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# Editorial

This edition comprises one article, several notes and general information. The article from Canada describes their research efforts through a competitive analysis study of a number of current web-mapping applications that deliver ocean related data to the scientific community. Their analysis of the data types, uncertainty, time, basemaps, operators and technologies should provide useful information to other groups establishing web mapping capabilities. As more data becomes available to the open community, finding the right balance to meet a wide user expectation of web map data content and presentation will be challenging.

The establishment of a hydrographic service in Mauritius through the IHO Capacity Building program along with the support of several national Mauritius government agencies is a terrific success story and a good model for other nations who are in the early stages of establishing their own hydrographic service. The establishment of this organisation and the work that has been undertaken in the last 5 years is a positive testament to the goals and aspirations of IHO capacity building and what can be achieved.

A further note from one of my Australian colleagues describes some innovative development to improve the generation of depth contours particularly when compiling Electronic Navigation Charts (ENCs). Having spent many hours compiling contours for charting myself, it is satisfying to know that automated processes to improve the near-final depiction are available. Contouring within the nautical cartographer community will always present a variety of opinions, but the work undertaken within the AHO, I hope will be of interest may be considered by other HOs wanting to improve productivity whilst not compromising quality or aesthetics.

The USA has provided an update on their program to evaluate the bathymetry holdings within the IHO's Data Centre for Digital Bathymetry that is hosted by the National Oceanic and Atmospheric Administration (NOAA). The authors presented a comprehensive paper at the 2018 Joint Hydrographic and National Surveyor's Conference and the link to this paper is provided in the Reference section of the Note.

Finally, we include an obituary for Rear Admiral Kenneth Barbor, USN (USA) who was a past Director of the IHB Directing Committee. It is always sad to farewell a fellow professional but it is pleasing to recognise his achievements.

On behalf of the Editorial Board, I hope this edition is of interest to you and may inspire you to submit a future paper on the work that you have done or are currently engaged in. Thank you to the authors for your contributions and to my colleagues who provided peer reviews for the article in this edition.

Ian W. Halls
Editor

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# COMPETITIVE ANALYSIS OF CURRENT OCEAN WEB-MAPPING APPLICATIONS

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## Abstract

A competitive analysis study is a usability engineering method administered to critically analyze and compare a set of similar applications according to their relative merits. This paper presents a competitive analysis study of current ocean web-mapping applications that deliver ocean related data to the scientific community. The analysis is part of a User-Centered Design (UCD) approach that was applied to develop the Ocean Web-Mapping Application of the Ocean Mapping Group (OMG) at the University of New Brunswick (UNB), a web mapping application to deliver ocean mapping data to ocean modellers. A total of twenty-four existing applications were critically analyzed and compared across two broad themes in cartography: (1) representation and (2) interaction; adding topics to consider the potential needs of ocean modellers. The results helped to establish trends and gaps and to discover new opportunities for ocean web-mapping development. Using the conclusions drawn from this study, an online survey was prepared to be conducted by ocean modellers and continue the UCD methodology of the Ocean Web-Mapping Application.

## Résumé

Une analyse concurrentielle est un procédé d'ergonomie informatique appliqué afin d'effectuer une analyse critique et une comparaison d'une série d'applications similaires selon leurs mérites respectifs. L'article qui suit présente une analyse concurrentielle des applications existantes de cartographie en ligne des océans fournissant à la communauté scientifique des données relatives à l'océan. Cette analyse entre dans le cadre de l'approche axée sur l'utilisateur (UCD) qui a servi à développer l'application de cartographie en ligne des océans du groupe de cartographie océanique (OMG) à l'université du Nouveau Brunswick (UNB), application de cartographie en ligne dont l'objectif est de fournir des données de cartographie océanique aux spécialistes de la modélisation des océans. Un total de vingt-quatre applications existantes ont fait l'objet d'une analyse critique et ont été comparées à travers deux thèmes généraux de cartographie : (1) représentation et (2) interaction ; d'autres thèmes ont été ajoutés pour évaluer les besoins potentiels des spécialistes de la modélisation des océans. Les résultats ont permis d'aider à dégager des tendances et à déceler des lacunes, ainsi qu'à découvrir de nouvelles opportunités de développement de la cartographie en ligne des océans. A partir des conclusions tirées de cette étude, une enquête en ligne a été élaborée pour être effectuée par les spécialistes de la modélisation des océans et en vue de la poursuite de la méthodologie UCD des applications de cartographie en ligne des océans.

Article

## Resumen

Un estudio de análisis competitivo es un método de ingenieria de la usabilidad utilizado para analizar y comparar de forma crítica un conjunto de aplicaciones similares según sus méritos relativos. Este artículo presenta un estudio analítico competitivo de aplicaciones de mapas web actuales que ofrecen datos relacionados con las ciencias oceánicas a la comunidad científica. El análisis forma parte de un enfoque UCD (User-Centered Design - Diseño Centrado en el Usuario), que fue aplicado para el desarrollo de la Aplicación Web de Cartografía Oceánica del OMG (Ocean Mapping Group - Grupo de Cartografía Oceánica) de la Universidad de New Brunswick (UNB), una aplicación de mapas web que ofrece datos de cartografía oceánica para la generación de modelos oceánicos. Un total de veinticuatro aplicaciones existentes fueron analizadas y comparadas críticamente en dos amplias temáticas de la cartografía: (1) la representación y (2) la interacción, añadiendo tópicos que consideren las posibles necesidades durante la generación de modelos oceánicos. Los resultados ayudaron a establecer tendencias y deficiencias, y a descubrir nuevas oportunidades para el desarrollo de aplicaciones web de cartografía oceánica. A partir de las conclusiones sacadas en este estudio, se preparó una encuesta en línea que será realizada por científicos dedicados a la generación de modelos oceánicos y permitirá la continuación de la Metodología UCD de la Aplicación Web de Cartografía Oceánica.

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## *1. Introduction*

User-Centered Design (UCD) can be described as the approach followed for the creation of a new object in which end users influence how the design process takes shape (McLoone et al., 2010). Regarding web interfaces design, Nielsen (1992; 1994) developed a usability engineering model based on eleven design stages, including the competitive analysis method on the third stage. A competitive analysis critically compares existing products supporting similar use cases to determine how the proposed product should look to fill unmet needs. If several products are available, an analysis of the different design approaches can provide ideas for a new design, and guidelines for good or bad approaches. Therefore, during a competitive analysis, designers and developers evaluate the interface themselves using theoretical frameworks (Roth, Ross, and MacEachren, 2015).

The analysis was completed during the early stages of the UCD methodology of the Ocean-Web Mapping Application, a web mapping application to deliver ocean mapping data to ocean modellers. Previous stages included an informal interview with an ocean modeller, which allowed the identification of potential data and functionality to include within this analysis. The competitive analysis method was chosen next because it would depict the state of the art regarding ocean web mapping applications, and it would help to discover trends and gaps within these applications, opening new opportunities for development.

The theoretical framework used by this analysis is based on the one described by Roth et al. (2015) and follows Roth's (2013a) distinction within cartography: (1) representation and (2) interaction, adding additional topics which consider the needs of ocean modellers, extracted from the previous informal interview. The methodology and results are followed by a summary of design recommendations that will be used to prepare an online survey for ocean modellers as the next stage of the UCD methodology of the Ocean Web-Mapping application. Combining the previous informal interview, the competitive study and the next online survey, a requirements document will be prepared to support the development of the Ocean Web-Mapping Application prototype. An application developed using this kind of UCD approach makes the data available to the community considering its context of use, and it will bridge the gap between ocean modellers and ocean data, providing them with the data and functionalities they need.

## *2. Methodology*

A competitive analysis study of twenty-four existing ocean web mapping applications was conducted. The requirements for the inclusion in the analysis were:

a. The application is a web-map based application, and
b. The application provides potentially useful data for the ocean community, such as bathymetry, temperature, salinity, weather data or other information.

The applications evaluated are shown in ***Table 1***, including name, a brief description of the application, and the link to the web portal. For the rest of this article, numbers shown are referenced to the first column (#) of ***Table 1***.

Bathymetry and ocean mapping data collection are usually part of government or research organizations, as every country needs to map their territory and marine jurisdiction for political and environmental purposes. The government usually offers this data to the public, either freely (NOAA, 2013), or by limited licensing agreements (e.g. Canadian Hydrographic Service).

In the United States, ten applications were developed, supported or funded by U.S. Federal agencies [1, 2, 3, 5, 6, 7, 8, 20, 24], one by an alliance of U.S. State agencies [5], a university research project [6], an alliance between several organizations and non-profit agencies [2], and two of them are owned by private companies or industries [4, 9]. In Europe, there are four applications developed by national institutions [10, 11, 12, 14] and one common for the European Commission [13]. Within Canada, several applications were included in the analysis: the government of Canada web portal for data products and surveys [16], a federal and provincial government organization application [22], one application owned by a private company [21], a project from the University of Victoria [23], and two research projects from the University of New Brunswick [18, 19]. The government of Australia also provides a web portal for bathymetry and backscatter data [17]. Finally, one of the tools analyzed [15] is an alliance between EU, Canada and US for Atlantic Ocean Research Cooperation.

Regarding geographic coverage, seven applications have a coverage of the entire globe [1, 2, 3, 4, 7, 9, 21]; seven by a single country [8, 9, 12, 15, 16, 20, 23]; three by several US states [5, 6, 24]; three are regional [18, 19, 22]; and five include several countries and jurisdictions [10, 11, 13, 14, 17].

The methodology to perform the competitive analysis followed Roth's (2013a) distinction within cartography: **Representation**, i.e. the way the information in the map is encoded, and **Interaction**, i.e. the ways a user can manipulate the map. The topics covered were based on those analyzed by Roth (2015) but included several additional topics that considered the potential needs of the ocean modelling community.

Related to **representation**, a total of four topics were analyzed:

(a) data offered/represented (see 3.1),
(b) inclusion of uncertainty as a variable of the information (see 3.2),
(c) inclusion of time as a variable of the information (see 3.3), and
(d) variation in the basemap provided (see 3.4).

Related to **interaction**, a total of four topics were analyzed:

(a)variation across supported interaction operators that will include data download functionalities and analysis tools (see 3.5);
(b)supported formats, distinguishing between:
  a.bathymetry formats (see 3.6);
  b.other kinds of data formats (see 3.7); and
(a)variation in the web mapping technology used to implement the web application and mobile support (see 3.8).

***Table 1.*** *Web mapping applications included in the Competitive Analysis*

| # | Name | Description |
|---|---|---|
| 1 | NOAA Bathymetry Data Viewer | Bathymetry downloading service by the U.S. National Oceanic & Atmospheric Administration (NOAA). It includes multibeam and single beam data, Bathymetric Attributed Grid (BAG) surfaces, Digital Elevation Models (DEM), etc. Multibeam and single beam data are available for the entire globe. BAG surfaces/Lidar and DEM mostly limited to the U.S. |
| 2 | IEDA Data Browser / GMRT MAP TOOL | Allows downloading bathymetry grid files of any part of the world using the Global Multi-Resolution Topography (GMRT) dataset. |
| 3 | International Hydrographic Organization Data Centre for Digital Bathymetry Viewer | Web-application to download digital bathymetry products. Bathymetry data is available for the entire globe. BAG surfaces/Lidar mostly limited to the U.S. |
| 4 | Bathymetrics Data Portal | Simple web-mapping application that allows purchasing bathymetry datasets (2m or 90m resolution). |

| | | |
|---|---|---|
| 5 | MID-ATLANTIC OCEAN DATA PORTAL | Data portal including different ocean datasets that allows building ocean stories using storytelling techniques. |
| 6 | Pacific Islands Ocean Observing System Voyager | An interactive map interface for visualizing and downloading oceanographic observations, forecasts, and other ocean related data. |
| 7 | NOAA Grid Extract | Simple NOAA downloading service for the global bathymetry models. |
| 8 | Data Access Viewer | NOAA downloading portal for elevation, imagery and land cover. It includes coastal bathymetry lidar. |
| 9 | Planet OS | Data hub from different providers. Access to weather, climate and environmental datasets. |
| 10 | CCLME ECO-GIS Viewer | Dynamic Geographic Information Systems (GIS) analytic tool aimed to create meaningful data products of the ocean. |
| 11 | Mareano | Data portal for bathymetry, sediment composition, biodiversity, habitats, biotopes and other kinds of biological and ocean data for the Norwegian offshore areas. |
| 12 | INFOMAR Data Viewer | The INtegrated Mapping FOr the Sustainable Development of Ireland's MARine Resource integrates mapping products of the physical, chemical and biological features of the seabed. |
| 13 | EMODnet portal for Bathymetry | Web-application from the European Marine Observation and Data Network (EMODnet). It allows downloading bathymetry products for the European Union region. Gaps with no data coverage are completed by integrating the General Bathymetric Chart of the Oceans (GEBCO) digital Bathymetry. |
| 14 | Baltic Sea Bathymetry Database | The Baltic Sea Bathymetry Database (BSBD) distribute bathymetry data for the areas of all Baltic Sea countries. |
| 15 | North Atlantic Data Viewer | Bathymetry from different sources: NOAA, EMODNet, Natural Resources Canada (NRCan) and Mareano |
| 16 | Data products and surveys | Bathymetry data products from the government of Canada. |
| 17 | Bathymetry and Backscatter Data Access | Different resolution bathymetry and backscatter data for the Australian area. Maintained by Geoscience Australia. |
| 18 | Lower Saint John River Data Overview | Web portal for the bathymetric surveys performed by the OMG at the UNB. It also includes Conductivity, Temperature and Depth (CTD) data. |
| 19 | ArticNet Amundsen Multibeam Data | Bathymetry and Backscatter data web application that includes the multibeam data collected for the ArticNet Amundsen project. |
| 20 | Tide data viewer | NOAA tidal and currents sensors viewer. |
| 21 | Ocean Viewer | Data hub that links to the different providers for real time ocean and weather variables. Data is retrieved as animated grids. Note: web site is not operational. The following link is given in case it is resumed: http://oceanviewer.org/atlantic-canada/water-temperature/global-rtofs/test554 |
| 22 | Marine Conditions | The application displays a wide range of recent and near real-time data collected by various monitoring systems installed in a vast territory from the Great Lakes to the St. Lawrence Gulf. They recently included data for the Canadian west coast. |
| 23 | Ocean Networks Canada | The organization operates ocean observatories around Canada, collecting data on physical, chemical, biological, and geological aspects of the ocean to support the scientific and research community. |
| 24 | SECOORA | South East Coastal Ocean Observing Regional Association. Real-time sensors data visualization and downloading for the U.S. South Coast. |

## *3. Results*

Analyzing the set of existing applications, there exist several patterns worth mentioning. First, some applications are only focused on bathymetry data, while others include bathymetry as well as other ocean data observations. In the first group, most of the applications are intended for data distribution and download; some for free [1, 2, 3, 7, 9, 15, 18, 19], free under request [1, 3, 15] or by purchase [1, 3, 4, 8, 9, 15, 16]. Bathymetry focused applications usually limit their functionality to show only what data is available for a given organization, providing a link for download and serving as data repositories. Planet OS [9] is a special case of a website, being a Datahub linking to ocean, weather and climate data from the main government organizations and companies. In contrast to the first group, other applications support data exploration, enabling more user interaction through querying, filtering and basic analysis or calculations, such as depth profiles, measuring tools [10, 13, 14, 17], area statistics [6], or even storytelling techniques to support marine planning [5].

## 3.1. Data included

The web applications were analyzed to determine if they include the different data types expected to be useful for an ocean modeller (***Table 2***). This information was provided from the previous informal interview and identified bathymetry, CTD profiles, weather, tidal, coastlines, water level, river discharge and currents as important data.

***Table 2.*** *Data types included in the web mapping applications*

| # | Name | Bathymetry | CTD Profiles | Weather | Tidal | Coast lines | Water level | River discharge | Currents | TOTAL | Other kinds of data |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | NOAA Bathymetry Data Viewer | ✓ | | | | | | | | 1 | Lidar Bathymetry. DEM |
| 2 | GMRT MAP TOOL | ✓ | | | | | | | | 1 | Cruise tracks, geochemistry data, seismic data, etc. |
| 3 | Crowdsourced Bathymetry | ✓ | | | | | | | | 1 | DEM |
| 4 | Bathymetrics Data Portal | ✓ | | | | | | | | 1 | |
| 5 | MID-ATLANTIC PORTAL | ✓ | | ✓ | | | | | | 2 | Oceanographic data, seabed forms, |
| 6 | Voyager | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | | 7 | Benthic habitats, ocean glider data |
| 7 | NOAA Grid Extract | ✓ | | | | | | | | 1 | |
| 8 | Data Access Viewer | ✓ | | | | | | | | 1 | Imagery, Land Cover, Elevation |
| 9 | Planet OS | ✓ | | ✓ | | | | | ✓ | 3 | Climate and environmental data |
| 10 | CCLME ECO-GIS Viewer | ✓ | ✓ | ✓ | | | ✓ | ✓ | | 5 | Upwelling index, floating devices profiles, biological data |
| 11 | Mareano | ✓ | | | | ✓ | | | ✓ | 3 | Sediments, habitats, etc. |
| 12 | INFOMAR Data Viewer | ✓ | ✓ | | | | | | | 2 | Seabed classification, survey track lines, etc. |
| 13 | EMODnet | ✓ | | | | ✓ | | | | 2 | |
| 14 | Baltic Sea Bathymetry Database | ✓ | | | | | | | | 1 | |
| 15 | North Atlantic Data Viewer | ✓ | | | | | | | | 1 | |
| 16 | Data products and surveys | ✓ | | | | | | | | 1 | Nautical charts, Natural Resources maps |
| 17 | Bathymetry and Backscatter Data Access | ✓ | | | | | | | | 1 | Backscatter data |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | Lower Saint John River Data Overview | ✓ | | | | | | | | 2 | Survey footprints |
| 19 | ArticNet Amundsen Multibeam Data | ✓ | | | | | | | | 1 | Backscatter |
| 20 | Tide data viewer | | | ✓ | ✓ | | ✓ | | ✓ | 4 | |
| 21 | Ocean Viewer | | | ✓ | ✓ | | | | ✓ | 3 | Salinity, Chlorophyll, etc. |
| 22 | St. Lawrence Global Observatory | | | ✓ | | | ✓ | | ✓ | 3 | |
| 23 | Ocean Networks Canada | | ✓ | ✓ | | | | | ✓ | 3 | |
| 24 | SECOORA | | | ✓ | | | ✓ | ✓ | ✓ | 4 | Stream Height |
| **TOTAL** | | 19 | 4 | 9 | 3 | 3 | 5 | 3 | 7 | | |

There are nineteen applications that provide bathymetry (n=19), nine applications that provides weather data (n=9), seven that provide current data (n=7), five that provide water level data (n=5), four that provide CTD data (n=4), and three that provide tidal, coastlines or river discharge data (n=3). The results from the analysis subdivide the web pages into three main categories:

(a) bathymetry data portals (n=14), which exclusively deliver bathymetry data and they do not include additional data [1, 2, 3, 4, 7, 8, 12, 13, 14, 15, 16, 17, 18, 19];
(b) sensors and observations data portals (n=5), as the opposite of bathymetry data portals, they deliver all kinds of data but bathymetry, only focusing on observations (either real time or historical) [20, 21, 22, 23, 24];
(c) data portals that combine both bathymetry and other kinds of data (n=5) [5, 6, 9, 10, 11].

CCLME ECO-GIS Viewer [10] and Pacific Islands Ocean Observing System Voyager [6] are the web portals which offer almost all the different datasets, being the most complete. However, none of the applications provide all the data expected to be useful by an ocean modeller. In particular, CTD profile data, although the main product of ocean mapping surveys is not usually delivered, with only four web portals offering it [10, 12, 18, 23]. Furthermore, river discharge, tidal data and coastlines are useful data for ocean modellers; however, only three web applications deliver this kind of data, and not usually in combination with bathymetry products.

### 3.2 Inclusion of Uncertainty

Uncertainty is a measure that describes any mismatch between reality and the user's understanding of reality (Roth, 2009). It can appear at any part of the process of converting the reality into knowledge:

- reality,
- variable-definition,
- data-collection,
- information-assembly,
- knowledge-construction (Longley et al. 2005).

Information uncertainty in Geomatics is described using (at least) three components (MacEachren et al., 2012):
(a) accuracy/error, or the correctness of a measurement or estimate,
(b) precision/resolution, or the exactness of a measurement or estimate, and
(c) trustworthiness, or the confidence that the user has in the information.

The results from the analysis show that uncertainty is not represented on the map as a cartographic variable in any of the web applications. Moreover, weather data and other observations are not accompanied by the uncertainty of the measurement. As an exceptional case, INFOMAR Data Viewer [12] includes data quality as one of the attributes for the Moving Vessel Profiler (MVP) surveys. However, this information is limited to good/fair/unknown/DNP, without any explanation about the meaning of these values.

Some of the bathymetric tools however do include uncertainty information related to two themes:
(a) bathymetry uncertainty (the uncertainty associated to the depth measurement) and
(b) bathymetry resolution (the pixel size in the real world of the grid).

***Table 3*** provides an overview of the inclusion of these two kinds of uncertainty across the web applications. Bathymetry uncertainty is included in four tools [1, 3, 15, 18], but only as a component of the BAG bathymetry format (not represented on the map). Bathymetry resolution is included in six tools [4, 6, 8, 12, 14, 17]. There are different resolution options depending on the area in four applications [4, 6, 12, 14], usually due to different surveys that were performed at different scales. In the Baltic Sea Bathymetry Database [14], the resolution is limited to high/low, with no numerical values; and INFOMAR Data Viewer [12] provides a tool to resample every 2$^{nd}$ or 10$^{th}$ cell but does not provide numerical values of the actual resolution. In the other two tools [8, 17], information about the resolution is only included as metadata (name of the layer), and no different options are given. Blue squares in ***Table 3*** indicate that the tool considers uncertainty data.

***Table 3.*** *Inclusion of uncertainty in the web mapping applications*

| # | Name | Bathymetry uncertainty | Bathymetry resolution |
|---|---|---|---|
| 1 | NOAA Bathymetry Data Viewer | ✓ | |
| 3 | Crowdsourced Bathymetry | ✓ | |
| 4 | Bathymetrics Data Portal | | ✓ |
| 6 | Pacific Islands Ocean Observing System Voyager | | ✓ |
| 8 | Data Access Viewer | | ✓ |
| 9 | Planet OS | Depends on the data source | |
| 12 | INFOMAR Data Viewer | | ✓ |
| 14 | Baltic Sea Bathymetry Database | | ✓ |
| 15 | North Atlantic Data Viewer | ✓ | |
| 17 | Bathymetry and Backscatter Data Access | | ✓ |
| 18 | Lower Saint John River Data Overview | ✓ | |
| TOTAL | | 4 | 6 |

### 3.3 Inclusion of Time

***Table 4*** summarizes the inclusion of time across the web mapping applications. The results show that time is not represented or usually considered in bathymetric focused applications. The only way to know the date and time a survey was performed is by querying the layer or searching through the metadata. Both UNB tools [19, 20] include the year of the survey as the name of the layer; therefore, a user would be able to select the bathymetry depending on the year. NOAA applications provide a time search (by year) for the surveys.

As opposed to bathymetry tools, time is considered in all the web applications that contain sensor observations, either as a search tool that applies a filter or as a time slider that allows the user to change the date/time of the visible measurements. Ocean viewer [21] includes a sophisticated animation tool that allows the user to visualize on the map the different gridded data provided as a time series.

Other interesting inclusions of time in ocean web mapping applications include the ones related to ocean gliders and CTD data. Pacific Islands Ocean Observing System Voyager [6] provides an animation tool for visualizing the movement of ocean gliders; however, it does not provide a search or query tool to retrieve data based on date or time (the only filter is by vessel). CCLME ECO-GIS Viewer [10] provides a spatiotemporal data viewer that allows the user to find CTD data for a specific month or year. Blue squares in ***Table 4*** indicate that the tool includes time as a variable.

***Table 4.*** *Inclusion of time across the web mapping applications*

| # | Name | Time filter | Time slider | Time search | File name | TOTAL |
|---|---|---|---|---|---|---|
| 1 | NOAA Bathymetry Data Viewer | | | ✓ | | 1 |
| 3 | Crowdsourced Bathymetry | | | ✓ | | 1 |
| 6 | Pacific Islands Ocean Observing System Voyager | | ✓ | | | 1 |
| 10 | CCLME ECO-GIS Viewer | ✓ | | ✓ | | 2 |
| 18 | Lower Saint John River Data Overview | | | | ✓ | 1 |
| 19 | ArticNet Amundsen Multibeam Data | | | | ✓ | 1 |
| 20 | Tide data viewer | ✓ | | ✓ | | 2 |
| 21 | Ocean Viewer | | ✓ | | | 1 |
| 22 | St. Lawrence Global Observatory | ✓ | | ✓ | | 2 |
| 23 | Ocean Networks Canada | ✓ | | ✓ | | 2 |
| 24 | SECOORA | | ✓ | | | 1 |
| TOTAL | | 4 | 3 | 6 | 2 | |

## 3.4. Basemap context information

Web mapping applications are usually organized into basemaps and overlays. Basemap layers are usually rasterized, serving as a set of tiles to provide context information to the user, who will retrieve information about overlay layers. ***Table 5*** provides an overview of the most important basemap options available across the web mapping applications. Some of the applications offer other kinds of basemaps not included in ***Table 5***. Blue squares in ***Table 5*** indicate the kind of basemap that is included in the application. A darker blue shaded square, indicate the default basemap when the application is loaded.

***Table 5.*** *Kinds of basemaps used across the web mapping applications*

| # | Name | Street Map | Satellite Image | Hybrid map | Topographic | Ocean basemap | Nautical Charts | Bathymetry | Simple | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | NOAA Bathymetry Data Viewer | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | 7 |
| 2 | IEDA Data Browser / GMRT MAP TOOL | | | | | | | ✓ | | 1 |
| 3 | Crowdsourced Bathymetry | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | 7 |
| 4 | Bathymetrics Data Portal | | | | | | | ✓ | | 1 |
| 5 | MID-ATLANTIC OCEAN DATA PORTAL | ✓ | ✓ | ✓ | | ✓ | ✓ | | | 5 |
| 6 | Pacific Islands Ocean Observing System Voyager | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | 6 |
| 7 | NOAA Grid Extract | | | | | | | ✓ | | 1 |
| 8 | Data Access Viewer | ✓ | ✓ | | | | | | ✓ | 3 |
| 9 | Planet OS | | | | | | | | ✓ | 1 |
| 10 | CCLME ECO-GIS Viewer | | | | | ✓ | | ✓ | | 2 |
| 11 | Mareano | | | | | | | ✓ | | 1 |
| 12 | INFOMAR Data Viewer | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | 6 |
| 13 | EMODnet portal for Bathymetry | | | | | ✓ | | | | 1 |
| 14 | Baltic Sea Bathymetry Database | | | | | | | ✓ | | 1 |
| 15 | North Atlantic Data Viewer | | ✓ | ✓ | | ✓ | | ✓ | ✓ | 6 |
| 16 | Data products and surveys | | | | | ✓ | | | | 1 |
| 17 | Bathymetry and Backscatter Data Access | | ✓ | | | ✓ | | | | 2 |
| 18 | Lower Saint John River Data Overview | ✓ | | | | | | | | 1 |
| 19 | ArcticNet Amundsen Multibeam Data | ✓ | ✓ | | ✓ | | | | | 3 |
| 20 | Tide data viewer | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | 7 |
| 21 | Ocean Viewer | ✓ | ✓ | | | | | | ✓ | 4 |
| 22 | St. Lawrence Global Observatory | ✓ | ✓ | | | | | | | 2 |
| 23 | Ocean Networks Canada | | ✓ | | | | | | | 1 |
| 24 | SECOORA | | ✓ | | | | | | | 1 |
| **TOTAL MAIN** | | 2 | 6 | 1 | 0 | 7 | 0 | 5 | 3 | |
| **TOTAL** | | 9 | 14 | 7 | 4 | 11 | 3 | 10 | 9 | |

The analysis identified eight different basemap types: satellite image (n=14), simple basemap (as a grey/black/white map) (n=13), ocean basemap (ocean basemap from Esri) (n=11), global bathymetry (as any layer portraying the global bathymetry of the oceans) (n=10), street map (n=9), hybrid map (n=7), topographic/terrain (n=4) and nautical charts (n=3). None of the applications provides all the basemaps options, and there are many tools that only provide one basemap (n=10). This fact might be explained because they only support downloading operations and the user interaction is limited (and not necessary). There are a large number of tools providing simple basemaps (n=9), and it is the starting basemap in three tools (n=3). This could show a tendency of ocean web mapping applications to be simplistic, either because the main purpose is just downloading data or because of design purposes.

Also, there is a trend for some of the web mapping applications to simply use the basemap tool from Esri, which provides a set of standard basemaps options. This might be the reason why the number of web applications that provides street maps as a basemap is high (n=9). A street map might be viewed as of little use for ocean web mapping applications. On the other hand, a nautical chart basemap might seem like one of the best regarding ocean web mapping applications; however, there are only three tools which provide it (n=3). This information is usually owned by government organizations and not openly available to the public. Therefore, it may be hard to access.

As an exceptional case, Pacific Islands Ocean Observing System Voyager [6] provides more than 20 additional different options for basemaps, apart from the one mentioned on Table 5. The provision of more number of basemap options might seem useful as it could support a wider range of user tasks, allowing the map to be personalized (Roth, 2015). However, a huge number of options might overwhelm the user and be unnecessary for the purpose of the map.

### 3.5. Supported interaction functionalities

Interaction functionalities describe any functionality which allows the user to interact with the map or the application (Roth 2012; Roth 2013b). ***Table 6*** provides an overview of the supported interaction functionalities across the web mapping applications. The most commonly implemented functionality is **metadata retrieval** (n=19). This allows users to retrieve metadata of a set of data, either as a link or as information shown in the same map view. The second most implemented functionality is requesting **help or tutorials** about the tools (n=17). The applications provide a page or help button explaining how the application must be used. The third most common functionality implemented was **information retrieval** (n=15), or the ability to request specific details about a feature on the map, which is a common functionality in web mapping applications.

**Data download**, which is one of the main purposes in ocean web mapping applications, was subdivided into two functionalities: bulk download (n=12), downloading whole datasets; and data download by area (n=13), allowing the user to draw an area on the map to download only a specific set of data. Most of the applications include one or both options [6, 8, 13, 17, 23]; and there are only four applications [5, 10, 11, 19] which do not provide any options.

The **filter** and the **search** functionality are implemented in twelve applications (n=12), and somewhat related to each other. **Filtering** is the ability to adjust the map to only show map features that match one or more user-defined conditions. **Searching** is the ability to identify map features of interest. Most of the applications provide a search tool that applies a filter on the map when a specific kind of feature is selected. Blue squares in ***Table 6*** indicate that the functionality is implemented in the application.

***Table 6**. Supported interaction functionalities across the web mapping applications*

| # | Bulk Data download | Area Data download | Filtering | Searching | Area of interest | Info retrieval | Change projections | Measuring tools | Save/print map | Own data | Map annotation | Metadata retrieval | Longitudinal profiles | Vertical profiles | Export profiles | Area statistics | User profiles | Help/tutorials | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ✓ | | ✓ | ✓ | | | ✓ | | | | | ✓ | | | | | | ✓ | 6 |
| 2 | | ✓ | | | | | ✓ | | | | | | ✓ | | ✓ | | | | 4 |
| 3 | ✓ | | ✓ | ✓ | | | ✓ | | | | | ✓ | | | | | | ✓ | 6 |
| 4 | | ✓ | | | | | | | | ✓ | | | | | | | ✓ | | 3 |
| 5 | | | | ✓ | | ✓ | | | ✓ | ✓ | ✓ | ✓ | | | | | ✓ | | 7 |
| 6 | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | | | ✓ | | ✓ | ✓ | ✓ | | ✓ | 1 |
| 7 | | ✓ | | | | | | | | | | | | | | | | | 1 |
| 8 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | ✓ | | | | | | ✓ | 8 |
| 9 | ✓ | | ✓ | ✓ | | ✓ | | | | | | ✓ | | | | | ✓ | | 6 |
| 10 | | | ✓ | ✓ | | ✓ | | | | ✓ | | | ✓ | ✓ | ✓ | | | ✓ | 8 |
| 11 | | | | ✓ | | ✓ | ✓ | ✓ | ✓ | | | ✓ | | | | | | ✓ | 7 |
| 12 | | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | ✓ | 1 |
| 13 | ✓ | ✓ | | | | ✓ | | ✓ | | ✓ | | ✓ | ✓ | | ✓ | | | ✓ | 9 |
| 14 | | ✓ | | | | | | | | | | ✓ | ✓ | | | | | ✓ | 4 |
| 15 | ✓ | | | | | | | | | | | ✓ | | | | | | ✓ | 3 |
| 16 | ✓ | | ✓ | | | | | | | | | | | | | | | ✓ | 3 |
| 17 | ✓ | ✓ | | | | ✓ | | ✓ | | | | ✓ | ✓ | | | | | | 6 |
| 18 | ✓ | | | | | ✓ | | | | | | ✓ | | | | | | ✓ | 4 |
| 19 | | | | | | ✓ | | | | | | ✓ | | | | | | | 2 |
| 20 | | ✓ | ✓ | ✓ | | ✓ | | | | | | ✓ | | | | | | ✓ | 6 |
| 21 | ✓ | | | | | ✓ | | | | | | ✓ | | | | | | ✓ | 4 |
| 22 | | ✓ | ✓ | | | | | | | | | ✓ | | | | | ✓ | ✓ | 5 |
| 23 | ✓ | ✓ | ✓ | ✓ | | ✓ | | | | | | ✓ | | | | | ✓ | ✓ | 8 |
| 24 | | ✓ | ✓ | ✓ | | ✓ | | | | | | ✓ | | | | | | ✓ | 6 |
| TOTAL | 1 | 1 | 1 | 1 | 1 | 1 | 4 | 5 | 4 | 5 | 2 | 1 | 6 | 2 | 4 | 1 | 5 | 1 | |

### 3.6. Bathymetry Supported formats

***Table 7*** provides the results from the analysis of bathymetry supported formats. The most supported formats are GeoTIFF (n=6) and BAG, LAS/LAZ and ArcGIS ASCII formats (n=5). Most of the tools make available more than one format for downloading bathymetry data. There are only three applications [8, 16, 18] which only provide one format. Blue squares in ***Table 7*** indicate that the application provides that data format.

***Table 7.*** *Kind of bathymetry formats offered to the user across the web mapping applications*

| # | BAG | Raw data | LAS/LAZ | GeoTIFF Float 32 | GeoTIFF RGB | GMT | ArcGIS ASCII | NetCDF | XYZ | ArcGIS Grid | Fledermaus Scene | PNG Image | NGrid | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ✓ | ✓ | ✓ | | | | | | | | | | | 3 |
| 2 | | | | ✓ | | ✓ | ✓ | ✓ | | | | | | 4 |
| 3 | ✓ | ✓ | ✓ | | | | | | | | | | | 3 |
| 4 | Data Available only under purchase (format unknown) | | | | | | | | | | | | | |
| 6 | | | | ✓ | | | | ✓ | | | | | | 2 |
| 7 | | | | ✓ | | ✓ | ✓ | ✓ | ✓ | | | | | 5 |
| 8 | | | ✓ | | | | | | | | | | | 1 |
| 9 | Need for an account | | | | | | | | | | | | | |
| 12 | | | ✓ | | | | | | | ✓ | ✓ | | | 3 |
| 13 | | | | ✓ | ✓ | | ✓ | | | | | | | 3 |
| 14 | | | | ✓ | ✓ | | ✓ | | ✓ | | | ✓ | | 5 |
| 15 | ✓ | ✓ | ✓ | | | | | | | | | | | 3 |
| 16 | ✓ | | | | | | | | | | | | | 1 |
| 17 | | | | ✓ | | | ✓ | | | | | | ✓ | 3 |
| 18 | ✓ | | | | | | | | | | | | | 1 |
| TOTAL | 5 | 3 | 5 | 6 | 2 | 2 | 5 | 3 | 2 | 1 | 1 | 1 | 1 | |

## 3.7. Other Data Supported formats

***Table 8*** lists other kinds of data supported by the web applications include alphanumerical data (time series observations or profiles) and vector data. The most common format for delivering this kind of data is CSV format, a simple standardized format to provide tabular data (numbers and text) in plain text. Blue squares in ***Table 8*** indicate that the application provides that kind of format.

***Table 8.*** *Kind of formats for other data supported across the web mapping applications*

| # | Excel | XML | JSON | CSV | KML | PNG/JPEG/SVG | ASCII | NetCDF | SHP | TOTAL | Type of data |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | ✓ | ✓ | ✓ | | | | | | | 3 | Ocean gliders profiles |
| 11 | | | | ✓ | | ✓ | ✓ | ✓ | | 4 | Vertical profiles and charts |
| 13 | | | | | ✓ | | | | ✓ | 2 | N/A |
| 21 | | | | ✓ | | ✓ | | | | 2 | Charts |
| 22 | Links to different providers | | | | | | | | | - | N/A |
| 23 | | | | ✓ | | | | | | 1 | N/A |
| 24 | | | ✓ | ✓ | | ✓ | ✓ | ✓ | | 5 | Time series |
| 25 | | | | ✓ | | | | | | 1 | N/A |
| **TOTAL** | 1 | 1 | 2 | 6 | 1 | 3 | 2 | 2 | 1 | | |

### 3.8. Web Mapping Technologies and Mobile Support

Web mapping technologies support the implementation of maps and specific functionalities in web mapping applications. ***Table 9*** provides an overview of the client-side web mapping technologies used to implement the set of web mapping applications analyzed. Esri products take the lead on web mapping technologies used to develop ocean web mapping applications (n=10), followed by Google Maps (n=5) and leaflet (n=4).

The widespread use of Esri products might be explained as it provides a wide range of services (for example, ArcGIS Server, ArcGIS Online, and ArcGIS API for JavaScript) to develop and support web mapping applications. Bathymetry datasets are usually large and need a powerful server development which is already built into the ArcGIS suite. However, ArcGIS is commercial software and is not open source, which means high pricing for licensing, storage and development, and less possibilities for plugins and personalization. For this reason, many of the applications have the same look, as they are developed using basic Esri templates. Google Maps is also widely used; however, it shares the same problem as Esri Products, plus does not provide built-in web map servers. Regarding open source web mapping technologies, leaflet is the most used technology, followed by Mapbox. The rest of the web mapping technologies (Open Layers, GeoExplorer) have decreased in popularity during recent years, and their APIs are not well-maintained, resulting in maps which are inferior in appearance.

Concerning mobile support, sixteen of the twenty-four applications provide support for mobile devices, adapting the interface for smaller screens and maintaining all the functionalities available.

A blue square in ***Table 9*** indicates that the application is built using that technology. A green square indicates mobile support.

***Table 9.*** *Web Mapping technologies and mobile support across the web mapping applications*

| # | Name | Google Maps | Mapbox | Leaflet | Esri Products | GeoExplorer | Open Layers | Bing Maps | Mobile support |
|---|---|---|---|---|---|---|---|---|---|
| 1 | NOAA Bathymetry Data Viewer | | | | ✓ | | | | ✓ |
| 2 | IEDA Data Browser / GMRT MAP TOOL | ✓ | | | | | | | ✓ |
| 3 | Crowdsourced Bathymetry | | | | ✓ | | | | ✓ |
| 4 | Bathymetrics Data Portal | | ✓ | | | | | | |
| 5 | MID-ATLANTIC OCEAN DATA PORTAL | | | | ✓ | | | | |
| 6 | Pacific Islands Ocean Observing System Voyager | ✓ | | | | | | | |
| 7 | NOAA Grid Extract | | | | ✓ | | | | ✓ |
| 8 | Data Access Viewer | | | | ✓ | | | | |
| 9 | Planet OS | | | ✓ | | | | | ✓ |
| 10 | CCLME ECO-GIS Viewer | | | | ✓ | | | | |
| 11 | Mareano | | | | | ✓ | | | ✓ |
| 12 | INFOMAR Data Viewer | | | | ✓ | | | | ✓ |
| 13 | EMODnet portal for Bathymetry | | | | | | ✓ | | ✓ |
| 14 | Baltic Sea Bathymetry Database | | | ✓ | | | | | ✓ |
| 15 | North Atlantic Data Viewer | | | | ✓ | | | | ✓ |
| 16 | Data products and surveys | | | | ✓ | | | | |
| 17 | Bathymetry and Backscatter Data Access | | | | ✓ | | | | ✓ |
| 18 | Lower Saint John River Data Overview | | | ✓ | | | | | ✓ |
| 19 | Artic Net Amundsen Multibeam Data | ✓ | | | | | | | ✓ |
| 20 | Tide data viewer | | | ✓ | | | | | ✓ |
| 21 | Ocean Viewer | ✓ | | | | | | | |
| 22 | St. Lawrence Global Observatory | | | | | | | ✓ | ✓ |
| 23 | Ocean Networks Canada | ✓ | | | | | | | |
| 24 | SECOORA | | ✓ | | | | | | ✓ |
| **TOTAL** | | 5 | 2 | 4 | 10 | 1 | 1 | 1 | 16 |

## *4. Conclusions*

This paper presents a competitive analysis study of current Ocean Web Mapping Applications that deliver Ocean related data to the scientific community. A total of twenty-four existing applications were critically analyzed and compared, across the following topics:

- data offered/represented,
- inclusion of uncertainty as a variable of the information, inclusion of time as a variable of the information, and
- variation in the basemap provided;
- variation across supported interaction operators; supported formats, distinguishing between (2b) bathymetry and
- other kinds of data; and
- variation in the web mapping technology used to implement the web application and mobile support.

The study shows that ocean web mapping applications could be classified in three main categories: those focused mainly on bathymetry data, those focused on ocean data observations (sensor data) and those which combine both. Due to the particularity of the ocean modelling field and the ocean science community in general, an ocean web mapping application should include both, combining data distribution and download with more data exploration and visualization tools to know what data is available.

None of the applications provide all of the data expected to be useful by an ocean modeller, and CTD profiles data, river discharge, tidal data and coastlines are not usually delivered or combined with bathymetry products. An application particularly designed for ocean modellers should include all the data necessary to develop an ocean model, gathering heterogeneous data from different sources in the same application.

Concerning the inclusion of **uncertainty** in ocean web mapping applications, uncertainty is not represented on the map as a cartographic variable, and it is an unusual value to include along with an observation or measurement. As an important part of any measurement, and being a crucial point for decision making, more attention should be given to the inclusion of uncertainty in ocean web mapping applications.

Regarding **bathymetry resolution**, the ideal scenario for an ocean modeller would be to provide different resolutions under request (i.e. even if the survey was performed in another resolution, resampling the data per user request). Also, the inclusion of **time** in ocean web mapping applications is unusual, especially the applications focused on bathymetry. The only way to know the date and time a survey was performed is by querying the layer or searching through the metadata. Special attention should be given to time, as it is important to know when a survey was performed to be able to compare between years and select the most convenient data. Regarding **contextual information**, there is a wide range of basemaps included in the applications analyzed. Many of the tools use the Esri predefined set of basemaps, and nautical charts are not a common basemap to include while streets maps are common (although being potentially useless regarding ocean mapping applications). It should be studied what would be the context information required by the user to provide them with the most appropriate basemap, instead of providing all the options. Moreover, there are alternatives to Esri basemaps that could better enrich an ocean web mapping application (i.e. bathymetry and nautical charts).

In considering **functionalities**, the results from the analysis reveal several opportunities for improvement. Several functionalities are under-represented in existing applications: Area of interest (n=1), area statistics (n=1), map annotation (n=2), and vertical profiles (n=2). These functionalities are more analytical and task specific, rather than general purpose functionalities, such as data

download. The ideal scenario would be to combine all these tools to improve analytical workflow and support ocean modelling tasks.
The study also identifies what **formats** are used by ocean web mapping applications. However, these formats may not align with the formats used by other scientific fields (like ocean modelling). Therefore, further analysis and considerations should be taken to decide what formats to deliver depending on what users require.

Considering **web mapping technologies**, the results align with those found by Roth, Donohue, and Wallace (2014), indicating a broad transition in web mapping technologies from proprietary plugins to modern web standards, and an increase in popularity of open source solutions. Open source options are free to use and include several possibilities for plugins and personalization. However, proprietary solutions are known as having better performance. Depending on the requirements of the application, further analysis is necessary to determine whether an open source solution meets the performance, storage or computing requirements. If these requirements are not a high priority, open source solutions provide an easier way to produce visually appealing web maps of comparable functionality to those of Esri or Google Maps and can result in a more satisfying development experience given the openness and extensibility of the code repository. Moreover, most of the current applications already provide mobile support, being a common trend in ocean web mapping applications. Whether or not to include this support depends on whether the application is intended to be used in a mobile device or is only intended for desktop use.

Overall, this analysis served as the second stage of the UCD methodology of the Ocean Web-Mapping Application of the OMG at UNB and helped to establish trends and gaps concerning ocean web mapping applications and to discover new opportunities for ocean web mapping development. The insights generated from the analysis will be combined with the previous informal interview to prepare an online survey to be conducted by ocean modellers. This method allows user input from the target user group and organizations and serves to generate a requirements document to support the development of the first application prototype. After the first prototype, an evaluation of the tool will be performed to close the UCD cycle and to continue the improvement of the Ocean Web-Mapping Application.

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**Emmanuel Stefanakis** is a professor and the head of Geomatics Engineering department at the University of Calgary. His academic career spans for twenty years and it includes multiple academic institutions in Canada and Europe as well as various programs in Engineering and Science. He has been involved in multiple research projects mostly funded by the European Union, Canadian Agencies, and the Greek Government. He has supervised a significant number of students and researchers of various disciplines, while his teaching portfolio includes various programs in Engineering and Science, and a variety of teaching modes (classroom-based, online & distance-learning). He has an active involvement with the Canadian Board of Examiners for Professional Surveyors (CBEPS), the Canadian Institute of Geomatics (CIG), and the International Society for Photogrammetry and Remote Sensing (ISPRS). Since January 2014 he has been the Editor-in-Chief of Cartographica Journal.

# ESTABLISHING HYDROGRAPHIC SERVICES IN MAURITIUS

## *1. Need for Hydrographic Services in Mauritius*

Mauritius is an Island nation of 2,040 $Km^2$ situated 20° South of the Equator and on longitude 57.5° East with a large Exclusive Economic Zone (EEZ) of around 2.3 million $Km^2$. In addition, an area of 396,000 $Km^2$ of seabed in the Mascarene region is jointly managed by the Government of Mauritius and the Republic of Seychelles. This enormous EEZ provides the maritime state significant economic opportunities waiting to be embraced. Furthermore, sea borne trade is vital for our national and economic development.

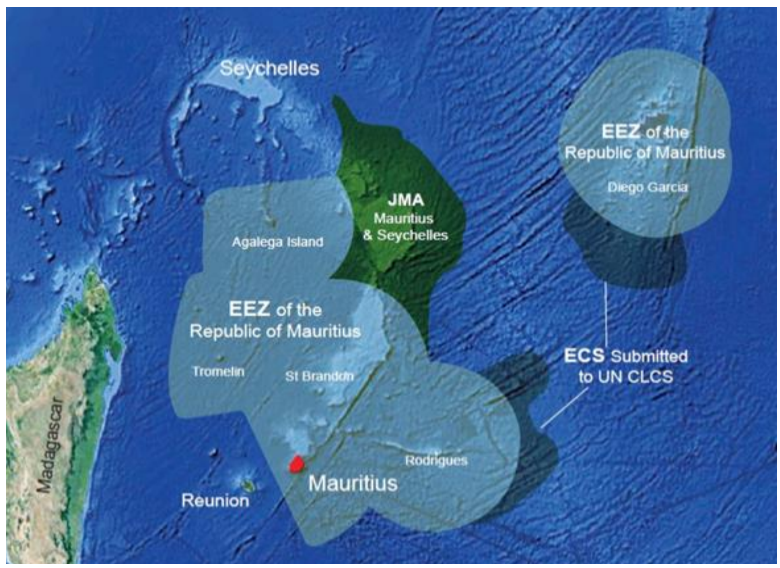


***Figure 1.*** *EEZ of the Republic of Mauritius*

The fragile coastal area requires environmental protection and management based on scientific research for sustainable development. Maritime security, environmental protection, ensuring safety of life at sea, marine scientific research and exploration for living and non-living resources in the vast EEZ hold the key to the future of Mauritius. The island nation is heavily dependent on sea borne trade for meeting requirements of energy and other essential commodities. Updated nautical products are one of the most essential tool for safety of navigation at sea and also the foundation for any further study and development in the marine environment. Therefore, fully evolved Hydrographic services are a critical instrument in realizing the government's vision of ocean based economy.

Recognizing the vital and valuable role of hydrographic information in fulfilling the vision of ocean economy, the need for establishing hydrographic services at Mauritius was identified. The ***Hydrographic Unit, Mauritius*** was established in November 2013 consisting of surveyors from the Ministry of Housing and Lands (MHL) and hydrographers from the Indian Navy with the aim:

**To develop indigenous capability of hydrographic surveying at Mauritius using the capacity building program and MoU on Hydrographic Cooperation**.

The defined objectives were to:

a) Carry out hydrographic surveys of navigable waters and passes around mainland Mauritius and outer Islands.
b) Provide quality training in the field of hydrography to develop local expertise.
c) Develop and strengthen hydrographic research capability.
d) Provide nautical information to the international marine community for safe navigation.
e) Provide hydrographic and geodetic data for the delimitation of maritime zones.
f) Promote technical cooperation in the domain of hydrographic surveying and marine cartography.
g) Provide training to surveyors, officers from MHL and other stakeholders in the field of hydrography.
h) Cooperate with other stakeholders and provide expertise on matters related to maritime domain.

## *2. Achieving the Objectives*

The goal of developing the hydrographic services was pursued in a systematic manner. The key steps followed were:

(a) **Consultation with National Stakeholders**: In addition to the seagoing fraternity, organizations related to marine navigation, protection of marine environment, tourism, maritime security, scientific research, disaster management, meteorology experts and ocean exploration are major stakeholders in hydrographic services. The identified stakeholders were consulted for their data requirements, areas of interest and were in parallel appraised of potential use of hydrographic services in their respective spheres.

(b) **Compilation and Prioritization of Hydrographic Requirements**: Coordination meetings were held for compiling the detailed survey requirements. A total of 112 requests were received during the initial interaction with various stakeholders resulting in 78 surveys in near shore/coastal areas and four deep sea surveys warranting ocean data collection for exploitation of resources. Requirements concerning expertise on matters related to coastal zone management, navigation and the delimitation of maritime boundaries emerged during the meetings. The requirements were prioritised based on available resources and importance of surveys towards maritime safety/development projects.

(c) **Asset Operationalization and Management**: Hydrographic equipment was received from the Governments of Japan and India in the year 2005 and 2013 respectively. The equipment was made operational in a phased manner with in-house efforts and innovation.

(iii) **Inshore Survey Vessel "*Pathfinder*"**: This vessel was supplied by the Government of India in 2013. Its shallow draught and good maneuverability made the vessel ideal for operating in shallow, reef-strewn waters.

***Figure 2.*** *ISV "Pathfinder" at work*

(ii) **Portable Equipment**: Harbour inspection and sea trials of portable equipment received from the Government of India and Japan was carried out. The vintage sets were re-energised and reconfigured to make the output data compatible with the modern data processing suite. Necessary modifications were carried out for deploying the equipment on-board any available craft of opportunity. The portable equipment later added the capability of collecting bathymetric data in extremely shallow lagoons.


***Figure 3.*** *Sounding operations using portable equipment on a Craft of Opportunity*

(iii) **Data Logging System:** The hydrographic suite of ISV *Pathfinder* includes an echo sounder, satellite Differential Global Positioning System (DGPS), Dynamic Motion Sensor, data logging software, Side Scan Sonar (SSS) and Sound Velocity Profiler (SVP). The equipment were tested, serviced, configured, successfully interfaced and made fully operational in-house by the team.

(iv) **Procurement of Additional Equipment and Establishing Office Infrastructure**: The available inventory of equipment was considered insufficient considering the nature of operations envisaged. Therefore, after due deliberations, the following new additional equipment were procured:

a) Very High Frequency (VHF) Radio and Emergency Position Indicating Radio Beacon (EPIRB) to enhance communication with shore authorities and safety of life at sea.

b) Current meter (Infinity EM)

c) Sound Velocity Probe (SVP)

d) Seabed Grab

e) Tide gauge

f) Office infrastructure at Ministry of Housing & Lands (MHL), consisting of work-stations, digital data processing suite and necessary peripherals for producing CAD and hydrographic drawings.

g) The Hydrographic Unit has recently procured and operationalized Portable Echo-Sounder Hydrotrac-II. A multipurpose portable pole has been designed in-house to mount the transducer on any craft of opportunity.

(d) **Training and Human Resource Development:** Trained and professional man-power is the bedrock of any successful organization and certainly, one of the main pillars of dependable hydrographic services. Formal training involving theoretical classes and On Job Training (OJT) were conducted for land surveyors of MHL, Survey Recorders of NCG and officers from other organisations. To date, numerous personnel have been trained. This includes Officers from MHL, Mauritius Oceanographic Institute (MOI), National Coast Guard (NCG), Mauritius Meteorological Services (MMS) and Ministry of Environment. The training encompasses the entire range of survey operations including planning and execu-tion of surveys, data processing, rendering of data and compilation of hydrographic products. The surveyors are regularly exposed to emerging surveying techniques, latest equipment and developments in the fields related to hydrography for continuous skill development. Apart from the in-house training efforts, the officers from the MHL have also benefited from a number of IHO CAT A, CAT B and Diploma certification programs con-ducted by University of Southern Mississippi, University of New Hampshire and National Institute of Hydrography, India under various IHO Capacity Building Schemes.

(e) Establishing clearly defined procedures for data collection, processing, Quality Assurance, Quality Control and data archival as per IHO standards, to meet accuracy requirements for charting purpose.

(f) Enhancing cooperation with International Hydrographic Organization (IHO), South African Islands Hydrographic Commission (SAIHC), North Indian Ocean Hydrographic Commission (NIOHC) and utilising their capacity building programs for meeting carto-graphic and hydrographic training requirements.

(g) Streamlining procedures for correction, update and sales of nautical products. Focussing on providing updates to the mariner by establishing procedures for reporting, collation of navigational dangers and issuing Navigational Area warnings through the NAVAREA coordinator.

## *3. Enhancing Awareness about Hydrographic Services*

As hydrography is a novel field in the country, very few individuals were previously exposed to the hydrographic profession and related services. In the beginning, introductory sessions and lectures on the role of hydrography in national development were organised for officers of various ministries and departments. Equipment demonstrations, interaction at various forums and conduct of World Hydrography Day (WHD) events on a grand scale have contributed immensely towards increasing awareness about hydrographic services.

(a) Establishing clearly defined procedures for data collection, processing, Quality Assurance, Quality Control and data archival as per IHO standards, to meet accuracy requirements for charting purpose.

(b) Enhancing cooperation with International Hydrographic Organization (IHO), South African Islands Hydrographic Commission (SAIHC), North Indian Ocean Hydrographic Commission (NIOHC) and utilising their capacity building programs for meeting cartographic and hydrographic training requirements.

(c) Streamlining procedures for correction, update and sales of nautical products. Focussing on providing updates to the mariner by establishing procedures for reporting, collation of navigational dangers and issuing Navigational Area warnings through the NAVAREA coordinator.

## *4. Results Achieved To Date*

In the past two years, the hydrographic unit has grown from strength to strength, adding new survey capabilities and equipment. Expanding its reach to the outer islands of Mauritius has strengthened the Maritime Safety Information Services framework and is now well on its way to become a fully evolved Hydrographic Service capable of meeting the emerging requirements associated with the ocean economy.

The efforts of the unit have been recognized at the International level, the Mauritius Hydrographic Service has been awarded the Certificate of Distinction as finalist during the **International Innovation Awards** (***Figure 4***) conducted by the Commonwealth Association for Public Administration and Management (CAPAM) at Guyana in 2018.


***Figure 4.*** *Certification of Distinction from CAPAM*

During the past five years, phenomenal success has been achieved in providing hydrographic services at the national level. Apart from supporting the seagoing fraternity, hydrographic services have been provided to the Continental Shelf, Maritime Zones Administration & Exploration Division - Prime Minister's Office, Shipping Division, Mauritius Ports Authority (MPA), National Coast Guard, Department of Fisheries, Ministry of Tourism & External Communication, Ministry of

Environment, Sustainable Development and Beach Nourishment, MOI, National Disaster Risk Reduction and Management Authority and Mauritius Meteorological Services. Our activities have contributed to the implementation of various projects of national importance.

Apart from 25 major hydrographic surveys undertaken by this Office, numerous other commitments to various stakeholders have also been fulfilled, including:

(a) **Surveys of Passes around mainland Mauritius**: The bathymetric data on the existing chart (INT 7737) Mauritius is inadequate for navigation through the passes due to sparse soundings and limited information on seabed topography. Bathymetry in lagoons is a critical input for storm surge and tsunami inundation modelling. Various other stakeholders also identified the requirement of surveying navigable passes in the lagoons. To address these multilateral requirements, the survey of 78 passes around Mauritius has been initiated. To date, 28 passes have been surveyed. The surveys completed cover from Grande Riviere Noire Bay in the south west to Cap Malheureux in the north of Mauritius.

(b) **Data for implementation of Early Warning System for Storm Surge and Tsunami Modelling**: Being an island nation in an equatorial region, Mauritius is under constant threat of storm surge. Bathymetric data surrounding Mauritius, Rodrigues and Agalega has been provided to establish the model for the storm surge early warning system. The model has significantly enhanced disaster management capabilities in case of such catastrophe.

(c) **Data for Extended Continental Shelf Claim**: Bathymetric data for supporting the extended continental shelf claim east of Rodrigues was provided to The Continental Shelf, Maritime Zones Administration & Exploration Division - Prime Minister's Office.

(d) **Charting Scheme for Mauritius**: Finalization of the charting scheme consisting of 14 navigational charts covering Mauritius and other Islands in consultation with National Hydrographic Office, India. The new charting scheme will significantly enhance the navigational safety in Mauritian waters.

(e) **Delineation of islets**: A detailed survey was carried out for three newly formed islets north of Port Louis harbour. The detailed coordinates for the islands were forwarded for updating of national records.

(f) **Interfacing of GIS data sets for enhancing scientific research and inundation modelling**: To strengthen hydrographic research and improve appreciation of sea and land based topography to multiple agencies on a master fair sheet required numerous spatial and non-spatial data sets to be combined through innovative use of a wide variety of software tools.

(g) Survey for Petroleum Hub Project being developed at Albion.

(h) The unit has also developed capabilities to carry out hydrographic surveys for the support of outer islands around Mauritius including Rodrigues and Agalega to meet the requirements of various stakeholders.

(i) All the seven (07) series charts for Mauritius through collaboration with India have been accorded INT status.

## *5. Roadmap for the Future*

Significant milestones have been achieved in terms of developing hydrographic capability. The expansion of the services is currently being pursued with a firm roadmap for the future. The main areas of focus are:

(a) Transition from current data processing practice to GIS-based processing and data compilation tools. Adding marine cartographic capability for paper chart compilation and implementing related Quality Control procedures.

(b) Establish maintenance and support procedures for specialized equipment to ensure sustained availability for hydrographic operations.

(c) Provide legal framework for hydrographic services.

(d) Develop deep sea surveying capability.

(e) Procurement of advanced hydrographic equipment suite like Portable MBES, ADCP, ROV, Unmanned Surface Vessels (USV), etc. suitable for this region.

## *6. Conclusion*

Significant milestones have been achieved since the inception of this unit in 2013. The unit interacts on a regular basis with national and international agencies on matters related to Hydrography. Therefore, in order to better reflect its role and capabilities, the unit has been renamed the ***Mauritius Hydrographic Service***.

As a result of establishing the hydrographic services, the country now has the capacity to survey areas critical for shipping and surface navigation, carry out underwater search operations for wreck/obstruction detection and survey of extremely shallow lagoons surrounding Mauritius for supporting economic/tourism related activities. In addition, significant progress has been made towards hydrographic support for scientific research and disaster management and expertise in matters related to maritime domain. The unit has now developed capability to independently undertake surveys in outer islands including Agalega and Rodrigues which are a few hundred miles from Mauritius.

Through innovation, resourcefulness and active support of the Ministry of Housing and Lands (MHL), seminal work in the field of hydrography has been carried out. The first steps taken in this novel field have the potential to bring the country closer to exploitation of huge ocean resources available in the surrounding waters.

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Notes

# SEMI-AUTOMATED GENERATION OF DEPTH CONTOURS FOR ELECTRONIC NAVIGATION CHARTS (ENCs)

By P. Rustomji, Australian Hydrographic Office (AHO)
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## *Abstract*

This note presents a largely automated method to create bathymetrically safe, legible, scale appropriate depth contours for Electronic Navigation Charts (ENCs) using the CARIS BASE Editor version 4.4 software installed in the Australian Hydrographic Office (AHO). The method is suitable for contouring modern high density multi-beam survey data as well as sparser single beam data (or a combination of both). Being a largely automated process, the time required to incorporate new bathymetric data into navigation products is significantly reduced. The method facilitates finer resolution depth encoding within ENCs and therefore a more realistic portrayal of safe water to the mariner.

## *1. Introduction*

The era of rapidly acquired, high resolution bathymetric surveys, coupled with mariner expectations for timely incorporation of the latest data into ENCs represents a challenge for all hydrographic offices to keep their chart portfolio up to date. The time it takes for nautical cartographers to manually compile charts represents one constraint in achieving this. Nautical cartographers play an important role in exercising judgement about the generalisation and portrayal of the sea floor on both paper and electronic charts to present to the mariner a scale appropriate, legible picture of their operating environment.

The skill of generalising complex bathymetry is one learned over time and applied to each compilation task. Being a manual process, it is time consuming and potentially error prone. High definition bathymetric surveys have arguably only made the challenge harder by capturing ever more sea floor detail that needs to be suitably portrayed. Hydrographic offices may also wish to include a wider selection of contours (and depth areas) within ENCs as compared to traditional depth contours shown on paper charts. This facilitates a more refined portrayal of safe and unsafe waters by more closely matching a vessel's Electronic Chart Display and Information System (ECDIS) safety contour to actual sea floor depths. Additional contouring does however extend the compilation workload if done manually. All these factors mean that alternatives to manual contouring need to be explored.

This paper describes a method using CARIS BASE Editor 4.4 software to generate, in a largely automated way, bathymetrically safe, legible, scale appropriate depth contours (and associated depth areas) for ENCs. The terms bathymetrically safe, legible and scale appropriate mean that the contours are on the safe (deep) side of the bathymetric data, they neatly complement the displayed size of charted soundings (according to the S-52 presentation standard) and have a degree of curvature appropriate for the compilation scale. The method is suitable for modern high resolution bathymetric data (usually with full sea floor coverage) as well as older, lower resolution data with incomplete seafloor coverage, or a combination of both. Being a largely automated process, large areas of new survey data and a greater range of contour intervals can be efficiently compiled irrespective of sea floor complexity, thus improving the responsiveness of the Australian Hydrographic Office's (AHO) chart compilation process to mariner requirements. An overview of the process is presented as a flow diagram in ***Figure 1***.

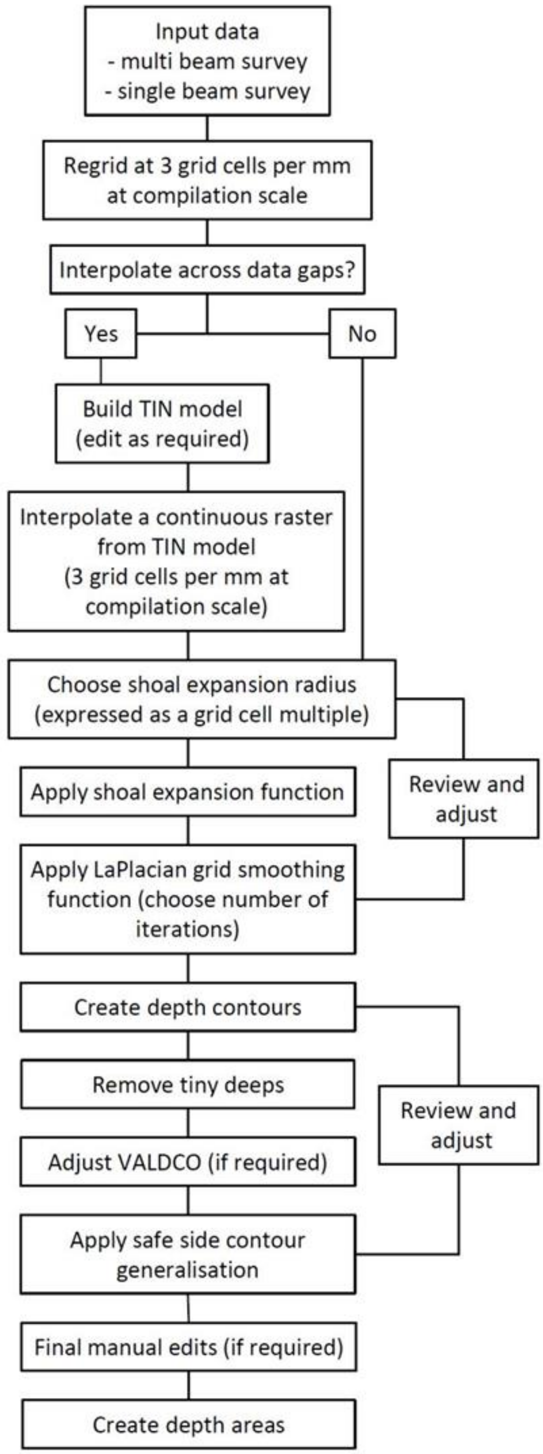


***Figure 1.*** *Flow diagram of the bathymetric feature creation method using CARIS BASE Editor tools*

## *2. Input data*

This workflow utilises a single input file in CARIS CSAR format, either as point cloud or raster. In practice at the AHO, multibeam or LIDAR surveys are processed and stored at an (arbitrary) grid resolution (typically 1 to 5 m). Single beam surveys are represented in raster format using a 1m grid resolution (i.e. each single beam "ping" is allocated to a single 1 m grid cell surrounded by blank cells). This input data could comprise a single survey or a multi-survey bathymetric dataset combined (deconflicted) according to a specific rule set.

The demonstration dataset is shown in ***Figures 2 to 6.*** The data is a Laser Airborne Depth Sounder (LADS) survey from the Great Barrier Reef. The data for compilation was provided at 5m grid resolution and has areas of both full and partial coverage. Reef areas are typically amongst the most challenging environments to chart. In ***Figure 2***, the 0, 2, 5, 10, 15, 20 and 30m contour set has been directly derived from the survey data and is shown at a display scale of 1:45,000 (this compilation and symbolisation scale is used throughout this paper). Direct gridding of the raw data results in an illegible, overly detailed representation and is unsuitable for inclusion in an ENC product. ***Figure 3*** shows a manually created contour set and sounding selection for the same data, illustrating the generalisation typically required of such data.

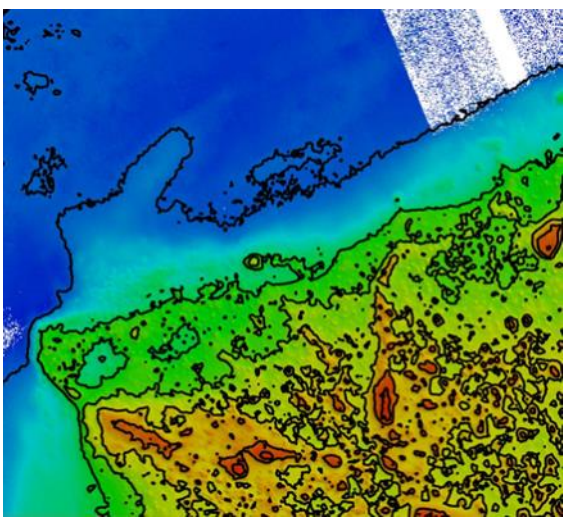

***Figure 2.*** *Example bathymetric surface (5m grid resolution)*

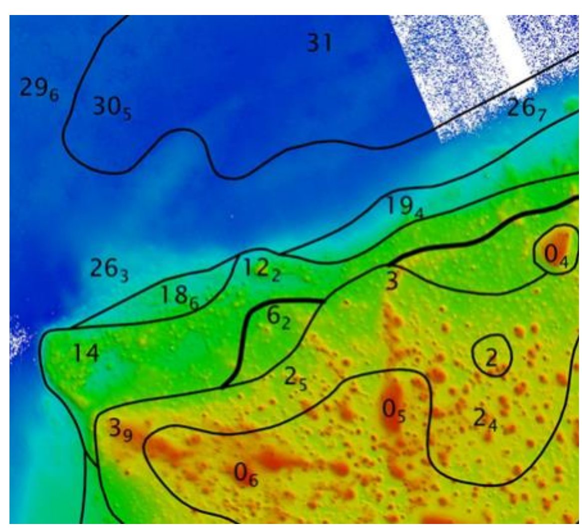


***Figure 3.*** *Manual contouring and sounding selection fro the area covered by Figure 2*

### *3. Scale appropriate re-gridding*

Having defined a compilation scale and spatial extent for a compilation task, the input data is re-gridded to a scale-appropriate grid resolution. Our experience has shown a resolution of three pixels per mm at compilation scale to be a suitable minimum value. For a 1:45,000 scale compilation task, three grid cells per mm equates to a re-grid resolution of 15m. Re-gridding is done by selecting the shoalest depth within each output grid cell (using a **shoalest depth true position** algorithm in CARIS parlance). This step is important as it addresses the issue of compilation scale in this process. Subsequently, all other choices reflect decisions about how the data should look at compilation scale rather than choices made because of the scale.

### *4. TIN Interpolation and secondary re-gridding*

Unless there is full grid coverage of the compilation area after the re-gridding, a triangulated irregular network (TIN) model is used to interpolate across data gaps. Data gaps could comprise gaps in the survey coverage or space between single beam soundings. Decisions should be made about what gaps in coverage can be reasonably interpolated across (and at least represented by appropriate M_QUAL attribution) and those which should be represented as an unsurveyed area.

CARIS provides a number of tools to edit TIN models to constrain interpolation only to desired areas. Once the TIN model is finalised, a new continuous bathymetric grid is re-interpolated from the TIN model at the same re-grid resolution selected previously (i.e. three grid cells per mm). This step is optional, but contour interpolation will not occur across holes in the raster data.

### *5. Bathymetric (grid) generalisation*

This workflow utilises two functions provided with CARIS BASE Editor to generalise bathymetric surfaces. First, the **shoal expansion** function is used first to enlarge tiny peaks in the bathymetric grid. This is an important step because it allows for ENC sounding features representing the least depth over these peaks to neatly fit within the derived contours (at least for depths < 10m for example). This step also sets the minimum radius of curvature for convex contour segments. Experience has shown a minimum target diameter of approximately 4mm (at compilation scale) is required for legible portrayal of most isolated shoals (with a sounding) on an ECDIS using the S-52 presentation standard. Note the 4mm "target diameter" nominated is the end goal and at this stage of compilation it is necessary to allow for contour expansion in a vector generalisation step that follows, where about 1mm of extra expansion in diameter occurs for isolated shoals. So at this point, a 3mm shoal expansion radius is appropriate. Given the re-grid resolution was set at 3 grid cells per mm, to achieve a 3mm radius shoal expansion result, the multiple of resolution parameter in the CARIS shoal expansion function should be set to 9, which equals 3 grid cells per mm multiplied by desired 3mm initial expansion radius (other "target" values could be used and the expansion multiple adjusted accordingly). Note this shoal expansion radius is a dimensionless parameter and is thus scale independent.

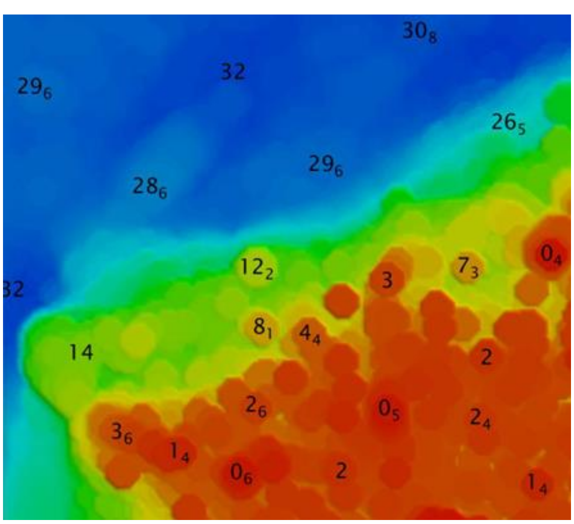


***Figure 4.*** *Application of the shoal expansion function to the re-gridded bathymetric surface*

This function creates circular columns in the bathymetric grid centred on shoal peaks. ***Figure 4*** shows the results of applying this function to the test data. The circular expanded shoals are evident in the new bathymetric grid and they generally are sufficiently expanded to encircle what will be the charted soundings.

The second step is to apply the **Laplacian grid smoothing** function. This function raises the elevation of grid cells based on the local elevation differences within each cell's neighbourhood. It has the effect of infilling low areas within a bathymetric grid. In doing so, smaller isolated features coalesce into a lesser number of larger, generalised features. It automates what a cartographer would do manually to generalise and simplify the portrayal of complicated, hummocky bathymetry typically found in areas of coral reef or rocky sea floors.

The Laplacian algorithm is controlled by specifying the number of iterations of the process. Again, being a dimensionless parameter, it is scale independent and the question of how much smoothing is desired becomes a question of how the cartographer wishes the product to look at a given scale, rather than because of the scale. Typically we would use somewhere between 1 and 20 iterations (usually around 10 for most cases). ***Figure 5*** illustrates the application of the Laplacian smoothing function to the shoal-expanded surface. Depth contours are then derived from the generalised grid surface. The AHO utilises a depth offset value (say 0.049 m, meaning the 2 m contour is calculated using a value of 2.049m) when deriving contours to account for the sounding rounding rules employed by the AHO.

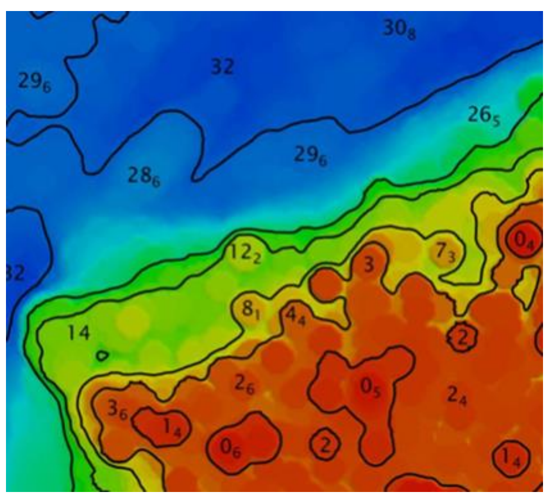


***Figure 5.*** *Application of the Laplacian smoothing algorithm after the shoal expansion*

## *6. Contour (vector) generalisation*

Having derived a set of vector contours, a number of steps are used to refine the (vector) contours. First, "tiny deep" contours are deleted. "Tiny deep" contours are those enclosing depressions in the bathymetric grid (the attribute **isotyp = deep** is set when using the BathyDataBASE catalogue) but which are too small to include at compilation scale. "Tiny" is defined here as being smaller in area (metres squared in projected coordinates) than that corresponding to a 10mm diameter circle at compilation scale. For example, a circle of 10mm diameter at a 1:45,000 compilation scale equates to approximately 160,000m$^2$ (this value can be varied to suit). Next, the VALDCO attribute of each contour is shifted back to its nominal value (e.g. 2.0 m thus reversing the sounding rounding offset).

The CARIS **“safe side” vector generalisation** functions are then used to reduce the number of vertices and generalise the depth contours. Apart from the improvements in legibility that result, this is an important step. The contours, derived from what appears to be a “hidden” TIN created from the smoothed bathymetric grid by the CARIS software, have an excessive number of vertices that reflect artefacts of the interpolation and contouring algorithms rather than the genuine shape of the underlying data.

At a conceptual level, if the re-grid resolution was set to three pixels per mm at compilation scale and the contours are derived from the triangular facets of a “hidden” TIN model, there are going to be about nine vertices per mm of linework at compilation scale, which is an excessive vertex density for ENC geometry. Experience has shown that the predefined “Minimal” and “Detailed” options provided with the CARIS BASE Editor function work well in most cases, reducing vertex density to roughly one quarter of the original values. However, the CARIS depth contour generalisation function does not consider any topological relationships between contours, treating each contour in isolation. This can result in topological errors where contours intersect. Such intersections can be identified using the CARIS validation tests within BASE Editor and manually rectified. The depth contour generalisation function can also be applied differentially to different selections of contours to minimise or eliminate intersection errors (for example, different levels of generalisation can be applied to widely spaced contours as opposed to those close together where the risk of intersections is higher).

Another optional (but manual) task is to generalise out any “tiny valleys” that remain in the contour dataset. Once an acceptable set of contours is derived, BASE Editor’s automated depth area creation tools are used to create DEPARE features with DRVAL1 and DRVAL2 populated. ***Figure 6*** shows a larger view of the results of this workflow to the test data along with a sounding selection and the original bathymetric surface shown as a background layer.

Arguably the overwhelming majority of the contours are acceptable in this example, with perhaps 5% requiring some (optional) manual editing to improve presentation on the ECDIS.

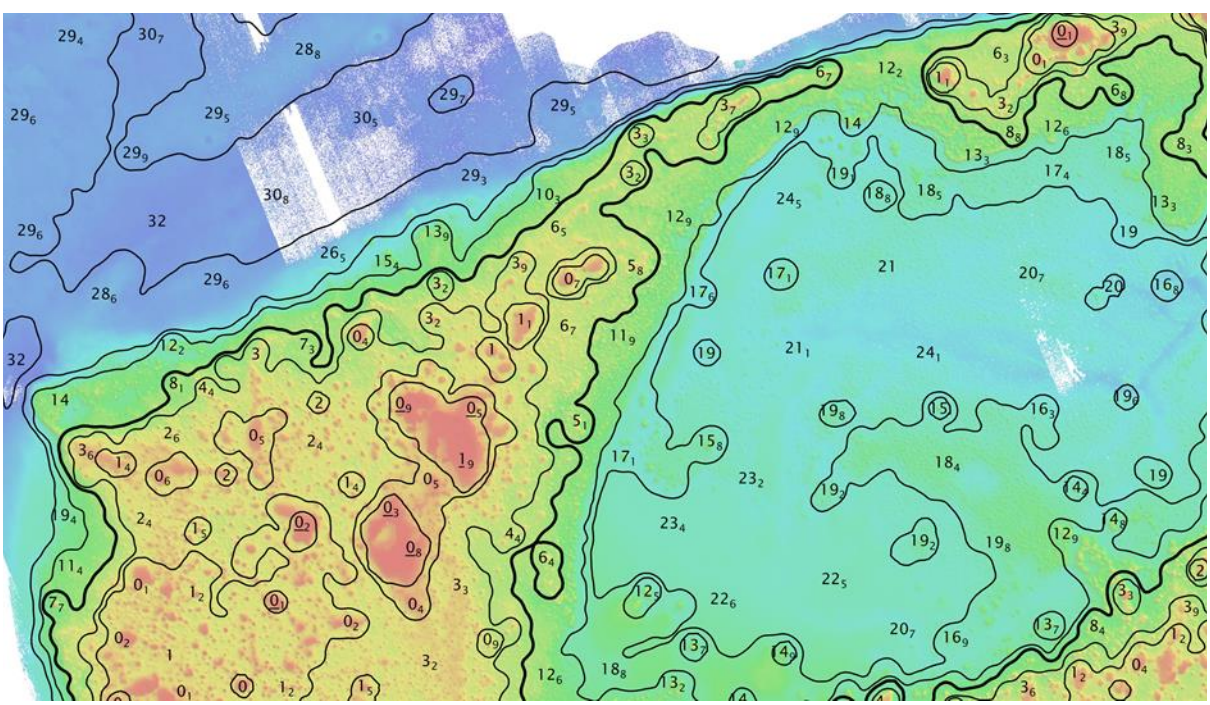

***Figure 6.*** *Illustration of a near complete contour set and sounding selection*

## *7. Discussion*

This workflow, using CARIS BASE Editor software, produces a set of legible, scale appropriate depth contours and depth areas suitable for ENC products. The contours neatly enclose charted soundings within small isolated shoals, have an appropriate level of curvature for a given compilation scale and can be efficiently generated. Experience at the AHO has been that the automated component of the process can usually be completed in a few hours and this time is largely independent of the spatial extent of the compilation area or degree of bathymetric complexity. The manual review and editing steps are generally of similar duration meaning that a contouring task that would have taken days to weeks to compile manually can now realistically be processed in a single day. The more complex the bathymetry and greater the degree of generalisation required, the greater the relative time savings.

The contours differ in presentation from “traditional” manual contouring in that shoal contours are not “pushed out” to cover deeper contours in steep-to areas (for example, a 2m depth contour would not be pushed out to cover everything up to the 30m contour along a steep reef edge, for example). Contours may be pushed out because of the grid generalisation steps (which, by only ever raising grid cell values, tend to shift contours outwards), but the full suite of contours is still portrayed.

This can lead to “bullseyes” around tiny isolated shoals or “guitar strings” along steep-to areas. However, this arguably represents a realistic portrayal of the bathymetry (at the compilation scale) and any sequence of closely spaced contours visible on an ECDIS clearly indicates a rapid change in bathymetry. Interpreting individual contours on an ECDIS is arguably less important than providing greater refinement in the depth area encoding as the safe/unsafe depth portrayal on an ECDIS relies on the DRVAL1 encoding of depth area features rather than the depth contours.

A big advantage for the maritime community is that, using this approach, bathymetric contouring for ENCs can now be largely automated, enhancing the ability of hydrographic offices to incorporate new data into ENC products. A minimal degree of manual editing will remain for tasks such as edge matching of old and new data and to achieve minor cartographic improvements.

Because the manual overhead of contouring is largely removed, this approach facilitates the efficient incorporation of a larger number of depth contours into ENC products. This should allow ENCs to have greater utility in cases where draft constraints restrict vessel access to a port (for example) and provides the ability to set a safety depth more closely related to a vessel’s actual draft (based on finer contour intervals and associated DEPARE encoding) to enable more efficient and safer maritime operations.

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Notes

# ASSESSING GAPS VIA BATHYMETRIC SOUNDING DENSITY

By M. Westington[1], J. Varner[2], P. Johnson[3], M. Sutherland[2], A. Armstrong[1], J. Jencks[4]

In support of ocean and coastal mapping strategies, the United States has designed a method for assessing gaps in bathymetry through a visualization of sounding density. This method was first reported at the Canadian Hydrographic and National Surveyors' Conference in Victoria, British Columbia, March 2018 (Westington et al., 2018).

This analysis evaluates openly accessible bathymetric data holdings at the International Hydrographic Organization's Data Centre for Digital Bathymetry, which is hosted by the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information (NCEI). All modern depth soundings from 1960 to present are incorporated into 100-m resolution local grids covering U.S. waters, which extend from land to the exclusive economic zone and potential juridical continental shelf.

To accommodate different definitions of "mapped," the sounding densities are reclassified into two categories: 1 to 2 soundings per cell, which corresponds to "minimally mapped" and 3 or more soundings per cell, which corresponds to "better mapped" and is often associated with modern survey instruments that produce more measurements over a particular area. Unmapped areas have no soundings per cell and are blank.

The resulting grids are published as a geospatial web service using Esri ArcGIS Enterprise software. ***Figure 1*** shows the NOAA GeoPlatform web page with official links to the visualization product, http://noaa.maps.arcgis.com/home/item.html?id=4d7d925fc96d47d9ace970dd5040df0a.

1. *National Oceanic and Atmospheric Administration (NOAA), National Ocean Service, Office of Coast Survey*
2. *NOAA, National Centers for Environmental Information (NCEI) - Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado, Boulder*
3. *Center for Coastal & Ocean Mapping - Joint Hydrographic Center, University of New Hampshire*
4. *NOAA, NCEI - International Hydrographic Organisation (IHO), Data Center for Digital Bathymetry*

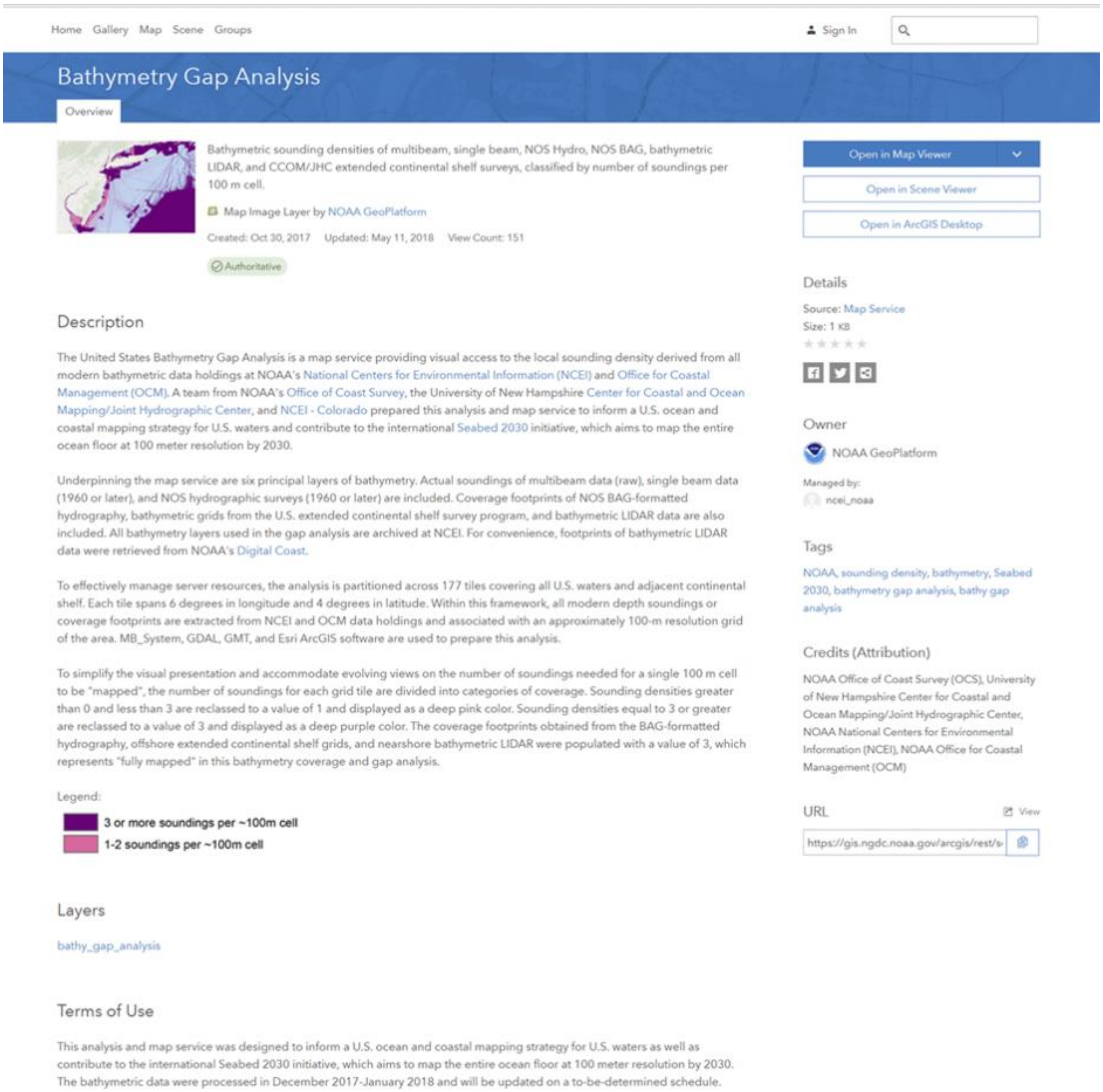


***Figure 1.*** *NOAA GeoPlatform web page for the Bathymetry Gap Analysis*

This gap analysis provides a first look at how many individual depth measurements contribute to the overall picture of "mapped." One may argue that a single measurement in a 100-m grid cell (the pink areas show in ***Figure 1***) is not adequate to constitute "mapped." However, when considering that less than 10% of the global seafloor has been mapped, others may equally argue that one sounding is better than no sounding at all. The product is intended to start a conversation about what it means for an area to be "mapped" and support actions to fill the gaps. To facilitate this dialogue, the service is also available on the U.S. Federal Mapping Coordination website (www.fedmap.seasketch.org). The website is shown on ***Figure 2***.

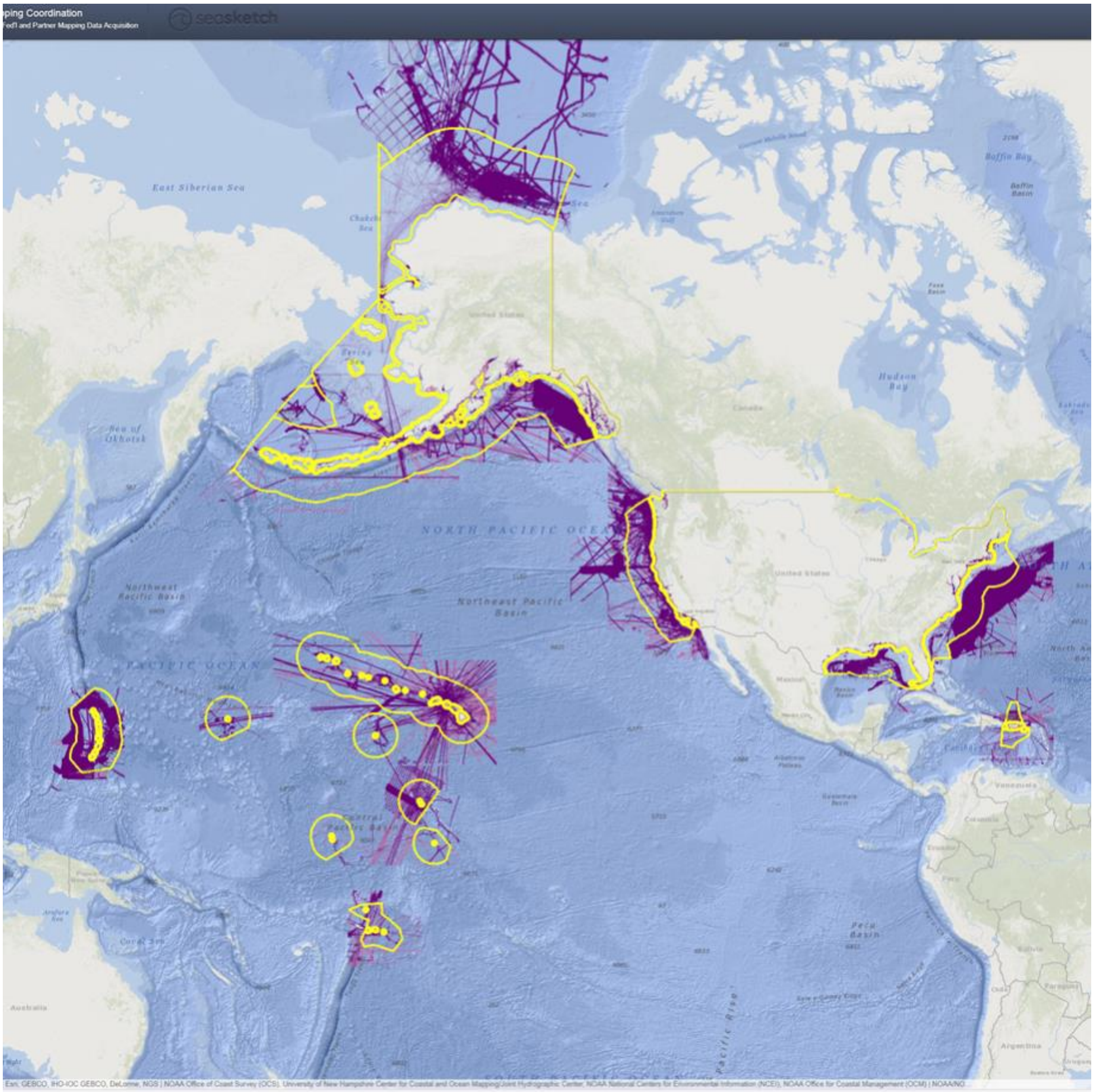


***Figure 2.*** *. The Bathymetry Gap Analysis as shown on the U.S. Federal Mapping Coordination website*

Instructions for how to use this visualization to identify gaps in bathymetry will be available in a new chapter of the IHO-IOC GEBCO Cook Book (2016; http://www.gebco.net) in the upcoming update.

## References

International Hydrographic Organization, Intergovernmental Oceanographic Commission (IHO-IOC), (2016). **The IHO-IOC GEBCO Cook Book**, IHO Publication B-11, Monaco, Dec. 2016, 475 pp - IOC Manuals and Guides 63, France, Dec. 2016, 475 pp.

Westington, M., Varner, J., Johnson, P., Sutherland, M., Armstrong, A., & Jencks, J., (2018). “Assessing Sounding Density for a Seabed 2030 Initiative,” in proceedings of the 2018 Joint Canadian Hydrographic and National Surveyors’ Conference, Victoria, British Columbia, 26-29 March 2018, https://www.eiseverywhere.com/ehome/chc-nsc2018/711593/.

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*OBITUARY*

# FOR REAR ADMIRAL KENNETH BARBOR, USN

by Vice Admiral Alexandros Maratos,
President of the IHB Directing Committee (2002 – 2012)

In 2002 during the XVI$^{th}$ International Hydrographic Conference, I was elected as the President of the IHB Directing Committee together with Ken Barbor and Hugo Gorziglia for a five year period. I remember the three of us met for the first time at the Bureau on the 21$^{st}$August 2002, in order to be briefed and take on board our duties.

Ken explained to us that he had arrived in Monaco after sailing the Atlantic Ocean from the east coast of the United States in his small boat.

I was a bit curious about that trip and one afternoon the two of us were drinking coffee in his office and we discussed some aspects of this trip. I was surprised by his enthusiasm and I asked him whether he had had any fear of making the trip. He responded by saying that if you have fear to achieve a goal then you will not succeed. You have to prepare yourself in order to face all challenges of such a trip. You have to respect the sea and find ways to compromise with the difficulties that may arise. I asked him what somebody needed to know and do in order to achieve such a trip. He said three things were very important. Firstly the need to study carefully the area that you sail and decide on the optimum route that you will follow, based on a variety of information that you need to collect and evaluate. Secondly to choose the appropriate equipment to sail safely and be able to communicate with other mariners or coastal stations whenever is needed. Thirdly and most importantly choose experienced crew to assist you on the trip. When I asked him if he had anybody onboard to help him, he looked at me and smiled, took a sip of his coffee and said: of course, my wife Leslie, the best mariner and lover of the sea. I could not have succeeded without her.

This was Ken. A true mariner, a true navigator but above all a true hydrographer. This is the way that we will always remember him.

Ken, as he was so fond of the sea, it was not a surprise that he had managed to study, practice and teach the three “marine academic sisters” as they are called. Hydrography, oceanography and marine meteorology. Not forgetting that Ken, before coming to the IHB, was the Commander of the US Naval Meteorology and Oceanography Command and inaugural Director of the Southern Mississippi Hydrographic Science Research Center. With his vast experience he came to the Bureau to help the organization achieve and further its tasks and goals. I believe that all of us who met and worked with Ken will agree that he succeeded. He was always ready to provide good ideas on various hydrographic aspects and not only co-operate and support Member and non-Member States, listen and provide solutions to problems that arose, represent the organization on various international and local activities to raise awareness of its role and importance. But as a true mariner he was caring on issues concerning safety at sea, protection of the marine environment and security.

# General Information

Ken was a very pleasant, quiet, generous and cooperative person at the Bureau. He used to say that if the Bureau is effective and efficient to conclude its task, then the Organization will also be effective and efficient. For this reason we have to work towards achieving this goal. He loved hydrography, he loved sailing, he loved to be challenged on maritime issues.

He worked very hard for five years at the IHB and speaking on behalf of all of us who worked with and who met Ken, I can safely say that he will be greatly missed and we will always remember him with love, fondness and respect.

To his wife Leslie and relatives, our deepest condolences.