Future direction of Greenland broadband seismographic observation project

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Recent investigations of the causes and consequences of changes in the Greenland ice sheet have highlighted the links between the ice– ocean– atmosphere– solid Earth system and the need for better observations of all four parts of the system. We have conducted continuous broadband seismographic observation under the collaboration with the Greenland Ice Sheet Monitoring Network (GLISN) project—a collaboration between Canada, Denmark, France, Germany, Italy, Japan, Norway, Poland, South Korea, Switzerland, and the United States—which provides real-time broadband seismological observations to help address critical, poorly understood aspects of the Arctic system during the past 6 years. Our broadband seismographic observation consists of maintaining the ice-sheet observatory, ICESG station, which equipped with the broadband seismograph and GPS instrument. The operation has been successfully conducted in collaboration of IRIS PASCAL. The seismograms observed at ISESG station for past 4.5 years has been used to process by the ambient noise surface wave analysis (Toyokuni et al., 2017) to retrieve seismic speed changes beneath the ice-sheet, which has been interpreted as a increase of melt water due to pressure melting at the bottom of the ice sheet. The continuous GPS measurement at ICESG station also reveals horizontal movement of ice sheet, which is consistent to the total ice sheet movement around ICESG station. These results demonstrate that the further continuous observation of both seismographic and geodetic measurement is necessary at the ice sheet station. We plan to maintain ICESG station in collaboration with IRIS PASCAL group and for next several years and discuss the possible extension of research activity in this presentation.

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Features of T-phase recorded at Syowa Station in Antarctica

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Tectonic earthquakes and tremors related to ice (ice tremor) have been observed by seismic stations in Antarctica. In 2014, four type (type A –D) tremors characterized by their frequency components and waveforms were recorded around Syowa Station. Type A is the tremor of which duration is long (about ten thousands seconds) and the amplitude is small over the waveform. Type B shows that the dominant frequency changes irregularly over the waveform. Type C shows that the dominant frequency continuously decreases and the overtone is recognized. Type D has the waveform with spindle-shape and short duration (about hundreds seconds). Especially, the tremors of type D are similar to T-phase of tectonic earthquakes. The purpose of this study is to reveal the relationship between the type D tremors and earthquakes.
We use the waveform data recorded by STS-1 at Syowa Station. The analysis period is from January to December in 2014. We define here the tremor as tremors of which P-waves and S-waves are not clear and the duration is longer than five minutes. We count the ice tremors by visual inspection of seismograms and spectrograms calculated from FFT of velocity waveforms.
We find the total of nine tremors of type D in 2014, four from February to May, one in October and four in November and December, respectively. The features of type D recorded at Syowa station are the spindle-shape waveform, the dominant frequency of 1 –8 Hz and the duration ~400 s. We recognize that tectonic earthquakes occurred 10 - 20 minutes before the arrival of the four of type D. Each tectonic earthquake occurred on March 14 in South of Africa region (53.2S25.2E, Mb=5.5), on April 15 in Bouvet Island region (53.5S8.7E, Mb=6.8), on October 15 in South of Africa region (52.2S25.2E, Mb=5.5) and on November 17 in Prince Edward Islands region (46.3S33.8E, Mb=6.1), respectively. We calculate the residual of the travel times of each P-wave and T-phase as the seismic velocity are 6.5 km/s (P-wave) and 1.5 km/s (T-phase) and the average residual is 20 minutes 15 seconds. This theoretical residual corresponds to the observed value. The features of the remaining five tremors are similar to T-phase, but tectonic earthquakes are not recorded prior to the arrival of them. We suggest that these five tremors are not T-phase of earthquakes but ice tremors or relate to the earthquakes that radiate low P-wave and S-wave and high T-phase.

キーワード：昭和基地、Tフェイズ、氷震微動
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Seismic observations in Greenland by a joint USA and Japanese GLISN team (2011-2016)

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The Greenland Ice Sheet (GrIS) is a huge storehouse of water on Earth, and has the potential to raise the global sea level by approximately 7 m if completely melted. Although researchers have been mainly studying the GrIS surface snowmelt as a response to climate warming, recent progress in ice-core drilling, remote sensing, and theoretical analyses has turned a spotlight on its basal conditions. However, the traditional observation techniques, such as ice-core drilling and ice-penetrating radar, provide only discontinuous information in both time and space.

Seismic observation is now drawing widespread attention as an alternative method for monitoring the GrIS. The Greenland Ice Sheet Monitoring Network (GLISN), an international project between 11 countries that began in 2009, now provides broadband, continuous, and real-time seismic data from 33 stations 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, a joint USA and Japanese GLISN team installed the dual seismic–GPS station ICESG-GLS2 in the middle of the GrIS. During 2012-2015, we conducted maintenance of three stations on the GrIS (station codes: ICESG-GLS2, DY2G-GLS1, and NEEM-GLS3), and three stations on bedrock in coastal areas (NUUK, DBG, and SOEG).

We had succeeded in real-time transmission of broad-band and 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 are transferred from the ice sheet. The data is now open to public and available from the IRIS Data Management Center (http://www.iris.edu/ds/nodes/dmc/).

In 2016, we installed another seismic station (PILOT) on the GrIS to test a new system of data transmission. This presentation will summarize our field activities for 2011-2016, and introduce the future plans.

Related presentation: Analyses of the GLISN data revealed highly heterogeneous basal conditions of the GrIS. The results will be presented in this session, entitled "Seismological evidence for heterogeneous ice sheet basal conditions".

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