Long-period teleseismic detectability and its response to cryosphere variation around Syowa Station, Antarctica since 1967

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Phase identifying procedure for teleseismic events at Syowa Station (69.0S, 39.6E; SYO), East Antarctica have been carried out since 1967 after the International Geophysical Year (IGY; 1957-1958). From the development of INTELSAT telecommunication link, digital waveform data have been transmitted to the National Institute of Polar Research (NIPR) for utilization of phase identification. Arrival times of teleseismic phases, P, PKP, PP, S, SKS have been reported to the International Seismological Centre (ISC), and published by "JARE Data Reports" from NIPR. In this paper, hypocentral distribution and time variations for detected earthquakes are demonstrated over the last four decades in 1967-2010. Characteristics of detected events, magnitude dependency, spatial distributions, seasonal variations, together with classification by focal depth are demonstrated. Besides the natural increase in number for occurrence of teleseismic events on the globe, a technical advance in observing system and station infrastructure, as well as the improvement of procedure for reading seismic phases, could be efficiently combined to produce the increase in detection number in last few decades. Variations in teleseismic detectability for longer terms may possibly by associate with cryosphere dynamics and evolution, meteorological environment, as well as the sea-ice spreading area around the Antarctic continent. Recorded teleseismic and local seismic signals have sufficient quality for many analyses on dynamics and structure of the Earth’s as viewed from Antarctica. The continuously recorded data are applied not only to lithospheric studies but also to Earths deep interiors, as the significant contribution to the Federation of Digital Seismological Network (FDSN) from high southern latitude.

Keywords: teleseismic event, ISC, sea-ice variation, Antarctica, phase detection

Classification of ice tremor recorded at Syowa Station in Antarctica

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It was found that tectonic earthquakes and tremors related ice (ice tremor) have been occurred by seismic observations in Antarctica. The ice tremor is the tremor which is originated in collision of sea ice, crack opening and closing, collapse of icebergs and so on (Kanao et al., 2012). However, there are only few reports related to the waveform of ice tremors and seasonality in Antarctica. Purposes of this study are to classify ice tremors based on the feature of their waveforms and to reveal the time variation in the number of generation.
We use the north -south component of the waveform data recorded by STS -1 at Syowa Station. Analysis duration is from January to December in 2014. We made seismic waveform image and spectrogram and counted ice tremors with them. We define here 'ice tremor' as the tremor of which P-wave and S-wave are not clear and duration is longer than 5 minutes.
We found total 231 ice tremors in 2014. Monthly number of ice tremors changed similarily to monthly mean temperature except for from January to March. Monthly cumulative duration of ice tremors changed similarily to monthly mean temperature except for January. The number of ice tremors is low in February, but the cumulative duration is longest. We classified ice tremors into 4 types based on the feature of their spectral time variation. Type A is the ice tremor which duration is long (about ten thousands seconds) and amplitude is small over the waveform. Type B is the one which dominant frequency changes irregularly over the waveform. Type C is the one which dominant frequency continuously decreases and the overtone can be seen. Type D is the one which duration is short (about hundreds) and the amplitude gradually increases and after that gradually decreases.
Microbaroms data are useful tool for characterizing ocean wave climate (Ishihara et al., 2015), so we compared them with seismic data. In summer, both seismic amplitude and microbaroms amplitude is large and the peak of type A is almost same with the peak of microbaroms, so type A is considered to be excited by sea wave. In winter, only the amplitude of microbaroms is large, so ice tremor wave is considered to be not recorded well because of grown coastal ice (Grob et al, 2011). On April in 2006, at Neumayer Stations in Antaectica, an ice tremor was recorded and the source of that is seems to be the iceberg (Eckstaller et al., 2006). The spectral feature of this is similar to which of type C, so type C may be occurred by iceberg.

Keywords: Antarctica, Syowa Station, ice tremor, microbarom

Characteristics of seismic waveform recorded by seismic array at East Ongul Island, Antarctica

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In polar region, various vibration phenomena are exited in association with physical interaction between solid earth, atmosphere, ocean and cryosphere systems. These phenomena can be observed as seismic and infrasonic waves, and it is important to investigate their features and generation process in order to reveal relationship between their occurrence and environmental variations.
An array observation helps us to get information of incident waves on the stations. In order to detect source locations of seismic event around Showa station, East Ongul Island, East Antarctica, we carried out a seismic array observation from January 2 to February 2, 2015. We installed 7 temporary seismic stations in a rocky area located at 1 km away from Showa station, consisting of 1-Hz three-component seismometers with a site spacing of about 100 m. During this period, two characteristic waveforms were recorded. One occurred from January 11 at 22:40 (UTC) to January 12 at 11:20 (UTC), corresponding to ice-breaking by a ship. The peak frequency was about 10 Hz. The other occurred on January 14 at 3:45 (UTC) and its duration was about 13 minutes. Peak frequencies of the tremor were about 2, 4 and 6 Hz, and these peaks varied over time. It seems that the tremor arrived from south-southeast direction with a small slowness by semblance analysis. We will reveal characteristics of these seismic events in more detail and estimate location of their sources by using data recorded at other seismic and infrasound stations around East Ongul Island.

Keywords: seismic array, tremor, Antarctica

Infrasound signal detected at the Lützow-Holm Bay region, East Antarctica, and their relation to surface environment

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A single infrasound sensor has been making continuous recordings since 2008 at Syowa Station (SYO; 69.0S, 39.6E) in the Lützow-Holm Bay (LHB) of East Antarctica. The continuously recorded data clearly show the contamination of background oceanic signals (microbaroms) throughout all seasons. In austral summer 2013, several field stations with infrasound sensors were established along the coast of the LHB. Two infrasound arrays of different diameters were set up: one at SYO (with a 100-m spacing triangle) and one in the S16 area on the continental ice sheet (with a 1000-m spacing triangle). In addition to these arrays, isolated single stations were deployed at two outcrops in the LHB.

Detailed and continuous measurements of infrasound waves in Antarctica could prove to be a new proxy for monitoring regional environmental change as well as temporal climate variations in high southern latitudes.

Until now, these arrays clearly detected the propagation direction and frequency content of microbaroms from the Southern Ocean. In addition to the microbaroms, several other remarkable infrasound signals were detected, including regional earthquakes, and so on.

In this presentation, we would introduce detected infrasound signals.

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Keywords: Infrasound, Seismic waves, Antarctica, Microbaroms, icequake, Sensor array

Multi-Sphere interactions in the coastal and marine environment inferred from infrasound and seismic data at Teranova Bay, west Antarctica

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Characteristic features of infrasound waves observed in the Antarctic reveal physical interaction involving surface environments around the continent and Southern Ocean. An infrasound array (100 m spacing) by using three sensors (Chaparral Physics Model 25, with a detectable frequency range of 0.1-200 Hz), together with a broadband barometer (Digiquartz Nano-Resolution Model 6000-16B Barometer, with a detectable frequency range of 0-22 Hz) were installed at Jang Bogo Staion, Tera Nova Bay, West Antarctica in December 2015 by the Korea Arctic and Antarctic Research Program (KAARP). The initial data recorded by the broadband barometer include several signals originated surrounding surface environment, in addition to the local wind noises such as katabatic signals. Clear signals from background oceanic origin (the "microbaroms") are continuously recorded at the austral summer on mid-December with predominant frequency around 5 s. Variations of their frequency context and strength appeared in Power Spectral Density are affected by evolution of the sea-ice surrounding the Tera Nova Bay. In contrast, several infrasound monitoring stations have been conducting around the Lützow-Holm Bay (LHB), East Antarctica by Japanese Antarctic Research Expedition (JARE) since 2008. Two infrasound arrays with different diameter triangles have been deployed at both inside the Syowa Station (100 m spacing) and on the continental ice sheet (1000 m spacing). Besides the arrays, isolated single stations are deployed at three outcrops. These arrays in LHB clearly identified the predominant propagating directions in NWN and their frequency content variations of "microbaroms" from Southern Indian Ocean. In this presentation, characteristic features recorded by the initial data observed at Jang Bogo Staiton is presented, as compared with that obtained at the LHB. Microbaroms measurement is a useful tool for characterizing ocean wave climate, complementing other oceanographic, cryospheric and geophysical data in the Antarctic. Detail and continuous observations of infrasound waves in Antarctica is a new proxy for monitoring a environmental changes such as global warming affecting on polar regions.

Keywords: Infrasound, Antarctica, KAARP, JARE

Seismic observations in Greenland by a joint USA and Japanese GLISN team (2011-2015)

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Global climate change is currently causing melting of the Greenland ice sheet. Recently, a new type of seismic event, referred to as a “glacial earthquake”, has been recognized. Such earthquakes are generated by the movements of large masses of ice within the terminal regions of glacier, and represent a new approach for monitoring ice sheet dynamics. In 2009, the GreenLand Ice Sheet monitoring Network (GLISN) was initiated as international project to monitor changes in ice sheet by constructing a large broad-band seismological network in and around Greenland.

Japan is a partner country from when the GLISN project was launched, and has been sending an expedition team every year since 2011. In 2011, the joint USA and Japanese GLISN team installed the dual seismic–GPS station ICESG-GLS2 in the middle of the Greenland ice sheet. During 2012-2015, we conducted maintenance of the three stations on ice (ICESG-GLS2, DY2G-GLS1, and NEEM-GLS3), and three stations on bedrock in coastal region (NUUK, DBG, and SOEG).

Especially, in 2014, we had succeeded in real-time transmission of broad-band continuous seismic waveform data from the three ice stations. It was the first time in the world that the seismic data with such a high sampling rate is transferred from the ice sheet. The data is now open to the public and available from the IRIS Data Management Center (http://www.iris.edu/ds/nodes/dmc/). Also in 2015, we relocated a seismic sensor at the station ICESG, which had been covered by snow of 5 m depth due to accumulation for four years. All of the excavation and reinstallation processes were achieved within two days by human labor of only three workers.

This presentation will summarize our field activities, and introduce the future plans. The Japanese GLISN team has been supported by JSPS KAKENHI 24403006.

Keywords: Greenland, Seismic observation, ice sheet

A review of seismicity, structure and tectonics in the Arctic region

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The “Arctic” region, where the North Pole occupies the center of the Arctic Ocean, has been affecting the environmental variation of the Earth from geological time to the present. However, the seismic activities in the area are not adequately monitored. Therefore, by conducting long term monitoring of seismic phenomenon as sustainable parameters, our understanding of both the tectonic evolution of the Earth and the dynamic interaction between the cryosphere and geosphere in surface layers of the Earth will increase. In this paper, the association of the seismicity and structure of the Arctic region, particularly focused on Eurasian continent and surrounding oceans, and its relationship with regional evolution during the Earth’s history is studied. The target areas cover representative tectonic provinces in the Eurasian Arctic, such as the wide area of Siberia, Baikal Rift Zone, Far East Russia, Arctic Ocean together with Greenland and Northern Canada. Based on discussion including characteristics of seismicity, heterogeneous structure of the crust and upper mantle, tectonic history and recent dynamic features of the Earth’s surface in the Arctic are summarized.

Keywords: Arctic region, seismicity, crustal structure, tectonics, glacial earthquakes