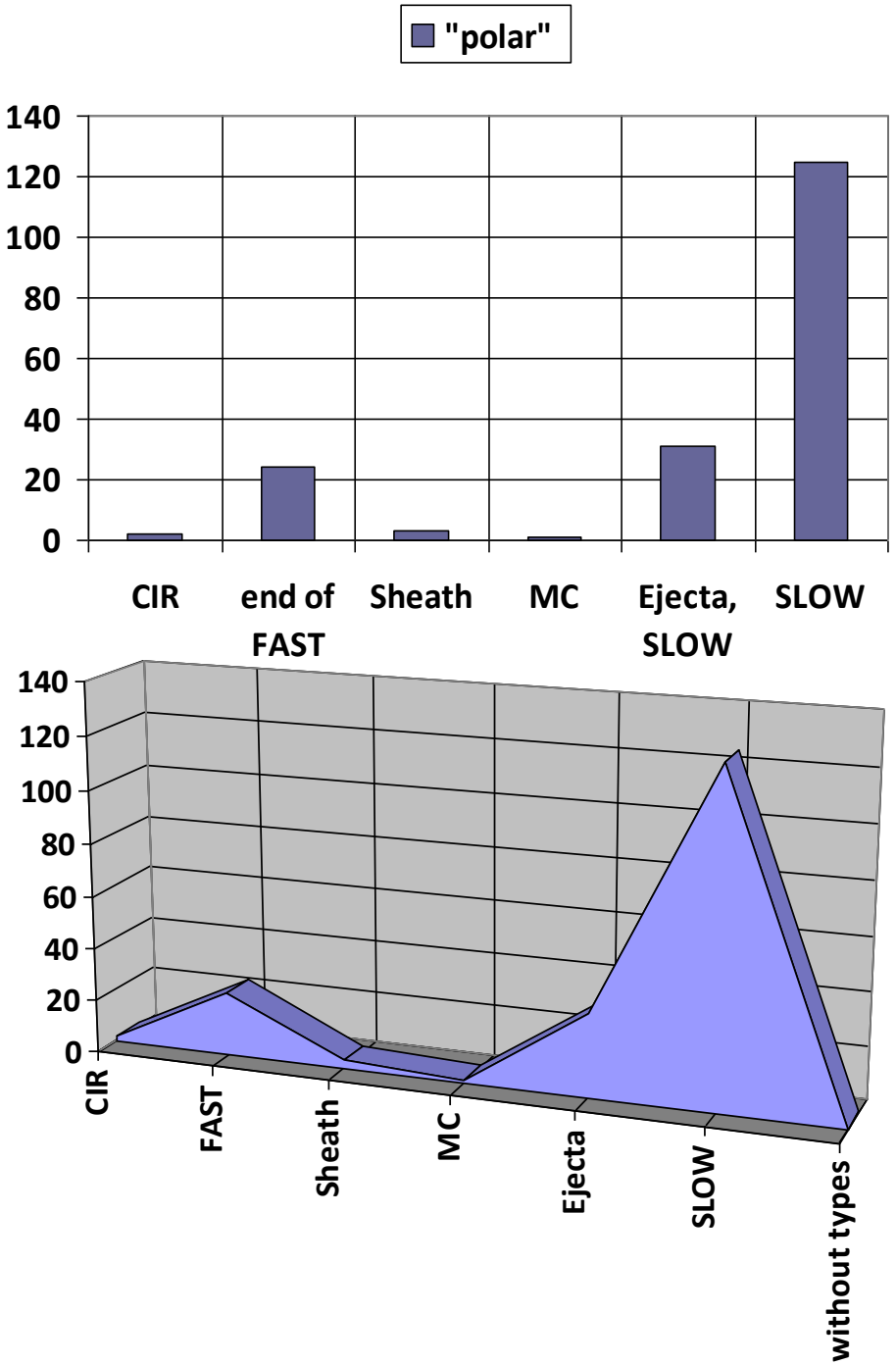








Histograms of the number of "polar" substorms recorded under different types of the solar wind



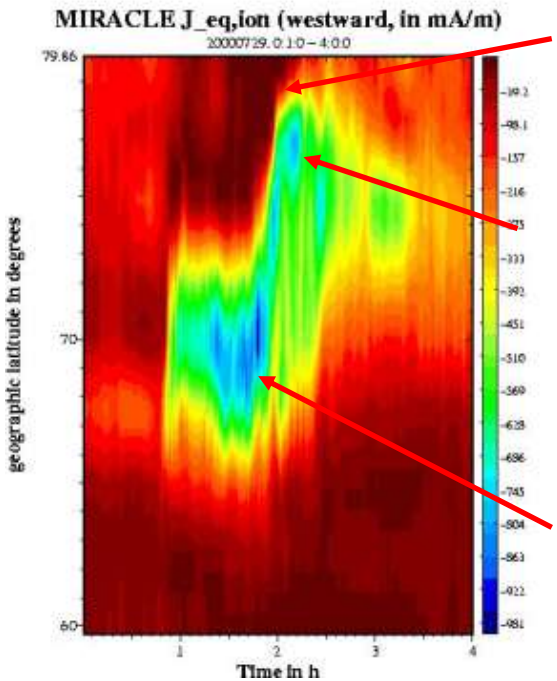
1) Mainly during slow streams of the solar wind (*SLOW*) (67,2%).

2) At the end of the high-speed stream FAST (~12,9%).

3) during *EJECTA* (16,7%). However it was only during *EJECTA* against to background of the slow stream (*EJECTA*, *SLOW*)

4) not observed during magnetic clouds (*MC)*

«Expanded» substorms



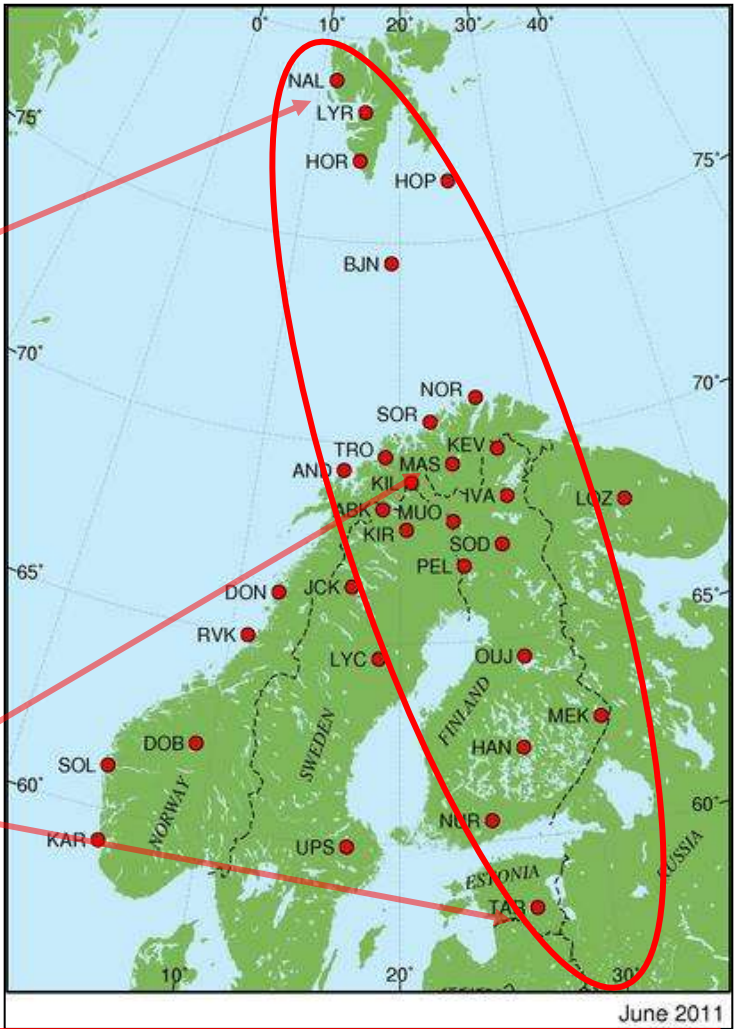
Fpk - latitude of the westward electojet poleward edge

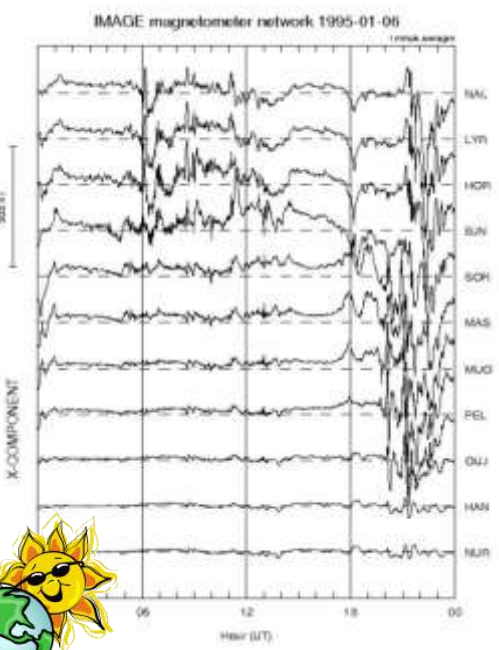
F_m -maximum latitude of the center of the westward electrojet

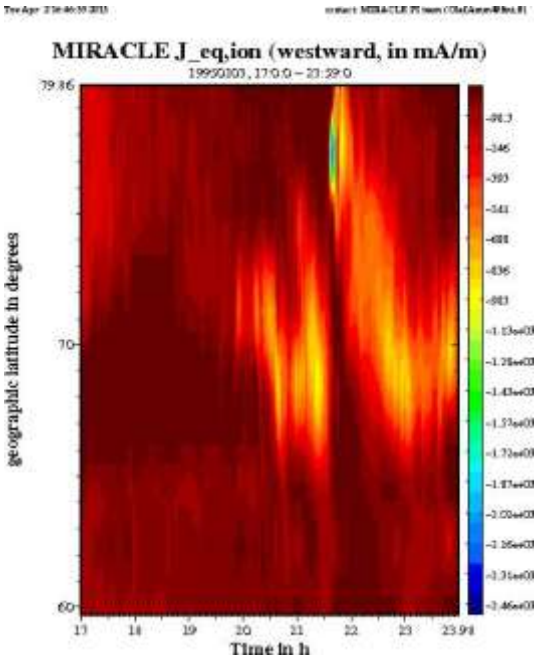
F_o- onset latitude of the center of the westward electojet

Maximal phase of substorm

Onsets of substoms

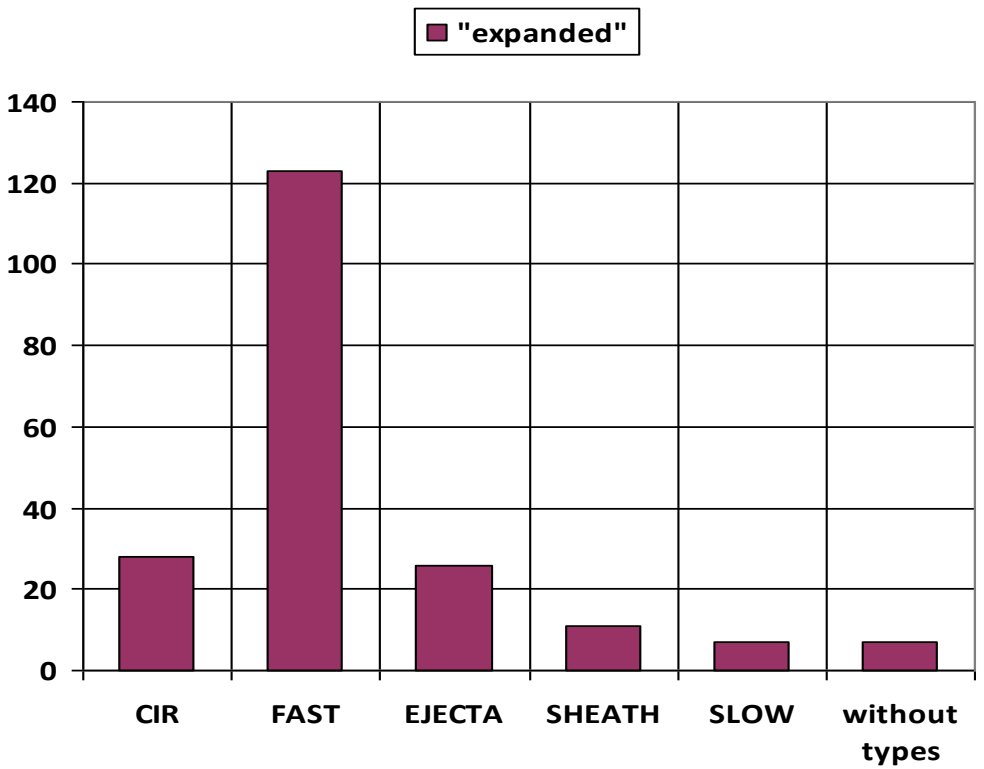


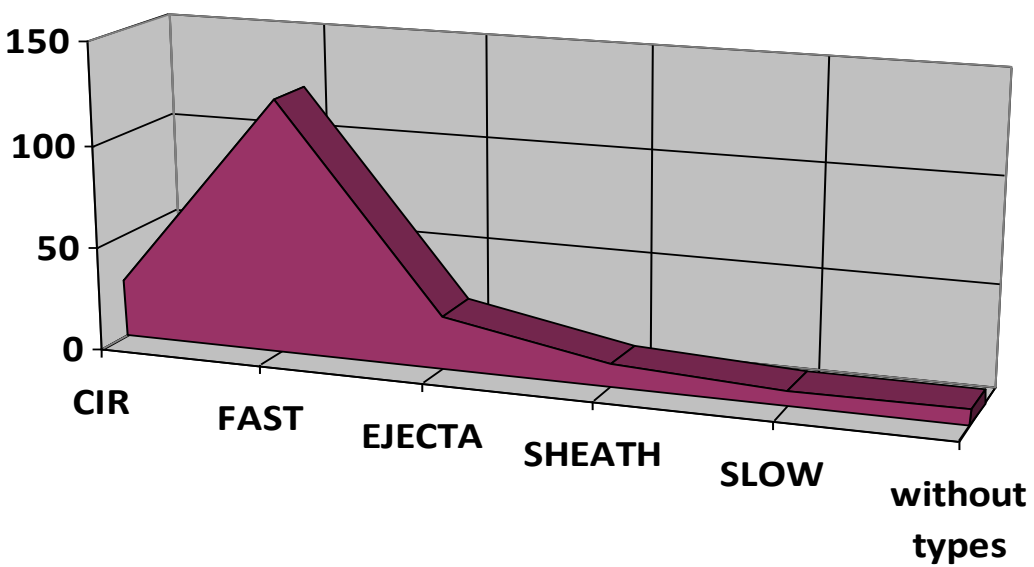




These substorms start at auroral latitudes and later on drift to the polar ones, higher than typical auroral oval location.
Namely, the substorm onset was observed at latitudes from
54º to 66º CGLAT (TAR- MAS), in the substorm maximal phase, the westward electrojet "center" was observed at latitudes 75.1-75.2º CGLAT (LYR-NAL).

Histograms of the number of "expanded" substorms recorded under different types of the solar wind





1) mainly during the high-speed streams (***FAST***) **(~ 61 %).**

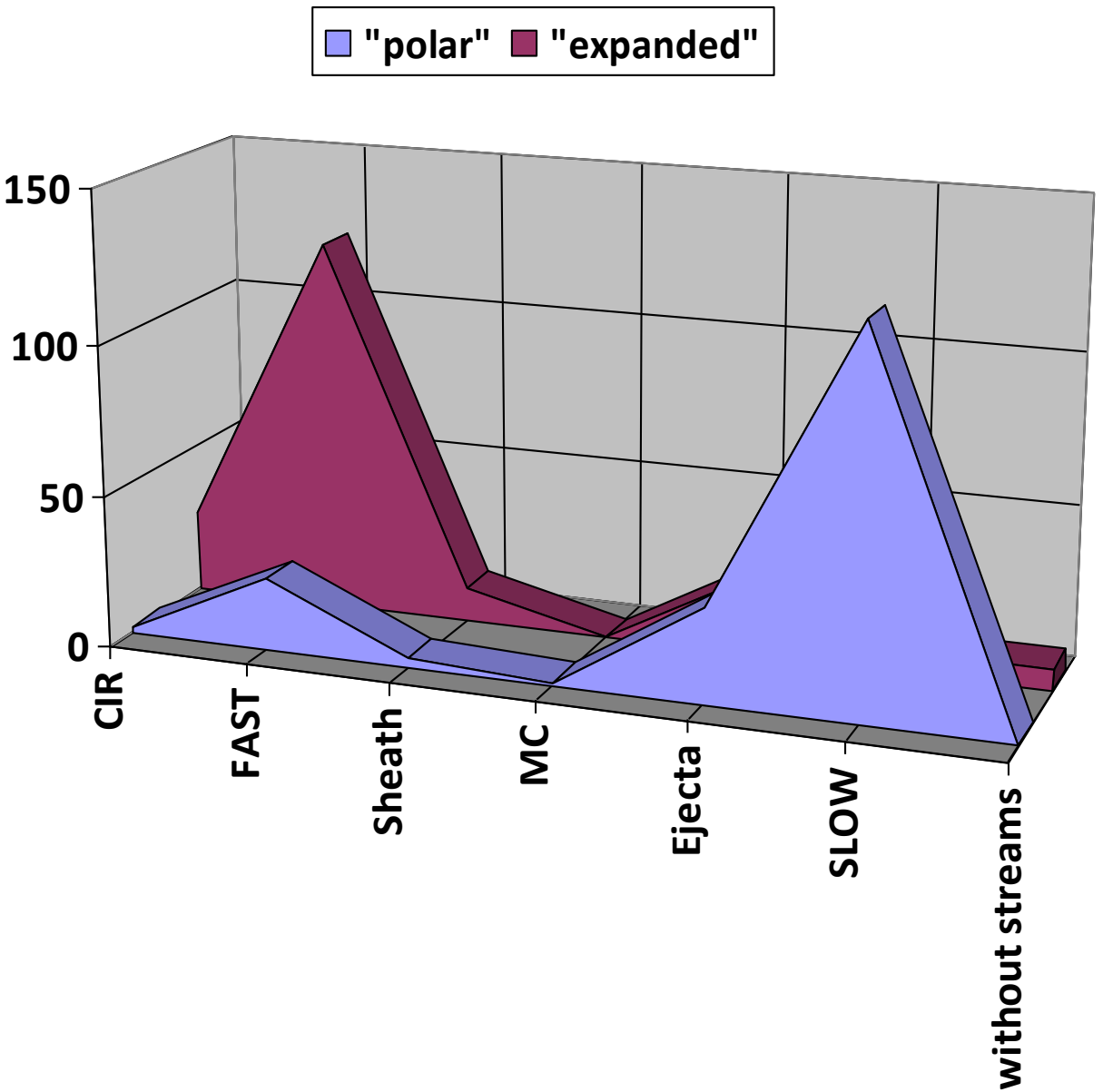
2) during two regions of the plasma compressions regions **CIR** and **SHEATH (~19 %).** These substorms could be observed not only against the background of fast stream **(CIR, FAST; SHEATH, FAST),** but against the background of a slow stream **(CIR, SLOW; SHEATH, SLOW).**

3) during ***EJECTA*** **(~13 %).** As a rule, against the background of a high-speed stream **(EJECTA, FAST).**

4) only few events **(~ 3,5%)** were registered during slow streams **(*SLOW*)**

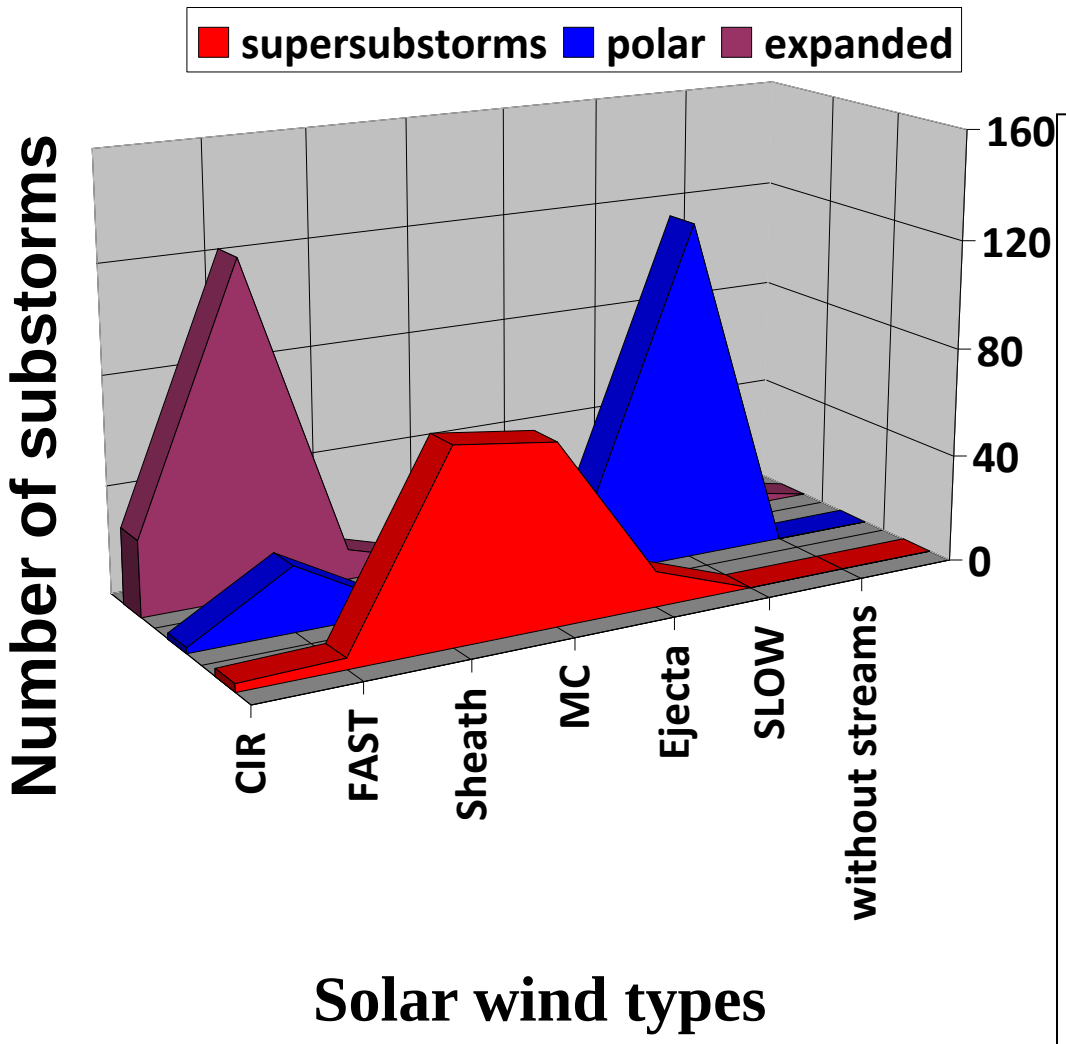
5) Some events **(~ 3,5%)** were observed **without certain types** of solar wind

Comparative histograms of the distribution of *two types of high-latitude substorms*



It is seen, that the distributions of these substorms differ sharply, the observation conditions of the "polar" and "expanded" substorms are almost opposite.

Comparative histograms of the substorm distributions by types of solar wind



Under different space weather conditions, different types of substorms are observed on the Earth's surface.

1. SSS **are observed during interplanetary manifestations of coronal mass ejections, i.e. during SHEATH, MC, EJECTA**

2. "expanded" substorms are registered during high-speed streams from coronal holes *(FAST, CIR*) and compressed plasma regions ahead MC*/EJECTA;*

***3*. "polar" substorms - during slow streams (SLOW) and EJECTA, which are associated with a slow stream, and at the end or beginning of a high-speed streams (FAST), when it is too late or too early for the solar wind speed to reach high values.**

Conclusions

The comparative analysis of the space weather conditions for "Expanded", "polar" substorms and "supersubstorms" demonstrated that they appear under different solar wind types.

The "polar" substorms behavior was opposite to the "expanded" substorms and to the "supersubstorms" behavior. So we can suppose that they reflect different sources. But this question is open yet.