Geographical Database Integrity Validation

ODURF Project # 193711

NASA NAG-1-2199

August 24, 2000

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Introduction

Background

Airport Safety Modeling Data (ASMD) was developed at the request of a 1997 White House Conference on Aviation Safety and Security. Politicians, military personnel, commercial aircraft manufacturers and the airline industry attended the conference. The objective of the conference was to study the airline industry and make recommendations to improve safety and security. One of the topics discussed at the conference was the loss of situational awareness by aircraft pilots.

Loss of situational awareness occurs when a pilot loses his geographic position during flight and can result in crashes into terrain and obstacles. It was recognized at the conference that aviation safety could be improved by reducing the loss of situational awareness. The conference advised that a system be placed in the airplane cockpit that would provide pilots with a visual representation of the terrain around airports. The system would prevent airline crashes during times of inclement weather and loss of situational awareness.

The system must be based on accurate data that represents terrain around airports. The Department of Defense and the National Imagery and Mapping Agency (NIMA) released ASMD to be used for the development of a visual system for aircraft pilots. ASMD was constructed from NIMA digital terrain elevation data (DTED).
Purpose

The purpose of this report is to determine the accuracy of ASMD, to support the goal of the national aviation program and to increase safety and security around airports. An aspect of the aviation safety program is to provide commercial aircraft pilots with a real time visual system that displays the airspace of terrain impacted (surrounded by hazardous geographical landforms such as mountains) airports. Pilots would utilize the system during times of inclement weather when they are unsure of their geographical location.
Objectives

The objective of this report is to determine the accuracy of the ASMD. This report has three primary goals: identify a database to be used as a benchmark for comparison to the ASMD, develop a methodology to determine the accuracy of the ASMD and formulate information extraction techniques to reduce the amount of data utilized during the study. The secondary goal of this report is to determine other airports that should be included in the study of ASMD accuracy.

Benchmark Database

A literature review was conducted to find a database that can be used as a benchmark (accepted true value). The ideal benchmark database will have a scope that covers the continuous United States including Alaska and Hawaii. The data density of the benchmark database should be higher than the data density of the ASMD. The data density is referred to as the number of elevations over a geographic region. The United States Geologic Survey (USGS) was chosen as the benchmark database.

Error Measurement

This project developed a method to measure the error in the ASMD. An error matrix was acquired by taking the difference of the ASMD and the benchmark database. A technique was developed to measure the error matrix of the databases since these two databases have different data densities and reference points.

Using tradeoffs in sample size and data density, a comparative of average error was developed using the two databases. A statistical analysis of the error was made and
conclusions were drawn from the information. Histograms were created to visually display the ASMD error of the airports.

**Data Reduction**

Methods were developed to reduce the amount of data used in the study. The principles of data mining were applied to the data to extract useful information. Algorithms and neural networks were utilized during the development of data reduction techniques. Other areas of study include accuracy requirements for the visual display, resolution with respect to sample size for the visual display and alternative methods for measuring accuracy.
Databases

The ASMD database is the source data that was used to develop the real time visual system for commercial aircraft pilots. The derivation and format of the ASMD database and the benchmark database must be understood before a methodology can be developed to make error measurements. Data accuracy and data availability are criteria that must be taken into consideration during the selection of a benchmark database. Both criteria are reviewed in this report.

ASMD

ASMD data was developed for use as the source data of a real time visual system for commercial aircraft pilots. ASMD was synthesized from DTED1 data and contains data for one hundred fourteen terrain-impacted airports in the United States.

ASMD contains data in two categories: ASM12 and ASM100. ASM12 contains data within a six mile radius of the airport reference point (ARP) while ASM100 contains data within a fifty mile radius (one hundred mile diameter) of the ARP. The ARP is the geographic center of an airport’s runways. This radius is illustrated in Figure 1.
Figure 1 Airport Reference Point

The scope of this report is to analyze the data within a thirty mile radius of the ARP. Since the ASM12 data file does not cover the entire geographic area, it was excluded from this report and the ASM100 data file was utilized for each airport analyzed in this study. For the purpose of clarity whenever ASMD is used in this report the author is referring to the ASM100 data file.

Each ASMD data file is representative of a one degree by one degree quadrangle. The data file for each airport contains more than two hundred thousand (200,000) cells. Each cell is representative of a fifteen arc second by fifteen arc second (15" x 15") geographic area. The cells are arranged in ascending order from the southwestern most cell to the northeastern most cell. Figure 2 describes the structure of an ASMD file. Each data file has exactly four hundred rows and more than five hundred columns.
Each cell in the ASMD data file contains a latitudinal coordinate, longitudinal coordinate and an elevation. The latitudinal and longitudinal coordinate determines the geographic location of the cell. The elevation is the approximate vertical elevation of the cell and is given in meters.

It is essential to understand how the approximate vertical elevation of the cell was derived from DTED data since the approximation of vertical elevation is the primary source of error in the ASMD database. The elevation for each cell in the ASMD data file is actually the maximum elevation of the thirty-six elevation posts located within the cell.

**Figure 3** describes the structure of an ASMD cell.
The thirty-six elevations are DTED1 data and are organized in three arc second (3") intervals. One of the elevations in the ASMD cell is recorded as the elevation for the cell and the other thirty-five cells are discarded. One arc second is equivalent to thirty meters. The fifteen arc second by fifteen arc second cell is equivalent to two hundred two thousand five hundred square meters (202,500 m²). The ASMD data file contains only one elevation measurement for the entire 202,500 m² area.

The goal of this study is to determine how much error is associated with these approximations and to determine if the ASMD data file is suitable for basing a real time visual system for aircraft pilots.

Data Accuracy

The purpose of this report is to determine the suitability and accuracy of the ASMD database for use as the source data for a real time visual system for aircraft pilots. The elevations in the ASMD database represent only terrain elevations, they do not contain any obstacle elevations. The vertical datum for elevation in the ASMD data is
mean sea level. The horizontal datum for ASMD data is the World Geodetic System (WGS) of 1984. The elevations do not necessarily represent the elevation at its exact horizontal position. The elevations represent an interpolated value of the surrounding terrain within the cell (ASMD CD-ROM handout).

The horizontal accuracy of the ASMD data is fifty meters. Ninety percent (90%) of the elevations are within fifty meters of its actual horizontal geographical position. The vertical accuracy of the ASMD data is thirty meters. Ninety percent (90%) of the elevations are within thirty meters of its actual elevation.

**Data Availability**

NASA Langley Research Center supplied the ASMD data on a CD-ROM. The Department of Defense and NIMA developed the CD-ROM. The data was synthesized from DTED1 data.

The CD-ROM contains data from one hundred twenty five airports in the United States. The data is in ASCII format. **Appendix 1** contains a listing of the header of the ASM100 file for the Denver International Airport. The CD-ROM contains a text file that describes the derivation and organization of ASMD data.

**USGS**

After an extensive literature review it was determined that a United States Geologic Survey (USGS) Digital Elevation Model (DEM) would be utilized as the benchmark database. The USGS DEM is widely accepted as the most accurate and comprehensive geological survey of terrain in the United States. The USGS has been designated as a lead federal agency for the collection of digital cartographic data.
(Standards for Digital Elevation Models). It will be explained later in this section why the USGS was selected as the benchmark database.

DEM data consist of a sampled array of regularly spaced elevation values referenced horizontally either to a Universal Transverse Mercator (UTM) or a geographic coordinate system (USGS Fact Sheet 102-96, April 1998). The grid cells within a DEM are spaced at regular intervals dependent upon latitude along south to north columns and than from west to east rows (Fact Sheet 102-96). The USGS uses four methods to collect DEM data: interpolations from vectors or digital line graph hypsographic and hydrographic data, the Gestalt Photo Mapper II, manual profiling from photogrammetric stereomodels and interpolation of the elevations from stereomodel digitized contours (Fact Sheet 102-96). Only the first method is used today, the other three methods have been discontinued or deactivated.

The USGS produces five types of DEM data. They are listed in Table 1 along with coverage and spacing information. The 7.5 minute DEM will be used as the benchmark database because of its high data density and coverage of the entire United States. Data density is referred to as the number of elevation posts per geographic region. The 7.5 minute DEM has a higher data density than the other DEMs in Table 1. It also covers the entire geographic area within the scope of this study.

<table>
<thead>
<tr>
<th>DEM Type</th>
<th>Coverage</th>
<th>Interval Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5 minute</td>
<td>Contiguous United States, Hawaii and Puerto Rico</td>
<td>1 arc second by 1 arc second</td>
</tr>
<tr>
<td>30 minute</td>
<td>Contiguous United States and Hawaii</td>
<td>2 arc second by 2 arc second</td>
</tr>
<tr>
<td>1 degree</td>
<td>Contiguous United States</td>
<td>3 arc second by 3 arc second</td>
</tr>
<tr>
<td>7.5 minute Alaska</td>
<td>Alaska</td>
<td>Dependent upon latitude; 1 arc second (lat) by 2 arc second (long)</td>
</tr>
<tr>
<td>15 minute Alaska</td>
<td>Alaska</td>
<td>2 arc second (lat) by 3 arc second (long)</td>
</tr>
</tbody>
</table>

Table 1 USGS DEMs
The 7.5 minute DEM covers a 7.5 minute by 7.5 minute geographic region. The DEM corresponds to the 1:24000 and 1:25000 scale topographic quadrangle map. The 7.5 minute DEM is cast on the UTM. **Figure 4** is an illustration of the structure for a typical 7.5 minute DEM. **Figure 4** was reproduced *from Standards for Digital Elevation Models*. The elevations are organized from south to north in columns and then west to east along rows.

The data is organized at thirty-meter intervals between elevations. Some areas within the contiguous United States have ten-meter interval spacing. We will only use the thirty-meter interval spacing for consistency. Some airports only have interval spacing of thirty meters.

**Data Accuracy**

The elevations in a 7.5 minute DEM have units of feet or meters. The DEMs are cast on the UTM of the North American Datum (NAD) of 1927 or NAD 83 (Fact Sheet 102-96). The vertical elevations are referenced to the National Geodetic Vertical Datum of 1929.
Figure 4 7.5 minute DEM

Root Mean Square Error (RMSE) is the criteria used to determine DEM accuracy. RMSE is calculated by comparing linearly interpolated elevations in a DEM with corresponding known elevations and computing the associated statistical standard deviation. For a 7.5 minute DEM derived from a photogrammetric source, ninety percent must have a RMSE of seven meters or better and ten percent are in the eight to fifteen meter range (Fact Sheet 102-96). The horizontal accuracy of a 7.5 minute DEM requires that ninety percent of all points tested must be accurate within $1/50^{th}$ of an inch (.005 centimeters) on a map, which corresponds to forty feet (12.2 meters) at 1:24000 scale

Data Availability

7.5 minute DEM data can be obtained by either purchasing it directly from the USGS or downloading it from the Internet. All of the 7.5 minute DEMs used in this
report were downloaded from the Internet. **Figure 5** is a flowchart of the process used to download the 7.5 minute DEMs in this report.

![Flowchart of the process used to download the 7.5 minute DEMs](image)

**Figure 5 USGS Acquisition Process**

While downloading the data care should be taken to ensure that the file extension 
".tar.gz" is maintained. Netscape Navigator and Microsoft Internet Explorer attempt to replace the ".tar.gz" file extension with the ".tar.gz" file extension. If the files are improperly renamed it will cause problems when the files are decompressed with WinZip.

The original format of the data after decompression is the Spatial Data Transfer Standard (SDTS). The DEM must be converted into ASCII format by using MICRODEM. When the DEM is being converted from SDTS format to ASCII format use the lat/long geographical system in MICRODEM to ensure the consistency of the
data file. The entire process of downloading DEMs from the Internet should be repeated until there are a sufficient number of DEMs to cover a thirty-mile radius from the ARP.
Methodology

Table 2 compares the cell size, units, horizontal datum and vertical datum for the ASMD data and the 7.5 minute USGS DEM. It is not possible to determine the error in the ASMD data by taking the algebraic difference of the two databases because they have different cell sizes and datum. A methodology was developed that does not require the two databases to have the same cell size or datum.

<table>
<thead>
<tr>
<th>Database</th>
<th>Cell Size</th>
<th>Units</th>
<th>Horizontal Datum</th>
<th>Vertical Datum</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASMD</td>
<td>15&quot; by 15&quot;</td>
<td>Meters</td>
<td>WGS 1894</td>
<td>mean sea level</td>
</tr>
<tr>
<td>7.5 minute DEM</td>
<td>30 m by 30 m</td>
<td>Feet or meters</td>
<td>UTM of NAD 1927 or NAD 1983</td>
<td>NGVD 1929</td>
</tr>
</tbody>
</table>

Table 2 ASMD and USGS Comparison

The methodology used to determine the error in ASMD data builds upon how the ASMD data was derived. The elevations in ASMD data are associated with fifteen arc second cells. The elevation of each cell is the maximum of thirty six sampled elevations located in the cell. The methodology in this paper uses the same ASMD cell but samples two hundred fifty six elevations located in the cell to determine the cell elevation. The two hundred fifty six elevations will come from the USGS 7.5 minute DEM. The basis of the methodology is that two hundred fifty six elevations are more likely to find the maximum elevation in a cell then thirty six elevations. Figure 6 is a flowchart of the methodology.
The first step in the methodology requires that you determine the ARP of the airport. The ARP is located in the ASMD data file. All coordinates in the ASMD data file are listed in degrees minutes seconds format (DDMMSS). The coordinates are converted to degrees format (DD.DDDD) so that they will be consistent with the format of coordinates in the USGS data file.

After the ARP is determined the region of interest (ROI) is calculated. The ROI is defined as the geographic area within thirty miles (.44706 degrees) of the ARP. Theoretically, the ROI is a circle with a thirty mile radius with the ARP located in the center. Due to computational concerns the actual ROI in this study is a square with sixty mile sides as described in Figure 7. This modification reduces computation time and increases the ROI. The modification will not affect the results because it does not reduce the number of ASMD cells that will be analyzed.
After the ROI has been defined all of the ASMD cells within the ROI must be analyzed. The cells are analyzed sequentially starting from the southwestern most corner of the ROI and ending at the northeastern most corner of the ROI. Each cell is analyzed by finding all of the USGS elevations that are located within the ASMD cell. Approximately two hundred fifty six USGS elevations will be located for each ASMD elevation. Figure 8 describes the location of ASMD and USGS elevations in an ASMD cell.

After the USGS elevations have been located they will be scanned to determine the maximum USGS elevation for the ASMD cell. If the ASMD cell does not contain any error, the elevation in the ASMD data file will be identical to the maximum USGS
elevation. **Equation 1** defines the error in the ASMD cell by taking the difference between the ASMD elevation and the maximum USGS elevation.

\[
ASMD_{\text{error}} = USGS_{\text{Max elevation}} - ASMD_{\text{elevation}}
\]

**Equation 1 ASMD Error**

After the ASMD error is calculated it is stored in an error matrix. Each ASMD cell will have an error associated with the cell. After the error has been stored, it is determined if all the cells in the ROI have been analyzed. If all of the cells have not been analyzed the next sequential ASMD cell in the ROI is analyzed. If all of the cells in the ROI have been analyzed the methodology has been completed and a statistical analysis of the error matrix can be performed.

![Figure 8 ASMD & USGS elevations](Image)

**Buffer**

The methodology must be modified to correct for the fifty meter horizontal accuracy of the ASMD cell. The instrumentation that collected the data could possibly
include an elevation within the fifty meter buffer of the cell as being within the cell. The fifty meter horizontal accuracy means that the geographical area within fifty meters of the ASMD cell boundary may contain the elevation (See Figure 9).

![50 m Buffer Area](image)
![15" x 15" Cell](image)

**Figure 9 Modified ASMD Cell**

The entire ASMD cell must be changed to correct for the horizontal accuracy. The dimensions of the modified ASMD cell are eighteen and one third arc second by eighteen and one third arc second \((15" + (50+50)/30 = 18.333")\). Due to the correction of the buffer each ASMD cell will actually have more than two hundred fifty six USGS elevations associated with the cell. The boundary of the ROI must be increased by fifty meters to account for the horizontal accuracy.

**Datum Shift**

The methodology developed in this paper cannot be applied to the data without correcting the datum shift. Table 2 showed that the horizontal datum for the ASMD database is the World Geodetic System of 1984 and the horizontal datum for the 7.5
minute DEM is the North American Datum of 1927. Since the databases have different horizontal datum, coordinates in one database do not correspond to the exact same coordinates in the other database.

The horizontal datum establishes the reference point from where the coordinates are projected. **Figure 10** is a .gif image taken from URL http://www.wgs84.com/wgs84/wgs84.htm. Latitudinal and longitudinal coordinates are relative to the horizontal datum from which they are projected. The latitudinal and longitudinal coordinates for a geographic region in the ASMD database will correspond to a different geographic region in the USGS database because of the difference in the horizontal datum. The datum shift could result in an elevation in the ASMD database being several arc seconds away from the corresponding elevation in the USGS database.

![Diagram showing local and global reference frames](image)

**Figure 10 Datum Shift**

The datum shift was corrected by modifying the coordinates of the USGS 7.5 minute DEM. The USGS coordinates have a higher accuracy and were projected into the ASMD coordinates to reduce error propagation. The correction for the datum shift was based on the ARP. MICRODEM software was used to determine the equivalent USGS
coordinates for the ASMD ARP. The latitudinal and longitudinal adjustments are then used to correct the coordinates for the entire USGS data file.
Results

The methodology presented in this report was implemented by writing a computer program using Microsoft Visual Basic 6.0. Appendix 2 is a printout of the computer program. Data was collected and analyzed for five airports. Table 3 lists the five airports and their ARP. Latitudinal and longitudinal coordinates are relative to the horizontal datum of WGS 84. The airports are located on the West Coast, East Coast and Midwest of the United States.

<table>
<thead>
<tr>
<th>Airport Name</th>
<th>State</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scappoose Industrial Air Park</td>
<td>Oregon</td>
<td>N45 46 21.0</td>
<td>W122 51 44.4</td>
</tr>
<tr>
<td>Denver International Airport</td>
<td>Colorado</td>
<td>N39 51 30.2</td>
<td>W104 40 01.2</td>
</tr>
<tr>
<td>Delta Municipal Airport</td>
<td>Utah</td>
<td>N39 22 59.8</td>
<td>W112 30 34.8</td>
</tr>
<tr>
<td>Asheville Regional Airport</td>
<td>North Carolina</td>
<td>N35 26 10.3</td>
<td>W082 32 30.5</td>
</tr>
<tr>
<td>McClellan-Palomar Airport</td>
<td>California</td>
<td>N33 07 41.6</td>
<td>W117 16 48.8</td>
</tr>
</tbody>
</table>

Table 3 ASMD Airports

Background

The program computed and stored the ASMD error, the maximum USGS elevation for each cell, and the number of USGS posts located in each cell for the five airports listed in Table 3. Microsoft Excel was used to calculate statistics from the stored data and develop a histogram for the ASMD airports. Modifications were made during the analysis that affected the computation of the statistics.

Some cells located in the ROI had less than two hundred USGS posts located inside of it. Each cell located in the ROI should contain at least two hundred fifty six USGS posts. If a cell had less than two hundred USGS posts it was discarded from the calculations because it had insufficient data. The cell may have had insufficient data because of collection techniques, bordering, the curvature of the earth and buffering.
Since some cells located within the ROI were discarded from the analysis it affected the derivation and computation of the statistics. The cells located in the ROI with more than two hundred USGS posts will be referred to as qualified cells.

**Statistics**

The average ASMD elevation in the ROI was calculated by determining the average of all the elevations located in the ROI. The ASMD error is calculated by subtracting the ASMD elevation from the maximum USGS elevation for each qualified cell. ASMD error was not calculated for non-qualified cells. The average ASMD error was calculated by taking the average of the ASMD errors for each airport.

The USGS elevation was calculated by taking the maximum of the USGS posts for each qualified cell. The USGS elevation was not stored for non-qualified cells. The average USGS elevation was calculated by taking the average of the USGS elevation for each airport. Due to the existence of non-qualified cells the average ASMD error is not necessarily equal to the difference of the average ASMD elevation and the average USGS elevation.

**Tables 4-8** list the statistics for the five ASMD airports. The ASMD error, maximum USGS elevation and the number of USGS posts for each qualified cell are displayed (All calculated by computer program). The average, standard deviation, maximum, minimum, median and mode were calculated using Microsoft Excel.

**Figures 11-15** are histograms for the airports.
The average ASMD elevation in the ROI at Scappoose airport was two hundred twenty six meters (225.83 m). The average USGS elevation in the ROI was two hundred thirty eight meters (237.56 m). The range of the USGS elevations was from one thousand three hundred sixty three meters to zero meters. The ASMD error was twelve meters (11.73 m). Figure 11 is a histogram of the ASMD error for Scappoose airport.
Table 5 Denver Airport

The average ASMD elevation in the ROI at Denver airport was one thousand six hundred thirty meters (1629.9 m). The average USGS elevation in the ROI was one thousand six hundred forty three meters (1642.9 m). The range of the USGS elevations was from two thousand two hundred eighty three meters to one thousand three hundred fifty three meters. The ASMD error was six meters (6.34 m). Figure 12 is a histogram of the ASMD error for Denver airport.

<table>
<thead>
<tr>
<th>asmderror</th>
<th>usgselev</th>
<th>USGS posts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>6.34</td>
<td>1642.91</td>
</tr>
<tr>
<td>Std</td>
<td>10.26</td>
<td>149.20</td>
</tr>
<tr>
<td>max</td>
<td>115</td>
<td>2283</td>
</tr>
<tr>
<td>min</td>
<td>-43</td>
<td>1353</td>
</tr>
<tr>
<td>median</td>
<td>5</td>
<td>1620</td>
</tr>
<tr>
<td>mode</td>
<td>3</td>
<td>1679</td>
</tr>
</tbody>
</table>

Figure 12 Denver Histogram
The average ASMD elevation in the ROI at Delta Municipal airport was one thousand five hundred ninety meters (1589.86 m). The average USGS elevation in the ROI was one thousand six hundred one meters (1600.62 m). The range of the USGS elevations was from three thousand eighty three meters to one thousand three hundred eighty meters. The ASMD error was sixteen meters (16.31 m). Figure 13 is a histogram of the ASMD error for Delta Municipal airport.

![Delta Municipal Histogram](image)

**Table 6 Delta Municipal Airport**

<table>
<thead>
<tr>
<th></th>
<th>asmderror</th>
<th>Usgselev</th>
<th>USGS posts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>16.31</td>
<td>1600.62</td>
<td>275.67</td>
</tr>
<tr>
<td>Std</td>
<td>28.34</td>
<td>303.01</td>
<td>8.00</td>
</tr>
<tr>
<td>max</td>
<td>342</td>
<td>3083</td>
<td>285</td>
</tr>
<tr>
<td>min</td>
<td>-49</td>
<td>1380</td>
<td>201</td>
</tr>
<tr>
<td>median</td>
<td>7</td>
<td>1464</td>
<td>276</td>
</tr>
<tr>
<td>mode</td>
<td>-1</td>
<td>1392</td>
<td>285</td>
</tr>
</tbody>
</table>

**Figure 13 Delta Municipal Histogram**
The average ASMD elevation in the ROI at Asheville Regional airport was eight hundred six meters (805.67 m). The average USGS elevation in the ROI was eight hundred forty four meters (843.56 m). The range of the USGS elevations was from two thousand twenty nine meters to two hundred fifty seven meters. The ASMD error was forty three meters (42.91 m). **Figure 14** is a histogram of the ASMD error for Asheville Regional airport.

![Histogram](image-url)
Table 8 McClellan Airport

The average ASMD elevation in the ROI at McClellan-Palomar airport was two hundred thirty three meters (232.67 m). The average USGS elevation in the ROI was three hundred thirty nine meters (339.39 m). The range of the USGS elevations was from one thousand eight hundred seventy three meters to zero meters. The ASMD error was thirty meters (30.07 m). Figure 15 is a histogram of the ASMD error for McClellan-Palomar airport.

Figure 15 McClellan Histogram
Discussion

This section analyzes the ASMD error results. The Asheville histogram (See Figure 14) appeared to have several spikes imposed over a normal distribution. Upon review it was noticed that the spikes occurred every second or third bin and were caused by the way Microsoft Excel calculated the number of whole numbers in each bin (See Table 9). If Microsoft Excel had calculated bin widths so that each bin would have the same number of whole numbers the spikes would have disappeared (See Figure 16).

<table>
<thead>
<tr>
<th>Bin</th>
<th>Frequency</th>
<th>Whole Numbers Included in Bin</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.77</td>
<td>599</td>
<td>4</td>
</tr>
<tr>
<td>6.18</td>
<td>1763</td>
<td>5, 6</td>
</tr>
<tr>
<td>7.59</td>
<td>882</td>
<td>7</td>
</tr>
<tr>
<td>9.00</td>
<td>2094</td>
<td>8, 9</td>
</tr>
<tr>
<td>10.41</td>
<td>1180</td>
<td>10</td>
</tr>
<tr>
<td>11.82</td>
<td>1063</td>
<td>11</td>
</tr>
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<td>13.23</td>
<td>1923</td>
<td>12, 13</td>
</tr>
<tr>
<td>14.64</td>
<td>826</td>
<td>14</td>
</tr>
<tr>
<td>16.05</td>
<td>1494</td>
<td>15, 16</td>
</tr>
<tr>
<td>17.45</td>
<td>567</td>
<td>17</td>
</tr>
<tr>
<td>18.86</td>
<td>550</td>
<td>18</td>
</tr>
<tr>
<td>20.27</td>
<td>1055</td>
<td>19, 20</td>
</tr>
<tr>
<td>21.68</td>
<td>478</td>
<td>21</td>
</tr>
<tr>
<td>23.09</td>
<td>879</td>
<td>22, 23</td>
</tr>
<tr>
<td>24.50</td>
<td>433</td>
<td>24</td>
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<td>25.91</td>
<td>404</td>
<td>25</td>
</tr>
<tr>
<td>27.32</td>
<td>817</td>
<td>26, 27</td>
</tr>
<tr>
<td>28.73</td>
<td>375</td>
<td>28</td>
</tr>
</tbody>
</table>

Table 9 Asheville Bin Width

The histogram for the McClellan airport (See Figure 15) had an unusually large spike. The spike can easily be explained by investigating the geography of the airport. Almost thirty percent of the McClellan airports ROI contained the Pacific Ocean. The
ASMD error for a cell located in the Pacific Ocean is zero. The bin with the large spike contained zero for its ASMD error.

The average ASMD error for all five airports is positive. The author anticipated these results because the 7.5 minute DEM sampled more elevations in the cell than the ASMD. The larger the number of samples in the cell the more likely you are to obtain the maximum.

Figure 16 Modified Asheville Histogram
Summary

The three objectives of this report were accomplished. The USGS was utilized as the benchmark database. A methodology to measure error was developed and implemented by writing a computer program. Data reduction was achieved through the use of descriptive statistics.

Five airports were investigated during the study. The average ASMD error ranged from six meters (Denver) to forty-three meters (Asheville). The publishers of ASMD claimed that ninety percent of the elevations are within thirty meters of the actual elevation. Four of the five investigated airports had average errors that were less than thirty meters. More airports need to be studied before I can accept or reject the publisher’s claim of ninety percent of the elevations falling within thirty meters of the actual elevation.

Recommendations for future work include using hypothesis testing. The publishers claim could be used as the null hypothesis. The number of airports could be increased to include a more representative sample of the terrain impacted airports. Percentiles of the ASMD error could be developed to enhance the understanding of the data.

The primary limitation of this report is that it only analyzed the qualified ASMD cells located in the ROI. An area of future work would include developing a methodology to measure the error in the non-qualified ASMD cells. This report only analyzed the ASMD cells that had at least two hundred USGS elevations. If the non-qualified cells could be studied the entire region of interest could be analyzed.
References


World Geodetic System (WGS 84), downloaded 2000, April 13, WGS 84 - Background, URL http://www.wgs84.com/wgs84/wgs84.htm.

United States Geologic Survey (USGS), downloaded 1999, June 7, Readme File for 7.5 minute DEM, updated 5-22-98, URL http://edcftp.cr.usgs.gov/pub/data/DEM/7.5min/00README

USGS, downloaded 1999, February 26, GCMD Data Set Description, URL http://gcmd.gsfc.nasa.gov/cgi-bin/...t=FGDC&entry=USGS_dem&form-gliswww


Appendix 1  ASM100 Header
Header File Version 2.0
Product = Airport Safety Model (ASM)
Creation Date = 1998149 05/29/1998
Produced by = Office of Aeronautical Charting and Cartography, U.S. Government

SITE ID = DEN
Model Type = ASM100
Site Number = 02573.000*A
Airport Name = DENVER INTL
City = DENVER
State = CO
Country = US
ARP Latitude = N39 51 30.2
ARP Longitude = W104 40 01.2
Northern Model Boundary = N40 41 45
Southern Model Boundary = N39 01 15
Eastern Model Boundary = W103 34 00
Western Model Boundary = W105 46 00
Degree Blocks North-South = 2
Degree Blocks East-West = 3
Bin Rows = 402
Bin Columns = 528
Bin Resolution in seconds North-South = 15
Bin Resolution in seconds East-West = 15
Maximum Model Elevation in meters = 4344
Minimum Model Elevation in meters = 1269

Source Data = DTED-1
Source Data Code = A1
Source Data Horizontal Datum = WGS84
Source Data Vertical Datum = MSL
Source Data Horizontal Accuracy Objective = +- 50 Meters at 90% CE
Source Data Vertical Accuracy Objective = +- 30 Meters at 90% LE

// Note: Accuracy statements of DTED source data are provided by the National Imagery and Mapping Agency (NIMA), which specifies that such statements are individually calculated for every product, and provided in the Accuracy Header Record of those products. Concerning the Airport Safety Model (ASM), which is based on this data, no greater accuracy is implied or should be assumed.

Source Data = Not Available
Source Data Code = NA
// Note: Default elevation = -999 when source data is unavailable.

File Structure:

<table>
<thead>
<tr>
<th>Field Name</th>
<th>Format</th>
<th>Bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field 1: Meters above\below Mean Sea Level</td>
<td>NNNN</td>
<td>4</td>
</tr>
<tr>
<td>Field 2: Latitude</td>
<td>ANNNNNN</td>
<td>7</td>
</tr>
<tr>
<td>Field 3: Longitude</td>
<td>ANNNNNNN</td>
<td>8</td>
</tr>
<tr>
<td>Field 4: Data Source Code</td>
<td>AA</td>
<td>2</td>
</tr>
</tbody>
</table>
Field 5: End-of-Line 0D0A[Hex] 2
// Note: Each record corresponds to a different model bin. Bin records are
// listed from south to north, starting at the western edge of the model and
// proceeding east. Delimiters (AAAA NNNNA) are placed at the start of each
// column.
//
#EOH
Column 0001:
2685N390127W1054600A1
2687N390139W1054545A1
Appendix 2  Computer Program Printout
Private TextLine As String, t2 As String, t3 As String, t4 As String, i As Integer, elev As Long, usgspts As Long, lat(10500000) As Single, lng(10500000) As Single, elv(10500000) As Single, dling As Single, asmdelev(70000) As Single, 1atl(10500000) As Single, lng(10500000) As Single, 1atl(10500000) As Integer, 1atl(10500000) As Single, ely(10500000) As Single, dlng As Single, asmdlat(70000) As Single, asmdelev(70000) As Single, asmdlong(70000) As Single, asmderror(70000) As Single
Public number As Long, duration As Date, j As Integer, jj As Long, nlat As Single, slat As Single, elong As Single, wlong As Single, ROI As Single, q As Long, datafile As String, ii As Long, nn As String
Private Sub cmdstart_Click()
openasmd
ROIboundary
openheader
opendatafile
DoEvents
pbar.Max = Val(Right(Text7, 4))
openusgs
readasmd
Text6.Text = elev / number
Close #1
pbar.Visible = False
Rem nn = InputBox("How many cells do you wish to sample in the ROI do you wish to sample? ", "Sampling", number)
nn = number
If nn < number Then sample
If nn = number Then nosample
Close #3
TextLine = cdb.FileName 'airport name
' mean elevation
Text8 = DateDiff("s", duration, Now) 'time to read data
DoEvents
CmdUSGS.Visible = True
End Sub
Private Sub CmdUSGS_Click()
End
End Sub
Private Sub openasmd()
cdb.ShowOpen
CmdStart.Visible = False
j = 0
Open cdb.FileName For Input As #1
k = 0
elev = 0

40
Private Sub openheader()
    Dim x As Single
    duration = Now 'sets initial time
    Text8 = duration
    For i = 1 To 58
        Line Input #1, TextLine
        If i = 22 Then Text7 = TextLine '# of rows
        If i = 13 Then Text10 = Right(TextLine, 11) 'latitude arp
            x = convert(Text10, 10)
            Text12 = "N" & x
            nlat = x + ROI 'region of interest
            Text17 = "N" & nlat
            slat = x - ROI 'region of interest
            Text15 = "N" & slat
        If i = 14 Then Text11 = Right(TextLine, 12) 'longitude arp
            x = convert(Text11, 11)
            Text13 = "W" & x
           elong = x + ROI 'region of interest
            Text16 = "W" & elong
            wlong = x - ROI 'region of interest
            Text14 = "W" & wlong
        If i = 9 Then Text9 = Mid(TextLine, 16, 30) 'airport name
    Next i
End Sub

Private Sub readasm()
    Do While Not EOF(I)
        Line Input #1, TextLine
        t2 = Left(TextLine, 4) 'elevation
        If t2 = "Clmn" Then 'column check
            j = j + 1
            Text8 = DateDiff("s", duration, Now)
            DoEvents
        Else
            t3 = Mid(TextLine, 5, 7) 'latitude
            t3 = convert(t3, 6)
            If t3 > slat And t3 < nlat Then
                t4 = Mid(TextLine, 12, 8) 'longitude
                t4 = convert(t4, 7)
                If t4 > wlong And t4 < elong Then
                    number = number + 1 'Region of interest
        Next i
End Sub
Text18 = number
elev = elev + Val(t2)
asmdlat(number) = t3
asmdlong(number) = t4
asmdelev(number) = t2

End If
End If
End If

Loop
End Sub

Public Function convert(ByVal TI0, n) As Single
Dim dummy As String
Dim x As Single, y As Single, z As Single
dummy = Right(T10, n)
x = Val(dummy)
convert = Int(x / 10000)
y = Int((x - convert * 10000) / 100) / 60
z = (x - convert * 10000 - y * 6000)
convert = convert + y + z / 3600
convert = Int(convert * 10000 + 0.5) / 10000
End Function

Private Sub Form_Load()
MMControl1.Visible = False
End Sub

Public Sub findusgsdata()
Dim nbound As Single, sbound As Single, wbound As Single, ebound As Single,
maxpost As Single, zz As Integer
Rem radius is .0020833 and buffer is .0004629
nbound = t3 + 0.0025462
sbound = t3 - 0.0025462
wbound = t4 + 0.0025462
ebound = t4 - 0.0025462
maxpost = -100000
zz = 0
For jj = 1 To usgspts
Input #2, dlng, ddd, eelv
If ddd < nlat Then
  If ddd > sldlat Then
    If -dlng > wdlong Then
      If -dlng < edlong Then
        usgspts = usgspts + 1
        lng(usgspts) = -dlng + 0.0008 'datum adjustment
        lat(usgspts) = ddd - 0.0001 'datum adjustment
        elv(usgspts) = eelv
      End If
    End If
  End If
End If
End If
End If
Loop
Close #2
Text19 = usgspts
t27 = 0
t28 = 230
t24 = 0
t25 = 250
For ii = 1 To 20
  Beep
Next ii
For ii = 1 To usgspts
  If lng(ii) < t28 Then t28 = lng(ii)
  If lng(ii) > t27 Then t27 = lng(ii)
  If lat(ii) > t24 Then t24 = lat(ii)
  If lat(ii) < t25 Then t25 = lat(ii)
Next ii
Text24 = t24
Text25 = t25
Text27 = t27
Text28 = t28
Text23 = eelv(Int(usgspts / 2))
DoEvents
End Sub

Public Sub ROIboundary()
XROI = InputBox("What is the radius for the Region of Interest (ROI) for the ASMD", "ROI Radius", 0.44706)
ROI = CSng(XROI)
End Sub

Private Sub sample()
Dim z As Long

Text8 = DateDiff("s", duration, Now)
Write #3, "ASMD ROI average elevation is "; Text6
Write #3, "counter"; "asmdlat"; "asmdelev"; "asmdlong"; "asmdeleverror"; "usgselev";
"USGS posts", "ERROR"

For ii = 1 To nn 'sample n cells from a population of number cells
Randomize
Text21 = ii
z = number - ii + 1 'Upper bound of set, decrements each iteration
q = Int(z * Rnd + 1) 'Pick a random # from 1 to n-ii
t3 = asmdlat(q)
t4 = asmdlong(q)
elev = asmdelev(q)
findusgsdata

Rem swap selected cell out of set to ensure no duplication
asmdlat(q) = asmdlat(z)
asmdlong(q) = asmdlong(z)
asmdelev(q) = asmdelev(z)

DoEvents

Next ii
End Sub

Public Sub opendatafile()
datafile = InputBox("What name do you wish to use for an output file?", "Select Output
File", Text9)
datafile = "c:\" & datafile & ".dat"
Open datafile For Output As #3

Write #3, Text9

DoEvents
End Sub

Public Sub nosample()
Dim z As Long
Text8 = DateDiff("s", duration, Now)
Write #3, "ASMD ROI average elevation is "; Text6
Write #3, "counter"; "asmdlat"; "asmdlong"; "asmdelev"; "asmderror"; "usgselev"; "USGS posts"; "ERROR"

For ii = 1 To nn 'sample n cells from a population of number cells

Text21 = ii

q = ii
t3 = asmdlat(q)
t4 = asmdlong(q)
elev = asmdelev(q)
findusgsdata

DoEvents

Next ii
End Sub