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Research paper

Infrasound observations at Syowa Station, East Antarctica: Implications for detecting the surface environmental variations in the polar regions

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ABSTRACT

Characteristic infrasound waves observed at Antarctic stations demonstrate physical interaction involving environmental changes in the Antarctic continent and the surrounding oceans. A Chaparral-type infrasound sensor was installed at Syowa Station (SYO; 39°E, 69°S), East Antarctica, as one of the projects of the International Polar Year (IPY2007–2008). Data continuously recorded during the three seasons in 2008–2010 clearly indicate a contamination of the background oceanic signals (microbaroms) with peaks between 4 and 10 s observed during a whole season. The peak amplitudes of the microbaroms have relatively lower values during austral winters, caused by a larger amount of sea-ice extending around the Lützow-Holm Bay near SYO, with decreasing ocean wave loading effects. Microbaroms measurements are useful tool for characterizing ocean wave climate, complementing other oceanographic and geophysical data. A continuous monitoring by infrasound sensors in the Antarctic firmly contributes to the Comprehensive Nuclear-Test-Ban Treaty (CTBT) in the southern high latitude, together with the Pan-Antarctic Observations System (PAntOS) under the Scientific Committee on Antarctic Research (SCAR). Detailed measurements of the infrasound waves in Antarctica, consequently, could be a new proxy for monitoring regional environmental change as well as the temporal climate variations in the polar regions.

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1. Introduction

The “infrasound” is defined as sub-audible sounds, that is pressure waves with frequencies ranging from the cut-off frequency of sound (3.21 mHz, for a 15 °C isothermal atmosphere) to the lowest frequency of the human audible band (20 Hz) (Hedlin et al., 2002). This frequency range is a new horizon for the remote sensing of the Earth’s atmospheric physical environment and comparison can be made on the same frequency range as that of the broadband seismometer. There have been several previous reports regarding the existence of infrasound waves generated by many environmental sources, such as volcanic eruptions, ocean waves, earthquakes, as well as the passage of airplanes (Wilson and Olson, 2005; Garces et al., 2007, 2008; Matoza et al., 2007). The observations of infrasound in Japan, in contrast, were begun in the 1980s by Prof. Tahira at Aichi University of Education, using three arrayed sensors.

Recently, there have been several reports of infrasound waves, possibly generated by thunders, sprites, fireballs, meteorite falls, artificial re-entry of vehicles, as well as by the auroral activities in polar regions (Wilson, 1996, 2005; Arrowsmith et al., 2005; Le Pichon et al., 2005, Fig. 1). A striking example is given by the simultaneous observations of infrasound and seismic waves, involving the shock waves generated by a large volume of meteorites that overflew a Japanese island (Ishihara et al., 2004). The trajectory of the large bolide was determined by combining the shock waves recorded by a high-density seismic network in Japan and the sky images taken by a video camera.

Another significant example associated with the atmosphere–ocean–solid Earth interaction is the Sumatra–Andaman earthquake of 26 December 2004, which not only produced the ‘tsunami waves’ that was recorded as far away as the Antarctic stations (Nawa et al., 2007), but also produced recordable infrasound waves in the atmosphere (Iyemori et al., 2005). Yet another remarkable example is the 2011 Tohoku-Oki, Japan earthquake ($M_w = 9.0$) which produced unequivocal infrasound signals associated with the large tsunami (Arai et al., 2011). Evidence exists for the free vibration mode of the shaking Earth itself affecting the shallow part of the atmosphere overlying the ground surface. Moreover, an artificial hypersonic reentry of the Hayabusa capsule and spacecraft also created infrasonic shock waves (Yamamoto et al., 2011; Ishihara et al., 2012).

The world’s most diverse international science program which was held recently to unveil the present status and changes of the planet Earth, with a polar region perspective, is the International Polar Year (IPY 2007–2008) (Rapley et al., 2004). It was conducted on the fiftieth anniversary of the International Geophysical Year (IGY 1957–1958). The sort of interdisciplinary scientific exchanges that took place helped us understand and address the grand challenges, such as rapid environmental change in the polar regions, and its impact on society. During the IPY, a significant number of science projects have been conducted, including 63 Japanese-endorsed activities (Sato et al., 2011).

From a geological perspective, in the IPY the ‘Polar Earth Observing Network’ (POLENET; http://www.polenet.org) made the largest contributions, through establishing a seismic and GPS network in Antarctica. Several kinds of environmental signals associated with the atmosphere–ocean–cryosphere–solid Earth systems were detected in the continent and surrounding oceans (Fig. 1). Ice-related seismic motions for small magnitude events are generally named ‘ice-quakes’ (or ‘ice-shocks’) and can be generated by glacially-related dynamics (Kanao et al., 2012). Such types of cryoseismicity result from the movements of ice sheets, sea-ice, oceanic tide-cracks, oceanic gravity waves, icebergs and the calving fronts of ice caps. Nettles and Ekström (2010), moreover, determined the hypocenter and magnitude of several large ice-quakes (glacial earthquakes) around Antarctica by using the long period surface wave data. These hypocenters are located mainly at the outlet of the large glaciers, or otherwise at the edge of ice shelves. Cryoseismic and oceanic waves are likely to be influenced by the variations in environmental conditions, including atmosphere, and the continuous study of their time-space variation provides indirect evidence of climate change.

In April 2008, an infrasound observation was started at Japanese Syowa Station (SYO; 69°S, 39°E; Fig. 2), East Antarctica, as one of the endorsed projects of IPY. This region has been the target of multidisciplinary scientific studies for the past several decades (Kanao et al., 2011; Tsunogae and Shimizu, 2013). In this paper,

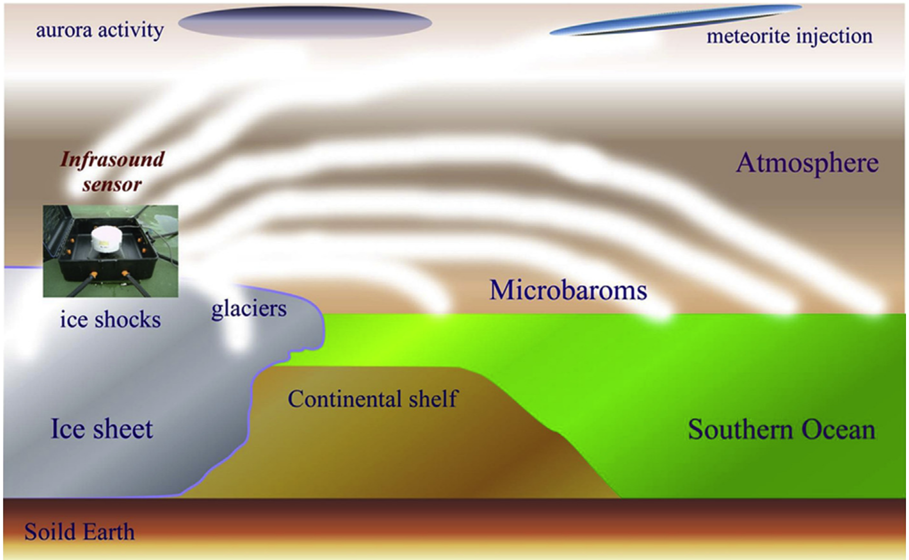

Figure 1. Schematic illustration of several plausible sources of the infrasound generation and their propagation schemes onto the Antarctic margins. A complex Earth system between the atmosphere–ocean–cryosphere–solid Earth environments of the continental margins and Southern Ocean are involved. The prominent infrasound powers (microbaroms) come from source regions in Southern Ocean and continental shelf along the margin of East Antarctica and are recorded by the Chaparral sensor at SYO.