Development and Assessment of Airborne Lidar Bathymetry Products for Shoreline Mapping

Lynnette V. Morgan, Shachak Pe’eri, and Andrew Armstrong

1. Abstract

Accurate and consistent shoreline determinations play a major role in nautical charting and coastal management boundary assessment. Deliverables along the 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

A - Seapoint, ME

B - Fort Point, NH

C - Rye, NH

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 shallow 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 scattered 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

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

- Infrared-Saturation (IRsat) (Guenther et al., 1994)
  - IR channel waveform
  - Saturation – Land
  - No saturation – Water

- Infrared-Red Ratio (IRR) (Pe’eri and Philpot, 2007)
  - Ratio of IR to Red
  - High IR & Low Red – Land
  - High IR & High Red – Water

- Red Standard Deviation (Rsdv)

6. Algorithms

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

8. Affiliation

Joint Hydrographic Center / Center for Coastal and Ocean Mapping
University of New Hampshire, Durham, NH 03824
lynnette.v.morgan@noaa.gov.

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