Point clouds and DEMs

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Tutorial notes (April 2016)

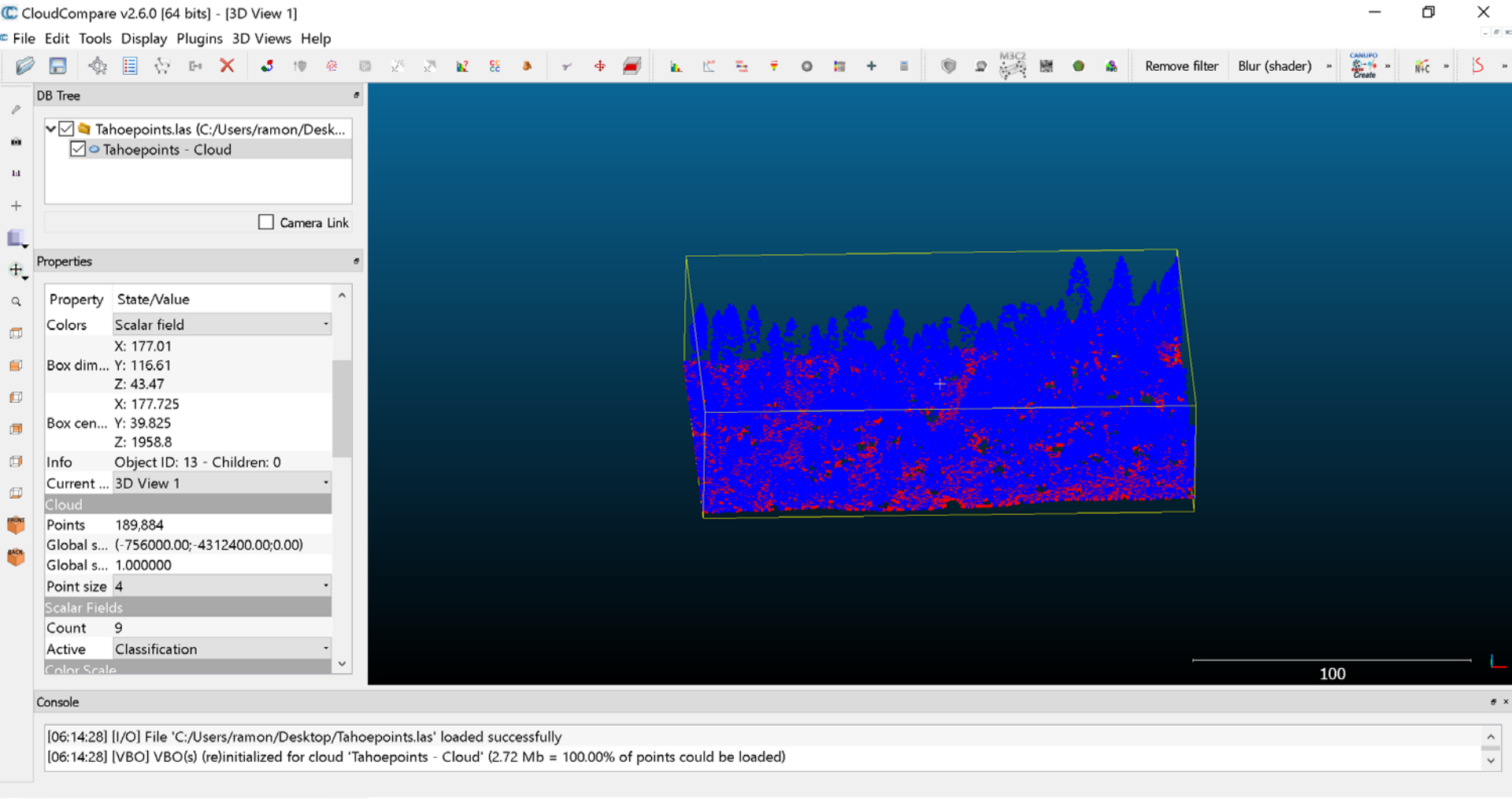
OpenTopography

High-Resolution Topography Data and Tools

Point clouds and DEMs

1. Download tahoe.las
2. Open in CloudCompare
   - Increase point size, color by different scalar fields, select ground returns
   - Tools-Projection-Rasterize
3. Lasview (right click to change functions)
4. Lasinfo (lasinfo -i "C:\Users\ramon\Desktop\Tahoepoints.las" -odir "C:\Users\ramon\Desktop" -o "tahoe.txt“)
5. Lasboundary (output file format kml)
6. Las2txt

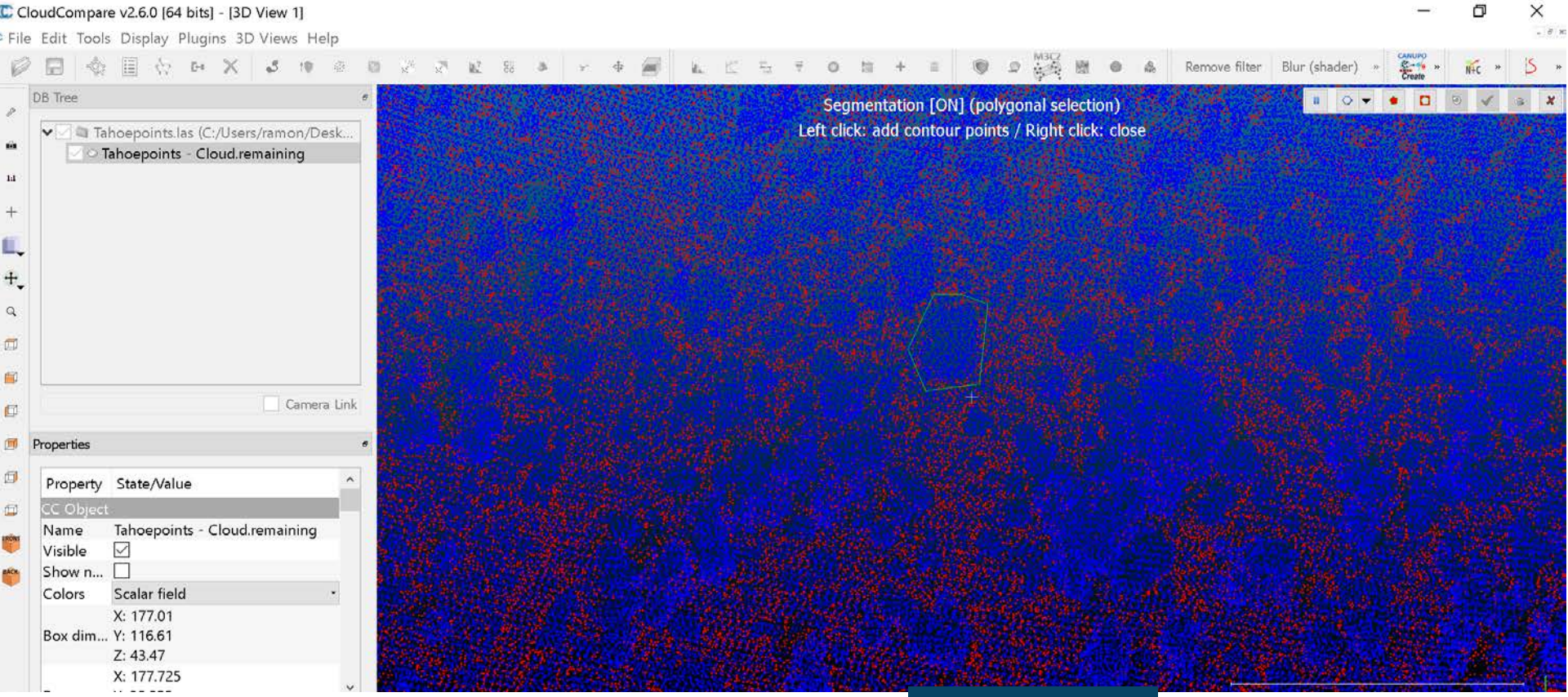
Cloud Compare



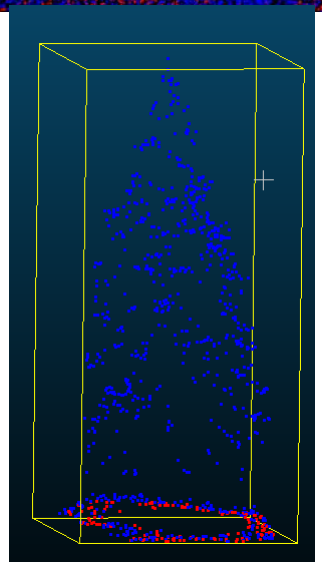
ASPRS Standard LIDAR Point Classes

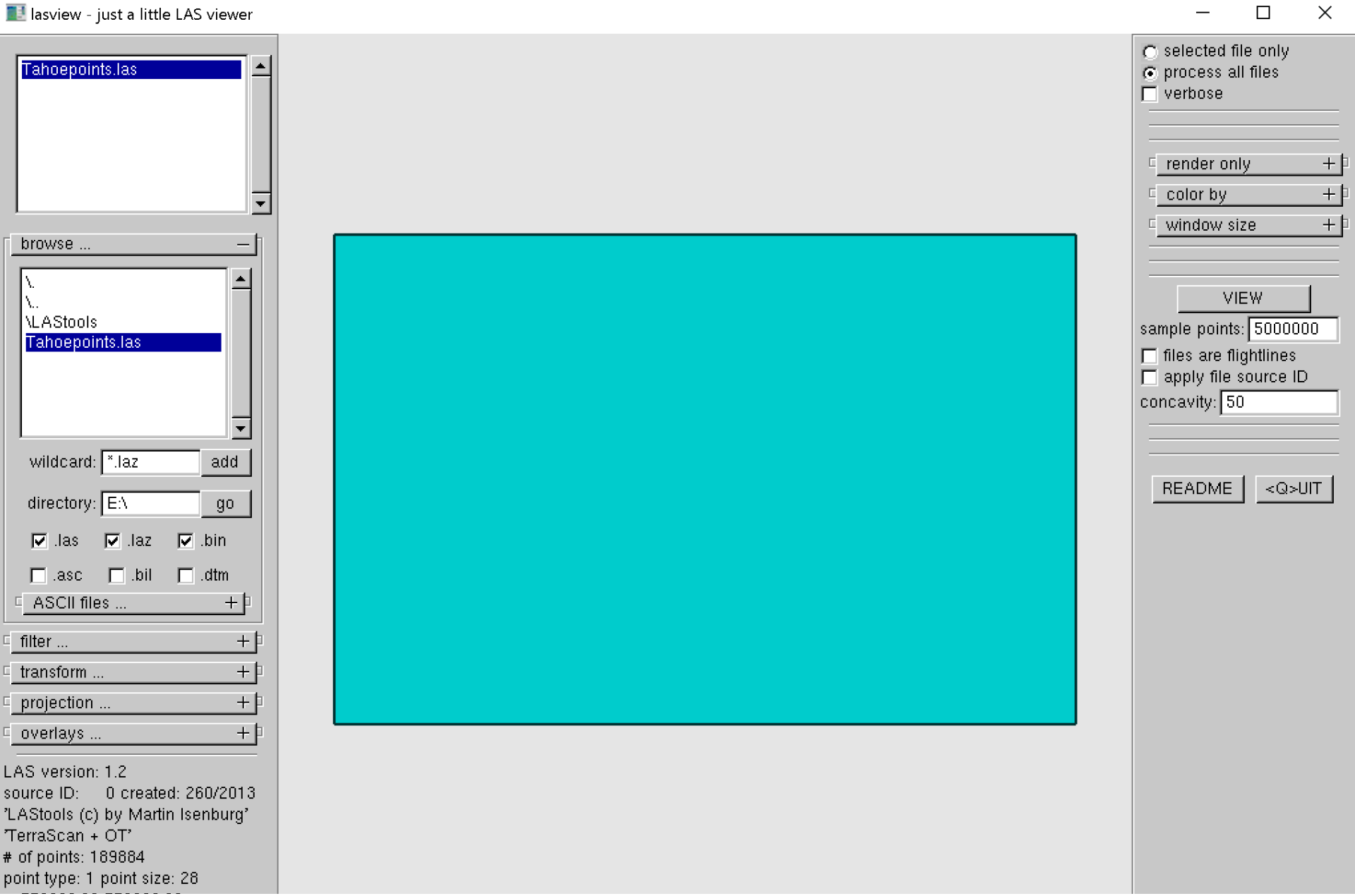
Classification Value (bits 0:4)	***Meaning***
0	Created, never classified
1	Unclassified[1]
2	Ground
3	Low Vegetation
4	Medium Vegetation
5	High Vegetation
6	Building
7	Low Point (noise)
8	Model Key-point (mass point)
9	Water
10	*Reserved for ASPRS Definition*
11	*Reserved for ASPRS Definition*
12	Overlap Points[2]
13-31	*Reserved for ASPRS Definition*

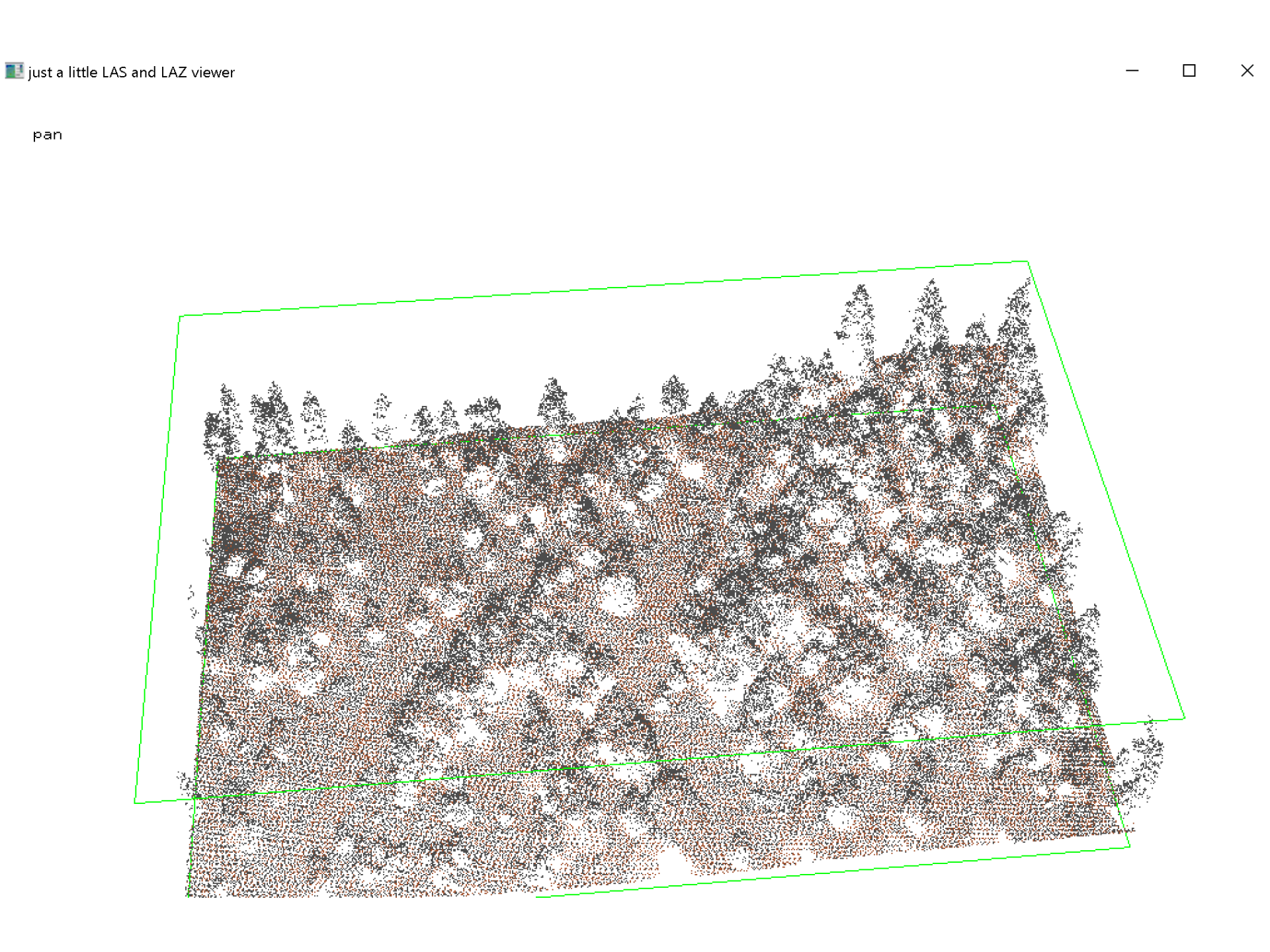
http://www.asprs.org/a/society/committees/standards/asprs_las_format_v12.pdf

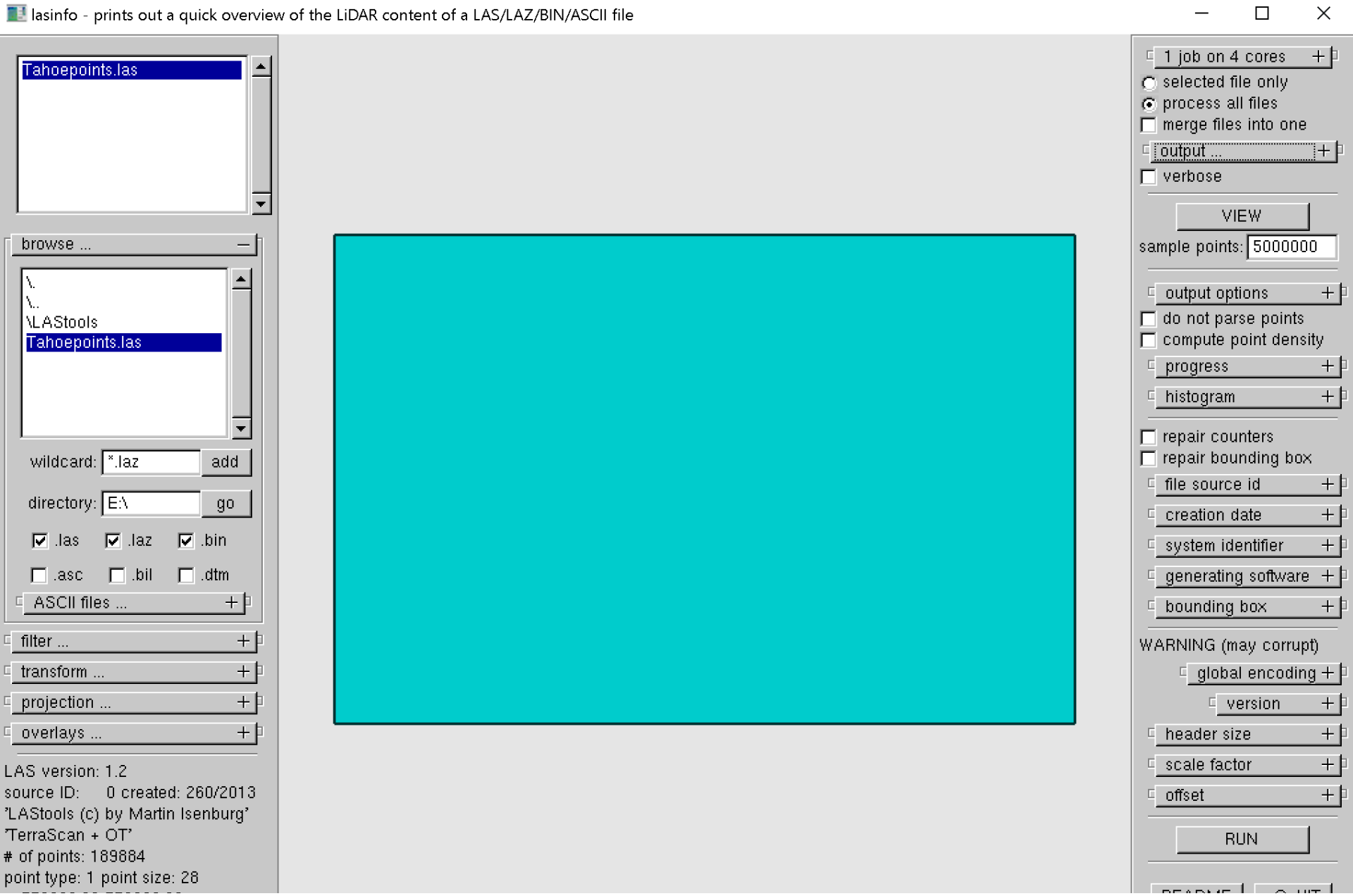


Use the scissor tool for segmentation




lasview - just a little LAS viewer
Tahoepoints.las
browse ...
\.
\..
\LAStools
Tahoepoints.las
wildcard: *.laz
add
directory: E:\
go
.las
.laz
.bin
.asc
.bil
.dtm
ASCII files ...
filter ...
transform ...
projection ...
overlays ...
LAS version: 1.2
source ID: 0 created: 260/2013
'LAStools (c) by Martin Isenburg'
'TerraScan + OT'
# of points: 189884
point type: 1 point size: 28
selected file only
process all files
verbose
render only
color by
window size
VIEW
sample points: 5000000
files are flightlines
apply file source ID
concavity: 50
README
<Q>UIT


just a little LAS and LAZ viewer
pan


lasinfo - prints out a quick overview of the LiDAR content of a LAS/LAZ/BIN/ASCII file
Tahoepoints.las
browse ...
\.
\..
\LAStools
Tahoepoints.las
wildcard: *.laz
add
directory: E:\
go
.las
.laz
.bin
.asc
.bil
.dtm
ASCII files ...
filter ...
transform ...
projection ...
overlays ...
LAS version: 1.2
source ID: 0 created: 260/2013
'LAStools (c) by Martin Isenburg'
'TerraScan + OT'
# of points: 189864
point type: 1 point size: 28
1 job on 4 cores
selected file only
process all files
merge files into one
output ...
verbose
VIEW
sample points: 5000000
output options
do not parse points
compute point density
progress
histogram
repair counters
repair bounding box
file source id
creation date
system identifier
generating software
bounding box
WARNING (may corrupt)
global encoding
version
header size
scale factor
offset
RUN

lasboundary - computes the exact boundary polygon for massive amounts of LiDAR points

Tahoepoints.las

browse ...

\.
\..
\LAStools
Tahoepoints.las

wildcard: *.laz add

directory: E:\ go

.las .laz .bin

.asc .bil .dtm

ASCII files ...

filter ...

transform ...

projection ...

overlays ...

LAS version: 1.2
source ID: 0 created: 260/2013
'LAStools (c) by Martin Isenburg'
'TerraScan + OT'
# of points: 189884
point type: 1 point size: 28

1 job on 4 cores

selected file only
process all files
merge files into one

output ...

verbose

VIEW

sample points: 5000000

use points
use bounding box
use tile bounding box
use LAX information

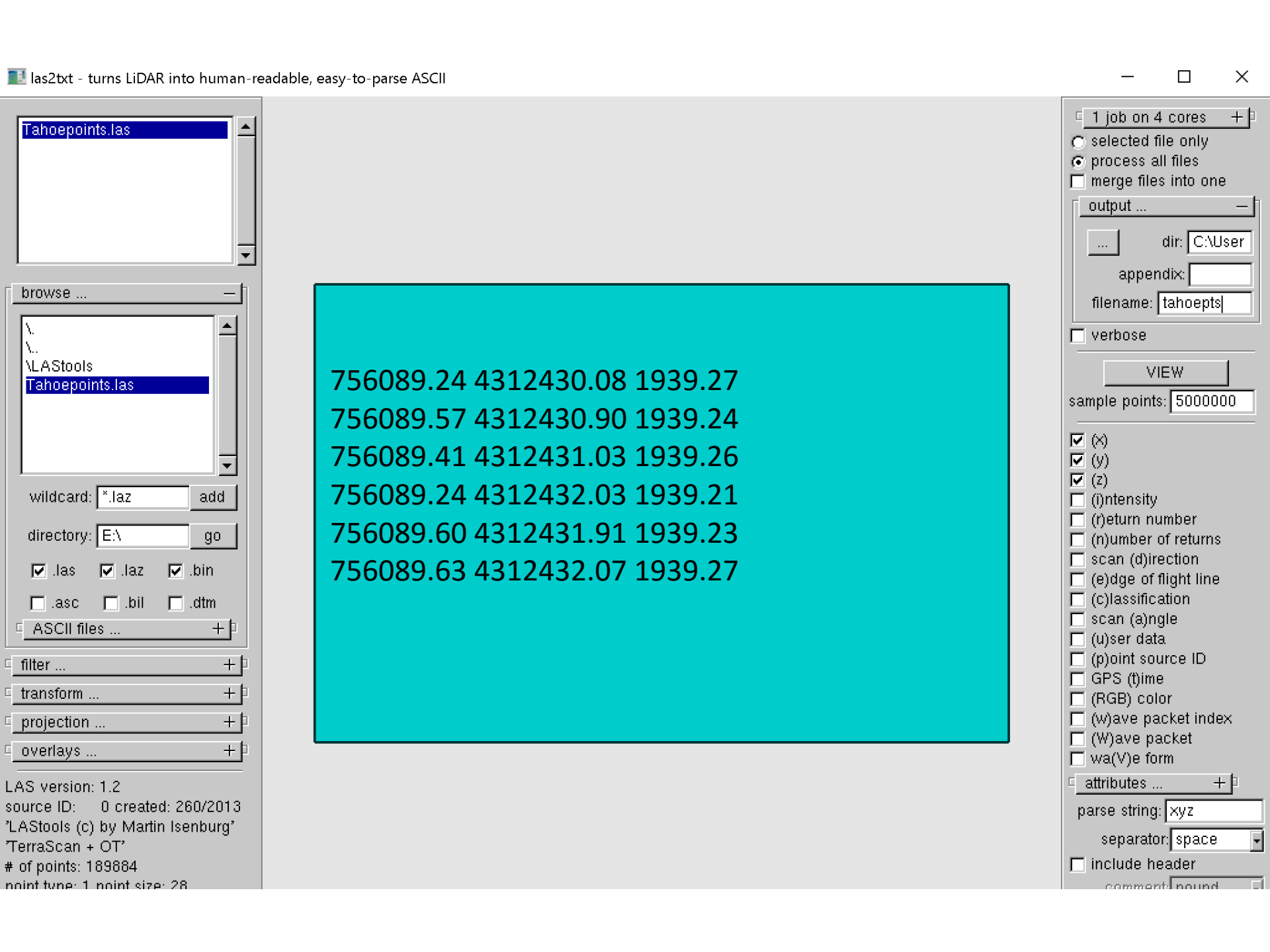
concavity: 50

holes
disjoint
convex hull

output: kml

RUN

README <Q>UIT


las2txt - turns LiDAR into human-readable, easy-to-parse ASCII
Tahoepoints.las
browse ...
\.
\..
\LAStools
Tahoepoints.las
wildcard: *.laz
add
directory: E:\
go
.las
.laz
.bin
.asc
.bil
.dtm
ASCII files ...
filter ...
transform ...
projection ...
overlays ...
LAS version: 1.2
source ID: 0 created: 260/2013
'LAStools (c) by Martin Isenburg'
'TerraScan + OT'
# of points: 189884
point type: 1 point size: 28
756089.24 4312430.08 1939.27
756089.57 4312430.90 1939.24
756089.41 4312431.03 1939.26
756089.24 4312432.03 1939.21
756089.60 4312431.91 1939.23
756089.63 4312432.07 1939.27
1 job on 4 cores
selected file only
process all files
merge files into one
output ...
...
dir: C:\User
appendix:
filename: tahoepts
verbose
VIEW
sample points: 5000000
(x)
(y)
(z)
(i)ntensity
(r)eturn number
(n)umber of returns
scan (d)irection
(e)dge of flight line
(c)lassification
scan (a)ngle
(u)ser data
(p)oint source ID
GPS (t)ime
(RGB) color
(w)ave packet index
(W)ave packet
wa(V)e form
attributes ...
parse string: xyz
separator: space
include header

Point clouds and DEMs

7. las2las

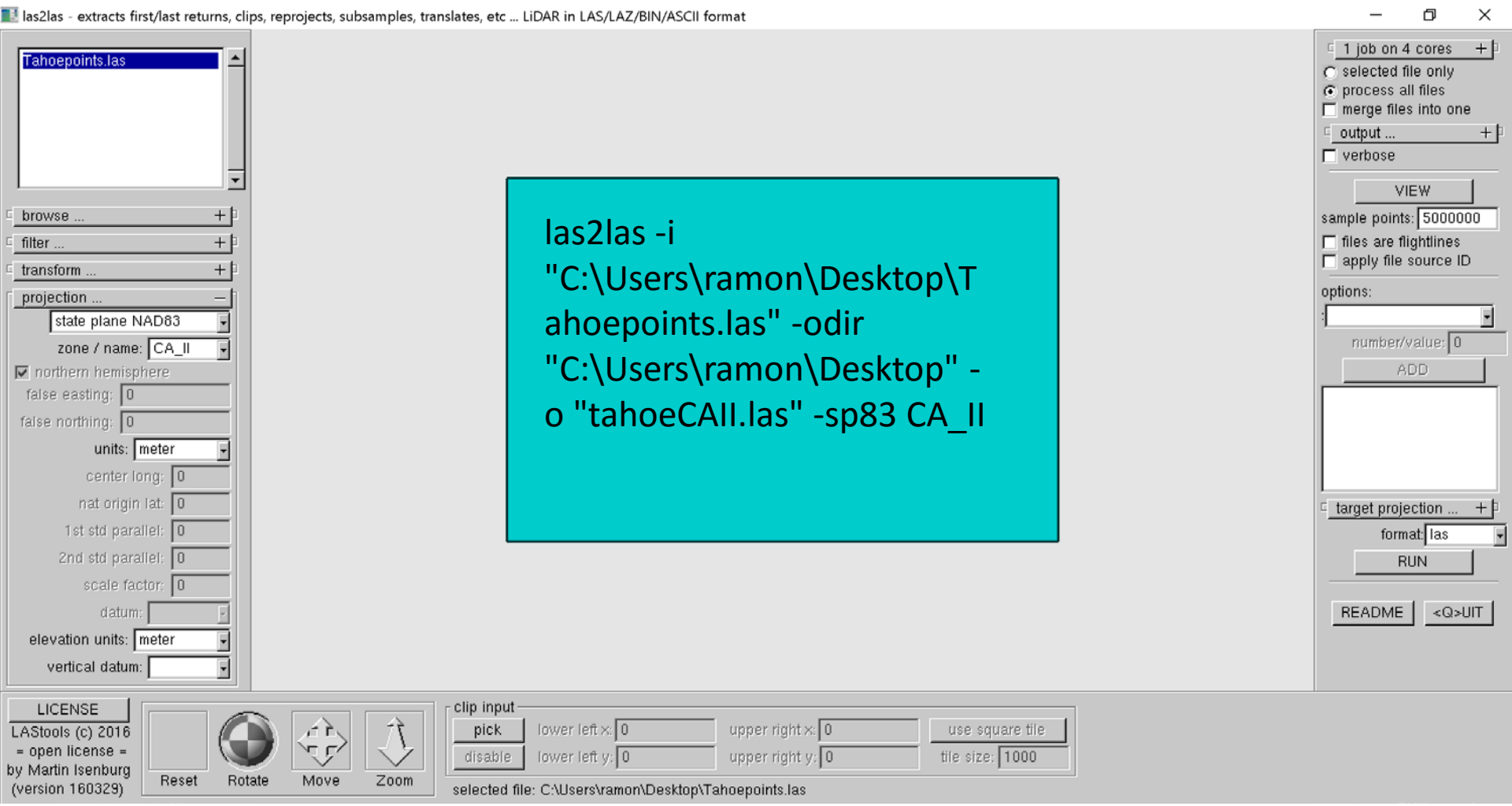
Datum and projection

http://geology.isu.edu/wapi/geostac/Field_Exercise/topomaps/ref_datum.htm

http://geology.isu.edu/wapi/geostac/Field_Exercise/topomaps/utm.htm

http://geology.isu.edu/wapi/geostac/Field_Exercise/topomaps/state_plane.htm


California State Plane
Coordinate System
Lake Tahoe
1
2
3
4
5
7
6



GeoKeyDirectoryTag version 1.1.0 number of keys 4

key 1024 tiff_tag_location 0 count 1 value_offset 1 - GTModelTypeGeoKey: ModelTypeProjected

key 3072 tiff_tag_location 0 count 1 value_offset 26942 - **ProjectedCSTypeGeoKey: NAD83 / California zone 2**

key 3076 tiff_tag_location 0 count 1 value_offset 9001 - ProjLinearUnitsGeoKey: Linear_Meter

key 4099 tiff_tag_location 0 count 1 value_offset 9001 - VerticalUnitsGeoKey: Linear_Meter

Point clouds and DEMs

8. Lecture burst on generating DEMs from points
9. Lasgrid point density (view .tif in ArcMap)
10. Lasgrid DEM
11. blast2dem

    Discuss tiling workaround

Digital Elevation Models

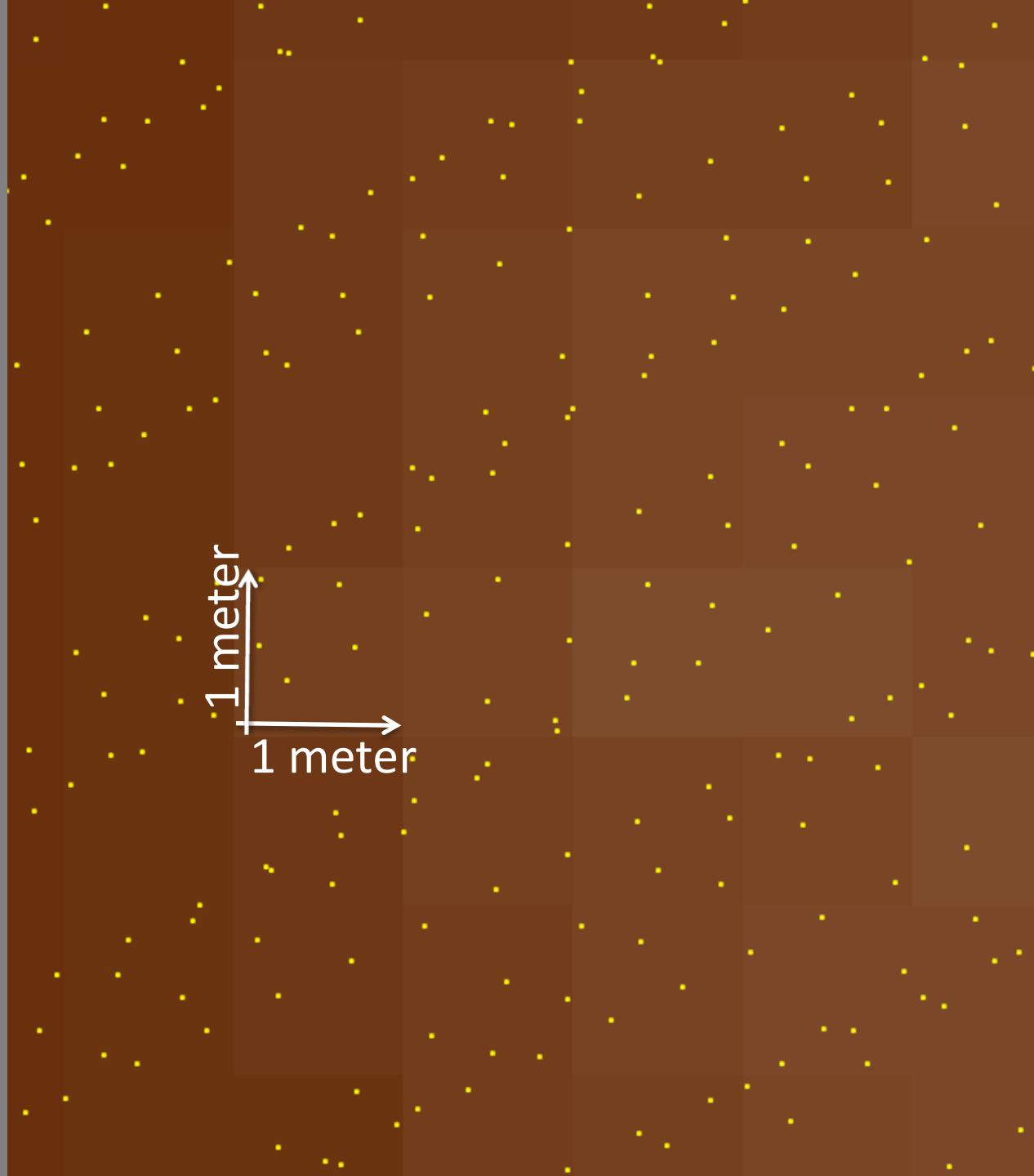
- Digital representation of topography / terrain
  - "Raster" format – a grid of squares or "pixels"
  - Continuous surface where Z (elevation) is estimated on a regular X,Y grid
  - "2.5D"

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	0
0	50	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	100	50	0
0	50	100	150	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	200	150	100	50	0
0	50	100	150	200	250	300	300	300	300	300	250	200	150	100	50	0
0	50	100	150	200	250	300	350	350	350	300	250	200	150	100	50	0
0	50	100	150	200	250	300	350	400	350	300	250	200	150	100	50	0
0	50	100	150	200	250	300	350	350	350	300	250	200	150	100	50	0
0	50	100	150	200	250	300	300	300	300	300	250	200	150	100	50	0
0	50	100	150	200	250	250	250	250	250	250	250	200	150	100	50	0
0	50	100	150	200	200	200	200	200	200	200	200	200	150	100	50	0
0	50	100	150	150	150	150	150	150	150	150	150	150	150	100	50	0
0	50	100	100	100	100	100	100	100	100	100	100	100	100	100	50	0
0	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

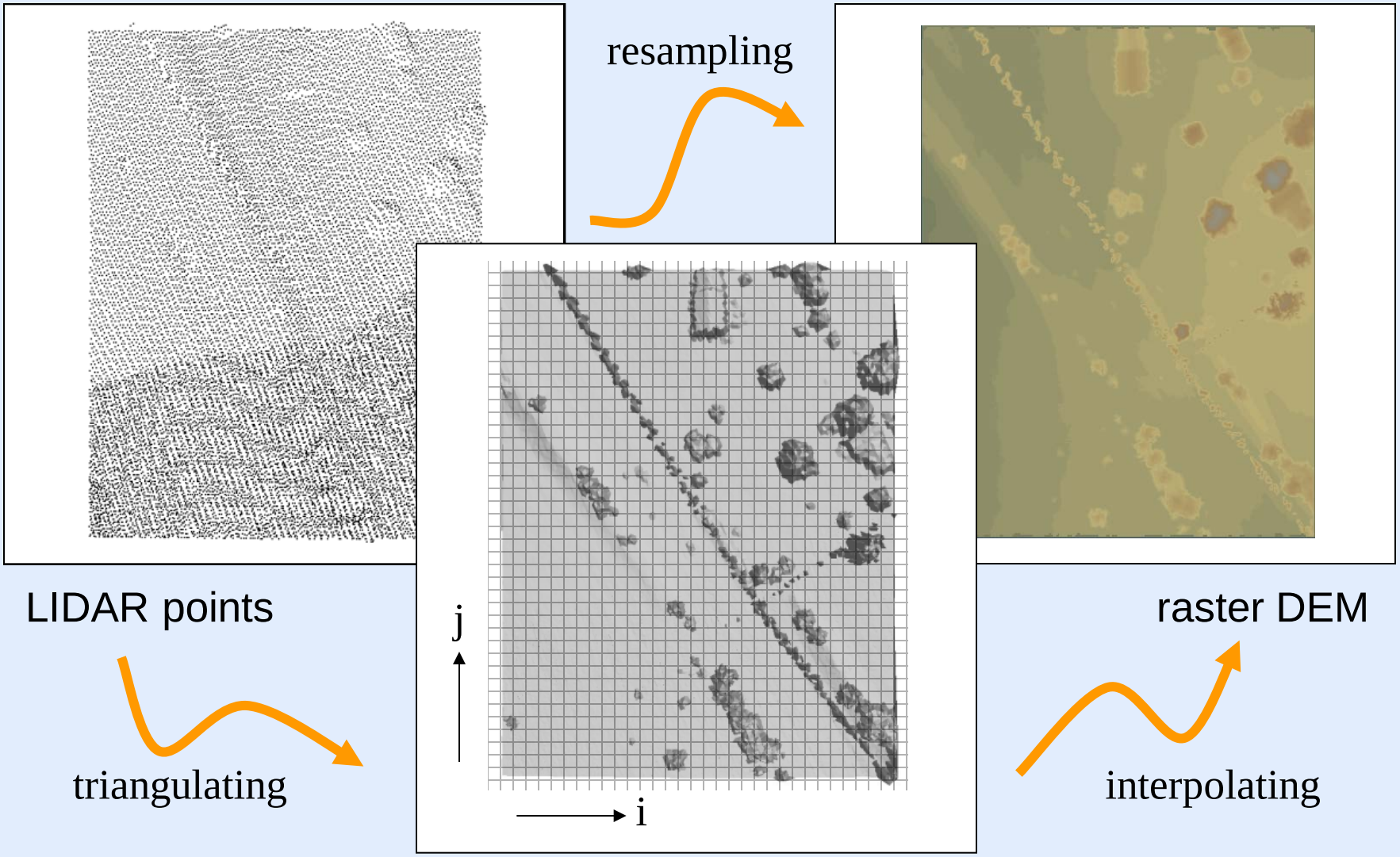
Source: http://www.ncgia.ucsb.edu/giscc/extra/e001/e001.html

- Grid resolution is defined by the size in the horizontal dimension of the pixel
  - 1 meter DEM has pixels 1 m x 1m assigned a single elevation value.

- 1 meter grid
- LiDAR returns from EarthScope data collection
- Example from flat area with little or no vegetation so ground is sampled approx. 5+ times per square meter
- How do we best fit a continuous surface to these points?
- Ultimately wish to represent irregularly sampled data on a regularized grid.



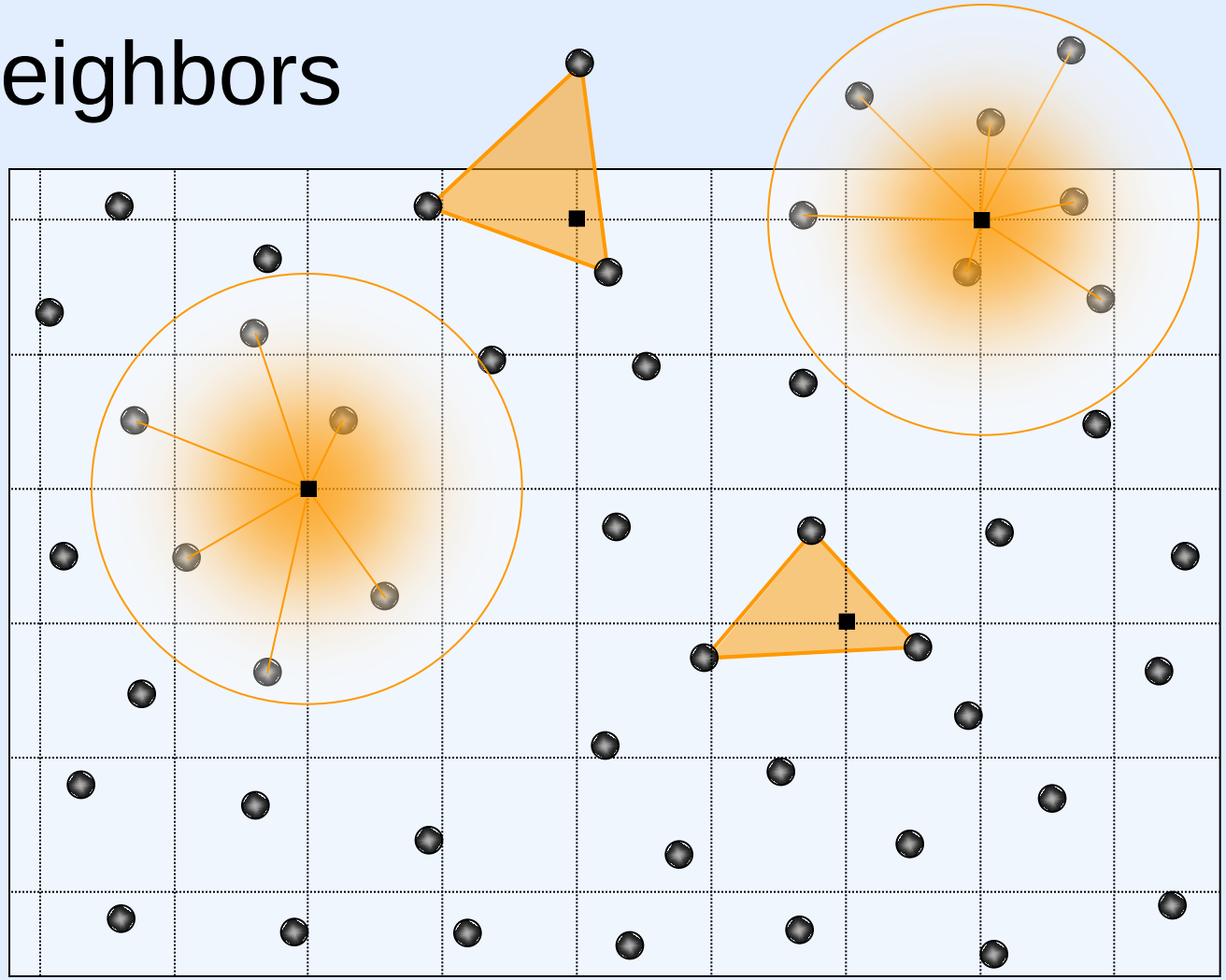
Generating DEMs from LIDAR



Isenburg, et al., 2006

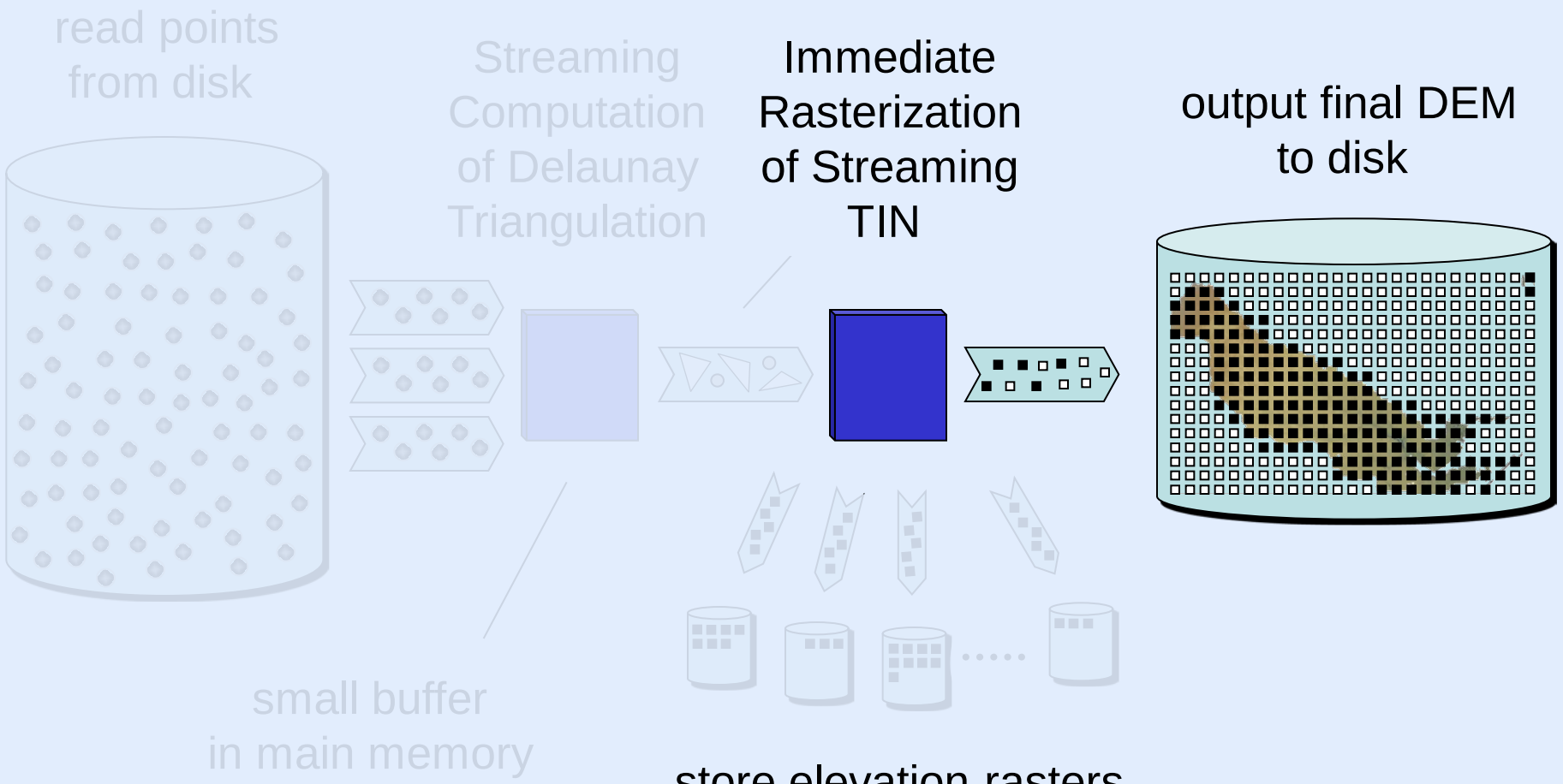
Interpolation Methods

- Inverse Distance Weighting (IDW)
- Natural Neighbors
- Kriging
- Splines
- TIN
  - linear
  - quintic
- …



Isenburg, et al., 2006

DEM Generation via TIN Streaming

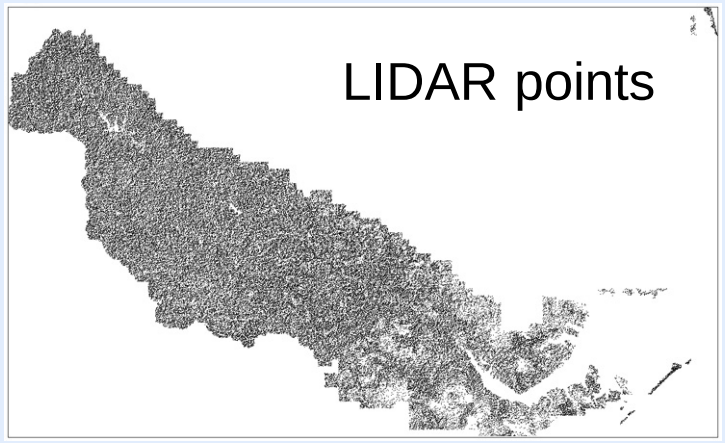


Isenburg, et al., 2006

Example Result

500,141,313 Points
11 GB
(binary, xyz, doubles)

50,394 × 30,500 DEM
3 GB
(binary, BIL, 16 bit, 20 ft)



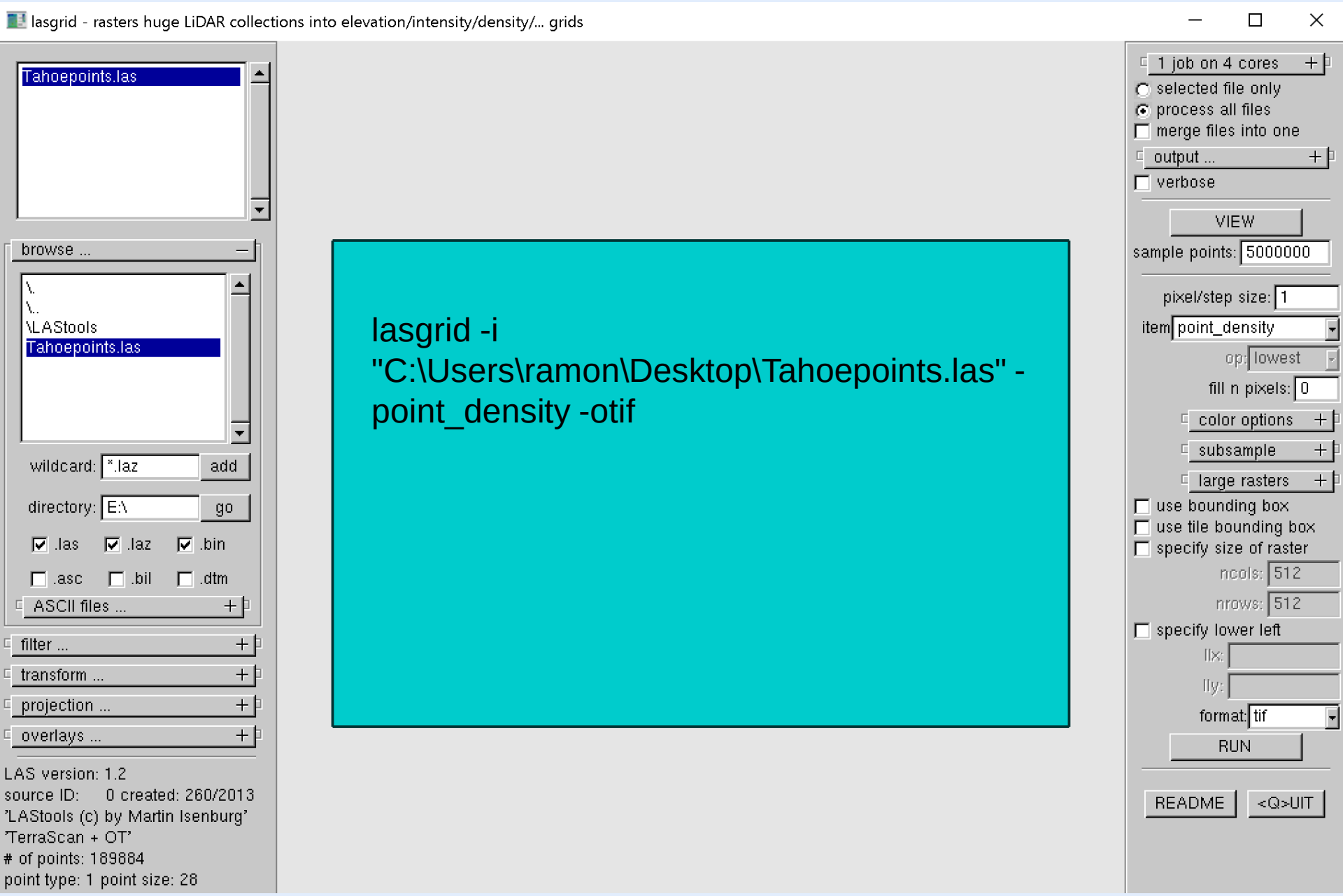
▫ on a household laptop with two harddisks ▫

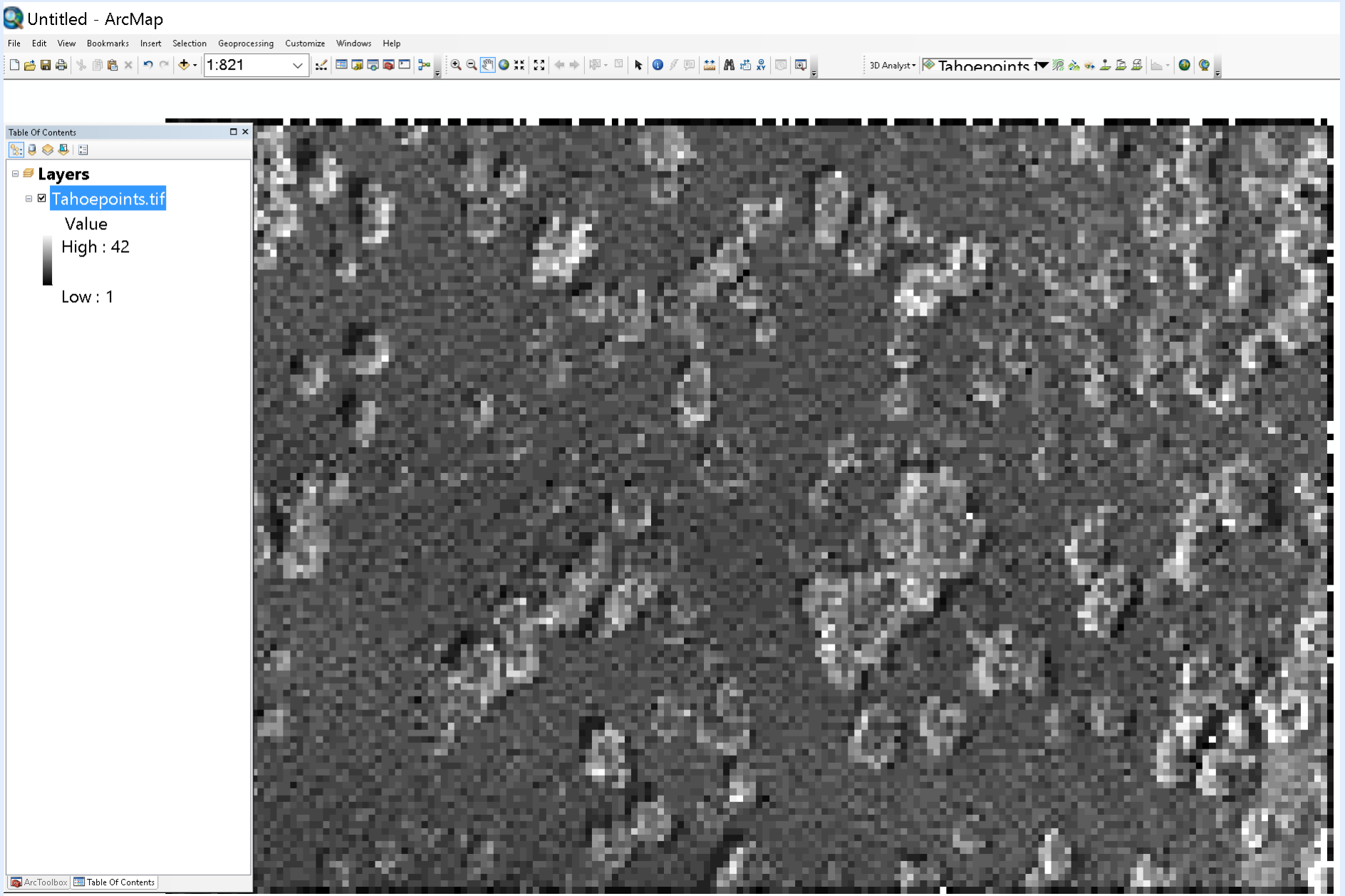
▫ in 67 minutes ▫

▫ 64 MB of main memory ▫

▫ 270 MB temporary disk space ▫

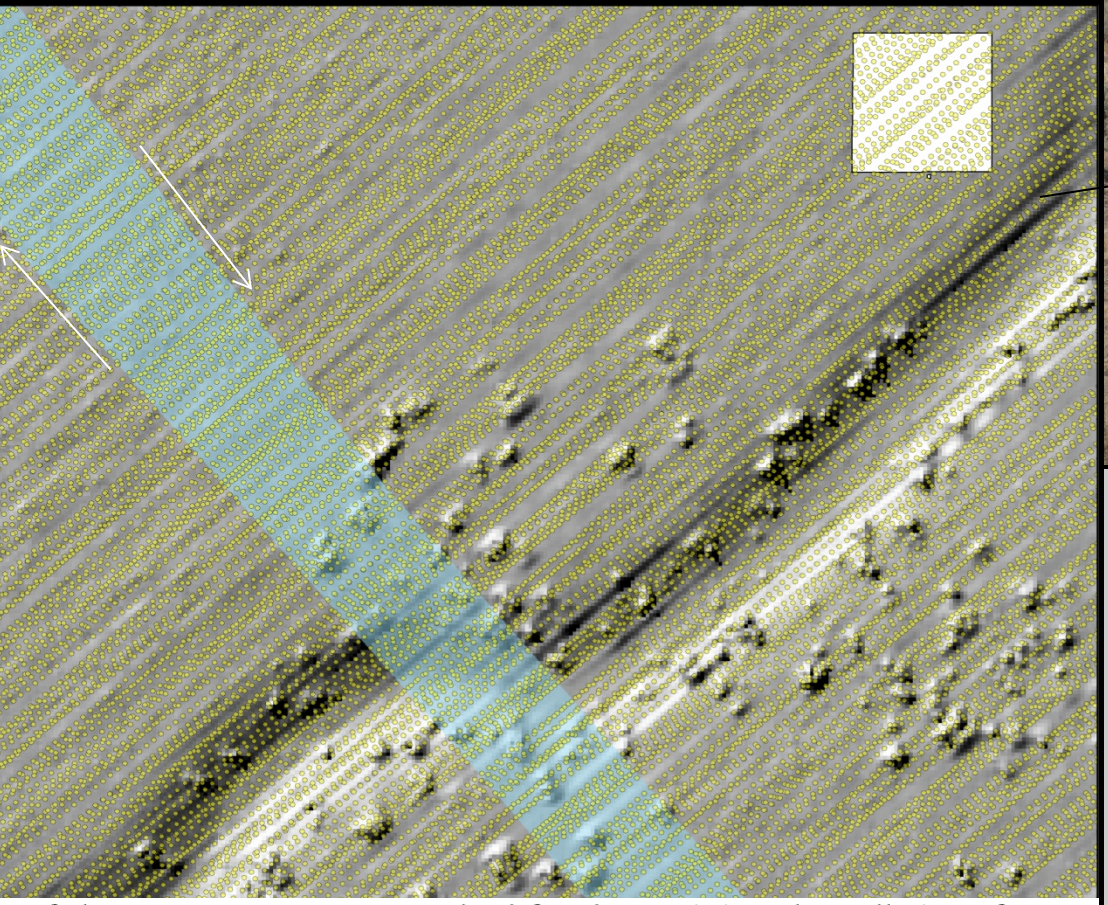
Isenburg, et al., 2006

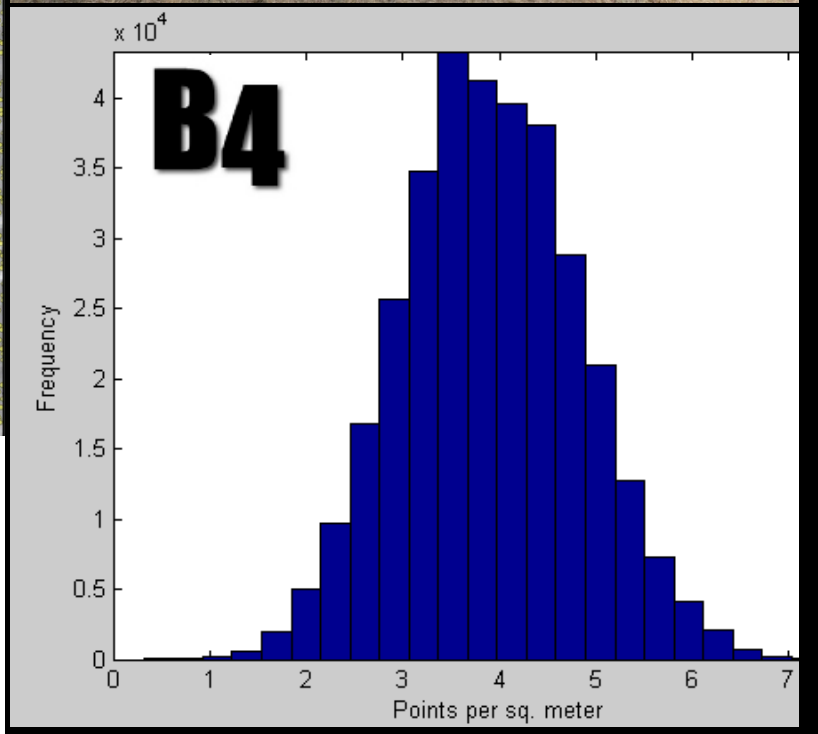

lasgrid - rasters huge LiDAR collections into elevation/intensity/density/... grids
Tahoepoints.las
browse ...
\.
\..
\LAStools
Tahoepoints.las
wildcard: *.laz
add
directory: E:\
go
.las
.laz
.bin
.asc
.bil
.dtm
ASCII files ...
filter ...
transform ...
projection ...
overlays ...
LAS version: 1.2
source ID: 0 created: 260/2013
'LAStools (c) by Martin Isenburg'
'TerraScan + OT'
# of points: 189884
point type: 1 point size: 28
lasgrid -i "C:\Users\ramon\Desktop\Tahoepoints.las" -point_density -otif
1 job on 4 cores
selected file only
process all files
merge files into one
output ...
verbose
VIEW
sample points: 5000000
pixel/step size: 1
item point_density
op: lowest
fill n pixels: 0
color options
subsample
large rasters
use bounding box
use tile bounding box
specify size of raster
ncols: 512
nrows: 512
specify lower left
llx:
lly:
format: tif
RUN
README
<Q>UIT


Untitled - ArcMap
File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help
1:821
3D Analyst
Tahoepoints
Table Of Contents
Layers
Tahoepoints.tif
Value
High : 42
Low : 1
ArcToolbox
Table Of Contents

Measure fault slip at the appropriate scale

B4 LiDAR topography 0.25 m DEM





of the DEM. A common method for determining the cell size of a DEM has been defined by Hu (2003). The grid size of a DEM can be estimated by:

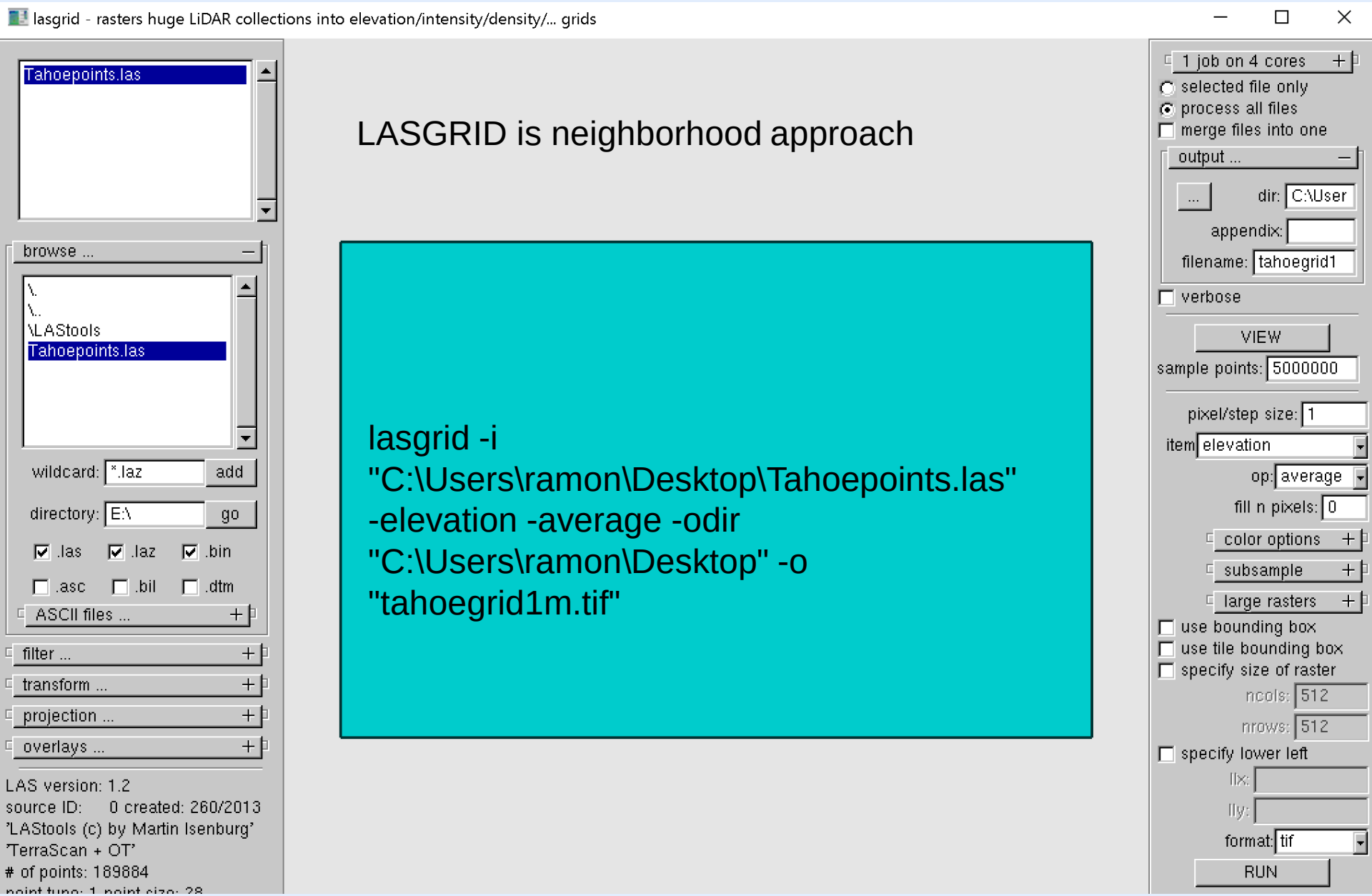
Langridge, et al. 2014

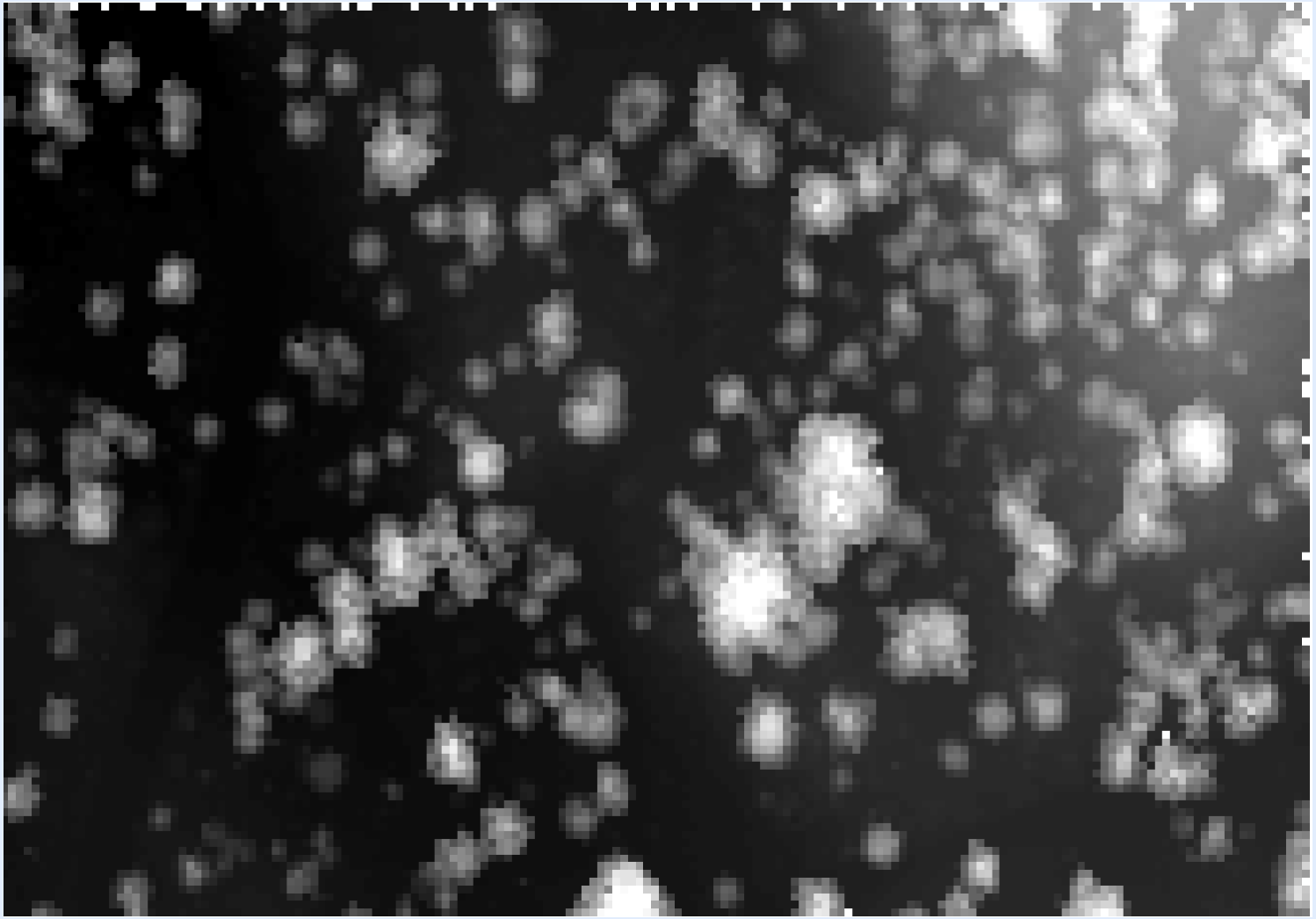
$$s = \sqrt{\frac{A}{n}} \qquad (1)$$

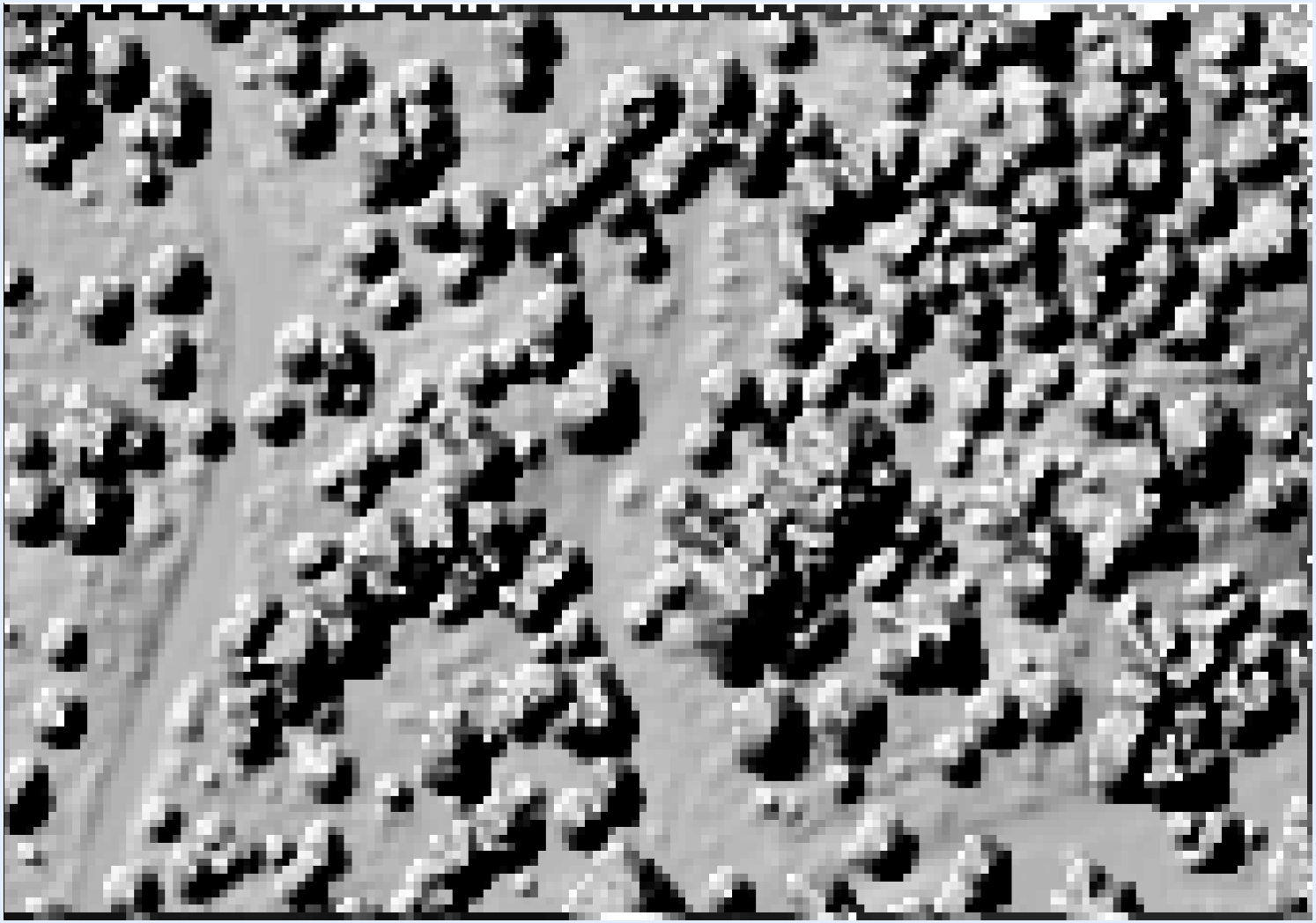
Sqrt(1m²/4)= 0.5 m/pix

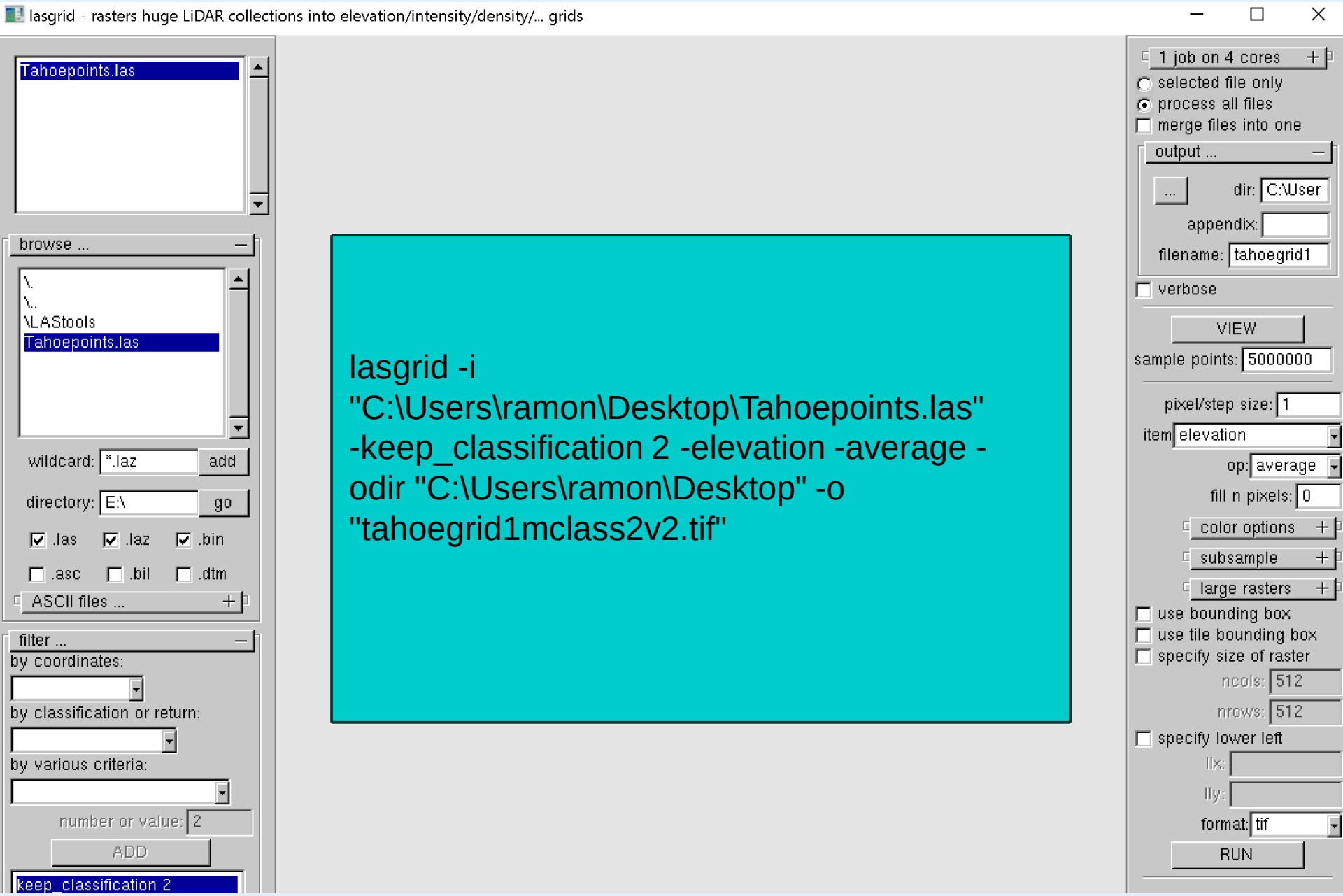
where s is the estimated cell size (typically in m), n is the number of sample points and A is the area containing the sample points. The

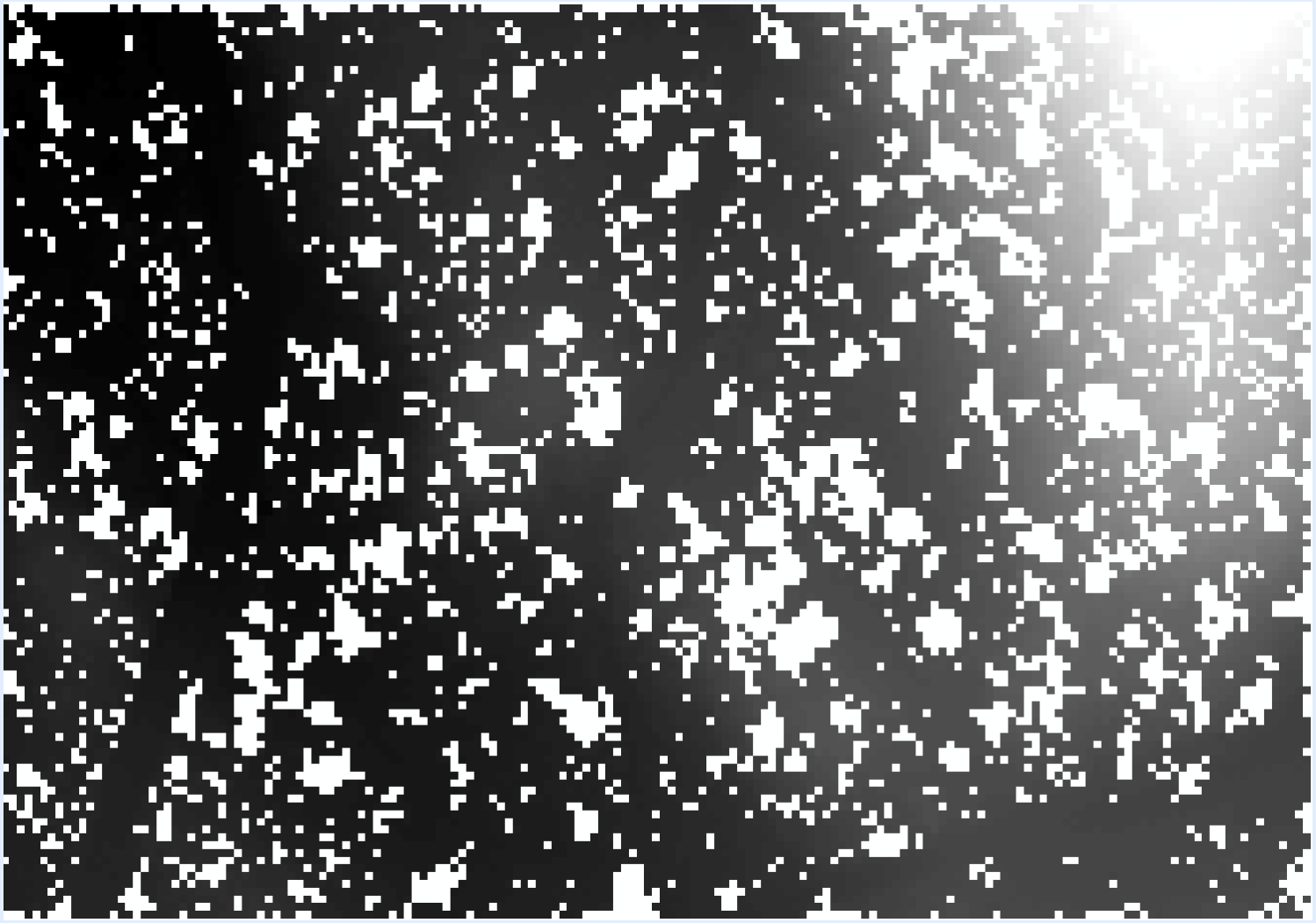
Mean ~4 shots/sq. m

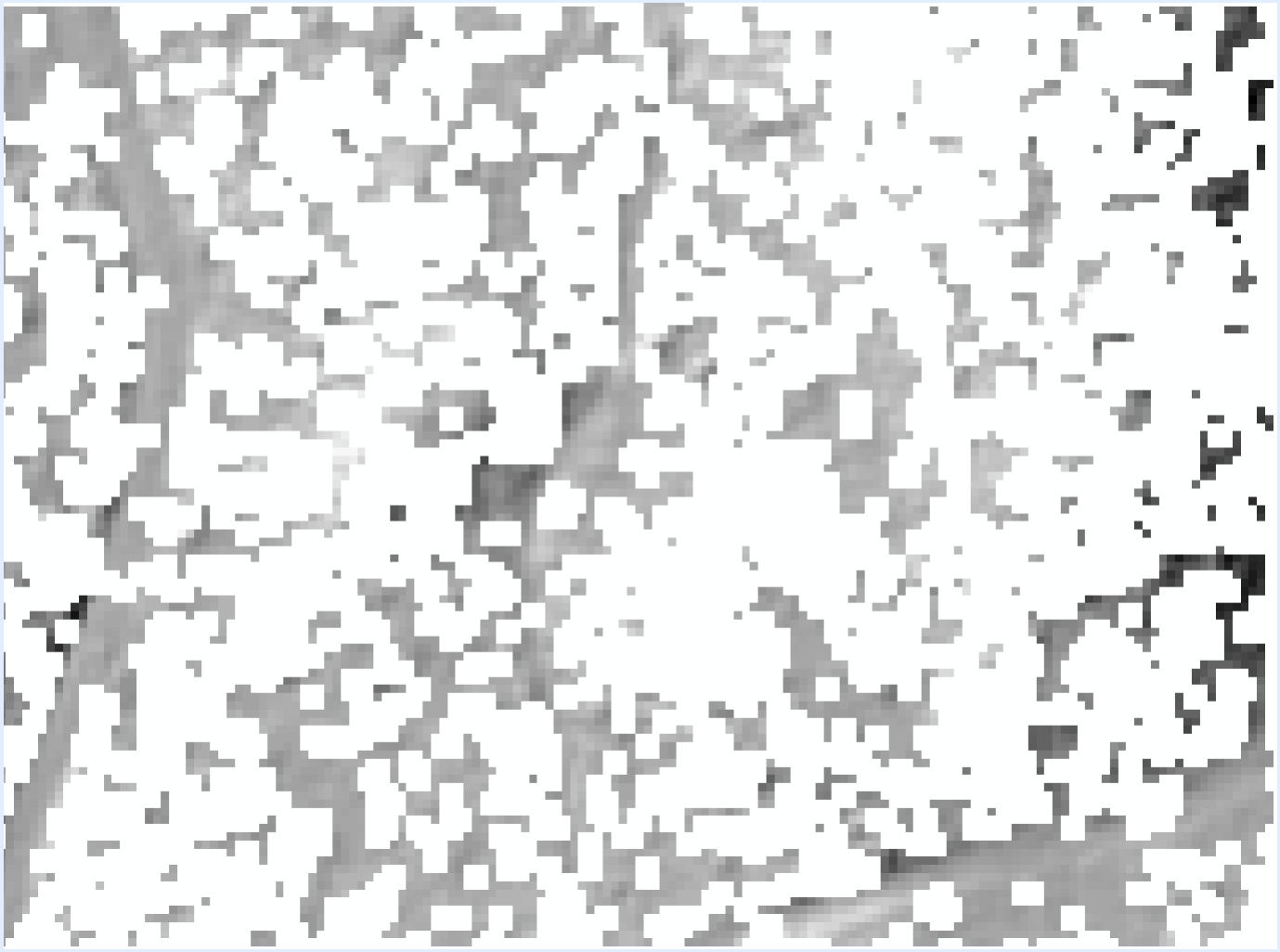

lasgrid - rasters huge LiDAR collections into elevation/intensity/density/... grids
Tahoepoints.las
browse ...
\.
\..
\LAStools
Tahoepoints.las
wildcard: *.laz
add
directory: E:\
go
.las
.laz
.bin
.asc
.bil
.dtm
ASCII files ...
filter ...
transform ...
projection ...
overlays ...
LAS version: 1.2
source ID: 0 created: 260/2013
'LAStools (c) by Martin Isenburg'
'TerraScan + OT'
# of points: 189884
LASGRID is neighborhood approach
lasgrid -i "C:\Users\ramon\Desktop\Tahoepoints.las" -elevation -average -odir "C:\Users\ramon\Desktop" -o "tahoegrid1m.tif"
1 job on 4 cores
selected file only
process all files
merge files into one
output ...
...
dir: C:\User
appendix:
filename: tahoegrid1
verbose
VIEW
sample points: 5000000
pixel/step size: 1
item elevation
op: average
fill n pixels: 0
color options
subsample
large rasters
use bounding box
use tile bounding box
specify size of raster
ncols: 512
nrows: 512
specify lower left
llx:
lly:
format: tif
RUN

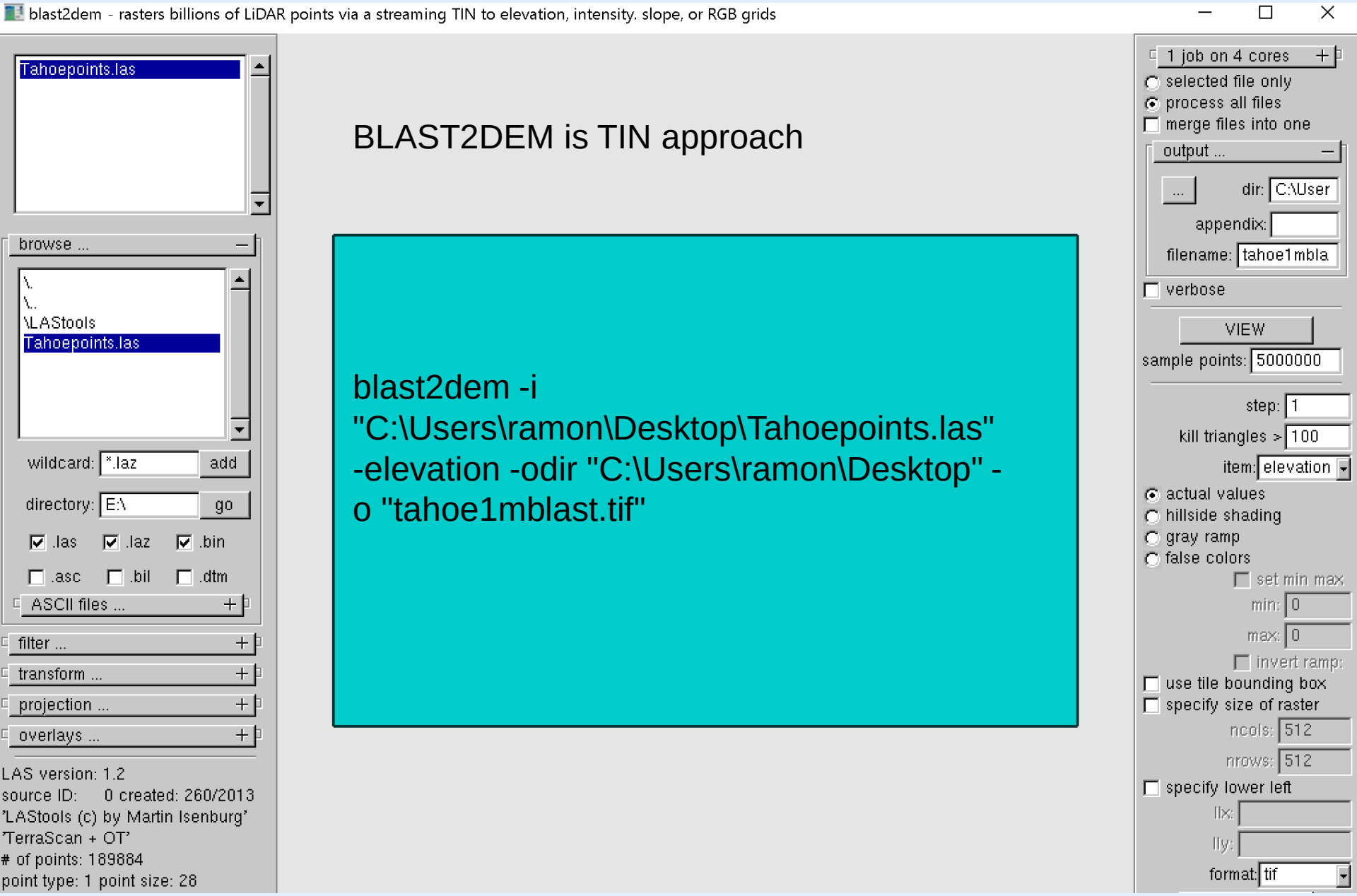


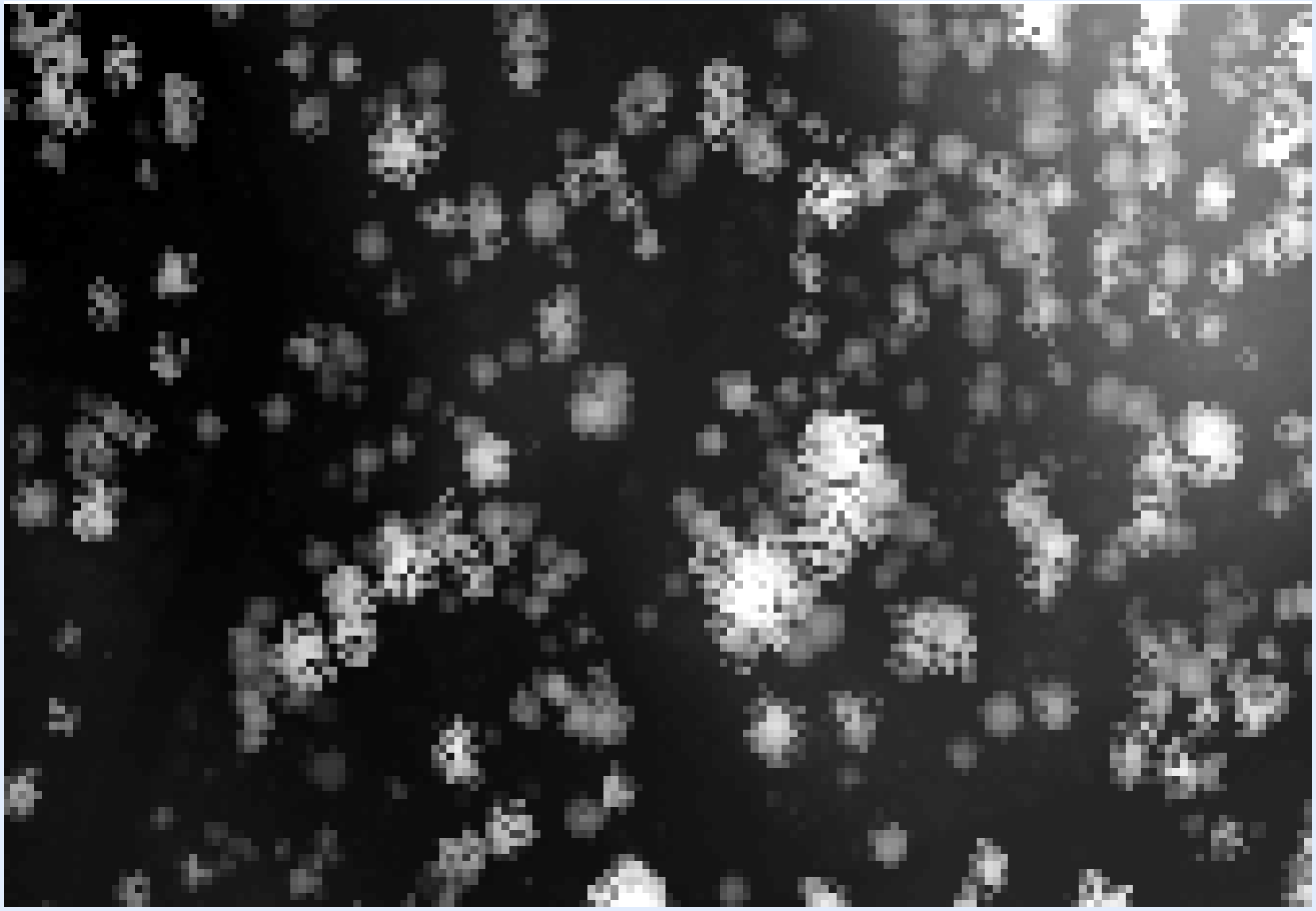


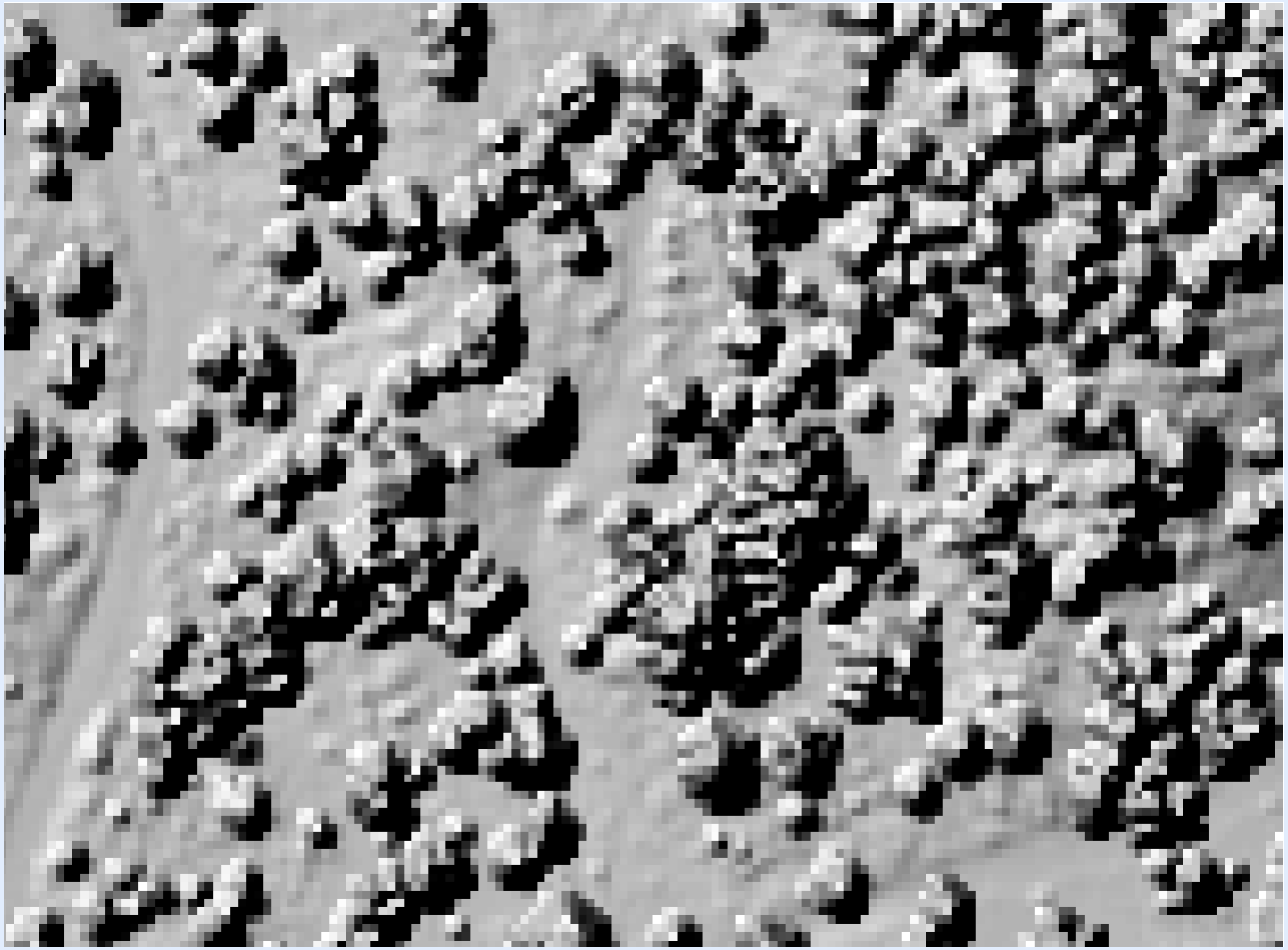

lasgrid - rasters huge LiDAR collections into elevation/intensity/density/... grids
Tahoepoints.las
browse ...
\.
\..
\LAStools
Tahoepoints.las
wildcard: *.laz
add
directory: E:\
go
.las
.laz
.bin
.asc
.bil
.dtm
ASCII files ...
filter ...
by coordinates:
by classification or return:
by various criteria:
number or value: 2
ADD
keep_classification 2
lasgrid -i "C:\Users\ramon\Desktop\Tahoepoints.las" -keep_classification 2 -elevation -average -odir "C:\Users\ramon\Desktop" -o "tahoegrid1mclass2v2.tif"
1 job on 4 cores
selected file only
process all files
merge files into one
output ...
...
dir: C:\User
appendix:
filename: tahoegrid1
verbose
VIEW
sample points: 5000000
pixel/step size: 1
item elevation
op: average
fill n pixels: 0
color options
subsample
large rasters
use bounding box
use tile bounding box
specify size of raster
ncols: 512
nrows: 512
specify lower left
llx:
lly:
format: tif
RUN

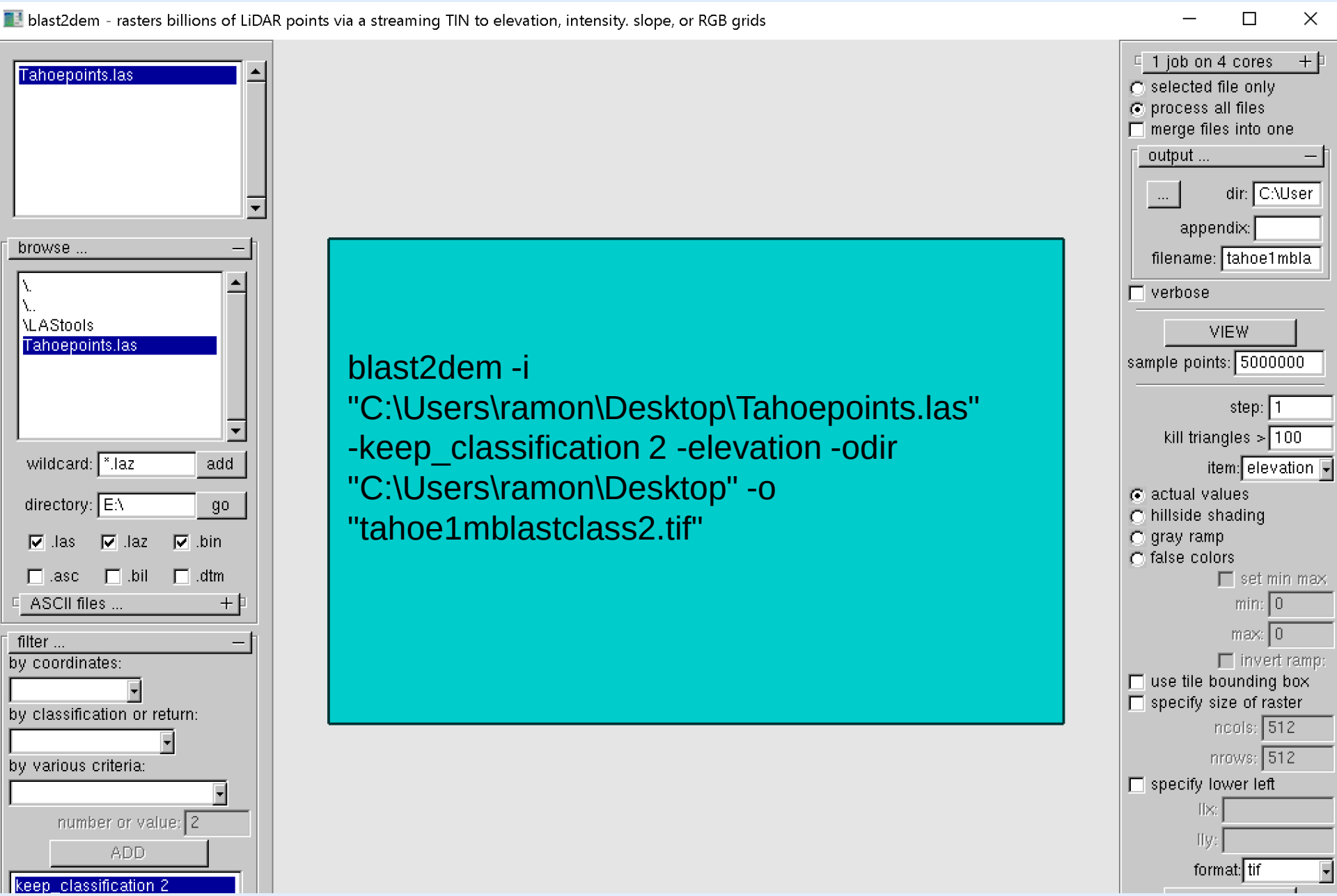


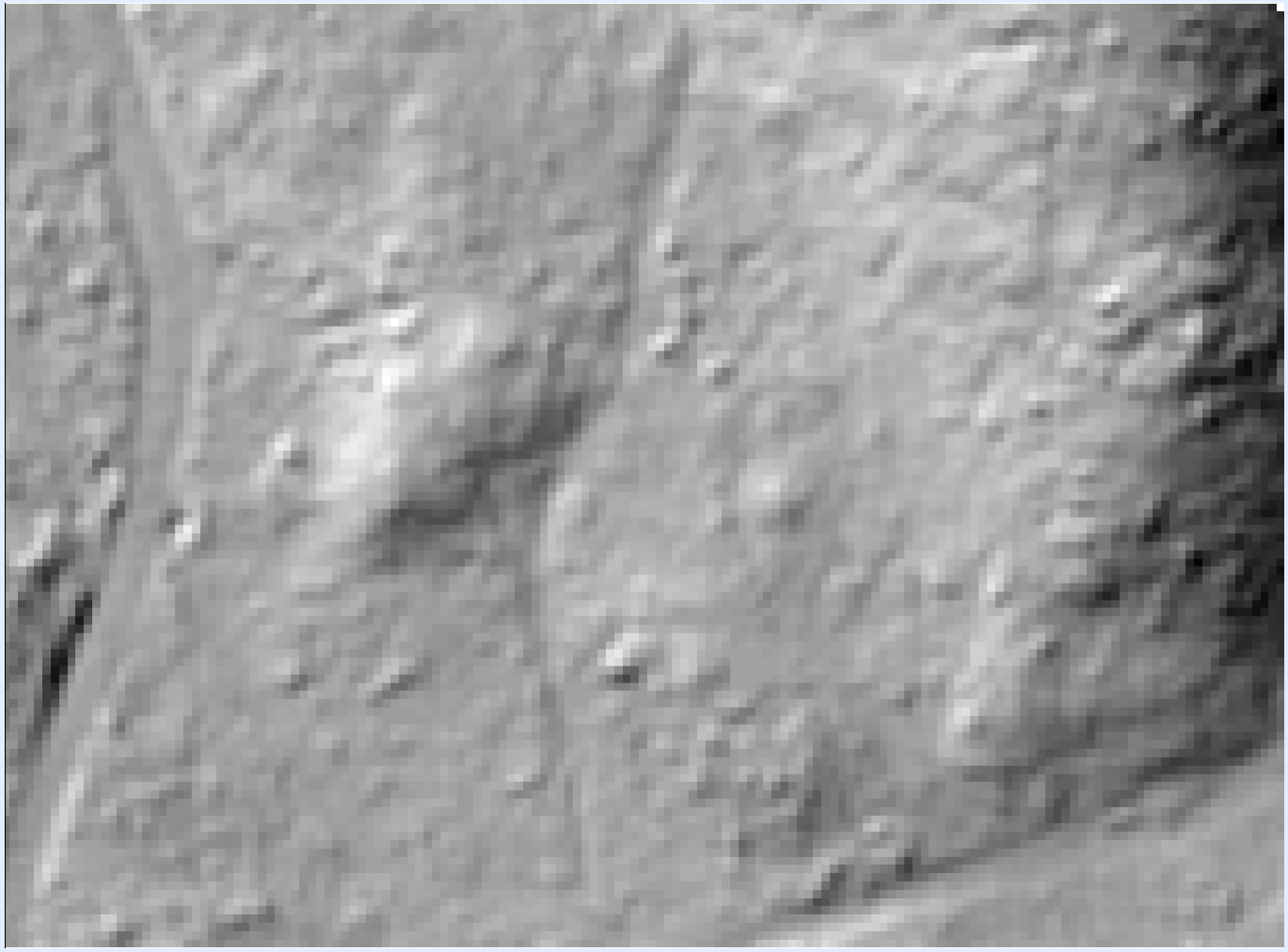



blast2dem - rasters billions of LiDAR points via a streaming TIN to elevation, intensity. slope, or RGB grids
Tahoepoints.las
browse ...
\.
\..
\LAStools
Tahoepoints.las
wildcard: *.laz
add
directory: E:\
go
.las
.laz
.bin
.asc
.bil
.dtm
ASCII files ...
filter ...
transform ...
projection ...
overlays ...
LAS version: 1.2
source ID: 0 created: 260/2013
'LAStools (c) by Martin Isenburg'
'TerraScan + OT'
# of points: 189884
point type: 1 point size: 28
BLAST2DEM is TIN approach
blast2dem -i "C:\Users\ramon\Desktop\Tahoepoints.las" -elevation -odir "C:\Users\ramon\Desktop" -o "tahoe1mblast.tif"
1 job on 4 cores
selected file only
process all files
merge files into one
output ...
...
dir: C:\User
appendix:
filename: tahoe1mbla
verbose
VIEW
sample points: 5000000
step: 1
kill triangles > 100
item: elevation
actual values
hillside shading
gray ramp
false colors
set min max
min: 0
max: 0
invert ramp:
use tile bounding box
specify size of raster
ncols: 512
nrows: 512
specify lower left
llx:
lly:
format: tif






blast2dem - rasters billions of LiDAR points via a streaming TIN to elevation, intensity. slope, or RGB grids
Tahoepoints.las
browse ...
\.
\..
\LAStools
Tahoepoints.las
wildcard: *.laz
add
directory: E:\
go
.las
.laz
.bin
.asc
.bil
.dtm
ASCII files ...
filter ...
by coordinates:
by classification or return:
by various criteria:
number or value: 2
ADD
keep_classification 2
blast2dem -i "C:\Users\ramon\Desktop\Tahoepoints.las" -keep_classification 2 -elevation -odir "C:\Users\ramon\Desktop" -o "tahoe1mblastclass2.tif"
1 job on 4 cores
selected file only
process all files
merge files into one
output ...
...
dir: C:\User
appendix:
filename: tahoe1mbla
verbose
VIEW
sample points: 5000000
step: 1
kill triangles > 100
item: elevation
actual values
hillside shading
gray ramp
false colors
set min max
min: 0
max: 0
invert ramp:
use tile bounding box
specify size of raster
ncols: 512
nrows: 512
specify lower left
llx:
lly:
format: tif



DEMs in ArcMap

Basic visualization and colorization

Point and profile measurements

Raster Math (difference and conditional)

Canopy

3D viewing in ArcScene

Raster Calculator

Map Algebra expression

Layers and variables
- tahoeblast1m.tif
- tahoeblast1mshd.tif
- tahoeblast1mclass2.tif
- tahoeblast1mclass2shd.tif

7	8	9	/	==	!=	&
4	5	6	*	>	>=	|
1	2	3	-	<	<=	^
0		.	+	(	)	~

Conditional
Con
Pick
SetNull

Math
Abs
Exp
Exp10
Exp2

"tahoeblast1m.tif" - "tahoeblast1mclass2.tif"

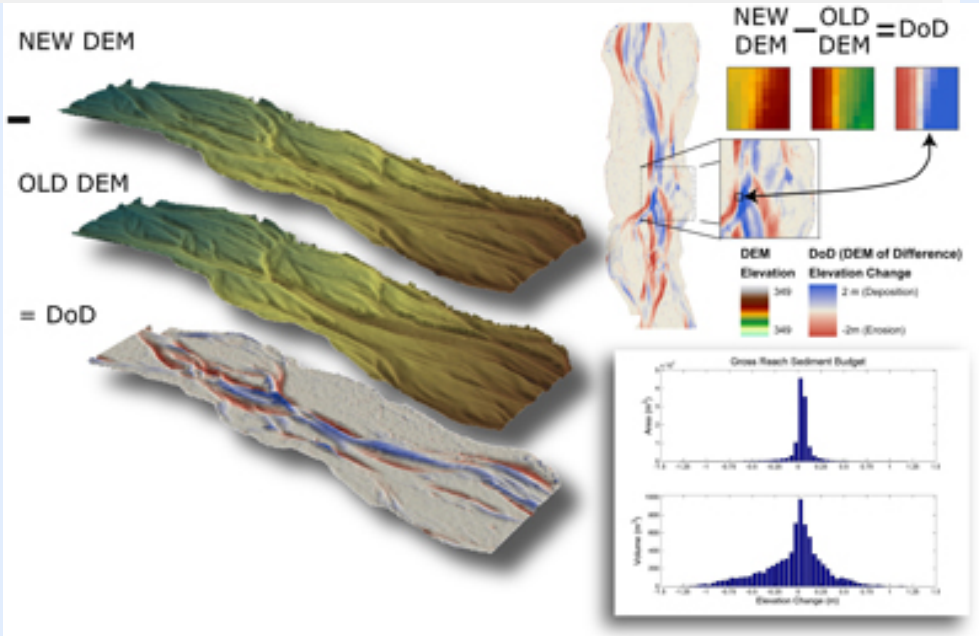
Output raster

C:\Users\ramon\Desktop\canopy.tif

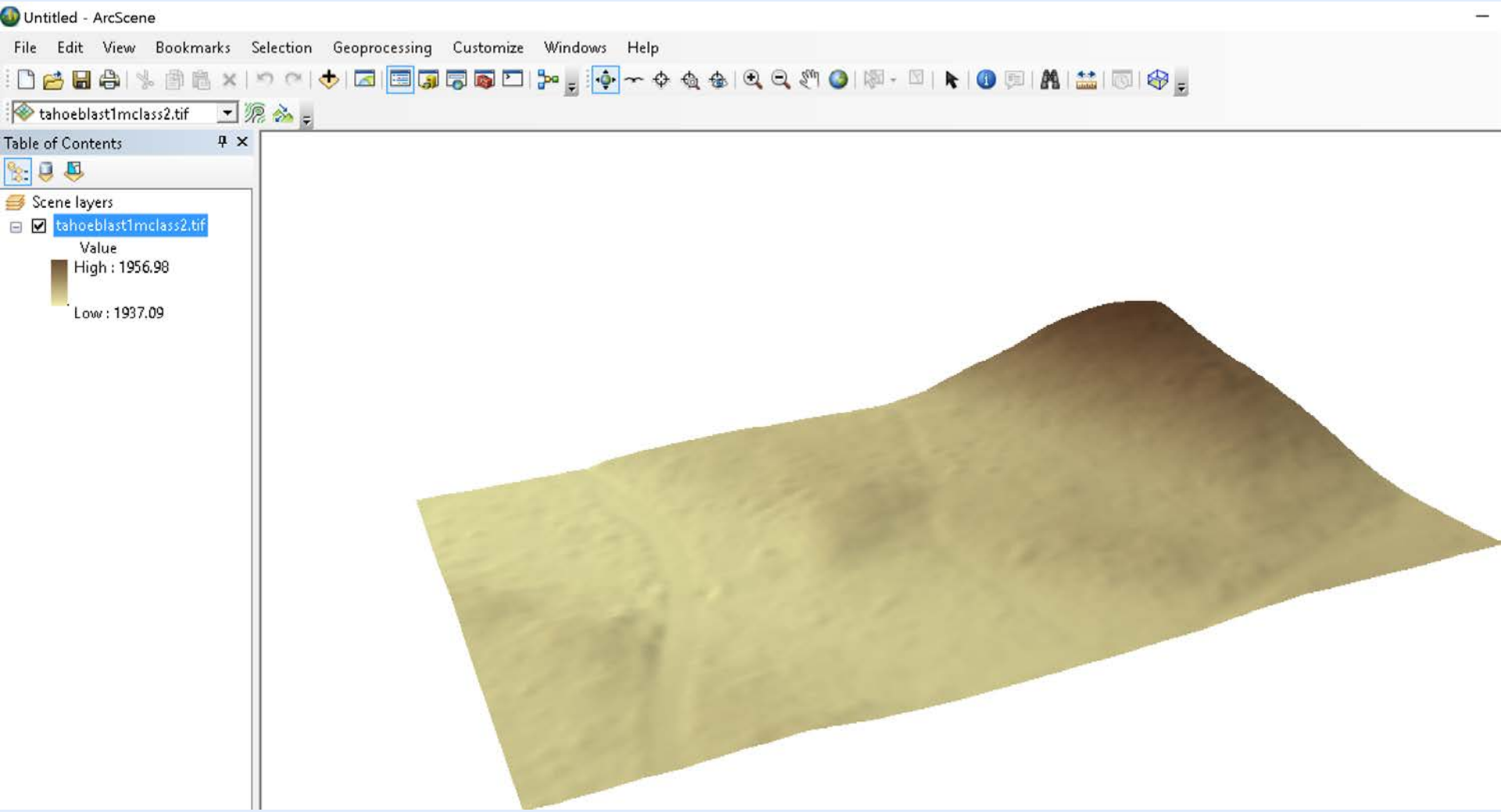
Note that is the beginning of other sorts of topographic differencing e.g., Morphological sediment budgeting

JOSEPH M. WHEATON
Research Linking Fluvial Geomorphology & Ecohydraulics

http://www.joewheaton.org/

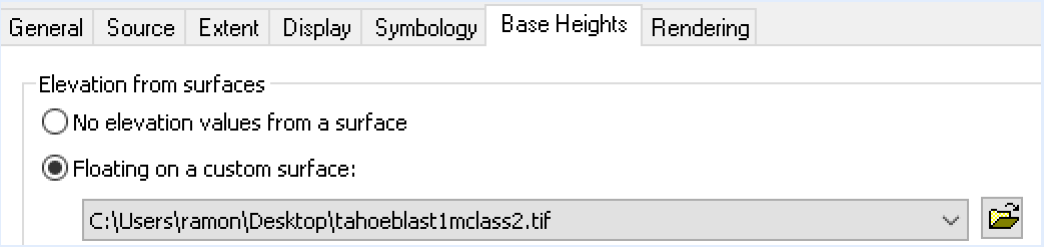


Con: Performs a conditional if/else evaluation on each of the input cells of an input raster.
Really powerful!!!



ArcScene Properties tabs:

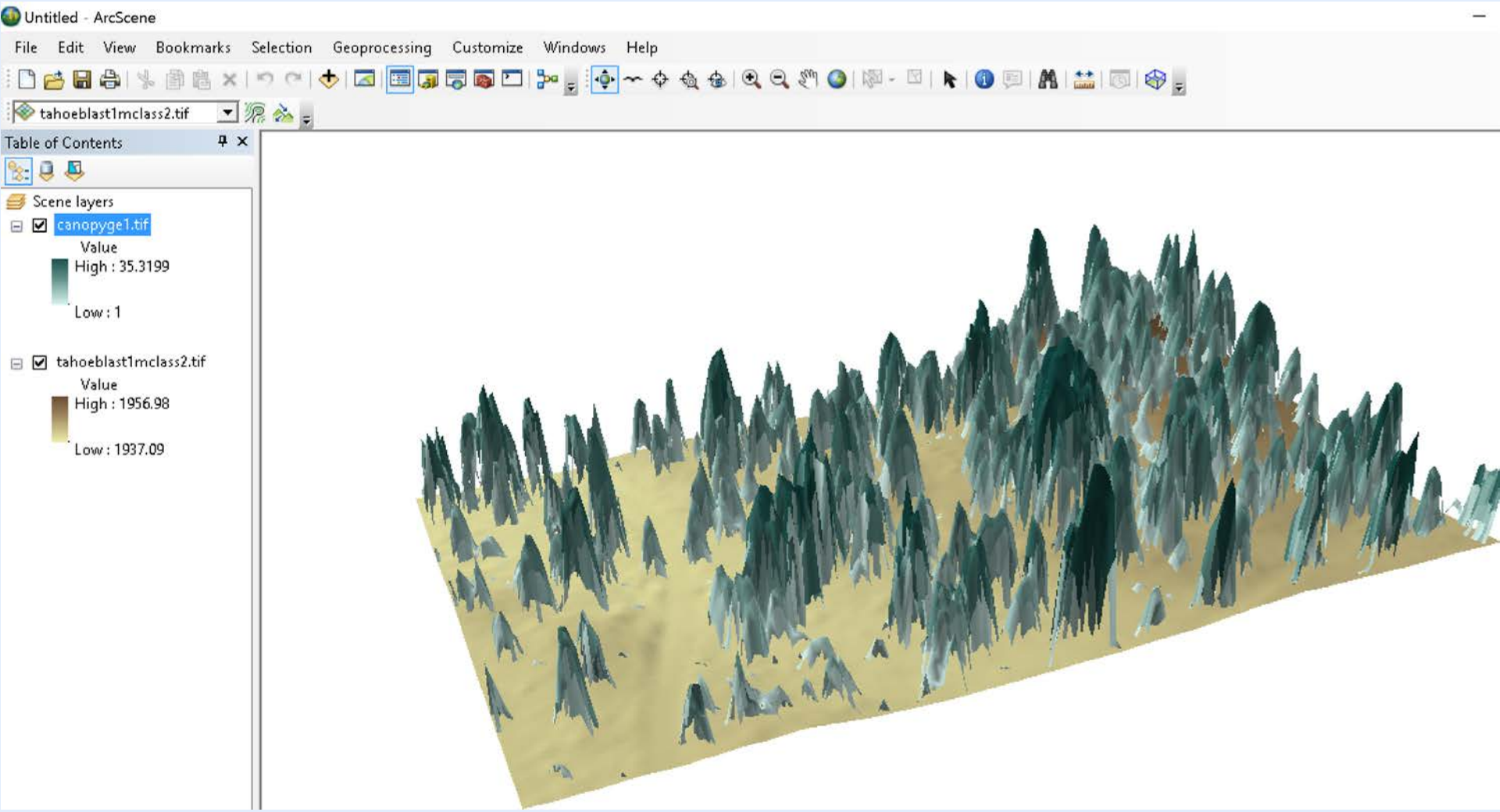
Symbology—change colormap



Rendering

Shade areal features

High quality enhancement



ArcScene Properties tabs:

Symbology—change colormap

Rendering

Shade areal features

High quality enhancement