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

MAGNETIC SUBSTORMS OF DIFFERENT TYPES DURING THE 23 AND 24 SOLAR CYCLES

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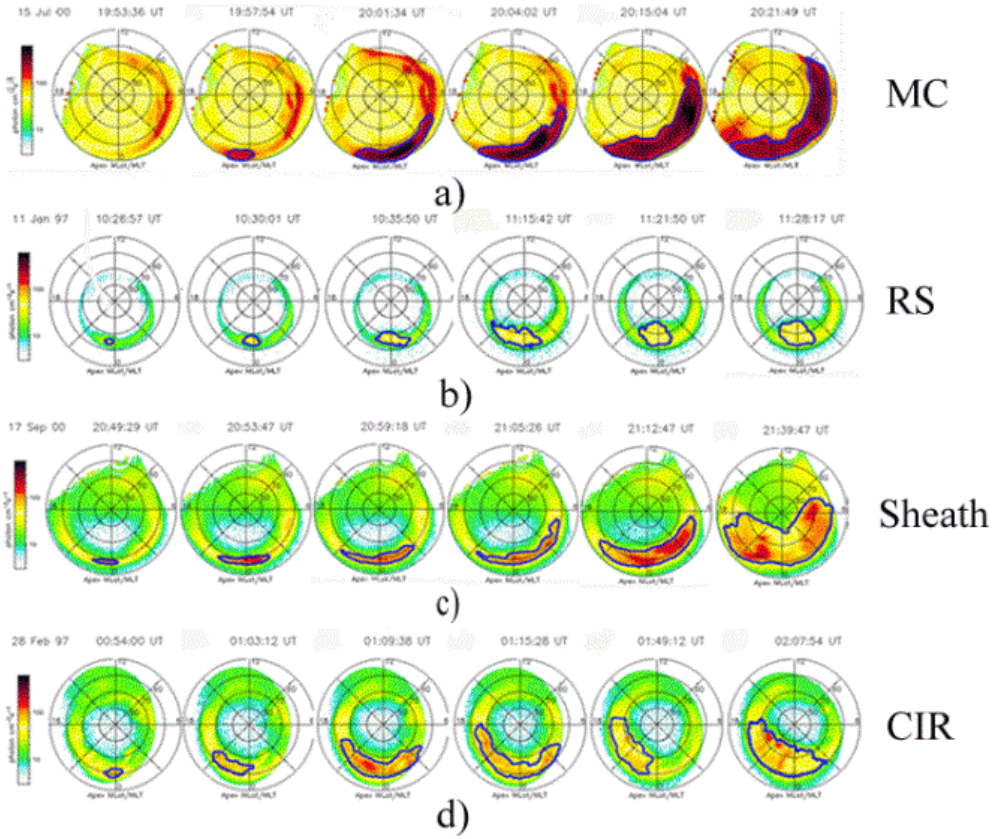
Sunny Beach, Bulgaria, May 30 - June 3, 2016

Introduction: auroral substorm



Examples of substorm development by Polar UVI data during the passage of different solar wind structures: magnetic cloud (3a), recurrent stream (3b), Sheath (3c) and CIR (3d). On each auroral image the blue curve delimits the bulge region.

Auroral substorm scheme:

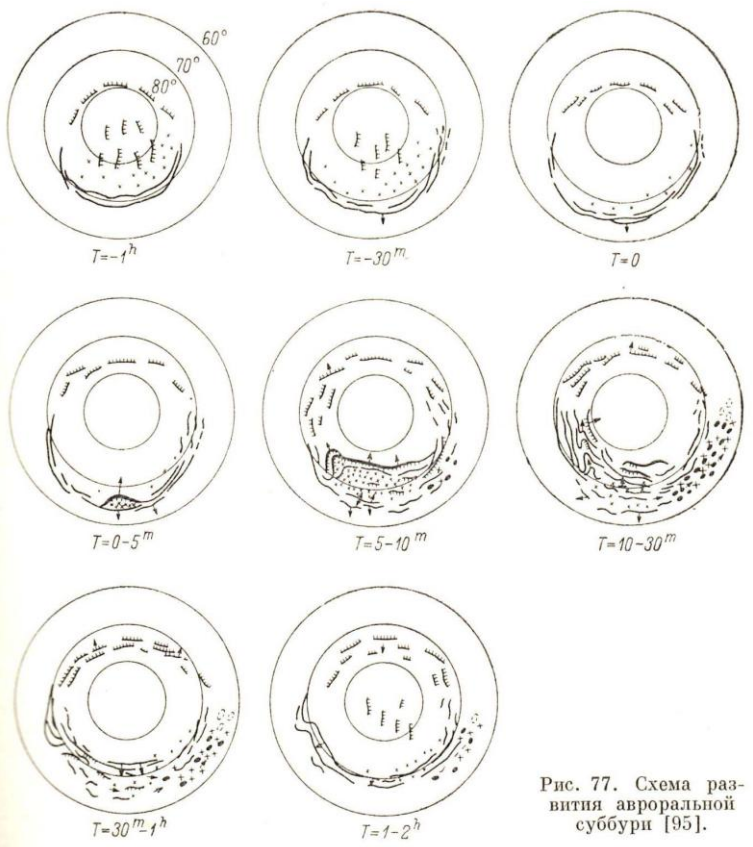


Рис. 77. Схема развития авроральной суббури [95].

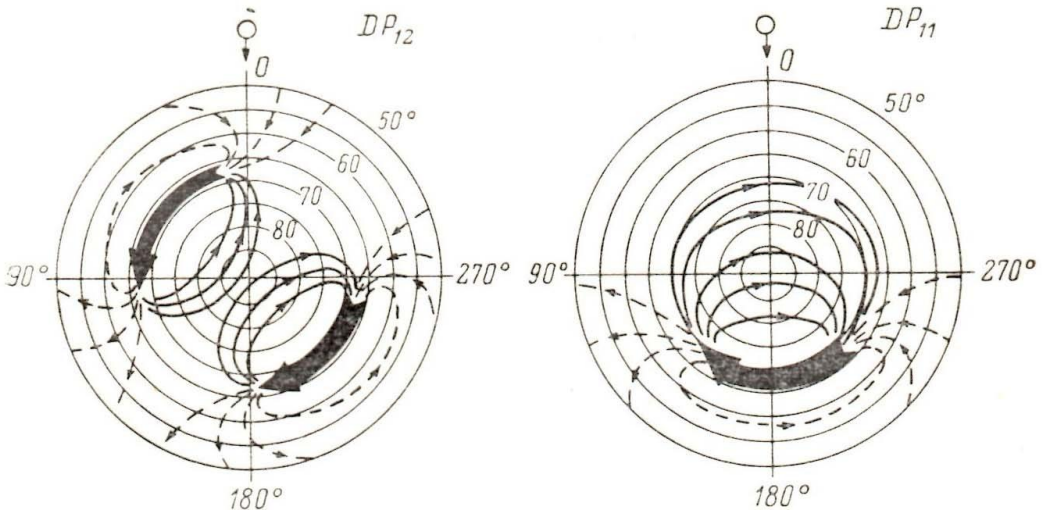
Solid lines- homogeneous aurora arcs;
Solid lines with vertical lines- rays form of auroras;
Shaded circles - pulsating auroras;
Crosses - diffuse glow.

It was established that the substorm development goes on in the following way: the substorm expansion phase begins with the flash of one arc, usually the most equatorial one between the existing already discrete auroral arcs.

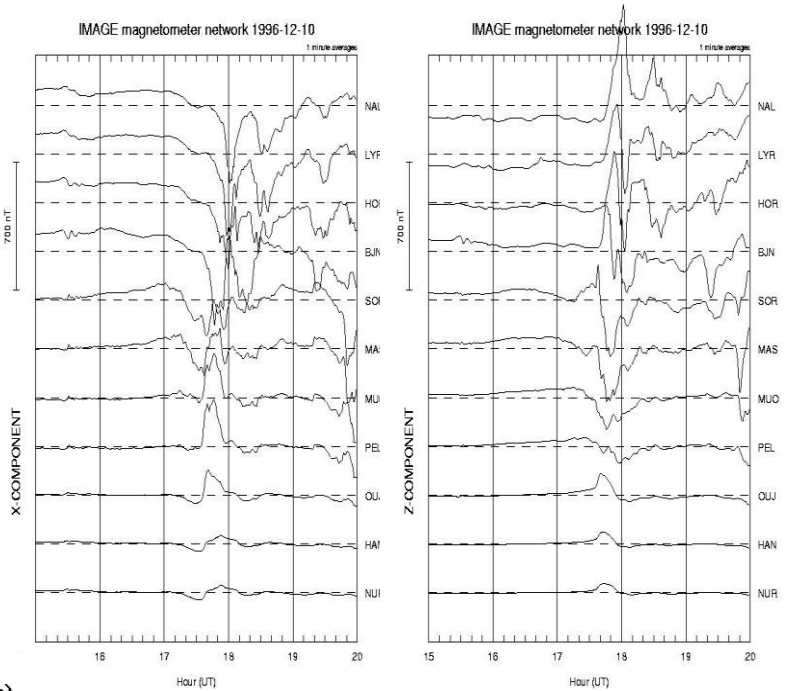
After this the auroral bulge - an area occupied by bright, short-lived arcs, forms. It is expanding in all directions, mainly toward the pole, to the West and to the East. Further, during the recovery phase, the auroral bulge begins to shrink, its polar edge moves to the equator and, the South one – to the pole, the bright discrete arcs fade.

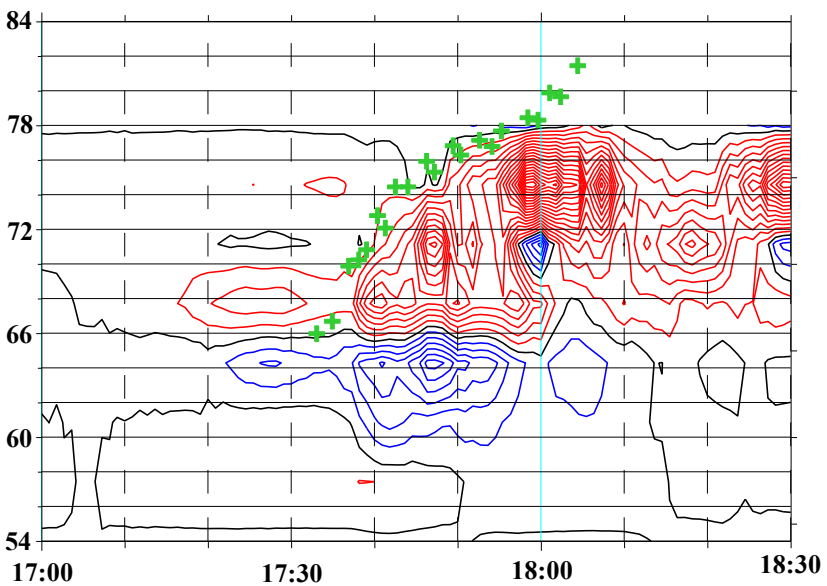
Introduction: magnetic substorm

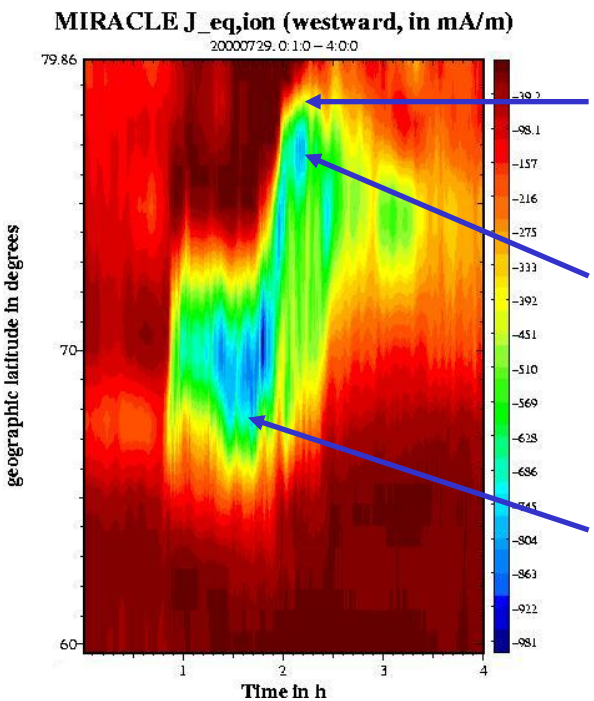
Equivalent current system of magnetic disturbances DP12 and DP11



Magnetograms of the IMAGE network:







Fpk - latitude of the westward electojet poleward edge

F_m -maximum latitude of the center of the westward electrojet

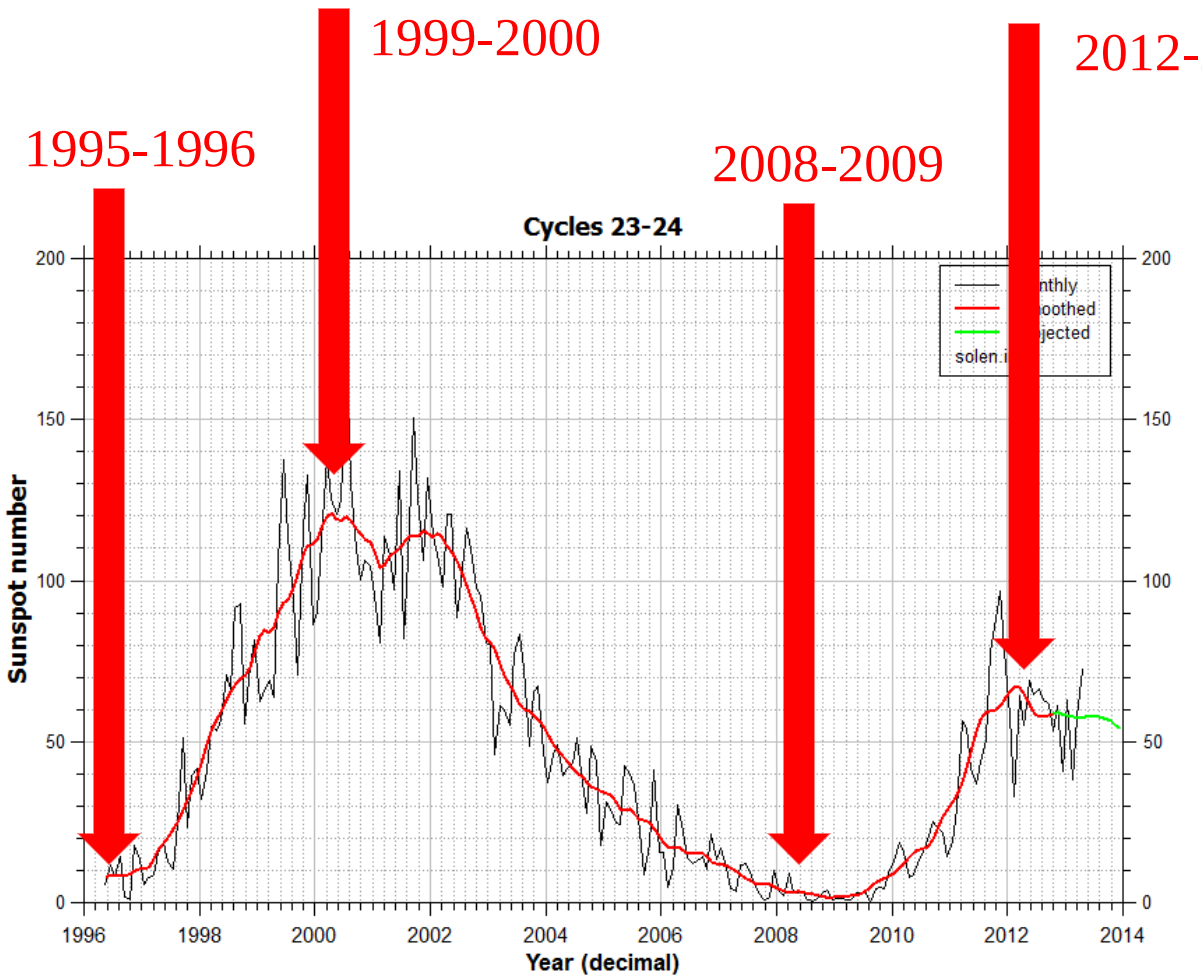
F_o- onset latitude of the center of the westward electojet

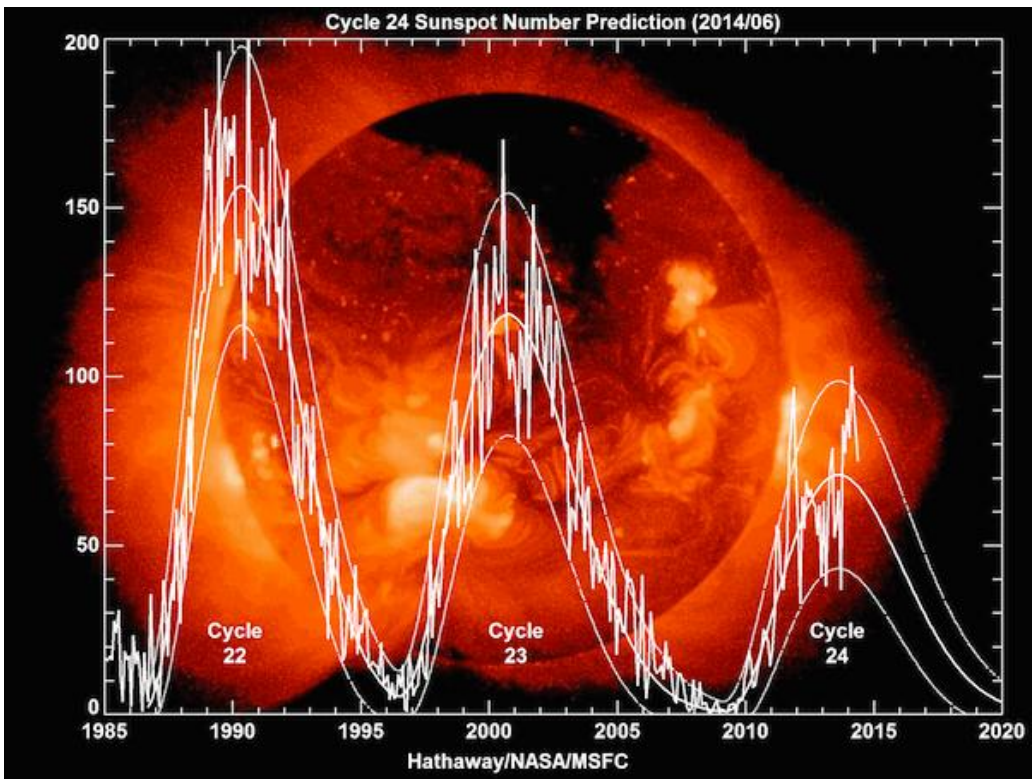
Isolines of the density of the ionosphere currents for substorm December 10, 1996. Symbols «+» shows the position of the polar edge of the auroral bulge, determined according to the Polar satellite.

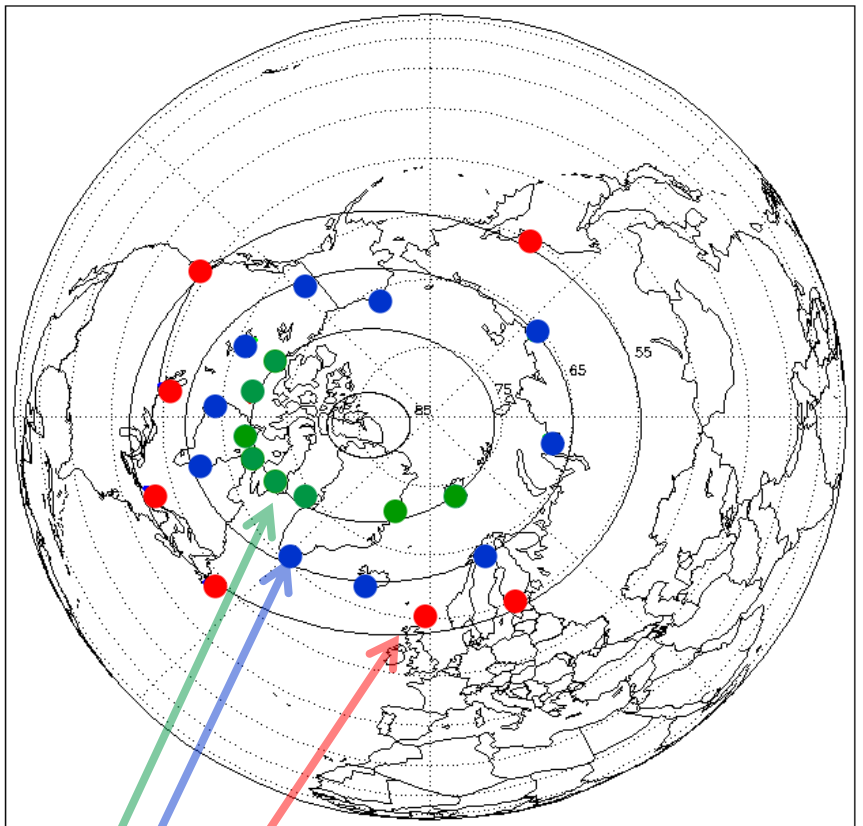
We analyzed occurrence of magnetic substorms during the 23 and 24 solar cycles:

1) during periods close to the solar cycles maximum (1999-2000, with the Wp> 100) and (2012-2013 with Wp ~ 60)

2) during the two solar cycles minimums (1995-1996) and (2008-2009)







Green points - the stations of contracted oval

Blue points - the normal oval stations

Red points - the extended oval stations

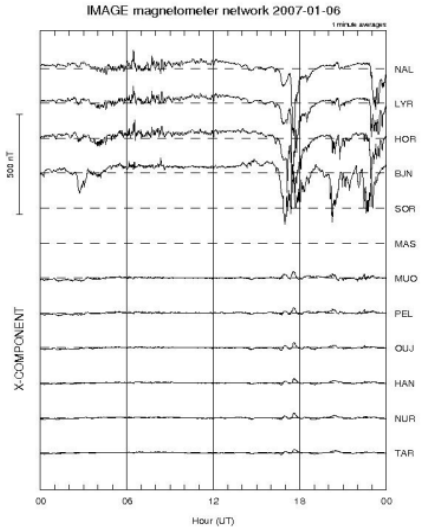
All considered substorms were divided into 3 types according to their location in relation to the auroral oval dynamics:

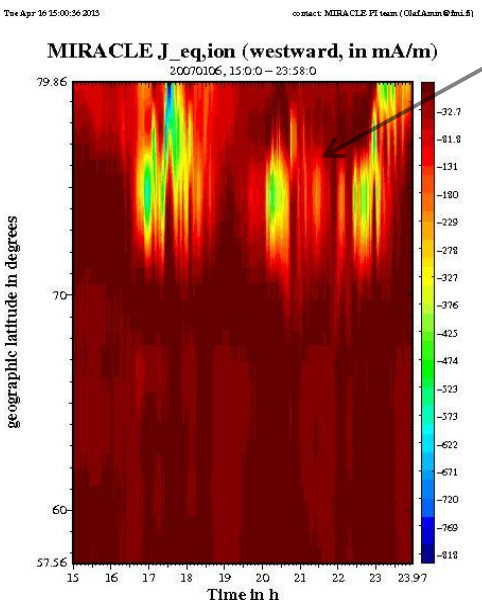
1) **The first type** – the substorms which are observed only at the auroral latitudes (called **"usual"** substorms);

2) **the second type** – the substorms which propagate from the auroral geomagnetic latitudes to the polar ones (called **"expanded"** substorms, according to an expanded oval dynamics);

3) **the third type** – the substorms which are observed only at the geomagnetic latitudes above ~70 degrees in the absence of simultaneous magnetic disturbances below 70 degrees (called **"polar"** substorms, according to a contracted oval dynamics).

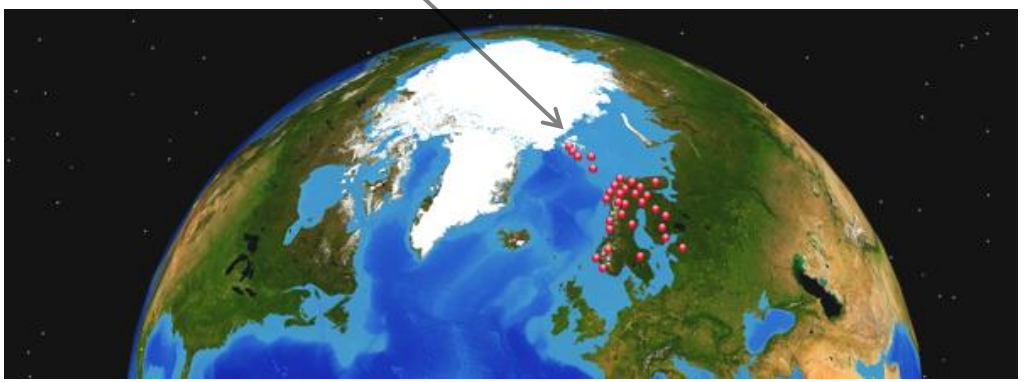
Examples of "polar" and “expanded" substorms

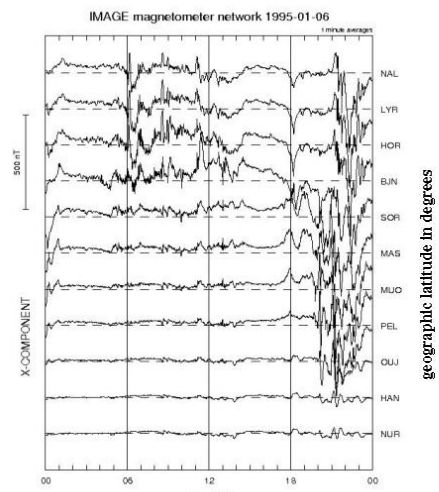


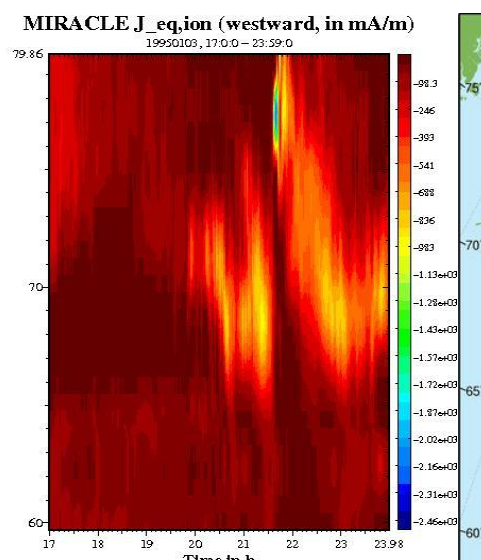


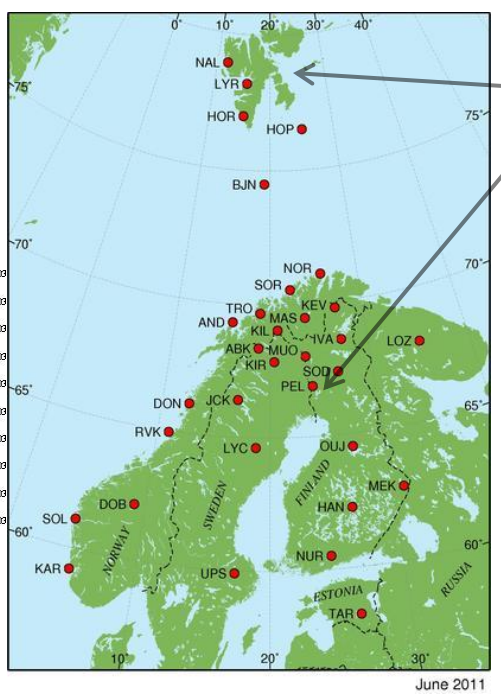
1) "polar" substorms:

the disturbance begins at geomagnetic latitudes above 71º, and at latitudes below 70º geomagnetic disturbances are absent.



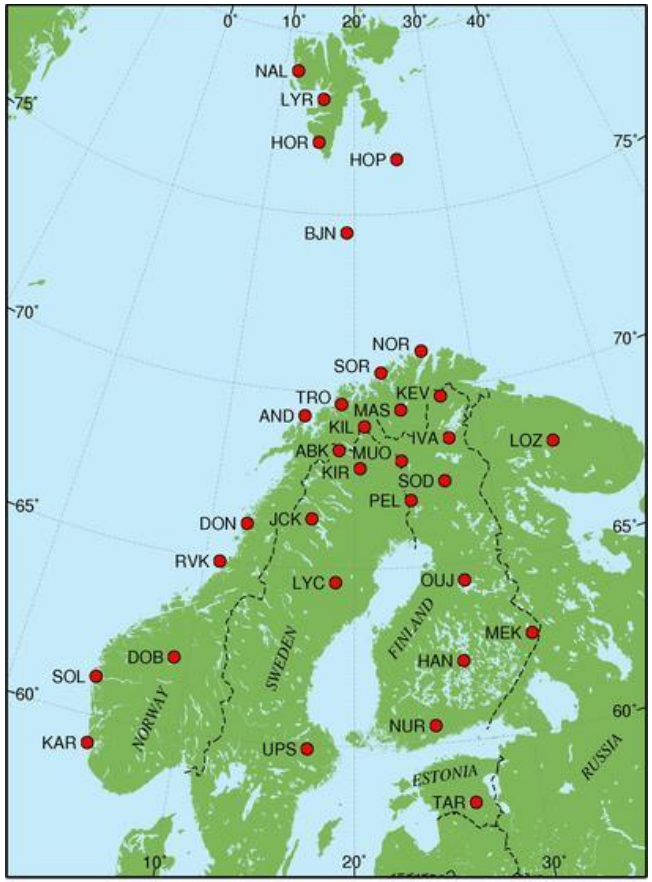






2) “expanded” substorms:

The second type of substorms begin at latitudes of the auroral zone, then the disturbances move to the pole.
In the maximum of the substorm development westward electrojet (namely "center" of the westward electrojet) is observed at very high geomagnetic latitudes (>75º).

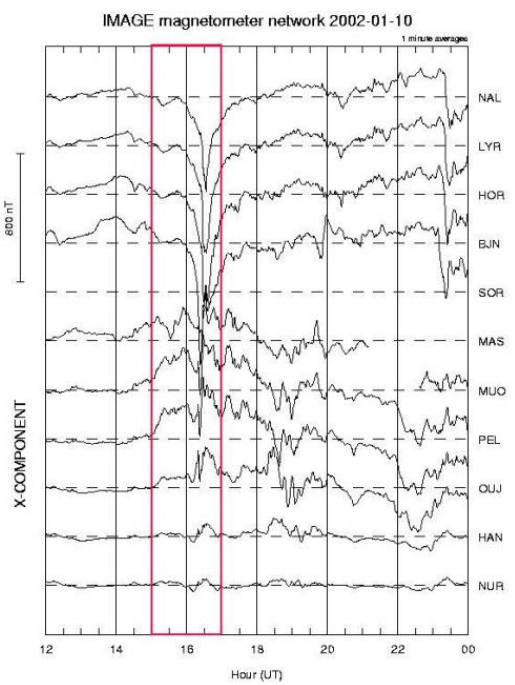


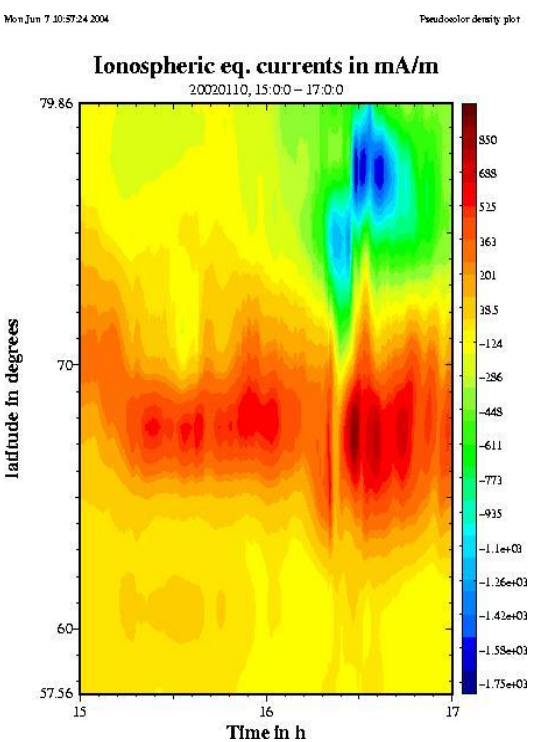
To study the shift of the westward electrojet in latitude ground-based magnetometer stations chain IMAGE was used, namely the meridional chain NUR-NAL (Nurmijarvi - Ny Alesund) from 56.89° to 75.25° geomagnetic latitude.

<u>The aim of this work</u> is analysis of the space weather conditions before the onset of diferent types of substorms, namely to compare the following substorm characteristics :

1) **seasonal variation,**
2) **PC-index before substorms.**
3) **the solar wind and IMF parameters before the substorm onset;**
4) **the occurrence of substorm of three types during different types of the solar wind streams.**

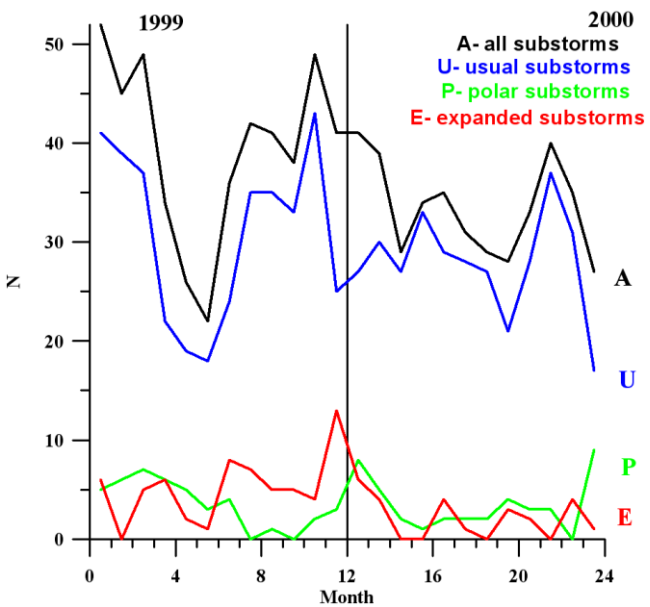
Data from IMAGE magnetometer network for periods in 1995-96, 1999-2000, 2008-2009, 2012-2013, close to two minimums and two maximums of solar activity, are used.

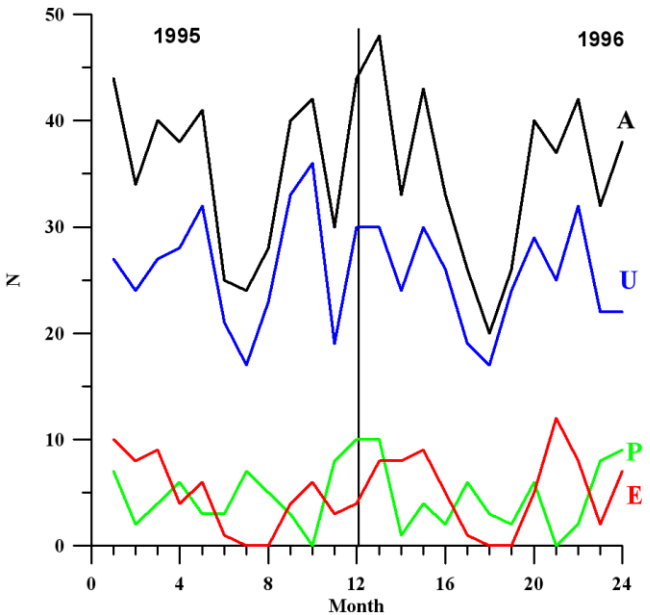


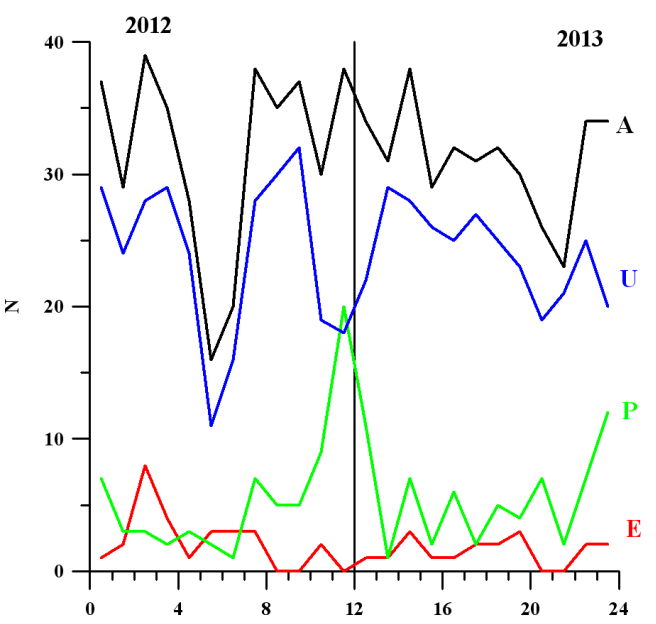


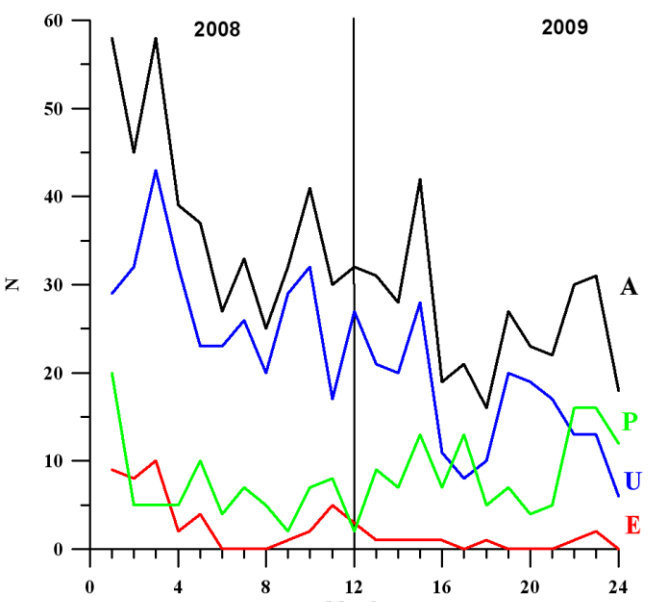
The characteristics of the solar wind and the interplanetary magnetic field were determined according to OMNI base.

Seasonal variations of substorm number during solar cycle maxima (1999-2000 и 2012-2013) and solar cycle minimums (1995-96 и 2008-2009)



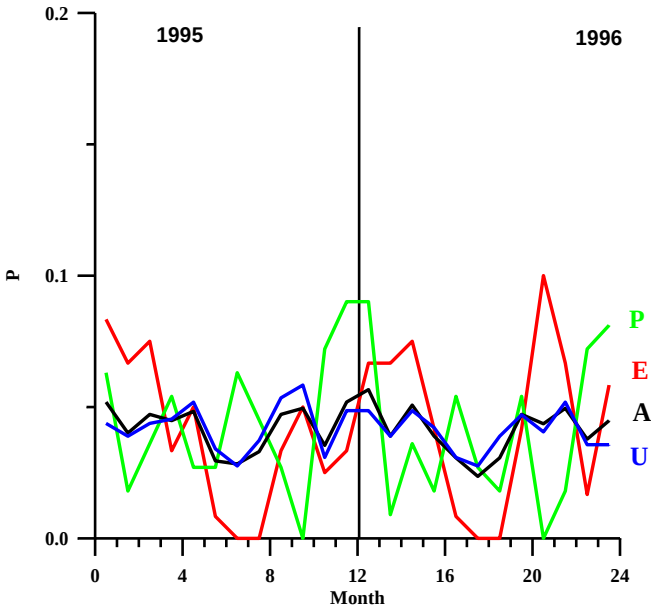


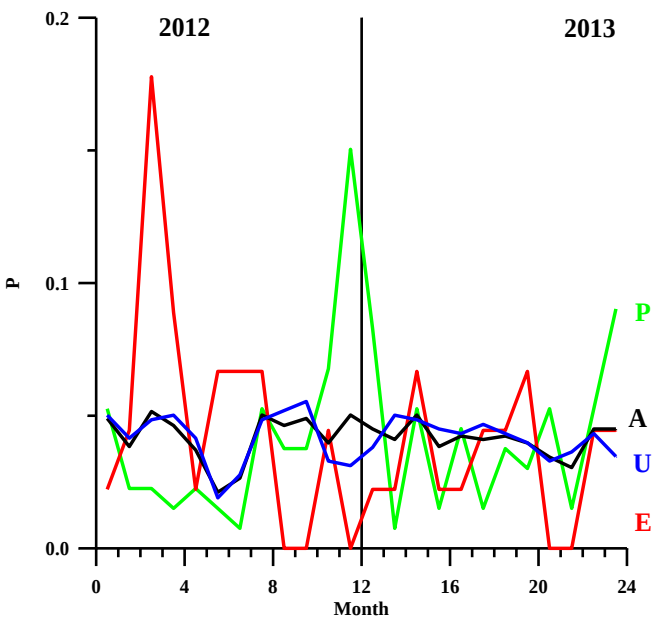




Number of substorms is higher in 1999-2000 (1995-96) than in 2012-2013 (2008-09); the summer minimums of substorms number and spring and autumn maxima are common to both periods;

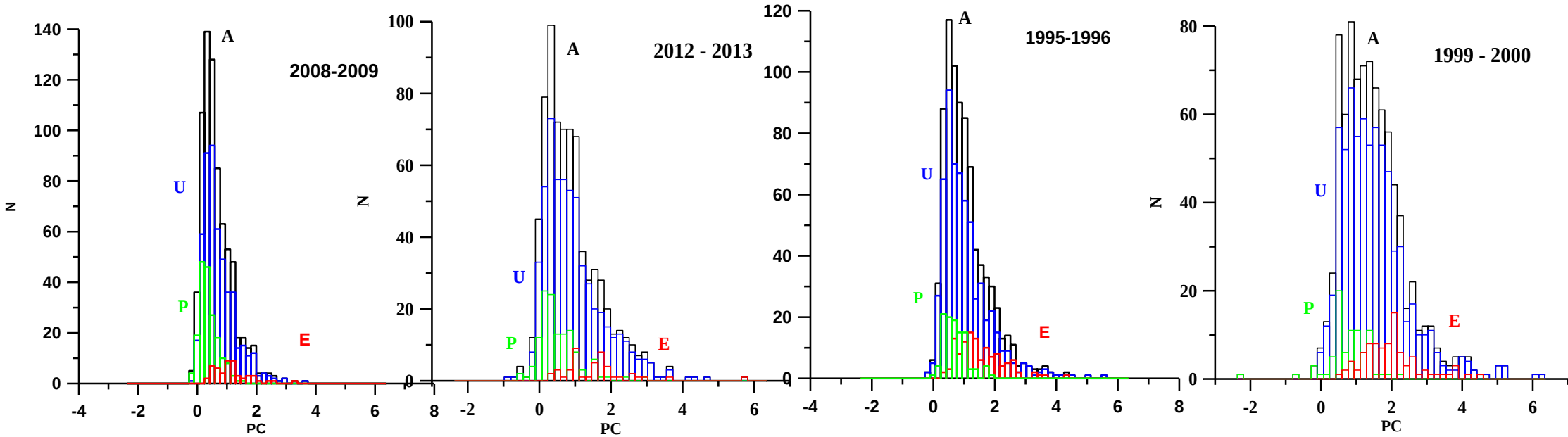
The normalized distribution of substorm number by month:





the “polar” substorms behavior was opposite to “expanded” substorms behavior

The values of the PC index before substorms during the two solar cycle maxima and two minimums



Type of substorms	1995-1996	1999-2000	2008-2009	2012-2013
"expanded" substorms	1.5±0.7	2.0±0.8	1.1±0.8	1.6±0.9
"polar" substorms	0.7±0.4	0.77±0.6	0.4±0.3	0.52±0.5
"usual" substorms	1.1±0.8	1.5±0.9	0.7±0.5	0.95±0.8
All substorms	1.1±0.8	1.47±0.9	0.7±0.5	0.9±0.8

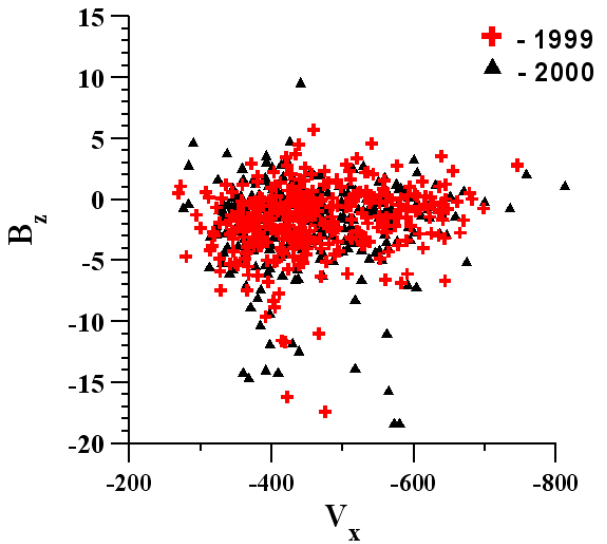
1) For all three types of substorms which observed during 24 solar cycle the PC-index values are lower than for substorms during the 23 solar cycle;

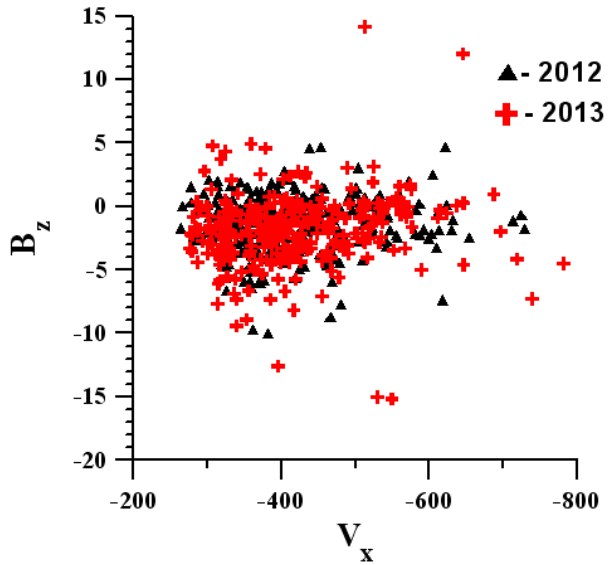
2) the PC-index values for substorms during solar cycle minimums (1995-96 and 2008-09) are ~ 1.3 times lower than for substorms during the solar cycle maximums (1999-2000 and 2012-2013).

3) the PC-index values are 2.6 - 3.0 times lower for the "polar" substorms than for the "expanded" substorms.

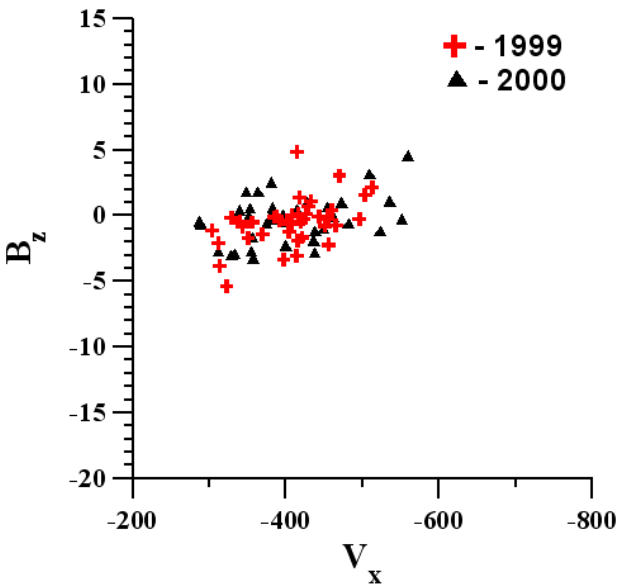
Solar wind parameters before the onset of substorms

"usual" substorms:

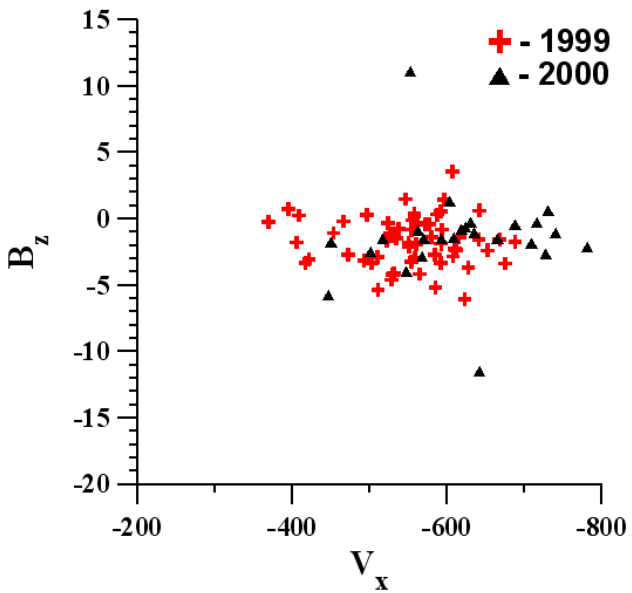


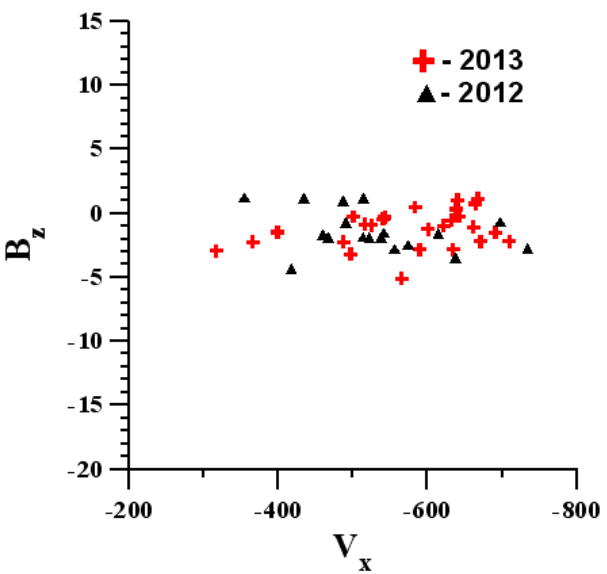


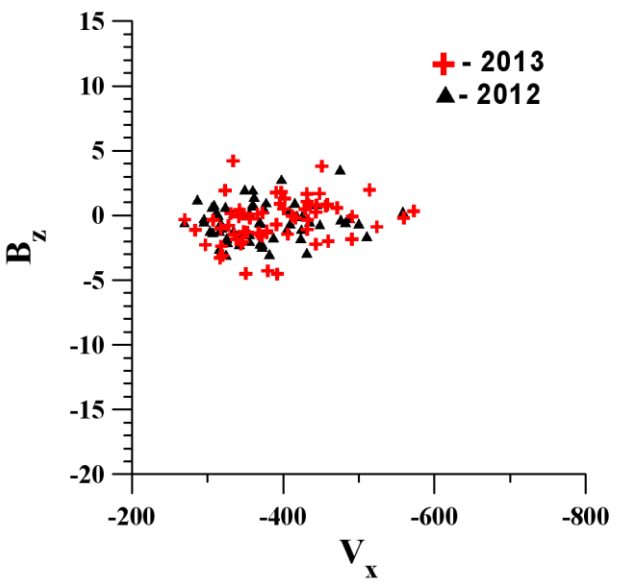
"polar" substorms:



"expanded" substorms :

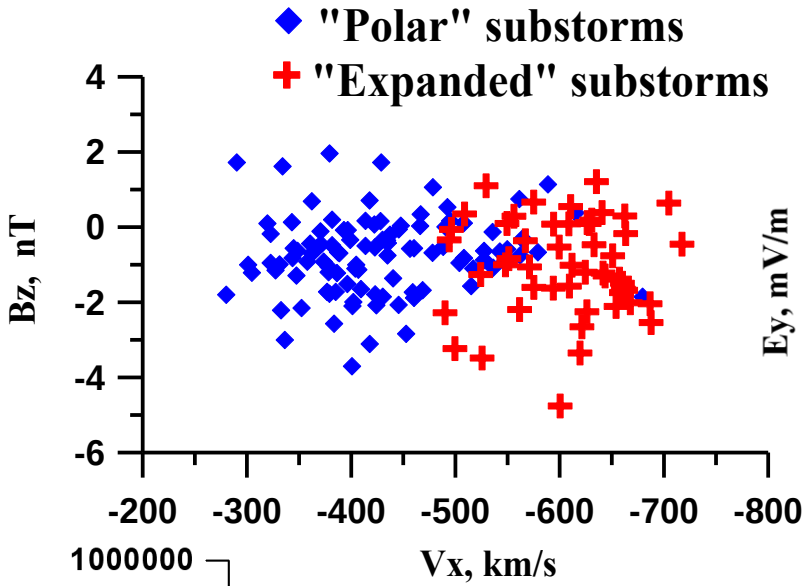


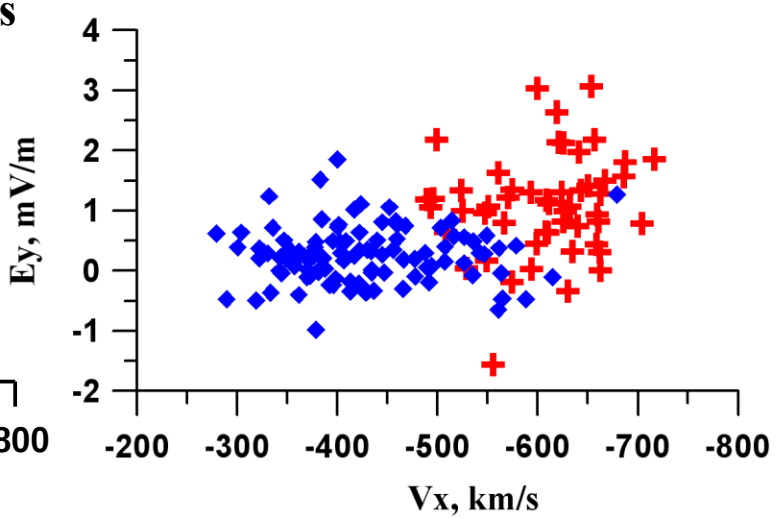


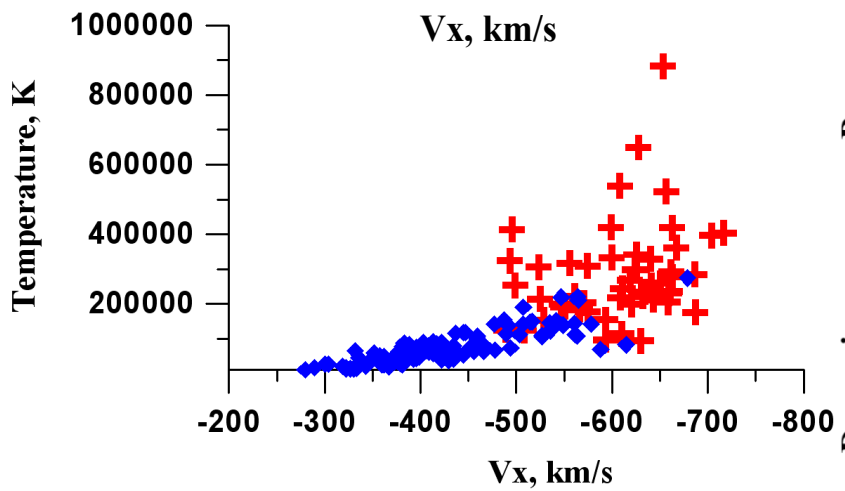


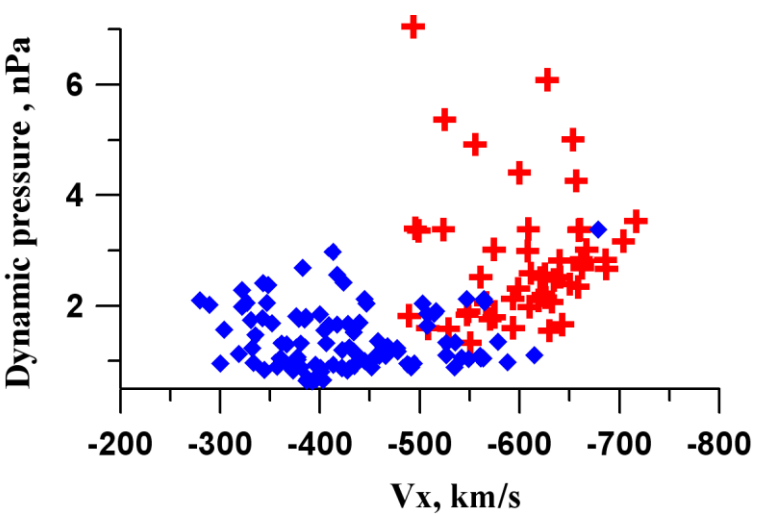
Significant differences in distributions of the solar wind parameters (Vx, Bz, P, N, T) before the onset of substorms between different solar activity periods have been not found.

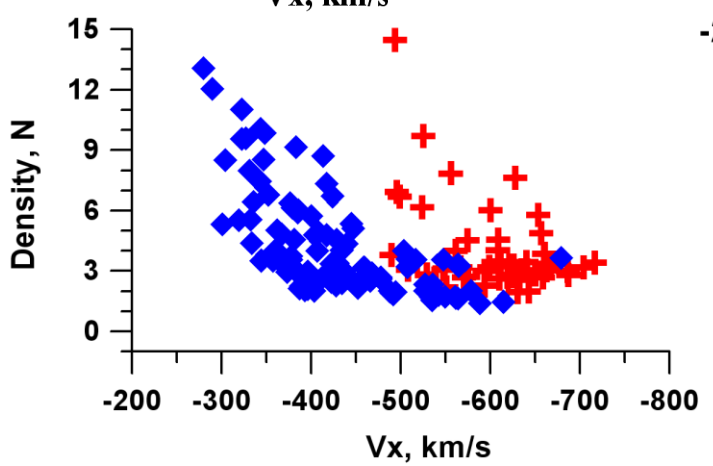
Solar wind parameters before the appearance of “polar” and “expanded” substorms









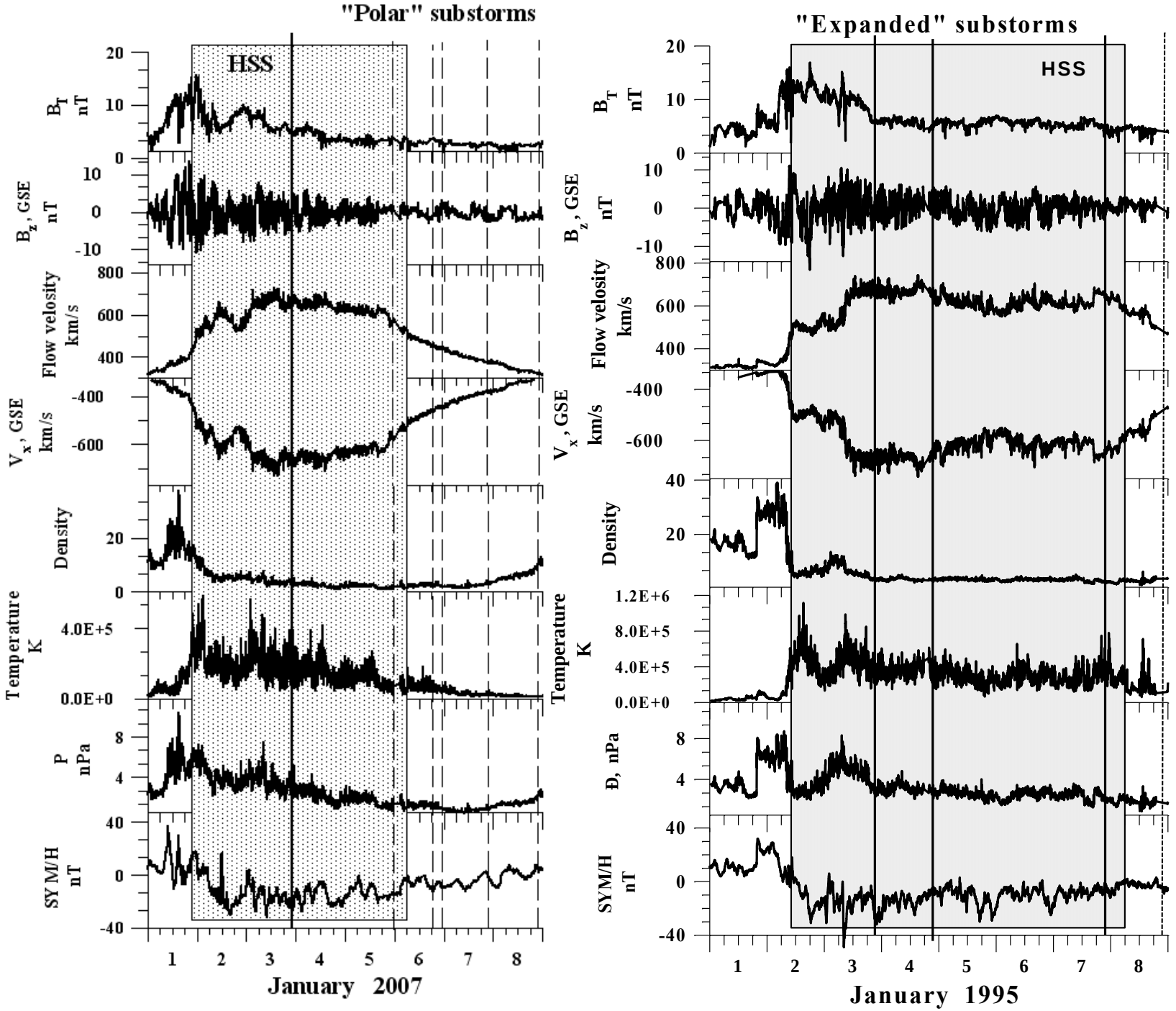


The average B_Z component of IMF, the E_Y component of the interplanetary electric field, the temperature (T), the dynamic pressure (P) and the density (N) of the solar wind, observed before the "polar" and “expanded" substorms, are shown in the figures.

The main factor on which the difference between these two types of substorms is clearly expressed is the solar wind velosity.

The “expanded” substorms are observed at higher values of temperature and pressure of the solar wind than "polar" substorms.

Solar wind conditions for the appearance of “polar” and “expanded" substorms



Parameters of the solar wind and the IMF (B_T, B_Z, V, V_X, N, T, P) and index SYMN \ H for two high-speed streams: January 2-8, 2007 and January 2-8, 1995. The boundaries of the high-speed streams (HSS) are shown by shaded gray rectangles. The onset of the "polar" and “expanded" substorms according IMAGE are marked by vertical solid and dashed lines, respectively.

Conclusions

1. Seasonal variations:

(i) Number of substorms is higher in 1999-2000 (1995-96) than in 2012-2013 (2008-09);
(ii) the summer minimums of substorms number and spring and autumn maxima are common to all periods**;**
(iii) the “polar” substorms behavior was opposite to “expanded” substorms behavior.

2. Solar wind and IMF parameters:

(i)There were no significant differences of the solar wind parameters (V_X , B_Z, P, N, T) before substorms in different solar cycle periods.
(ii) “Polar” substorms are observed after the passage of a HSS of the solar wind (when the velocity is reduced from high to low values). “Expanded" substorms , on the contrary, are observed during the passage of a HSS of the solar wind, increased temperature and pressure of the solar wind.

3. PC-index:

(i) For all three types of substorms which observed during 24 solar cycle the PC-index values are lower than for substorms during the 23 solar cycle;
(ii) the PC-index values for substorms during solar cycle minimums (1995-96 and 2008-09) are ~ 1.3 times lower than for substorms during the solar cycle maximums (1999-2000 and 2012-2013);
(iii) the PC-index values are 2.6 - 3.0 times lower for the "polar" substorms than for the "expanded" substorms.


Thank you for your attention !!