LiDAR Estimation of Forest Leaf Structure, Terrain, and Hydrophysiology

Airborne Mapping Project Report

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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 Cessna Skymaster (Tail Number N337P). 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 - 30 cm; 1 sigma
Range Capture	Up to 4 range measurements, including 1^{st}, 2^{nd}, 3^{rd}, 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 BD950 12-channel 10Hz GPS receiver
Laser Wavelength/Class	1047 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

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

2. Survey Area.

The survey area was a rectangle, 6.25Km by 6.7Km (41.8 Km^2 area), located 15Km south of Franklin, NC. The location is shown below:

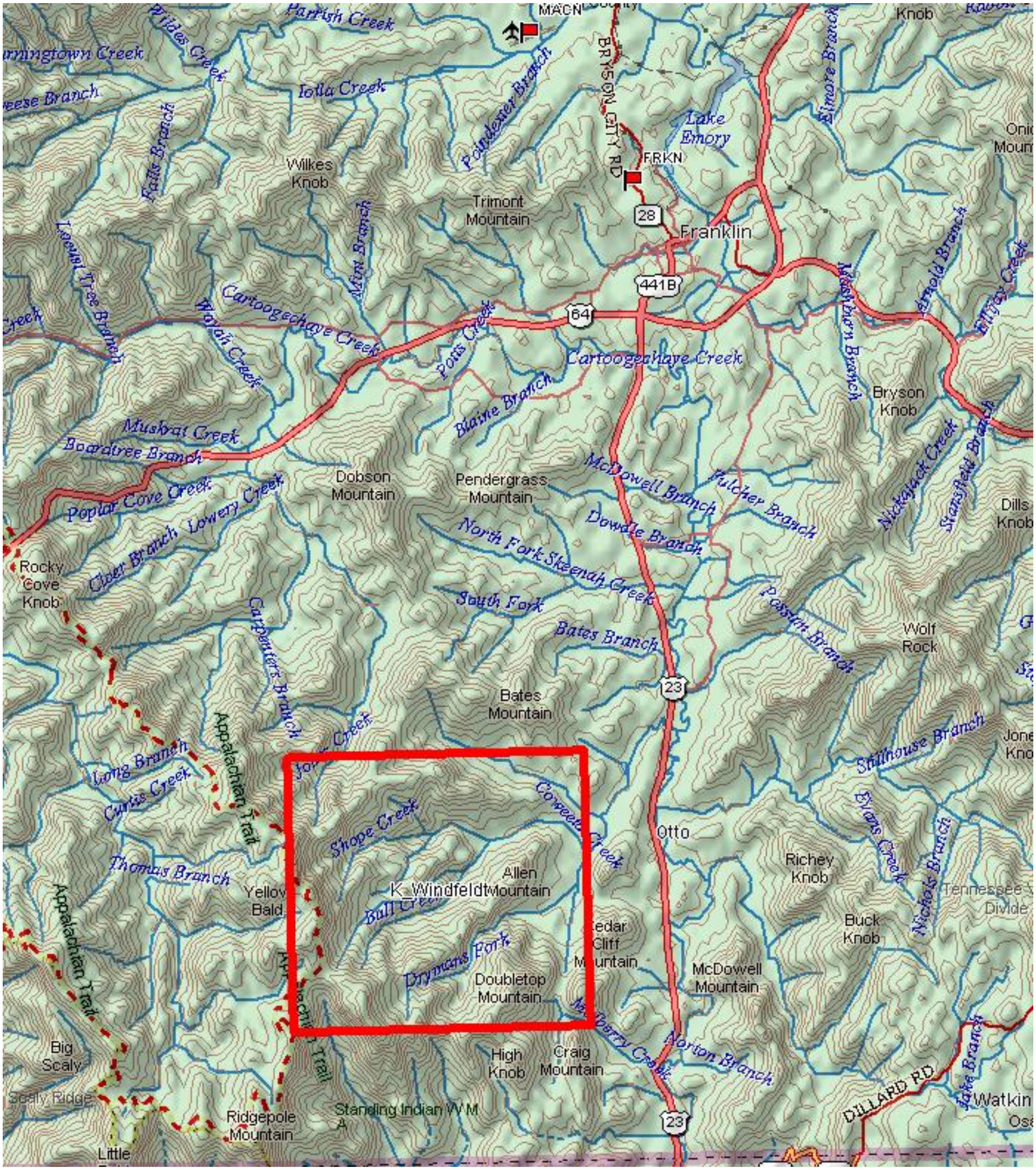

Figure 1(a) – Shape and location of survey polygon and Control GPS stations (TopoUSA)

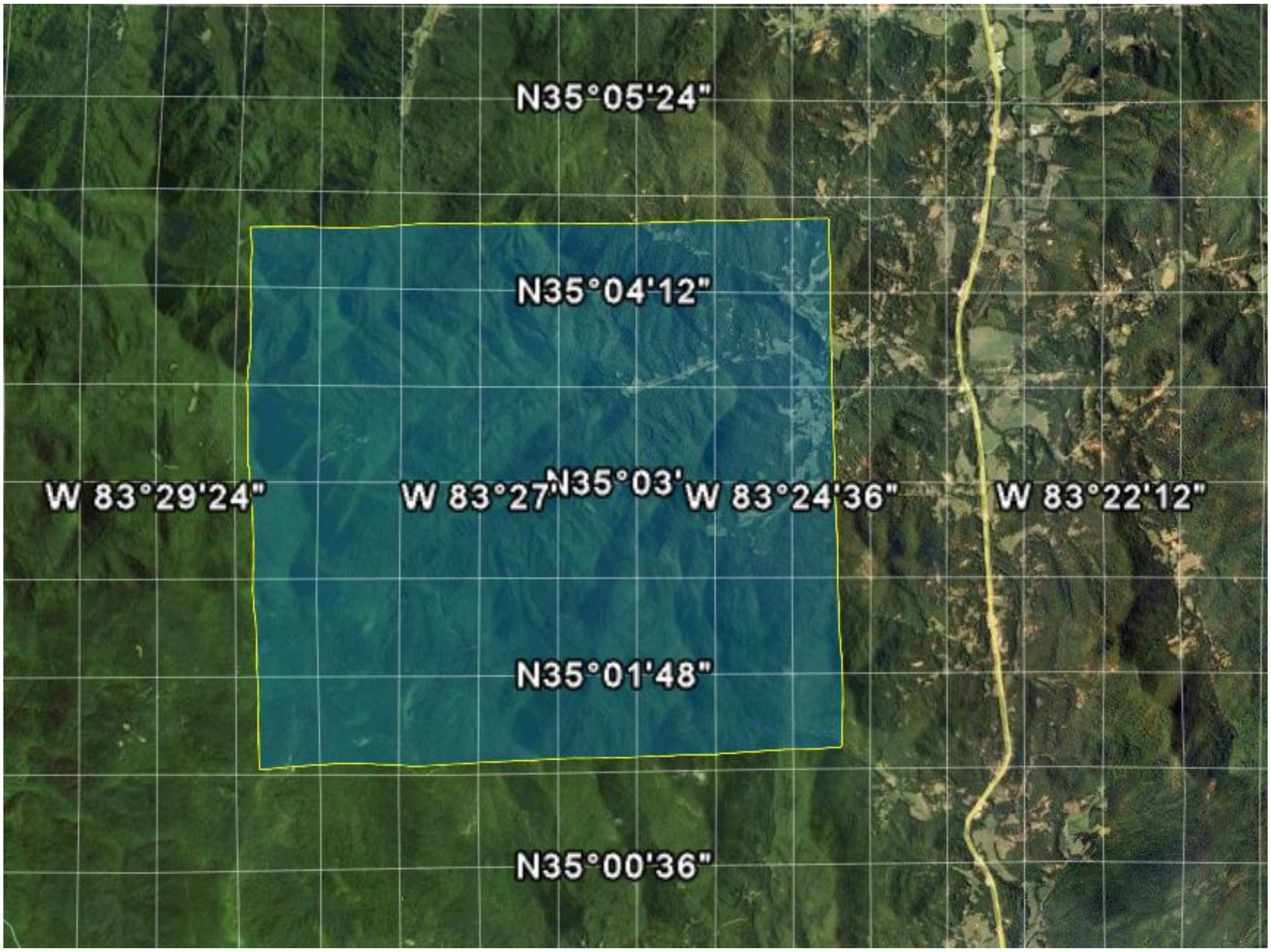

Figure 2(b) – Shape and location of survey polygon (Google Earth)

3. Survey Planning and Parameters.

The survey composed of a 36 total passes going in North-South direction Figure 2 below shows the planning software along with the sets of planned flight lines and the survey parameters.

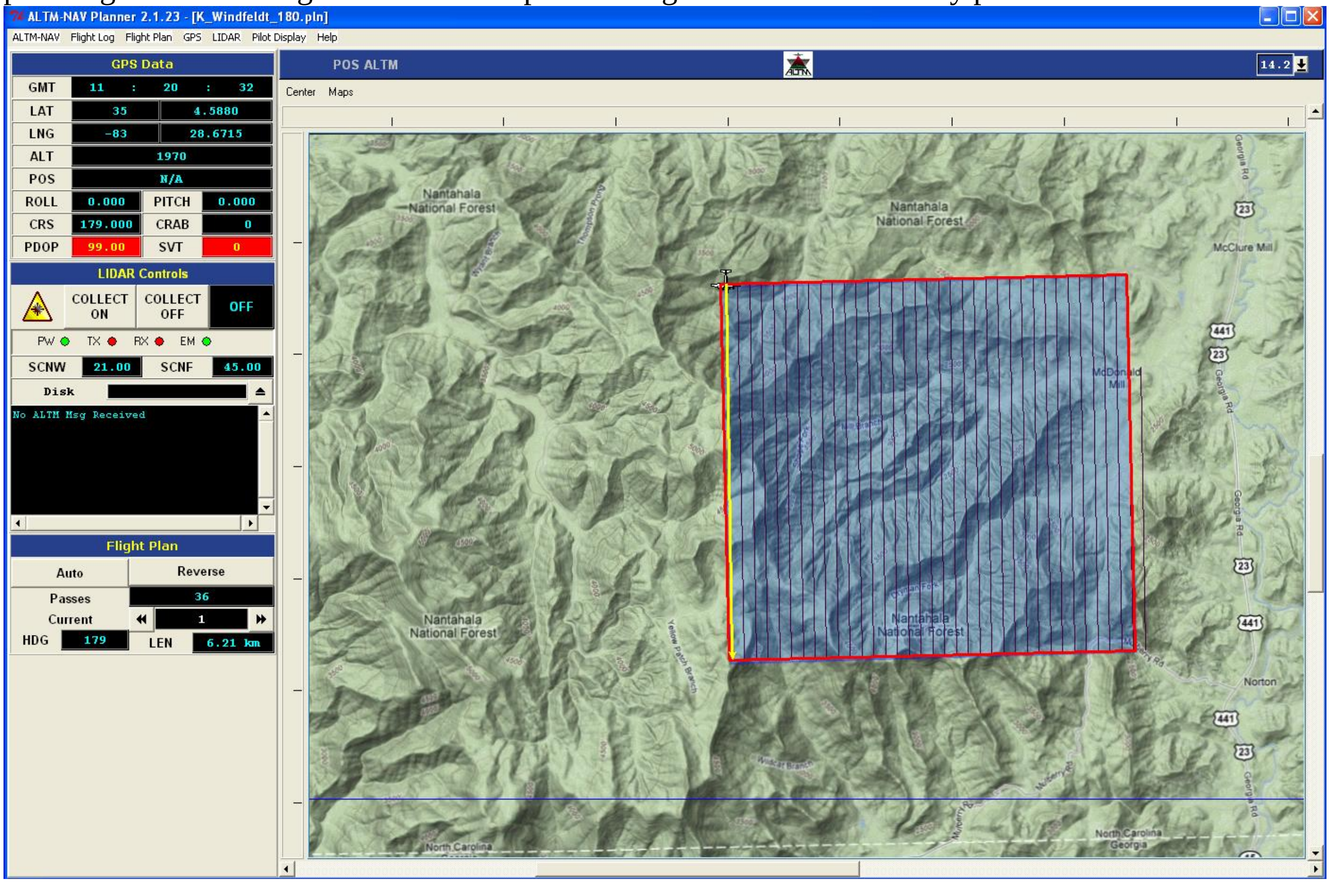

Figure 3 Flight lines from the planning software

Survey parameters are given below in Table 3.

Survey Parameters		Survey Totals	
Altitude (m)	600	Total Length (Km)	222
Swath Width (m)	400	Swath Area (Km^2)	43
Overlap (%)	59	Area of Interest (Km^2)	41
Laser PRF (kHz)	100	No. of Passes	36
Scan Freq (Hz)	45		
Scan Angle (degrees)	21		
Scan Cutoff (degrees)	3		

Table 3 – Survey parameters

4. LIDAR and GPS Data Collection Campaign.

This survey was flown as a part of Seed Money Survey Campaign that took place in Aug-Sept 2009. This section was surveyed on Aug 26, 09(Day of the Year 238) and was flown out of Macon County airport in Franklin, North Carolina. The total flight time was 4 hrs 52mins and the total Laser on time was 1 hrs 26 min.

Two GPS reference stations were used for ground control. One was a CORS (Continuously operated Reference system) station and the other one was set up and operated by NCALM. GPS observations were logged at 1 Hz. Ground equipment at NCALM reference station consisted of ASHTECH (Thales Navigation) Z-Extreme receivers, with a choke ring antenna (Part# 700936.D) mounted on 1.3-meter fixed-height tripods. The list of the station and their locations is given below in table 4. The airborne receiver is an integrated GPS receiver module Trimble BD950, logging at 10 Hz.

Station Name	Lat	Long	Station Type
MACN	35.2219	-83.4206	NCALM
FRKN	35.1918	-83.3949	CORS

Table 4 Ground Control Stations

5. Data Processing

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

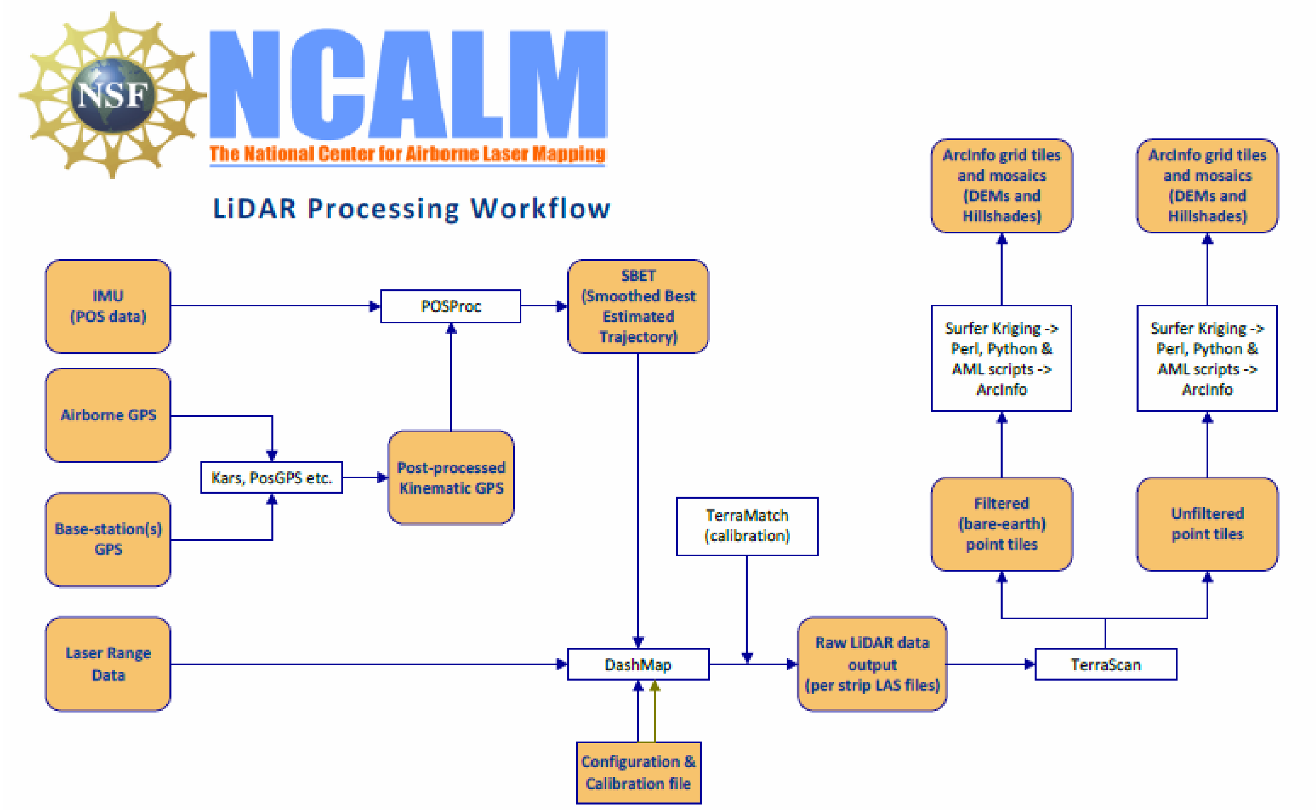

Figure 3 NCALM LiDAR Processing Workflow

5.1. GPS & INS Navigation Solution.

Reference coordinates and the GPS data for the CORS stations was obtained from their website. Reference coordinates for the NCALM station was obtained using OPUS (Online Positioning User Service), 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 GPS trajectories for this survey were processed using KARS (Kinematic and Rapid Static), software created by Dr. Gerry Mader. 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. GPS trajectories are created using all the above four mentioned ground control stations. These trajectories are then differenced to determine the best solutions. Figure 3 shows the plot for positional difference between trajectories obtained from MACN and FRCN.

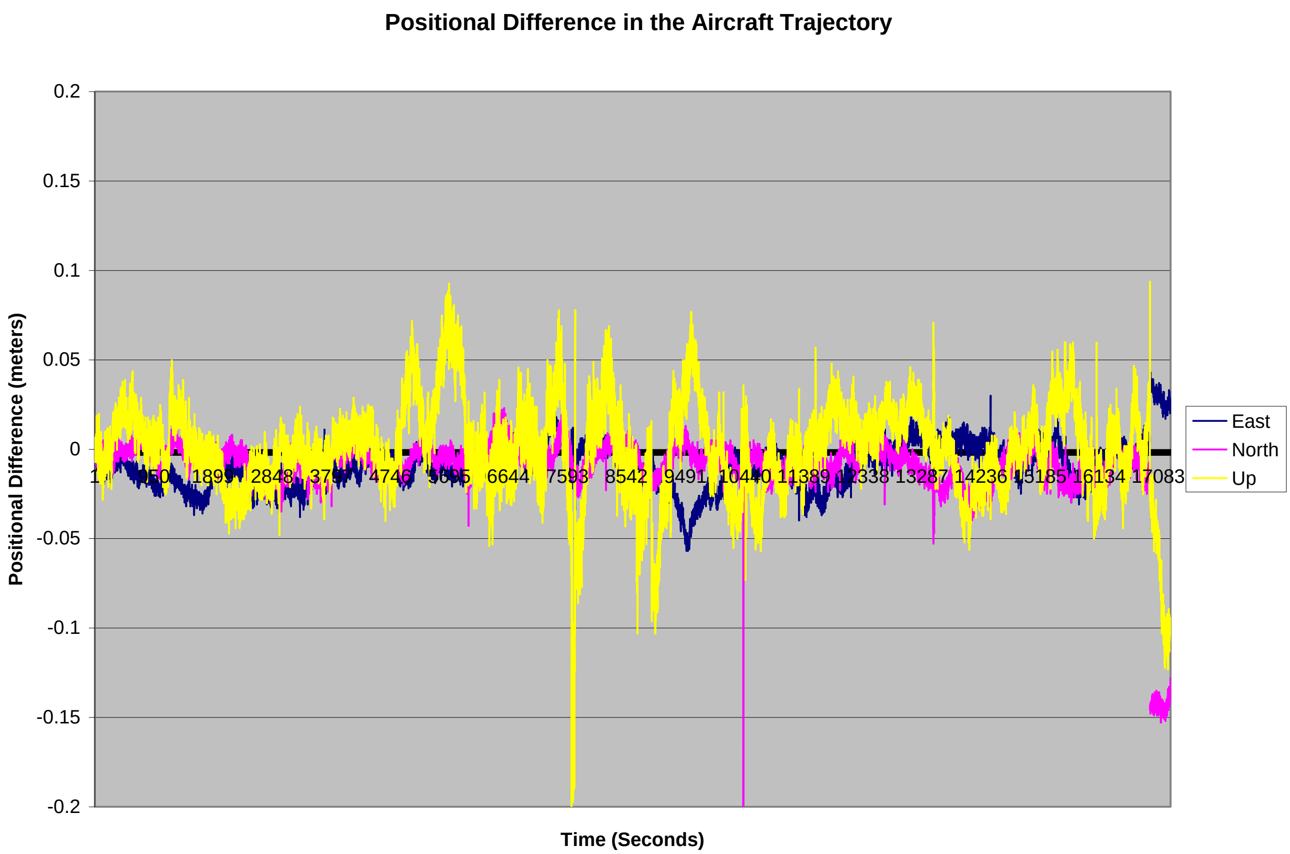

Figure 3 Positional differences between the two trajectories

After GPS processing, the 1Hz differential GPS trajectory and the Inertial Measurement Unit (IMU) data are processed together in the POSProc software (version 5.2). POSproc software combines GPS trajectory with the orientation information in a Kalman Filter to produce a final, smoothed and complete navigation solution at 200Hz. This final solution is known as the SBET (Smoothed Best Estimated Trajectory).

5.2 Laser Point Processing

An SBET together with laser ranges and mirror angles are finally combined in Optech's DashMap software (Version 4.1) to generate a flight-strip point cloud in LAS format. All point cloud coordinates were processed with respect to **NAD83** and referenced to the international CORS network. The projection is UTM Zone 17, with units in meters**. Heights are NAVD88** orthometric heights computed using the **NGS GEOID 03.** Scan angle cut-offs are done to improve the overall DEM accuracy as points farthest from the scan nadir are the most affected by small errors in pitch, roll and scanner mirror angle measurements. Moreover, scan angle cut-offs are done to eliminate points at the edge of the scan lines for improving the overall DEM accuracy as the points farthest from the scan nadir are the most affected by small errors in pitch, roll and scanner mirror angle measurements. A scan cutoff angle of 3 degrees was used.

5.3 Classification and Filtering

Classification done by automated means using TerraSolid Software. More information about the software can be found at http://www.terrasolid.fi/en/products/4

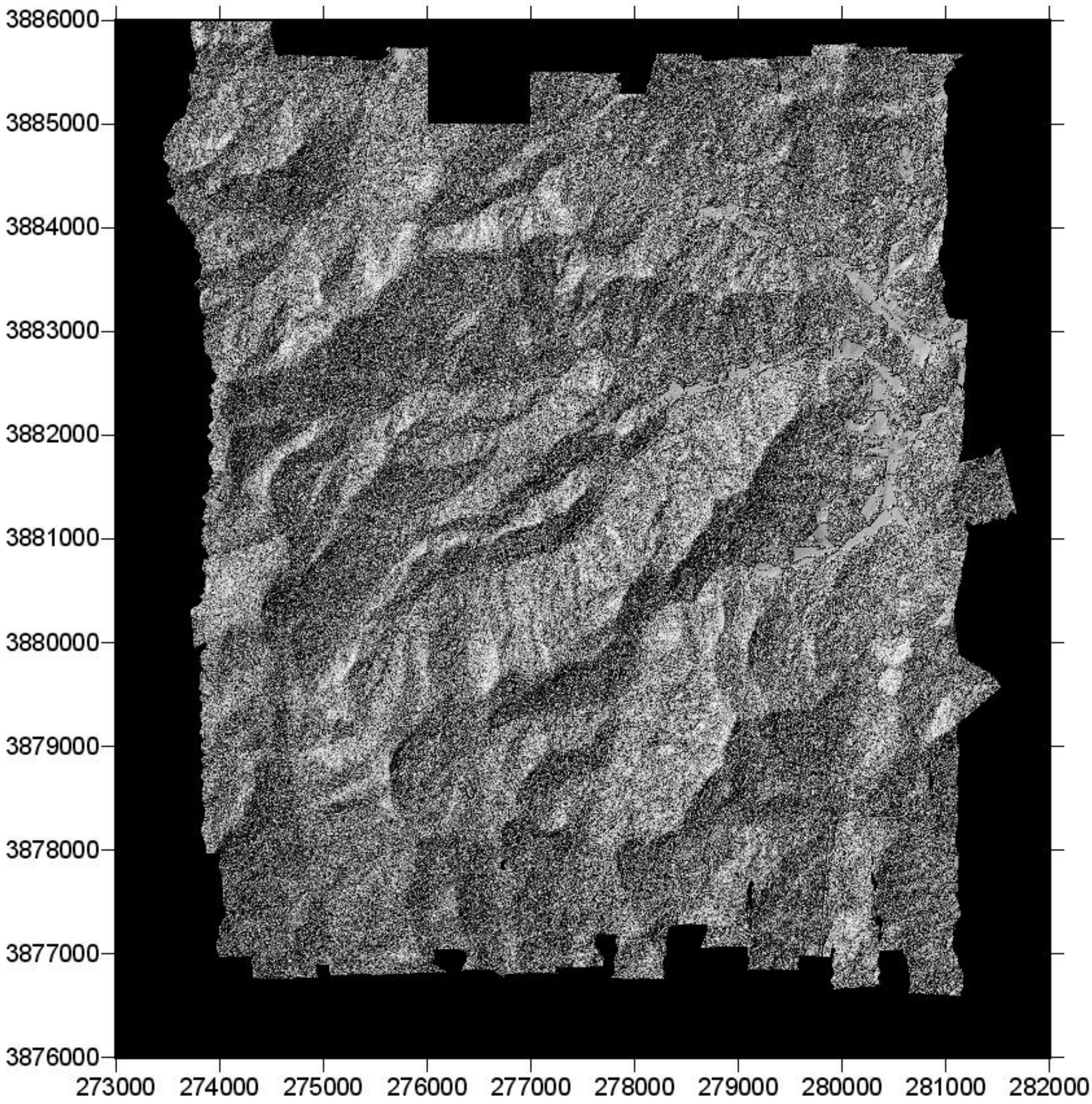

Figure 4a Unfiltered DEM

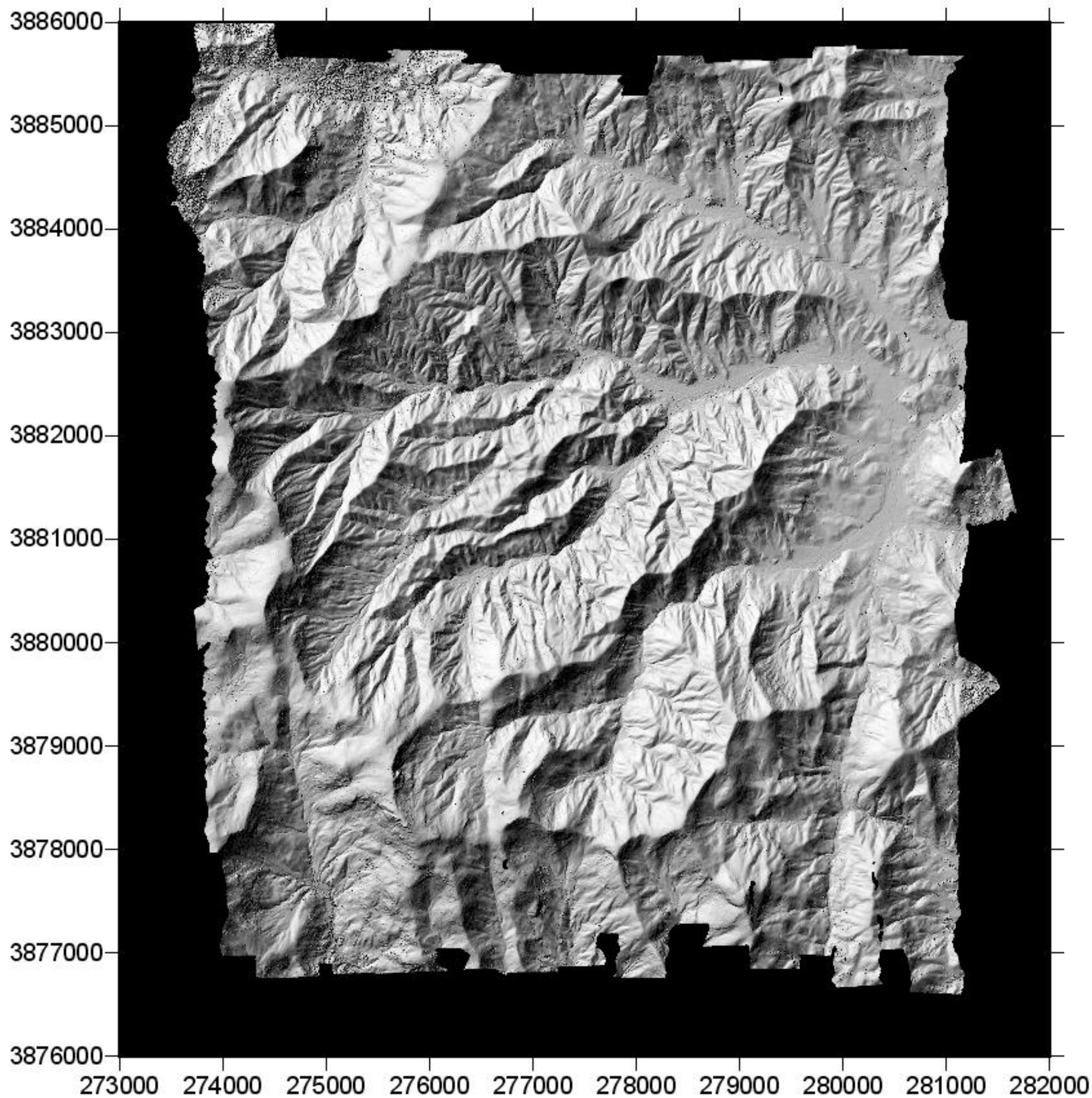

Figure 4b Filtered DEM

5.4 Gridding and Tiling.

The flight strip point cloud files were tiled into 1 kilometer square blocks, illustrated in the figure below

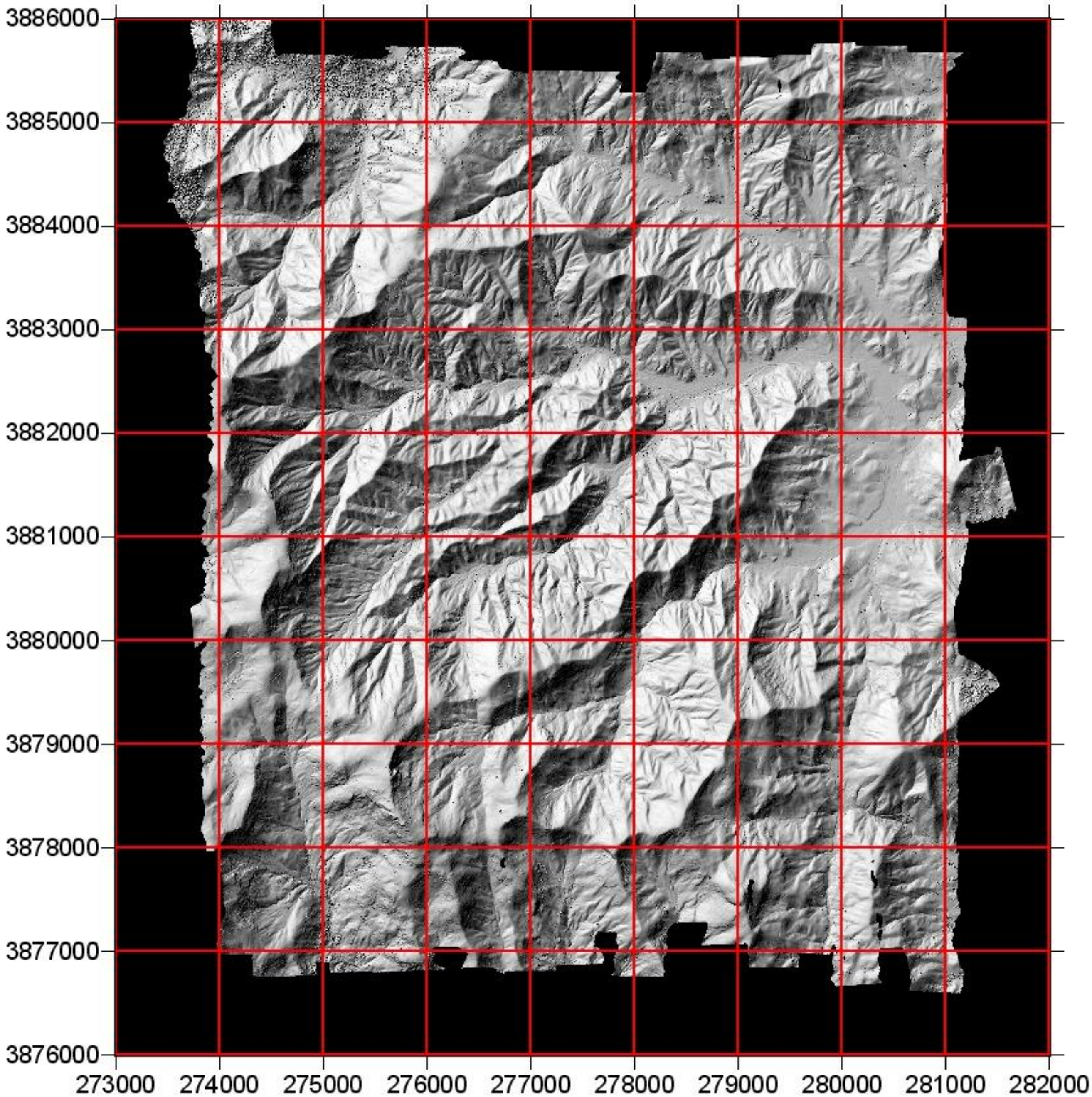

Figure 5 - Tile footprints overlaid on bare-earth shaded relief image.

Tiles follow a naming convention using the lower left coordinate (minimum X, Y) as follows: XXXXXX_YYYYYYY. For example if the tile bounds coordinate values from easting equals 274000

through 275000, and northing equals 3878000 through 3879000 then the tile is named as '275000_3878000'. The project totaled 90 tiles.
Digital Elevation Models were produced in SURFER (Golden Software) Version 8 at 1.0 meter resolution using krigging routine.

6 File Formats

The point cloud files are delivered in the 1000mX1000m tiles in ".Las" format. It is a binary format contains all the information associated with each point i.e. its position in X,Y,Z, intensity, flight line, timestamp, scan angle etc. The individual Las files can be converted to ASCII using the LAS to ASCII converter tool developed by the UNC. It can be accessed at http://www.cs.unc.edu/~isenburg/lastools . It gives users the freedom to create ASCII files with whichever point features they want to access. Raster grids are delivered in ArcInfo grid and hillshade format as 10KM mosaics. Incase of sections smaller than that in size, a single ArcInfo grid and hillshade file is delivered. The point tiles, the corresponding grids and mosaics are all positioned in the NAD83 reference frame and projected into UTM coordinates Zone 17N. The elevations are NAVD88 orthometric heights computed using the NGS GEOID 03. All units are in meters.