2004 Southern Maine Lidar Data Validation Report

Prepared by IM Systems Group and Perot Systems Government Services for the NOAA Coastal Services Center

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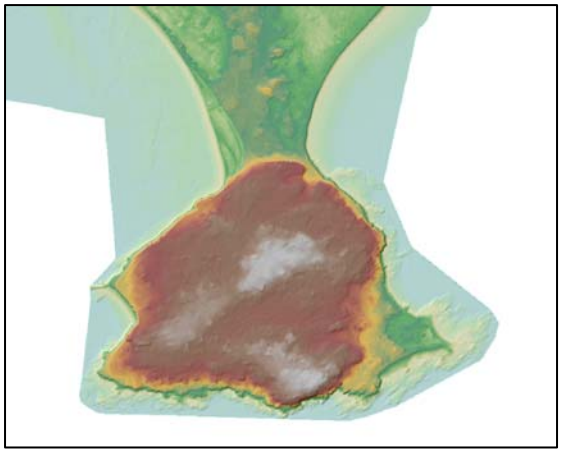

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2004 Southern Maine Lidar Data Validation Report

Introduction

The National Oceanic Atmospheric Administration (NOAA) Coastal Service Center Topographic Change Mapping (TCM) project seeks to aid coastal managers with their topographic needs. This can include issues ranging from beach geomorphologic change to storm surge inundation to determination of invasive species habitat. Additionally, the TCM project creates derived information products and analysis tools to facilitate the coastal resource manager's decision-making process. The TCM project collected Light Detection and Ranging (Lidar) data along the southern coast of Maine in April 2004 and will distribute the data from its Web-based Lidar Data Retrieval Tool (LDART).

In 2003 the NOAA Coastal Service Center (CSC) contracted with EarthData International to collect and deliver topographic elevation point data derived from multiple return lidar measurements along the coast of southern Maine. The survey area covered approximately 225 square kilometer (*Figure 1*). The survey was conducted under tidally controlled conditions to ensure maximum shoreline exposure during the data collection. The contract with EarthData International specified data postings every 2 meters and a vertical accuracy requirement of 95% confidence limit of 29.4 centimeters.

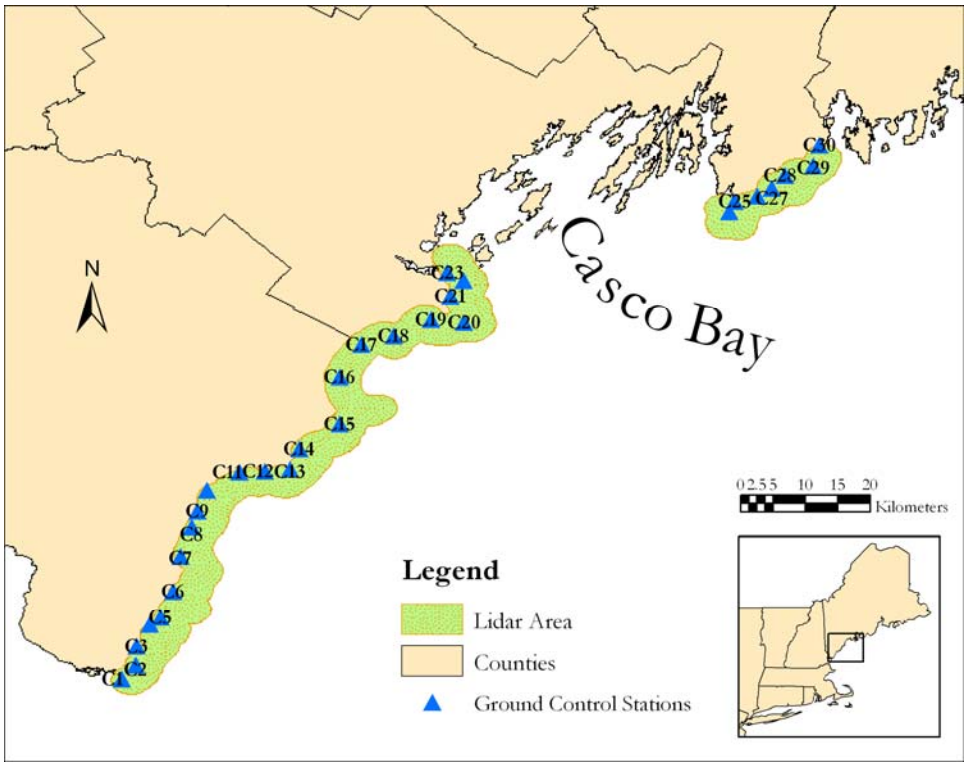

Figure 1. Extent of the southern Maine lidar survey and ground control station locations.

In conjunction with the lidar survey, an independent survey company, Terrasurv, Inc., was contracted by EarthData to provide ground control points to EarthData for the lidar quality control. Additional ground control points were delivered by Terrasurv, Inc. to the Center for use in validating the accuracy of the topographic lidar data (*Figure 1*).

This report presents the results of a quantitative error assessment conducted to verify the vertical accuracy of the lidar data in open terrain using the independent ground control points as check points. This assessment followed procedures and recommendations presented in the *Guidelines for Digital Elevation Data* prepared by the National Digital Elevation Program (NDEP) and the *ASPRS Guidelines for Vertical Accuracy Reporting for Lidar Data* prepared by the ASPRS Lidar Committee.

Methods

Thirty independent control points were used in the validation process. Terrasurv, Inc. used two Trimble dual frequency GPS receivers in static differential mode to measure the interstation vectors. This data was post-processed using the WAVE (Weighted Ambiguity Vector Estimator) processor in Trimble Geomatics Office, version 1.6, and adjusted using GEOLAB, which is a least squares adjustment program from Microsearch Corporation.

The post edited bare earth point data (.las format) delivered by EarthData were used by the Center to perform this data validation. The nature of topographic lidar data collection limits the ability to survey precise horizontal (xy) locations; therefore, some form of interpolation of lidar data is required to accurately compare ground control points and lidar elevation measurements. The Guidelines for Digital Elevation Data by NDEP recommends interpolation from a surface generated from a triangulated irregular network (TIN) derived from the lidar point data for assessing the accuracy of mass points. This method was employed in this evaluation. Elevation values at the location of each of the 30 ground control points were interpolated from the triangulated bare earth point data. The vertical error at each ground control point location was calculated by subtracting the interpolated lidar elevation value from the control point elevation value. After calculating the error at each control point, the overall root mean square error ($RMSE_{(z)}$) for the survey was calculated. The overall vertical accuracy at 95 percent confidence level was then calculated with the following equation:

Vertical Accuracy at 95% confidence level = 1.9600 * $RMSE_{(z)}$
(if errors are normally distributed)

Results

The overall $RMSE_{(z)}$ error was ±0.10 meters which is based on 30 samples (i.e., N=30). A Shapiro-Wilk statistical test performed on the errors for the quantitative assessment indicated the errors were normally distributed (W = 0.97; p = 0.66; skew = -0.41). The Shapiro-Wilk test was chosen because it works well with a small sample size as long as there are not identical values, of which there are none in this instance.

Figure 2 shows the elevation difference calculated at each of the ground control stations. A mean error of -0.04 meters and a standard deviation of 0.09 meters were reported. The maximum error was -0.24 meters at C16 (see *Appendix A*).

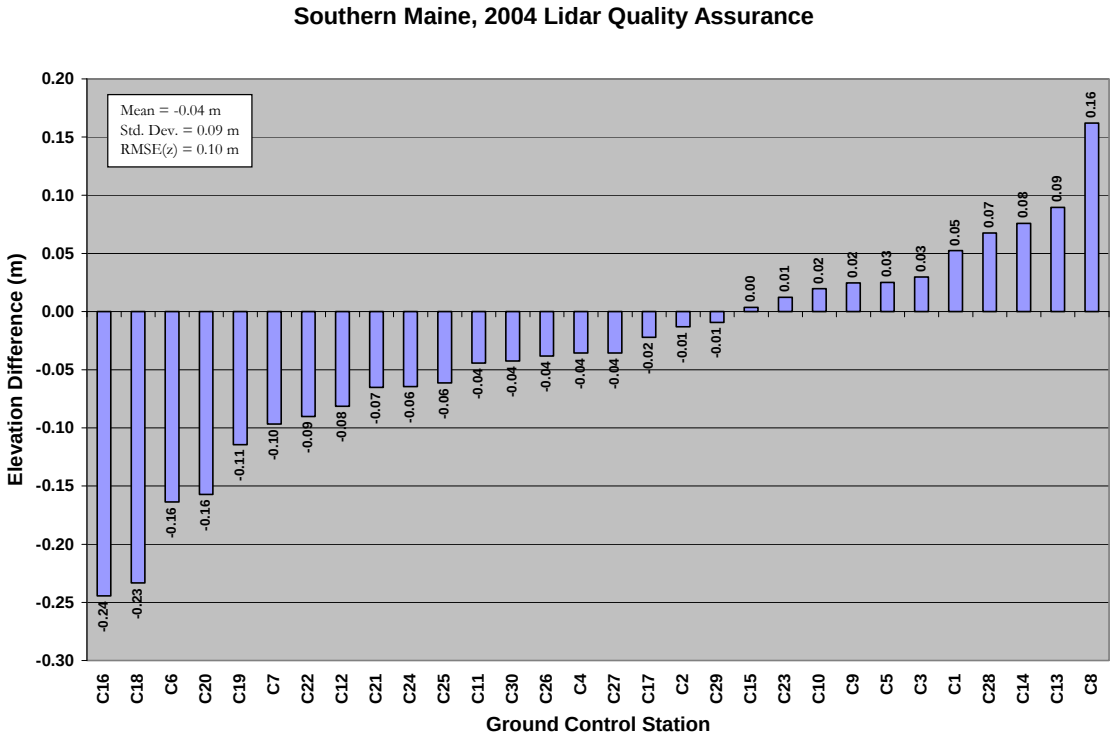

Figure 2. Elevation differences at each control station (Control point elevation – Lidar elevation).

The spatial distribution of the elevation differences is presented in *Figure 3* and the actual values are presented in a table in *Appendix A*. Each ground control point is colored according to the magnitude of the error identified for the lidar elevation calculated at the station's horizontal (xy) location. Lidar elevation values greater than the ground controls (i.e. negative differences) are symbolized with red and blue triangles; while lidar elevations lower than the ground controls (i.e. positive differences) are symbolized with green and orange triangles.

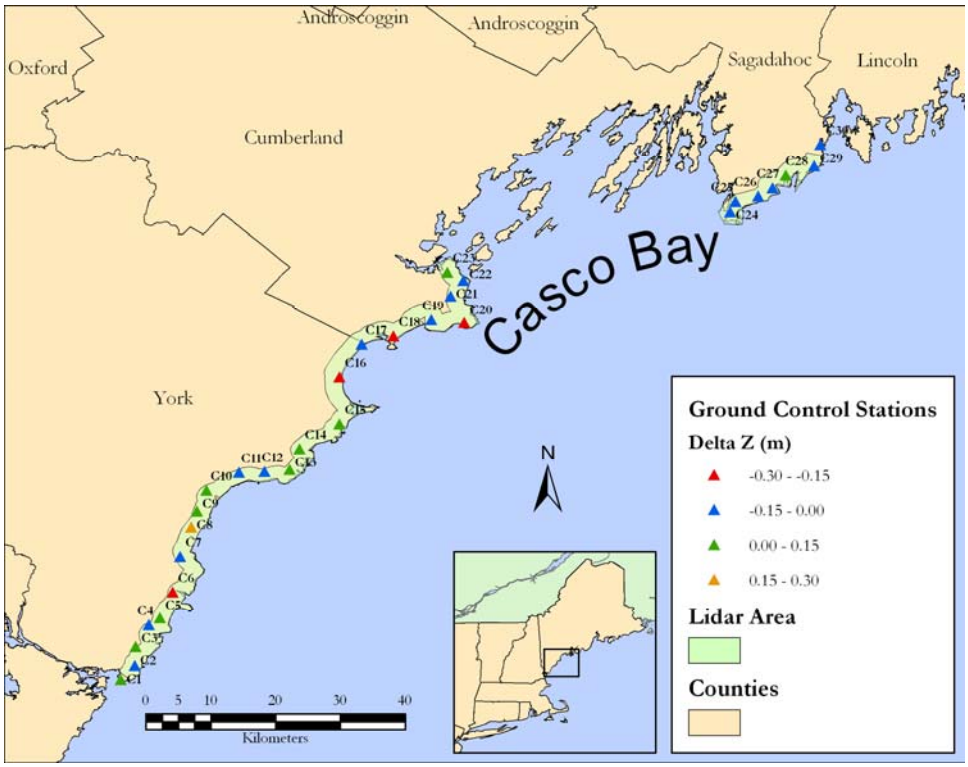

Figure 3: Map showing the spatial distribution of elevation differences between ground control point elevations and interpolated lidar elevations (Control point elevation – Lidar elevation).

Discussion

The vertical errors calculated from the ground control points are within the prescribed accuracy limits. Given that the control stations were located in open terrain, these errors are generally believed to be random errors in the lidar sensor system as opposed to systematic errors generated from vegetated areas.

The horizontal accuracy of this lidar data was not assessed. The high vertical accuracy is indicative of good horizontal accuracy, though slight horizontal inaccuracies are difficult to detect using these ground control points because they were located in relatively flat terrain.

Based on this assessment, the 2004 Southern Maine lidar survey meets the prescribed vertical accuracy level since at least 95% of the positions have an error less than or equal to 29.4 cm (equivalent to root mean square error of 15 cm).

> **"Tested 0.20 meter fundamental vertical accuracy at 95 percent confidence level in open terrain using $RMSE_{(z)}$ x 1.9600."**

Appendix A

The following table shows the elevation difference calculated at each of the ground control stations. The differences (Delta Z) were calculated by subtracting the orthometric lidar height (meters) from the ground control height.

Station	UTM E (m)	UTM N (m)	Delta Z (m)	Delta Z^2 (m)
C1	362291.374	4769807.076	0.05	0.00
C2	363909.045	4771940.272	-0.01	0.00
C3	364069.285	4774853.583	0.03	0.00
C4	365616.075	4778201.705	-0.04	0.00
C5	366870.057	4779274.208	0.03	0.00
C6	368386.493	4783248.525	-0.16	0.03
C7	369331.716	4788721.588	-0.10	0.01
C8	370664.323	4793134.894	0.16	0.03
C9	371363.392	4795576.77	0.02	0.00
C10	372486.94	4798823.769	0.02	0.00
C11	376200.084	4801552.078	-0.04	0.00
C12	379070.933	4801587.577	-0.08	0.01
C13	381910.703	4801875.706	0.09	0.01
C14	383059.888	4805073.588	0.08	0.01
C15	387640.967	4808914.147	0.00	0.00
C16	387752.018	4816044.681	-0.24	0.06
C17	390296.611	4821064.797	-0.02	0.00
C18	393903.724	4822299.001	-0.23	0.05
C19	398155.904	4824789.338	-0.11	0.01
C20	401841.562	4824281.09	-0.16	0.02
C21	400379.418	4828431.969	-0.07	0.00
C22	401879.134	4830818.332	-0.09	0.01
C23	400070.658	4832084.193	0.01	0.00
C24	431796.414	4840933.683	-0.06	0.00
C25	432431.377	4842511.07	-0.06	0.00
C26	434980.709	4843301.363	-0.04	0.00
C27	436600.924	4844530.615	-0.04	0.00
C28	438090.899	4846502.674	0.07	0.00
C29	441277.667	4847923.472	-0.01	0.00
C30	441982.956	4851187.301	-0.04	0.00
			Mean	-0.04
			Standard deviation	0.09
			$RMSE_{(z)}$	0.10
			Skew	-0.41
			$Accuracy_{(z)}$	0.20