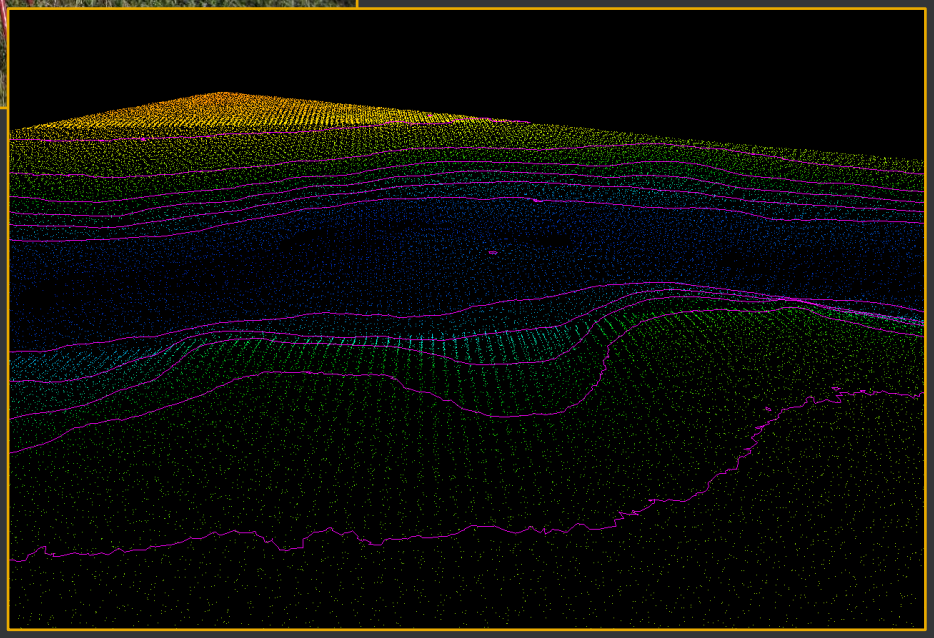
aerometric
Geospatial Solutions
2014 Merrill Field Dr
Anchorage, AK 99501
P:907-272-4495
www.aerometric.com



6130608 Arctic Coastal Plain LiDAR

Acquisition, Processing, and QA / QC Report

Table of Contents

List of Figures

List of Tables

Introduction

In July of 2013 Aero-Metric, Inc. (AeroMetric) collected high density airborne LiDAR data in the coastal region of Alaska's North Slope near Nuiqsut. This project was undertaken for the University of Alaska Fairbanks, Geographic Information Network of Alaska (UAF/GINA).

Final products will be used for watershed analysis and related studies. Acquired swaths and the areas of interest provided by UAF / GINA are illustrated in Figure 1 below. The Crea Creek area of interest is notably covered by a second group of collected swaths to insure exceptional point densities.

Figure 1 – Arctic Coastal Plain LiDAR Acquisition

Planning

The AeroMetric staff evaluated the area of interest and considered terrain, project specifications, and various relevant logistical matters prior to acquisition. Efforts were made to choose optimum flight paths that ensured full coverage of the primary area of interest with at least the required 8 pulses per square meter, with additional swaths to cover the Crea Creek area of interest with at least the required 16 pulses per square meter. Table 1 outlines the LiDAR settings and specifications utilized for this project.

Table 1 – LiDAR Settings and Specifications (Primary AOI / Crea Creek AOI)

Sensor	Leica ALS70
Aircraft	Piper Navajo 812TB
Altitude	~1065 m
Pulse Rate	245 khz / 253 khz
Pulse Diameter	21 cm
Field of View	30 degrees / 20 degrees
Maximum Laser Returns	4
Target Density	Average 8 ppm^2 / 16 ppm^2
Target Accuracy	≤ 15 cm

Acquisition

The airborne LiDAR survey was carried out between July 12th and 14th, 2013. A total of 141 flight lines were flown during this time (see Figure 1). A shapefile of the collected swaths, SBET trajectory, and the Leica ALS70 flight log are included in this delivery under the 'Acquisition_Data' directory.

Per this project's requirements, differential GPS was controlled utilizing Primary Airport Control Station AQT-A at the Nuiqsut Airport. The published NGS position for this station was used, and is listed in Table 2 below. Segments of the LiDAR acquisition were controlled using advanced precise point positioning (PPP) techniques when the differential solutions proved to be inadequate.

Table 2 – PACS Position Referencing NAD83 (2011) Epoch 2010.0

Monument	Latitude	Longitude	Ellipsoid Height (m)
AQT-A	70 12 46.71442	-150 59 35.87672	9.241

LiDAR Processing

Point Cloud Calibration

The AeroMetric processing staff utilizes a variety of automated and manual tools to process the acquired LiDAR data. Front end processing consists of GPS control computations, smoothed best-estimated trajectory (SBET) calculation, and point cloud generation.

The geometric relationships between overlapping and perpendicular swaths are analyzed to identify deviations in systematic attitude parameters. The automated calibration routines within TerraSolid's TerraMatch were used to solve for misalignment offsets (roll, pitch, and heading) and mirror scale. The final calibration step evaluates and corrects for vertical differences between adjacent flight lines to optimize relative accuracy of the data.

Data Classification

LiDAR point cloud classification is carried out using a combination of automated and manual techniques within TerraSolid's TerraScan suite. During this process AeroMetric considers both the terrain in the area of interest and the intended application of the data. This allows for custom tailored methodologies to maximize workflow efficiency.

For this project, AeroMetric classified ground, vegetation, buildings, bridges, and water. Files were formatted as LAS v. 1.2 with Adjusted GPS timestamps. Table 3 outlines the classes utilized for Arctic Coastal Plain.

Table 3 – LAS Classification Schema for Arctic Coastal Plain

Class Number	Name	Description
1	Unclassified	Objects not appropriate for any other class (cars, man-made non-building objects, etc.)
2	Ground	Bare Earth as determined through manual and automated routines
3	Low Vegetation	Vegetation within 0.75m of ground surface
6	Buildings	Permanent man-made structures
7	Noise	Returns associated with common errors such as bird strikes or erroneous last returns
8	Model Keypoints	Points selected at intervals from the ground class for ease of use in contour generation etc.
9	Water	Lakes > 2 acres, Rivers > 30m wide
10	Breakline Proximity	Points Within Buffer of Breaklines on Land Side
13	Bridge Decks	Points on surface of bridge features

LiDAR QA/QC

In consideration of the project specifications provided by UAF / GINA, AeroMetric completed the following evaluations for the Arctic Coastal Plain project. All assessments detailed below were made using a minimum 25 meter buffer of the area of interest provided by UAF/GINA.

Data Completeness

Verification of point cloud completeness consists of two main components. First the point cloud data is reviewed to confirm the absence of voids. This is through the examination of intensity imagery and density grids.

The imagery can be used to identify clouds or other obstructions when present; the density grids provide a visual reference for areas where returns have thinned. In both cases raster data sets show NODATA where LiDAR points are lacking entirely.

The second completeness check is evaluating the first-return density of the data set. The Arctic Coastal Plain project specifications called for a design pulse density of 8 points per square meter for the primary area of interest, and a pulse density of 16 points per square meter for the Crea Creek Area of interest.

First return densities as calculated for 300 meter cells are shown in Figure 2. The regions not visibly meeting the density requirements for this project are large water bodies. The Crea Creek are of interest is outlined, and notable is covered by a much greater density than the required 16 points per square meter.

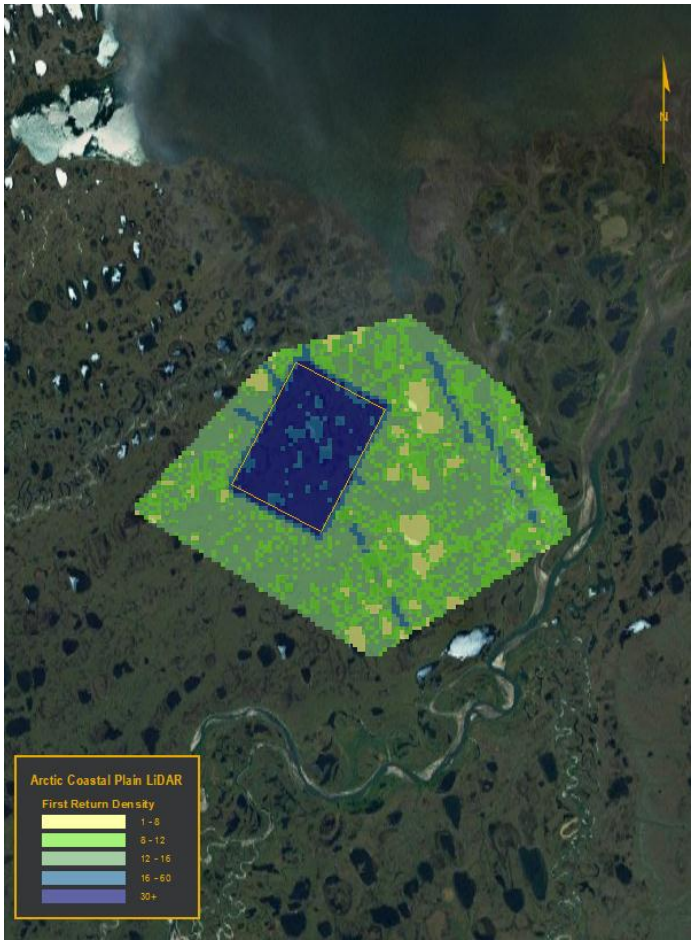


Figure 2 - Point Density of 30 meter Cells

Relative Accuracy Assessment

Relative accuracy is assessed to determine the internal consistency of a LiDAR data set. This is done through statistical analysis of laser ranges within individual swaths, as well as the relationships between multiple adjacent swaths.

Range Reproducibility

The specifications for Arctic Coastal Plain called for a 5 centimeter or less RMSE of range reproducibility within individual swaths. This was tested by selecting a nearly planar portion of the Nuiqsut airstrip within the project area and analyzing each swath of data that covered it.

A total of two point sets were used in this analysis: two swaths over the airstrip. Orthogonal regression was used to compute the least-squares best fit plane to each set of points. The results of this analysis are listed in Table 4; a spreadsheet of the computations and shapefile of the test patch location are included in the 'Range_Reproduciblity' directory included in this delivery.

While the RMSE achieved in this evaluation is quite near the 5cm criterion, it is worth noting that a rural airstrip is not likely to be a truly "flat" surface, which will contribute to the results listed below.

Table 4 - Range Reproducibility Results

Flight Line	Surface	Point Count	RMSE (meters)
2066	Nuiqsut Airstrip	46,616	0.047
2067	Nuiqsut Airstrip	30,394	0.048

Horizontal Accuracy

The stated requirement for horizontal reproducibility was ≤ 40 centimeters RMSE for the project as a whole. Computing the horizontal accuracy of a LiDAR point cloud directly is the topic of research, and presently there exists no standardized method for doing so. It is therefore common to rely on the stated sensor capabilities as published by the manufacturers.

Figure 3 is taken from Leica Geosystems product specifications for the ALS70, the sensor model utilized on this project. This graph shows that horizontal accuracy is expected to be less than 20 centimeters at the 1 sigma level for a flying height of 1065 meters, the height this data was collected at.

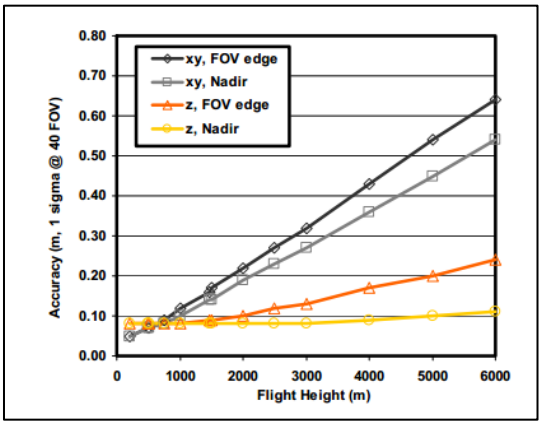


Figure 3 - Leica ALS70 Accuracies

Intra-Survey Reproducibility

The project specifications for Arctic Coastal Plain required intra-survey reproducibility to have a vertical RMSE of no greater than 10 centimeters. Intra-survey reproducibility is a measure of agreement between swaths where they overlap. This is calculated by comparing bare-earth point elevations to those of overlapping flight lines. For the entire project area the overall RMSE from these calculations was 0.01 meters.

Absolute Accuracy Assessment

Absolute accuracy is assessed to determine the consistency between a LiDAR data set and an external control source of higher accuracy, typically in the form of ground-surveyed check points. The Arctic Coastal Plain absolute accuracy requirement as stated in the project specifications is a vertical RMSE of no greater than 15 centimeters as evaluated in open areas with slopes less than 20 degrees.

It is common practice within the LiDAR industry to test and report vertical accuracy in accordance with the methodology put forward by the National Digital Elevation Program (NDEP) in 2004. Notable organizations that have adopted these standards into their own include ASPRS and USGS.

Using these guidelines the Fundamental Vertical Accuracy (FVA) is computed using check points in open, relatively moderate terrain. As such it is assumed that for a well calibrated LiDAR data set, the errors will conform to a normal distribution. As a result, NDEP calls for reporting the FVA as $RMSE_z$ * 1.96 to obtain the accuracy at the 95% confidence interval per the National Standard for Spatial Data Accuracy (NSSDA).

Table 5 contains the computed FVA value for this project. Point listings and full statistical results are available in the 'Vertical_Accuracy' directory included in this delivery.

Table 5 – Vertical Accuracy Results

Category	Number of Points	Accuracy (meters)	Method
FVA	188	0.145	RMSE * 1.96

Deliverable Production

Deliverable Tiling Scheme

Once it has been fully verified that the LiDAR point cloud data was collected, calibrated, and classified to meet project specifications, final products are generated. Figure 5 shows the tiling scheme utilized for all deliverables generated for the Arctic Coastal Plain LiDAR.

The tiling scheme is comprised of 500 x 500 meter tiles, set on even intervals relative to the Alaska State Plane Zone 4 origin. Tiles are named sequentially beginning in the northwest and progressing to the southeast. The same format is duplicated for the Crea Creek layout, which is used for the higher resolution DEMs.

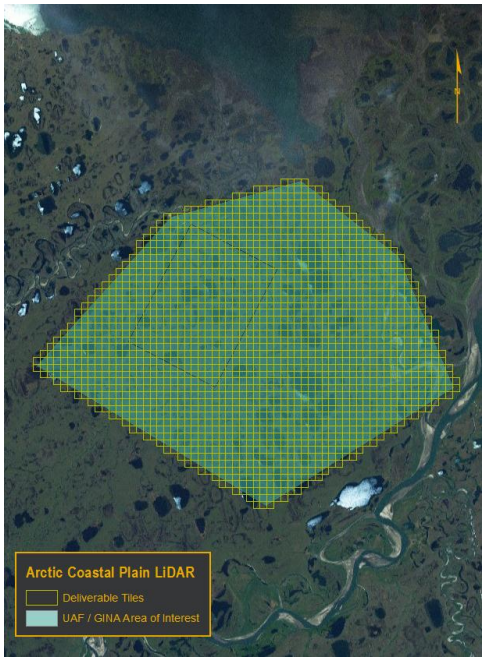


Figure 4 - Final Tile Layout

Spatial Reference

LiDAR data was horizontally tied to the NGS CORS network through the use of OPUS derived positions in the GPS processing phase. Vertically the data is tied to NAVD88 through the application of undulation values from the published GEOID12A model to the ellipsoid heights computed using processed GPS and range data. Table 4 outlines the final spatial reference parameters.

Table 6 – Deliverable Spatial Reference

Horizontal Datum	NAD83 (2011) Epoch 2010.0
Coordinate System	Alaska State Plane Zone 4
Vertical Datum	NAVD88
Geoid Model	GEOID12A
Units	Meters

Final Products

Final deliverable products were generated using a variety of industry standard and proprietary tools. Table 5 outlines the products included in this delivery.

Table 7 – Deliverable Product Listing

Product	Resolution	Format	Notes
Bare Earth Digital Elevation Models	1 meter / 0.25 meter	GeoTIFF	Higher Resolution Files Created for Crea Creek Area
Unclassified Point Cloud	N/A	LAS 1.2	All points in Class 0
Classified Point Cloud	N/A	LAS 1.2	See Table 3 for Classes
Intensity Images	1 meter	GeoTIFF	
AOI / Tile Index	N/A	ESRI Shapefile	As Approved by UAF / GINA
Metadata	N/A	FGDC Compliant XML	
Project Reports	N/A	PDF / Other	Acquisition, Survey, and Processing Reports with Supplemental Files