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Evaluating methods to obtain high resolution nearshore bathymetry and coastal topography for Puget Sound

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Washington State Department of Ecology

Overview

The Washington State Department of Ecology Coastal Monitoring & Analysis Program (CMAP) performed a coastal topographic and bathymetric survey of Port Gamble Bay in March 2014. Boat-based topographic lidar data were collected along the shoreline and multibeam bathymetric sonar data were collected throughout the bay to obtain a seamless topographic-bathymetric surface with complete coverage of Port Gamble Bay.

The Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX) performed an airplane-based topographic-bathymetric (topobathy) lidar survey of Port Gamble Bay in September 2014. The Coastal Zone Mapping and Imaging Lidar (CZMIL) system obtained seamless coverage of the coastal and upland topography and nearshore and intertidal bathymetry of Port Gamble Bay.

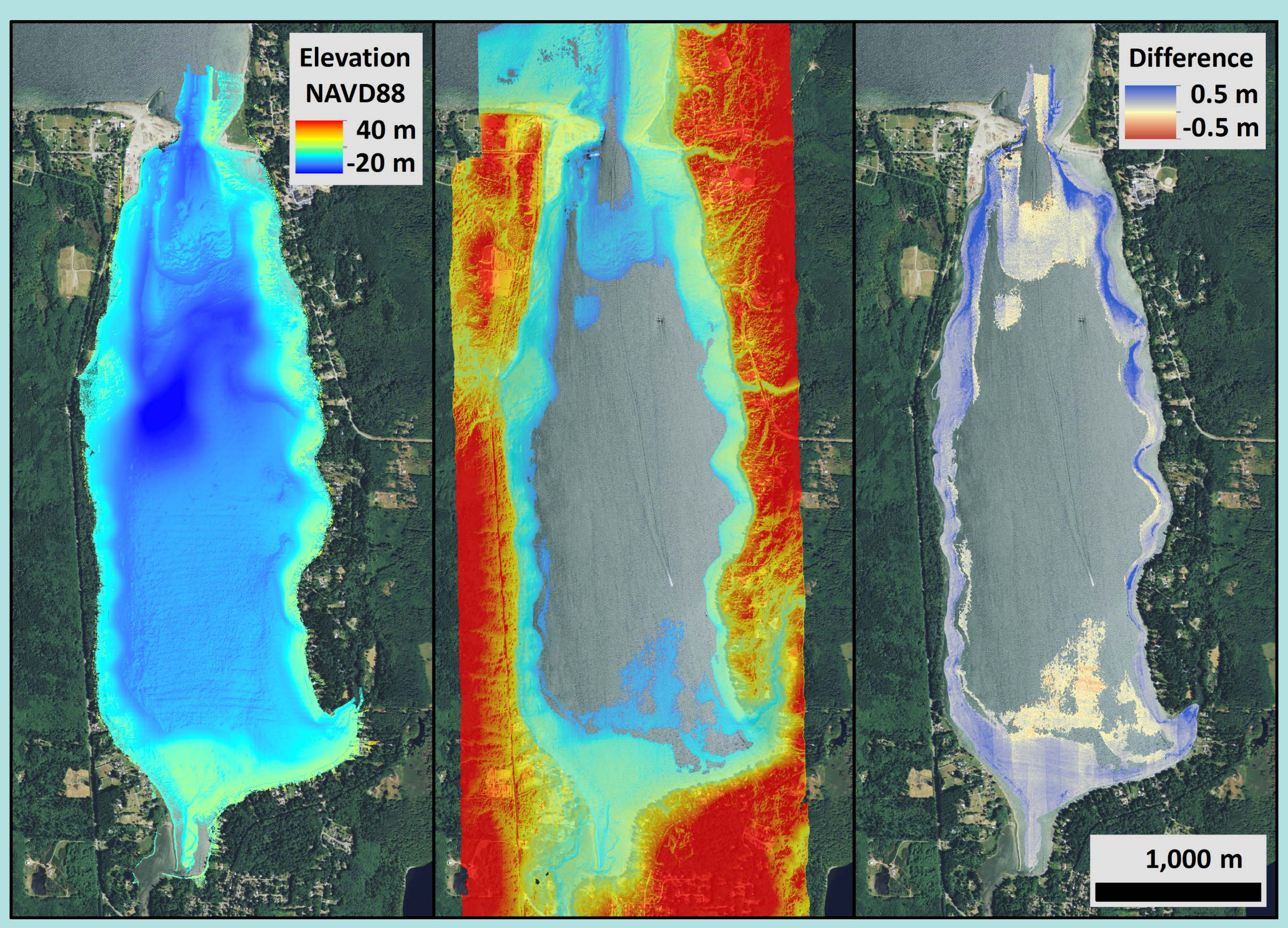
The availability of these two datasets provides the unique opportunity to compare data between high-resolution boat-based lidar and multibeam systems and the state-of-the-art airborne topobathy lidar system. This project evaluates overall data agreement, airborne lidar depth of extinction, small-scale object detection, and the effects of aquatic vegetation.

Data Acquisition and Processing

CMAP's R/V *George Davidson* is equipped with an R2Sonic 2022 multibeam echosounder (MBES), an Optech ILRIS HD ER laser scanner, and an Applanix POS MV 320 IMU. Position and motion were post-processed with POSPac MMS. Vegetation & structures were cleaned from both datasets. MBES data were gridded using a CUBE algorithm and combined with gridded laser data.

JALBTCX utilizes the Optech CZMIL laser scanner and a combination of Novatel and Applanix POS AV 510 IMUs for positioning, post-processed with POSPac MMS. Navigation is combined with the lidar data to produce 3D positions for each lidar shot. Water surface data are removed and non-ground data are flagged. Valid ground and bathymetry points are linearly interpolated with a TIN and gridded.

Datasets

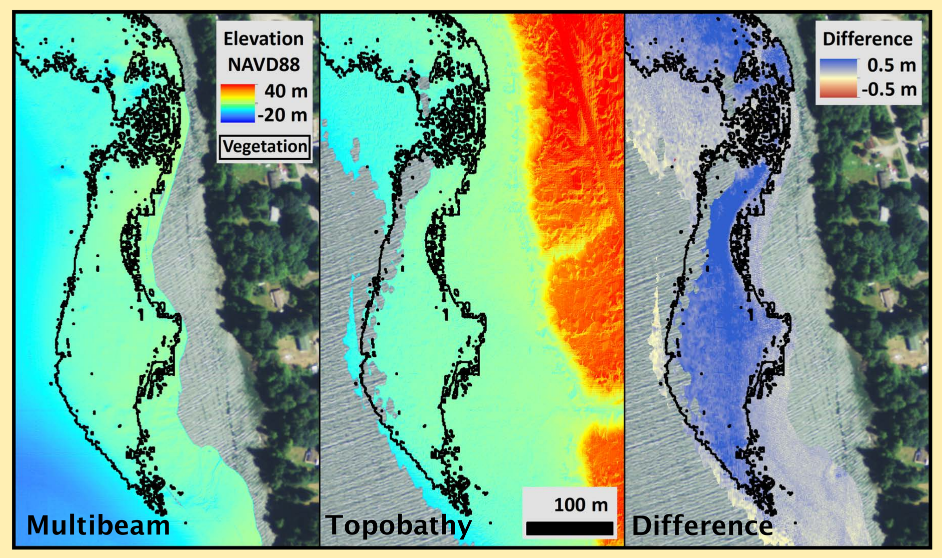


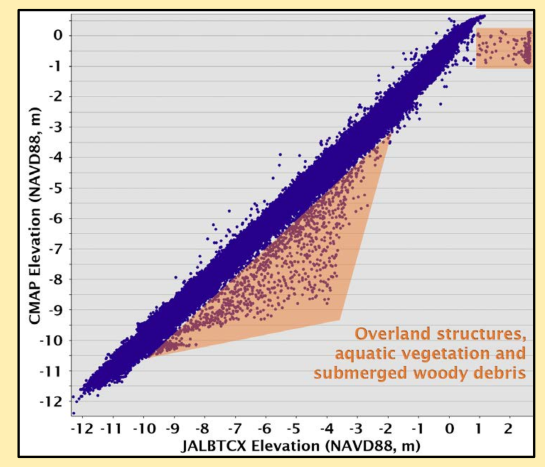
Left—CMAP multibeam and boat-based lidar of Port Gamble Bay
Center—JALBTCX airborne topobathy DEM of Port Gamble Bay (same scale)
Right—Surface difference (positive values = JALBTCX above CMAP)

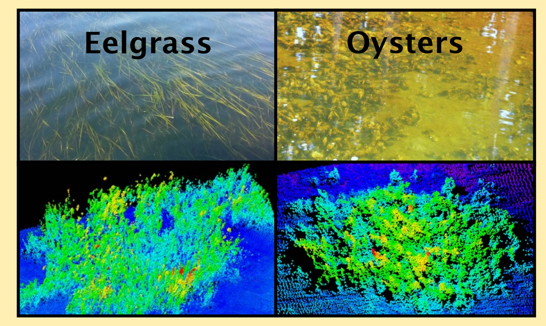
Data Comparison

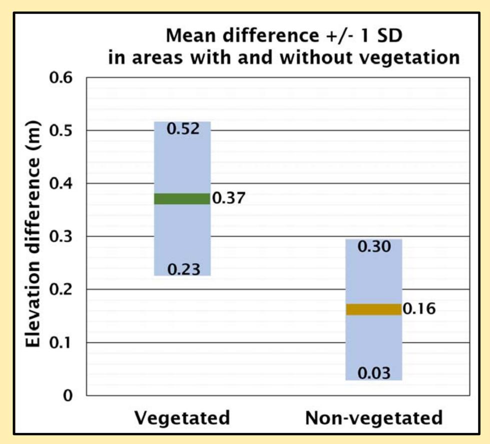
Vertical Agreement

The JALBTCX dataset is higher than the CMAP bathymetry by an average of 19 cm. The difference varies with depth and presence of vegetation.



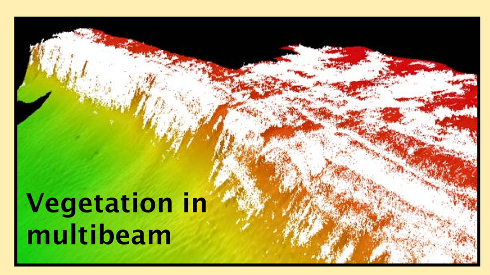




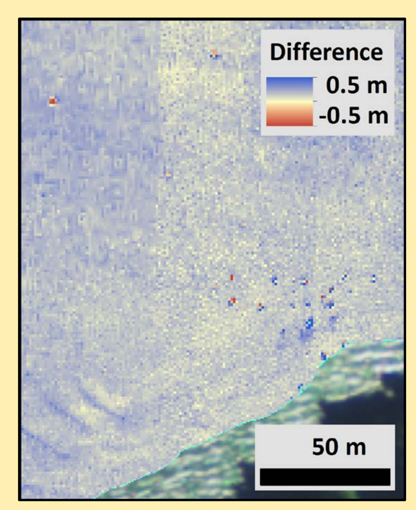


Vegetation

Dense aquatic vegetation impedes the topobathy laser and can result in a data gap or returns off the vegetation. In contrast, MBES soundings off aquatic vegetation can be identified and removed from the DEM, with enough density to resolve the ground surface underneath.

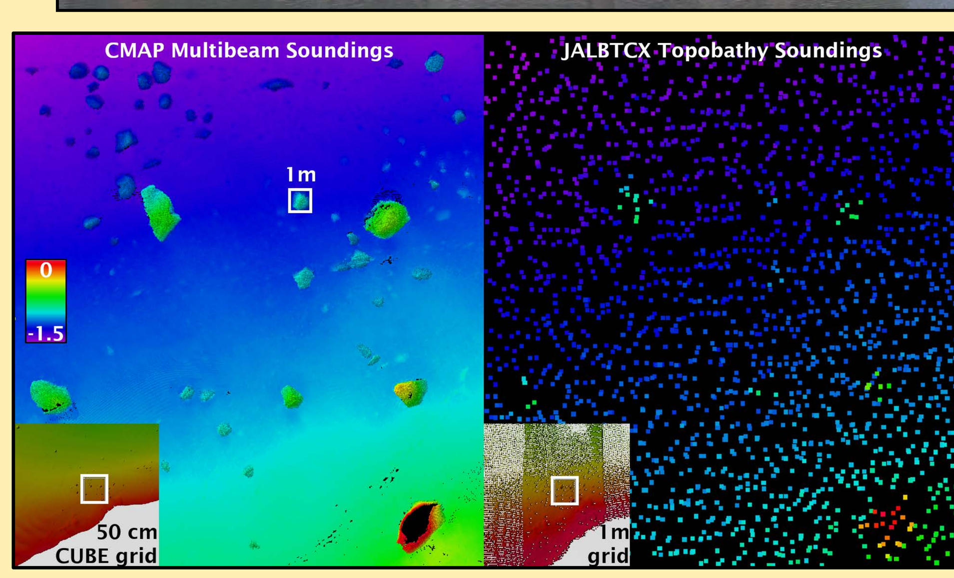


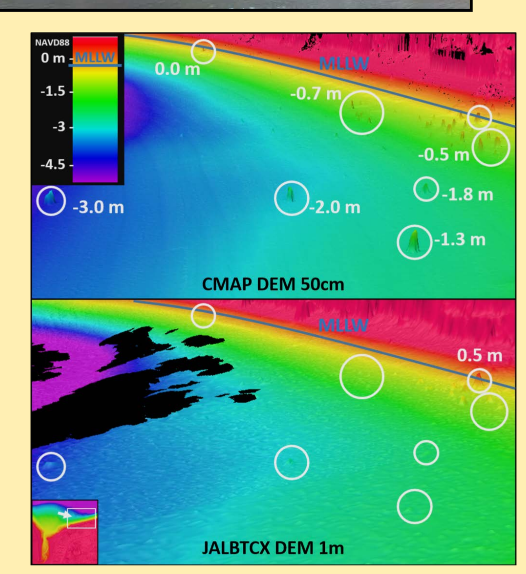
Areas with aquatic vegetation (as seen in the MBES data) show a greater vertical discrepancy between MBES and topobathy than areas without (0.37 vs. 0.16 m, respectively). Deeper areas with vegetation were more likely to result in data gaps than shallower areas.



Object Detection

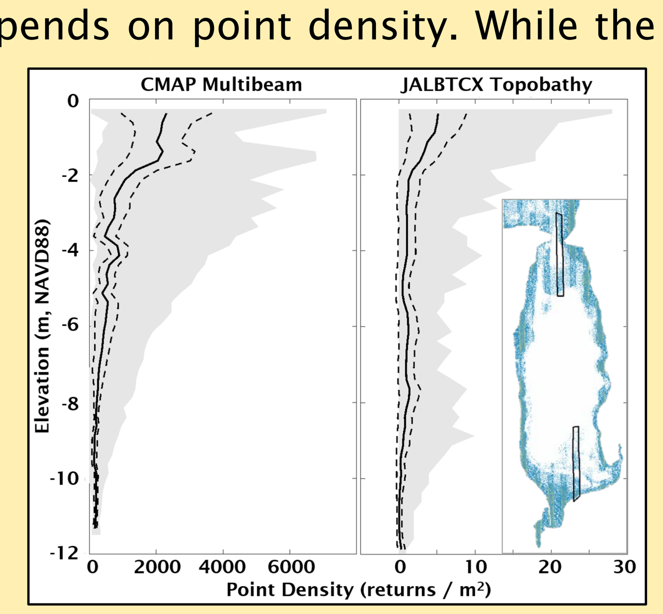
At the south end of the bay, the surface difference shows meter-scale discrepancies in a boulder field. The MBES dataset shows many more rocks than the topobathy dataset and more frequently obtains a shoaler value. The exception is where full coverage of a boulder was not achieved by MBES due to insufficient clearance in shallow water.





Point Density

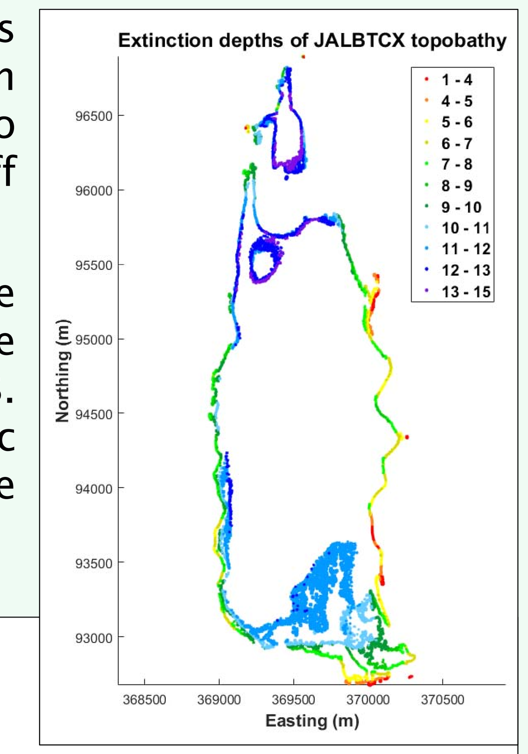
Resolution and accuracy of the final DEM depends on point density. While the point density profile with respect to depth is similar in shape between the MBES and topobathy lidar data, there are two orders of magnitude difference. The sample graphed at right was taken from an area of overlap between adjacent flight lines and shows topobathy with 0-30 pts/m² and MBES with 0-7,000 pts/m². Topobathy sounding density averages 5 pts/m² at 0 m NAVD88 (2 m depth) and decreases significantly at 4 m depth. This increases the difficulty of object detection in shallow water.



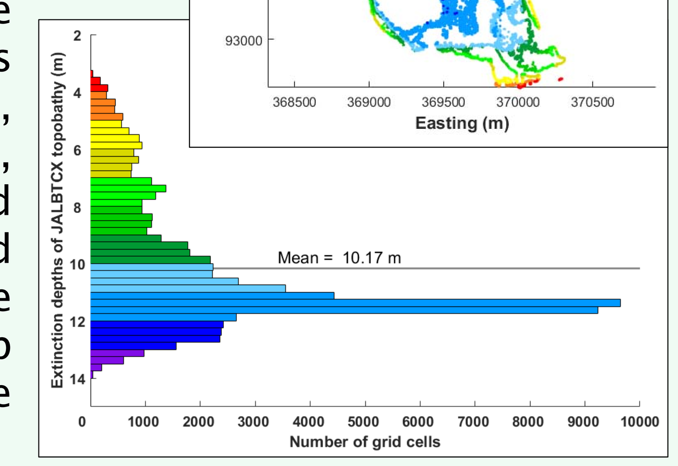
Topobathy Lidar Extinction Depth

Airborne lidar depth of extinction is controlled by turbidity and bottom reflectivity. Light penetrates farther into clear water and reflects more strongly off of light-colored substrate.

The average water surface during the topobathy survey was measured by the topobathy survey acquisition laser to be 1.98 m NAVD88. This value was used to convert orthometric heights to depths below water level at the time of the survey.

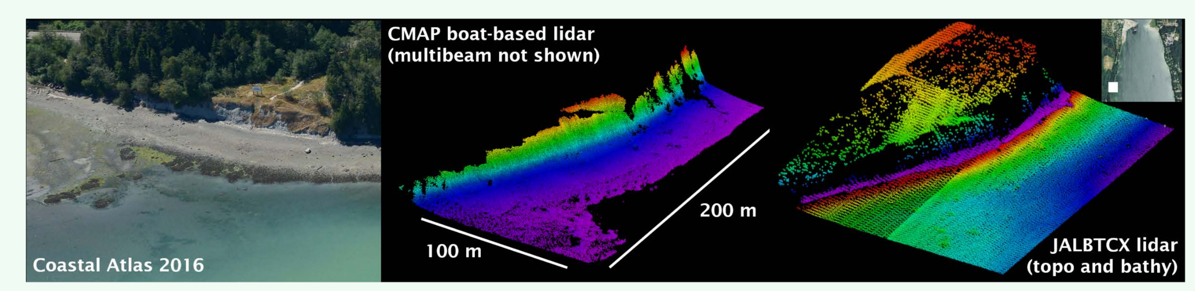


Extinction points in Port Gamble Bay, as defined by grid cells adjacent to the edge of the DEM, had depth values from 2 to 14 m, with the shallowest values found along the eastern shoreline and the deepest penetration at the mouth of the bay. A large deep extent can also be seen at the wide flat region in the south of the bay.

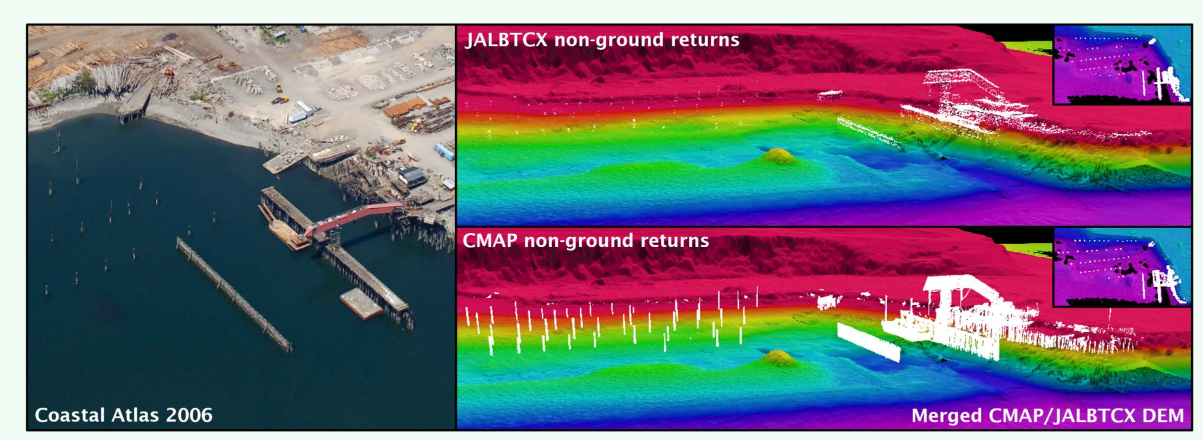


Boat-based Lidar vs. Topobathy Lidar

Boat-based lidar data collected at low tide complement CMAP's multibeam bathymetry, creating seamless data coverage to the top of the bluff. Dense point coverage on the bluff face allows for high-resolution mapping of the steep terrain and monitoring of bluff change, and complements airborne lidar above the bluff.



Both airborne and boat-based lidar can show presence/absence of objects on the scale of pilings. Airborne lidar has a significant advantage on horizontal surfaces that cannot be seen from a boat, such as upland plateaus. However, the point density and horizontal look-angle of the boat-based lidar allow for easier object detection, identification, and analysis of both vertical surfaces and objects under overland structures such as piers.



Conclusions

Airborne topobathy lidar and boat-based multibeam and lidar have been optimized for different projects and have benefits and tradeoffs that include acquisition time, coverage of uplands, coverage below 10 m, object detection, influences from vegetation, and DEM resolution. These factors should be considered when determining methods for a survey or use of existing datasets.

Acknowledgements

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- The topobathy point cloud data and DEM were provided by the U.S. Geological Survey / JALBTCX
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