Bathymetric mapping remains incomplete in the Arctic and Southern Oceans. Some proposed IPY activities could help improve the situation by collecting new soundings during vessel transits to and from their operating areas, and by making their observations available for inclusion in existing international data bases.

By Ron Macnab, Geological Survey of Canada (Retired), Dartmouth, Canada; Martin Jakobsson, Stockholm University, Sweden; Norbert Ott and Hans Werner Schenke, Alfred Wegener Institute, Germany; and Dmitri Travin, Intergovernmental Oceanographic Commission, France

The International Polar Year

Opportunities for Ocean Mapping at the Ends of the Earth

Introduction

The Arctic and Southern Oceans present significant challenges to marine scientists whose investigations require detailed maps of the seabed.

For example, physical oceanographers need fine-scale portrayals of seafloor roughness and topography, to understand and predict the transport of water through deep, intermediate, and shallow regions. Benthic ecologists need to know the detailed morphology and character of the seabed, to help explain the occurrence and distribution of specific bottom-dwelling and bottom-feeding species.

Earth scientists seeking to understand ancient and recent geological history look for clues in the patterns left on the seabed by sediment erosion and deposition, and in the finer structures of rock outcrops. Similarly, students of paleoglacialogy and paleoclimate search for indicators of past conditions, which help establish a context for understanding climate change and rising sea levels.

Unfortunately, studies such as those listed above cannot proceed satisfactorily in the polar areas: their bathymetry is poorly known, given the remoteness of these regions and their unfriendly operating environments. To be sure, there have been some advances, but much remains to be done in order to develop research-grade portrayals of seafloor morphology that are coherent and reliable.

Current IPY proposals identify a number of marine scientific missions to the polar regions. At relatively minor expense, these expeditions could easily collect bathymetric observations if their operational plans included transits or activities in areas where the quantity and quality of depth observations remain inadequate for scientific purposes. When assimilated into existing data bases, these new soundings would no doubt enhance our understanding of regional bathymetry.

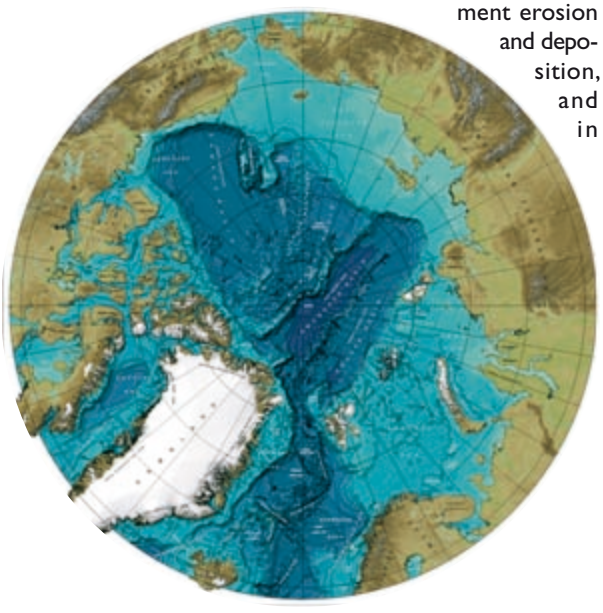

Figure 1: The International Bathymetric Chart of the Arctic Ocean (IBCAO), downloadable as a digital grid from 1.

Current Compilation Initiatives

At present, two international initiatives are maintaining bathymetric data bases for use in the construction of detailed portrayals of the seafloor in the polar regions: the International Bathymetric Chart of the Arctic Ocean (IBCAO), and the International Bathymetric Chart of the Southern Ocean (IBCSO). Both initiatives are led by researchers operating in academic and research environments.

IBCAO and IBCSO have been endorsed by the International Arctic Science Committee (IASC) and the Scientific Committee for Antarctic Research (SCAR), respectively. These affiliations reflect high levels of acceptance by the Arctic and Antarctic research communities. Moreover, the technical integrity of the projects is assured through close liaison with the Intergovernmental Oceanographic Commission (IOC) and the International Hydrographic Organization (IHO).

IBCAO

Launched in 1997, IBCAO produced by 2000 a preliminary description of the Arctic seafloor in grid and map form (Jakobsson et al, 2000). (See Figure 1)

At first glance, the IBCAO map appears to provide a complete morphological description of the Arctic Ocean basin and the surrounding land masses. However, in the oceanic zone it is necessary to keep in mind that the grid and map are derived from a compiled data base that is incomplete, and which features a highly uneven distribution of disparate depth points (see Figure 2).

Many of the data points shown in Figure 2 do not correspond to actual sounding locations, having been extracted from isobaths on hand-drawn contour maps. Moreover, many of the points that do correspond to real measurements are characterized by observational and navigational uncertainties, along with

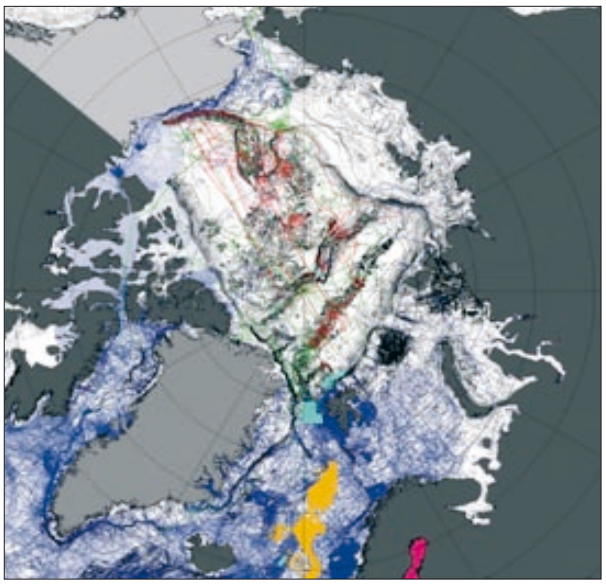

Figure 2: Distribution of data points used in the construction of IBCAO.

inconsistencies in the procedures that have been applied in their reduction and processing. In the construction of IBCAO, significant time and effort were expended in harmonizing these points so they would constitute a coherent body of information.

An examination of Figure 2 reveals numerous regions (particularly in the central ocean basin) where depth values were obtained from isobaths supplemented by widely- and randomly-spaced sounding tracks. These areas would benefit significantly from any new soundings - but the same could be said for nearly all other parts of the map, including those where controlled surveys have been carried out.

IBCSO

IBCSO was first proposed in 2002 as an activity within the framework of the German Polar Ocean Bathymetry Coordination Effort (POBACE). The project's primary focus to date has concentrated on the identification of suitable data sets south of 50°S (see Figure 3) and on the development of procedures for assembling and merging these data sets (Schenke and Ott, 2007).

Figure 3 portrays the distribution of depth information in two forms: grids (solid coloured areas) developed from compilations of all available data, and tracklines (yellow and blue lines) that correspond to an accumulation of numerous sounding profiles. In essence, the grids occupy two main sectors: one ranges from 75°W to 25°E and from the coastline of Antarctica to 60°S; the other occupies the Ross Sea. The tracklines are highly variable in their density distribution, with a noticeable scarcity of observations in the Pacific sector. New soundings would improve the situation anywhere within the IBCSO extent.

So far, there has been no attempt to combine the data for the purpose of developing a regular grid throughout the compilation area. New bathymetric data would be easy to assimilate at this stage of the project, however additions will be accepted at any future date for absorption into the data base and grid.

Measuring Ocean Depths

At present, the acoustic echo sounder represents the only effective technology for mapping ocean depths with the accuracy and resolution necessary for many types of scientific investigations.

Certain types of acoustic measurements are better than others; for optimum results, sounding equipment and operating characteristics must be specified with care. For instance, a multibeam sounding system is preferable to single-beam: the former will map a swath of underlying seabed in the same amount of time that the latter will measure depth along a single profile, and the end result will be far more informative (see Figure 4).

Multibeam equipment tends to be more expensive than a single-beam sounder, and more demanding in its operation. Not many polar-capable vessels are fitted with multibeam sounders, while most if not all carry single-beam sounders that are at least capable of operating in shallow (<200m) waters. Of the icebreakers that can operate in thick Arctic or Antarctic ice, few are equipped with multibeam sounders.

It is acknowledged that satellite altimetry has been used to good effect to develop maps of global bathymetry that offer generalized portrayals of major seafloor features (Smith and Sandwell, 1997). However, it must be appreciated that the methodology suffers from depth inaccuracies that exceed one hundred metres in areas with complicated seafloor sediment accumulations or crustal density variations, and that it is limited to coarse resolutions in the 5-10 km range (Smith and Sandwell, 2004). Moreover, the inclined planes of most polar-orbiting satellites militate against their use for measuring Arctic depths because they do not overfly the central basin.

Capitalising on IPY Cruises

Unfortunately, the polar regions do not lend themselves well to sounding operations on conventional vessels. To improve prospects for collecting useful observations, echo sounders must usually be operated from nuclear submarines operating beneath the ice, or from large ice-strengthened vessels that can cope with unfavourable sea and climate conditions during extended cruises to distant places. Such vessels are expensive to operate, and their services are in heavy demand. On polar scientific deployments, their missions tend to assume a multidisciplinary character; circumstances permitting, research organizers and managers are encouraged to add bathymetric mapping to the mix of cruise activities.

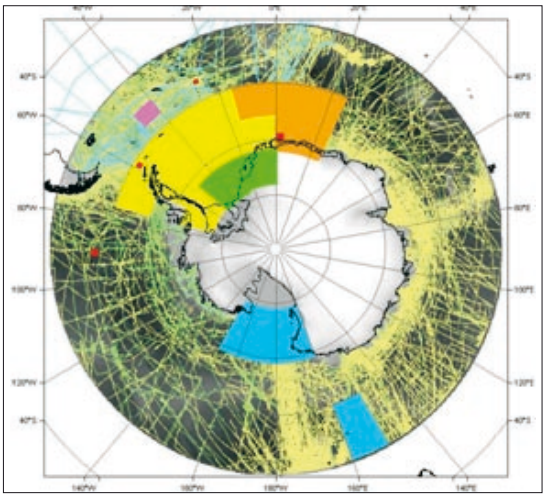

Figure 3: Distribution of data points in the IBCAO data base.

It is recognized that observations collected under such circumstances may not meet all of the rigourous standards that qualify the readings gathered during conventional hydrographic surveys. However in regions where little is known about the seabed, all new soundings must be perceived as pro-

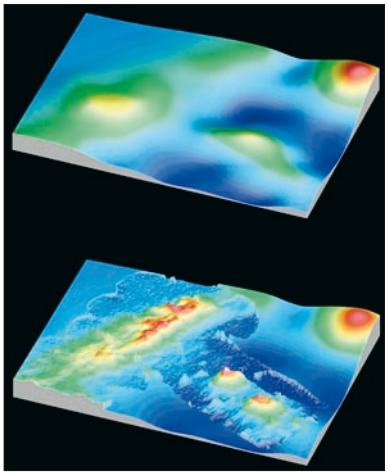

Figure 4: Two views of the seafloor: the upper, generalized image was constructed from a few randomly-spaced single-beam sounding profiles; the more detailed portions of the lower image were constructed from multibeam soundings acquired during a systematic survey.

spective improvements to existing data bases, particularly when accompanied by appropriate metadata such as navigation and sounding specifications, accuracy estimates, sound velocities, and corrections for sound velocity variations.

Collecting and Submitting Depth Observations

IPY marine investigators who will be traversing or operating in regions that remain poorly mapped and who will have echo sounding equipment at their disposal are encouraged to contact the project leaders for IBCAO or IBCSO as appropriate, with outlines of cruise deployment plans and descriptions of anticipated sounding opportunities.

In return, project leaders will provide information concerning areas where new soundings could enhance existing data bases. They will also recommend track locations and orientations that would maximize prospective benefits. All data contributions will be fully acknowledged.

The IBCAO and IBCSO project leaders are Martin Jakobsson of Stockholm University and Norbert Ott of the Alfred Wegener Institute, respectively. ■

Acknowledgement

Parts of this article were presented March 1 in Tokyo, 2007 during the International Symposium on Asian Collaboration in IPY 2007-2008 (Macnab et al, 2007).

Biography of the Author

Ron Macnab is a retired marine geophysicist who maintains an active interest in matters relating to the delimitation of the outer continental shelf according to the provisions of Article 76 of UNCLOS. Included among his affiliations, are memberships in the IAG/IHO/IOC Advisory Board on the Law of the Sea (ABLOS) and in the Canadian Polar Commission.

Further Reading

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Email: martin.jakobsson@geo.su.se (for IBCAO), norbert.ott@awi.de (for IBCSO)

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