DSM, DTM, and watershed characteristics in OpenTopography

J Ramón Arrowsmith
School of Earth and Space Exploration
Arizona State University

Christopher J. Crosby
UNAVCO

Tutorial notes
Applications of High Resolution Topography to Geologic Hazards in Utah
September, 2017, Salt Lake City, Utah

OpenTopography
High-Resolution Topography Data and Tools
Overview
Demonstrate the OpenToporaphy point cloud to raster workflow. Using predominantly the digital terrain model (“bare earth”) compute topographic metrics emphasizing the drainage network contributing area and topographic roughness using ArcGIS.

Outline
1. Short lecture on watersheds and flow related terrain information
2. Compute DSM and DTM on selected data in OpenTopography.
3. Select data and run DTM computations including using TAUDEM for watershed calculations in OpenTopography.
4. Compute topographic roughness in ArcMap
5. Manipulate and visualize drainage network in ArcMap and ArcScene
Watershed Delineation Using TauDEM

A tutorial for using TauDEM to delineate a single watershed
Representation of Flow Field

Steepest single direction

\[
\begin{array}{cc}
48 & 52 \\
56 & 67 \\
\end{array}
\]

\[
\frac{67 - 52}{30} = 0.50
\]

Table 2. Differences Between Theoretical and DEM-Computed Upslope Area for Test Examples Expressed in Terms of the Mean Error and Mean Square Error

<table>
<thead>
<tr>
<th>Method</th>
<th>Outward Cone</th>
<th></th>
<th>Inward Cone</th>
<th></th>
<th>Plane</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bias Mean (\bar{A} - \hat{A})</td>
<td>MSE Mean ((\bar{A} - \hat{A})^2)</td>
<td>Bias Mean (\bar{A} - \hat{A})</td>
<td>MSE Mean ((\bar{A} - \hat{A})^2)</td>
<td>Bias Mean (\bar{A} - \hat{A})</td>
<td>MSE Mean ((\bar{A} - \hat{A})^2)</td>
</tr>
<tr>
<td>D8</td>
<td>-0.13</td>
<td>2.13</td>
<td>1.76</td>
<td>118.88</td>
<td>-0.17</td>
<td>0.065</td>
</tr>
<tr>
<td>MS</td>
<td>-0.81</td>
<td>0.69</td>
<td>-1.07</td>
<td>5.70</td>
<td>-1.37</td>
<td>2.065</td>
</tr>
<tr>
<td>Lea's [1992] method</td>
<td>-1.29</td>
<td>2.41</td>
<td>-4.05</td>
<td>44.00</td>
<td>-2.57</td>
<td>7.912</td>
</tr>
<tr>
<td>DEMON</td>
<td>-0.37</td>
<td>0.17</td>
<td>-0.37</td>
<td>19.23</td>
<td>-0.40</td>
<td>0.161</td>
</tr>
<tr>
<td>D∞</td>
<td>-0.13</td>
<td>0.20</td>
<td>1.87</td>
<td>30.58</td>
<td>-0.17</td>
<td>0.065</td>
</tr>
</tbody>
</table>
Log in to OpenTopography with your email and password.

Username (Email) *
ramon.arrowsmith@asu.edu

Password *

Remember my login

LOG IN
Pick with mouse

**State of Utah Acquired Lidar Data - Wasatch Front**

**OpenTopography**
High-Resolution Topography Data and Tools

**Data Selection Coordinates:**
- Manually enter selection coordinates (in the horizontal coordinate system listed above)

- **Horizontal Coordinates:** UTM Zone 12N, NAD83 (2011) [EPSG: 26912]
- **Vertical Coordinates:** NAVD88 (GEOID12A) [EPSG: 5703]

- **Data Selection Coordinates:**
  - $X_{min} = 427611.125064$
  - $X_{max} = 429837.230033$
  - $Y_{min} = 4436738.937367$
  - $Y_{max} = 4437758.70923$

Choose Return Classification:
- Ground
- Unclassified

**All points**

**2. Point Cloud Data Download**
- Point cloud data in LAS format
- Point cloud data in LAZ format
- Point cloud data in ASCII format

**3. DEM Generation (Streaming TIN)**
- Grid Method
- Calculate TIN

- **Gridding Parameters**:
  - Grid Resolution (Default = 1 meter)
  - Max. triangle size (Default = 50 units)

- **Grid Format**
  - GeoTiff

**Compute 1m DSM with slope map, hillshades and kmz in OpenTopography**

**4. Derivative products**
- Generate hillshade and slope grids in grid format

**5. Visualization**
- Generate hillshade images from DEMs
- Generate additional color-relief and colored hillshades
- Generate additional Google Earth KMZ files

Description:
- Options allow users to describe and keep track of their jobs. Information entered below is recorded along with other job parameters. In your personal lidar job list, you can access via the OpenTopography (available only to registered OpenTopography users).

Altitude of the light, (in degrees) 45
Azimuth of the light, (in degrees) 315

Meaningful name and submit

Click for KMZ
Modify and resubmit: just a couple of changes for the DTM and tauDEM; can also find it in MyOpenTopo

1. Coordinates & Classification

Horizontal Coordinates: UTM Zone 12N, NAD83 (2011) [EPSG: 26912]
Vertical Coordinates: NAVD88 (GEOID12A) [EPSG: 5703]

Data Selection Coordinates: □ Manually enter selection coordinates (in the horizontal coordinate system listed above)

\[ X_{\text{min}} = 427601.376371 \quad Y_{\text{min}} = 4436717.985397 \quad X_{\text{max}} = 429846.630333 \quad Y_{\text{max}} = 4437779.667239 \]

The selection area contains approximately 15,071,000 points.

Choose Return Classification

- Ground
- Unclassified

Select Ground Only

6. Hydrologic Terrain Analysis Products (tauDEM)

- ✔ Hydrologically correct DEM with pits filled
- ✔ D-Infinity Flow Direction
- ✔ D8 Flow Direction:
- ✔ D-Infinity Specific Catchment Area
- ✔ D8 Contributing Area
- ✔ Topographic Wetness Index

Change job title

Job title (up to 100 characters)
West Mountain TauDEM

Job description (up to 500 characters)
Job description

Enter your e-mail address for notification upon completion of processing
ramon.arrowsmith@asu.edu
myOpenTopo Workbench
Welcome Ramon Arrowsmith

Jobs currently running: 2

User Point Cloud Jobs

<table>
<thead>
<tr>
<th>Job Id</th>
<th>Dataset</th>
<th>Title</th>
<th>Submission</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>pc1505706544249</td>
<td>UGS_Wasatch</td>
<td>West Mountain TauDEM</td>
<td>2017-09-17 20:49:04</td>
<td>Querying</td>
</tr>
<tr>
<td>pc1505615743550</td>
<td>UGS_Wasatch</td>
<td>UGS Pearsons Canyon demo</td>
<td>2017-09-16 19:35:44</td>
<td>Done</td>
</tr>
<tr>
<td>pc1504304147938</td>
<td>UGS_Wasatch</td>
<td>weber test ground</td>
<td>2017-09-01 15:15:48</td>
<td>Done (Expired)</td>
</tr>
<tr>
<td>pc1504304037763</td>
<td>UGS_Wasatch</td>
<td>weber test</td>
<td>2017-09-01 15:13:57</td>
<td>Done (Expired)</td>
</tr>
</tbody>
</table>

1. **Point Cloud Jobs**: View currently submitted and previous point cloud jobs.
2. **Raster Jobs**: View currently submitted and previous raster jobs.
Download products and quick visualization in Google Earth

Download point cloud data in LAS format points.las (1.1 GB)

Download DEM (TIN) dems.tar.gz (5.9 MB)

Download Hillshade & Slope Products (TIN) viz.tar.gz (9.4 MB)

View KMZ in Google Earth

View with Google Map
# Point Cloud Job Report

Modify and resubmit this job  
Full job metadata report

<table>
<thead>
<tr>
<th>Job Id</th>
<th>Dataset</th>
<th>Title</th>
<th>Submission</th>
<th>Completion</th>
<th>Duration</th>
<th>Num points</th>
<th>Final Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>pc1505706544249</td>
<td>UGS_Wasatch</td>
<td>West Mountain TauDEM</td>
<td>2017-09-17 20:49:04</td>
<td>2017-09-17 20:52:16</td>
<td>192 secs</td>
<td>17,715,525</td>
<td>Done ✔️</td>
</tr>
</tbody>
</table>

## Download Job Results

### Point Cloud Results
- Download point cloud data in LAS format  
  points.las (574.4 MB)

### DEM Results
- Download DEM (TIN)  
  dems.tar.gz (6.1 MB)

### Derivative Products
- Download Hillshade & Slope Products (TIN)  
  viz.tar.gz (9.8 MB)

### TauDEM Products
- Download PitRemove file  
  pitRemove.tar.gz (5.9 MB)
- Download D-Infinity: Flow Direction file  
  dinfFlowDirection.tar.gz (6.4 MB)
- Download D-Infinity: Slope file  
  dinfSlope.tar.gz (5.9 MB)
- Download D-Infinity Specific Catchment Area file  
  Dinfarea.tar.gz (7 MB)
- Download Topographic Wetness Index file  
  TWI.tar.gz (6.7 MB)
- Download D8 - Flow Direction file  
  d8FlowDirection.tar.gz (497.3 KB)
- Download D8: Slope file  
  d8Slope.tar.gz (3.8 MB)
- Download D8 Contributing Area file  
  D8area.tar.gz (2.5 MB)

### Visualization Products
- **Ztin DEM**
  - View with Google Map

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**Download products and quick visualization in Google Earth**

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**Download dems as DTM**

**Hillshades too**
1) Load OT output into ArcMap

2) ArcToolbox -> Spatial Analyst -> Neighborhood

3) 5 m radius height range on DTM is a topographic roughness (~exposed rock). [Change color ramp and make 50% transparent over hillshade]
### Analyze D∞ catchment area in ArcMap

Download products to a watershed folder and uncompress.

### Download Job Results

**Point Cloud Results**
- Download point cloud data in LAS format: points.las (574.4 MB)

**DEM Results**
- Download DEM (TIN): dems.tar.gz (6.1 MB)

**Derivative Products**
- Download Hillshade & Slope Products (TIN): viz.tar.gz (9.8 MB)

**TauDEM Products**
- Download PitRemove file: pitRemove.tar.gz (5.9 MB)
- Download D-Infinity: Slope file: dinfSlope.tar.gz (5.9 MB)
- Download D-Infinity Specific Catchment Area file: DinfArea.tar.gz (7 MB)
- Download Topographic Wetness Index file: TWI.tar.gz (6.7 MB)
- Download D8: Flow Direction file: d8FlowDirection.tar.gz (497.3 KB)
- Download D8: Slope file: d8Slope.tar.gz (3.8 MB)
- Download D8 Contributing Area file: D8area.tar.gz (2.5 MB)
Mosaic to new raster the output files

Note that this is number of cells above a given point. Given resolution of 1m/pix this is in sq. m.
Compute log10 of the area using Raster Calculator

Now we are getting a sense of the drainage network.
Extract contributing areas greater than $10^3 \text{ m}^2$ using Raster Calculator

Display stable drainage network over hillshade
1) Load DTM. Right click and select properties

2) Set it to float on itself and increase the base surface resolution to 1 m under the Base Heights tab

3) Set Shade areal features and maximize quality enhancement under the Rendering tab

4) Change color Ramp under the Symbology tab
Change the background to black in ArcScene

Right click on scene layers and change the background color to black.
Visualize drainage network in ArcScene

1) Load drainage area. Right-click and select properties

2) Set it to float on the DTM, increase the base surface raster resolution to 1 m, and elevate it by 5 m to make it more visible under the Base Heights tab

3) Set maximize quality enhancement under the Rendering tab (no need to shade it)

4) Change color Ramp under the Symbology tab
Visualize drainage network in ArcScene ("skeleton of the landscape")