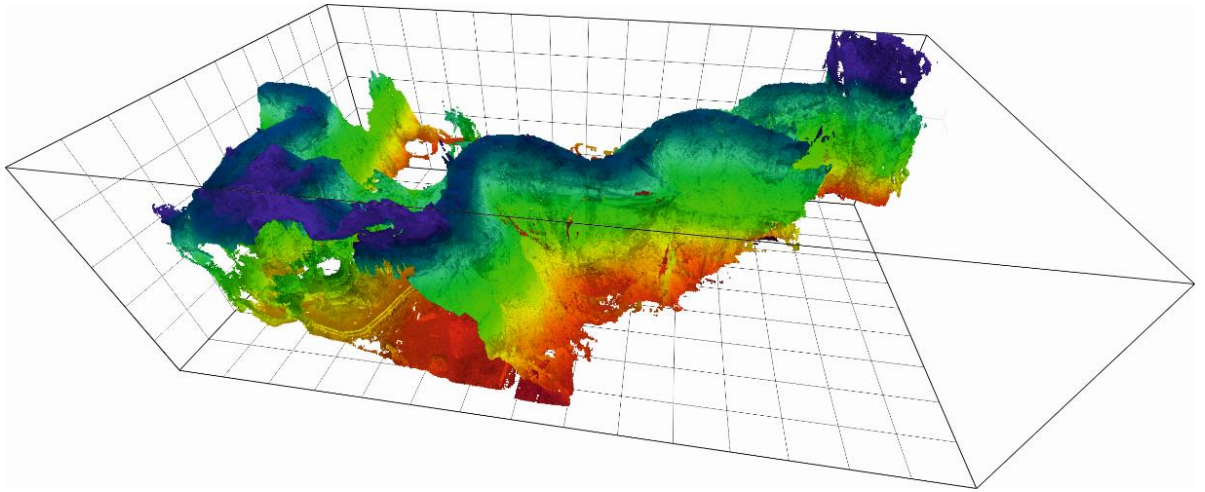
State Nature Conservancy of the Slovak Republic
Slovak Caves Administration

10-th international conference:
Research and Protecting the Caves of Slovak and Aggtelek karst

22. – 25. september 2015 Rožňava – Bódvaszilas, Slovakia - Hungary



Mapping the Domica cave using laser scanning and hydroclimate monitoring

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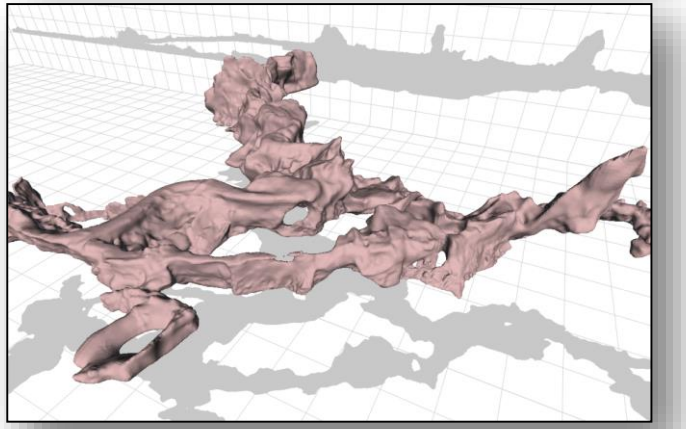
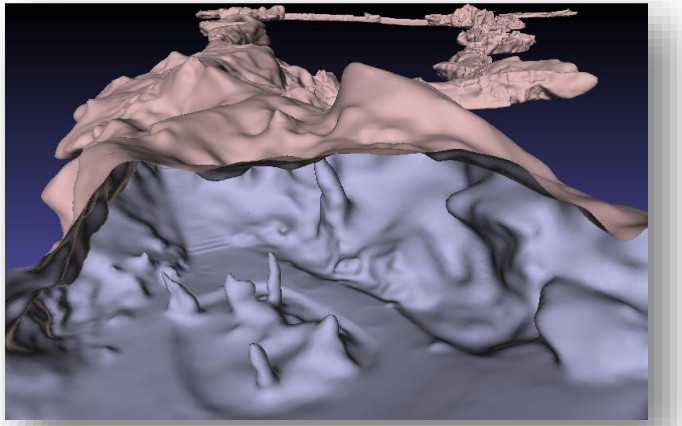
Structure of talk

- Motivation
- Terrestrial laser scanning in Domica cave
- Generating the 3-D cave surface model
- Integration with 3-D GIS
- Future research

Motivation

- Terrestrial Laser Scanning (TLS) becomes increasingly popular in cave mapping
- TLS in cave mapping has its specifics arising from harsh environmental and space conditions
- The cave is usually part of more complex landscape system
- New 3-D methods are needed to fully understand the cave system

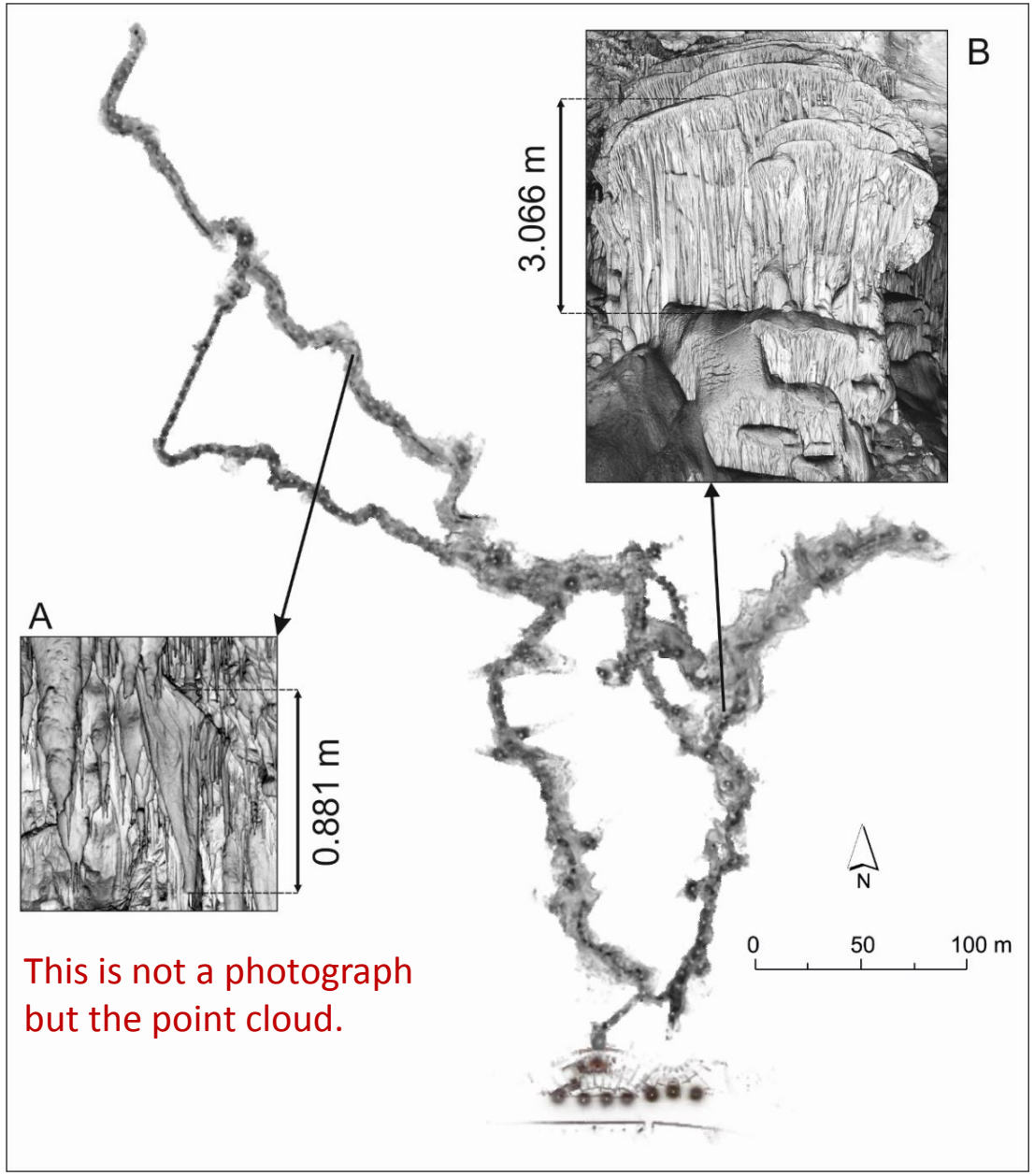




TLS of the Domica Cave

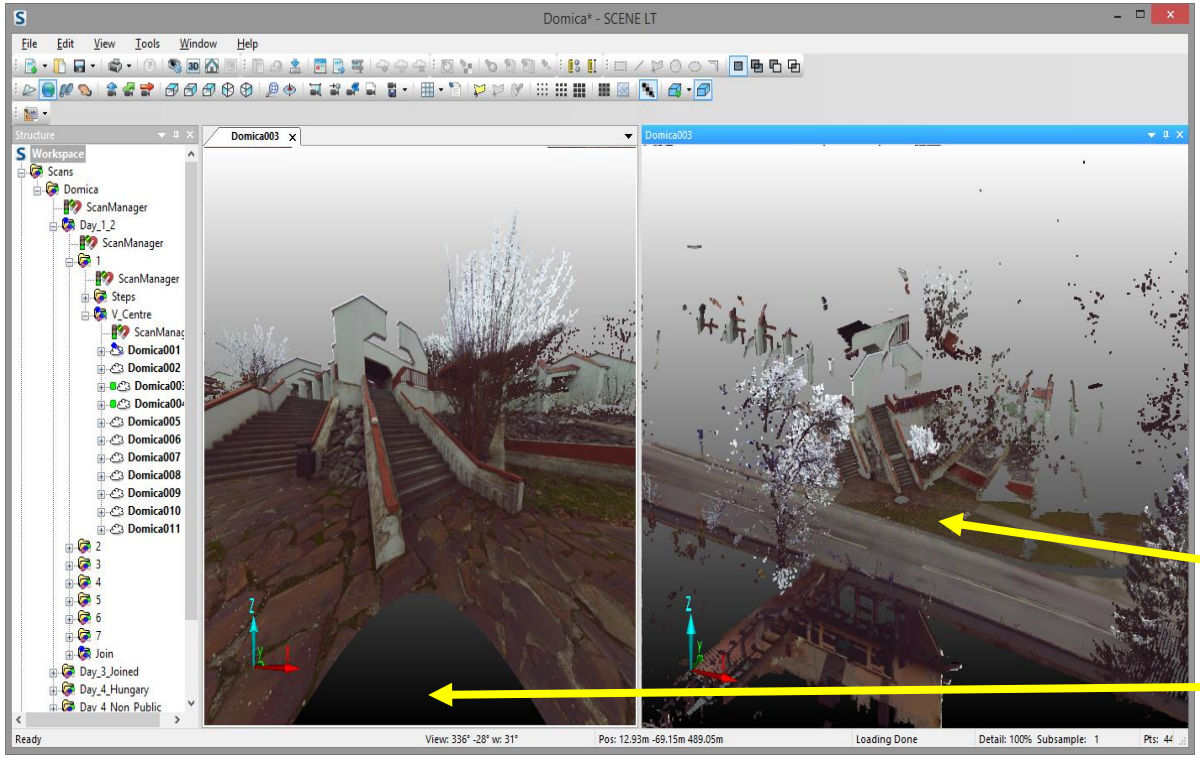
Data acquisition – basic information

- Surveying mission within 5 days in March 2014
- Faro Focus 3D 120S scanner
- 1,600 metres of cave passages scanned
- almost 12 billion of coordinates
- Measurement sampling 20 mm at 10 m distance
- 327 scannig positions
- Overall registration error 2.24 mm
- Georeferencing error 12 mm



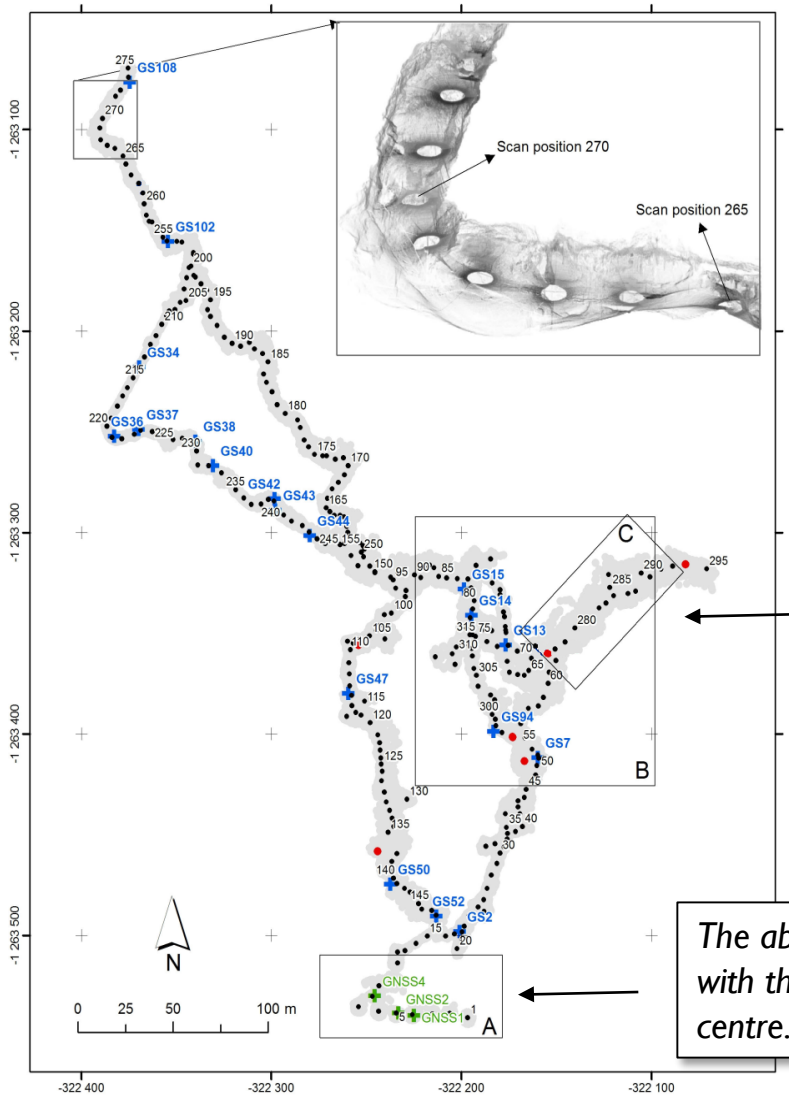
Georeferencing the scans

- Semi-automatic registration of these scans was carried out using reference spheres placed in the position area
- Georeferencing of the final registered point cloud from its local coordinate system to the national cartographic system (SJTSK, EPSG 5514) was based on 4 reference points labeled as GNSS1-3, GS108 in the map



TLS Point cloud model of the Domica cave

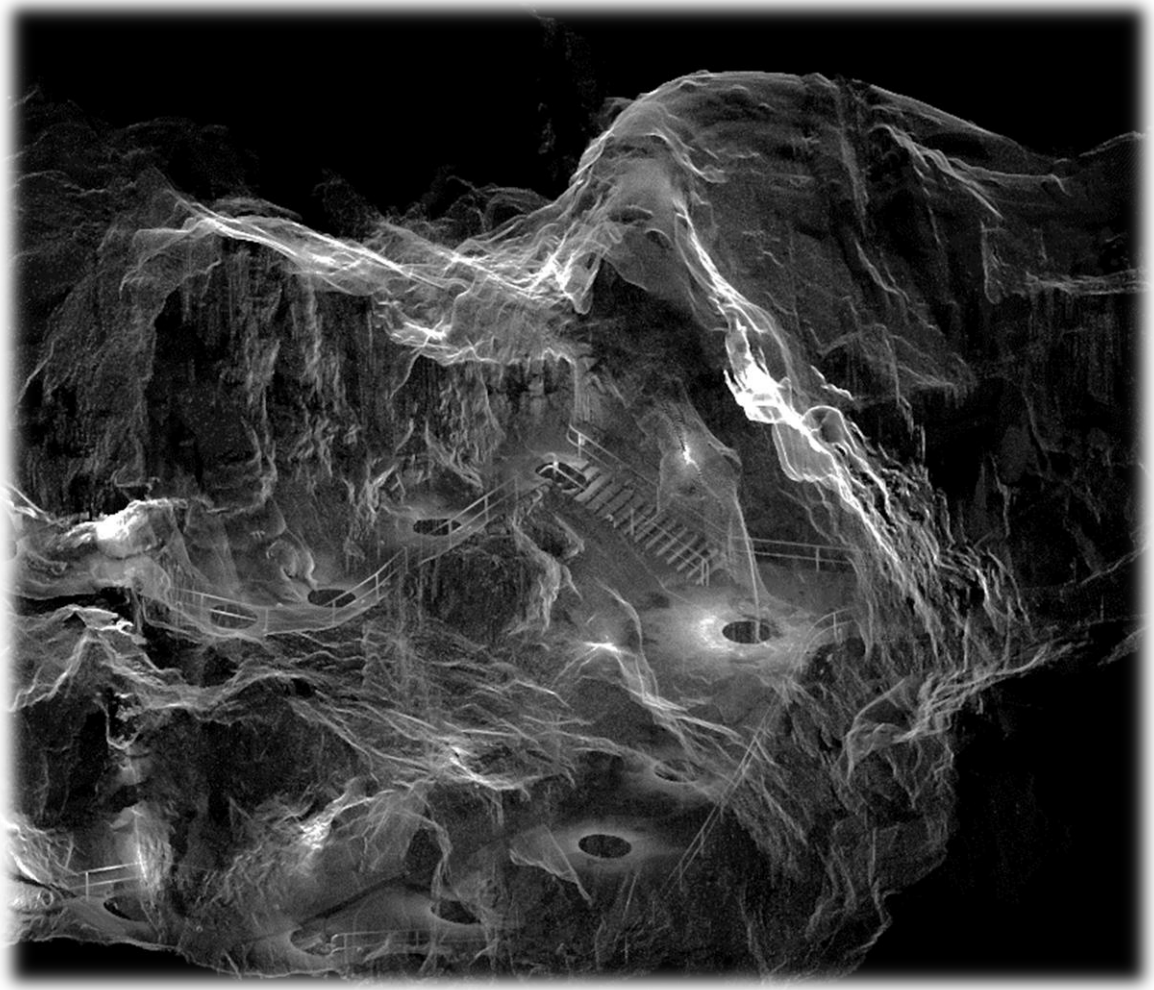
Orthogonal projection of the TLS point cloud footprint with the scanner positions and network of reference points from GNSS survey and previous surveys.



Closer view of individual point clouds after registration.

Area viewed below as the detailed 3D cave model.

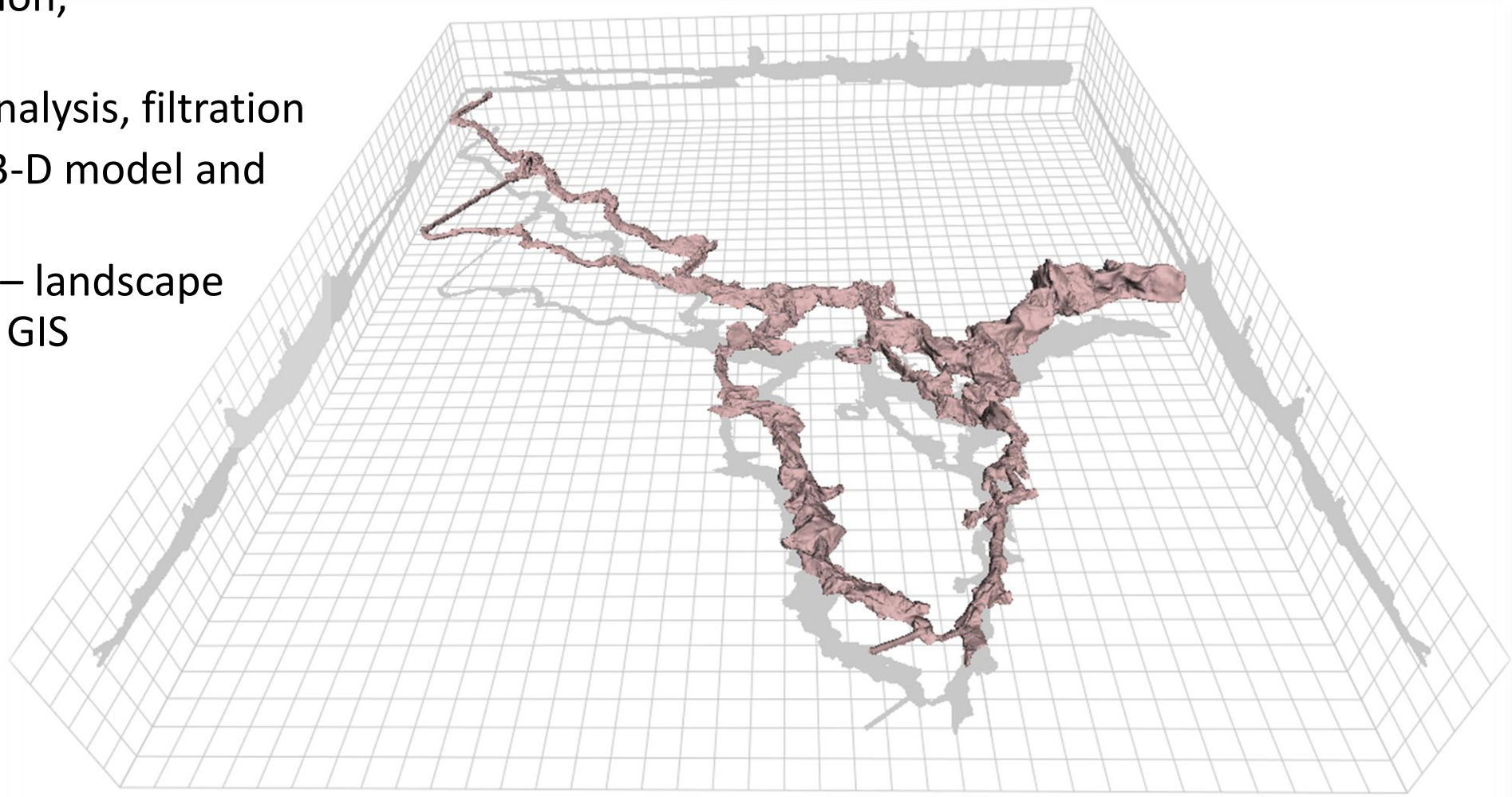
The above surface area with the cave visitors centre.



Selecting the right position makes the trick ...

From point cloud to 3D model

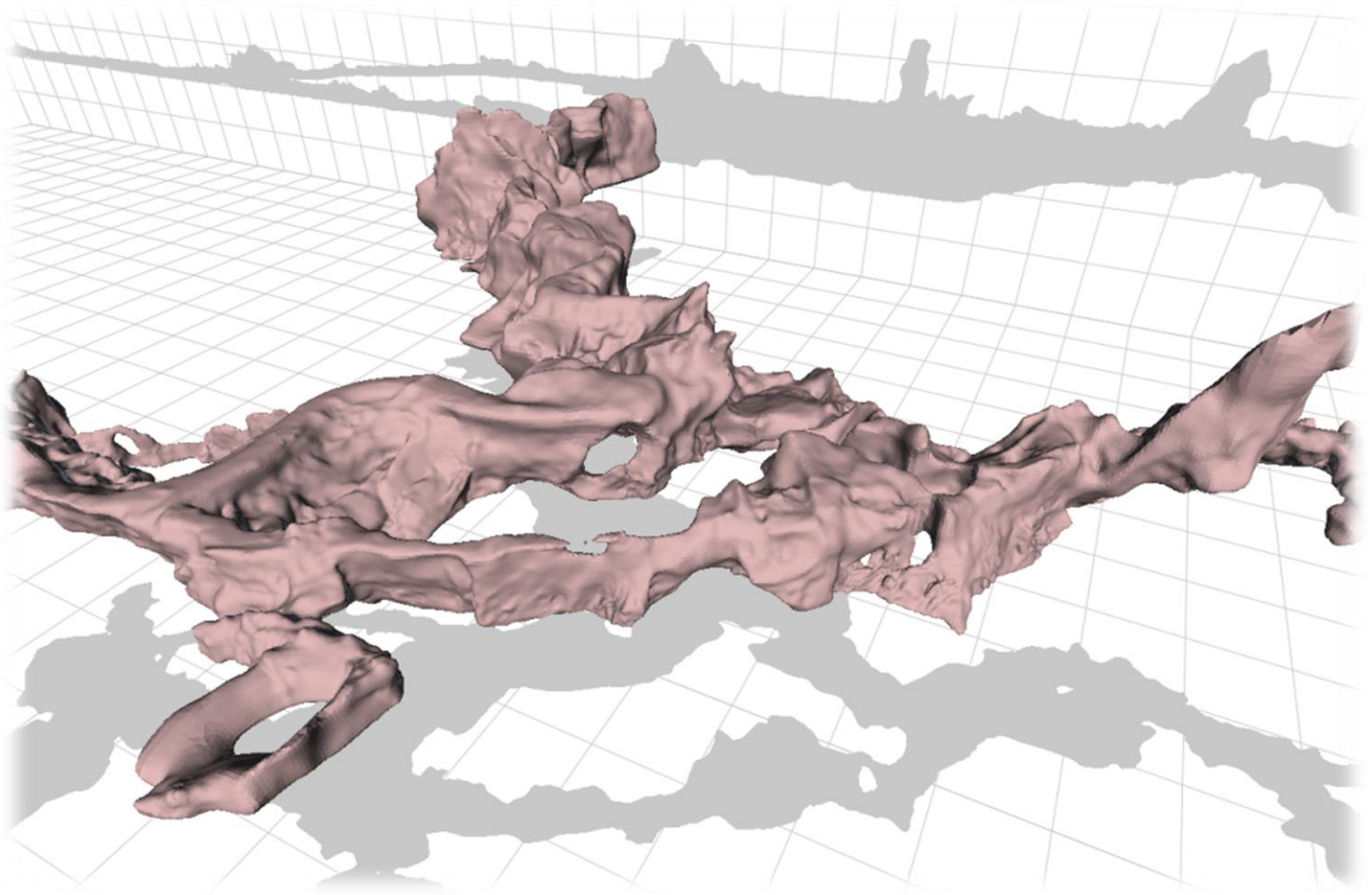
- Pointools (*.ptl) Blender – effective visualisation, crosssections
- Lastools (*.las) – analysis, filtration
- Meshlab (*.ply) – 3-D model and analysis
- ArcGIS/GRASS GIS – landscape data integration in GIS



From point cloud to 3D model

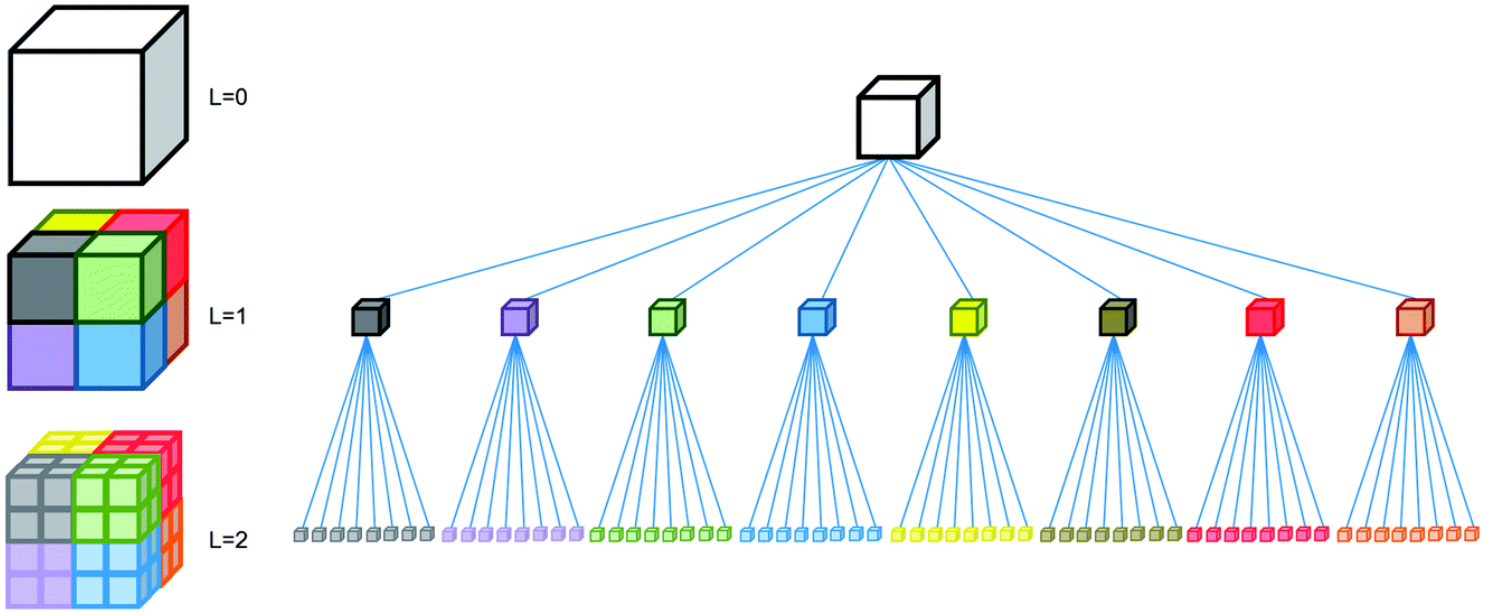
Step by step

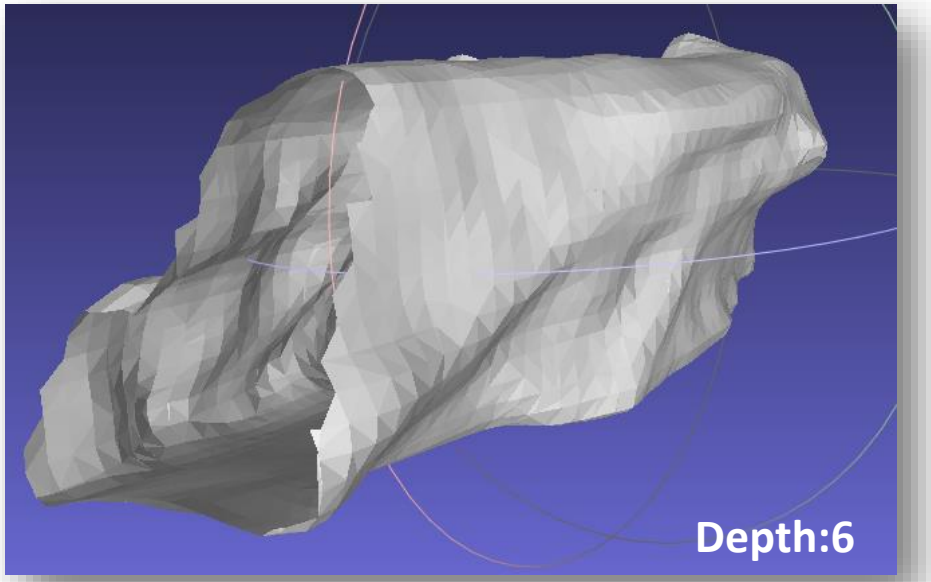
- Selection of smaller cave section
- Decimation of the original point cloud to 1% (268,000 points)
- Calculation of normals for the points (future mesh vertices)
- Production of the 3-D cave surface model (a triangular mesh)
- Poisson surface reconstruction approach by Khazdan et al. (2006)

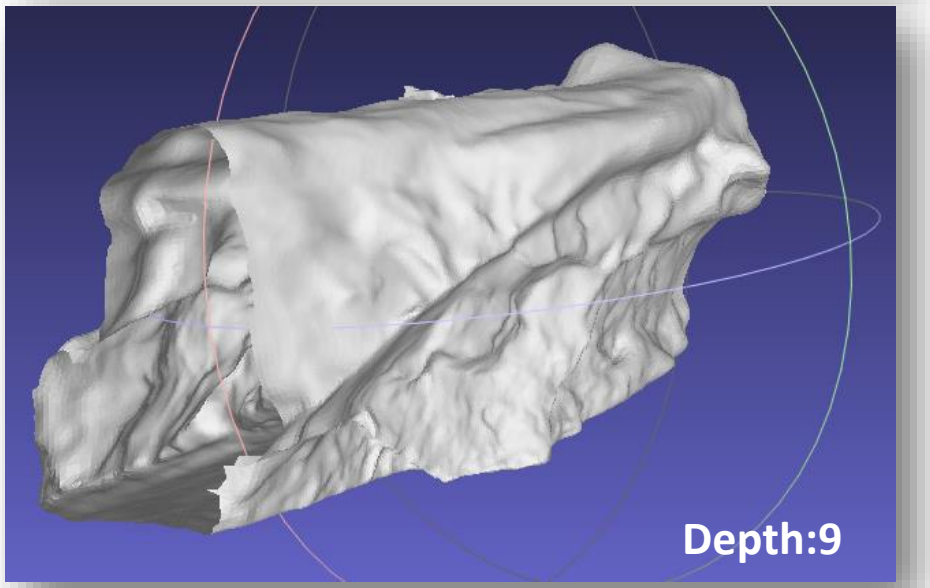


Generating the 3-D cave surface model

- Poison surface reconstruction
- Resolution controlled by:
  - the input point density (kept constant: 268,000 points)
  - the **octree depth parameter**





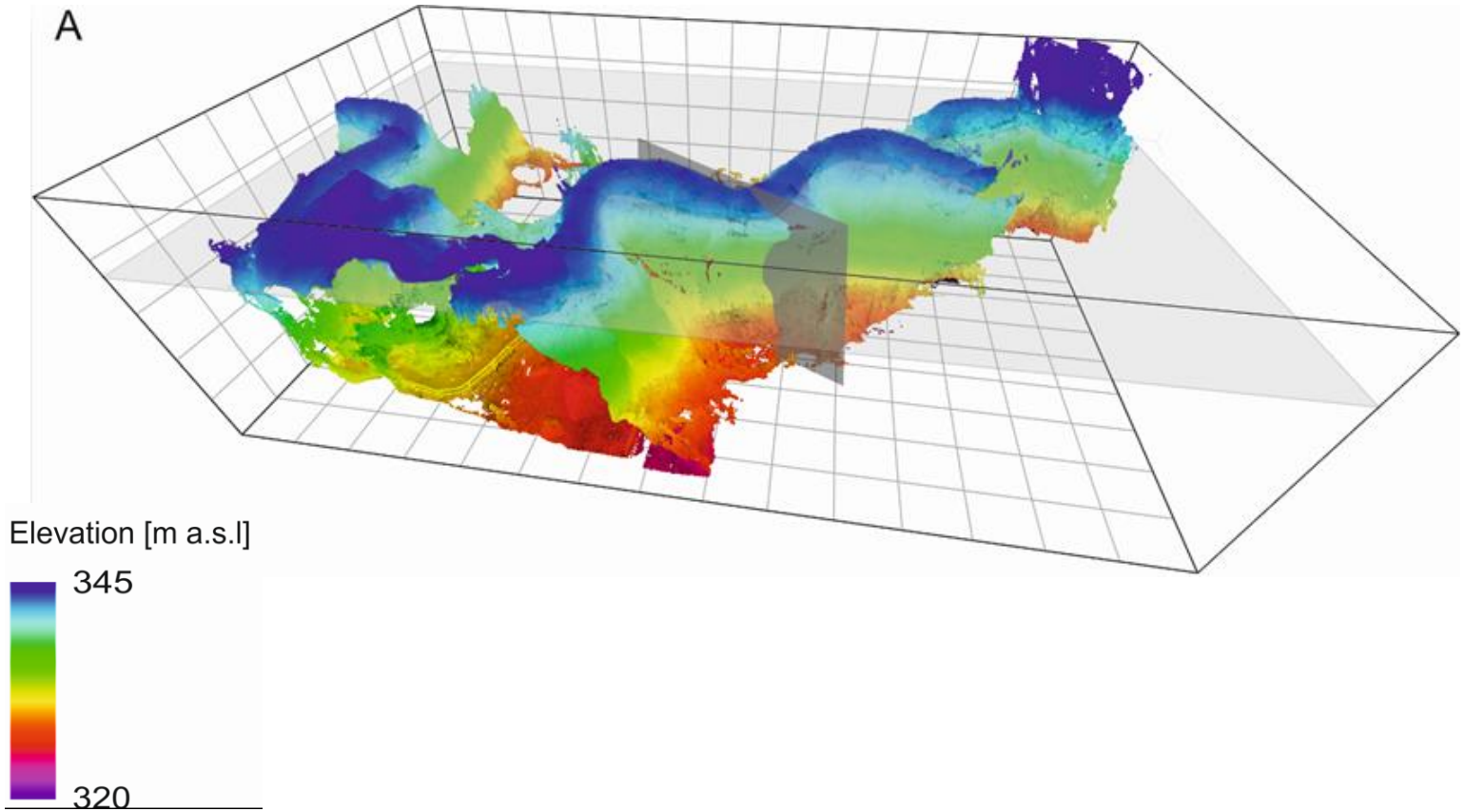


Generating the 3-D cave surface model

Dataset	Octree depth	Processing time [sec]	Number of vertices in the mesh
Cave corridor	6	0.5	4,310
	8	5.4	6,712
	9	13.8	140,631
Cave ceiling 1 m sq	10	3.5	28,091
	12	9.1	58,577
	13	25.5	66,025

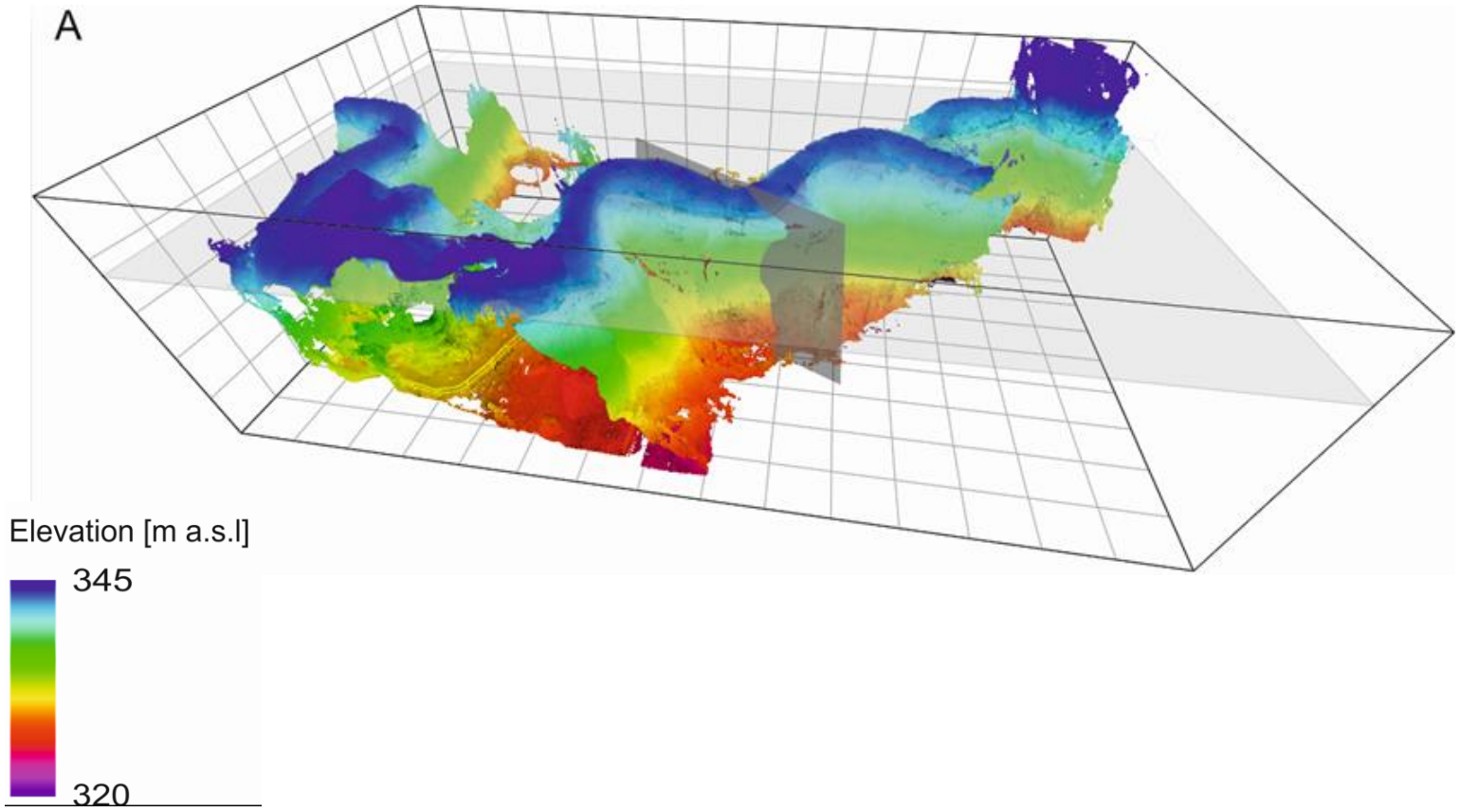
However, increasing the octree dpth parameter increases the processing time.

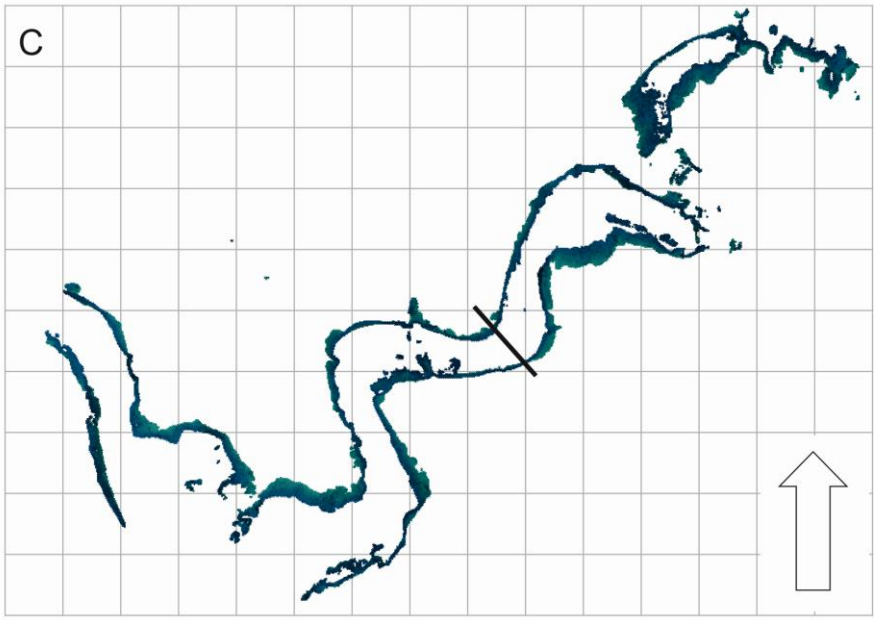
Analysing the 3-D cave surface model

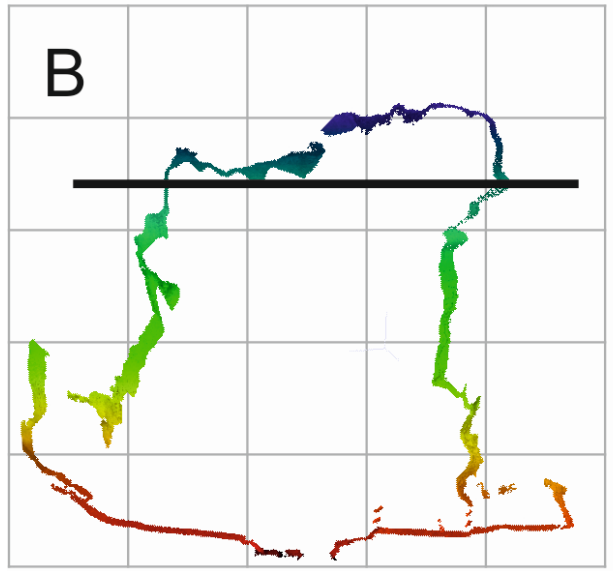


Colorizing the TLS point cloud (A) reveals ceiling channels which can be further measured as vertical cross-sections (B), and as a horizontal profile at 338 m a.s.l (C) shown as grey cutting plane in A. The scale is given by the grid of 5 x 5 m cell size in all three directions.

Analysing the 3-D cave surface model







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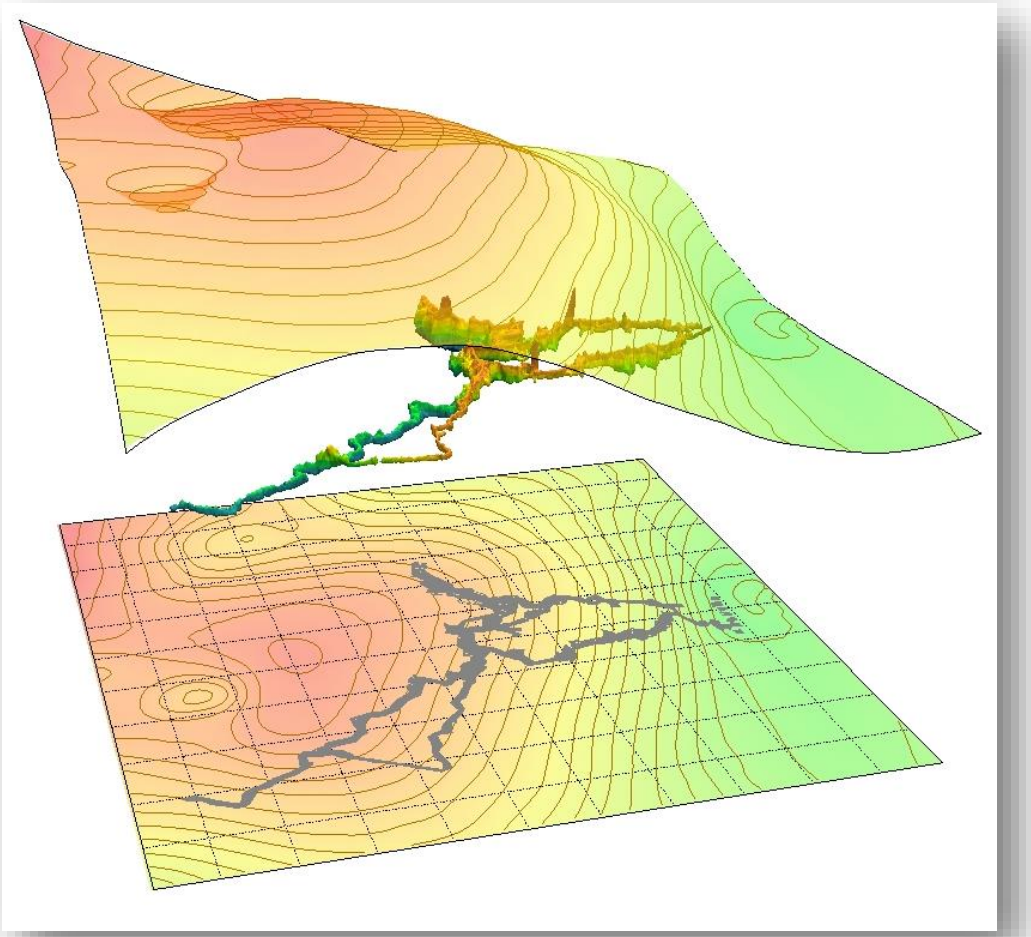
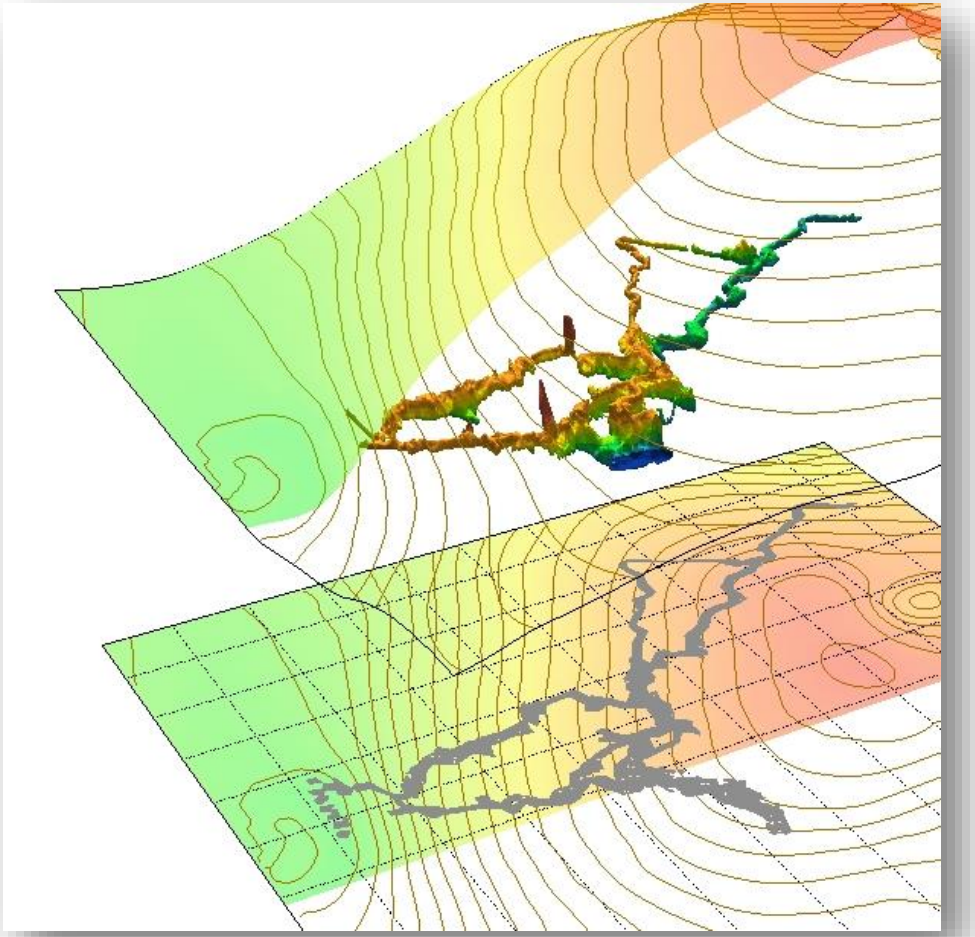
Integration with a 3-D GIS

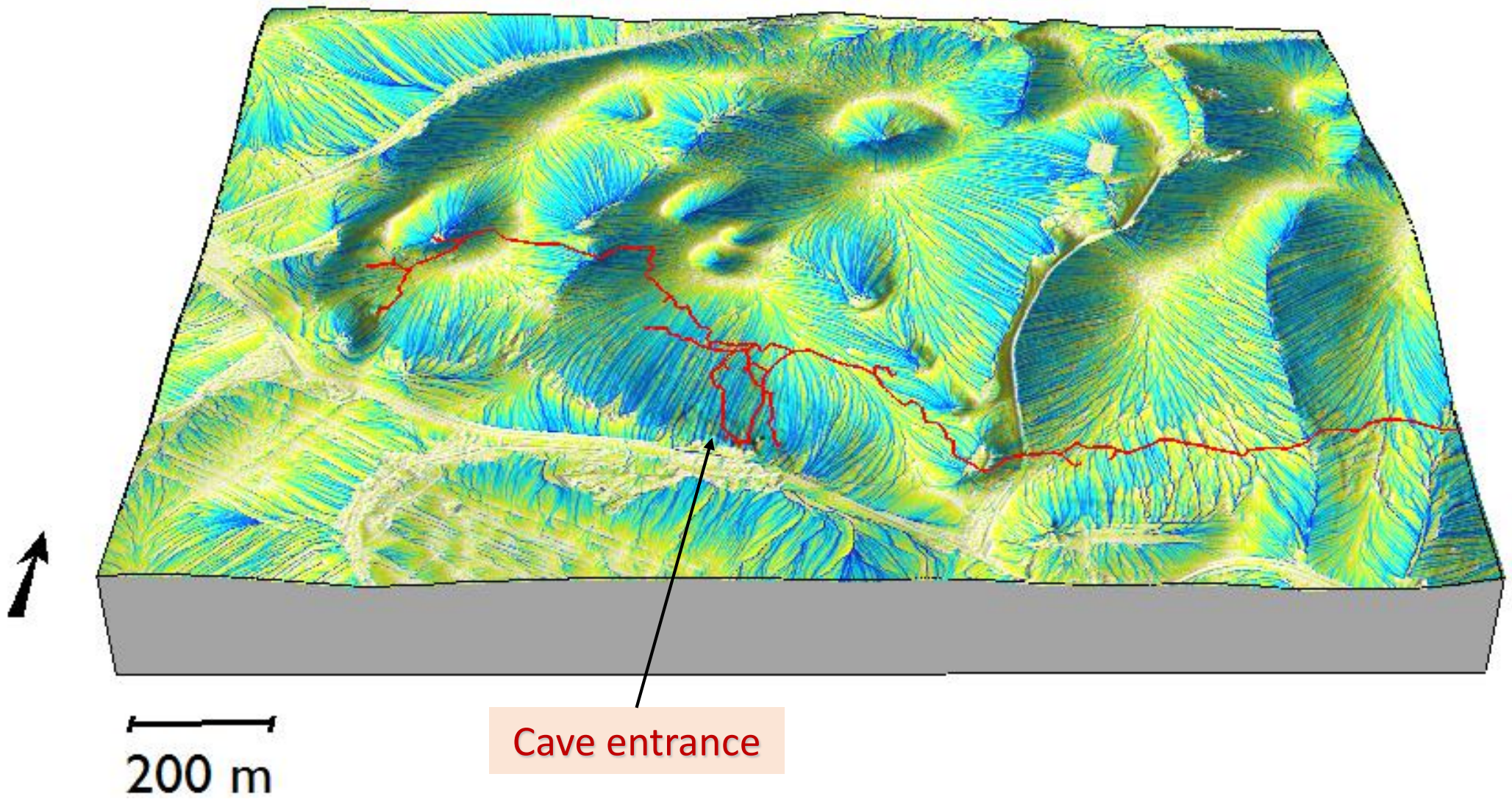




Vertical cross-sections of the 3D landscape model enable studying relationships between the underground and the surface above

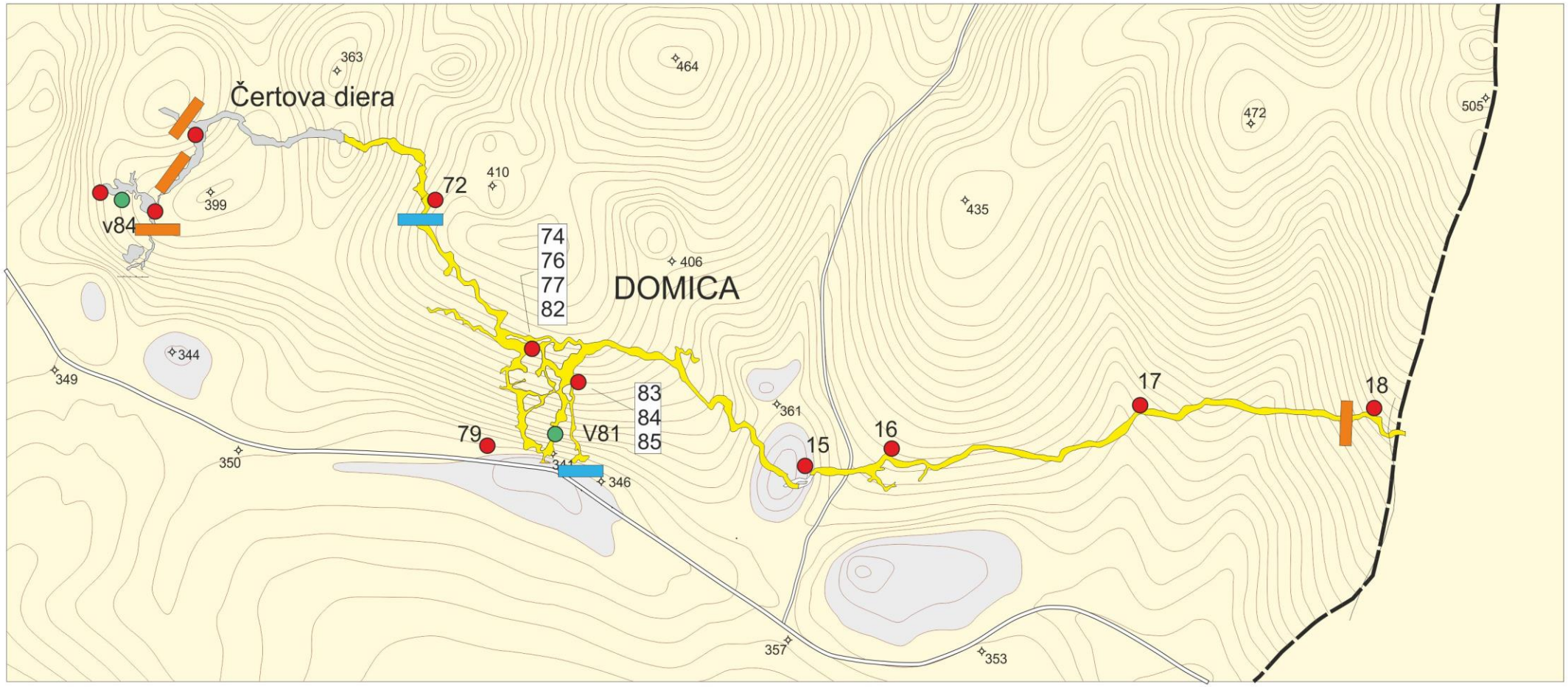
Modelling landscape phenomenon

3-D view of landforms and water flows above the cave derived from airborne laser scanning



Hydro-climatic monitoring

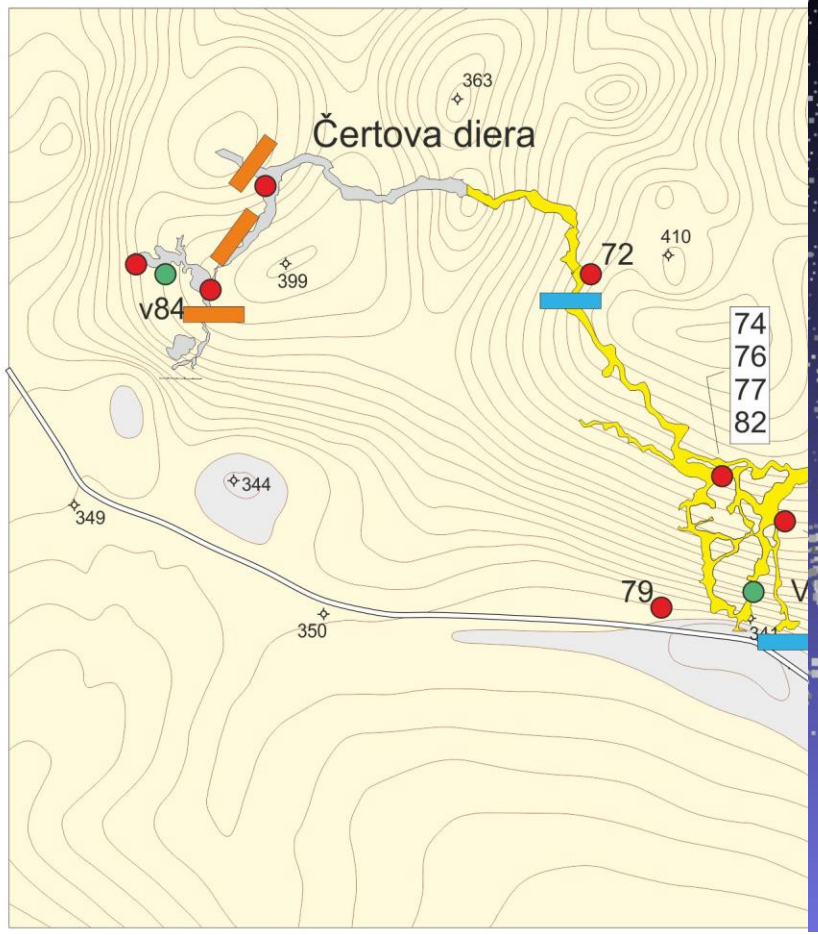
Position of dataloggers:

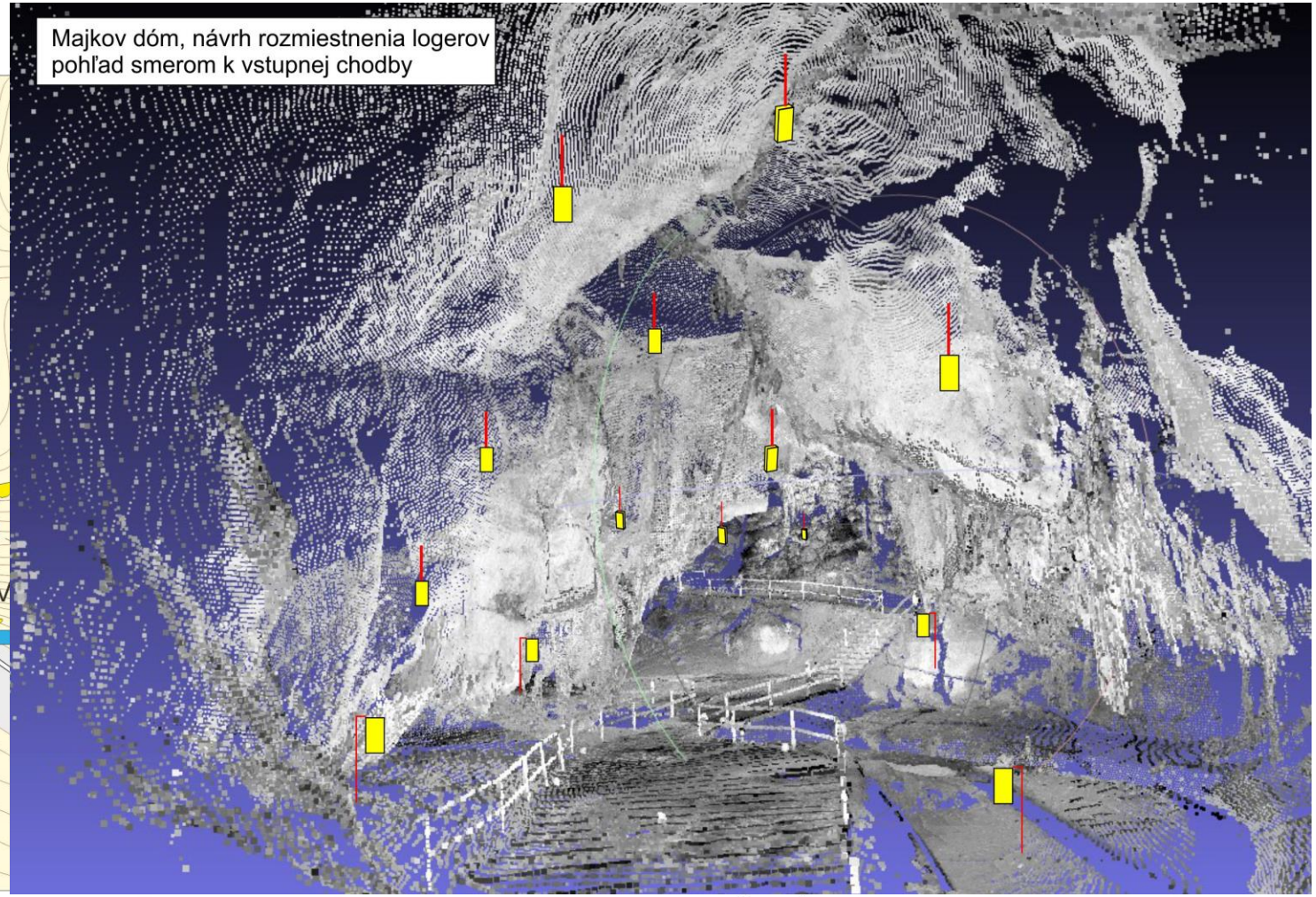


- Registered thermometers
- Registered thermometers with hygrometers
- Hydrological profiles (SCA)
- Hydrological profiles (IGU, PJSU)

Hydro-climatic monitoring

Position of dataloggers:





- Registered thermometers
- Registered thermometers with hygrometers
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Future research

- Designing methodologies for efficient processing of much larger 3-D datasets to reconstruct a 3D model of the entire point cloud on multiple-levels of scale
- Developing tools for analyzing 3-D surfaces in GIS analogous to the 2.5-D terrain analyses (3-D geomorphometry)
- Developing dynamic, fully 3-D models of caves integrated with landscape GIS data to explore the relationship between environmental processes acting underground and on the above-surface

More information

GALLAY, M., KAŇUK, J., HOCHMUTH, Z., MENEELY, J., HOFIERKA, J., SEDLÁK, V. (2015): Large-scale and high-resolution 3-D cave mapping by terrestrial laser scanning: a case study of the Domica Cave, Slovakia. *International Journal of Speleology*, 44(3), 277-291.

GALLAY, M., KAŇUK, J., HOFIERKA, J., HOCHMUTH, Z., MENEELY, J.(2015): Mapping and geomorphometric analysis of 3-D cave surfaces: a case study of the Domica Cave, Slovakia. In Jasiewicz, J., Zwoliński, Z., Mitasova, H., Hengl, T. (Eds.) *Geomorphometry for Geosciences*, Poland: Bogucki Wydawnictwo Naukowe, Adam Mickiewicz University in Poznań - Institute of Geoecology and Geoinformation, 69-73.

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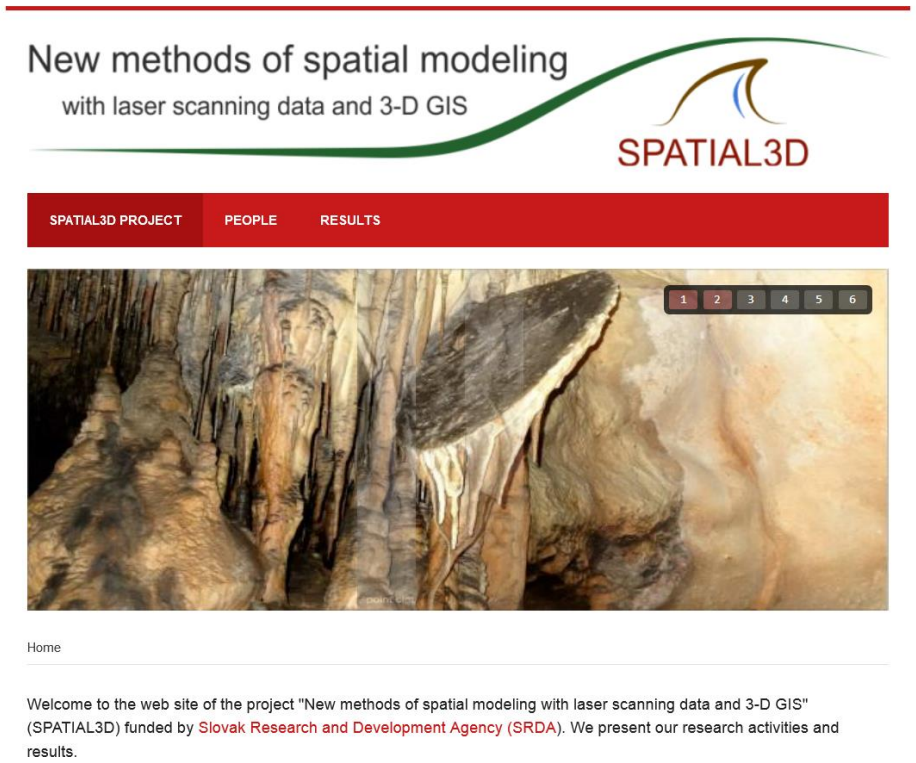

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