Climate control of hillslope erosion across a steep rainfall gradient on Kaua'I (Kimberly Huppert)

The interplay of cliff erosion, landsliding, and knickpoint retreat along the Na Pali Coast, Kaua'I (Mathieu Lapotre)

Principal Investigators

Kimberly Huppert Advisor Taylor Perron Massachusetts Institute of Technology Earth, Atmospheric, and Planetary Sciences 77 Massachusetts Ave 54-1024 Cambridge, MA 02139 Email: khuppert@mit.edu Phone: (510) 282-9668 Fax: (617) 253-8298	Mathieu Lapotre Advisor: Michael P. Lamb California Institute of Technology Caltech GPS Division, MC 170-25, 1200 E. California Blvd, Pasadena, CA 91125 Email: mlapotre@caltech.edu Phone: (626) 232-5494 Fax: (626) 568-0935

1. Sensor Systems Description and Specifications

The **LiDAR** data for this survey were collected with an Optech Gemini Airborne Laser Terrain Mapper (ALTM) serial number 06SEN195 mounted in a twin-engine Aero Commander 500S (piloted by Air Flight Service; Tail Number N500SJ). 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 BD950 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. Area of Interest.

The requested survey area consisted of a single irregular polygon of approximately 80 km^2 on the island of Kauai, Hawaii. The requested polygon is shown below in Figure 1 with a red outline.

Figure 1 – Shape and location of the requested survey polygon shown as red outline (Google Earth).

3. Data Collection

a) Survey Dates: The survey attempts took placed from February 14, 2013 through February 16, 2013 (DOY 045 through 047).

b) Airborne Survey Parameters: Nominal survey parameters for the LiDAR collection are provided in Table 2 below.

Nominal Flight Parameters		Equipment Settings		Survey Totals	
Flight Altitude	600-800 m	Laser PRF	100 kHz	Total Flight Time	7 hrs.
Flight Speed	+/- 60 m/s	Beam Divergence	0.25 mRad (narrow)	Total Laser Time	3.1 hrs.
Swath Width	366 m	Scan Frequency	45 Hz	Total Swath Area	48 km^2
Swath Overlap	Min 50 %	Scan Angle	± 21°	Total AOI Area	80 km^2
Point Density	6 p/m^2	Scan Cutoff	1.0°		

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

c) Ground GPS: Six GPS reference station locations were used during the survey: Three of them (KOK5, KOK6 and KOKB) are part of the National Geodetic Survey's (NGS) network of Continuously Operating Reference Stations (CORS). The other three stations (KAU1, KAU2 and KAU3) were set up by NCALM on February 14, 15 and 16 respectively. All NCALM reference stations as well as KOKB observations were logged at 1 Hz; whereas KOK5 and KOK6 were logging at a 5-second rate and were interpolated to 1 Hz. Table 3 (below) gives the coordinates of the stations and Figure 2 (following page) shows the project area and the GPS reference station locations.

STATION	Latitude	Longitude	Elevation(m)	Agency
KAU1	21.982465°	-159.343747°	54.966	NCALM
KAU2	21.982459°	-159.343735°	55.132	NCALM
KAU3	22.051133°	-159.329731°	21.042	NCALM
KOK5	21.983490°	-159.758162°	23.458	NGS-CORS
KOK6	21.983768°	-159.758250°	23.446	NGS-CORS
KOKB	22.126260°	-159.664923°	1167.008	NGS-CORS

Table 3 – GPS Coordinates of ground reference stations. NAD_83(PA11) (EPOCH: 2010.0000)

Figure 2 - Project area and GPS reference locations. Red lines illustrate the area of the virtual GPS network.

d) Reference coordinates for NCALM stations are derived from multiple hour observation sessions. Data from these sessions was submitted to the NGS on-line processor OPUS which processes static differential baselines tied to the CORS network. The final coordinate value for these two stations is an average of these OPUS results. Reference coordinates for NGS stations were downloaded from their respective NGS data sheets. 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/

4. GPS/IMU Data Processing

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 the different stations.

After GPS processing, the trajectory solution and the 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).
 integers to obtain centimeter level positioning. The final result is a smoothed navigation solution including both aircraft position and orientation at 200 Hz. This final navigation solution is known as an SBET (Smoothed Best Estimated Trajectory). See http://www.applanix.com/articles-and-papers/pos-av.html#.UVYDuxyG0Z4 for additional information.

5. LiDAR Data Processing Overview

The following diagram (Figure 3) shows a general overview of the NCALM LiDAR data processing workflow.

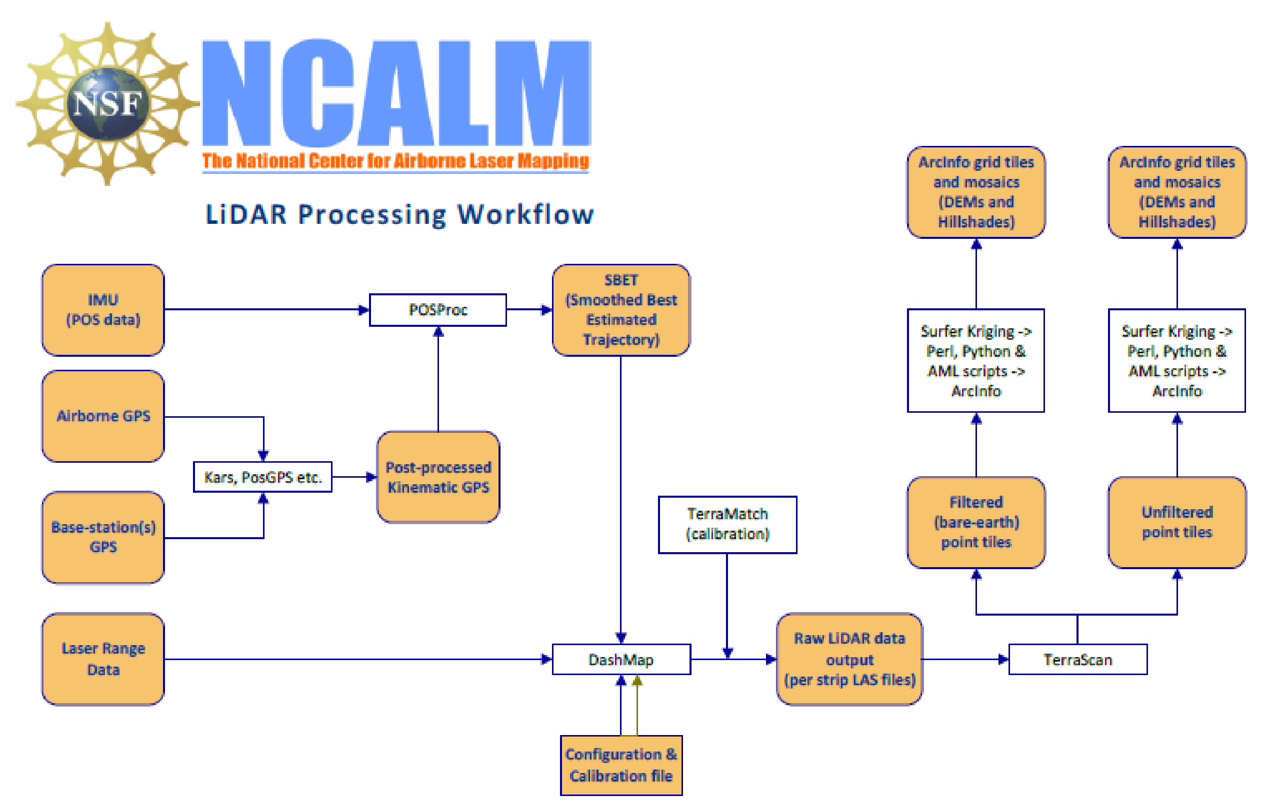

Figure 3 - NCALM LiDAR Processing Workflow

These LiDAR data were collected in flight strips and the initial observations are of course not classified but are associated with certain collection attributes such as time stamp, scan angle, intensity value, echo number (only echo, first of many, intermediate, last echo) etc. TerraSolid software is used to do the ground point classification, the emphasis being on first removing blunder points and outliers and then finding the final set of ground class points from which the bare-earth Digital Elevation Model (DEM) is constructed. Classification of the ground-class points is done by automated routines using TerraSolid Software (TerraScan Version 13.004). http://www.terrasolid.fi/en/products/4

6. Calibration and relative accuracy

System calibration of the three sensor boresight angles (roll, pitch, and yaw) and the 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 13.002). Surfaces are constructed from the ground-class points of all individual flight lines from each survey flight and then a best-fit solution of the roll, pitch, yaw, and scanner mirror scale factor is computed through an iterative algorithm. This procedure is run on a flight-by-flight basis and all calibration values were found to have remained stable for every survey flight on this project.

After optimal calibration values are determined, project flight line point clouds are output in their final form and then checked for internal consistency. This is done by computing an average mismatch in surfaces again constructed from only ground-class points of individual flight lines in overlap areas. **Average project mismatch (individual flight line overlap areas) magnitude: 0.092 meters**

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.

7. Data Deliverables

a) **Horizontal Datum**: NAD83(PA11)(Epoch: 2010)
b) **Vertical Datum:** GEOID 12A
c) **Projection:** UTM Zone 04 N
d) **Units:** Meters
e) **File Formats:**
    1. Classified Point Cloud in LAS 1.2 format in 1 km square tiles.
    2. ESRI format 0.5-m DEM from default-class points.
    3. ESRI format 0.5-m DEM from ground-class points.
    4. ESRI format 0.5-m Hillshade raster from default-class points.
    5. ESRI format 0.5-m Hillshade raster from ground-class points.

f) The ESRI DEMs are single mosaic files created by combining together the 1KM tiles