2004 Saginaw Bay, Michigan Lidar Data Validation Report

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

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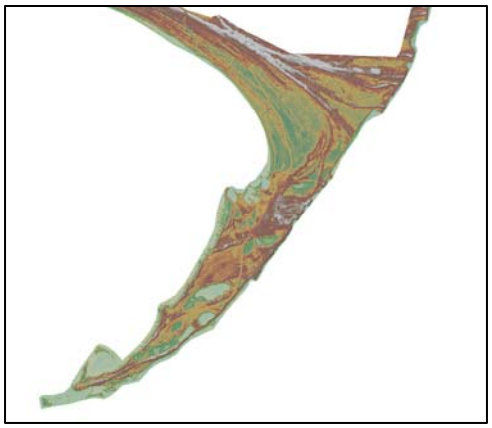

Table of Contents

Introduction **2**

Methods **3**

Results **3**

Discussion **5**

Appendix A **6**

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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 shoreline of Saginaw Bay, Lake Huron, Michigan. The survey area covered approximately 375 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 ±0.15-meter root mean square error ($RMSE_{(z)}$).

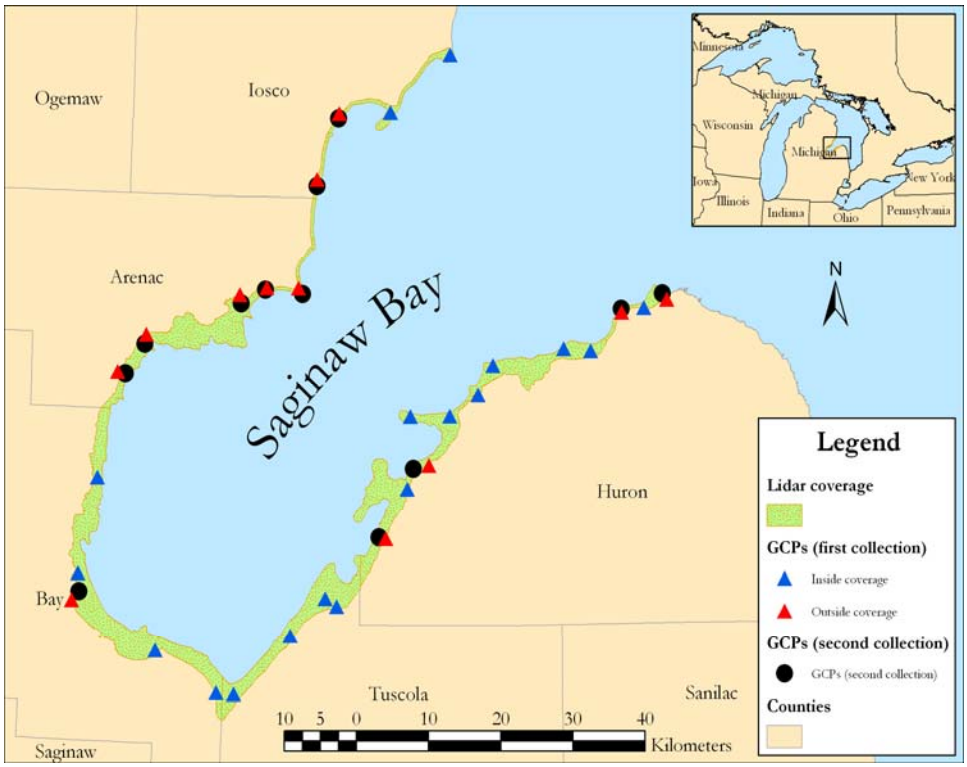

Figure 1. Extent of the Saginaw Bay, Michigan lidar survey and ground control station locations.

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 validation 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

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.

An initial ground control point collection was conducted on June 8-10, 2004. Thirty points were measured, of which 12 fell outside of the lidar coverage area. Terrasurv, Inc. subsequently collected an additional 12 points in October, 2004 to replace the 12 points that did not meet the requirements for the validation procedure. The final independent ground control data consisted of thirty control points that were believed to have an absolute accuracy of ±0.03 meters.

The post edited bare earth point data (.las format) delivered to CSC 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, a form of interpolation of lidar data is required to accurately compare ground control points and lidar derived elevation models. 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 the 95th percentile was then calculated with the following equation:

Vertical Accuracy = 95^{th} percentile error

Results

The overall $RMSE_{(z)}$ error was ±0.12 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 not normally distributed (W = 0.91; p = 0.01; skew = -1.01). The Shapiro-Wilk test was chosen because it works well with a small sample size as long as there are not identical values.

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 0.12 meters were reported. The greatest elevation difference was -0.33 meters at C1b (see *Appendix A*). This point was located in a large open and flat grassy area adjacent to the lakeshore. There were no apparent obstructions during the lidar collection, so the lidar elevation data in this area tend to be higher than the actual elevation.

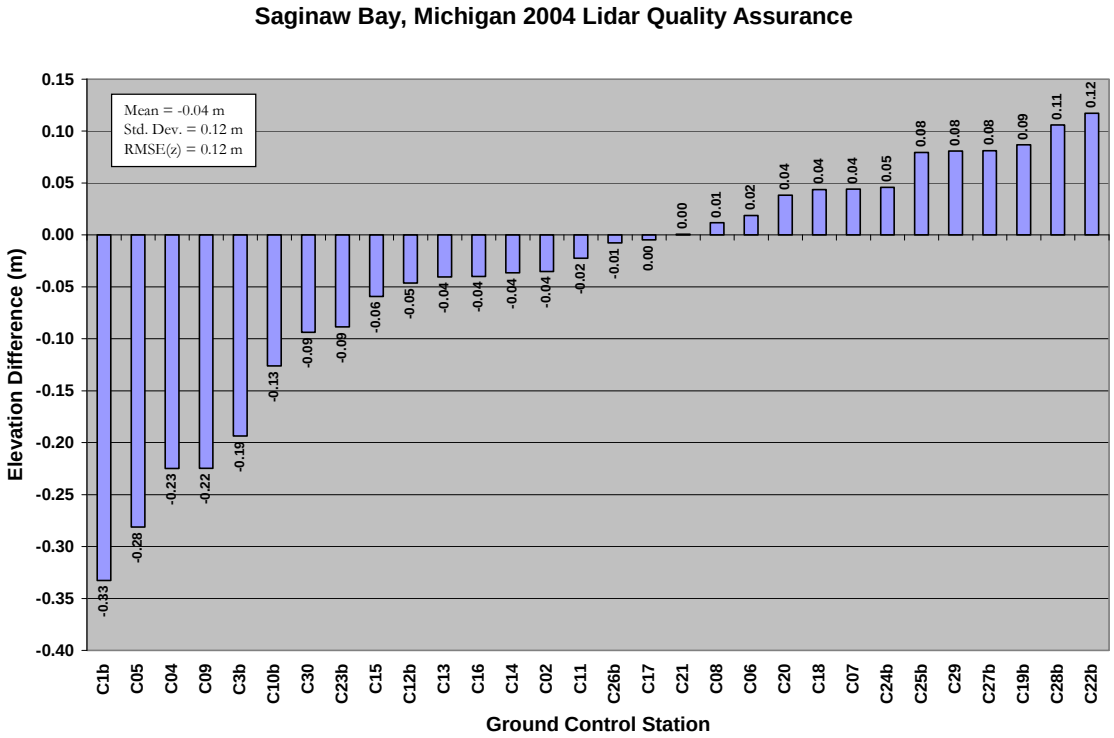

Figure 2. Elevation differences at each control station (Control point elevation – Lidar elevation).

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, yellow, and blue triangles; lidar elevations lower than the ground controls (i.e. positive differences) are symbolized with green triangles.

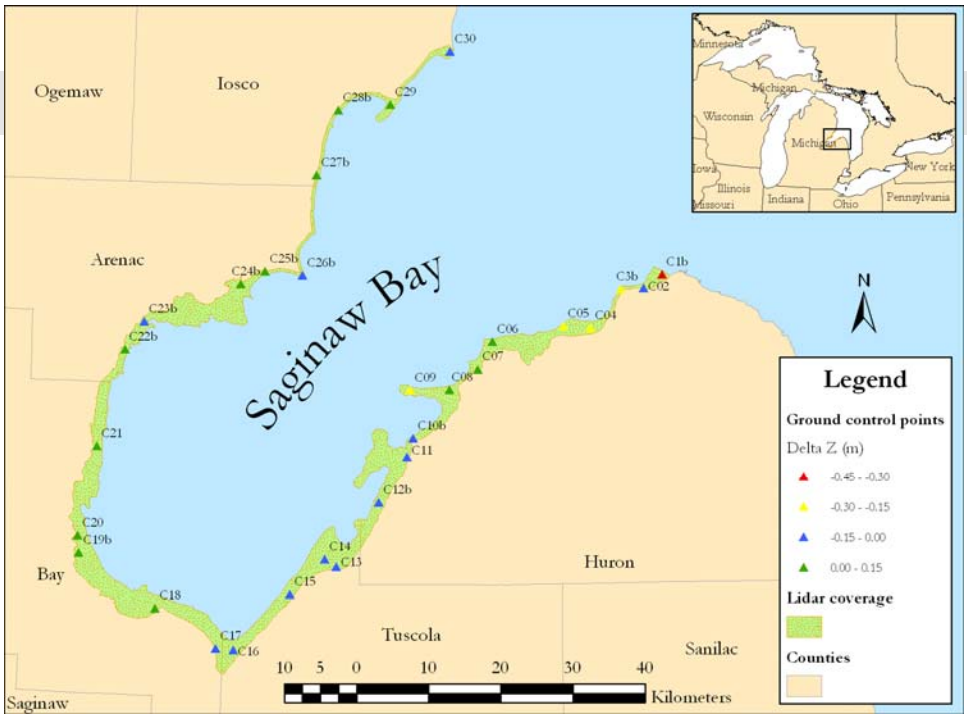

Figure 3: Map showing the spatial distribution of elevation differences between ground control point elevations and interpolated lidar elevations (Ground control point elevation – Lidar elevation).

Discussion

The overall vertical error calculated from the collection of ground control points is within the prescribed accuracy limits. Given that the control stations were located in flat and 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 Saginaw Bay, Michigan lidar survey data meet the prescribed vertical accuracy level since more than 95% of the measured positions have an error less than or equal to 29.4 cm (equivalent to root mean square error of 15 cm for normally distributed data). The 95th percentile error was used to calculate the overall accuracy of the lidar data because the errors were distributed non-parametrically.

> **"Tested 0.26 meter fundamental vertical accuracy at 95th percentile in open terrain."**

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 interpolated (via tinning) orthometric lidar heights (meters) from the coincident ground control point heights.

Station	UTM E (m)	UTM N (m)	Delta Z (m)	Delta Z^2 (m)
C1b	343139.011	4880828.482	-0.33	0.11
C05	329473.168	4873720.091	-0.28	0.08
C04	333212.36	4873401.186	-0.23	0.05
C09	308184.036	4864897.964	-0.22	0.05
C3b	337457.562	4878819.366	-0.19	0.04
C10b	308645.06	4858219.43	-0.13	0.02
C30	313722.522	4911732.539	-0.09	0.01
C23b	271368.479	4874342.577	-0.09	0.01
C15	291537.302	4836531.356	-0.06	0.00
C12b	303879.892	4849274.922	-0.05	0.00
C13	297969.635	4840367.981	-0.04	0.00
C16	283660.898	4828939.132	-0.04	0.00
C14	296389.215	4841370.731	-0.04	0.00
C02	340569.569	4878943.535	-0.04	0.00
C11	307769.702	4855593.882	-0.02	0.00
C26b	293267.988	4880695.87	-0.01	0.00
C17	281224.545	4829123.478	0.00	0.00
C21	264787.204	4857180.939	0.00	0.00
C08	313677.834	4864972.086	0.01	0.00
C06	319638.89	4871508.942	0.02	0.00
C20	262082.712	4844689.341	0.04	0.00
C18	272810.18	4834643.197	0.04	0.00
C07	317613.873	4867737.326	0.04	0.00
C24b	284738.201	4879496.688	0.05	0.00
C25b	288107.66	4881294.852	0.08	0.01
C29	305459.473	4904365.382	0.08	0.01
C27b	295253.878	4894706.269	0.08	0.01
C19b	262227.082	4842336.905	0.09	0.01
C28b	298256.211	4903621.512	0.11	0.01
C22b	268657.434	4870512.026	0.12	0.01
			Mean	-0.04
			Standard deviation	0.12
			$RMSE_{(z)}$	0.12
			Skew	-1.01
			$Accuracy_{(z)}$ (95th percentile)	0.26