Large-scale traveling ionospheric disturbances over eastern Europe

SERGII V. PANASENKO[1], DALIA BURESOVA[2], KATERYNA D. AKSONOVA[1,2], OLEKSANDR V. BOGOMAZ[1,3], TARAS G. ZHIVOLUP[1], ALEXANDER V. KOLOSKOV[3,4]

[1] INSTITUTE OF IONOSPHERE, KHARKIV, UKRAINE

[2] INSTITUTE OF ATMOSPHERIC PHYSICS OF THE CZECH ACADEMY OF SCIENCE, PRAGUE, CZECH REPUBLIC

[3] STATE INSTITUTION NATIONAL ANTARKTIC SCIENTIFIC CENTER. UKRAINE

[4] INSTITUTE OF RADIO ASTRONOMY, KHARKIV, UKRAINE

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HORIZON 2020 TechTIDE project network (including possible extensions)

1D Altitude profile of TID
- Detailed view of propagation along z-axis
- Pin-point to particular altitude region

Sensitivity (amplitude)
- Detection of a 5% TID vs underlying density
- TID are always present < 2%

Direction, Velocity, Wavelength

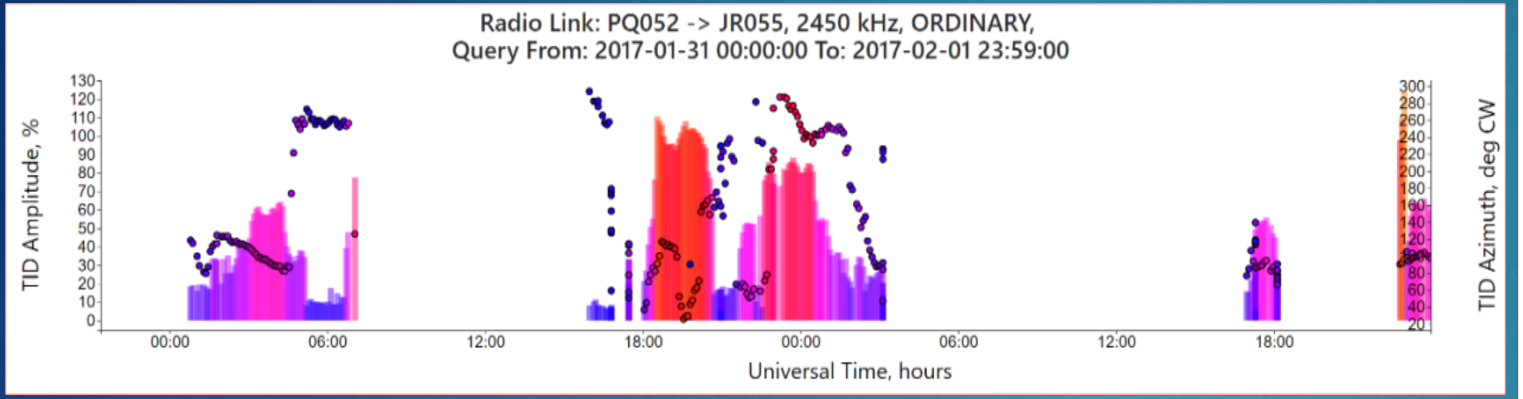
Direct measurement
- Static platform
- No geometric transformation needed
- 24/7 operations with automatic intelligent system analysis

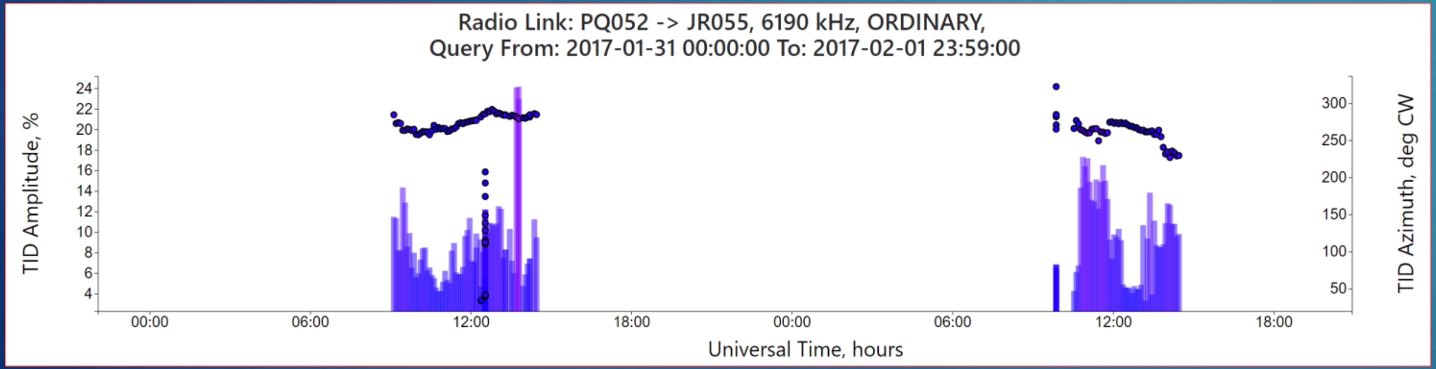
Fig. 1. A network of Digisondes in Europe has been established to monitor travelling ionospheric disturbances (TIDs) by simultaneously making vertical and oblique incidence Digisonde-to-Digisonde (D2D) fixed frequency measurements. The distances between the observatories involved in the project range from about 500 km to over 2000 km.

The challenge for the fixed-frequency D2D skymap measurements is the automatic selection of the sounding frequencies depending on the geometry of the sounding paths, the diurnal and seasonal ionospheric changes, and space weather induced events. (Verhulst *et al.*, 2017; Reinisch *et al.*, 2018).

January-February 2017 geomagnetic storm

Geomagnetic field activity ranged from quiet to G1 (Minor) geomagnetic storm conditions. Total field and SW speed began to increase indicating the arrival of a **CIR** followed by a negative polarity **CH HSS** and reached a maximum of 17.2 nT and 796 km/s, respectively, at 31/20:41 UTC.
No Earth-directed coronal mass ejections were observed.
No proton events were observed at geosynchronous orbit.





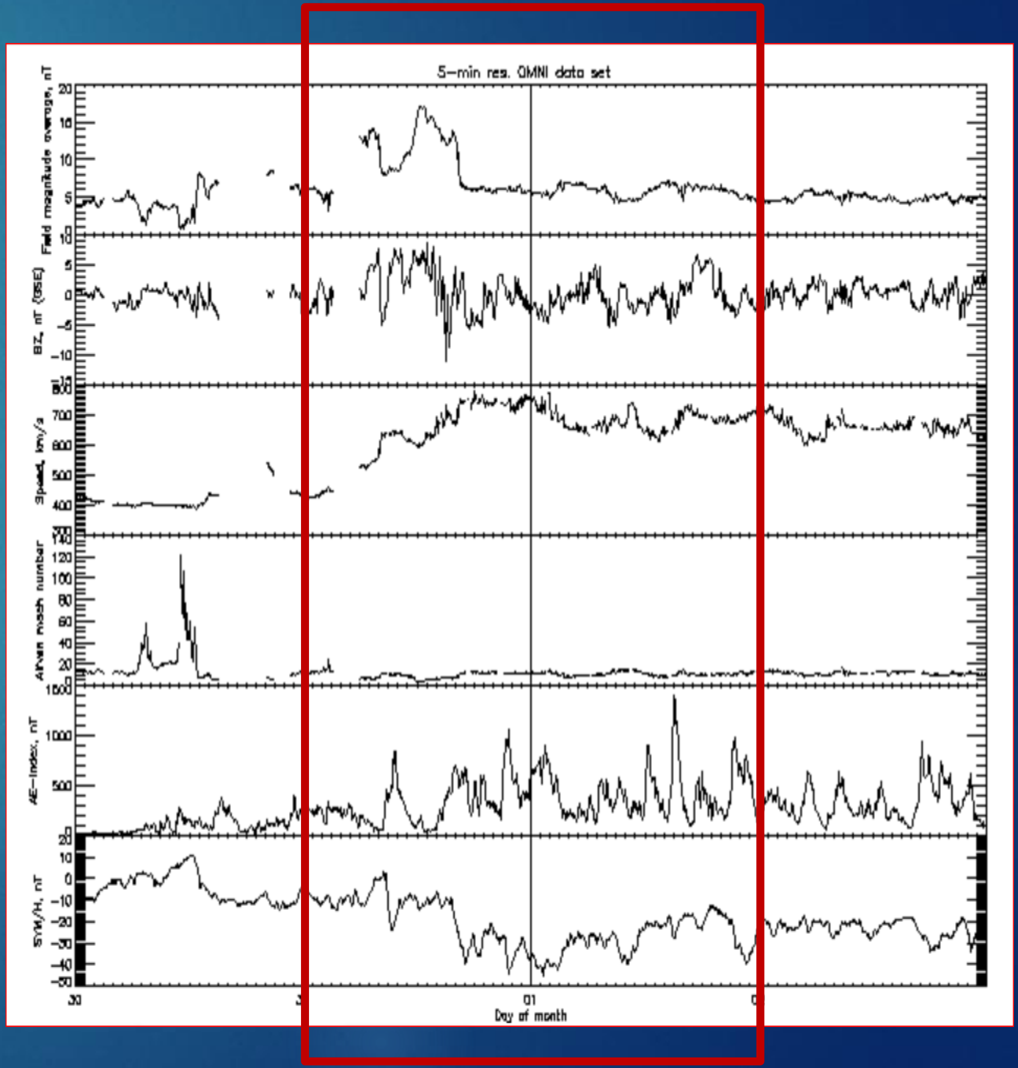
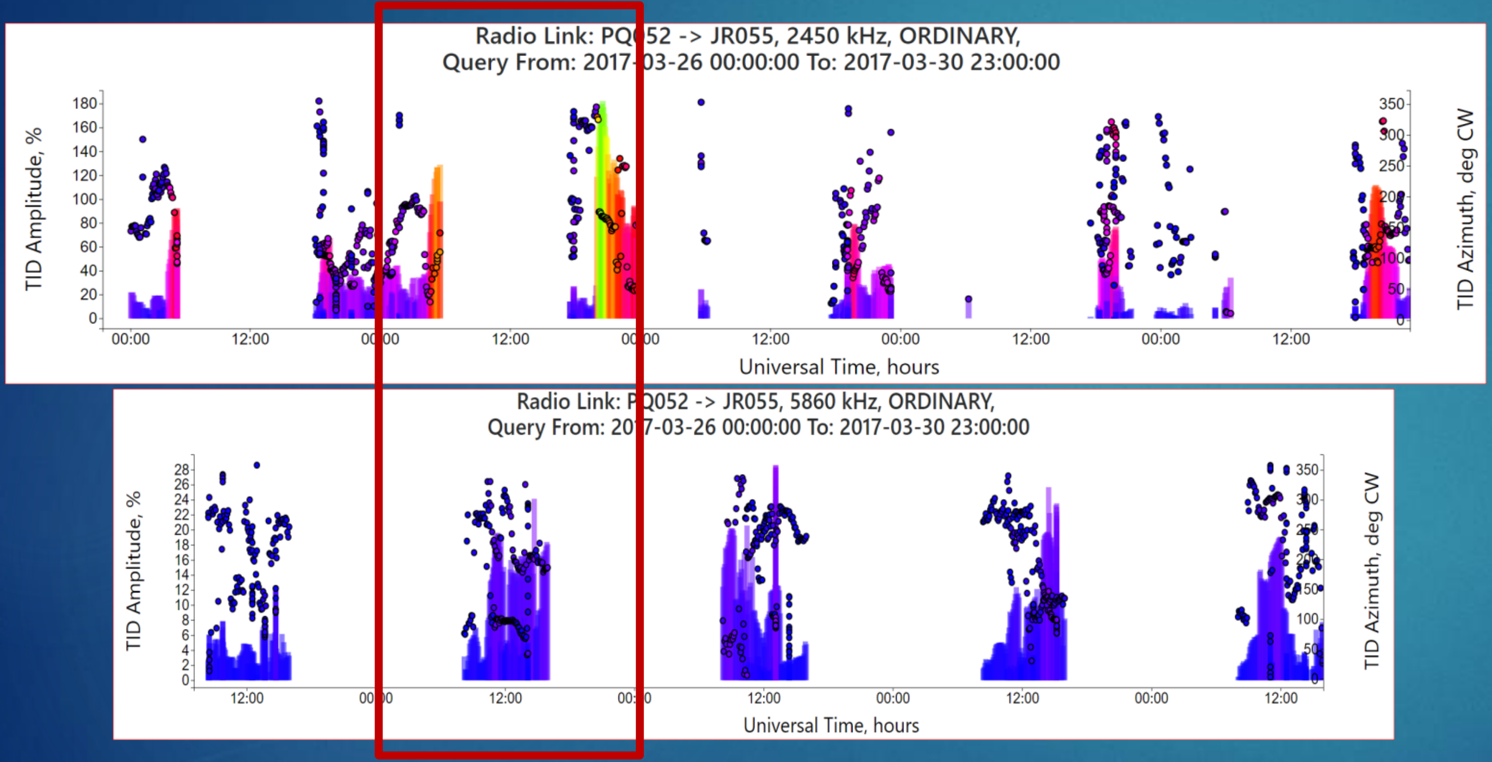


Fig. 2. LSTID activity observed on the radio path Juliusruh-Pruhonice during the event with the HF TID technique on the Pruhonice-Juliusruh link with two sounding frequencies. Space weather conditions for the analysed event on the right.

March 2017 geomagnetic storm

The geomagnetic field responded with G2 (Moderate) storm conditions on 27 March under the influence of a recurrent, polar connected, negative polarity **CH HSS**. The period began under a nominal solar wind conditions. Total field increased to a maximum of 19 nT at 27/0752 UTC. SW speeds started the period near 375 km/s and peaked to a maximum speed of 781 km/s at 28/0711 UTC. No Earth-directed CMEs were observed during the period. No proton events were observed at geosynchronous orbit.



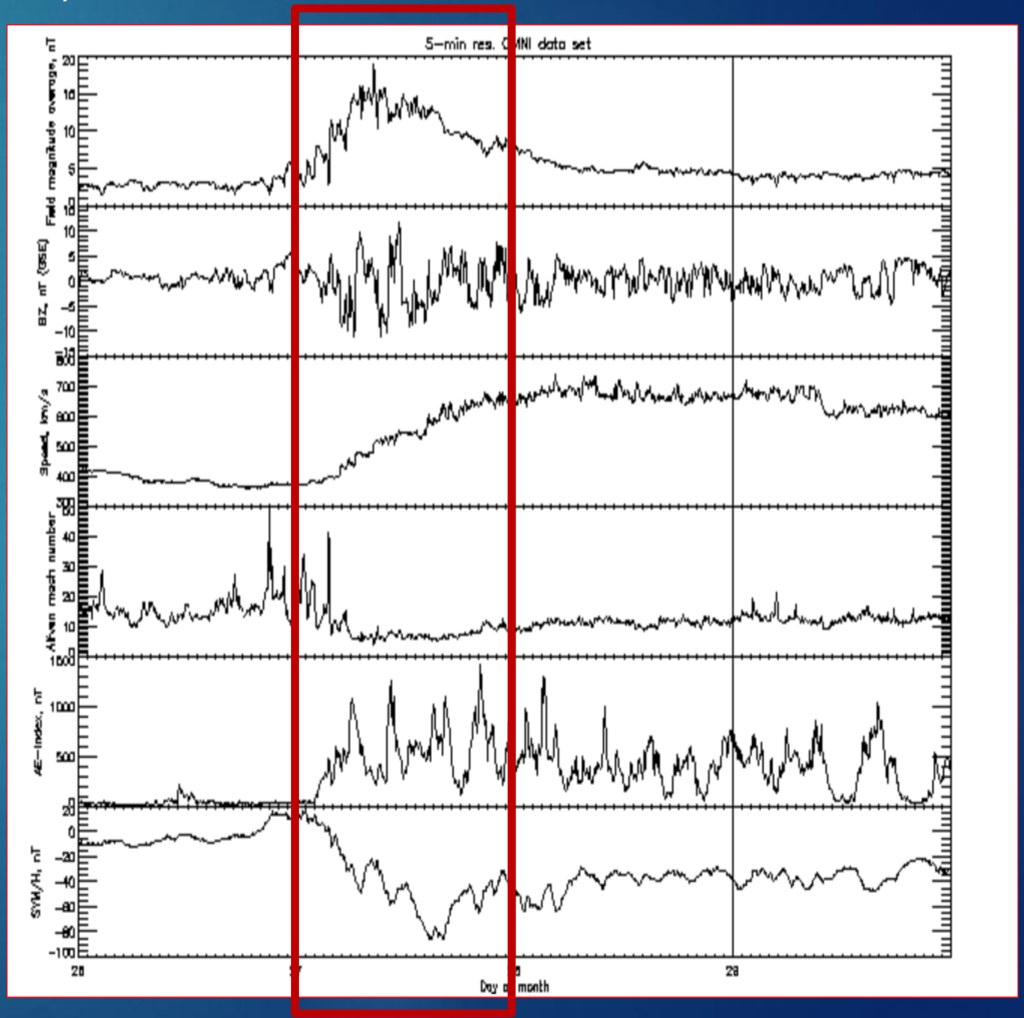


Fig. 3. LSTID activity observed on the radio path Juliusruh-Pruhonice during the event with the HF TID technique on the Pruhonice-Juliusruh link with two sounding frequencies. Space weather conditions for the analysed event on the right.

Space weather conditions for the analysed September 22-24, 2020 geomagnetic storm

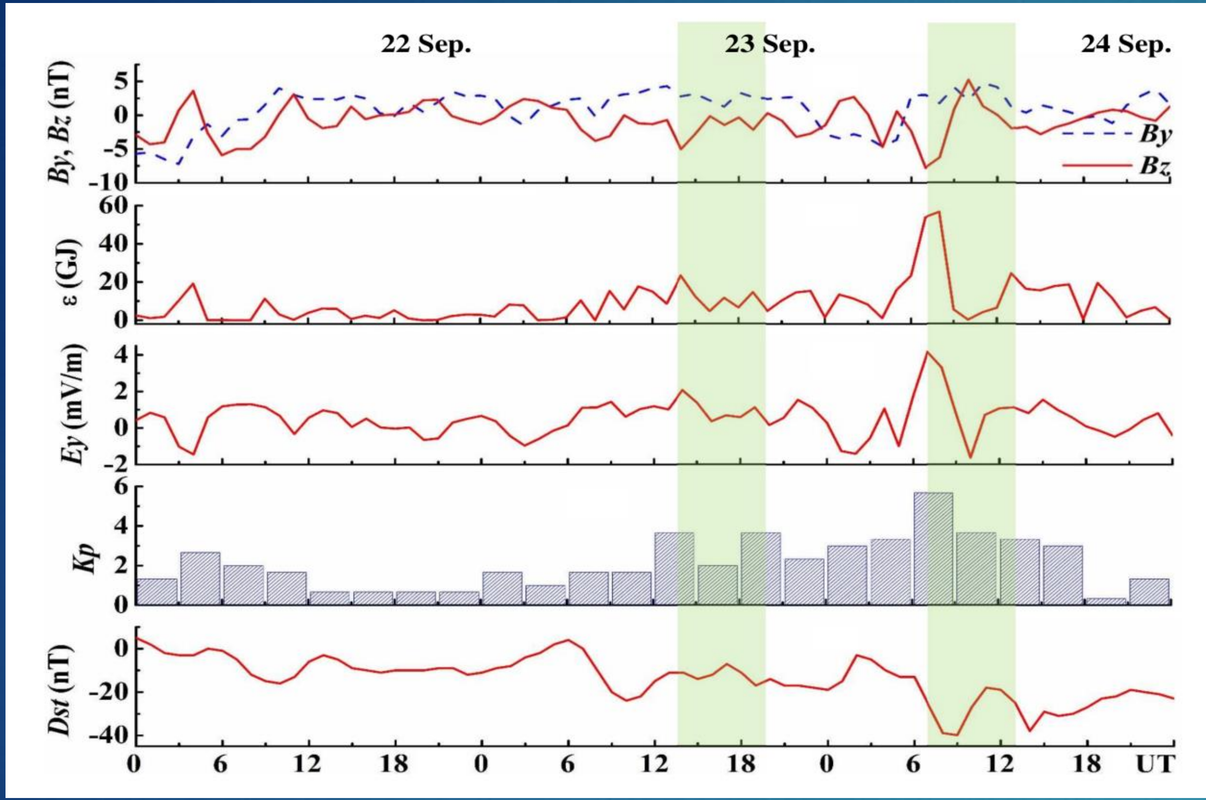


Fig. 5. Space weather conditions characterized by variations in interplanetary magnetic field (*By*, *Bz*), Akasofu function (ε), transverse electric field (*Ey*) as well as *Kp* and Dst indices. Shaded light green strips show the time intervals where magnetic storm related LSTIDs occurred.

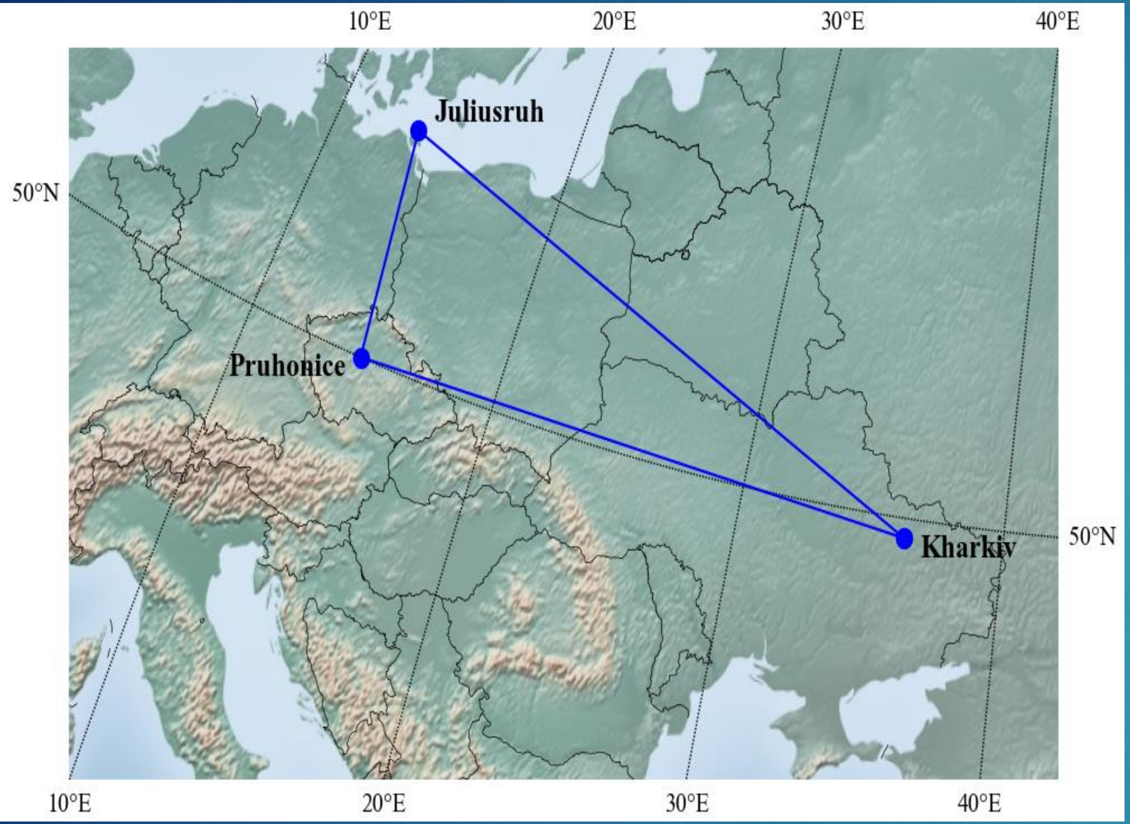
Solar activity was very low since September 14.

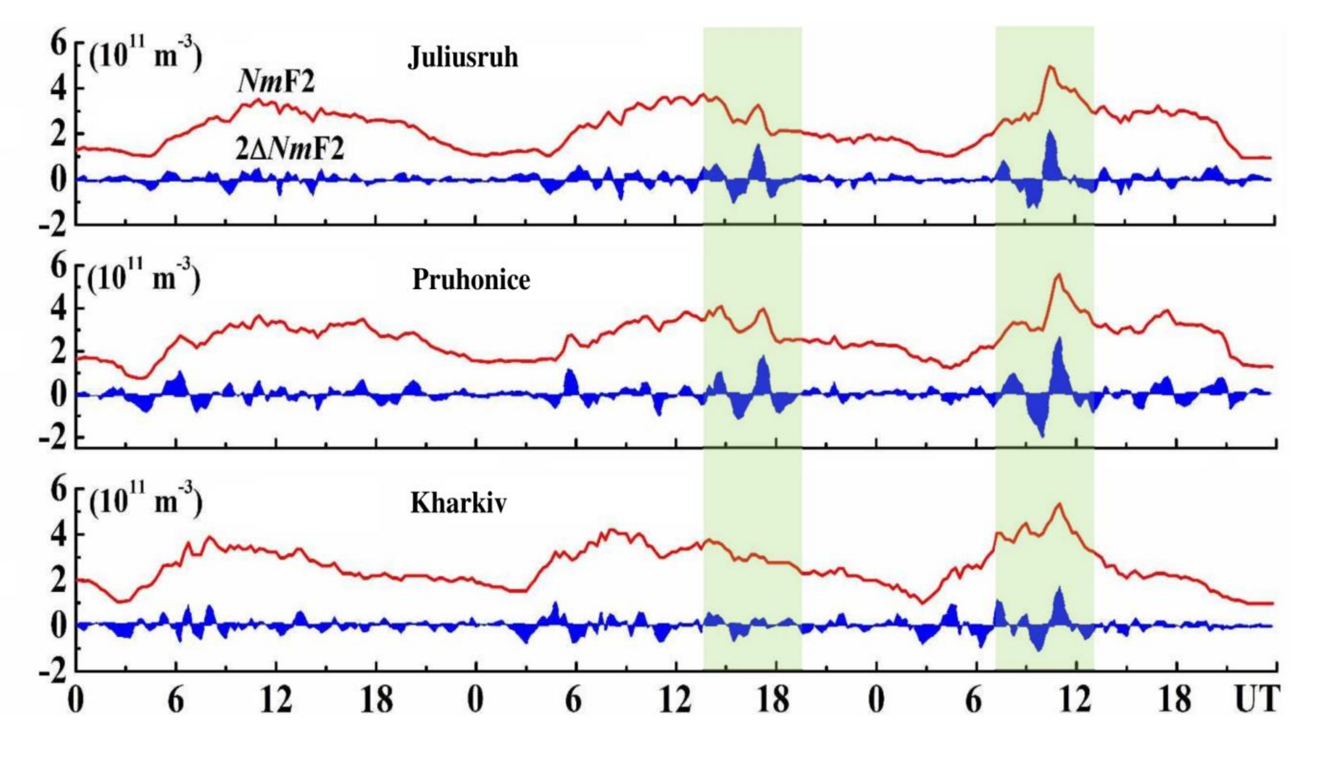
No spotted regions were observed on the visible disk.
No Earth-directed CMEs were detected .
No proton events were observed at geosynchronous orbit.

Active conditions were observed on September 23. Geomagnetic field activity reached G1(Minor) storm level on September 24. All enhancements in geomagnetic activity were due to multiple, positive polarity **CH HSSs**.

NOAA SWPC PRF 2352 28 September 2020

Location of instruments and observed ionospheric variations during September 22 – 24, 2020 geomagnetic storm





Site	Facility	Geographic coordinates	Distance (km)	Azimuth (deg)
Pruhonice	DPS-4 ionosonde	50.0° N, 14.6° E	–	–
Juliusruh	DPS-4 ionosonde	54.6° N, 13.4° E	518	351.4
Kharkiv	PCDI Incoherent scatter radar	49.6° N, 36.3° E	1553	96.7

Fig. 4. Location of the instruments (on the left) and ionospheric storm evolution(on the right) as observed in time series of NmF2 along with its doubled absolute variations *2ΔNmF2* over Juliusruh (top), Pruhonice (middle) and Kharkiv (bottom). Shaded light green strips show the time intervals where magnetic storm related LSTIDs occurred.

TID signatures in time and period domain

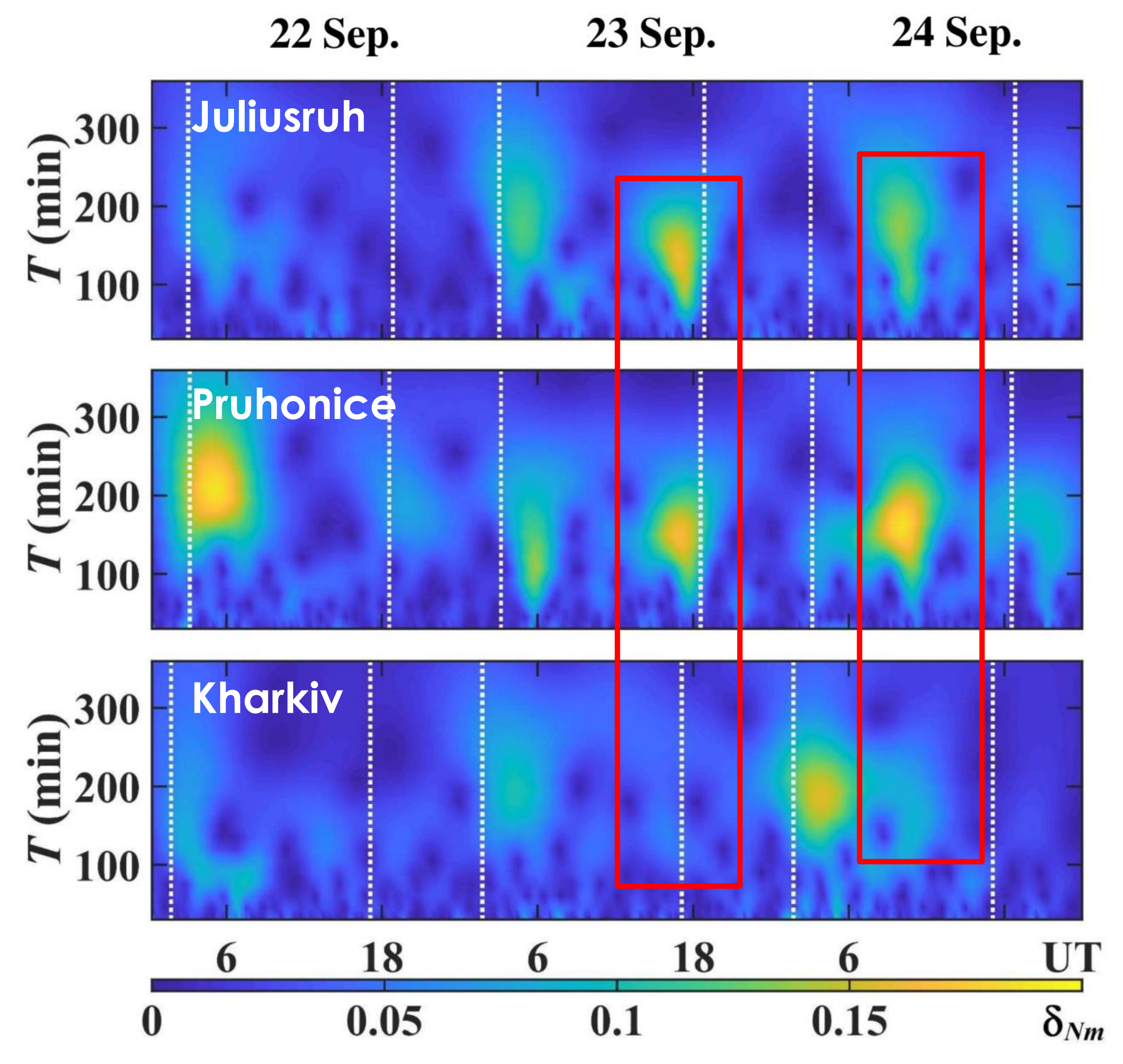


Fig. 6. Amplitude spectra of relative variations in *Nm*F2 derived from the Juliusruh (top), Pruhonice (middle) and Kharkiv (bottom) ionosonde data. Dotted white lines mark the local solar terminator passage times at the 250-km height. Red rectangles embrace areas of storm related TIDs signatures.

The magnetic storm related TIDs have very close periods of about 160 and 180 min and are observed nearly simultaneously over all three sites. The TID onset difference shows these disturbances to be propagated from the auroral region. We detected a longitude dependence of TID signatures in ionosonde-derived data. In particular, the relative amplitudes of TIDs over Kharkiv are less than those over Juliusruh and Pruhonice for both marked intervals. For the time interval of 14 – 20 UT on 23 Sep., this can be due to increase of *hm*F2 to the heights where AGWs are dissipated. For the second one, at 07 – 13 UT on 24 Sep., an interference occurs with TIDs originated by solar terminator and leads to wave suppression.

LSTID patterns from Kharkiv incoherent scatter data

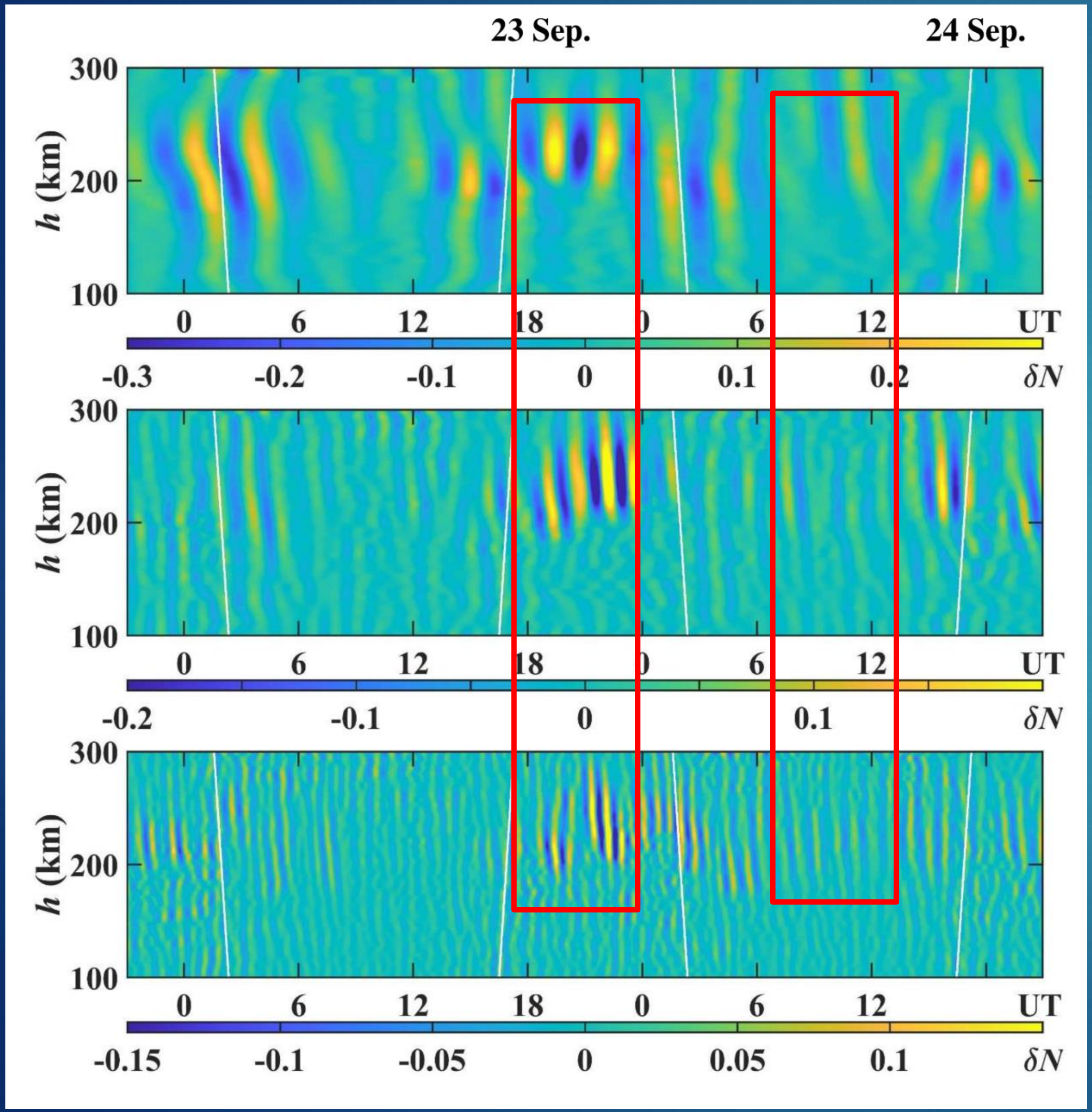


Fig. 6. Altitude-time maps of Kharkiv ISR power relative variations (after subtraction of 6-hour trend and normalization by it) band-pass filtered in the ranges of 120 – 240 min (top), 60 – 120 min (middle) and 30 – 60 min (bottom). Solid white lines show the local solar terminator passage times at the studied heights. Red rectangles embrace areas of storm related LSTID patterns.

Using incoherent scatter data, we detected storm-related LSTIDs over Kharkiv at heights of 200 – 250 km on 23 Sep having a wide range of periods. These disturbances were barely revealed from *Nm*F2 fluctuations because *hm*F2 values were about 300 km during the first marked time interval.

The TID response to much more intensive energy deposit into the auroral region during the second marked interval was weak probably due to the effect of solar terminator related disturbances.

Conclusions

CIR/HSS-related events are significant sources of the LSTIDs.

The CIR/HSS-related LSTID activity has longer duration.

We detected the longitudinal dependence of CH HSS magnetic storm-related LSTIDs in both ionosonde and incoherent scater radar data for the measuring facilities spaced of about 1600 km.

The dependence of TID response on the time of day was also confirmed.

ACKNOWLEDGEMENTS

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