NCALM
The National Center for Airborne Laser Mapping

Data Collection & Processing Report for 2015 Seed Project: Using Shallow Water Bathymetric LiDAR Data to Characterize Seagrass Beds to Parameterize Storm Surge and Sea Level Rise Models

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1. LiDAR System Description & Specifications

This survey was performed with an Optech Titan multispectral airborne LiDAR sensor (serial number: 14SEN340) mounted in a twin-engine Piper PA-31-350 Navajo Chieftain (tail number: N154WW). The instrument nominal specifications are listed in **Table 1**.

Parameter	Specification
Laser Wavelength	Channel 1: 1550 nm, Channel 2: 1064 nm, Channel 3: 532 nm
Operating Altitude	300–2000 m AGL nominal (topographic) 300–600 m AGL nominal (bathymetric)
Horizontal Accuracy	1/7500 × altitude (1σ)
Vertical Accuracy	< 5–10 cm (1σ)
Minimum Target Separation Distance	< 1.0 m (discrete)
Range Capture	Up to 4 range measurements per pulse, including last return
Intensity Capture	12-bit dynamic measurement and data range
Scan FOV	0–60°
Scan Frequency	0–210 Hz
Pulse Rate Frequency	50–300 kHz (per wavelength)
Beam Divergence	0.35 mrad (1/e) (1550 and 1064 nm) 0.7 mrad (1/e) (532 nm)
Position/Orientation System	POSAV AP50 (OEM), 220-channel dual frequency GNSS receiver

Table 1: Optech Titan specifications

2. Area of Interest

The requested survey area consisted of five polygons located on the Gulf Coast, near Apalachicola, FL. The polygons enclose approximately 40.4 km^2 (15.6 mi^2). **Figure 1** is an image from Google Earth showing the location of the survey.

Figure 1: Location of survey polygons (in red) and GPS reference station

3. Data Collection

a) Survey Dates: The survey took place on August 20–21, 2015 (DOY 232–233). The airport that served as the base of operation was the Apalachicola Regional Airport (KAAF).

b) Airborne Survey Parameters: Survey parameters are provided in **Table 2**.

Nominal Flight Parameters		Equipment Settings		Survey Totals	
Flight Altitude	350 m	Laser PRF	50 kHz	Total Flight Time	5.42 hr
Flight Speed	+/- 65 m/s	Beam Divergence	0.35/0.7 mrad	Total Laser Time	
Swath Width	300 m	Scan Frequency	20 Hz	Total Swath Area	61.2 km^2
Swath Overlap	~50%	Scan Angle	± 30°	Total AOI Area	40.4 km^2
Point Density	18 pt/m^2	Scan Cutoff	± 5°	Pass spacing	200 m

Table 2: Nominal flight parameters, equipment settings, and survey totals for flights (actual parameters vary with terrain)

c) Ground GPS: One GPS reference station was used during the survey; it was established by NCALM at the Apalachicola Regional Airport. The GPS reference observations were logged at 1 Hz. **Table 3** gives the coordinates of the station, and **Figure 1** (above) shows the project area and GPS reference station location.

GPS Station	KAAF
Agency	NCALM
North Latitude	29°43’27.18151”
West Longitude	85°01’34.57137”
Ellipsoidal Elevation	-20.641 m

Table 3: Coordinates of GPS reference station in NAD83(2011) epoch 2010.00

4. GPS/IMU Data Processing

Reference coordinates (NAD83(2011) epoch 2010.00) for all stations are derived from observation sessions taken over the project duration and submitted to the NGS's on-line processor OPUS, which processes static differential baselines tied to the international CORS network. For further information on OPUS see: http://www.ngs.noaa.gov/OPUS/, and for more information on the CORS network see: http://www.ngs.noaa.gov/CORS/.

Airplane trajectories for this survey were processed using KARS (Kinematic and Rapid Static) software, written by Dr. Gerald Mader of the NGS Research Laboratory. KARS kinematic GPS processing uses the dual-frequency phase history files of the reference and airborne receivers to determine a high-accuracy, fixed integer, ionosphere-free differential solution at 1 Hz. All final aircraft trajectories for this project (except in rare instances) are blended solutions from at least two of the three available stations.

After GPS processing, the 1-Hz trajectory solution and the 200-Hz raw inertial measurement unit (IMU) data, collected during the flights, are combined in APPLANIX software POSPac MMS (Mobile Mapping Suite Version 7.1). POSPac MMS implements a Kalman Filter algorithm to produce a final, smoothed, and complete navigation solution, including both aircraft position and orientation at 200 Hz. This final navigation solution is known as an SBET (Smoothed Best Estimated Trajectory).

5. LiDAR Data Processing Overview

The following diagram (**Figure 2**) shows a general overview of the NCALM LiDAR data processing workflow.

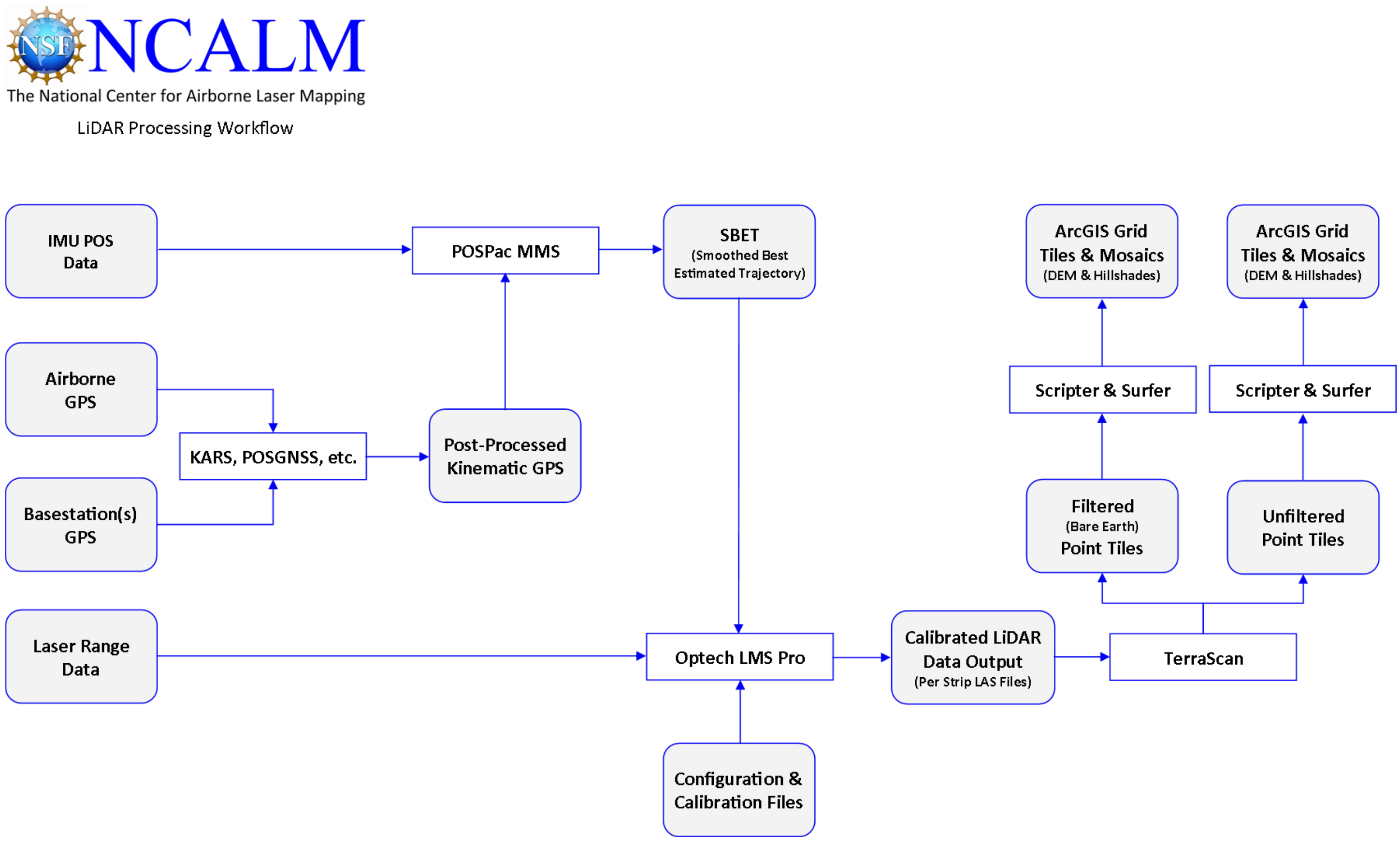

Figure 2: NCALM LiDAR processing workflow

There are some important differences in processing range data from the Channel 3 laser with respect to the processing of traditional terrain or bathymetric systems. The main difference concerns the fact that the laser pulse can travel through both air and water. For the accurate determination of ranges, it is necessary to determine what portion of the laser pulse trajectory occurred in each medium, to account for the difference in the speed of light. Therefore, additional steps are involved in processing bathymetric data. This includes the classification of points representing laser shots that penetrated the water and correcting the elevation values for the above-mentioned phenomena.

Classification was done by automated means, using TerraSolid Software (TerraScan Version 15.006): www.terrasolid.com/products/terrascanpage.php.

NCALM makes every effort to produce the highest quality LiDAR data possible, but every LiDAR point cloud and derived DEM will have visible artifacts if it is examined at a sufficiently fine level. Examples of such artifacts include visible swath edges, corduroy (visible scan lines), errors in bathymetry determination, and data gaps. A detailed discussion on the causes of data artifacts, and how to recognize them, can be found here: ncalm.berkeley.edu/reports/GEM_Rep_2005_01_002.pdf.

A discussion of the procedures NCALM uses to ensure data quality can be found here: ncalm.berkeley.edu/reports/NCALM_WhitePaper_v1.2.pdf.

NCALM cannot devote the required time to remove all artifacts from datasets. If researchers find areas with artifacts that influence their applications, they should contact NCALM (ncalm.cive.uh.edu), and we will assist them in removing the artifacts to the extent possible – but this may well involve the PIs devoting additional time and resources to this process.

6. Accuracy Assessment

a) Relative Accuracy: System calibration of the sensor's three boresight angles (roll, pitch, and yaw) and scanner mirror scale factor was done by automated means using Optech LMS Pro software (Version 2.4.2). Project lines or off-project lines flown with opposite headings, combined with perpendicular cross lines, are used as input in TerraMatch. These calibration values are checked on a flight-by-flight basis.

After the calibration values are optimized, project flight lines are output and classified into ground and non-ground classes. Surfaces are developed for each flight strip from the ground class points, then these individual flight strip surfaces are differenced, and a value for the magnitude of the height mismatch over the entire project area is calculated.

For the surveyed area, the average magnitude for vertical mismatch of ground surfaces (unsigned vertical differences between flight strips) in overlap zones for Channel 1, Channel 2, and Channel 3 data is 0.050, 0.042, and 0.056 m, respectively.

b) Absolute Accuracy: No ground check points were collected for this project, so a small (< 0.15 m) vertical bias in the elevations of the final point cloud and DEM may exist, with respect to NAVD88. Note that any LiDAR-derived DEM accuracy will usually degrade on steep terrain and under canopy. Bathymetry points from the Aquarius (green laser) data were determined using Gemini (infrared laser) data as control, so any bias may potentially be compounded further.

7. Data Deliverables

a) Horizontal Datum: NAD83(2011)

b) Vertical Datum: NAVD88 (GEOID12A)

c) Projection: UTM Zone 16N

d) Units: Meters

e) File Formats:

1. Point cloud in LAS format (Version 1.2), classified with ground, bathymetry (where applicable), and non-ground returns, in 1000-m × 1000-m rectangular tiles
2. ESRI FLT format 1-m DEM from classified ground and bathymetry points
3. ESRI-created 1-m Hillshade raster from classified ground and bathymetry points
4. ESRI FLT format 1-m DEM from first-return points (canopy and buildings included)
5. ESRI-created 1-m Hillshade raster from first-return points (canopy and buildings included)

f) File Naming Convention: The 1000-m × 1000-m tiles follow a naming convention using the lower-left coordinate (minimum X, Y) as the seed for the file name as follows: *XXXXXX_YYYYYYY*. For example, if the tile bounds are the coordinate values from Easting 550000 through 551000, and Northing 4330000 through 4331000, then the tile file-name incorporates *550000_4330000*. Due to the limited number of characters that can be used for ArcGIS data products, the following format was used: *area#_x*. Where "area#" corresponds to the project area (5 total, numbered in order from the most northerly to the most southerly); "x" represents the type of return used for creating the raster ("u" for first-return (unfiltered) points and "f" ground and bathymetry (filtered) points). For a hillshade file, the suffix *_hs* was added after the name.

g) LAS File Information: Each of the returns contained on the LAS tiles have been encoded with a laser channel value. As noted above, the Optech Titan has three channels: 1550, 1064, and 532 nm. The values used are *1* (1550 nm), *2* (1064 nm), and *3* (532 nm), and are stored in the User Data record of the Point Data records in the LAS file. Additionally, the Classification Values follow the ASPRS Standard:

www.asprs.org/Committee-General/LASer-LAS-File-Format-Exchange-Activities.html