Broadband seismic array deployments and crust – upper mantle structure around the Lützow-Holm Bay Region, East Antarctica

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Summary Broadband seismic array deployments have been carried out from 1996 on the coastal outcrops in the Lützow-Holm Bay Region (LHB), East Antarctica. The recorded teleseismic and local seismic signals have sufficient quality for the various analyses to clarify the dynamics and heterogeneous structure of the crust and upper mantle. Conventional passive source studies such as receiver functions and shear wave splitting were carried out; indicating heterogeneous structure from the north to the south along the coast in LHB. Data obtained may be applied not only to lithospheric studies, but to study of the Earths deep interior by integration with large span arrays from Eastern Dronning Maud Land. The broadband array deployments in LHB could make effective contributions to the 'Global Alliance of Regional Networks; GARNET', principle international Antarctic Array programs, together with 'POLEr observation NETwork; POLENET' during IPY 2007-2008.

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Introduction

Deployments of the broadband seismic arrays on the whole Antarctic continent have been ambitious dreams of the involved scientists. Existing seismic stations belonging the Federation Digital Seismographic Network (FDSN) allows resolution of the structure beneath Antarctic continent at a horizontal scale of 1000 km, which is sufficient to detect fundamental differences in the lithosphere beneath East and West Antarctica, but not to clearly define the structure within each sector. In addition, seismicity around the Antarctic is limited by the sparse station distribution and the detection level for earthquakes remains inadequate for full evaluation of tectonic activity (Reading, 2002). A strategy of attaining a sufficient density of seismic stations on the Antarctic continent allows optimal ray path coverage across Antarctica and improves tomographic resolution (e.g., Ritzwoller, et al., 2001).

Several temporary field broadband deployments have been carried out in the past decades around the continental margins of Antarctica (e.g., Bannister and Kennett, 2002; Muller and Eckstaller, 2003; Reading, 2003; Robertson, et al., 2002). A monitoring observation, on the contrary, have been conducted almost ten years at several outcrops around the Lützow-Holm Bay Region (LHB), Eastern Dronning Maud Land, East Antarctica, by the Japanese Antarctic Research Expedition (JARE). The broadband array deployments in LHB could have an significant contribution not only to the improvement of station resolution to the FDSN, but also to several seismic array projects; for instance, the Global Alliance of Regional Networks (GARNET), Antarctic Arrays (http://www.antarcticarrays.org; including Regional Leapfrogging Arrays, together with Program Oriented Experiments); and to the SCAR / Antarctic Neotectonics (ANTEC) program.

Seismic deployments

Broadband seismic array deployments have been carried out since the end of 1996 to the present in March 2007, at several outcrops and on ice sheet along the Soya Coast – Prince Orav Coast, in LHB. The observation system consists of a portable broadband seismometer, a data-recorder (LS8000-WD), shield-type lead batteries and solar-panels. The CMG-40T seismometers have been used with a three-component velocity-response (flat frequency response for velocity from 0.1 s to 20 s). The signal is digitized at the sampling frequency rate of 10 / 20 Hz with a dynamic range of 90 dB (16 bits), followed by stored on a hard-disk (2GB capacity) attached in the data logger. The total powers of the solar panels are 250-270 W, with 12 V DC output, and the total capacity of the lead batteries is more than 500 Ah for each station.

Except for power supply failure in some stations during winter seasons, observations have been conducted fairly well and significant number of teleseismic events and local earthquakes / ice-quakes were recorded. As of May 2007, a total number of six field stations (TOT, LNG, SKV, SKL, S16 and RDV) have been continued to recording. The last two stations were set up particularly for the IPY 2007-2008 period. In near future, it is planned to transmit the stored data in digital data-recorders to the PC/WS servers of the adjacent permanent station Syowa (SYO: 69S, 39E), together with the

National Institute of Polar Research (NIPR) at Tokyo, via telecommunication system by way of Iridium satellite transmission.

The obtained data including IPY period can be initially stored and published to the related cooperatives by Internet from the data library server of NIPR (POLARIS system; http://polaris.nipr.ac.jp/~pseis/garnet/). Then immediately offered to the world data centers of seismology, such as Incorporated Research Institute of Seismology / Data Management System (IRIS/DMS), FDSN, PACIFIC21 centers. These global centers are opened in general seismologists and also the meta-data (summary of the deployments and information of the contact persons, URL, etc.) shall be offered to the Joint Committee on Antarctic Data Management / Antarctic Master Directory (JCADM/AMD) simultaneously.

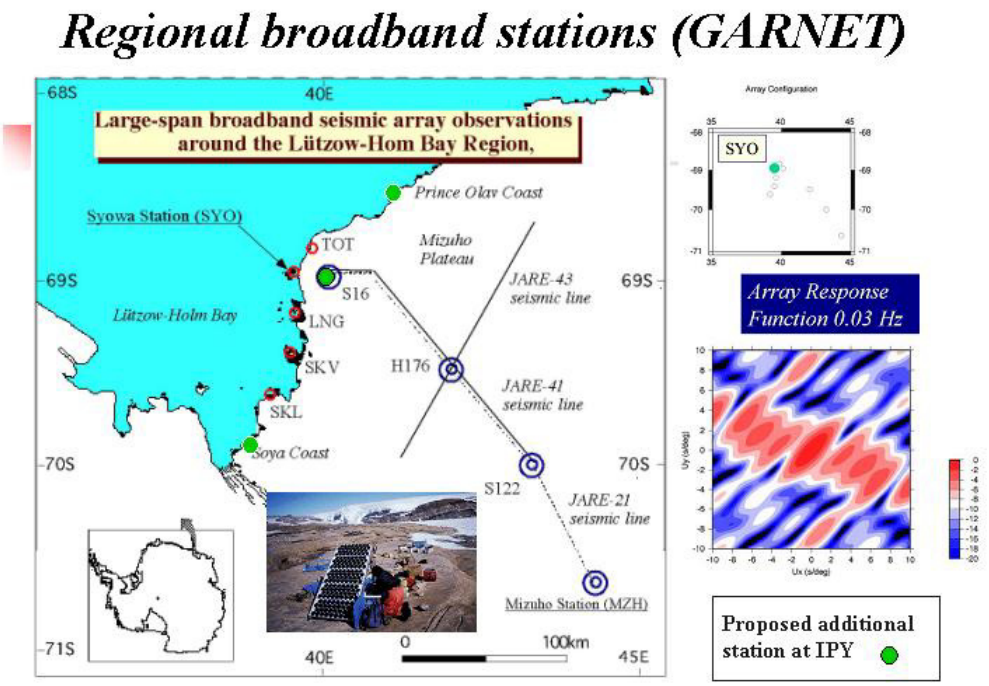

Figure 1. (left) Existing and proposed broadband stations around LHB including IPY and next future. (right) Calculated array response in dominant frequency of 0.03Hz for reviver distribution in a total number of planed stations.

Crust and upper mantle structure

Several remarkable geophysical evidences to reveal the structure and dynamics of the LHB have been achieved by JARE's geo-scientific activities in these few decades. By analyzing the teleseismic data recorded by broadband deployment on this area, more detailed information can be obtained concerning tectonics and structure in the depth ranges from lithosphere to asthenosphere, together with heterogeneous characteristics of the deep interior of the Earth. Moreover, glacial related seismic events have been detected by the local seismic arrays; which give rise to unique information in relation to the local impact of global climate changes on East Antarctica.

The recorded waveform data have enough quality for the uses of various analyses in order to clarify the heterogeneous structure and dynamics of Antarctica. The conventional passive seismic source studies such as receiver functions and shear wave splitting, surface wave tomography have been carried out for the outcrop stations along the Coast. For example, the shear velocity models resulting by short period receiver function inversion indicate the gradual complex structure from the north to the south along the coast in LHB, toward the Shirase Glacier, in depth ranges of the crust and the uppermost mantle (Kanao et al., 2002).

Figure 2 shows depth variations of the upper mantle seismic discontinuities (410 km and 660 km) beneath the LHB, derived from long period receiver function analysis by using 62 teleseismic events recorded at the local broadband arrays. Strong depth variations are identified particular for the 660 km discontinuity. Shallow depths in topography of the 660 km discontinuity are found beneath the continental ice sheet SE apart form the Arrays, which might reflect the paleo upwelling of the mantle plume associated with super-continent break-up.

Mantle anisotropy derived by SKS splitting analysis in this area (Usui et al., 2007) anticipate the relationship between 'fossil' anisotropy and the past tectonics involving break-up and amalgamation of the Gondwana. Since the fast polarization directions are mainly NE-SW direction in the LHB; which is consistent with paleo compression stress during Pan-African age. We consider that the origin of mantle anisotropy originated chiefly by lattice preferred orientation

produced involving the Gondwana assembly, rather than present asthenospheric flow parallel with the absolute plate motion.

In addition to the crust – upper mantle studies, the obtained teleseismic waveforms have advantages to the investigation of the deeper Earth's interior such as the lower mantle, D" zones, CMB and the Inner Core by applying as a large span arrays located in the southern high latitude.

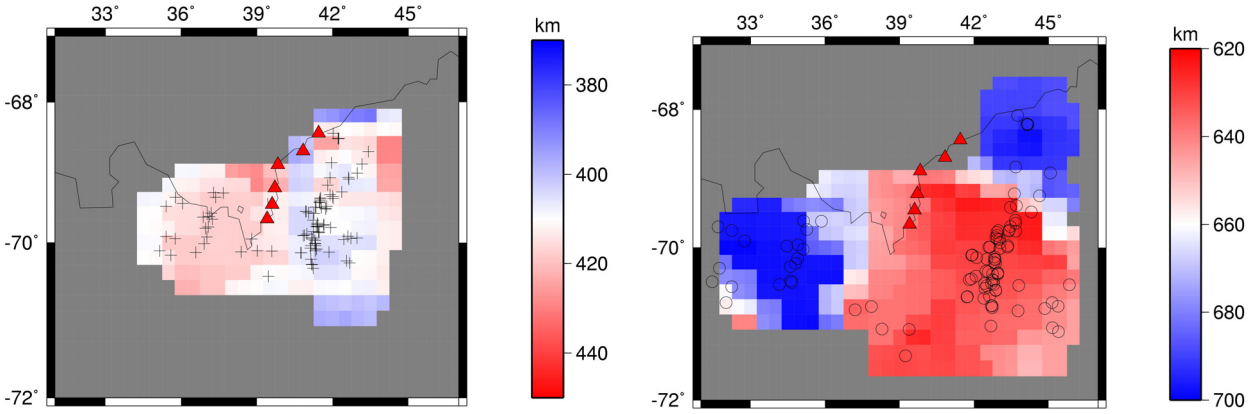

Figure 2. Receiver function results to detect the variations of the upper mantle discontinuities beneath LHB. (left; 410 km discon., right; 660 km discon.)

Concluding remarks

Broadband seismic array deployments around the LHB, East Antarctica, could offer sufficient quality for the various analyses of the heterogeneous structure of the Earth's interior. Conventional passive source studies such as receiver functions and shear wave splitting were carried out; indicating heterogeneous structure from the north to the south along the coast in LHB. Thus, the broadband deployments in LHB could achieve an effective contribution to the 'Global Alliance of Regional Networks;GARNET', in addition to principle international Antarctic Array programs.

Discussions at the SCAR / ANTEC (Siena, Italy, 2001) and SEAP (Structure and Evolution of the Antarctic Plate, Boulder, Colorado, 2003) workshops have led to the development of a strategy to radically improve our knowledge of the Antarctic seismic array deployments. These kind of Antarctic array projects are endorsed by Japanese national committee and combined with individual international Antarctic program, such as the 'TransAntarctic Mountain SEISmic experiment (TAMSEIS; Lawrence, et al., 2006)', 'Antarctica`s GAmburtsev Province / GAmburtsev Mountain SEISmic experiment (AGAP / GAMSEIS)' and 'POLEr observation NETwork (POLENET)' during the IPY 2007-2008.

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