# Antarctic Multibeam Bathymetry and Geophysical Data Synthesis: An On-Line Digital Data Resource for Marine Geoscience Research in the Southern Ocean

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**Abstract** The **A**ntarctic **M**ultibeam **B**athymetry and Geophysical Data **S**ynthesis (AMBS) is a web-accessible data resource for marine geoscience research in the Southern Ocean. The primary focus is to preserve and provide public access to multibeam bathymetry acquired during expeditions of research vessels supported by the U.S. National Science Foundation. Since its inception in 2003, our primary goal has been to facilitate visualization and exploration of the sub-sea landscape to the full detail of the original data by both specialists and non-specialists. Visualization across a wide-range of map scales at high latitudes is made possible by dynamic access to a gridded synthesis in both Polar and Mercator projections. A second goal is to support multi-disciplinary research needs by offering data discovery and visualization of numerous complementary geoscience datasets. In this report, we describe the design objectives and architecture of the AMBS, as well as recent developments regarding data submission and delivery via Web Services.

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## Introduction

Over the past decade rapid advances in cyber technology have enabled new opportunities for scientists, educators, and the public to work with and comprehend large and complex datasets. These technical advances include new interactive tools for analysis and integration that free the user from the requirement of prior knowledge of data formats and descriptors. With access to well-documented, comprehensive digital data collections of Antarctic-related data, the Antarctic research community can benefit from these developments to address new research questions and conduct new cross-disciplinary studies. As emphasized in the recent report of the National Science Board (NSB-25), open public access to digital data collections holds great promise for broadening participation in research at all levels of education, while also providing new opportunities for education and outreach.

The Antarctic Multibeam Bathymetry and Geophysical Data **S**ynthesis (www.marine-geo.org/antarctic) was initiated to preserve circum-Antarctic bathymetry of high value that had been collected at great cost during expedition*s* in the Southern Ocean supported by the U.S. National Science Foundation (NSF). Multibeam bathymetry datasets from these cruises resided on digital tape and hard drives belonging to individual investigators at universities and laboratories scattered across the U.S. and abroad. These data were at risk of loss due to media degradation or of being misplaced or discarded after analyses. Bathymetry data are uniquely valuable among the marine geophysical data types in their relevance for a broad range of scientific investigations. Bathymetry data provide the fundamental characterization of the physical environment for studies ranging from ocean circulation to biological habitats, as well as serving as primary base maps for multidisciplinary programs. These data are also essential for a wide range of management and commercial applications, including marine resource management and the routing of seafloor communication cables. At present, specialist expertise has been needed to decode multibeam bathymetry field data and turn it into useful maps. These data are recorded as single swaths along survey tracks (ping data files), in raw formats of many varieties. File sizes are large, and data quality and data processing needs vary depending on sensor and survey conditions.

An important goal of the AMBS since inception has been to support both specialist and non-specialist access to multibeam bathymetry data by providing a gridded synthesis to the full spatial resolution of the data. The synthesis is composed of sets of grids covering the whole Southern Ocean, each at a fixed spatial resolution, ranging from a single global view down to the view of a few square kilometers. The synthesis is maintained as a dynamic compilation, which is updated as new data are released. This approach differs from previous bathymetric compilations in that new data are added as released by scientists and are then immediately available to users. Compilations such as GEBCO, or ETOPO5 are static products updated with publication of new versions every 5-10 yrs. The multibeam bathymetry data of the AMBS are integrated with other publicly available data for the global oceans, and together they overlay the global predicted topography of Smith and Sandwell [1997] and surround the BEDMAP sub-ice topography beneath Antarctica compiled by the British Antarctic Survey (Lythe et al., 2000; http://www.antarctica.ac.uk/aedc/bedmap/). The raw multibeam swath files are served from the AMBS along with the gridded compilation. The swath files will contribute to a new International Bathymetric

Chart for the Southern Ocean (IBCSO) in collaboration with international partners.

## Design Principles and Data System Components

Components of the AMBS data system include a metadata catalog, digital data repository, and data discovery and visualization tools. The content of the AMBS is primarily from expeditions of the dedicated polar research vessels, the R/V *N.B. Palmer* and *L. Gould*, but also from other research vessels dating back to the 1960's. Cruise metadata, including basic expedition information, data inventories and acquisition metadata reside in an open-source relational database (PostgreSQL®) with links for immediate download to the user's hard drive. We create FGDC standard metadata for multibeam data sets to enable exchange with the World Data Center for Marine Geophysics at the National Geophysical Data Center of NOAA in Boulder, CO (NGDC; http://www.ngdc.noaa.gov/). For users wishing to search the database for particular expeditions of interest, data discovery is via a text-based web search interface (Data Link, www.marine-geo.org/link) with options to search on key parameters including geographic range, ports, chief scientist and data types. The data system has been developed following recommendations of the 2001 Workshop on Data Management for Marine Geology and Geophysics (Smith et al., 2001). An advisory committee meets annually to review progress and provide feedback on system developments.

The primary data visualization tool of the AMBS is GeoMapApp, a virtual map viewer coded in Java™, which permits dynamic exploration of a wide range of maps, grids, images, profiles, and tabular data with capabilities for customized map generation (Figs. 1-3). GeoMapApp is designed to enable users with different operating systems to visualize and interact with seafloor data without requiring a specialist understanding of the underlying data structures. Another important goal has been to provide basic analytic capability rather than visualization only. Popular virtual map viewers such as Google Earth and NASA World Wind permit users to locate placemarks and overlay images, but lack the analytic capability necessary for many quantitative tasks. With GeoMapApp, tools are provided to extract bathymetric profiles, digitize site locations, contour and shade elevation models and examine the co-variance of multiple parameters. Selected items of tabular datasets can be plotted and colored by value. Seismic reflection horizons can be digitized and then transformed into surfaces. These kinds of analytical functions have typically required specialist applications (e.g. GMT, ARC, seismic interpretation packages), and sufficient expert knowledge of underlying data structures to conduct required file format conversions. With GeoMapApp, the basic tools and data of a seismic or bathymetric specialist are available to a wider spectrum of user.

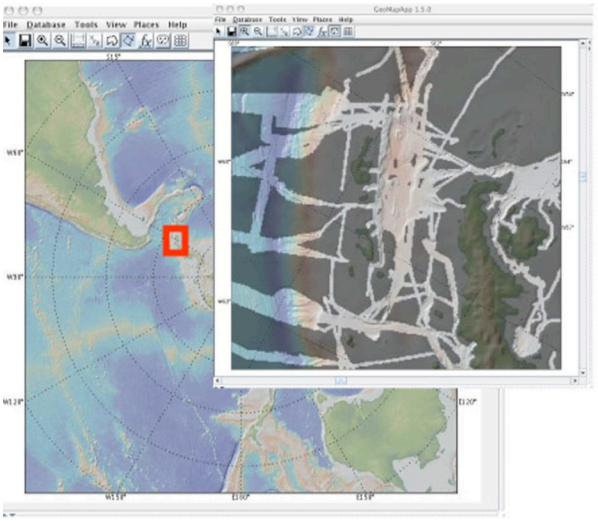

**Figure 1**. Example of GeoMapApp interface with south Polar projection showing blow-up of bathymetry (right) within area of red box. Users can customize the color display and sun illumination, draw contours, and download the bathymetric grid and image corresponding to the map display.

In addition to bathymetry data, GeoMapApp provides access to a variety of other data sets, enabling exploration of relationships between different data types. Underway trackline geophysical data from the GEODAS database of the NGDC, the Antarctic Digital Gravity Synthesis (ADGRAV), as well as non-proprietary data from the *Palmer* can be accessed. Isochrons from Mueller et al. (1997) can be superimposed on the bathymetry, showing seafloor age. Earthquake epicenters from the International Seismological Center (http://www.isc.ac.uk/) can be plotted according to magnitude and depth. Single-channel seismic profiles from the archives of the Lamont-Doherty Earth Observatory reveal sediment thickness and stratigraphic relationships throughout the Southern Ocean (Figure 2). Sediment cores and downhole logs of the Deep Sea Drilling Project unravel a 200 Myr history of climate change and ocean circulation. A variety of other global data sets can be accessed and displayed including cores from the Florida State Antarctic Research Facility and seafloor photos throughout the Southern Ocean (Figure 3). Options are also available for users to import their own data tables and grids and make custom maps using GeoMapApp tools.

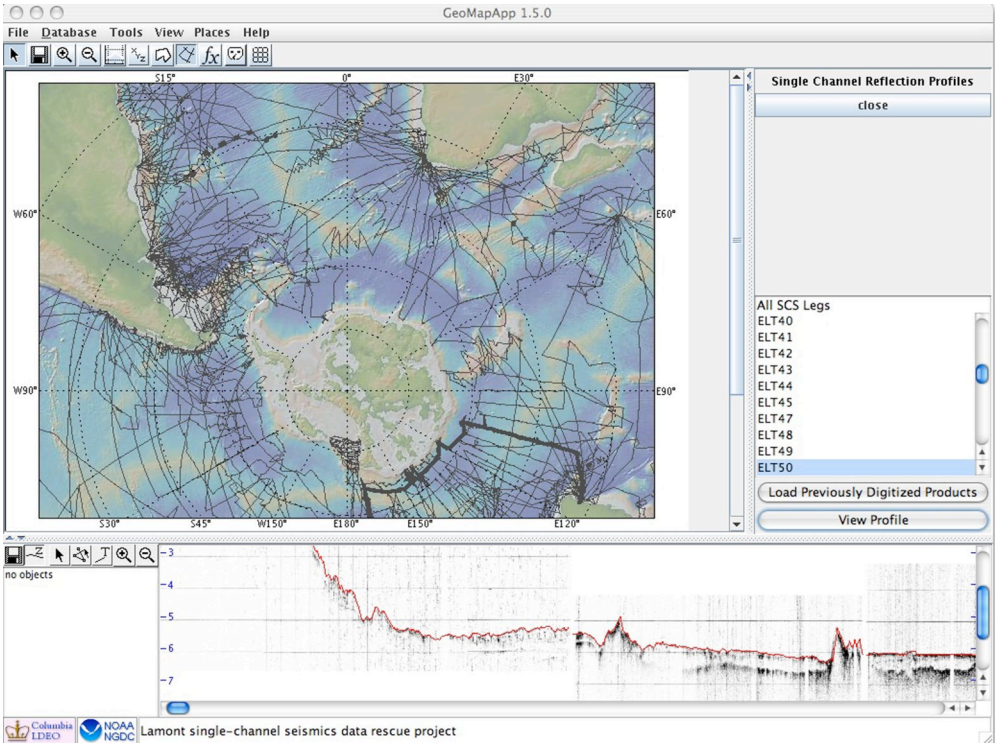


**Figure 2.** Example of GeoMapApp interface for single-channel seismic profiles. By clicking on a selected track in the map display users can load and view the corresponding seismic image. Users can then browse the seismic image and view the corresponding location in the map display. Options are provided to digitize horizons in the seismic image and download the digitized points.

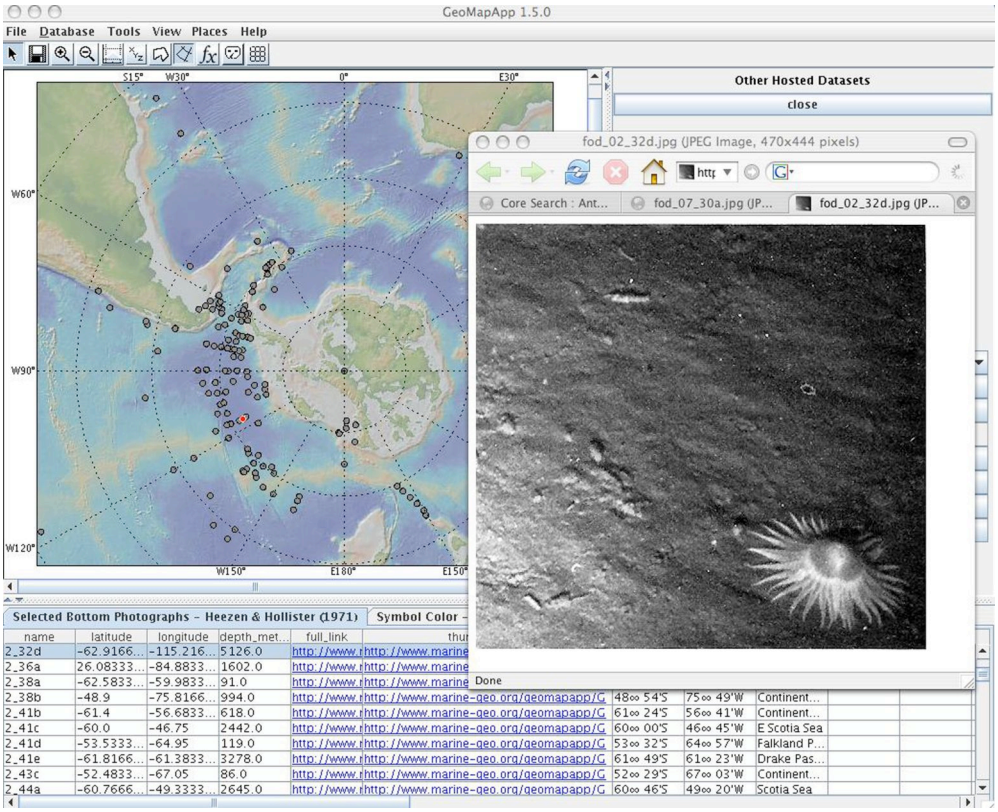


**Figure 3**. Example of deep-sea photo stations with photo viewer. Users can select photo station in map view and click on links provided to view corresponding photograph. Photos have been scanned from Heezen and Hollister (1971).

## New Directions

***Streamlined transfer of data from ships to data archives***

The AMBS was initially populated with data obtained through extensive correspondence with sea-going scientists and technicians from cruises spanning more than a decade to locate disparate datasets and solicit contribution. On many expeditions, multibeam bathymetry data were not the primary dataset of interest and these data were not examined after original collection. Hence the preservation of these data had not always been a priority and data from many expeditions were difficult and time-consuming to locate and recover. Beginning in 2005, the direct transfer to AMBS of an archive copy of digital data from *Palmer* and *Gould* by shipboard personnel (Raytheon Polar Services) was negotiated with the help of funding agency program managers. With this transition to routine data submission at the end of each expedition leg, AMBS personnel can now focus on ensuring a comprehensive data inventory is developed with adequate data documentation, rather than the laborious task of contacting many individual scientists to obtain contribution of individual data sets. Direct transfer of files from shipboard operators to data archives is feasible for most field datasets. Direct transfer to an onshore archive is a goal that should be encouraged more broadly in the global marine research community.

***Data System Interoperability and Web Services***

New technologies for database interoperability in the form of Web Services offer great promise for linking data systems, enabling users to seamlessly find and receive data of interest across distributed repositories. Web Services are Internet-based applications that use XML standards to exchange data upon request from a calling client application. An important advantage of adopting a service-oriented architecture for data exchange (e.g. Foster, 2005) is that it removes the need to use the graphical user interface provided by a data system as sole point of entry for data access, thus broadening the range of options available to scientists for data search, delivery and visualization. A major focus of current work within AMBS is to develop Web Services for map imagery and other hosted data sets. We have adopted standards-compliant Web Services as defined by the Open Geospatial Consortium (OGC) and have developed a Web Map Service (WMS) to serve the multi-resolution global bathymetry and a Web Feature Service (WFS) for station and tabular data (available at www.marine-geo.org/ws). Users can now choose to access these data through any OGC-enabled client (e.g. ArcGIS with OGC extensions, MapServer, UDig). Our WMS can feed into NASA's World Wind application, enabling users to explore the global bathymetry in a virtual 3-D globe environment. We have also developed a customized implementation of the WMS for Google Earth (www.marine-geo.org /Data4GoogleEarth.html). A new module has been written for GeoMapApp using the open source Java GIS toolkit GeoTools (http://geotools.codehaus.org/) to enable the import of data through a WFS. We have pursued this effort in collaboration with partners at the Incorporated Research Institutions for Seismology (IRIS), University NAVSTAR Corporation (UNAVCO), and the NGDC. With many data centers actively moving to develop Web Services for their data holdings, the connectivity of data resources is rapidly expanding.

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