Data Collection and Processing Report for "The Ecological Drill Hypothesis: Biotic Control on Carbonate Dissolution in a Low-Relief Patterned Landscape"

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1. LiDAR System Description and Specifications

This survey was performed with an Optech Gemini Airborne Laser Terrain Mapper (ALTM) serial number 06SEN195 mounted in a twin-engine Piper PA-31-350 Navajo Chieftain (Tail Number N931SA). The instrument nominal specifications are listed in Table 1.

Operating Altitude	150-4000 m, Nominal
Horizontal Accuracy	1/5,500 x altitude (m AGL); 1 sigma
Elevation Accuracy	5 - 35 cm; 1 sigma
Range Capture	Up to 4 range measurements, including 1st, 2nd, 3rd, last returns
Intensity Capture	12-bit dynamic range for all recorded returns, including last returns
Scan FOV	0 - 50 degrees; Programmable in increments of ±1degree
Scan Frequency	0 – 70 Hz
Scanner Product	Up to Scan angle x Scan frequency = 1000
Roll Compensation	±5 degrees at full FOV – more under reduced FOV
Pulse Rate Frequency	33 - 167 kHz
Position Orientation System	Applanix POS/AV 510 OEM includes embedded BD960 72-channel 10Hz (GPS) receiver
Laser Wavelength/Class	1064 nanometers / Class IV (FDA 21 CFR)
Beam Divergence nominal (full angle)	Dual Divergence 0.25 mrad (1/e) or 0.80 mrad (1/e)

Table 1 – Optech GEMINI specifications (http://www.optech.ca/pdf/Gemini_SpecSheet_100908_Web.pdf).

See http://www.optech.ca for more information from the manufacturer.

2. Areas of Interest.

The requested survey area consisted of 8 rectangles – each enclosing 2 square kilometers - located approximately 100 km WNW of Miami, Florida and just north of Everglades National Park. These rectangles are shown below in Figure 1 (Google Earth) and represent the location of the requested survey. The yellow push pins (1043, MTNT) represent the locations of the GPS reference stations.

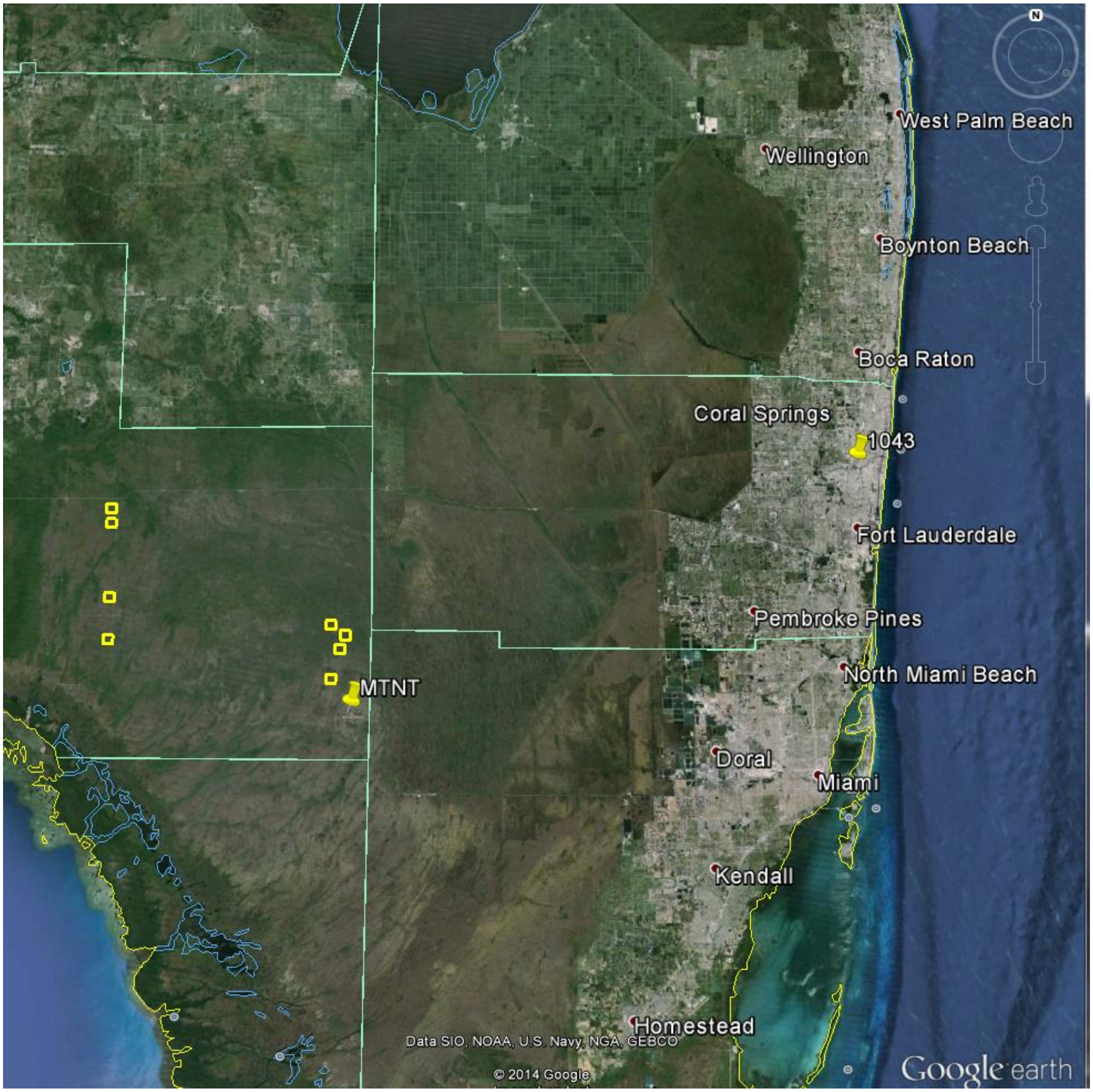

Figure 1 – Shape and location of 8 survey rectangles. Yellow push pins represent GPS reference station locations. (Google Earth).

In the interest of efficiency, these 8 rectangles were surveyed with 48 flight lines running north-south, therefore a much larger area than requested was actually surveyed as illustrated by the red polygons below in Figure 2. For more information on the availability of these extended data please contact NCALM.

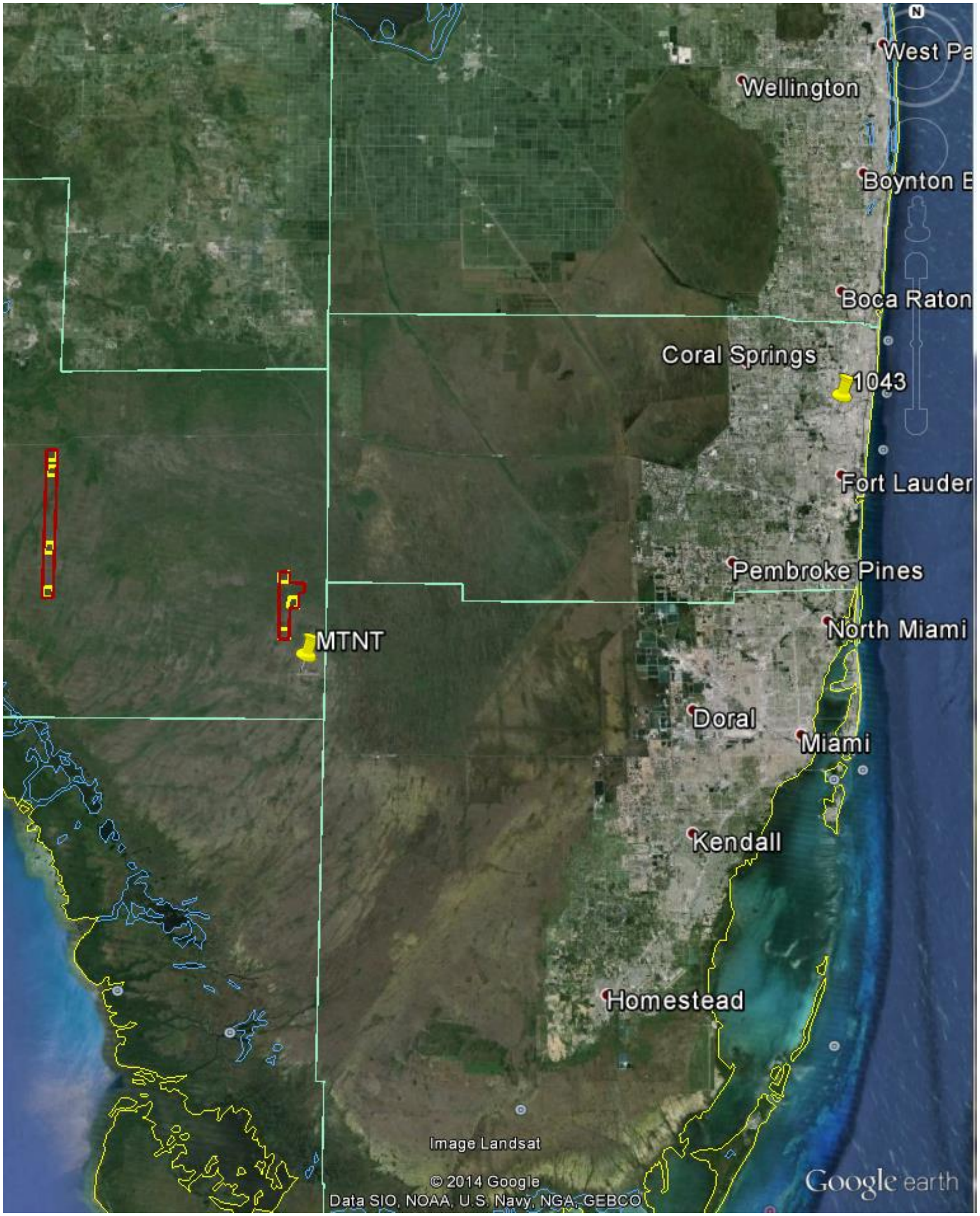

Figure 2. Red polygons show actual data extent.

3. Data Collection

a) **Survey Dates**: The survey took place on May 27 and 28, 2014 (DOY 147 and 148).

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

Nominal Flight Parameters		Equipment Settings		Survey Totals	
Flight Altitude	500 m	Laser PRF	100 kHz	Total Flight Time	6.3 hrs.
Flight Speed	+/- 60 m/s	Beam Divergence	0.25 mrad 0.80 mrad	Total Laser Time	1.0 hrs.
Swath Width	231 m	Scan Frequency	45 Hz	Total Swath Area	16 (60) km^2
Swath Overlap	Min 50 %	Scan Angle	± 14°	Total AOI Area	16 (60) km^2
Point Density	12.3 p/m^2	Scan Cutoff	1.0°	Pass spacing	115 m

Table 2 – Nominal flight parameters, equipment settings and survey totals; actual parameters vary with the terrain.

c) **Ground GPS:** Two GPS reference station locations were used during the survey: one belongs to the national CORS network and the remaining one was established by NCALM near the Fort Lauderdale Executive airport. All GPS reference observations were logged at 1 Hz. Table 3 (below) gives the coordinates of the stations and Figures 1 and 2 (above) show the project area and the GPS reference station locations.

GPS station	1043	MTNT
Agency	NCALM	NOAA/NGS
Latitude	26.207527	25.865767
W Longitude	80.141209	80.906996
GRS80 Height	-22.187	-18.928

Table 3 – Coordinates of GPS reference stations in NAD83 (2011) Epoch 2010.0000 - Ellipsoid Height in meters.

4. GPS/IMU Data Processing

Reference coordinates (NAD83 (2011) Epoch 2010.0000) for all stations are derived from observation sessions taken over the project duration and submitted to the NGS 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 are blended solutions from at least three of the five 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 5.2). 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 3) shows a general overview of the NCALM LiDAR data processing workflow

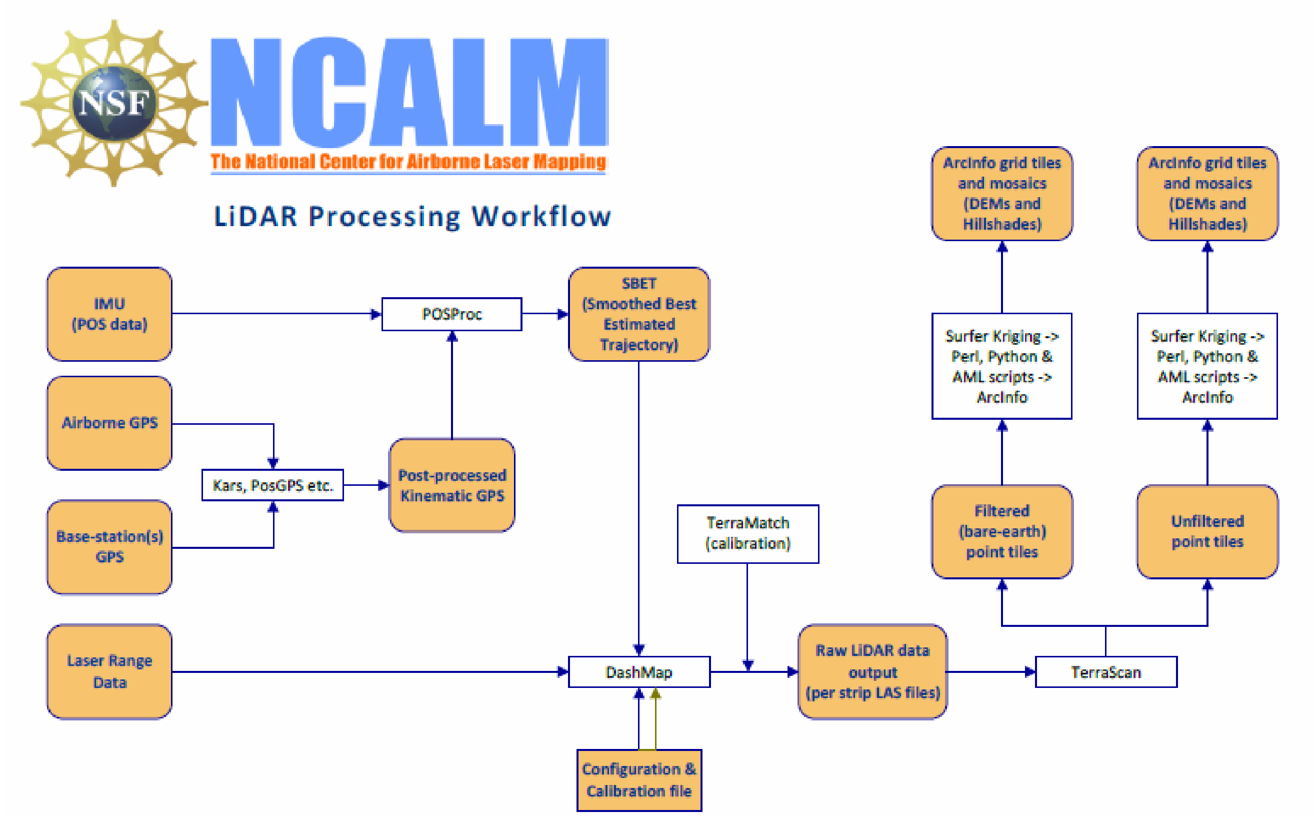

Figure 3 - NCALM LiDAR Processing Workflow

Classification done by automated means using TerraSolid Software (TerraScan Version 14.013).
http://www.terrasolid.fi/en/products/4

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), and data gaps. A detailed discussion on the causes of data artifacts and how to recognize them can be found here:
http://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:
http://ncalm.berkeley.edu/reports/NCALM_WhitePaper_v1.2.pdf

NCALM cannot devote the required time to remove all artifacts from data sets, but if researchers find areas with artifacts that impact their applications they should contact NCALM 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 3 sensor bore sight angles (roll, pitch, and yaw) and scanner mirror scale factor is done by automated means using TerraSolid Software (TerraMatch). Project lines and off-project lines flown with opposite headings combined with perpendicular cross lines are used as input to TerraMatch (Version 13.006). These calibration values are checked on a flight-flight basis.

After calibration values are optimized, project flight lines are output and then classified into ground and non-ground classes. Surfaces are developed for each flight strip from the ground class points, and 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 western rectangles the average magnitude for vertical mismatch of ground surfaces (unsigned vertical differences between flight strips) in overlap zones is **0.056 m**. For the eastern rectangles the average magnitude for vertical mismatch of ground surfaces (unsigned vertical differences between flight strips) in overlap zones is **0.041 m**.

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.

7. Data Deliverables

a) **Horizontal Datum**: NAD83 (2011)
b) **Vertical Datum:** NAVD88 (GEOID 12a)
c) **Projection:** UTM Zone 17N – units in meters.
d) **File Formats:**

1. Point Cloud in LAS format (Version 1.2), classified as ground or non-ground, in 2 km^2 rectangles.
2. ESRI format 1-m DEM from ground classified points.
3. ESRI format 1-m Hillshade raster from ground classified points
4. ESRI format 1-m DEM from all points (canopy included).
5. ESRI format 1-m Hillshade raster from all points (canopy included).

e) **File naming convention:** Rectangles 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 coordinate values from easting equals 505500 through 507000, and northing equals 2873000 through 2874500 then the tile filename incorporates 505500_2873000. These tile footprints are available as an AutoCAD DXF or ESRI shapefile.