

Lesson 06

Point cloud processing

GE01015.2025

Hugo Ledoux

Appendices of terrain book are important!

APPENDICES	161
A Point cloud file formats	163
A.1 ASCII formats	163
A.2 PLY format	164
A.3 LAS format	165
A.4 LAZ format	167
B Extra information about the AHN datasets	169
C Estimating the normals in a point cloud	171
D Some useful equations	173
D.1 Centre of a circle defined by 3 points	173
Bibliography	175
Index	181

PC in text files

ASCII

```
x y z
84499.948 446610.324 0.407
84499.890 446609.862 0.434
84499.832 446609.420 0.442
84499.777 446608.987 0.454
84499.715 446608.528 0.444
84499.839 446612.808 0.493
```

PLY

```
ply
format ascii 1.0 ← encoding and ply version number
comment This is an example file!
element vertex 7 ← number of points, start of point record definition
property float x
property float y
property float z
property int custom_attribute
end_header
91443.89 438385.69 -0.80 11
91443.94 438386.10 -0.78 43
91444.00 438386.51 -0.79 44
91444.06 438386.94 -0.83 31
91444.11 438387.36 -0.86 31
91443.88 438383.50 -0.83 22
91443.93 438383.91 -0.80 65
```

point record definition

point records

PC in binary files: LAS

- LASer file format (LAS)
- most widely used standard for the dissemination of point cloud data.
- designed for datasets that originate from (airborne) lidar scanners.
- classes are fixed (but space for user-defined ones):

Code	Meaning
0	never classified
1	unclassified
2	ground
3	low vegetation
4	medium vegetation
5	high vegetation
6	building
7	low point (noise)
8	reserved
9	water
13–31	user-defined

Format 0

Table A.1: LAS Point Data Record Format 0

Field	Format	Length (bits)	Description
X	int	32	X coordinate
Y	int	32	Y coordinate
Z	int	32	Z coordinate
Intensity	unsigned int	16	The pulse return amplitude
Return number	unsigned int	3	The total pulse return number for a given output pulse
Number of returns	unsigned int	3	Total number of returns for a given pulse
Scan Direction Flag	boolean	1	Denotes the direction at which the scanner mirror was travelling at the time of the output pulse. A bit value of 1 is a positive scan direction, and a bit value of 0 is a negative scan direction (where positive scan direction is a scan moving from the left side of the in-track direction to the right side and negative the opposite).
Edge of Flight Line	boolean	1	Has a value of 1 only when the point is at the end of a scan. It is the last point on a given scan line before it changes direction.
Classification	unsigned int	5	Classification code
Scan Angle Rank	int	4	The angle at which the laser pulse was output from the scanner including the roll of the aircraft
User Data	unsigned int	4	May be used at the user's discretion
Point Source ID	unsigned int	8	Indicates the file from which this point originated Non-zero if this point was copied from another file

$$X_{coordinate} = (X_{record} * X_{scale}) + X_{offset}$$
$$Y_{coordinate} = (Y_{record} * Y_{scale}) + Y_{offset}$$
$$Z_{coordinate} = (Z_{record} * Z_{scale}) + Z_{offset}$$

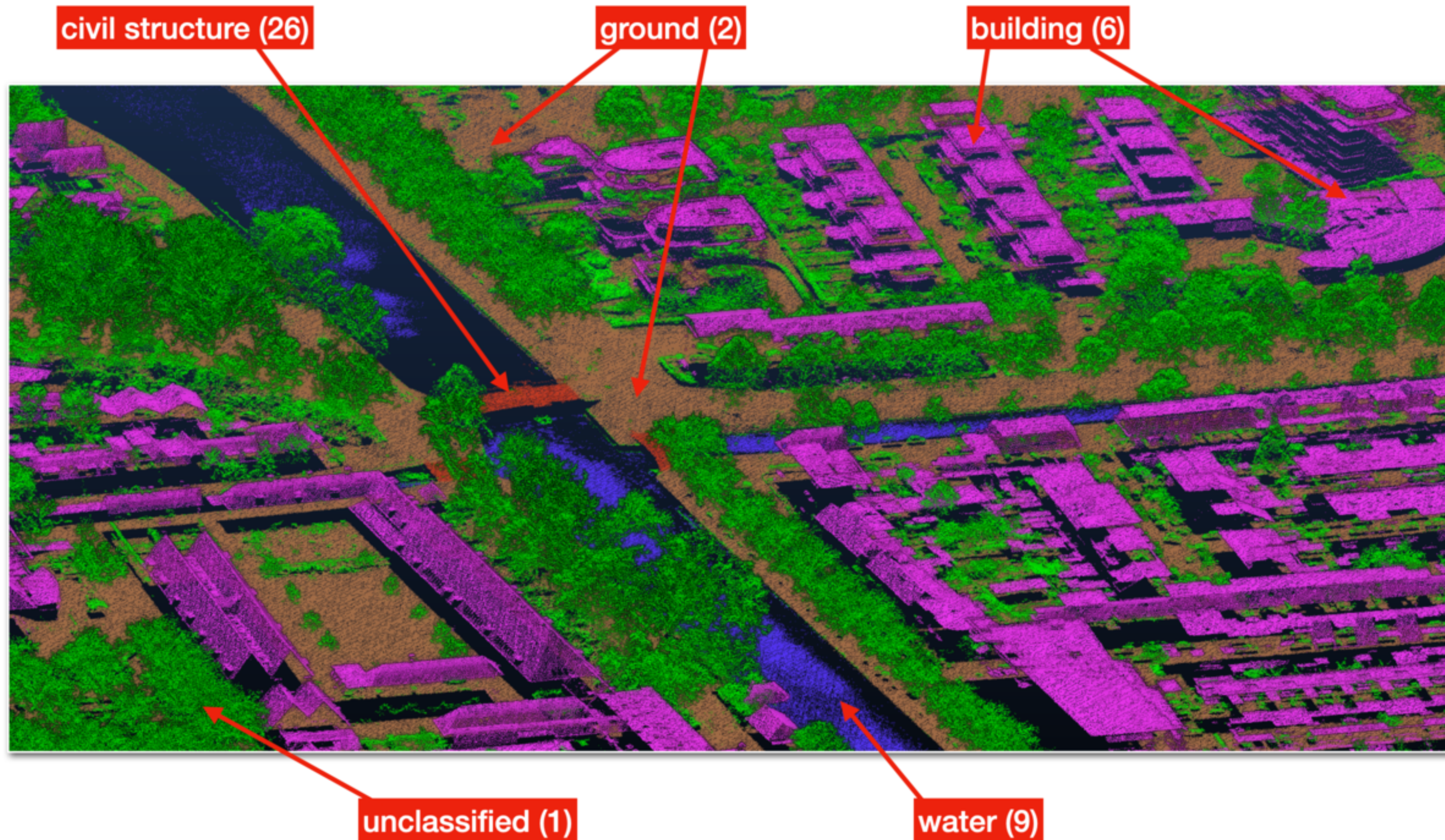
Compressed LAS == LAZ

- Compression == 10X I'd say: try with AHN4!
- point records are grouped in blocks of 50,000 records
- Each block is individually compressed, which makes it possible to partially decompress only the needed blocks from a file (instead of always needing to decompress the whole file).
- a greater compression factor can often be achieved after spatially sorting the points.
- Read/write is slower...

Not an official standard!

!= zLAS

AHN4+5 classification

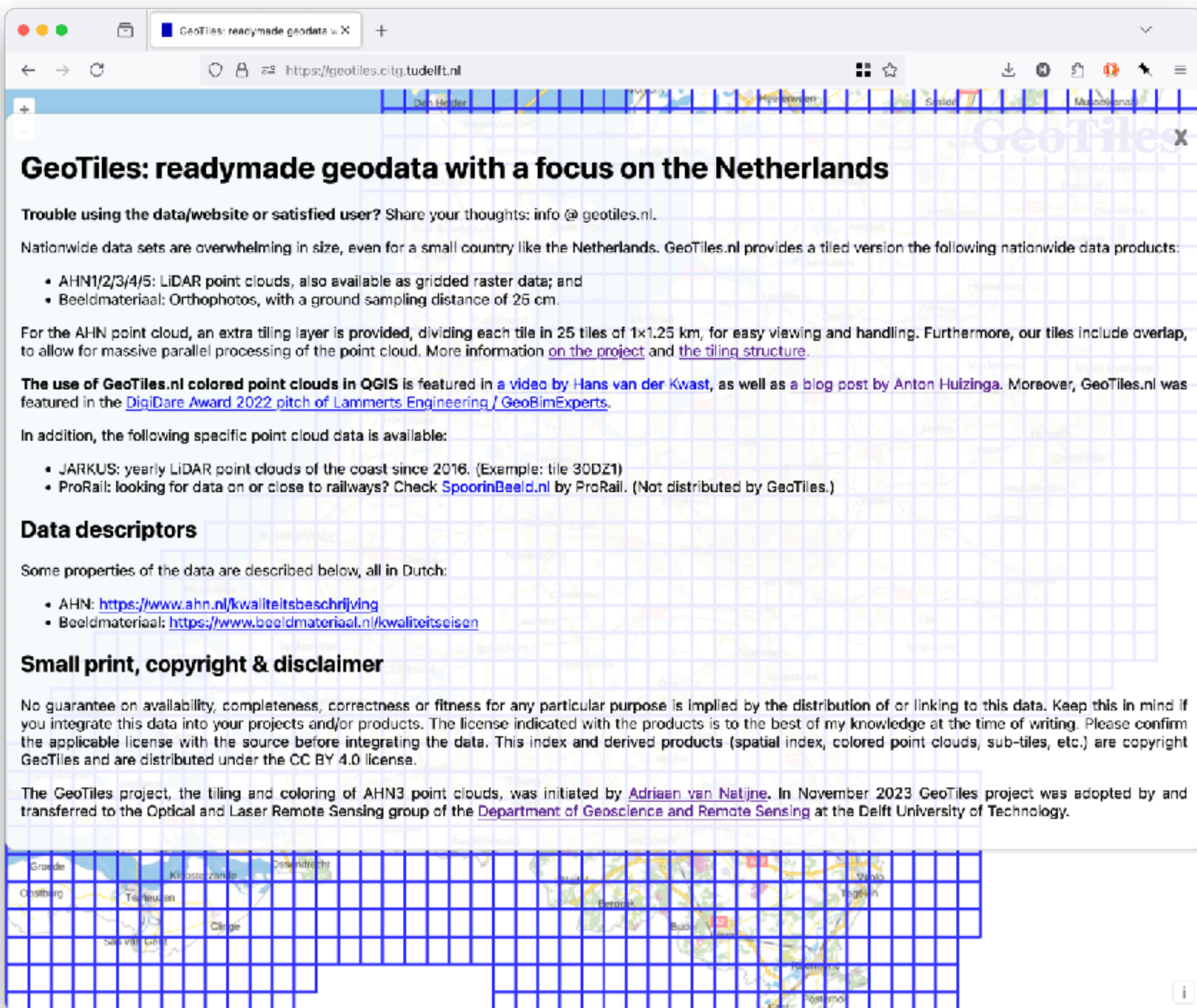


Class 1
=
unclassified
(includes many things!)

Class 14
=
High-voltage
pylons+cables

Class 26
=
bridges, statues, and
viaducts

You want to download AHN?



The screenshot shows the GeoTiles website in a web browser. The page has a blue header with the GeoTiles logo and a navigation bar. The main content area is white with a blue grid overlay. The text on the page is as follows:

GeoTiles: readymade geodata with a focus on the Netherlands

Trouble using the data/website or satisfied user? Share your thoughts: info@geotiles.nl.

Nationwide data sets are overwhelming in size, even for a small country like the Netherlands. GeoTiles.nl provides a tiled version the following nationwide data products:

- AHN1/2/3/4/5: LIDAR point clouds, also available as gridded raster data; and
- Beeldmateriaal: Orthophotos, with a ground sampling distance of 25 cm.

For the AHN point cloud, an extra tiling layer is provided, dividing each tile in 25 tiles of 1x1.25 km, for easy viewing and handling. Furthermore, our tiles include overlap, to allow for massive parallel processing of the point cloud. More information [on the project](#) and [the tiling structure](#).

The use of GeoTiles.nl colored point clouds in QGIS is featured in a [video by Hans van der Kwast](#), as well as a [blog post by Anton Huizinga](#). Moreover, GeoTiles.nl was featured in the [DigiDare Award 2022 pitch of Lammerts Engineering / GeoBimExperts](#).

In addition, the following specific point cloud data is available:

- JARKUS: yearly LIDAR point clouds of the coast since 2016. (Example: tile 30DZ1)
- ProRail: looking for data on or close to railways? Check [SpoorinBeeld.nl](#) by ProRail. (Not distributed by GeoTiles.)

Data descriptors

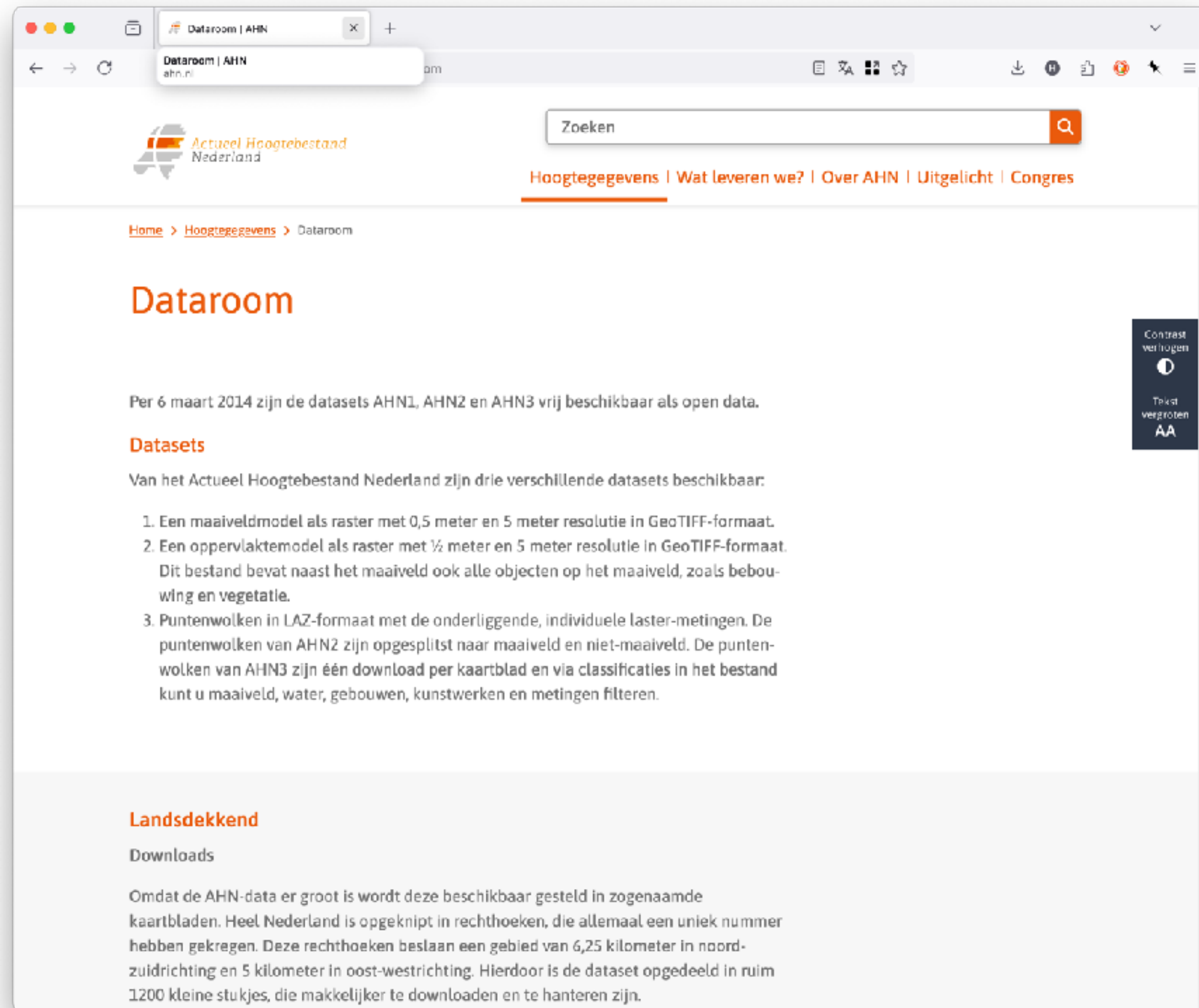
Some properties of the data are described below, all in Dutch:

- AHN: <https://www.ahn.nl/kwaliteitsbeschrijving>
- Beeldmateriaal: <https://www.beeldmateriaal.nl/kwaliteitseisen>

Small print, copyright & disclaimer

No guarantee on availability, completeness, correctness or fitness for any particular purpose is implied by the distribution of or linking to this data. Keep this in mind if you integrate this data into your projects and/or products. The license indicated with the products is to the best of my knowledge at the time of writing. Please confirm the applicable license with the source before integrating the data. This index and derived products (spatial index, colored point clouds, sub-tiles, etc.) are copyright GeoTiles and are distributed under the CC BY 4.0 license.

The GeoTiles project, the tiling and coloring of AHN3 point clouds, was initiated by [Adriaen van Nuijine](#). In November 2023 GeoTiles project was adopted by and transferred to the Optical and Laser Remote Sensing group of the [Department of Geoscience and Remote Sensing](#) at the Delft University of Technology.



The screenshot shows the Dataroom website in a web browser. The page has a white header with the Dataroom logo and a navigation bar. The main content area is white with a light blue grid overlay. The text on the page is as follows:

Dataroom

Per 6 maart 2014 zijn de datasets AHN1, AHN2 en AHN3 vrij beschikbaar als open data.

Datasets

Van het Actueel Hoogtebestand Nederland zijn drie verschillende datasets beschikbaar:

1. Een maaiveldmodel als raster met 0,5 meter en 5 meter resolutie in GeoTIFF-formaat.
2. Een oppervlaktemodel als raster met 1/2 meter en 5 meter resolutie in GeoTIFF-formaat. Dit bestand bevat naast het maaiveld ook alle objecten op het maaiveld, zoals bebouwing en vegetatie.
3. Puntenwolken in LAZ-formaat met de onderliggende, individuele laster-metingen. De puntenwolken van AHN2 zijn opgesplitst naar maaiveld en niet-maaiveld. De puntenwolken van AHN3 zijn één download per kaartblad en via classificaties in het bestand kunt u maaiveld, water, gebouwen, kunstwerken en metingen filteren.

Landsdekkend

Downloads

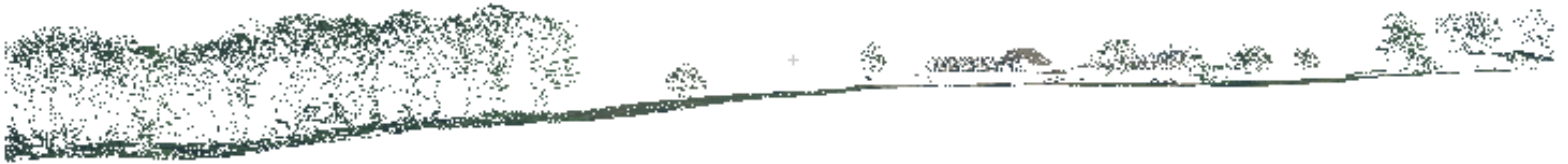
Omdat de AHN-data er groot is wordt deze beschikbaar gesteld in zogenaamde kaartbladen. Heel Nederland is opgeknipt in rechthoeken, die allemaal een uniek nummer hebben gekregen. Deze rechthoeken beslaan een gebied van 6,25 kilometer in noord-zuidrichting en 5 kilometer in oost-westrichting. Hierdoor is de dataset opgedeeld in ruim 1200 kleine stukjes, die makkelijker te downloaden en te hanteren zijn.

Thinning

- ▶ **random:** randomly keep a given percentage of the points, eg 10%.
- ▶ ***n*th-point:** keep only the *n*th point in the dataset. For instance, if $n = 100$, we would keep the 1st, the 101th, the 201th, etc; a dataset with 100 000 points is reduced to 1000 points. This is the quickest thinning method.
- ▶ ***n*th-point random:** if there is some structure in the input points (eg if generated from a gridded terrain) then *n*th-point could create datasets with artefacts. The randomised variation chooses randomly in the *n* points one point.
- ▶ **grid:** overlay a 2D or 3D regular grid over the points and keep *m* points per grid cell. That can be one of the original points, an average of those, or the exact centre of the cell. The thinning factor depends on the chosen cell-size. Notice that the result is often a point cloud with a homogeneous point density on all surfaces (only on the horizontal surfaces if a 2D grid is used).

Ground filtering

This does not use the
classification, only
geometry!



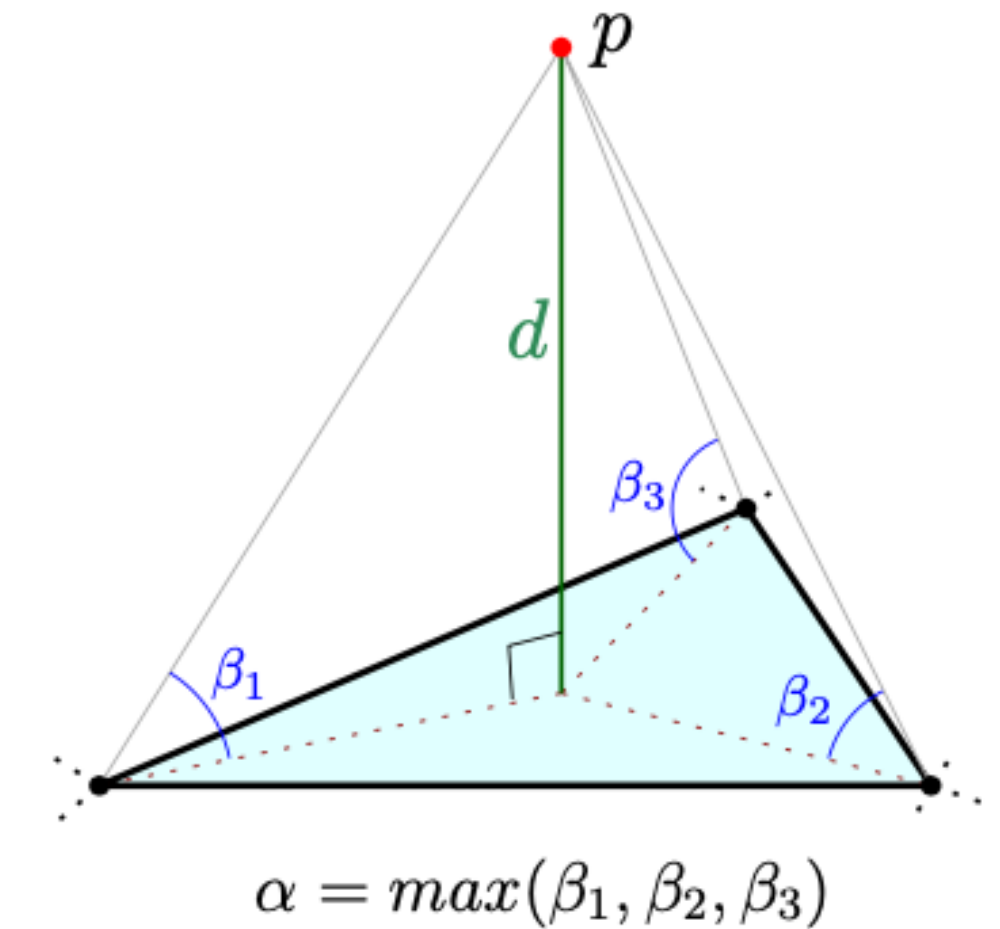
(a) Original point cloud



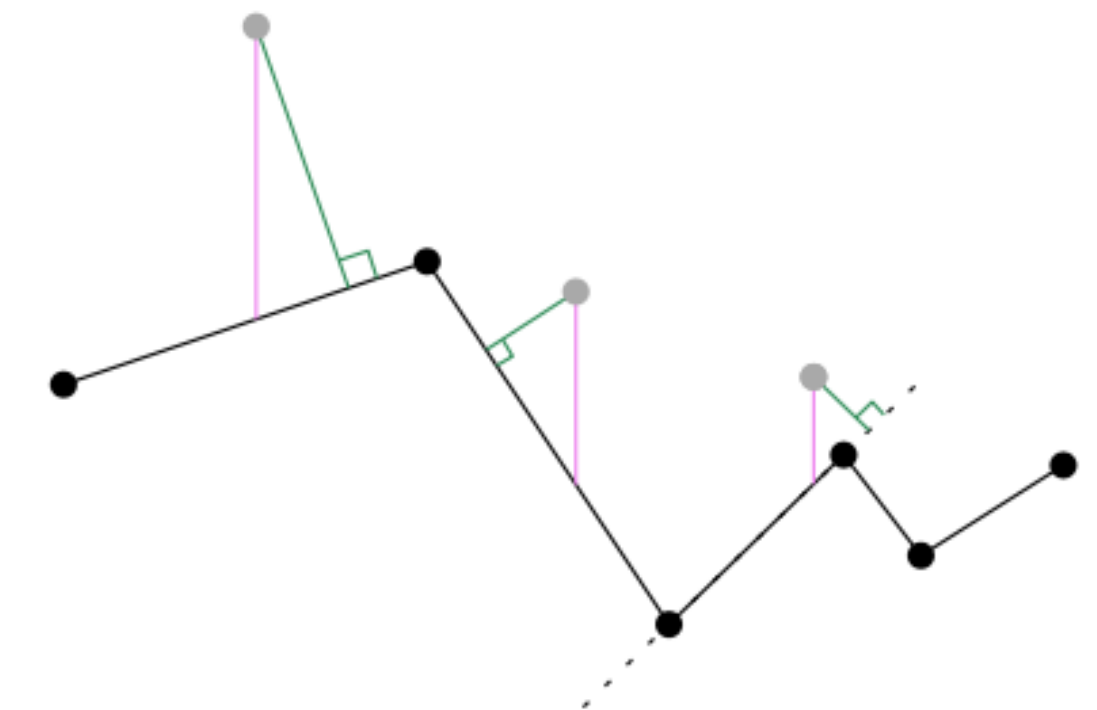
(b) After ground filtering

Method #1: Ground filtering with TIN (GFTIN)

1. construction of a rudimentary initial TIN (usually a Delaunay TIN);
2. computation of two geometric properties for each point that is not already labelled as ground;
3. incremental insertion of points that pass a simple and local 'ground test' based on the computed geometric properties.



(a) The two ground filter criteria: d and α .



(b) Profile view of a TIN with the vertical projections (pink) and the closest distances to the plane (green) shown for 3 different points. Notice that it is possible that the closest projection falls outside the triangle, as shown for the point on the right.

Figure 11.5: Ground filtering with a TIN.

Method #2: Cloth simulation filter (CSF)

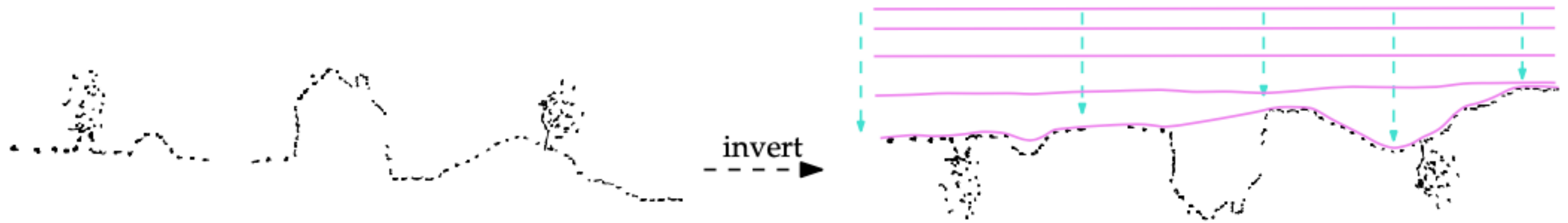


Figure 11.6: Basic idea behind the CSF algorithm for ground filtering of a point cloud: inverting the data and letting a cloth fall.

Method #2: Cloth simulation filter (CSF)

Two factors influence the z -value of a particle during the cloth falling process:

1. **external forces:** in this case this is the gravity pulling down a particle;
2. **internal forces:** the tension in the cloth, which is modelled by the interactions between a particle and its neighbours.

As particles fall down, some will reach the ground and become *unmovable*. These will potentially be neighbours to *movable* ones, whose elevation will be controlled by how we define the rigidity of the cloth.

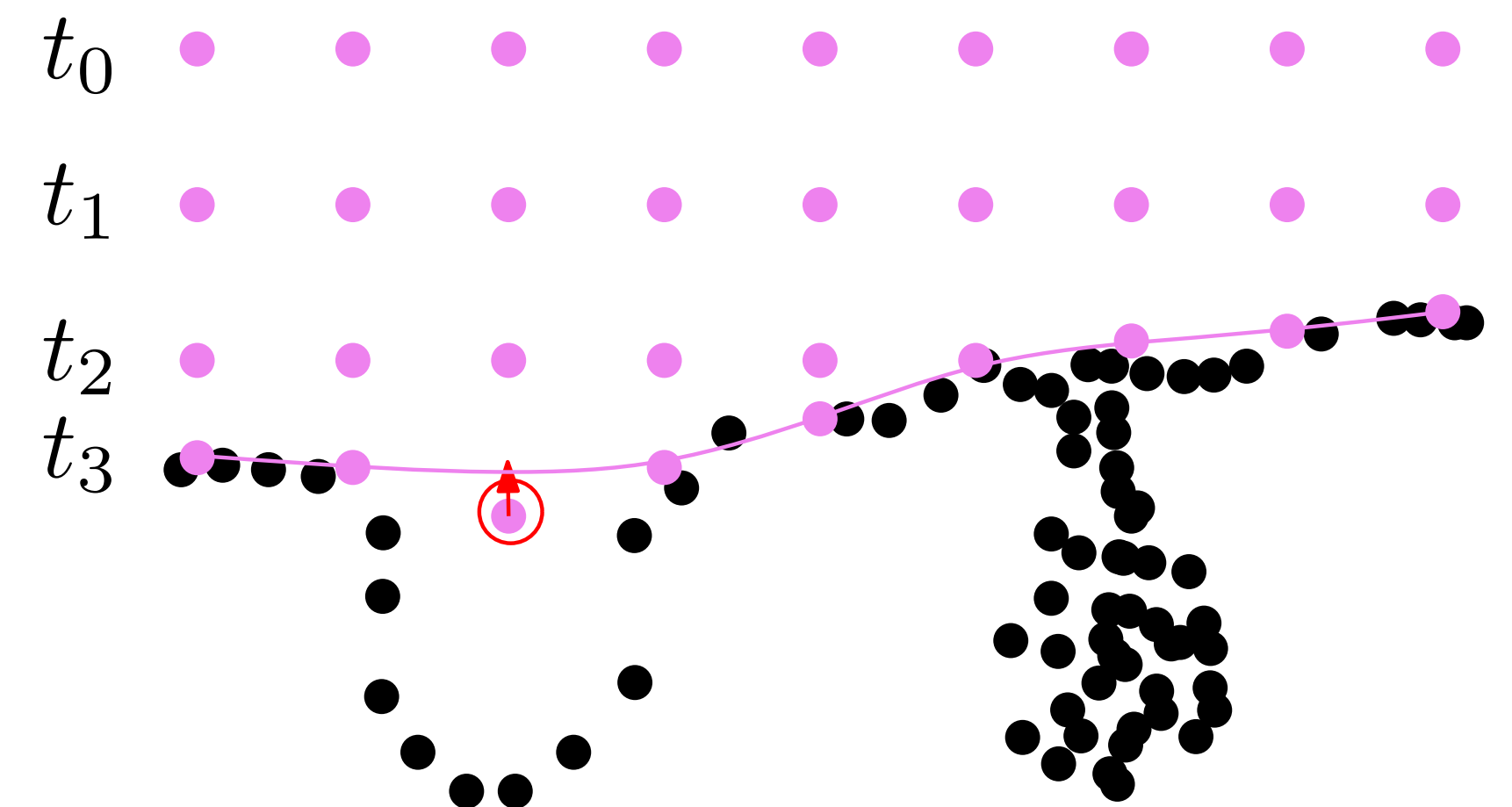
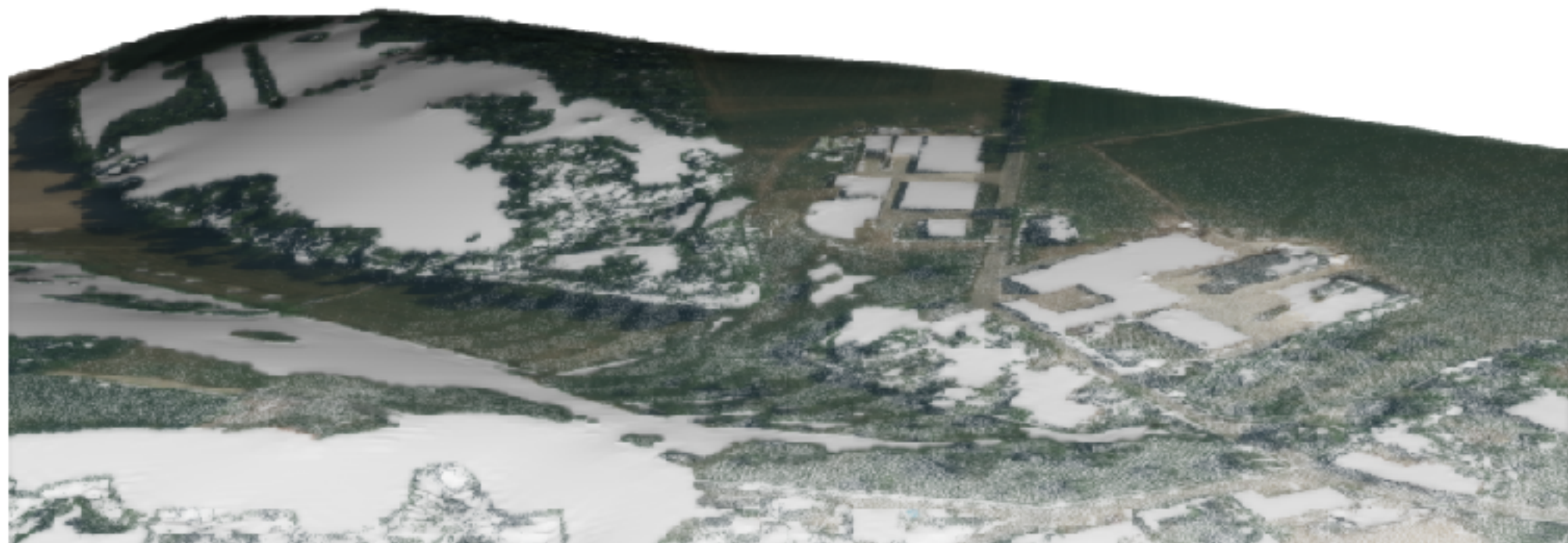


Figure 11.7

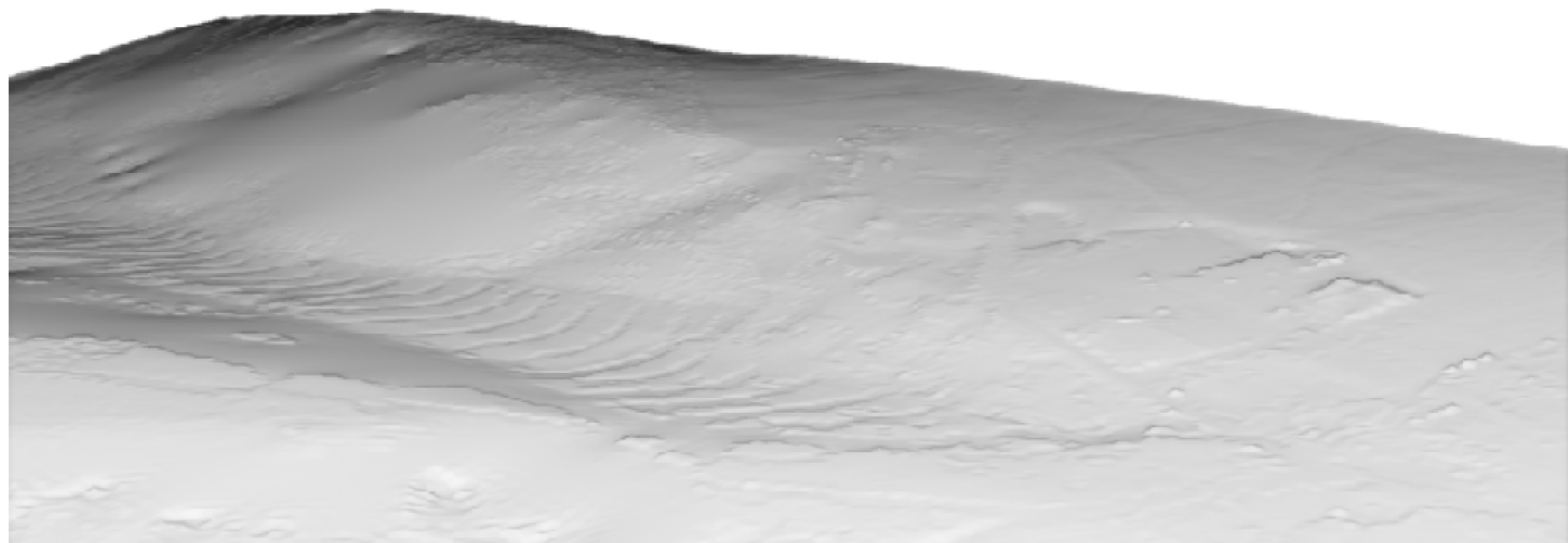
CSF: 2 outputs



(a) Original point cloud



(b) Output #1: the ground points (with the ground surface shown in grey)



(c) Output #2: the ground surface

<https://3d.bk.tudelft.nl/courses/geo1015/>