Ionosonde observations of ionospheric disturbances due to the 15 February 2013 Chelyabinsk meteor explosion

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Abstract

We report the results of our investigations on ionospheric effects potentially caused by the 15 February 2013 Chelyabinsk meteor explosion. We used the observation data from a number of digisonde stations located in Europe and Russia to detect the traveling ionospheric disturbances (TIDs) likely to have been caused by the meteor explosion. We found that certain characteristic signatures of the TIDs can be identified in individual ionogram records, mostly in the form of Y-forking/splitting of the ionogram traces. Based on the arrival times of the disturbances, we have inferred the overall propagation speed of the TIDs from Chelyabinsk to be $171 \pm 14$ m/s. In addition to the natural fulfillment of scientific endeavors, this work also highlights the importance of maintaining the mastery of ionosondes as ionospheric diagnostic instruments (in terms of operation, data analysis, representation, and interpretation) for many generations of space researchers to come.
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Abstract:
We report the results of our investigations on the potential ionospheric effects caused by the 15 February 2013 Chelyabinsk meteor explosion. We used the data from a number of digisonde stations located in Europe and Russia to detect the traveling ionospheric disturbances (TIDs) likely to have been caused by the meteor explosion. We found that certain characteristic signatures of the TIDs can be identified in individual ionogram records, mostly in the form of Y-forking/splitting of the ionogram traces. Based on the arrival times of the disturbances, we have inferred the overall propagation speed of the TIDs from Chelyabinsk to be 171 ± 14 m/s.

Situational Overview

A large meteor explosion happened on 15 February 2013 at approximately 03:20 UTC. The map shows great circle arcs from Chelyabinsk (the meteor explosion site) toward several ionosonde stations located in Europe and Russia.

The Basics: Characteristic Signatures of TIDs in Ionograms

Ionogram Records: Arrivals of TIDs from the Chelyabinsk Meteor Explosion

A plot of the great circle distances from Chelyabinsk to each ionosonde station versus the corresponding time delay for the traveling ionospheric disturbances to arrive. The result of a linear fit to the data points is also overlaid on the graph (solid red line), revealing a propagation speed of roughly 171 m/s. The dashed magenta lines indicate the 95% confidence interval bounds.

Closer Look at the TID Signatures

An RTI-style plot of ionogram data from the Dourbes station, covering a representative time window 07:00-21:00 UTC on 14 and 15 February 2013. The colormap indicates the level of the total echo amplitude count at any given virtual height and time, summed over all sounding frequencies. Shown also are samples of individual ionogram at four specific times during the passage of traveling ionospheric disturbances over this station after the Chelyabinsk meteor explosion several hours earlier.