Lidar Report

For

Coastal Georgia

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Final Report

PHOTO SCIENCE
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Project Description

The purpose of this project is to provide professional surveying and mapping services to collect and deliver topographic elevation data derived from multiple return light detection and ranging (LiDAR) measurements for areas in southeast / coastal Georgia. These data are intended for use in coastal management decision making, including applications such as sea level rise and coastal flood mapping. The project area is shown in the graphic below.

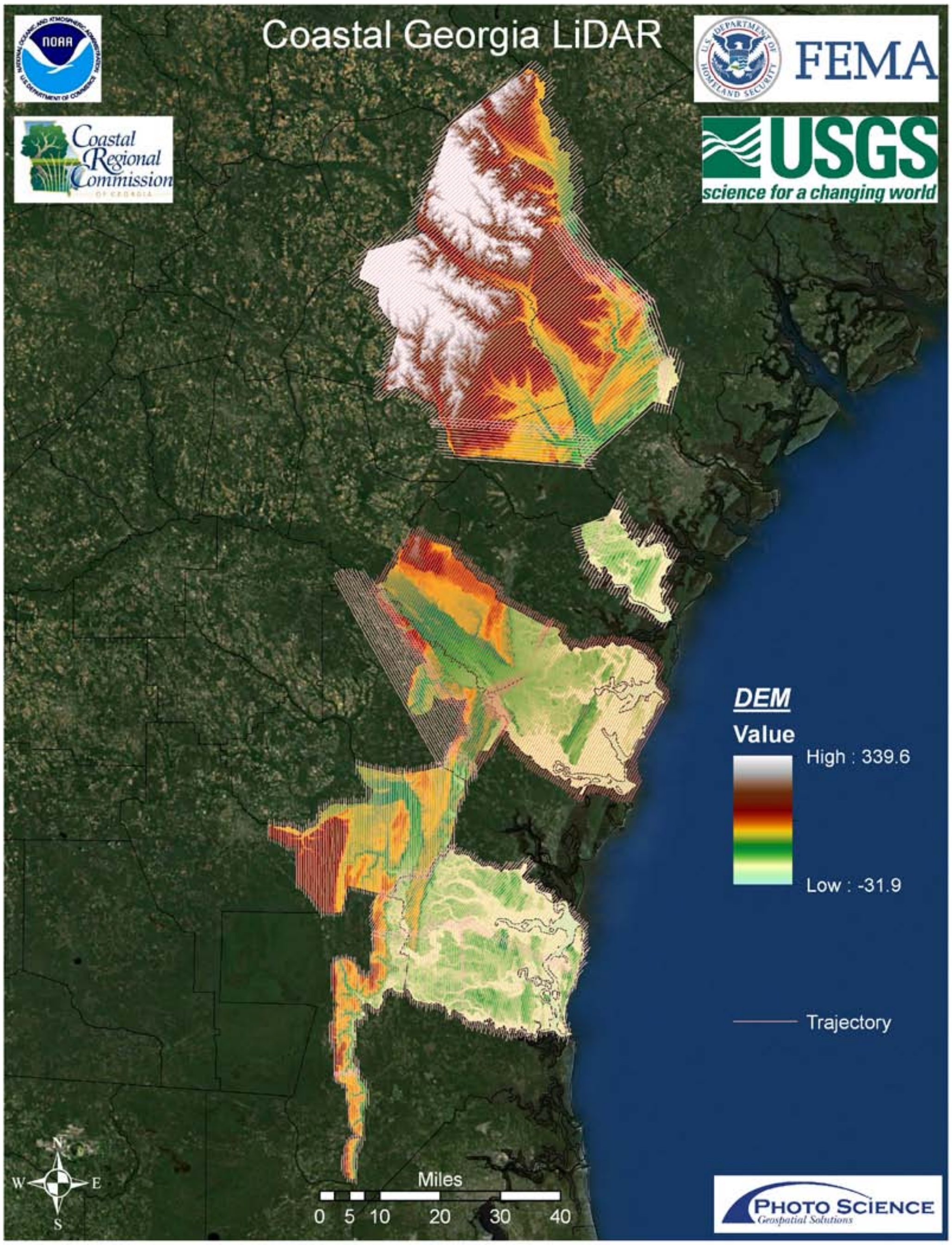

Figure 1: Overall Project Outline

Aerial Platform / Lidar Sensor

All flights for the project were accomplished with customized aircraft outfitted with state of the art navigation systems and the latest in LiDAR sensor technology. The LiDAR sensors used for this project consisted of Leica ALS 50-II's and ALS 60 and Optech Gemini. Each was configured to meet or exceed the project specifications which included:

1. Multiple Discrete Return, capable of at least 3 returns per pulse with Intensity values for each return.
2. Nominal **Pulse** Spacing (NPS) no greater than 1 meter with distribution of geometrically usable points expected to be uniform and free from clustering.
3. Scan Angle (total Field-of-View (FOV)) should not exceed 40°. Quality assurance on collections performed using scan angles wider than 34° will be particularly rigorous in the edge-of-swath areas.
4. Accuracy, *The National Standard for Spatial Data Accuracy (NSSDA) of 95% confidence level, equal to ($RMSE_Z$ * 1.96) in a set of errors assumed to be normally distributed.*

   Fundamental Vertical Accuracy (FVA) of NSSDA $RMSE_Z$ = 18cm (NSSDA $Accuracy_Z$ 95% = 36 cm) or better; assessment procedures to comply with FEMA guidelines.
5. Horizontal accuracy of 4 feet RMSE or better. Additionally, the Consolidated Vertical Accuracy (computed using NDEP and ASPRS methodology in five (5) separate land cover classes (TBD)) shall meet ASPRS Class 1 (or National Map Accuracy Standard) guidelines for the generation of 2 foot contours ($Accuracy_z$ = 36 cm). LiDAR data from different flight lines shall be consistent across flight lines, *i.e.*, there is minimal vertical offset within the noise level of the LiDAR system between adjacent flightlines. Maximum vertical offset between flightlines should be no more than 6 cm.
6. Flightline overlap 20% or greater, as required to ensure there are no data gaps between the usable portions of the swaths.
7. Base stations for GPS surveys shall be based on first or second order survey control stations that are part of the National Geodetic Survey's Spatial Reference System.
8. Collection Area: Defined Project Area, buffered by a minimum of 200*NPS.
9. Tide +/- 2 hours of low tide

Flight Parameters

Detailed project planning was performed for this project. This planning was based on project specific requirements and the characteristics of the project site. The basis of this planning included the required accuracies, type of development, amount and type of vegetation within the project area, the required data posting, and potential altitude restrictions for flights in the general area. The basic parameters utilized for the sensors were as follows (different Sensors may have slightly different parameters, but in all cases the parameters met or exceeded the specifications indicated above):

Parameter	Value
Flying Height (AMT)	5000 feet
Nominal ground speed	100 knots
Field of View	31°
Laser Rate	135 kHz
Scan Rate	51.3 Hz
Maximum Cross Track Posting	1.0 meters
Maximum Along Track Posting	1.0 meters
Nominal Sidelap	30%

Table 1: Aerial acquisition parameters

These collection parameters resulted in a swath width of 2,772 feet with a 1.0 meter pulse or post spacing and an average point distribution of 2.0 points per square meter at NADIR.

Dates Flown

Collection occurred as weather permitted between January 28 and March 19, 2010. In all, a total of 726 flightlines were flown within this time frame.

File Information

5000x5000 foot tiles were delivered in LAS format and 10000x10000 foot tiles were delivered for DEMs. The file naming schema is based on the lower left hand corner of each tile along with which county it falls into.

Deliverable Dataset	File Type	Count
LAS Files	*.las	
DEM Files	ESRI GRID Format	
Breaklines	ESRI File-Geodatabase Format	

Table 2: Deliverable File Formats

Base Stations Used

ABGPS stations were Trimble 5700 data collection units, logging at 2 hertz, paired with Trimble Zephyr Geodetic antennas, which were mounted on variable height tripods with the H.I. measured at the beginning and end of each logging session.

The overall study area was divided into sections based on relation to potential base station set-ups. Requirements indicated that two separate base stations were needed for each lift, additionally CORS stations could also be utilized and each area was flown in relation to at least one GPS base station with local CORS SCCC used as a backup for each lift.

Aside from weather, aircraft airworthiness, and sensor readiness, there were other limiting factors. One was no data collection during periods of PDOP above 3.5 or periods with less than 6 visible satellites, and another was no collection with excessive aircraft yaw (due to wind conditions). To these ends, PDOP was checked each morning with a fresh almanac from Trimble's website and newly updated satellite health status from the US Coast Guard Navigation Center website. Excessive yaw (or crab), such as used to compensate for crosswinds while maintaining aircraft track and speed during flight lines, was referenced periodically throughout each flight, using 15 degrees as an upper limit, to ensure preservation of sidelap and even point distribution.

GPS Collection Parameters

Collection parameters for this project included the following:

Parameter	Value
Maximum PDOP	3.5
Minimum number of SVs	6
Ground collection epoch	2 Hz (0.5 sec)

Table 3: Collection parameters

Projection / Datum

All data for this project were reduced to State Plane Georgia East (1001), using NAD 83 (2007 adjustment). All elevations were presented as NAVD88 (Geoid09). Horizontal and vertical units were survey feet.

Data Processing

Applanix software was used in the post processing of the airborne GPS and inertial data that is critical to the positioning and orientation of the sensor during all flights. POSPac MMS provides the smoothed best estimate of trajectory (SBET) that is necessary for Optech's post processor to develop the point cloud from the LiDAR missions. The point cloud is the mathematical three dimensional collections of all returns from all laser pulses as determined from the aerial mission. At this point this data is ready for analysis, classification, and filtering to generate a bare earth surface model in which the above ground features are removed from the data set. The point cloud was manipulated within the Optech or Leica software; GeoCue, TerraScan, and TerraModeler software was used for the automated data classification, manual cleanup, and bare earth generation from this data. Project specific macros were used to classify the ground and to remove the side overlap between parallel flight lines.

All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Class 2 LIDAR was used to create a bare earth surface model. The surface model was then used to heads-up digitize 2D breaklines of inland streams and rivers. The National Elevation Dataset (1/3 arc-second) was used as a supplement to calculate streams with a contributing drainage area of greater than 1 square mile. Inland Ponds, Lakes, and Mudflats of 0.5 acres or greater were also collected along with the Coastal Shoreline. Elevation values were assigned to all Inland Ponds, Lakes, and Shorelines using TerraModeler functionality. Elevation values were assigned to all Inland streams, rivers, and mudflats using a combination of TerraScan, TerraModeler, and Photo Science proprietary software. All Class 2 LIDAR data inside of the collected breaklines were then classified to Class 9 using TerraScan macro functionality.

The breakline files were then translated to ESRI File-Geodatabase format using ESRI conversion tools. Data was then run through additional macros to ensure deliverable classification levels matching LAS ASPRS Classification structure. GeoCue functionality was then used to ensure correct LAS Version. In house software was used as a final QA/QC check to provide LAS Analysis of the delivered tiles.
Buffered LAS files were created in GeoCue to provide overedge to the DEM creation. These tiles were then run through automated scripting within ArcMap and were combined with the Hydro Flattened Breaklines to create the 4' DEM. Final DEM tiles were clipped to the tile boundary in order to provide a seamless dataset.

A manual QA review of the tiles was completed in ArcMap and Global Mapper to ensure full coverage with no gaps or slivers within the project area.

QA / QC Analysis

The vertical accuracy assessment compares the measured survey checkpoint elevations with those of the TIN as generated from the bare-earth LiDAR. The X/Y locations of the survey checkpoints are overlaid on the TIN and the interpolated Z values of the LiDAR are recorded. These interpolated Z values are then compared with the survey checkpoint Z values and this difference represents the amount of error between the measurements. Once all the Z values are recorded, the Root Mean Square Error (RMSE) is calculated and the vertical accuracy scores are interpolated from the RMSE value. The RMSE equals the square root of the average of the set of squared differences between the dataset coordinate values and the coordinate values from the survey checkpoints.

The first method of evaluating vertical accuracy uses the FEMA specification which follows the methodology set forth by the National Standard for Spatial Data Accuracy. The accuracy is reported at the 95% confidence level using the Root Mean Square Error (RMSE) which is valid when errors follow a normal distribution. By this method, vertical accuracy at the 95% confidence level equals RMSEZ x 1.9600. For CGEP, vertical accuracy must be 1.2 ft (36 cm) or less based on an RMSEz of 0.6 ft (18 cm) x 1.9600.

The second method of testing vertical accuracy, endorsed by the National Digital Elevation Program (NDEP) and American Society for Photogrammetry and Remote Sensing (ASPRS) uses the same (RMSEZ x 1.9600) method in open terrain only; an alternative method uses the 95th percentile to report vertical accuracy in each of the other land cover categories (defined as Supplemental Vertical Accuracy – SVA) and all land cover categories combined (defined as Consolidated Vertical Accuracy – CVA). The 95th percentile method is used when vertical errors may not follow a normal error distribution, as in vegetated terrain. For CGEP, CVA must be 1.2 ft (36 cm) or less when computed using the 95th percentile method. The CVA is accompanied by a listing of the 5% outliers that are larger than the 95th percentile used to compute the CVA; these are always the largest outliers that may depart from a normal error distribution.

The Fundamental Vertical Accuracy (FVA) is calculated in the same way when implementing FEMA/NSSDA and NDEP/ASPRS methodologies; both methods utilize the 95% confidence level (RMSEZ x 1.9600) in open terrain where there is no reason for LiDAR errors to depart from a normal error distribution.

Quantitative Criteria	Measure of Acceptability
Fundamental Vertical Accuracy (FVA) in open terrain at the 95% confidence level using RMSEz x 1.9600	1.2 ft (based on RMSEz x 1.9600)
Consolidated Vertical Accuracy (CVA) in all land cover categories combines using the 95th percentile method	1.2 ft (based on 95th percentile of all checkpoints)
Supplemental Vertical Accuracy (SVA) reported for each land cover type computed using the 95th percentile method	1.2 ft (based on 95th percentile of checkpoints in each land cover type)

Table 4: CGEP Acceptance Criteria

	$RMSE_z$(ft) Spec=0.6 ft	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	# of Points	Min (ft)	Max (ft)
Consolidated	0.33	0.05	0.03	-0.01	0.33	453	-0.89	0.90
Open Terrain	0.33	0.02	-0.02	-0.04	0.33	164	-0.89	0.87
High Grass	0.35	0.12	0.09	0.06	0.33	75	-0.67	0.90
Brush	0.33	0.16	0.15	-0.04	0.29	58	-0.53	0.79
Forest	0.36	0.03	0.01	0.13	0.36	69	-0.88	0.87
Urban	0.29	-0.04	-0.01	0.29	0.29	87	-0.88	0.64

Table 5: Calculated RMSEz values for CVA, FVA, and SVA as well as associated statistics of the errors for CGEP

Limiting Factors of LIDAR Collection

There are several limiting factors to LiDAR data collection which include:

Weather: there can be no clouds, excess moisture (rain, fog or excessive humidity) between the sensor and the ground we are profiling. Additionally, high winds which if blowing perpendicular to the line of flight could provide for excessive crab resulting in “slivers” or “holidays” between flight lines as well as unsafe flight conditions such as wind shear or clear air turbulence.

Ground Conditions: Such as standing water from recent heavy rains, excessive “ponding” or “pooling” of water which will affect the accuracy of the LiDAR returns as will snow and Ice. This is especially apparent in ditches with high water and along roadways and fence lines with drifting snow.

Satellite Configuration: Typically one does not want to collect LiDAR during time of high Positional Dilution of Precision (PDOP), as this would result in the GPS configuration providing accuracy less than desired. Higher values for the PDOP indicate ess than ideal geometric configuration of the satellites. For this project there was no data collection during periods of PDOP above 3.5 or periods with less than 6 visible satellites. To these ends, PDOP was checked each morning with a fresh almanac and newly updated satellite health status from the US Coast Guard Navigation Center website.