TauDEM Processing Tools on OpenTopography and Visualization in QGIS

AGIC Short Course: Intro to Lidar, Data Access, and Processing with OpenTopography

Wednesday, August 31, 2022
Topography defines the watershed, fundamental control on hydrology
|   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 0 |
| 0 | 50 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 50 | 0 |
| 0 | 50 | 100 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 100 | 50 | 0 |
| 0 | 50 | 100 | 150 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 150 | 100 | 50 | 0 |
| 0 | 50 | 100 | 150 | 200 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 250 | 150 | 100 | 50 | 0 |
| 0 | 50 | 100 | 150 | 200 | 250 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 250 | 200 | 150 | 100 | 50 | 0 |
| 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 250 | 200 | 150 | 100 | 50 | 0 |
| 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 350 | 400 | 350 | 350 | 350 | 350 | 350 | 250 | 200 | 150 | 100 | 50 | 0 |
| 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 350 | 250 | 200 | 150 | 100 | 50 | 0 |
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| 0 | 50 | 100 | 150 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 150 | 100 | 50 | 0 |
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| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Source: http://www.ncgia.ucsb.edu/giscc/extra/e001/e001.html
Hydro-flattened DEMs

- Cartographic enhancement, removes lidar artifacts
- Waterbodies are considered to have a single elevation
- Elevation is estimated from the adjacent terrain and is not representative of any measured water

Credit: USGS
Hydrologically Enforced DEMs

• Modified so waterbodies are level and streams flow downhill
• Contains surface modifications to allow water to flow across the surface, as it does in the real world
  • Road fills are cut through at drainage culverts
**TauDEM (Terrain Analysis Using Digital Elevation Models)**

Suite of Digital Elevation Model (DEM) tools to extract and analyze hydrologic information from topography

Many of these tools are available on OpenTopography for high resolution and global topography datasets

OpenTopography’s guided browser-based tools generate these TauDEM products in the cloud, which can be visualized in GIS software
TauDEM Workflow

Raw DEM

Flow Field

• D8
• D-Infinity

Pit Removal (Filling)

Channels, Watersheds, Flow Related Terrain Information

From David Tarboton
Supercomputer resources are available to all users via a user-friendly web browser interface.
D8 Flow Direction

- Simplest model for water flow
- Models flow direction from each cell to its steepest downslope neighbor
-Encoded as a number 1 – 8

Flow Direction Coding:
1 – East
2 – Northeast
3 – North
4 – Northwest
5 – West
6 – Southwest
7 – South
8 - Southeast

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<td>6</td>
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<tr>
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<td></td>
</tr>
</tbody>
</table>

From David Tarboton
Grid Network

Contributing Area (Flow Accumulation)

From David Tarboton
D-Infinity Flow Direction

- Calculates steepest outward flow direction, distributes flow between neighboring grid cells based on flow direction angles
- Encoded as an angle in radians counter-clockwise from East between 0 and 2 pi

Numbers 1-8 represent grid cells, not direction like D8 method
Edge Contamination

- Occurs when the contributing area may be underestimated due to grid cells outside of the domain not being counted

- Ensure that DEM area selected includes all of headwater region, or trunk streams may result in “no data”
Mapping of San Gabriel Mountains, CA 2009 Fire

Download and Access Products:

- Point Cloud Data
- Bulk Download opentopoid: OTLAS.012019.269111.1
- Raster Data
- Bulk Download opentopoid: OTSDEM.012019.269111.1

https://doi.org/10.5069/G94M92N4

Collection Overview: Survey conducted by NCALM for investigators Arjun Heimsath and Kelsin Whipple, Arizona State University; Michael Lamb, California Institute of Technology; and Ken Hudnut, U.S. Geological Survey, through funding from their institutions to investigate tectonics and geomorphology of the San Gabriel Mountains, California.

Dataset Acknowledgement: Any use of this data should acknowledge lidar data acquisition and processing completed by the National Center for Airborne Laser Mapping (NCALM). NCALM funding provided by NSF’s Division of Earth Sciences, Instrumentation and Facilities Program (EAR# 1830734).

1a. Select area of data to download or process
1. Coordinates & Classification

Horizontal Coordinates: NAD83 / UTM Zone 11N [EPSG: 26911]
Vertical Coordinates: NAVD88 [EPSG: 5703]
Units: meter

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

\[ X_{\text{min}} = 420173.053934 \quad Y_{\text{min}} = 3792626.445341 \quad X_{\text{max}} = 434302.602724 \quad Y_{\text{max}} = 3807234.659877 \]

The selection area contains 133,616,327 points.

Choose Return Classification  □ Building  □ Ground  □ Unclassified

2. Point Cloud Data Download

□ Point cloud data in LAZ format  □ Point cloud data in LAS format  □ Point cloud data in ASCII format

3A. DEM Generation (TIN)

Gridding Method
□ Calculate TIN

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

Grid Format
□ GeoTiff
7. 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

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**Download Data**

- **Point Cloud Results**
  - Download point cloud data in LAZ format [points.laz](#) (555.5 MB)

- **DEM Results**
  - Download DEM (TIN) [output.tin.tar.gz](#) (3.1 MB)

- **TauDEM Products**
  - Download PitRemove file [pitRemove.tar.gz](#) (3.1 MB)
  - Download D-Infinity; Flow Direction file [dinfFlowDirection.tar.gz](#) (3.3 MB)
  - Download D-Infinity; Slope file [dinfSlope.tar.gz](#) (3.6 MB)
  - Download D-Infinity Specific Catchment Area file [Dinfarea.tar.gz](#) (3.6 MB)
  - Download Topographic Wetness Index file [TWI.tar.gz](#) (3.5 MB)
  - Download D8 - Flow Direction file [d8FlowDirection.tar.gz](#) (343.7 KB)
  - Download D8: Slope file [d8Slope.tar.gz](#) (3.2 MB)
  - Download D8 Contributing Area file [D8area.tar.gz](#) (1.1 MB)

18 min
1. Coordinates

**Horizontal Coordinates:** NAD83 / UTM Zone 11N [EPSG: 26911]

**Vertical Coordinates:** NAVD88 [EPSG: 5703]

**Units:** meter

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

2. Data Output Formats

**Select Data Output Format:** GeoTiff

3. Layer Types & Additional SRTM Data

**Digital Elevation Models (DEMs)**

- Digital Terrain Model (DTM)
- Digital Surface Model (DSM)

**Include Global 30m SRTM Data** □

7. 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**
Download pre-generated data products
https://opentopography.org/workshops/AGIC2022
D8 Products

Visualize DEM as a hillshade
Visualize Flow Direction
Select "Classify"
Random color will be assigned 1-8
Choose a color ramp, here using “Spectral”
Can make a more ‘continuous’ color ramp, as $1 = $East
Edit the color ramp
Click on color droppers and adjust the color.
I’ve made a rainbow scheme that will be more continuous from 8 to 1
Double click on the label to edit the text.
Assign labels accordingly

1 – East
2 – Northeast
3 – North
4 – Northwest
5 – West
6 – Southwest
7 – South
8 - Southeast
1 – East
2 – Northeast
3 – North
4 – Northwest
5 – West
6 – Southwest
7 – South
8 – Southeast
Visualize the contributing area
Perform ‘Raster Calculator’ calculation:

\[ \log_{10}(\text{"d8Contributing Area"}) \]
Adjust the symbology
Select color ramp, like "Plasma"
Invert the color ramp so that blue indicates larger drainage areas.
Use Raster Calculator to visualize just the main channel network.
Select a threshold value of contributing area 

3.5 represents an area of $10^{3.5}$ (1,778), as this layer is a log

"logArea" / ("logArea" > 3.5) will return only values ≥ 3.5
Add same color scheme to river network
“Plasma” color ramp
Invert color ramp
Can turn on other layers to visualize context
Add OpenStreetMap layer to see how well streams match up.
Use 3D Map View for more visualizations
D-Infinity Products

Flow Direction, Singleband pseudocolor, values are an angle in radians counter-clockwise from east between 0 and 2 \pi
Adjust color ramp to make it more continuous
Take log of Catchment Area layer with Raster Calculator
Change layer symbology as before
Extract just the stream network with Raster Calculator. This Catchment Area layer has higher values, so we use a higher threshold area

"logDinfin" / ("logDinfin" > 4.25)

$10^{4.25} = 17,782$
Add color ramp to channel network
Visualize Topographic Wetness Index
Add color symbology
Visualize Slope layer
Select a color ramp, here using Red, Yellow, Green
Invert the color ramp so that red is the steepest slopes.