

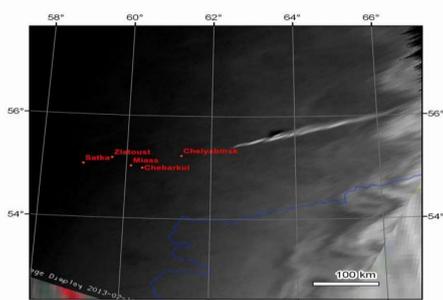
# The after-impact plume of Chelyabinsk bolide 15 Feb 2013: interaction with ionosphere, generation of transient magnetic fields

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Marina Kuzmicheva,  
[kuzm@idg.chph.ras.ru](mailto:kuzm@idg.chph.ras.ru)

Tatiana Losseva,  
[losseva@idg.chph.ras.ru](mailto:losseva@idg.chph.ras.ru)

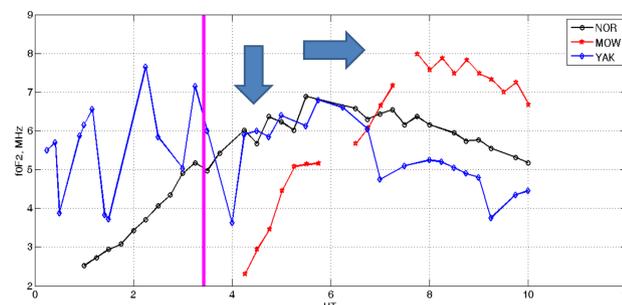
Institute of Geospheres  
Dynamics, Russian Academy of  
Sciences, Moscow, Russia



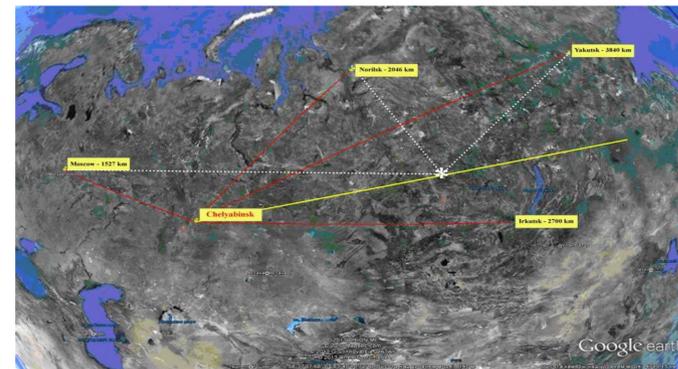
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Noticeable transient magnetic fields could be generated by interaction of E-layer of the ionosphere with plumes after oblique impacts while they moving across the Earth's magnetic field. An asteroid disruption and deceleration in the atmosphere emerges air blasts. If the released energy is sufficient for shock wave atmospheric breakthrough, then due to buoyancy hot air from the lower atmosphere rushes after the shock wave up and uprange. As a result of the plume generation a large bulk of relatively dense gas from the lower layers is ejected into the upper atmosphere. There the plume gas moves along ballistic trajectory, since environment is very sparse. Falling down, it decelerates at an altitude of approximately 100 km, compressing the air. The heated gas rises again into the upper layers of the atmosphere, the scenario repeats emerging atmospheric oscillations. (Nemtchinov, Loseva, 1994; Boslough, Crawford, 1997; Shuvalov, Artemieva, 2001).

## Evidences for emergence of ionospheres' oscillations



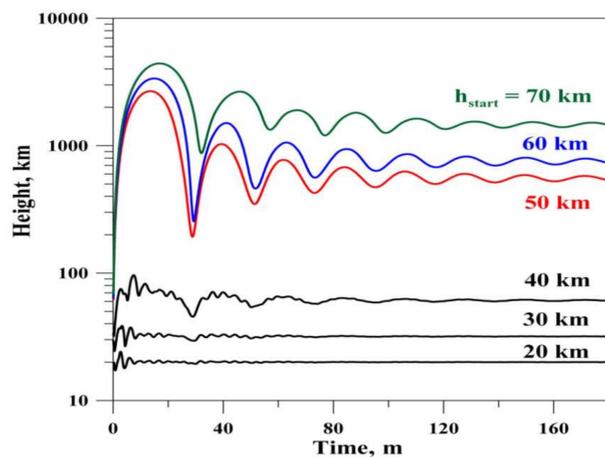
FoF2 values for Moscow, Norilsk, Yakutsk have been obtained by processing of ionograms from the Digital Ionogram Database (<http://ulcar.uml.edu/DIDBase/>). Stations of height probing of the ionosphere (locations are shown on the right panel) detected oscillations of F2-layer critical plasma frequency. The pink vertical line is time of the final flash. These oscillations comply density oscillations at a height 250 km with a period 30 min, transferred with sonic speed 650 m/c, in Moscow been detected after sunrise. While the oscillations started the upper portion of the plume was not over Chelyabinsk, but at a point of the trajectory at a distance ~2000 km up range, because perturbations reached to Yakutsk and Norilsk at the same time.



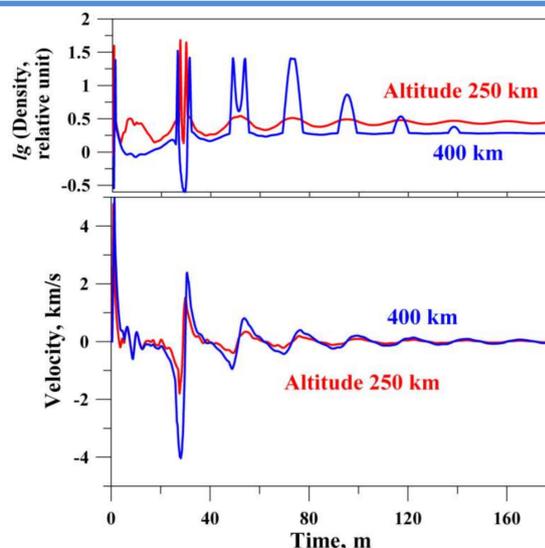
Also **tomography** of the midlatitude ionosphere (along 40E chain) has shown that wave-like perturbations in electron density were observed in the range 52-56N at -06:39UT-7:10UT. They covered the height range from 200 to 700 km. In the latitude-height cross-section there were 6 spatial oscillations. (Institute of Applied Geophysics, private communication). Each column was initiated by a regular rise of the plume. Nothing like these was seen at days before and after.

## Gas dynamic simulations of atmospheric oscillations.

It has been shown that the period, attenuation and density amplitudes are in a good agreement with observations if the air blast has occurred at a height of 40 km.



Trajectories of particles started from various heights  $h_{start}$

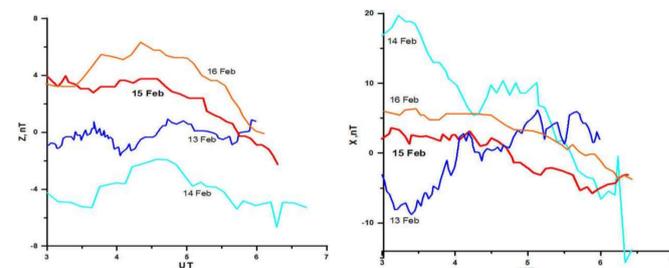


Distributions of densities and velocities obtained by numerical simulations at heights 250 and 400 km.

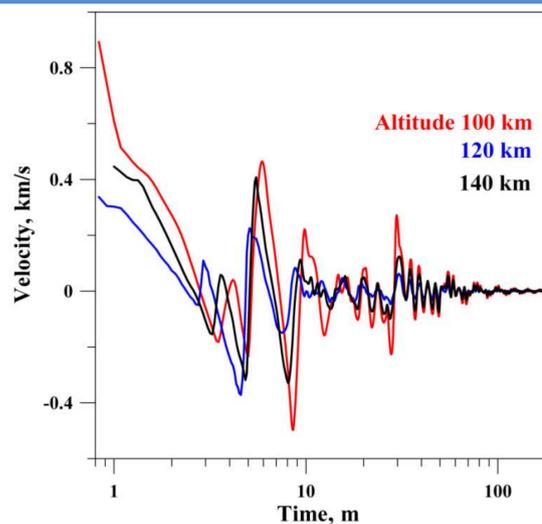
Periods and attenuation match observable ones. Amplitudes of density disturbances are close to density disturbances computed for observable foF2 oscillations, presented on the top picture.

## Interaction with E-layer of the ionosphere

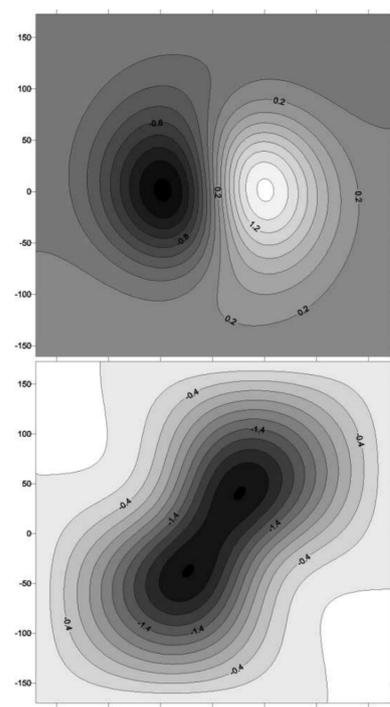
For generation of an electric dynamo field and electric currents in the E-layer it is important that the bolide moved along an inclined trajectory, so the plume had got a horizontal speed and moved across prevailed Z-component of the geomagnetic field. After Tunguska event 1908 the geomagnetic disturbances had been detected (Ivanov, 1961).



Here are magnetograms of the nearest station ARTI (56.43N, 58.57E), obtained from [http://www.intermagnet.org/Data\\_e.php](http://www.intermagnet.org/Data_e.php). No noticeable effect after 3:16UT. **Why?**



Plume induced oscillations got started at 3-4 min., vertical velocity is about 0.5 km/s, horizontal velocity is 0.85 and location is about 300 km from Chelyabinsk up range. 2D gas dynamical simulations of cylindrical explosion in inclined atmosphere have shown that radius of the uplift jet is 10-15 km.



Magnetic field of electric currents generated in the E-layer by interaction with the plume has been simulated (Kuzmicheva, Losseva, 2012). Z- and X- components are presented on the left upper and lower panels.

The values Z- and X-components of the induced magnetic field do not exceed a few nT, so they couldn't be detected.

## Discussion.

- Deceleration and disruption of an asteroid in the atmosphere is continuous process of energy release over the trajectory, which could exceed hundred km, but **some** flashes are usually detected, so the assumption of one of events, which initiated ionospheres' oscillations is quite cogent.
- The image of the asteroid, obtained by METEOSat (in the left corner), is made at the height of about 37 km above the final flash height, and can be interpreted like a swarm of debris, so the upper energy release has really occurred.
- The near-ground phenomena such as broken window glasses have been caused by an energy release, accompanied by the final flash. We appreciate help of A. Lyakhov in obtaining and processing of ionospheres' data.

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*Kuzmicheva M. Yu., Losseva T.V.* 43rd Lunar and Planetary Science Conference, held March 19–23, 2012 at The Woodlands, Texas. LPI Contribution No. 1659, id.2319