Yosemite National Park

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Figure 1 – Tuolumne Meadows from Pothole Dome.

Survey Parameters

This LiDAR survey was conducted in five days over six locations in Yosemite National Park from September 18 - 22, 2006 (GPS days 261-265). Data were collected with an Optech 1233 ALTM (serial# 99B112) mounted in a turbocharged twin engine Cessna 337 (tail number N86539). Color images were acquired over the Martel polygon with a Redlake MS 4100 digital camera. The survey required a total of six flights, with two flights occurring on September 21, 2006 and one flight occurring on all other days. Figures 2-4 (below) show the locations and relative sizes of the surveyed polygons.

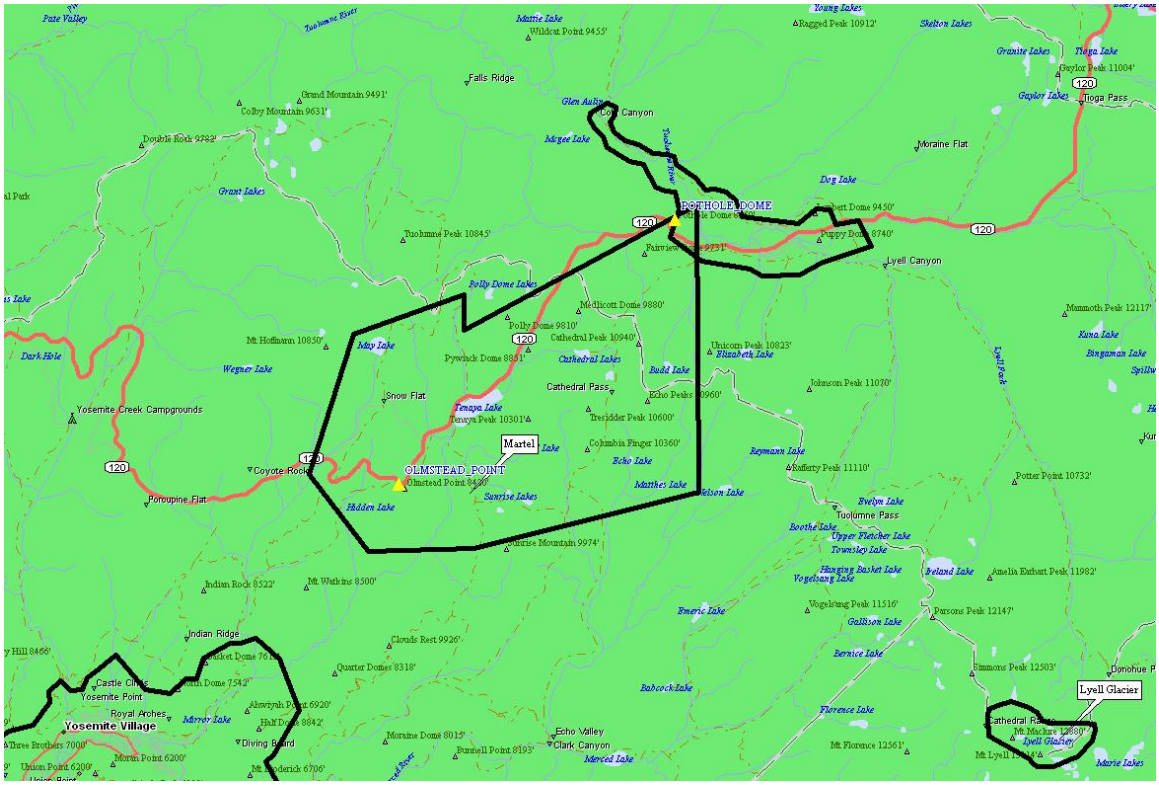


Figure 2 - Martel polygon (77 square kilometers), Tuolumne Meadows polygon (11 square kilometers) and the location of the Lyell Glacier. The yellow triangles are the GPS base station locations.

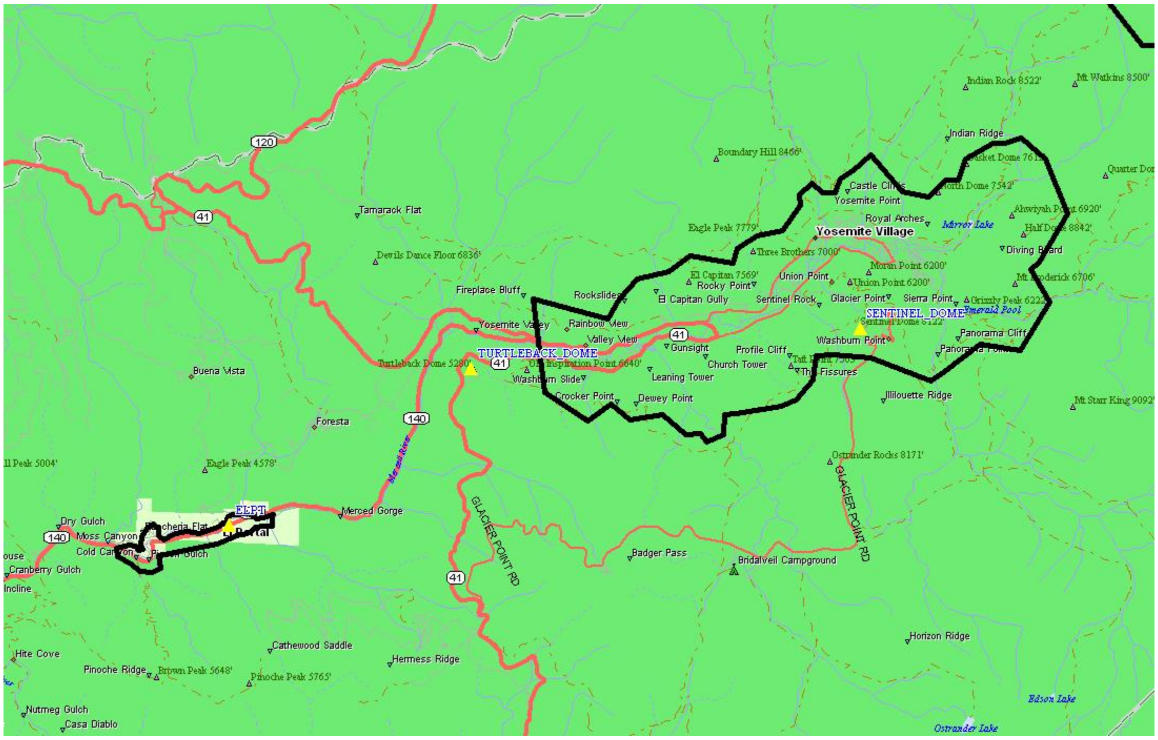


Figure 3 - Yosemite Canyon polygon (43 square kilometers), EL Portal polygon (11 square kilometers). Yellow triangles indicate locations of GPS base stations.

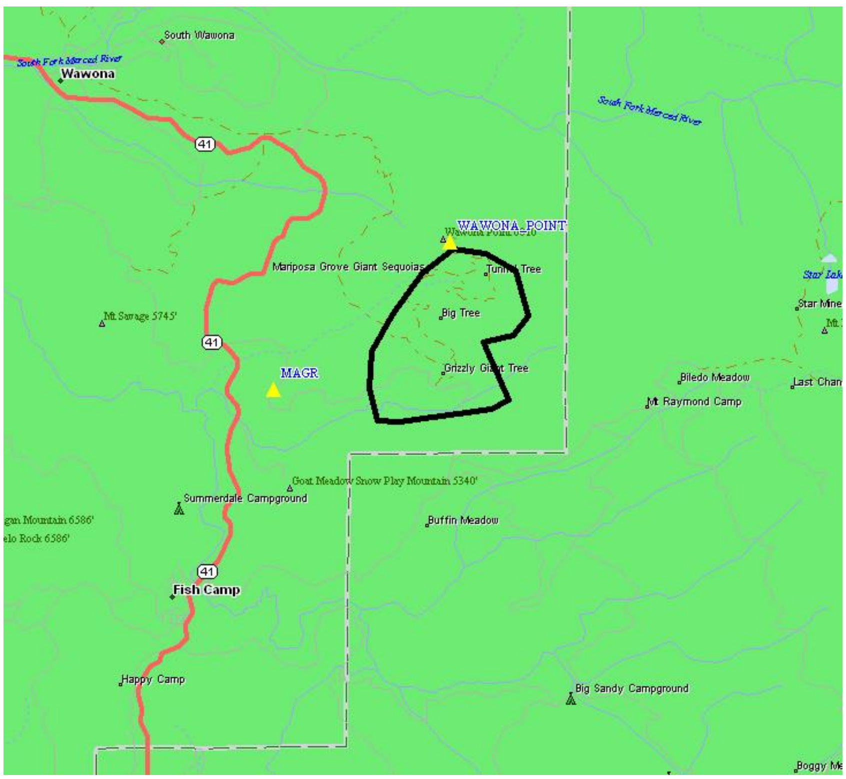


Figure 4 - Mariposa Grove polygon (3 square kilometers). Yellow triangles indicate GPS base station locations.

Accurate estimates of flying heights and point spacing at any particular instant are difficult due to the mountainous terrain and the steep canyons in Yosemite. LiDAR settings were held constant as follows: the flight line spacing was fixed at 200 meters. This fixed line spacing resulted in widely varying percentages of overlap depending on the height of the aircraft over the terrain at any particular instant. The scan angle was held constant at +/- 19 degrees, and scan frequency (mirror oscillation frequency) was fixed at 30 Hz for all flights.

Figure 5 (below) in a map showing the planned flight lines for all project polygons.

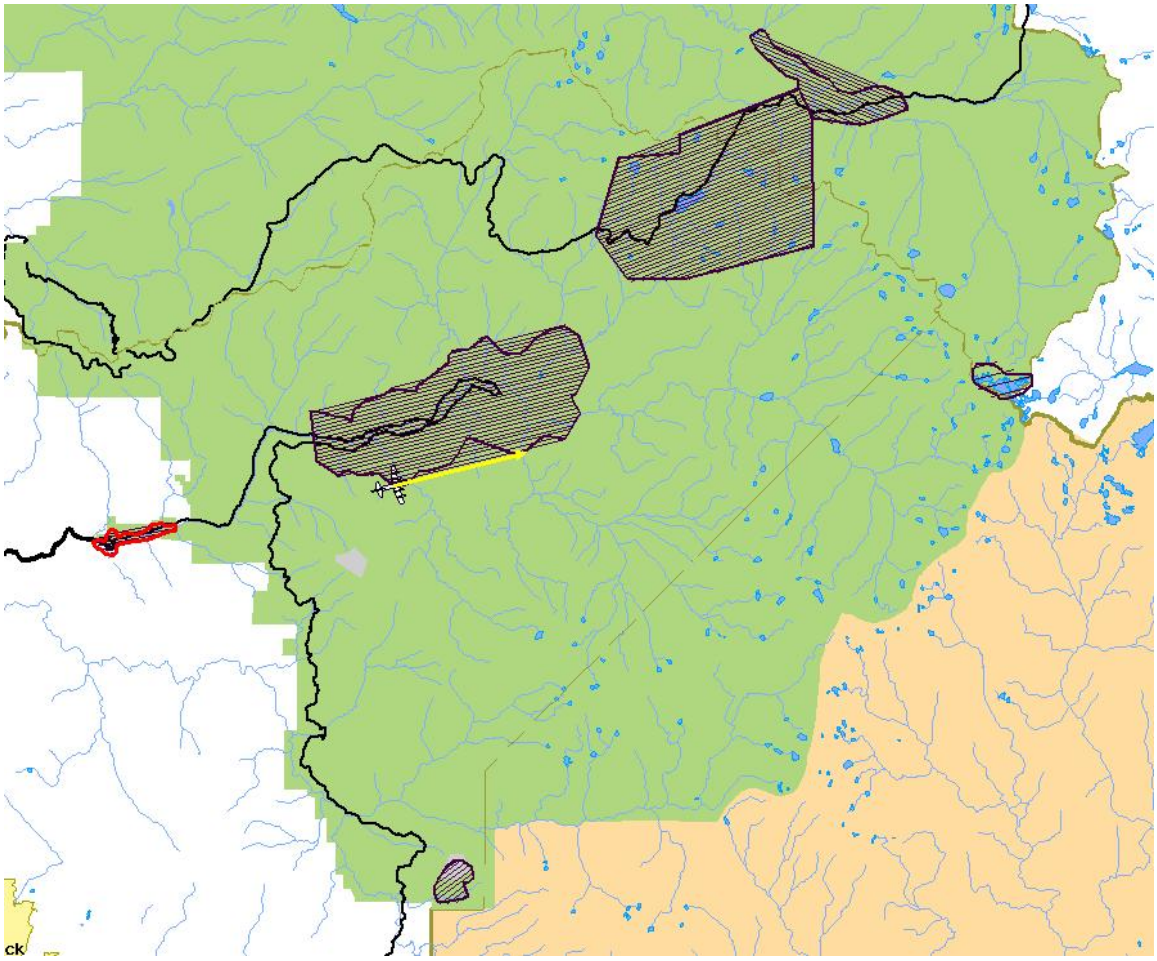


Figure 5 - Map showing planned flight lines on project polygons.

Below are some point space numbers that approximate the survey parameters for each polygon.

1. El Portal polygon - Above Ground Level (AGL) flying heights averaged 1000 – 1400 meters. At 1200 meters AGL the cross-track point spacing is 1.5 meters. At 125 knots (64.3 m/s) along track point spacing varies from 1.1 meters at nadir to 2.2 meters at the edge of the swath. The swath is 803 meters wide. Laser spot size is 0.36 meters.

2. Mariposa Grove polygon - AGL flying heights averaged 800 meters. At this height the cross-track point spacing is 1.0 meters. Along-track point spacing is solely dependent on the ground speed of the aircraft, and this always averaged around 125 knots – see above. Swath width is 535 meters. Laser spot size is 0.24 meters.
3. Yosemite Canyon polygon – This polygon had the most variability due to the extreme nature of the canyon. AGL flying heights varied from less than 100 meters to over 2000 meters. The average range computed from the day 263 canyon flight was 1050 meters. At this height the cross-track point spacing is 1.3 meters, while the along-track spacing remains as above, at 1.1 meters at nadir to 2.2 meters at swath edge. Swath width is 702 meters and laser spot size is 0.32 meters.
4. Martel polygon – AGL flying heights again averaged around 1000 meters but with less variability than in Yosemite canyon. At this height the cross-track point spacing is 1.2 meters, while the along-track spacing remains as above, at 1.1 meters at nadir to 2.2 meters at swath edge. Swath width is 670 meters and laser spot size is 0.30 meters.
5. Tuolumne Meadows polygon – Similar to the Martel polygon, AGL flying heights averaged around 1 kilometer. Again, much less variability than Yosemite Canyon.

By happenstance, NCALM learned that on 9/21/2006 – 9/24/2006 Park Geologist Greg Stock and a group of volunteers were scheduled to do a manual survey to attempt to measure the size and extent of the Lyell Glacier. In the interest of scientific research and in the hope of establishing a more accurate baseline measurement, NCALM decided to fly a few (unbudgeted) passes over this glacier. Coordinates were quickly provided by Bill Kuhn of the NPS and a flight plan was drawn up. Four passes were flown on Friday, September 22, covering a good portion of the target. Preliminary analysis of the laser-intensity images have shown that the ice extents of the northern portion of this glacier have been accurately mapped for the first time - see Figure 6. It is hoped that these data will provide a basis for future LiDAR mapping of glaciers in Yosemite.

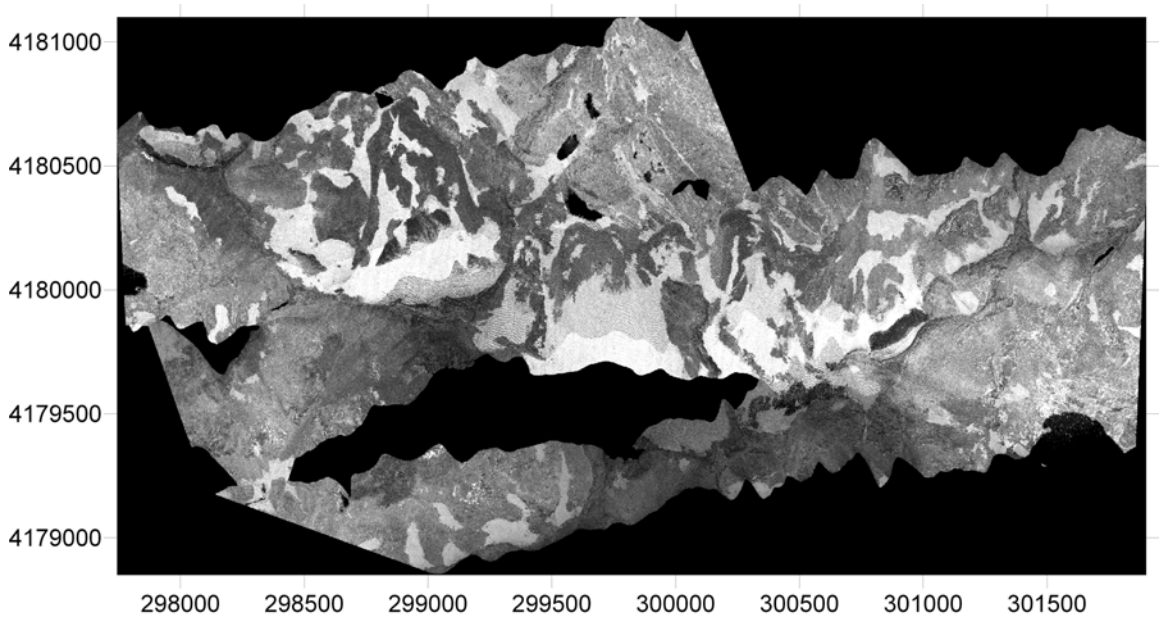


Figure 6 - Laser Intensity image of a portion of the Lyell Glacier.

GPS Reference Stations

Seven locations were selected and occupied as GPS reference stations for the six flights – with two stations running per survey. These stations are described as follows:

1. ELPT – 9-inch nail newly set on the south side of Route 140 in El Portal.
2. MAGR - 9-inch nail newly set in an open area 1.4 Km east of the South Entrance Station on Mariposa Grove Road.
3. WP-1 – Brass cap set in concrete at Wawona Point
4. TURT - Paint-mark newly set on granite at Turtleback Dome
5. DOME – Brass cap (VABM) on the top of Sentinel Dome
6. OLM_ - Mark newly set on granite at southwest parking area at Olmstead Point viewing area
7. POT_ - Mark newly set on granite at the highest point on Pothole Dome

All stations were occupied for a minimum of 3 hours; TURT, POT_ and DOME were each observed twice with longer sessions. Equipment included Ashtech dual-frequency Z-Extreme receivers with choke-ring antennas (ASH700936.D) on 1.500 meter fixed height tripods. All observations were submitted to the NGS on-line processor OPUS with solution files included as Appendix A. Final control coordinate values (NAD83) were obtained from the OPUS solutions and referenced to the 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/ .

Navigation Processing

Airplane trajectories were processed using both KARS (Kinematic and Rapid Static) software written by Dr. Gerry Mader of the NGS Research Laboratory and REALM, proprietary Laser-Processing Software from Optech, Inc.

KARS software yields ionosphere-free differential GPS solutions that are based on carrier phase double-differences with fixed integer ambiguities. These are the preferred solutions and have been shown to be accurate over long baselines – 60 to 100 kilometers.

REALM differential GPS processing provides a robust means of processing when only the L1 frequency observations are high quality and has been shown to be of similar accuracy to KARS over short baselines - 0 to 15 kilometers.

It was necessary to use REALM L1 GPS processing on the first two flights (El Portal and Mariposa Grove) of this LiDAR survey due to a bad aircraft GPS antenna that failed to collect high quality L2 observations – making processing with KARS impossible. Baseline lengths for these two flights processed with REALM were less than 15 kilometers long and a comparison of the L1 trajectories processed from two spatially distant reference stations show excellent agreement both horizontally and vertically (see Figure 7 below). Height RMS between these two solutions is 0.008 meters.

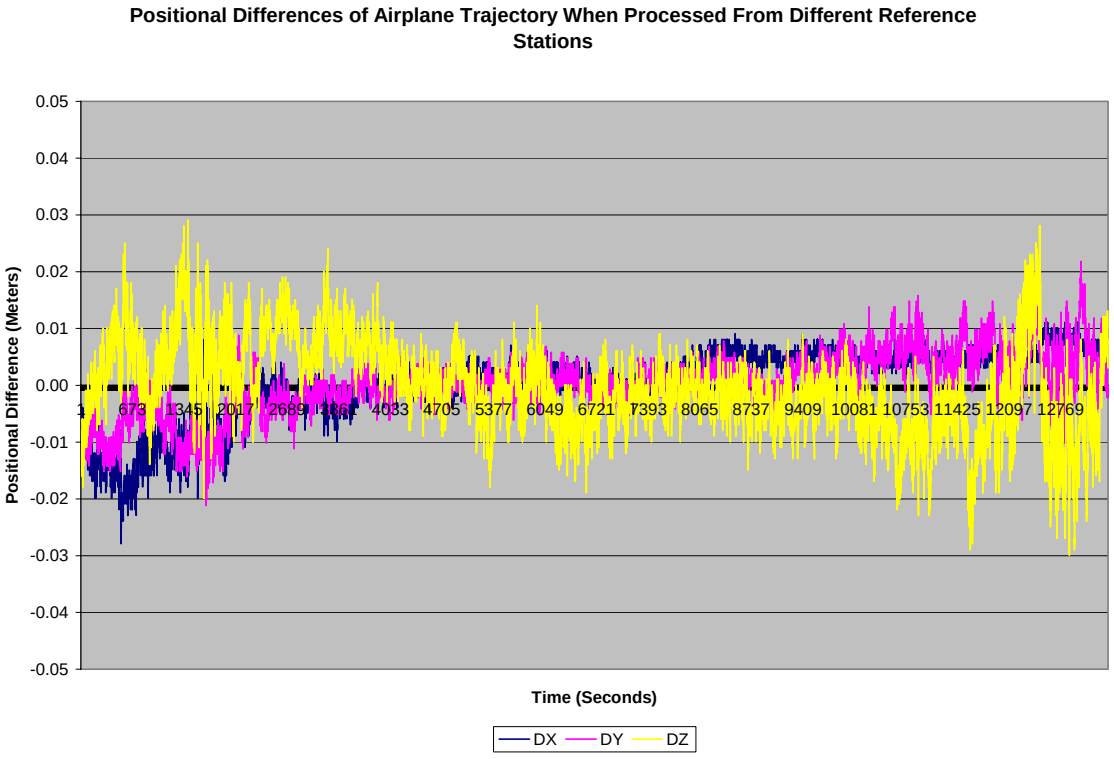


Figure 7 - Trajectory comparison – REALM L1 processing.

Figure 8 (below) shows a similar plot comparing the trajectory from day 265 as processed from POT_ and OLM_ using KARS. The Tuolumne Meadows polygon, portions of the Martel polygon and all of the Lyell Glacier passes were surveyed on this flight.

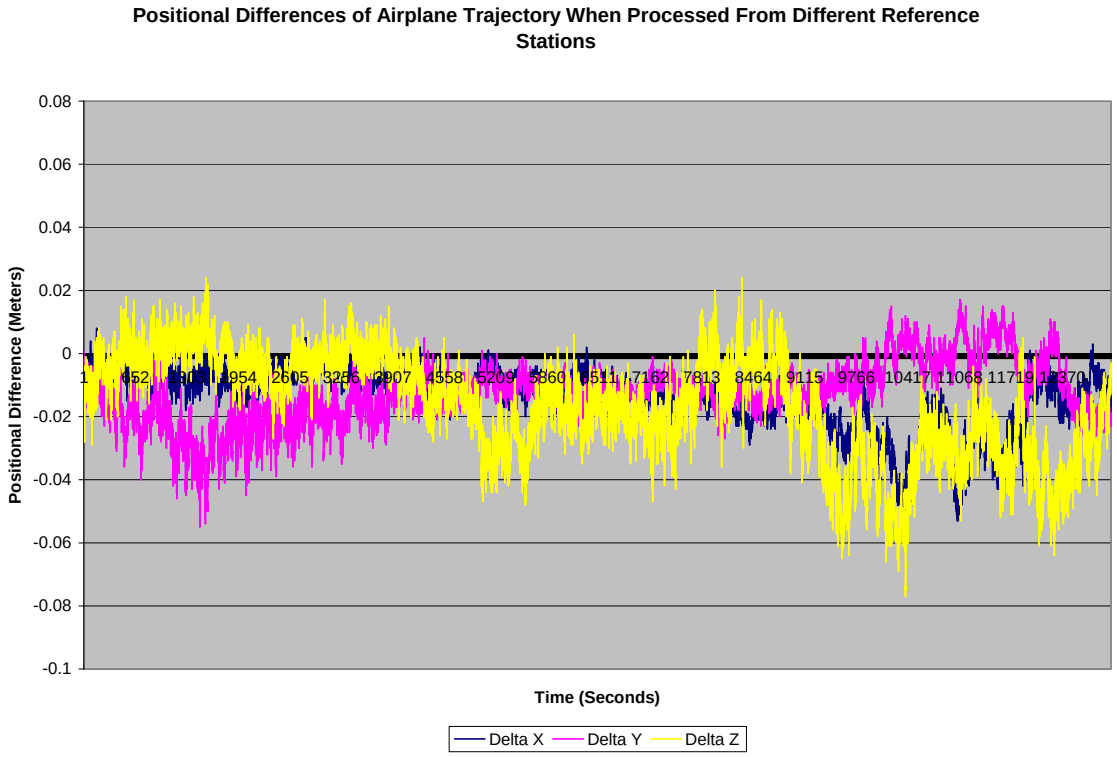


Figure 8 - Trajectory comparison:KARS processing

Figures 7 and 8 represent typical difference plots for all project flights.

After GPS processing was completed for all flights, the GPS and the raw IMU (Inertial Measurement Unit) data collected during each flight were input into APPLANIX software POSPROC. This software employs a sophisticated Kalman Filter algorithm to combine the 1-Hz final differential GPS solutions with the raw 50-Hz IMU data and their respective error models. The final result is a smoothed and blended solution of both aircraft position and orientation at 50 Hz, in SBET format (Smoothed Best Estimated Trajectory).

Calibration and Laser Point Processing

The SBET and raw laser range data were combined using Optech's REALM processing suite to generate the laser point dataset. System calibration was then performed as a 2-step process: step one (relative calibration) is to adjust the bore sight values of heading, roll, pitch, and scanner mirror scale such that systematic positional errors are minimized; and step two is an absolute calibration such that the laser DEM will match the height values of ground truth collected by vehicle-mounted GPS.

Step 1: Relative calibration was performed in TerraMatch software please see (**http://terrasolid.fi/ENG/Products.htm**) for detailed information.

A general description of the relative calibration procedure follows.

1. Cross-lines are flown for every flight with a heading perpendicular to the project flight line heading.
2. Small polygons containing these cross lines along with project flight lines are processed using approximate calibration values for heading, roll, pitch, and scanner mirror scale. Each line is processed separately.
3. Continuing to process each line separately, all lines are filtered to remove vegetation; then individual flight line surfaces are created.
4. TerraMatch uses an iterative algorithm to compute the best-fit between the individual flight line surfaces: simultaneously solving for the optimal changes to bore sight values of heading, roll, pitch, and scanner mirror scale.
5. These changes to the calibration values are updated in REALM; then output is checked for all flights using each flight's cross lines.
6. Complete and final output is run using the optimized calibration values for each flight.

This procedure yielded very tight results – once optimal values were computed from the El Portal flight (the first flight) all subsequent flights showed no change of any significance in any of these values.

Step 2: Absolute calibration is done by comparing the height of the nearest neighbor laser point to the height of a set of check points that are collected by vehicle-mounted GPS. The sample of good reliable vehicle-mounted GPS in Yosemite was small due to much difficulty in collecting these data. Clear open roadways that provide good GPS reception on the top of a Jeep are few and far between in this Park.

Using a set of 53 check points spread over 1 kilometer of open road collected near El Portal an average difference of +10 mm was computed (laser-ground). This bias was seen as statistically insignificant so no systematic adjustment to output processed from REALM L1 trajectories was done. The standard deviation of the laser – check point differences was 0.079 meters, which is fairly typical.

A REALM L1 trajectory will often have a small vertical bias relative to a KARS trajectory – typically around 10 – 15 CM. Because El Portal (REALM L1 trajectory) was the only place where vehicle-collected ground truth points were collected, a question arose concerning what vertical offset (if any) should be applied to laser points processed from KARS trajectories? To solve this problem a REALM L1 trajectory for flight 263 over the Canyon was computed and then differenced with the KARS solution for this same flight. The KARS trajectory averaged 8 cm higher in height than the REALM L1 trajectory. This offset was then applied to all laser data computed with KARS trajectories: all data output with KARS trajectories were lowered by 8 cm, while all REALM L1 trajectory output received no adjustment as these heights checked well with the vehicle GPS ground truth points.

Now some disappointing news: there is a fairly substantial data gap over the top of Half Dome. It was initially thought that this gap was caused solely by using a minimum-range-allowed data mask of 300 meters (to eliminate mist, cloud, and smoke points) when de-coding the range file and that the gap would be eliminated when the de-coding was repeated using a shorter mask – or no mask at all. But this was not the case: when the plane was less than 100 meters over the top of Half Dome (the operator said he felt like the pilot was trying to land on it!) the range gate automatically shut the laser off for 2.5 seconds. This is built into the system to protect the hardware and in this case caused a data gap. The operator was not aware that this happened – he was distracted by the close proximity of Half-Dome. Also it looks like Half-Dome itself may have "shadowed" out some coverage from adjacent lines. Recall that the pilot was concerned about ranges to the valley floor becoming excessively long, so he was doing his best to stay low. It might be possible to fill this gap using some values from the 10-meter DEM downloaded from the national GIS database. Not a perfect solution but perhaps worth a try.

All coordinates were processed with respect to NAD83 and referenced to the national CORS network. The 9-column output provides ellipsoid heights in UTM Zone 11, with units in meters.

The last return data was extracted from the 9-column format and ellipsoid heights were converted to orthometric heights in NAVD88 using NGS GEOID03 model with Corpscon v6.0 (Corps of Engineers Coordinate Conversion).

The complete output format is a 9-column ASCII file (space delimited), one file per flight strip. The nine columns are:

1. GPS time (seconds of week)
2. Easting last return
3. Northing last return
4. Height last return
5. Intensity last return
6. Easting first return
7. Northing first return
8. Height first return
9. Intensity first return

Note that in these 9-column files height values are ellipsoid heights which do NOT match orthometric heights (elevations) found in the 3-column files or 1-meter DEM grid nodes.

Filtering and DEM Production

Terrasolid's TerraScan (http://terrasolid.fi) software was used to classify the last return LIDAR points and generate the "bare-earth" dataset.

The classification routine consists of three algorithms:

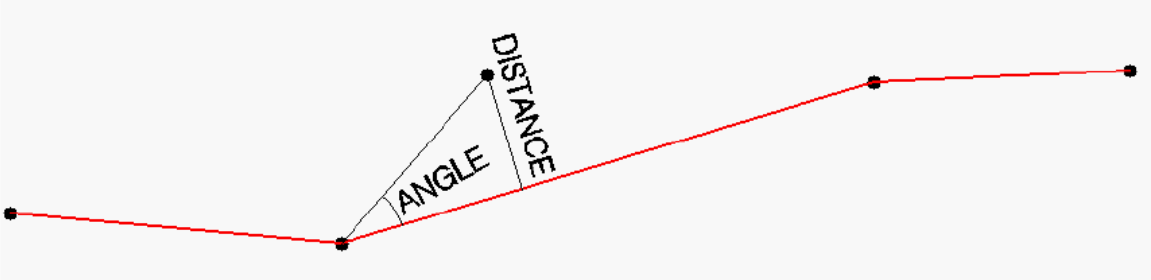
1) Removal of "Low Points". This routine was used to search for possible error points which are clearly below the ground surface. The elevation of each point (=center) is compared with every other point within a given neighborhood and if the center point is clearly lower then any other point it will be classified as a "low point". This routine can also search for groups of low points where the whole group is lower than other points in the vicinity. The parameters used on this dataset were:

```
Search for: Groups of Points
Max Count (maximum size of a group of low points): 6
More than (minimum height difference): 0.5 m
Within (xy search range):  10.0 m
```

2) Ground Classification. This routine classifies ground points by iteratively building a triangulated surface model. The algorithm starts by selecting some local low points assumed as sure hits on the ground, within a specified windows size. This makes the algorithm particularly sensitive to low outliers in the initial dataset, hence the requirement of removing as many erroneous low points as possible in the first step.

   The routine builds an initial model from selected low points. Triangles in this initial model are mostly below the ground with only the vertices touching ground. The routine then starts molding the model upwards by iteratively adding new laser points to it. Each added point makes the model follow ground surface more closely. Iteration

parameters determine how close a point must be to a triangle plane so that the point can be accepted to the model. **Iteration angle** is the maximum angle between point, its projection on triangle plane and closest triangle vertex. The smaller the Iteration angle, the less eager the routine is to follow changes in the point cloud. **Iteration distance** parameter makes sure that the iteration does not make big jumps upwards when triangles are large. This helps to keep low buildings out of the model. The routine can also help avoiding adding unnecessary point density into the ground model by reducing the eagerness to add new points to ground inside a triangle with all edges shorter than a specified length.



Ground classification parameters used:

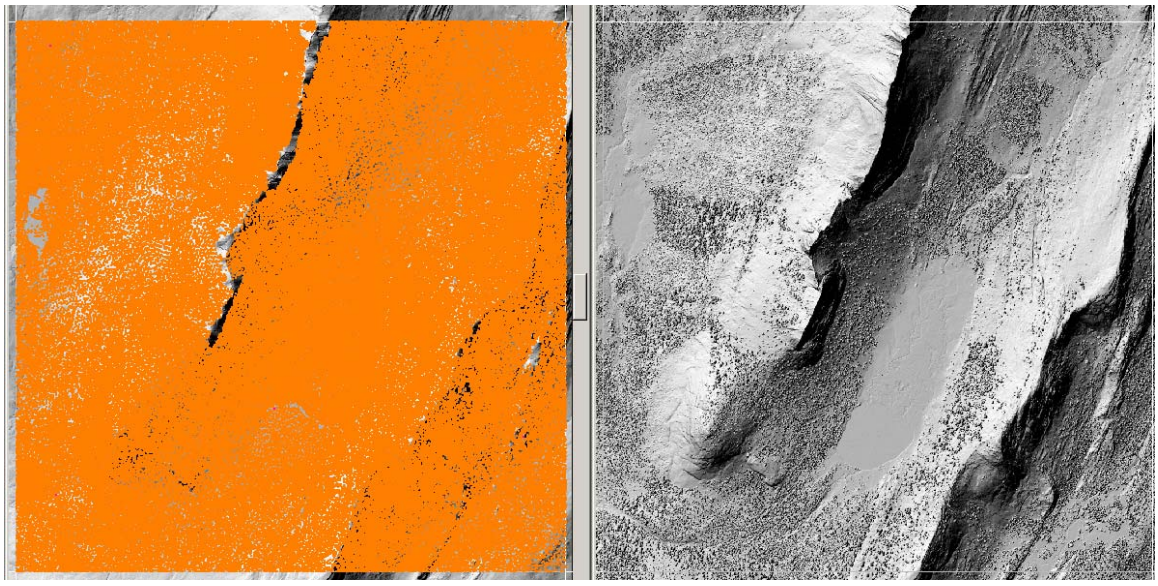
```
Max Building Size (window size): 40.0 m
Max Terrain Angle: 89.50
Iteration Angle: 6.10
Iteration Distance: 2.0 m
Reduce iteration angle when edge length < : 5.0 m
```

3) Below Surface removal. This routine classifies points which are lower than other neighboring points and it is run after ground classification to locate points which are below the true ground surface. For each point in the source class, the algorithm finds up to 25 closest neighboring source points and fits a plane equation through them. If the initially selected point is above the plane or less than "Z tolerance", it will not be classified. Then it computes the standard deviation of the elevation differences from the neighboring points to the fitted plane and if the central point is more than "Limit" times standard deviation below the plane, the algorithm it will classify it into the target class.

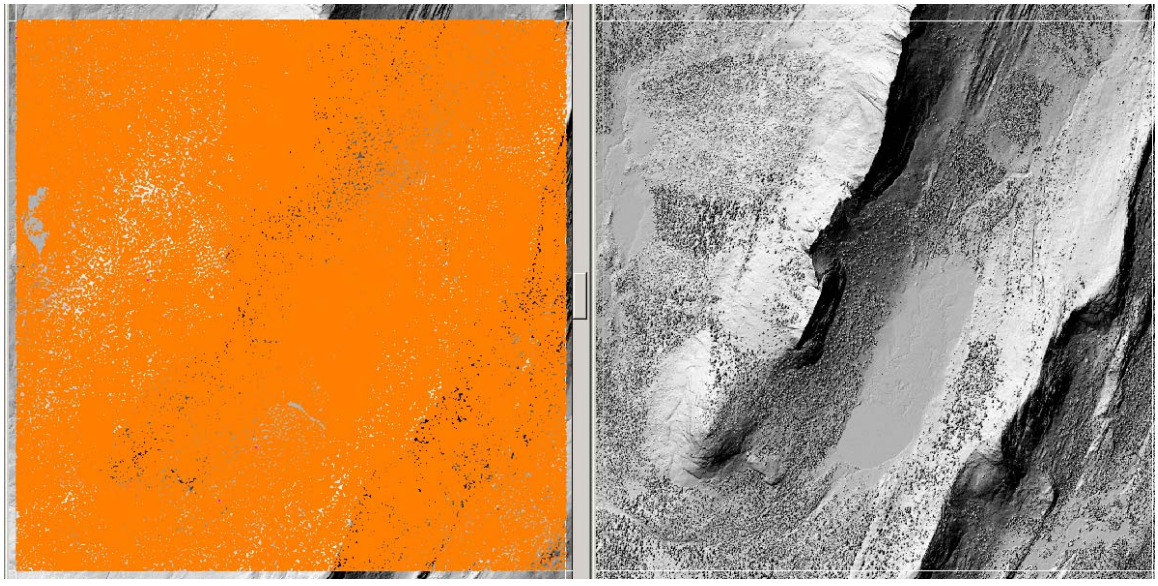
```
Parameters used:
Source Class: Ground
Target Class: Low Point
Limit: 8.00 * standard deviation
Z tolerance: 0.10 m
```

After analyzing the filtered point cloud data, it was discovered that the filtering algorithm was ineffective in very steep terrain and had the tendency to flatten the very sharp ridges found in the south-east area of the polygon.

Using TerraScan's manual classification tools we improved the ground model by adding key points to the ground class and re-running the filter routine over a surrounding area of 100m.
The following images show how the ground point density improved over problem areas after performing manual classification:



Block 25 point density plot before manual classification. Orange represents ground points. The image on the right is the unfiltered shaded relief map.



Block 25 point density plot after manual classification. Orange represents ground points. The image on the right is the unfiltered shaded relief map.

After classification the ground points were outputted in 2km x 2km overlapping tiles (60m overlap), ASCII format (XYZ), and gridded at 1m cell size using Golden Software's SURFER ver. 8.01. The tiles need to overlap in order to obtain consistent transitions from one tile to the adjacent ones.

Gridding parameters:

```
Gridding Algorithm: Kriging
Variogram: Linear
Nugget Variance: 0.07 m
MicroVariance: 0.00 m
SearchDataPerSector: 10
SearchMinData: 5
SearchMaxEmpty: 1
SearchRadius: 40m
```

The resulted Surfer grid tile set was exported to ESRI ArcInfo floting point binary format and using an in-house C++ application the overlap was trimmed from each tile. The trimmed tiles were exported to ESRI ArcInfo GRID format and merged into one seamless raster dataset.

A similar process was used to generate the unfiltered seamless grids. The unfiltered points were krigged using a 5m Search Radius because of the higher data density.

Appendix A – OPUS Solutions

```
                         NGS OPUS SOLUTION REPORT
                         ========================

      USER: michaels@ufl.edu                       DATE: September 26, 2006
RINEX FILE: dome263r.06o                           TIME: 15:14:38 UTC


  SOFTWARE: page5  0601.10 master10.pl            START: 2006/09/20  17:35:00
 EPHEMERIS: igr13933.eph [rapid]                   STOP: 2006/09/21  00:30:30
  NAV FILE: brdc2630.06n                      OBS USED: 15697 / 15724   : 100%
  ANT NAME: ASH700936D_M    NONE            # FIXED AMB:    55 /    56   :  98%
ARP HEIGHT: 1.500                           OVERALL RMS: 0.014(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)           ITRF00 (EPOCH:2006.7202)

         X:     -2494799.170(m)   0.018(m)          -2494799.886(m)   0.018(m)
         Y:     -4394442.483(m)   0.006(m)          -4394441.175(m)   0.006(m)
         Z:      3882678.423(m)   0.011(m)           3882678.457(m)   0.011(m)

       LAT:   37 43 23.14014      0.016(m)        37 43 23.15657      0.016(m)
     E LON:  240 24 56.48834      0.014(m)       240 24 56.43657      0.014(m)
     W LON:  119 35  3.51166      0.014(m)       119 35  3.56343      0.014(m)
    EL HGT:         2450.694(m)   0.004(m)             2450.094(m)   0.004(m)
 ORTHO HGT:         2476.258(m)   0.025(m) [Geoid03 NAVD88]

                       UTM COORDINATES    STATE PLANE COORDINATES
                        UTM (Zone 11)         SPC (0403 CA 3)
Northing (Y) [meters]     4178236.548          636134.960
Easting (X)  [meters]      272234.503         2080721.892
Convergence  [degrees]    -1.58187839          0.56061549
Point Scale                1.00023902          0.99992930
Combined Factor            0.99985451          0.99954491

US NATIONAL GRID DESIGNATOR: 11SKB7223578237(NAD 83)


                            BASE STATIONS USED
PID       DESIGNATION                       LATITUDE    LONGITUDE DISTANCE(m)
DH9030 P301 LILPANOCHECN2004 CORS ARP      N364822.632 W1204434.935  144669.9
DG8529 P304 MENDOTA___CN2004 CORS ARP      N364420.399 W1202123.702  128982.7
AI8802 DYER DYER CORS ARP                  N374434.077 W1180221.559  136249.5

                 NEAREST NGS PUBLISHED CONTROL POINT
HR2891      SENTINEL DOME                  N374323.141 W1193503.497       0.3
```

NGS OPUS SOLUTION REPORT

USER: michaels@ufl.edu
RINEX FILE: dome264o.06o
DATE: September 26, 2006
TIME: 15:29:35 UTC

SOFTWARE: page5 0601.10 master31.pl
EPHEMERIS: igr13934.eph [rapid]
NAV FILE: brdc2640.06n
ANT NAME: ASH700936D_M NONE
ARP HEIGHT: 1.500
START: 2006/09/21 14:56:00
STOP: 2006/09/21 23:10:00
OBS USED: 17898 / 17967 : 100%
FIXED AMB: 63 / 63 : 100%
OVERALL RMS: 0.010(m)

REF FRAME:	NAD_83(CORS96)(EPOCH:2002.0000)		ITRF00 (EPOCH:2006.7227)	
X:	-2494799.171(m)	0.010(m)	-2494799.887(m)	0.010(m)
Y:	-4394442.478(m)	0.011(m)	-4394441.170(m)	0.011(m)
Z:	3882678.424(m)	0.008(m)	3882678.458(m)	0.008(m)
LAT:	37 43 23.14024	0.014(m)	37 43 23.15667	0.014(m)
E LON:	240 24 56.48821	0.009(m)	240 24 56.43643	0.009(m)
W LON:	119 35 3.51179	0.009(m)	119 35 3.56357	0.009(m)
EL HGT:	2450.691(m)	0.005(m)	2450.092(m)	0.005(m)
ORTHO HGT:	2476.255(m)	0.025(m)	[Geoid03 NAVD88]	

	UTM COORDINATES (UTM (Zone 11))	STATE PLANE COORDINATES (SPC (0403 CA 3))
Northing (Y) [meters]	4178236.552	636134.963
Easting (X) [meters]	272234.499	2080721.889
Convergence [degrees]	-1.58187841	0.56061547
Point Scale	1.00023902	0.99992930
Combined Factor	0.99985451	0.99954491

US NATIONAL GRID DESIGNATOR: 11SKB7223478237(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DH9030	P301 LILPANOCHECN2004 CORS ARP	N364822.632	W1204434.935	144669.9
DG8529	P304 MENDOTA___CN2004 CORS ARP	N364420.399	W1202123.702	128982.7
AI8802	DYER DYER CORS ARP	N374434.077	W1180221.559	136249.5

NEAREST NGS PUBLISHED CONTROL POINT

HR2891	SENTINEL DOME	N374323.141	W1193503.497	0.4

NGS OPUS SOLUTION REPORT

USER: michaels@ufl.edu
RINEX FILE: pot_264s.06o
DATE: September 26, 2006
TIME: 15:23:55 UTC

SOFTWARE: page5 0601.10 master4.pl
EPHEMERIS: igr13934.eph [rapid]
NAV FILE: brdc2640.06n
ANT NAME: ASH700936D_M NONE
ARP HEIGHT: 1.500
START: 2006/09/21 18:23:00
STOP: 2006/09/21 23:25:00
OBS USED: 11321 / 11375 : 100%
FIXED AMB: 47 / 48 : 98%
OVERALL RMS: 0.011(m)

REF FRAME:	NAD_83(CORS96)(EPOCH:2002.0000)		ITRF00 (EPOCH:2006.7229)	
X:	-2475000.510(m)	0.003(m)	-2475001.233(m)	0.003(m)
Y:	-4393516.301(m)	0.017(m)	-4393514.998(m)	0.017(m)
Z:	3896621.526(m)	0.003(m)	3896621.550(m)	0.003(m)
LAT:	37 52 50.02294	0.011(m)	37 52 50.03909	0.011(m)
E LON:	240 36 22.04785	0.011(m)	240 36 21.99592	0.011(m)
W LON:	119 23 37.95215	0.011(m)	119 23 38.00408	0.011(m)
EL HGT:	2659.161(m)	0.009(m)	2658.560(m)	0.009(m)
ORTHO HGT:	2683.186(m)	0.026(m)	[Geoid03 NAVD88]	

	UTM COORDINATES UTM (Zone 11)	STATE PLANE COORDINATES SPC (0403 CA 3)
Northing (Y) [meters]	4195264.658	653791.593
Easting (X) [meters]	289468.486	2097302.078
Convergence [degrees]	-1.47042115	0.67720480
Point Scale	1.00014595	0.99993172
Combined Factor	0.99972879	0.99951466

US NATIONAL GRID DESIGNATOR: 11SKB8946895265(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DG8529	P304 MENDOTA___CN2004 CORS ARP	N364420.399	W1202123.702	152806.9
AI8802	DYER DYER CORS ARP	N374434.077	W1180221.559	120295.3
AI8823	GABB GABBS CORS ARP	N385813.180	W1175458.957	176910.9

NEAREST NGS PUBLISHED CONTROL POINT

HR0158	RTE 120 STA 1231+60.00	N375242.	W1192344.	288.7

NGS OPUS SOLUTION REPORT

USER: michaels@ufl.edu
RINEX FILE: pot_265r.06o
DATE: September 26, 2006
TIME: 15:28:31 UTC

SOFTWARE: page5 0601.10 master23.pl
EPHEMERIS: igr13935.eph [rapid]
NAV FILE: brdc2650.06n
ANT NAME: ASH700936D_M NONE
ARP HEIGHT: 1.500
START: 2006/09/22 17:32:00
STOP: 2006/09/22 21:46:00
OBS USED: 9458 / 9478 : 100%
FIXED AMB: 44 / 44 : 100%
OVERALL RMS: 0.009(m)

REF FRAME:	NAD_83(CORS96)(EPOCH:2002.0000)		ITRF00 (EPOCH:2006.7255)	
X:	-2475000.510(m)	0.014(m)	-2475001.233(m)	0.014(m)
Y:	-4393516.299(m)	0.008(m)	-4393514.996(m)	0.008(m)
Z:	3896621.527(m)	0.008(m)	3896621.551(m)	0.008(m)
LAT:	37 52 50.02300	0.006(m)	37 52 50.03915	0.006(m)
E LON:	240 36 22.04781	0.013(m)	240 36 21.99588	0.013(m)
W LON:	119 23 37.95219	0.013(m)	119 23 38.00412	0.013(m)
EL HGT:	2659.160(m)	0.011(m)	2658.559(m)	0.011(m)
ORTHO HGT:	2683.185(m)	0.027(m)	[Geoid03 NAVD88]	

	UTM COORDINATES (Zone 11)	STATE PLANE COORDINATES SPC (0403 CA 3)
Northing (Y) [meters]	4195264.660	653791.595
Easting (X) [meters]	289468.485	2097302.077
Convergence [degrees]	-1.47042115	0.67720479
Point Scale	1.00014595	0.99993172
Combined Factor	0.99972879	0.99951466

US NATIONAL GRID DESIGNATOR: 11SKB8946895265(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DG8529	P304 MENDOTA___CN2004 CORS ARP	N364420.399	W1202123.702	152806.9
AI8802	DYER DYER CORS ARP	N374434.077	W1180221.559	120295.3
AI8823	GABB GABBS CORS ARP	N385813.180	W1175458.957	176910.9

NEAREST NGS PUBLISHED CONTROL POINT

HR0158	RTE 120 STA 1231+60.00	N375242.	W1192344.	288.7

NGS OPUS SOLUTION REPORT

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      USER: michaels@ufl.edu                      DATE: September 26, 2006
RINEX FILE: turt261u.06o                          TIME: 15:31:42 UTC


  SOFTWARE: page5  0601.10 master29.pl            START: 2006/09/18  20:01:00
 EPHEMERIS: igr13931.eph [rapid]                   STOP: 2006/09/18  23:10:00
  NAV FILE: brdc2610.06n                      OBS USED:  6713 /  6750   :  99%
  ANT NAME: ASH700936D_M    NONE            # FIXED AMB:    31 /    31   : 100%
ARP HEIGHT: 1.500                           OVERALL RMS: 0.008(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)           ITRF00 (EPOCH:2006.7148)

         X:     -2504133.825(m)   0.006(m)          -2504134.546(m)   0.006(m)
         Y:     -4389120.799(m)   0.010(m)          -4389119.491(m)   0.010(m)
         Z:      3881262.524(m)   0.005(m)           3881262.556(m)   0.005(m)

       LAT:   37 42 46.98088      0.011(m)        37 42 46.99715      0.011(m)
     E LON:  240 17 37.89231      0.002(m)       240 17 37.84029      0.002(m)
     W LON:  119 42 22.10769      0.002(m)       119 42 22.15971      0.002(m)
    EL HGT:         1578.216(m)   0.007(m)             1577.619(m)   0.007(m)
 ORTHO HGT:         1604.424(m)   0.026(m) [Geoid03 NAVD88]

                       UTM COORDINATES    STATE PLANE COORDINATES
                        UTM (Zone 11)         SPC (0403 CA 3)
Northing (Y) [meters]     4177425.441           634922.161
Easting (X)  [meters]      261462.728          2069991.620
Convergence  [degrees]    -1.65614646           0.48602590
Point Scale                1.00030090           0.99992940
Combined Factor            1.00005323           0.99968182

US NATIONAL GRID DESIGNATOR: 11SKB6146377425(NAD 83)



                            BASE STATIONS USED
PID       DESIGNATION                       LATITUDE    LONGITUDE DISTANCE(m)
AF9702 MHCB MT HAMILTON BARD CORS ARP      N372029.501 W1213833.227  176093.5
DG8529 P304 MENDOTA___CN2004 CORS ARP      N364420.399 W1202123.702  122571.4
AI8802 DYER DYER CORS ARP                  N374434.077 W1180221.559  147007.5

                 NEAREST NGS PUBLISHED CONTROL POINT
HR0727      176+20.06                      N374300.    W1194222.        402.6
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NGS OPUS SOLUTION REPORT

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      USER: michaels@ufl.edu                       DATE: September 26, 2006
RINEX FILE: turt263q.06o                           TIME: 15:30:00 UTC


  SOFTWARE: page5  0601.10 master24.pl            START: 2006/09/20  16:31:00
 EPHEMERIS: igr13933.eph [rapid]                   STOP: 2006/09/21  01:14:00
  NAV FILE: brdc2630.06n                      OBS USED: 18956 / 19033   : 100%
  ANT NAME: ASH700936D_M    NONE            # FIXED AMB:    58 /    63   :  92%
ARP HEIGHT: 1.500                           OVERALL RMS: 0.015(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)           ITRF00 (EPOCH:2006.7202)

         X:     -2504133.820(m)   0.013(m)          -2504134.541(m)   0.013(m)
         Y:     -4389120.799(m)   0.002(m)          -4389119.491(m)   0.002(m)
         Z:      3881262.521(m)   0.005(m)           3881262.553(m)   0.005(m)

       LAT:   37 42 46.98085      0.007(m)        37 42 46.99712      0.007(m)
     E LON:  240 17 37.89249      0.012(m)       240 17 37.84047      0.012(m)
     W LON:  119 42 22.10751      0.012(m)       119 42 22.15953      0.012(m)
    EL HGT:         1578.212(m)   0.006(m)             1577.615(m)   0.006(m)
 ORTHO HGT:         1604.420(m)   0.026(m) [Geoid03 NAVD88]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 11)         SPC (0403 CA 3)
Northing (Y) [meters]     4177425.440           634922.160
Easting (X)  [meters]      261462.733          2069991.624
Convergence  [degrees]    -1.65614643           0.48602593
Point Scale                1.00030090           0.99992940
Combined Factor            1.00005323           0.99968182

US NATIONAL GRID DESIGNATOR: 11SKB6146377425(NAD 83)



                              BASE STATIONS USED
PID       DESIGNATION                       LATITUDE    LONGITUDE DISTANCE(m)
AF9702 MHCB MT HAMILTON BARD CORS ARP      N372029.501 W1213833.227  176093.5
DG8529 P304 MENDOTA___CN2004 CORS ARP      N364420.399 W1202123.702  122571.4
AI8802 DYER DYER CORS ARP                  N374434.077 W1180221.559  147007.5

                    NEAREST NGS PUBLISHED CONTROL POINT
HR0727      176+20.06                      N374300.    W1194222.        402.6
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NGS OPUS SOLUTION REPORT

USER: michaels@ufl.edu
RINEX FILE: elpt261u.06o
DATE: September 26, 2006
TIME: 15:27:03 UTC

SOFTWARE: page5 0601.10 master24.pl
EPHEMERIS: igr13931.eph [rapid]
NAV FILE: brdc2610.06n
ANT NAME: ASH700936D_M NONE
ARP HEIGHT: 1.500
START: 2006/09/18 20:47:00
STOP: 2006/09/19 00:17:00
OBS USED: 6905 / 7125 : 97%
FIXED AMB: 33 / 33 : 100%
OVERALL RMS: 0.009(m)

REF FRAME:	NAD_83(CORS96)(EPOCH:2002.0000)		ITRF00 (EPOCH:2006.7149)	
X:	-2510851.296(m)	0.009(m)	-2510852.020(m)	0.009(m)
Y:	-4387376.411(m)	0.017(m)	-4387375.103(m)	0.017(m)
Z:	3877240.740(m)	0.001(m)	3877240.770(m)	0.001(m)
LAT:	37 40 27.72468	0.011(m)	37 40 27.74083	0.011(m)
E LON:	240 13 4.54425	0.000(m)	240 13 4.49210	0.000(m)
W LON:	119 46 55.45575	0.000(m)	119 46 55.50790	0.000(m)
EL HGT:	557.825(m)	0.016(m)	557.229(m)	0.016(m)
ORTHO HGT:	584.840(m)	0.030(m)	[Geoid03 NAVD88]	

	UTM COORDINATES UTM (Zone 11)	STATE PLANE COORDINATES SPC (0403 CA 3)
Northing (Y) [meters]	4173328.772	630575.145
Easting (X) [meters]	254640.880	2063330.222
Convergence [degrees]	-1.70117487	0.43953911
Point Scale	1.00034157	0.99993007
Combined Factor	1.00025402	0.99984255

US NATIONAL GRID DESIGNATOR: 11SKB5464173329(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
AF9702	MHCB MT HAMILTON BARD CORS ARP	N372029.501	W1213833.227	168611.7
DG8529	P304 MENDOTA___CN2004 CORS ARP	N364420.399	W1202123.702	115664.0
AI8802	DYER DYER CORS ARP	N374434.077	W1180221.559	153883.2

NEAREST NGS PUBLISHED CONTROL POINT

HR0933	M 235	N374030.	W1194654.	78.9

NGS OPUS SOLUTION REPORT

USER: michaels@ufl.edu
RINEX FILE: magr262t.06o
DATE: September 25, 2006
TIME: 21:17:46 UTC

SOFTWARE: page5 0601.10 master24.pl
EPHEMERIS: igr13932.eph [rapid]
NAV FILE: brdc2620.06n
ANT NAME: ASH700936D_M NONE
ARP HEIGHT: 2.000

START: 2006/09/19 19:25:00
STOP: 2006/09/19 22:27:00
OBS USED: 5946 / 6079 : 98%
FIXED AMB: 30 / 30 : 100%
OVERALL RMS: 0.013(m)

REF FRAME:	NAD_83(CORS96)(EPOCH:2002.0000)		ITRF00 (EPOCH:2006.7175)	
X:	-2505071.884(m)	0.023(m)	-2505072.607(m)	0.023(m)
Y:	-4405076.839(m)	0.031(m)	-4405075.527(m)	0.031(m)
Z:	3862722.281(m)	0.035(m)	3862722.311(m)	0.035(m)
LAT:	37 30 7.14119	0.004(m)	37 30 7.15742	0.004(m)
E LON:	240 22 26.56922	0.004(m)	240 22 26.51724	0.004(m)
W LON:	119 37 33.43078	0.004(m)	119 37 33.48276	0.004(m)
EL HGT:	1615.534(m)	0.052(m)	1614.931(m)	0.052(m)
ORTHO HGT:	1642.572(m)	0.058(m)	[Geoid03 NAVD88]	

	UTM COORDINATES UTM (Zone 11)	STATE PLANE COORDINATES SPC (0403 CA 3)
Northing (Y) [meters]	4153801.026	611561.674
Easting (X) [meters]	267876.737	2077280.079
Convergence [degrees]	-1.59936476	0.53511958
Point Scale	1.00026374	0.99993858
Combined Factor	1.00001022	0.99968514

US NATIONAL GRID DESIGNATOR: 11SKB6787753801(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DH7211	P242 FRAZIERAIRCN2004 CORS ARP	N365714.136	W1212747.402	174040.3
DG8529	P304 MENDOTA___CN2004 CORS ARP	N364420.399	W1202123.702	106729.4
AI8802	DYER DYER CORS ARP	N374434.077	W1180221.559	142626.6

NEAREST NGS PUBLISHED CONTROL POINT

HR0758	10.130+00	N373011.	W1193751.	447.2

NGS OPUS SOLUTION REPORT

USER: michaels@ufl.edu
RINEX FILE: olm_265q.06o
DATE: September 26, 2006
TIME: 15:16:05 UTC

SOFTWARE: page5 0601.10 master13.pl
EPHEMERIS: igr13935.eph [rapid]
NAV FILE: brdc2650.06n
ANT NAME: ASH700936D_M NONE
ARP HEIGHT: 1.500
START: 2006/09/22 16:57:00
STOP: 2006/09/22 22:35:30
OBS USED: 12115 / 12182 : 99%
FIXED AMB: 44 / 44 : 100%
OVERALL RMS: 0.014(m)

REF FRAME:	NAD_83(CORS96)(EPOCH:2002.0000)		ITRF00 (EPOCH:2006.7256)	
X:	-2484370.359(m)	0.022(m)	-2484371.075(m)	0.022(m)
Y:	-4393580.718(m)	0.010(m)	-4393579.411(m)	0.010(m)
Z:	3890445.425(m)	0.010(m)	3890445.457(m)	0.010(m)
LAT:	37 48 39.17952	0.004(m)	37 48 39.19595	0.004(m)
E LON:	240 30 49.72440	0.022(m)	240 30 49.67264	0.022(m)
W LON:	119 29 10.27560	0.022(m)	119 29 10.32736	0.022(m)
EL HGT:	2550.916(m)	0.015(m)	2550.315(m)	0.015(m)
ORTHO HGT:	2575.480(m)	0.029(m)	[Geoid03 NAVD88]	

	UTM COORDINATES (Zone 11)	STATE PLANE COORDINATES SPC (0403 CA 3)
Northing (Y) [meters]	4187744.498	645966.720
Easting (X) [meters]	281142.785	2089265.799
Convergence [degrees]	-1.52477991	0.62068839
Point Scale	1.00018999	0.99992972
Combined Factor	0.99978979	0.99952963

US NATIONAL GRID DESIGNATOR: 11SKB8114387744(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DG8529	P304 MENDOTA___CN2004 CORS ARP	N364420.399	W1202123.702	141859.0
AI8802	DYER DYER CORS ARP	N374434.077	W1180221.559	127731.1
AI8823	GABB GABBS CORS ARP	N385813.180	W1175458.957	188128.3

NEAREST NGS PUBLISHED CONTROL POINT

HR2434	E 1410	N374843.	W1192918.	222.6

NGS OPUS SOLUTION REPORT

USER: michaels@ufl.edu
RINEX FILE: wp1_262s.06o
DATE: September 25, 2006
TIME: 21:15:11 UTC

SOFTWARE: page5 0601.10 master3.pl
EPHEMERIS: igr13932.eph [rapid]
NAV FILE: brdc2620.06n
ANT NAME: ASH700936D_M NONE
ARP HEIGHT: 1.500
START: 2006/09/19 18:14:00
STOP: 2006/09/19 21:56:30
OBS USED: 6810 / 7656 : 89%
FIXED AMB: 42 / 51 : 82%
OVERALL RMS: 0.016(m)

REF FRAME:	NAD_83(CORS96)(EPOCH:2002.0000)		ITRF00 (EPOCH:2006.7174)	
X:	-2502759.243(m)	0.005(m)	-2502759.965(m)	0.005(m)
Y:	-4405494.254(m)	0.016(m)	-4405492.942(m)	0.016(m)
Z:	3864451.224(m)	0.003(m)	3864451.255(m)	0.003(m)
LAT:	37 31 7.01248	0.008(m)	37 31 7.02877	0.008(m)
E LON:	240 23 56.80772	0.012(m)	240 23 56.75578	0.012(m)
W LON:	119 36 3.19228	0.012(m)	119 36 3.24422	0.012(m)
EL HGT:	2049.652(m)	0.009(m)	2049.049(m)	0.009(m)
ORTHO HGT:	2076.398(m)	0.026(m)	[Geoid03 NAVD88]	

	UTM COORDINATES UTM (Zone 11)	STATE PLANE COORDINATES SPC (0403 CA 3)
Northing (Y) [meters]	4155585.020	613428.290
Easting (X) [meters]	270143.936	2079478.547
Convergence [degrees]	-1.58468326	0.55046594
Point Scale	1.00025083	0.99993737
Combined Factor	0.99992922	0.99961585

US NATIONAL GRID DESIGNATOR: 11SKB7014455585(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DH7211	P242 FRAZIERAIRCN2004 CORS ARP	N365714.136	W1212747.402	176765.5
DG8529	P304 MENDOTA___CN2004 CORS ARP	N364420.399	W1202123.702	109557.9
AI8802	DYER DYER CORS ARP	N374434.077	W1180221.559	140104.3

NEAREST NGS PUBLISHED CONTROL POINT

HR0751	D 246	N373120.	W1193709.	1663.2