Infrasound from natural phenomena observed by infrasound observation network for study on early detection of tsunami

*Takayuki Otsu[1], Nobuo Arai[2], Takahiko Murayama[1], Masashi Motohashi[1], Toyomi Sakamoto[1], Makiko Iwakuni[1], Mami Nogami[1]

1. Japan Weather Association, 2. Disaster Mitigation Research Center, Nagoya University

At the time of the 2011 off the Pacific coast of Tohoku Earthquake, several microbarographs around focal region recorded pressure changes associated with atmospheric boundary wave excited by large scale sea-level change in tsunami source region (Arai et al., 2011). We have decided to study infrasound monitoring technique to detect large tsunami generation, then have started experimental infrasound observation using microbarographs in Ofunato city and Shima district since July 2013, June 2015 respectively. We are now planning to make those data available on the web to facilitate study on infrasound by any researchers.

Since a variety of phenomena can excite infrasound as well as large scale sea-level change, such infrasonic signals are frequently observed at the infrasound observation sites mentioned above. In this presentation, we will introduce some cases of detected signals traveling from known sources such as a volcanic eruption, a bolide and so on. Through the analysis on observed signals from a variety of phenomena, it is expected to accumulate useful information for application to source identification and propagation characteristics of signals.

Keywords: Infrasound, Tsunami, Volcanic eruption, Bolide, Microbarograph

Consideration on the Exciation of Lamb Waves, Internal Gravity Waves, and, Acoustic Gravity Waves

*Kensuke Nakajima[1], Hibiki Jonai[2]

1. Department of Earth and Planetary Sciences, Faculty of Sciences,Kyushu University, 2. Department of Earth and Planetary Sciences, Graduate School of Sciences,Kyushu University

See Japanese abstract.

Keywords: Lamb waves, internal gravity waves, acoustic gravity waves, infrasound, earthquake

Ionospheric volcanology: GNSS-TEC observation & modeling of the 2015 Kuchinoerabujima eruption

*Yuki Nakashima[1], Kiwamu Nishida[2], Yosuke Aoki[2], Giovanni Occhipinci[3], Kosuke Heki[1]

1. Natural History Sciences,Graduate School of Science, Hokkaido University, Earth and Planetary Dynamics, 2. Earthquake Research Institute, University of Tokyo, 3. Institut de Physique du Globe de Paris

Efforts in last decade prove that ionosphere, mainly observed by GNSS measuring the total electron content (TEC), is sensitive to geophysical phenomena as earthquakes, tsunamis, and, more recently, volcanic explosions.
Kuchinoerabujima is a volcanic island located in ~200 km southwest of Kyushu, Japan. The volcano erupted at 0:59 UT May 2015 (VEI 3).
We found a concentric acoustic wave following the eruption in GNSS-TEC time series. We used 1 Hz GEONET (GSI) data for this analysis. The observed wave seems include high frequency (5–10 mHz) pulse disappearing in the first ~300 km around the volcano and a monochromatic wave (~5 mHz) observable for more than ~20 min and reaching the distance of ~400 km. The traveltime indicates the wavefront is almost spherical. We interpreted those signals as a combination of, first, the direct shock wave propagating within the atmosphere/ionosphere and, second, the acoustic wave trapped in the lower atmosphere/ionosphere by the effect of the cut-off frequency change with the altitude.
Our observation are also supported by various ground observations: barometers (NIED; AIST), microphones (NIED; JMA) and broadband seismometer (NIED). We detected ~1 hPa wide frequency range (2–70 mHz) air wave in near-field and ~15 mHz perturbation reflecting or refracting once or twice at ~100 km from the volcano. The difference of frequency components derives from the instruments noise level or dispersion of the wave.
In order to validate our hypothesis we support and discuss our observations with the light of the modeling with the main goal of constrain some physical parameters of interest in volcanology.

Acknowledgement: We thank AIST for barometric records by the integrated groundwater observation well network for earthquake prediction of the Tonankai/Nankai earthquake. We also thanks IPGP, ERI and Hokkaido Univ. exchange programs to make our collaboration possible.

Keywords: Ionosphere, GPS, GNSS, Volcano

Observation of shockwave from the 17 December 2013 Biwako bolide using 3D seismic array

*Naoto Takeda[1], Kazutoshi Imanishi[1], Norio Matsumoto[1]

1. National Institute of Advanced Industrial Science and Technology

There are many reports of observation of bolides by using seismic record. Compared with other approaches such as video camera or acoustic microphone, seismological observations have advantages in terms of their ease of multipoint observations and their independence on weather conditions (e.g. Ishihara et al. EPS 2003). In these reports, there is a case of unclear onsets and no distinct N shape in waveforms (Yamada and Mori EPS 2012). That case, a velocity of the fireball was not determined. Here we report seismic records of shockwave from the fireball that appeared on the night of 17 December 2013 around Biwako and determine the moving velocity by using a dense three dimensional seismic array.

We performed a 3D array observation in Mie prefecture since February 2011 to monitor non-volcanic low frequency tremor activity (e.g. Takeda et al. JpGU 2015). The array is composed of a 3-level vertical seismic array at a depth of 25m, 164m, and 595m (Imanishi et al. 2011), and a 46-element surface array centered on the vertical array. The radius of the surface array is 10 km, with a station spacing of about 50 m to 5 km. Seismograms recorded at the surface array show clear onsets of the shock wave with a downward polarity, while those of the vertical (borehole) array have unclear onsets. Therefore, we used only seismograms of the surface array for the determination of a source trajectory.

We manually picked arrival times of the shock wave, and estimated the source location by a grid search, assuming a point source or a moving source with a constant velocity. Theoretical arrival times for the moving source model show better fit to the observations than those for the point source model. We estimated the velocity of source to be 27km/s and an incident elevation angle to be 43 degree. Our result agrees with the estimation by video camera records, which are 25km/s and 47 degree (SonotaCo Network Japan).

Keywords: bolide, seismic array

Remote Sensing by Multi-site Observation of Infrasound

*Ko Saito[1], Satoshi Mizumoto[1], Ryosei Sorimachi[1], Masa-yuki Yamamoto[1]

1. Kochi University of Technology

1. Introduction: We have been observing the infrasound generated by earthquakes, tsunami, thunder and other geophysical phenomena as wave sources. Some of the geophysical phenomena occur rarely, while the others occur at a relatively high frequency per year. In order to establish stationary monitoring observations of infrasonic waves with detectable intensities, we started comprehensive multi-site observation with infrasound sensors, cameras and radio wave reception system installed at 3 sites in Kochi pref. In this paper, we report the observation results and considerations about thunder and a bright meteor (fireball) simultaneously observed by the system.

2. Multi-site observation: Since December 2016, we have been operating multi-site comprehensive observation at three points of Kochi University of Technology (KUT) (Kami City), Geisei Astronomical observatory (Geisei Village), Midori Clock Tower (Otoyo Town) with infrasound sensors (Chaparral Physics Model 25), optical cameras, radio wave receiving systems. There is infrasound and radio wave observation system at Otoyo, and all three observation systems are constantly in operation at two other points. Operation status of each device at each remote site can be confirmed at KUT through the mobile network connection, and file transmission and reception is also possible.

Here, observatioal result of the lightning strike (thunder) occurred on 13th December 2016 and a meteor observed on 5th January 2017 are described. Sonic waves of thunder strikes occurred at 18:59 on December 13, 2016 were observed at every 3 observation site, and the lightning strike position and time were calculated from the time difference between them. In addition, the camera installed at KUT and radio wave receiving systems at each observation site observed luminescence and impulsive radio waves. N type atmospheric pressure waveform with on amplitude of 0.06 Pa was detected at Otoyo 24 km away from the lightning strike point.

Sonic waves generated by the meteor observed at 22:33 on January 5, 2017 were detected at two sites. A pressure waveform similar to a shock wave with an amplitude of 0.05 Pa was observed at Geisei. Radio waves (steady transmitted from Fukui National College of Technology) reflected by the ionizing column formed during the meteor entry into the atmosphere were observed at 2 sites and meteor video movie was observed by the camera at KUT.

3. Results and discussion: We found a one second delay between the thunder striking time obtained from the observed time-difference of infrasound impulse among each site and the time when the radio system observed the radio wave impulse. It is considered that this is due to assumptions such as constant sound speed, uniform wind direction, direction of discharge path, etc. In addition, there are some factors of the measurement error of the calculated lightning strike position, and an error of ±300 m is considered in this analysis. Sound amplitude attenuation by distance was calculated from the power spectrum of each site. There were 20 dB difference between KUT and Otoyo where the distance difference from the lightning strike point was 18 km at the maximum case.

Infrasound generated by the meteor entry into the atmosphere was observed at Geisei with shock wave type waveform of a period of 1.53 seconds. The power spectra of 10 seconds before and after the event about were compared, and it was confirmed that the power spectrum amplitude in lower frequency range of 10 Hz or less was 10 dB larger. It could be considered that this is because the detection of very low frequency disturbance when the shock wave occurred in the upper atmosphere passed. The camera installed at KUT confirmed about 3 times of erupting light emission, which is considered to be relatively larger meteor (fireball) than the normal one. It is extremely rare to be observed for an infrasound generated by an object entering from the outer space into the atmosphere, and such observation is extremely difficult unless there exists stationary operated remote sensing.

4. Conclusion: When calculating the time and position of the event by the acoustic observation, the wind speed has a great influence as an error factor, so it is necessary to set a temperature sensor in each observation site in the future and take temperature information. Moreover, frequency attenuation can be confirmed by sensing the audible range. We have succeeded in observing very low frequency sound generated by geophysical phenomena by conducting steady remote sensing. We will continue to accumulate various observation data by comprehensive observation.

Keywords: Infrasound, Lightning, Thunder, Meteor