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Waves Generated by Russian Meteor Detected Crossing the US

An extensive network of stations with seismometers and air pressure sensors detected the blast waves from the terminal burst of the meteoroid near Chelyabinsk as these waves crossed the US on Friday morning, February 15, 2013.

Seismograph stations supported by the National Science Foundation (NSF) to study earthquakes and the Earth's deep interior observed spectacular signals from the Chelyabinsk meteor. While thousands of earthquakes from around the globe are recorded by seismometers of the permanent Global Seismographic Network (GSN) and EarthScope's temporary Transportable Array (TA) each year, large meteorite impacts are far less common. However, the meteorite explosion on February 15 near Chelyabinsk, Russia, generated both ground motions and air pressure waves in the atmosphere. The ground motions were recorded by stations in the GSN and the TA, and the pressure waves were detected by special sensors that have been part of the TA station instrumentation for several years.

The Chelyabinsk meteor exploded in the atmosphere at approximately 03:20 GMT (9:20 AM local time) on February 15. The pressure wave from the blast caused significant damage in the city, breaking thousands of windows and injuring more than 1000 people. The energy from the blast created pressure waves in the atmosphere that rapidly moved outward from the terminal burst and spread around the globe. The downward directed blast coupled into the ground and spread outward as a seismic wave in the Earth. These two waves – the seismic wave in the Earth and the pressure wave in the atmosphere – travel at very different speeds. The waves in the ground travel quickly – at about 3.4 km per second – and attenuate rapidly, whereas the waves in the atmosphere are much slower (~0.3 km per second) and can travel great distances.

GSN stations in Russian and Kazakhstan show the ground-traveling wave as a strong, abrupt pulse with a duration of about 30 seconds (Figure 2 at http://www.iris.edu/dms/nodes/dmc/specialevents/2013/02/19/chelyabinsk-russia-bolide-meteor).

The atmospheric waves – referred to as infrasound – are detected over a broad range of sub-audible frequencies and are observed at great distances on infrasound microphones. When the infrasound waves reached the eastern US, after traveling 8.5 hours through the atmosphere across the Arctic from the impact site in Russia, they were recorded at TA stations at the Canadian border. The infrasound waves reached Florida three hours later, nearly 12 hours after the blast. The spectacular TA recordings from the meteor (Figures 9-15 on the web page referenced above) show complex signals in the frequency band 0.02 – 0.12 Hz lasting for almost an hour. There is some evidence of the infrasound wave producing strong enough ground vibration to also be recorded on the TA's seismometers. Infrasound sensors at additional TA stations along the Pacific coast and in Alaska also recorded the blast (Figure 8 on the web page referenced above), but with signatures that are shorter and simpler than that recorded by the stations located in the midcontinent and along the southeastern seaboard. The extended duration of the signals and the differences between the waveforms in the east and west are presumably related to the way in which the energy travels and bounces on its long path through the atmosphere. The exact reasons for the differences will be the subject of future studies that may reveal important new insights into the complex structure and mode of propagation in the stratosphere.

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The Transportable Array is operated by the IRIS Consortium (www.iris.edu) as part of the National Science Foundation's (www.nsf.gov) EarthScope project (www.earthscope.org) and consists of 400 stations that are gradually traversing the US, occupying sites 70 km apart and recording at each site for two years. Each of the TA stations (see http://www.iris.edu/hq/gallery/album/317) was originally equipped with sensitive broadband seismometers for measuring ground motions, but in 2010, the National Science Foundation awarded the University of California, San Diego, in cooperation with IRIS, funding to equip each station in the array with pressure and infrasound sensors. These special sensors help in understanding how changes in pressure affect the ground motions recorded by the TA's seismometers and provide a unique view of regional-scale pressure changes related to weather patterns. The sensors also record interesting – and sometimes mysterious – events such as tornadoes, derechos, rocket launches, chemical explosions, bolides and meteorite impacts. The Chelyabinsk meteor is the largest signal recorded to date, however, many events per week are seen on the infrasound array. Analyses of these signals will provide important information on the detailed velocity structure of the atmosphere and the impact of high altitude winds.

In 2013, the Transportable Array will reach the states in the northeast, completing its traverse of the contiguous US and southern Canada. Plans are being developed to deploy TA stations in Alaska in 2014, where it is expected that both seismic and infrasound signals from volcanic eruptions can be added to the collection of interesting events recorded by this unique research array. The dense grid of stations has proved so valuable that Federal Agencies have cooperated in a plan for some of the TA stations in the central and eastern US to linger an additional five years where they would continue to provide important information on both earthquakes and interesting atmospheric disturbances in the eastern half of the country.

The Global Seismographic Network's (GSN) primary mission is collecting data to monitor worldwide earthquakes and for the studying the Earth's deep interior. The GSN is funded jointly by the National Science Foundation and US Geological Survey (www.usgs.gov) and managed and operated by IRIS in collaboration with the US Geological Survey's Albuquerque Seismological Laboratory and the University of California, San Diego. As part of a worldwide network of seismic stations, data from the GSN have also contributed over the past three decades to the monitoring of nuclear explosions at test sites in the US, the former Soviet Union, India, Pakistan and Korea. As another recent example of a multi-use application, stations of the GSN provided important observations of the Korean nuclear test of February 12, 2013 (http://www.iris.edu/dms/nodes/dmc/specialevents/2013/02/12/north-korea-nuclear-explosion). The Comprehensive Test Ban Treaty Organization in Vienna, Austria, is the international body responsible for treaty monitoring, using its own network of stations, supplemented by data contributed by other open global networks, such as the GSN.

Web Resources:

IRIS Special Event page for the Chelyabinsk meteor:
www.iris.edu/dms/nodes/dmc/specialevents/2013/02/19/chelyabinsk-russia-bolide-meteor/

IRIS Teachable Moment for Chelyabinsk meteor:
http://www.iris.edu/hq/retm

Information about the EarthScope Transportable Array:
www.usarray.org/researchers/obs/transportable

Information about the Global Seismographic Network
www.iris.edu/hq/programs/gsn

Information about IRIS:
www.iris.edu

Information about EarthScope:
www.earthscope.org

Photographs of Transportable Array stations:
www.iris.edu/hq/gallery/album/317

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