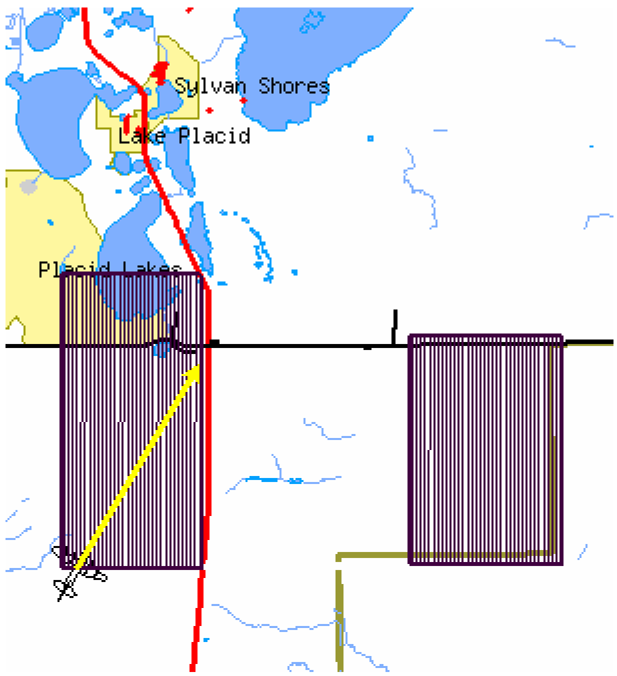
# Precise Topography for Biological Study

**Contact Information**
Dr. Hilary Swain
Archibold Biological Station
P.O. Box 2057
Lake Placid, FL 33862-2057
Tel: 863-465-2571
Fax: 863-699-1927
hswain@archibold-station.org




## Survey Area

The survey consisted of two polygons south of Lake Placid, Florida (Figure 1). The Archibold Biological Station (ABS), an NSF funded project, was located 3 miles south of Lake Placid and flown with 33 flight lines covering 85 $km^2$ (Figure 2). The MAERC Buck Island Ranch (Not funded by NSF) was located 9 miles southeast of Lake Placid and flown with 36 flight lines covering 72 $km^2$ (Figure 3).

The ABS was surveyed on April 11, 2006 (Day 101). The MAERC site was flown on April 13, 2006 (Day 103). Equipment issues led to a re-flight of several lines in both areas which was completed on April 21, 2006 (Day 111). Data was collected using an Optech 1233 Airborne Laser Terrain Mapper (http://www.optech.ca/) system mounted in a twin engine Cessna 337.

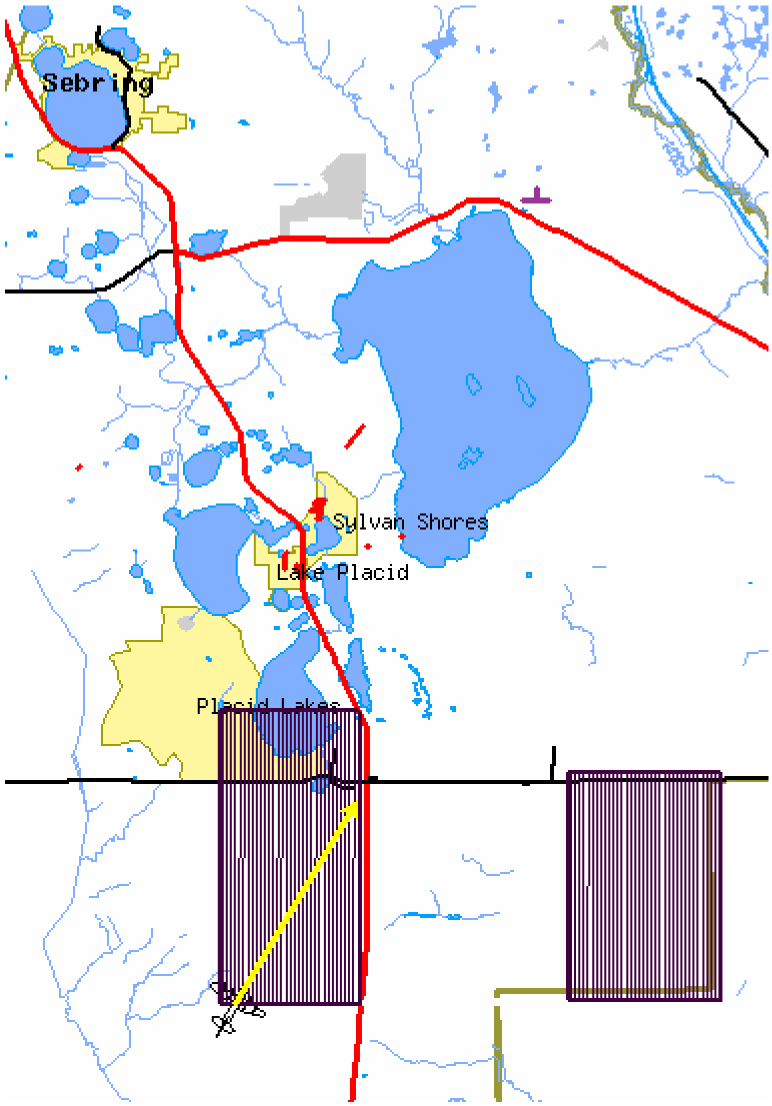


**Figure 1. Two survey areas south of Lake Placid, Florida. Archibold Biological Station located on the west and MAERC Buck Island Ranch located on the east. The low altitude diagonal pass is highlighted.**

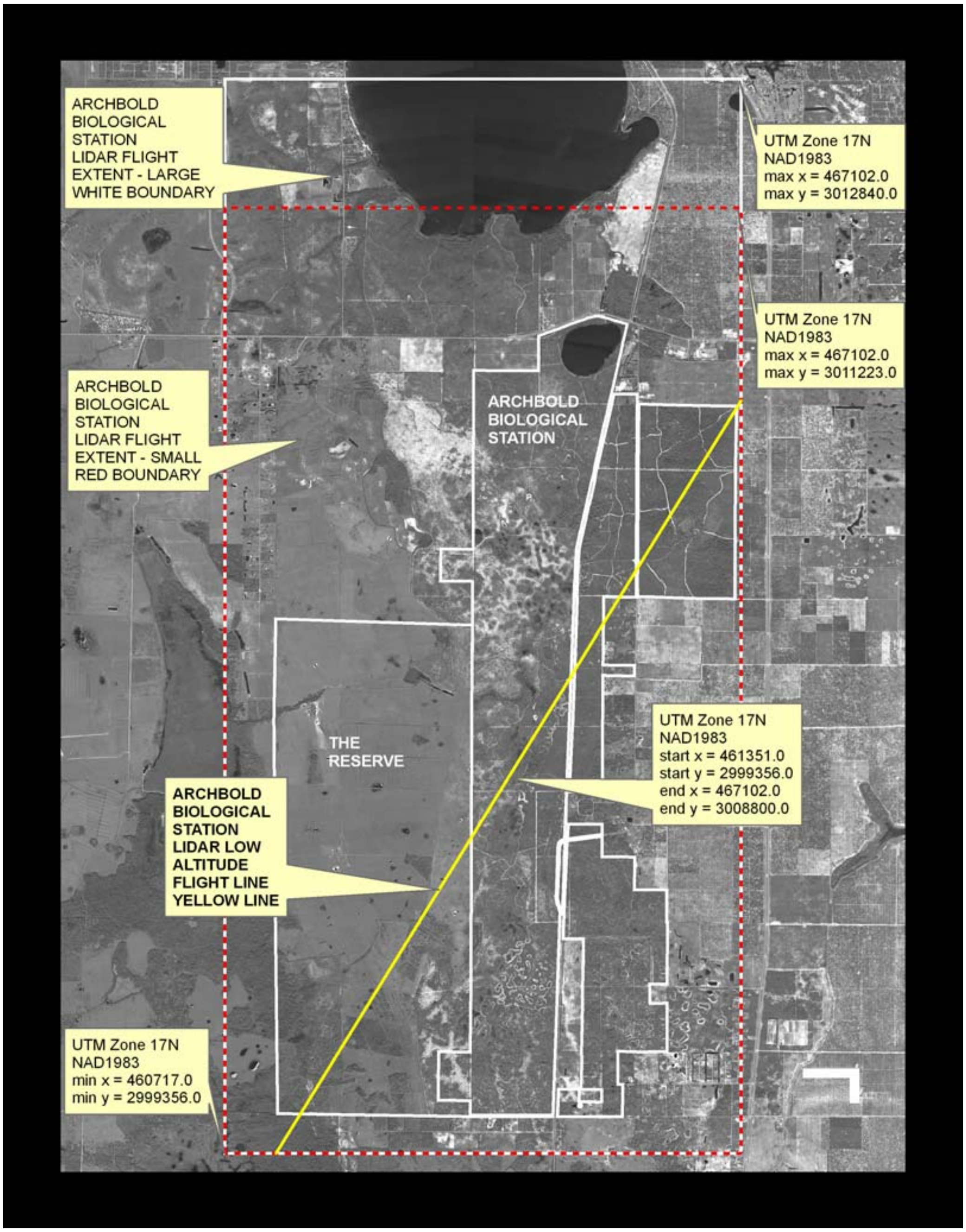



**Figure 2. Archibold Biological Station survey area.**

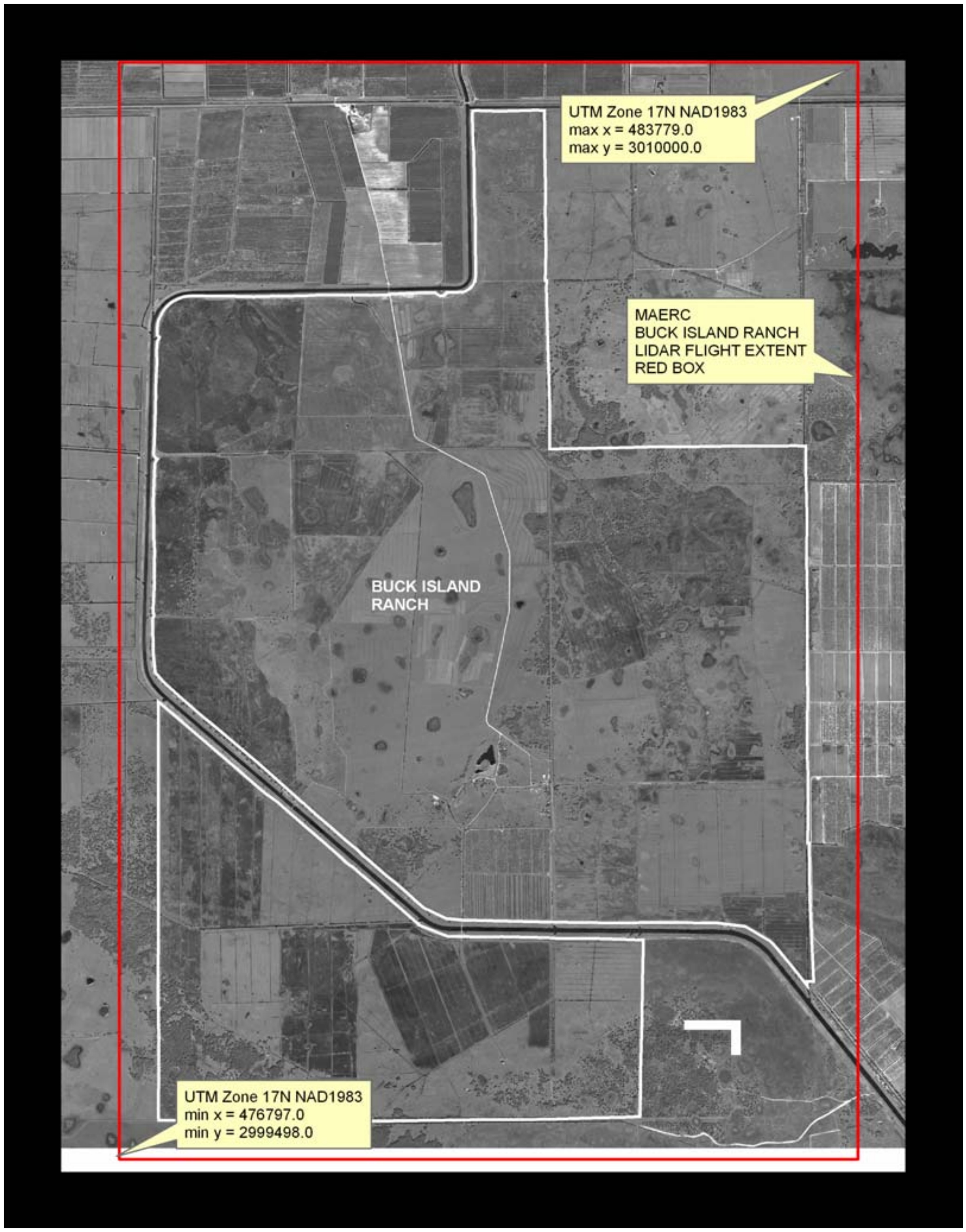



**Figure 3. MAERC Buck Island Ranch survey area.**

## Survey Parameters

A total of 70 flight lines were required to cover the survey areas. Three additional crosslines were flown for calibration purposes. The ABS consisted of 33 north-south flight lines which were 13.54 km in length. The MAERC site included 36 north-south flight lines, each one being 10.55 km in length. Each area was flown in a racetrack pattern at 600 m above ground level (AGL). A single low altitude pass was flown diagonally across the ABS at 300 m.

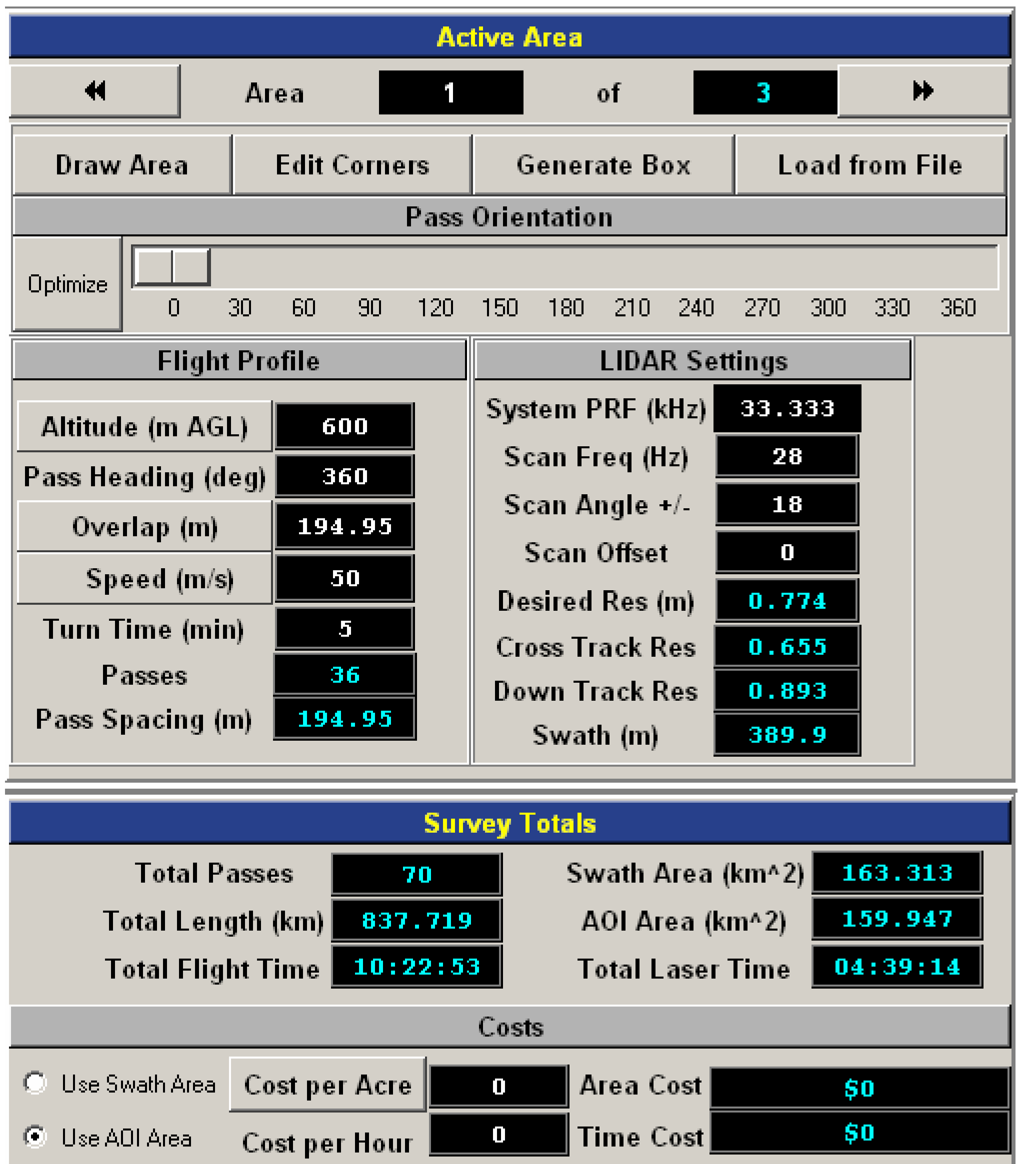



**Figure 4. Survey planning parameters and totals.**

## GPS Reference Stations

Two GPS reference station locations were used during the survey. One station was a high-accuracy bench NGS monument (PID AJ7235) stamped A518 and the other was the FDOT CORS station OKCB. All GPS observations at A518 were logged at a 1-second rate and submitted to the NGS online processor OPUS (Appendix A). Final coordinates for the reference station A518 was based on these OPUS solutions. For more information on the CORS network, refer to http://www.ngs.noaa.gov/CORS/. Ground equipment included ASHTECH Z-Extreme receivers and choke ring antennas (Part #700936.D) mounted on a 1.5 m conventional tripod.

## Navigation Processing

The airplane trajectories for this survey were processed using KARS software (Kinematic and Rapid Static) by Dr. Gerry Mader of the NGS Research Laboratory.

After GPS processing, the trajectory and the inertial measurement unit (IMU) data collected during the flights were input into APPLANIX software POSPROC which uses a Kalman Filter to produce a final navigation solution (aircraft position and orientation) at 50 Hz, in SBET format (Smoothed Best Estimated Trajectory).

## Calibration and Laser Point Processing

The SBET and the raw laser range data were combined using Optech's REALM processing suite to generate the laser point dataset. A few small test sites containing crossing flight-lines were initially extracted and used for relative calibration with TerraSolid's TerraMatch software. This application measures the differences between laser surfaces from overlapping flightlines and translates them into correction values for the system orientation -- easting, northing, elevation, heading, roll and/or pitch. After obtaining adjustments to calibration values using TerraMatch, laser point processing was re-done and the calibration rechecked.

Absolute ground calibration was performed on these data by collecting test points by vehicle mounted GPS on SR 70 running East-West through the project. Analysis of the test point elevation versus the laser point elevations revealed a small shift (0.15 meters) which was then applied to the laser point output. The RMS of the differences between the laser points and the test points was 0.06 meters. All coordinates were processed with respect to NAD83 and referenced to the national CORS96 network. The projection for the 9 column output is UTM Zone 17, with ellipsoid heights, and units in meters. The last return data was extracted from the 9-column format and the heights reprojected to orthometric heights in NAVD88, computed using NGS GEOID03 model with the Corpscon v6.0 software (Corps of Engineers Coordinate Conversion).

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 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 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 files or in the 1-meter DEM grid nodes.

During processing, a scan cutoff angle of 0.5 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.

## 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. Each of the 7 corridors was processed individually.

The classification routine consists of three algorithms:

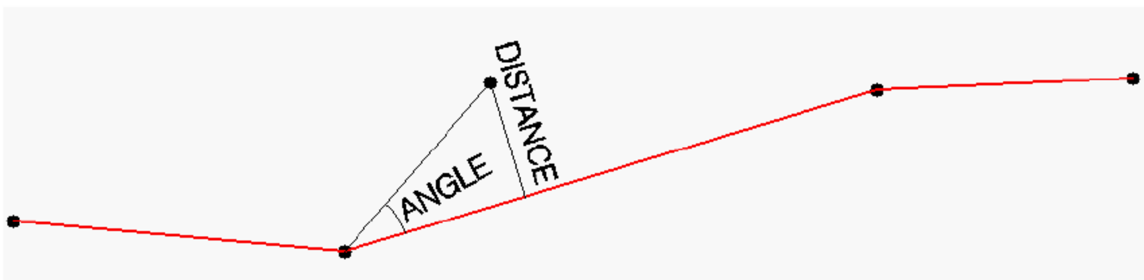
1) Removal of "Low Points". This routine was used to search for possible error points which are clearly below the ground surface. The elevation of each point (=center) is compared with every other point within a given neighborhood and if the center point is clearly lower then any other point it will 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): 140.0 m
Max Terrain Angle: 60.0
Iteration Angle: 5.8
Iteration Distance: 1.2 m
Reduce iteration angle when edge length < : 5.0 m
```

We used a window size of that magnitude in order to effectively remove some large buildings present in the North West side of the survey site.

3) <u>Below Surface removal</u>. 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.

Below Surface classification parameters used:

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

After classification the ground points were outputted in 2km x 2km overlapping tiles (140m overlap), ASCII format (XYZI), 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: 0.15 m
MicroVariance: 0.00 m
SearchDataPerSector: 10
SearchMinData: 5
SearchMaxEmpty: 1
SearchRadius: 40m
```

The resulted Surfer grid tile set was exported to ESRI ArcInfo floating 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.

# Appendix A: OPUS Solutions

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

      USER: michaels@ufl.edu                      DATE: April 17, 2006
RINEX FILE: a518101r.06o                          TIME: 14:58:37 UTC


  SOFTWARE: page5  0601.10 master4.pl            START: 2006/04/11  17:48:00
 EPHEMERIS: igr13702.eph [rapid]                  STOP: 2006/04/11  22:31:00
  NAV FILE: brdc1010.06n                      OBS USED: 10764 / 10970   :  98%
  ANT NAME: ASH700936D_M    NONE             # FIXED AMB:    45 /    45   : 100%
ARP HEIGHT: 1.500                           OVERALL RMS: 0.016(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)            ITRF00 (EPOCH:2006.2763)

         X:       855786.512(m)   0.009(m)           855785.847(m)   0.009(m)
         Y:     -5611556.880(m)   0.026(m)         -5611555.305(m)   0.026(m)
         Z:      2898667.509(m)   0.028(m)          2898667.297(m)   0.028(m)

       LAT:   27 12 26.16976      0.015(m)        27 12 26.18825      0.015(m)
     E LON:  278 40 15.75051      0.013(m)       278 40 15.73525      0.013(m)
     W LON:   81 19 44.24949      0.013(m)        81 19 44.26475      0.013(m)
    EL HGT:           16.451(m)   0.035(m)               14.880(m)   0.035(m)
 ORTHO HGT:           41.493(m)   0.043(m) [Geoid03 NAVD88]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 17)         SPC (0901 FL E)
Northing (Y) [meters]     3009435.330           318411.989
Easting (X)  [meters]      467422.298           167411.178
Convergence  [degrees]    -0.15040456          -0.15040456
Point Scale                0.99961310           0.99995428
Combined Factor            0.99961052           0.99995170

US NATIONAL GRID DESIGNATOR: 17RML6742209435(NAD 83)



                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
AJ3139 MCD1 MAC DILL AFB 1 CORS ARP        N275059.338 W0823156.336  138564.0
DH3757 WACH WAUCHULA CORS ARP              N273051.042 W0815256.616   64456.4
DE9138 OKCB OKEECHOBEE CORS ARP            N271557.715 W0805119.182   47360.9

                 NEAREST NGS PUBLISHED CONTROL POINT
AJ7235      A 518                          N271226.169 W0811944.249       0.0

This position and the above vector components were computed without any knowledge by the
National Geodetic Survey regarding the equipment or field operating procedures used.
```

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

      USER: michaels@ufl.edu                       DATE: April 17, 2006
RINEX FILE: a518103n.06o                           TIME: 14:58:52 UTC


  SOFTWARE: page5  0601.10 master3.pl             START: 2006/04/13  13:31:00
 EPHEMERIS: igr13704.eph [rapid]                   STOP: 2006/04/13  18:06:00
  NAV FILE: brdc1030.06n                       OBS USED:  8893 /  9004   :  99%
  ANT NAME: ASH700936D_M    NONE             # FIXED AMB:    38 /    42   :  90%
ARP HEIGHT: 1.500                            OVERALL RMS: 0.018(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)            ITRF00 (EPOCH:2006.2813)

         X:       855786.526(m)   0.003(m)           855785.861(m)   0.003(m)
         Y:     -5611556.904(m)   0.025(m)         -5611555.329(m)   0.025(m)
         Z:      2898667.519(m)   0.025(m)          2898667.307(m)   0.025(m)

       LAT:   27 12 26.16966      0.012(m)        27 12 26.18815      0.012(m)
     E LON:  278 40 15.75088      0.006(m)       278 40 15.73562      0.006(m)
     W LON:   81 19 44.24912      0.006(m)        81 19 44.26438      0.006(m)
    EL HGT:           16.479(m)   0.032(m)                14.908(m)   0.032(m)
 ORTHO HGT:           41.521(m)   0.041(m) [Geoid03 NAVD88]

                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 17)         SPC (0901 FL E)
Northing (Y) [meters]     3009435.327           318411.986
Easting (X)  [meters]      467422.308           167411.189
Convergence  [degrees]    -0.15040451          -0.15040451
Point Scale                0.99961310           0.99995428
Combined Factor            0.99961051           0.99995169

US NATIONAL GRID DESIGNATOR: 17RML6742209435(NAD 83)



                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
AJ3139 MCD1 MAC DILL AFB 1 CORS ARP        N275059.338 W0823156.336  138564.0
DH3757 WACH WAUCHULA CORS ARP              N273051.042 W0815256.616   64456.4
DE9138 OKCB OKEECHOBEE CORS ARP            N271557.715 W0805119.182   47360.9

                 NEAREST NGS PUBLISHED CONTROL POINT
AJ7235      A 518                          N271226.169 W0811944.249       0.0

This position and the above vector components were computed without any knowledge by the
National Geodetic Survey regarding the equipment or field operating procedures used.
```