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Multi-dimensional, multi-national, multi-faceted hydrographic training: the Nippon Foundation GEBCO training program at the University of New Hampshire

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Recommended Citation

C. Angwenyi et al., "Multi-dimensional, multi-national, Multi-faceted Hydrographic training; the Nippon foundation GEBCO training program at the university of new Hampshire," 2005. [Online]. Available: http://ushydro.thsoa.org/hy05/10_2.pdf.

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Production of this paper is supported financially by the Nippon Foundation

Abstract

Hydrographic training entered a new era when students arrived at the University of New Hampshire in August of 2004 to form the first class of the Nippon Foundation GEBCO (General Bathymetric Chart of the Oceans) training program. Born out of the need to replenish GEBCO's aging human material, and of the desire to spread deep ocean mapping capabilities more widely throughout the world, the program attracted applications from 57 students in over thirty countries. The seven selected each had post graduate training and several years experience, but differed in that three were hydrographers, two geologists and two oceanographers. Classes planned for the next two years will bring in a further fourteen students.

The UNH program had been selected as the closest match to the general course requirements GEBCO considered that ocean bathymetrists should have. Subjects include all types of depth measurements, oceanography, acoustics, tides, plate tectonics, sea floor morphology, ocean basins, sedimentary processes, hydrothermal-thermal processes, gravity-magnetic relationships to seafloor fabrics, positioning and geodesy, maps and charts, IHO standards, GIS, data bases, gridding, contouring, spatial statistics, and the history of GEBCO and ocean mapping. These are taught at the graduate level as part of the graduate degree program at UNH.

In this paper, the experiences that participants from the different backgrounds underwent are recounted with the overall goal of improving the general education required to map the floors of the deep ocean. Recommendations are made regarding the prior preparation of students entering the program, the content and intensity of courses comprising the program, and follow-up actions to solidify the learning experience. Intangibles such as the networking of professional contacts are also evaluated. Extrapolations to training in other areas of hydrography are made.

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Introduction

Hydrographers, like all seafarers, have always cooperated with other hydrographers both at a personal level and organizationally. Indeed the reason hydrographers created and maintain the IHO is to make it easier for them to cooperate on a world-wide basis. Through it, hydrographers cooperate in many ways, including contributing to the production of bathymetric maps of the deep ocean through the General Bathymetric Chart of the Oceans (GEBCO). GEBCO predates the IHO, and since 1974 has been allied with both IHO and the Intergovernmental Oceanographic Commission of UNESCO. The GEBCO community has produced five editions of paper world bathymetry maps, and two digital editions, the most recent including both contours and a 1 minute grid of depths. In recent years, GEBCO has come to need a revitalization of its human resources, and one response has been to establish an international training program in deep ocean bathymetry. In partnership with the Nippon Foundation of Japan, GEBCO has contracted with the Center for Coastal and Ocean Mapping/NOAA-UNH Joint Hydrographic Center of the University of New Hampshire, to develop and offer a certificate in Ocean Mapping. This paper reports on the first few months of this program that involves not only three international organizations, a benevolent society, a university supported by its nation's Ocean Mapping service, but the seven national organization of which the first class are representatives.

Need for and uses of oceanic hydrography

Bathymetry contributes substantially to solving societal problems. The demand for accurate and up-to-date bathymetric charts and gridded data sets is increasing in the fields of oceanographic modeling to predict ocean circulation and its impact on climate, modeling that predicts tides and tsunami propagation, evaluating fisheries resources and habitats, assessing the impact of coastal sediment transport and pollution, geological modeling of ocean basin evolution, delineating the limits of the Continental Shelf (UNCLOS) and assisting the International Seabed Authority to manage the oceans. GEBCO contour maps are routinely used as base maps on a regional scale and on a global scale, and the GEBCO bathymetric grid forms the basis for numerical modeling in many applications.

Potential users of high resolution bathymetry, include:

- * cable and pipeline routes
- * fishing grounds (seabed character, hazards to gear, damage to habitats)
- * seabed mining
- * Article 76 - UNCLOS requirements
- * tsunami propagation modeling

- * ocean circulation models
- * geological processes
- * tectonic processes
- * Defense (mine counter-measures)
- * offshore waste disposal
- * baseline monitoring

Lists like these, although useful, do little to capture the dynamics of the field, and the changes it is undergoing. Those are better captured through a brief look at developments that recently have taken place that impact deep sea bathymetry . These include a change from hand-drawn relief to computer-generated relief, positioning by satellites being made public, seafloor mapping evolving from single beam echo sounders to side scan sonar to multibeam and satellite altimetry, the Deep Sea Drilling Project launched, the cooperative union of two independent and very different International organizations in a common cause, the United Nations Convention on the Law of the Sea conceived, developed and signed, and the major paradigm in earth science make the transition from untested theory to dogma. More recently we have seen GIS as a common and widespread tool, the Internet evolved as the major communication and information tool, GPS de-restricted and improved to the point where positioning at sea is no longer an issue, data that had been collected for military purposes released to the public domain, computer power and storage increase by leaps and bounds, the GEBCO Digital Atlas released and updated, grids derived from the GEBCO contours, satellite altimetry data combined with echo soundings...and more. Practitioners in the field must be prepared for diversity and change

Relationship of hydrography and bathymetry

As we all are very well aware, the role of hydrography continuously changes. At this Conference in 2001, Horst Hecht proposed a new definition of hydrography (Hecht 2001):

“Hydrography is the total set of spatial data and information, and the applied science of its acquisition, maintaining and processing, necessary to describe the topographical, physical and dynamical nature of the hydrosphere and its borders to the solid earth, and the associated facilities and structures.”

It is normal to subdivide this “total set” into sub categories, and one useful subdivision is that proposed by (United Nations Economic and Social Council 1978):

Coastal hydrography is concerned with the development of ports and harbours, coastal erosion problems, the utilization of

harbour and coastal conservation services and, especially, the safety of navigation in coastal waters.

Off-shore hydrography is concerned with (a) the provision of hydrographic data as an extension of the coastal zone normally encompassing the continental shelf, (b) the development of mineral deposits, including hydrocarbons, and (c) provision of data for fisheries management.

Oceanic hydrography is concerned with the acquisition of hydrographic data in the deep ocean areas for the depiction of sea-floor geomorphology.

GEBCO and its products lie firmly within the domain of oceanic hydrography. They cover the entire world ocean, and show the surface of the seafloor from a geomorphologic perspective.

Relationship of bathymetric maps and navigation charts

Although all hydrographers recognize the three types of hydrography outlined above, the overwhelming majority spend their careers working to improve navigation safety. Consequently a brief description of the two main products of the different branches of hydrography, the Navigation Charts and the Bathymetric Map is offered to help differentiate between their purpose, and to illustrate the differences in training required by those who produce them.

Bathymetric Maps and Navigation Charts are highly specialized products, designed for different purposes and showing different things. Since they both show water depths, it is sometimes mistakenly believed that they can be substituted one for the other, but this is not the case.

Navigation Charts are carefully constructed instruments designed to provide a basis for charting at sea. To do so, a Navigation Chart must

- (1) form the base for the graphical exercise of charting;
- (2) provide information on the nature and position of navigational hazards; and
- (3) provide information on the identification and characteristics of navigational aides. Notice that nowhere is depth per se mentioned.

The navigation hazards whose nature and position must be charted to meet objective two are both natural and man-made. Natural ones include those parts of the sea floor on which a ship can run aground. If the surface of the earth were a flat, inclined plain, some of which was covered with water, a straight line at a certain critical depth would suffice to delineate all hazardous areas. This "danger line" would mean "stay outside this line or you will run aground". .

By contrast, a bathymetry map is not constrained by the need to protect mariners and their vessels. Like its land-based equivalent, the topographic map, it shows the relief of the seafloor in as much detail as possible at the scale of the map.

Consider an area that has been intensively surveyed and the sea floor found to be undulating. Over this surface it is possible to construct a line that captures every nook and cranny on the sea floor in its correct location, within the limits of the spacing of the data. Bathymetric maps show such a line but navigation charts do not, must not. For example, suppose that there was an isolated elevation outside that line that came close enough to the surface to constitute a danger to navigation but which was of such small extent as to be almost invisible on the map. It would not be safe to show it on a navigation chart as being as minuscule as it really is, since that dot on a chart could translate into a hole in a belly of a ship. The peak must be distorted by being enlarged to a size where it will attract the navigator's attention. Another example: narrow depressions inside the danger zone are usually omitted since it is unlikely that a ship would ever want to enter them. As map scale is made smaller, smaller features tend to disappear. In the case of depressions, this does not matter, but allowing a dangerous peak to disappear could prove tragic. Consequently, the portrayal of the peak is enlarged so as to be readable at the new scale; the peak may in reality be many times smaller than it is shown to be. Depressions, of course, are not drawn larger and do in fact disappear from the chart. The hydrographer's overriding consideration is safety of shipping and protection of the marine environment; and all decisions about where the danger line should be placed are made on the basis that doubtful cases will be resolved by drawing the safest lines. The "stay outside this line or you will run aground" now has the implicit addendum "it is possible that safe areas exist within this line, but your safety is only assured if you stay outside it".

The danger line varies with a draft of the vessel, the stage of the tide and the state of the sea. To cover all possibilities, several danger lines are drawn at various depths. These lines are usually called contours and since they have a depth associated with them they often erroneously are called depth contours. In actual fact, they are danger contours, the five-meter contour for example showing that it is dangerous for ships to whom the depth of five meters is critical to venture inshore of that line. These contours do not connect all points of that depth within the area, nor is there any need for them to do so and navigation charts do not portray the actual shape of the sea floor with much fidelity.

On a bathymetric map, on the other hand, every contour is shown in its best-known location, there is no bias towards depicting shoaler rather than deeper depths, and isolated deeps are included. In fact, the aim of the bathymetric map is to show every "nook and cranny" of the sea floor in the best possible way permitted by the data available and the horizontal scale of the map. (Monahan 2000)

Deep water is different from hydrography for conventional navigation

In the deep ocean there are very few routine surveys and only a very small percentage of sea floor has been ensonified (estimates range from 0.1 to 10 percent). Unlike a navigation chart which is usually constructed from cohesive survey data, bathymetry maps must be made from data that was originally measured from a variety of platforms, using different positioning and sounding systems, using (or not using) different sound velocities, units and plotting methods. Data may appear to be the same as in shallow water, but there are more differences between a sounding of 25 m and a sounding of 2500 m than just two zeros. The following table summarizes the elements that comprise a depth contour: most of them vary with depth.

Table 1. Factors which contribute to the fidelity with which contours reproduce the sea floor.(after (Monahan and Wells 1999)

ELEMENTS THAT CONTRIBUTE TO THE UNCERTAINTY OF A DEPTH CONTOUR	
A. Factors that add to the uncertainties associated with a single sounding	
Depth measurement	Sound speed variations Beam width Constant errors
Positioning	Of survey platform Of seafloor sensed by instrument
Datums	Vertical or tidal datum Geodetic datum
B Factors that effect soundings collected along a track or profile	
Depth measurement	Masking of short wavelength features due to beam effect Smoothing of the seafloor
Positioning	Position of the survey platform at fixes and between fixes
Sounding selection	Distance between soundings selected along track Selection at even intervals introduces wavelengths
C Factors that effect the fitting of contours to sounding data	
Arrangement of soundings	Density of soundings Pattern of tracks, including crossovers Orientation of tracks to seafloor features
Seafloor physiography	Simplicity or complexity
Method of contouring	Methods of surface fitting Honouring Data Size of the grid cells if gridding used
Complementary information	eg bottom composition eg sidescan eg predicted (satellite) bathymetry
D Complications particular to legacy data (collections of older data)	
Compilation errors or blunders. Non-availability of original echograms Scale and accuracy of hand plotted data Biases in sounding selection Accuracy of older instruments	

Producers of Deep Ocean Bathymetry

The world ocean laps on the shores of almost all the countries on earth, and is enormously vast. Even if it could be surveyed by modern multibeam methods, (Carron, Vogt et al. 2001) have calculated that to survey only the areas deeper than 500m would require something like 800 ship years. Clearly the world ocean must be mapped by the Coastal States of the world working in concert.

GEBCO

The General Bathymetric Chart of the Oceans (GEBCO), a non-profit organization which recently celebrated its centenary, is an international organization which has benefited from contributions of data and expertise from many countries, and, as this paper will show, its membership is growing. GEBCO produces charts and digital grids of the world ocean by collating, interpreting and contouring, with the aid of directional fabrics revealed by satellite gravity, soundings and multibeam bathymetry collected by surface ships. GEBCO also evaluates and authorizes undersea feature names for use on its products which are published in a Gazetteer. Only a small percentage of the seafloor has been completely examined and in some remote areas of the world ocean sounding tracks are many miles apart, so that contouring depends heavily on interpolation and interpretation.

GEBCO is an unusual organization in that it depends almost entirely on the voluntary contributions of time, effort, knowledge and skill by enthusiastic scientists and hydrographers, from around the world. GEBCO has no regular or permanent income and therefore attracts charitable status e.g. by the Inland Revenue Service of the USA. GEBCO is run by a Guiding Committee and underpinned by two main Sub-Committees and specialist Working Groups that meet at least annually. It is supported by only two full-time staff, one in Southampton Oceanography Centre, UK (Bathymetric Editor) and one in the British Oceanographic Data Centre (Digital Atlas Manager) who are employed by a separate organization, and by a voluntary part-time Permanent Secretary. GEBCO has formal links to the scientific and hydrographic communities through the Intergovernmental Oceanographic Commission (IOC of UNESCO) and the International Hydrographic Organization (IHO), respectively.

GEBCO and the International Bathymetric Charts

Through eight Editorial Boards and a Coordinating Committee on Ocean Mapping (CGOM), IOC publishes regional bathymetric maps of specialized areas. Starting with the Mediterranean IBC (IBCM), there were now eight IBCs, the latest covering the Arctic Ocean (IBCAO) and Southeast Pacific (IBCSEP). Some IBCs such as the IBCAO were already integrated into GEBCO, and but not all of the eight Editorial Boards agree to this strategy as yet. The IBCs use the output

of SCUFN. IOC wants to collect all data into a single data centre available to anyone so that charts may be produced at any scale. NGDC is working with the IBC Editorial Boards, which increases the global marine geology and geophysics holdings in national and international data centers. Some Hydrographic Offices supply data to the IBCs.

The IHO supports both GEBCO and the IOC IBCs. IHO sees the data involved as a resource that will be exchanged freely. The IHB sees the IBCs as forming a bridge between navigation charts and GEBCO charts. Because of pressure on resources, it makes little sense to keep separate the bathymetry collected by the three parties. The future participation of VHOs is very dependent on the future relationship between GEBCO and the IBCs. This relationship must be structured in a way that it is seen as positive to the VHOs and one that uses limited resources for maximum return.

GEBCO and its Data base / data centre

GEBCO is supported by a well-established infrastructure for handling bathymetry data once it has been collected at sea. NOAA's National Geophysical Data Center (NGDC) operates the IHO's Data Center for Digital Bathymetry (DCDB), to which depth data can be submitted directly or through a national Hydrographic Office. Data can be in virtually any format, and both single-beam and multi-beam data are supported. Submitted data are combined with existing data, and depth data sets are available for any geographic area. GEBCO participating scientists use the data sets to update and refine existing GEBCO maps and to produce more detailed ones where the quantity of data will support doing so. An additional input comes from the IOC's International Bathymetric Charts (IBC) projects at a regional scale. The IBC projects are encouraged to feed their regional maps into the GEBCO global map. A common comprehensive data base allows data to be interpreted once and distributed through one portal. (Sharman 2002)

Need for the training program

Very generally, the rate at which mapping of the sea floor progresses is a function of:

- a) the size of the surface to be mapped
- b) the efficiency of the mapping tools that can be applied
- c) the speed of the platforms that carry those tools, their amount of use and the areas that they are deployed in
- d) the organizational structures in place to assimilate the raw data and transform it into maps
- e) the number of skilled people who work at the task.

While no organization can alter the size of the oceans, recent efforts with multibeam and satellite altimetry have greatly improved the second and third items on this list. As outlined in the preceding section, the organizational structures necessary are in place. This section addresses the need to train new workers so that the number of skilled people can be maintained. The Nippon Foundation project will bring new workers into the field so that the “area of ocean to active bathymetrist” ratio is improved.

Current status of world-wide bathymetry

“...even today, only of the order of 10% of the seafloor has been measured with direct echosounding.”(Harper and Sharman 2003)

“Despite our intimate connection with the sea much of the world’s oceans remain unexplored. Some estimates suggest about 95% of the world’s oceans and 99% of the seafloor are unexplored” (Committee on Exploration of the Seas 2003)

“Although, as digital data files, the size of these files is enormous, they represent coverage of only a small minority of the area of the world's continental margins.”(Holcombe and Moore 2000)

“We do not agree on how much of the ocean remains un-explored, but estimates as high as 95% are not uncommon.”(Monahan 2003)

“Bathymetric maps tend to be taken as gospel with inadequate appreciation of the sketchy database on which they may be built, or the inadequate quality of (some) of the original data.” (SCOR Working Group 107 1996)

“The world ocean floor, almost equal in area to two moons plus two Mars-sized planets, is one of the most poorly and inhomogeneously mapped solid exterior surfaces in our solar system” (Vogt 2000)

These statements indicate that, on a world scale, there is much more to be done in the future than has been done in the past.

Demographics of Professionals in bathymetric Mapping

The celebration of GEBCO’s Centenary in 2003 was bitter-sweet since it marked by the retirement of several experienced, dedicated and very productive members at a time when it is becoming increasingly difficult to find younger scientists and hydrographers whose employers and careers will allow them to spend substantial periods of time working on bathymetry projects. GEBCO does not have the resources to pay people to work for it, but unfortunately, research funding agencies generally no longer consider creating bathymetric charts, in spite of the widely acknowledged usefulness to society of such charts, to be

'cutting edge' research. Therefore, GEBCO faced a very serious, and even threatening, core problem which was *a growing lack of personnel, with a deep knowledge of marine Earth science and extensive skills in IT, to take projects forward*. Either GEBCO had to find a means to bolster its human resources or else face falling behind in assimilating new data and updating its products, which would have been to the detriment of the world-wide community that it serves.

Bathymetry is not alone in facing human resources shortages: see, for example, (Preston 2004) for a discussion of the scientific disciplines in general, (Broadbent 2002) for oceanography and (Canadian Institute of Geomatics 1999) for Geomatics.

The skill sets needed

A GEBCO working group established the topics in which a modern bathymetrist should be skilled: these are listed in Annex I. Not surprisingly, these share much in common with the fundamental subjects necessary for all types of hydrography. (See the publications of the FIG/IHO/ICA International Advisory Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers, for example.) It must be stressed that these are graduate level courses with a particular emphasis on the different demands of working in deep water, and the need to apply geomorphologic knowledge to the interpretation of sparse data sets of the sea floor.

(Monahan 2003) summarized the interpretation issues as follows: "In the past, data valuable to GEBCO was usually collected at little direct cost since research ships would normally operate an echo sounder as part of their regular program. Single beam echo sounders required little in the way of operator or servicing at sea. While this is still true, MBES is a different story since it has not yet evolved to the point of requiring no operator intervention. Data processing for MBES is similarly resource intensive. Nevertheless, independent tracks of multibeam can be sent to NGDC where it is archived reviewed for quality, and inventoried for ready access, retrieval, and redistribution. Since processing multibeam data requires sophisticated software and equipment, it is made available as entire data sets or reduced data sets.

Within the area of seafloor ensonified during a multibeam survey, there is no need to interpret the shape of the seafloor and express it in contours as there was during the single beam, widely spaced track days. There is so much data that it creates the contours itself. Within the ensonified area, interpretation can focus on what the contours mean. Between multibeam passes, there will still be a need to interpret the seafloor from single beam tracks, and ways may be devised to use, in the areas between tracks, the extra information provided by the multibeam.

At the opposite end of the scale, altimetry provides long wavelength information. While combining altimetry and single beam has been made operational (Smith and Sandwell, 1994), interpreting the three data types together awaits development”

Establishing the program

The Nippon Foundation

“Goals and Objectives of The Nippon Foundation. The Nippon Foundation is an independent, non-profit, grant-making organization founded in 1962. It was established by legislation that set aside 3.3 percent of the revenues from motorboat racing to be used for philanthropic purposes. The Foundation is providing aid to projects that fall under one of the following four major categories: 1) public welfare in Japan; 2) voluntary programs in Japan; 3) maritime and ship-related projects; and 4) overseas cooperative assistance. Under the category of Overseas Grants for Maritime and Ship-related Projects, we especially respect cross-border, transnational activities; regional undertakings that may fall outside the reach of the public sector or other donor agencies; and initiatives to tackle pressing issues and long-range or persistent problems that require prompt and systemized care. Please refer to the following section for more detailed information about our grants.”

Downloaded from http://www.nippon-foundation.or.jp/eng/how/marine_affairs.html

In 2003, GEBCO proposed to Nippon Foundation, as a solution to the shortfall in the numbers of skilled people who can participate in GEBCO’s mapping activities, the training of a new generation of younger scientists and hydrographers, mostly from less developed countries, in a Post-graduate Certificate in Ocean Bathymetry (PCOB). The proposal was accepted by the Nippon Foundation and the PCOB course was funded. Since no suitable teaching program was known to exist anywhere in the world, the *ad hoc* Project Management Group began by designing the learning objectives for training course that would help produce the next generation of bathymetrists. They then established performance criteria against which potential University teaching organizations could be evaluated. Based on these two documents, a search for a suitable university teaching organization which could run the course in ocean bathymetry was undertaken. This process led to the submission of proposals from six universities in five countries. Since many members of the GEBCO community had university affiliations, to make the final choice between these well-qualified teaching organizations GEBCO set up a neutral Evaluation Group consisting of six members, three from the GEBCO community and three independent advisors. The six members ranked the six organizations according to criteria established earlier. The Evaluation Group announced their unanimous decision that the best candidate was the Centre for Coastal and Ocean Mapping/Joint Hydrographic Center at the University of New Hampshire (UNH) on 25 February.

Advertising for potential students resulted in 57 applications from a range of people in 32 countries. From these, seven students had to be selected who would most likely be successful in the program and return home where they would participate in bathymetric mapping of oceanic areas adjacent to their home country. GEBCO and the Nippon Foundation jointly selected students on the basis of previous education, language competency, likelihood of successful completion, support/endorsement of home organization, likelihood of working in ocean mapping upon completion, possibility of participating in a Nippon Foundation work package or fellowship upon completion and geographic distribution of home state to offer maximum cross-fertilization among the class. Students for this pioneer class come from Argentina, Fiji, India, Japan, Kenya, Nigeria and Peru, with backgrounds in hydrography, geology, geophysics and oceanography.

Upon acceptance, the seven selected students were asked to confirm that they were ready to move to the USA for a year and to apply to the university for admittance. Upon being accepted by the university, they were able to apply for a visa and plan their travel. At the university, housing in the Graduate Students residence was reserved, and a special laboratory in CCOM/JHC was furnished with a new computer installed and networked for each student. These pioneering students began their work in the Fall Semester of 2004 and they were quickly immersed in lectures, laboratory exercises, assignments, field work and field trips. All settled in well and are working hard. Perhaps more importantly, they are working together and forging friendships and a network that will last them for the duration of their careers.

Components of the training program

The intensive 12-month training program comprises four elements: completion of graduate courses, participation in research cruises, working visits to other laboratories, and construction of a bathymetry map.

University Courses

Graduate courses at CCOM/JHC consist of lectures, practical laboratory-based projects and day boat exercises. Teaching staff consists of UNH faculty and research scientists as well as other experts brought in from elsewhere for limited periods to give specialist lectures. Other graduate students not sponsored by Nippon Foundation also take the same courses, allowing further cooperation and network building.

Ship cruises

This year's students have all worked at sea, but not necessarily on a deep ocean cruise. It is desirable that they participate as working members on a cruise, with

watch keeping and data processing duties. Of course, the experience will be much more beneficial if the PI is a member of the GEBCO community. At the time of writing, this year's cruise plan is not finalized, but students have been offered places aboard cruises ranging from crossing the Arctic Ocean to working between Madagascar and the African mainland.

Visits to associated laboratories

To round out their training, to help them build networks and feel that they are part of GEBCO, to apply some of their newly-acquired theoretical knowledge and hopefully to improve the bathymetry map they are producing, a visit to another lab can be enormously useful. This would include familiarization with the programs is engaged in, as well as some directed work under supervision. Negotiations for the 2005 placements are still ongoing.

Mapping projects

The Nippon Foundation students have, as one of their program requirements, to produce a bathymetry map of an area pertinent to their home organization. Figure 1 shows the approximate areas chosen. Red = Nippon Foundation students, Green = non-Nippon Foundation students taking the class.

Personal experiences and reflections

In this section, personal comments by individual students are included un-edited and un-attributed. They are grouped into categories that hopefully capture some of the energy and enthusiasm of this outstanding group of young people.

Different backgrounds of students

The seven selected each had post graduate training and several years experience, but differed in that three were hydrographers, two geologists and two oceanographers.

"it is a great idea to have students from different parts of the world and with different (but related) backgrounds. If all seven of us were the same then we would all think alike and there would be very limited ways to look at a problem. But having various academic backgrounds and work experiences, we learn a lot from each other's professional experiences. There is always room for debate, which is a good learning process."

"Another thing I like is the composition of the students and the diversity of backgrounds encompassing oceanographers, hydrographers, geologists and geophysists. This richness in diversity brings in another dimension of knowledge sharing. I have learnt more about other disciplines than oceanography which is my background through interactions with the other students."

Personal Growth

“I can say that these first months as one of the students of the GEBCO Program have been an invaluable experience. My whole perspective as a Hydrographer has changed. I am not the same person I was five months ago and I know I am still in the process.”

“Being from a very remote area of the world, ... this training program is an eye opener for me, to realize the importance of water depths and topography, in relation to the marine resources and oceanic processes. “

“I’m glad that I got selected for the training and I do not regret having made up my mind to take the training. There are always challenges that come with new things and this was true in the first few class sessions.”

“I have personally gained so much within the last four months and now trying to give my best to the system.”

“After a successful completion of the first semester, I have a different prospective of the coastal/oceanic processes in relation to bathymetry than the day I arrived here. During my Masters Thesis research, the bathymetry of the study area was the first component, when creating the Concentration Diffusion Hydrodynamic model. But not much emphasis was given to the data accuracy; the best available data was used. Now if I look at that model I will have some questions regards the data acquisition methods and the way it was interpolated”

“One thing crossed over my mind when I saw the advertisement about the GEBCO/Nippon foundation ocean bathymetry course, the problems I had run into earlier on during my oceanography research project especially on the bathymetry of the area I was working on”

“The GEBCO program provided me a good opportunity to learn systematically and deeply knowledge and skills necessary for ocean mapping. I have experiences several hydrographic surveys...but I knew only what a hydrographer should do to obtain data and make a map. Here I am happy that I could spend much time to understand the physics based on which we can explore the seafloor, such as acoustics, geodesy etc.”

“Having an academic background in physical oceanography and work experience in GIS and remote sensing, this training program is a learning experience and career enhancement opportunity.”

Capacity Building after Returning Home

“There is a well known expression “the knowledge brings responsibility”, and I understand it very clearly. I have lots of expectations of returning to my home

country and share what I am learning; I can see many fields of application that before I could not have even imagined. “

Teamwork In The Class And As Part Of The Larger GEBCO Community

“I can imagine myself the next years asking my GEBCO colleagues in different parts of the world for their opinions about one project, or sharing new techniques and experiences with them. I know the task of mapping the whole ocean will be hard and long but I am proud and happy to have a part in it.”

“... being a part of a winning team with fantastic people is a very big challenge. GEBCO and NIPPON have challenged us and our promise to them is that we are not only going to win but to improve on our performance.”

“ The most important thing I got during this program is the friendship among colleagues from all over the world. This program has just started last August. Our young network will expand further as years. I hope that the young generation of GEBCO will become a strong power to push forward the mapping of ocean in the world. “

“Every single thing has contributed with this change on my outlook. It is not only the fact of study in a different language and the opportunity to share time and experiences with other students from countries all around the world, but every lecture and of course the opportunity to experiment with all the fascinating ways in which the bathymetric data can be processed.”

Reaction to CCOM/ JHC and the rest of UNH

“Unlike all other institutions I have attended, the university has an enabling environment with tremendous facilities and activities to make learning very exciting. Specifically speaking, the Centre of coastal and Ocean mapping combines the pursuit for excellence with very renowned Professors and scientists who all the time are willing to solve your problems. I believe that the exemplary leadership of the Director has contributed immensely in making everyone feel like a part of a single happy family “

“However the supportive attitude of the staff at the Coastal and Ocean Mapping Center at the University of New Hampshire gave me the motivation to keep going. I can say without any reservations that I have learnt quite a lot even within the short time that I have been in the course.”

“I appreciate the dedication and passion of the teacher group, and their invaluable patient to the students, especially who have English as a second language.”

Comments relating program to home country

“Peru, my home country has an extend coast along the southern Pacific Ocean, and an important part of its economy is connected, in one or another way, with the sea. There many maritime activities like fishing, the hydrocarbon industry, and international commerce on the other hand there is an uncountable lost due to the El Niño phenomenon which has a big impact on the economy of the country. These are just a few of the potential fields of application I am learning.

The Peruvian Directorate of Hydrography and Navigation for which I work, is the only institution in the country involved in bathymetric activities. We used to focus our activities on providing the navigators all the resources to safety navigation; but in the latest years, we have understood that we can contribute with the development of other fields. I think this Program is giving me the tools to work more effectively on these new objectives.”

“I also learned that the seas around Japan are one of the best-surveyed areas in the world whereas many of areas remain unsurveyed, and that a small amount of bathymetric data is available to the public even if the data exists. In Japan, several organization and institutes conduct surveys using multibeam echosounders. So, it is not often to compile data by surveys conducted in the different ages and in the different ways in order to make a bathymetric map. But, such works are required to make a map of the world. “

“Having basic understanding of physical oceanography and GIS, after completion of this training, I think I would be in a better position to apply this knowledge and make sound judgments; and to appreciate the number of days scientists spend out at sea, battling harsh conditions, to measure those depths.”

“The principal activity of my Office is to publish nautical charts in order to keep safe navigation. The economical resources mostly are drawn to the navigation chart production and Ocean Bathymetry is in a second plane as support to oceanographic researches. In my case I would need tools to set me on work, mapping softwares packages (license, technical support) and compatible hardware to use it, because I have the place, the young people to train but I need the tools. “

Benefits

The Nippon Foundation project is not designed to advance the instruments used in mapping the oceans. Rather it is focused on the human component of mapping. As pointed out above, vast areas of the seafloor are not measured but

must be interpreted. The number of scientists trained in interpretation will be vastly increased through the Graduate Diploma component of the project.

It is very likely that the Nippon Foundation project will significantly impact the choice of areas of the ocean to which Ocean Mapping tools are deployed. The Graduate Diploma component will provide trained bathymetrists to areas of the world where such talent is presently in short supply or totally lacking. Their new technical skills, reinforced by the network of other ocean scientists they will have developed during the training program, will be applied to a Capacity Building project that focuses on an area of the ocean that has not benefited from much attention in the past.

Where we are heading

The personnel trained and developed by the above means will extend the existing network of the GEBCO community into developing countries which, prior to this program, would not have been capable of producing bathymetric maps. The work carried out in the Bathymetric Capacity Building Projects will enable the rescue of a large volume of old data, produce a new world map in paper form, enable detailed regional map production, and increase the capabilities of scientists in developing countries through networking and reinforced training. Thus, at the end of the project, GEBCO will be ideally poised to meet the challenges ahead, supported by a network of active, younger, well-trained GEBCO scientists and hydrographers from developing countries. It is expected that many of these people will participate in GEBCO's Working Groups and Committees, where they will contribute to their on-going work and continue to develop their personal capacities through such active involvement.

Capacity Building Projects

The first group of seven trainees is doing very well in class work at the University of New Hampshire. In addition to learning, they are also teaching GEBCO members about the difficulties they envision on returning to their home countries and establishing seafloor mapping programs there. In most cases, there is very little existing infrastructure in place to support them. They will have to obtain resources (fiscal, human and equipment) and build a bathymetric mapping capability from the ground up. This will take time, and they may have to compete for scarce resources within their own country. It is now recognized that there is a risk that the excellent training they have received during the Certificate program will not be utilized to develop the home country's capacity, unless there is some support to help the returning students through the first year or two after they complete the Certificate. The Bathymetric Capacity Building Projects are designed to mitigate this risk though providing tangible products with which the returnees can demonstrate the value of bathymetry, with support to organize and convert data within their area, and with basic resources to help them become established. Without this, there is a real possibility that the gains realized during the formal training phase will not be capitalized upon. A description of the Bathymetric Capacity Building Projects is given in Annex 3

Spreading the word

The training, work and research opportunities proposed above are intended to launch a new generation of skilled bathymetrists who will form a world-wide network, based in developed and less developed countries, through the common training and education they have received and through their GEBCO contacts. The significance of this is that it will invigorate and speed up the process by which GEBCO updates and expands its products for the benefit of the whole of society including fields such as climate research, tide and tsunami prediction, fisheries, coastal processes and offshore pollution as well as scientific research.

“I do hope that the course extends beyond three years originally slated for the scholarship so as to have enough man power to explore and map our great ocean.”

Recommendations from the current students

The first intake of students have all risen to the challenge of being pioneers, and realized that the first year of a brand new program will inevitably have a few hiccups. They have also taken a very responsible position regarding the future of the course and have offered the following recommendations.

Academic Level of the Certificate

Students feel that the course is offered at a high enough level and contains sufficient content that successful candidates should be awarded more than a Graduate Certificate. They have made comparisons between their program and the published catalogues describing other programs and suggested that the content exceeds that of the FIG IHO Cat A certification since it has more courses and its courses are at a graduate level. Some have gone so far as to suggest that the course is equivalent to a non thesis Masters degree program.

Prior preparation of students entering the program

The present set of students appears to be a very good combination, as the science of ocean mapping comprises various aspects. No single branch of science offers includes everything needed. If possible, similar combinations of students (different backgrounds, knowledge and experience) should continue in the future. Students with background in Hydrography, Oceanography, Geology, applied marine science and geography should be able to cope with the course.

Content and intensity of courses comprising the program

Students have made different recommendations regarding the mix of core and elective courses, with some favoring promoting some of the present electives to core and others advocating demoting some core courses to elective status. All had suggestions about which courses should be offered in which term.

Networking

During the next three years, 21 students will study at UNH. Now, we, the first group of students have made good friends during the course. To expand our network further, it would be preferable that we have opportunities to meet the second and third year's students. Follow-up activities that provide us such opportunities would contribute much to globalizing and tightening our network for ocean mapping.

Incoming students

I recommend that next year's students bring brochures of the organization or institute where each student works in their home country. That will help other students easily know about all the projects the organization is carrying out as well as its organizational structure.

Conclusion

This course demonstrates several elements of international cooperation in hydrography. It brings together students, already serious professionals in their field, from several countries, and their interaction is clear proof that they are willing and able to work together in a mutually supportive way. It brings guest instructors from outside the US to work with UNH Faculty to broaden the subject matter offered. It is supported by the voluntary membership of GEBCO, an organization with contributors from many countries. Most Member States of the IHO support GEBCO through submitting their data for use in bathymetry mapping. It has organizational affiliations with hydrographers world wide through the IHO and to oceanographers through the IOC. None of this would have been possible without the support of the Nippon Foundation, a national organization in Japan that has a major international cooperative leadership role.

Annex 1 Nippon Foundation /GEBCO Training Project: Postgraduate Diploma in Ocean Bathymetry

BASIC CORE SUBJECTS

Depth measurements

Multibeam echo-sounder (MBES), single-beam echo-sounder, multichannel seismics

Remote sensing - lidar

Instrumentation packages

Sidescan

AUVs

Oceanography

Acoustics; backscatter, physics of sound in the sea, chemistry of ocean water, propagation of sound

Associated science: fisheries, turbulence, tsunami modeling

Oceanography: tides

Environmental aspects: coastal oceanography, slope and shelf processes

Marine biota and mammals

Sea Floor

Plate tectonics, sea floor morphology, ocean basins, sedimentary processes, hydrothermal-thermal processes

Gravity-magnetic relationships to seafloor fabrics

Positioning

Geodesy

Satellites

Navigation and positioning on and in sea

Maps and Charts**IHO standards**

Map/chart production

GIS

Nomenclature of features

Data processing**Digitizing, sampling**

Data bases

Gridding

Contouring

Spatial statistics: Kriging, fractals

Post processing of MBES data

IT subjects

Web site creation and authoring

Programming/coding: applications of, use of,

GEBCO as an entity

History of GEBCO and Ocean Mapping

Needs and requirements: use of GEBCO by cable layers, oil companies, defense, and v.v.

Copyright, who owns soundings, contours, charts

Outreach, community relationships

UNCLOS - Maritime Law

Personal Skills

Writing, oral presentation, communication

Annex 2. Training Program - Post-graduate Certificate in Ocean Bathymetry

Length of course: 12 months. Three courses to be run over three successive years.

Entry qualifications: formal internationally recognized qualification in the English language (written and spoken), a minimum of a four year Bachelors degree in a relevant subject with evidence of a suitable level of IT skills.

Recruiting students: The course will be advertised at least six months in advance of its commencement through all suitable means such as national Hydrographic Offices (via the IHO), the International Bathymetric Chart Editorial Boards and other international marine contacts (via the IOC) as well as directly through the GEBCO web site, Directors of national oceanographic laboratories and members of the GEBCO community. An advertisement will be displayed in a professional weekly newspaper (EOS) which members of the community normally receive.

Selection and number of students: Seven students will be trained per year. Candidates will be sought from developing coastal states on a regional basis plus one student from Japan. Students will be chosen on the basis of their application, recommendations from home institution and results of telephone interviews.

Location of course: University of New Hampshire, Durham, NH, USA.

Supervision of course: the course will be supervised and reviewed externally on an annual basis by representatives of GEBCO and the Nippon Foundation.

Exit qualification: successful students (judged by an appropriate combination of examination, course work and written project reports) will be awarded a Post-graduate Certificate in Ocean Bathymetry by the University of New Hampshire.

Design of course: the course will be designed by members of GEBCO in collaboration with staff of the host institution.

Content of course: the course will be taught, and written and spoken coursework will be conducted, in English. The course will consist of formal lectures for approximately 8 months, practical exercises, project work and secondments to one other laboratory and to a research/survey cruise, if possible.

Students selected for the PCOB program enroll in the Certificate of Ocean Mapping program. This is a recognized program of the Graduate School thus providing PCOB students with official graduate student status. Students in the Certificate Program are required to take the following courses:

ESCI/OE 870	Introduction to Ocean Mapping	4 Credits
ESCI/OE 871	Geodesy and Geomatics	3
ESCI/OE 972	Hydrographic Field Course	4
ESCI/OE 759/859	Marine Geology and Geophysics	4
ESCI 895/896	Bathymetric Mapping	3

These subjects are covered in various degrees of detail but in all cases, enough detail to have received recognition as IHO Category A course content. In addition to these courses Certificate Program students are required to take two electives from the following list:

ESCI 907	Geostatistics	3 Credits
ESCI 973	Seafloor Characterization	3
EOS/OE 854	Ocean Waves and Tides	4
OE 810	Ocean Measurements Lab	4
OE 885	Underwater Acoustics	4
OE/CS 867	Data Visualization	3
OE	Special Topics	4
NR 857	Photo Interpretation and Photogrammetry	4
NR 860	GIS in Natural Resources	4
ESCI 895,896	Topics in Earth Sciences	1-4
ESCI 959	Data Analysis Methods in Ocean Science	4
ESCI 995,996	Advanced Topics	1-4

There are numerous other continuing education short courses on IT and GIS subjects offered at the University and these will be available to the PCOB students. Visiting specialists will also provide specialized lectures.

Students will take the field course in the late spring of the year. Upon completion of the field course, students will participate in a deep-water cruise (if timing works out) and visit a laboratory elsewhere that has data or material relevant to their mapping project. They will complete their mapping project based on this experience and archived data.

Annex 3 Bathymetric Capacity Building Projects (CPBs)

(CBP1) A paper version of the GEBCO World Map. This project is envisioned as being one that will update the existing GEBCO world map of digital bathymetry on CDs to incorporate the localized maps produced by the students in the first year of the Nippon Foundation training program. The objective is to produce paper versions of the map rather than digital ones so they can be distributed freely to institutions and schools that do not have access to digital printing facilities themselves. Full credit to Nippon Foundation as the sponsor of the map

will be included. The updated world map, to replace one last printed in 1984, will be produced using the very latest in cartographic techniques. Land depiction will be satellite imagery rather than the normal simple colour layers. The water areas will be shown by shaded relief so that non-specialist viewers will be given a full impression of the seafloor as it would appear if the sea water were removed and illuminated by the sun. This will be a valuable educational tool and a means of bringing the Nippon Foundation/GEBCO Training Project and its objectives to the attention of many people worldwide. The project will be undertaken at the University of Stockholm in Sweden under the mentorship of Professor Martin Jakobsson (a member of the GEBCO community). It will involve one graduate from the first year of the Nippon Foundation training program. At the University of Stockholm the student will apply what he or she has learned at the University of New Hampshire as well as additional techniques developed under Dr Jakobsson.

(CBP2) Regional Map Production. By the end of their course students in the first class of the teaching program at the University of New Hampshire will have produced a map of part of the portion of the seafloor near their own country. One means of multiplying this effort and expanding this capability is to extend the area included in the map. Doing so will frequently require working with neighboring countries to demonstrate techniques learned during the teaching program and to obtain existing, and possibly new, data in adjacent areas. The newly trained Nippon Foundation graduates will be able to extend and apply their knowledge through teaching, demonstrating and explaining the importance of bathymetric mapping, not only within their own countries but also with neighboring countries and engage them in the production of a map at larger scales. It is envisioned that, initially, one of the returning students be funded to undertake such a project and have a technical assistant who will also become trained. The outcomes will be the production of a map of a larger portion of the seafloor, the building of capacity to build and create such maps in countries adjacent to that of the returning student's, and the development of cooperation in Ocean Mapping between the neighboring countries.

(CBP3) Reinforcement of training. Trainees in the Nippon Foundation teaching program at UNH have expressed a strong desire to build capacity further in their home organization by applying their newly-acquired skills on their return. This capacity building project will provide returning graduates with a computer and a modest budget to help them establish bathymetry mapping capability in their home institutions.

(CBP4) Conversion of hand-drawn sounding sheets into digital form. Quantities of hand-lettered depth soundings on sounding sheets are stored, sometimes under poor conditions, in laboratories around the world. The depths recorded on these sheets can be made enormously more valuable and accessible if they are converted into digital form and assimilated into GEBCO's data bases. This can be done at a minute fraction of the cost of using a ship to reacquire the data but requires teams of trained staff to rescue, digitize and quality control the individual

soundings and transfer them to a suitable digital format. Until a few months ago, this required laborious input of each data point by hand. However, a digitizing scanner was purchased by the Margaret Kendrick Blodgett Foundation and donated to GEBCO in response to the opportunity provided by the Nippon Foundation/GEBCO Training Project. In this project, up to 7 PCOB students from around the world will travel to the University New Hampshire for a few weeks each year bringing analogue data (sounding sheets) from their home country area. At UNH, they will use the digital scanner to convert the hand-drawn sheets into digital data to which modern mapping tools can be applied, and build their own knowledge base through interaction with UNH.

(CBP5) Local Network Building In some of the countries, to which Nippon Foundation trainees will return, some bathymetric data already exist but they are dispersed through different laboratories and organizations. As such, the data cannot be used in map production since there are neither trained workers nor even the facilities to submit them to the World Data Centers. In this project, returning students would be funded at a low level to visit different institutions in their local geographic area, examine their data holdings, and enlist their support for having the data submitted to the World Data Centers. This will use the Nippon Foundation graduates to build local capacity and knowledge to support bathymetric mapping in remote areas.

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