# ANALYSIS OF THE INFRASOUND DATA ASSOCIATED WITH THE ANNAMA FIREBALL (19 APRIL 2014).

E. A. Silber[1] and M. Gritsevich[2,3,4]

[1]Department of Earth, Environmental and Planetary Science, Brown University, Providence, RI, USA, 06912 (e-mail: elizabeth_silber@brown.edu), [2]Finnish Fireball Network, Helsinki, Finland, [3]Department of Physics, University of Helsinki, Gustaf Hällströmin katu 2a, P.O. Box 64, FI-00014 Helsinki, Finland (maria.gritsevich@helsinki.fi), [4]Institute of Physics and Technology, Ural Federal University, Mira str. 19. 620002 Ekaterinburg, Russia.

**Introduction:** Infrasound is low frequency sound, lying below the human hearing range. Among many sources of infrasound, are the meteoroids larger than a few centimeters. As a meteoroid interacts with the Earth's atmosphere during its hypersonic flight, it produces a shock wave, which decays to low frequency infrasonic waves that propagate over great distances [1]. Infrasound is a valuable tool in estimating energy release by meteoric events and validation of existing models (e.g. [2]). Here we study the infrasound data associated with the meteorite-producing fireball Annama observed by the Finnish Firebal Network on April 19, 2014 [3-7].

**Methodology:** The waveform data from IMS network [8] of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) within 5000 km of the event were examined for possible infrasound signals. To search and identify probable infrasonic signals emanating from the fireball, we used two software packages: the Progressive Multi-Channel Correlation (PMCC) algorithm, and MatSeis 1.7. PMCC is optimized for locating signals with low signal-to-noise ratio. It employs element pair-wise correlation algorithm to search for detections based on signal coherency and common back azimuth, identifying return "families" in time and frequency. Details about relative advantages of these two software packages and references can be found in [9].

**Summary:** A coherent airwave, consistent with the back azimuth and timing of the fireball, was identified at IS43RU (56.72°N, 37.22°E), 1359 km from the point of origin. Other IMS stations did not show evidence of infrasound signals. The infrasonic wave arrived in two stratospherically ducted packets (phases), with the overall frequency content of approximately 1 Hz. The first arrival was recorded at 23:26:36 UTC, with the primary phase persisting for 174 seconds. The measured back azimuth of 348.9° is in excellent agreement with the theoretical back azimuth of 348.6°. The second arrival occurred shortly thereafter, at 23:30:09 UTC, in a burst lasting only 44 s.

The dominant signal period was measured in two ways; first, by measuring the zero crossings at maximum peak-to-peak amplitude (maximum Hilbert envelope), and second, by finding the inverse of the signal frequency, with the noise subtracted, at the maximum signal power density (PSD). The dominant signal period, tabulated from the frequency at maximum PSD, is 1.83 s, which is consistent, within the measurement uncertainty, with the period measured at the maximum amplitude. Using the empirical period-energy AFTAC relation [10], the signal period corresponds to energy release of approximately 30 t of TNT equivalent (1 TNT = 1.184·109 J).

**Acknowledgements:** This work was supported, in part, by the ERC Advanced Grant No. 320773, and the Russian Foundation for Basic Research, project nos. 18-08-00074 and 19-05-00028. Research at the Ural Federal University is supported by the Act 211 of the Government of the Russian Federation, agreement No 02.A03.21.0006.

**References:** [1] Silber E. A. et al. (2018) *Adv. Sp. Res.*, 62, 489-532. [2] Moreno-Ibáñez M. et al. (2018) *The Astrophysical Journal* 863(2), 174. [3] Gritsevich M. et al. (2014) *Meteoritics and Planetary Science*, 49, A143. [4] Trigo-Rodríguez J. M. et al. (2015) *MNRAS*, 449(2), 2119-2127. [5] Dmitriev V. et al. (2015) *Planetary and Space Science*, 117, 223–235. [6] Lyytinen E. and Gritsevich M. (2016) *Planetary and Space Science*, 120, 35-42. [7] Kohout et al. (2017) *Meteoritics and Planetary Science*, 52, 1525–1541. [8] Christie D. R. and Campus P. (2010) "The IMS Infrasound Network: Design and Establishment of Infrasound Stations", In: A. Le Pichon, E. Blanc and A. Hauchecorne (Eds.), *Infrasound Monitoring for Atmospheric Studies*, Springer, New York, pp. 29-75. [9] Silber E. A. and Brown P. G. 2014. Optical Observations of Meteors Generating Infrasound – I: Acoustic Signal Identification and Phenomenology, *JASTP*, 119, 116-128. [10] ReVelle D. O. (1997) "Historical Detection of Atmospheric Impacts by Large Bolides using Acoustic-Gravity Waves", Annals of the New York Academy of Sciences, Near-Earth Objects - The United Nations International Conference (Ed. J. L. Remo), 822, 284-302.