

Contact information

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Project Name: Transient response of a desert river to forced diversion: Furnace Creek Wash, Death Valley National Park, California

1. Survey areas

The survey area is an 8 kilometer by 5 kilometer rectangle (40 square kilometers) near the Furnace Creek Inn and Ranch in Death Valley National Park, California. This area was flown on February 27, 2005. Figure 1 (below) is an image showing the project shape and location.

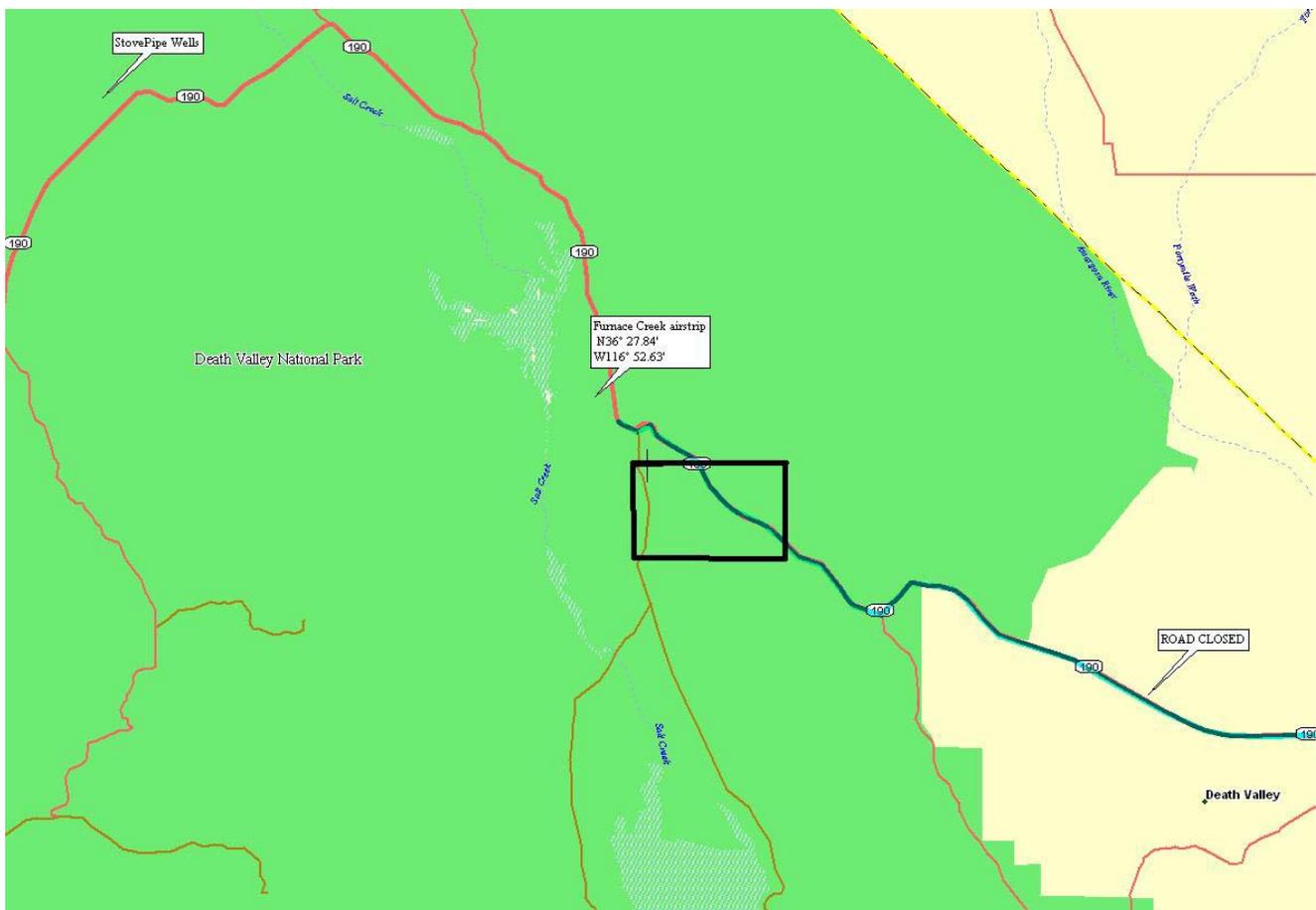


Figure 1 - Project shape and location

2. Survey Parameters

The project area was flown with 23 flight lines oriented East-West and 2 additional cross lines for field calibration purposes. The flying height was targeted at 600 meters Above Ground Level (AGL) but varied during the survey from 350 to 900 meters due to the mountainous terrain. Flying speed was variable, but targeted at 117 knots. Planned point spacing per swath was approximately 1 meter along-track at nadir, 2.1 meters at the scan edge and 0.73 meters cross-track. Overlap coverage was targeted at approximately 100%, (50% sidelap). Additional parameters are shown below in Table 1. Table 2 lists the survey parameters at 800 meters for comparison.

Flying Speed (m/s)	Scan Spacing (m)	Pulse Rate (p/sec)	
60.0	2.1		33333.0
Indicated Air Speed (nm/h)	Scan Width (m)	Pulses Per Scan	
116.6	436.8		595.2
Scan Rate (+/- degrees)	Scan Angle (d)	Distance Between Range Points Along Scan (m)	
28.0	20.0		0.73
Flying Height (meters AGL)	Flight line Spacing (m)	Swath Overlap (m)	
600	219.8		260.0

Table 1 - Survey Parameters at 600 meters AGL.

Flying Speed (m/s)	Scan Spacing (m)	Pulse Rate (p/sec)	
60.0	2.1		33333.0
Indicated Air Speed (nm/h)	Scan Width (m)	Pulses Per Scan	
116.6	582.4		595.2
Scan Rate (+/- degrees)	Scan Angle (d)	Distance Between Range Points Along Scan (m)	
28.0	20.0		0.98
Flying Height (meters AGL)	Flight line Spacing (m)	Swath Overlap (m)	
800	219.8		363.0

Table 2 - Survey Parameters at 800 meters AGL.

Table 3 (below) gives the combined laser-on and air time totals for the project.

Laser-on	1.35	Hours
Air Time(Laser-off)	2.18	Hours
Total Flight Time	3.53	Hours

Table 3 - Laser-on time, air time, and total flight time.

3. GPS Reference Stations

Two GPS reference station locations were used during the survey. One receiver was placed on a newly set mark (FURN) at the Furnace Creek airstrip. This station was observed on February 26, 27, and 28 for a total of 19 hours. The other receiver was placed on a newly set mark named BAD1 located in the project area just west of the paved road to Badwater. BAD1 was observed for 3 continuous hours on

February 26 and again for 3.5 hours on the day of the flight. All GPS observations were logged at a 1-second rate, and were submitted to the NGS on-line processor OPUS with solution files included as Appendix A. The repeat session results on mark FURN yielded reference station coordinate differences of less than 0.020 meters in both horizontal and vertical positions, and less than 0.011 meters for the two sessions on BAD1. Final coordinates for the reference stations FURN and BAD1 were calculated from the OPUS solutions as weighted averages. 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/>. Ground equipment consisted of ASHTECH (Thales Navigation) Z-Extreme receivers, with choke ring antennas (Part# 700936.D) mounted on 2-meter fixed-height tripods.

4. Navigation Processing

Airplane trajectories for this survey were processed using both Ashtech processing software and REALM processing software by Optech, Inc. The Ashtech solution is dual-frequency phase-differenced fixed integer, while the REALM solution is phase-differenced L1 only, without fixing phase ambiguities; these types of solutions (REALM) are generally less suitable over long baseline lengths (over 25 kilometers) but usually very good over short baseline separation distances. Trajectories were processed separately using REALM and Ashtech and then coordinate differences between the separate solutions were plotted. Figure 2 (below) is a plot of the differences in Easting, Northing, and Height of two trajectories one being the L1 REALM trajectory from BAD1 and the other being the dual-frequency Ashtech solution from the same point. A systematic difference introduced by the processing software between these 2 trajectories has been removed.

Positional differences in trajectory positions: L1 only vs dual frequency solution (Short Baseline)

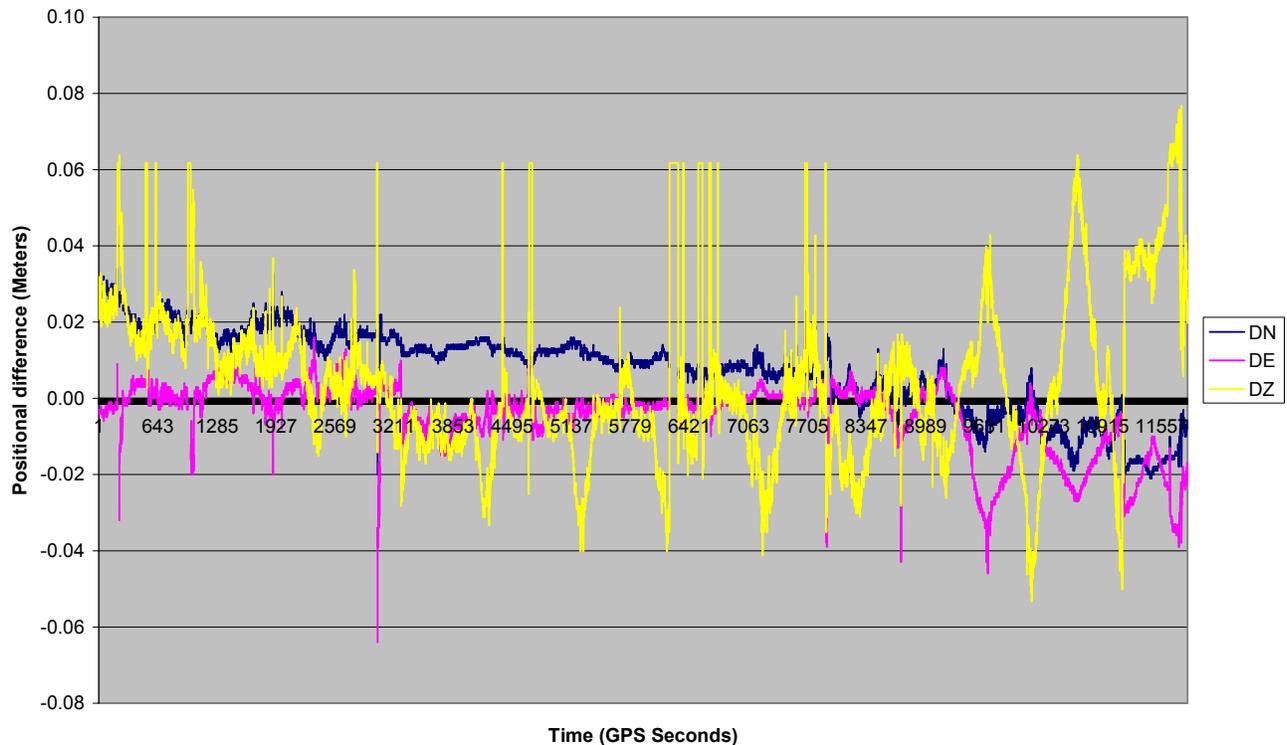


Figure 2 - Positional differences in aircraft trajectories with respect to time.

Note that the L1 solution does not vary significantly with the dual frequency solution. The standard deviation of the differences in the Easting position of these two trajectories is 1 cm, in Northing 1 cm, and in height 2 cm.

A comparison was also made processing the airplane trajectory from two different base stations, FURN and BAD1 using the Ashtech dual-frequency processor. The comparison is shown below in Figure 3.

Positional differences in trajectory positions:dual frequency solutions, different base stations

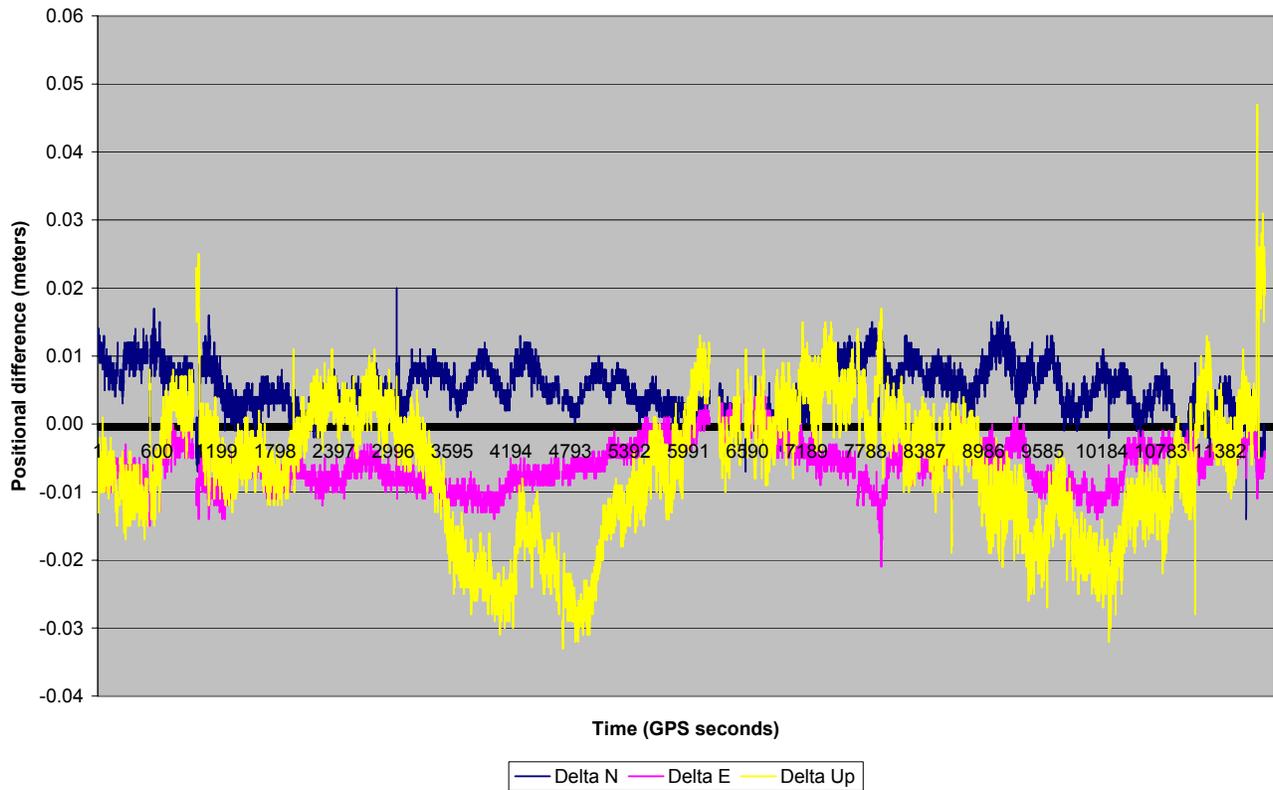


Figure 3 – Positional differences in trajectory positions as processed from 2 base stations

The REALM L1 trajectory was used for the processing of the final navigation solution because the L1/L2 solution was incomplete due to a problem with the aircraft GPS antenna and/or cable, which has since been corrected.

5. Laser Point Processing

All coordinates were processed with respect to NAD83 and referenced to the national CORS network. The projection is UTM Zone 11, with units in meters. Heights are NAVD88 orthometric heights computed using NGS GEOID03 model.

The most complete output format is nine-column ASCII (space delimited), one file per flight strip. The nine columns are as follows: 1. GPS time (seconds of week); 2. Easting last stop; 3. Northing last stop; 4. Height last stop; 5. Intensity last stop; 6. Easting first stop; 7. Northing first stop; 8. Height first stop; 9. Intensity first stop. Note that in these 9-column files no geoid model has been applied - height values are ellipsoid heights and these height values will NOT match orthometric heights (elevations) found in the 3-column output or in the 1-meter DEM grid nodes.

Note that the UTM zone code (11) is appended to the Easting coordinate in this nine-column format. The UF has utility software to reformat these files, for example to extract last stop elevations and intensities and remove the UTM zone code. These utilities are written in C /C++ programming language and are available for distribution.

During processing, a scan cutoff angle of 1.5 degrees was used to eliminate points at the edge of the scan lines. This was done to improve the overall DEM accuracy (points farthest from the scan nadir are the most affected by small errors in pitch, roll and scanner mirror angle measurements). Points with very low intensity values were also filtered out (intensity values less than 7), because these points also tend to be the least accurate. This is due to the fact that very weak return pulses yield the noisiest range measurements. These points represent a very small percentage of the total number of points, usually in the neighborhood of a few hundredths of one percent. An almost total absence of vegetation makes this project area ideal, because removal of scan edges and very low intensity points does not reduce the point density of bare-earth shots as it might in a heavily canopied project area.

All calibration files as well as all raw observation files (both GPS and ALTM) necessary to reprocess this project in its entirety are archived by UC Berkeley.

6. Ground Truth and Calibration

In order to provide on-site calibration and ground truth, a section of Badwater road running south from the Furnace Creek Resort was surveyed using vehicle-mounted GPS, and then surveyed with the ALTM during the flight. Comparisons were made between the heights of the vehicle-collected GPS and the airborne laser scanner. This allowed for a check on the calibration of the airborne scanner as well as a measure of the accuracy of the scanner heights. Figure 4 is a shaded relief image of the project area showing the location of the test points collected by vehicle-mounted GPS.

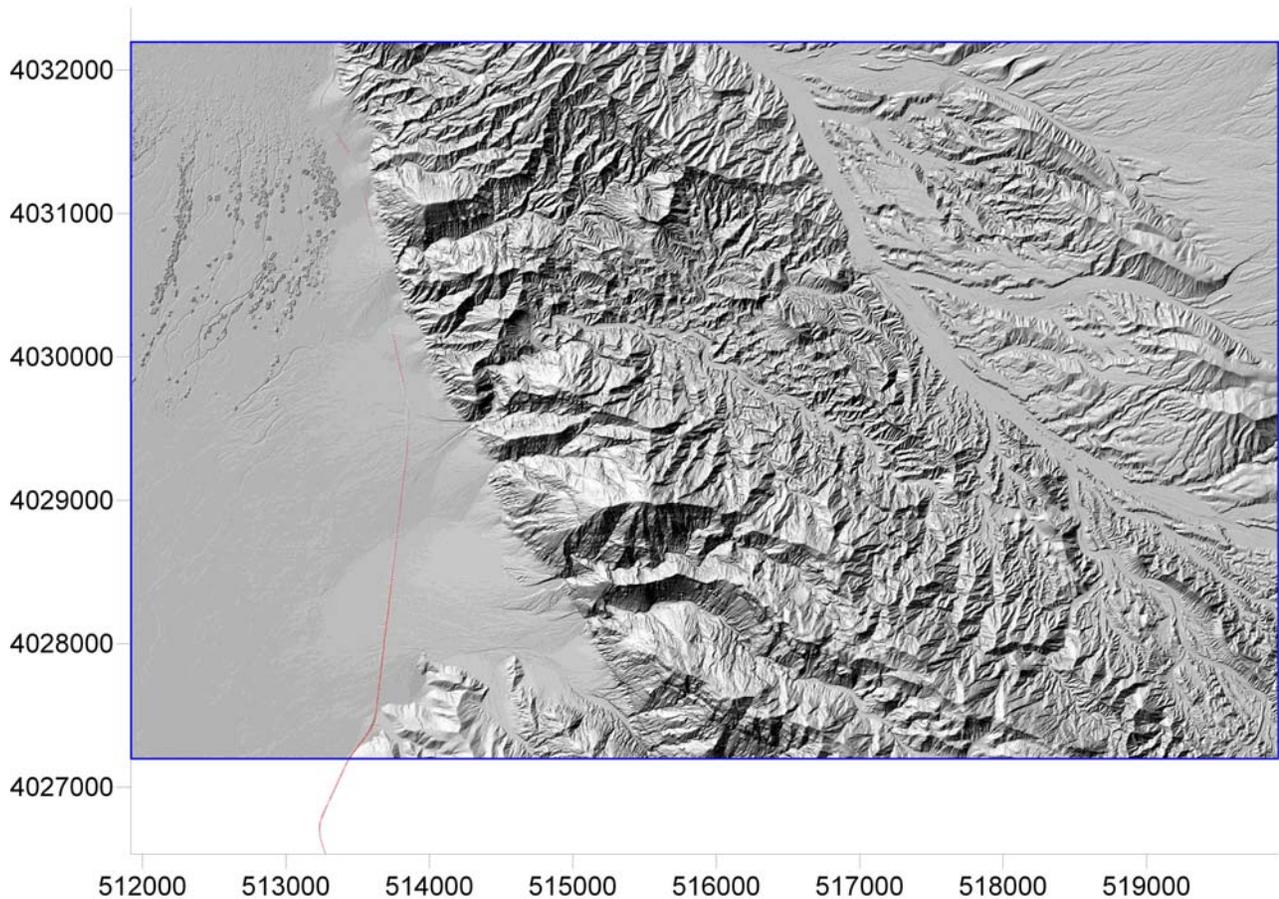


Figure 4 – Location of check points (red crosses) collected by vehicle-mounted GPS on Badwater road

After analysis, the REALM trajectory height shift was -0.10 meters.

7. Filtering and DEM Production

Digital Elevation Models were produced at 1.0 meter spacing for all areas from last stop elevations using SURFER (Golden Software) Version 8.04. Interpolation parameters were as follows in Table 3.

Algorithm	Kriging
Variogram	Linear
Nugget Variance	0.10 meters
MicroVariance	0.00 meters
Quadrant Search	4
Search Radius	5 meters
Minimum points per quadrant	5
Maximum points per quadrant	7

Table 3 - Gridding parameters.

No vegetation removal (filtering) was done for the project area.

APPENDIX A.

GPS Reference Station Coordinates from OPUS

NGS OPUS SOLUTION REPORT

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USER: michael@ufl.edu
 RINEX FILE: bad1058v.05o

DATE: March 10, 2005
 TIME: 18:18:03 UTC

SOFTWARE: page5 0411.19 master23.pl	START: 2005/02/27 21:08:00
EPHEMERIS: igr13120.eph [rapid]	STOP: 2005/02/27 22:59:30
NAV FILE: brdc0580.05n	OBS USED: 3941 / 3968 : 99%
ANT NAME: ASH700936D_M	# FIXED AMB: 29 / 29 : 100%
ARP HEIGHT: 2.000	OVERALL RMS: 0.011 (m)

REF FRAME: NAD83 (CORS96) (EPOCH:2002.0000) ITRF00 (EPOCH:2005.1587)

X:	-2320629.075 (m)	0.009 (m)	-2320629.777 (m)	0.009 (m)
Y:	-4583819.292 (m)	0.026 (m)	-4583817.986 (m)	0.026 (m)
Z:	3766588.132 (m)	0.020 (m)	3766588.112 (m)	0.020 (m)

LAT:	36 25 46.07558	0.013 (m)	36 25 46.09140	0.013 (m)
E LON:	243 8 54.54486	0.012 (m)	243 8 54.49603	0.012 (m)
W LON:	116 51 5.45514	0.012 (m)	116 51 5.50397	0.012 (m)
EL HGT:	-87.097 (m)	0.030 (m)	-87.791 (m)	0.030 (m)
ORTHO HGT:	-57.683 (m)	0.039 (m)	[Geoid03 NAVD88]	

	UTM COORDINATES	STATE PLANE COORDINATES
	UTM (Zone 11)	SPC (0404 CA 4)
Northing (Y) [meters]	4031594.401	623782.919
Easting (X) [meters]	513309.640	2192633.187
Convergence [degrees]	0.08817520	1.28175835
Point Scale	0.99960218	0.99994661
Combined Factor	0.99961585	0.99996027

US NATIONAL GRID DESIGNATOR: 11SNA1331031594 (NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE (m)
DG4265	NVTR TROPICANA CORS ARP	N360557.001	W1151944.433	141646.1
AJ1826	LVWD LAS VEGAS VALLEY CORS ARP	N360934.026	W1151128.797	152112.3
DG4673	NVCS CARLTON SQUARE CORS ARP	N361311.196	W1151019.335	152592.1

NEAREST NGS PUBLISHED CONTROL POINT

GS0247	A 680	N362607.	W1165104.	648.0
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This position was computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

NGS OPUS SOLUTION REPORT

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USER: michael@ufl.edu
 RINEX FILE: bad1057v.05o

DATE: March 10, 2005
 TIME: 18:34:17 UTC

SOFTWARE: page5 0411.19 master18.pl
 EPHEMERIS: igr13116.eph [rapid]
 NAV FILE: brdc0570.05n
 ANT NAME: ASH700936D_M
 ARP HEIGHT: 2.000

START: 2005/02/26 21:04:00
 STOP: 2005/02/26 22:59:30
 OBS USED: 3605 / 3796 : 95%
 # FIXED AMB: 38 / 39 : 97%
 OVERALL RMS: 0.011 (m)

REF FRAME: NAD83 (CORS96) (EPOCH:2002.0000) ITRF00 (EPOCH:2005.1559)

X:	-2320629.074 (m)	0.025 (m)	-2320629.775 (m)	0.024 (m)
Y:	-4583819.300 (m)	0.013 (m)	-4583817.994 (m)	0.013 (m)
Z:	3766588.137 (m)	0.011 (m)	3766588.117 (m)	0.011 (m)
LAT:	36 25 46.07558	0.010 (m)	36 25 46.09141	0.010 (m)
E LON:	243 8 54.54504	0.023 (m)	243 8 54.49625	0.023 (m)
W LON:	116 51 5.45496	0.023 (m)	116 51 5.50375	0.023 (m)
EL HGT:	-87.088 (m)	0.015 (m)	-87.783 (m)	0.016 (m)
ORTHO HGT:	-57.674 (m)	0.029 (m)	[Geoid03 NAVD88]	

	UTM COORDINATES	STATE PLANE COORDINATES
	UTM (Zone 11)	SPC (0404 CA 4)
Northing (Y) [meters]	4031594.401	623782.919
Easting (X) [meters]	513309.645	2192633.191
Convergence [degrees]	0.08817523	1.28175838
Point Scale	0.99960218	0.99994661
Combined Factor	0.99961585	0.99996027

US NATIONAL GRID DESIGNATOR: 11SNA1331031594 (NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE (m)
DG4265	NVTR TROPICANA CORS ARP	N360557.001	W1151944.433	141646.1
AJ1826	LVWD LAS VEGAS VALLEY CORS ARP	N360934.026	W1151128.797	152112.3
DG4673	NVCS CARLTON SQUARE CORS ARP	N361311.196	W1151019.335	152592.1

NEAREST NGS PUBLISHED CONTROL POINT

GS0247	A 680	N362607.	W1165104.	648.0
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This position was computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

NGS OPUS SOLUTION REPORT

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USER: michael@ufl.edu
 RINEX FILE: furn059p.05o

DATE: March 10, 2005
 TIME: 18:21:39 UTC

SOFTWARE: page5 0411.19 master28.pl
 EPHemeris: igr13121.eph [rapid]
 NAV FILE: brdc0590.05n
 ANT NAME: ASH700936D_M
 ARP HEIGHT: 2.000

START: 2005/02/28 15:30:00
 STOP: 2005/03/01 04:17:00
 OBS USED: 17891 / 17993 : 99%
 # FIXED AMB: 82 / 82 : 100%
 OVERALL RMS: 0.010 (m)

REF FRAME: NAD83 (CORS96) (EPOCH:2002.0000) ITRF00 (EPOCH:2005.1614)

X:	-2321829.586 (m)	0.008 (m)	-2321830.287 (m)	0.008 (m)
Y:	-4580718.588 (m)	0.028 (m)	-4580717.282 (m)	0.029 (m)
Z:	3769582.400 (m)	0.018 (m)	3769582.382 (m)	0.018 (m)
LAT:	36 27 47.07203	0.030 (m)	36 27 47.08790	0.031 (m)
E LON:	243 7 15.27533	0.008 (m)	243 7 15.22650	0.008 (m)
W LON:	116 52 44.72467	0.008 (m)	116 52 44.77350	0.008 (m)
EL HGT:	-96.947 (m)	0.015 (m)	-97.640 (m)	0.015 (m)
ORTHO HGT:	-67.519 (m)	0.029 (m)	[Geoid03 NAVD88]	

	UTM COORDINATES	STATE PLANE COORDINATES
	UTM (Zone 11)	SPC (0404 CA 4)
Northing (Y) [meters]	4035319.085	627456.477
Easting (X) [meters]	510833.252	2190078.875
Convergence [degrees]	0.07185733	1.26530754
Point Scale	0.99960145	0.99994478
Combined Factor	0.99961666	0.99995999

US NATIONAL GRID DESIGNATOR: 11SNA1083335319 (NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE (m)
AI8802	DYER DYER CORS ARP	N374434.077	W1180221.559	175537.8
DG4265	NVTR TROPICANA CORS ARP	N360557.001	W1151944.433	145006.0
AJ1826	LVWD LAS VEGAS VALLEY CORS ARP	N360934.026	W1151128.797	155275.6

NEAREST NGS PUBLISHED CONTROL POINT

GS0250	-178	N362726.	W1165203.	1225.3
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This position was computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

NGS OPUS SOLUTION REPORT

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USER: michael@ufl.edu
 RINEX FILE: furn058r.05o

DATE: March 10, 2005
 TIME: 18:35:51 UTC

SOFTWARE: page5 0411.19 master17.pl
 EPHemeris: igr13120.eph [rapid]
 NAV FILE: brdc0580.05n
 ANT NAME: ASH700936D_M
 ARP HEIGHT: 2.000

START: 2005/02/27 17:57:00
 STOP: 2005/02/27 22:59:30
 OBS USED: 7845 / 7903 : 99%
 # FIXED AMB: 41 / 41 : 100%
 OVERALL RMS: 0.011 (m)

REF FRAME: NAD83 (CORS96) (EPOCH:2002.0000) ITRF00 (EPOCH:2005.1585)

X:	-2321829.589 (m)	0.010 (m)	-2321830.290 (m)	0.010 (m)
Y:	-4580718.589 (m)	0.013 (m)	-4580717.282 (m)	0.013 (m)
Z:	3769582.405 (m)	0.007 (m)	3769582.387 (m)	0.007 (m)
LAT:	36 27 47.07211	0.010 (m)	36 27 47.08801	0.010 (m)
E LON:	243 7 15.27524	0.009 (m)	243 7 15.22640	0.009 (m)
W LON:	116 52 44.72476	0.009 (m)	116 52 44.77360	0.009 (m)
EL HGT:	-96.942 (m)	0.011 (m)	-97.636 (m)	0.011 (m)
ORTHO HGT:	-67.514 (m)	0.027 (m)	[Geoid03 NAVD88]	

	UTM COORDINATES	STATE PLANE COORDINATES
	UTM (Zone 11)	SPC (0404 CA 4)
Northing (Y) [meters]	4035319.088	627456.480
Easting (X) [meters]	510833.249	2190078.873
Convergence [degrees]	0.07185732	1.26530753
Point Scale	0.99960145	0.99994478
Combined Factor	0.99961665	0.99995999

US NATIONAL GRID DESIGNATOR: 11SNA1083335319 (NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE (m)
DG4265	NVTR TROPICANA CORS ARP	N360557.001	W1151944.433	145006.0
AJ1826	LVWD LAS VEGAS VALLEY CORS ARP	N360934.026	W1151128.797	155275.6
DG4673	NVCS CARLTON SQUARE CORS ARP	N361311.196	W1151019.335	155610.3

NEAREST NGS PUBLISHED CONTROL POINT

GS0250	-178	N362726.	W1165203.	1225.3
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This position was computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

NGS OPUS SOLUTION REPORT

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USER: michael@ufl.edu
 RINEX FILE: furn057u.05o

DATE: March 10, 2005
 TIME: 18:18:09 UTC

SOFTWARE: page5 0411.19 master24.pl
 EPHemeris: igr13116.eph [rapid]
 NAV FILE: brdc0570.05n
 ANT NAME: ASH700936D_M
 ARP HEIGHT: 2.000

START: 2005/02/26 20:47:00
 STOP: 2005/02/26 22:59:30
 OBS USED: 4289 / 4330 : 99%
 # FIXED AMB: 28 / 28 : 100%
 OVERALL RMS: 0.010 (m)

REF FRAME: NAD83 (CORS96) (EPOCH:2002.0000) ITRF00 (EPOCH:2005.1559)

X:	-2321829.588 (m)	0.021 (m)	-2321830.289 (m)	0.020 (m)
Y:	-4580718.603 (m)	0.014 (m)	-4580717.297 (m)	0.014 (m)
Z:	3769582.402 (m)	0.011 (m)	3769582.383 (m)	0.011 (m)

LAT:	36 27 47.07180	0.010 (m)	36 27 47.08766	0.010 (m)
E LON:	243 7 15.27553	0.018 (m)	243 7 15.22670	0.018 (m)
W LON:	116 52 44.72447	0.018 (m)	116 52 44.77330	0.018 (m)
EL HGT:	-96.934 (m)	0.018 (m)	-97.628 (m)	0.018 (m)
ORTHO HGT:	-67.506 (m)	0.031 (m)	[Geoid03 NAVD88]	

	UTM COORDINATES	STATE PLANE COORDINATES
	UTM (Zone 11)	SPC (0404 CA 4)
Northing (Y) [meters]	4035319.079	627456.471
Easting (X) [meters]	510833.257	2190078.880
Convergence [degrees]	0.07185736	1.26530757
Point Scale	0.99960145	0.99994478
Combined Factor	0.99961665	0.99995999

US NATIONAL GRID DESIGNATOR: 11SNA1083335319 (NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE (m)
DG4265	NVTR TROPICANA CORS ARP	N360557.001	W1151944.433	145006.0
AJ1826	LVWD LAS VEGAS VALLEY CORS ARP	N360934.026	W1151128.797	155275.6
DG4673	NVCS CARLTON SQUARE CORS ARP	N361311.196	W1151019.335	155610.3

NEAREST NGS PUBLISHED CONTROL POINT

GS0250	-178	N362726.	W1165203.	1225.3
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This position was computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.