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Identifying Gaps in Bathymetric Coverage in U.S. Deep Waters

Jesse Varner[1,4], Meredith Westington[2], Mashkoor Malik[3], Rachel Medley[3], Jennifer Jencks[4], Meme Lobecker[3]

(1) Cooperative Institute for Research in Environmental Sciences (CIRES), Univ. of Colorado
(2) NOAA Office of Coast Survey (OCS)
(3) NOAA Office of Ocean Exploration and Research (OER)
(4) NOAA National Centers for Environmental Information (NCEI)

Introduction

The Nippon Foundation - GEBCO Seabed 2030 project has revitalized international and national interest in ocean floor mapping. NOAA, in cooperation with federal, state and academic partners, seeks to achieve 100% mapping of the U.S. seafloor by 2030. Recognizing the challenge in mapping such an expansive area, coordination of future mapping efforts among various partners will be critical and requires a detailed inventory of existing mapping data. To inventory existing data, publicly-available bathymetric data are analyzed from the IHO Data Center for Digital Bathymetry (IHO DCDB), hosted at NOAA's National Centers for Environmental Information (NCEI), and NOAA's Digital Coast.

To optimize mapping activities over the gaps in bathymetric data coverage, NOAA seeks to match its current technological capacities and mandates with the physical oceanographic environments. NOAA's Ocean Exploration and Research (OER) program, in cooperation with NOAA's Office of Coast Survey (OCS), is focused on mapping and exploring the deep ocean seafloor environments (>200m depth), and seeks to fill gaps in these areas in a systematic way.

The percentages of mapped and unmapped are powerful, high-level messages of U.S. progress toward a Seabed 2030 goal. NOAA has been tracking these metrics since 2017 using polygon-based methods; however, as this analysis grows and expands to include other use cases, this polygon-based approach is not sustainable. To prepare for broader user access to these reporting capabilities, we tested raster-based methods and checked for consistency.

U.S. Bathymetry Gap Analysis

In 2017, a bathymetry coverage and gap analysis of sounding density was produced by OCS, University of New Hampshire Center for Coastal and Ocean Mapping/Joint Hydrographic Center (UNH CCOM/JHC), and NCEI (Westington et al., 2018) to inform an ocean and coastal mapping strategy for U.S. waters and contribute to the Seabed 2030 initiative. **The U.S. Bathymetry Gap Analysis is now planned for updates every six months (last update Jan. 2020).**

The U.S. Bathymetry Gap Analysis incorporates all publicly-accessible bathymetric data in U.S. waters as well as adjacent areas of potential extended continental shelf. The underlying data are archived at NOAA NCEI / IHO DCDB and NOAA's Digital Coast.

Data layers included in the U.S. Bathymetry Gap Analysis:

- Extended Continental Shelf Grids (UNH CCOM/JHC)
- Bathymetric LIDAR
- NOAA/NOS Hydrography (BAG-formatted + MB)
- Multibeam Bathymetry
- NOAA/NOS Hydrography (> 1960)
- Single-beam Bathymetry (> 1960)
- Crowdsourced Bathymetry

The resulting product depicts the bathymetric sounding densities in two categories: pink denotes 1-2 soundings per ~100m cell or "minimally mapped", and purple denotes 3+ soundings per ~100m cell or "better mapped" (Figure 1).

The GIS web service can be found at: http://tinyurl.com/yaq7h9ly. It is a useful visual guide to help with planning and is included in websites such as the U.S. Mapping Coordination SeaSketch site.

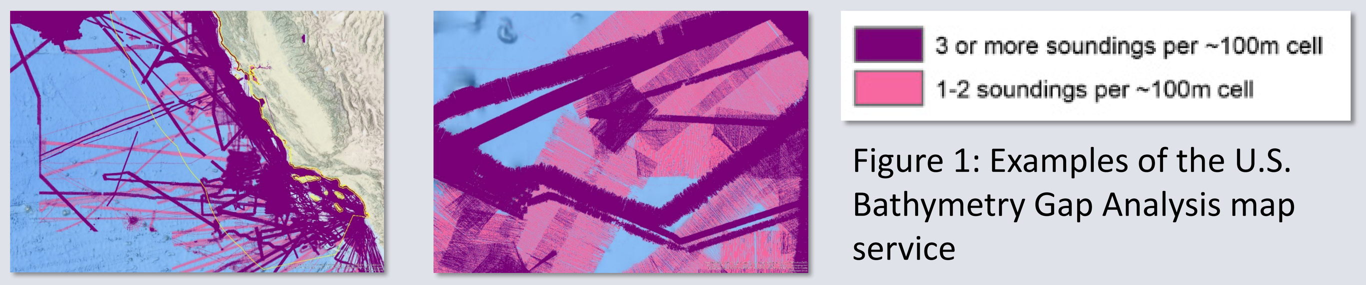
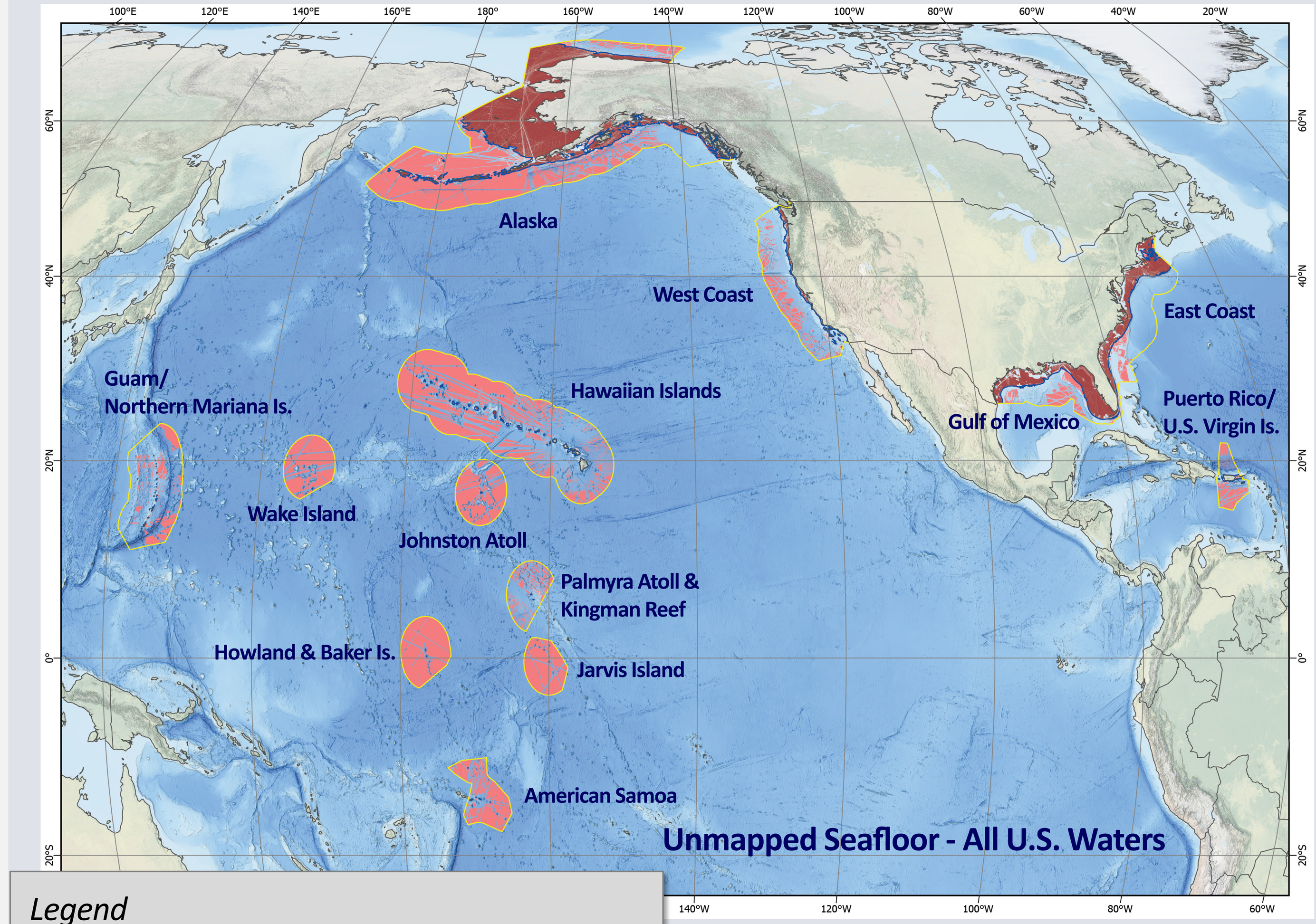


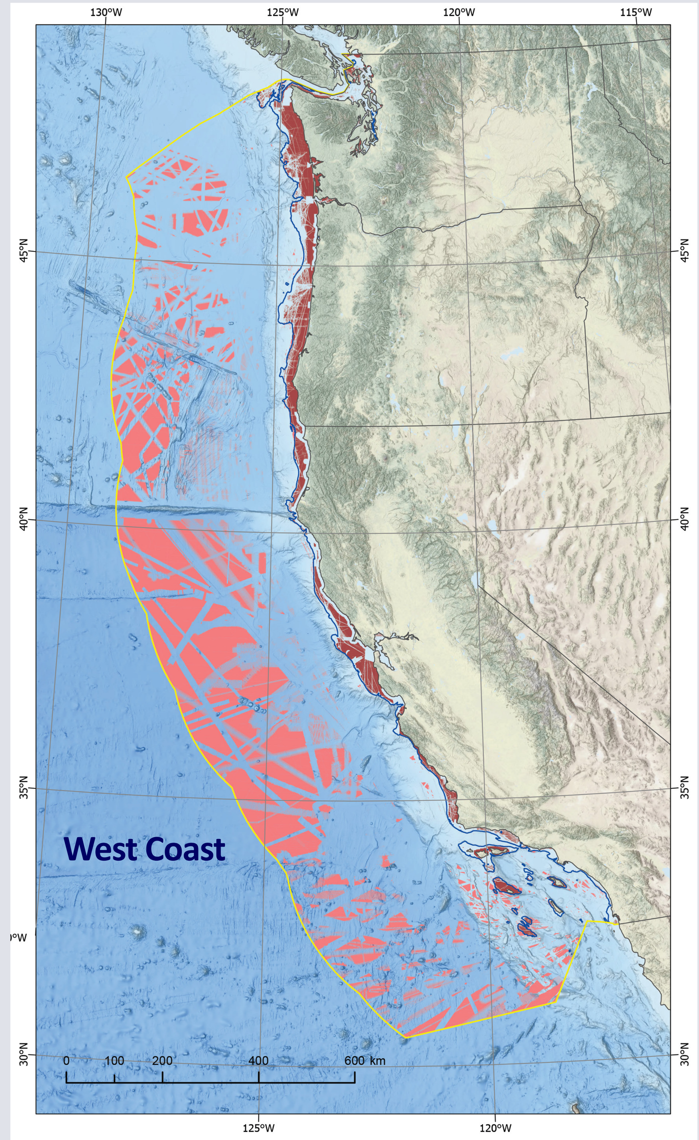
Figure 1: Examples of the U.S. Bathymetry Gap Analysis map service

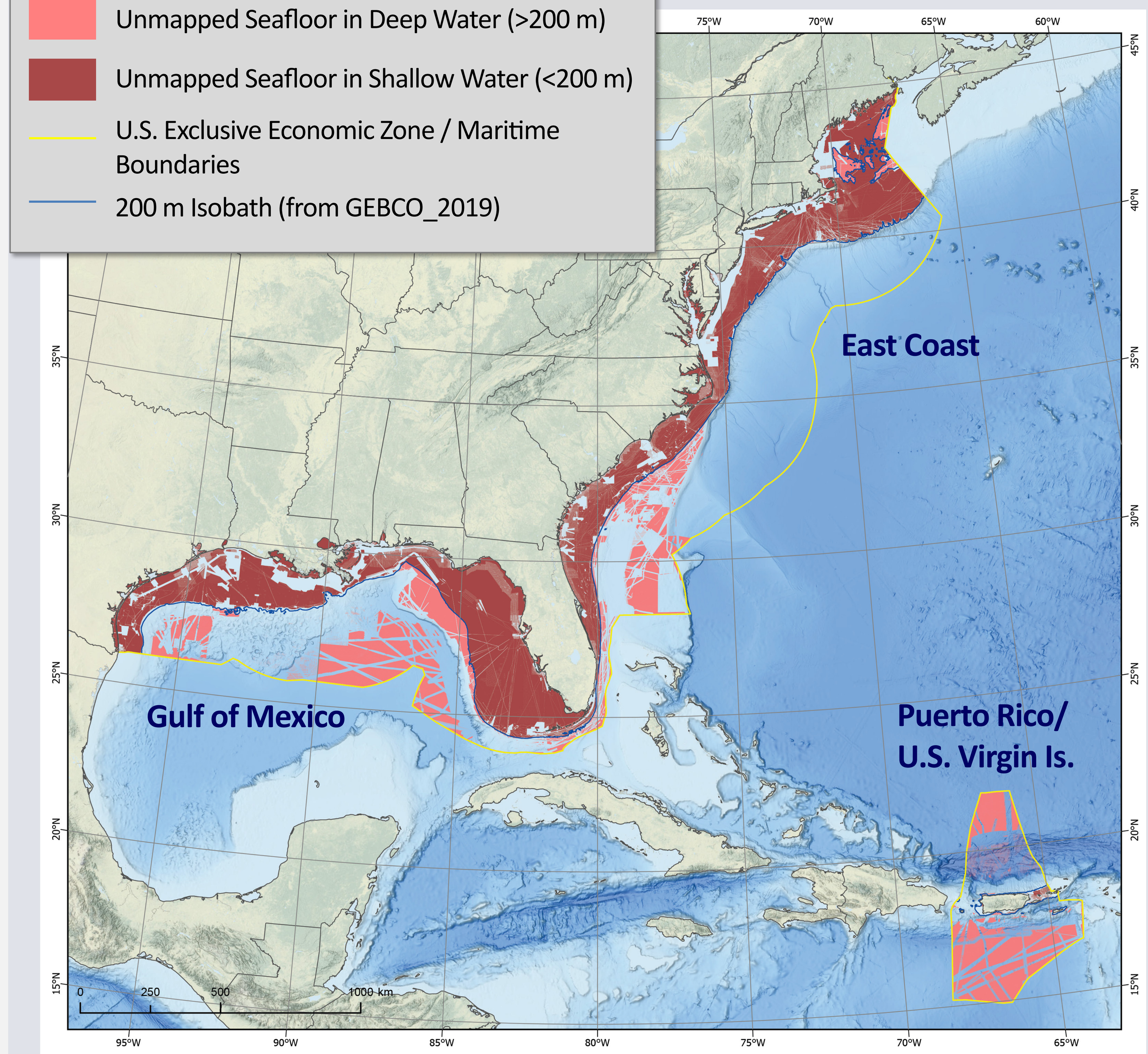
As of Jan. 2020, 45% of U.S. coastal, ocean, and Great Lakes waters to the outer limit of the U.S. exclusive economic zone are minimally mapped. Conversely, approximately 55% of U.S. waters are left to map. Within these unmapped areas, water depths and conditions vary greatly. As a result, the level of effort required with filling this gap is not uniform across all the unmapped areas. This poster highlights the geographic scope and breadth of the data gaps in waters deeper than 200 m.

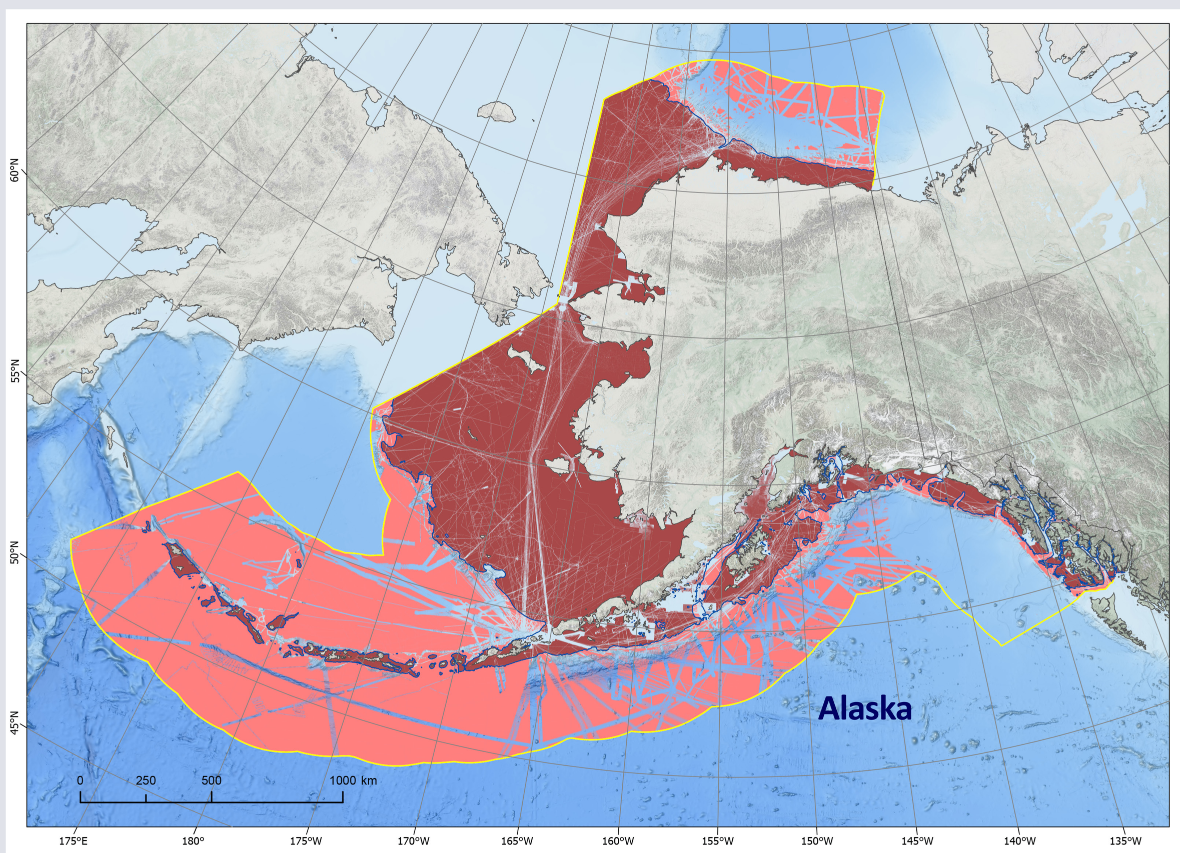


Legend

- Unmapped Seafloor in Deep Water (>200 m)
- Unmapped Seafloor in Shallow Water (<200 m)
- U.S. Exclusive Economic Zone / Maritime Boundaries
- 200 m Isobath (from GEBCO_2019)







Unmapped Area Statistics in U.S. Deep Waters (>200m) as of Jan. 2020

By Region:

Region	Unmapped area >200m depth (km²)	Total Area >200m depth (km²)	% Unmapped*
Alaska	1,506,249	2,332,969	64.6%
American Samoa	265,066	405,547	65.4%
East Coast	75,029	568,241	13.2%
Guam/CNMI	173,588	969,385	17.9%
Gulf of Mexico	111,039	356,910	31.1%
Hawaiian Islands	1,103,922	2,454,667	45.0%
Howland & Baker Islands	400,287	434,877	92.0%
Jarvis Island	266,845	315,058	84.7%
Johnston Atoll	300,469	442,248	67.9%
Palmyra Atoll & Kingman Reef	88,862	351,258	25.3%
Puerto Rico/USVI	87,377	203,457	42.9%
Wake Island	302,391	407,734	74.2%
West Coast	166,157	756,487	22.0%
Total	**4,847,283**	**9,998,836**	**48.5%**

By Depth Band:

Depth band	Unmapped Area (km²)	Total Area (km²)	% Unmapped*
200-1000m	245,462	609,875	40.2%
1000-2000m	119,431	515,005	23.2%
2000-3000m	194,956	902,806	21.6%
3000-4000m	627,071	1,752,102	35.8%
4000-5000m	1,385,718	3,010,803	46.0%
5000-6000m	2,166,643	2,946,914	73.5%
>6000m	108,089	261,396	41.4%

*Area error approximately +/- 0.2%

Preparing the Data

The Bathymetry Gap Analysis results were obtained using these processing steps:

- Create depth band polygons from the GEBCO_2019 global bathymetry grid (ArcGIS Contour tool: "Contour shell")
- Clip depth band polygons to the extent of U.S. waters (from NOAA OCS)
- Split depth band polygons into U.S. regions
- Clip Bathymetry Gap Analysis rasters: 1) by region and 2) by depth bands. (ArcGIS "Extract by Mask" tool)
- Create output showing the unmapped areas for map figures (use ArcGIS "Is Null")

Calculating Geodesic Areas

When determining areas on the surface of the Earth, care must be taken to perform accurate geodesic area computations. Starting with the Bathymetry Gap Analysis as a set of rasters in WGS84 geographic (unprojected) coordinates, three possible strategies are:

Option 1: Convert rasters to polygons, compute area

Use GDAL "gdal_polygonize" to create polygon shapefiles. Calculate geodesic area of shapefile in ArcGIS using `!Shape!.getArea('GEODESIC', 'SQUAREKILOMETERS')`.

Advantage:

- Most accurate results

Disadvantages:

- Very complex polygons are generated (millions of vertices). Many hours of computation and large amount of RAM required for clipping, etc. Can crash GIS software.
- Area computation can be slow (hours)
- Resulting polygons are slow to draw in desktop GIS or web services
- Not adaptable as a geoprocessing web service for users to compute statistics

Option 2: Project raster to an equal-area projection, count the pixels

In ArcGIS, project raster to "Cylindrical Equal Earth" projection, (cell size 25m). "Build Raster Attribute Table" to get the cell count, multiply by area of cell.

Advantage:

- Similar results to other methods (within ~0.2%)

Disadvantages:

- Raster must be resampled (can introduce artifacts)
- Can be small inaccuracies where pixels overlap curved boundaries

Option 3: Keep rasters in WGS84 geographic coordinates, compute geodesic area of raster row-by-row

The area of a WGS84 cell varies by latitude. A Python script was written to sum the area for each row (latitude band) in the raster. A code snippet to perform this calculation was found at: https://gis.stackexchange.com/a/288034.

Advantages:

- Much faster than the other methods (only seconds to process)
- Similar results to other methods (within ~0.2%)
- Raster does not need to be re-projected
- More readily adaptable for use in a GIS web service/geoprocessing service

Disadvantages:

- Can be small inaccuracies where pixels overlap curved boundaries

Option 3 (raster-based) is the most efficient, repeatable method and was used for these latest statistics for U.S. waters >200m depth. We will use this method for future updates.

For more information, contact:
Jesse.Varner@noaa.gov
Meredith.Westington@noaa.gov

Reference:
Westington, M.; Varner, J.; Johnson, P.; Sutherland, M.; Armstrong, A.; Jencks, J., 2018. Assessing Sounding Density for a Seabed 2030 Initiative. Proceedings of the Canadian Hydrographic Conference. Victoria, British Columbia. (Retrieved from https://www.eiseverywhere.com/file_uploads/88d4852d59327aec9aee1f08b5f64e84_AssessingSoundingDensityforaSeabed2030Initiative_CHC20181Meredith.pdf)

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