



Seventh Workshop “Solar influences on the magnetosphere, ionosphere and atmosphere”

Substorms observations during two strongly disturbed periods - in March 2012 and March 2015

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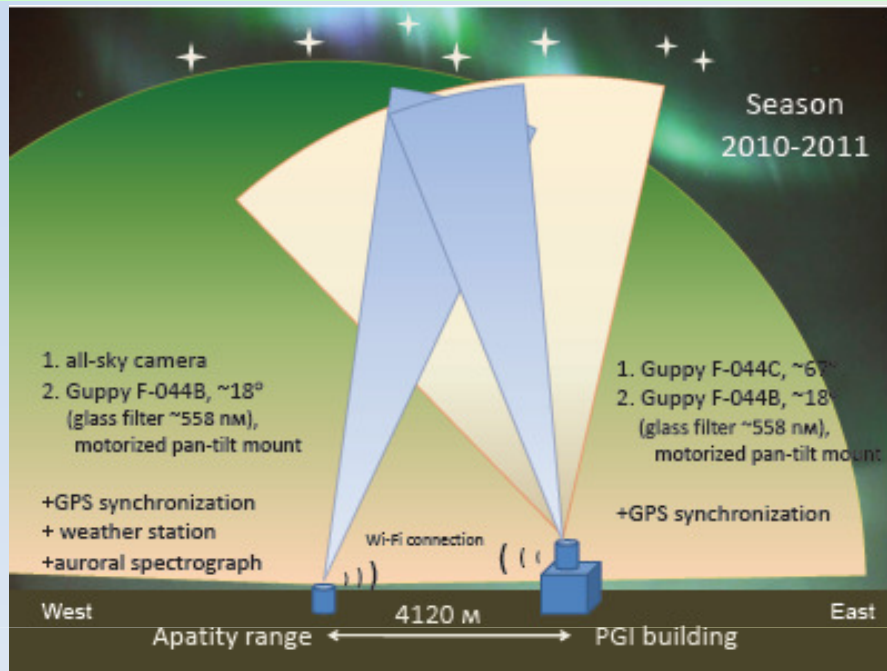
1–5 June 2015, Sunny Beach, Bulgaria

Instrumentation and data used

Goal: to study substorm developments during different storms under strongly disturbed geomagnetic conditions.

- Measurements from **MAIN** (Multiscale Aurora Imaging Network) in Apatity during two strongly disturbed periods in March 2012 and March 2015 have been used.
- Solar wind and interplanetary magnetic field parameters were taken from CDAWeb (http://sdaweb.gsfc.nasa.gov/cdaweb/istp_public/). OMNI data (spacecraft-interspersed, near Earth solar wind data) were used to reveal different solar wind streams.
- K_p indices were taken from NOAA National centers for environmental information:
http://www.ngdc.noaa.gov/stp/GEOMAG/kp_ap.html via ftp.
- Substorms presence was verified by ground-based data of IMAGE magnetometers network, and the substorms development was studied by data of Apatity all-sky camera.

Instrumentation and data used



MAIN (Multiscale Aurora Imaging Network) in Apatity

Location of the cameras during winter seasons

Apatity is situated at auroral latitudes, and the IMAGE stations closest to it are Muonio, Lovozero and

Pello, and by CGM lat. the closest station is Pello.

Stations coordinates

Abbrev.	name	geogr. lat., N	geogr. long., E	CGM lat., N	CGM long., E
MUO	Muonio	68.02	23.53	64.72	105.22
LOZ	Lovozero	67.97	35.08	64.23	114.49
APT	Apatity	67.58	33.31	63.86	112.9
PEL	Pello	66.90	24.08	63.55	104.92

Instrumentation and data used

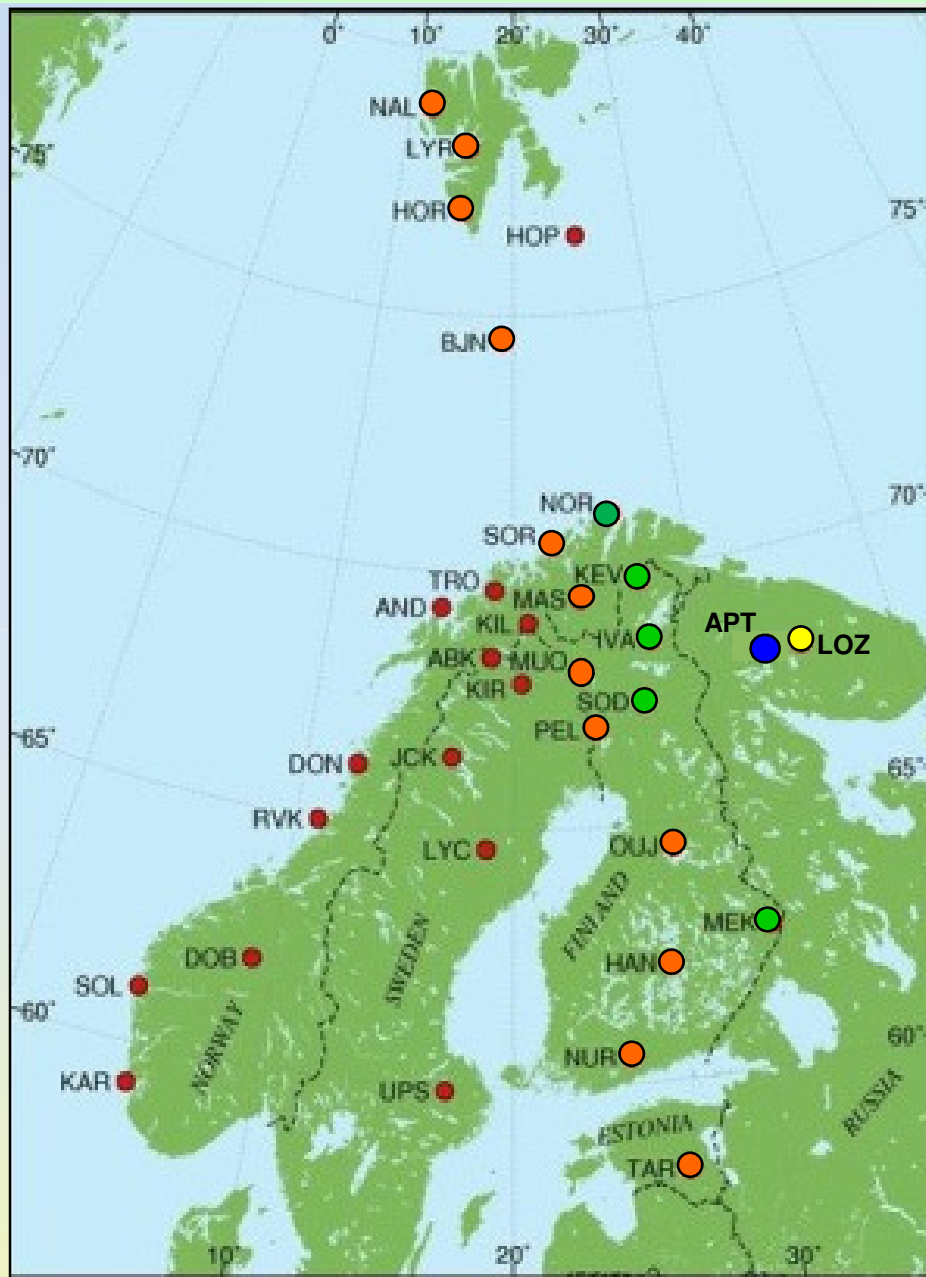
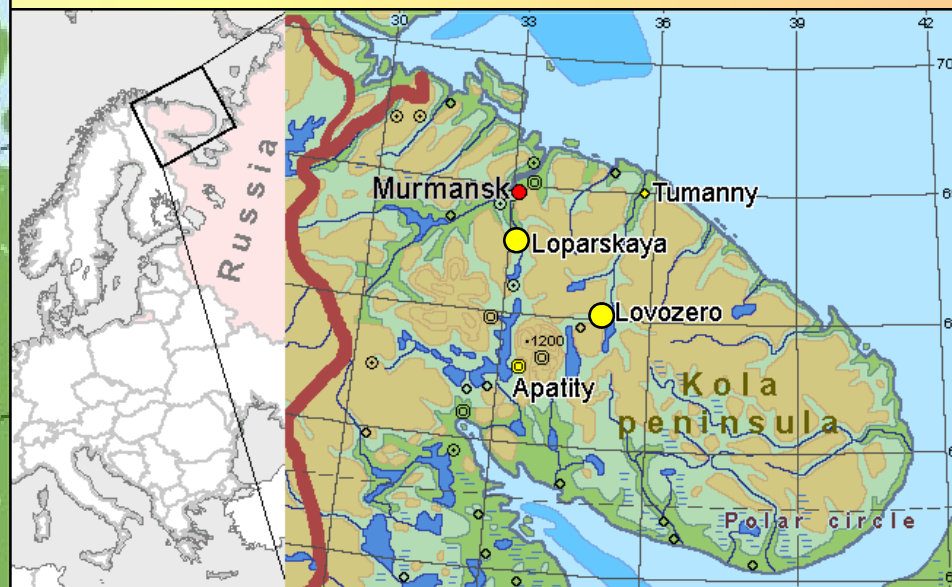
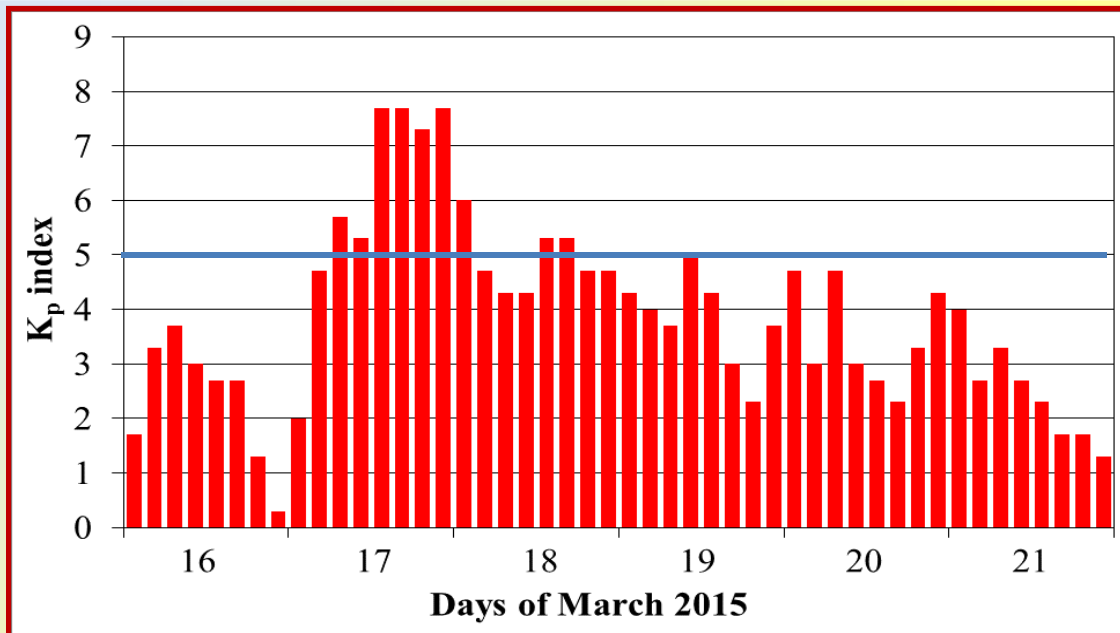
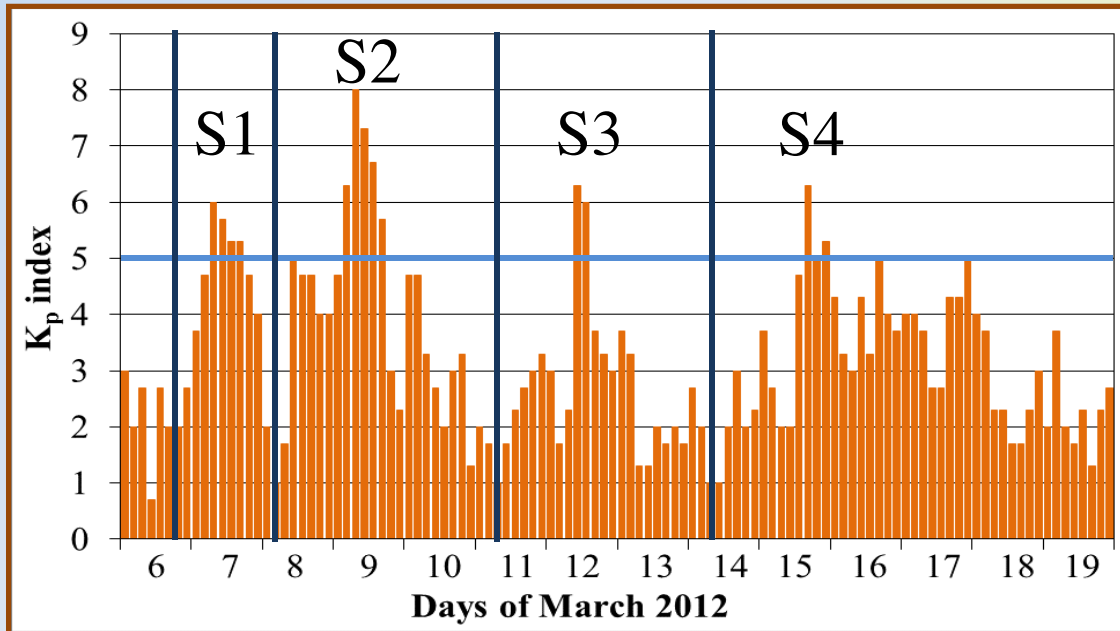


Image magnetometer set

- Apatity location
- Stations from the TAR-NAL chain
- Meridional stations nearer Apatity
- Loparskaya and Lovozero stations
- Other IMAGE stations

Apatity region map





k_p index variations during the examined periods. The border of the “storm” conditions is marked by the blue vertical line. During the first period there are 4, relatively short, periods of storm activity, named events S1, S2, S3 and S4. During S2 the level of severe storm was reached, the others are at the level of moderate storms. In the second period, a fast increase of k_p was observed, and it reached the level of severe storm.

Instrumentation and data used

Presented cases:

7-17 March 2012:

Case 1: 7.03.2012, 18:45UT

- Dst min =-98 nT,
- near the Dst min,
- recovery phase, Dst=-45nT;

Case 2: 10.03.2012, 18:35 UT

- Dst min =-148 nT,
- late recovery phase, Dst=-50 nT;

17-20 March 2015:

Dst min =-235 nT

Case 3: 17.03.2015, 17:36:40 UT

- Main phase, Dst =-163 nT;

Case 4: 17.03.2015, 19:59:40 UT

- Main phase, Dst = -160 nT

Case 5: 17.03.2015, 22:56:40 UT

- recovery phase, close to Dst min
- Dst=-230 nT;

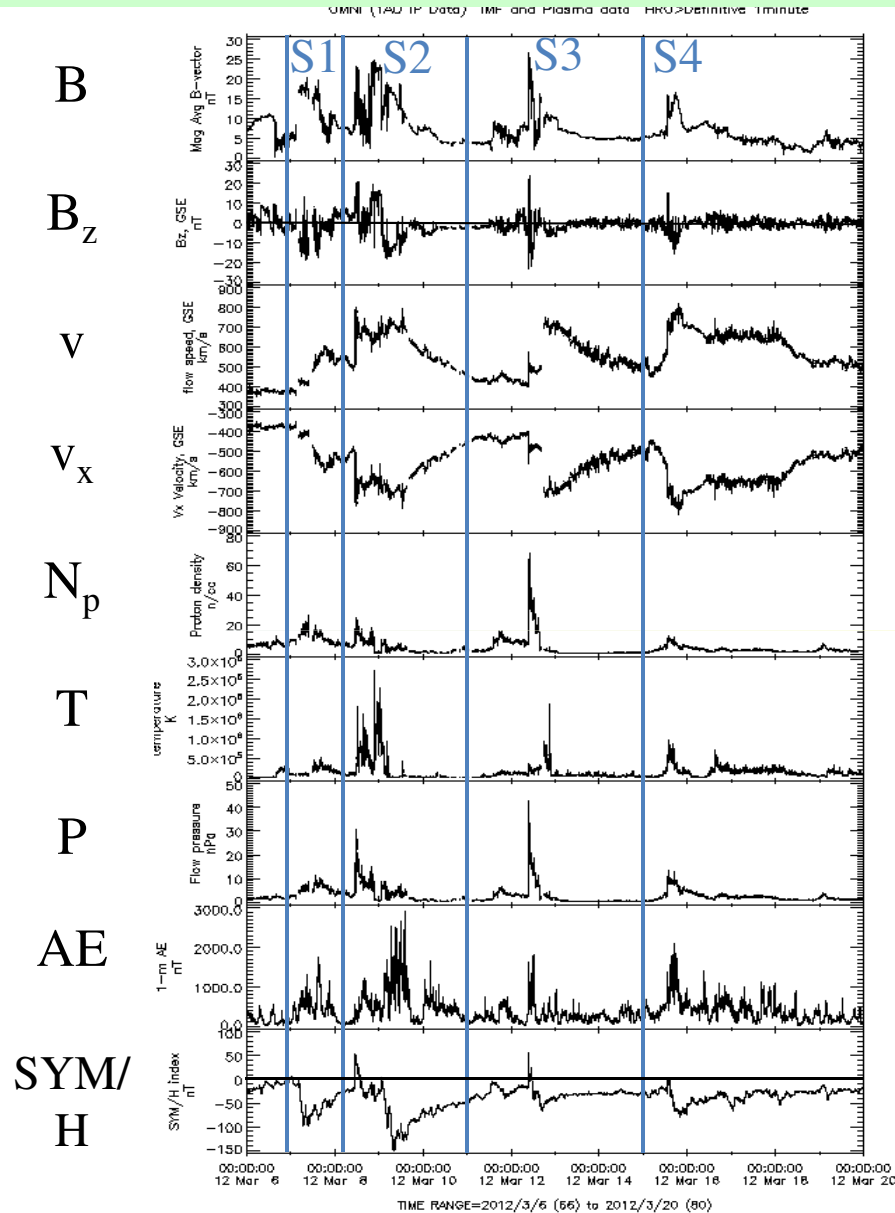
Case 6: 20.03.2015, 21:43:20 UT

- Late recovery phase, Dst=-45 nT

Data from the all-sky camera (images and keograms) and Guppy F-044C (GC) camera with field of view $\sim 67^\circ$ (keograms) are shown.

The GC camera data were corrected regarding the exposition time, the gain, the heterogeneity of the dark field, and the objective transmittance change depending on the angle of observation. The keograms were constructed in direction magnetic North (up). The zero angle coincides with zenith.

Interplanetary conditions, 7-20.03.2012



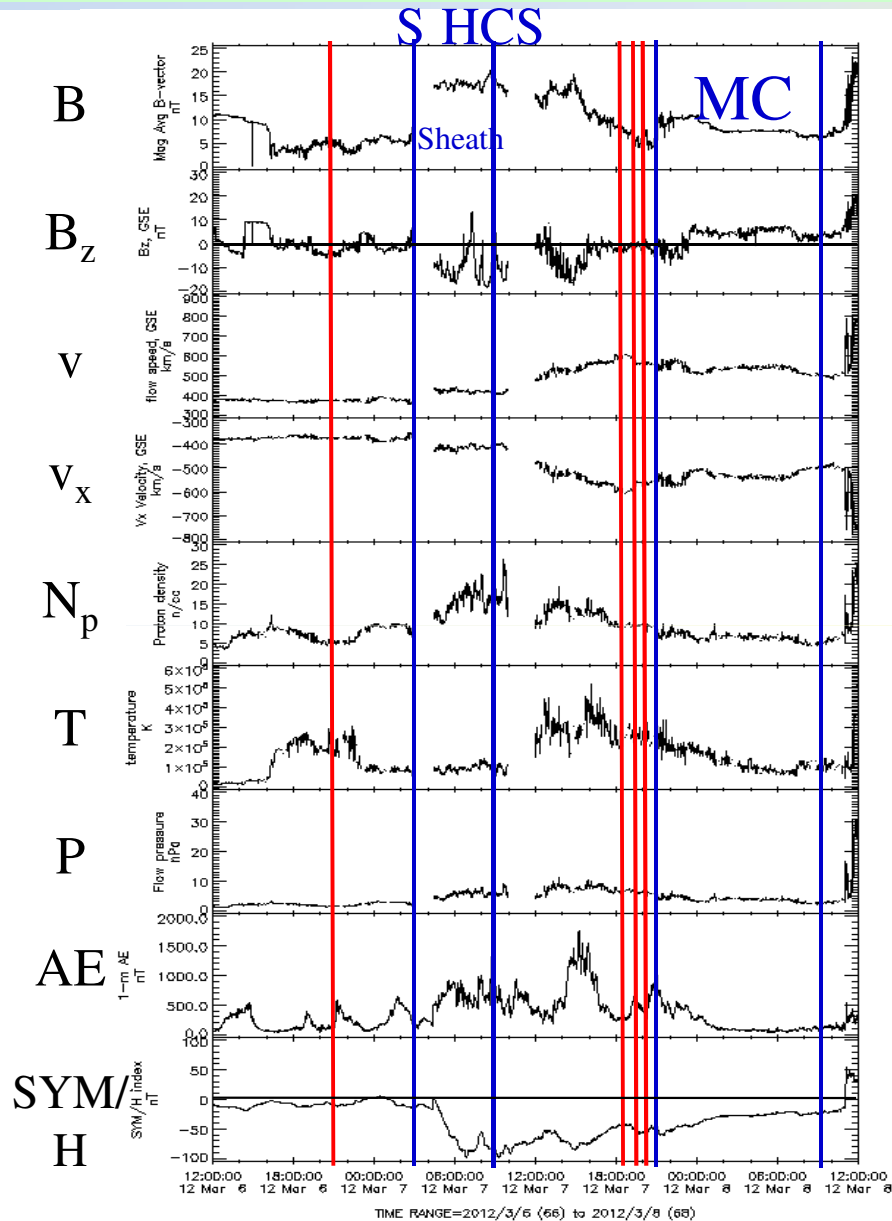
Please acknowledge data provider, J.H. King, N. Papataashvili at AdnetSystems, NASA GSFC and CDAWeb when using these data.
Generated by CDAWeb on Sun Nov 9 03:02:20 2014

Overview of the interplanetary conditions during 7-17.03.2012

The active interval 7-17 March 2012 was examined and the detected features were described (Valchuk, Astron. Tsirkulyar, N1585, 2013; Tsurutani et al., J. Space Weather Space Clim., 4, 2014; Maris et al., 6th Workshop “Solar influences on the magnetosphere, ionosphere and atmosphere”, 26-30 May 2014).

During this period four consecutive magnetic storms occurred on 7, 9, 12, and 15 March. These storms were caused by Sheath, MC and HSS, and the detailed scenario for each of them was different.

Interplanetary conditions, 7-20.03.2012



TIME RANGE=2012/3/6 (66) to 2012/3/8 (68)
 Please acknowledge data provider, J.H. King, N. Papataashvili
 at AdnetSystems, NASA GSFC and CDAWeb when using these data.
 Generated by CDAWeb on Sun Nov 9 03:07:15 2014

Interplanetary conditions during
 6-8.03.2012 and substorm times

Interval 1: 6-8.03.2012:

Halo CME, MC1

Sheath: from 03:28UT, 7.03.2012

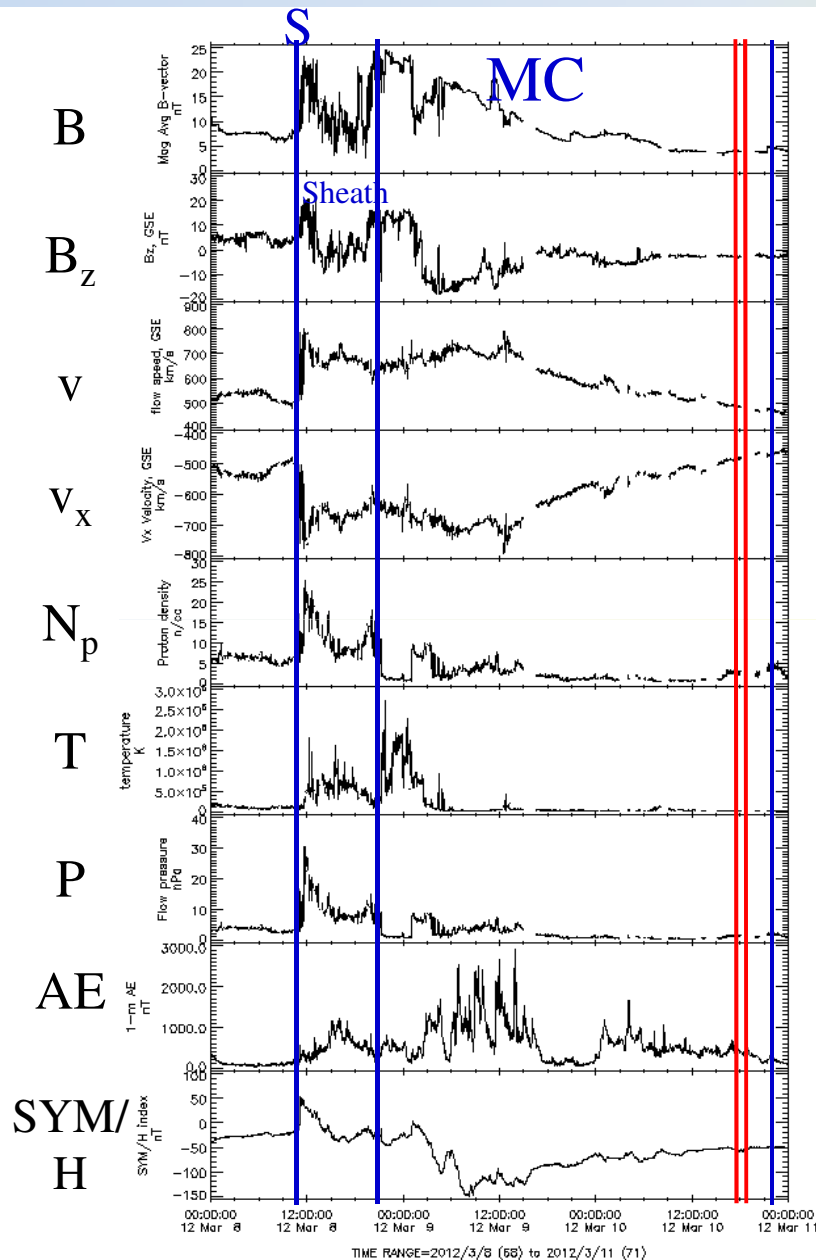
MC: 21:30 UT, 7.03.2012 to 9:20
 UT, 8.03.2012

Geomagnetic storm: min Dst = -98
 nT

Substorms:

- 6.03.2012, 21:03UT, before the disturbances, Dst=-10nT;
- 7.03.2012, 18:45UT, near the Dst min, recovery phase, Dst=-45nT;
- 7.03.2012, 19:37UT, Dst=-60nT;
- 7.03.2012, 20:15 UT, Dst=-55nT.

Interplanetary conditions, 7-20.03.2012



Please acknowledge data provider, J.H. King, N. Papataashvili at AdnetSystems, NASA GSFC and CDAWeb when using these data.

Interplanetary conditions during 8-11.03.2012 and substorm times

Interval 2: 8-11.03.2012 (to the left, bottom):
ICME, MC2

Sheath: from 10:30 UT, 8.03.2012

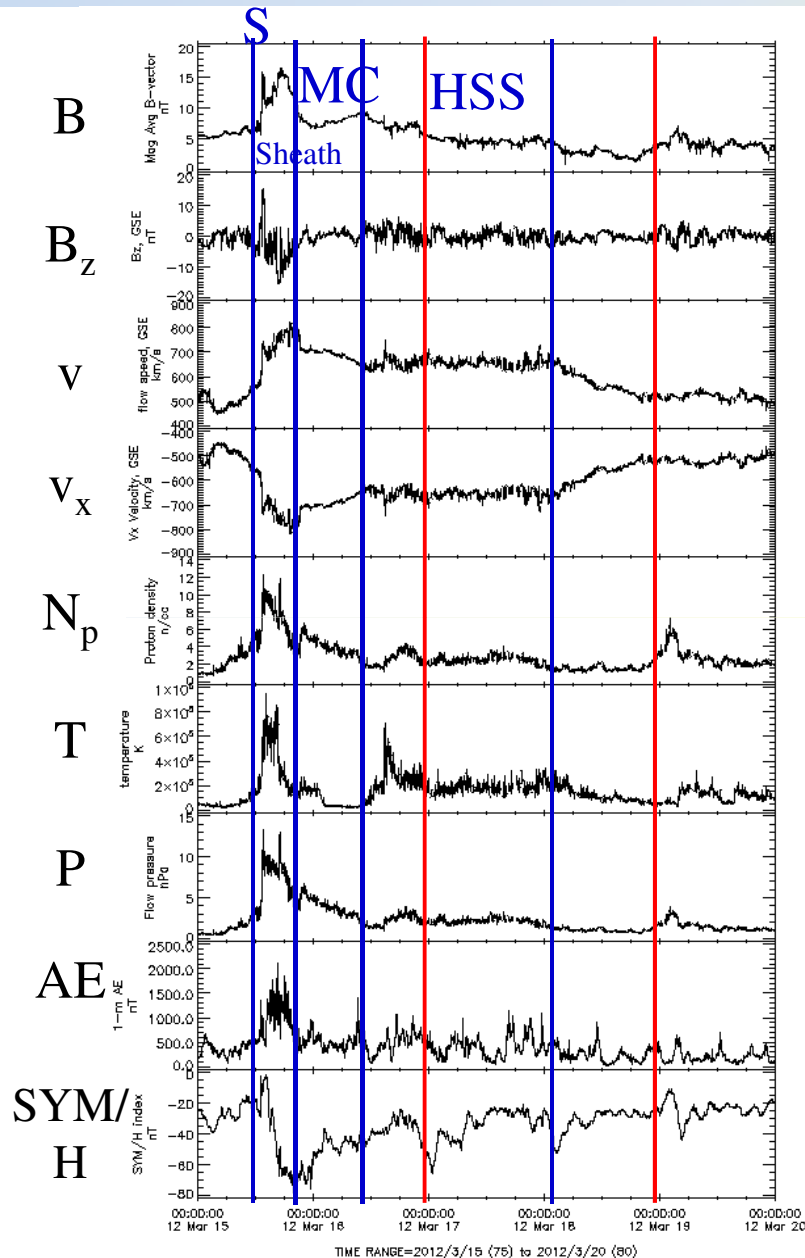
MC: 20:30 UT, 8.03.2012 to 22 UT, 10.03.2012

Geomagnetic storm: min Dst= -148nT

Substorms - on 10.03.2012, far from the Dst min, during the late recovery phase, Dst = -50 nT:

- 10.03.2012, 17:45 UT;
- 10.03.2012, 18:35 UT, late recovery phase, Dst=-50 nT;
- 10.03.2012, 18:49:50 UT.

Interplanetary conditions, 7-20.03.2012



TIME RANGE=2012/3/15 (75) to 2012/3/20 (80)
Please acknowledge data provider, J.H. King, N. Papatashvili
at AdnetSystems, NASA GSFC and CDAWeb when using these data.

Interplanetary conditions
during 15-20.03.2012 and
substorm times

Interval 4: 15-20.03.2012 (to the right):

MC4 and HSS

Sheath: from 12:33 UT, 15.03.2012

MC: 21:35 UT, 15.03.2012 to 10:50 UT, 16.03.2012

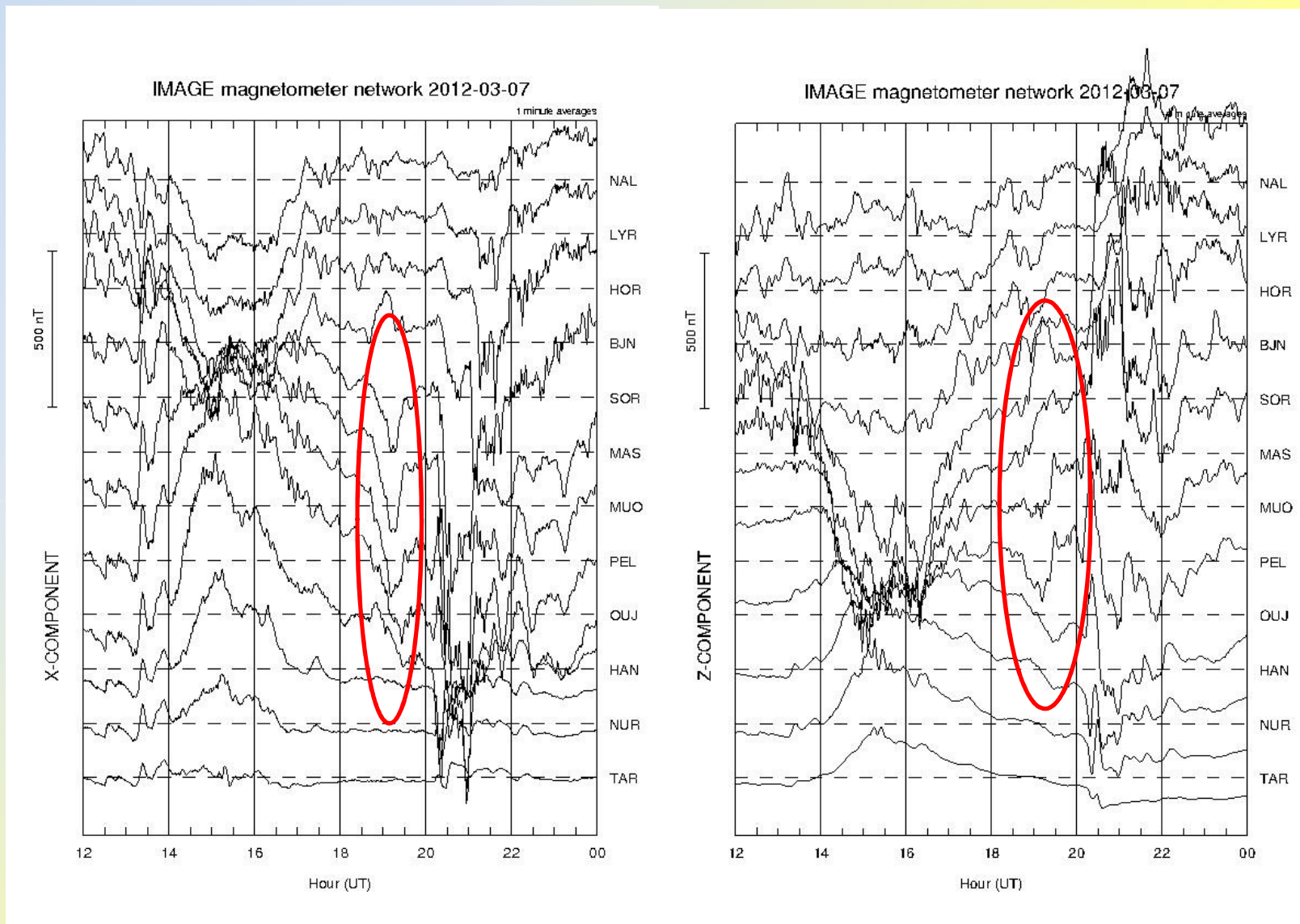
HSS: 12:00 UT, 16.03.2012 to 02:00 UT, 18.03.2012

Geomagnetic storm: min Dst=-79 nT

Substorms (the late rec. phase):

- 17.03.2012, 23:17 UT, during HSS, Dst=-52 nT;
- 18.03.2012, 23:20 UT, after HSS;
- 18.03.2012, 23:34 UT, Dst= - 23 nT.

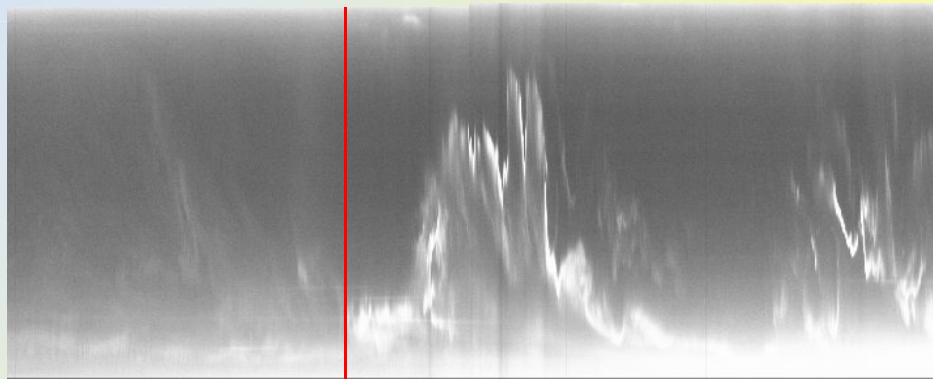
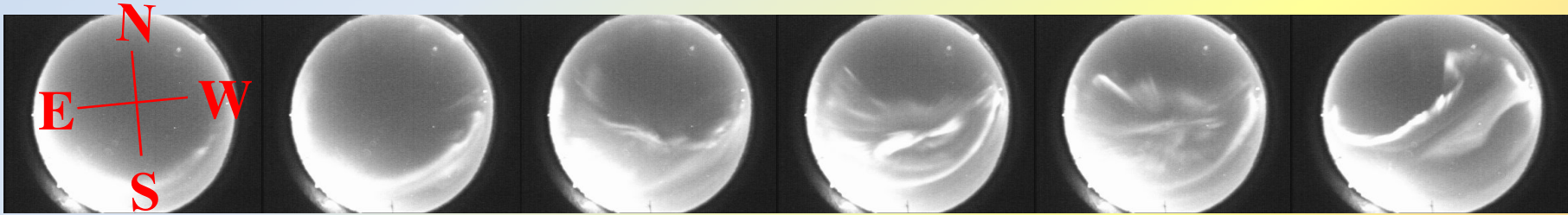
Case 1: magnetic field data 7.03.2012



Magnetic field data, 7.03.2012. The substorm time is marked by a red ellipse.

Case 1, all-sky and GC cameras data, 07.03.2012

UT: 18:45:00 18:49:50 18:53:00 18:55:10 18:56:30 19:04:50

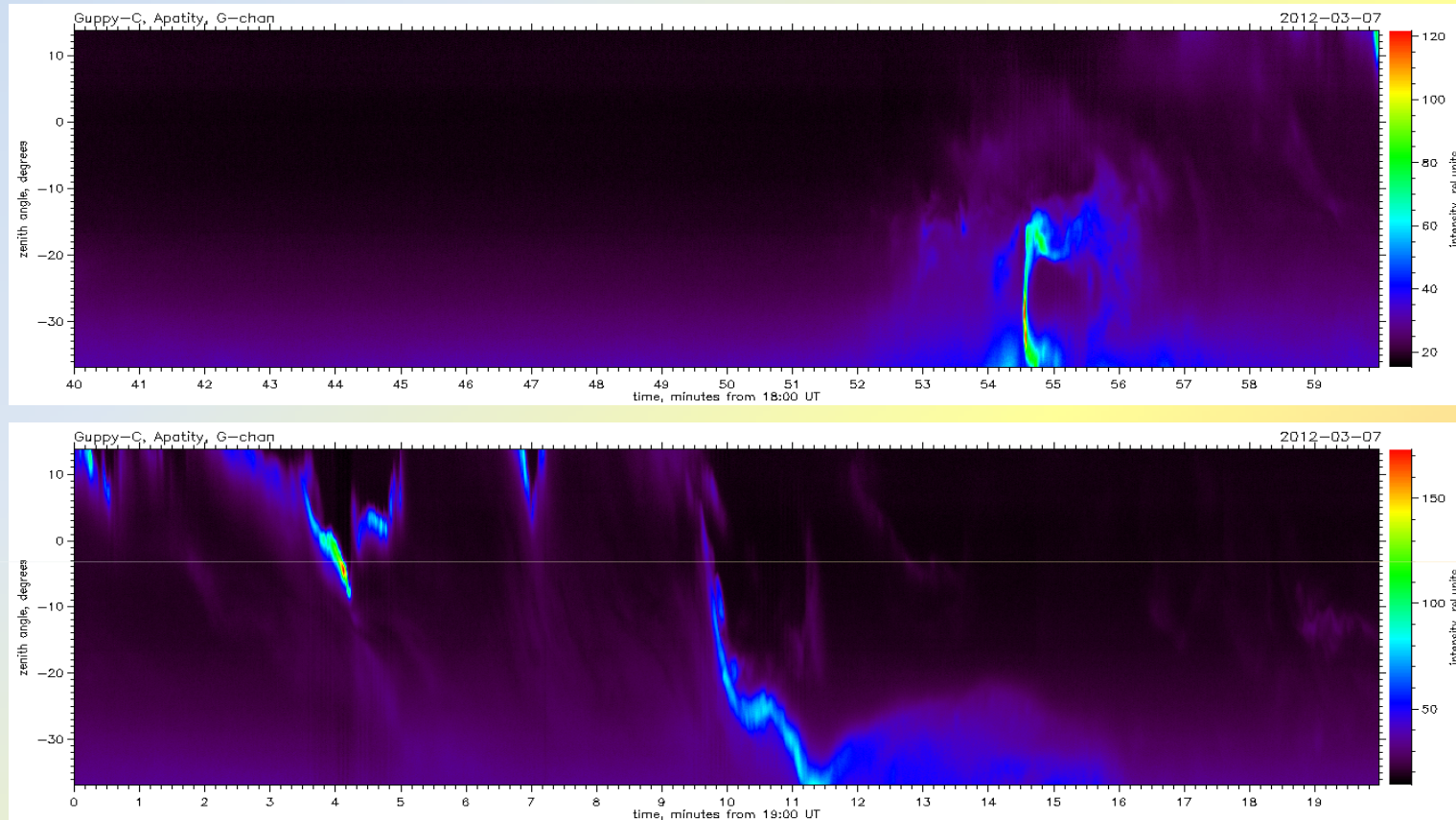


18:45

Hourly AS keograms for 18:00-19:00 UT and 19:00-20:00 UT.

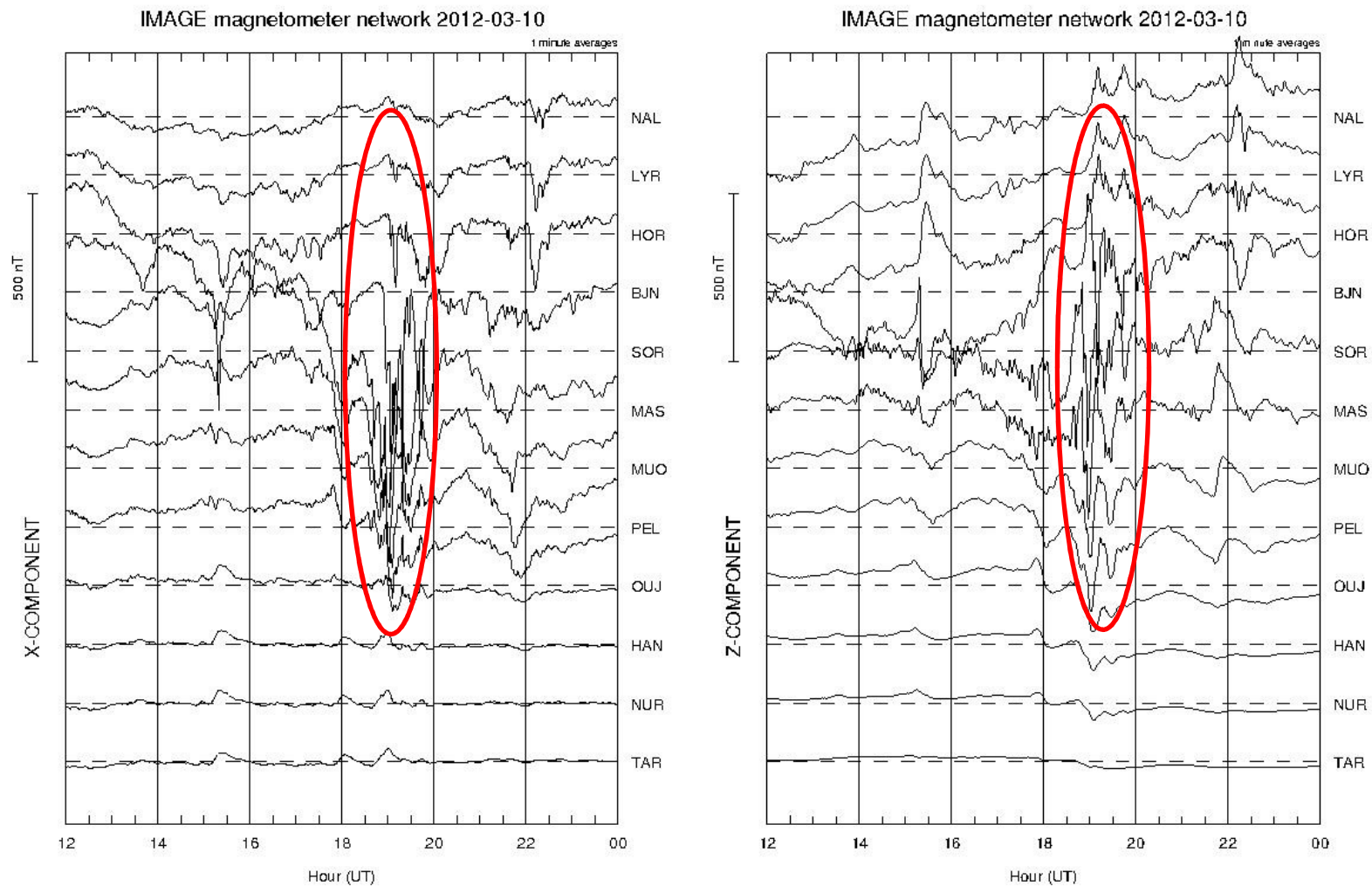
Chosen images of the substorm development by the all-sky camera (up). The substorm began in 18:45 UT on 7.03.2012 to the South of the station zenith. The auroras reached zenith in about 18:53 UT and after that auroras surpassed the zenith.

Case 1, all-sky and GC cameras data, 07.03.2012



The substorm development by the GC camera keograms 18:40 – 19:00 UT and 19:00 – 19:20 UT. In the GC keograms the substorm auroras are seen first in 18:52 UT. The substorm development is clearly expressed up to 19:20 UT.

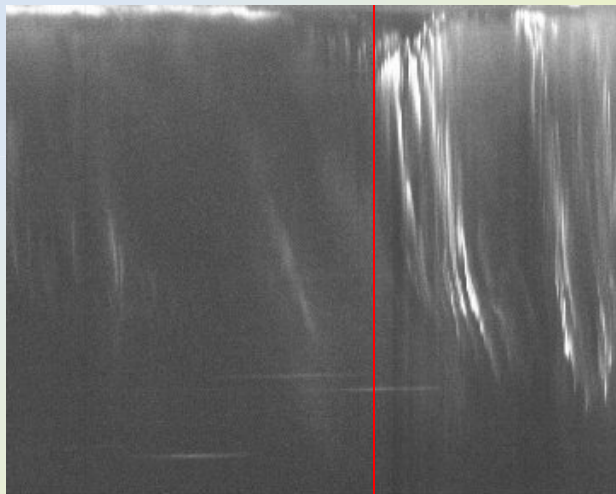
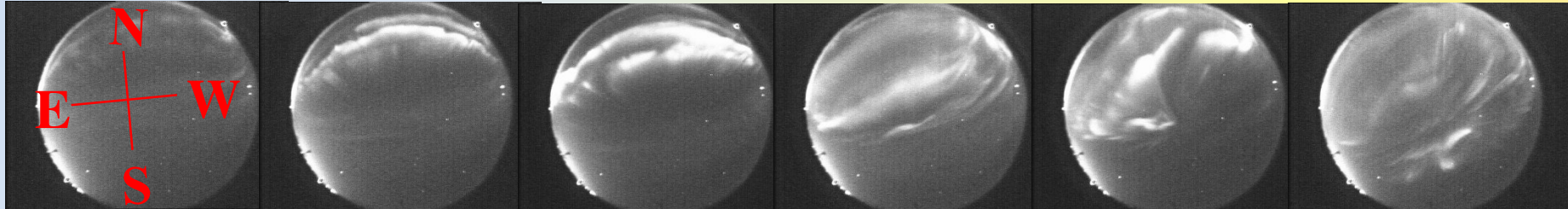
Case 2: magnetic field data 10.03.2012



Magnetic field data, 10.03.2012. The substorm time is marked by a red ellipse.

Case 2, all-sky and GC cameras data, 10.03.2012

UT: 18:35:50 18:37:00 18:38:20 18:43:10 18:52:50 18:58:30

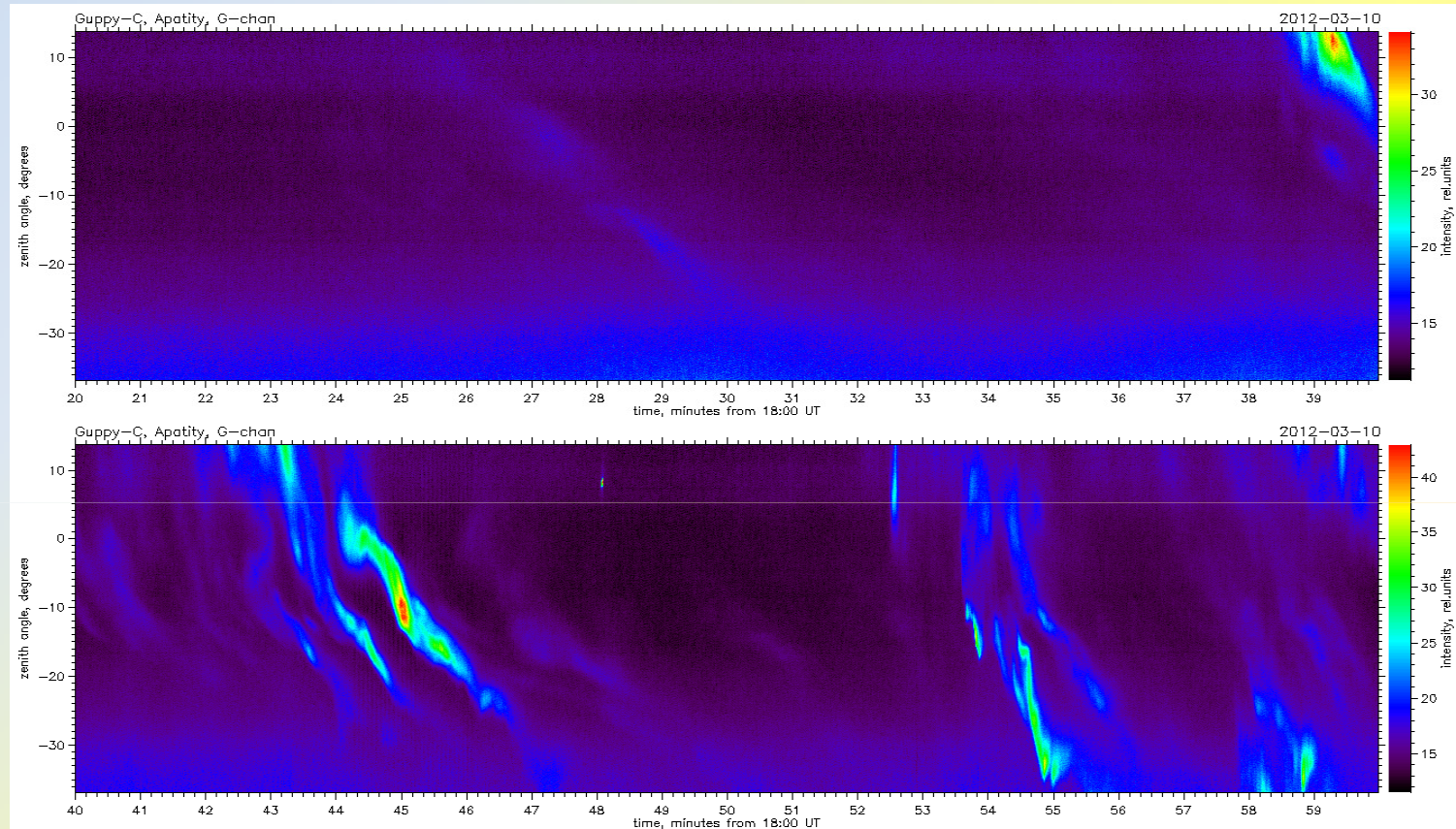


18:35:50

Hourly AS keogram for 18:00-
19:00 UT on 10.03.2012.

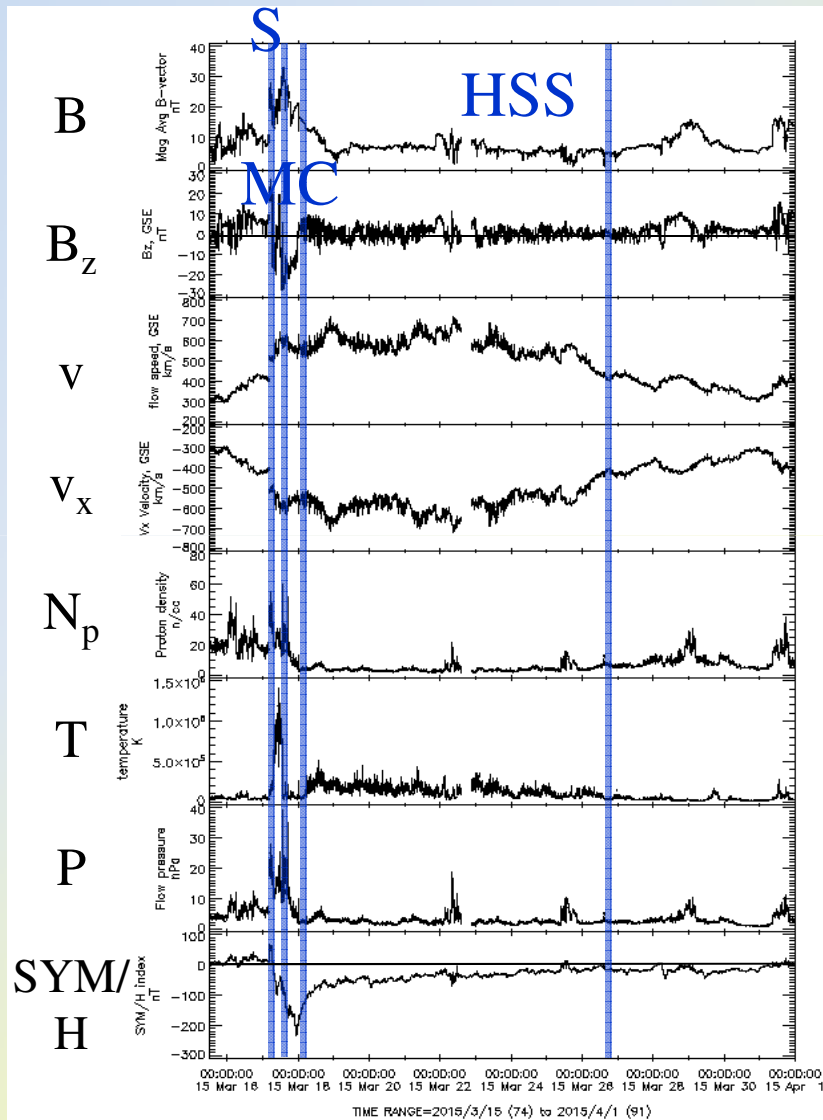
The substorm onset over Apatity occurred in 18:35:50 UT on 10.03.2012 to the North of Apatity. In 18:39 UT the auroras reached zenith and traveled further to South.

Case 2, all-sky and GC cameras data, 10.03.2012



The substorm by the GC keograms from 18:20 to 19:00 UT. In the keograms, the substorm auroras are seen from 18:38:30 UT at about 15° to North from zenith.

Overview of the interplanetary conditions during the severe storm on 17 March 2015



Two CME' which combined, MC Sheath from 4:45, 17.03.2015; MC from 11:00UT, 17.03.2015 to 00:10UT, 18.03.2015

A HSS superposed and contributed to the storm duration: HSS up to 18:00UT, 26.03.2015.

St Patrick's day severe geomagnetic storm (G4):

Sudden commencement – 4:45 UT, 17.03.2015

Main phase – to 22:47 UT, 17.03.2015

Dst min = -235 nT

long recovery phase, lasting several days

Please acknowledge data provider, J.H. King, N. Papotashvili at AdnetSystems, NASA GSFC and CDAWeb when using these data. Generated by CDAWeb on Thu May 21 07:19:09 2015

Interplanetary conditions and observed substorms, 17 – 21 March 2015

17 March 2015

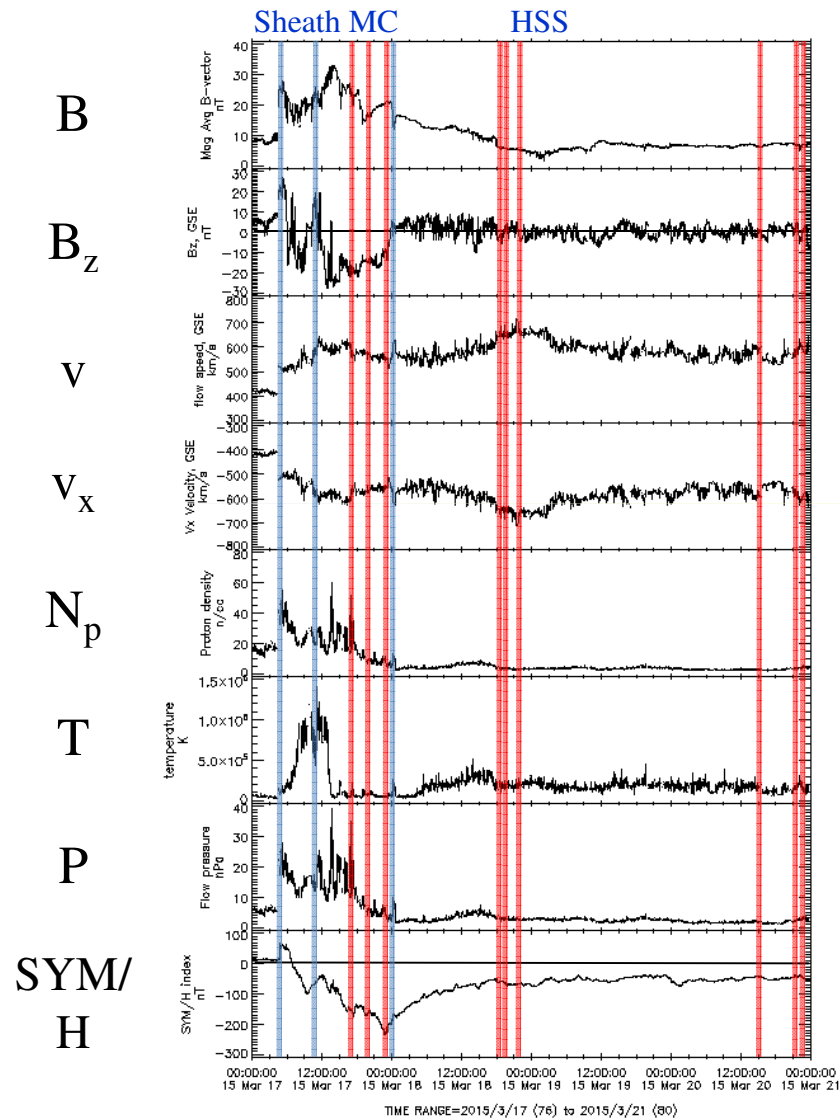
- 17:36:40 UT, during the main storm phase, Dst=-163 nT
- 19:59:40 UT, during the main storm phase, Dst=-160 nT;
- 22:56:40 UT, Dst=-230 nT, close to the the storm maximum

18 March 2015, recovery phase

- 18:29:50 UT, Dst=-59 nT;
- 19:11:10 UT, Dst=-61nT;
- 22:19:40 UT, Dst=-67 nT.

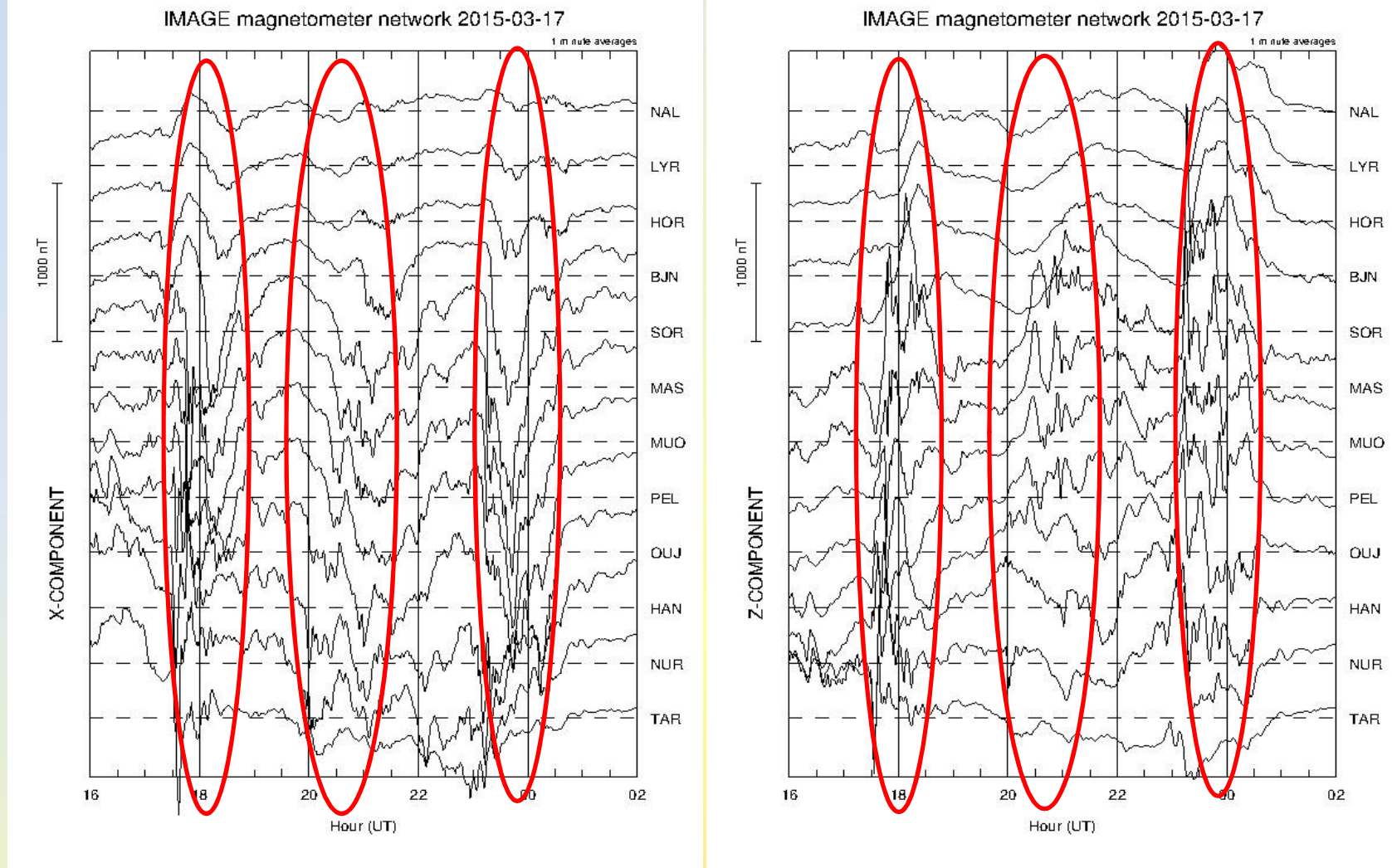
20 March 2015, late recovery phase

- 18:13:40 UT, Dst=-52 nT;
- 21:43:20UT, Dst=-45 nT;



Please acknowledge data provider, J.H. King, N. Papadashvili at AdnetSystems, NASA GSFC and CDAWeb when using these data.
Generated by CDAWeb on Mon May 25 00:48:07 2015

Cases 3, 4, 5: magnetic field data 17.03.2015



Magnetic field data, 17.03.2015. The substorm times are marked by red ellipses.

Case 3, all-sky and GC cameras data, 17.03.2015

UT: 17:36:40

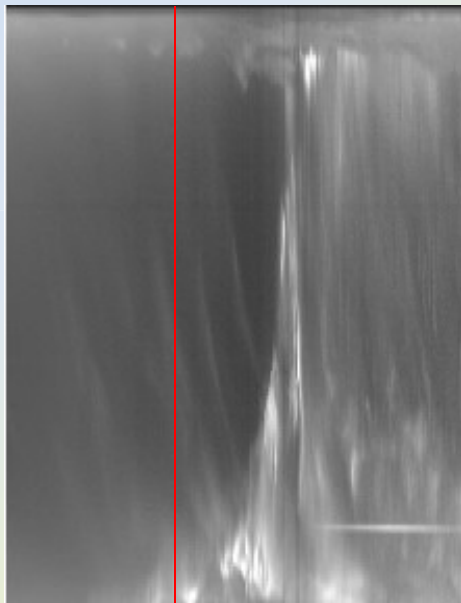
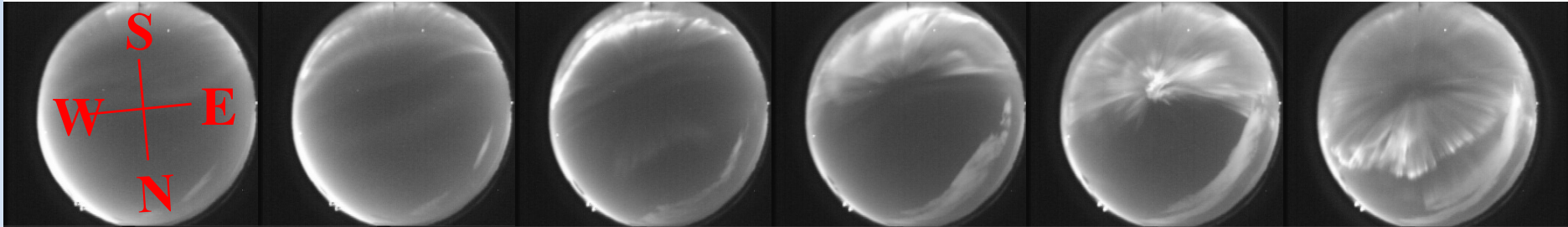
17:38:30

17:41:10

17:43:20

17:44:30

17:45:30



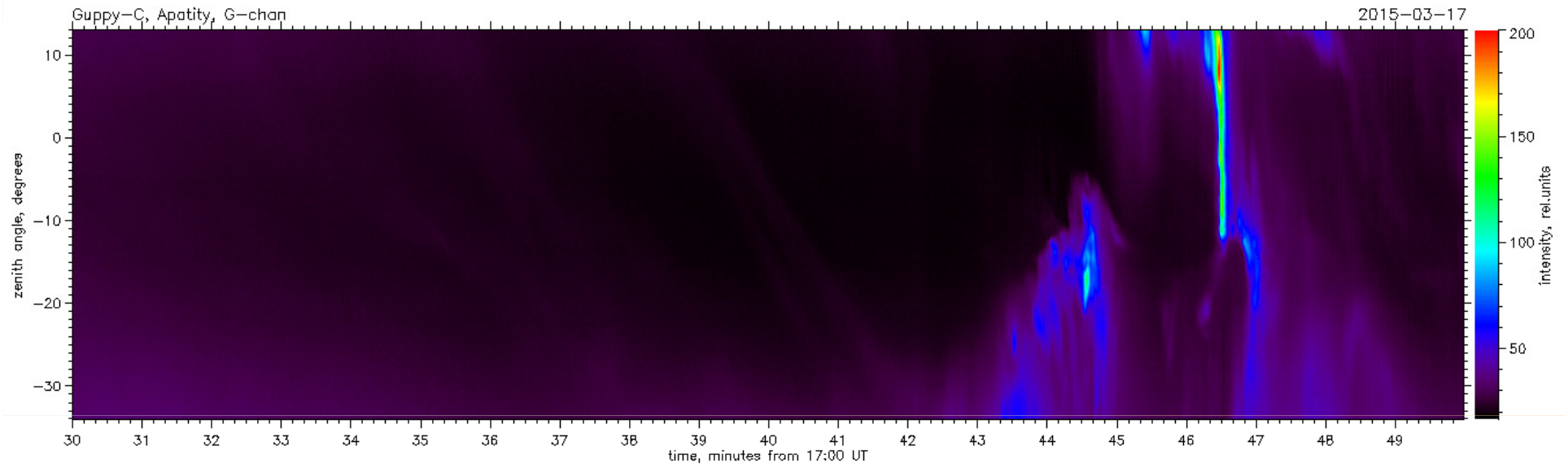
17:36:40

AS keogram

17:23-18:00 UT

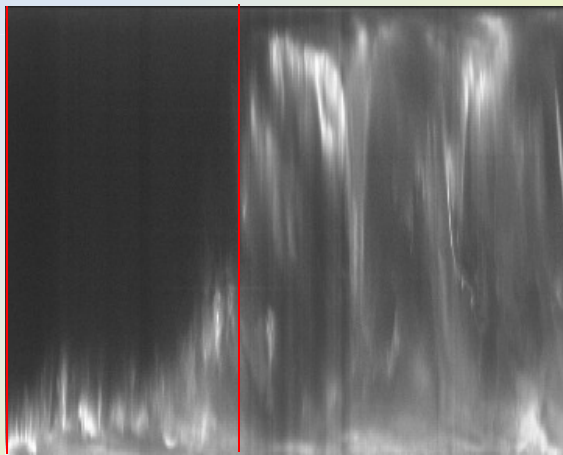
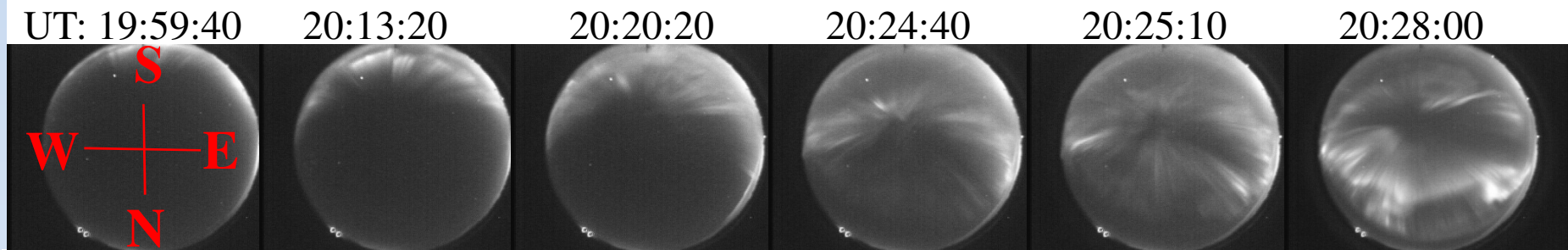
The substorm development can be followed by the AS images and keograms. The substorm was seen from Apatity in 17:36:40 UT on 17.03.2015 to the South of the station. In 17:42 UT a fast motion towards North was observed and in 17:45:30 UT the auroras occupied the whole field of view.

Case 3, all-sky and GC cameras data, 17.03.2015



The substorm by the GC keogram from 17:30 to 17:50 UT. In the keogram, the substorm auroras are seen from 17:42:30 UT at the South part of the field of view, at 35° from zenith, due to the fast movement to North.

Case 4, all-sky and GC cameras data, 17.03.2015

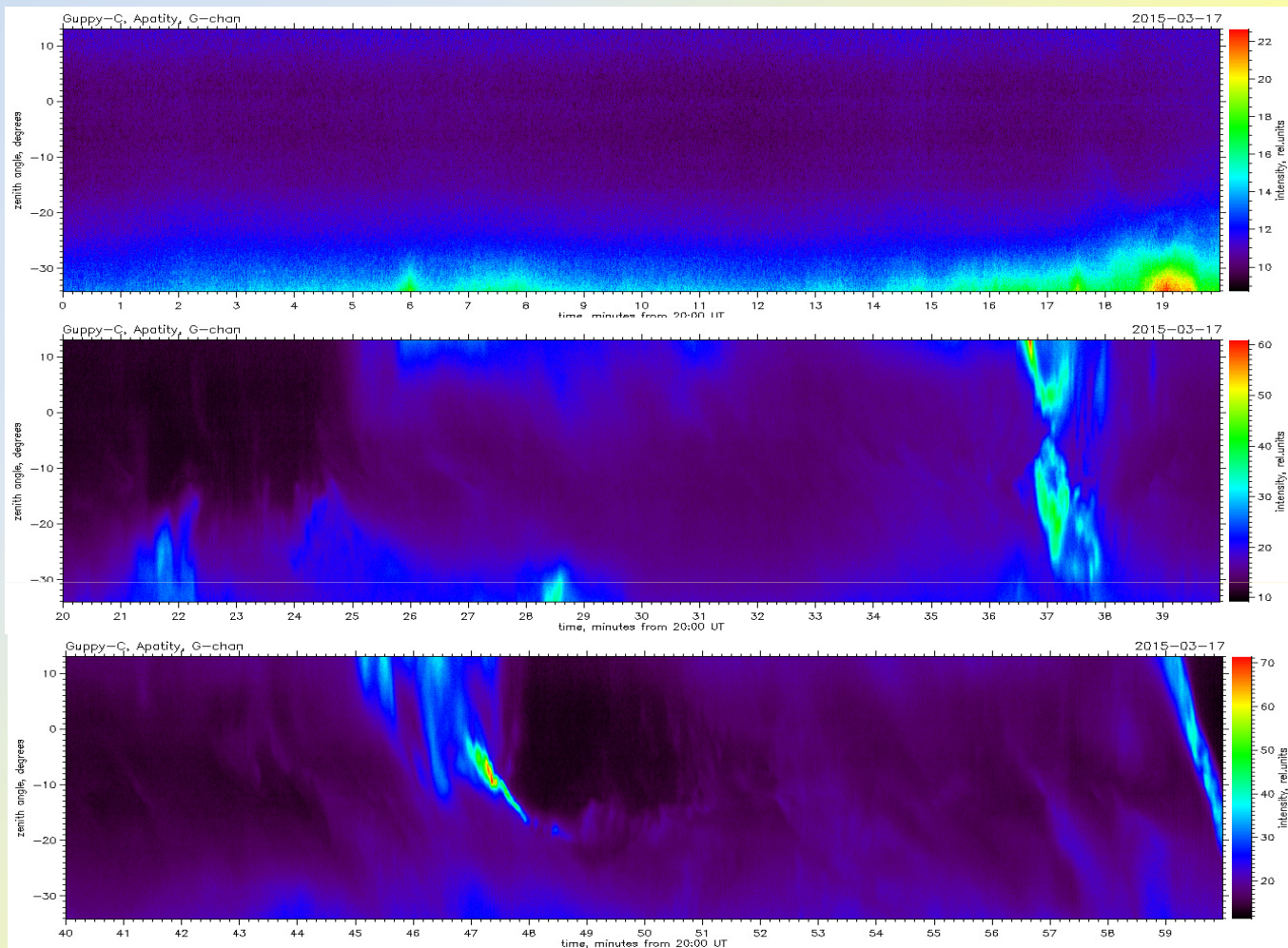


20:00 20:24:30

AS keogram 20:00-21:00 UT

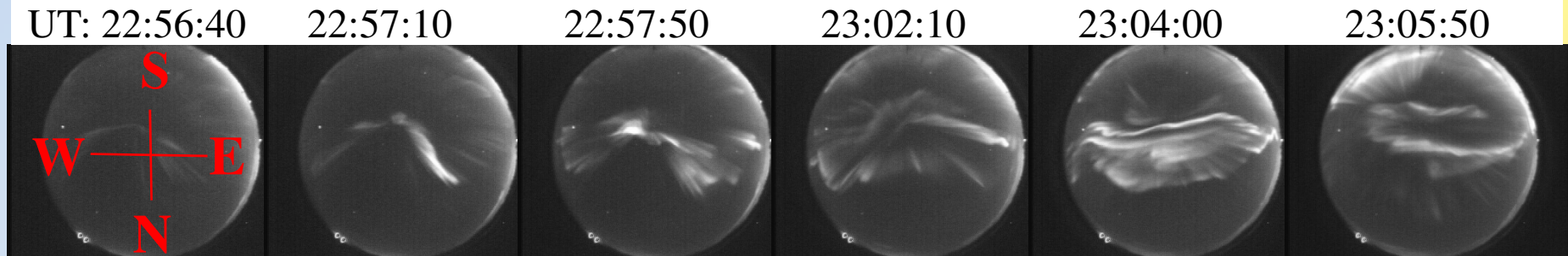
Chosen AS images of the substorm development. The substorm onset was to the South of Apatity in 19:59:40.

Case 4, all-sky and GC cameras data, 17.03.2015

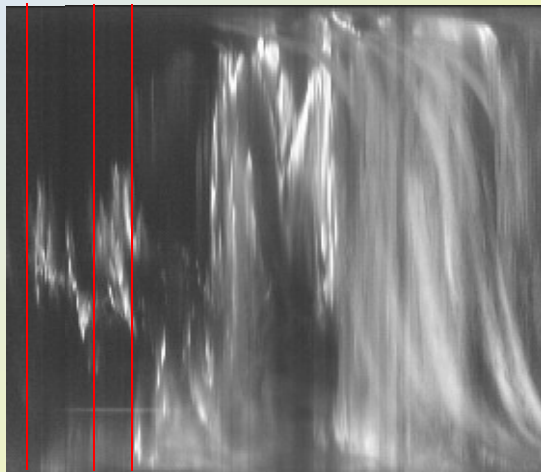


The substorm by the GC keogram from 20:00 to 21:00 UT. The auroras are seen at about 25° to the South from zenith (the upper picture) and the rise in 20:24:30 UT is clearly expressed.

Case 5, all-sky and GC cameras data, 17.03.2015



23:02

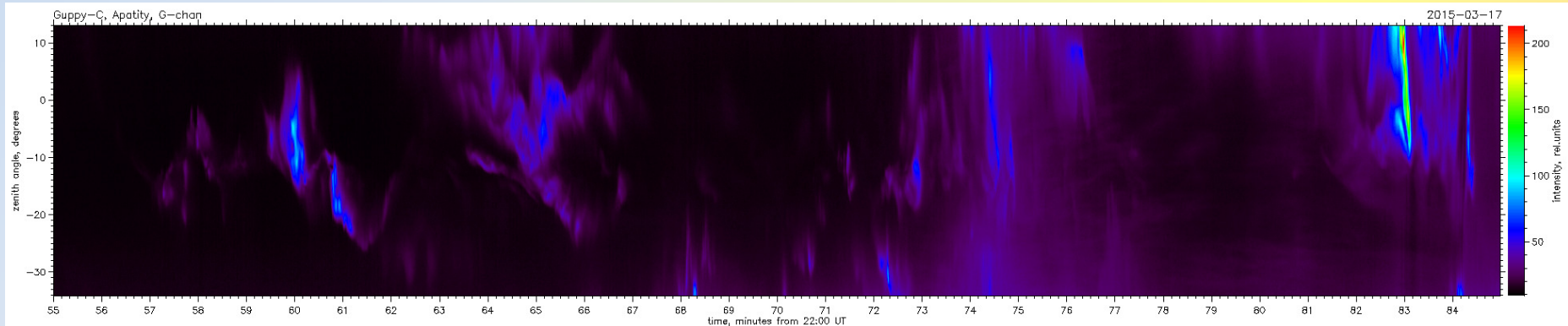


22:56 23:06

AS keogram 22:55-23:40 UT

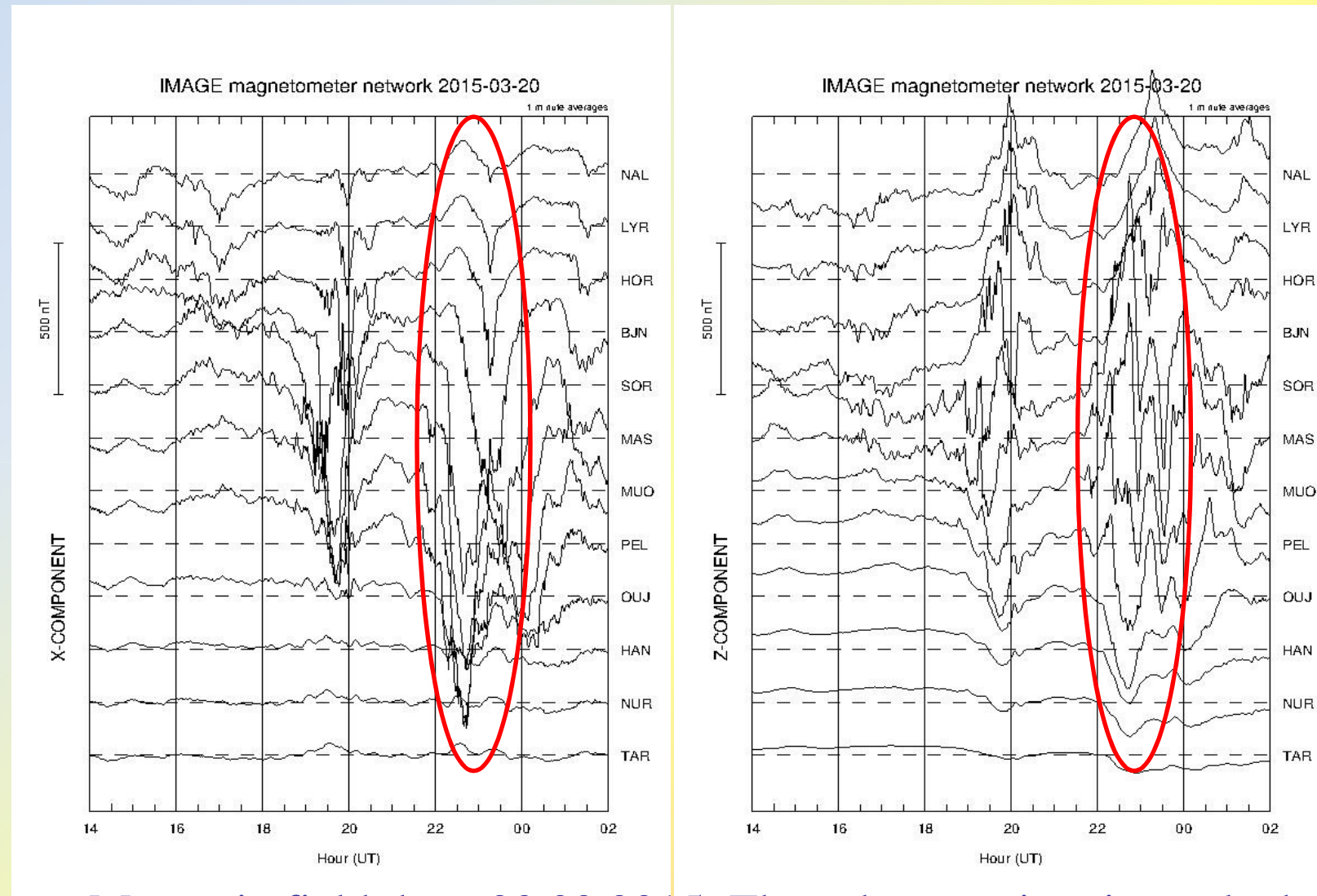
The substorm began in highly disturbed conditions. It was the most intensive from the substorms occurred in the examined period. The substorm onset was in 22:56:40 UT near the station zenith. In 23:02 UT a sharp broadening of the auroras took place, but the auroras stayed still in the AS field of view. In 23:06 an outburst felt out, the auroras expanded sharply and covered the whole field of view.

Case 5, all-sky and GC cameras data, 17.03.2015



Substorm development as seen by the GC keogram from 22:55 UT to 23:15 UT. The substorm onset took place in 22:57:00 UT at 17° to the South from zenith. The auroras expansion in 23:02 UT is clearly expressed. The second outburst cannot be observed in the GC field of view.

Cases 6: magnetic field data 20.03.2015



Magnetic field data, 20.03.2015. The substorm time is marked by a red ellipse.

Case 6, all-sky and GC cameras data, 20.03.2015

UT: 21:43:20

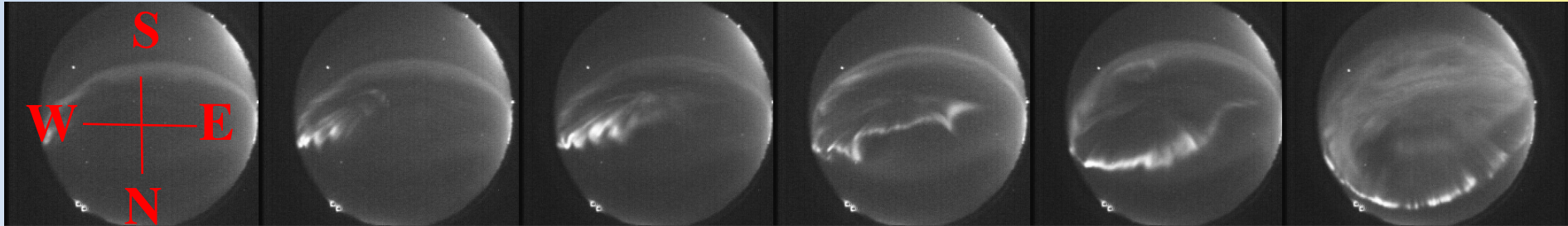
21:43:40

21:44:00

21:45:00

21:45:50

21:52:30

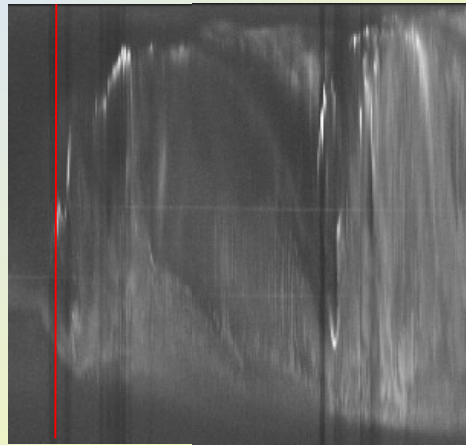
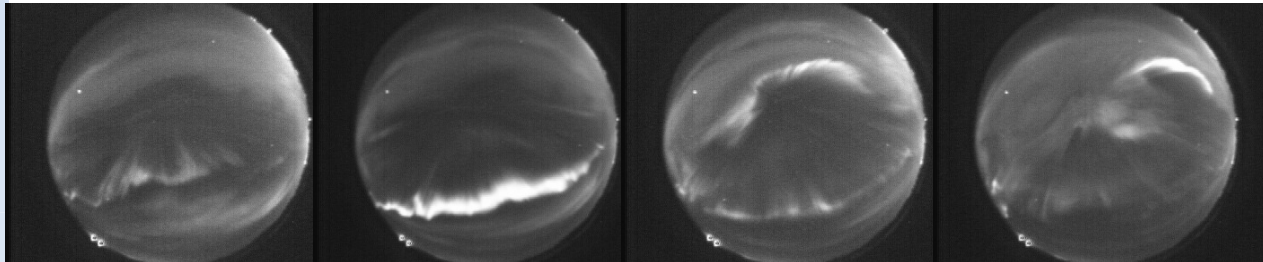


UT: 22:13:40

22:14:10

22:15:20

22:16:00

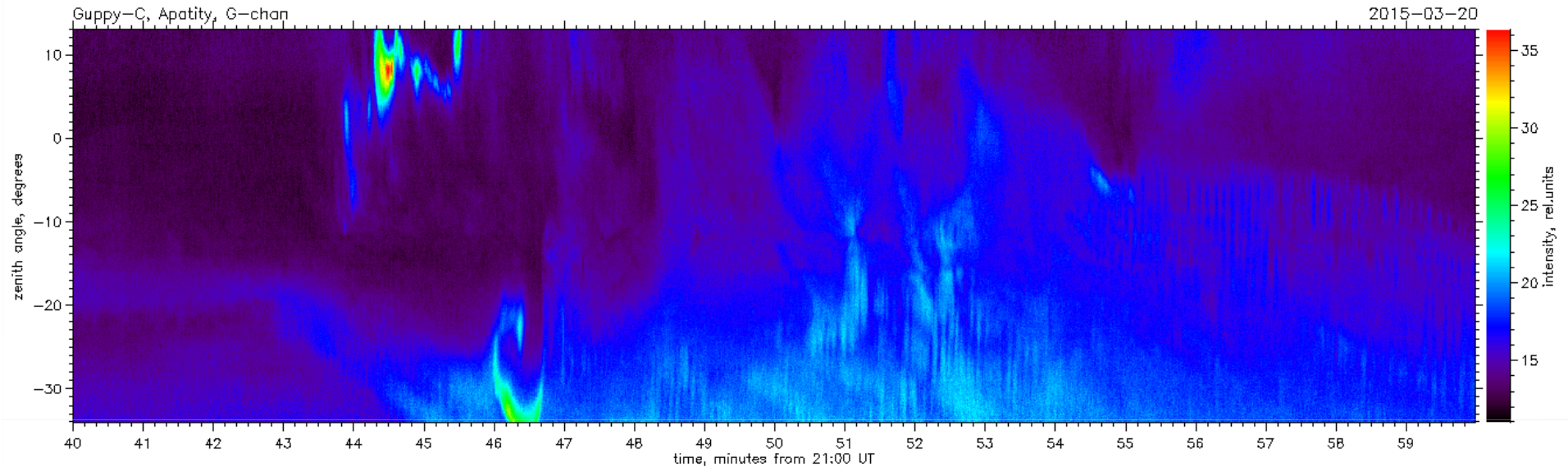


21:43:20

AS keogram 21:40-22:30UT

The substorm onset happened in 21:43:20 UT near the station zenith. The auroras expanded very fast, but they were still seen in the AS images up to 22:16 UT.

Case 6, all-sky and GC cameras data, 20.03.2015



GC keogram, 21:40 – 22:00 UT. The substorm onset is seen in the station zenith in 21:43:50 UT.

Results and conclusions

Two highly disturbed periods: 7-17 March 2012 and 17-20 March 2015 were examined by data of the Apatity MAIN system; 18 substorms were registered under clear sky conditions: 10 substorms were identified during the first period and 8 substorms – during the second one.

- Substorms, originated during the main storm phase or near the Dst minimum in the recovery phase, occurred to the South of Apatity, and substorm auroras expanded in North direction;
- For substorms during the recovery phase or the late recovery phase, auroras were observed near the station zenith or to the North of the Apatity station, and their motion from North to South was registered.

The background of the slide is a dark, almost black, space. It features several faint, ethereal green patterns that resemble the aurora borealis or aurora australis. These patterns are composed of soft, glowing bands and patches of light green, with some areas appearing more vibrant and others more faded. The overall effect is a subtle, atmospheric glow against the dark backdrop.

Thanks for the attention