Development and Assessment of Airborne Lidar Bathymetry Products for Shoreline Mapping

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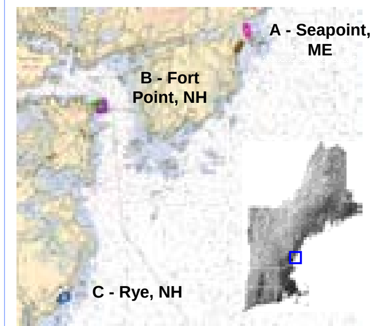
1. Abstract

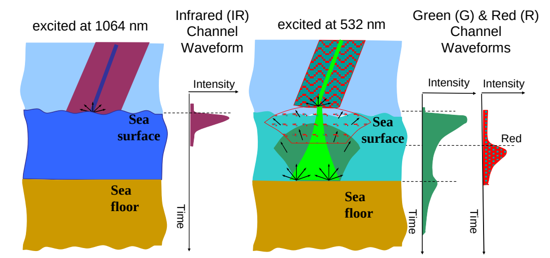
Accurate and consistent shoreline determinations play a major role in nautical charting and coastal management boundary assessment. Delineations along this dynamic margin are dependent upon the stage of tide and are demarcated by tidal datums such as Mean High Water (MHW) and Mean Lower Low Water (MLLW). This study investigated airborne lidar bathymetry (ALB) as a potential tool to support shoreline mapping. A computerized process was devised to obtain shoreline determinations from a lidar dataset processed using various algorithms and by devising a threshold to distinguish land and water. The algorithm-derived land-water interfaces are analyzed against the reference shoreline constructed from the ortho-rectified aerial imagery simultaneously collected with the ALB data. The study area includes a variety of shoreline types such as rocky, sandy, and man-made, to evaluate the performance of the various algorithms in differing environmental conditions. Examination of the results assesses the quality of the shoreline products in comparison to current shoreline methods and considers whether ALB provides a solution to problems currently associated with shoreline mapping. This evaluation included analysis of the reliability, resolution, and uncertainty of the shoreline determinations and an assessment as to whether the land-water interfaces derived from ALB can meet charting standards.

2. Case Study Areas



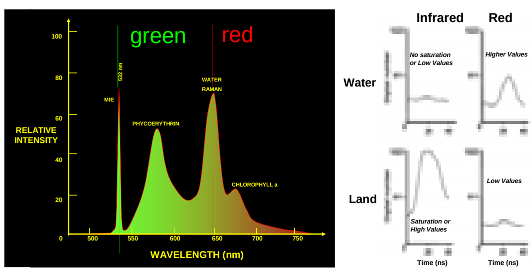
3. ALB Laser Pulse Geometry

Most ALB systems use a ND:YAG laser that has a natural infrared wavelength emission at 1064nm and a frequency doubled wavelength at 532nm. Depending on the ALB system, the receiver may detect up to four channels: infrared; two green channels, one tuned for deeper depths and one tuned for shallower depths; and a red channel. The IR-channel registers a surface waveform peak for returns from water; returns from land may saturate the detector.



4. Waveforms

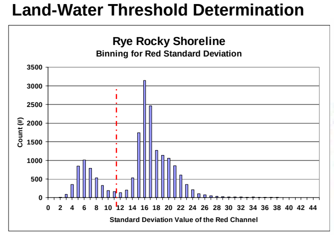
The green emitted pulse interacts with the penetrated water column, this scattering can be split into elastic and inelastic categories. One form of inelastic scattering is associated with the volume of water, the Raman Effect. The recorded green energy shifted by Raman backscatter is often referred to as the red waveform due to the location of the resultant wavelength, 647nm, along the spectrum.



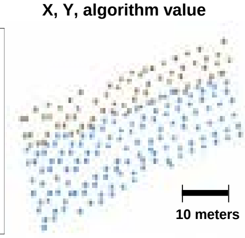
5. Methodology

A procedure was developed for production of an automated land-water interface using an ALB dataset. The lidar-algorithm results were analyzed and transformed into vectors via tinning and contouring of the point data. Assessment of the shorelines was realized by comparing each of the algorithm produced vectors with a reference shoreline digitized independently from aerial imagery using area and offset distances. The processing and spatial analysis utilized currently available off the shelf software (COTS). The aim of using existing functionality within COTS products was to devise production and analysis procedures that are reproducible and readily available to other user groups. Numerical analysis, graphing, and basic calculations were conducted using Microsoft Excel. Vector production and spatial analysis were completed with existing ESRI ArcMap/ArcGIS tools.

Land-Water Threshold Determination



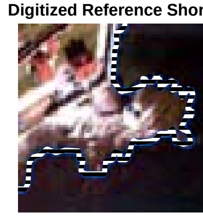
ALB Point Data: X, Y, algorithm value



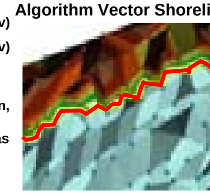
Legend

- Digitized Reference from aerial imagery
- ALB data < 11 (Rsdv)
- ALB data > 11 (Rsdv)
- Algorithm Vector contoured from a tin, with the algorithm value triangulated as mass points

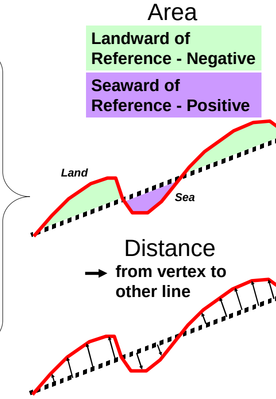
Digitized Reference Shoreline



Algorithm Vector Shoreline



Comparison Techniques



6. Algorithms

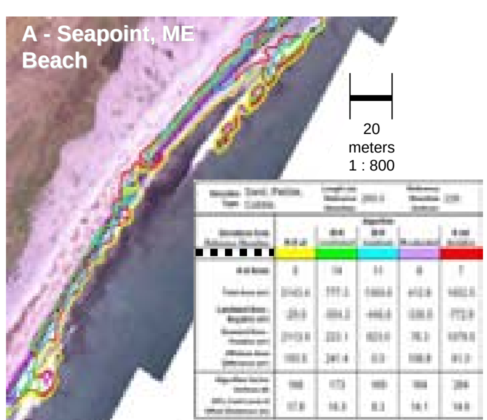
Five algorithms were used for land-water determinations, the distribution and values of the numeric results from each algorithm are unique. Differences are attributable to the physical behavior of each ALB-channel waveform over land and water and the mathematical operation of the algorithm.

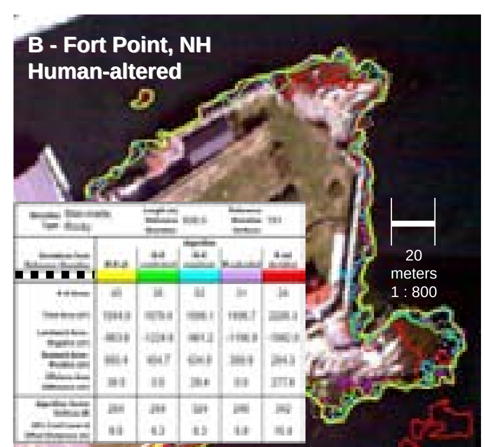
- **Infrared-Saturation** (IRst)
  - (Guenther et al., 1994)
  - IR channel waveform
    - Saturation – Land
    - No saturation – Water
- **Infrared-Red Ratio** (IRRa, IRRc, IRRm)
  - (Pe'eri and Philpot, 2007)
  - Ratio of IR to Red
    - High IR & Weak Red – Land
    - Higher R & Low IR – Water
- **Red Standard Deviation** (Rsdv)
  - (Pe-eri et al., 2007)
  - Red channel waveform
    - Low standard deviation – Land
    - High standard deviation - Water

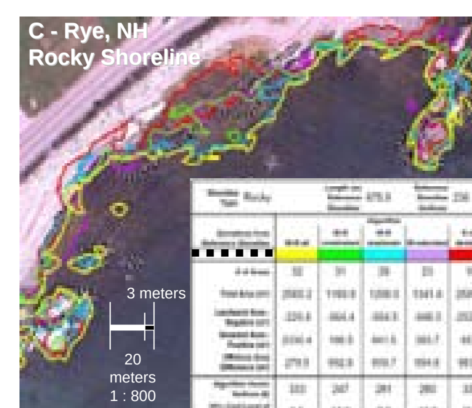
7. Results

Land-water threshold determinations and the corresponding algorithm vectors were produced for each case study location. After production of the algorithm vectors, the area and offset distance comparison techniques were applied to each vector separately against the digitized reference shoreline. The results from three of the case study areas are displayed below.

The study found that viable land-water interfaces were produced from the IRst, IRRa, IRRc, and IRRm algorithms. In beach environments, the IRst algorithm produces the most consistent interface. Along rocky coast and in areas with kelp covered rocks, the IRRa algorithm may best represent the land-water interface due to its capability in areas with vegetation.







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9. Acknowledgement

This project was sponsored by the National Oceanic and Atmospheric Administration and the Joint Hydrographic Center / Center for Coastal and Ocean Mapping at the University of New Hampshire. Special thanks go to Larry Ward, Andy McLeod, Yuri Rzhanov, Lysandros Tsoulos, Jerry Mills, Jeff Rogers, Will Fessenden, Nick Forfinski, Janice Felzenberg, and Eric Heiner.

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