

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

Vaclav Petras (Vashek)

Douglas Newcomb, Helena Mitasova

Center for Geospatial Analytics

NC STATE UNIVERSITY

March 18, 2016



available at

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

# Points

- ▶ collected by lidar
- ▶ generated by Structure from Motion (SfM) from UAV imagery
- ▶ a lot of points



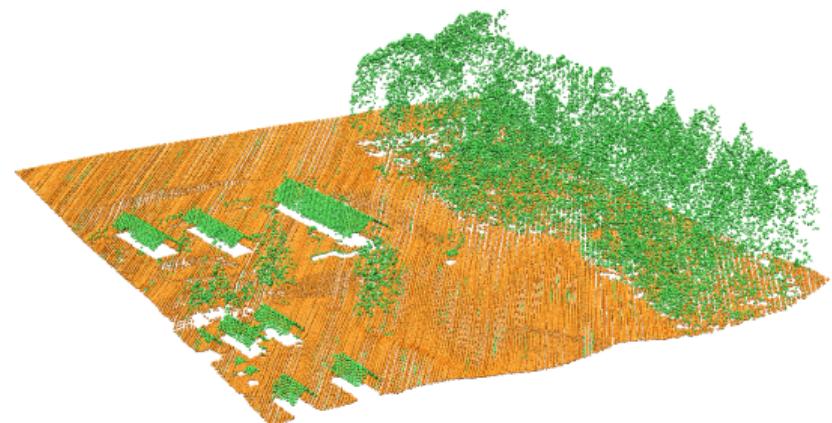
surface interpolated from points from SfM

# 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. Obtained from OpenTopography.  
<http://dx.doi.org/10.5069/G9HT2M76>



# Free, libre and open source

## Scripts and code I'm writing

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

## Software I'm using

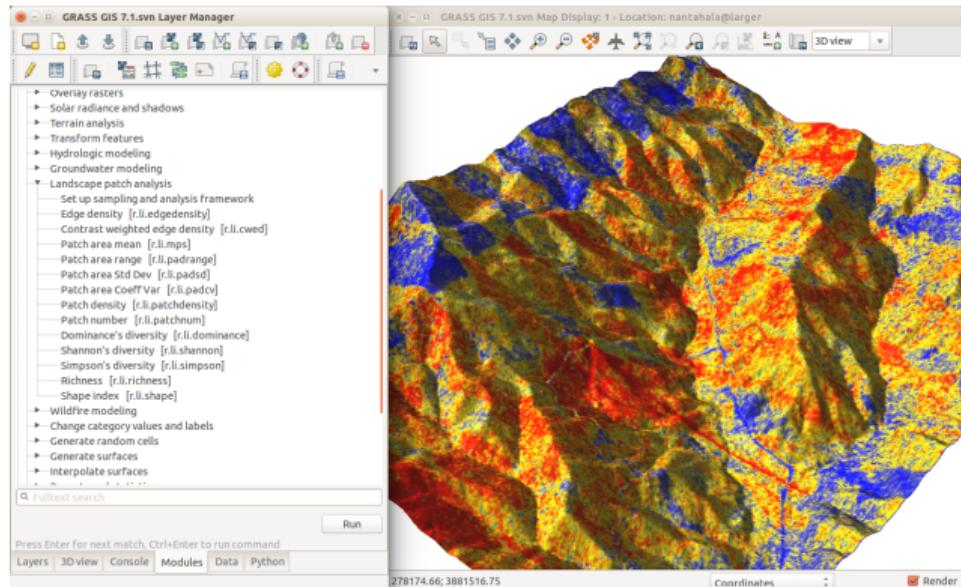
- ▶ driven by needs of users
- ▶ longevity
  - ▶ learn now, use forever
  - ▶ GRASS GIS: over 30 years of development



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



# 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.



# 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, ...



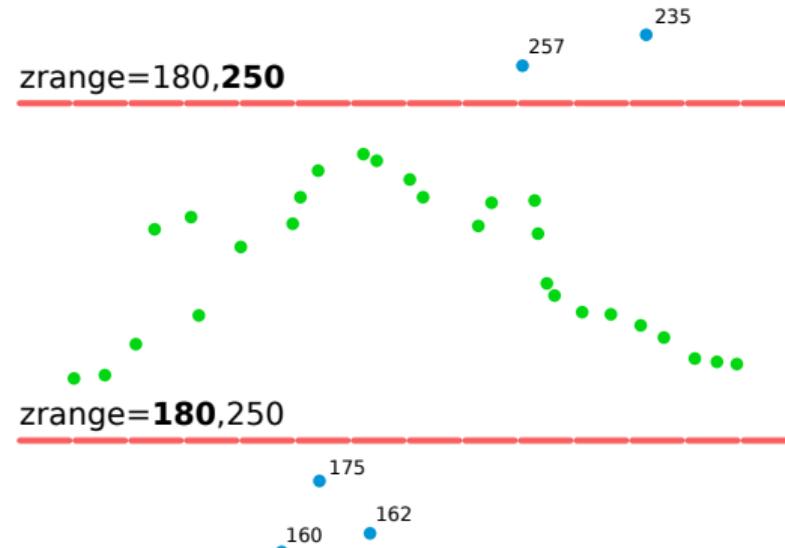
# Practical functions

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



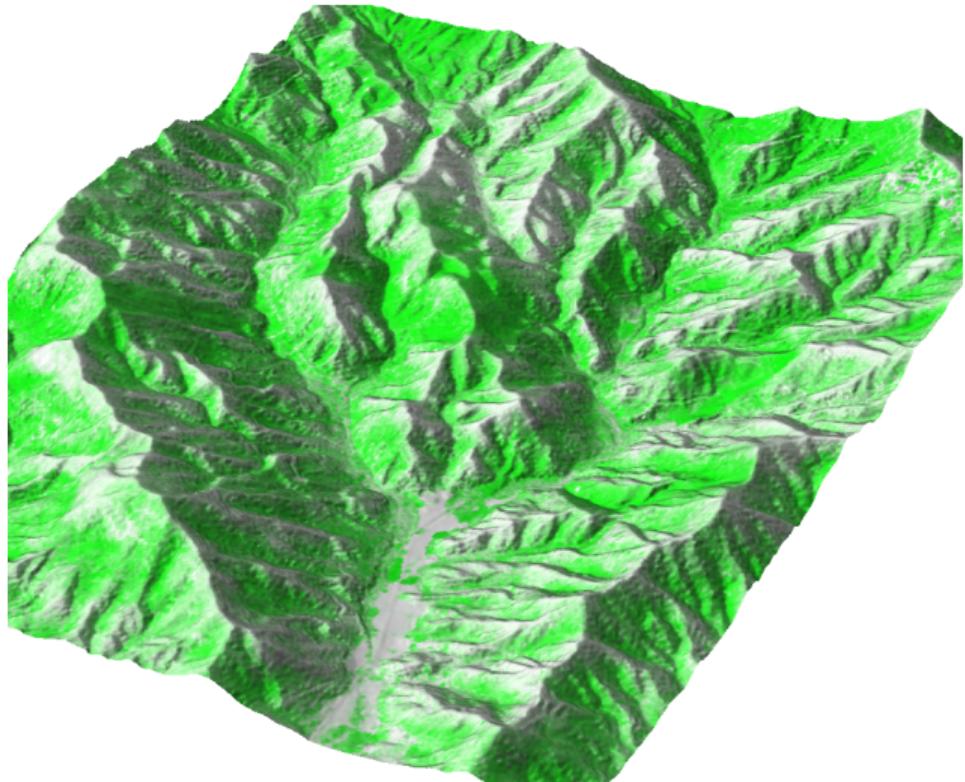
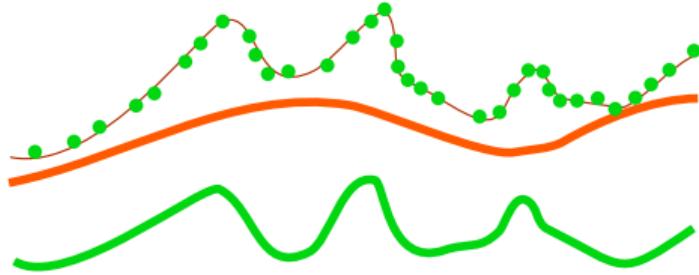
# Filtering points

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



# Height above a surface

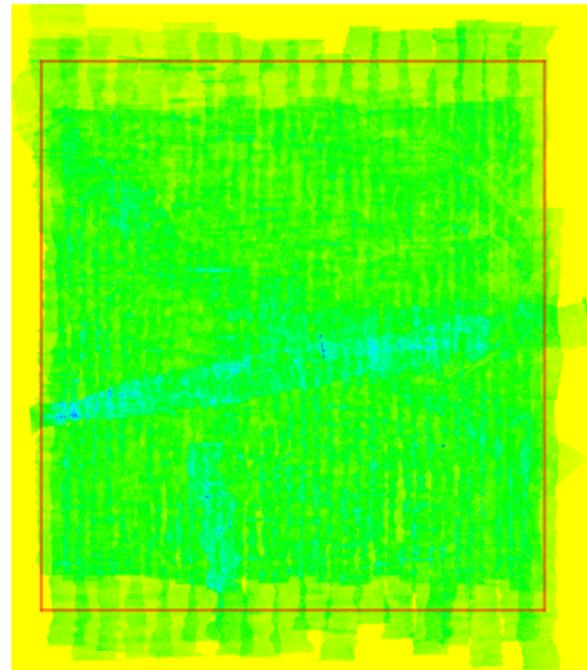
- ▶ new base raster feature in  
*r.in.lidar*
- ▶ given surface + points cloud  
→ height of features



- ▶ not limited by memory

# Rasterize early

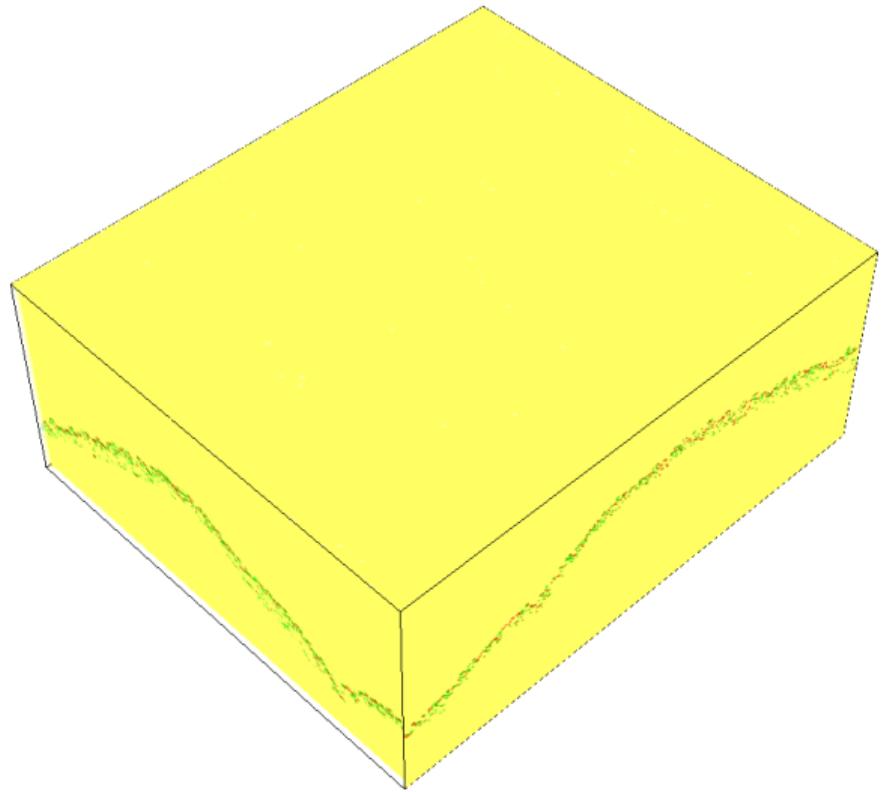
- ▶ less cells than points
  - ▶ 578 mil points (ground 30 mil)
  - ▶ 15 mil cells in  $8\text{km} \times 7\text{km}$  at resolution 2m
    - ▶ faster to loop through
    - ▶ less disk space
- ▶ raster
  - ▶ natural spatial index
  - ▶ that's what the algorithms use



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

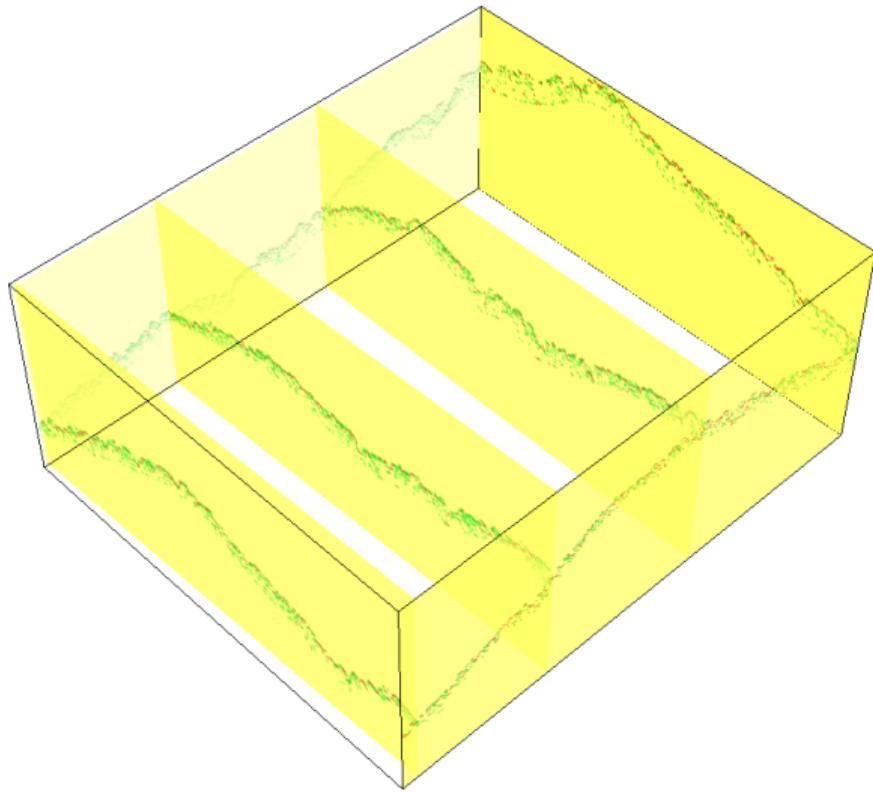
## 3D raster

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



# 3D raster

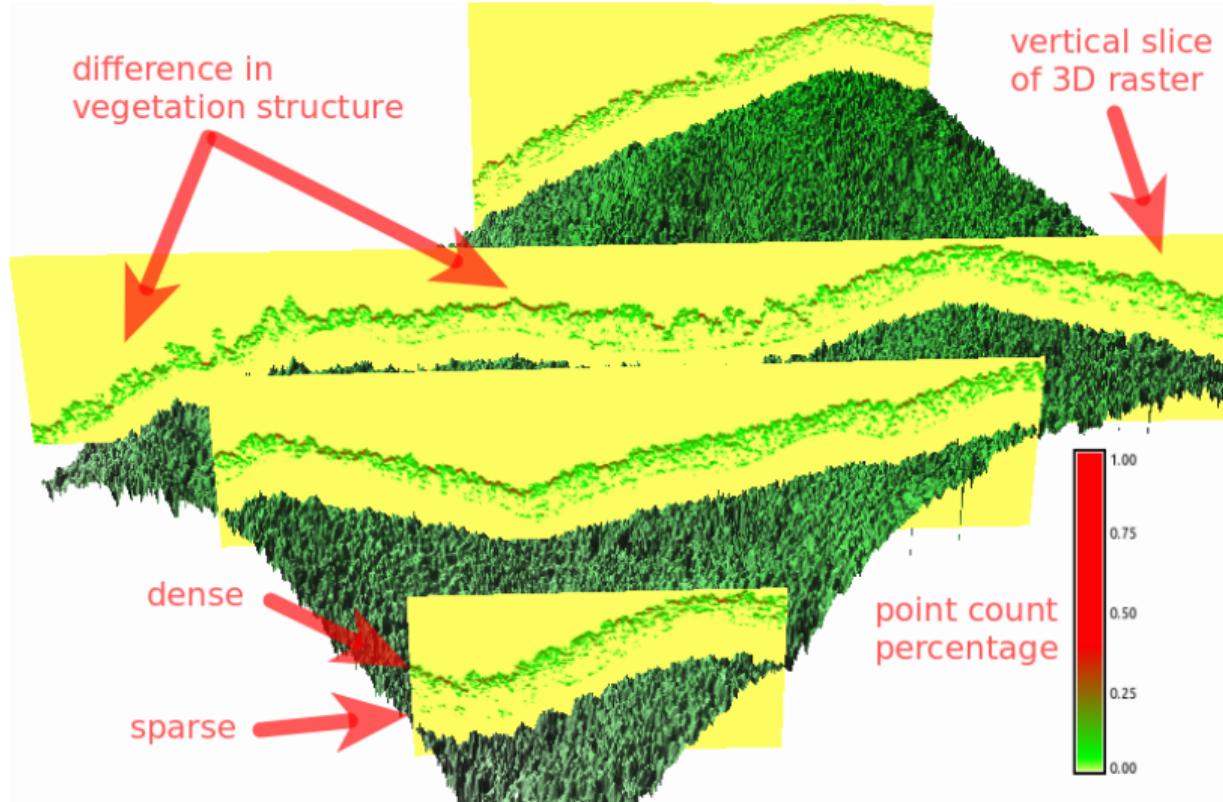
- ▶ stacked 2D rasters
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- ▶ same principles as in 2D
  - ▶ e.g. 3D raster map algebra



# Binning points to 3D raster

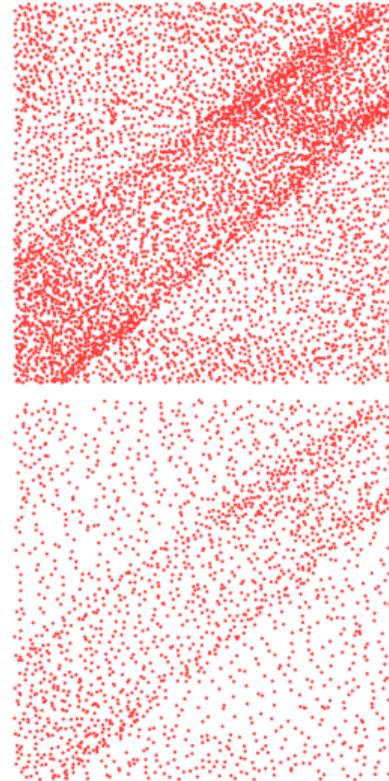
- ▶ *r3.in.lidar*
- ▶ proportional count
  - ▶ count per 3D cell relative to the count per vertical column
- ▶ intensity can be used instead of count

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
  - ▶ your operating system may limit max memory

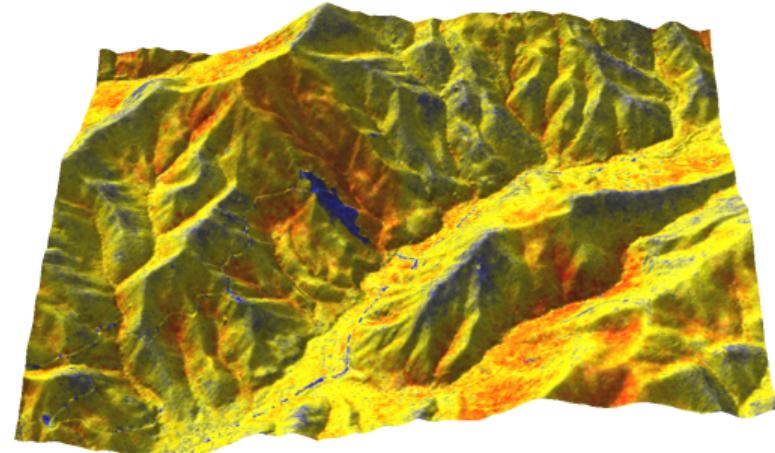
Brunswick county: binning,  $\approx 1050$  files,  
 $> 9$  billion points

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

$\approx 0.5\text{-}3$  hours, 1-13GB of memory (in-memory mode)

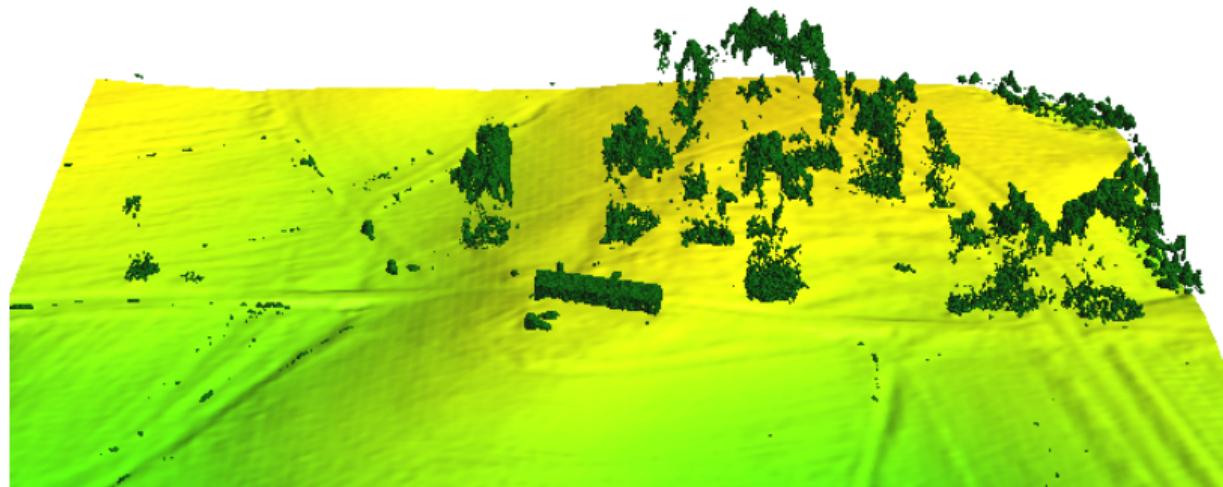
## Vectors (points as points)

- ▶ 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

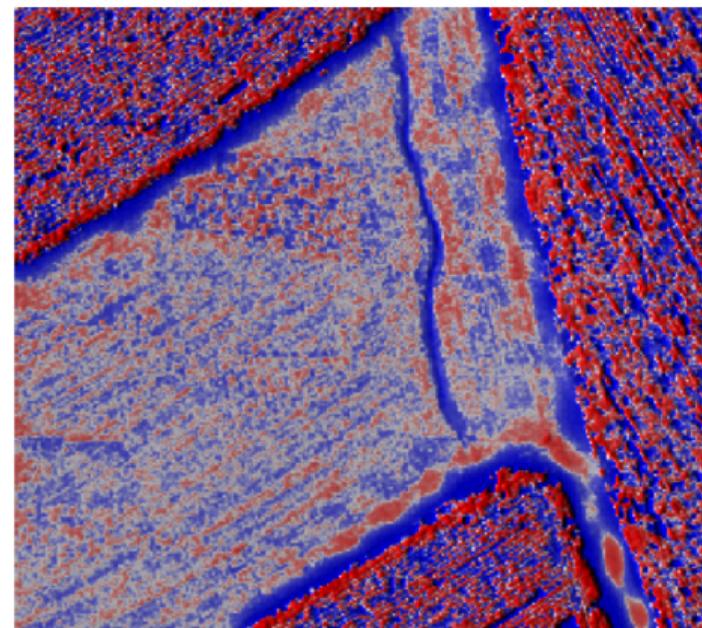
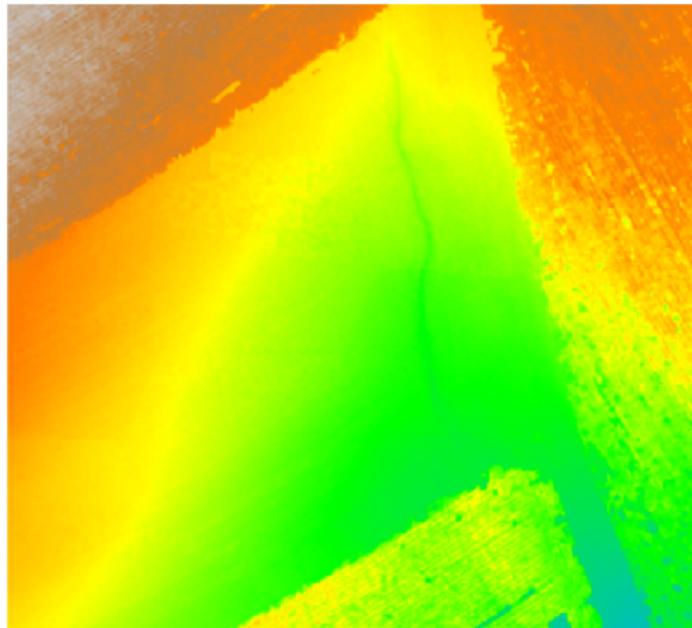
- ▶ *r.skyview* (percentage of visible sky)



comparison of shaded relief and sky-view factor

# Local relief model (LRM)

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

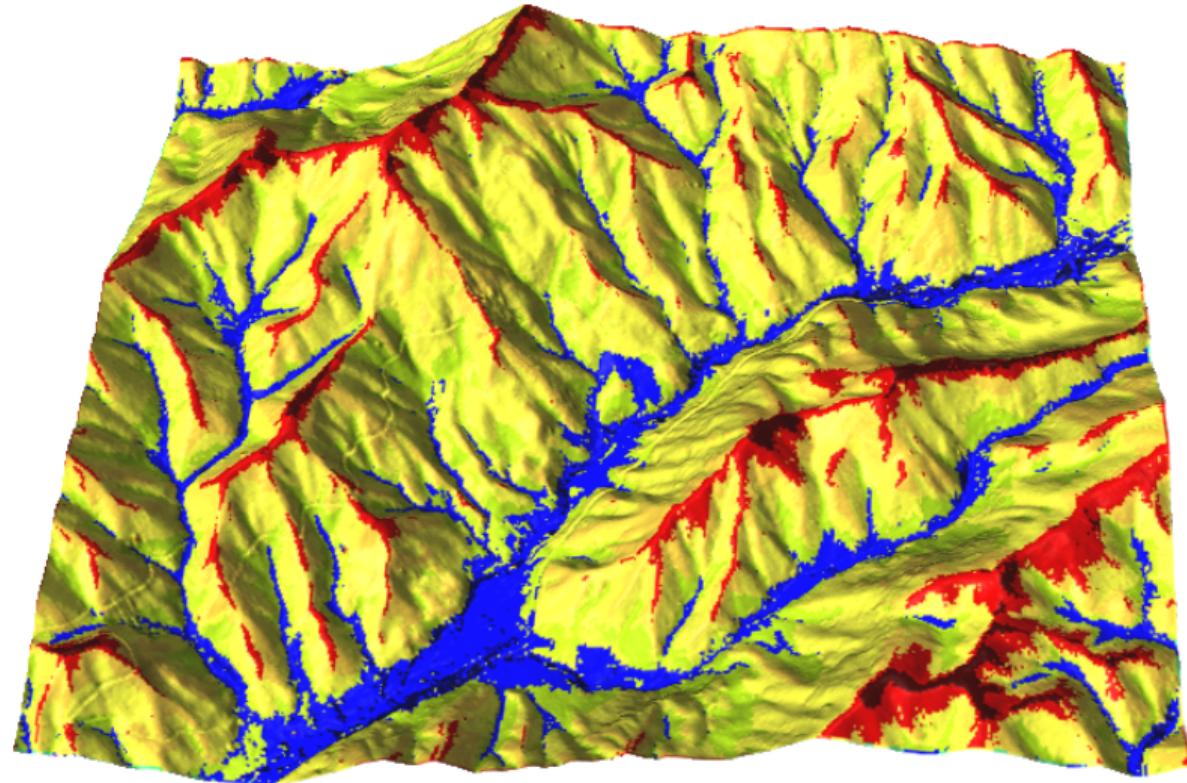


30-60cm wide, 30cm deep, 60m long gully (resolution 30cm)

# 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*



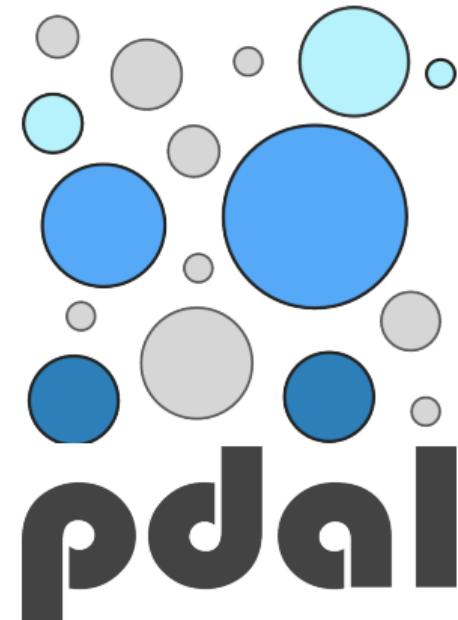
# Integration with PDAL

## PDAL

- ▶ Point Data Abstraction Library
- ▶ 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



**GRASS** GIS

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*

