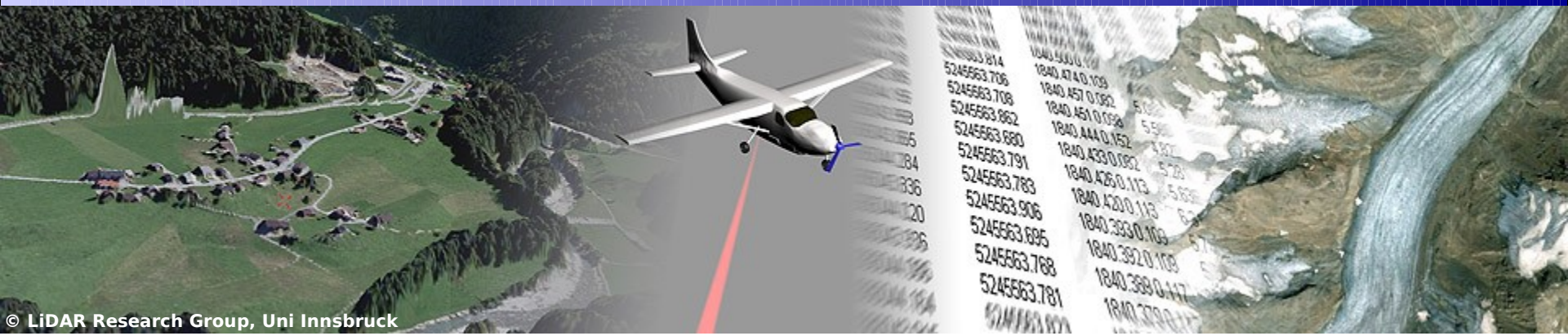


LiDAR Point Cloud Processing with SAGA

Volker Wichmann

Wichmann, V.; Conrad, O.; Jochem, A.: LiDAR Point Cloud Processing with SAGA GIS.
In: Hamburger Beiträge zur Physischen Geographie und Landschaftsökologie 20, S. 81-90.

SAGA | Introduction to LiDAR

LiDAR: Light **D**etection **A**nd **R**anging

- Scanning mechanism
  - Measurement of transit time
  - Calculation of range
  - Measurement of scan angle
- Laser's path through a basic scene
- Resulting point cloud

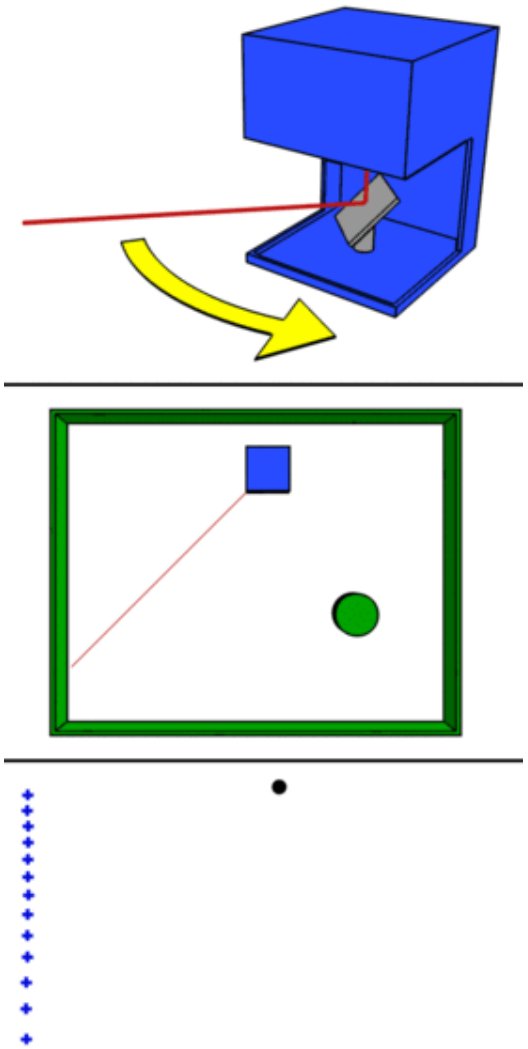


Figure: http://en.wikipedia.org/wiki/File:LIDAR-scanned-SICK-LMS-animation.gif

SAGA | Introduction to LiDAR

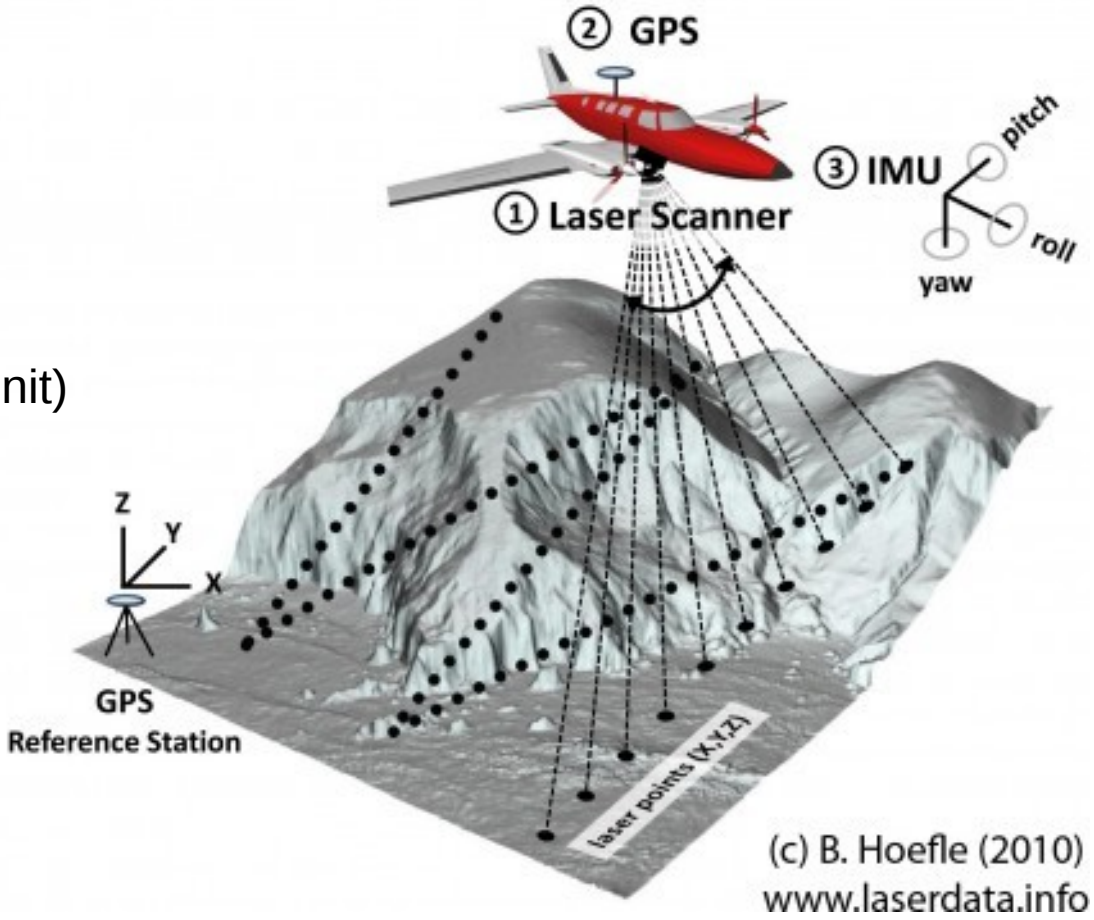
LiDAR: Light **D**etection **A**nd **R**anging

Airborne Laser Scanning (ALS):

(1) Laser scanner

(2) GPS

(3) IMU (inertial measurement unit)



SAGA | Introduction to LiDAR

LiDAR: Light **D**etection **A**nd **R**anging

$$R = \frac{c * dt}{2}$$

R … range
c … speed of light
t … time

recording of multiple echoes per pulse

results of the measurements:

- Plane positions: t x y z
- Echoes (“points”): t x y z i

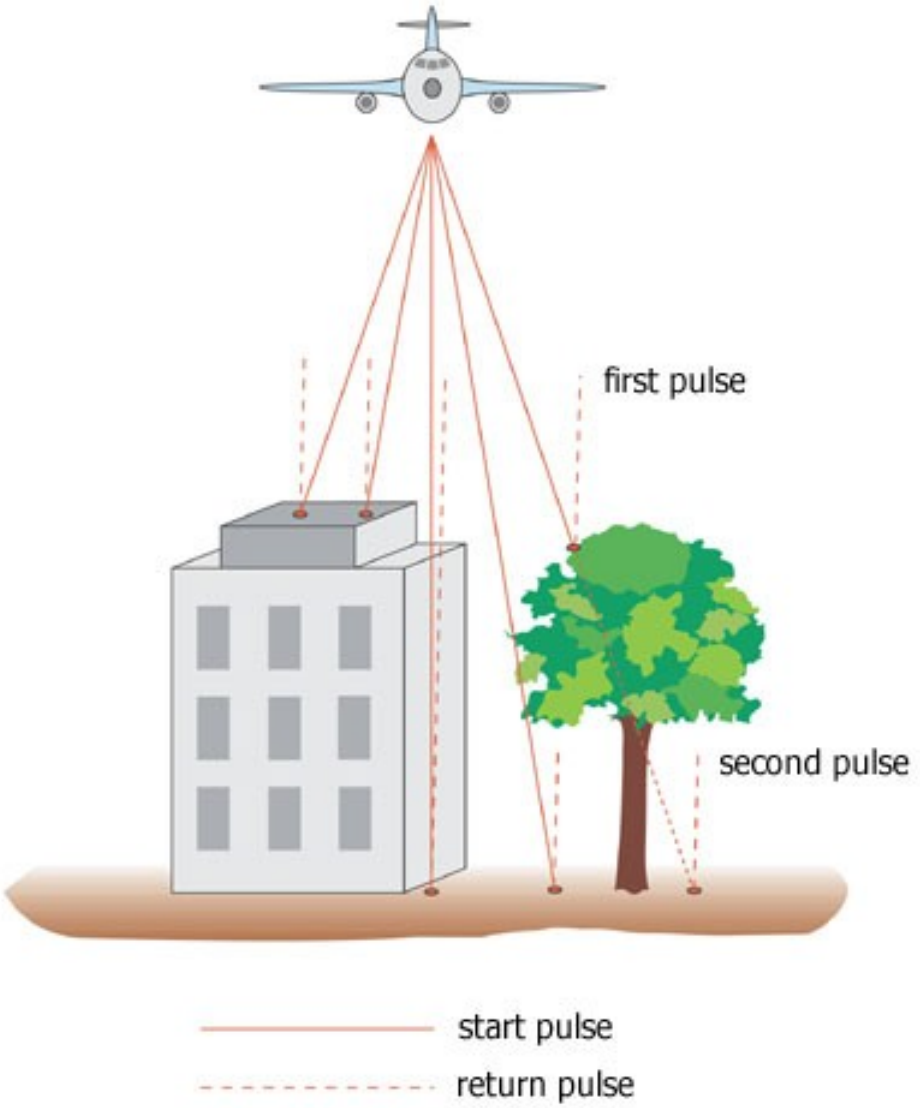


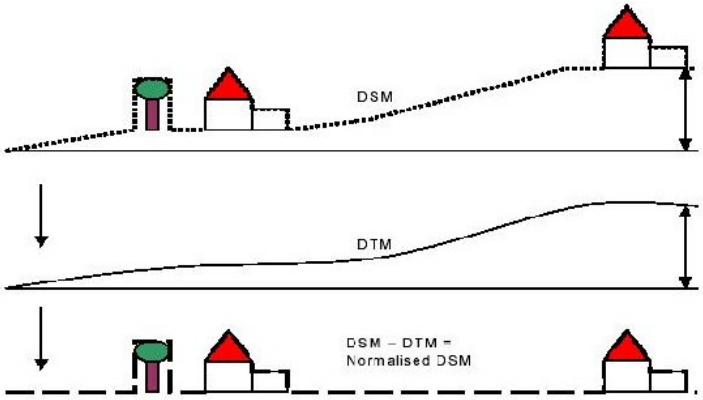
Figure: http://www.terraimaging.de

SAGA | Introduction to LiDAR

Typical products derived from ALS data:

- Digital Surface Model (DSM)
- Digital Terrain Model (DTM)
- Normalized Digital Surface Model (nDSM)

nDSM = DSM - DTM



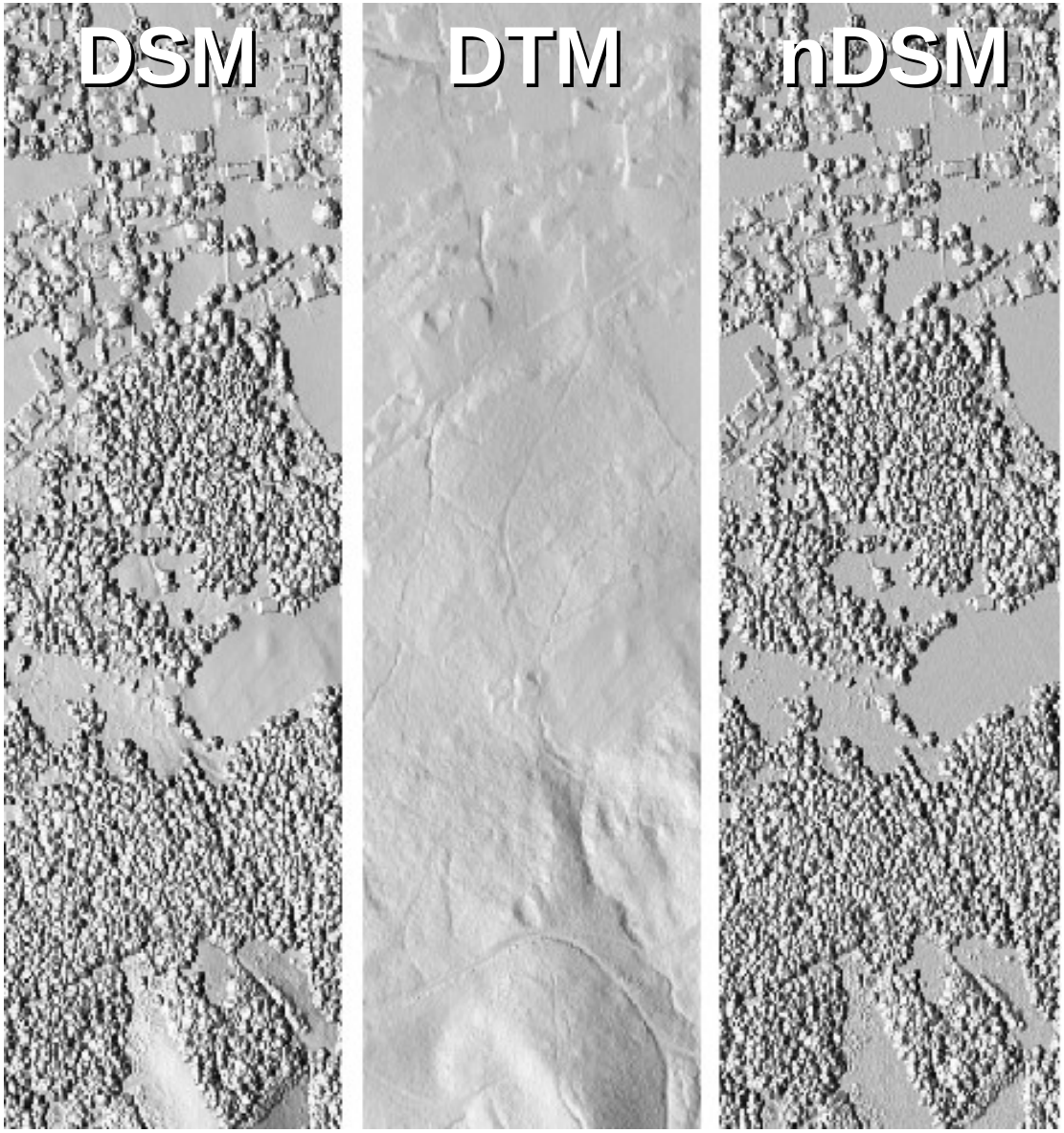


Figure: Höfle in Geist et al. 2008

SAGA | Modules For Point Cloud Processing

Import/Export: Reading and writing files in common LiDAR formats.

- **Import Point Cloud from File** - creates a point cloud dataset from an ESRI point shapefile.
- **Import Point Cloud from Text File** - creates a point cloud dataset from a raw ASCII file.
- **Import Stereo Lithography File (STL)** - creates a point cloud dataset from a STL file.
- **Import LAS Files** - creates a point cloud dataset from an ASPRS LAS file (versions 1.0, 1.1 and 1.2). The module makes use of the libLAS library (see http://liblas.org).
- **Export LAS Files** - creates an ASPRS LAS file (version 1.2) from a point cloud dataset. The module makes use of the libLAS library.
- **Export Point Cloud to Text File** - creates an ASCII file from a point cloud dataset.

SAGA | Modules For Point Cloud Processing

Conversion: Conversion of point clouds to other SAGA data types and vice versa.

- **Point Cloud from Grid Points** – creates a point cloud dataset from a SAGA grid.
- **Point Cloud from Shapes** – creates a point cloud dataset from a point shapefile.
- **Point Cloud to Grid** – aggregates a point cloud to a grid.
- **Point Cloud to Shapes** – creates a point shapefile from a point cloud.

SAGA | Modules For Point Cloud Processing

Tools: Manipulation of point clouds.

- **Point Cloud Cutter** – clipping of a point cloud. The region of interest is either a user defined extent, a grid system extent, a shapes extent or a polygon shapes layer. Besides the latter, all other support the inversion of the region of interest.

- **Point Cloud Cutter [interactive]** – interactive clipping of a point cloud by dragging a box or digitizing a polygon in a map view. It is possible to invert the selection.

- **Point Cloud Thinning (simple)** – thinning of a point cloud. The module simply removes every i-th point from a point cloud and thus is best suited for data sorted by GPS time.

- **Transform Point Cloud** – shifting, rotation and scaling of a point cloud.

- **Drop Point Cloud Attribute** – dropping an attribute from a point cloud dataset.

SAGA | Modules For Point Cloud Processing

Analysis:

- **Cluster Analysis for Point Clouds** – the module is a fork of the “Cluster Analysis for Grids” module and runs a cluster analysis on one or several point cloud attributes. It provides two cluster algorithms: an iterative minimum distance (Forgy 1965) and a hill climbing (Rubin 1967) classifier. Besides the number of clusters to calculate, the module provides the option to normalize the input data by standard deviation before clustering.

- **Point Cloud Attribute Calculator** – calculates a new point cloud attribute based on existing attributes and a mathematical formula. The module uses the CSG_Formula class as parser, just like the “Grid Calculator”, “Table Calculator” and “Table Calculator for Shapes” modules. Besides common operators for addition, subtraction, multiplication and division, it supports trigonometric, root, exponential and logarithmic functions as well as conditional queries (e.g. >, <, if - then - else constructs).

SAGA | Modules For Point Cloud Processing

Analysis:

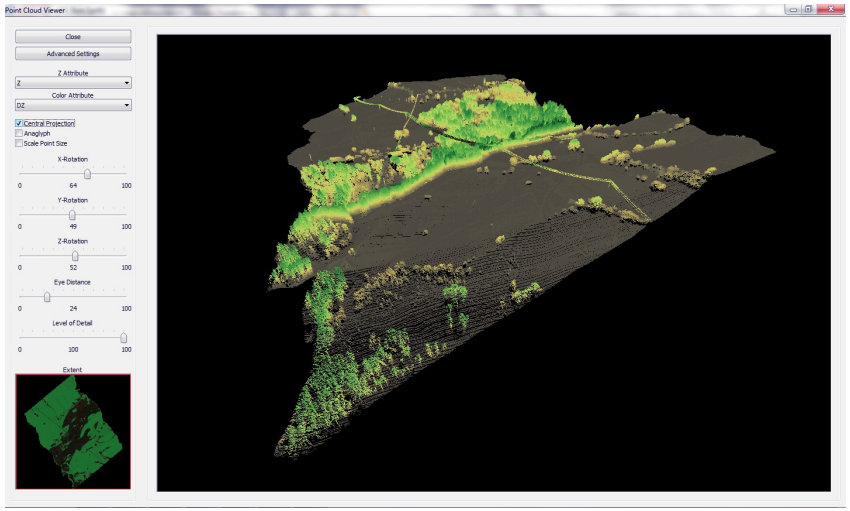
- **Point Cloud Reclassifier / Subset Extractor** – reclassification of a point cloud attribute or extraction of a subset of a point cloud dataset based on the values of an attribute. The condition is applied either to single values, a range of values or value ranges specified in a lookup table, just like with the corresponding “Reclassify Grid Values” module for grid datasets. In combination with the “Point Cloud Attribute Calculator” module this allows complex calculations based on coordinates and attributes.

- **DTM Filter (slope-based)** – this module does not work on point clouds directly, but on grid datasets derived from LiDAR point datasets. It can be used to derive a bare earth dataset (DTM) by filtering: all input cells get either classified as ground or non-ground cells. The filter algorithm is based on concepts described by Vosselman (2000). A structure element (kernel) is moved over the grid, and subject to the height differences within the kernel, the central cell is classified.

SAGA | Modules For Point Cloud Processing

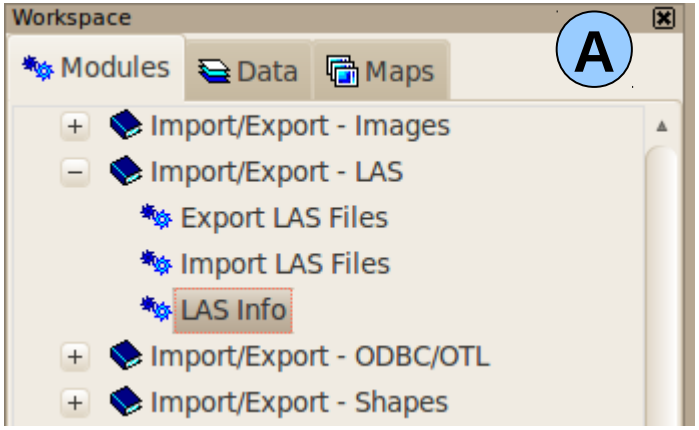
Visualization:

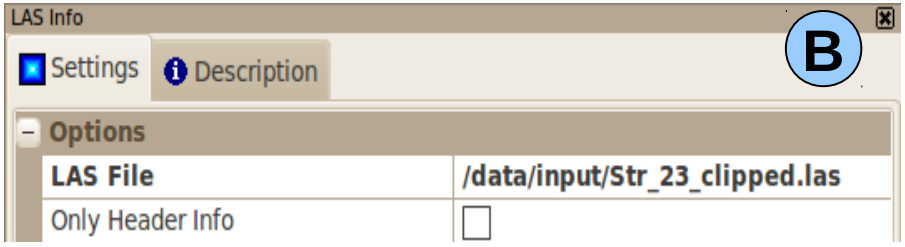
- **Point Cloud Viewer** – a 3D viewer for point clouds. Among other things, the viewer supports attribute based coloring, exaggeration, point size scaling based on viewing distance, level of detail control and a stereo anaglyph modus to use with red/green glasses for a three dimensional impression. 3D navigation is done with the mouse. A small view provides a 2D map overview to select a region of interest, i.e. a subset to be displayed in the main view.

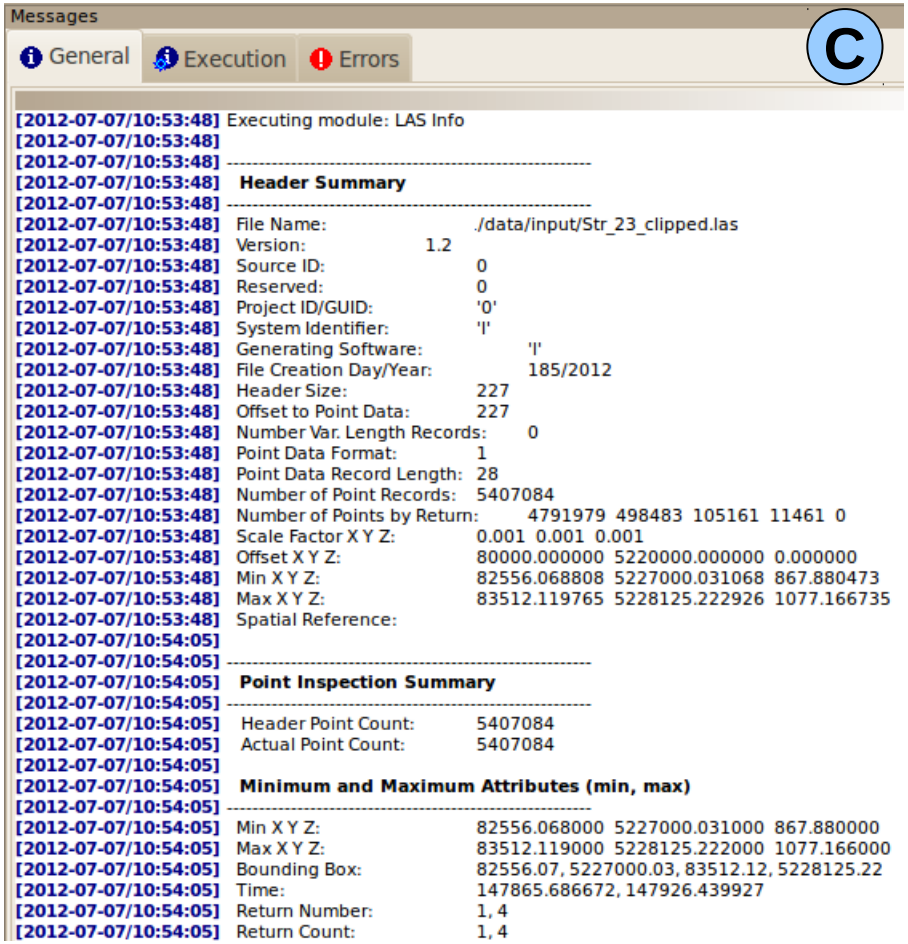


SAGA | Data Import from LAS

Import/Export - LAS → LAS Info: Prints information on ASPRS LAS files

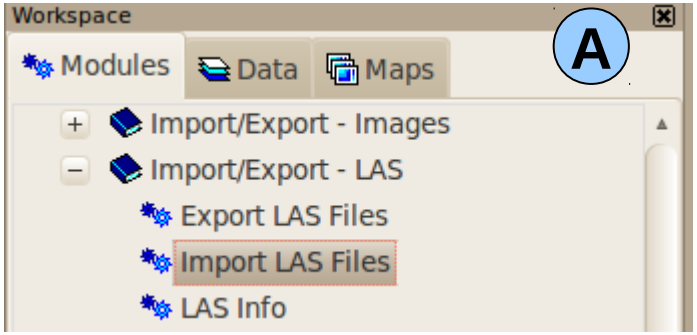


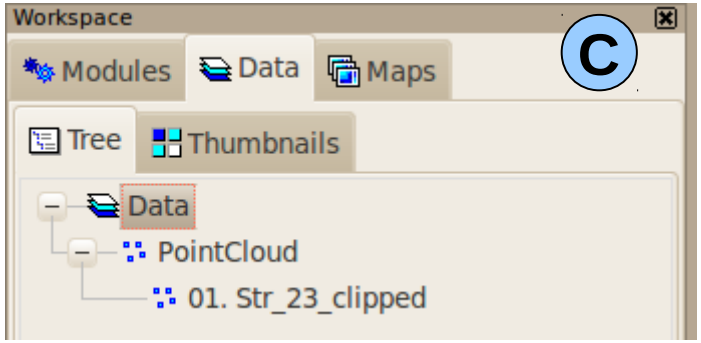


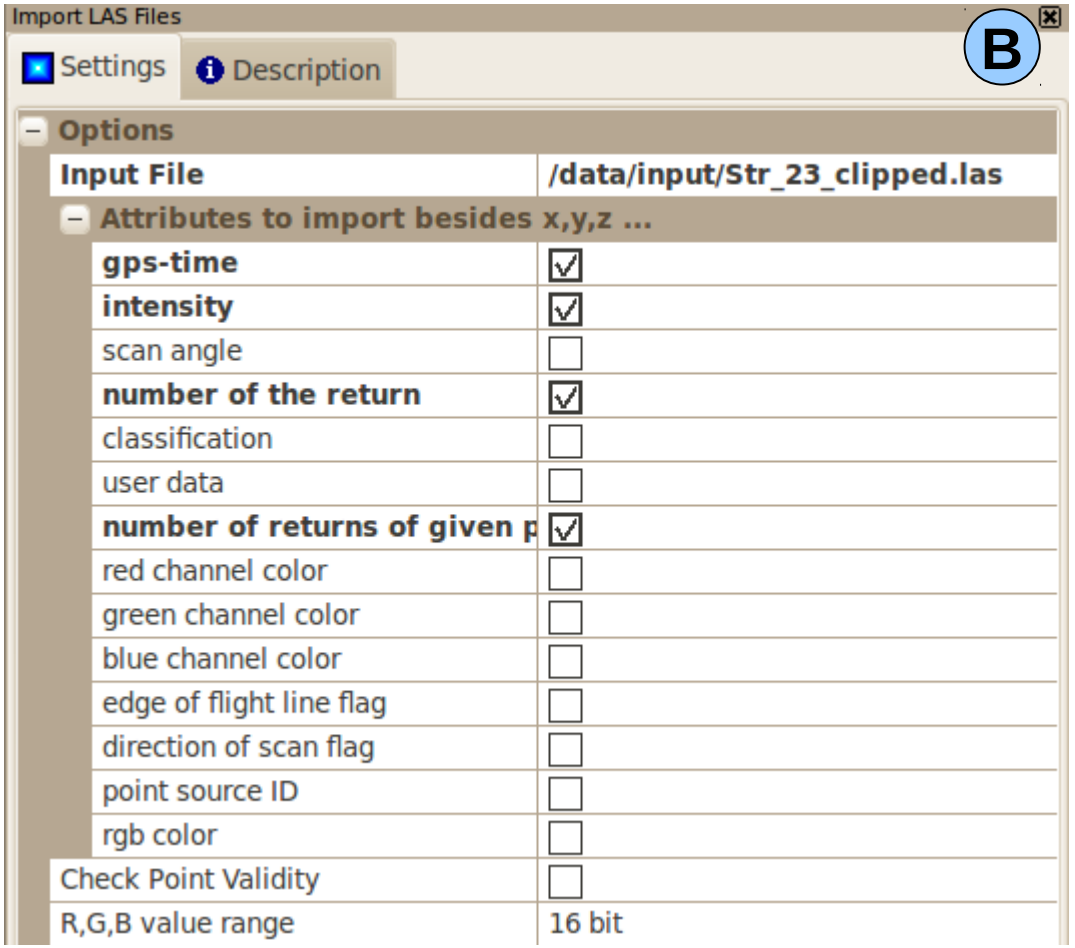


SAGA | Data Import from LAS

Import/Export - LAS → Import LAS Files: Imports ASPRS LAS files

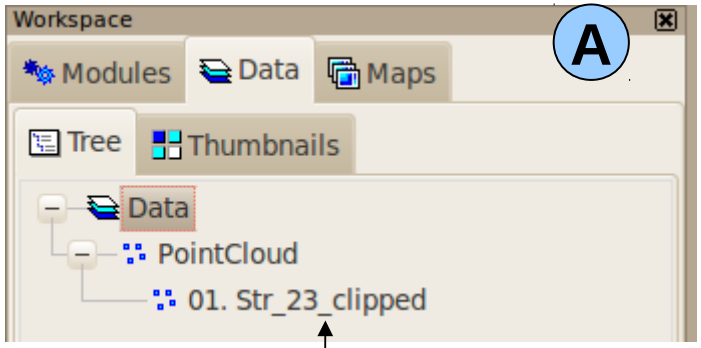




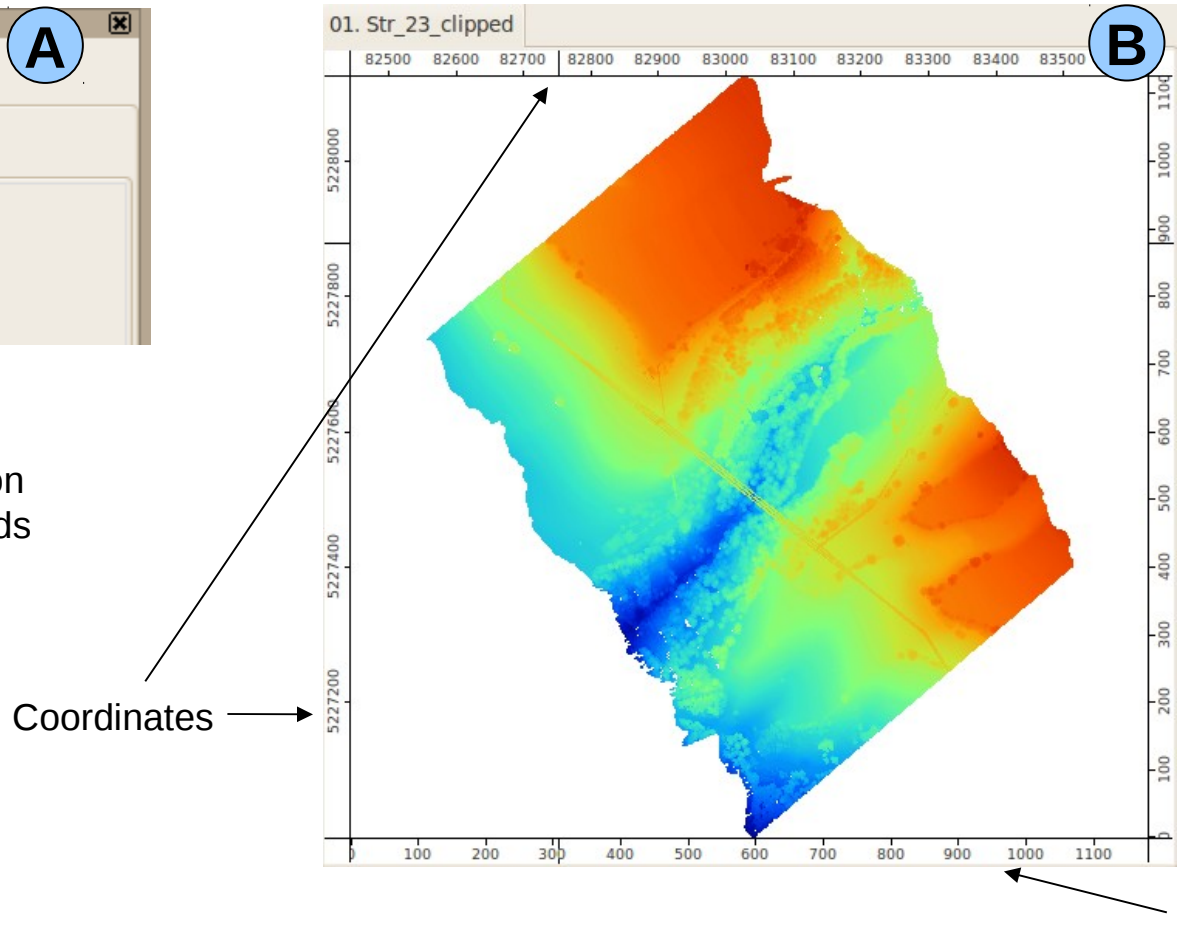


SAGA | Point Cloud Visualization

Visualization in a Map View

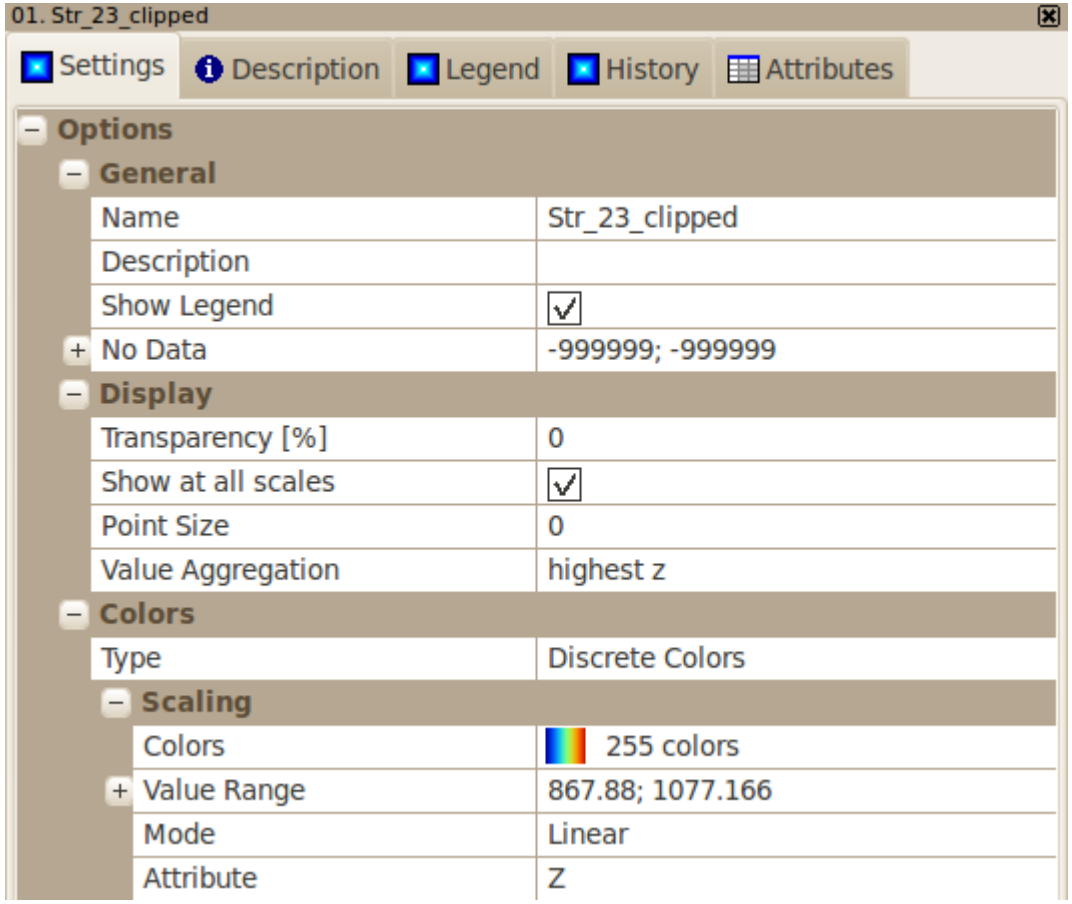


Double-click (or right-click) on a dataset in the *Data* tab adds the dataset to a *Map View*



SAGA | Point Cloud Visualization

Visualization in a Map View: Attribute and colorization settings



← No Data Range

← Transparency

← Point Size

← Point Drawing Order: e.g. highest/lowest

← Color Type: e.g. LUT, graduated, RGB

← Color Palette

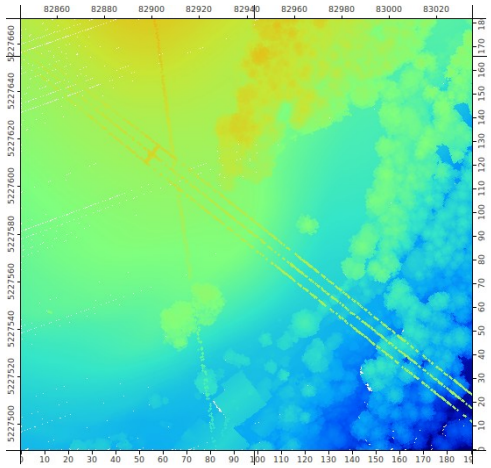
← Attribute to visualize

SAGA | Point Cloud Visualization

Visualization in a Map View: Navigation

Navigation: Zoom to…

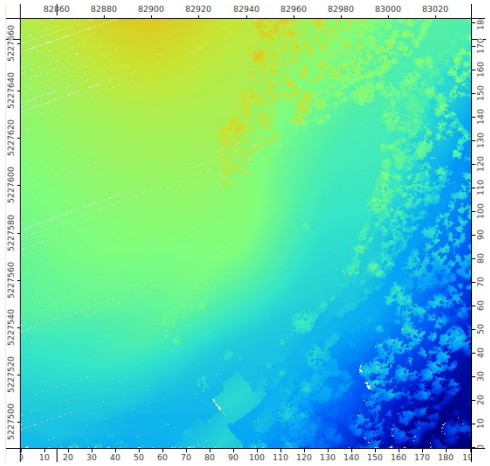
- Previous extent
- Next extent
- Full extent
- Selected layer
- Selected layer object
- Synchronize all map's extents



Highest Z
→ First Return

Mouse Tools:

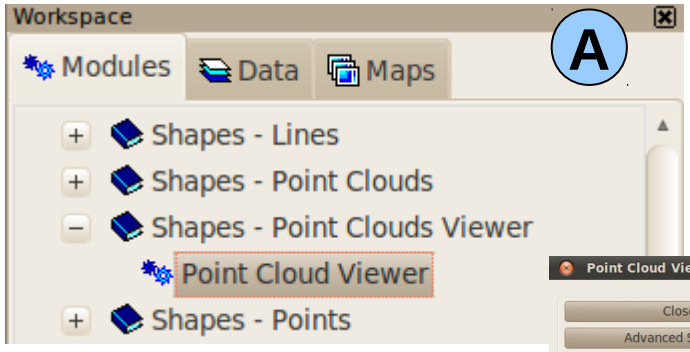
- Action
- Zoom
- Pan
- Measure distance

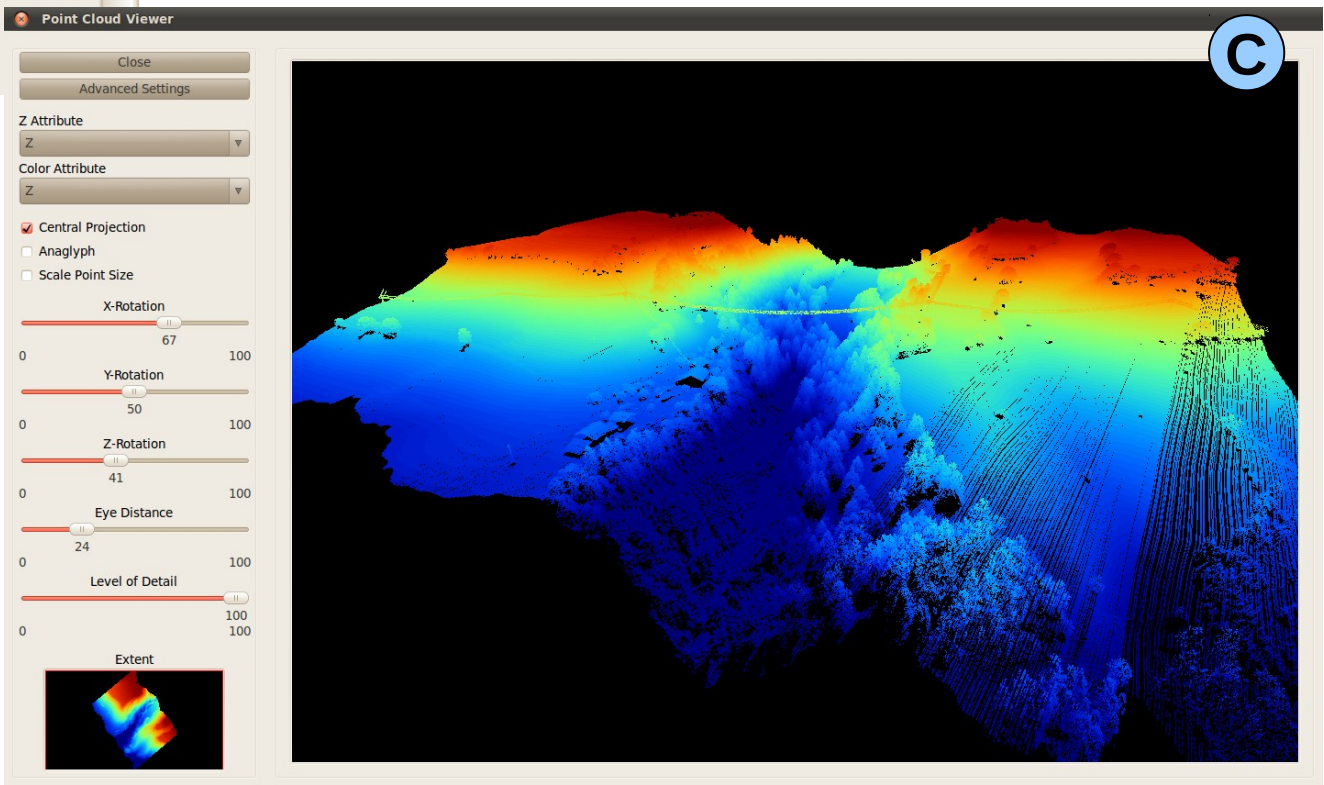


Lowest Z
→ Last Return

SAGA | Point Cloud Visualization

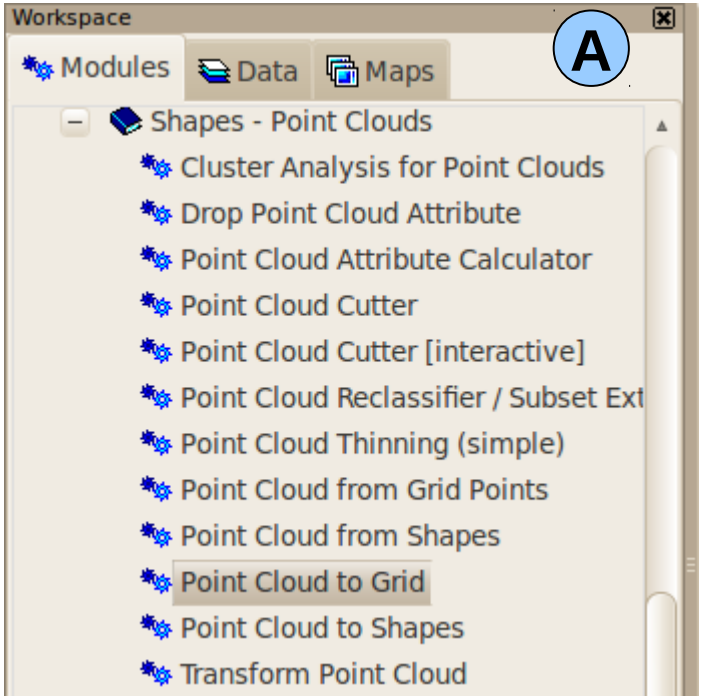
Shapes – Point Clouds Viewer → Point Cloud Viewer: 3D Viewer for Point Clouds

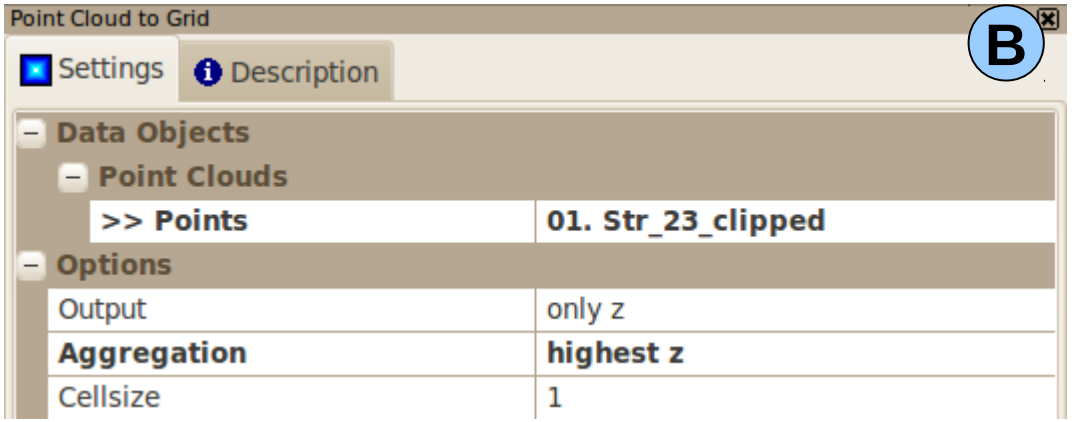


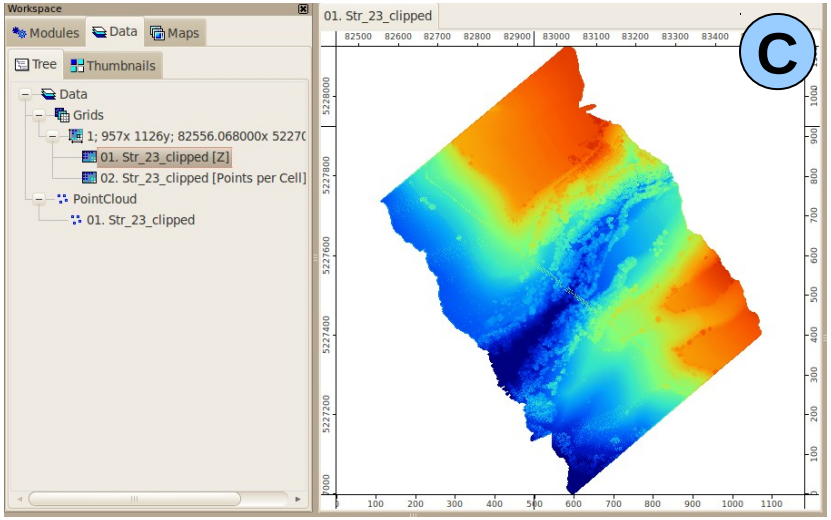


SAGA | DSM Generation

Shapes – Point Clouds → **Point Cloud to Grid:** Gridding of Point Clouds

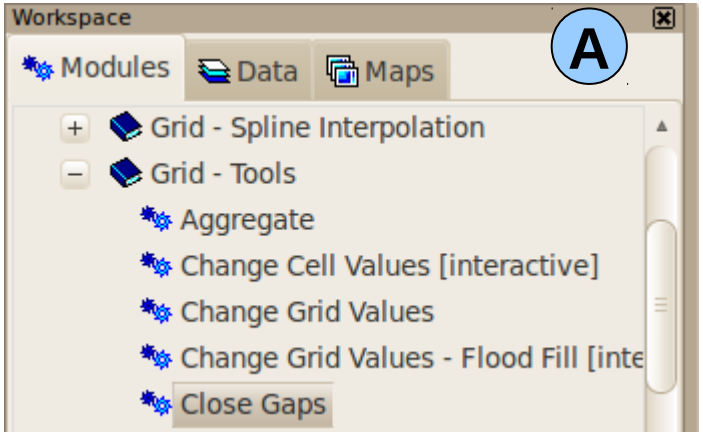


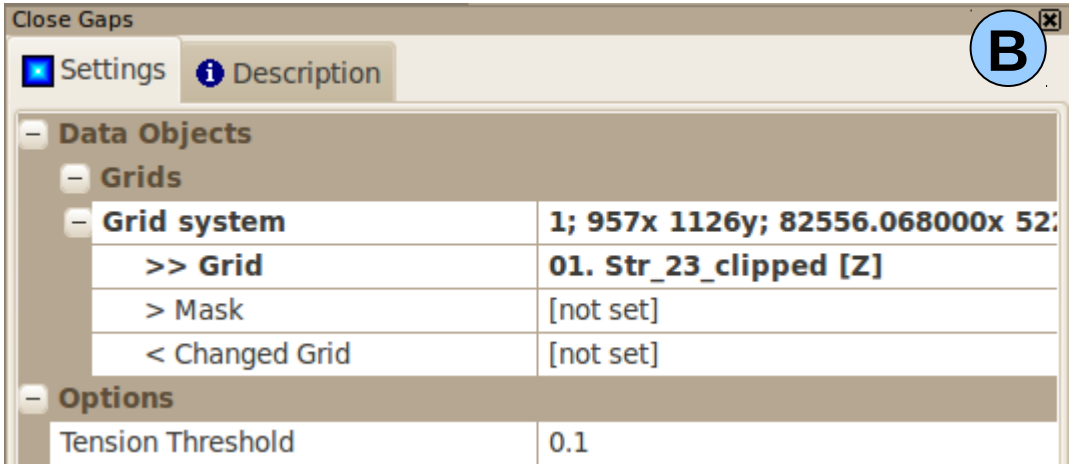


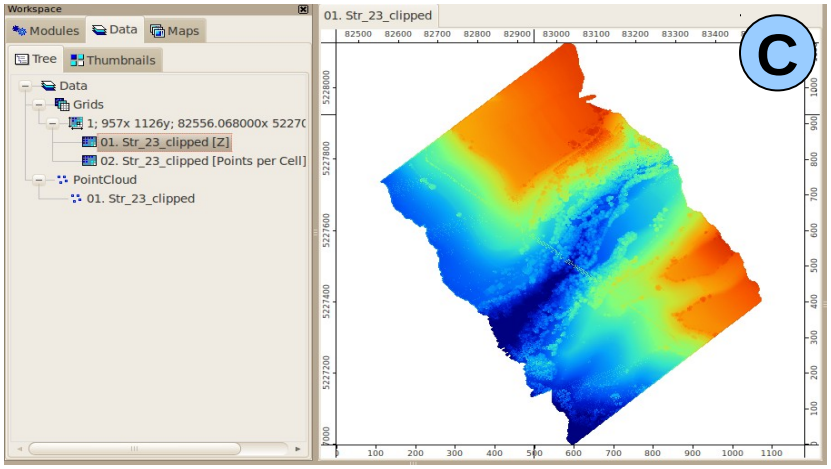


SAGA | DSM Generation

Grid – Tools → Close Gaps: Gap closing by Spline Interpolation

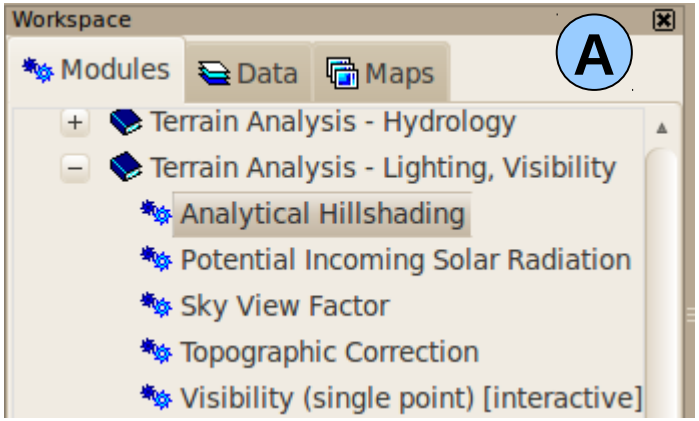


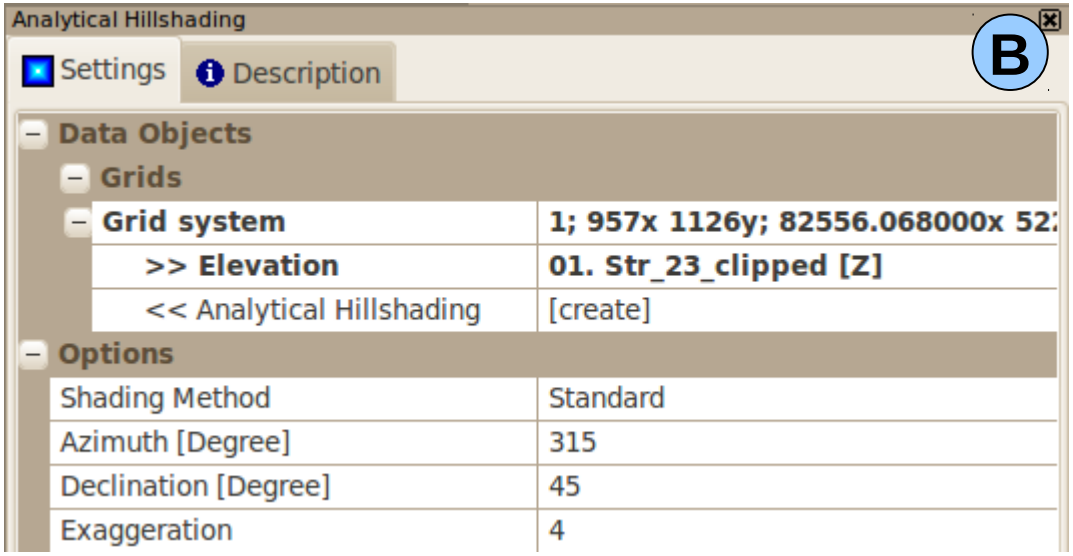




SAGA | DSM Generation

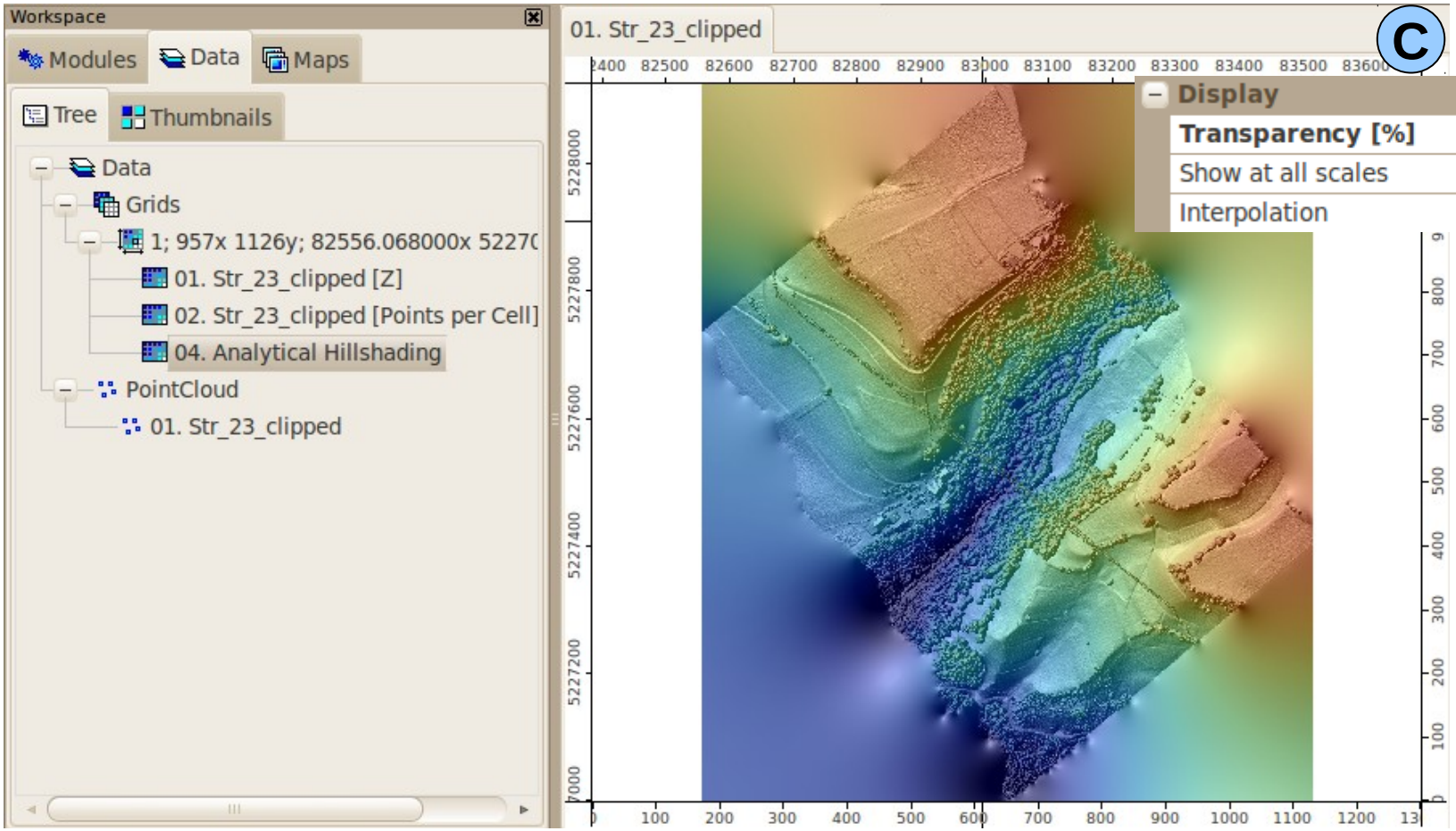
Terrain Analysis – Lighting, Visibility → **Analytical Hillshading:** Shading





SAGA | DSM Generation

Terrain Analysis – Lighting, Visibility → **Analytical Hillshading:** Shading

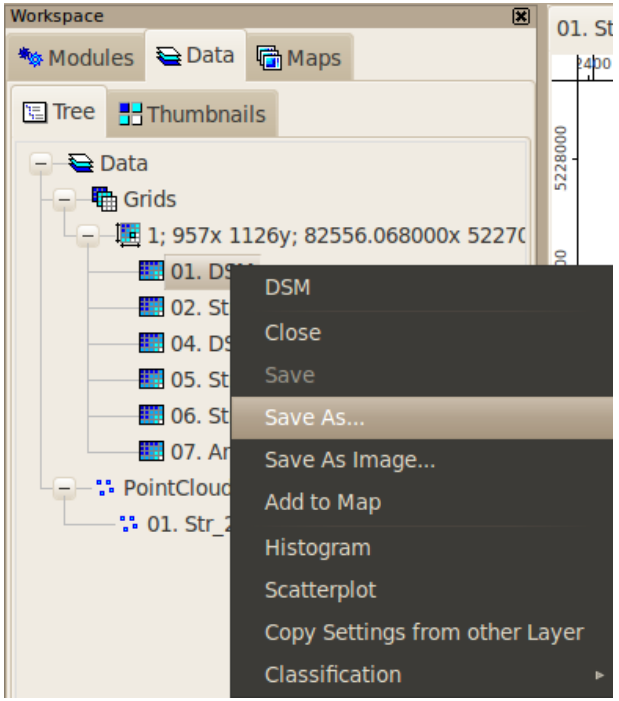


SAGA | Renaming and Saving Datasets

Organization of datasets: Renaming and saving datasets.

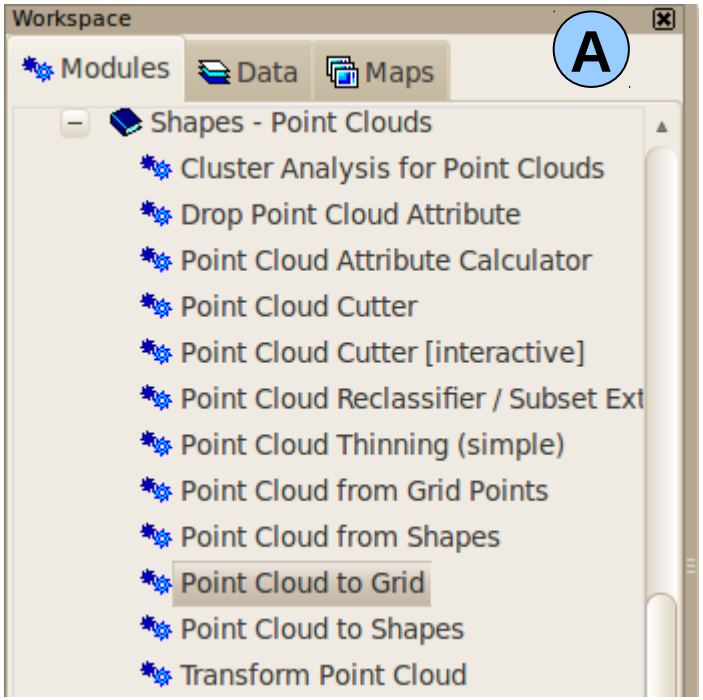
- **Renaming:** Select the dataset in the *Data* tab, this will show its *Settings* in the *Object Properties* window. The first parameter is “Name”, change it and **apply** the changes.
  - Str_23_clipped [Z] → **DSM**
  - Analytical Hillshading → **DSM_Shade**

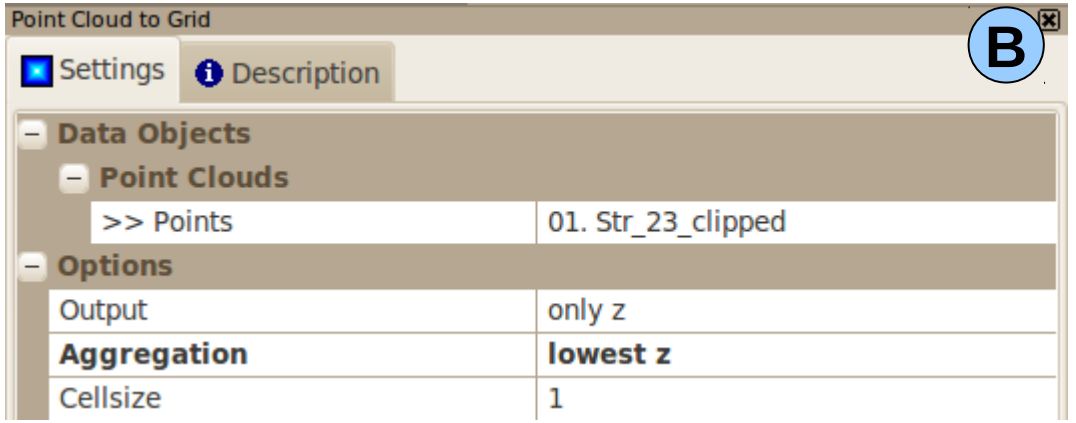
- **Saving:** Do a right-click on the dataset in the *Data* tab, this will pop-up a context menu. Select “Save as ...” and save the dataset.

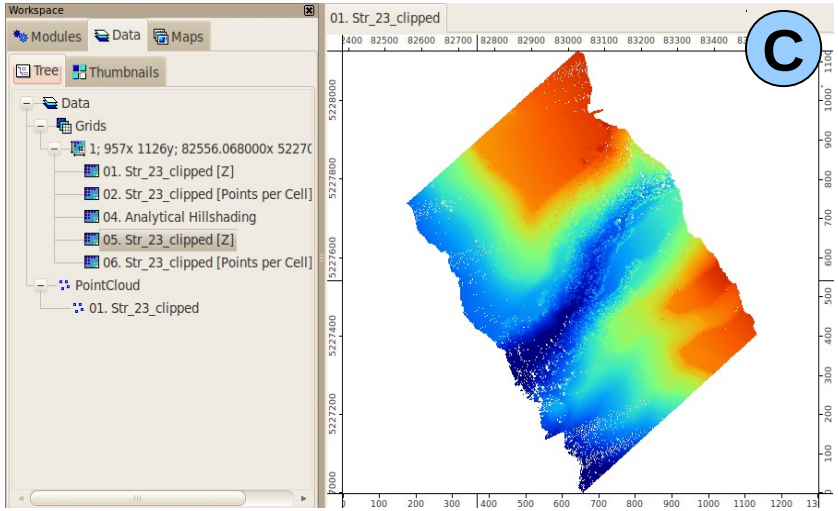


SAGA | DTM Generation

Shapes – Point Clouds → **Point Cloud to Grid:** Gridding of Point Clouds

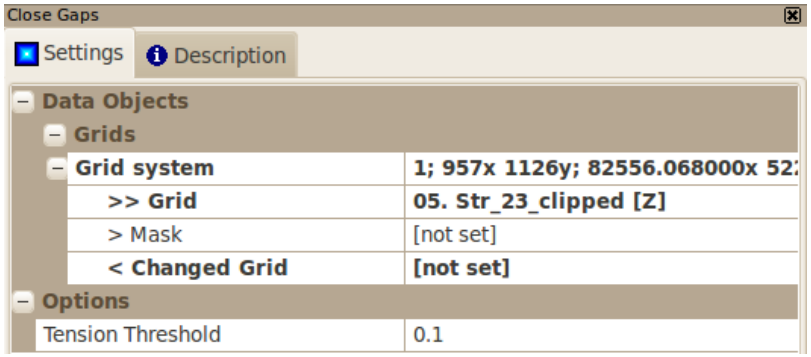






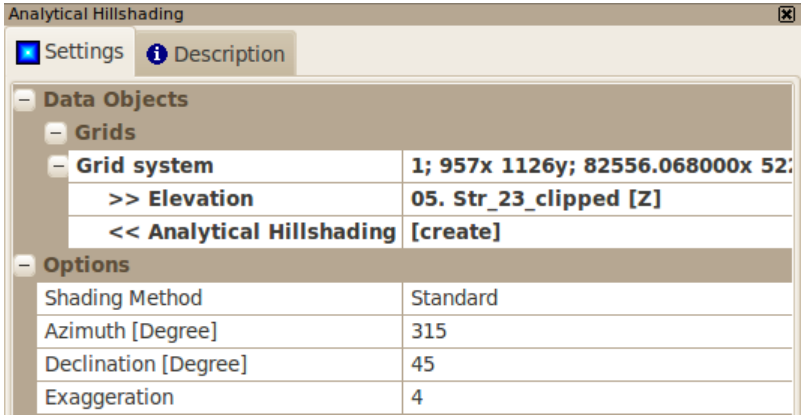
SAGA | DTM Generation

Grid – Tools → Close Gaps: Gap closing by Spline Interpolation



← Do **NOT** overwrite grid from previous module run **!**

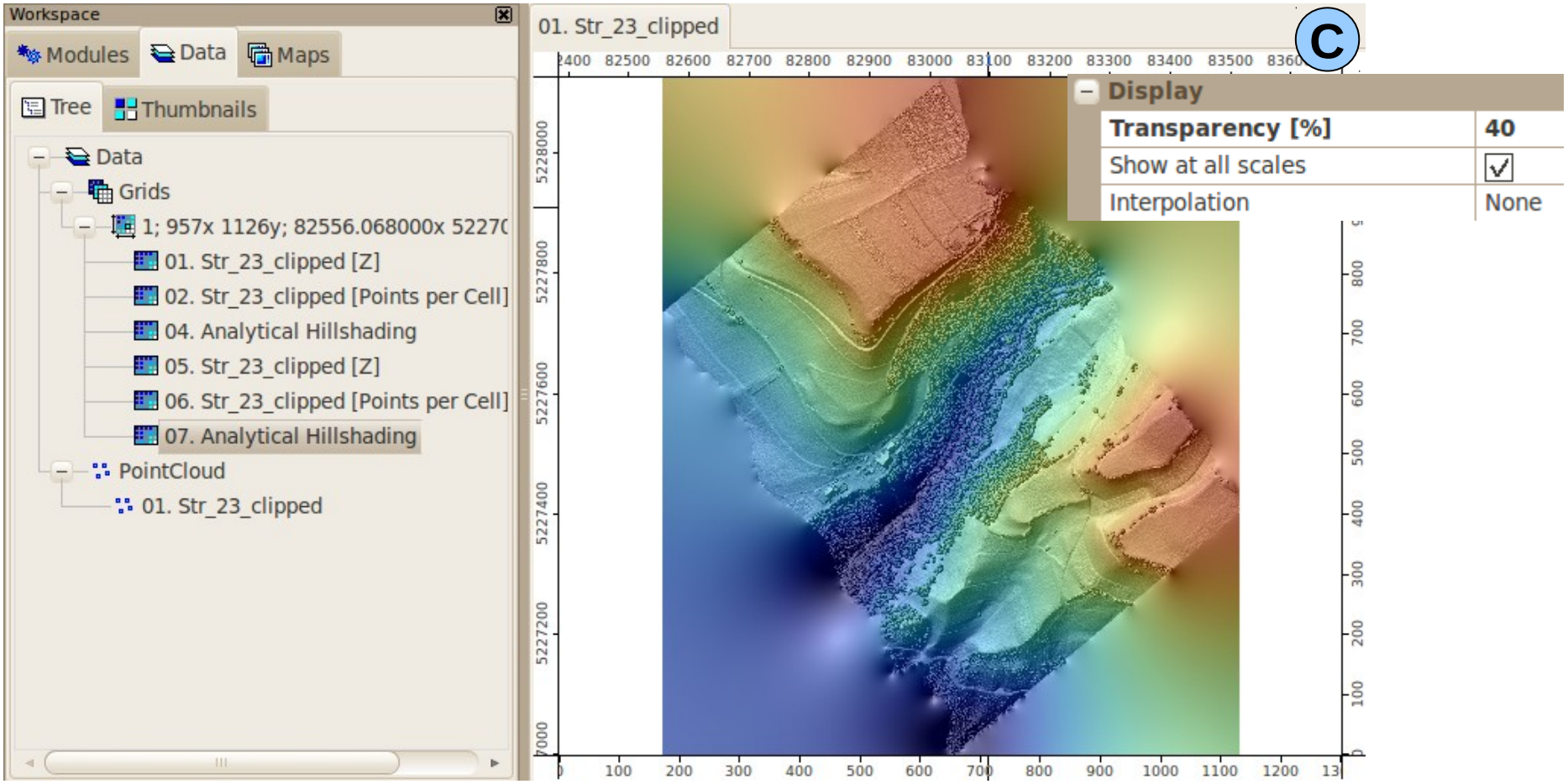
Terrain Analysis – Lighting, Visibility → Analytical Hillshading: Shading



← Do **NOT** overwrite grid from previous module run **!**

SAGA | DTM Generation

Terrain Analysis – Lighting, Visibility → Analytical Hillshading: Shading



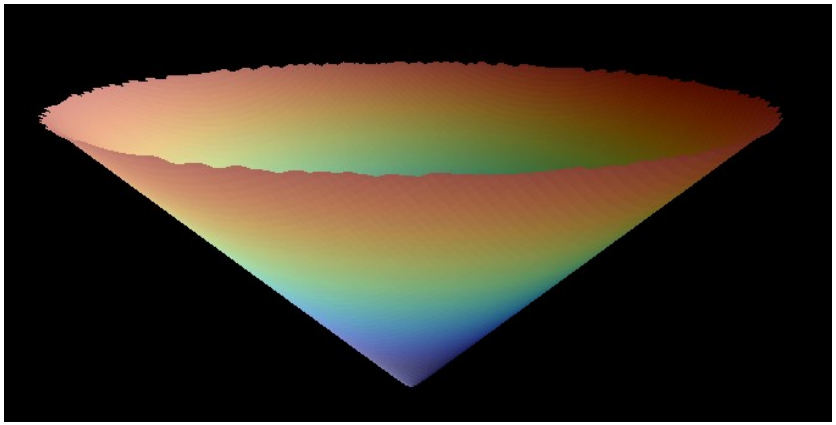
SAGA | DTM Generation

Grid – Filter → DTM Filter (slope-based): Removing non-ground cells

The filter approach implemented with the “DTM Filter (slope-based)” module is based on concepts described by Vosselman (2000). It is assumed that a large height difference between two nearby grid cells is unlikely to be caused by a steep slope in the terrain.

The probability that the higher cell could be a ground cell increases with a larger distance between the two cells. Therefore **the filter defines an acceptable height difference between two cells as a function of the distance between the cells**. The central cell is classified as ground if there is no other cell within the kernel’s search radius with a height difference larger than the allowed maximum height difference at each distance.

Filter kernel: maximum allowed height difference



central grid cell

SAGA | DTM Generation

Grid – Filter → DTM Filter (slope-based): Removing non-ground cells

A **terrain slope parameter** is used to modify the filter function to match the overall slope in the study area and a confidence interval can be used to reject outliers during computation.

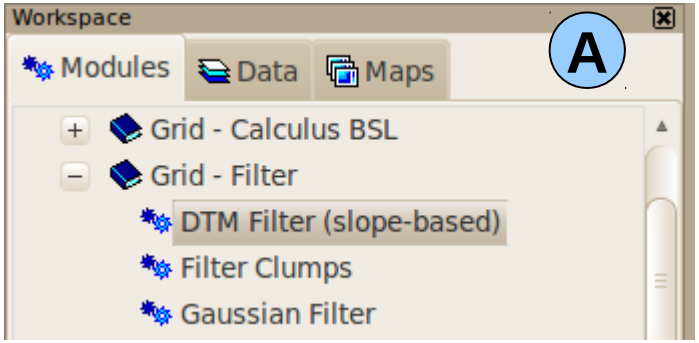
Besides an approximate terrain slope (s), the module requires the kernel size as input. The **radius of the kernel** (r) must be at least half of the size of the largest object to remove.

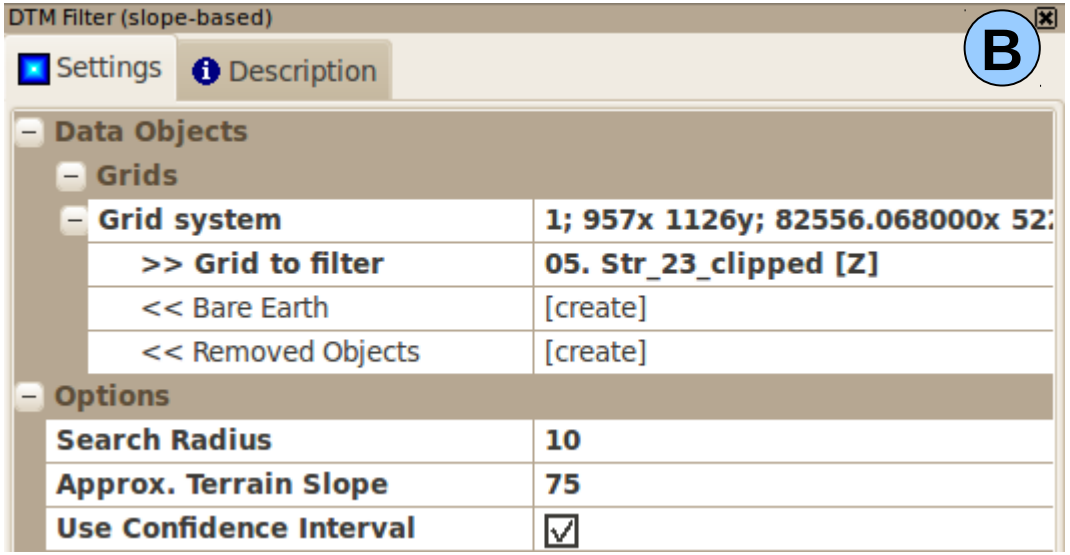
Both parameters have a great influence on the filtering result (commission and omission errors) and usually several attempts are required to find an appropriate parameter set. The overall goal is to retain as much ground cells as possible, while removing all non-ground cells.

Due to the filter design and its strong dependence on terrain slope, it is difficult to find a unique parameter set for terrain composed of both gentle and steep slopes.

SAGA | DTM Generation

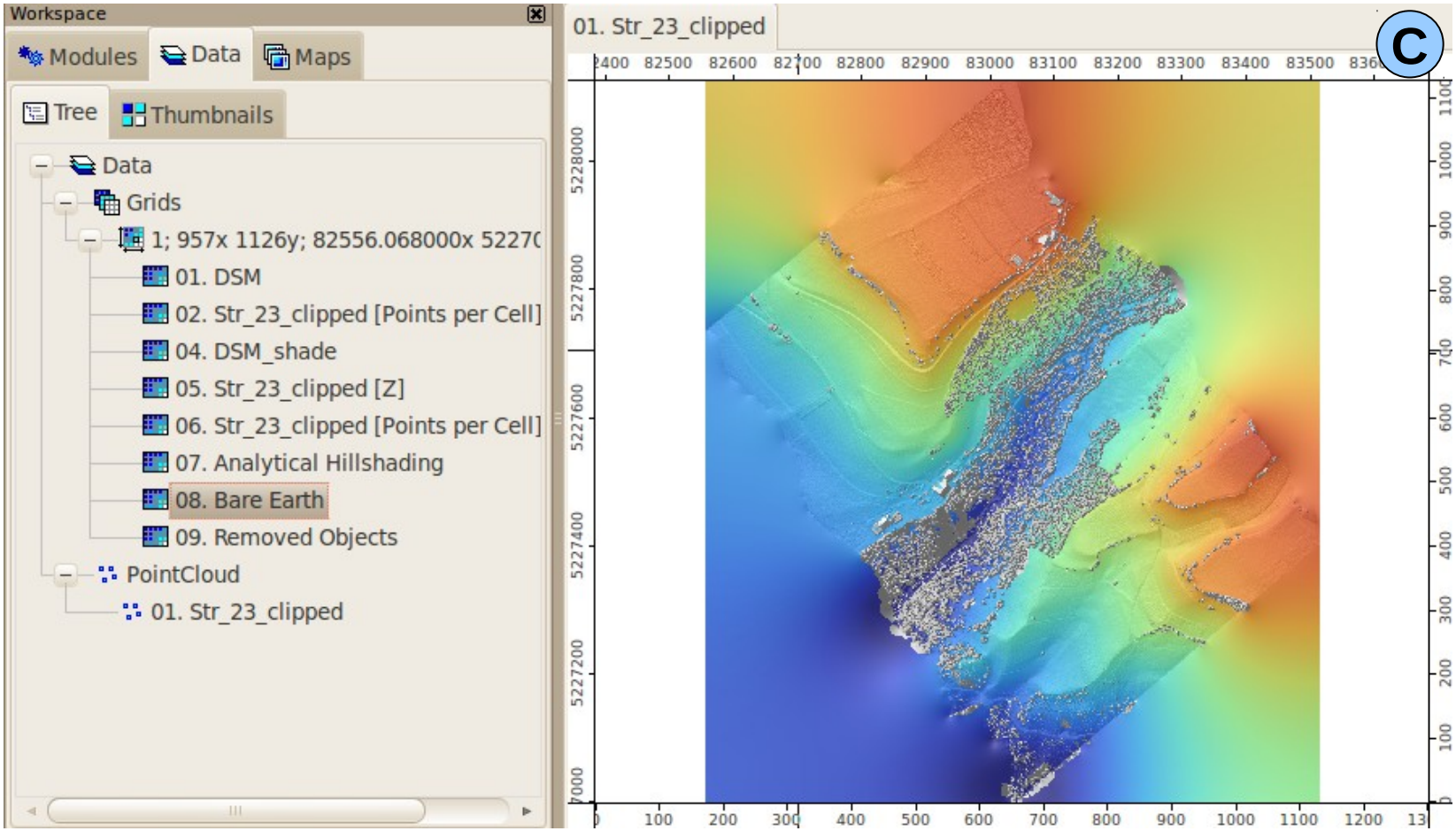
Grid – Filter → DTM Filter (slope-based): Removing non-ground cells





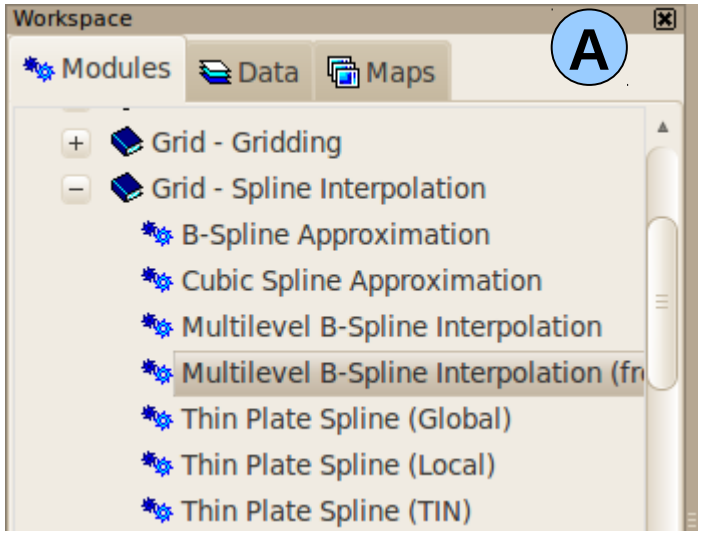
SAGA | DTM Generation

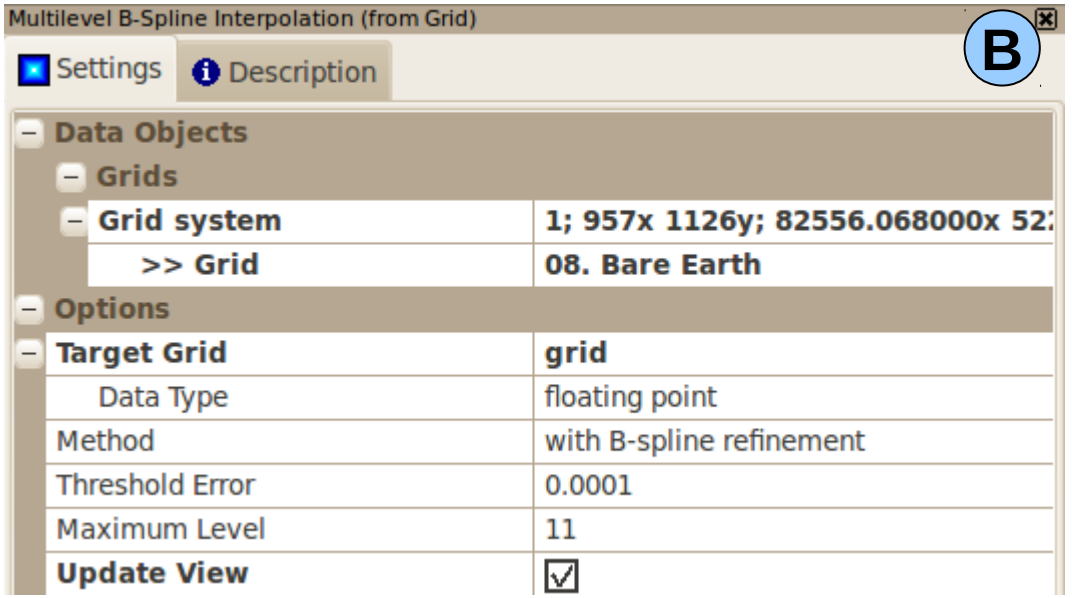
Grid – Filter → DTM Filter (slope-based): Removing non-ground cells

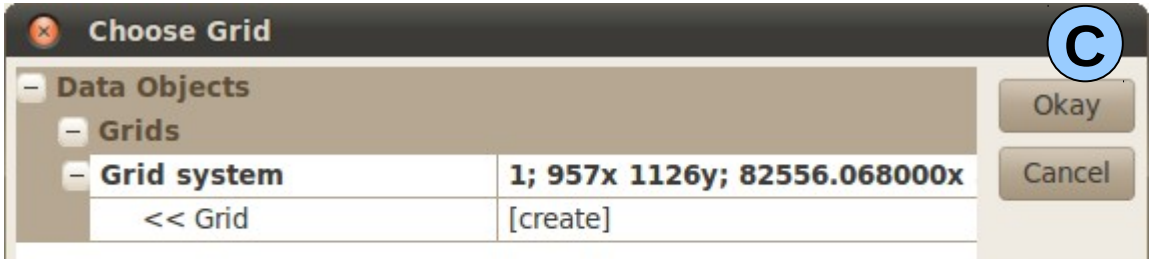


SAGA | DTM Generation

Grid – Spline Interpolation → Multilevel B-Spline Interpolation (from Grid):
Interpolation of a DTM surface

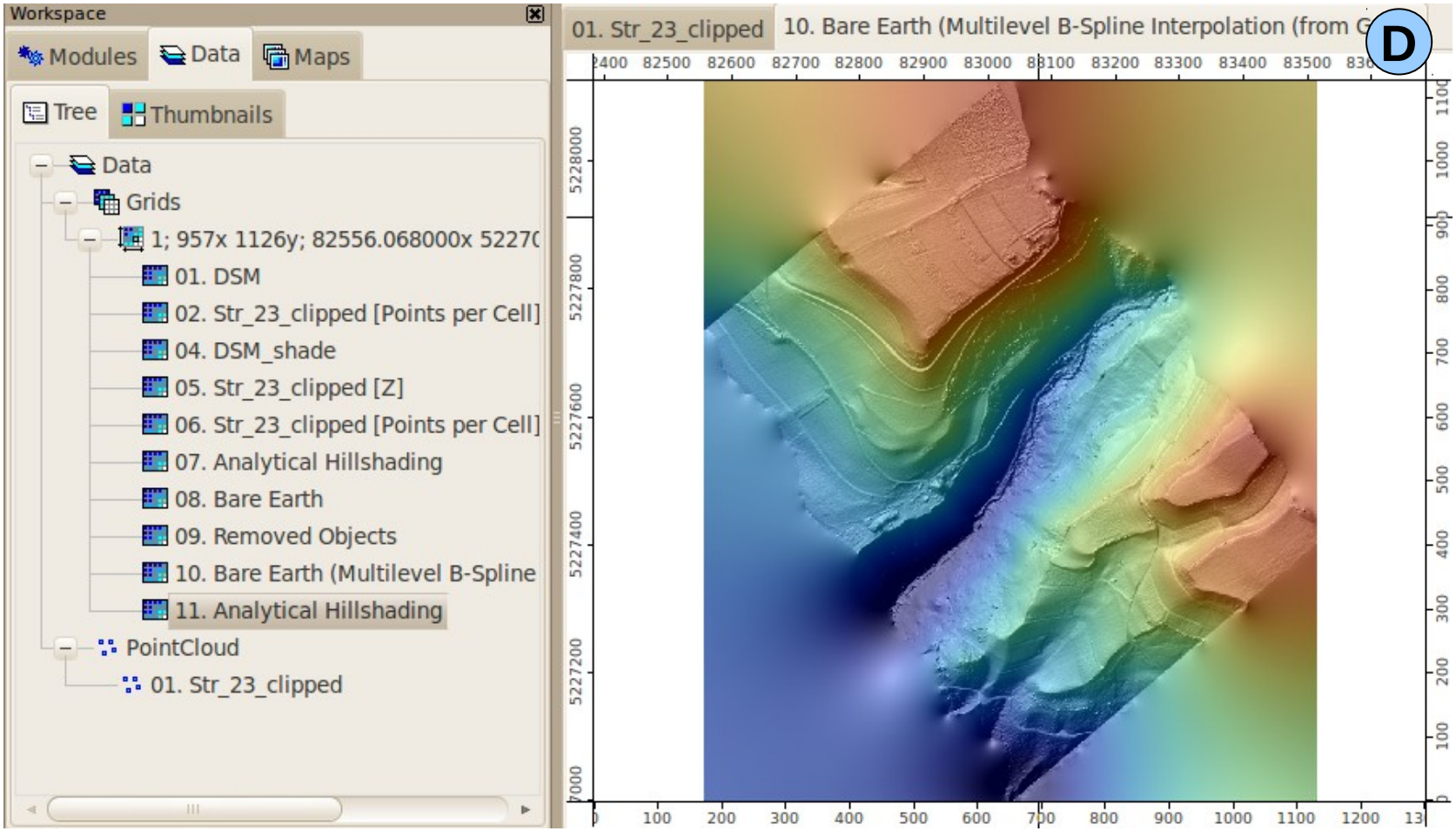






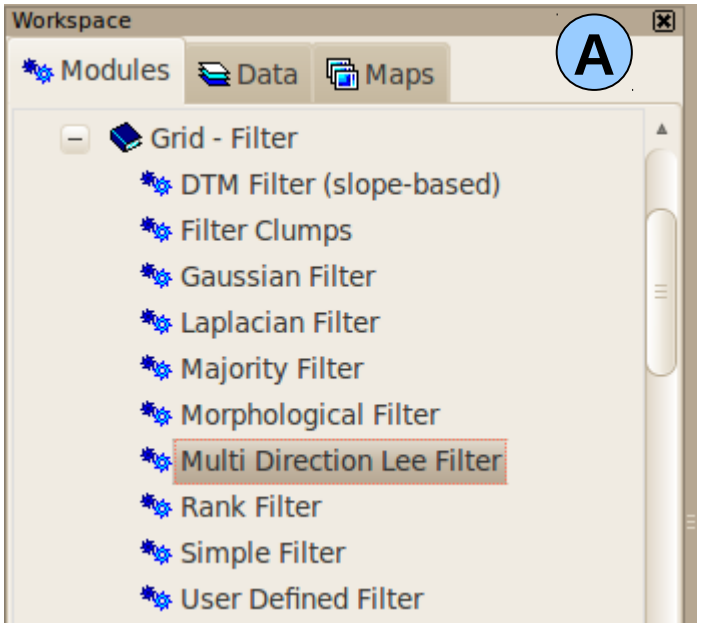
SAGA | DTM Generation

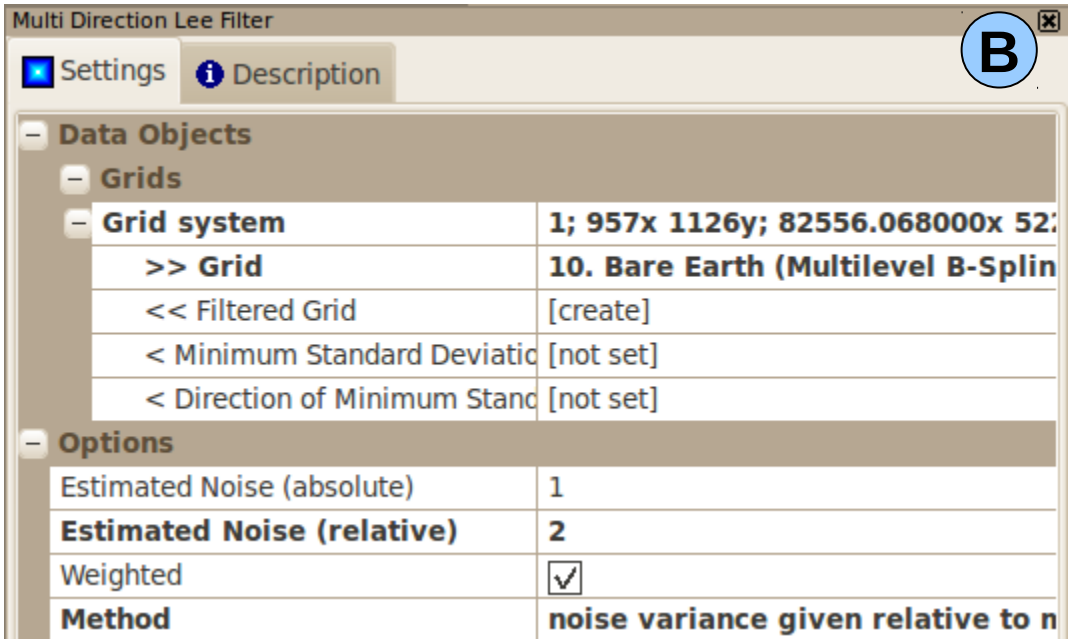
Grid – Spline Interpolation → Multilevel B-Spline Interpolation (from Grid):
Interpolation of a DTM surface



SAGA | DTM Generation

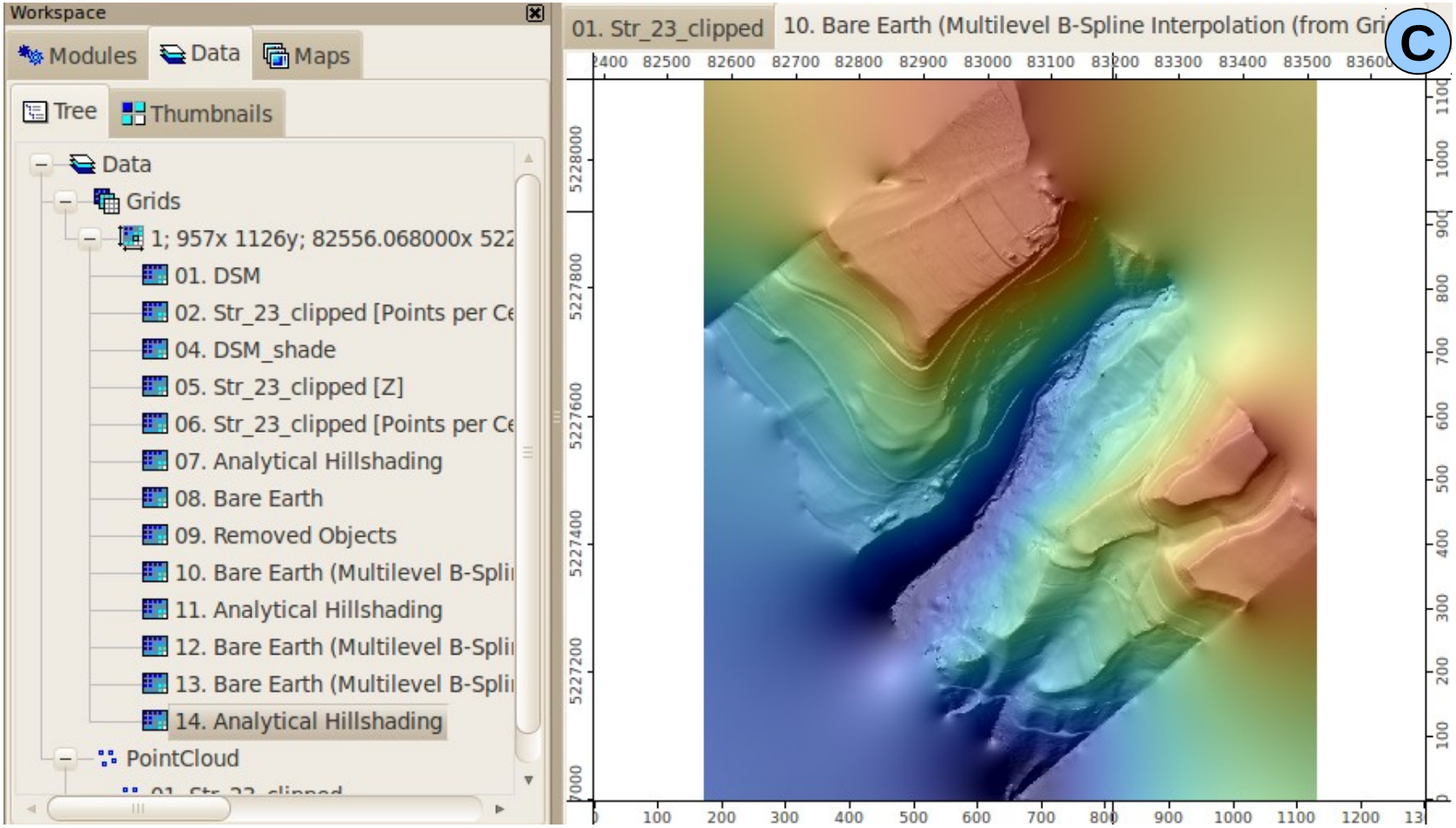
Grid – Filter → Multi Direction Lee Filter: Smoothing the DTM





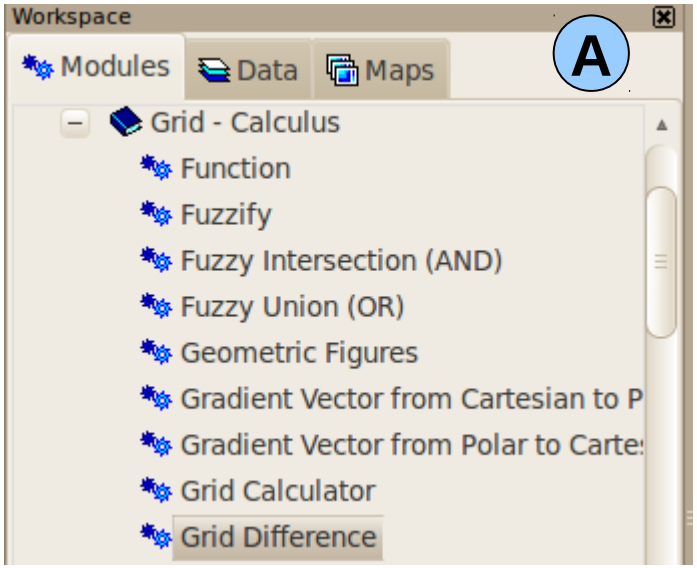
SAGA | DTM Generation

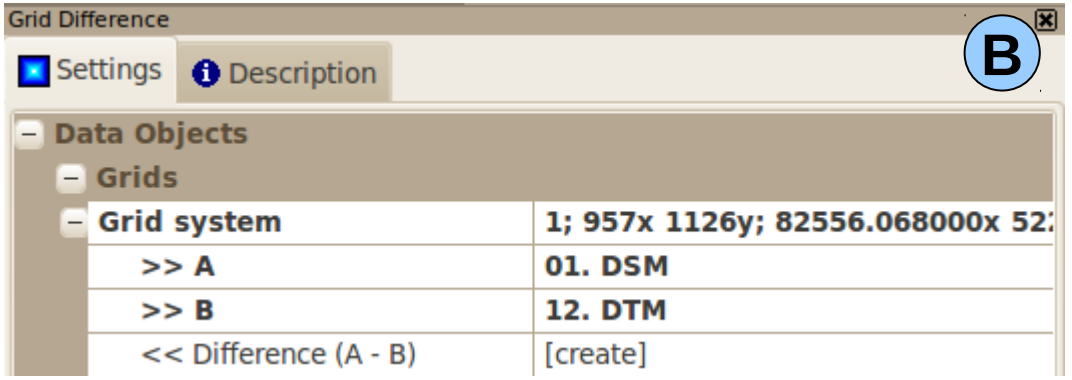
Grid – Filter → Multi Direction Lee Filter: Smoothing the DTM



SAGA | nDSM Generation

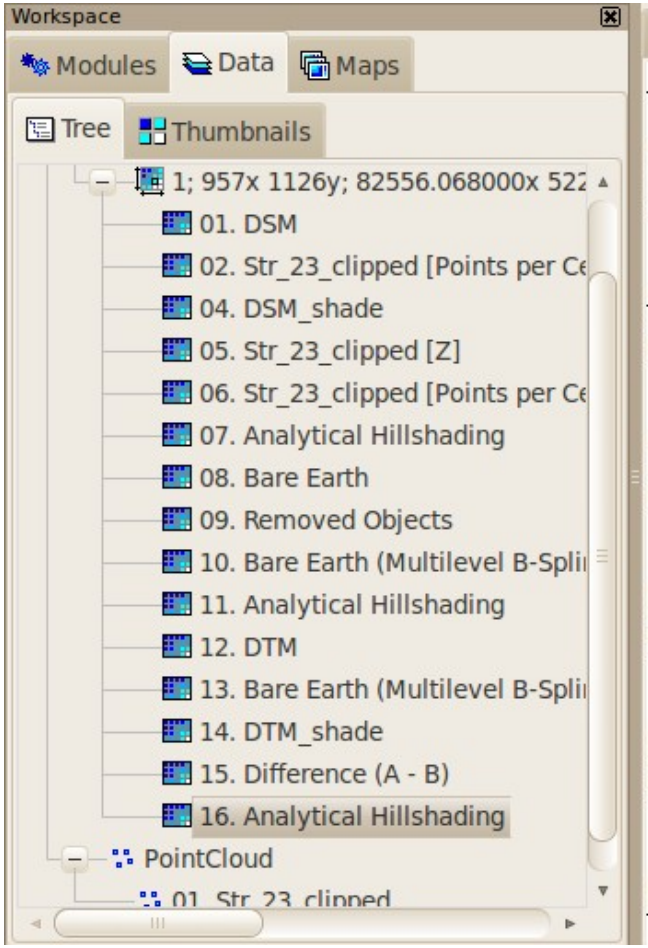
Grid – Calculus → Grid Difference: nDSM = DSM - DTM

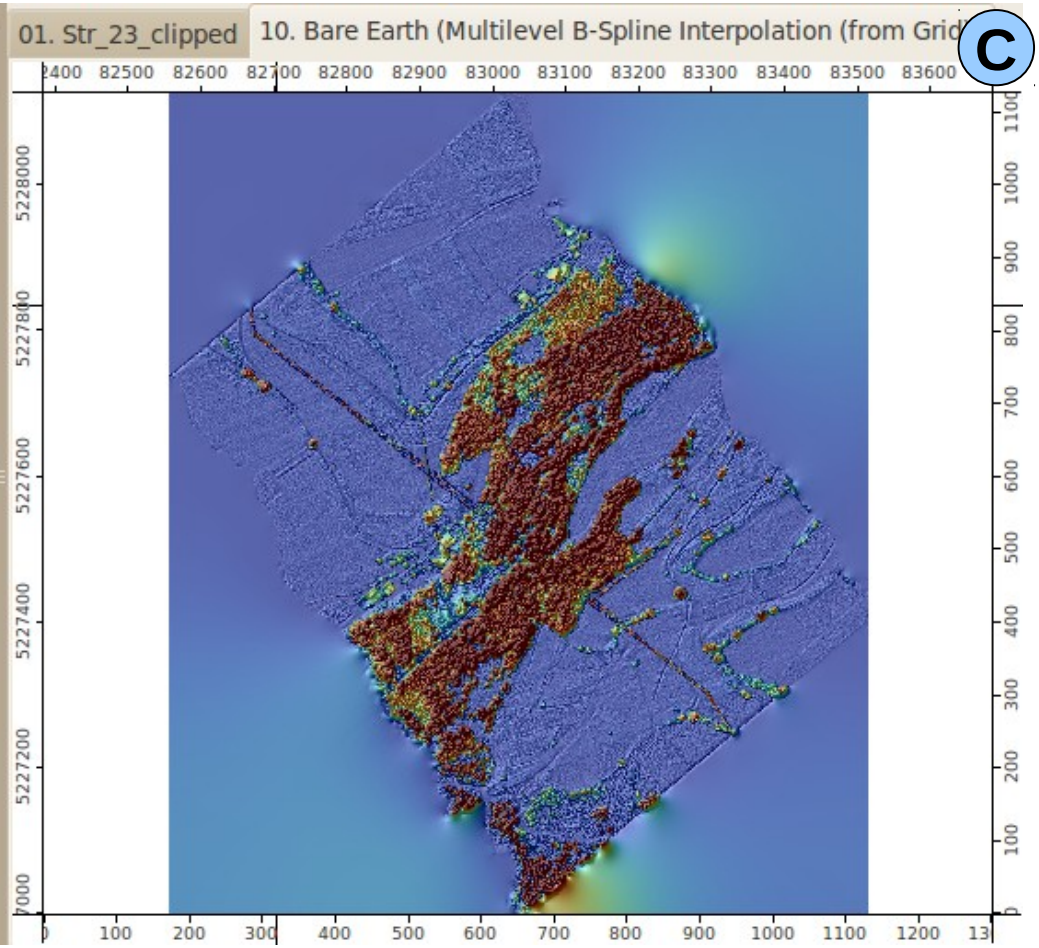




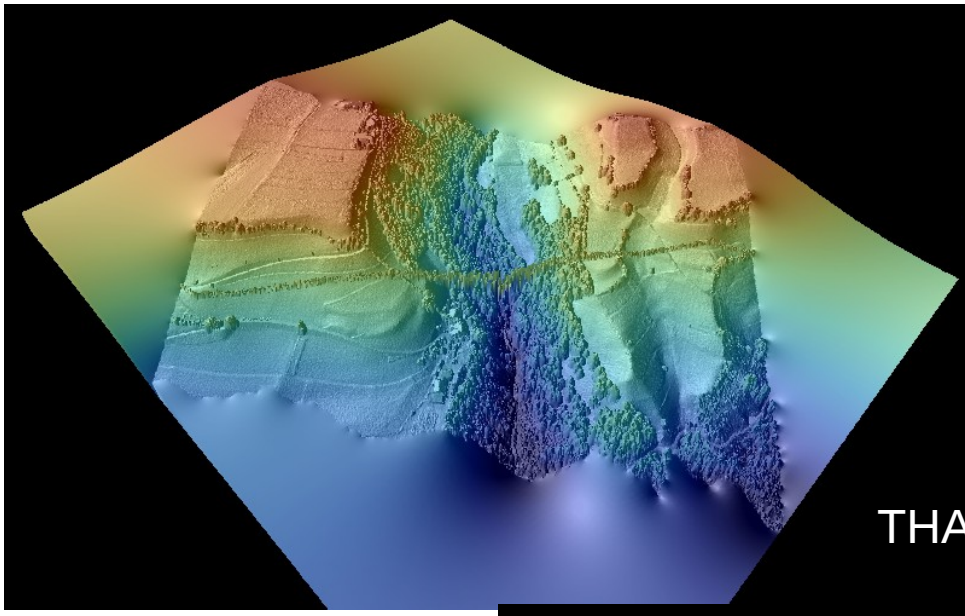
SAGA | nDSM Generation

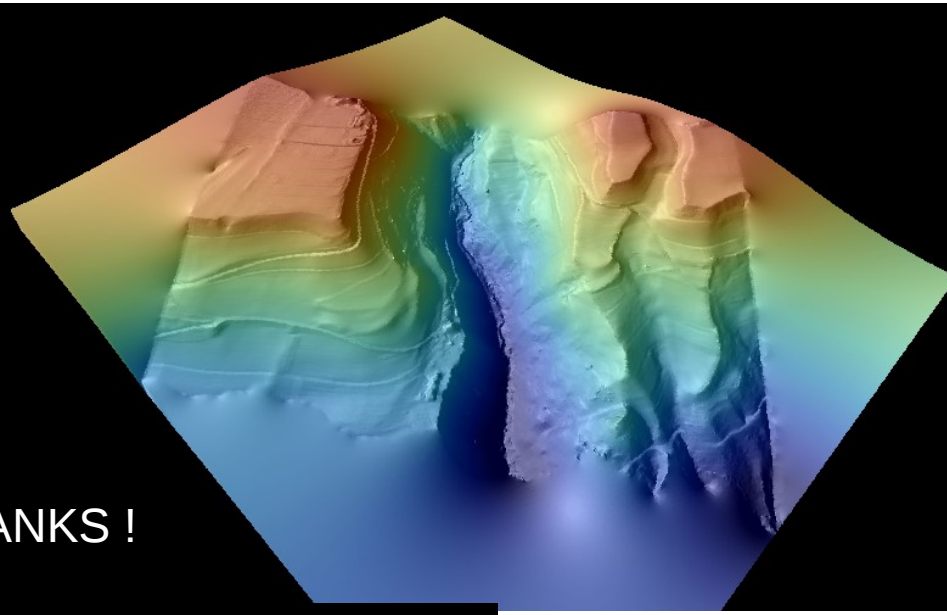
Grid – Calculus → Grid Difference: nDSM = DSM - DTM





SAGA | ...





THANKS !