Poster # **OS33D-3295**

An Analysis of Bathymetric Sounding Density to Inform Ocean Mapping Strategies

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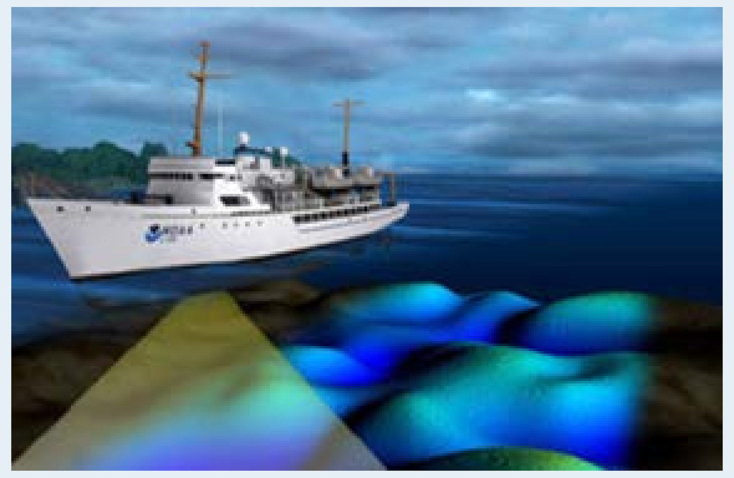
International Goal: Map the Entire Ocean Floor by 2030

Seabed 2030 Project Sponsor: The Nippon Foundation-GEBCO[1]

Current state: < 5% of the world's seafloor is mapped using high resolution, multibeam echosounders[2]



What Constitutes "Mapped"? How Do We Assess U.S. waters?

Basic U.S. Definition of "Mapped"

- Survey Vintage: 1960 to present
- Data Density
  - 1–2 measurements per 100 meter cell
  - 3 or more measurements per 100 meter cell = Better Mapped
- Analytical extent: U.S. coastal waters, exclusive economic zone, and adjacent continental shelf

As a leader in hydrographic surveying since 1807, NOAA's Office of Coast Survey (OCS) proposes a broad definition of "mapped" for the purpose of this bathymetry coverage and gap analysis. OCS chooses to analyze the density of the bathymetric data collected from 1960 to the present. This timeframe marks a significant change in survey techniques, as electronic positioning and GPS, the modern method for determining positioning, became prevalent. *A resolution of 100 m is chosen to reflect the overarching goals of Seabed 2030.*

Principal Layers of Bathymetry

NOAA NCEI/IHO Data Center for Digital Bathymetry

- Multibeam Bathymetry
- NOS/OCS Hydrography (>1960)
- Single-beam Bathymetry (>1960)
- Crowdsourced Bathymetry
- NOS/OCS Hydrography (BAG-formatted + multibeam)
- Extended Continental Shelf Grids

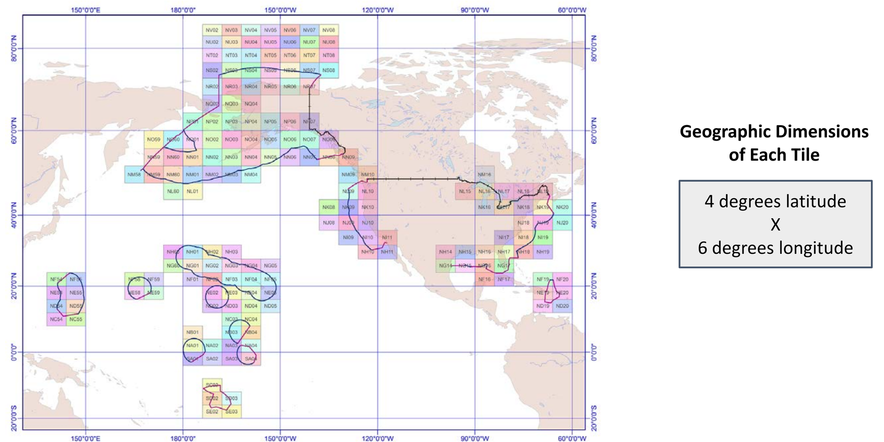
NOAA's Digital Coast

- Bathymetric LIDAR

Openly accessible bathymetry is a key aspect of this analysis. NOAA's National Centers for Environmental Information (NCEI) is the bathymetric data repository and archive for the U.S. as well as for much of the international community. NOAA's Digital Coast application, which is hosted by NOAA's Office for Coastal Management, provides easy access to bathymetric LIDAR that is archived at NCEI.

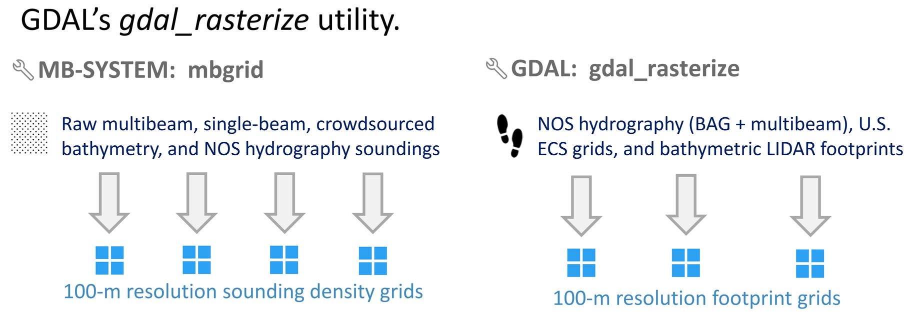
Within this definition of "mapped," there are 3 types of hydrographic survey instruments in use: single-beam echosounder, multibeam echosounder, and bathymetric LIDAR. Of these 3 types of instruments, multibeam and bathymetric LIDAR provide full-coverage. This type of modern instrumentation is used in all of the analytical layers, except Single-beam and Crowdsourced Bathymetry. Though not full-coverage, the single-beam echosounder data associated with the remaining two layers can be highly precise over specific portions of the seafloor.

Processing and Gridding Framework



To process seven layers of bathymetry across the expanse of U.S. waters, 177 processing tiles are used. The geographic dimensions of each tile are based on the International Map of the World scheme.[3]

Individual sounding measurements from the NCEI's Multibeam, Single-beam, NOS Hydrography, and Crowdsourced Bathymetry databases are gridded using MB_System's *mbgrid* utility. The survey footprints associated with high density bathymetric data sources, such as the extended continental shelf grids (ECS), bathymetric LIDAR, and BAG-formatted NOS Hydrography, are gridded using GDAL's *gdal_rasterize* utility.



Supersession Rules for Grid Merge

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

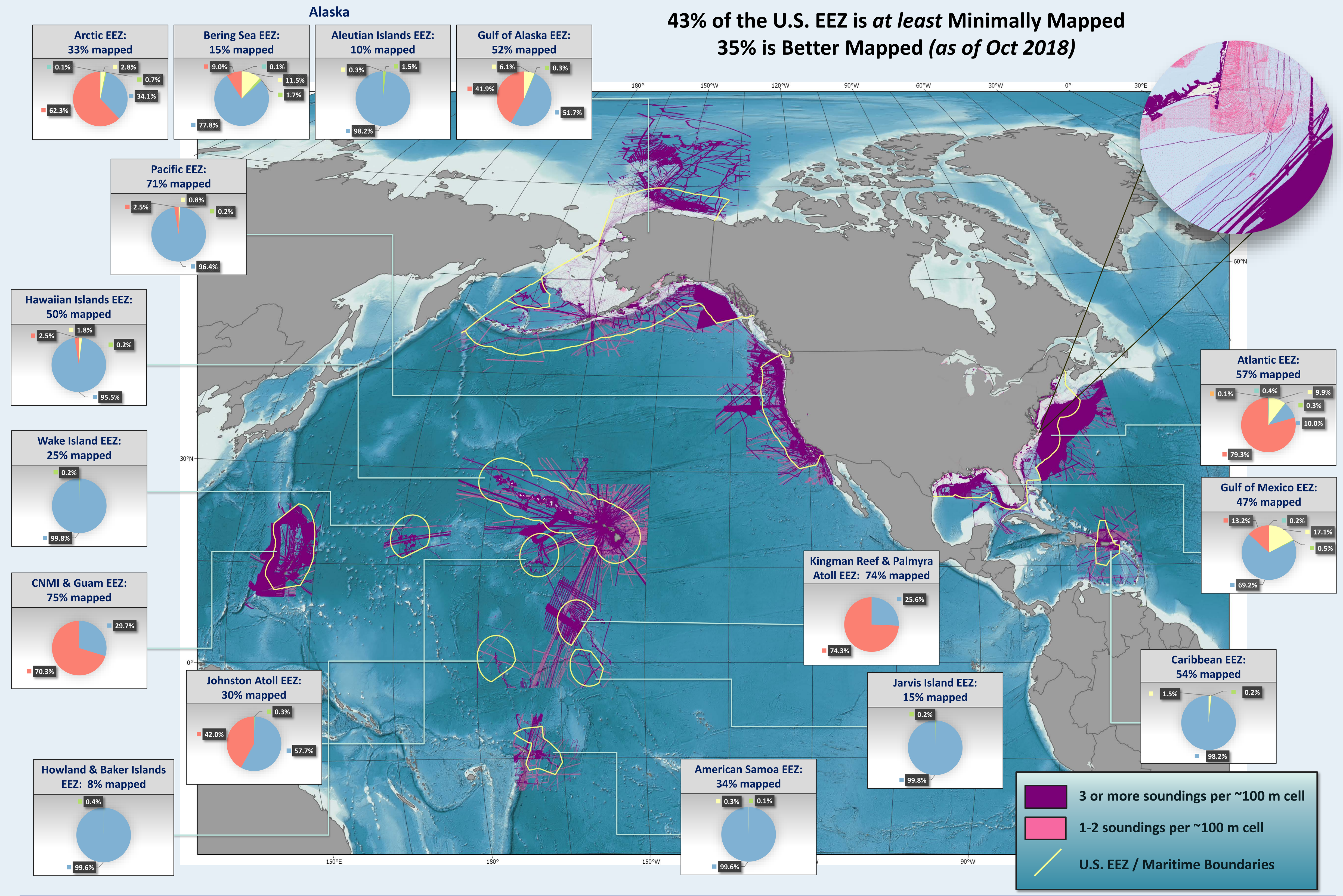
The individual bathymetry layers are merged using an *AND* operator. Instead of adding the sounding densities of each layer, this operator replaces information in one layer with another. The stacking shown above places the highest density, highest quality data on top of all other data layers.

(Note: The colors shown above match the pie charts to the right.)

Bathymetry Coverage and Gap Analysis

The following map depicts the NOAA geospatial web service display. After merging the grids, the sounding densities in each cell are reclassified to either 1 or 3. A cell with a value of 1 (shown in pink) represents sounding densities with 1 to 2 measurements. A cell with a value of 3 (shown in purple) represents sounding densities equal to 3 or more measurements. For the portion of U.S. waters that is within the exclusive economic zone, the pie charts indicate the % contribution of each bathymetry layer to the total area of minimally mapped (1+ soundings per cell). Note that for some regions, such as the Atlantic and Arctic, dedicated ocean mapping campaigns in support of the U.S. Extended Continental Shelf Project make up a large portion of the bathymetric coverage.

43% of the U.S. EEZ is *at least* Minimally Mapped
35% is Better Mapped *(as of Oct 2018)*



The U.S. exclusive economic zone (EEZ) is 3.4 million square nautical miles. Generally, it encompasses federal waters from approximately 3 to 200 nautical miles. The coastal and Great Lakes waters are an additional 200,000 square nautical miles. Generally, these waters are landward of the Exclusive Economic Zone and include ports, bays, and rivers. For simplicity, the percentage and source proportions for these coastal waters are not shown here.

Visualization

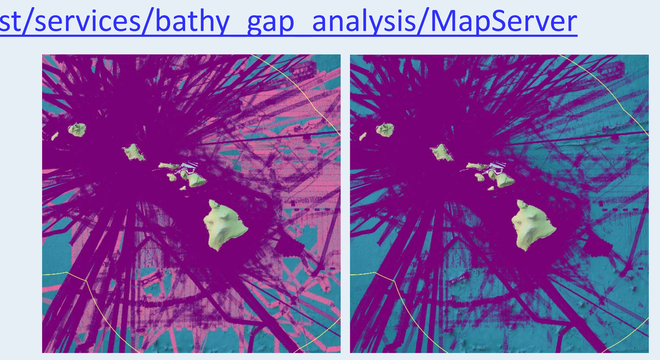
1-2 soundings are displayed as pink, and 3+ soundings as purple. Unmapped areas are transparent.

- Start with 177 grids of the analysis
- Divide into separate rasters for 1-2 soundings and 3+ soundings
- Render as RGBA images (RGB with alpha/transparency channel) using GDAL
- Add RGBA images to 2 separate ArcGIS mosaic datasets
- Generate mosaic dataset overviews (down-sampled images; improves drawing performance for smaller scales)
- Transparency is smoothly blended in the down-sampled images. This improves visual interpretation by neither over nor under-portraying the coverage.

Geospatial Web Service

- ArcGIS map service published with 2 sub-layers: 1-2 soundings and 3+ soundings https://gis.ngdc.noaa.gov/arcgis/rest/services/bathy_gap_analysis/MapServer

More info on NOAA GeoPlatform: http://tinyurl.com/yaq7h9ly



The map service layers can be toggled separately to highlight "better mapped" areas.

How Will We Fill the Gaps?

With only 43% of the U.S. EEZ mapped to minimal standards, there is a gap of 57%, or 1.97 million square nautical miles, of U.S. EEZ to fill by 2030. The challenge is large. To put it into perspective, the dedicated Extended Continental Shelf mapping campaign surveyed approximately 1 million square nautical miles of deep water EEZ and adjacent continental shelf over a span of 15 years. To make the most of a surveying effort, NOAA is actively working with industry partners and the maritime community to acquire crowdsourced bathymetry. In addition, NOAA is requesting vessels to adjust their transits, so new data may be collected with minimal effort. While additional surveying is most certainly needed to fill the gaps, there are many instances where bathymetric data has been collected, but not sent to NCEI for open access. To help break down the barrier to delivery, NCEI has created a tool (CruisePack) to seamlessly take data from the ship and organize it for archive and open access.

Integrated Ocean and Coastal Mapping
"map once, use many times"

Key Strategies

- Plan for transits to acquire bathymetric data en route
- Coordinate on projects using tools like http://fedmap.seasketch.org
- Optimize use of existing data to fill gaps
- Agree on common standards/resolutions
- Leverage new technologies, force multiplier
- IHO Crowdsourced Bathymetry initiative
- Collaborative mapping campaigns

[1]National Oceanic and Atmospheric Administration (NOAA), National Ocean Service, Office of Coast Survey
[2]Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder - NOAA/NESDIS/National Centers for Environmental Information
[3]University of New Hampshire's Center for Coastal and Ocean Mapping/Joint Hydrographic Center
[4]NOAA/NESDIS/National Centers for Environmental Information

References

[1] The Nippon Foundation-GEBCO, 2016. "The Nippon Foundation – GEBCO – Seabed 2030: Roadmap for Future Ocean Floor Mapping." (Retrieved from https://seabed2030.gebco.net/documents/seabed_2030_roadmap_v10_low.pdf)

[2] Mayer, L.; Jakobsson, M.; Allen, G.; Dorschel, B.; Falconer, R.; Ferrini, V.; Lamarche, G.; Snaith, H.; Weatherall, P. The Nippon Foundation—GEBCO Seabed 2030 Project: The Quest to See the World's Oceans Completely Mapped by 2030. *Geosciences* 2018, 8, 63.

[3] Rugg, Dean S., 1951. The International Map of the World. The Scientific Monthly, Vol. 72, No. 4. American Association for the Advancement of Science, pp. 233-240.

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See technical paper:
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)

Office of Coast Survey
National Oceanic and Atmospheric Administration

National Centers for Environmental Information
National Oceanic and Atmospheric Administration

Center for Coastal and Ocean Mapping/Joint Hydrographic Center
University of New Hampshire/National Oceanic and Atmospheric Administration

Cooperative Institute for Research in Environmental Sciences
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December 2018