Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

MTT40-01 Room:203 Time:May 24 09:00-09:15

Studies on the acoustic, infrasonic and gravity waves since the 1960s

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Since the basic theory of acoustic gravity wave was established in the 1960s, many small dynamic disturbances in the upper atmosphere, taking place either naturally or artificially, have been well understood in terms of these waves. Particularly, travelling ionospheric disturbances (TID) were found to be a manifestation of gravity waves. Later, nuclear explosions have been considered to be detected as the acoustic gravity wave sources. Also aurora particles has been found to be the wave sources. Recently, tsunami produced by earth quakes has been interested as acoustic gravity wave sources though the precise detection system has been far from complete. In understanding gravity waves whose propagating velocity, is as slow as local winds, we have to consider the frequencies to be often seriously Doppler-shifted by local winds. In the 1980s gravity waves, propagating from the lower to upper atmosphere, are considered to be saturated dynamically and thermodynamically, resulting to release the angular momentum to the ambient atmosphere, contributing to the peculiar mesosphere general circulation.

As to atmospheric tides which are gravity waves with global scales and with periods of one solar-day or its submultiples, the classical tidal theory was established in the 1960s clarifying tides and other planetary-scale wave structures as consisting of both positive and negative modes, each of which depends on either positive and negative sign of the eigen value of the fundamental equation i.e. the Laplace tidal equation, respectively. The classical tidal theory has solved an outstanding problem on the geomagnetic Sq variation which is the geomagnetic variation originating in the ionosphere being observed on the earth's surface. Thus, we have realized that various atmospheric waves contribute to coupling between the lower and upper atmosphere.

We saw since the 1980s remarkable steps forwards in observation of the atmospheric waves particularly by radars and lidars. The Mesosphere, Stratosphere and Troposphere (MST) radars have been constructed in many places in the world providing observational supports of the theories. Particularly, the MU radar Kyoto University, constructed in 1984, has played an important role in showing the saturation spectrum and momentum release of gravity waves for contributing to the mesosphere general circulation. It should be remarked that while a lot of observation data about atmospheric waves is available now, very often the data analysts may be lacking in clear understanding the basic theories. Hopefully, the present paper may help them improve the lacking.

Keywords: acoustic waves, gravity waves, atmosphere, tide, MST radar, propagation

MTT40-02 Room:203 Time:May 24 09:15-09:30

Chelyabinsk meteorite fall: analysis of shockwave signals recorded by broadband seismometers and infrasound sensors

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A huge bolide was appeared in the skies over the Ural district, Russia around 03:20 UTC, and a few minutes after, strong shockwave struck at Chelyabinsk city. The shockwave destroyed lots of window glasses of buildings and injured more than 1,000 residents. The shockwave signals were clearly recorded by global broadband seismic network and CTBT-IMS infrasound monitoring array stations. At the small meteorite fall (e.g., Jan. 20th, 2013 fireball event, Iwakuni et al., this JpGU meeting), the shockwave related signal detection range is limited as wide as 150 km from terminal burst point or atmospheric trajectory. However, the case of Chelyabinsk bolide, we could identify shockwave related wave phenomena at least beyond 1,000s km in range. It is no doubt that this is the largest bolide event since 1908, when the Tunguska event occurred.

In this presentation, we will present the results of analysis of shockwave related phenomena based on seismic, infrasound, and GPS TEC records.

Keywords: meteorite fall, shockwave, infrasound

MTT40-03 Room:203 Time:May 24 09:30-09:45

Attenuation curve of infrasound signal from a sounding rocket launch detected by multiple-sites arrayed sensors

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Infrasound and audible sound propagation in atmosphere is one of the open fields of the atmospheric science. Infrasound and atmospheric gravity waves propagating vertically up to the thermosphere is important in energy transportation way from the ground/ocean to the thermosphere. These waves can possibly be a seed of observable waves in upper atmosphere as many kinds of horizontal waves observed by optically or electromagnetically at each fixed altitude, suggesting they might be a key of atmospheric studies in vertical interactions. Many kinds of sources in naturally and artificially on ground, ocean, or troposphere like volcanic eruptions, earthquakes, tsunamis, artificial explosions, traffic of vehicles and planes can emit acoustic/infrasonic waves, however, experiments of direction finding by multiple-sites arrayed infrasound sensors in mesoscale region have been limited.

Determination of wave source coordinates of infrasonic waves was studied by using multiple eruptions of Sakurajima volcano and 3 sounding rocket launches from Uchinoura Space Center (USC), JAXA. In August 2012, we deployed 8 infrasound sensors at 4 sites as 2 triangles of 3-sensor arrays (Chaparral Model-2.5) and 2 independent sensors (Model-2) at 4 independent azimuths in separations within 14 km from the launch pad. During the experiment, JAXA's S-310-41 sounding rocket was launched at USC at 16:30 JST on Aug. 7, 2012. A clear infrasound pulse was detected at each 3 of 4 sites, however, not at 1 site. Based on the wind measurement on ground and by radiosondes, wind vector was ENE to WSW at the launch time. The observation site in negative result was located in SW azimuth and a high mountain was located between the launch pad and the site, implying the site was in the shadow region of the infrasound propagation at that time. According to the pulse signal at the other 3 sites and previous two rocket launches, attenuation curve by atmospheric viscosity was clearly observed between 1 km and 63 km, suggesting maximum propagation distance of about 40 km from the launch pad for S-310 and S-520 type sounding rockets.

The data were recorded as win-format files by Hakusan LS-8000WD and LS-8800 data loggers as well as SAYA 16 bit A/D boards with a PC at each site. Data viewer software directly from the win-format binary files was developed for the direction finding of wave source azimuth by each 3-sensor array. Using the software, infrasonic wave source coordinates by the Sakurajima eruptions and the rocket launches were successfully confirmed within a few km radius. In this paper, we will present a summary of direction finding experiments and introduce planned multiple-sites arrayed observation of infrasound in Kochi seacoast.

Keywords: infrasound, direction-finding, sensor array, sounding rocket, attenuation, atmospheric viscosity

MTT40-04 Room:203 Time:May 24 09:45-10:00

Infrasound observation in polar region by multiple-sites sensor arrays at around Syowa station

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Not only seismic observation but also infrasound monitoring in Antarctica is important for investigating polar region phenomena like icequakes. At Syowa station (SYO; 39E, 69S), we built a pilot infrasound site with single Chaparral Model-2 sensor in 2008 as a chance of IPY (international Polar Year) campaign. Since then, infrasonic signals have been recorded continuously at Syowa, revealing the existence of continuous low-frequency pressure waves corresponding to the Double-Frequency Microbaroms (DFM) with peaks between 4 and 10 s in whole season. Signals with same period are recorded in broadband seismograph at SYO (microseisms). The peak amplitudes of DFM reflect the influence of winter cyclonic storms in Southern Ocean, indicating relatively lower amplitudes during winters, possibly caused by sea-ice extent around the coast with decreasing oceanic loading effects. In contrast, Single-Frequency Microseism-baroms (SFM, between 12 and 30 s) are observable under storm conditions particularly in winter. Several characteristic waves detected by seismographs in Antarctica are originated from physical interaction between solid earth and atmosphere-ocean-cryosphere, involving environmental changes.

On infrasound data, stationary signals are identified with harmonic over tones at a few Hz to lower most human audible band, which appear to be local effects, such as sea-ice cracking vibration. Microseism-baroms are useful proxy for characterizing ocean wave climate, and continuous monitoring by multiple-sites seismographs and infrasound sensors contribute to FDSN and CTBT in southern high latitude. In JARE-54 program, we expanded infrasound sensors to the suburbs of SYO and multiple-sites infrasound observation was realized in February 2013. In order to detect the realistic wave source locations near SYO, array observation and multiple-sites monitoring of infrasonic and seismic waves are extremely important. The current observation project at around SYO is expected to show the existing phenomena in Antarctica with their underlying physical processes. In this paper, infrasound observation at SYO and surroundings will be discussed.

Keywords: infrasound, seismic waves, Antarctica, microbaroms, icequake, sensor array

MTT40-05 Room:203 Time:May 24 10:00-10:15

Data assimilation system to comprehend atmospheric variations associated with the solid Earth

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We have been developing a data assimilation system for better comprehension of atmospheric variations originated from the solid Earth.

Keywords: data assimilation, microbarometer, seismoacoustic wave

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MTT40-06 Room:203 Time:May 24 10:15-10:30

R&D of a highly sensitive barometer using an optical fiber transducer

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Highly sensitive barometers optimized for dense array observations are required to facilitate infrasound observation, noise reduction in gravity measurements and other geoscience applications.

The authors have been working on the R&D of such barometer, by using an optical fiber transducer.

The concept and R&D status of the work will be presented.

Keywords: sensitive barometer, optical fiber transducer

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MTT40-07 Room:203 Time:May 24 11:00-11:15

The Infrasound Observation Network for the CTBT's verification regime and its expectations for scientific studies

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The purpose of the verification regime of the Comprehensive Nuclear-Test-Ban Treaty (CTBT) is to monitor countries' compliance with the CTBT which bans all nuclear explosions on the planet. The CTBT's global alarm system is designed to detect any nuclear explosion conducted on Earth ? in the underground, underwater or in the atmosphere. The CTBT Organization is establishing and operating the International Monitoring System (IMS) which consists of 337 facilities located all over the world. The IMS uses four different technologies, which are seismic, hydroacoustic, infrasound and radionuclide, to monitor the planet for nuclear explosions. Atmospheric waves with very low frequencies are called infrasound and the CTBTO is establishing its observation network which has 60 stations in 35 countries around the world. Each station is composed of an array of infrasound sensors with an aperture of about 2 km.   Infrasound sensors measure micropressure changes in the atmosphere which are produced by a variety of natural and man-made sources, for example, exploding volcanoes, earthquakes, meteors and storms in the natural world and nuclear, mining and large chemical explosions in the man-made arena. Nowadays, 45 stations have been installed and are sending data to the International Data Centre in Vienna in real time basis. And observed data are available for CTBT member states. The Infrasound Observation Network is unique by its global and homogeneous coverage and its data quality and has considerable potential for civil and scientific applications.

Keywords: infrasound, observation network, atmospheric pressure

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MTT40-08 Room:203 Time:May 24 11:15-11:30

Ionospheric disturbance caused by acoustic wave due to the tornade on 6 May 2012 observed by the HF Doppler network

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The analysis results of ionospheric disturbances caused by acoustic waves of the tornade occurred from 12:35 to 12:55 JST on 6 May 2012 around Tsukuba city in Ibaraki Prefecture was described in this paper. The Doppler fluctuation observed by the HF Doppler (HFD) network which has the reflection points just over the tornade were used to this analysis. It is interpreted based on the spectral characteristics that the spectral peaks from 20 to 300 sec in the Doppler fluctuations are cased by the acoustic wave due to the cutoff around 300 sec.

There were many reports related to the tornades such as Davies and Jones (1977), but the distance from reflection point to the tornade of this observation was much shorter than the old reprots so that we could fortunately perfom the detailed analysis to shorter periods. Based on the spectral analysis of the Oarai 5006 kHz Doppler which was observed just over the tornade revealed three peak periods, 120, 170 and 240 seconds, and short-lived and short peirods had been existing through the tornade activity. The three characteristic peiods are lmost the same as those of Davies and Jones (1977), but the shoter periods are found for the first time. Additionally snice the shorter periods were greatly attenuated at higher altitude, it can be interpreted as the result of upward porpagation of acoustic waves.

Then we have analysed the three periods according to the cavity resonance model of Chimonas and Peltier (1973). At the first, we have derived the horizontal speed of the three period wave with the phase differeces of the three HFD stations in the Ibaraki Prefecture, and obtained 132, 66 and 46 m/s, respectively. By using these speeds and the assumed reflection height, it is found that the resonance periods can be indentified with the tornade location. Moreover, the wavefront direction deduced by the reflection points were also consistent with the same tornade location. Details will be presented in the meeting.

References

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Keywords: ionospheric disturbance, acoustic wave, tornade on 6 May 2012, HF Doppler observation

MTT40-09 Room:203 Time:May 24 11:30-11:45

Ionospheric disturbances induced by acoustic waves excited by earthquakes and tsunamis

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Since the first report of atmospheric perturbation associated with earthquakes in 1960's, many evidences of ionospheric perturbation have been reported using ionosondes. A dense GPS array is a good 2-D monitoring tool for studying ionosphere because total electron content (TEC) can be estimated using the phase difference of two L-band (f1=1575.42 MHz and f2=1227.60 MHz) carriers emitted from GPS satellites. Recently, using the GPS-TEC, ionospheric disturbances induced by infrasound excited by earthquakes and tsunamis have been well investigated.

After the M 9.0 Tohoku earthquake (Tohoku EQ) occurred on March 11 of 2011, many types of ionospheric disturbance such as acoustic resonance and gravity wave were observed. The initial TEC variation was observed 9 min after the main shock. Distribution of the intensities of the initial TEC variation showed clear inclination and declination effect of magnetic field. After the initial TEC variation, deep plasma density depletion named "tsunamigenic ionospheric hole" was observed over the tsunami source area. Similar depletion was also found in the 2010 M8.8 Chile, the 2004 M9.1 Sumatra earthquakes and others.

Asymmetry of propagation of the initial TEC variation was found. A faster coseismic ionospheric disturbance (CID) propagated at ?3.0 km/s only in the west-southwest, while a slower CID propagated concentrically at 1.2 km/s or slower from the tsunami source area in the Tohoku EQ. Taking the propagation speed and oscillation cycle into account, the faster CID was possibly induced by acoustic waves excited by a Rayleigh wave but the slower CID was associated with an acoustic or gravity wave. If the acoustic wave excited by the Rayleigh wave induced the faster CID at each point, the faster CID must be observed even at north of the epicenter because the Rayleigh wave propagated all directions from the epicenter. Therefore, the acoustic wave excited by the Rayleigh wave formed superimposed wave front and then it disturbed the ionosphere.

A CID associated with acoustic resonance also showed asymmetry of the distribution. North edge of the CID associated with acoustic resonance corresponded to north edge of the tsunamigenic ionospheric hole. Further, the propagation velocity of the CID is similar to that of acoustic waves. The results imply the source of acoustic resonance was located over the tsunami source area and acts as a point source.

Keywords: ionospheric disturbance, GPS-TEC, earthquake, Rayleigh wave, acoustic resonance, tsunamigenic ionospheric hole

MTT40-10 Room:203 Time:May 24 11:45-12:00

Numerical simulations of ionospheric disturbances induced by tsunami and tsunami source

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Observational, theoretical and numerical studies have revealed that tsunamis excite atmospheric gravity waves and induce ionospheric disturbances. To understand the response of the ionosphere to an extreme tsunami and its source is useful to understand upward coupling of the atmosphere and the ionosphere, and to apply ionospheric observations to tsunami early warning systems. TEC (Total Electron Content) observed by Japanese GPS receiver network after the 2011 Tohoku-oki earthquake had propagating oscillations with phase velocities of 220-290 m/s, similar to that of a tsunami. Not only the tsunami but also its source could be sources of the TEC oscillations because the tsunami and its source were close to each other. Contributions of tsunami and its source to the TEC oscillations should be separated to understand the each response. In this study, a coupled model of two-dimensional tsunami, three-dimensional nonhydrostatic and compressible atmosphere, and three-dimensional ionosphere is developed to investigate the tsunami and the tsunami source contributions to the TEC oscillations. Our simulations reveal that the amplitude of TEC oscillations of 220-290 m/s induced by the tsunami source is comparable to that induced by the tsunami. The observed and simulated TEC also have propagating oscillations with phase velocities of 420-780 m/s, and other oscillations confined near the epicenter with periods of about 4 min. These oscillations are shown to be induced only by the tsunami source. The relation between the TEC amplitude and the tsunami amplitude can be derived indirectly by using the relation between the TEC amplitude and the tsunami source amplitude.

Keywords: gravity wave, acoustic wave, earthquake, tsunami, TEC

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MTT40-11 Room:203 Time:May 24 12:00-12:15

Development of a high-resolution atmosphere-ionosphere model for analyzing acoustic-gravity wave phenomena

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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, 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 upper atmosphere is an extremely complicated system and 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, we developed a nonhydrostatic compressible atmosphere-ionosphere model. The model successfully reproduced atmospheric waves and large-scale electron density variations associated with the tsunamis of the 2004 Sumatra earthquake and of the 2011 Tohoku-oki earthquakes. We are now developing a high-resolution global atmosphere-ionosphere model including more physical processes. We expect that the model is able to reproduce atmospheric-ionospheric phenomena associated with acoustic-gravity waves produced by various kinds of phenomena. We will review previous results of the present model and present a plan for developing a new model.

Keywords: acoustic wave, gravity wave, atmosphere, ionosphere, coupling, model

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MTT40-12 Room:203 Time:May 24 12:15-12:30

A comparison of Pc5 micro-pulsations associated with vertical acoustic resonance and those with substorm onset

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The Pc5 geomagnetic micro-pulsations associated with the vertical acoustic resonance is frequently observed just after large earthquakes, during strong volcanic eruptions or under severe meteorological conditions. On the other hand, the so-called storm-time Pc5 frequently appears around substorm onset. The frequency of such Pc5s is often rather close to that of the fundamental mode of the vertical acoustic resonance. For example, at an "outerrise earthquake" on December 7, 2012, we observed a Pc5 pulsation having a period of 270seconds at 90-160 minutes after the origin time. Because of the coherent phase among the data obtained at different geomagnetic stations, it seems to be magnetospheric origin rather than the acoustic resonance effect. We compare the characteristics of both type Pc5s.

Keywords: geomagnetic micro-pulsation, substorm, vertical acoustic resonance