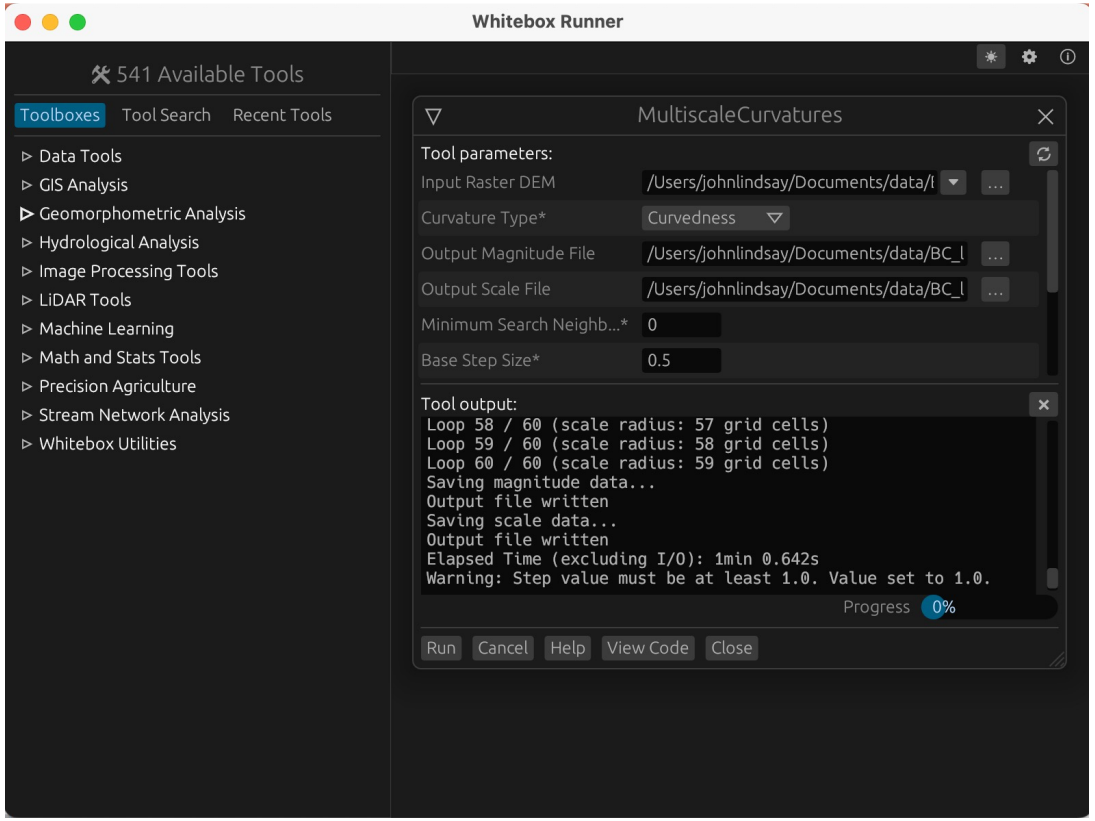

UNIVERSITY of GUELPH
CHANGING LIVES IMPROVING LIFE
WhiteboxTools for Geomorphometry
Prof. John Lindsay
Department of Geography, Environment & Geomatics
University of Guelph, Canada
@whiteboxgeo
GHRG
Geomorphometry & Hydrogeomatics Research Group

WhiteboxTools (WbT)

- An advanced geospatial analysis back-end application
- MIT open-source license
- Rust source code on Github
- Scriptable from Python and R
- QGIS and ArcGIS front-ends



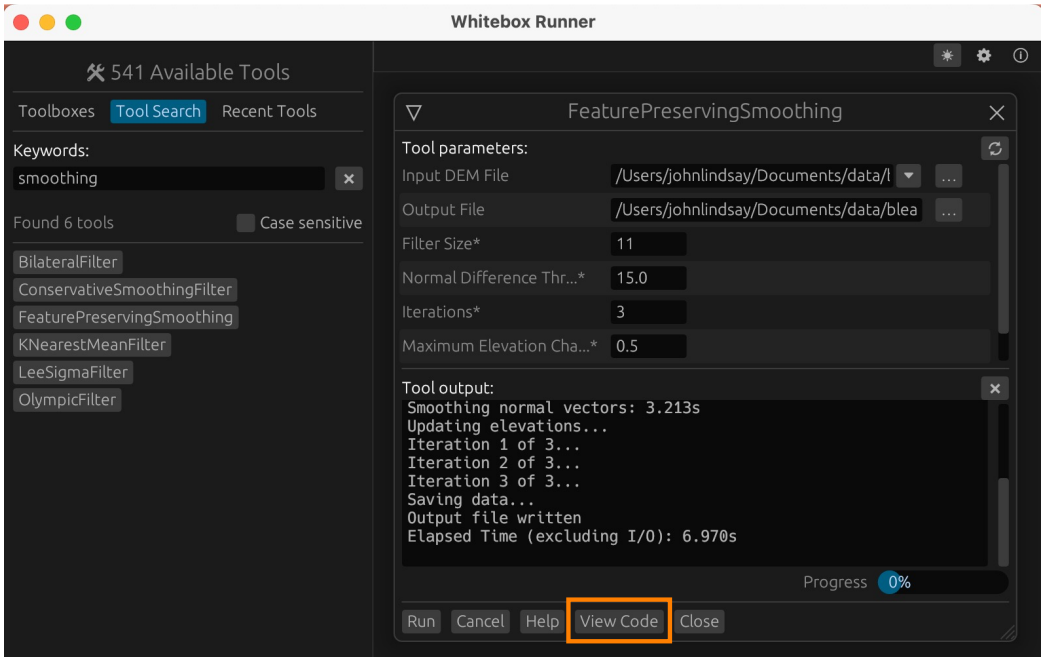
Download https://www.whiteboxgeo.com/download-whiteboxtools/

Where did WhiteboxTools come from?

- Terrain Analysis System (TAS)
  - 2001-2008, developed out of my PhD
- Whitebox Geospatial Analysis Tools (Whitebox GAT)
  - Desktop GIS application, developed 2009-2017
- WhiteboxTools (WbT)
  - Dec. 2017-present
  - Start-up company, **Whitebox Geospatial Inc**. founded in 2021 to support ongoing development.
  - www.whiteboxgeo.com

The Whitebox Design Philosophy

- Code transparency
  - Easy code access via the 'View code' button
  - Most of the logic for a tool should live in one file
  - Extensive tool docs
- One-tool/one-function
- Develop for speed first
- No user-installed dependencies
- Innovative functionality



The Whitebox platform

- WhiteboxTools Open Core (WbT):
  - Open-source foundation of the platform.
  - Powerful geospatial app containing 470+ tools.

- Whitebox Toolset Extension (WTE):
  - Contain about 65 proprietary tools.

- Whitebox Workflows for Python (WbW):
  - Wraps WbT as a native Python extension module, i.e., a library rather than a command-line application.
  - Makes writing advanced Wb-based Python geoprocessing scripts easy.
  - Allows low-level manipulation of raster, vector, and lidar data from Python.

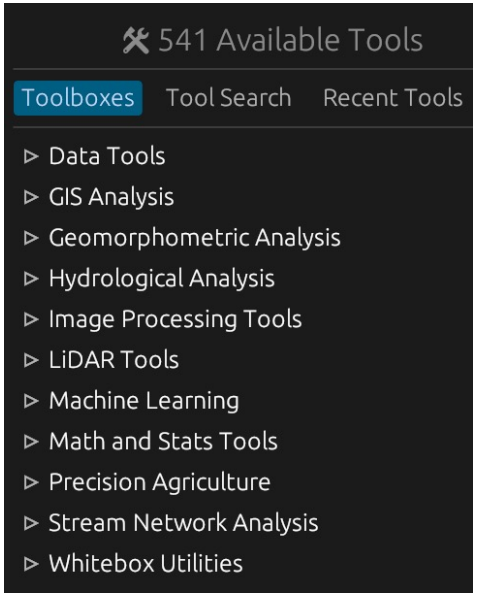
Example Whitebox Workflows for Python script

```python
import whitebox_workflows

wbe = whitebox_workflows.WbEnvironment()

lidar = wbe.read_lidar('path/to/data/lidar.laz')

dem = wbe.lidar_tin_gridding(
    input_lidar=lidar,
    returns_included='last', # only interpolate last returns
    excluded_classes=[3,4,5,6,7,18] # exclude veg, buildings, noise
)

dem_no_missing_data = wbe.fill_missing_data(dem, filter_size=21)

dem_smoothed = wbe.feature_preserving_smoothing(dem_no_missing_data)

dem_breached = wbe.breach_depressions_least_cost(dem_smoothed)

flow_accum = wbe.dinf_flow_accum(dem_breached)

wbe.write_raster(flow_accum, 'dinf.tif', compress=True)
```

WhiteboxTools functionality

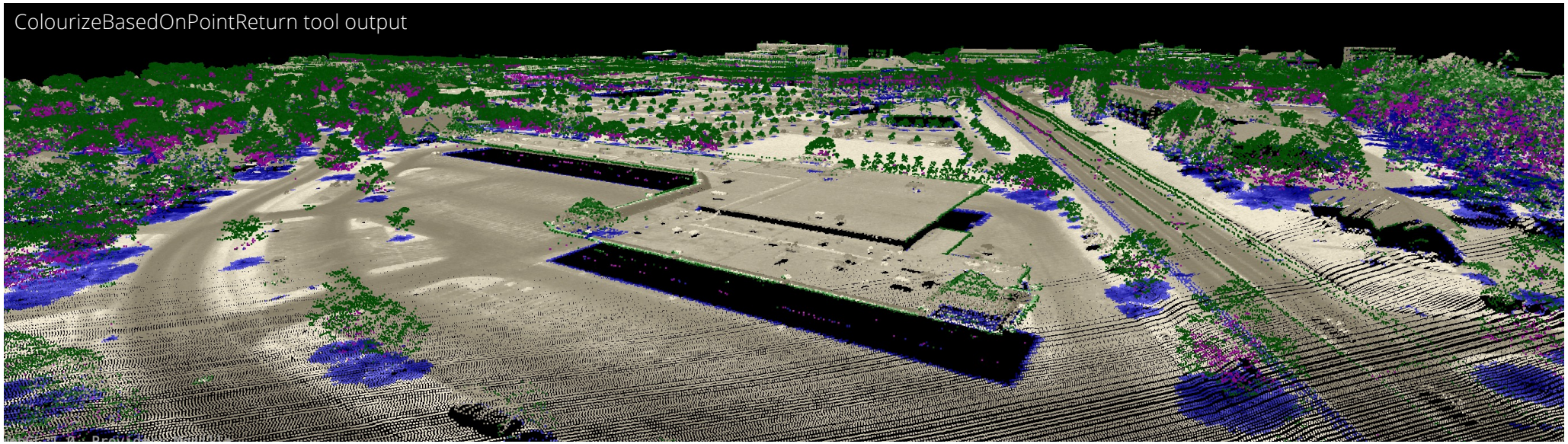
- Over 540 geospatial analysis tools, with strength in:
  - LiDAR processing and remote sensing
  - DEM generation and pre-processing
  - Spatial hydrology and stream network analysis
  - Geomorphometric analysis

- Let's take a brief look at some of these functions in greater detail...



Lidar analysis

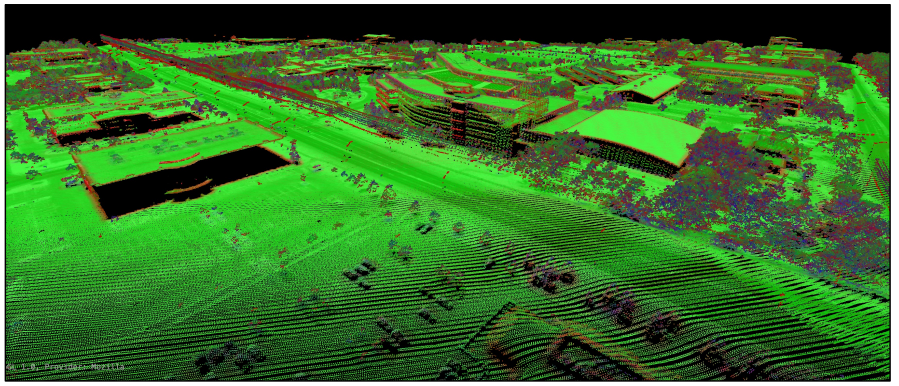
- Batch lidar interpolation (IDW, TINing, NN, Sibson's method, RBF, DSM), block min/max, contouring
  - Interpolate elevation, intensity; all/first/last returns; exclude pt. classes
- FilterLidar, ModifyLidar, SplitLidar, SortLidar, LidarEigenvalueFeatures, HeightAboveGround



Lidar point classification

ClassifyLidar output

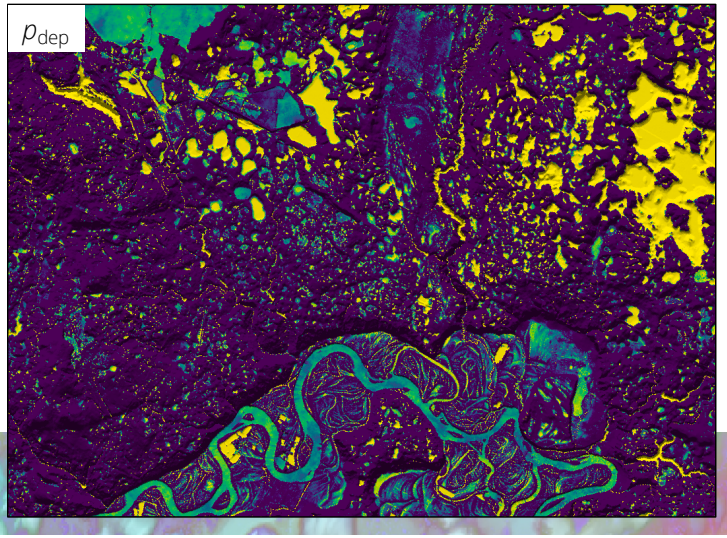
- Classify ground, vegetation, building, and noise points.



LidarEigenvaluesFeatures, red=linearity, green=planarity, blue=sphericity

Modelling surface flow

- Flow accumulation using D8, Rho8, D∞, Freeman, Quinn, MD∞, Qin
- Watershedding operations, map catchments, hillslopes, Strahler-order basins, isobasins, etc.
- Sink mapping, stochastic depression mapping (p_{dep})
- Other hydrological LSPs, such as wetness index, sediment transport index, stream power index, depth-to-water, hydrologic connectivity, downslope index, impoundment size index



Modelling surface flow

- WbT contains several DEM pre-processing algorithms.
- Efficient depression filling and least-cost constrained breaching algorithms.
- Stream burning, including BurnStreamsAtRoads.
- Road embankment removal.

Lindsay *(2016; 2018; 2020)*; Van Nieuwenhuizen et al. (2021); Lindsay and Dhun (2015)

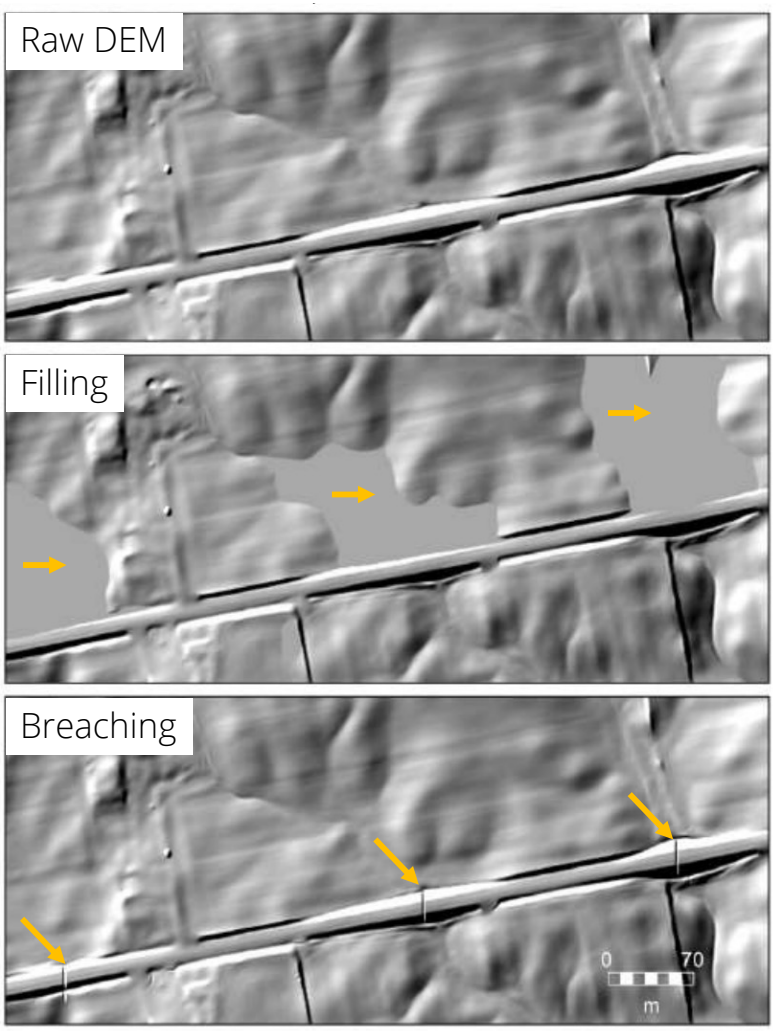
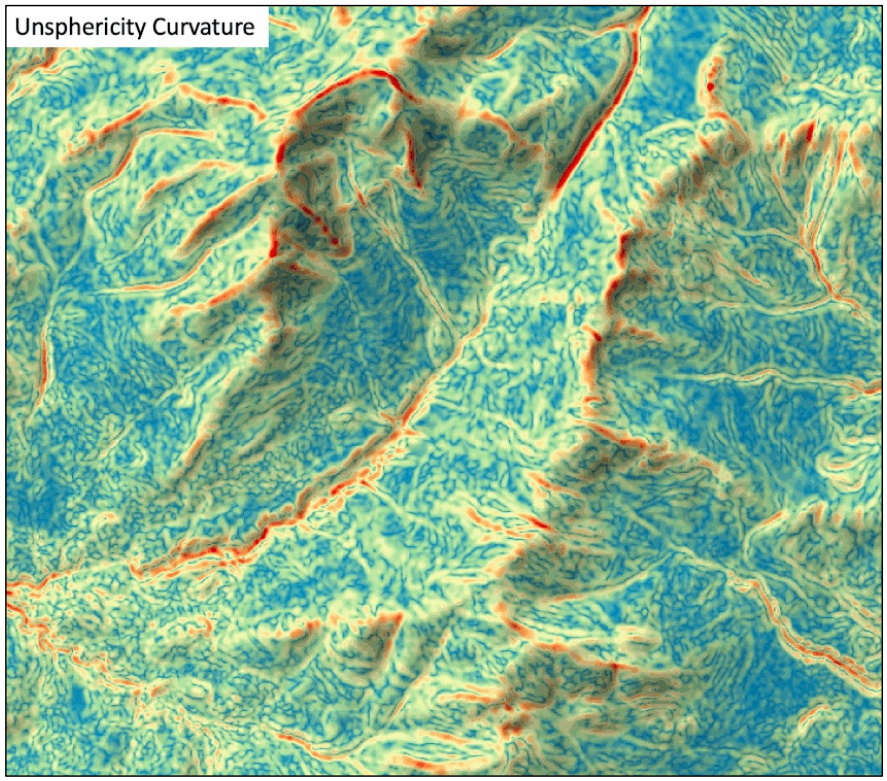


Figure 2. Hillshade images of a road embankment in the Catfish Creek Watershed, derived from A) the raw DEM, B) the pit-centric filled DEM, and C) the pit-centric least-cost breached DEM.

Surface curvatures

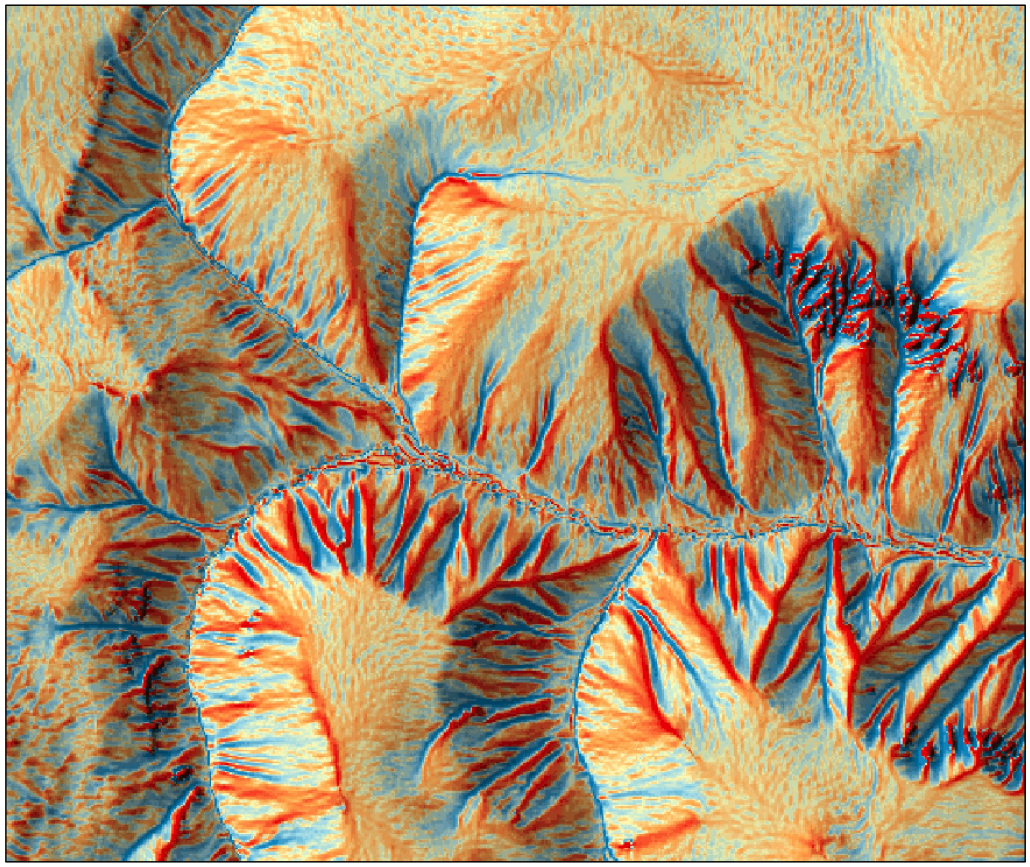
- 18 curvatures/curvature indices
  - Accumulation, Difference, Gaussian, Horizontal/Vertical Excess, Minimal/Maximal, Mean, Plan, Profile/Tangential, Ring, Rotor, Total, Curvedness, Generating Function, Shape Index, Unsphericity

- Calculated using the 5x5 method of Florinsky (2017) for projected DEMs and his 3x3 method for DEMs in geographic coordinates.



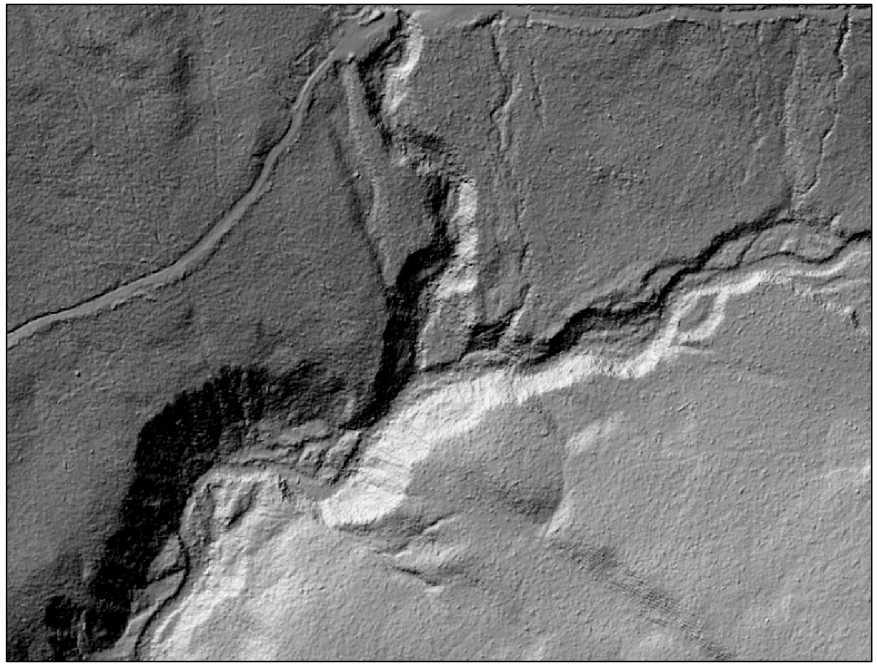
Surface curvatures

- Multi-scale curvatures
- Very useful for measuring larger-scale hillslope curvature from rough/noisy fine-resolution lidar DEMs

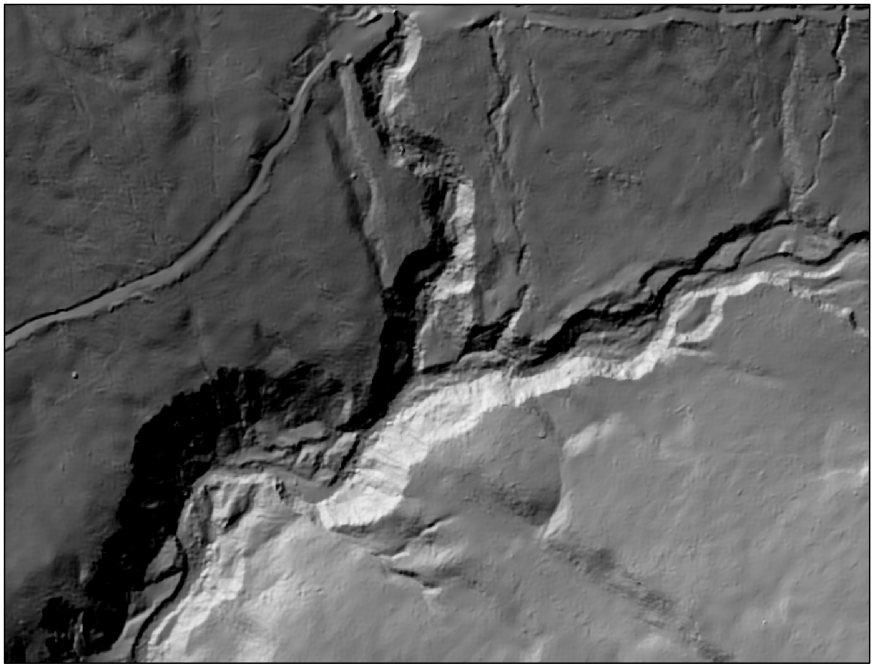


Tangential curvature measured across a range of spatial scales

Feature-preserving DEM smoothing

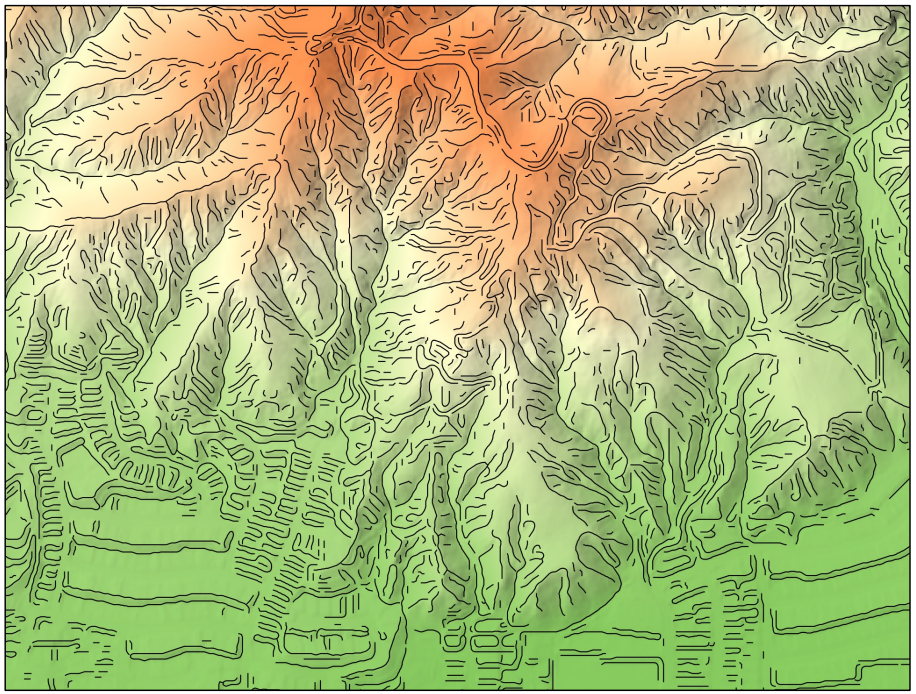


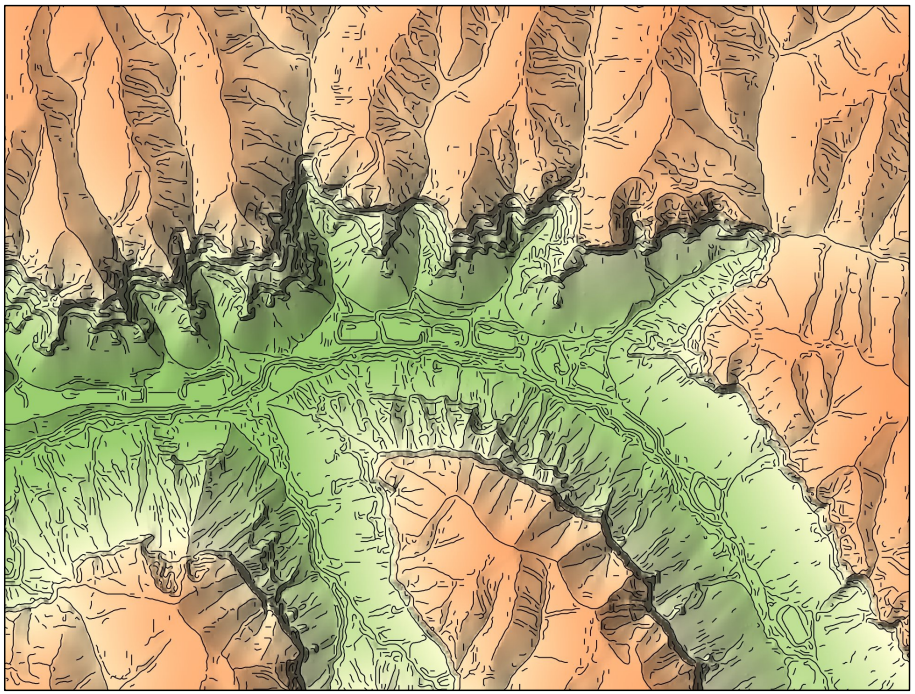
Original DEM under heavy forest cover



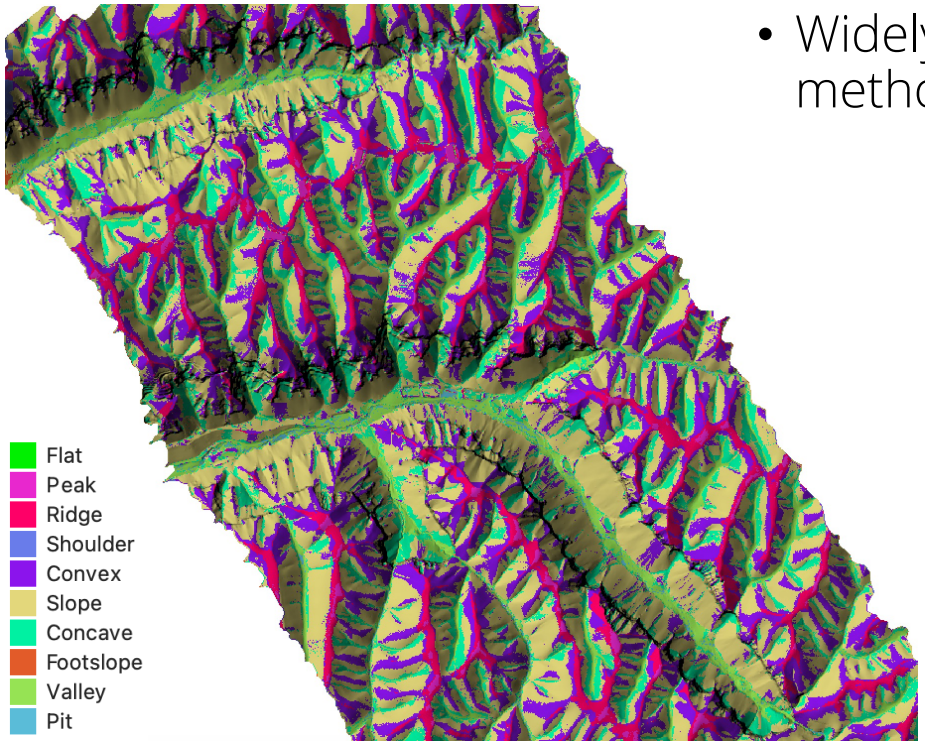
Result of the feature-preserving smoothing method of Lindsay et al. (2019) *Remote Sensing*

Breakline mapping





Geomorphons (Jasiewicz and Stepinski, 2013)



Grand Junction, CO

- Widely applied landform classification method based on line-of-site analysis.

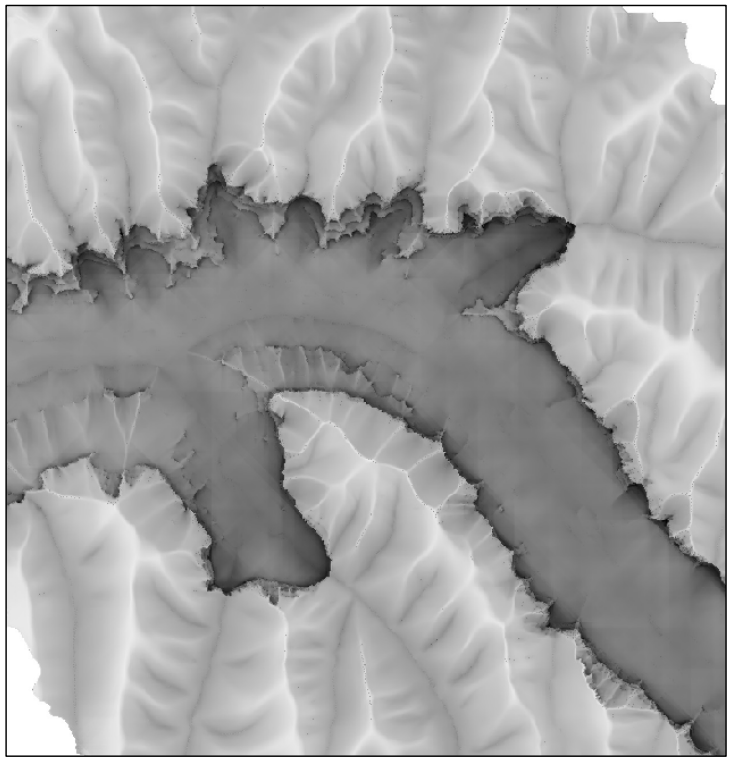
Multi-directional hillshading

Regular hillshade

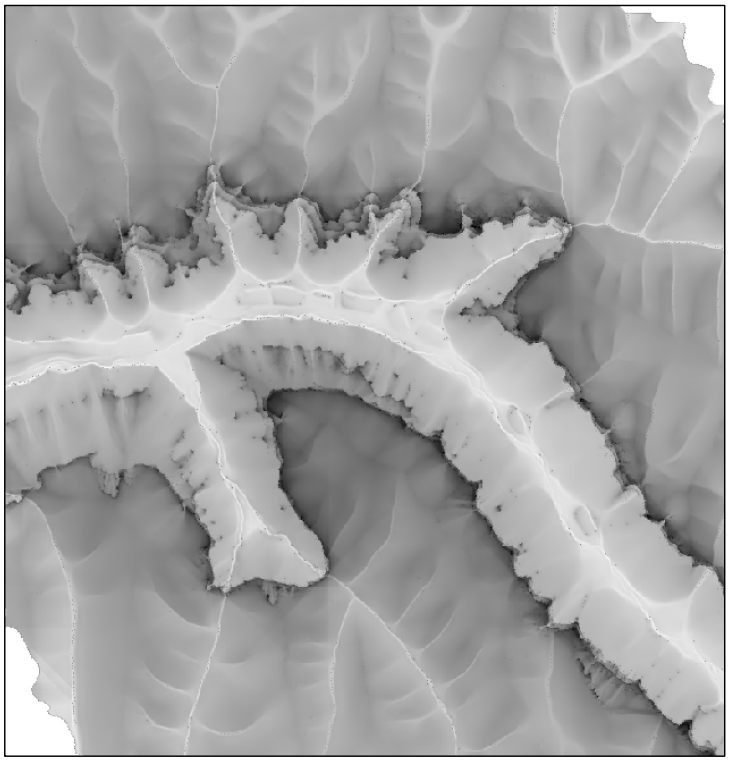
4-direction hillshade

8-direction hillshade

Openness (Yokoyama et al., 2002)



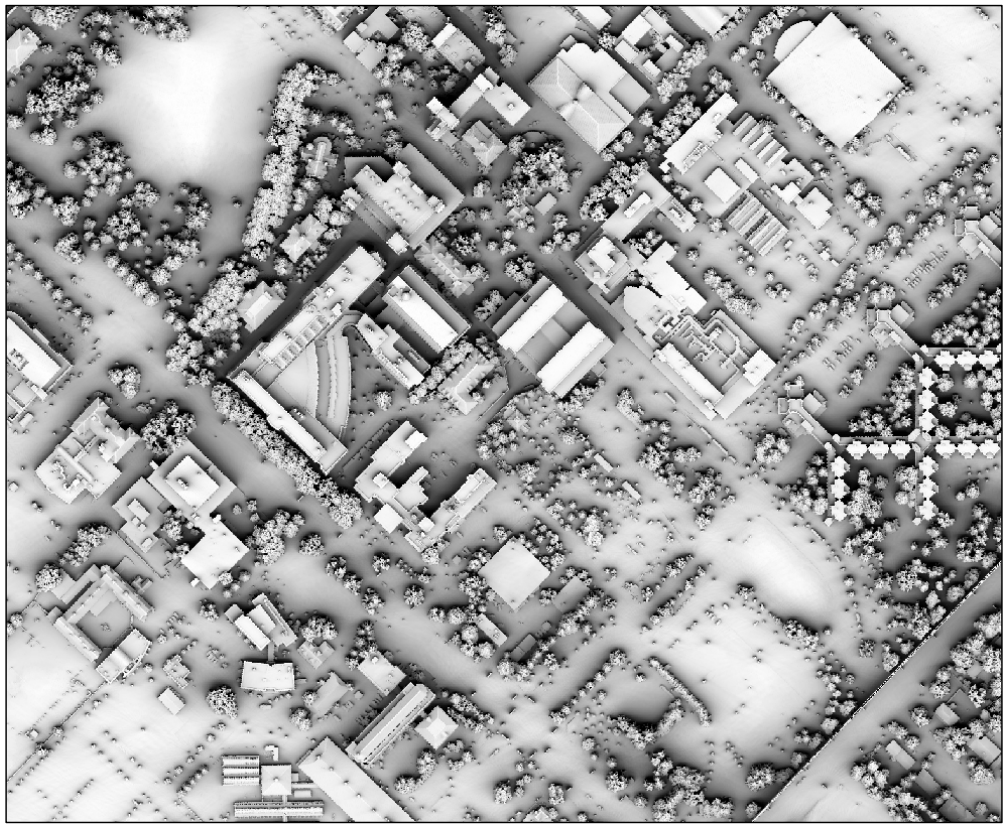
Positive openness for Grand Junction, Colorado



Negative openness for Grand Junction, Colorado

Lighter colours indicate higher openness values

Time-in-daylight



University of Guelph Campus

Proportion of a time period that a site is exposed to daylight.

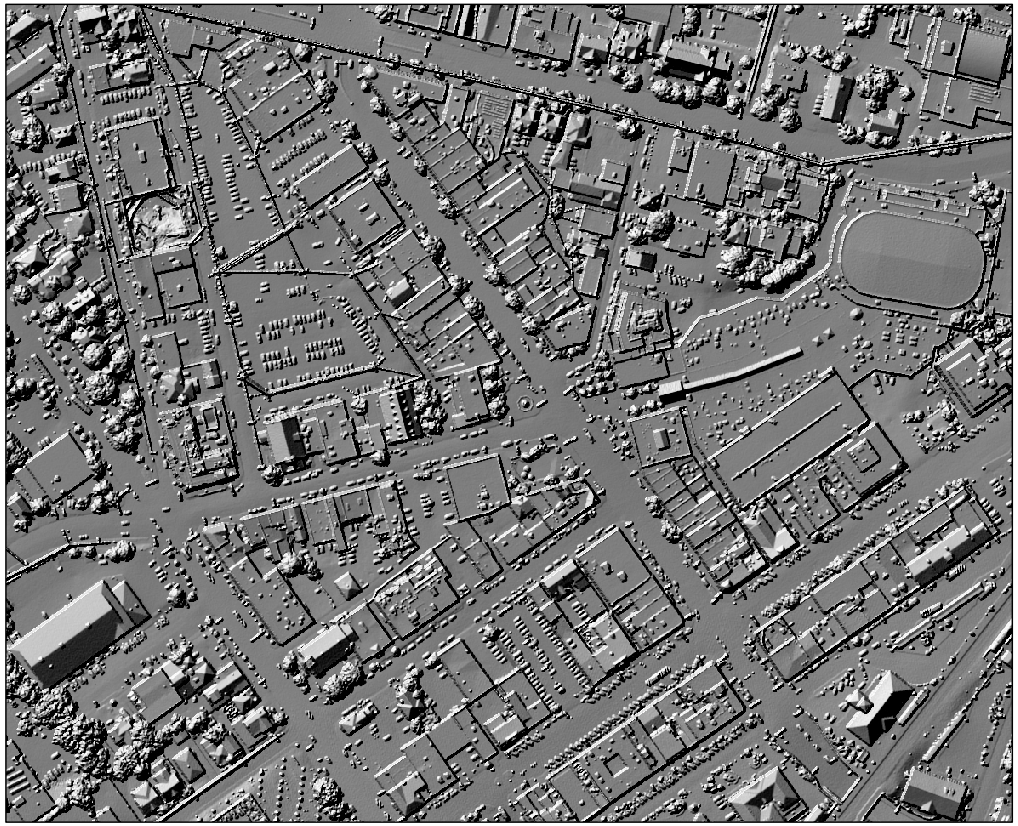
0 = full shade, 1 = full sun

Based on modelling sun position and shadows cast by distant terrain.

Better suited as a covariate related to insolation input than hillshade.

Good for solar power studies.

Time-in-daylight



Traditional hillshade image, downtown Guelph, ON (0.5 m DSM)

Time-in-daylight, downtown Guelph, ON (0.5 m DSM)

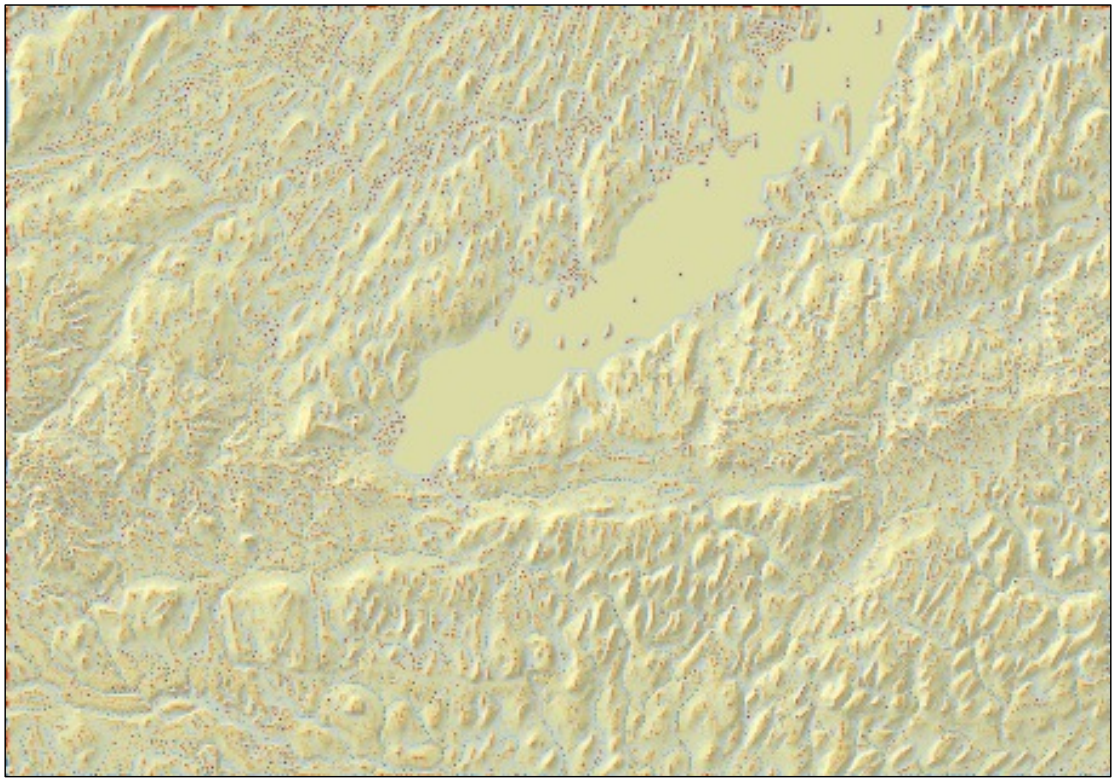
Shadow animations

Wb can create shadow animations from digital surface models (DSMs).

Effective for visualization and insolation studies.

https://jblindsay.github.io/ghrg/WhiteboxTools/samples/shadows/small_farm_shadows_Aug15.html

Multi-scale land-surface parameters and scale mosaics

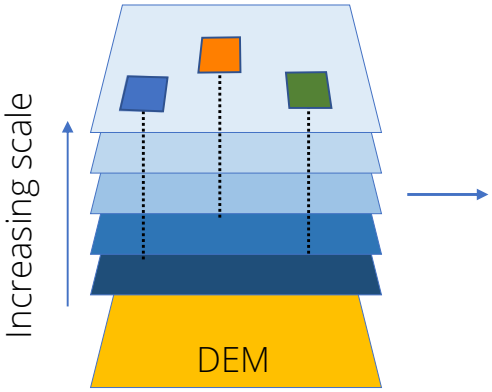


- An animation of deviation from mean elevation (*Dev*) measured using a wide range of window sizes, i.e., calculated using increasingly larger neighbourhoods.

- Notice how different topographic features are picked out at different scales.

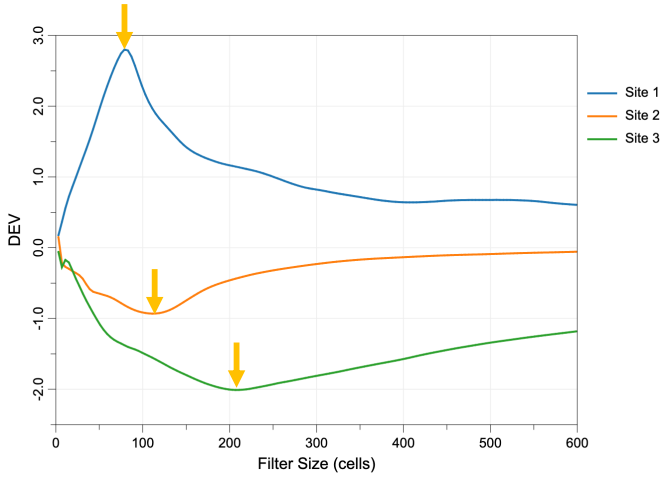
Multi-scale land-surface parameters and scale mosaics

LSP scale stack



Take advantage of advanced computational methods to efficiently compute a very dense scale stack.

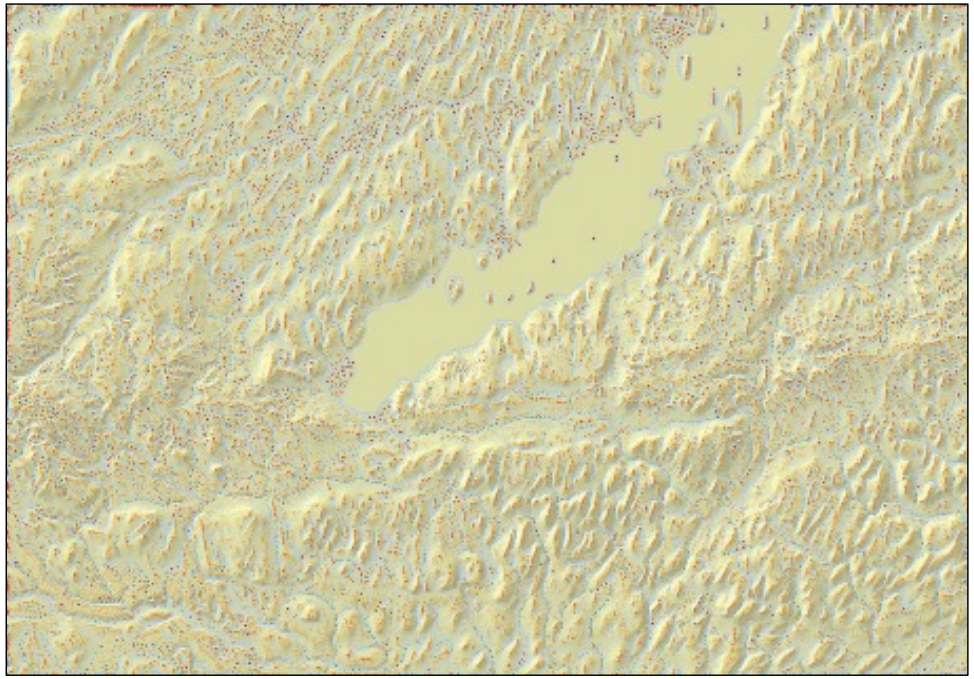
Each grid cell has a unique scale signature and key scales.



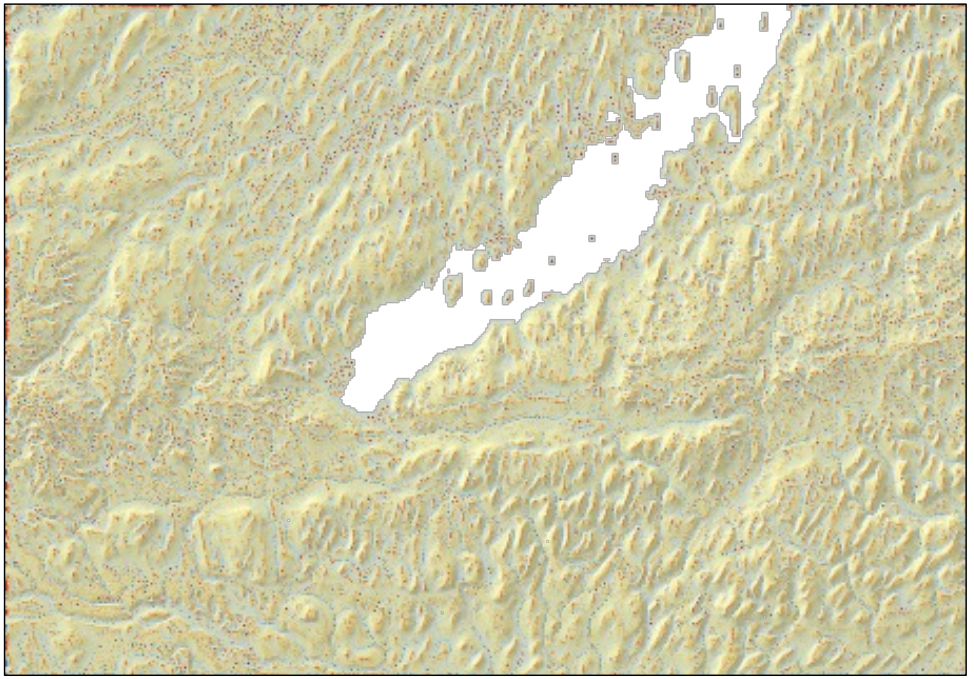
The scale stack is collapsed by finding the optimal scale for each grid cell. The resulting raster is a locally scale optimized LSP scale mosaic.

We also get an ancillary raster of optimal scales.

Homogeneous deviation from mean elevation (Dev)



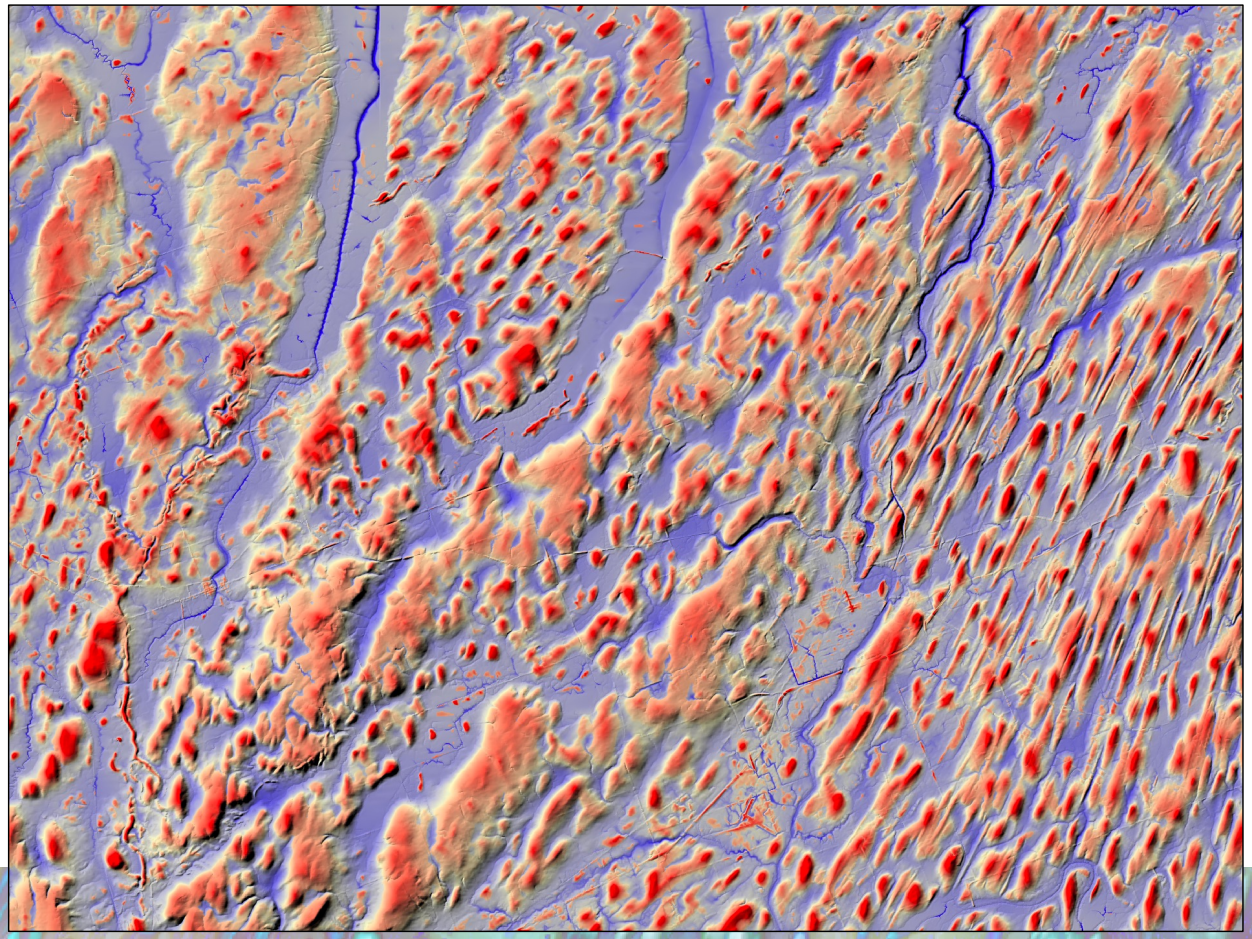
Heterogeneous Dev



No sparse sub-set of frames from the homogeneous scale stack (left) can represent the range of topographic features in this complex landscape as well as the single top frame of the heterogeneous scale mosaic (right).

Lindsay et al. (2015; 2018) *Geomorphology*; Newman et al. (2018a, 2018b, 2022a, 2022b)

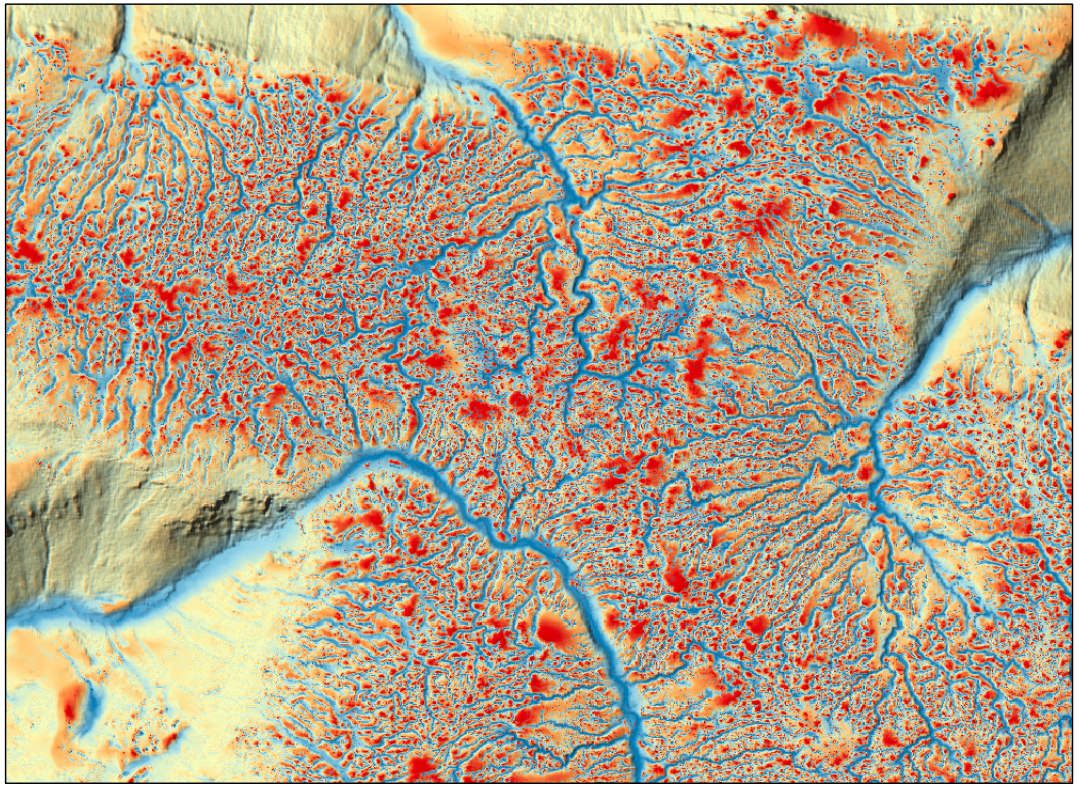
Multi-scale land-surface parameters and scale mosaics



A Dev scale mosaic for a complex drumlin field.

Multi-scale land-surface parameters and scale mosaics

- Gullies with a range of widths dissect the Kinder Scout peat plateau.
- An elevation percentile (EP) scale mosaic maps gullies more effectively than any single-scale EP raster would.



Elevation percentile scale mosaic (6-142 m)

Summary

- WhiteboxTools is built on a legacy of geomatics software centered around geomorphometry that goes back more than 20 years.

- With so much broad functionality, any short presentation will necessarily have to focus on specific capabilities at the exclusion of others. I invite you to check it out yourself!

- Download: https://www.whiteboxgeo.com/

- Help docs: https://www.whiteboxgeo.com/manual/wbt_book/preface.html

- Source code: https://github.com/jblindsay/whitebox-tools

Summary

- Financial contributions to the project are welcome.
  - You can support the project by purchasing a WbT binary. We have adopted a ‘pay what you can’ model.
  - Buying extension or Whitebox Workflows (WbW) licenses directly contributes to the ongoing support of the open-core.
  - Sponsor the open-sourcing of tools to the open core.
  - Goal is to hire a full-time employee who can serve the user community.

- Code contributions are also very welcome.
  - Code contributions must be in pure Rust.
  - Contributing new tools is an easy way to get started. The new plugin structure for tools helps greatly.