Broadband seismic deployments in East Antarctica: International collaboration and IPY contribution to understanding the Earth's deep interior

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Summary "Deployment of Broadband Seismic Stations on the Antarctica Continent" is an ambitious project to improve the special resolution of seismic data across the Antarctic Plate. The project has several components, including 1) process-oriented experiments such as 3D-arrays; 2) evolving regional arrays; and 3) a permanent backbone network. Temporary broadband stations deployed on outcrops and continental ice sheet around Eastern Dronning Maud Land – Enderby Land areas will contribute strongly to IPY related major programs such as the 'POLEr observation NETwork (POLENET) (IPY project #185)'. The observed data during IPY will be available from Japanese library servers (ex., POLARIS of NIPR), and sent to world data centres (IRIS/DMS, PACIFIC21), and to AMD/JCADM of the SCAR/ANTEC. In addition to lithospheric studies, data from the large span arrays of broadband stations will allow more detailed investigations of the Earth's deep interior under high southern latitudes.

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Introduction

Existing permanent seismic stations belonging to the Federation of Digital Seismographic Network (FDSN) allows resolution of the structure beneath Antarctica at a horizontal scale of 1000 km, which is sufficient to detect fundamental differences in the lithosphere beneath East-West Antarctica, but not to clearly define the structure within each sector. While, observation of 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). In addition to lithospheric studies, the observed teleseismic waveforms have advantages in investigating the deeper part of Earth's interior such as lower mantle, D" layers, the core-mantle boundary (CMB) and the inner core as they are effectively a large span array located in the southern high latitude.

The justification for developing broadband arrays addresses both the unique aspects of seismology in Antarctica and general issues that would be common to global Earth sciences; for example: - lithospheric dynamics in an ice-covered environment;- how lithospheric processes drive and may be driven by global environmental change (sea level, climate);- the scale and nature of rifting as a process that has shaped the continent and dominated its evolution;- the role of Antarctica as the keystone in the super-continent formation and break-up throughout Earth's history;- how the tectonic and thermal structure of the Antarctic lithosphere affect current ice sheet dynamics;- age, growth, and evolution of the continent and processes that have shaped the lithosphere;- the effect of improved seismic coverage on global models of the lithosphere, together with deep interior of the Earth.

The International Polar Year 2007-2008 provides a good opportunity to make significant advances in seismic array deployment to achieve these science targets.

Significant advance at IPY

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 improve our knowledge of the Antarctic by using broadband deployments. The originally named 'Antarctic Arrays' is an ambitious program to improve seismic instrumentation on and around the Antarctica (http://www.antarcticarrays.org). A science plan designed to improve the understanding of the Antarctic Plate with this array deployment had been developed prior to the initiation of the IPY when it was transferred into the chief category of the 'POLEr observation NETwork (POLENET)' (IPY project #185).

The original idea of 'Antarctic Arrays' strategy has several components, including 1) process-oriented experiments such as 3D-arrays; 2) evolving regional arrays; and 3) an enhanced permanent backbone network. The strategy of attaining a sufficient density of stations (20-30) in symmetrically disposed sectors of the continent allows optimal ray path coverage across Antarctica and improves tomographic resolution (Ritzwoller, et al., 2001).

Several temporary field broadband experiments have been carried out in the past a decade around continental marginal areas of Antarctica (e.g., Bannister and Kennett, 2002; Muller and Eckstaller, 2003; Reading, 2003; Robertson, et al., 2002; Kanao et al., 2002). The broadband monitoring observations at several outcrops around the Lutzow-Holm

Bay area also contribute to the improvements of spatial resolution of the stations in Antarctica over the marginal part of Eastern Dronning Maud Land.

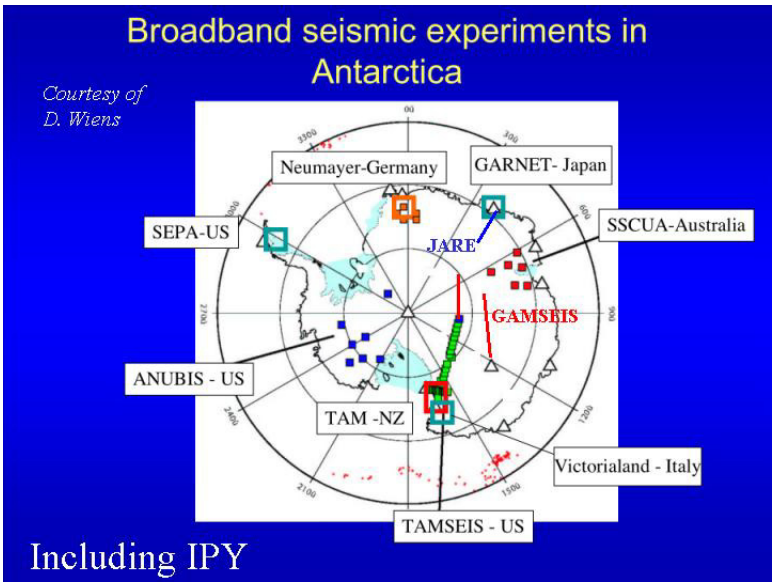

Figure 1. Existing and proposed broadband seismic experiments in Antarctica including IPY 2007-2008.

Project management and structure

It is clear that this deployment strategy can only be achieved through strong international cooperation. Nations with winter-over bases (existing or planned) and with logistical capabilities in a particular sector can contribute to the deployment of permanent stations in the backbone network and / or portable instruments in the evolving regional arrays.

More than twenty cooperative researchers from Japanese and international institutions have specific tasks to carry out in this project. Several members will install field stations to record the data during the IPY period: others will make analyses of specific topics by use of the observed data sets combined with regional and global data. After the assembly of the results from national participants, it is planned to hold an international workshop to integrate these results with results from international collaborators. There will be a number of opportunities for the researchers in the project to meet and discuss the progress of the project deployments and results and future deployments.

For education, some members will give lectures and talks for a wide range of school children about the research of the project and its results, together with an introduction to IPY and polar investigation. We sincerely believe that we have an obligation to teach the younger generation for the advancement of natural sciences.

Field activities

The main field area targeted by the Japanese contribution is Eastern Dronning Maud Land - Enderby Land, East Antarctica. Several distinctive geophysical observations that reveal the structure and evolution of this area have been made by the Japanese Antarctic Research Expedition (JARE) in the last few decades. By carrying out the broadband deployments on this area, more detailed signatures can be obtained concerning tectonics and structure from lithosphere to ascenosphere, together with the heterogeneous characteristics of the deep interior of the Earth.

A northern part of the Eastern Dronning Maud Land, particular from Mizuho Plateau to Dome-F area, would be the most plausible place with enough logistical support to make a deployment of the portable seismic stations. The temporary stations along the inland traverse routes on the continental ice-sheet on the Plateau would be installed for the IPY periods by using snow terrain vehicles with support from aircraft. These temporary observation stations, that have long-term batteries and large capacity digital data-loggers, can be utilized for the other science purposes, such as geophysical, meteological, glaciological and biological studies.

The ‘Antarctica`s GAmburtsev Province / GAmburtsev Mountain SEISmic experiment (AGAP / GAMSEIS) (IPY project # 67)’ project, in contrast, is an internationally coordinated deployment of 25-35 broadband seismographs over the crest of the Gambursev Mountains (Dome-A area). The proposed seismological investigations would provide detailed information on crustal thickness and mantle temperatures and thus provide key constraints on the origin of the Gamburtsev Mountains, and more broadly on the structure and evolution of the entire East Antarctic craton. Understanding the origin of the Gamburstev Mountains and the structure of the East Antarctic craton is also vitally linked

to other first-order problems, such as the geological history of East Antarctica, the role of its topography and heat flow on Earth's climate and glacial history, and the geophysical and geological controls on subglacial lakes.

Study of the deep interior

In addition to the crust – upper mantle studies, the teleseismic waveforms observed with the GAMSEIS have a great advantage for investigating the deep Earth interior, such as the lower mantle, the D" region and the CMB by using the seismographs as a large aperture array located in the southern high latitude. Many earthquakes will be observable at the GAMSEIS planned area. The epicentral distance range from 60° to 90° would be especially suitable for the observation of the D" reflected phases as well as the core reflected phases of ScS and PcP. That from 90° to 130° would be appropriate for the observation of the core diffracted phases of Pdiff, and Sdiff, and a core phase of SKS. So far we have only a few regions in the southern hemisphere where the deep mantle structure has been examined in detail. Thus a new broadband observation program in Antarctica is expected to be an important opportunity to get valuable data.

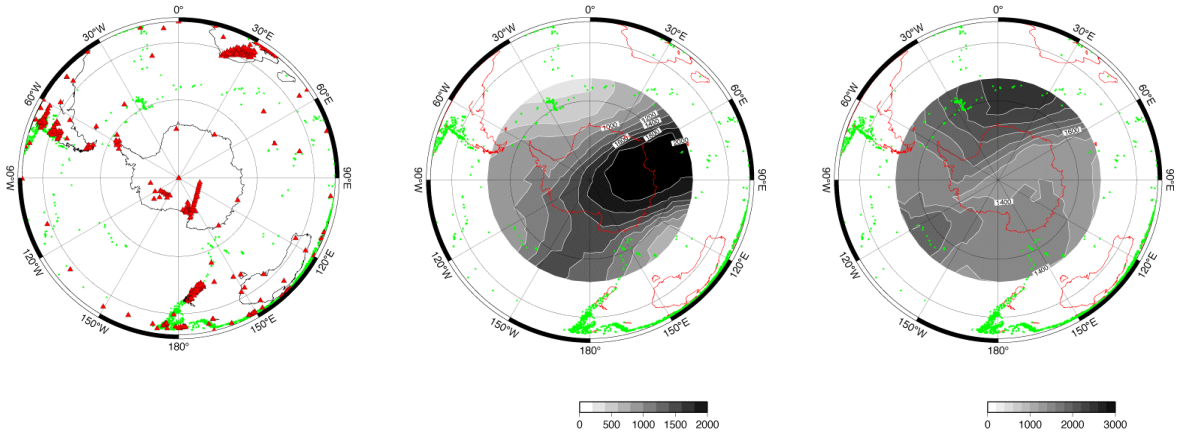

Figure 2. (left) Distribution map of the permanent and temporary stations in Antarctica (red color; from IRIS/DMS and PASSCAL). Hypocentral data collected in 1990-2004 (green color). Maps of observable earthquake numbers for the epicenter distances of 60°-90° (central), 90°-130° (right), respectively. Gray scales show the earthquake numbers that are counted at each location using an earthquake list for the period from 1990 to 2004.

International collaboration

The broadband deployment project is endorsed by several national Antarctic committees and contribute to individual international program of 'TransAntarctic Mountain SEISmic experiment (TAMSEIS; Lawrence, et al., 2006)', 'AGAP / GAMSEIS (IPY project # 67)' and 'POLENET (IPY project #185)' during the IPY 2007-2008. The data set observed during the IPY will be initially stored and available for all the related cooperatives and the other geo-scientists by Internet service from the data library server of the National Institute of Polar Research (POLARIS system). Then it will immediately be offered to the world data centers of seismology, such as Incorporated Research Institute of Seismology / Data Management System (IRIS/DMS), FDSN/ GSN, PACIFIC21 centers. The web-pages are available in general and also contribute to the Joint Committee on Antarctic Data Management / Antarctic Master Directory（JCADM/AMD）.

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