Synthesizing Bathymetric Data for Analysis and Dissemination

Caitlyn Raines

Esri Professional Services

Abstract:

For over a decade, Esri has been supporting the oceanographic and hydrographic communities, and the challenges they face such as sea level rise, ocean acidification, and coastal resiliency to name a few. The ArcGIS platform has a rich toolset for visualization, data management and analysis.

This presentation will outline the modern production cycle of a bathymetric survey using the Esri Living Atlas of the World content program as an example. Esri's Living Atlas of the Worldis the foremost collection of authoritative, ready-to-use, global geographic information ever assembled. The presentation will demonstrate how Esri synthesizes multiple data sources using Esri's bathymetric data management tools for the Esri Ocean Basemap, including a new basemap in beta testing. It will cover a synthesis workflow that:

- Identifies Data
- Develops Data Display Ordering Precedence
- Corrects Horizontal Datum Discrepancies
- Corrects Vertical Datum Discrepancies

Biography: Ms. Raines joined Esri as a project manager in 2013 after completing her Masters of Science in Geographic Information Systems at the University of Redlands. A 2009 graduate of the US Coast Guard Academy, Ms. Raines served as a deck watch officer on the USCGC RUSH (WHEC 723) in Honolulu HI before attending graduate school.

Esri's Role in the Hydrographic and Bathymetric Communities

For over a decade, Esri has been supporting the oceanographic and hydrographic communities and the challenges they face. The ArcGIS platform has a rich toolset for visualization, data management and analysis. The ArcGIS platform offers the ability to manage authoritative hydrographic data as a system of record and as a system of engagement. As a system of record, the ArcGIS platform gives the flexibility to integrate workflows across the organization to manage data and information products. As a system of engagement, the platform connects new users with new business cases to authoritative data using emerging technology. Being both a system of record and a system of engagement allows Esri to breakdown traditional data stovepipes and open data and information to an entire organization.

Maximizing Use of Hydrographic Data

While the technology supporting hydrographic data collection continues to advance and improve, the fact remains that hydrographic data is expensive to collect and process. To get the maximum amount of return on an investment in any survey, it is important that the data can be used multiple times or for multiple purposes. The edict of "map once, use many times" is critical in a mapping discipline where data collection is difficult and sparse.

This often means that organizations will defer surveying in one area if another organization or agency has collected data in that area. Since different agencies collect data for different purposes, the collection methods and requirements of one agency are rarely the same as another. Hydrographers and researchers working in a region will often have to harmonize data formats, horizontal and vertical coordinate systems, and determine precedence in the event of overlap in order to create a complete picture of the seabed.

Esri's Southern Ocean Basemap: A Data Synthesis Case Study

While there are many supported workflows and the ability to customize any workflow to a specific need, developing the Southern Ocean Basemap required the compilation of data provided by multiple entities into a product that is not a traditional use of detail hydrographic and bathymetric data. The Esri Ocean Basemap program is part of Esri's Community Maps program. Users can donate their high quality authoritative data to the program to include in the basemaps, which then serve as a cartographically beautiful representations of the seafloor.

The Ocean Basemap program currently has two maps in production: the Ocean Basemap (Esri Ocean Basemap) and the Arctic Ocean Basemap (Esri Arctic Ocean Basemap. The Ocean Basemap covers the world oceans between 85°North and 85°South. The Arctic Ocean Basemap is a polar stereographically projected map of the ocean north of 60°North.

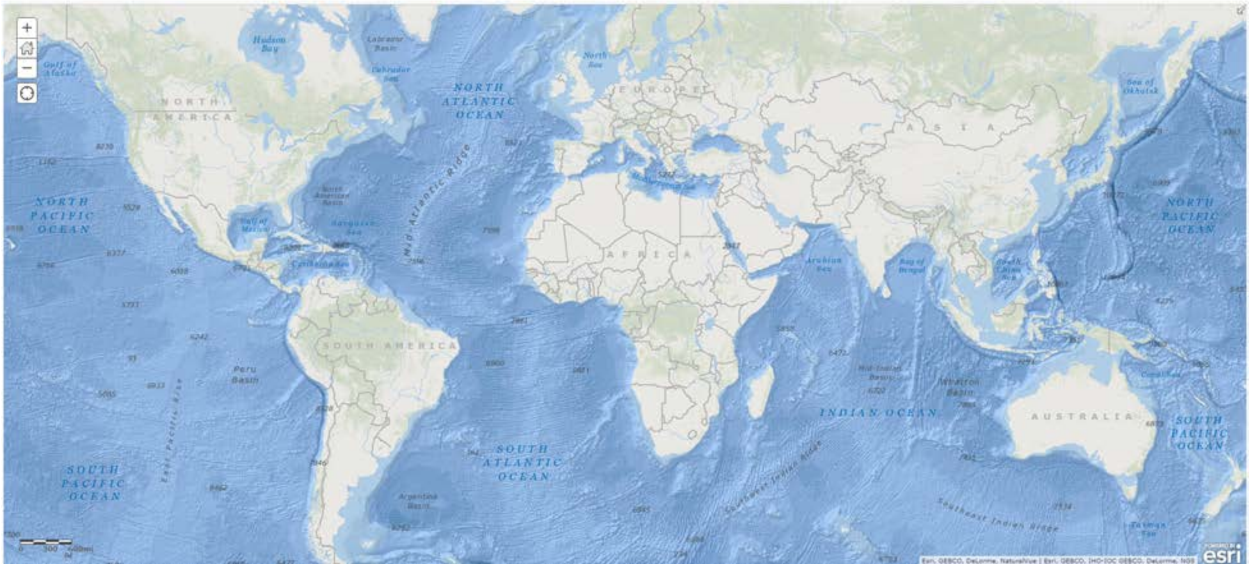

Figure 1. Esri Ocean Basemap

To complete global coverage, the team began to work on a Southern Ocean Basemap. While there are several considerations when developing basemaps, creating the seafloor is the most important for one that focuses on the ocean. Several challenges with developing the seafloor for the map were quickly identified. First, all available data needed to be identified for inclusion in the map. Second, display precedence for the data needed to be determined and codified. Third, the data needed to be re-projected into the same horizontal projection and coordinate system. Finally, the vertical datums between the various sources had to be harmonized.

Identifying Data

ArcGIS for Maritime: Bathymetry was the key to identifying previous contributed data that would contribute to the Southern Ocean Basemap. To manage and better understand their data holdings, the Ocean Basemap program uses a Bathymetry Information System (BIS). The BIS, the core of ArcGIS for Maritime: Bathymetry, is a specialized geodatabase that allows users to develop bathymetric surface models based on filters and rules created using metadata associated with the individual surveys.

When registering bathymetric or topographic datasets with a BIS, users can manually or automatically add metadata to the datasets. This metadata is entirely configurable by the user, and can include fields that need to be captured, such as location, survey method, sensor, processing steps, survey date(s), and data quality. These metadata fields are then stored and indexed, allowing to query them and retrieve any dataset instantly, based on their spatial location or metadata attributes. Looking for datasets and data discovery is also facilitated by the solution, which displays in one view all the datasets with their footprints.

The Ocean Basemap programs uses a BIS for data management and discovery for the Ocean Basemap. This BIS is a complete record of all datasets participating in the Ocean Basemap. When identifying data from the Ocean Basemap that would contribute to both the Ocean Basemap and the Southern Ocean Basemap, a polygon representing the extent of the Southern Ocean Basemap was used as a spatial filter. Using this method, three contributors were identified:

- General Bathymetric Chart of the Ocean (GEBCO) (Weatherall et al)

- Lamont-Doherty's Global Multi-Resolution Topography (GMRT) (Ryan et al)

- GeoSciences Australia (GeoSciences Australia)

Determining Precedence

The Ocean Basemap program has an established order of precedence for data display in any of the basemaps it produces. Highest resolution data is rendered first, and if there is a conflict, the most recent data has precedence. If any other conflicts exist beyond that, they are resolved based on the data collection method. These ordering rules are codified in a ArcGIS for Maritime: Bathymetry rules file that can be applied to any surface model created in a BIS with those metadata attributes.

Horizontal Datum and Coordinate Systems

While the Esri Southern Ocean Basemap is still in development, the Esri Antarctic Imagery Basemap was published in February 2016 (Esri Antarctic Imagery). Since the Antarctic Imagery Basemap uses the WGS 1984 Antarctic Polar Stereographic projection (EPSG 3031), the Ocean Basemap program also decided to use that projection for the Southern Ocean Basemap.

None of the datasets identified for inclusion were in that projection, so the team decided to create a BIS in the WGS 1984 Antarctic Polar Stereographic projection to manage the data for the Southern Ocean Basemap. The metadata configuration was imported into the Southern Ocean BIS from the Ocean Basemap BIS, allowing the team to transfer the existing metadata and surface model rules to the new BIS. Since, the Southern Ocean BIS is in the publication projection, it will re-project all of the datasets on the fly whenever they are participating in a mosaic dataset and eliminates the need to duplicate and re-project every dataset that contributes to the Southern Ocean Basemap.

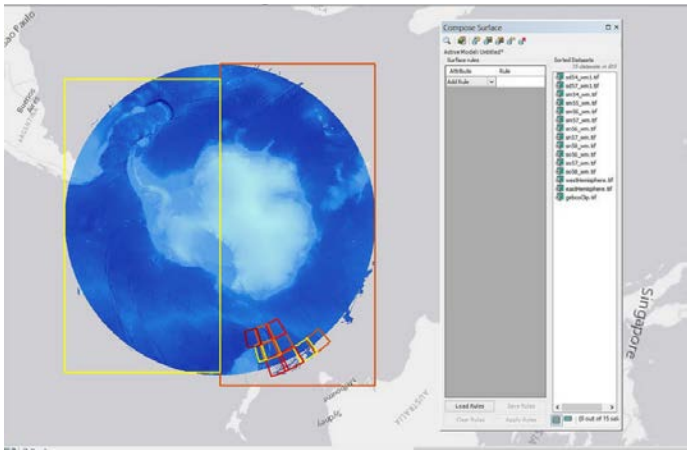

Figure 2. Southern Ocean Basemap BIS

Vertical Datum Harmonization

Often when synthesizing hydrographic and bathymetric data from different sources, data is provided at different vertical datums or vertical coordinate systems. It becomes important to convert or re-project those datasets to a common datum or coordinate system to minimize the impact of artefacts when synthesizing the data into one product.

Luckily, all three contributors in the Southern Ocean Basemap data published their data at the same vertical datum and conversion is currently not necessary. There are several ways to have conducted a vertical datum or coordinate system harmonization, had it been necessary. If the vertical projection existed in the Esri projection engine, the data could have been re-projected by taking advantage of the "vertical" option on the Project geoprocessing tool. If not, the data could be transformed with a separation model using raster functions to re-project the data on the fly or using the Raster Calculator geoprocessing tool to persist the output.

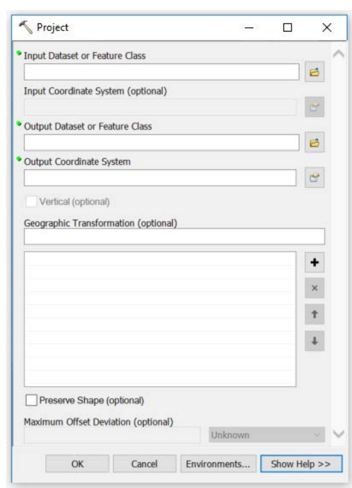

Figure 3. Project Geoprocessing Tool Dialog with Vertical Option

Putting It All Together

Once identifying and synthesizing the data for the Southern Ocean Basemap was complete, the cartographic and production work could begin. Using the ArcGIS Online tiling scheme established by the Esri Antarctic Imagery Basemap, a series of map documents were created to develop the cartography for global, medium, and large scales. Data was added into mosaic datasets for each map document based on its fitness for purpose at each scale. Once the mosaics were completed, the established cartographic color ramps were applied. After the map documents passed their first visual inspection, they were cached into tiles and published as a beta service for review.

Figure 4. Esri Southern Ocean Basemap Base Layer (Beta Version)

The Southern Ocean Basemap is still under review, but is expecting to be made available to the public Fall 2017.

Benefits of Synthesizing Data

Being able to synthesize data from multiple sources allows hydrographers and researchers to interact with all of the available hydrographic or bathymetric data as a singular unit. Looking at data in its single representative parts introduces the possibility that data is missed. It also requires that the same processes are run multiple times and can add extra work to manage edge effects created from running processes on individual pieces of data. Synthesizing data into a global unit simplifies data production cycles.

Synthesizing data also helps break hydrographic data out of traditional products which allows it to be applied in new and innovative way. Using the "map once, use multiple times" paradigm, data can be opened up to new audiences in a way that is intuitive and approachable. For example, bathymetric surface models can be served as color-coded 2D services or 3D services that visualize the sea floor. Having data available in this manner facilitates its use in non-hydrographic applications such as city and marine planning and coastal resiliency assessments.

Conclusion

While synthesizing hydrographic and bathymetric data certainly poses some challenges, the benefits are certain. Being able to streamline and combine data facilitates traditional hydrographic products, such as nautical charts. It is easier to justify continued and increased investment in hydrographic and bathymetry data collection if the audience is broader. Synthesizing data allows users to interact with data as one continuous surface which is an intuitive way of understanding the ocean floor. As technology becomes more sophisticated, the difficulties in stitching surveys together are lessoned and data dissemination methods have a lower cost of entry. It's important to start viewing hydrographic and bathymetry data as vital to multiple industries and actively working toward creating new ways to provide that data in a way that has the maximum impact.

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