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Seismic Observations Produced by the Sonic Boom of Chebarkul Meteorite

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The Chebarkul meteorite entered Earth's atmosphere over Russia on 3:20 February 15, 2013 (UTC) producing a strong sonic boom throughout Chelyabinsk Oblast. The dazzling light of the meteor was widely observed around Russia's Ural Mountains, and the strong pressure wave damaged many buildings, especially window glass. More than 1500 people were injured mostly by the broken glass, but none of them were killed.

A seismic signal was observed at the same time in the broadband seismic data of the IRIS network. The waveform travels at about the speed of S-wave or surface waves, which indicates that the signal travels through the ground, not in the air. The signal is observed as far as 2000 km from Chelyabinsk city.

We performed a waveform inversion using seven broadband seismic stations to obtain the source-time function of the signal. We used band-pass filtered displacement records with frequencies of 0.01 to 0.1Hz. Assuming a single force for the source mechanism, the waveform can be explained well with a point source model. We performed a grid search in space to find the location of the source. The best-fit source location was determined on the meteor track (Zuluaga and Ferrin, 2013) and 40km away from lake Chebarkul, where the large hole from the impact was detected after the meteor fall. Based on the residual surface of the waveform fitting, the error of the estimated source location is at most 20km. The force is predominantly in the vertical direction, and the maximum amplitude is $6x10^{11}$N. Since the location of the estimated source is separated from the impact point, we think the seismic wave was generated by the sonic boom, not the impact of the meteorite on the ground. If we assume the dimension of the source is a circle with radius of 20km, the average pressure will be 500Pa.

Figure caption: Trajectory of the Chelyabinsk meteor and the estimated source location of seismic signals.