

# GRASS GIS loves lidar

## FOSS4G NA 2016

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available at

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

- ▶ all in one
  - ▶ hydrology modeling, image segmentation, point clustering, ...
- ▶ from small laptops to supercomputers
  - ▶ Raspberry Pi, Windows, Mac, GNU/Linux, GNU/Hurd, FreeBSD, IBM AIX
- ▶ learn now, use forever
  - ▶ over 30 years of development and interface refinement
- ▶ probably used more than you think
  - ▶ similarly to C/C++ is often not mentioned but is somewhere in there



**GRASS** GIS



Welcome to GRASS GIS 7.1.svn (r68305M)

GRASS GIS homepage:

<http://grass.osgeo.org>

This version running through:

Bash Shell (/bin/bash)

Help is available with the command:

g.manual -i

See the licence terms with:

g.version -c

Start the GUI with:

g.gui wxpython

When ready to quit enter:

exit

To run a command as administrator (user "root"), use "sudo <command>".

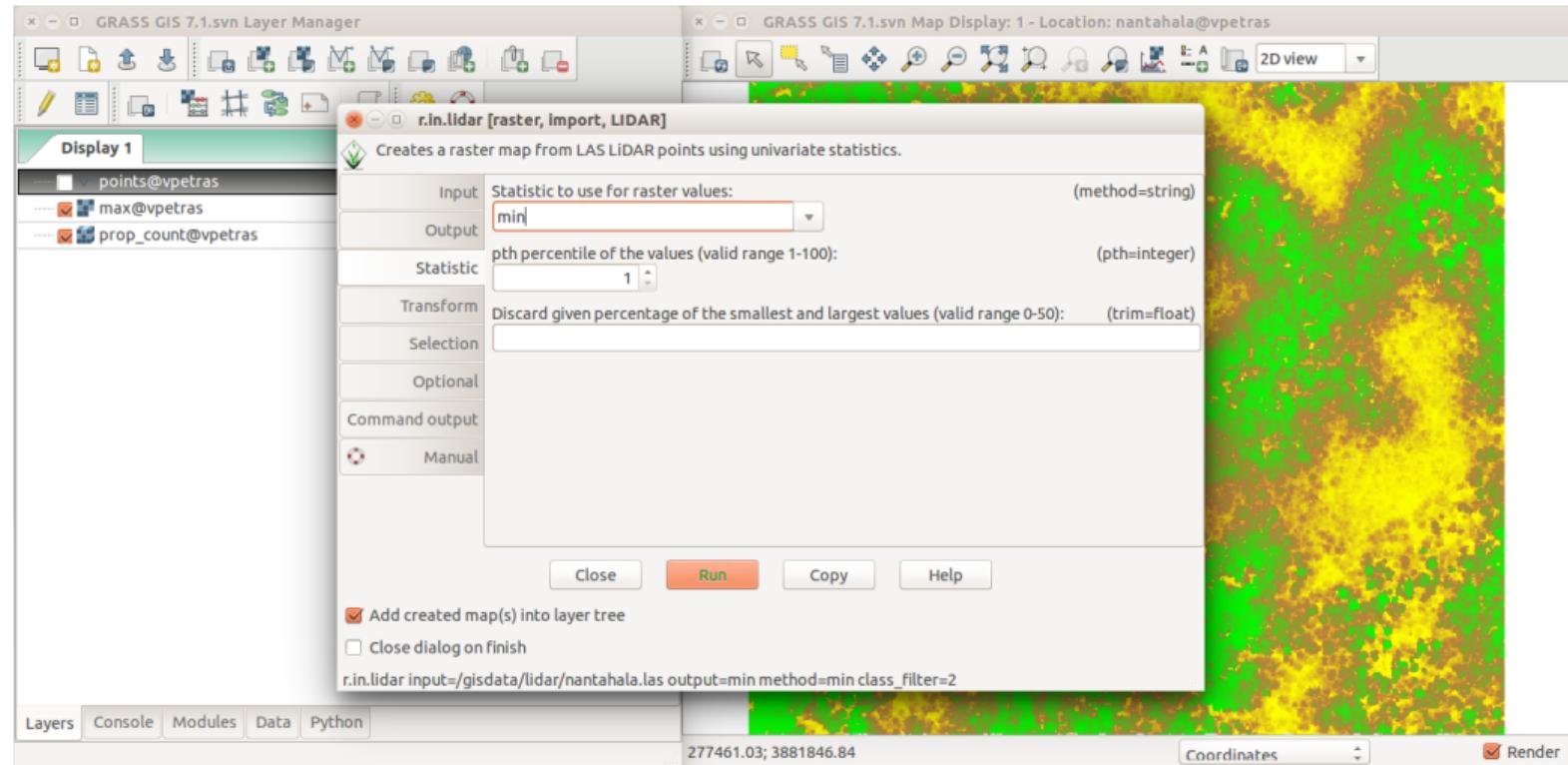
See "man sudo\_root" for details.

GRASS 7.1.svn (nantahala):~/dev/grass/gcc\_trunk > g.region vector=points

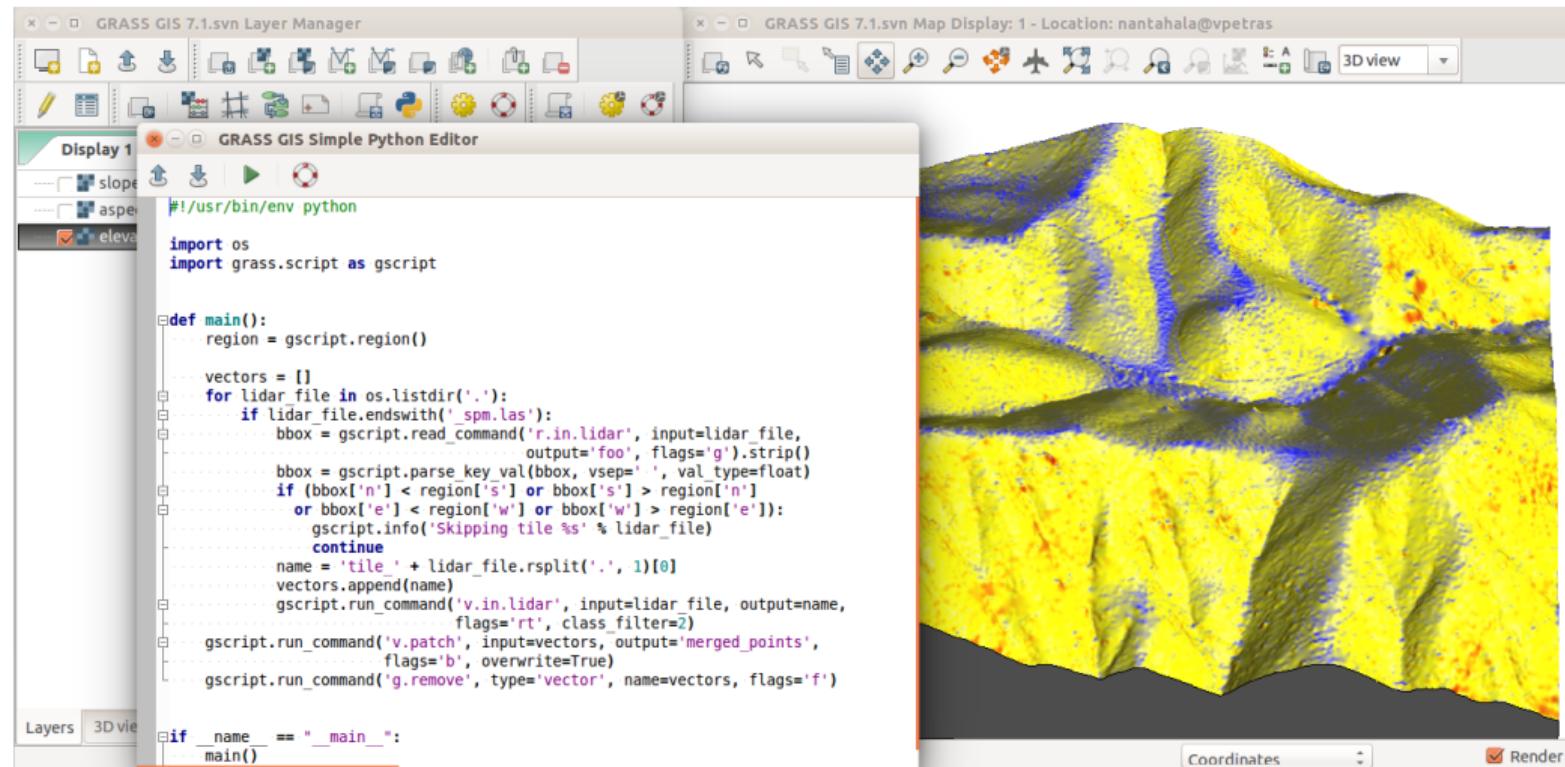
GRASS 7.1.svn (nantahala):~/dev/grass/gcc\_trunk > g.region res=5

GRASS 7.1.svn (nantahala):~/dev/grass/gcc\_trunk > r.in.lidar input=/gisdata/lidar/points.las output=mean

# GUI



# Python



## Python versus CLI

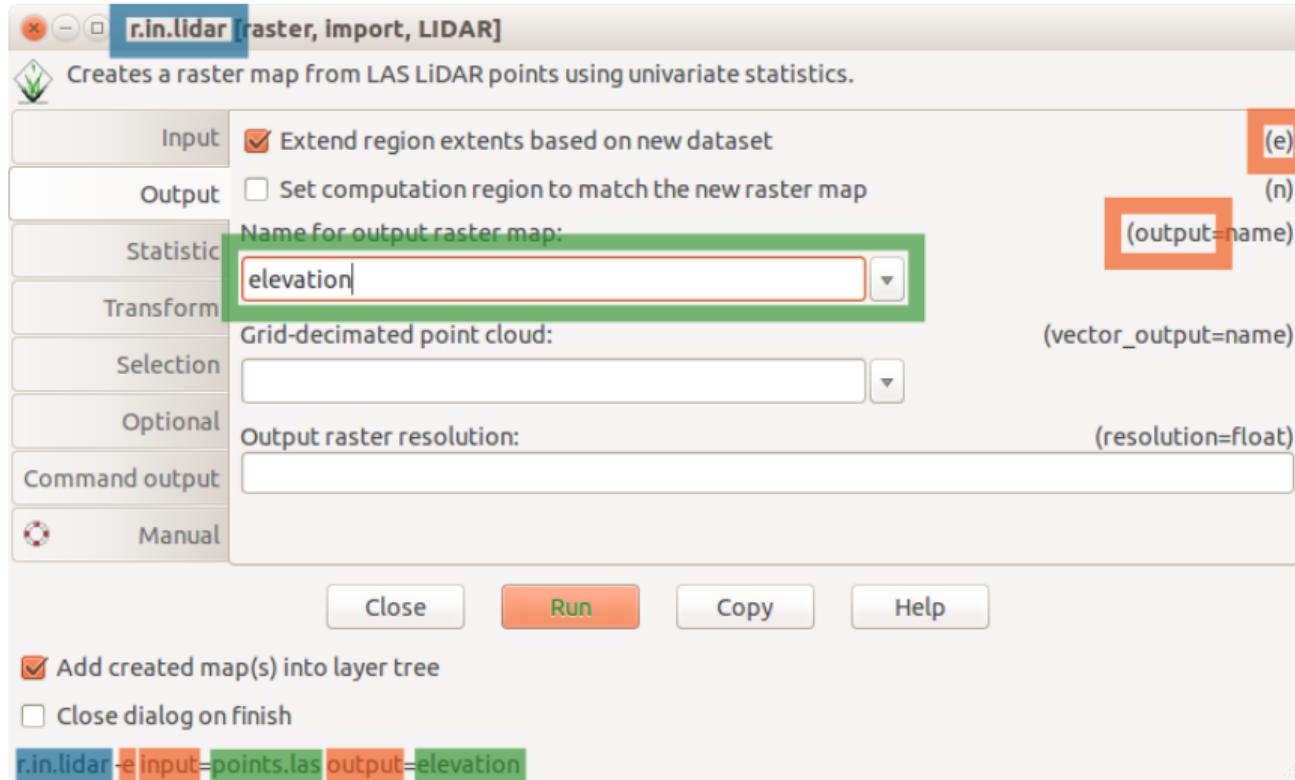
Documentation, Command Line (Shell, Bash, cmd.exe):

```
r.in.lidar input=points.las \
    output=elevation -e
```

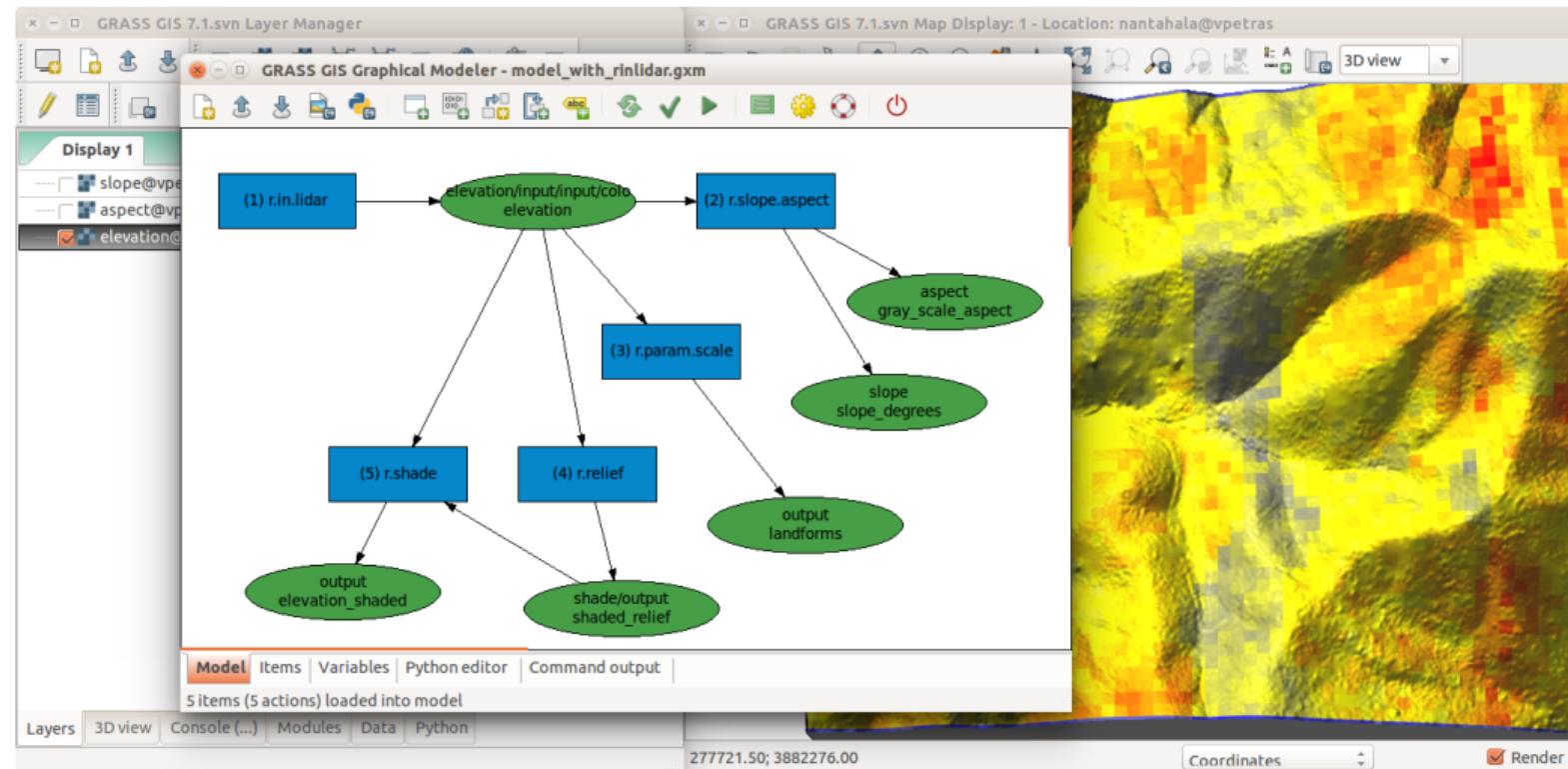
Python:

```
from grass.script import run_command
run_command('r.in.lidar',
            input="points.las",
            output="elevation",
            flags='e')
```

# Module GUI



# Graphical Modeler



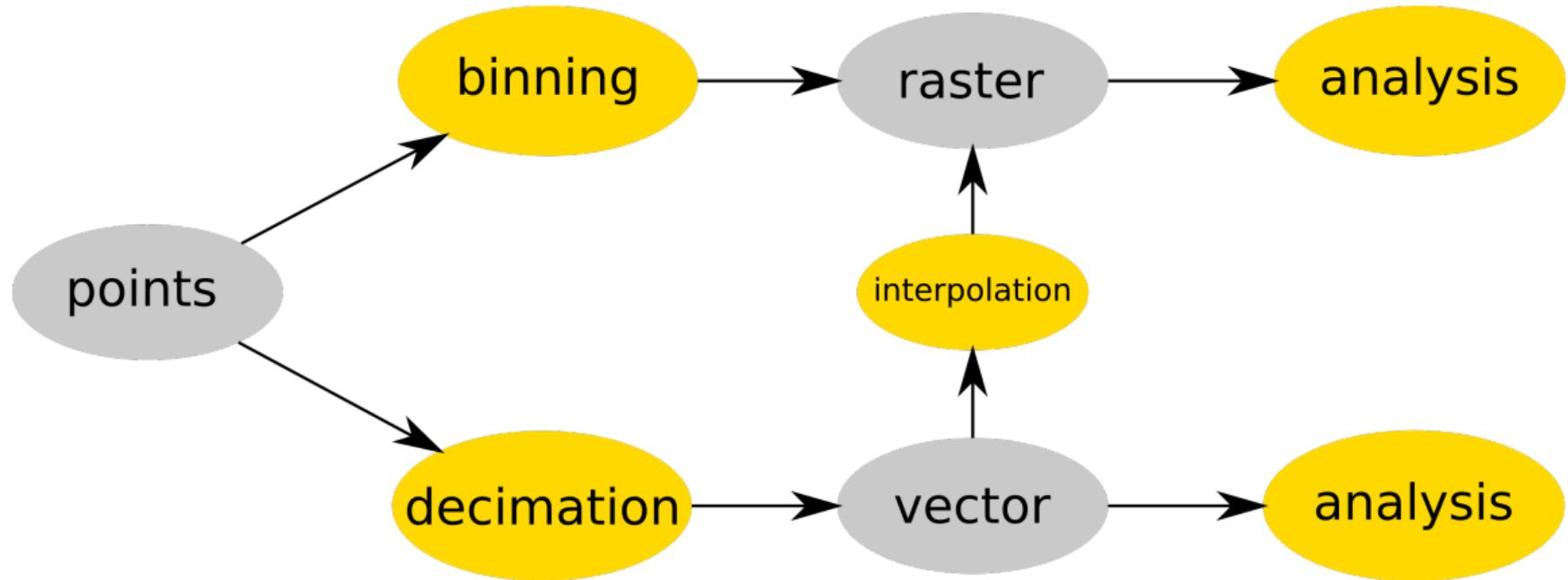
# Points

- ▶ collected by lidar
- ▶ generated by Structure from Motion (SfM) from UAV imagery



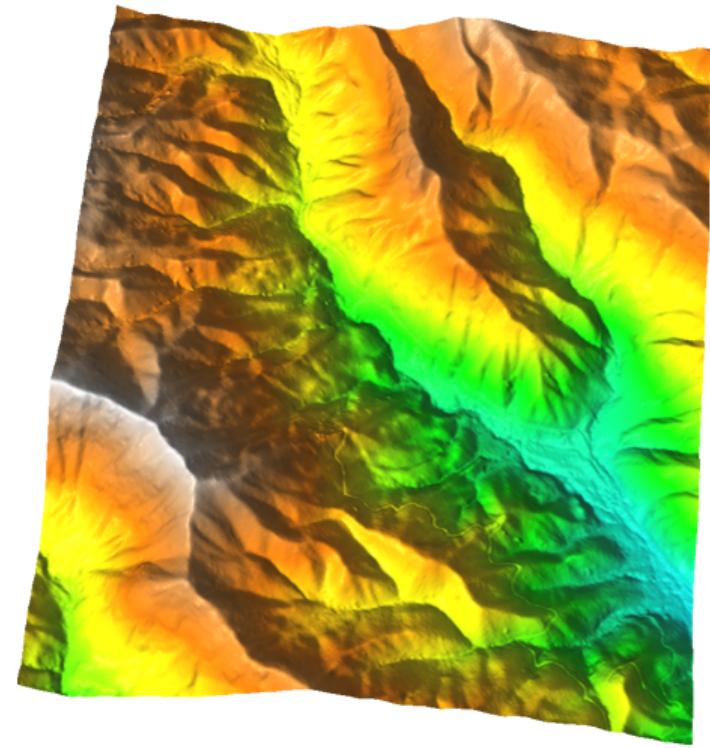
surface interpolated from points and visualized in GRASS GIS

# Workflow overview



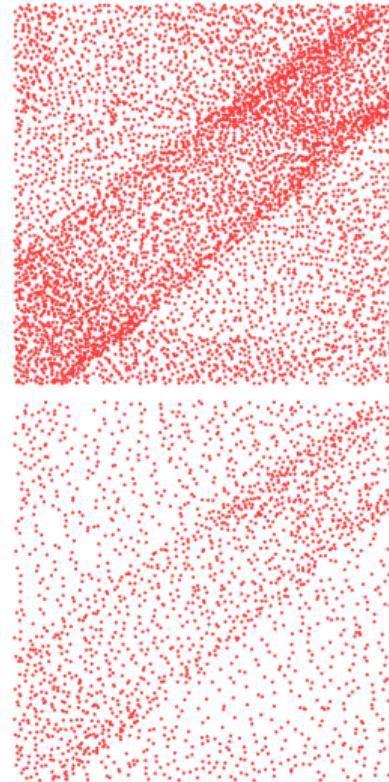
# Surface interpolation

- ▶ *v.surf.idw*
  - ▶ Inverse Distance squared Weighting
- ▶ *v.surf.bspline*
  - ▶ Bicubic or bilinear Spline interpolation with Tykhonov regularization
- ▶ *v.surf.rst*
  - ▶ Regularized Spline with Tension
  - ▶ *v.surf.rst.mp* (experimental)
    - ▶ 2 millions of points in 11 minutes



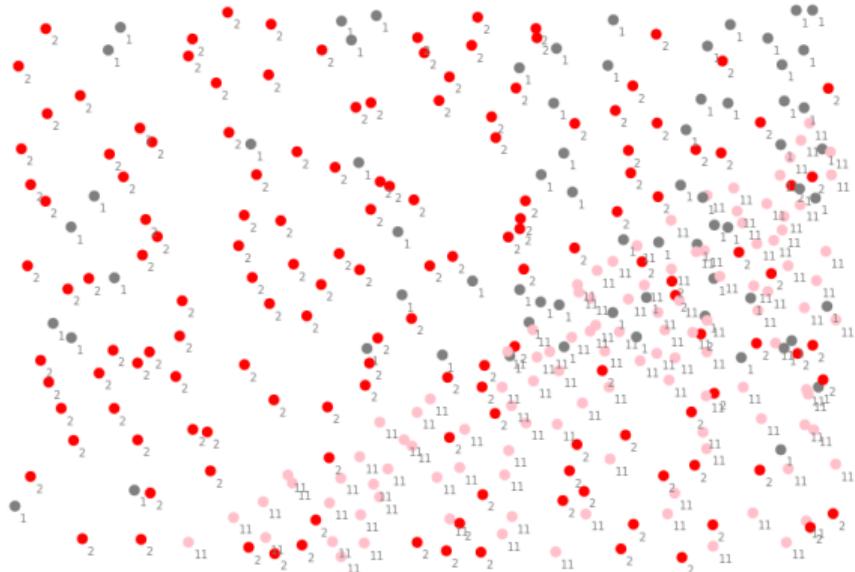
# Import and decimation

- ▶ *v.in.lidar*
  - ▶ libLAS
  - ▶ LAS/LAZ to GRASS GIS native vector
  - ▶ data stored in GRASS GIS database
- ▶ decimation  $\approx$  thinning  $\approx$  sampling
  - ▶ count-based decimation (skips points)
  - ▶ grid-based experimental, others needed?
  - ▶ fast count-based as good as more advanced decimations



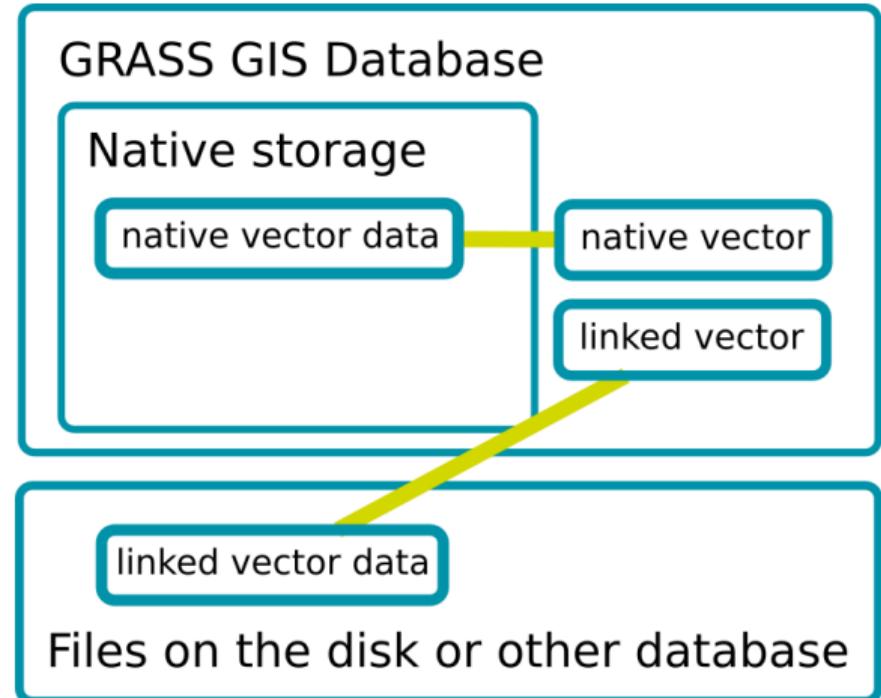
# GRASS vector model and format

- ▶ topology and index
  - ▶ can be disabled (`-b` flag)
- ▶ attributes in a database
  - ▶ SQLite, PostgreSQL, ...
  - ▶ can be disabled (`-t` flag)
- ▶ each feature can have any number of categories/classes
  - ▶ without attribute table



# Linked external data

- ▶ *r.external*
  - ▶ raster data (GDAL)
  - ▶ *r.external.out* for newly created data
- ▶ *v.external*
  - ▶ vector data
    - ▶ GDAL/OGR
    - ▶ PostGIS including topology
  - ▶ *v.external.out* for newly created data
  - ▶ alternative: @OGR  
`v.info map=.../directory@OGR layer=file`
- ▶ missing: libLAS/PDAL backend
  - ▶ intermediate C API needed in PDAL or GRASS GIS



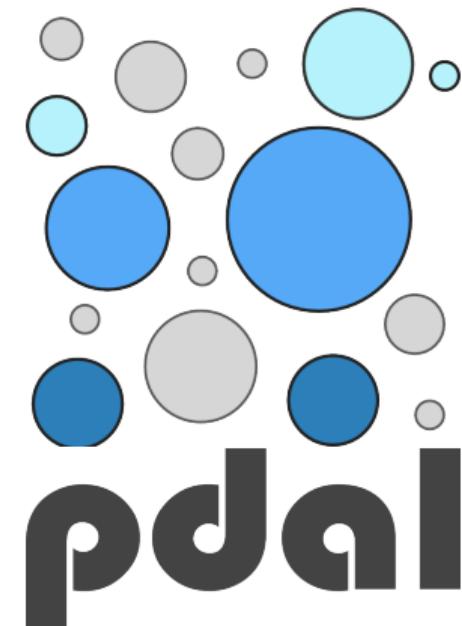
# Current state of integration with PDAL

## PDAL

- ▶ Point Data Abstraction Library
- ▶ format conversions
- ▶ processing, filtering

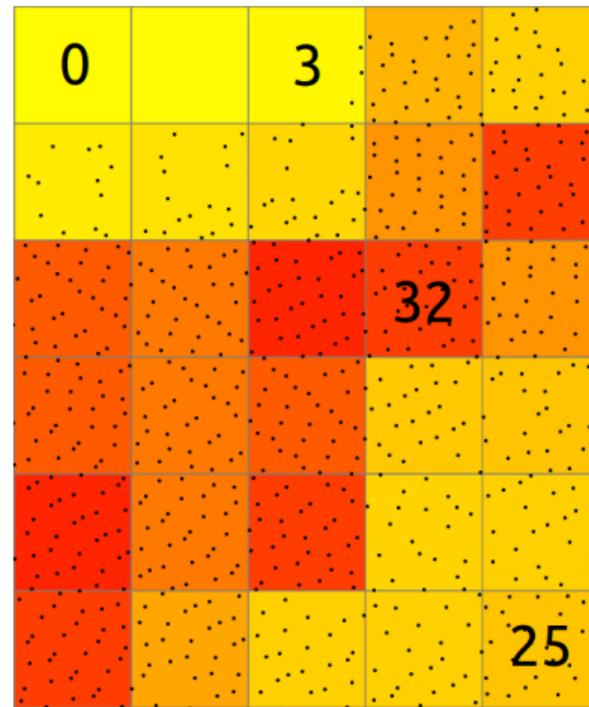
## Experimental integration

- ▶ *v.in.pdal*
  - ▶ next: *r.in.pdal*, *r3.in.pdal*
- ▶ runs PDAL filters during import
  - ▶ filters are followed by GRASS processing



# Binning points to raster

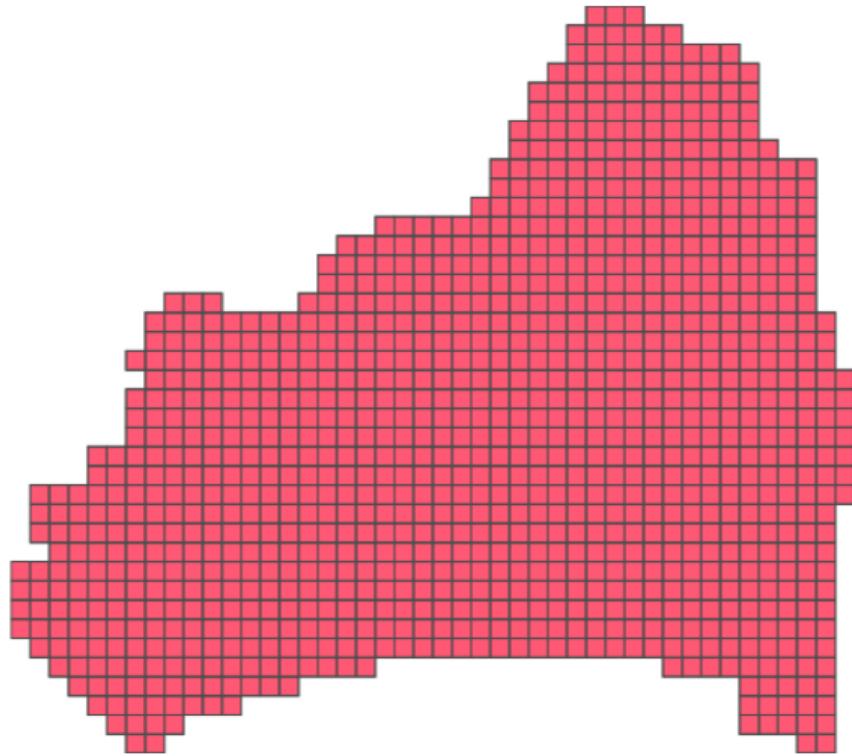
- ▶ *r.in.lidar*
- ▶ import and analysis
- ▶ statistics of point counts, height and intensity
  - ▶ n, min, max, sum
  - ▶ mean, range, skewness, ...



## Read multiple tiles as one

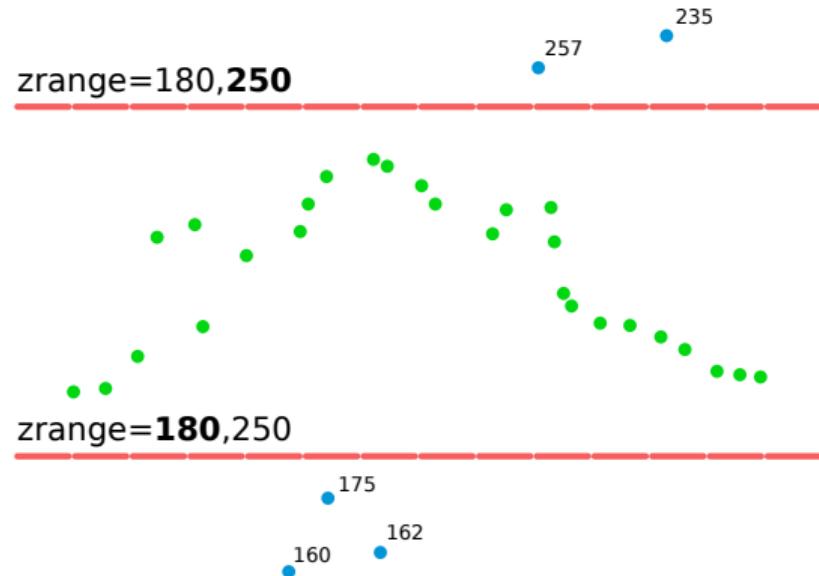
- ▶ *r.in.lidar*, option *file*
  - ▶ read multiple tiles as one
  - ▶ no merging

0.5 billion points in 90 files in minutes



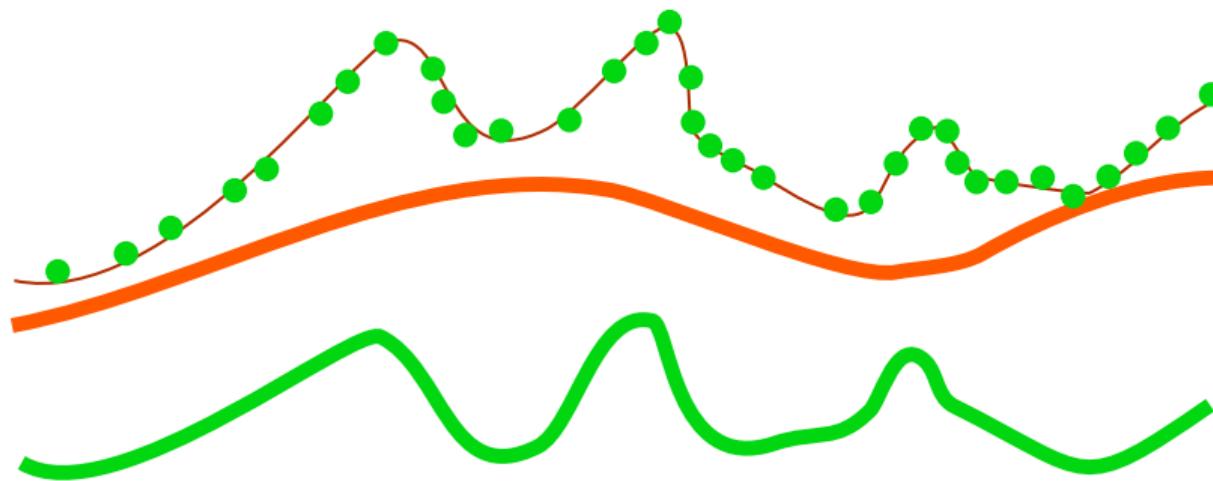
# Filtering points

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



# Height above a surface

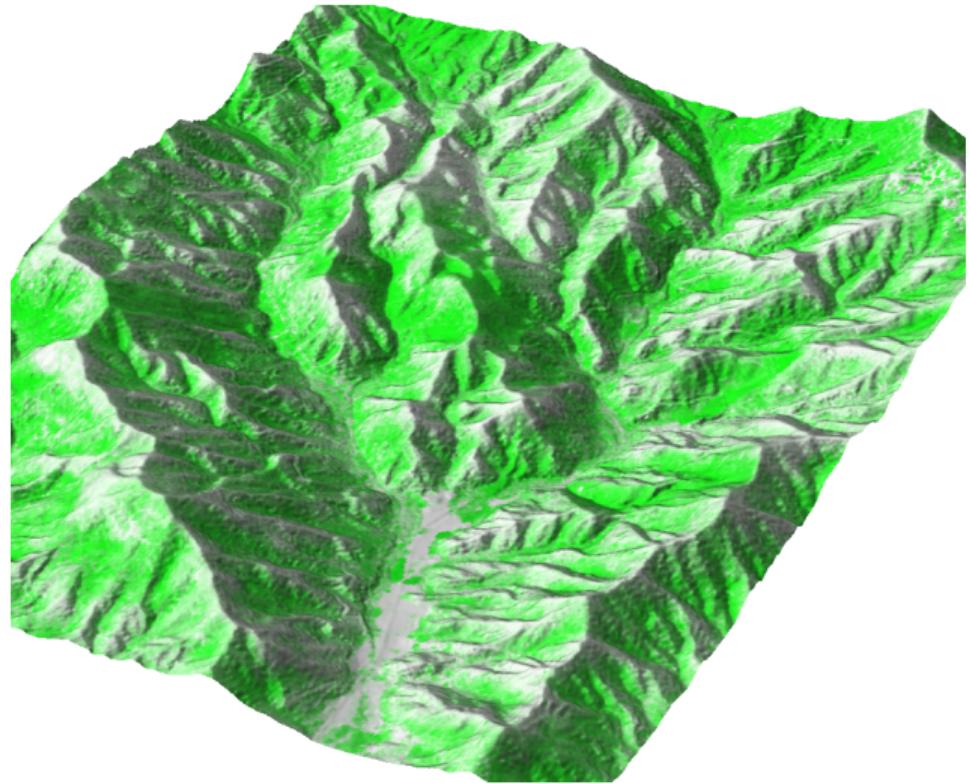
- ▶ `r.in.lidar`, option `base_raster`
- ▶ given surface + points cloud → height of features



- ▶ low additional memory requirements

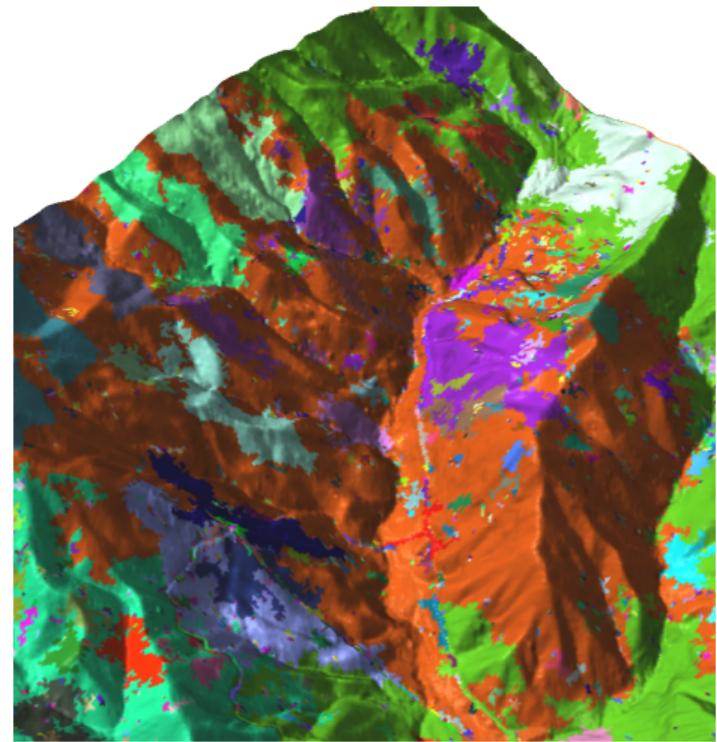
# Height above a surface

- ▶ different resolutions
  - ▶ 1m ground surface
  - ▶ 30m height above ground
- ▶ different statistics
- ▶ different combinations
  - ▶ surface can be e.g. top of the canopy
  - ▶ combine with *zrange*
  - ▶ combine with intensity



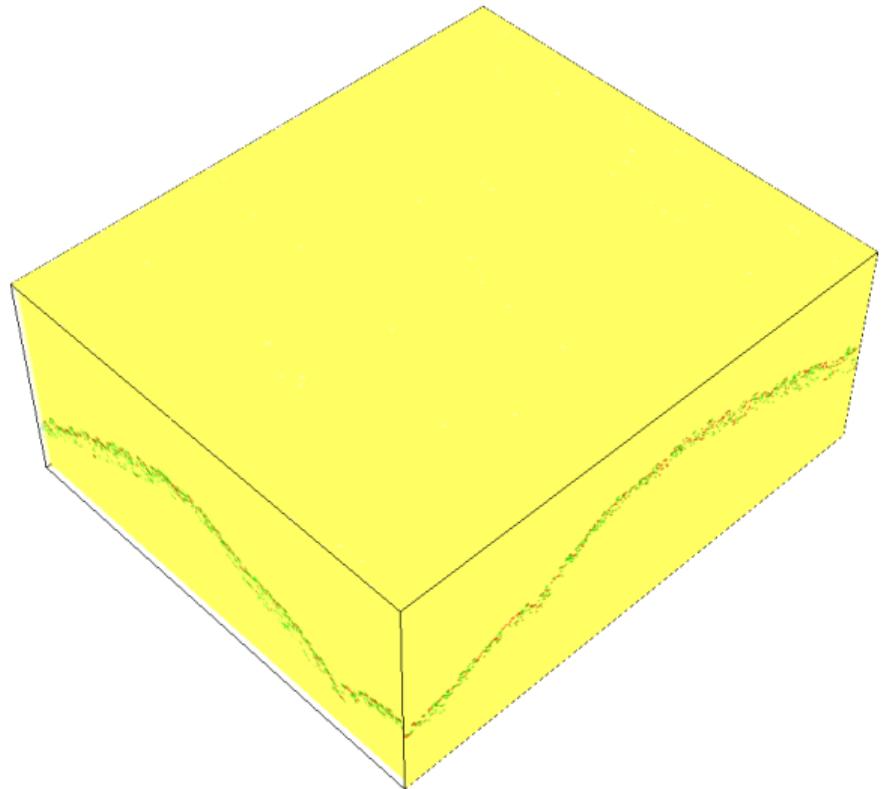
# Rastersize early

- ▶ many algorithms are raster-based
  - ▶ a lot of data with continuous nature
  - ▶ natural spatial index
- ▶ example:
  1. count of ground points
  2. count of non-ground points
  3. used as image bands
  4. segmentation using *i.segment*



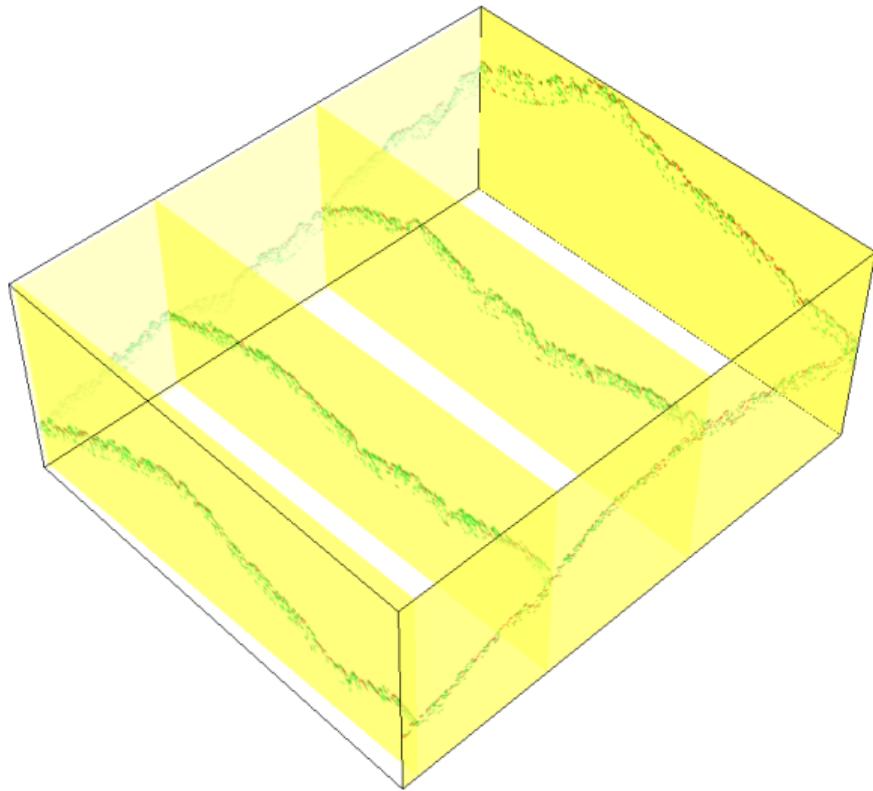
## 3D raster

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



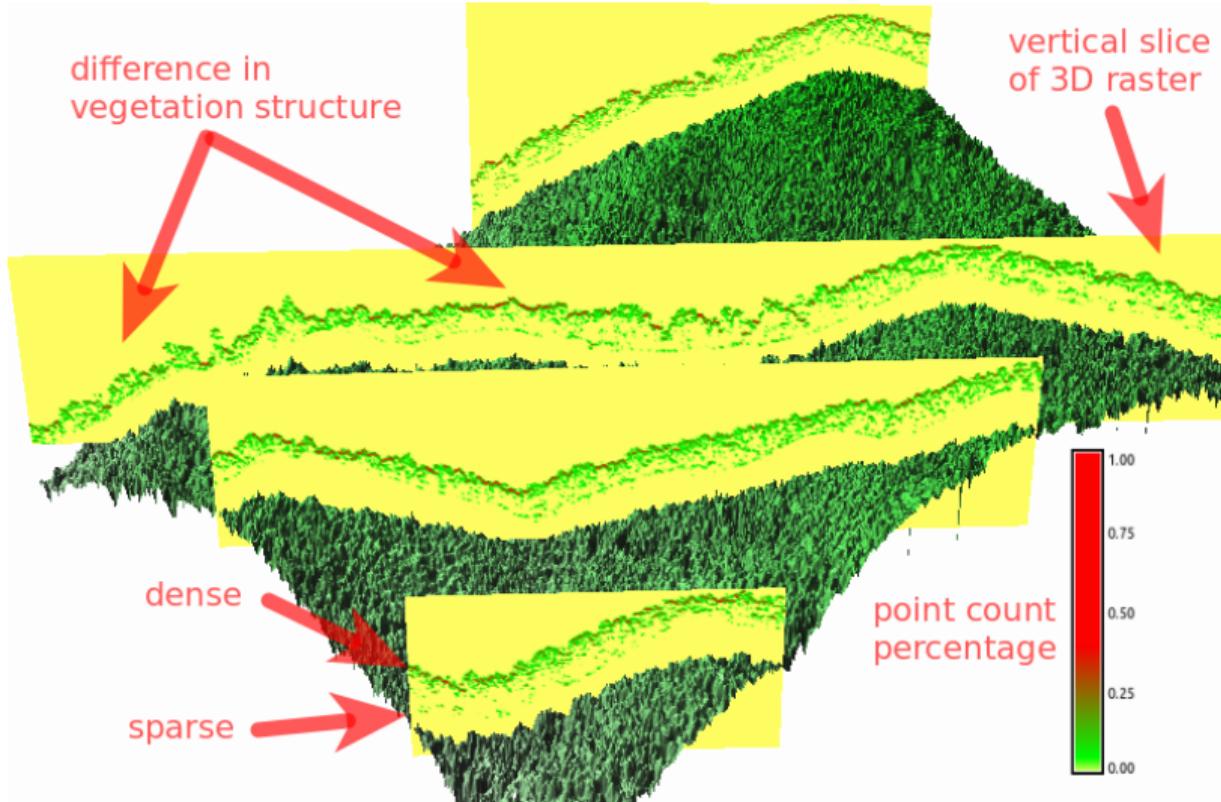
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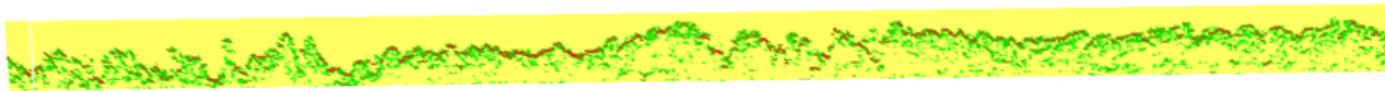
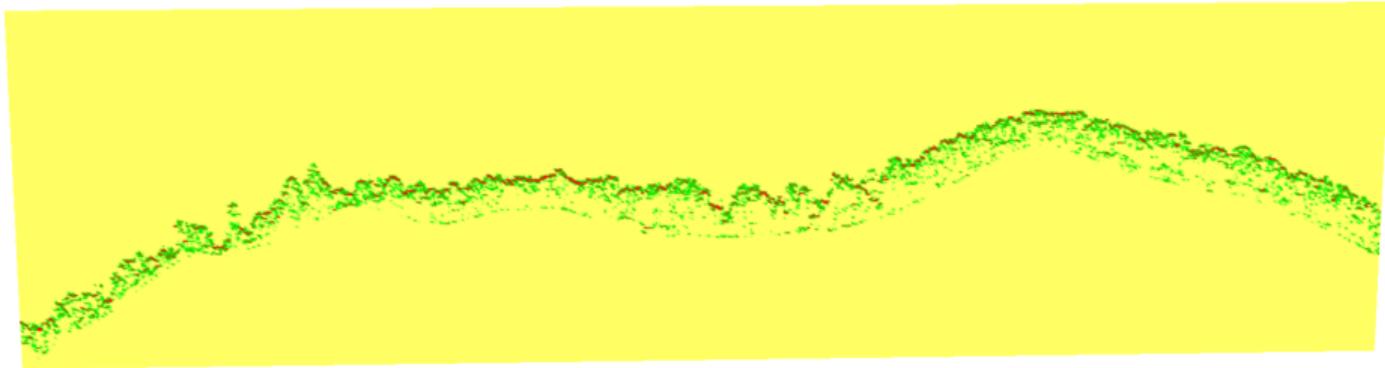


# Binning points to 3D raster

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



## Point heights reduced to surface



- ▶ `r3.in.lidar`, option `base_raster`
- ▶ height reduced by raster values

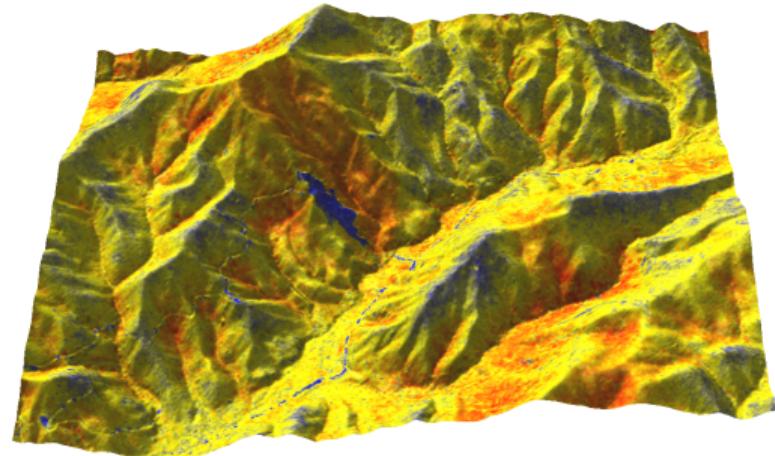
# Trade-offs

## Raster processing

- ▶ high memory (RAM) usage – fast
- ▶ low memory usage (high I/O) – slow

## Vector processing

- ▶ slower than raster
  - ▶ e.g., interpolation much slowed than binning
- ▶ hard to make general statements

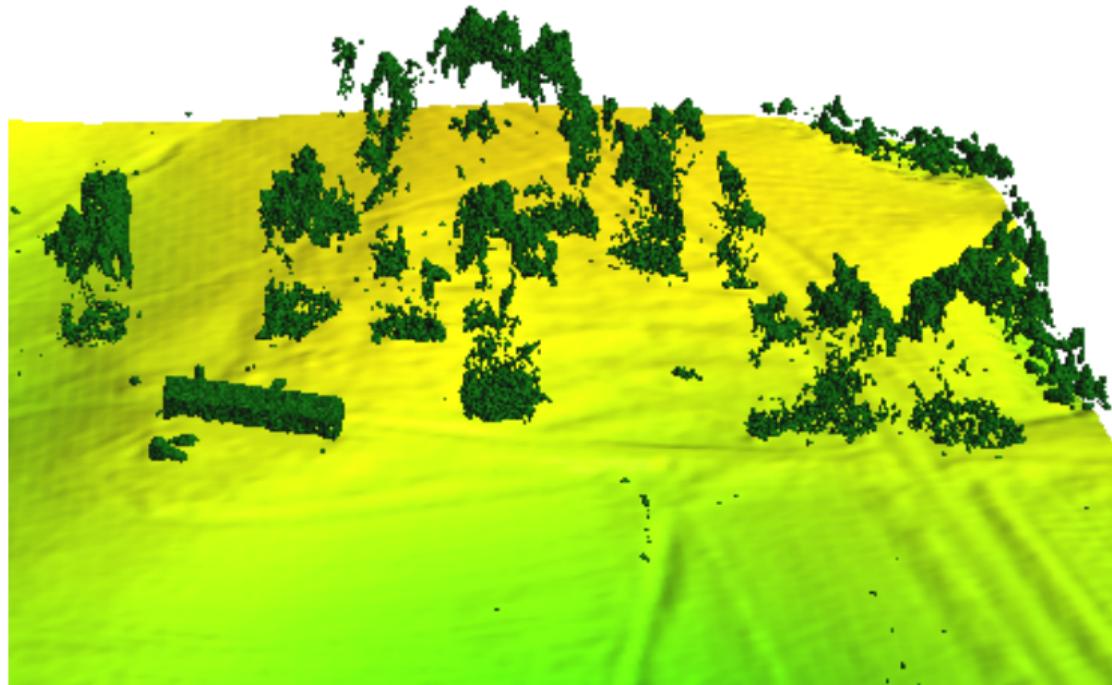


visualization: range from binning on interpolated surface

example: binning with base elevation subtraction:  
≈1000 files, > 9 billion points  
≈3 hours, ≈10GB of memory (in-memory mode)

# Ground detection

- ▶ *v.lidar.edgedetection*,  
*v.lidar.growing*,  
*v.lidar.correction*
  - ▶ by Brovelli, Cannata, Antolin & Moreno
- ▶ *v.lidar.mcc*
  - ▶ multiscale curvature based classification algorithm
  - ▶ by Blumentrath, according to Evans & Hudak
- ▶ PDAL filters.ground
  - ▶ now in *v.in.pdal*
  - ▶ progressive morphological filter by Zhang
  - ▶ provided by PCL



# Sky-view factor

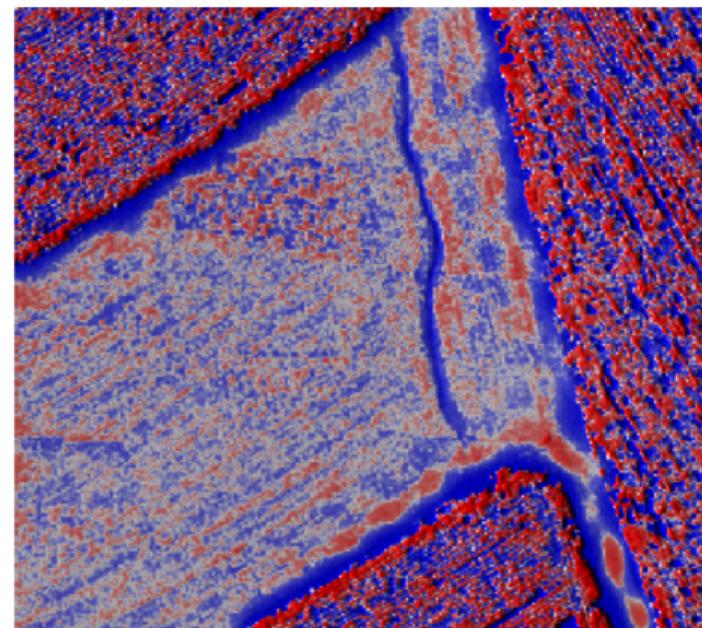
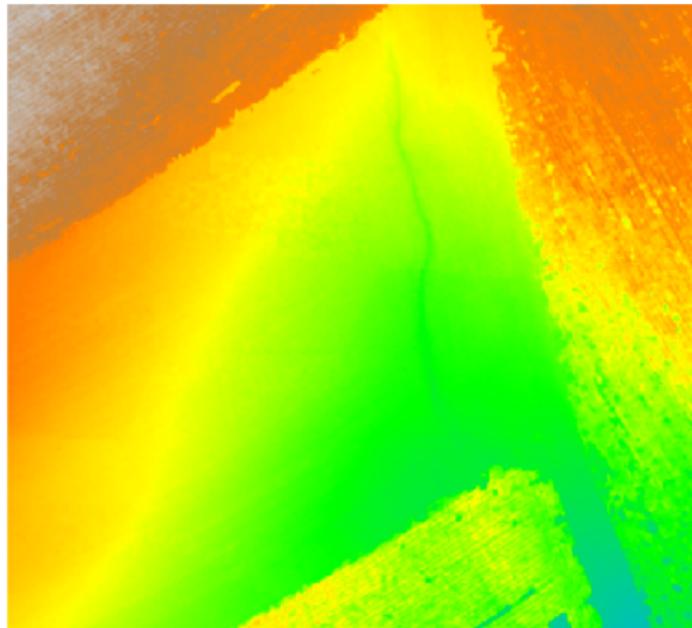
- ▶ *r.skyview* (percentage of visible sky)



comparison of shaded relief and sky-view factor

# Local relief model (LRM)

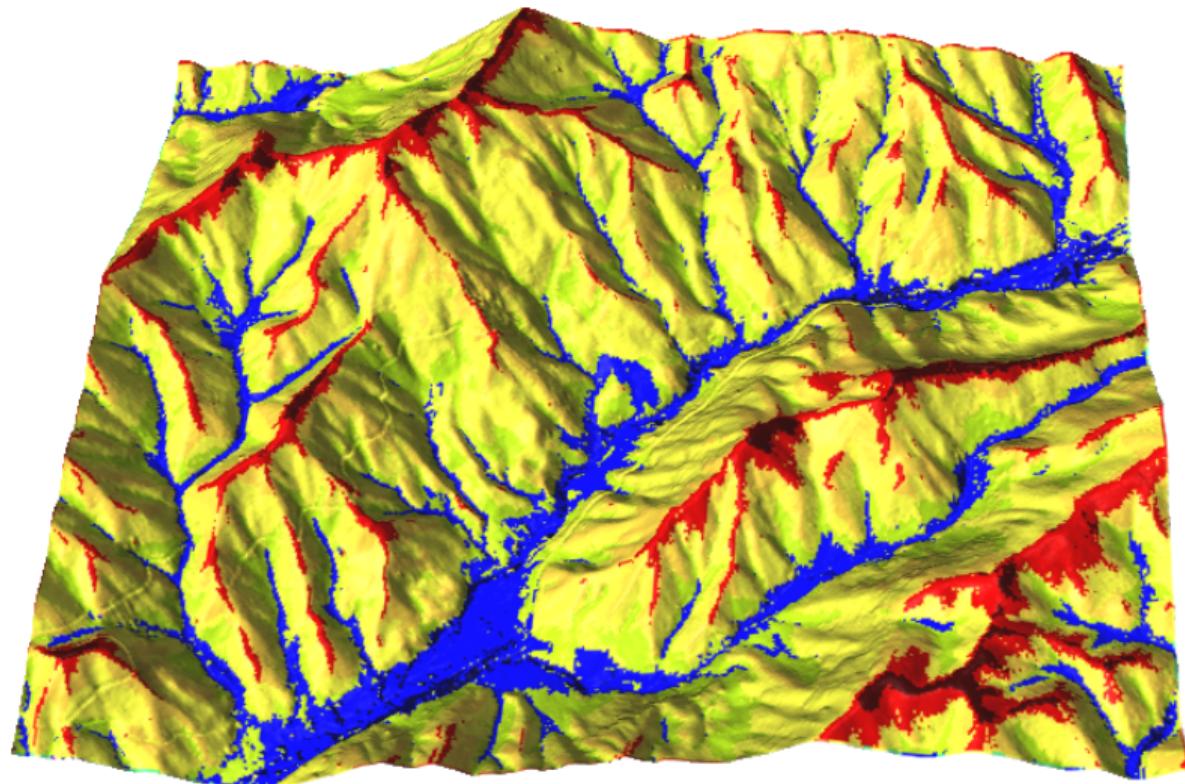
- ▶ `r.local.relief` (micro-topography, features other than trend)



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

# Landforms

- ▶ *r.geomorphon*
  - ▶ new landform classification approach
  - ▶ by Jasiewicz & Stepinski

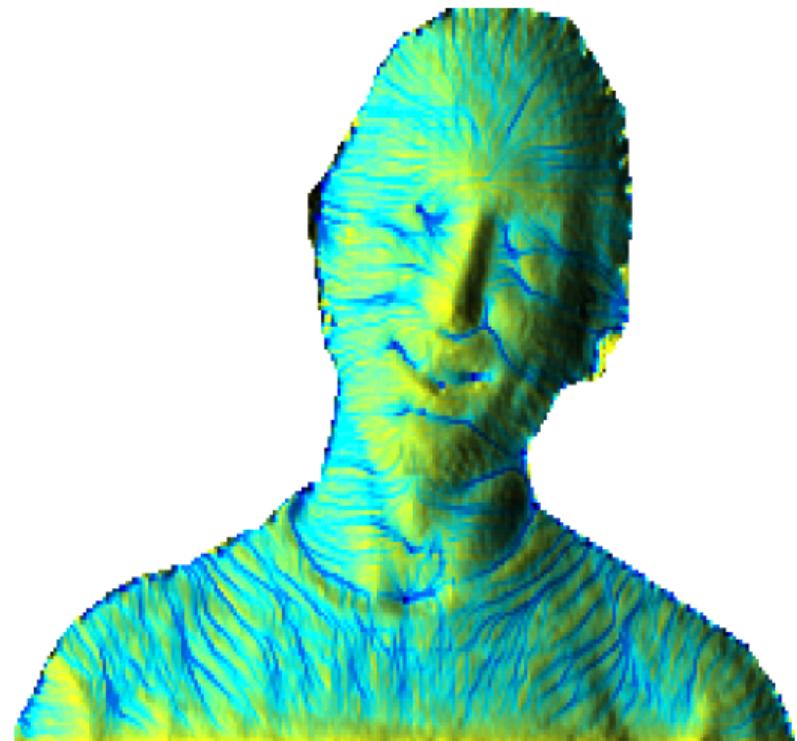


# libfreenect2 + PCL + GRASS GIS = *r.in.kinect*

## *r.in.kinect*

- ▶ scans using Kinect
- ▶ OpenKinect libfreenect2
- ▶ Point Cloud Library (PCL)
- ▶ GRASS GIS libraries
  - ▶ C API
  - ▶ raster processing
  - ▶ regularized spline with tension interpolation

used in Tangible Landscape



## Summary

- ▶ rasterize early
- ▶ GRASS modules can work with large data
  - ▶ sometimes a special flag is needed
  - ▶ if not, report a bug
- ▶ 3D rasters, PDAL integration



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

Slides and paper available at  
[wenzeslaus.github.io/grass-lidar-talks](http://wenzeslaus.github.io/grass-lidar-talks)  
GRASS user mailing list  
[lists.osgeo.org/listinfo/grass-user](mailto:lists.osgeo.org/listinfo/grass-user)



# Acknowledgements

## Software

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



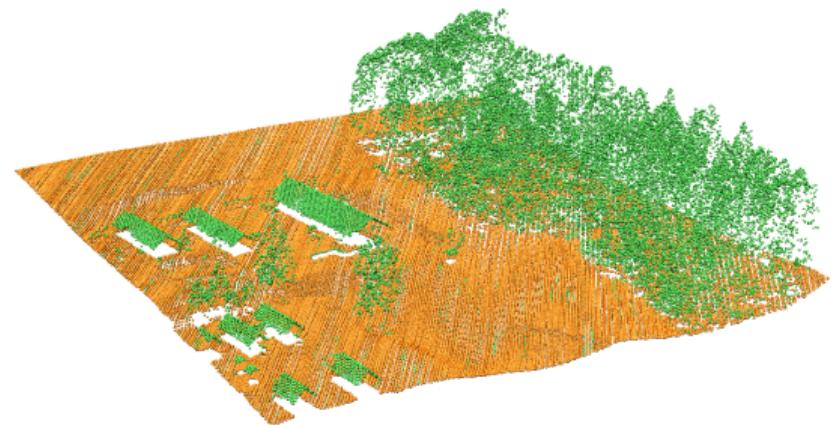
**GRASS** GIS

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



# Acknowledgements

## Presentation software

Slides were created in L<sup>A</sup>T<sub>E</sub>X using  
the BEAMER *class*.