Infrasound and Seismic Recordings of a US Airstrike on an ISIS Car Bomb Factory on June 3, 2015

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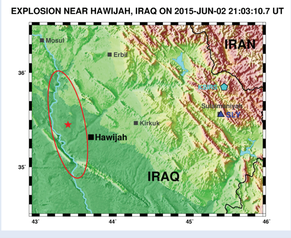
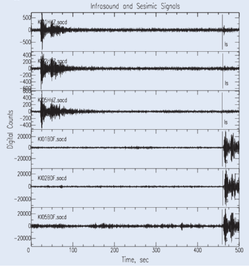
Abstract

Concurrent infrasound and seismic records of a jet airstrike in Iraq are presented. Media reports stated that US jets carried out a large airstrike on June 3, 2015, just after midnight local time, that targeted and destroyed an ISIS car bomb factory in Hawija, Iraq, just south of the city of Kirkuk, Iraq. The resulting explosion was felt within Kirkuk and at other locations as far as 34 km away from the Hawija factory. Seismic broadband stations located in northern Iraq, at a distance of about 160 km, show clear simultaneous signals of infrasound waves on the seismometers as well as on collocated infrasound equipment. From an analysis of the body waves, the Pg to Lg time difference is nearly ~20 sec, with a back azimuth of 250o to 260o, which is consistent with explosion location. The time difference between the Pg and infrasound signals is just over 7 minutes, consistent with sound speed in the atmosphere. No clear Rg wave was observed. As was demonstrated by Aleqabi, Wysession, and Ghalib [2016, BSSA, in press], broadband seismic recordings are able to identify and distinguish between several different kinds of MOUT (military operations in urban terrain) and even determine the magnitudes of ordinance used in certain blasts. The addition of collocated infrasound equipment provides additional constraints that can be used in the analysis of the size and form of the MOUT.

Introduction

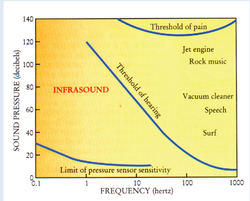
Media reports stated that an airstrikes on an ISIS (Islamic state in Iraq and Syria or Daesh) VBIED (vehicle-born improvised explosive device) facility (see pictures of damage at the bottom of the poster) "early" on June 3, 2015, that was heard at least 55 km (34 mi) away in Kirkuk. The facility was housing tanks, Humvees and large quantities of explosives. The reported factory is in Hawija in northern Iraq, Kirkuk.A clear infrasound signal is observed on the KSIRS (seismic array in northeastern Iraq, equipped with STSs-2 and Chaparral infrasound sensors), BDF (infrasound channel) and on the HHZ, HHN and HHE (seismic components) of KSIRS. The infrasound signal arrives at about 467 seconds after a local event with Pg arrival time of 21:03:42 UT. The Lg arrival is also about 20 sec after Pg, in good agreement with predicted value. The Pg is coherent and appears to have a backazimuth in WSW direction which agrees with predicted station to event back azimuth of 260.



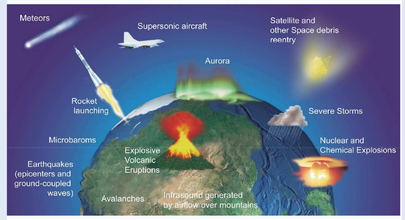


Background

Infrasound is sound that is lower in frequency than 20 Hz. Its frequency is below the "normal" limit of human hearing and for humans to perceive infrasound, the sound pressure must be sufficiently high. Infrasound is generated by many sources natural and anthropogenic. Challenges arises from their dual propagation in the ground and in the atmosphere. Therefore, it is imperative to have better understanding of the expected seismic wave field characteristics from these sources.



Infrasoud Generation and Atmospheric Structure (Temperature Profile)



Temperature of atmosphere varies significantly with altitude ⇒ speed of propagation of infrasonic waves varies over a wide range

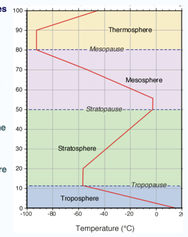
1-Troposphere: from 0 to ~18km: this region accounts for 80% of the mass of the atmosphere and for almost all storm activity. Temperature decreases with increasing height.

3-Stratosphere: from ~20 to ~50km: region of pronounced static stability with very little vertical mixing. Temperature increases with increasing height.

5-Mesosphere: from ~60 to ~90km: region less stable of the statosphere with some vertical mixing.
Temperature is decreasing with increasing height.

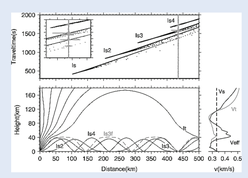
7-Thermosphere: from ~100 to ~120km: area of temperature continuously increasing until an asymptotic value is reached at the **thermopause** which depends strongly on solar activity.

The description of the propagation of infrasound around the globe will depend primarily on temperatures below an altitude of about 200 km



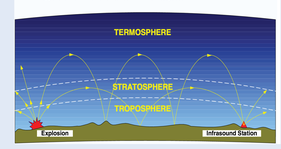
Infrasound Propagation, Wave Guides, Travel Time

- **Formation of infrasound:**
  - **shock wave slows down.**
  - **higher frequencies absorbed.**
  - **residual energy → infrasound which propagates for great distances.**

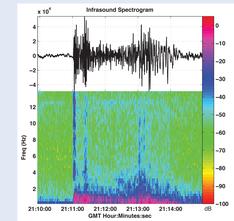


Waveguide is any region in which a layer of smaller sound velocity is bounded above or below by:
- **regions of higher velocity**
- **the Earth's surface**

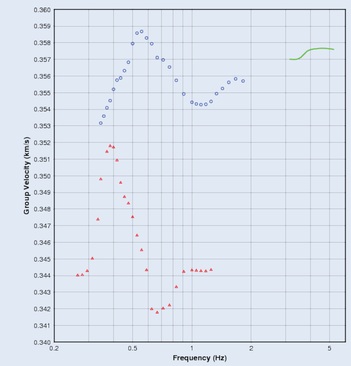
Two main waveguides (sound channels) in the atmosphere:
- **lower channel with an axis near 18 km in the troposphere**
- **upper channel with an axis near 90 km in the mesopause**

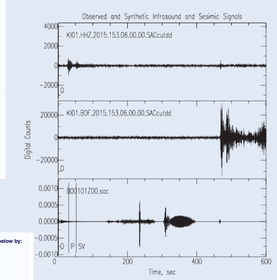


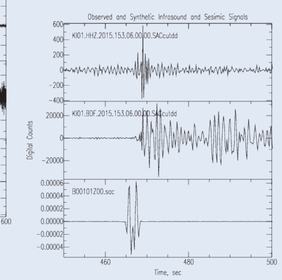
Infrasound Spectrogram, Observed dispersion and Infrasound Synthetic Seismograms



We performed time-frequency analysis using the spectrogram to visualize signals power levels and frequency content.

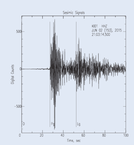






Dispersion of infrasound in waveguides is only recently observed by Herrin et al. (2006) and Negraru et al. (2009). Phase match filter of observed infrasound signal from Hawija destroyed VIVED factory show two dispersion signals with 30 seconds. The second signal is not predicted with atmospheric structure. Dispersion of infrasound indicates the presence of waveguide.

Pictures show a huge field of debris, cinderblocks, metal roofing, and twisted remains of vehicles, that stretches as far as



Infrasound signals recorded by seismometer