Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

MTT43-01 Room:311 Time:May 1 15:15-15:30

Multi-site infrasound observation around Syowa station, Antarctica

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Infrasound is one of the frontier fields in geophysics to observe atmospheric events. World wide infrasound observing network has been constructed as the CTBTO (Comprehensive Nuclear-Test-Ban Treaty Organization) to detect infrasound signal from huge artificial explosions, however, the CTBTO infrasound observing stations usually catch the natural infrasonic waves generated by many geophysical events, like volcanic eruptions, earthquakes, tsunamis, etc. For example, when a huge meteorite fall was observed near Chelyabinsk, Russia in 2012, the induced infrasonic waves reached to many distant CTBTO stations more than 10,000 km apart from. In the polar region, there exists local infrasound sources generated mainly by the ice sheets on ground, ice field, and glacier motions. Icequakes have been frequently monitored by seismic stations in polar region, however, monitoring of induced atmospheric infrasonic waves through lithosphere-atmosphere coupling is still in progress. We installed an infrasound sensor at Syowa station, Antarctica in 2008 during IPY (International Polar Year) period by JARE (Japanese Antarctic Research Expedition) 49 mission. However, the direction-finding of the infrasonic waves is significant to study the comparison between the seismic data, thus, 2 sensors were added on Syowa to make a triangle sensor array in 2013 by JARE 54. In addition, 5 more sensors were installed at 5 locations around Syowa in 2013 (Murayama et al., 2013).

The infrasound data observed at Syowa can be transferred to Japan via satellite connection, however, the data recorded by data logger at the stations near Syowa cannot be obtained without visiting there. In JARE 55 mission, we obtained one-year infrasound observation data recorded at several stations around Syowa and will return them back to Japan in March 2014. In this paper, we will introduce some preliminary results obtained in Antarctica as the first multi-site infrasound observation at the frozen continent.

Keywords: ifrasound, Antarctica, multi-site observation, JARE, ice quake

MTT43-02 Room:311 Time:May 1 15:30-15:45

Characteristic features of infrasound waves observed at Antarctica

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Characteristic features of infrasound waves observed at Antarctica reveal the physical interaction involving surface environmental variations in the continent and surrounding Southern Oceans. A single infrasound sensor has been continuously recorded since 2008 at Syowa Station (SYO; 39E, 69S), the Lutzow-Holm Bay (LHB), East Antarctica. The continuously recording data clearly represent a contamination of the background oceanic signals (microbaroms) during whole seasons. In austral summer in 2013, several field stations by infrasound sensors are established along the coast of the LHB. Two infrasound arrays with different diameter size are installed at both SYO (by 100 m spacing triangle) and S16 area on continental ice sheet (by 1000 m spacing triangle). Besides these arrays, two isolated single stations are deployed at two outcrops in LHB. These newly established arrays clearly detected the propagating directions and frequency contents of the microbaroms from Southern Ocean. Microbaroms measurements are a useful tool for characterizing ocean wave climate, complementing other oceanographic and geophysical data in the Antarctic. Moreover, several kind of remarkable infrasound signals are demonstrated, such as regional earthquakes, together with a detection of the airburst shock waves generated from meteorite injection at the Russian Republic on 15 February 2013. Detail and continuous measurements of the infrasound waves in Antarctica could be a new proxy for monitoring a regional environmental change as well as temporal climate variations in high southern latitude.

Keywords: infrasound, array observations, Lutzow-Holm Bay, East Antarctica, microbaroms, surface environment

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MTT43-03 Room:311 Time:May 1 15:45-16:00

Monitoring snow avalanches by using infrasound with an object of establishing remote detection system of snow avalanches

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It has been demonstrated that avalanches produce strong infrasonic vibrations in air during their movement (Bedard, 1988[1], Hejda, 1995[2]). These infrasonic vibrations propagate great distances and can follow the natural relief. This fact shows that it is possible to monitor remotely the snow avalanche by using infrasound detection system.

We aim to establishing remote detection system of snow avalanches. In order to study the feature of the signal associated with snow avalanches, as a first step, we carried out trial infrasound observation simultaneously with the video monitoring and the meteorological observation at mountainous region in Niigata Prefecture from January to April 2013. During the trial observation, some infrasound signals generated by snow avalanches were recorded. We analyzed these data and attempted to extract features from infrasound signals.

[References]

[1] Bedard, A. J. et al. 1988. On the feasibility and value of detecting and characterizing avalanches remotely by monitoring radiated sub-audible atmospheric sound at long distances. Proc. A Multidisciplinary Approach to Snow Engineering, Santa Barbara, CA.

[2] Hejda, D. 1995. Caracterisation de l'emission acoustique des avalanches, (These de diplome, E. P. F. Lausanne, Suisse.)

Keywords: Infrasound, Snow avalanches, Avalanche monitoring

MTT43-04 Room:311 Time:May 1 16:15-16:30

Micro-barometric variation associated with rainfall

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A sudden rainfall (shower) is often preceded by a micro-barometric variation. To examine quantitative relationships between them, we conducted observations of micro-barometric, rainfall and absorption of BS broadcasting radio waves and recorded the data with one second resolution.

As a result, we often observed the events where a pressure increase starts about one minute before a strong rainfall. Just after the start of the rainfall, micro-barometric variation with period about a few minutes were also observed. These results suggest that the dynamic pressure associated with the falling rain drops pushes the air and observed as a gradual increase of the pressure on the ground. If this is the case, a rarefaction waves may propagate upward over the rain cloud. In this paper, we will show the results obtained from many events.

Keywords: micro-barometric variation, gravity wave, rainfall, acoustic gravity wave

MTT43-05 Room:311 Time:May 1 16:30-16:45

Ionospheric disturbances by volcanic explosions: Observations with GNSS

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There have been numbers of reports that atmospheric waves, e.g. internal gravity waves and acoustic waves, excited by various natural or artificial phenomena on the ground, shake up the ionospheric F layer as high as 300 km [Calais et al., 1998 GJI; Heki and Ping, 2005 EPSL]. Acoustic waves from volcanic eruptions are observed as infrasound in near fields, but they also propagate upward and cause ionospheric disturbances [Heki, 2007 GRL]. We try to reveal the characteristics of ionospheric disturbances caused by volcanic explosions using Total Electron Content (TEC) data derived at the dense array of ~1240 Global Navigation Satellite System (GNSS) stations in the Japanese GEONET.

Heki [2006] detected TEC changes of ~0.1 TECU in the region to the south - southeast of the volcano ~10 minutes after the explosion of the Asama Volcano, central Japan, on Sep. 1, 2004, at 11:02 UT. He estimated the atmospheric wave energy from the amplitude of TEC disturbances, and inferred the explosion energy by comparing the TEC change amplitudes with those caused by an artificial explosion with known energy [Calais et al., 1998]. Later, Dautermann et al. [2009 JGR] performed a similar study for the 2003 explosion of the volcano in the Montserrat Island, West Indies.

Here we report on the TEC disturbances caused by the explosion of the Kirishima-Shinmoe volcano, southern Kyushu, Jan. 31 2011, 22:54 UT. According to the JMA documents issued in 2011 January, this explosion induced the infrasound of ~458 Pa, which blasted some window glasses in Kirishima-city, Kagoshima. We also detected 0.2-0.3 TECU peak-to-peak amplitude disturbances after the 2009 October explosion of the Sakurajima volcano, southern Kyushu. They appeared 10 minutes after the explosion and propagated southward with a sound speed at the F layer height. In contrast to the period of ~4 minutes of typical coseismic ionospheric disturbances, TEC changes by volcanic explosions were found to have periods of ~2 minutes or shorter.

In the presentation, we will compare new examples of ionospheric disturbances by volcanic explosions, such as the 2011 Shinmoe and 2009 Sakurajima cases, with older cases such as the 2004 Asama case.

Keywords: GPS, GNSS, infrasound, acoustic wave, volcanic explosion, ionosphere

MTT43-06 Room:311 Time:May 1 16:45-17:00

Simulation of ionospheric variations caused by acoustic waves generated in the lower atmosphere

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In the lower atmosphere of the earth, acoustic-gravity waves are generated by various kinds of natural and artificial sources, such as cumulus clouds, tornados, typhoons, earthquakes, tsunamis, volcanic eruptions, meteor impacts, nuclear explosions, rocket launches, etc. Previous theoretical and observational studies have suggested that acoustic-gravity waves induced by such sources can propagate up to the upper atmosphere, producing temporal and spatial variations in the thermosphere and in the ionosphere. However, specific mechanisms of upper atmospheric variations caused by the acoustic-gravity waves have not yet been fully understood because the atmosphere-ionosphere system is an extremely complicated and nonlinear, and it is easily disturbed by many other sources in the atmosphere and in space. In order to quantitatively study the ionospheric variations caused by tsunami-driven acoustic-gravity waves of the 2004 Sumatra earthquake and 2011 Tohoku-oki earthquake, we developed a nonhydrostatic compressible atmosphere-ionosphere model. The model successfully reproduced atmospheric waves and large-scale electron density variations that are caused by tsunami-driven acoustic-gravity waves. We are now developing an atmosphere-ionosphere model with higher spatial resolution and more realistic parameters. We expect that the model is able to reproduce atmospheric-ionospheric phenomena associated with infrasonic and gravity waves produced by various kinds of phenomena. We will report previous results and future prospects.

Keywords: acoustic wave, lower atmosphere, upper atmosphere, ionosphere, simulation, model

MTT43-07 Room:311 Time:May 1 17:00-17:15

Low-frequency atmospheric pressure waves associated with the outer-rise earthquake on Oct. 25, 2013, 17:10 UTC.

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Sensitive microbarographs in and around Japan recorded unequivocal signals associated with the 2011 Off the Pacific Coast of Tohoku, Japan earthquake (Mw = 9.0) (*Arai et al., 2011*).

These signals retained the original shape of the tsunami and traveled in the atmosphere significantly faster than the tsunami waves in the ocean, therefore, we think that an establishment of a network of infrasound observation along the coast line facing the subduction zone would improve the tsunami warning system.

According to this idea, we deployed three (3) microbarograph stations in Ofunato City, Iwate last July as the first step of the establishment of a network of infrasound observation and are trying to observe atmospheric pressure changes continuously.

The outer-rise earthquake occurred off the Fukushima region on Oct. 25, 2013, 17:10 UTC and the tsunami waves with few tens centimeter heights observed at coastal area of Tohoku region. And some curious atmospheric pressure waves detected at our Ofunato sites. The characteristics of the observed signals are consistent with the features of the tsunami source produced by the outer-rise earthquake.

Reference:

Arai et al. , Atmospheric boundary waves excited by the tsunami generation related to the 2011 great Tohoku-Oki earthquake, Geophysical Research Letters, Vol. 38, L00G18, doi:10.1029/2011GL049146.

Keywords: Infrasound, atmospheric pressure change, outer-rise earthquake, detection of tsunami

MTT43-08 Room:311 Time:May 1 17:15-17:30

Examination on Numerical Simulation of Tsunami-Induced Extremely Low Frequency Sound Waves with Geospatial Information

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Air pressure changes associated with earthquakes and/or tsunami have been investigated previously. As for air pressure changes associated with tsunami, some observation results have been reported (T. Mikumo (1964), T. Mikumo, et al. (2008) and William L. Donn and Eric S. Posmentier (1964), Y. Tamura (2011), N. Arai, et al. (2011)).

We have measured the air pressure in the terrestrial atmosphere with other meteorological parameters (temperature, humidity, etc.) continuously at Hosokura outdoor observation station (HSK) in Miyagi Prefecture, Japan. The extremely low frequency sound waves (so-called micro barometric waves) are also detected as large changes of air pressure in the 2011 off the Pacific coast of Tohoku Earthquake (M 9.0, origin time;14:46.18JST) (K. Okubo, et al. (2011)).

Although the power failure was caused by the earthquake occurrence, our observation system had been maintained by the UPS system and the private power generation. Therefore, in this earthquake, our observation system successfully observed extremely low frequency sound waves induced by tsunami. The waves were detectable at the observation point on the ground surface sufficiently early before the arrival of tsunami waves at coastal areas, because sound waves propagate faster than ocean waves (tsunami).

These results can encourage early tsunami detection (S. Iwasaki (1992), T. Izumiya (1994)) using multi-site observation and arrival time difference method. That is, detection of tsunamis might be possible by monitoring extremely low frequency sound waves at ground surface observation sites and/or sea-level observation at relatively low cost. It is important to obtain information of tsunami as soon as possible; arrival time, area and scale.

In this study we present a fundamental examination on analysis and visualization of extremely low frequency sound waves caused by tsunami using numeral approach. We employ the numerical simulation using the Finite-Difference method in Time-Domain (FDTD method) (Yee, 1966) with geospatial information for the large-scale sound wave propagation. As an elementary study, it is applied to the estimation of extremely low frequency sound waves' propagation and time-series analysis of sound pressure.

Through our study, we show the numerical results of sound pressure distribution and estimate the propagation phenomena of sound waves, compared with the observed data at HSK. This examination may help the development of the design of early tsunami detection system. In the future, further efforts can suggest new systems for early warning of destructive tsunami using a combination of other measurements.

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Keywords: Numerical Simulation, tsunami, sound field change, microbarometric wave, infrasound, numerical visualization

MTT43-09 Room:311 Time:May 1 17:30-17:45

Atmospheric Gravity Waves from the 2010 Maule, Chile earthquake (Mw8.8)

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Atmospheric pressure waves were recorded after the 2010 Maule, Chile earthquake (Mw=8.8) by microbarographs at seven International Monitoring System (IMS) stations in the distance range up to 7,680 km. By applying bandpass-filtering, we extracted low frequency gravity waves, removing atmospheric noise and higher-frequency acoustic modes, and then estimated their phase velocities around 332-341 m/s. To compare with these observations, we constructed synthetic waveforms, referring to the source dimension and coseismic vertical ground displacements based on geodetic measurements (Moreno et al., 2012), and incorporating a standard atmospheric sound velocity structure up to a height of 220 km. The comparison between the observed and synthetic waveforms provides generally satisfactory agreement, and suggests the time constant of ground displacements between 2 and 3 min in the northern and southern segments of the entire source region extending for about 500 km..

Keywords: 2010Maule, Chile earthquake, Mw=8.8, low-frequency, Atmospheric gravity waves