Final Report on
Creation of High Resolution, Precise Digital Elevation Models (DEM) of Ocean City and Assateague Island, MD

Bea Csatho, Tony Schenk
Young-Ran Lee, Samuel Megenta and Impyeong Lee
Byrd Polar Research Center and Department of Civil Engineering, The Ohio State University
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1. Introduction

NASA GSFC is currently developing a new laser scanning system (called Microaltimeter), funded out of NASA’s Instrument Incubator Project. This report summarizes the creation of a DEM from airborne laser scanning data over the Ocean City-Assateague area to validate this new system.

2. Data set

Several sections of the Atlantic and Pacific coast have been mapped by repeat airborne laser altimetry using the ATM conical scanning lidar altimeter of the Observational Science Branch (Code 972, NASA WFF, Sallenger et al., 1999, Wright et al., http://aol1.wff.nasa.gov/atm/rst97). The southern part of Ocean City, and the northern part of Assateague Island, both in Maryland, have been selected to create a precise Digital Elevation Model (Figure 1). The area is well suited for laser altimetry calibration purposes, because of its proximity to NASA WFF and the repeat laser altimetry coverage during 1996-1999 (Table 1). The accuracy of the ATM system has been rigorously evaluated by comparison with surface elevations obtained by using surveys on the Assateague Island (Wright et al., http://aol1.wff.nasa.gov/atm/rst97). Moreover, the surface elevations and location of objects have been compared by aerial photogrammetry over Ocean City (Csatho et al., 1998, Schenk et al., 1999, both available on http://sheger.mps.ohio-state.edu/occi_dem.htm). These studies
confirm the 0.1-0.2 m vertical and submeter horizontal accuracy of the ATM system (e.g., Krabill et al., 2000).

3. Generation of Digital Elevation Models

The DEMs cover the southern 5 km of Ocean City and the northern 5 km of the Assateague Island (Figure 2). To create the DEMs, laser altimetry data from the missions listed in Table 1 were combined. At the heart of the interpolation procedure is a bilinear interpolation that determines the surface elevation at the grid posts from planes fitted through all points within the 2 m by 2 m grid cells. The search region was extended to a 2.5 m by 2.5 m area if not enough well distributed points were available in a grid cell. To describe the accuracy and reliability of the interpolated elevations each grid post is labeled accordingly. Grid cells are assigned to a specific category by a label grid (integer values) according to the list below. This assignment is based on the validity of the planar surface approximation and on the spatial distribution of the laser measurements within the grid cell. The residuals of the laser points after plane fitting determine the validity of the planar surface approximation. Nearest neighbor interpolation is used if the number of observations was not sufficient for plane fitting or if their distribution was not isotropic enough. Outlier observations were removed by using the Least Median of Squares (LmedS) technique (Köster and Spann, 2000).

The categories are the following:

- **PLANE IN 10** (label:0)
  Elevation is computed by plane fitting interpolation. Points are distributed in at least 3 quadrants. All residuals are less than 10 cm.

- **PLANE IN 30** (label:1)
  Elevation is computed by plane fitting interpolation. Points are distributed in at least 3 quadrants. All residuals are between 10 and 30 cm.

- **PLANE B IN 10** (label:2)
  Elevation is computed by plane fitting interpolation. Points are distributed in at least 3 quadrants. Blunders are detected and removed by using LmedS before plane fitting. All residuals (except the residuals of blunders) are less than 10 cm.

- **PLANE B IN 30** (label:3)
  Elevation is computed by plane fitting interpolation. Points are distributed in at least 3 quadrants. Blunders are detected and removed by using LmedS before plane fitting. All residuals (except the residuals of blunders) are between 10 and 30 cm.
• **PLANE TH** (label:4)
  Elevation is computed by plane fitting. Points are distributed in at least 3 quadrants. There is at least one observation with a residual larger than 30 cm.

• **NN IN** (label:5)
  Elevation is computed by using nearest neighbor interpolation. There are not enough observations for plane fitting (less than 6 points) or the distribution of points is not sufficient (points in one or two quadrants only). The distance between the grid post and its nearest neighboring point is smaller than 1/3 cell size (0.6 m).

• **NN DIST** (label:6)
  Elevation is computed by using nearest neighbor interpolation. There are not enough observations for plane fitting (less than 6 points) or the distribution of points is not sufficient (points in one or two quadrants only). The distance between the grid post and its nearest neighboring point is larger than 1/3 cell size.

• **NA** (label:7)
  Elevation cannot be computed. There are no points within the DEM cell.

• **NN OUTRANGE** (label:8)
  Elevation is computed by using nearest neighbor interpolation. Although the number of points and their distributions is sufficient, the estimated z values by the plane fitting is larger than the predefined Z range of [-50m, 50m]. These points are usually on object boundaries.

The DEMs are depicted as color-coded imagery in Figure 3.

4. **Evaluation of the DEMs**

The accuracy of the DEMs has been investigated by various methods. We created and compared DEMs from different laser altimetry missions (see list of missions used in Table 1) and we also compared the object boundaries (e.g., buildings) extracted from the DEM with those mapped by photogrammetry. The accuracy of the DEM is excellent on flat, horizontal or gently sloping, man-made surfaces, such as roads, parking lots and large building roofs. The elevation error is larger in areas containing residential buildings, where the 2 m grid cell size is too large to depict the details of the building and vegetation.

There are several important issues one should consider when using the DEMs for calibration. The surface erosion on the beach reaches 0.5 m/year in several places, so the calibration should not be performed on the beach. The surface depicted by the laser altimetry data includes
temporary objects, for example cars on the road. Surface changes, for example new buildings or demolished ones, may have occurred between the airborne laser altimetry missions resulting errors in the DEM.

5. Recommendations for future work

There are several possibilities to refine the calibration/validation of the Microaltimeter over the test sites. One such possibility is to improve the DEM by removing temporary objects, for example cars. We have tested a technique on a small site within Ocean City, but did not apply it for the whole area because the procedure is very time consuming.

To study the surface structure within the Microaltimeter footprints, surface points from the original, irregularly distributed ATM data sets can be extracted and analyzed for each Microaltimeter footprint and its neighborhood. To determine the type of objects and their detailed structure, the Microaltimeter laser footprints can be backprojected to the aerial images. This will allow to view the laser points stereoscopically for more detailed analysis.

References


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Table 2. ATM data sets used to create the DEMs

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Figure 2. DEMs created for Microaltimeter calibration; Ocean City south (dashed box) and Assateague Island north (solid box)
Figure 3. Color-coded laser altimetry DEMs (blue: low elevation, red: high elevation, black: no data); Ocean City south DEM (left) and Assateague Island north DEM (right)

Data files on http://sheger.mps.ohio-state.edu/oc_city/occi_dem.htm

1. Ascii point files
Each grid post has one ascii record, which contains latitude, longitude, UTM X, UTM Y, elevation and label. Please note that the original DEM grids are compiled in local projection systems oriented along the islands. Therefore the points form regular grids with 2 meter grid cells that are rotated relative to the UTM coordinate system. The same points in geographic system do not form regular grids because of the projection distortions.
Files: oc_city_points.asc and as_island_points.asc
Format: latitude and longitude in decimal degree, UTM X and Y in meter (zone 18), elevation in meter on WGS-84 ellipsoid (no_data_value is 9999), label describing accuracy (see Section 2 for explanation on labels).

2. Ascii grid files
2.1 Grid in a local coordinate system
These grids are in a local coordinate system oriented along the islands. Elevation is given on WGS-84 ellipsoid and the cell size is 2 m by 2 m.
Files: oc_dem_local_grid, as_dem_local_grid, oc_label_local_grid and as_label_local_grid
2.2 Grids in a geographic system

The grids computed in local systems are re-gridded in geographic system providing an easy way to visualize and analyze the surface. The new DEMs are oriented NS in geographic system and the cell size is 0.00002 degree. These data sets are slightly less accurate than the point data set in #1 because of the re-gridding.

Files: oc_city_grid.asc and as_island_grid.asc

Format:

Number of columns
Number of rows
Longitude of lower left corner in decimal degree (E)
Latitude of lower left corner in decimal degree (N)
Cell size in decimal degree
No_data_value
1st row of DEM, elevation on WGS-84 ellipsoid
2nd row of DEM
.
last row of DEM

Header of as_island_grid.asc
ncols 1462
nrows 2162
xllcorner –75.1216
yllcorner 38.2840
cellsize 0.00002
nodata_value 999.00

Header of oc_city_grid.asc
ncols 1722
nrows 2341
xllcorner –75.0968
yllcorner 32.36
cellsize 0.00002
nodata_value 999.00
IDL, Fortran and C programs used for data conversion

i. Geographic to UTM conversion: geo2utm.f and convgeoutm.pro

ii. UTM to geographic conversion: utm2geo.c

Table 1 Corner coordinates of the DEM’s

a) Ocean City south DEM

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Table 2. ATM data sets used to create the DEMs

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