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. Deliberations along the dynamic margin are dependent upon the stage of tide and are demarcated by tidal datum lines 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 computationally 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 components 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 1064 nm and a frequency doubled wavelength at 532 nm. 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.

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 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.

6. Algorithms

Five algorithms were used for land-water determinations, the distribution and values of the numeric results from each algorithm differ. 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 (IrrS)
  - IrrS = \frac{\text{Irr}}{\text{Saturation}}
  - Saturation = \text{Land}
  - No saturation = \text{Water}

- Infrared-Red Ratio (IRR) (Pe’eri and Philpot, 2007)
  - IRR = \frac{\text{Irr}}{\text{Red}}
  - Ratios of Irr to Red
    - High Irr & Weak Red – Land
    - High Red & Low Irr – Water

- Red Standard Deviation (Rsdv)

- Algorithm Vector Shoreline

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.

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