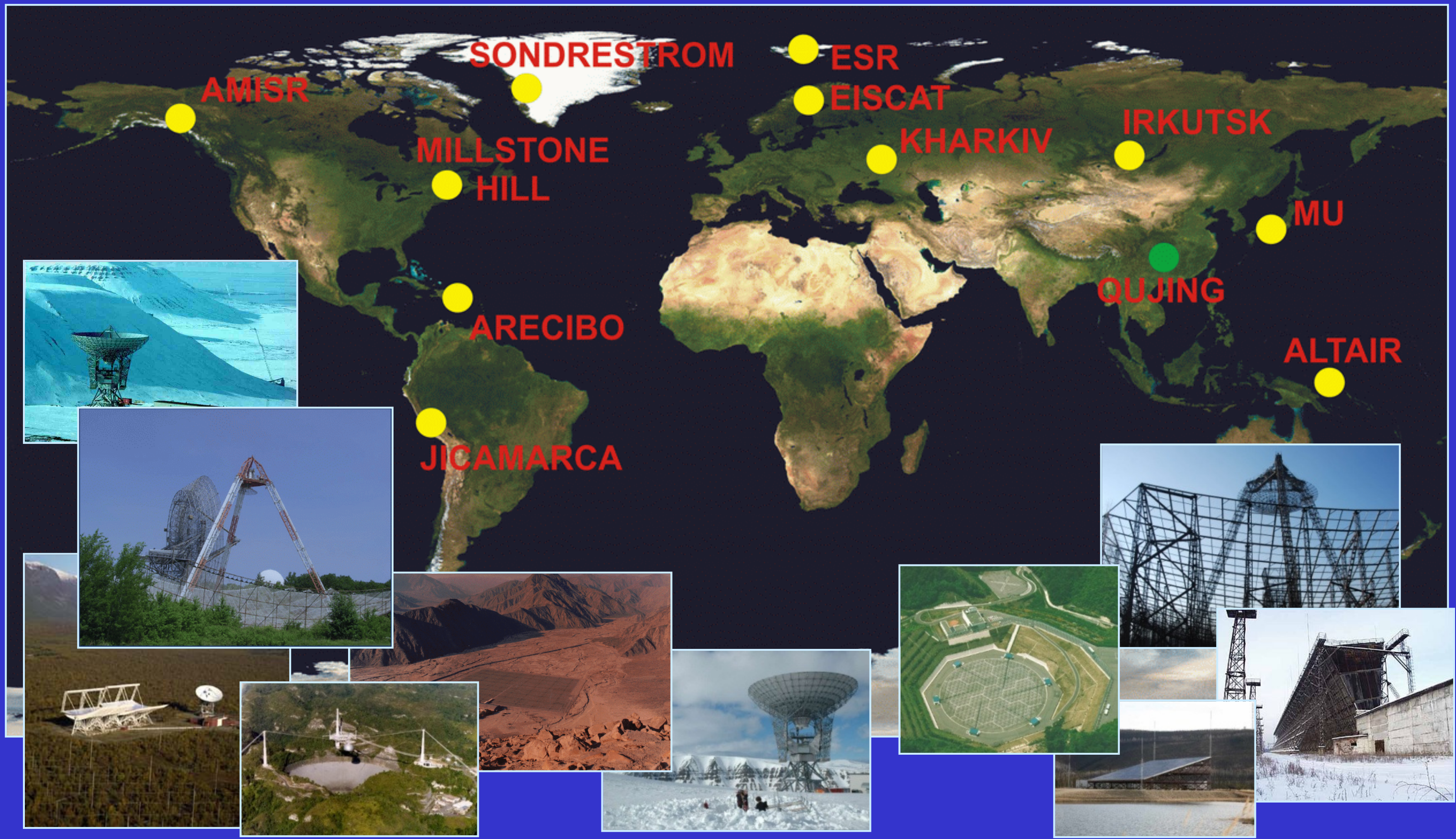
NATIONAL ACADEMY OF SCIENCES OF UKRAINE
MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

IION

INSTITUTE OF IONOSPHERE: THE MAIN SCIENTIFIC DIRECTIONS AND INVESTIGATION RESULTS

The Institute of Ionosphere is one of the largest over the world scientific centers which carry out investigations of physics of the near-Earth space and solar-terrestrial couplings with a current, the most accurate and informative method of incoherent scatter (IS) of radio waves. In 2001, the scientific center named as «Ionospheric sonde» was recognized as object of National Property of Ukraine.



The Kharkiv IS radar system is only facility of incoherent scatter at mid-latitudes of Europe. There are 11 such radars all over the world, 5 radars from them belong to the United States.

IONOSPHERIC OBSERVATORY

Ionospheric Observatory of the Institute for Ionosphere is located in 50 kilometers to the south-east from Kharkiv city. Its geographic and geomagnetic coordinates are: 49.6° N, 36.3° E and 45.7°, 117.8°, respectively.

The Ionospheric Observatory facilities include

- ❖ the 158-MHz VHF IS radar equipped with the zenith parabolic Cassegrain antenna of 100 m diameter;
- ❖ the 158-MHz VHF IS radar equipped with the fully steerable parabolic antenna of 25 m diameter;
- ❖ the HF heating facility with transmitter power of 100 kW and antenna array of 300 m x 300 m area operating in band 5.5 – 11 MHz;
- ❖ ionosonde “Bazis”.

IONOSPHERIC OBSERVATORY

The observatory has a single incoherent scatter radar complex in the middle latitudes of the European region (National property of Ukraine)

ISR with full-steerable antenna (25 meter diameter)

ISR with zenith parabolic antenna (100 meter diameter)

KHARKOV ISR EQUIPMENT

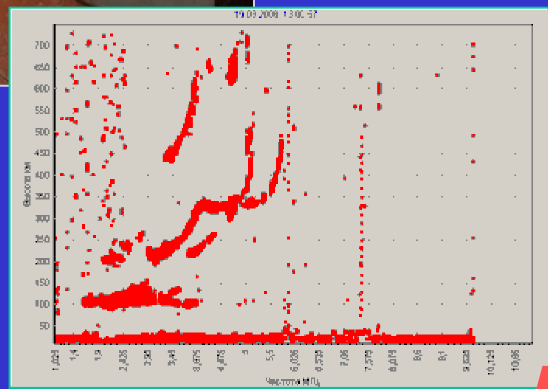
The receiver facility and processing system

Fragments of the Kharkov ISR transmitter facility

TECHNICAL CHARACTERISTICS OF THE KHARKOV INCOHERENT SCATTER RADAR

Geographic coordinates: 49.6° N; 36.3° E
Geomagnetic coordinates: Φ = 45.4°; Λ = 117.7°
Inclination of the geomagnetic field 66°
McIlvaine parameter $L \approx 1.9$
Frequency 158 MHz
Pulse power 2 – 4 MW
Average power 100 kW
Antenna gain 12700
The effective area of the antenna ~ 3700 m
Beam width ~ 1°
Pulse length 70 – 800 µs
Pulse repetition frequency 24.4 Hz
System noise temperature 1300 – 1800 K
Noise temperature of a two-channel receiver 240 K
Investigated range of heights 100 – 1500 km

TECHNICAL CHARACTERISTICS OF THE IONOSONDE “BAZIS”



Frequency band 1 – 40 MHz.
Effective power 1 – 10 kW
Pulse length 50 – 100 µs
Range of altitudes 100 – 400 km

THE MAIN DIRECTIONS OF SCIENTIFIC RESEARCH

- Experimental study of the ionospheric parameter variations by incoherent scatter method in the altitude range 150 – 1500 km;
- Modeling of the geospace parameter variations in quiet helio-geophysical conditions;
- Observations, analysis and interpretation of physical effects of the geospace storms of varying intensity;
- The study of wave disturbances of natural and artificial origins in the ionospheric plasma;
- Study of the effects in the atmosphere and ionosphere during partial solar eclipses;
- Development of the Kharkiv ISR database;
- Development of unique equipment for the near-Earth space research;
- Development of software for geophysical information processing.

INVESTIGATION RESULTS

THE EFFECTS IN IONOSPHERE DURING GEOSPACE STORMS

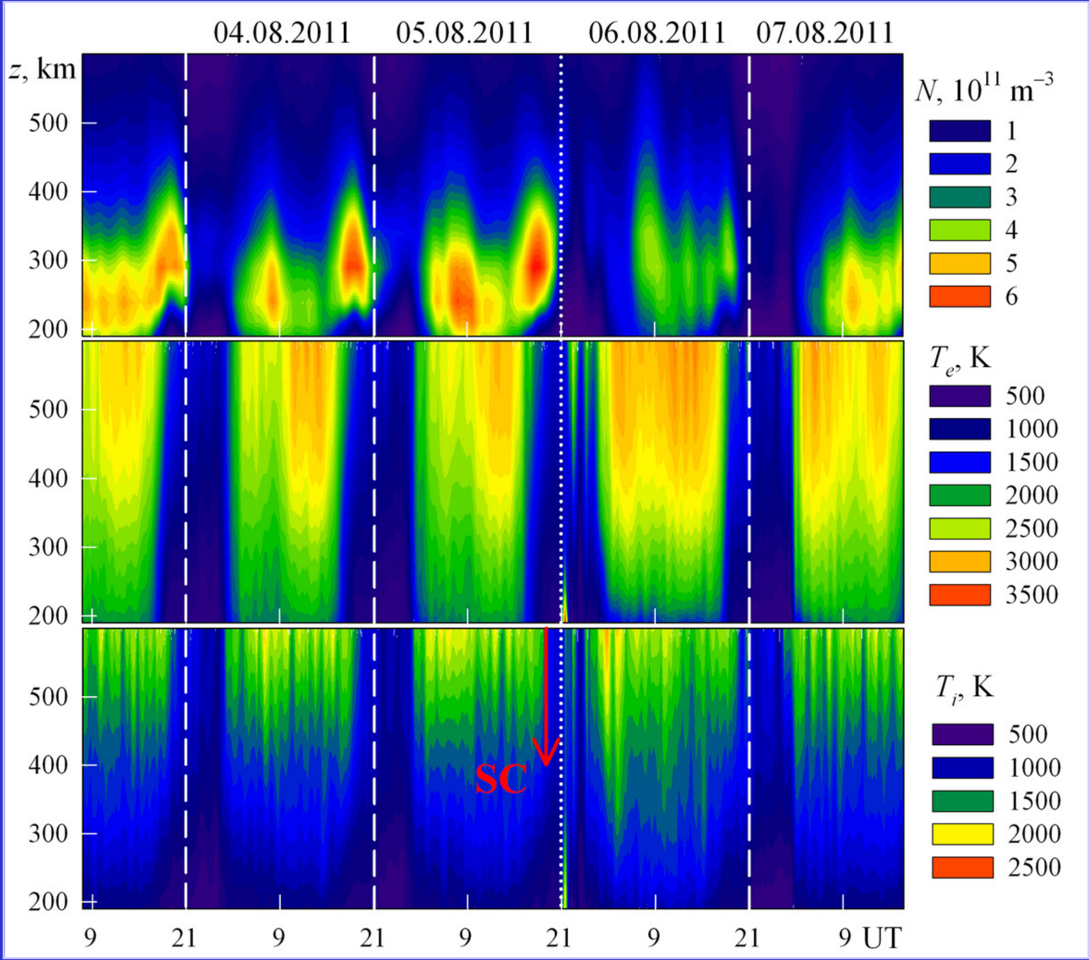
In the Institute of Ionosphere was created database of ionospheric storms. The peculiarities of 8 ionospheric storms were studied in detail. These storms accompanied the magnetic disturbances of various intensities and occurred during the period from 1998 till 2011.

The pronounced features of strong negative ionospheric disturbances accompanying severe magnetic storms on 25 September 1998, 29 – 30 May 2003, 7 – 10 November 2004 and 5 – 6 August 2011 were carefully investigated.

During these storms, indices of magnetic activity $Kp \geq 8$. Among these features, there were depletion in electron density by a factor of 3.5 – 7, uplifting of ionospheric F2 region by more than 100 km, unusual nighttime heating of plasma up to daytime values of electron and ion temperatures, decrease in relative density of hydrogen ions, oblique coherent backscatters, and other events.

These effects are explained in terms of thermospheric disturbances, particle precipitation, shift of auroral oval and related structures towards the radar latitude, etc.

Ionospheric storm on 5 – 6 August 2011



The super strong magnetic storm began at 19:03 UT on August 5, 2011. The geomagnetic activity index K_p during the main storm phase was 8–, D_{st} = –113 nT.

The electron density in the F2-layer maximum of ionosphere decreased approximately by a factor up to 2. The F2-layer maximum height in the main phase increased to 513 km (in quiet conditions $z_m \approx$ 315 km.

The electron density on heights 200, 250, 300, 350 and 400 km in the moment of the main phase of the ionospheric storm decreased approximately by 85, 91, 82, 61 and 27% accordingly.

The electron temperature in the main phase of the ionospheric storm increased approximately by a factor up to 4 and 2.5 at the heights 200 – 250 km, and in the range of heights 300 – 700 km T_e increased approximately by a factor up to 1.5 – 1.8 in comparison with the reference day.

The ion temperature in considered period also increased approximately on 700 – 1000 K in the range of heights 200 – 250 km. On heights 300 – 700 km T_i increased approximately by a factor up to 1.5.

THE WAVE PROCESSES IN IONOSPHERE FROM DIFFERENT SOURCES

The wave disturbances (WDs) in electron density have been studied with the help of the Kharkov IS radar.

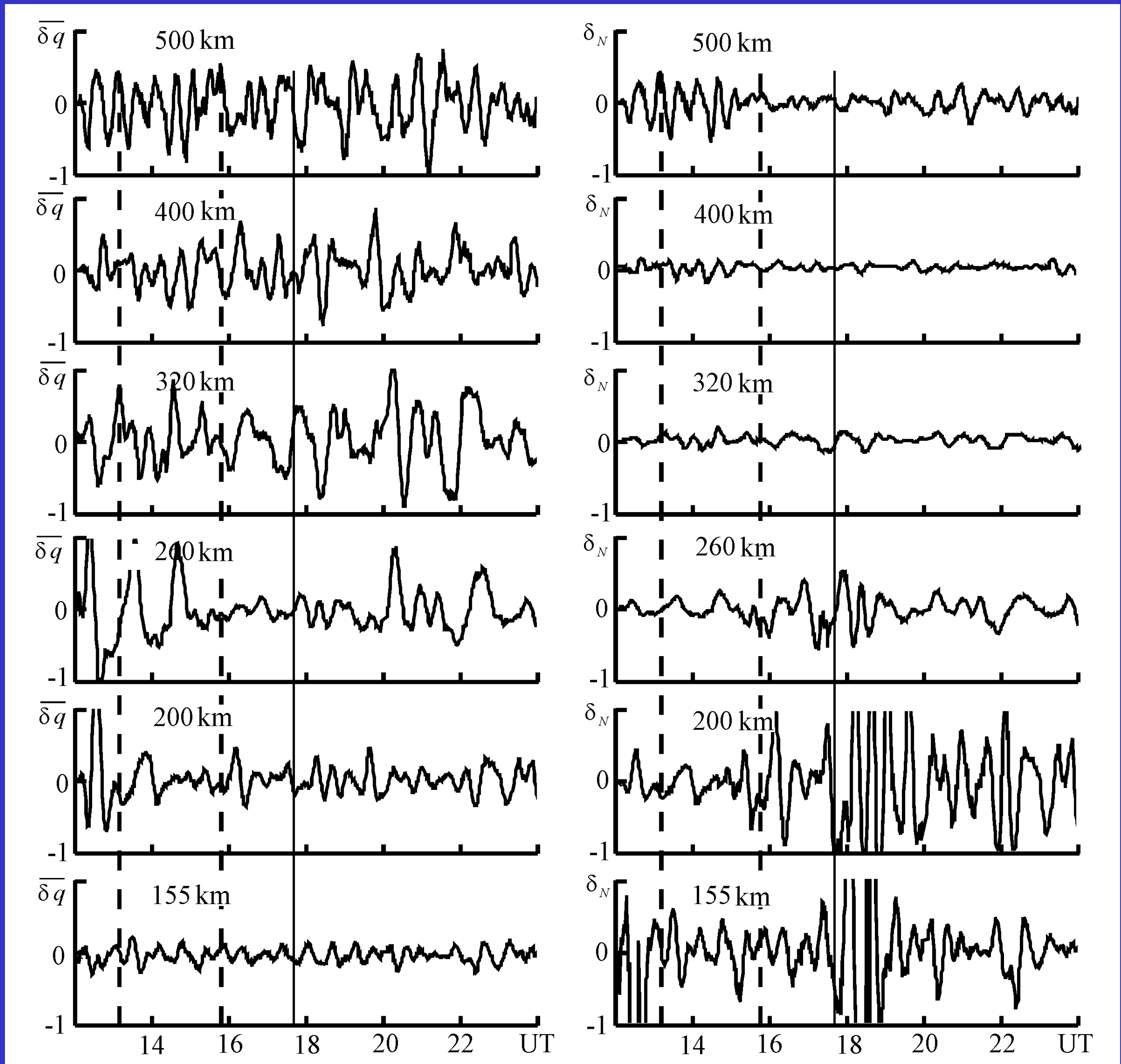
The objects of our research are:

- Wave activity during solstice and equinox periods in quiet conditions;
- WDs during partial solar eclipses;
- WDs during geomagnetic storms;
- WDs accompanying power rocket launches;
- WDs accompanying influence on the ionosphere of powerful radio emission.

It is shown that WDs in the ionosphere with 10 – 180 min periods exist almost permanently at altitudes of 100 – 500 km.

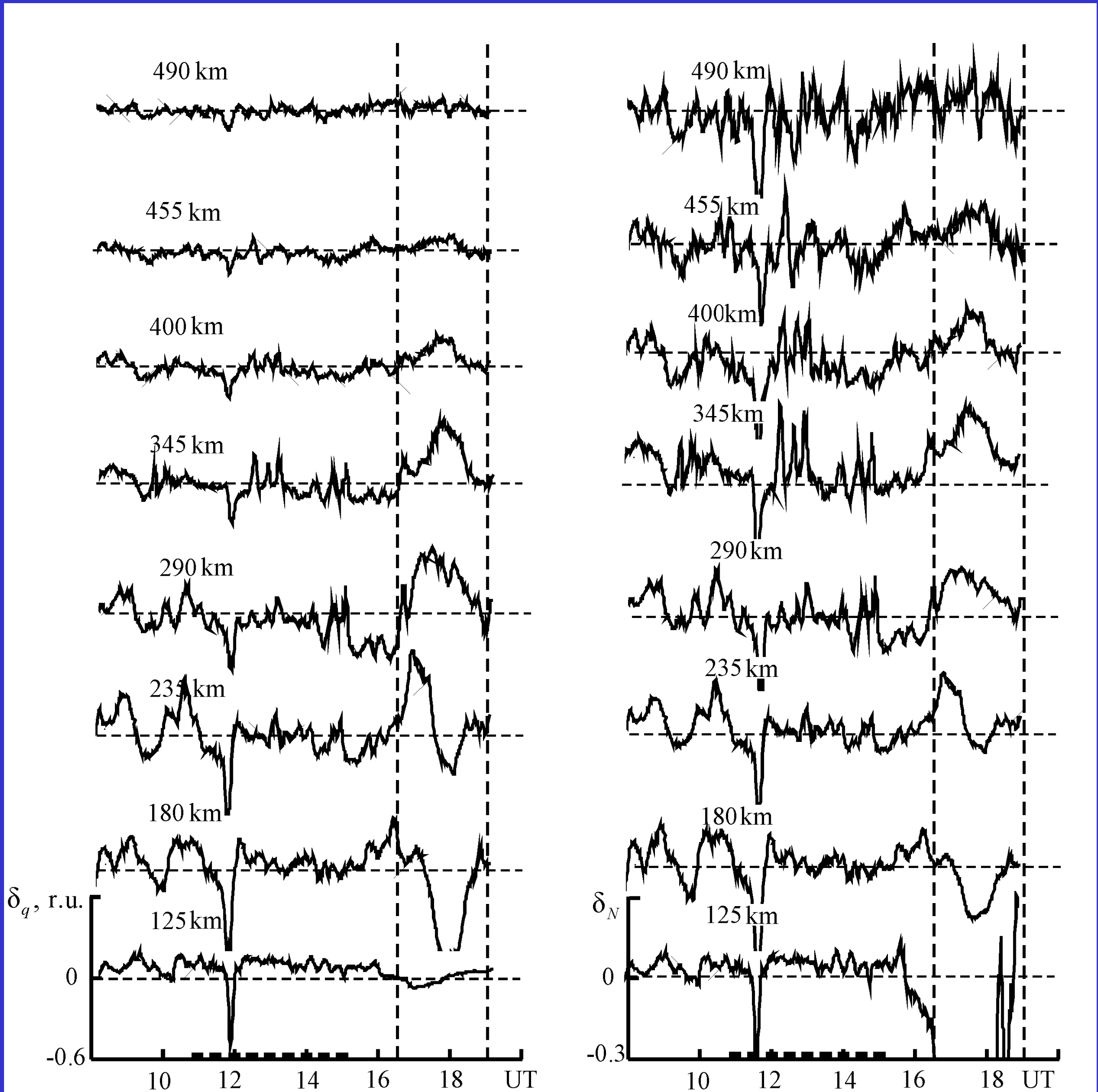
The influence of powerful sources of energy-release leads to the variations in spectral composition and amplitudes of wave disturbances.

The "Proton" rocket launch on December 10, 2003



Temporal variations in the WD amplitudes and relative amplitudes during the "Proton" (weight 700 tons) rocket launch at 17:42 UT (vertical solid line) on December 10, 2003 from Baikonur cosmodrome *R* ≈ 2000 km.

The high power HF emission of facility "Sura" influence on ionospheric plasma



Temporal variations in the WD amplitudes and relative amplitudes during the "Sura" operating time on August 31, 2009 (frequency is 4.3 MHz, effective power is 40 MW, *R* ≈ 1000 km).

THE EFFECTS IN IONOSPHERE DURING PARTIAL SOLAR ECLIPSES

With the help of IS radar made observations of six partial solar eclipses over Kharkiv during the period 1999 – 2011.

Considered the eclipse proceeded at different phases of the solar activity cycle and different geomagnetic activity levels.

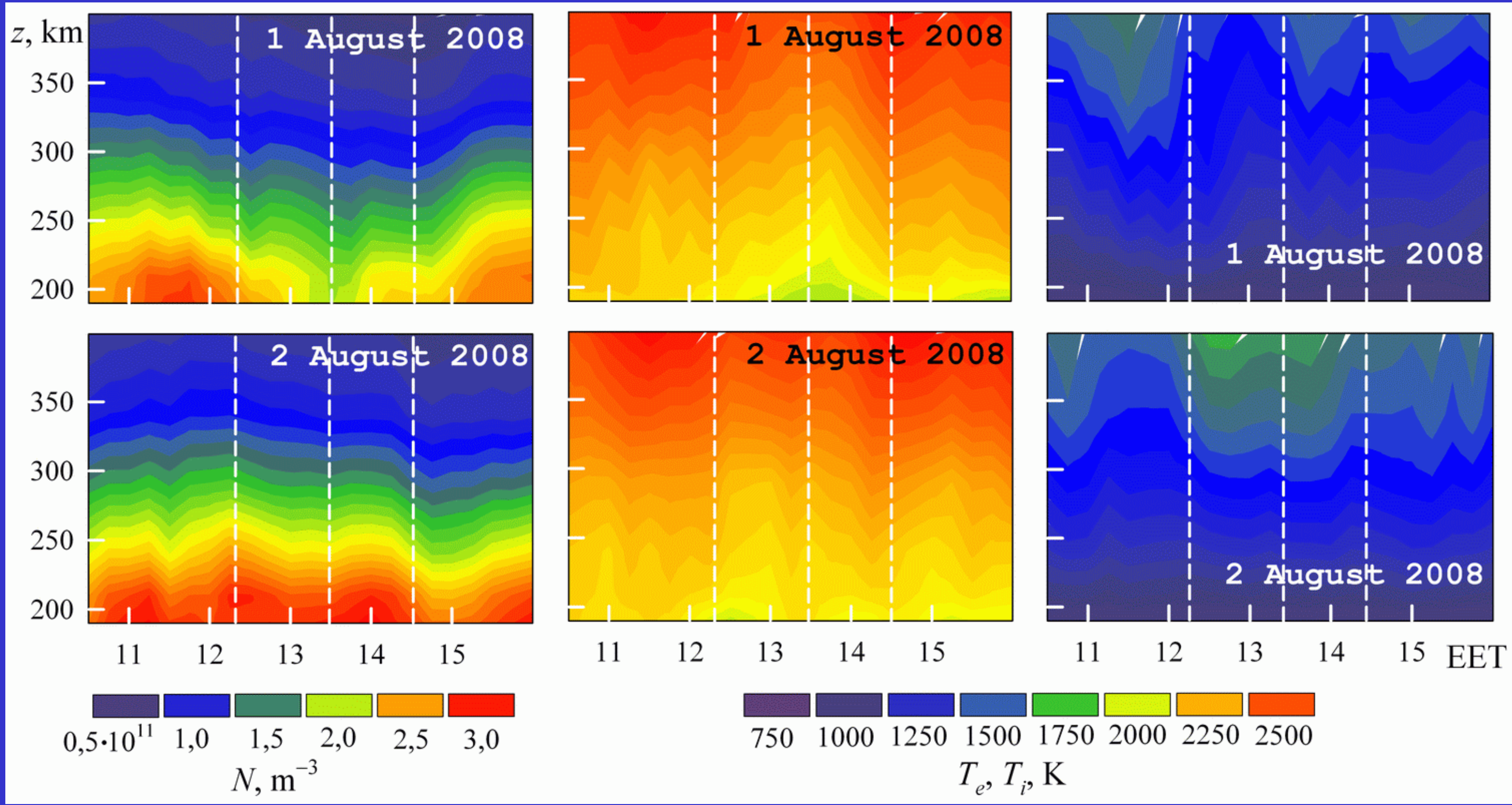
The analysis and interpretation of the variations in the ionospheric plasma during eclipses was performed. The theoretical simulation of the dynamic and thermal process parameter variations in the geospace during the solar eclipses was carried out.

General information about solar eclipses and helio-geophysical condition in period 1999 – 2011

Date	T_1, UT	T_{max}, UT	T_2, UT	A	D/D_0	$F_{10.7}$	$\langle F_{10.7} \rangle$	A_p
11.08.1999	09:57:32	11:15:40	12:29:27	0.746	0.794	131	158	6
31.05.2003	02:16:08	03:14:34	04:17:27	0.658	0.740	113	125	49
03.10.2005	08:41:40	09:41:57	10:42:34	0.153	0.263	74	79	7
29.03.2006	10:02:47	11:12:59	12:21:59	0.724	0.774	82	78	6
01.08.2008	09:11:28	10:15:41	11:17:47	0.329	0.439	66	66	3
04.01.2011	07:29:36	08:58:30	10:28:36	0.709	0.780	91	83	4

The SE on 1 August 2008

The SE on 1 August 2008 over Kharkov was partial. The eclipse was observed from 12:11 EET to 14:17 EET. Maximum obscuration of diameter and area of solar disk took place at 13:15 EET and amounted to values of 0.44 and 0.33, respectively. The illumination of the Earth's surface decreased approximately by a factor of 1.6 at the moment of the SE maximum phase. The total duration of the partial SE over Kharkov was 2 h 06 min.



Temporal variations of electron density, electron and ion temperatures during the SE on 1 August 2008 and reference day on 2 August 2008

THE REGIONAL IONOSPHERIC MODEL (CERIM IION) BASED ON THE KHARKOV INCOHERENT SCATTER RADAR DATABASE

CERIM IION

The aim of study is development of the region ionospheric model based on the Kharkov incoherent scatter radar (ISR) data.

Central Europe Regional Ionospheric Model (CERIM IION) consists of two parts. Empirical part of the CERIM IION based on experimental data obtained with the Kharkov ISR and ionosonde “Bazis” during period 1986 – 2006 that is corresponding to the 22-nd and 23-rd solar activity cycles.

This part of the model allows calculating the main geospace parameters – electron density, electron and ion temperatures, and vertical component of plasma drift velocity.

Electron Density (m^{-3})
Solar Activity Maximum
Summer Solstice

Altitude, km

Time, hour

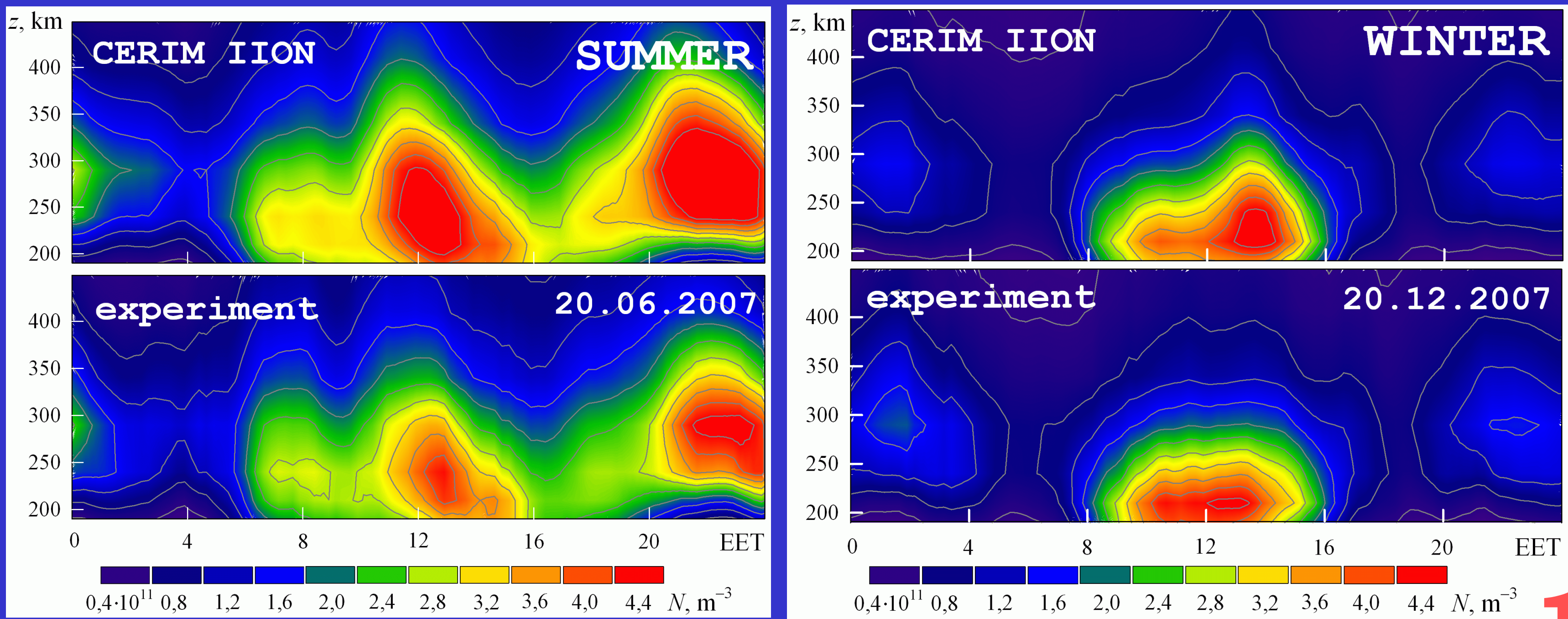
Время	200	250	300	350	400	450	500	550	600	650	700	750
0:15	1,09E+09	3,23E+11	6,39E+11	7,73E+11	7,01E+11	5,52E+11	4,03E+11	2,87E+11	2,05E+11	1,50E+11	1,10E+11	8,31E+10
0:30	1,21E+09	3,24E+11	6,23E+11	7,43E+11	6,72E+11	5,33E+11	3,92E+11	2,80E+11	2,00E+11	1,47E+11	1,08E+11	8,12E+10
0:45	1,35E+09	3,12E+11	5,90E+11	7,01E+11	6,37E+11	5,06E+11	3,74E+11	2,69E+11	1,94E+11	1,42E+11	1,04E+11	7,73E+10
1:00	1,48E+09	2,97E+11	5,59E+11	6,69E+11	6,15E+11	4,91E+11	3,63E+11	2,62E+11	1,88E+11	1,36E+11	9,92E+10	7,41E+10
1:15	1,72E+09	2,67E+11	5,12E+11	6,27E+11	5,88E+11	4,71E+11	3,49E+11	2,52E+11	1,81E+11	1,29E+11	9,25E+10	6,82E+10
1:30	1,75E+09	2,38E+11	4,78E+11	6,01E+11	5,72E+11	4,62E+11	3,43E+11	2,47E+11	1,76E+11	1,25E+11	8,89E+10	6,51E+10
1:45	1,67E+09	2,11E+11	4,42E+11	5,72E+11	5,54E+11	4,47E+11	3,30E+11	2,38E+11	1,70E+11	1,22E+11	8,69E+10	6,34E+10
2:00	1,57E+09	1,92E+11	4,17E+11	5,52E+11	5,42E+11	4,40E+11	3,25E+11	2,33E+11	1,67E+11	1,20E+11	8,68E+10	6,37E+10
2:15	1,48E+09	1,70E+11	3,89E+11	5,28E+11	5,27E+11	4,32E+11	3,19E+11	2,28E+11	1,63E+11	1,19E+11	8,68E+10	6,40E+10
2:30	1,45E+09	1,63E+11	3,78E+11	5,19E+11	5,21E+11	4,30E+11	3,19E+11	2,28E+11	1,64E+11	1,20E+11	8,88E+10	6,65E+10
2:45	1,59E+09	1,51E+11	3,58E+11	5,03E+11	5,16E+11	4,25E+11	3,14E+11	2,26E+11	1,62E+11	1,19E+11	8,83E+10	6,79E+10
3:00	2,12E+09	1,35E+11	3,34E+11	4,86E+11	5,12E+11	4,28E+11	3,20E+11	2,34E+11	1,69E+11	1,24E+11	9,22E+10	7,22E+10
3:15	3,37E+09	1,25E+11	3,21E+11	4,78E+11	5,09E+11	4,27E+11	3,21E+11	2,36E+11	1,73E+11	1,26E+11	9,43E+10	7,51E+10
3:30	5,57E+09	1,17E+11	3,08E+11	4,67E+11	5,07E+11	4,28E+11	3,24E+11	2,40E+11	1,77E+11	1,31E+11	9,88E+10	7,98E+10
3:45	8,99E+09	1,11E+11	2,94E+11	4,51E+11	4,95E+11	4,24E+11	3,25E+11	2,42E+11	1,80E+11	1,36E+11	1,05E+11	8,48E+10
4:00	1,40E+10	1,15E+11	2,95E+11	4,44E+11	4,83E+11	4,19E+11	3,26E+11	2,46E+11	1,87E+11	1,44E+11	1,13E+11	9,11E+10
4:15	2,11E+10	1,25E+11	3,01E+11	4,38E+11	4,69E+11	4,07E+11	3,19E+11	2,44E+11	1,88E+11	1,48E+11	1,18E+11	9,54E+10
4:30	3,04E+10	1,37E+11	3,02E+11	4,29E+11	4,57E+11	4,00E+11	3,19E+11	2,48E+11	1,95E+11	1,56E+11	1,25E+11	1,01E+11
4:45	4,20E+10	1,59E+11	3,21E+11	4,39E+11	4,62E+11	4,07E+11	3,30E+11	2,62E+11	2,08E+11	1,67E+11	1,35E+11	1,11E+11
5:00	5,56E+10	1,92E+11	3,53E+11	4,60E+11	4,72E+11	4,14E+11	3,38E+11	2,72E+11	2,18E+11	1,75E+11	1,42E+11	1,17E+11
5:15	7,09E+10	2,29E+11	3,86E+11	4,80E+11	4,84E+11	4,24E+11	3,48E+11	2,82E+11	2,28E+11	1,84E+11	1,50E+11	1,24E+11
5:30	8,73E+10	2,67E+11	4,26E+11	5,11E+11	5,05E+11	4,40E+11	3,62E+11	2,94E+11	2,38E+11	1,92E+11	1,56E+11	1,30E+11
5:45	1,04E+11	3,04E+11	4,66E+11	5,44E+11	5,28E+11	4,60E+11	3,78E+11	3,05E+11	2,44E+11	1,97E+11	1,60E+11	1,33E+11
6:00	1,21E+11	3,36E+11	4,94E+11	5,60E+11	5,32E+11	4,54E+11	3,68E+11	2,96E+11	2,37E+11	1,91E+11	1,55E+11	1,29E+11
6:15	1,37E+11	3,68E+11	5,18E+11	5,64E+11	5,20E+11	4,37E+11	3,53E+11	2,83E+11	2,27E+11	1,83E+11	1,49E+11	1,23E+11
6:30	1,53E+11	3,95E+11	5,34E+11	5,66E+11	5,12E+11	4,25E+11	3,40E+11	2,72E+11	2,18E+11	1,75E+11	1,42E+11	1,18E+11
6:45	1,67E+11	4,10E+11	5,41E+11	5,60E+11	4,98E+11	4,09E+11	3,26E+11	2,60E+11	2,08E+11	1,67E+11	1,35E+11	1,13E+11
7:00	1,79E+11	4,24E+11	5,46E+11	5,55E+11	4,87E+11	3,96E+11	3,15E+11	2,53E+11	2,04E+11	1,65E+11	1,35E+11	1,14E+11
7:15	1,91E+11	4,31E+11	5,46E+11	5,50E+11	4,83E+11	3,94E+11	3,15E+11	2,53E+11	2,06E+11	1,68E+11	1,39E+11	1,18E+11
7:30	2,01E+11	4,33E+11	5,47E+11	5,56E+11	4,95E+11	4,10E+11	3,31E+11	2,68E+11	2,17E+11	1,78E+11	1,47E+11	1,24E+11
7:45	2,10E+11	4,27E+11	5,44E+11	5,64E+11	5,12E+11	4,30E+11	3,50E+11	2,87E+11	2,34E+11	1,91E+11	1,56E+11	1,31E+11
8:00	2,17E+11	4,25E+11	5,42E+11	5,71E+11	5,27E+11	4,45E+11	3,63E+11	2,97E+11	2,42E+11	1,97E+11	1,62E+11	1,36E+11
8:15	2,24E+11	4,25E+11	5,43E+11	5,74E+11	5,32E+11	4,48E+11	3,65E+11	3,00E+11	2,44E+11	[illegible]	[illegible]	[illegible]
8:30	2,29E+11	4,30E+11	5,47E+11	5,75E+11	5,30E+11	4,47E+11	3,65E+11	2,97E+11	2,41E+11	[illegible]	1,60E+11	[illegible]

CERIM IION data table

Theoretical part of the CERIM IION includes well-known theoretical relations and serves for calculation of medium and dynamic process parameters. Parameters of neutral atmosphere were calculated using the NRLMSISE-00 model.

Results of theoretical modeling are values of heat and particle flux densities, energy input to electron gas as well as values of thermospheric winds, ion-electron and ion-neutral collision frequencies, heat conductivity and ambipolar diffusion tensors, plasma scale height.

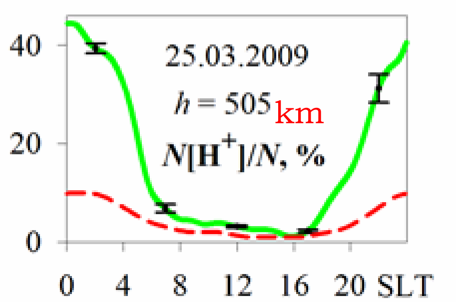
Modeled results of the ionospheric plasma parameters are presented in the tabular form. Each of the tables includes the diurnal ionospheric parameters variations for vernal and autumnal equinoxes, winter and summer solstices in the range heights of 200 – 750 km. Dependence of ionospheric parameters on solar activity (SA) is determined by the phase of SA cycle – minimum, maximum, descending and rising.



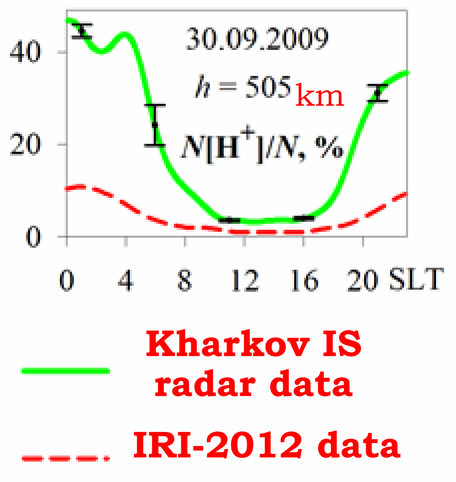
Comparison CERIM IION data with Kharkov ISR data

VARIATIONS IN H^+ IONS FRACTION EXTREME MINIMUM OF SOLAR ACTIVITY

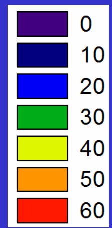
Vernal equinox:



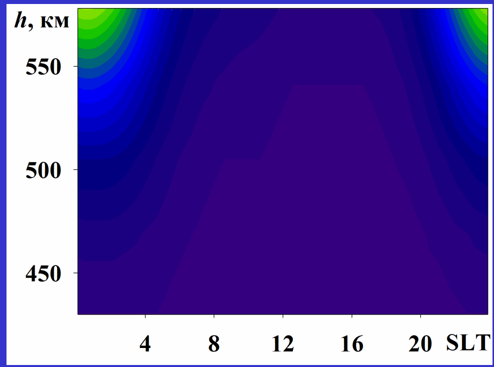
Autumnal equinox:



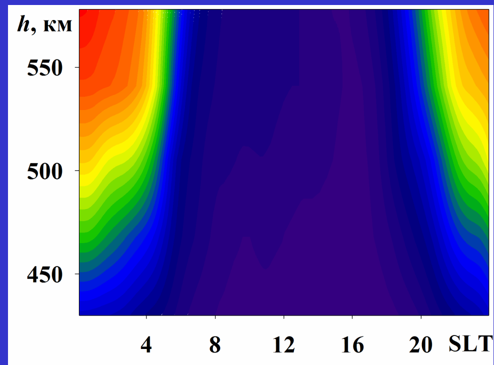
N[H+]/*N*, %



IRI-2012 data:

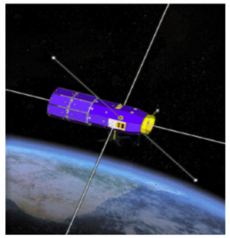


Kharkov IS radar data:

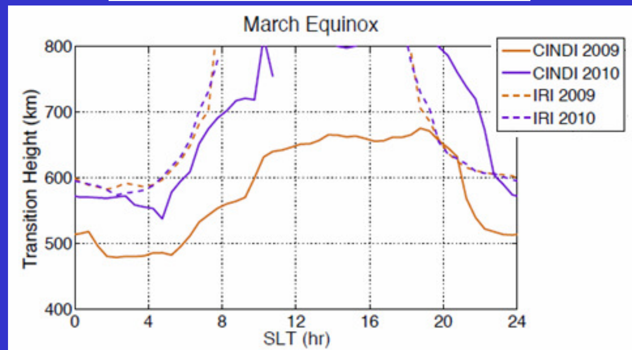


The C/NOFS Satellite

- Communication/Navigation Outage Forecast System
  - Launched in April 2008
  - 13° inclination orbit
  - 400-850 km
- CINDI (Coupled Ion Neutral Dynamics Investigation)
  - Ion Density
  - $[H^+]$, $[O^+]$

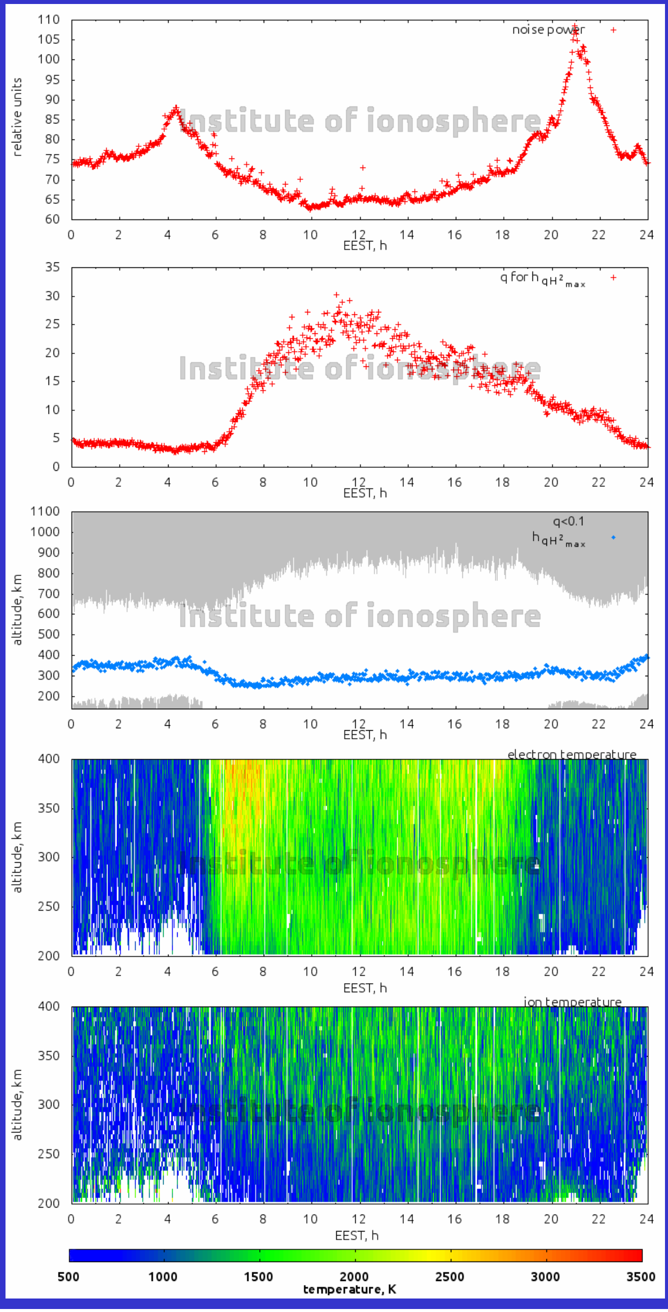


O^+/H^+ Transition Height

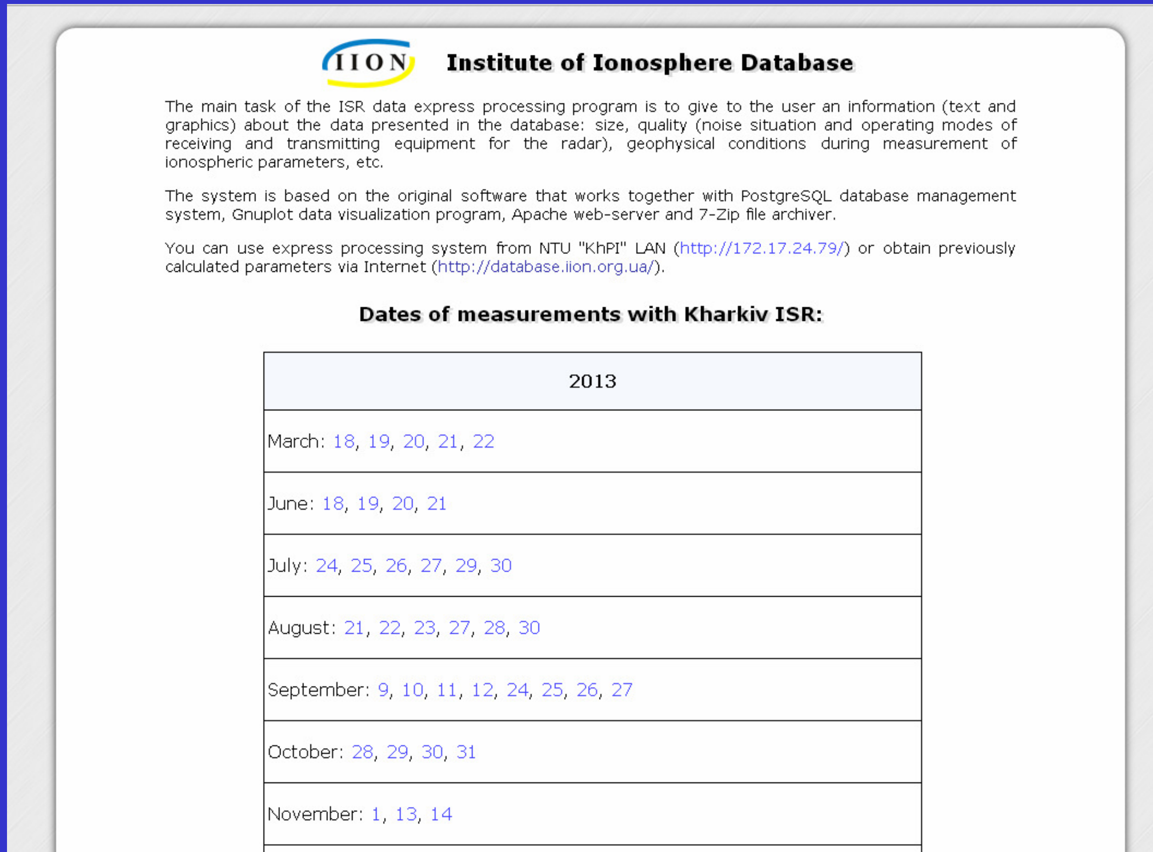


Kharkov IS radar light ions data are the only results for mid-latitude during the last extreme solar minimum. Comparison our mid-latitude results with the data from equatorial C/NOFS mission data shows surprising light ions behavior for last solar minimum

CREATION OF THE INCOHERENT SCATTER RADAR DATABASE



http://database.iion.org.ua/



IION **Institute of Ionosphere Database**

The main task of the ISR data express processing program is to give to the user an information (text and graphics) about the data presented in the database: size, quality (noise situation and operating modes of receiving and transmitting equipment for the radar), geophysical conditions during measurement of ionospheric parameters, etc.

The system is based on the original software that works together with PostgreSQL database management system, Gnuplot data visualization program, Apache web-server and 7-Zip file archiver.

You can use express processing system from NTU "KhPI" LAN (http://172.17.24.79/) or obtain previously calculated parameters via Internet (http://database.iion.org.ua/).

Dates of measurements with Kharkiv ISR:

2013
March: 18, 19, 20, 21, 22
June: 18, 19, 20, 21
July: 24, 25, 26, 27, 29, 30
August: 21, 22, 23, 27, 28, 30
September: 9, 10, 11, 12, 24, 25, 26, 27
October: 28, 29, 30, 31
November: 1, 13, 14

Visualization of the ionospheric parameter estimates in the processing system network