

# Efficient processing of dense point clouds in GRASS GIS at US-IALE 2016 Annual Meeting

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available at

[wenzeslaus.github.io/grass-lidar-talks](https://wenzeslaus.github.io/grass-lidar-talks)

# Acknowledgements

## Software

Presented functionality is work done by Vaclav Petras, Markus Metz, and the GRASS development team.

Thanks to users for feedback and testing, especially to Douglas Newcomb, Helena Mitasova, Markus Neteler, Laura Belica, and William Hargrove.



**GRASS** GIS

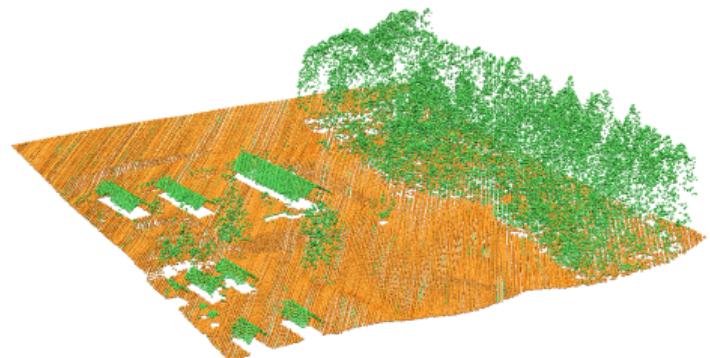
# Acknowledgements

## Datasets

Lidar and UAV Structure from Motion (SfM) data for GIS595/MEA792: UAV/lidar Data Analytics course

Nantahala NF, NC: Forest Leaf Structure, Terrain and Hydrophysiology: 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-1043051. Obtained from OpenTopography.

<http://dx.doi.org/10.5069/G9HT2M76>



# Points

- ▶ collected by lidar
- ▶ Structure from Motion (SfM) from UAV imagery
- ▶ a lot of points
  - ▶ often more than we need



surface interpolated from points from SfM

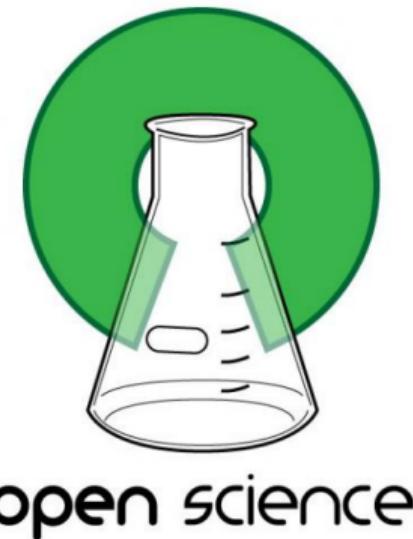
# Free, libre and open source

## Scripts and code I'm writing

- ▶ review
- ▶ re-usable
  - ▶ by other people
  - ▶ by future myself

## Software I'm using

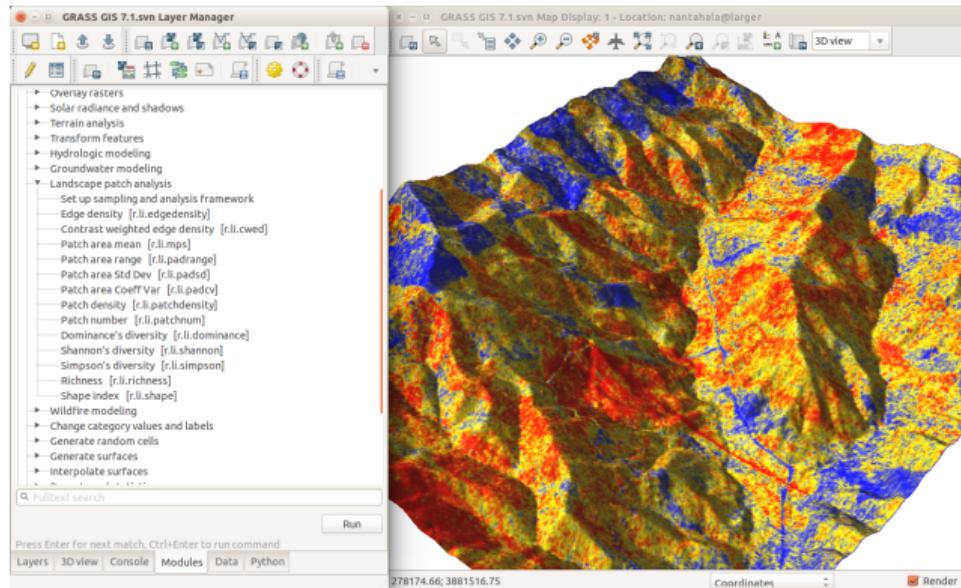
- ▶ driven by needs of users
- ▶ longevity
  - ▶ learn now, use forever
  - ▶ GRASS GIS: over 30 years of development



Open Science Logo, Greg Emmerich,  
CC-BY-SA-2.0

# GRASS GIS

- ▶ universal scientific and processing platform
  - ▶ GUI, CLI, Python API
  - ▶ from small laptops to supercomputers
- ▶ lidar processing included
- ▶ data size and type challenges

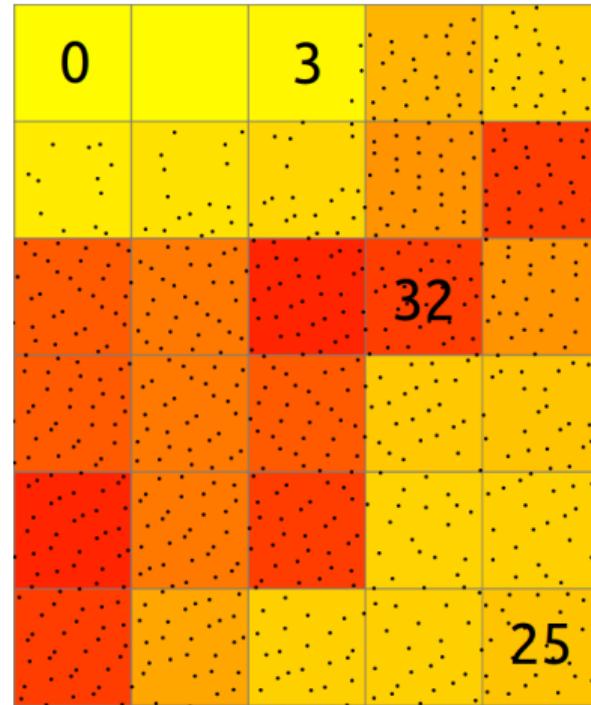


# Workflow overview



# Binning as 2D histogram

- ▶ number of points in cell



# Binning points to raster

- ▶ `r.in.lidar` (import and analysis)
- ▶ statistics of point counts, height and intensity
  - ▶ n, min, max, sum
  - ▶ mean, range, skewness, ...



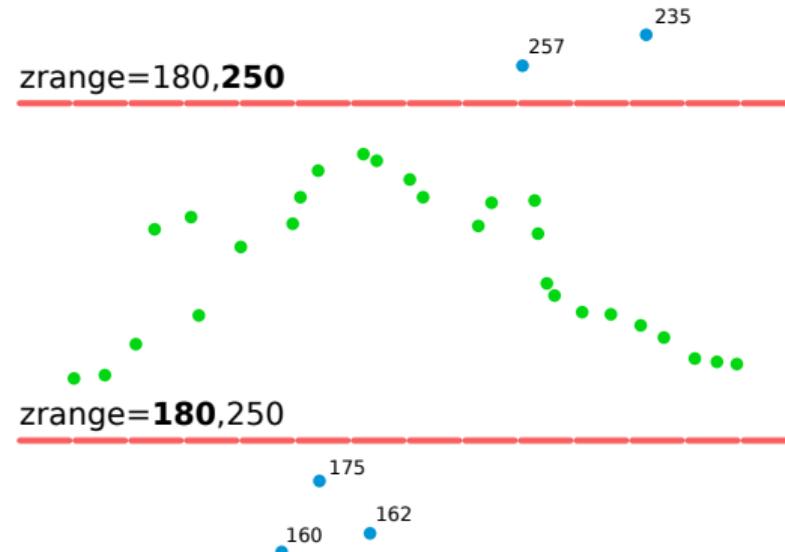
# Practical functions

- ▶ analytical and practical functions in *r.in.lidar*
- ▶ read multiple tiles as one
  - ▶ no merging
  - ▶ 0.5 billion points in 90 files in minutes



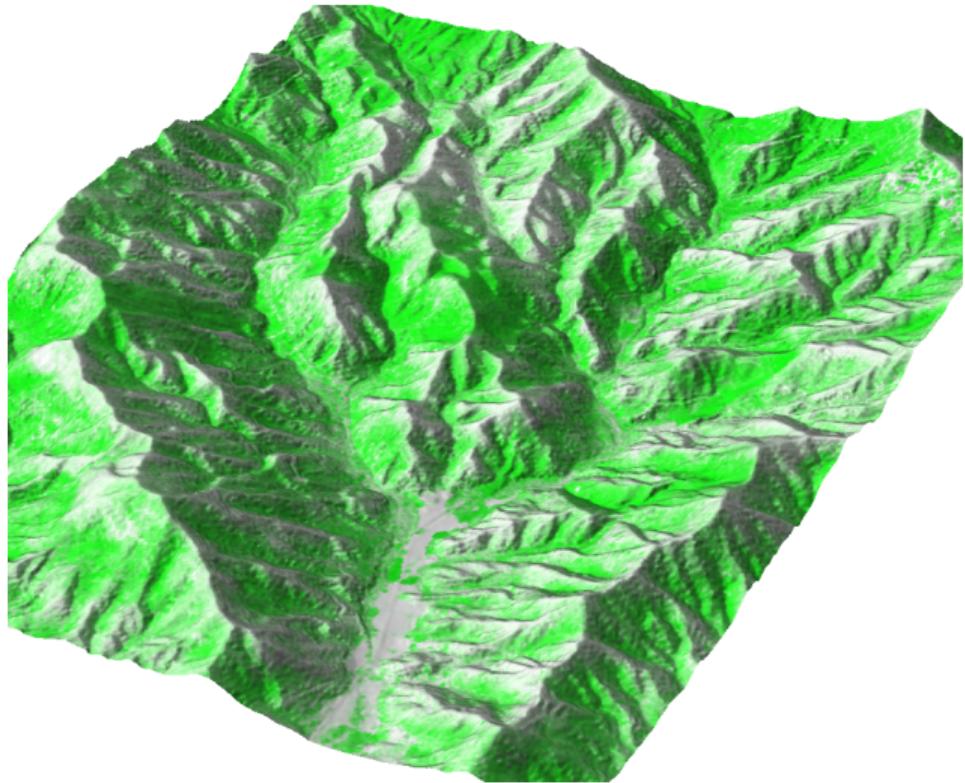
# Filtering points

- ▶ filter points by
  - ▶ range of Z
  - ▶ return
  - ▶ class
  - ▶ ...
- ▶ at the time of binning with *r.in.lidar*
  - ▶ minimal additional cost



# Height above a surface

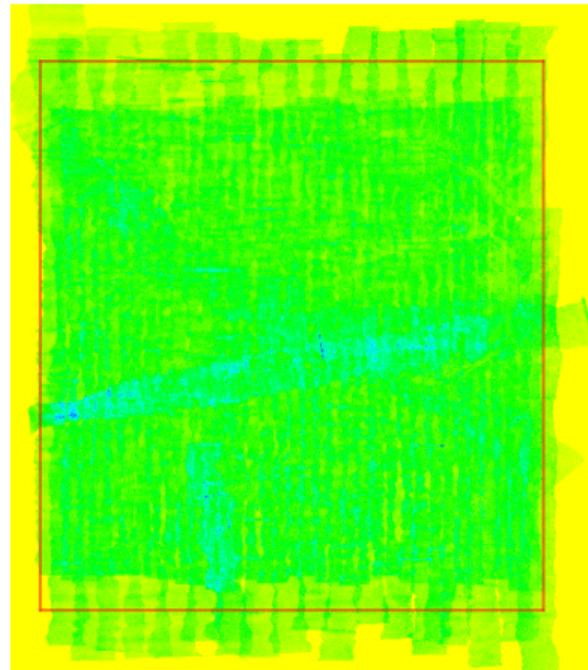
- ▶ new base raster feature in  
*r.in.lidar*
- ▶ given surface + points cloud  
→ height of features



- ▶ not limited by memory

# Rasterize early

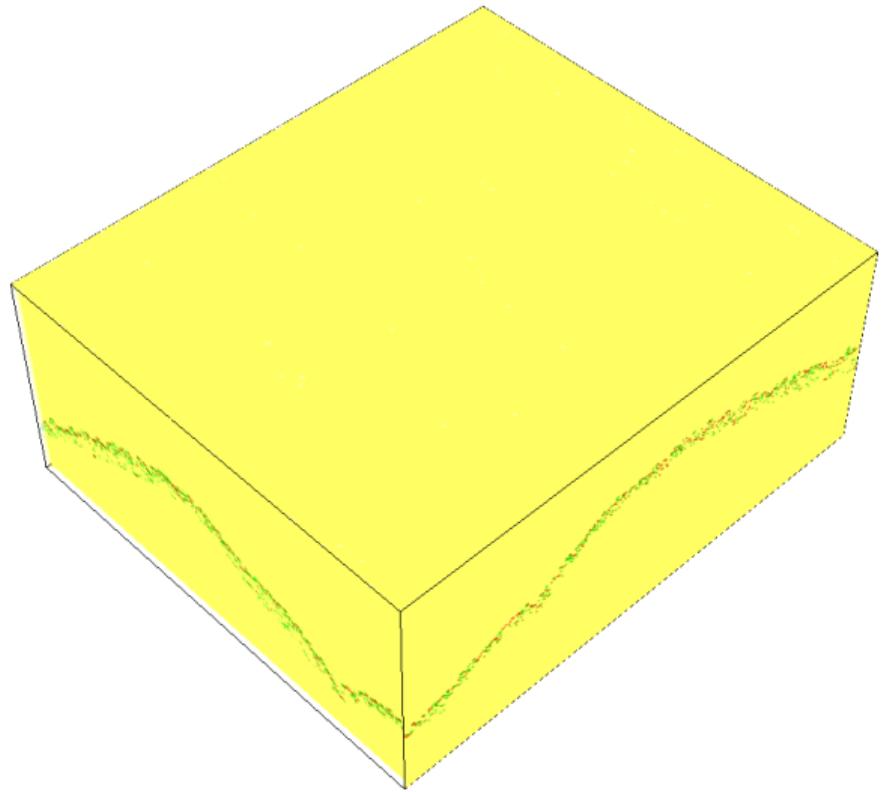
- ▶ less cells than points
  - ▶ 578 mil points (ground 30 mil)
  - ▶ 15 mil cells in  $8\text{km} \times 7\text{km}$  at resolution 2m
    - ▶ faster to loop through
    - ▶ less disk space
- ▶ raster
  - ▶ natural spatial index
  - ▶ that's what the algorithms use



point density (all classes) at 5m, green  $\sim 200$  points

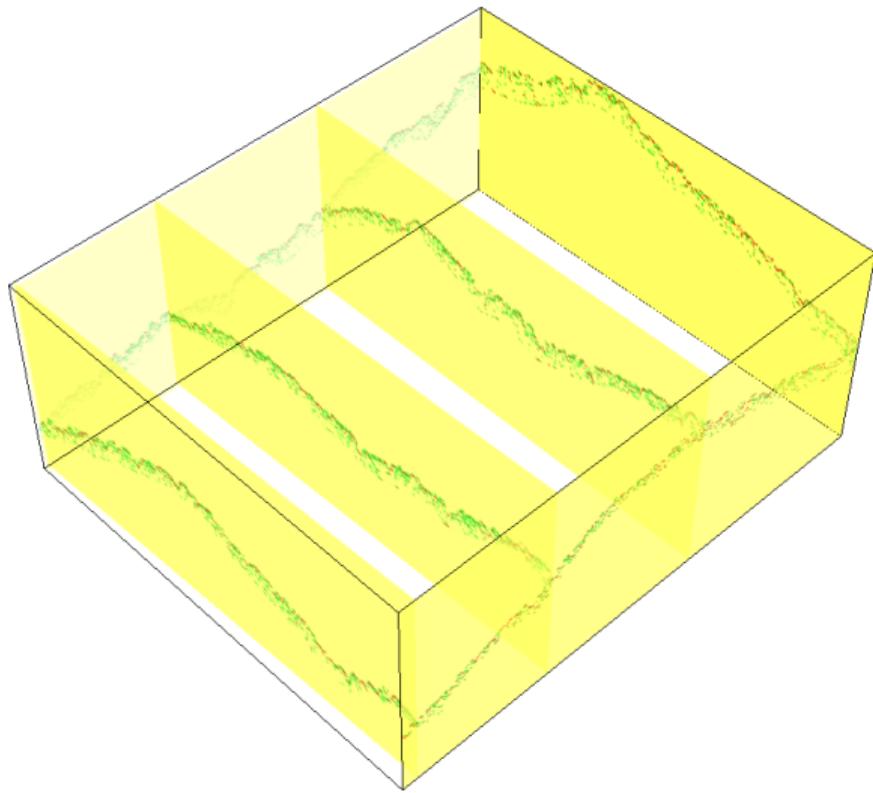
## 3D raster

- ▶ stacked 2D rasters
- ▶ challenging to visualize
- ▶ same principles as in 2D
  - ▶ e.g. 3D raster map algebra



# 3D raster

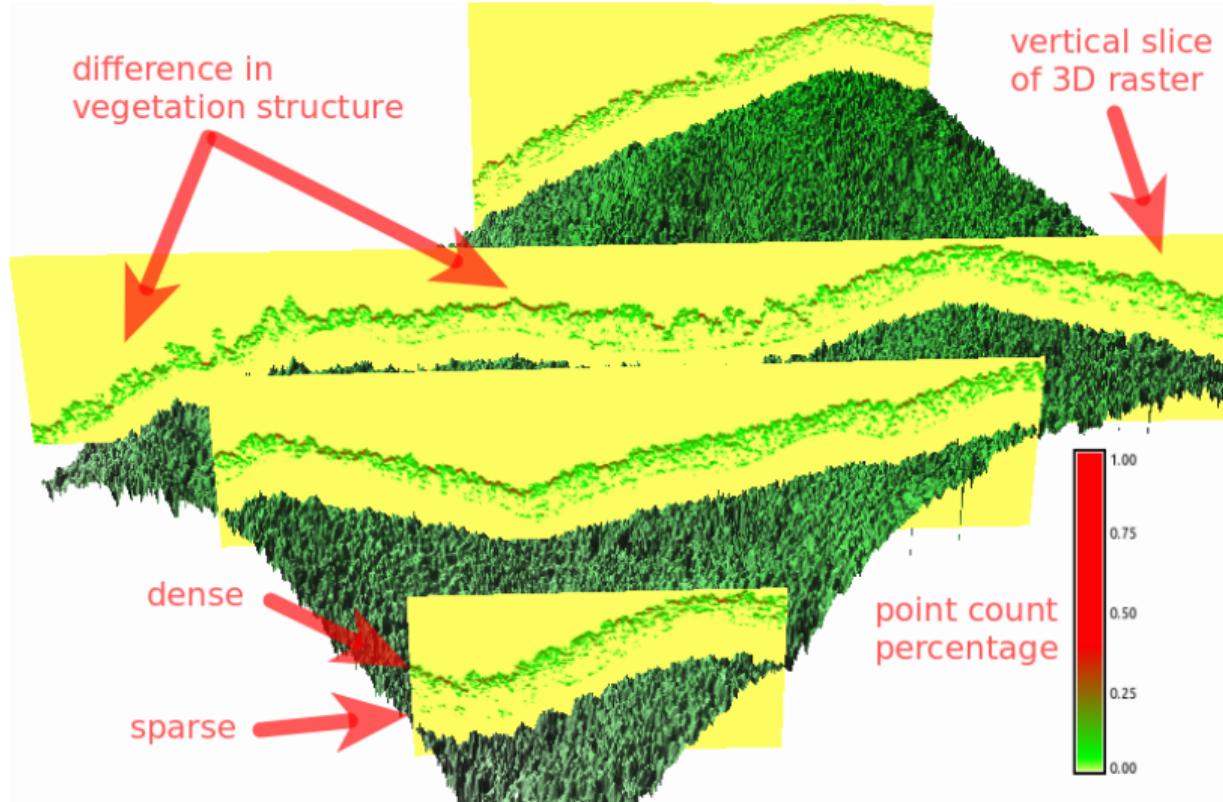
- ▶ stacked 2D rasters
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# Binning points to 3D raster

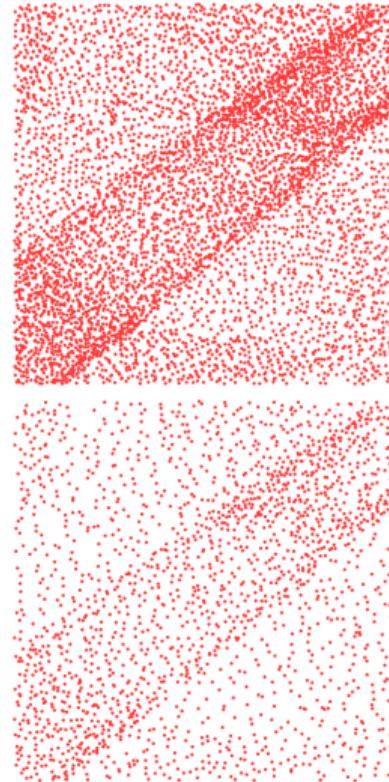
- ▶ *r3.in.lidar*
- ▶ proportional count
  - ▶ count per 3D cell relative to the count per vertical column
- ▶ intensity can be used instead of count

height reduction by base raster under development (analysis and space efficient)



# Decimation

- ▶ *v.in.lidar*
  - ▶ filtering same as in *r.in.lidar*
- ▶ often more points than we need  
(research shows, Singh et al. 2015, Petras et al. 2016)
- ▶ interpolation, clustering, ... are costly
- ▶ decimation  $\approx$  sampling
  - ▶ fast count-based as effective as more advanced decimation



# Large point clouds

## Rasters (binning of points)

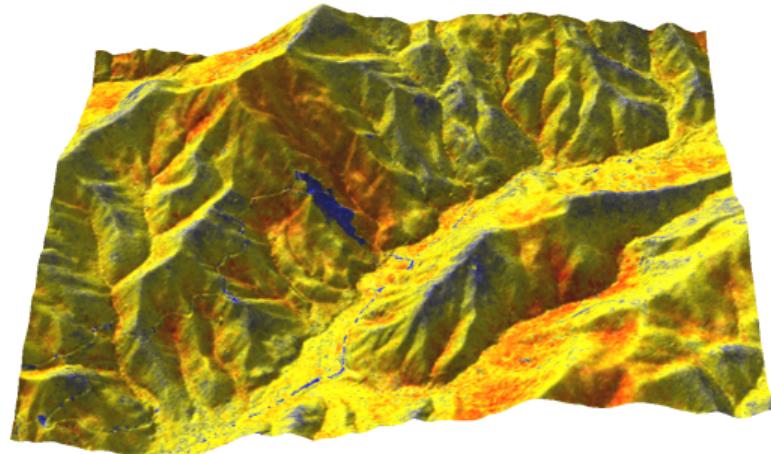
- ▶ trade-off: memory (RAM) or slow
- ▶ 64bit version

Brunswick county: binning,  $\approx 1050$  files,  $> 9$  billion points,  $\approx 0.5$  hour

Hyde county: binning,  $\approx 950$  files,  $> 4$  billion points, base elevation 5ft raster, 60ft height,  $\approx 3$  hours

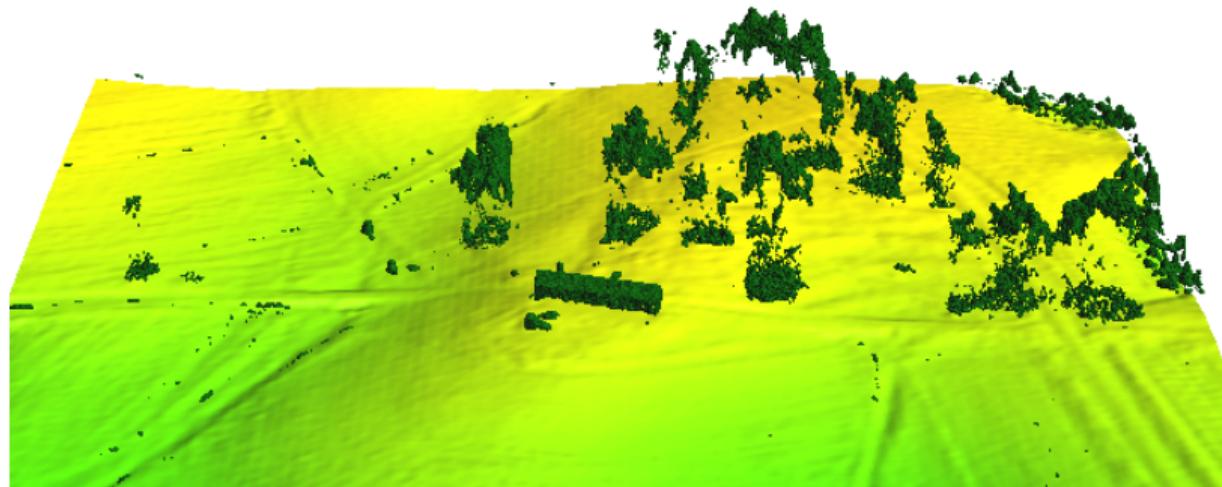
## Vectors (points as points)

- ▶ point cloud specific optimizations
  - ▶ no IDs stored
  - ▶ no attribute table
  - ▶ no topology created



# Ground detection

- ▶ *v.lidar.edgedetection*,  
*v.lidar.growing*,  
*v.lidar.correction*
  - ▶ uses returns
- ▶ *v.lidar.mcc*
  - ▶ multiscale  
curvature based  
classification  
algorithm<sup>1</sup>



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<sup>1</sup> Evans, J. S. & Hudak, A. T. 2007: A Multiscale Curvature Algorithm for Classifying Discrete Return LiDAR in Forested Environments.

# Sky-view factor

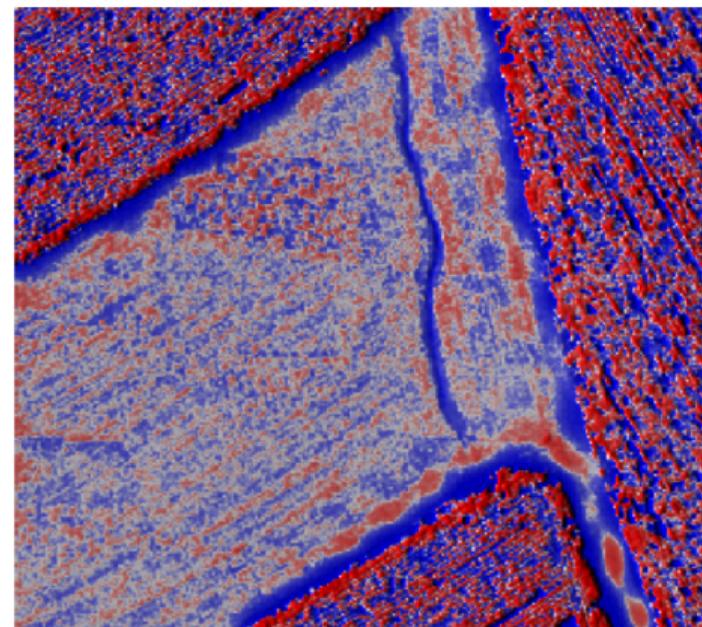
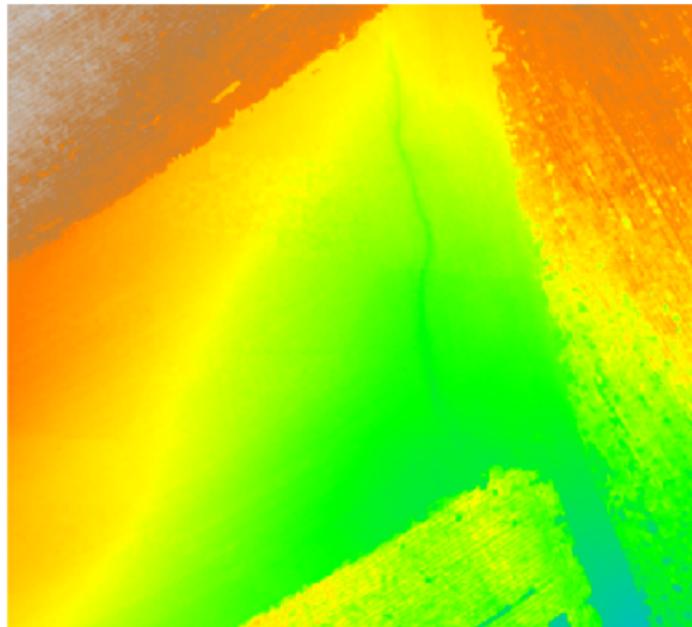
- ▶ *r.skyview* (percentage of visible sky)



comparison of shaded relief and sky-view factor

# Local relief model (LRM)

- ▶ `r.local.relief` (micro-topography, features other than trend)

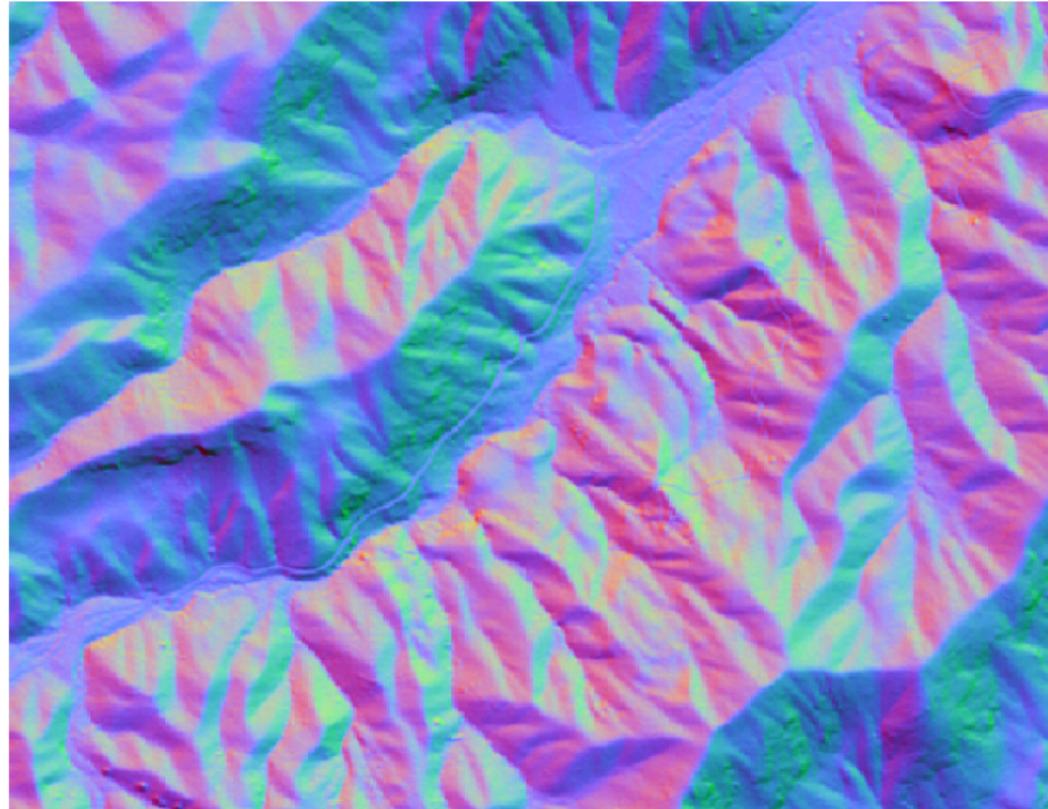


30-60cm wide, 30cm deep, 60m long gully (resolution 30cm)

# Analytical shading

- ▶ *r.shaded.pca*
- ▶ relief shades from various directions
- ▶ PCA of shades
- ▶ combined into RGB composition

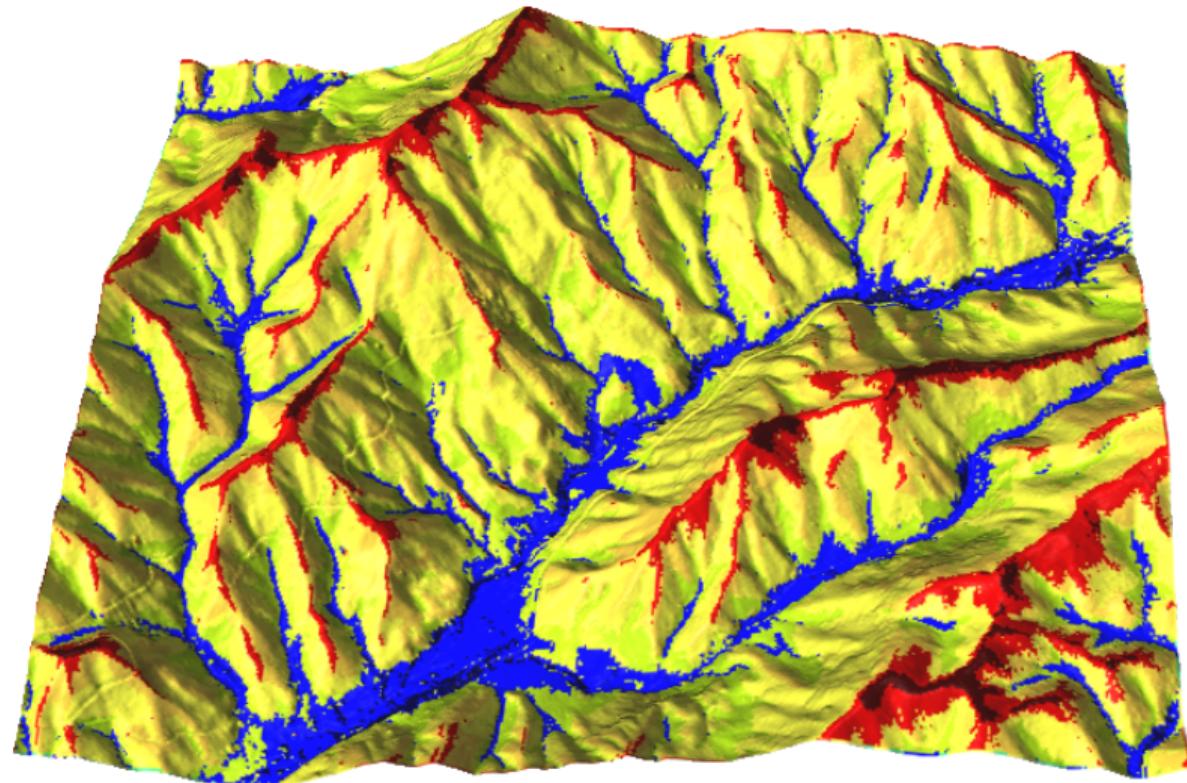
Devereux, B. J., Amable, G. S., & Crow, P. P. (2008). Visualisation of LiDAR terrain models for archaeological feature detection. *Antiquity*, 82(316), 470-479.



# Landforms

- ▶ *r.geomorphon*
- ▶ geomorphons - a new approach to classification of landform<sup>1</sup>

<sup>1</sup> Jasiewicz, J., Stepinski, T., 2013, Geomorphons - a pattern recognition approach to classification and mapping of landforms, *Geomorphology*



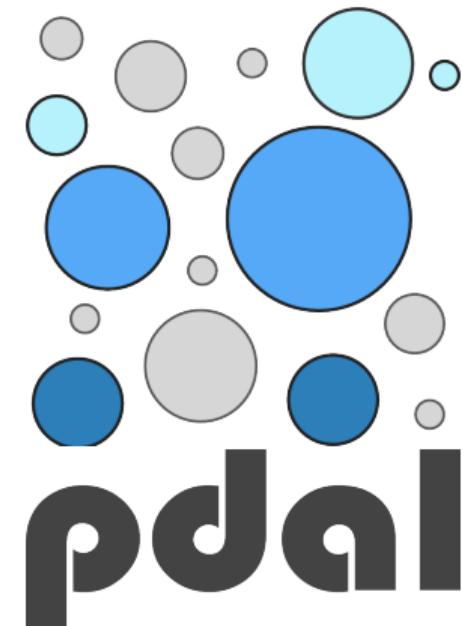
# Integration with PDAL

## PDAL

- ▶ formats besides LAS/LAZ
- ▶ algorithms, filters, decimations

## Experimental integration

- ▶ *v.in.pdal*
- ▶ reprojection during import
- ▶ ground filter
- ▶ compute height as a difference from ground



## Summary

- ▶ rasterize early
- ▶ make use of existing methods for raster and vector processing
- ▶ 3D rasters, PDAL integration
- ▶ the plan for next 30 years driven by users – grass-user mailing list



Get GRASS GIS 7.1 development version at  
[grass.osgeo.org/download](http://grass.osgeo.org/download)

Slides available at  
[wenzeslaus.github.io/grass-lidar-talks](http://wenzeslaus.github.io/grass-lidar-talks)

Paper in preparation: *Processing UAV and lidar point clouds in GRASS GIS*

