THE 15TH RUSSIAN-CHINESE WORKSHOP ON SPACE WEATHER

September 9–13, 2024, Irkutsk, Russia

SPACE WEATHER RESEARCH IN YAKUTIA

A. Moiseev, A. Gololobov, I. Ievenko, A. Korsakov, I. Petukhov, V. Popov, S. Starodubtsev

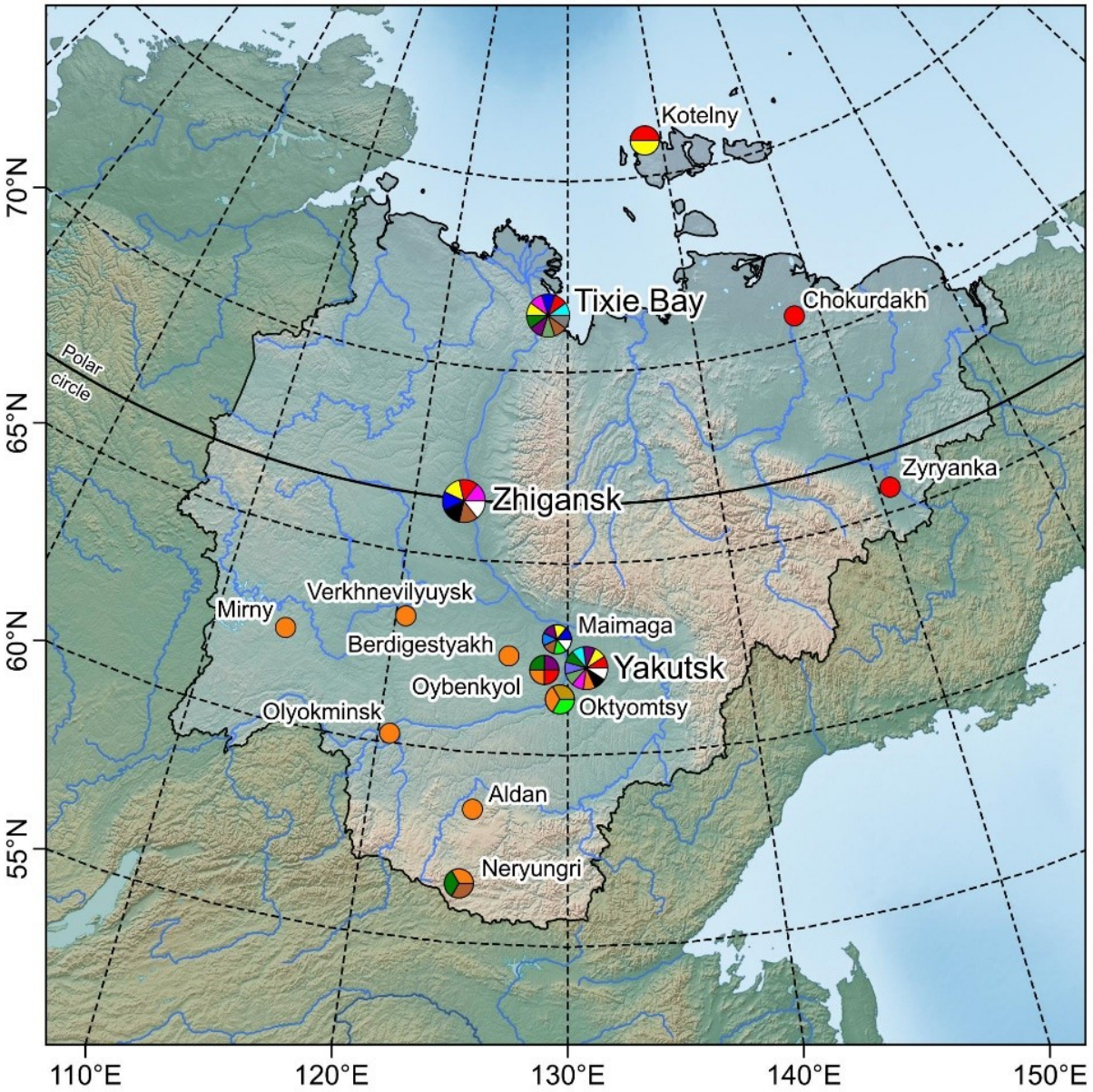
The Yu.G. Shafer Institute of Cosmophysical Research and Aeronomy SB RAS

Outline

The following topics of space weather manifestations presented:

- Comparative analysis of the azimuthal propagation of Pc5 pulsations and their current systems by ground-based and satellite observations;
- Study of the magnitude of sudden phase anomalies on VLF radio paths during a solar flares;
- Study of SAR arc dynamics by ground-based and satellite observations;
- Study of ionospheric disturbances based on numerical modeling of large-scale structure of the ionosphere;
- Explanation of Forbush decreases in cosmic rays based on a physical model developed by the Institute's staff;
- Forecast of geoeffective disturbances by cosmic ray measurements both by satellite and ground based observations.

Instruments location in Yakutia



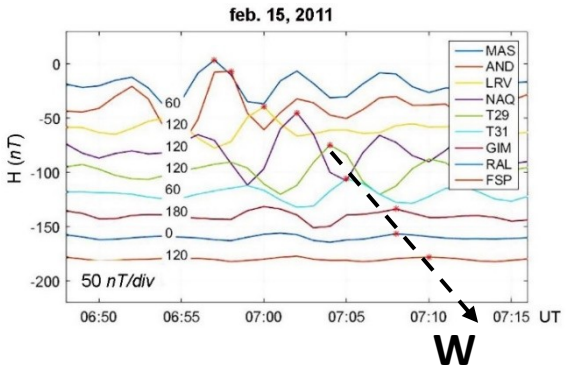
- All-sky camera
- CR spectrograph
- EAS array
- Fabry–Perot spectrometer
- Fluxmeter
- GNSS reciever
- Ionosonde
- IR spectrograph
- Lidar
- Lightning detector
- Magnetometer
- Meteo station
- Neutron monitor
- Riometer
- Rocket sounding station
- Photometer
- VLF reciever

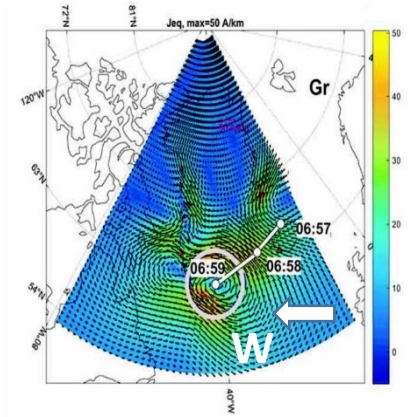
Pc5 pulsations VS Equivalent ionosphere vortices propagation on February 15, 2011 event

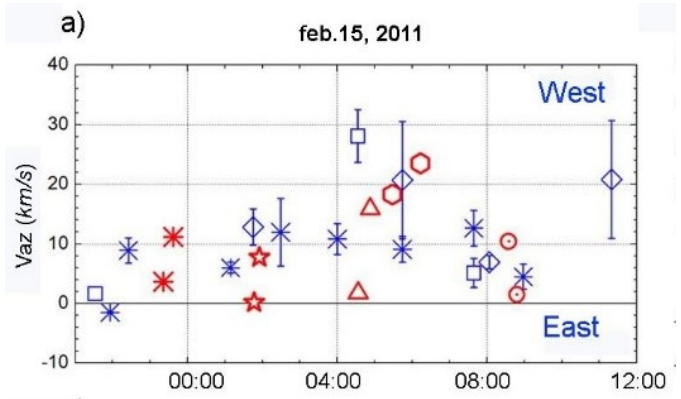
Pc5 pulsations azimuthal profiles at 65°–66°

Equivalent ionosphere current (EIC) vortices. Method of spherical elementary current systems [Amm and Viljanen, 1999]

[A.V. Moiseev, V.I. Popov, S.A. Starodubtsev INVESTIGATING AZIMUTHAL PROPAGATION OF Pc5 GEOMAGNETIC PULSATIONS AND THEIR EQUIVALENT CURRENT VORTICES: BASED ON GROUND-BASED AND SATELLITE DATA // Solar-Terrestrial Physics. 2024. Vol. 10. Iss. 3. P. XX–XX. DOI: 10.12737]

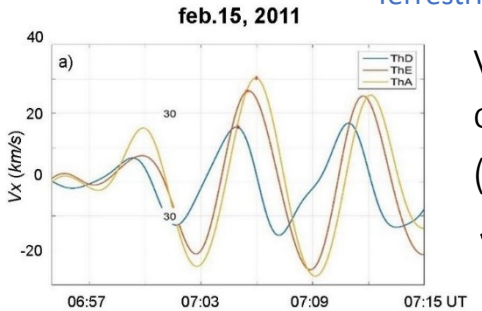






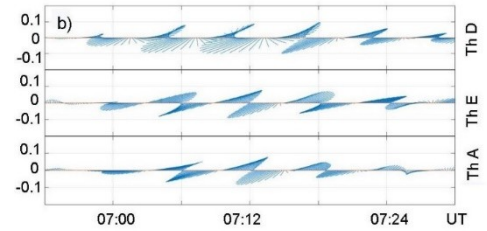
Distribution of azimuthal propagation velocities of geomagnetic pulsations and EIC vortex centers relative to MLT

Vaz=5-25 km/s

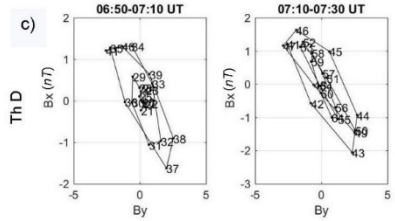


Variations in the ion velocity component *V* from satellites (Th D, E, A)

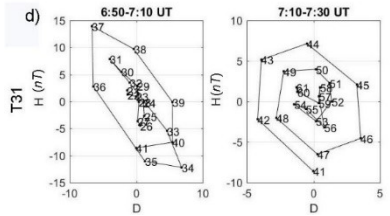
V_{D_E}= 235.75 km/s, V_{E_A} = 114.49 km/s



magnetic field hodographs from satellites

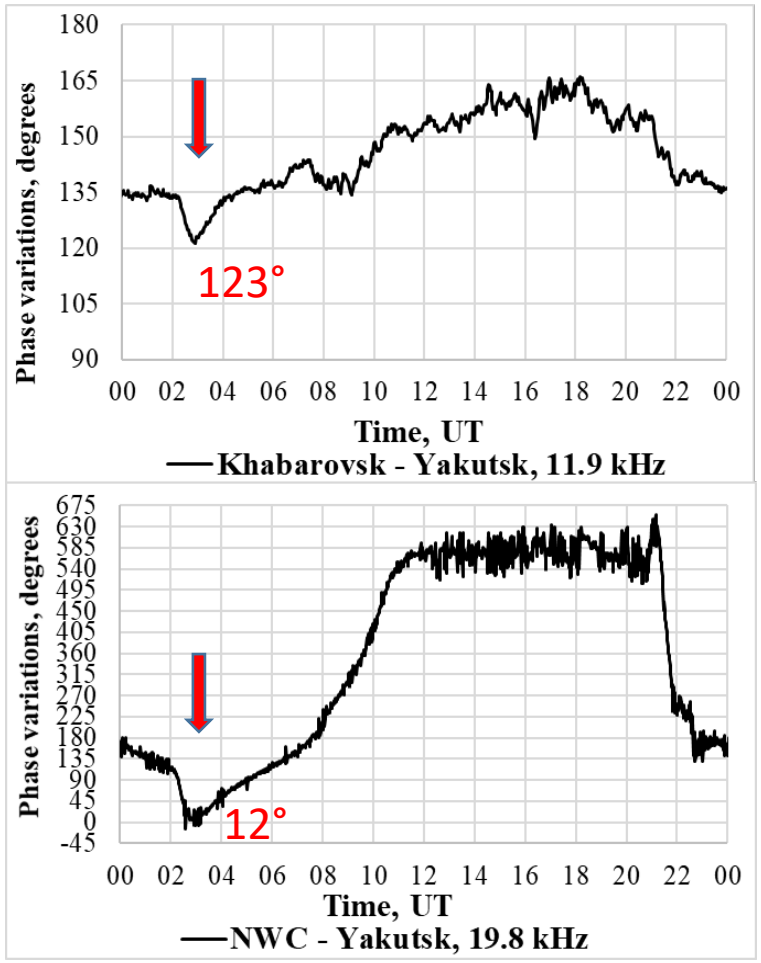


magnetic field polarization from the ThD satellite

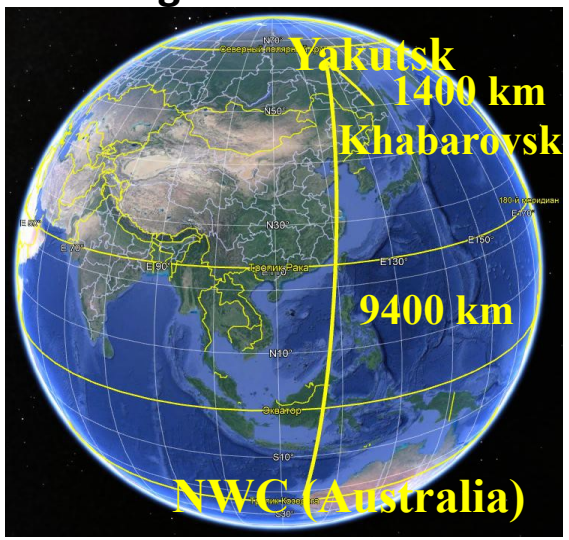


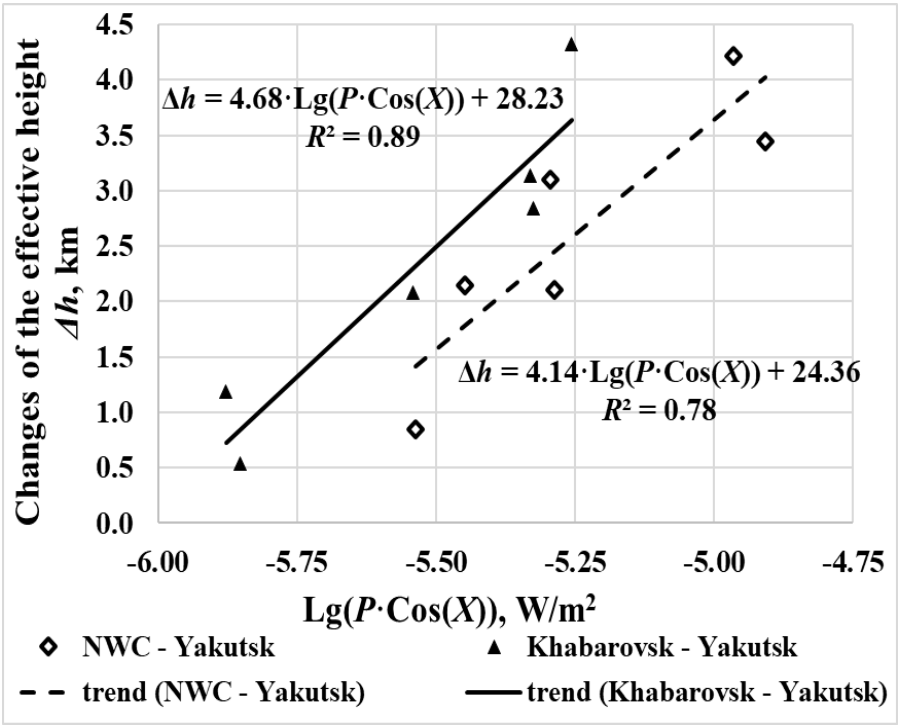
magnetic field polarization from ground station T31

Sudden phase anomaly (SPA) due to X-ray solar flare M1.7 November 2, 2021 03:01 UT

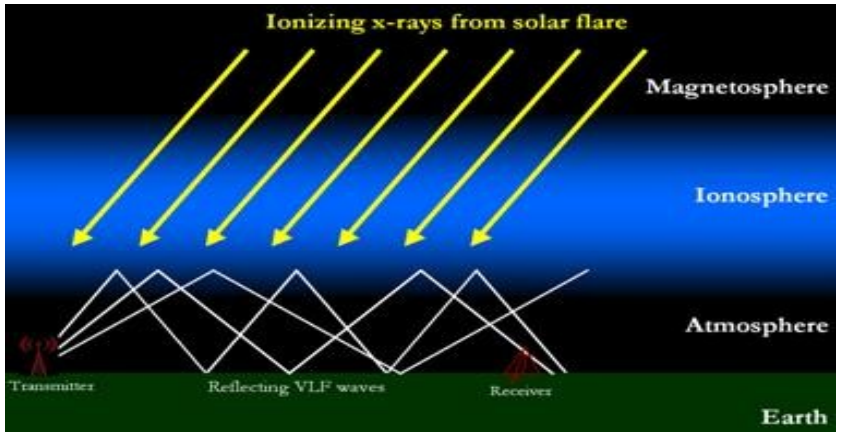


Length of traces

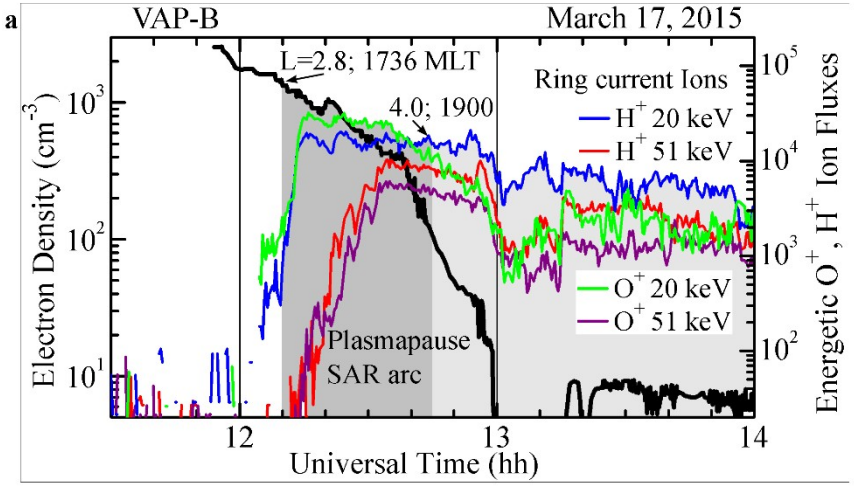


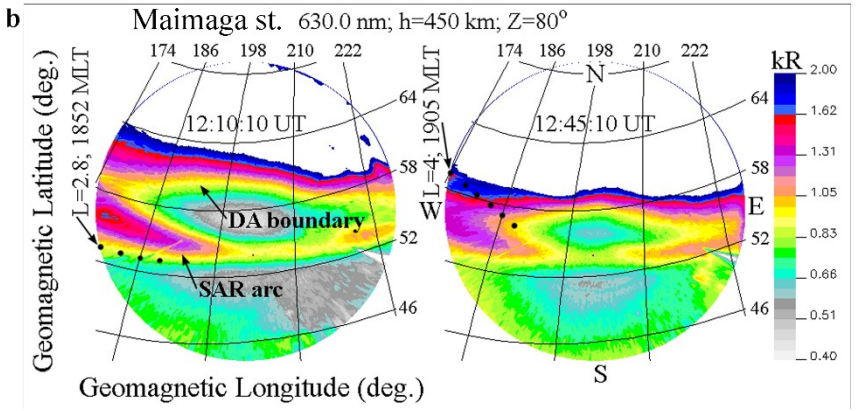


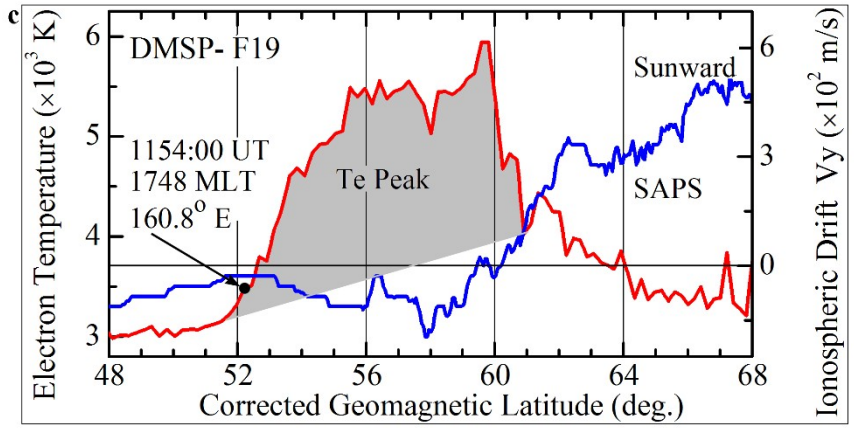
$$\Delta\varphi = \frac{360 \cdot d}{\lambda} \cdot \left(\frac{1}{2 \cdot R} + \frac{\lambda^2}{16 \cdot h_n^3} \right) \cdot \Delta h$$



where $\Delta\varphi$ – SPA (degrees), R – radius of the Earth (km), λ – wave length (km), d – radio path length (km). The average ionospheric altitude is $h_n \approx 72$ km [Mitra, 1977].







Relationship between the SAR arc and the boundary of the energetic ions flux inside the plasmasphere during a magnetic storm on March 17, 2015

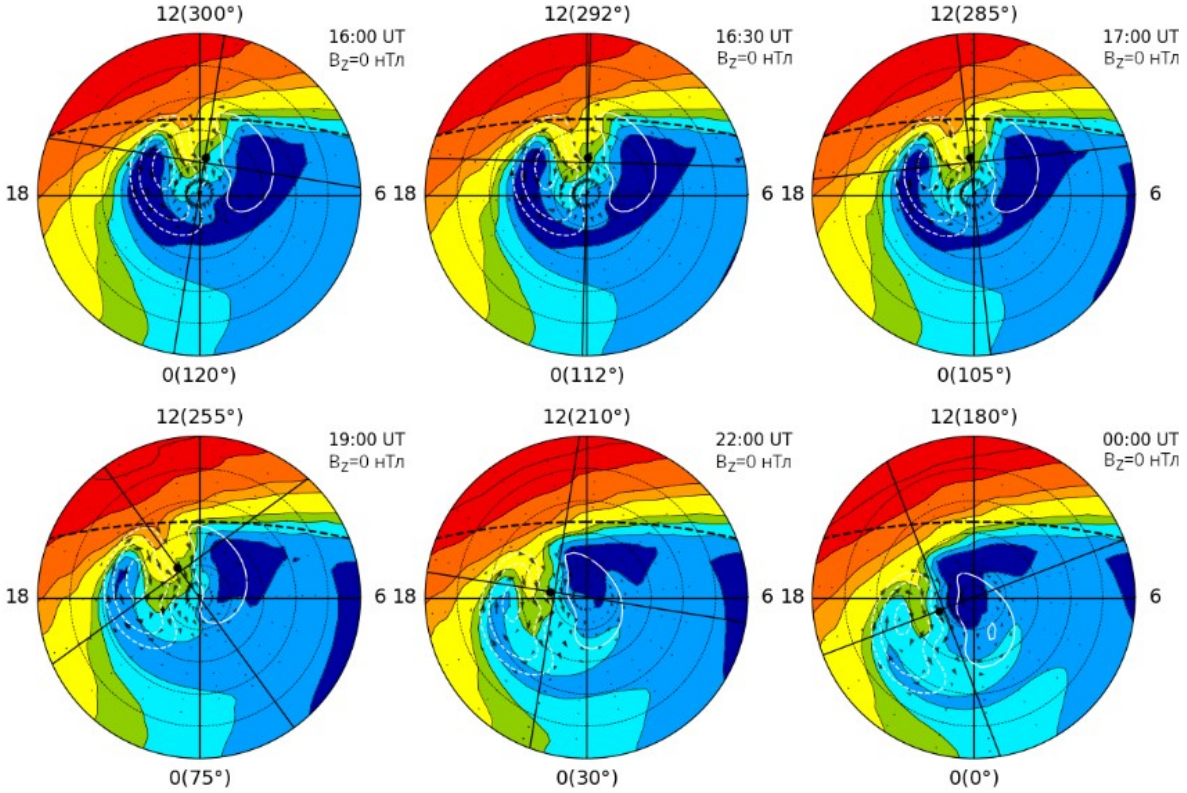
- The SAR arc was observed equatorward of the diffuse aurora at low auroral activity and reflected the region of overlap of energetic ring current ions with the outer plasmasphere according to measurements on board VAP-B.
- At 12.10:10 UT, the equatorial edge of the red arc at a geomagnetic longitude of ~179° coincided with the boundary of the flow of energetic ions inside the plasmasphere.
- At 12.45:10 UT, the polar edge of the arc at longitude ~174 ° was caused by a sharp decrease in the electron density to ~100 cm^-3 (plasmapause).
- The width and position of the SAR arc corresponded well with the intense Te peak measured on board DMSP F19 in the evening MLT sector. Electron temperature measurements verify ground-based observations of the SAR arc.

[Ievenko I.B. SAR arc observation during the overlap registration of an energetic plasma with a plasmapause aboard the Van Allen probe// Journal of Atmospheric and Solar–Terrestrial Physics. Vol. 209 (2020) 105386. 2020. https://doi.org/10.1016/j.jastp.2020.105386]

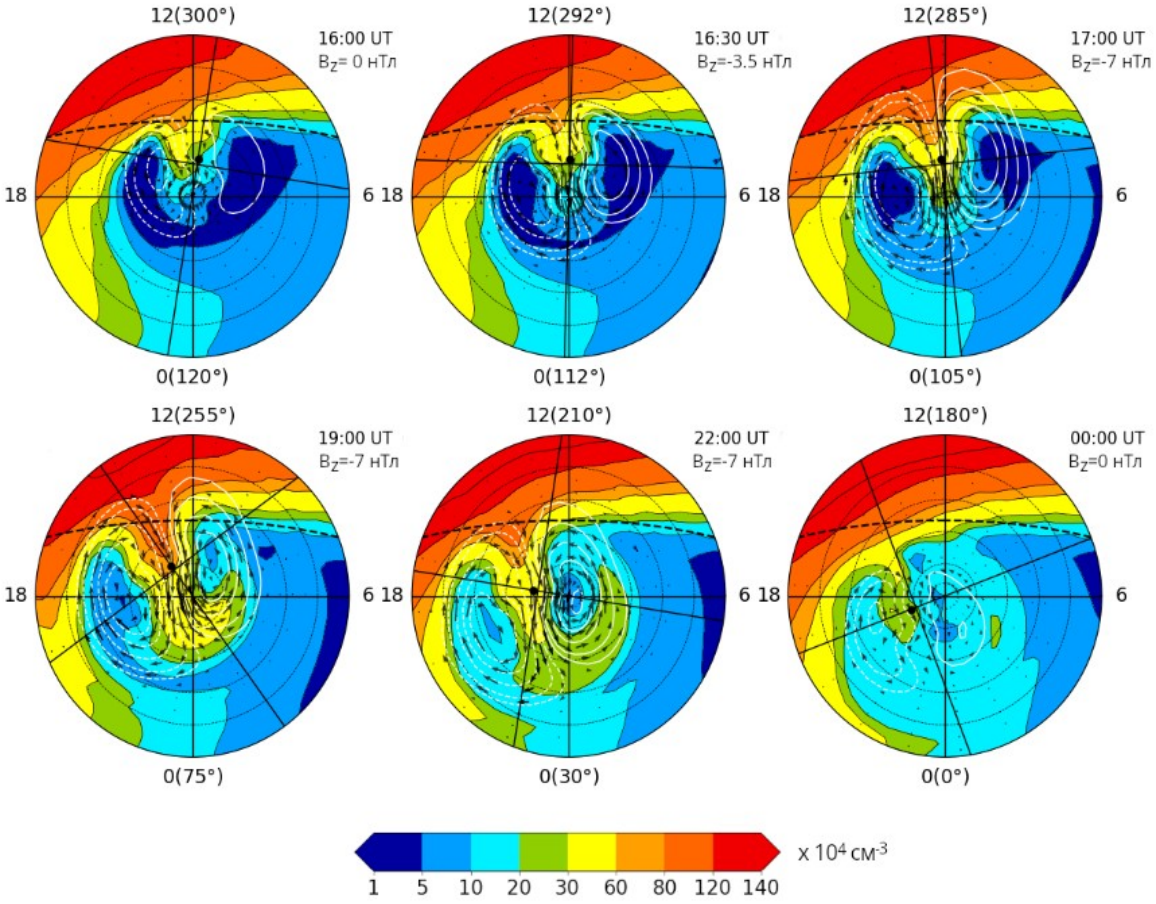
Modelling the influence of magnetospheric storm on the large scale structure of the high latitude ionosphere for winter solstice conditions

Spatial-temporal concentration distributions of electrons at the height of F2 maximum. Geographic latitudes shown by circles through 10° beginning from 40° are shown. Geomagnetic pole shown by solid lines intersection. Terminator position shown by dashed line.

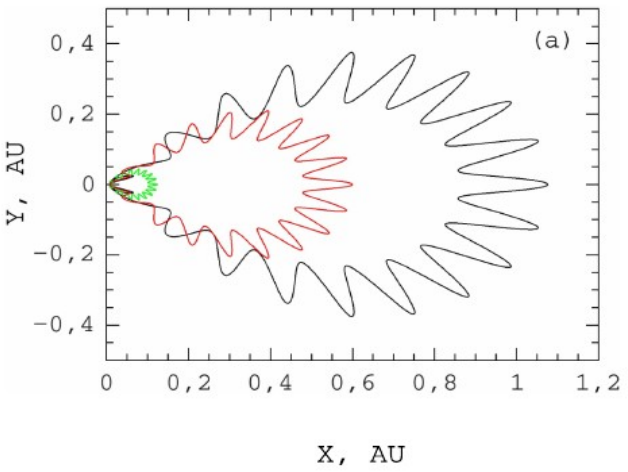
Quiet conditions



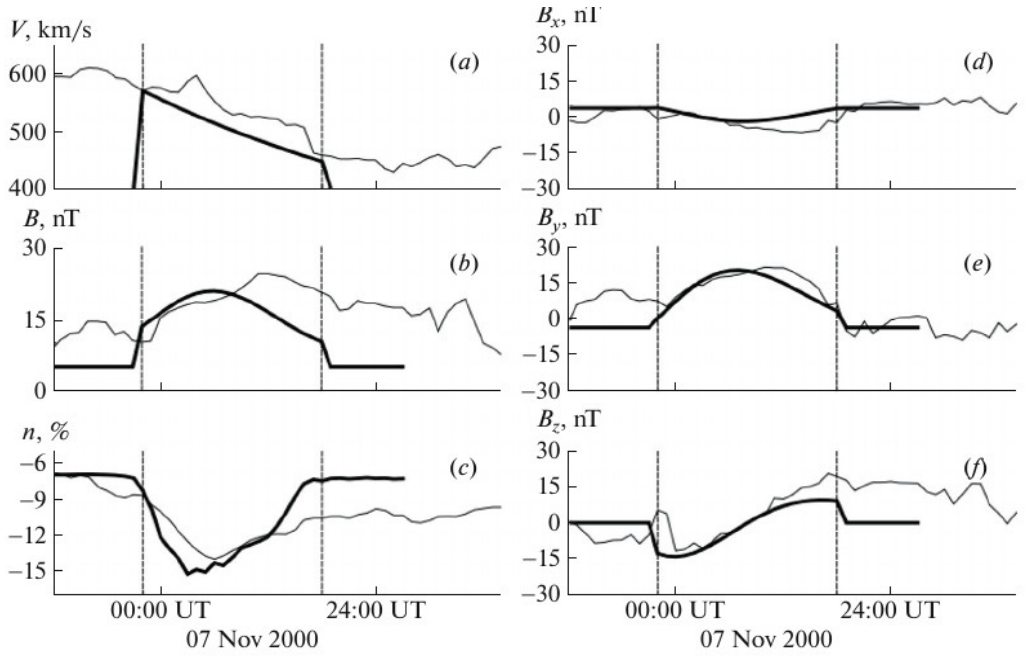
Disturbed conditions



Electromagnetic Theory of Forbush Effect Formation



proposed model of the magnetic field in a magnetic cloud in the form of an expanding loop



The model of the magnetic field in the cloud realistically reproduces the parameters on the satellite in the interplanetary medium and the Forbush effect from ground-based measurements

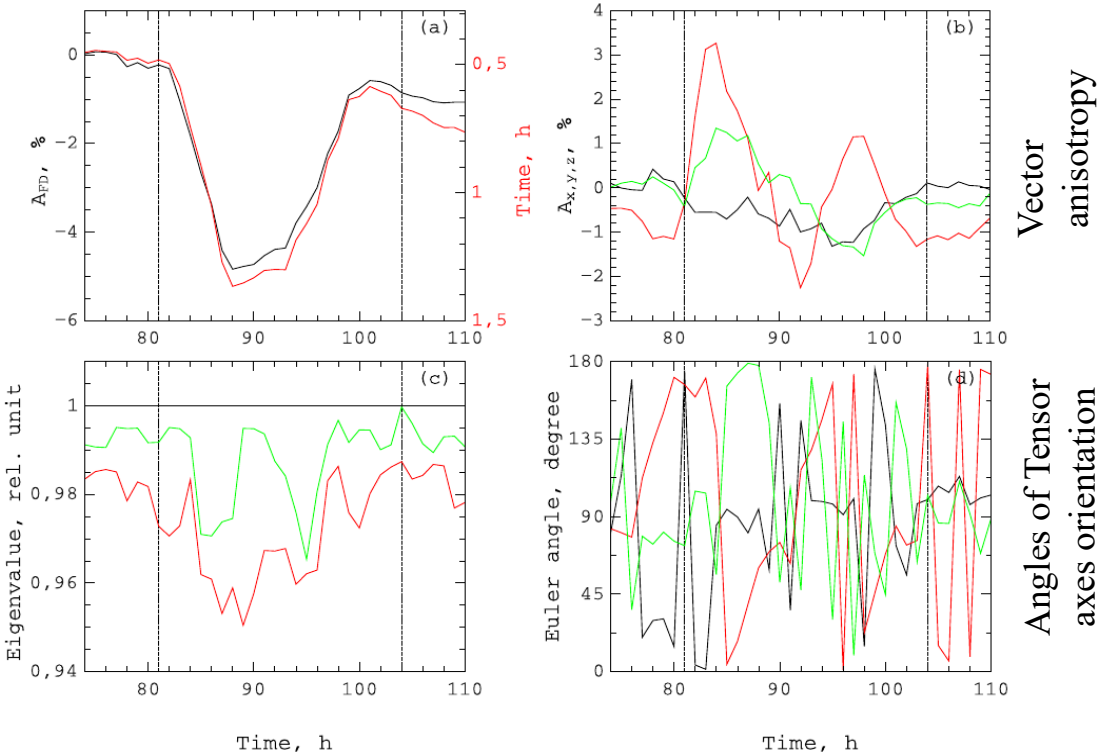
Calculated parameters

CR func. Distrib. & particle dencity

Vector anisotropy

Tensor anisotropy

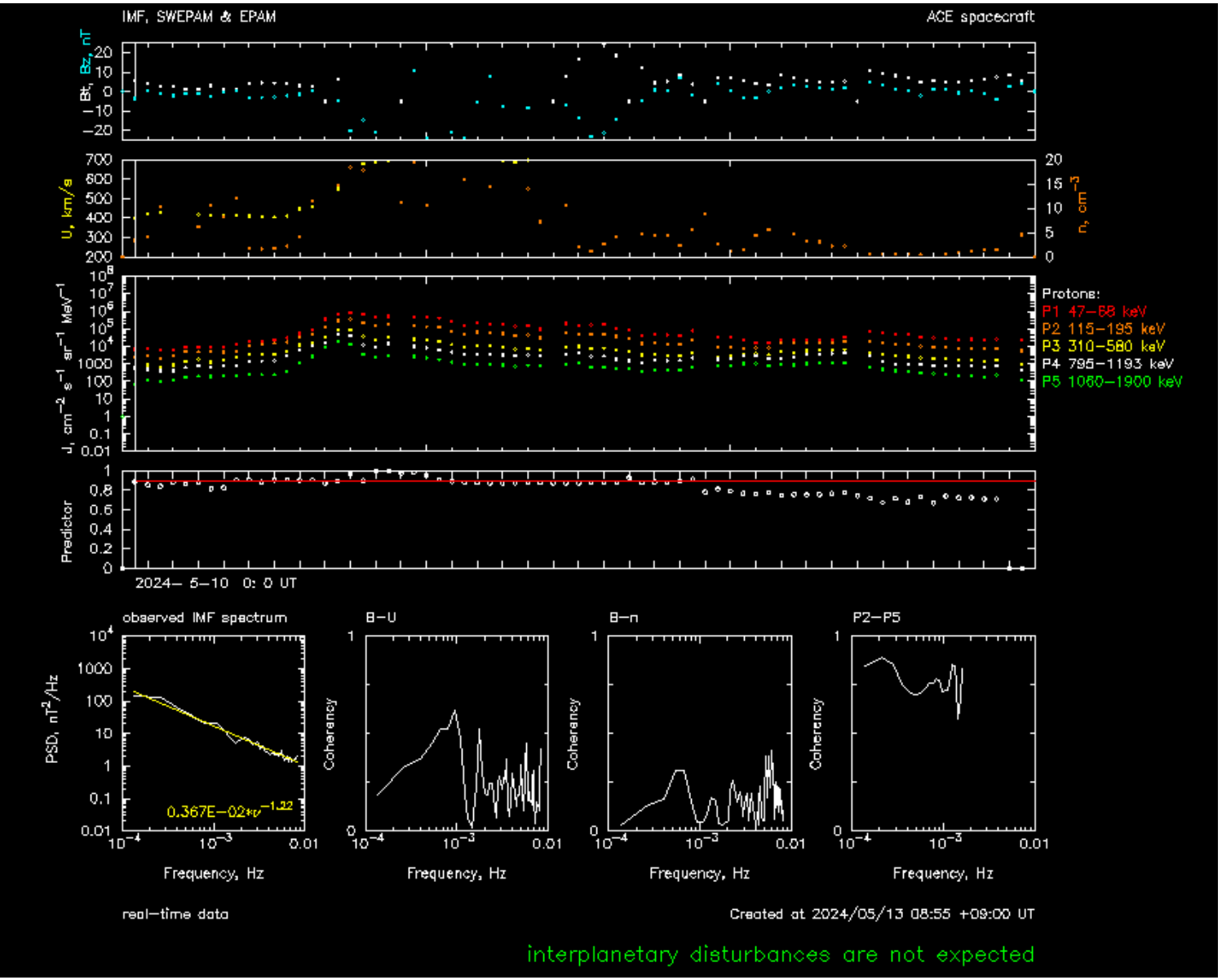
Angles of Tensor axes orientation



[A.S. Petukhova, I.S. Petukhov, S.I. Petukhov
Image of forbush decrease in a magnetic cloud by three moments of cosmic ray distribution function // J. Geophys. Res.: Space Phys., 124 (1) (2019), pp. 19-31, 10.1029/2018JA025964]

Interplanetary shock forecast by ACE satellite data during May 2024 extreme magnetic storm

[SA Starodubtsev, AS Zverev, PY Gololobov, VG Grigoryev Cosmic Ray Fluctuations and MHD-Waves in The Solar Wind // Solar-Terrestrial Physics 9 (2), 73-80, 2023]



IMF B and Bz component

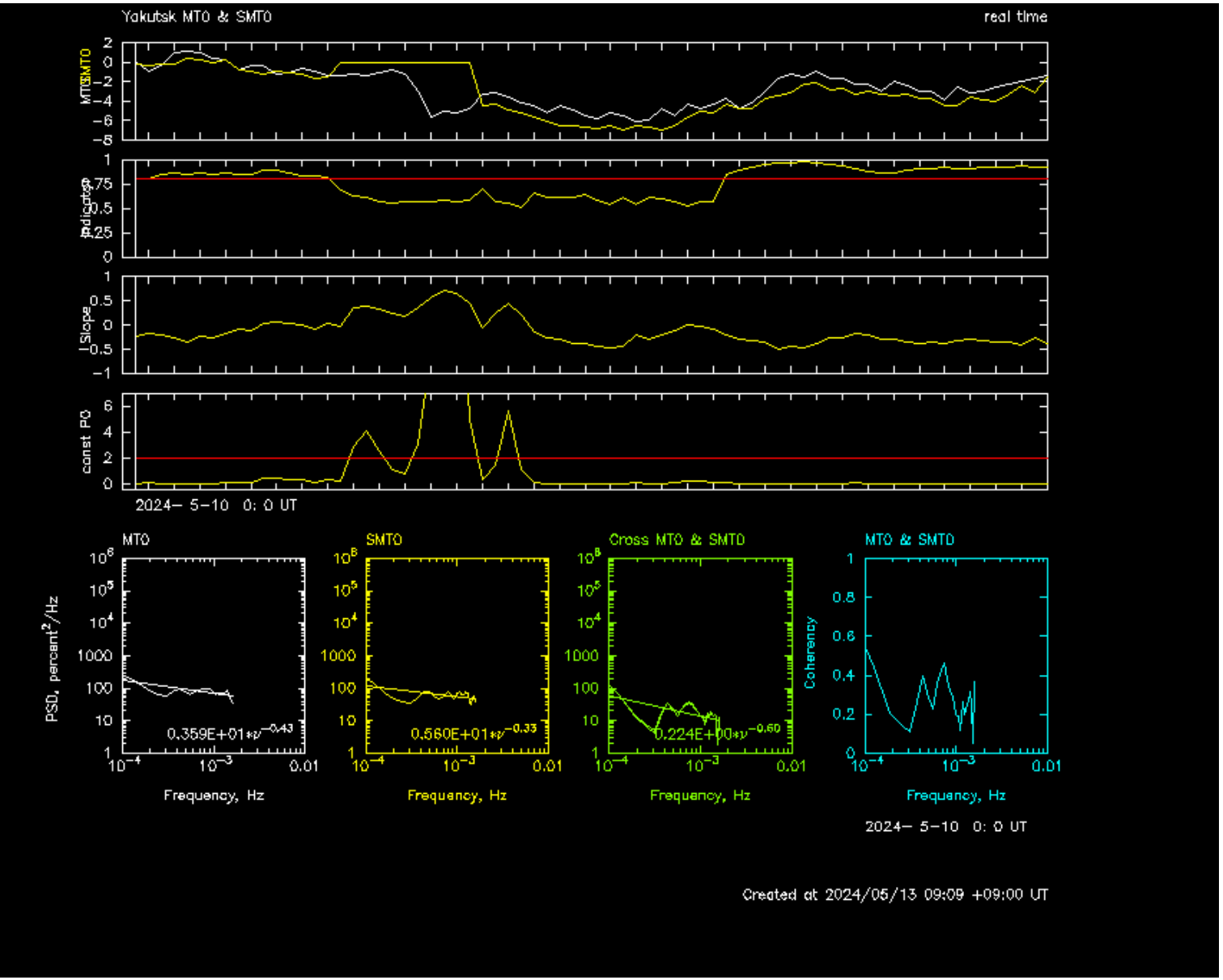
Solar wind speed and density

Energetic flux of low-energy CRs in 5 differential energy channels.

Predictor of the arrival of a quasi-parallel interplanetary shock wave, red - the corresponding critical level.

- Spectrum of fluctuations of the IMF B.
- Coherence between IMF B and velocity.
- Coherence between IMF B and concentration.
- Coherence between channel 2 and channel 5 of differential energetic flux.

Magnetic storm forecast (Dst<-50 nT) by ground data of neutron monitors during May 2024 extreme magnetic storm



[AS Zverev, VG Grigoryev, PY Gololobov, SA Starodubtsev Real-time monitoring of cosmic ray anisotropy parameters and short-term forecasting of geomagnetic disturbances // Solar-Terrestrial Physics 6 (4), 37-39, 2020]

Data from 2 neutron monitors Tiksi (white line) and Yakutsk (yellow).

The yellow line is a predictor of the onset of geophysical disturbance, the red line is the critical level.

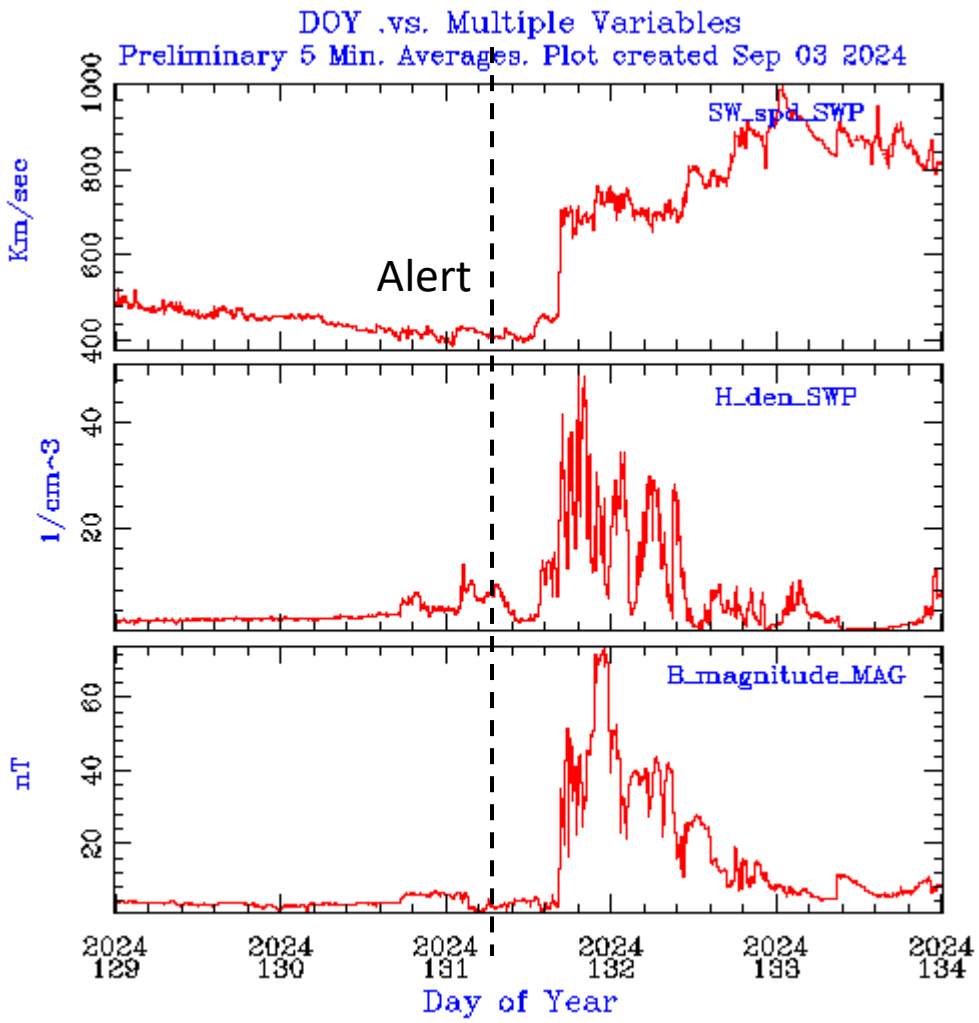
Index of the slope of the cross-spectrum of power fluctuations of cosmic rays.

Cross-spectrum constant of CR fluctuation power. It is used as supporting information, red is the corresponding critical level.

- Spectra of CR fluctuations according to the Tiksi and Yakutsk neutron monitors data and their approximation by a power law in the frequency range 0.0001 - 0.01 Hz.
- Cross-spectrum for both neutron monitor.
- Coherence coefficient for both neutron monitor

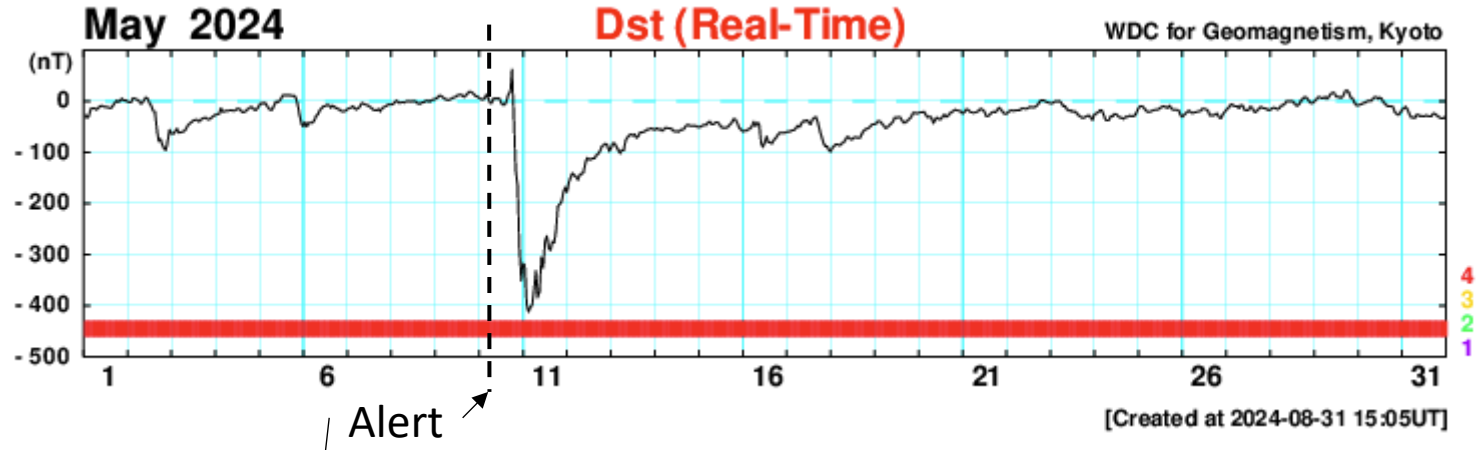
Forecasted disturbances

Interplanetary shock



https://izw1.caltech.edu/

Magnetic storm



6	-41	-50	-42	-42	-42	-38	-29	-26	-18	-14	-10	-10	-7	-8	-13	-9	-11	-14	-15	-17	-20	-20	-19	-16
7	-14	-13	-10	-14	-16	-14	-10	-4	-5	-7	-8	-10	-13	-16	-18	-18	-16	-20	-14	-12	-10	-8	-6	-7
8	-6	-2	1	-3	-3	-2	-3	-1	0	0	-1	0	0	-3	-5	-5	-2	-2	1	1	-1	2	3	4
9	6	10	11	5	5	3	2	3	5	7	8	11	12	13	10	8	12	16	19	17	14	10	9	6
10	4	3	5	13	6	-4	-3	6	4	6	5	-3	-7	-7	0	13	18	62	-36	-135	-165	-287	-351	-318
11	-322	-397	-412	-403	-399	-369	-332	-384	-373	-306	-326	-274	-264	-287	-292	-275	-277	-253	-206	-202	-197	-179	-169	-178
12	-159	-149	-141	-145	-148	-154	-144	-142	-140	-122	-111	-114	-114	-112	-112	-106	-103	-98	-89	-86	-83	-86	-98	-92
13	-83	-83	-89	-96	-102	-96	-96	-77	-71	-67	-65	-67	-65	-72	-68	-61	-61	-60	-58	-55	-55	-53	-55	-56
14	-53	-55	-55	-58	-55	-52	-53	-53	-54	-58	-59	-59	-60	-56	-56	-54	-48	-46	-48	-48	-48	-48	-50	-51
15	-50	-48	-46	-47	-42	-40	-45	-45	-42	-41	-44	-50	-52	-52	-52	-50	-46	-42	-35	-36	-43	-52	-56	-59

https://wdc.kugi.kyoto-u.ac.jp/dst_realtime/

Conclusion

- Manifestations of space weather based on magnetic, radiophysical and optical measurements, as well as the possibility of its short-term forecast based on observations of cosmic rays were presented
- All of the above research can be carried out jointly with the Chinese scientists as part of the Meridian circle project

Thank you!