Chelyabinsk meteoroid entry: analysis of acoustic signals in the area of direct sound propagation

D. Glazachev, E. Podobnaya, Yu. Rybnov, O. Popova
Institute for Dynamics of Geospheres Russian Academy of Sciences (IDG RAS), Russia (GlazachevD@gmail.com)

The Chelyabinsk airburst of 15 February 2013, was exceptional because of the large kinetic energy of the impacting body and the airburst that was generated, creating significant damage and injuries in a populated area. The meteor and the effects of the airburst were extraordinarily well documented, which allowed to determine meteoroid trajectory and orbit [1,2] and to study in detail its interaction with the atmosphere [1,2,3].
The blast wave from the event was recorded by infrasound stations at large distances. Signals recorded there are essentially modified by dispersion during propagation and it is difficult to extract information about the source of the blast. Acoustic signals in the area of direct sound propagation hold this information.

Numerous videorecords of flight and fragmentation of the Chelyabinsk meteoroid allowed to determine the blast wave arrival times [1-3] and to extract waveforms of acoustic signals. The blast is coming from the closest point of trajectory (in 3D). Comparing the arrival times from conical sources with different terminal altitudes to those observed at different locations demonstrated that a conical source can satisfactory describe the observed blast wave arrival times [1]. Modeling of Chelyabinsk event blast wave demonstrated that local shocks may be generated by energy release maxima [4]. These shocks propagate inside ballistic cone and may reveal as separate peaks after main arrival. Number of peaks, time delay between them is dependent on parameters of energy maxima and location of registration. One needs to be careful in attribution of local maxima on energy release curve as there is possibility to add artificial or to lose real one due to sophisticated shocks interaction inside ballistic cone.

Recorded waveforms are of complicated nature, there are successive arrivals of strong perturbations with different time delays (relatively to the first one) at waveforms (Fig.1). Number of peaks and time delays between subsequent arrivals depend on the location of the registration points.

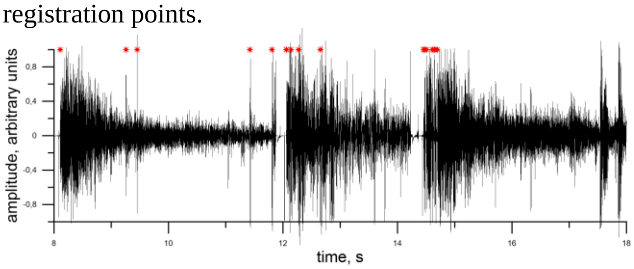

Fig.1 Waveform of acoustic signal recorded at the distance about 30 km to trajectory (in 3D). Red stars correspond to soniq boom identified by trained listener.

Some authors [1] suggested that subsequent acoustic arrivals correspond to separate fragmentation events. Trained listener is able to hear dozens of sound booms, some of them (especially closely spaced) could be reflections from surroundings. In order to determine the features of the blast source (i.e. prominent evidences of the fragmentation events, their number etc) one needs to analyze acoustic signals at different locations. Spectral, correlation and cepstral analysis could be useful. First results of different signal processing techniques applying to the Chelyabinsk meteoroid acoustic signals will be presented.

The work was partially supported by grant of the Russian Science Foundation 16-17-00107 To "Comprehensive assessment of the catastrophic effects impacts of cosmic bodies on Earth".

References

[1] Popova, O.P., and 59 coauthors, Chelyabinsk airburst, damage assessment, meteorite recovery, and character ization, Science, 2013, vol. 342, pp. 1069–1073.
[2] Jiri Borovicka, Pavel Spurny, Peter Brown, Paul Wiegert, Pavel Kalenda, David Clark & Lukas Shrbeny. The trajectory, structure and origin of the Chelyabinsk asteroidal impactor, Nature 503, pp. 235-237, 2013.
[3] Brown, P.G., and 32 coauthors, A 500kiloton airburst over Chelyabinsk and an enhanced hazard from small impactors, Nature, 2013, vol. 503, pp. 238–241.
[4] Shuvalov V., Artemieva N., Popova O. Estimates of the shock wave parameters caused by the Chelyabinsk meteoroid impact, In: Dynamic processes in geospheres. Issue 5.Geophisical effects of the Chelyabinsk impact. Moscow, GEOS, 2014, pp.48-58