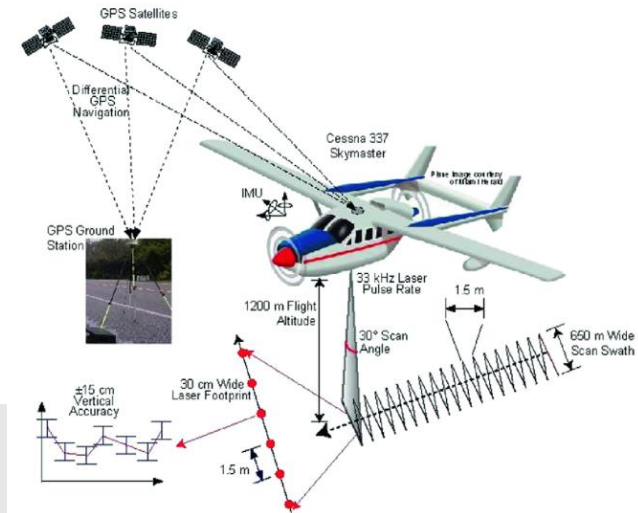
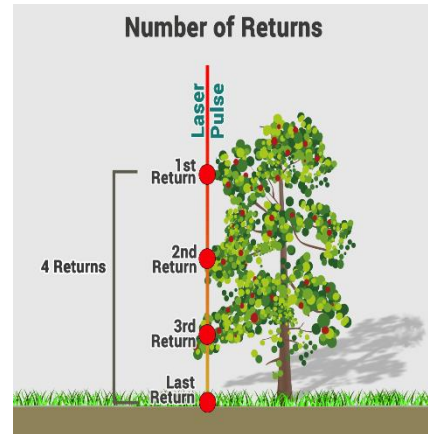


Creating a New Digital Terrain Model for Slovakia (2017 – 2023)

Matúš Fojtl, Katarína Leitmannová,
Peter Deák, Linda Gálová et al.

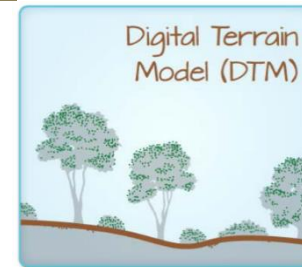
Terminology

- **LiDAR - Light Detection And Ranging**



- **Digital Terrain Model (DTM)**

- bare-earth raster grid



- **Digital Surface Model (DSM)**

- natural and built features



Motivation

■ Current state

■ DTM 3.5 (created in 2002 – 2005)

- **vectorization of elevation**, especially TM in 1 : 10 000 scale, in some parts of Slovakia in 1 : 25 000 scale
- GRID with 10 x 10 m
- DTM is freely available through the resort's Geoportal:

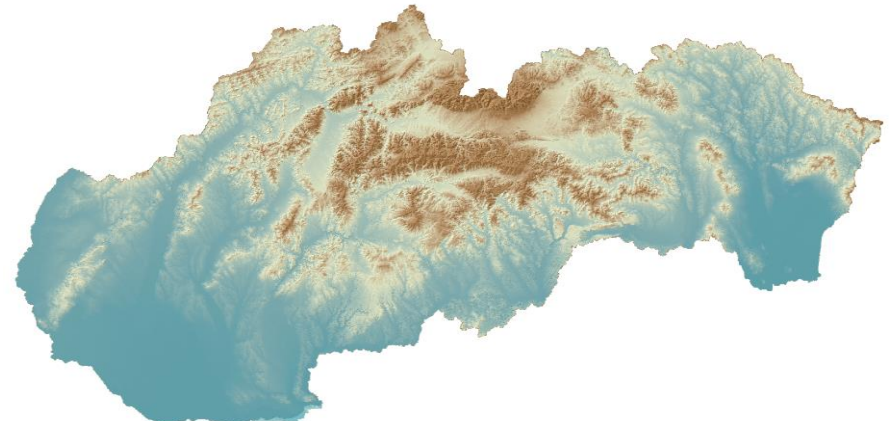
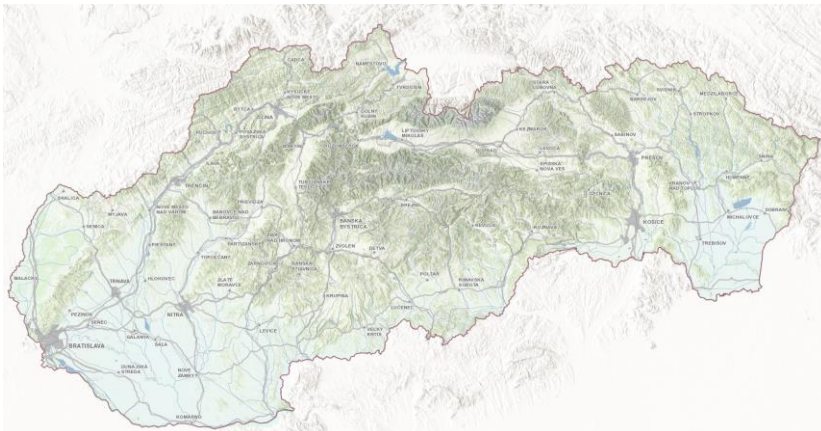
https://www.geoportal.sk/sk/zbgis_smd/na-stiahnutie/

WMS - https://zbgisws.skgeodesy.sk/zbgis_dmr3_wms/service.svc/get

Digitálny model reliéfu DMR3.5				
Rozlíšenie	10 m	25 m	50 m	100 m

Údaje DMR3.5 sú poskytované vo formáte TIFF v súradnicovom systéme S-JTSK a výškovom systéme Bpv.

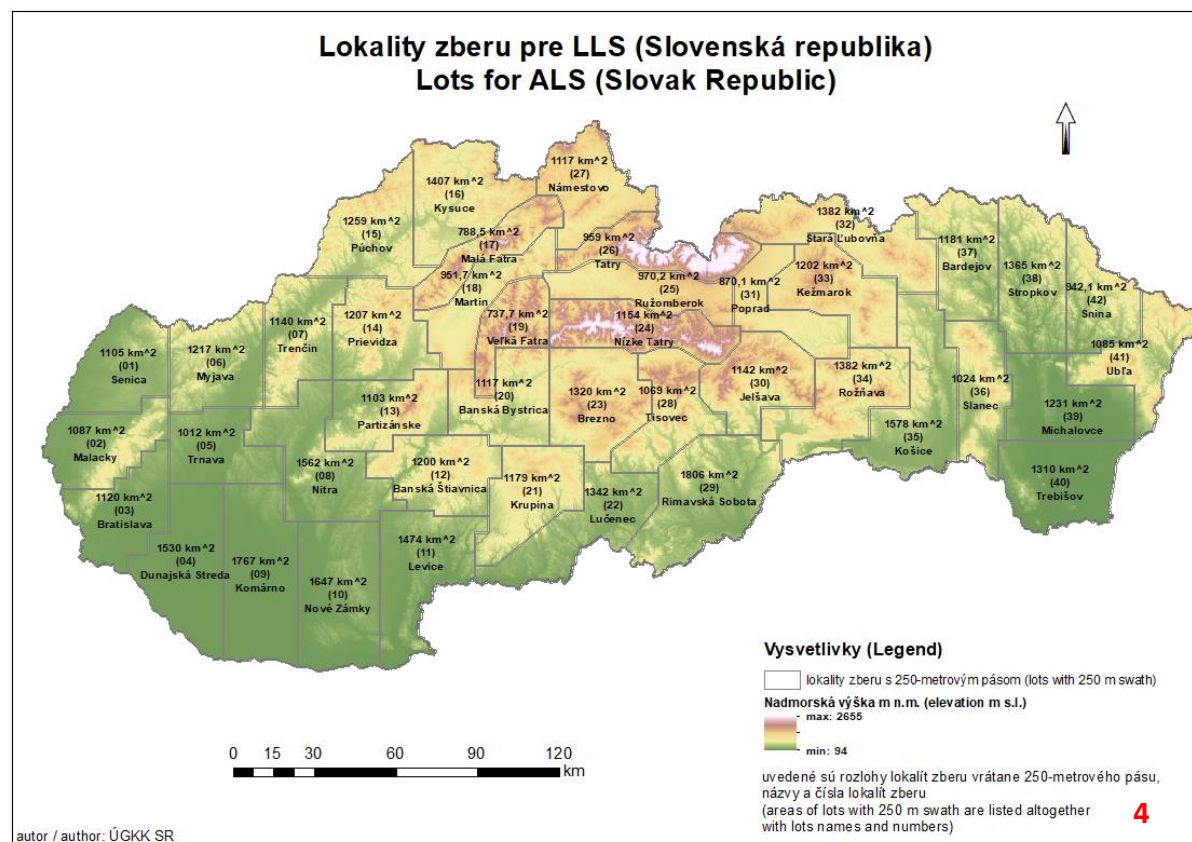
Licenčné podmienky	
Autor	GKÚ Bratislava; r. 2015
Licencia	CC-BY 4.0



DTM 5.0 - Basic information

- funded by state
- in 2017 public procurement
- project duration 2017 – 2023
- framework agreement with 5 suppliers
- reopening calls of the tender
- 42 lots

- area of Slovakia: 49 035 km²
- area of lots: 738 – 1 806 km²



Required quality criteria on ALS and DTM 5.0

■ Point Cloud

- Data collection during the non-vegetation period
 - without snow, haze, rain, etc.
- Scanning density of last reflection points is at least **5 points /1 m²**
- Absolute vertical accuracy of point cloud at ellipsoidal heights in ETRS89:
 $m_h \leq 0,15 \text{ m}$
- Absolute positional accuracy of point cloud in ETRS89-TM34:
 $m_p \leq 0,30 \text{ m}$
- classification: **ground, unclassified**, never classified

■ DTM 5.0

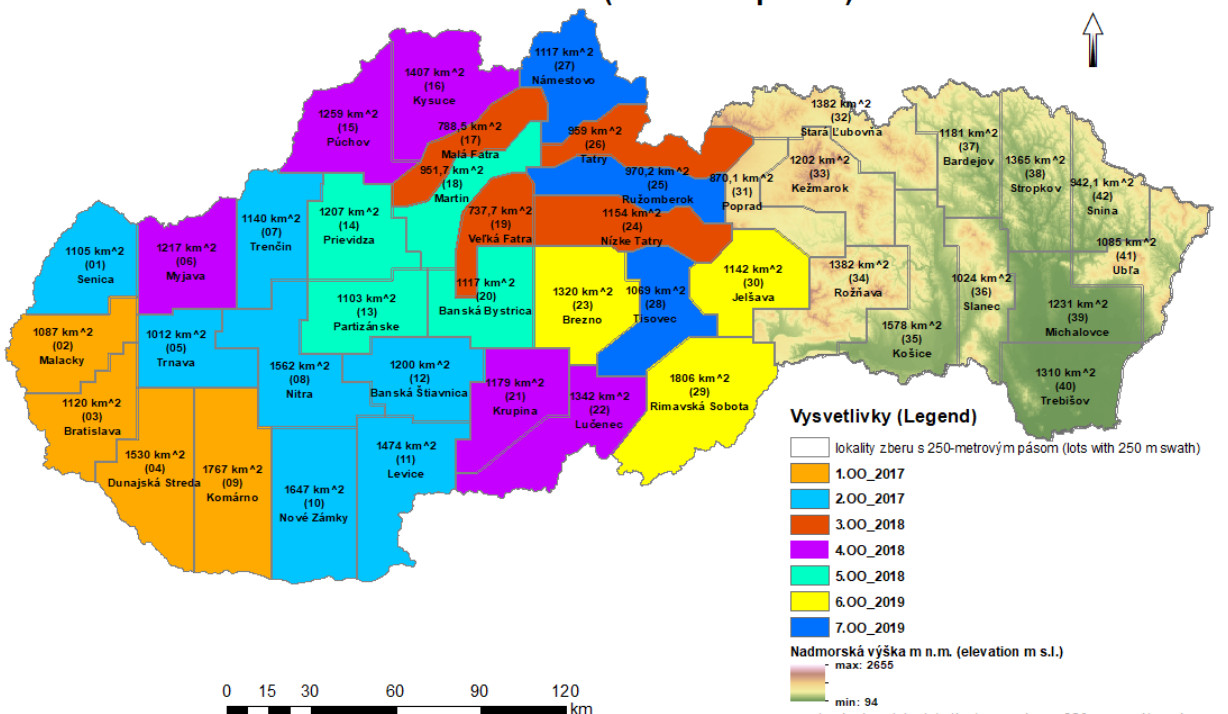
- ETRS89+h, S-JTSK(JTSK03)+Bpv
- ARC/INFO ASCII GRID
- **1 m** resolution
- vertical accuracy in Bpv: **$m_H \leq 0,25 \text{ m}$**
- positional accuracy: **$m_p \leq 0,50 \text{ m}$**

Contracted lots

- contracted 71,5% of Slovak territory

Year	Call	No. of lots	Area in km ²
2017	1.	4	5 504
	2.	7	9 140
2018	3.	4	3 639
	4.	5	6 404
	5.	4	4 349
2019	6.	3	4 268
	7.	3	3 156
Σ		30	36 490

Lokality zberu pre LLS (Slovenská republika)
Lots for ALS (Slovak Republic)



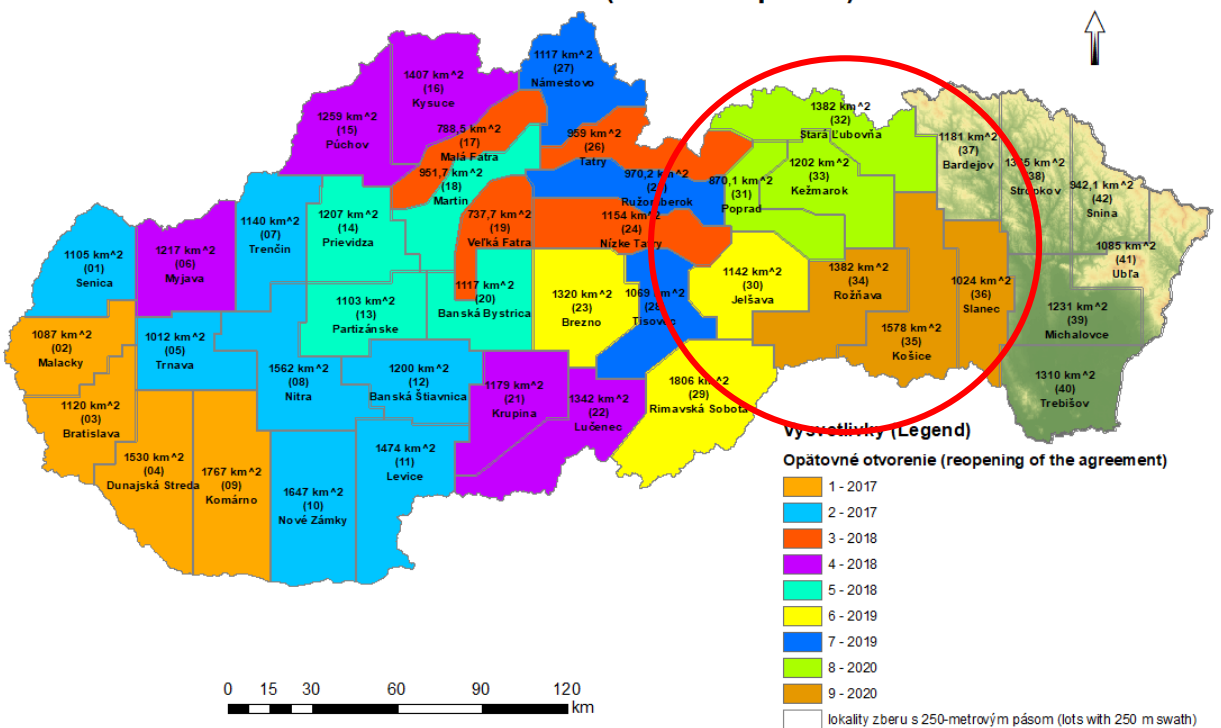
- average price for 1 km²
117 €

Contracted lots

- 86,1% of Slovak territory will be contracted in 2020

Year	Call	No. of lots	Area in km ²
2017	1.	4	5 504
	2.	7	9 140
2018	3.	4	3 639
	4.	5	6 404
	5.	4	4 348
2019	6.	3	4 268
	7.	3	3 156
2020	8.	3	3454
	9.	3	3984
Σ		36	43 928

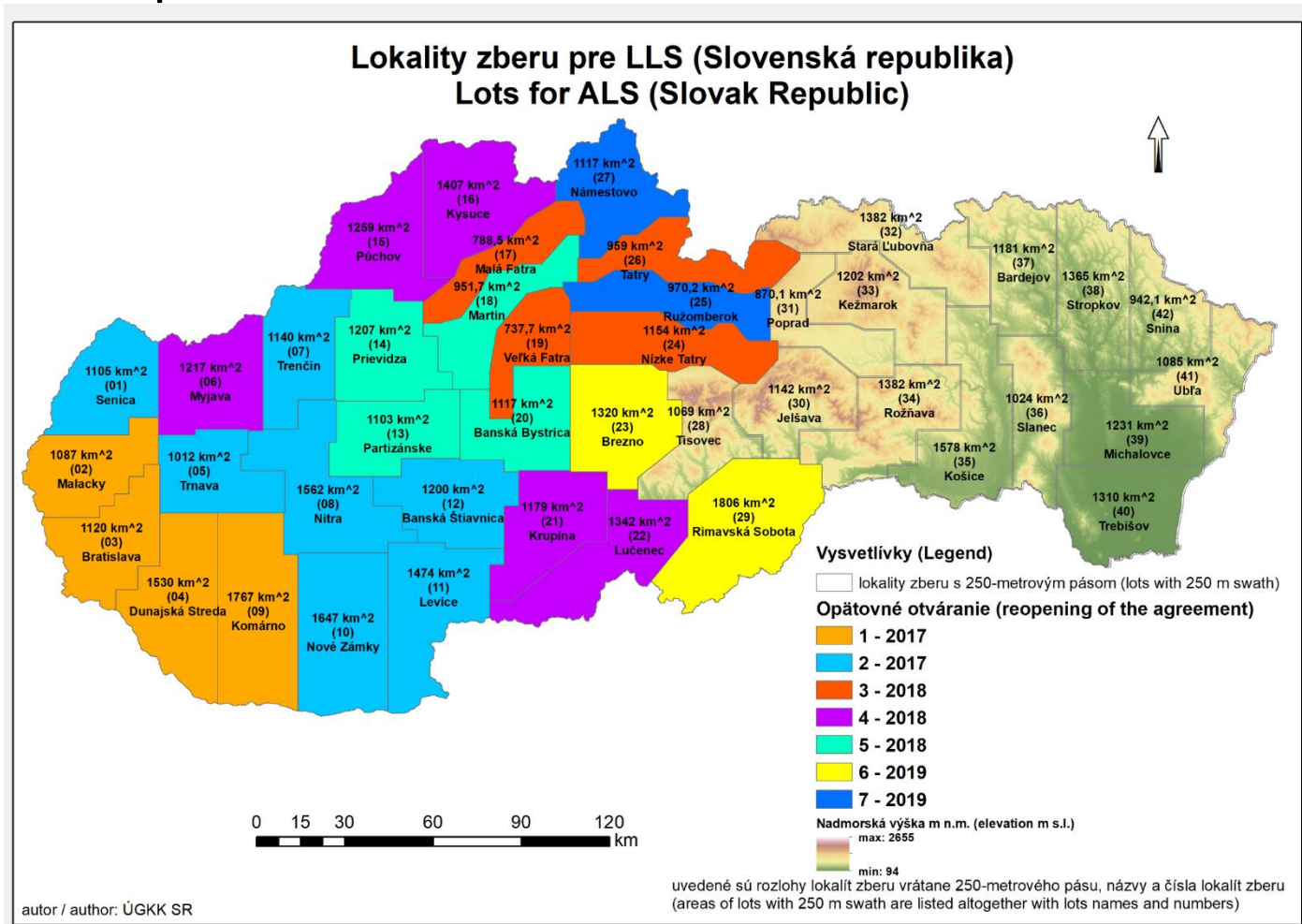
Lokality zberu pre LLS (Slovenská republika)
Lots for ALS (Slovak Republic)



uvedené sú rozlohy lokalít zberu vrátane 250-metrového pásu, názvy a čísla lokalít zberu
(areas of lots with 250 m swath are listed altogether with lots names and numbers)

Airborne laser scanning (ALS)

- scan completed 2017 - 2020



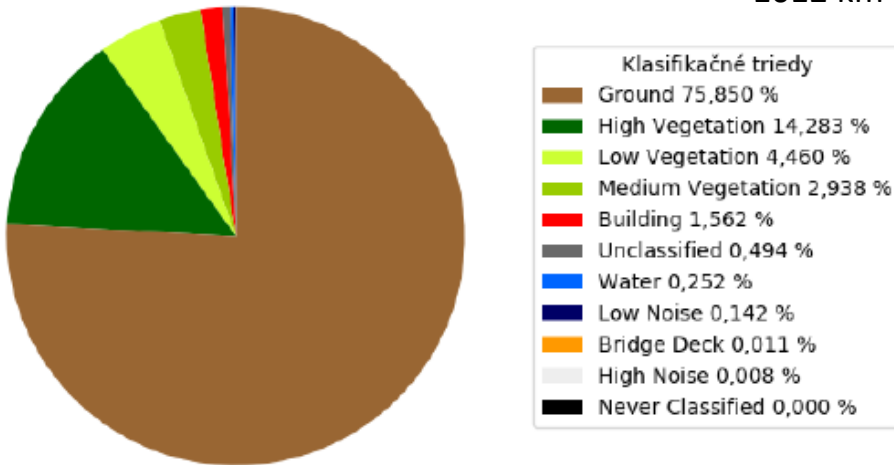
- 28 of the 30 contracted lots

Example

■ classification of points

LOT 05 - Trnava

■ 1012 km²



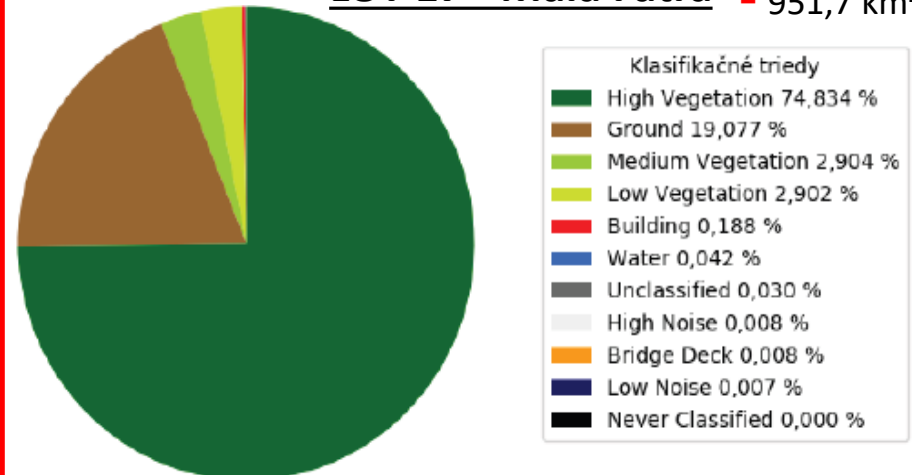
Total number of points: 31 098 853 376

Total density of points: 31 p./m²

Density of Ground points: **23 p./m²**

LOT 17 - Malá Fatra

■ 951,7 km²



Total number of points: 32 773 371 904

Total density of points: 41 p./m²

Density of Ground points: **8 p./m²**

Control of quality parameters

Stage 1 :

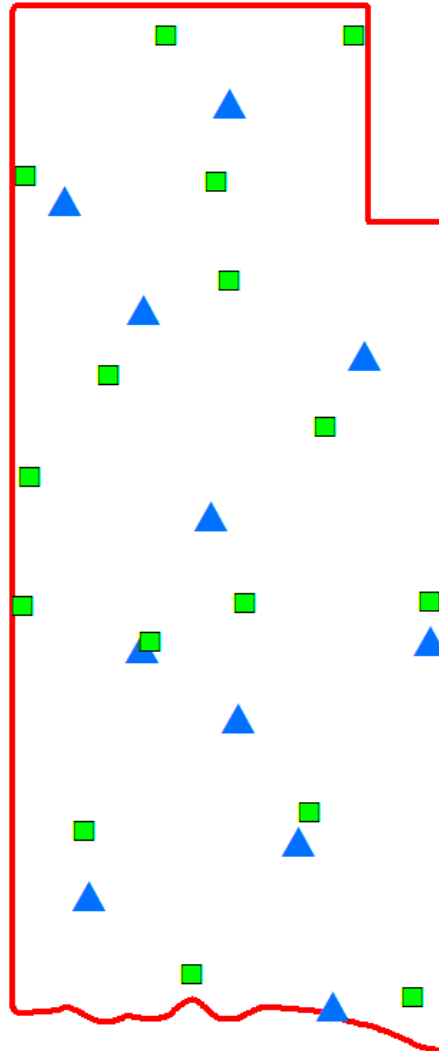
- density of last reflection points,
- holes in the data,
- relative vertical adjustment of the scanned strips ($|\Delta h| \leq 0,08 \text{ m}$),
- overlap of adjacent scanned strips (more than 40%).

Stage 2 :

- reliability of classification (class GR $\geq 99,5\%$ others $\geq 90\%$),
- absolute vertical and positional accuracy of cloud points,
- absolute vertical accuracy of DTM,
- elevations at the overlapped edges of individual lots,
- deformation on DTM (due to incorrect classification).

Control of vertical and positional accuracy

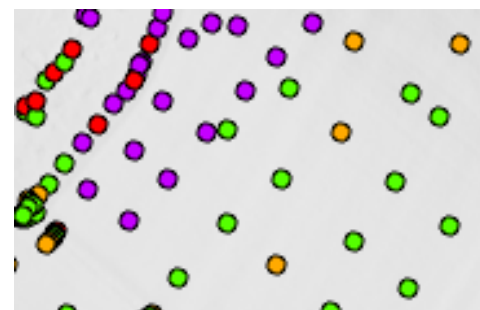
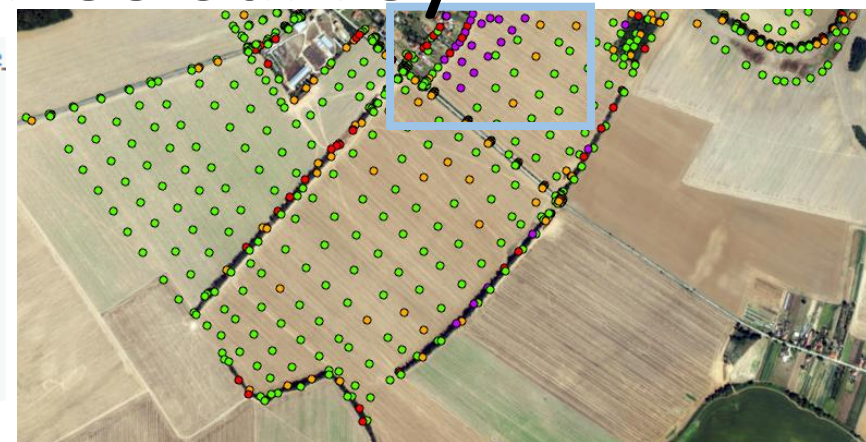
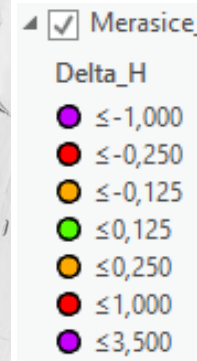
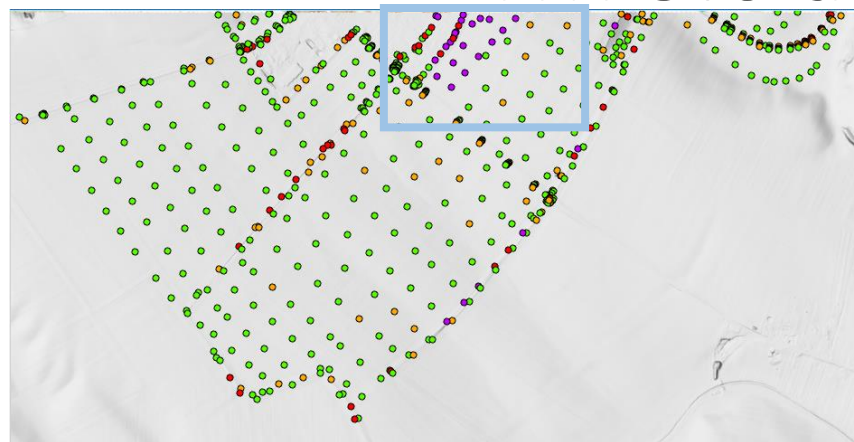
Overview of checkpoints for vertical accuracy



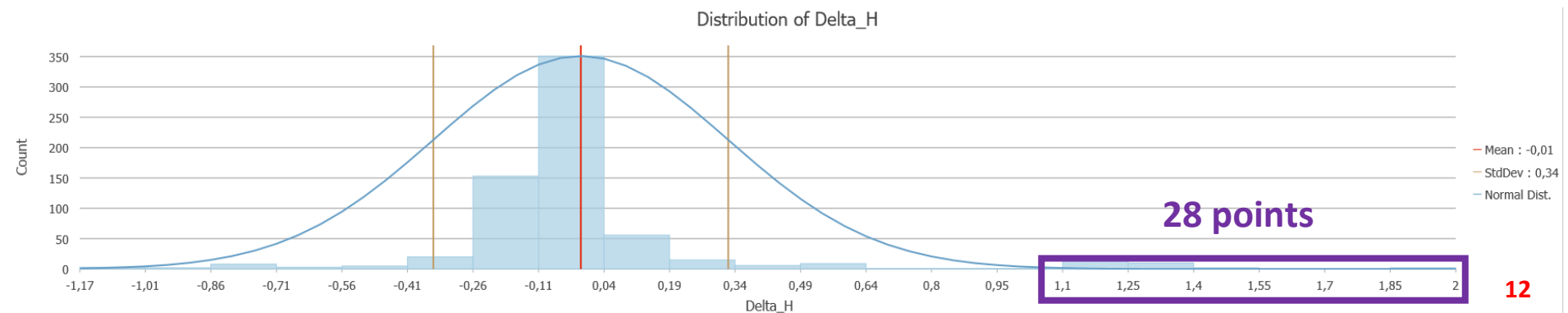
Checkpoints:

- 2 checkpoints/250 km²
- on open paved surfaces (parking lots)
- horizontally up to 5 ° inclination
- SKPOS

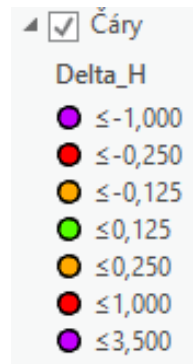
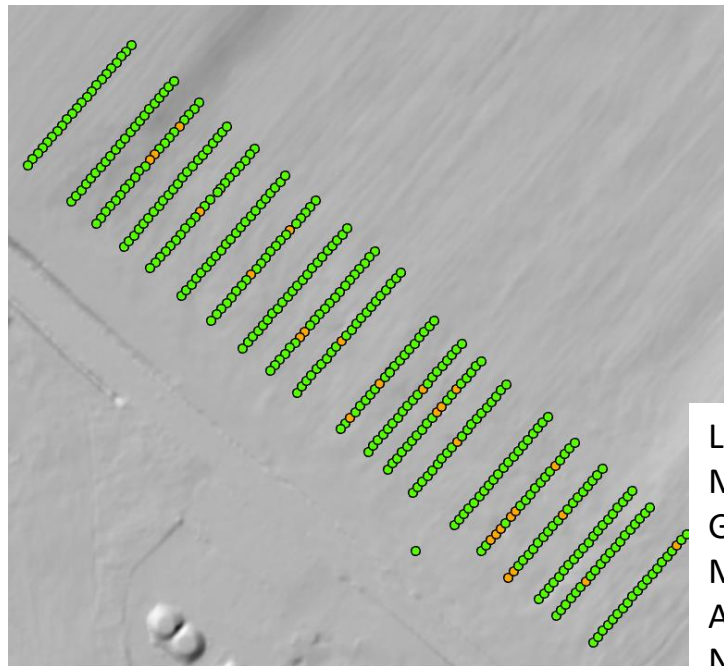
Comparison of spot elevations between DTM 5.0 and GNSS survey



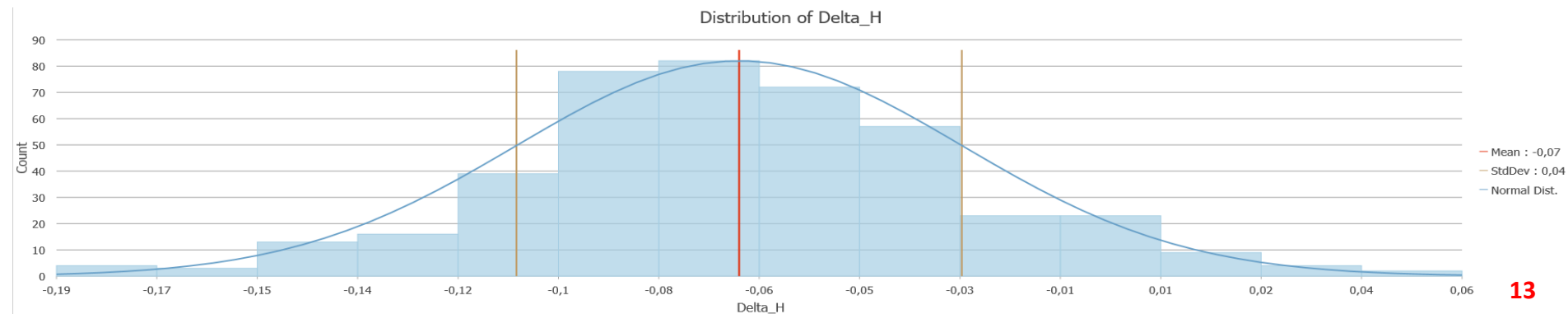
Location: **LOT 05 – Trnava**
 Municipality: **Merašice**
 LCP: **2009**
 Method : **SKPOS**
 ALS: **winter 2017-2018**
 Number of points: **662**
 Mean: **-0,01 m**
 Standard deviation: **0,34 m**



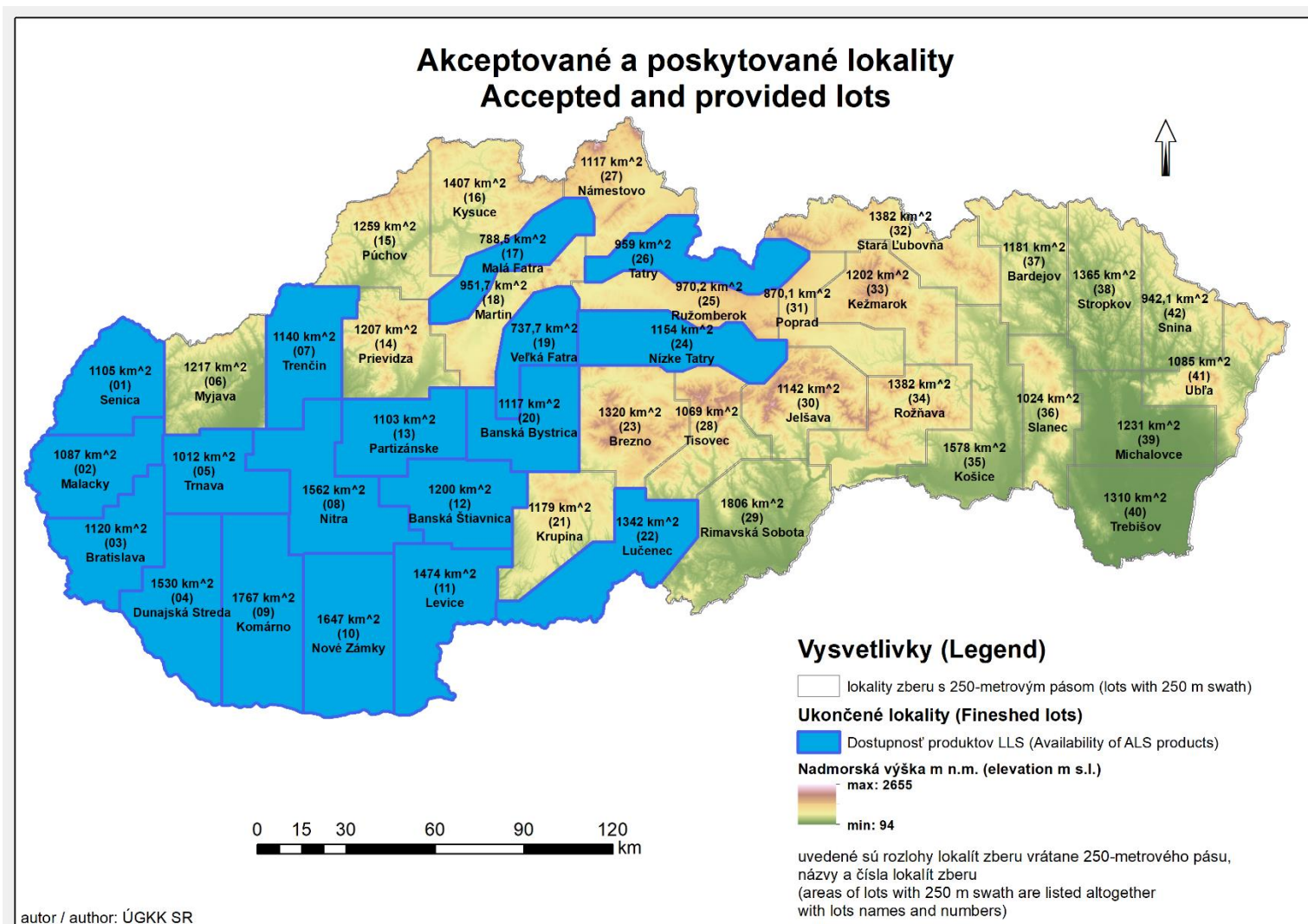
Comparison of spot elevations between DTM 5.0 and GNSS survey



Location: **LOT 01 – Senica**
Municipality: **Čáry**
Gravimetric meas.: **2018-2019**
Method: **SKPOS**
ALS: **winter 2017-2018**
Number of points: **425**
Mean: **-0,07 m**
Standard deviation: **0,04 m**



Completed lots



Quality parameters

Lots Number and Name	Vertical accuracy of cloud points in ETRS89-h [m]	Positional accuracy of cloud points in ETRS89-TM34 [m]	Average density of last reflection points [p/m ²]	Vertical accuracy of DTM 5.0 in Bpv [m]
	[m]	[m]	[point/m ²]	[m]
01 Senica	0,03	0,15	25	0,04
03 Bratislava	0,05	0,14	21	0,05
04 Dunajská Streda	0,05	0,14	17	0,05
05 Trnava	0,04	0,16	26	0,04
07 Trenčín	0,06	0,15	31	0,06
09 Komárno	0,03	0,07	33	0,03
10 Nové Zámky	0,04	0,14	23	0,03
11 Levice	0,02	0,15	26	0,02
17 Malá Fatra	0,04	0,09	28	0,04
19 Veľká Fatra	0,02	0,08	43	0,02
22 Lučenec	0,03	0,11	19	0,04
24 Nízke Tatry	0,05	0,10	31	0,06
26 Tatry	0,04	0,17	30	0,04

■ Parameters of all **18** accepted and provided lots are available through link:

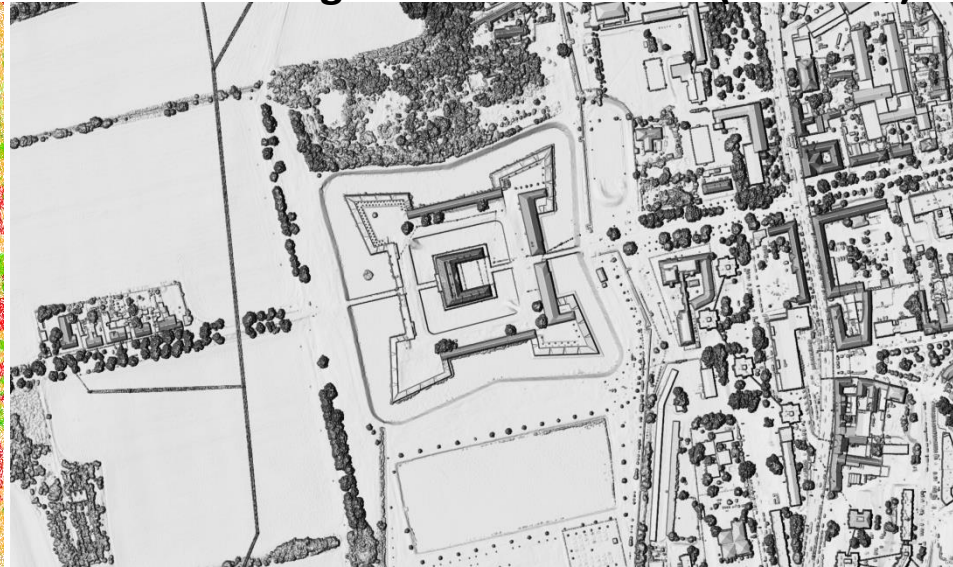
<https://www.geoportal.sk/files/zbqis/lis/parameters-als-data-collection-lots.pdf> 15

ALS Products

Classified Point Cloud



Digital Surface Model (DSM 1.0)



Digital Terrain Model (DTM 5.0)



*Manor house
in Holíč*

ALS products: off-line provision

- free of charge data provision,
- large volume data, e.g. whole lots (2 TB),
- order form,
- customer service centres in GKÚ in Bratislava and Prešov,
- external HDD,
- license terms & conditions,
- <https://www.geoportal.sk/en/zbgis/als-dtm.html>

Geoportal Search  

HOME GEODETTIC CONTROL CADASTRE **ZBGIS** ARCHIVE APPLICATIONS SERVICES INSPIRE FAQ

Home > ZBGIS > Airborne Laser Scanning and DTM 5.0

ZBGIS

- ⊗ ZBGIS
- ⊗ Orthophotomosaic
- ⊗ **Airborne Laser Scanning and DTM 5.0**
- ⊗ Digital Cartography
- ⊗ Geographical Names

★ LINKS

- ⊗ GKÚ
- ⊗ Products and services (Slovak only)
- ⊗ SKPOS®
- ⊗ Cadastre portal
- ⊗ ÚGKK SR
- ⊗ Geoportal purpose

Airborne Laser Scanning and DTM 5.0

A project for creating a new Digital Terrain Model (DTM 5.0) for the whole territory of Slovakia was launched in 2017 by the Geodesy, Cartography and Cadastre Authority of the Slovak Republic (ÚGKK SR). It is a 6 year long activity where the new DTM 5.0 will be created from the data of airborne laser scanning (ALS). The laser scanning and following post-processing of data is carried out by private segment. The whole territory of the Slovak Republic is divided into 42 localities (lots). Individual lots are scanned separately and the process of laser scanning goes from the west of the country to the east.

Project outcomes:

- collection of data by airborne laser scanning,
- processing of point cloud and delivering Classified Point Cloud,
- Digital Terrain Model DTM 5.0 in raster form,
- Digital Surface Model DSM 1.0 in raster form,
- quality control of point cloud and DTM.

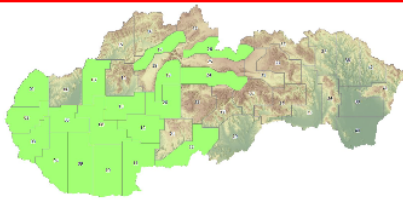
Mandatory quality criteria:

- scanning density is at least 5 points per m²,
- lots with 250m swath on 95% of their overlap,
- horizontal and vertical system: S-JTSK(JTSK03)+HBp; ETRS89-TM34+heTRS89,
- absolute vertical accuracy of point cloud at ellipsoidal heights ETRS89 - mh ≤ 0.15 m,
- absolute positional accuracy of point cloud in ETRS89-TM34 - mXY ≤ 0.30 m,
- absolute vertical accuracy of DTM 5.0 in ETRS89-h - mh ≤ 0.20 m,
- absolute vertical accuracy of DTM 5.0 in Bp - mh ≤ 0,25 m,

Quality control:
The control of absolute horizontal and vertical accuracy is performed at geodetically surveyed checkpoints located on open paved areas at several randomly selected locations within each lot. The quality control is independently performed by the supplier and the Geodesy, Cartography and Cadastre Authority of the Slovak Republic.

Finished lots available for use are highlighted in green. Due to the large volume of data (several TB) the data is provided only in offline mode by individual lots in their entirety. Users must bring or send an external HDD (USB 3.1 is recommended) to download the data. Please note that because of the large amount of data and time involved, the copying of data is not done while you wait. Data collection points are offices in Bratislava (Chlumckého 4) and Prešov (Suvorova 2). Smaller volume data (sections) can be downloaded via the **Map Client ZBGIS** application, more information [here](#).

- [Overview of lots in Shapefile format](#)
- [Overview of parameters of available lots](#)
- [How to work with DTM in QGIS application \(Slovak only\)](#)
- [How to unpack LAZ format to LAS format using LASzip \(Slovak only\)](#)



If you are interested in obtaining Classified Point Cloud, Digital Terrain Model 5.0 (DTM 5.0) or Digital Surface Model (DSM 1.0), please complete the order form and deliver it to the contact address [here](#):

- [Order form for Classified Point Cloud](#)
- [Order form for DTM 5.0](#)
- [Order form for DSM 1.0](#)

The provided products are subject to the [Terms and conditions of the provision and use of Airborne Laser Scanning Products](#).

ALS products: on-line provision

Data export (Terrain) <https://zbgis.skgeodesy.sk/mkzbgis/sk/teren>

- **DTM 5.0** in S-JTSK(JTSK03) and Bpv coord. system in Esri Grid or TIFF format
- **DSM 1.0** in S-JTSK(JTSK03) and Bpv coord. system in Esri Grid or TIFF format
- **Point cloud** in S-JTSK(JTSK03) and Bpv coord. system in LAS or LAZ format

The area size for DTM and DSM is limited to 400 km², for the Point Cloud to 2 km².

After the export is completed, a message will be sent to the specified e-mail address with a link to download the exported file.

Note:
S-JTSK (JTSK03) – EPSG:8353
Bpv – EPSG:8357

Products

☒ DTM 5.0 (S-JTSK(JTSK03), Bpv) ⓘ

☐ DSM 1.0 (S-JTSK(JTSK03), Bpv) ⓘ

☐ Point cloud (S-JTSK(JTSK03), Bpv) ⓘ

Select Export Region with

Current map extent ▼

File Format

Esri Grid ▼

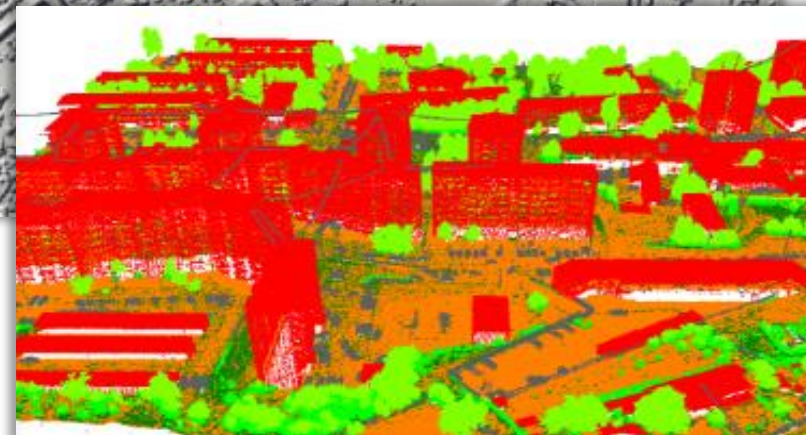
Email

Warning

Select export data according to the current map extent. Export is possible only after zooming in on the map.

The customer is obliged to state the source of LLS products when creating his own work and when publishing it as follows: "Source of LLS products: ÚGKK SR".

☐ I agree to the [license terms](#).



Use of ALS products

- Update of map series
 - Processing of the Orthophotomosaic of Slovakia
 - Elevation update on Basic Maps
- Land Consolidation
- Academic community
- Archaeology and Protection of Cultural Heritage
- Environment
 - Landslides
 - Flood maps
 - Landscape ecology
- Construction and Architecture
- Crisis management

LiDAR and the Protection of Cultural Heritage

„Archaeology of the invisible“

„Transparent archaeology“



„The number of new discovery-sites will grow in proportion to the publication of other areas mapped by LiDAR.“

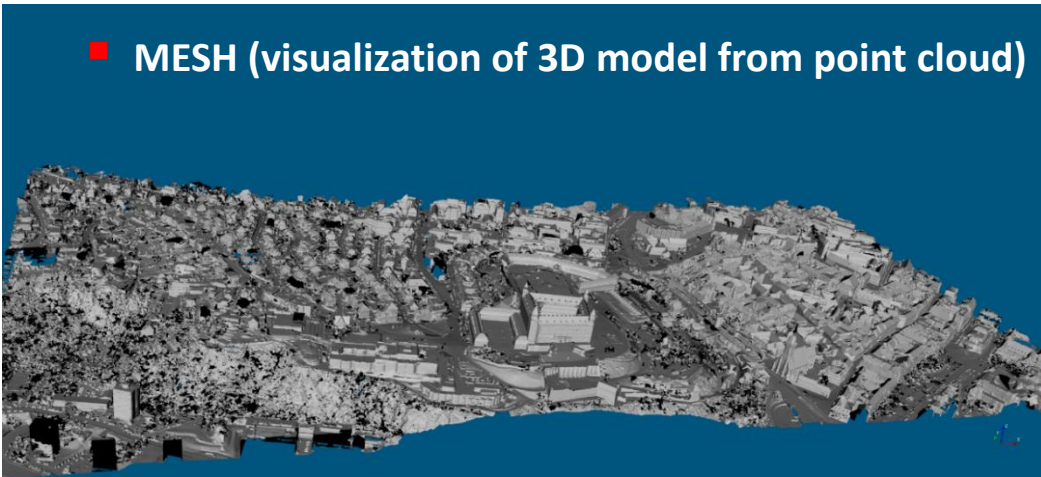
Peter Bisták, The Monuments Board of the Slovak Republic

■ Hill-fort in Neštich, *Ing. Tibor Lieskovský, PhD.*

Examples of ALS products

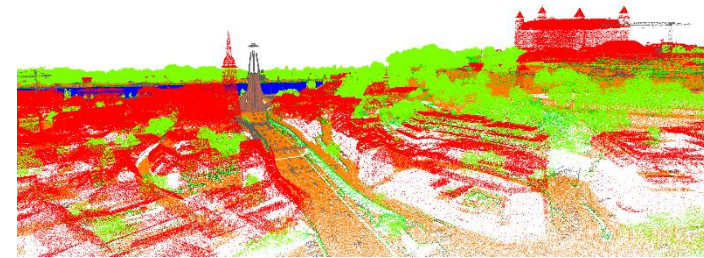
■ Bratislava

■ MESH (visualization of 3D model from point cloud)



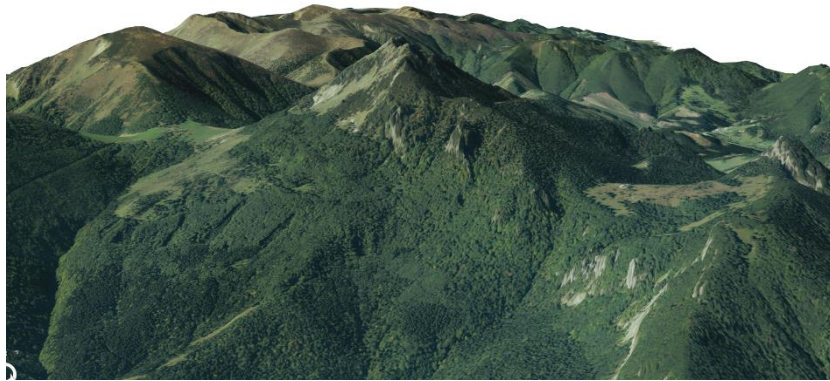
■ Point Cloud

■ Point Cloud coloured by Orthophoto

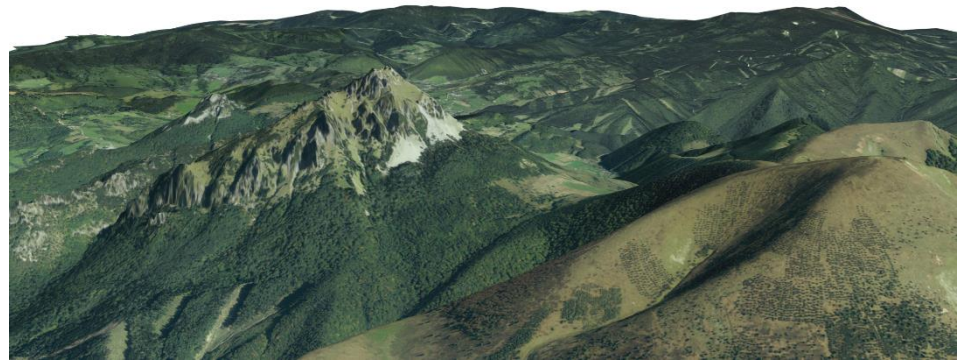


Examples of ALS products

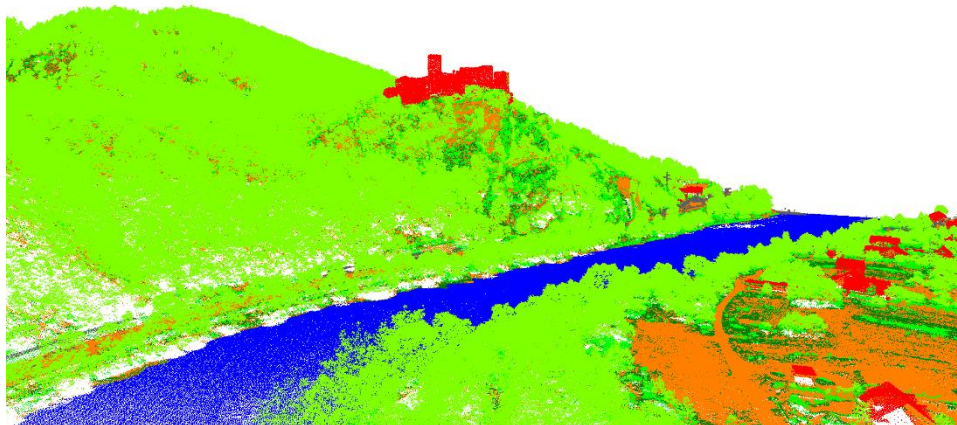
■ Malá Fatra



■ Point Cloud coloured by Orthophoto



■ Castle Strečno

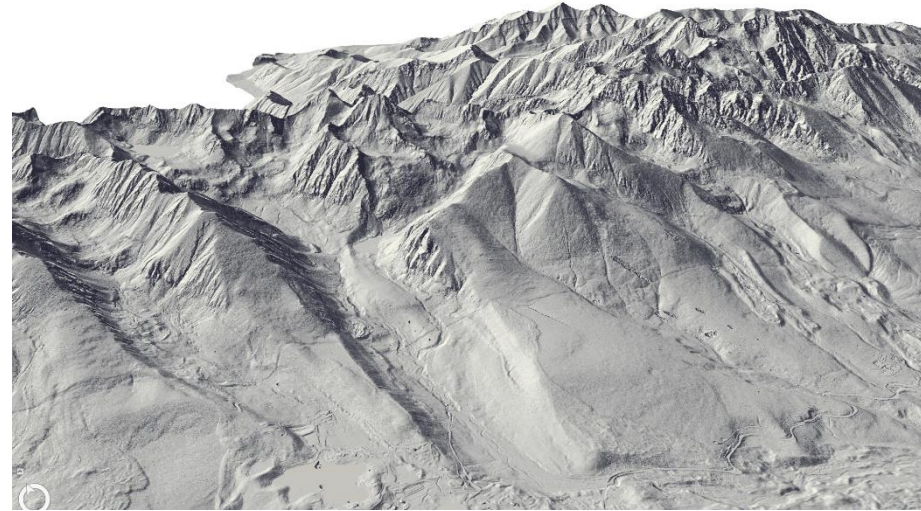


■ Mountain Kráľova hoľa



Examples of ALS products

■ Vysoké Tatry



■ DTM

■ DSM

■ Point Cloud coloured by Orthophoto



Gerlachovský štít

Elevation determined by
GNSS (2006): 2 654,79 m



Spatial triangulation in 1964:
2 654,78 m

Elevation determined from the Point Cloud:
2 654,75 m





**Thank you for
your attention.**

katarina.leitmannova@skgeodesy.sk
matus.fojtl@skgeodesy.sk
peter.deak@skgeodesy.sk
linda.galova@skgeodesy.sk