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Evidence of ionosphere perturbation caused by the Chelyabinsk meteor blast

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Abstract

Results of ‘raw’ vertical ionospheric sounding processing reveal the regional effect of the impact of the Chelyabinsk meteoroid on February 15, 2013 on the northern midlatitude ionosphere. Confirmed by ionospheric tomography at single longitude chain [1], wave-like perturbations of impact origin spread over thousands kilometers. Results of 3D gas dynamic simulation explain these phenomena.

1. Introduction

The Chelyabinsk meteor blast and fall of debris on February 15, 2013 were accompanied by light, sound, seismic and ionospheric instrumentally recorded phenomena. Hereafter we consider the ionosphere only. The quite geomagnetic environment on that day (Kp=4) makes possible influence of geomagnetic substorms negligible. Ionospheric disturbances at altitudes 100-700 km were registered by GPS tomography chain, by ionosonde network and by SuperDARN system. According to [2] the source of seismic signal was located at 54.8°N, 61.1°E at 03:20:33 UT. Energy release is estimated as 300-500 kT [2]. Tomographic reconstruction of midlatitude ionosphere [1] shows perturbations of electron density at 6.39UT and 7.10UT at altitudes 100-700 km, localized over 48°-60°N along the chain between 37°E and 42°E. Intense disturbances of total electron content (TEC) at 6:00-10:00UT were registered by GPS stations in Nizhny Novgorod, Yekaterinburg, Novosibirsk, Noril’sk, Irkutsk, Alma-Ata [3]. Disturbances in diurnal variations of critical frequency of F2-layer (foF2), monitored by stations of vertical sounding of ionosphere in Yekaterinburg, Moscow, Rostov-on-Don, Sankt-Petersburg on February 15 2014 were analyzed in [1]. Similar perturbations of foF2 in Moscow, Noril’sk, Irkutsk, Yakutsk and statistical analysis of these data for Moscow are shown in [4]. In [1] the relationship between foF2 perturbations in Noril’sk and Yakutsk and Chelyabinsk meteor was denied. To clarify the situation we processed ‘raw’ data of the selected stations of vertical sounding, as far as the automatic processing (we have seen in this) failed at some stations.

2. Vertical ionosphere sounding evidence

Method of visualization of single-point sounding, used here is 2D plot in coordinates: apparent altitude (h')- universal time (UT). A view of the summary map depends on a value shown. Thus, A_{Σ} -map is a histogram of sums of amplitudes of all reflected waves of the sounding interval at a given altitude, F_m-map is a plot of maximal frequency of a reflected wave at a given altitude and time moment versus apparent height h' and time UT, which allows to track the dynamics of electron concentration. On Fig. 1 F_m-maps and curves of foF2 versus universal time (UT) for data, obtained in Irkutsk (52°17'N and 104°18'E) on February 6, 2013 and February 15, 2013 are shown. February 6, 2013 is considered as a reference day because of the same Kp as on February 15, 2013, the black star marks the sunset terminator. Increasing of perturbations of electron concentration can be seen on February 15, 2013, the first one came up to Irkutsk ~40 min after the main flash, passing over a distance exceeding 2000 km.

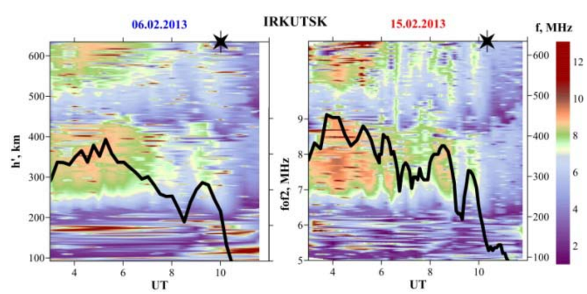

Figure 1: F_m–map and foF2 versus Universal Time (UT).

Similar maps have been plotted for 12 stations of vertical sounding of ionosphere. Perturbations are more structural on February 15 on the most of them. On the every map we attribute the former impulse, arrived ~ 1 hour after the main flash, and the latter others, arrived a few hours later, the time interval differs for various stations.

3. Results of 3D gas dynamic simulation

The 3D gas dynamic simulations of energy release in the atmosphere for the Chelyabinsk meteor blast was evaluated to grasp scenario of the event. Simulation anticipates formation and development of instabilities in the ionosphere 13 min later the main flash. The trajectory inclination was 16 degrees, entry velocity was 17.8 km/s and the brightness curve was chosen in accordance with [2], total released energy was approximately 440 kT TNT, the main flash (zero time on the brightness curve) occurs at an altitude of 25 km. The trajectory started at 90 km. On Fig. 2 vertical pressure distributions in the trajectory vertical plane are plotted.

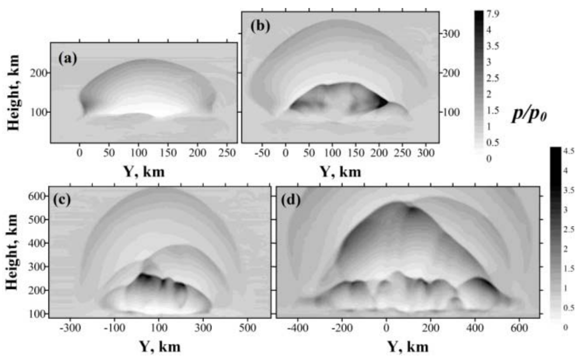

Figure 2 a,b,c,d: Relative pressure versus Y-coordinate and altitude at time moments 300s, 400s, 500s, 850s after the start of simulation (from lower panels up to uppers).

At this time the sonic wave from the meteor blast that rises up, is transforming into the shock wave. Instabilities, possibly caused by interaction of reflected air blast sonic wave and previously raised-up gas look like wave- and column structure (Fig. 2d), expanding radially. They reveal as transient ionosphere disturbances (TID).

4. Summary and Conclusions

TIDs, moving with ion sonic speed specific for altitude of 250 km, can reach monitoring stations after ~30 min-1 h after the event. It is consistent with appearance time of the first perturbation. We also compared results of gas dynamic simulation with radar and GPS observations [3], which revealed waves with speeds of 200 m/s and 380 m/s at altitudes 120 km and ~250 km. They are in a good agreement with simulations. So we conclude that some of detected TID can be attributed to aftermath of the Chelyabinsk meteor blast.

Acknowledgements

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References

[1] Givishvili, G. et al: Ionosphere effects, stimulated by the Chelyabinsk meteorite, Solar System Res., Vol. 47, №4, pp. 304-311, 2013.

[2] Emel'yanenko, V. et al: Astronomical and physical aspects of the Chelyabinsk event on February 15, 2013, Solar System Res., Vol. 47, №4, pp. 262-277, 2013.

[3] Berngardt, O., et al: Geophysical Phenomena, accompanied the fall of the Chelyabinsk meteorite, Proceedings of RAS, Vol. 452, № 2, pp. 205-207, 2013.

[4] Kuzmicheva, M and Losseva, T., The 43rd Lunar and Planetary Science Conference, held March 19–23, 2012 at The Woodlands, Texas. LPI Contribution No. 1659, id.2319.(http://www.lpi.usra.edu/meetings/lpsc2013/eposter/2765.pdf)