Space Weather Research in Kazakhstan

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Abstract. In Kazakhstan there is an experimental complex for space weather study and forecasting. This complex is situated near Almaty (Kazakhstan). It includes an experimental setup for records of cosmic ray intensity (neutron monitor) at the altitude of 3340 m above sea level, a magnetic observatory «Alma-Ata», an optical interferometer SATI for recording the emission of night sky, an ionospheric sounder and a solar radio telescope. Nowadays the measurements of the solar radio flux at frequencies of 1.078 GHz and 2.8 GHz (10.7 cm) is carried out on the regular basis with 1-second time resolution. A new Callisto radio spectrometer (eC37) was installed and configured while the «Orbita» ground station. All data are represented on the web site of the Institute of the Ionosphere (www.ionos.kz) in real time. Since July 2006 the space environment prediction laboratory represents the fore cast of geomagnetic activity every day on the same site.

Keywords: CALLISTO radio spectrometer, cosmic ray, neutron monitor, geomagnetic observatory, forecast of geomagnetic activity.

Introduction

Space weather and its effects are largely determined by the Sun, solar and galactic cosmic rays, solar wind, while the state of the Earth's magnetosphere, atmosthere and ionosphere also bear an influence. The effects of this phenomenon are many and varied: they include changes in electronic charging of satelllites, interruptions in telecommunications and navigational systems, hazards to astronauts and aircraft crews and many other effects (Baker, 2004). Space weather research is important for each country. However, these studies can be conducted only by uniting the efforts of scientists from different countries, as ground-based measurements of space weather parameters depends on the location of the experimental setup. Kazakhstan develops intensively space weather research to be part of an international collaboration to solve this important problem.

Experimental setups

Kazakhstan's space weather complex includes the neutron super monitor for registration of cosmic ray intensity, a geomagnetic observatory, a radio telescope, a new Callisto radio spectrometer, an ionospheric sounder and an optical interferometer SATI.

Almaty High Mountain Cosmic Ray Station (cosmic ray station Alma-Ata B) is situated near Almaty city on a distance of 28 kilometers at the altitude of 3340 m above sea level and 50 km from the Institute of the Ionosphere (Zusmanovich, Kryakunova and Shepetov, 2009). It has been operated since 1973. Present high mountain Alma-Ata neutron supermonitor (Alma-Ata B, 43.1 N latitude, 76.6 E longitude, geomagnetic rigidity cutoff 6.69 GV) consists of the 18 SNM15 type neutron counters, which are divided between three standard 6-counter units. The sum rate of the monitor count is ~4.5-5.0 10^6 pulse per hour (depending on the solar activity phase). The neutron monitor data are presented in the graphic and text form with a minutely updating in real time (Fig. 1) (cosray.ionos.kz/CosRay/index.htm).

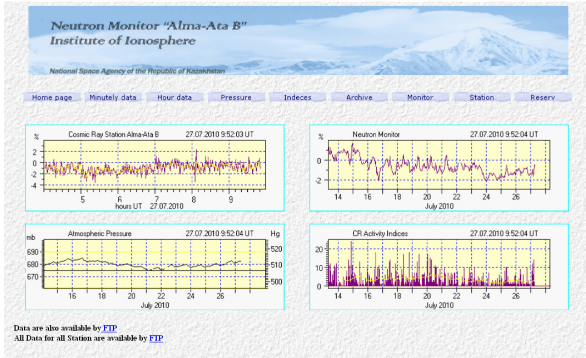

Figure 1: Website with neutron monitor data in real time with 1-min update.

The interface with cosmic ray intensity data in real time obtained by means of high-altitude neutron monitor has been realized on Institute of the Ionosphere web-site. Control panel allows to select a time interval, type of the data and the form of data presentation (Fig. 2).

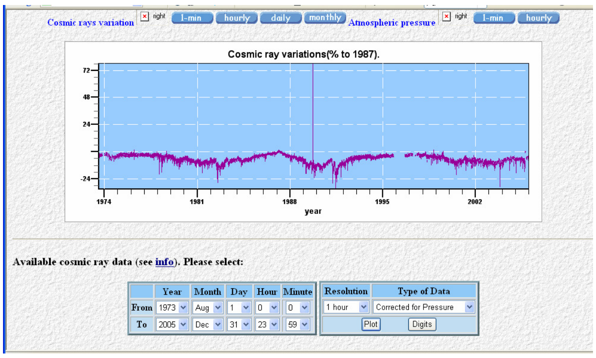

Figure 2: The interface with Almaty neutron monitor data.

For monitoring of the radiation situation, we use mid-latitude Almaty neutron monitor data and data of high-latitude Oulu neutron monitor (cosmicrays.oulu.fi). MySQL database at the Institute of the Ionosphere was created for visual control of neutron monitor 1-minute data in real time (Fig. 3) and identification of ground level enhancements (GLEs) because some not big GLEs may be registered only at high latitudes (Beisembaev et al., 2009). An example of such event we can see in Fig. 3 during last GLE on May 17, 2012.

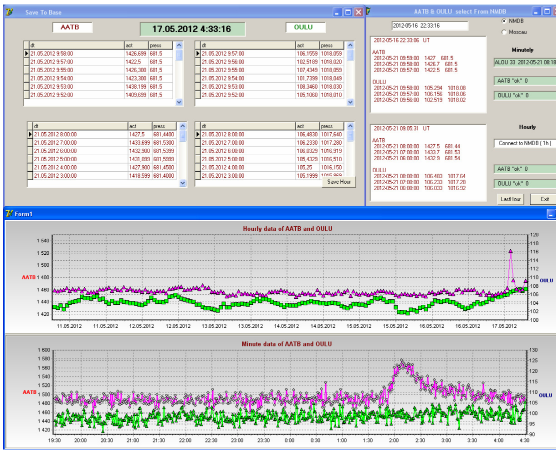

Figure 3: GLE on May 17, 2012 by means of Almaty (green) and Oulu (pink) real time neutron monitor data.

In the frame of cooperation between Institute of the Ionosphere (Almaty), Lebedev Physical Institute of Russian Academy of Sciences (Moscow), Institute for Physics and Technology (Almaty) and Physics Department of the Kazakh National University three experimental setups for registration of cosmic ray intensity (neutron monitors) at altitudes of 3340, 1750 and 850 m above sea level were integrated in common experimental complex (www.tien-shan.org/she/vardbaccess/index.html) - the ATHLET (Almaty THree Level Experimental Technique) collaboration (Amurina et al., 2005).

Now the mountain cosmic ray station of Institute of the Ionosphere of Kazakhstan Republic is a center for an experimental study of the non-stationary processes caused by cosmic rays of different origin in the interplanetary and near-Earth space, so as their influence on the state of the Earth's magnetosphere and the upper atmosphere layers.

Almaty Cosmic Ray station is included in the worldwide neutron monitor network and European database NMDB (www.nmdb.eu) for the real-time monitoring of primary cosmic rays in the (0.5-20) GeV energy range.

Geomagnetic Observatory "Alma-Ata" has operated since 1963. It is located at the altitude of 1300 m above sea level at the Institute of the Ionosphere, geographical coordinates of the observatory are 43.18 N, 76.95 E. Type of equipments are: a magnetometer LEMI-008, a portable single-component magnetometer LEMI-203, and a overhauser effect proton precession magnetometer QM Laboratory type POS-1. In late 2005, Geomagnetic Observatory "Alma-Ata" was certified as an international organization of INTERMAGNET (www.intermagnet.bgs.ac.uk). All experimental data and local K-indices are presented on website (geomag.ionos.kz) in real time (Fig. 4).

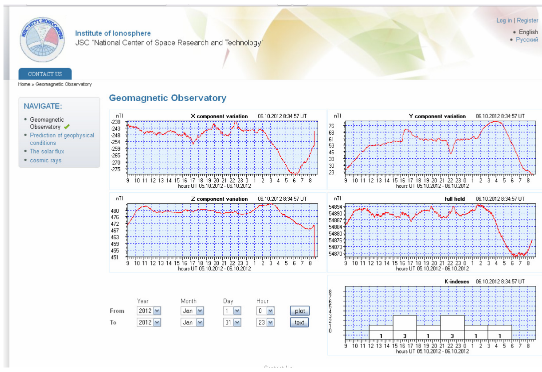

Figure 4: Website with geomagnetic data in real time.

Ionospheric sounding in Kazakhstan started in 1943 using the AIS ionosondes. In 2003 this was replaced by a Russian advanced digital ionosonde PARUS (izmiran.rssi.ru). The ionosonde provides accuracy of 2.5 km for h'(f) and 0.05 MHz for the $f_0F2(t)$. A local ionosonde data bankbased on input of all available ionospheric data is currently under development. The main direction of the ionospheric research for the Institute over the past years is to measure changes (both natural and man-made) in the E- and F- layers, long-term trends and effects of vertically propagated atmospheric waves in the upper ionosphere, night time and day-to-day variability, and irregular events in the ionosphere during geomagnetic storms. For example, it was recently shown an anomalous formation of the E-, E2-, F2-layers and appearance of the auroral-type sporadic E-layers in the night time ionosphere observed at the midlalitude Alma-Ata station during the great geomagnetic storms of October-November 2003 (Gordienko et al., 2005; Gordienko et al., 2011). The ionospheric observations indicated that, during strong storms (especially during the storm of October 30–31, 2003) the Kazakhstan power systems were affected by considerable GICs (Geomagnetically Induced Current) for a rather long time. It was found that processes associated with geomagnetic disturbances can be one of the main causes for creation of the travelling ionospheric disturbances (TIDs) accompanied by GPS positioning errors increasing.

The SATI instrument developed in Canada (stpl.cress.yorcu.ca/SATI) and installed at the experimental base area of the Institute of the Ionosphere “Orbita” at 2730 m altitude above sea level in the absolute absence of the Almaty city light. It has been in regular operation since October 2009. SATI is a spectral imaging interferometer using narrow band interference filters and a cooled CCD camera. It allows monitoring of the dynamics and temperature in the mesopause region by observing the 02 atmospheric (O-1) nightglow emission layers at 94 km and the OH Meinel (6-2) layer at 87 km. The short integration time

(120 sec and less) and the space resolution in azimuth coordinates allow also to detect gravity waves.

The solar flux density at 10.7cm and 27.8 cm wavelengths is measured using fully automated radio telescope. A 12-meter parabolic antenna and radiometers RM-10 and RM-30 are used for measurements. The two radiometers record solar flux density at 10.7cm and 27.8 cm wavelengths each day for as long as the Sun is above the local horizon. Real time and archival data of solar flux on 1 GHz and 2.8 GHz (10.7 cm) are presented on web-site (www.ionos.kz/?q=orbita) as shown in Figure 5.

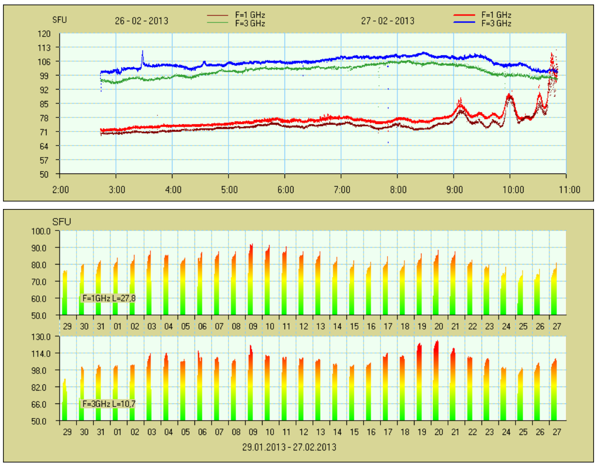

Figure 5: The solar flux density at 10.7cm and 27.8 cm wavelengths for the last 30 days.

A new Callisto radio spectrometer (eC37) was installed and configured at the «Orbita» ground station in May 2011. It operates between 45 and 870 MHz (different types of solar radiobursts) having a frequency resolution of 62.5 KHz. One of the radio burst recorded by means of Callisto radio spectrometer is shown in Figure 6. Twenty five of the CALLISTO instruments have already been deployed including Kazakhstan. Through the IHY/UNBSSI instrument deployment program, Callisto is able to continuously observe the solar radio spectrum for 24 hour per day through all the year. All Callisto spectrometers together form the e-Callisto network (www.e-calisto.org).

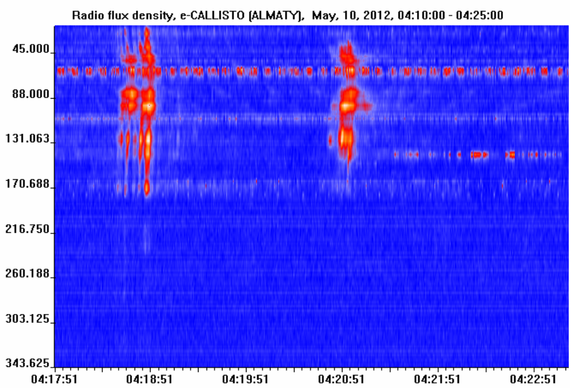

Figure 6: Radio burst of type III recorded on the 10 of May, 2012.

Data analysis and results

At the present time one of the focus of our attention is the influence of space weather factors on operation of the satellite's electronics. It was shown that the Almaty mountain cosmic ray station is one of the most suitable and sensitive stations for investigation and forecasting of the dangerous situations for satellites (Belov et al., 2004, 2005).

It was investigated the relation of satellite malfunctions to the behavior of cosmic ray activity indices (CRA-index) for Alma-Ata station (Belov et al., 1999). We applied the epoch method to our data, choosing day with each of satellite anomalies as zero-day. Figure 7 demonstrates that at the high altitude, just after CRA-index increase, a significant rise of the satellite malfunctions frequency is observed (Belov et al., 2005).

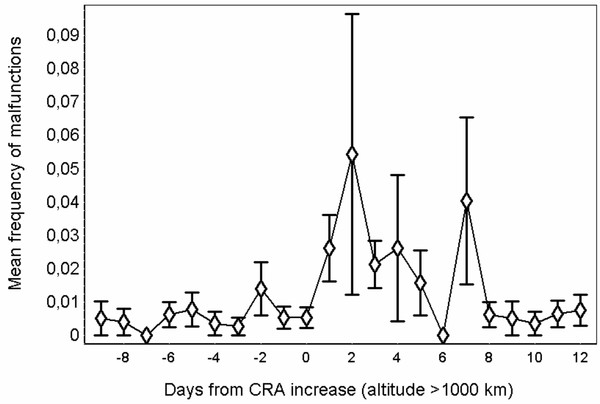

Figure 7: The satellite malfunction frequency (malfunctions per day per satellite) averaged by the epoch method. 0 is the day of the abrupt increase of the cosmic ray activity indices calculated by means of high-altitude neutron monitor data.

We present cosmic ray activity Indices in real time on website as shown in Figure 1.

Now cosmic ray station is included in the world-wide neutron monitor network for the real-time monitoring of the space weather conditions (Mavromichalaki et al., 2004). This work was supported by the Grants INTAS-2000-752 "Key parameters for the space weather" and INTAS-00-0810 "Improvement of the control and prognosis methods of the periods of dangerous influence of the space weather on satellite electronics".

One of the area of our research is monitoring and investigation of solar neutrons by the observations with ground level neutron monitors (Aushev et al, 1999).

The observation at the Earth of solar protons and neutrons, generated during powerful solar flares (in combination with X-ray and gamma-ray data) allows us to obtain unique information on the Sun's flare process and particle acceleration mechanisms.

The detection of solar neutrons is mostly probable near local noon at mid- and low-latitude mountain neutron monitors. There are only a few such cosmic ray stations in the world network (about 10), and high mountain (3340 m) neutron monitor at Alma-Ata (Institute of the Ionosphere) is among them. The combination of its geomagnetic cutoff rigidity (6.7 GV), altitude (3340 m) and high statistical accuracy makes this station enable to record solar neutrons of the energy order of 300 MeV (Belov et al., 2009).

All data are represented on the web-site of the Institute of the Ionosphere (www.ionos.kz) in real time. Since July, 2006 the space environment prediction laboratory represents the forecast of geomagnetic activity every day on the same site (www.ionos.kz/?q=en/node/21) as shown in Figure 8.

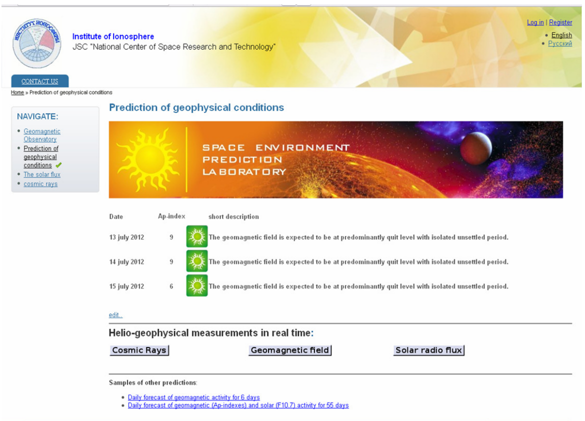

Figure 8: Website with the forecast of geomagnetic activity and the links to helio-geophysical measurements in real time.

Acknowledgments

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