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STUDY OF THE AURORAL 5577 Å AND 6300 Å EMISSIONS AND THE RELATED PHENOMENA UNDER QUIET AND DISTURBED CONDITIONS

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Abstract. *Measurements of the 5577 Ǻ and 6300 Ǻ emissions have been performed by All-Sky Imager (ASI), at Andøya Rocket Range (ARR), Andenes, Norway. The Norwegian island Andøya affords excellent opportunities for the Arctic atmosphere and ionosphere research thanks to its geographic position, and to the rich complex of instruments, installed and functioning in the Arctic Lidar Observatory for Middle Atmosphere Research (ALOMAR) and ARR, as well. Auroral images, obtained by ground-based imaging systems, are a useful tool for investigating the physical processes responsible for auroral emission. Simultaneous All-sky camera data are used to watch the atmospheric conditions. Data during a quiet night (November 7, 2005, 15:30:00 UT – November 8, 2005, 5:50:00 UT) and at highly disturbed geomagnetic conditions (November 3, 2005, 15:50:00 UT – November 4, 2005, 5:40 UT) are used for the study. The emissions distributions in both cases are compared.*

For better understanding of the auroral images and the arcs behaviour, resulting of a lot of phenomena, simultaneous data from other instruments are used together with solar activity, solar wind and IMF data. The activity in the energetic particle precipitation over a large area of the ionosphere is studied from the riometer beam data and absorption images, obtained using the measurements of the Imaging Riometer for Ionospheric Studies (IRIS) at Kilpisjärvi, provided by the Lancaster University. The Tromsø digisonde ionograms give information about the plasma parameters. The course of the terrestrial magnetic field components and the geomagnetic activity are provided by the Tromsø Geophysical observatory.

Analysis of the data is performed to look for the relations between the different processes and for their influence on the auroral arcs.

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Introduction. The generation and dynamics of the auroral arcs are in close relation with all processes in the magnetosphere and ionosphere, the Solar influence on the Earth atmosphere and the chemistry and the energy balance in the lower atmosphere. For that reason the study of the optical events at high latitudes and their connection to other occurring phenomena is of great importance for the understanding of the complex and multiform interactions, describing the Sun-Earth relations. The variety of the auroral forms and their behaviour, as a result of the complexity of the processes in the upper atmosphere at high latitudes and the connection between them as well as the large number of influencing factors give the researchers a lot of possibilities for new investigations. The improvement of the observational equipment and the opportunities for simultaneous multi-instrument observations by different instruments, as well by sets of instruments of the same kind, often including both ground-based and satellite or rocket measurements (for example Weiss, 1992, Berg et al., 1994, Safargaleev et al., 1996, Mathews, Mann and Moen, 1997, Pryse et al.., 2000, Sandholt et al., 2002, Kadokura et al., 2002, Chaston et al., 2003, etc.), nowadays are a precondition for an extensive research of the auroral forms. Each instrument individually provides valuable information concerning certain aspects of the ionosphere, yet taken together, the data from several different instruments complement each other to give a comprehensive picture of the polar ionosphere.

The auroral arcs are sorted into different categories according to their spatial structure and evolution (Kullen et al., 2002). The dynamics of single (Sandholt and Lockood, 1990, Qu et al., 1991, Milan, Lester and Moen, 1997, Kintneret al., 2002, Safargaleev et al., 2003) or multiple (Weiss, 1992, Berg et al., 1994, Thorolfsson et al., 2000, Mathews, Mann and Moen, 2003) arcs in different parts of the auroral oval is studied. Optical events during substorms (Foster et al., 1994, Farrugia et al., 2001, Kadokura et al., 2002, Sandholt et al., 2002, Liang, Sofko and Donovan, 2004) and under quiet conditions (Lassen and Danielsen, 1987, De La Beaujardiere et al., 1994, Kozlovsky et al., 2001) are examined. Ions (Sandholt and Lockood,

1990, De La Beaujardiere et al., 1994, Foster et al., 1994, Pryse et al., 2000, Stevenson et al., 2001), protons (Kadokura et al., 2002) or electrons (Lassen and Danielsen, 1987, Weiss, 1992, Gallagher, 1997, Farrugia et al., 2001, Jussila et al., 2001, Kozlovsky, Safagdeev and Jussila, 2003) precipitation over the arc regions are registered and studied. The relationship of the optical phenomena with the IMF and solar wind components (De La Beaujardiere et al., 1994, Milan, M. Lester and Moen, 1997, Milan et al., 1999, Pryse et al., 2000, Kullen et al., 2002, Zesta et al., 2003, Kozlovsky, Safagdeev and Jussila, 2003), the magnetospheric tail layers (Sandholt, and Lockood, 1990, Weiss, 1992, De La Beaujardiere, 1994, Sandholt et al., 2002, Zesta et al., 2003, Kozlovsky, Safagdeev and Jussila, 2003), the Earth magnetic field (Kozlovsky et al., 2001) is analysed.

In a number of cases, the connection of the optical events with the plasma convection (Berg et al., 1994, Foster et al., 1994, Doe et al.,1994, Kozlovsky et al., 2001, Conde et al., 2001, Zesta et al., 2003), the convection direction (Weiss, 1992, Pryse et al., 2000), velocity (Thorolfsson et al., 2000, Safargaleev et al., 2003) or reversal boundary (Sandholt and Lockood, 1990, Mathews, Mann and Moen, 2003) is studied. A relationship between the observed arcs and the field-aligned currents and other flow directions is found (Weber et al., 1991, Weiss, 1992, Gallagher, 1997, Milan, Lester and Moen, 1997, Stevenson et al., 2001, Kadokura et al., 2002, Lakkala, Aikio and Kozlovsky, 2002, Lotko and Streltsov, 2003).

Alfven waves above broad auroral arcs are found to be responsible for their generation (Lotko and Streltsov, 2003, Chaston et al., 2003, Mathews, Mann and Moen, 2003). On the other side, auroral arcs appear the effective generator of neutral wind oscillations and gravity waves (Oyama et al., 2001).

The thermospheric winds and ionospheric currents in the vicinity of auroral arcs are studied (Conde et al., 2001, Ishii et al., 2003).

Interesting phenomena such as Auroral poleward boundary intensifications (Farrugia et al., 2001, Sandholt et al., 2002, Zesta et al., 2002, Zesta et al., 2003), auroral cavities (Doe et al., 1994, Lakkala, Aikio and Kozlovsky, 2002), field line resonances and auroral vortex structures (Samson, Cogger and Rao, 1996, Sandholt et al., 2002) are examined.

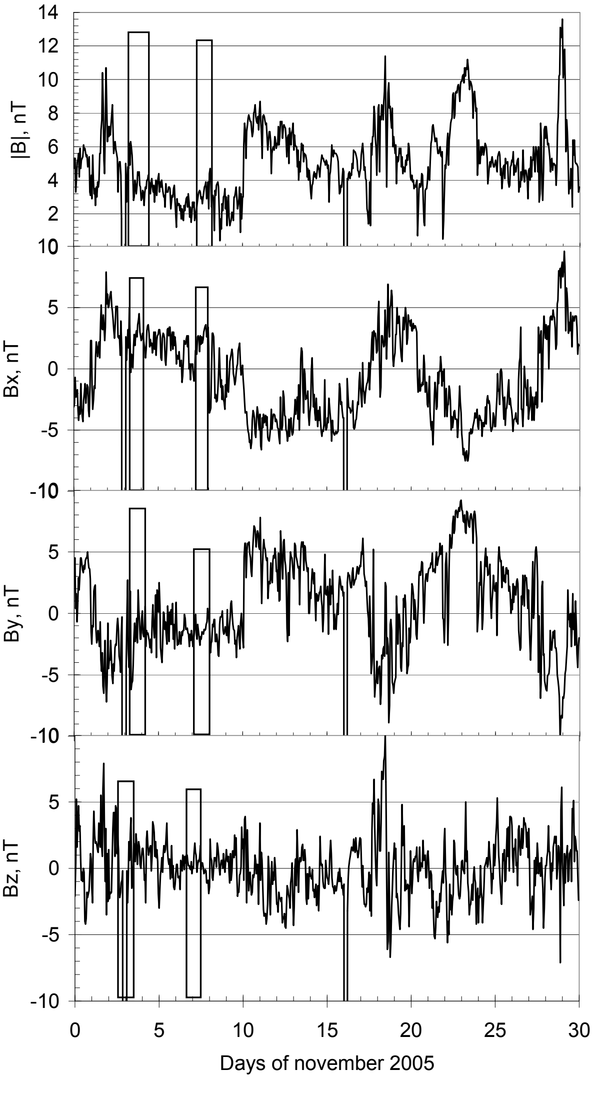

Fig. 1. *IMF components in November 2005 after ACE Satellite data*

For a number of cases, several interpretations of the observations can be presented (Weiss, 1992, Doe et al., 1994, Milan, Lester and Moen, 1997, Milan et al., 1999, Lakkala, Aikio and Kozlovsky, 2002) or suggestions can be made (Milan et al., 2003, Zesta et al., 2002, Kozlovsky, Safagdeev and Jussila, 2003). More multi-instrument observations and studies are needed to clarify and explain the high-latitude ionospheric phenomena and the complex relations between the optical auroral structures, and the geomagnetic conditions and the solar activity, solar wind and IMF parameters.

The Norwegian island Andøya affords excellent opportunities for the Arctic atmosphere and ionosphere research not only thanks to its geographic position, but to the rich complex of instruments, installed and functioning in ALOMAR and Andøya Rocket Range.

Space and geomagnetic conditions in November 2005. The purpose of this work was to study the emissions in the Northern polar oval areas under different space and geomagnetic conditions and to examine their relation to other ionospheric and magnetospheric processes. That is why satellite data are used to trace out the course of the Interplanetary Magnetic Field (IMF), the solar wind parameters, the energy input in the Northern hemisphere and the geomagnetic indices. The components of the IMF are shown in Fig.1. The solar wind speed, the proton density and the ion temperature are presented in Fig.2. These data are from the magnetometer (MAG) and the Solar Wind Electron Proton Alpha Monitor (SWEPAM) on board the Advanced Composition Explorer (ACE) satellite. The auroral particles power input in the Northern hemisphere in November 2005 is given in the lower plot of Fig.3. Data of the power flux carried by protons and electrons that produce aurora in the atmosphere are recorded by the instruments on board the NOAA Polar-orbiting Operational Environmental Satellite (POES). In Fig.4, the course of the planetary indices k_p and A_p in November 2005 is given. These indices are estimated on the basis of the measurements of a set of stations.

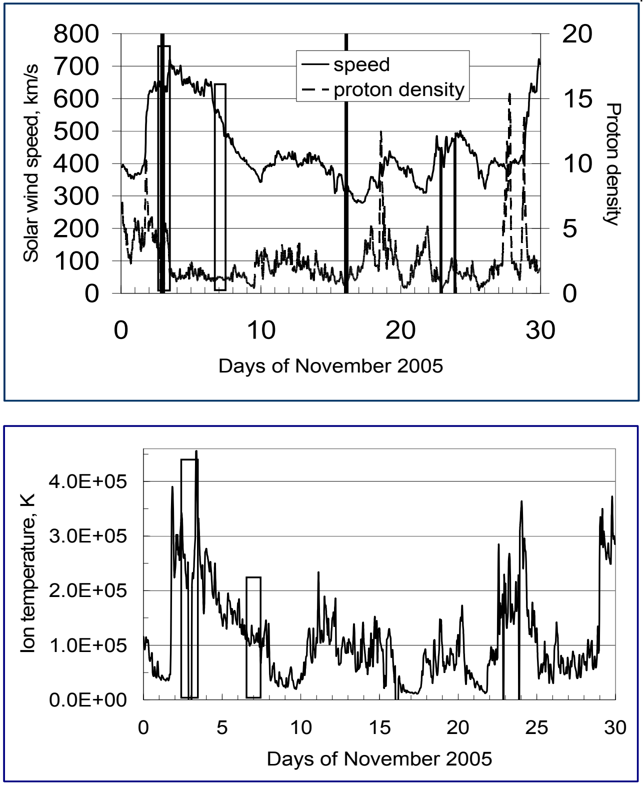

Fig. 2. Some Solar wind parameters in November 2005 (ACE data).

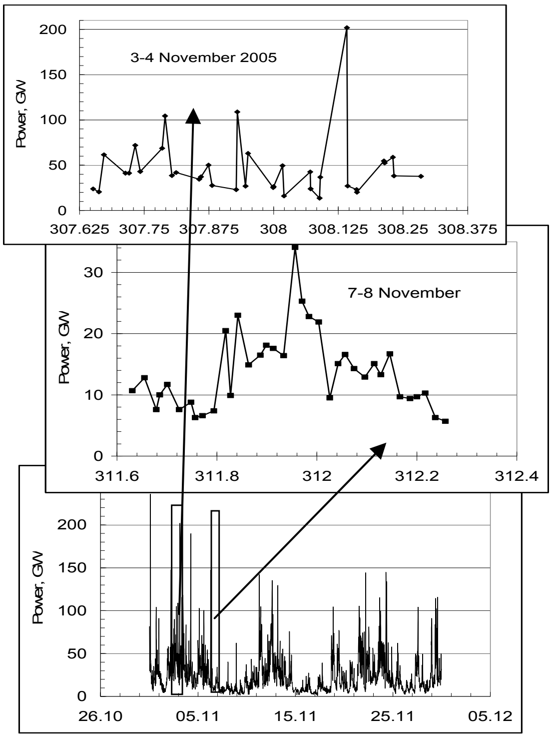

***Fig. 3.** Auroral particles power input in the Northern hemisphere during November 2005 (NOAA POES measurements). The examined periods are given in detail*

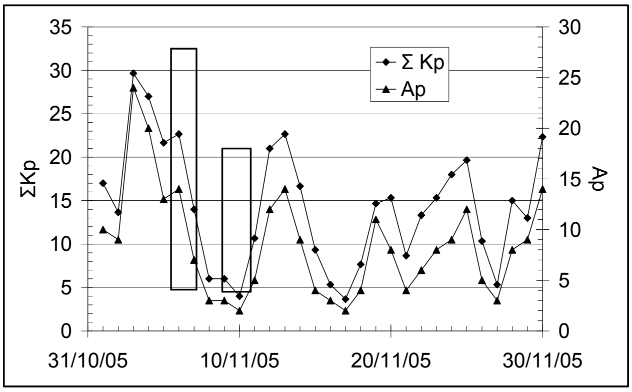

***Fig. 4.** k_p and A_p geomagnetic indices in November 2005*

Examined periods. During November 2005, measurements of the 5577 Å and 6300 Å emissions have been performed by the All Sky Imager (ASI), when the needed conditions were present. Simultaneous All-sky camera data are used to watch the atmospheric conditions.

Taken into account the measurement days and the course of the examined quantities in Fig.1-4, two periods were chosen when the space and geomagnetic conditions were considerably different: a quiet night (November 7, 2005, 15:30:00 UT – November 8, 2005, 5:50:00 UT) and at highly disturbed geomagnetic conditions one (November 3, 2005, 15:50:00 UT – November 4, 2005, 5:40 UT). The first night is among the quietest ones (Nov. 8 is Q4) and the second one – among the most disturbed ones (Nov. 3 and 4 are D1 and D2) for November 2005. The examined periods are marked with rectangles in the above figures. The power input is presented in detail for these periods in Fig.3.

Observations. Images of 5577 Å and 6300 Å emissions during the examined periods are obtained from the **All-Sky Imager (ASI).** For better understanding of the auroral images and the arcs behaviour, resulting of a lot of phenomena, simultaneous data from other instruments are used together with the solar activity, solar wind, IMF and geomagnetic activity data. The distribution of the energetic particles precipitation is given by the **Imaging Riometer for Ionospheric Studies (IRIS)** measurements. The changes in the magnetic field components are recorded by the **Andenes Magnetometer. The Tromso Digisonde** provides information about the plasma parameters.

All-Sky Imager (ASI). ASI is positioned at ARR, Andenes (69.3°N, 16.03°E). It records automatically the 5577 Å and 6300 Å emissions with 10 s time resolution, from a 180° field of view in a 512x512 matrix. The row data are processed in the Oslo University.

Imaging Riometer for ionospheric Studies (IRIS). IRIS, at Kilpisjärvi, Finland (69.05°N, 20.79°E), measures the absorption of cosmic noise at 38.2 MHz by 49 beams (7x7 area) every second. This absorption corresponds mostly to ionisation by electrons with energies in the range 10÷x100keV and deposition heights centered at about 90 km. The database is organized by the Lancaster University.

Andenes Magnetometer. The Andenes magnetometer (69.3°N, 16.03°E) measures the magnetic field components every second. The vertical component (Z), the horizontal one (H) (along the magnetic meridian) and the declination (D) (perpendicular to H) are accumulated and processed at the Tromsø Geophysical Observatory, University of Tromsø, Norway.

Tromsø Digisonde. Ionograms, describing the essential ionosphere parameters are acquired at 15 minutes' intervals after processing the data, registered by the Digisonde, situated at Tromsø (69.6N, 19.2E).

Projected fields of view in geographic coordinates of ASI and IRIS. ASI and IRIS are situated in the same area, not far each to other, and their fields of view overlap. The positions of the projected fields of view of the instruments are shown in Fig.5 in geographic coordinates for both cases: 5577 Å and 6300 Å measurements by ASI. The ASI field of view (fenced in the circles) is taken ±70° from zenith (the way the images are obtained), with assumed height of 120 km for the 5577Å emitting features and 250 km for the 6300 Å ones (the left and right pictures, respectively). The IRIS field of view is 18°÷23.5°E and –(65.2°÷66.8°N, with energy deposition height, considered 90 km (the black rectangles). It is seen that the IRIS field of view falls within the ASI field of view in both cases.

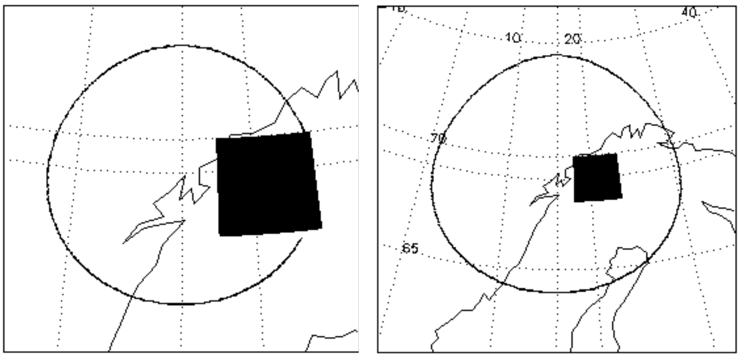

Fig. 5. Projected fields of view in geographic coordinates of ASI and IRIS

Spatial distributions. The obtained ASI and IRIS images with 1 min. resolution for the quiet and disturbed periods are examined. In Fig.6, typical examples of 1-hour plots of the 5577 Å (up) images and

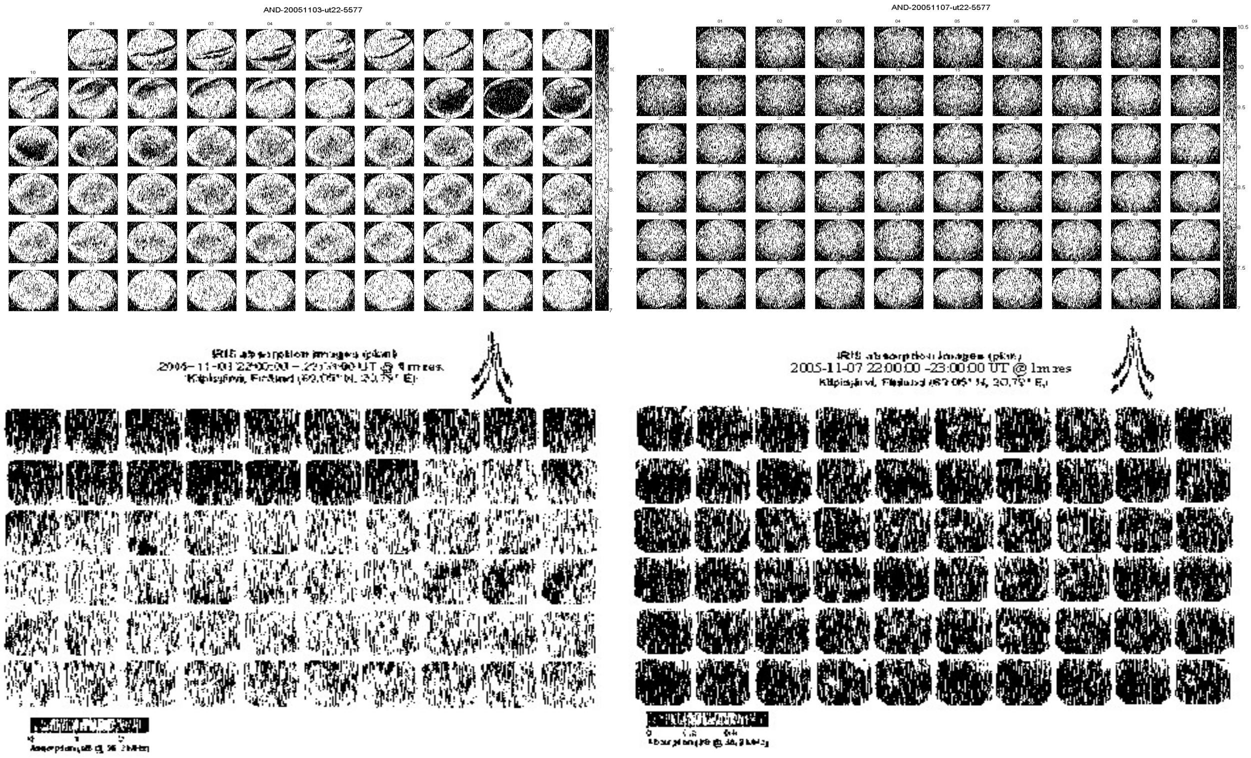

Fig. 6. Typical examples of 1-hour plots of the 5577 Å (up) images and IRIS absorption ones (down). The left column presents the images of 22:00÷23:00h on 3 Nov. 2005, and the right one is for 22:00÷23:00h on 7 Nov.2005 (when the most intensive glow for this day occurred). North direction is up.

IRIS absorption ones (down), are shown. The left column presents the images of 22:00÷23:00h on 3 Nov. 2005, and the right column is for 22:00÷23:00h on 7 Nov.2005 (when the most intensive glow for this day occurred). In all images, North direction is up.

The images present the spatial distribution of the auroral forms. The temporal evolution is given by the consecutive images. Fast glow changes (with the time scale of seconds) are observed during the disturbed period. Immense variety of forms generate, move through the field of view, changing in form and intensity. The observed arcs usually have sharp edges, and in most cases their direction is almost East-West, sometimes turning into NE-SW or NW-SE. On the common background of increased intensity, considerable glow enhancement occurred several times and persevered for more than half an hour (like the one presented in the figure). During the quiet period the glow is much weaker. Even in the time of higher glow values, the increase is slow and gradual. No separated arcs are observed. The enhanced glow represents just slightly brighter patches with smooth edges. A close connection between the distribution and development of the intensity of 5577Å and 6300 Å and the absorption images, presenting the electron flux distribution, is visible.

Temporal development. To see better the changes with the time, the so called “keograms” are constructed, shown in Fig.7. They present the data along a geomagnetic meridian in dependence of the time. The ASI keograms are obtained for the geomagnetic meridian, passing through the center of the field of view (100.23°E), ±70° from zenith, in log scale, from 6.5 to 8.5 for 6300Å (upper left picture in Fig.7), to 10 for 5577 Å (lower left one) on 3-4 Nov., and to 7.4 for 6300Å (upper right picture), and to 8 for 5577 Å (lower right) on 7-8 Nov. The IRIS keograms are created also for the central point of the instrument field of view (103.62°E) for geomagnetic latitudes range 65.2°÷66.8°N (bottom pictures). The absorption, registered by beam 15 (closest to the ASI center of the field of view) and the magnetic field components course, measured in Andenes, are examined, too. The bulk of emission is not symmetric towards midnight in the disturbed period. Highly enhanced glow is observed from about 16 h. till 3 h in the morning, but the most intensive part is up to midnight. During the quiet period, the glow intensity is more symmetric (20 h. to 4 h.), and again higher up to midnight. A good correlation between the optical emissions, the precipitating electron fluxes and the terrestrial magnetic field during the examined periods is observed.

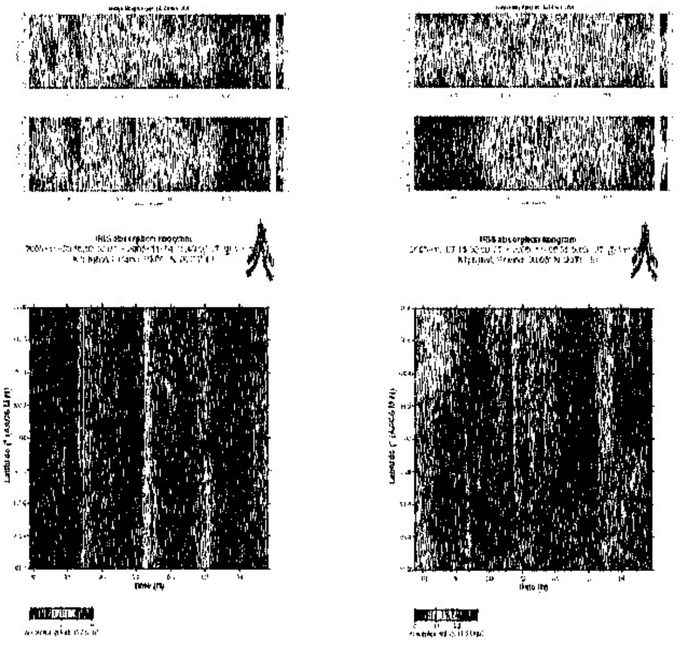

Fig. 7. *ASI (6300 Å up, 5577 Å down) and IRIS (further down) keograms for the examined periods. The keograms of 3-4 Nov. 2005 are on the left side and the ones of 7-8 Nov. 2005 are on the right side.*

Conclusions. Close connection between the space and geomagnetic conditions and the auroral emissions activity is observed. Fast glow changes (with the time scale of seconds) are observed during the disturbed period. The observed in the disturbed period arcs usually have sharp edges, and in most cases their direction is almost E-W, sometimes turning into NE-SW or NW-SE. Considerable glow enhancement occurred several times and persevered for more than half an hour.

During the quiet period the glow is much weaker, the increase is slow and gradual. No separated arcs are observed.

A close connection between the distribution and development of the intensity of 5577Å and 6300 Å and the absorption images, presenting the electron flux distribution, is seen. A good correlation between the optical emissions and the precipitating electron fluxes, and the terrestrial magnetic field during the examined periods is observed.

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