11th EUPOS® Council and Technical Meeting

Validation of CORS Networks and RTK Services in Slovenia

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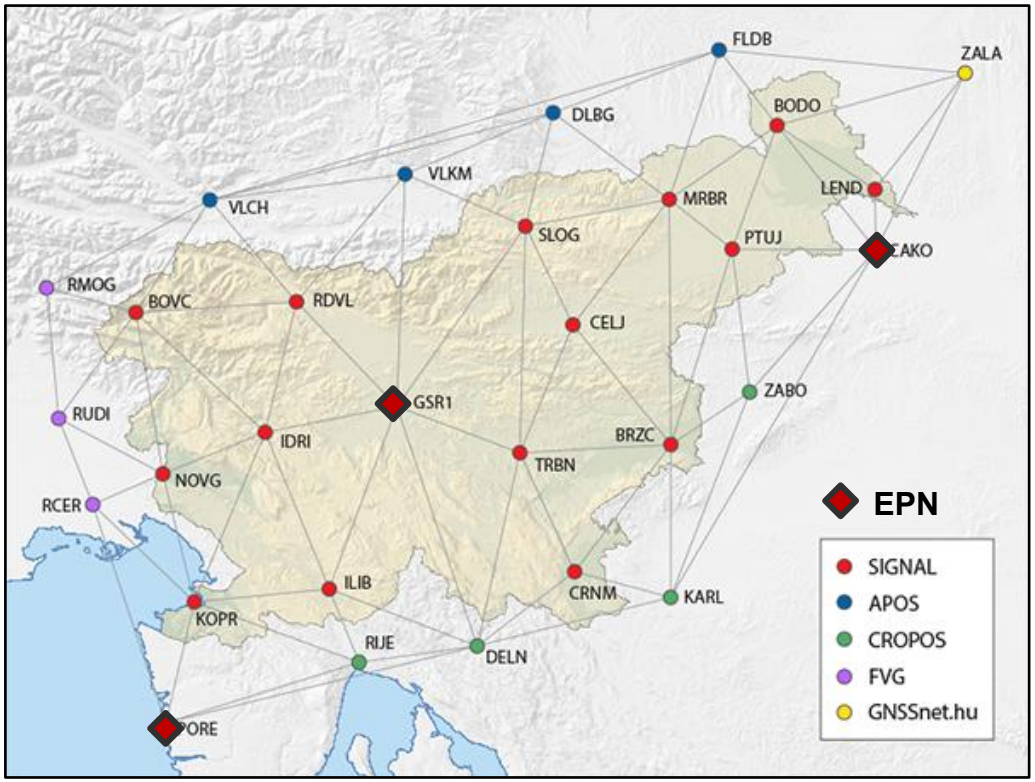
Presentation Topics

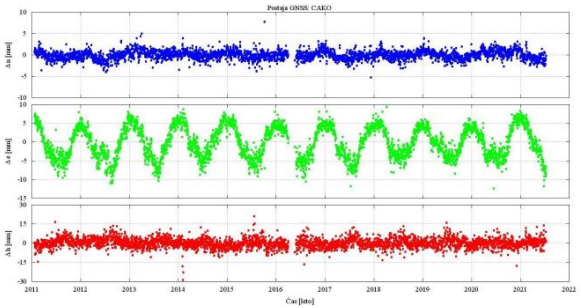
- **CORS networks: SIGNAL & Zero-Order Networks**
- **25-km square grid used for testing**
- **GNSS data for 2-daily sessions:**
  CORS RINEXes & GRID VRS RINEXes
- **Processing by using AUSPOS and CSRS-PPP free online services**
- **Transformation of coordinates from ITRF2020 into the national reference frame (D96-17)**
- **Comparison of CORS and GRID coordinates – reference vs. computed**

SIGNAL Network (GBAS)

- RTK services
- RINEX & Virtual RINEX data

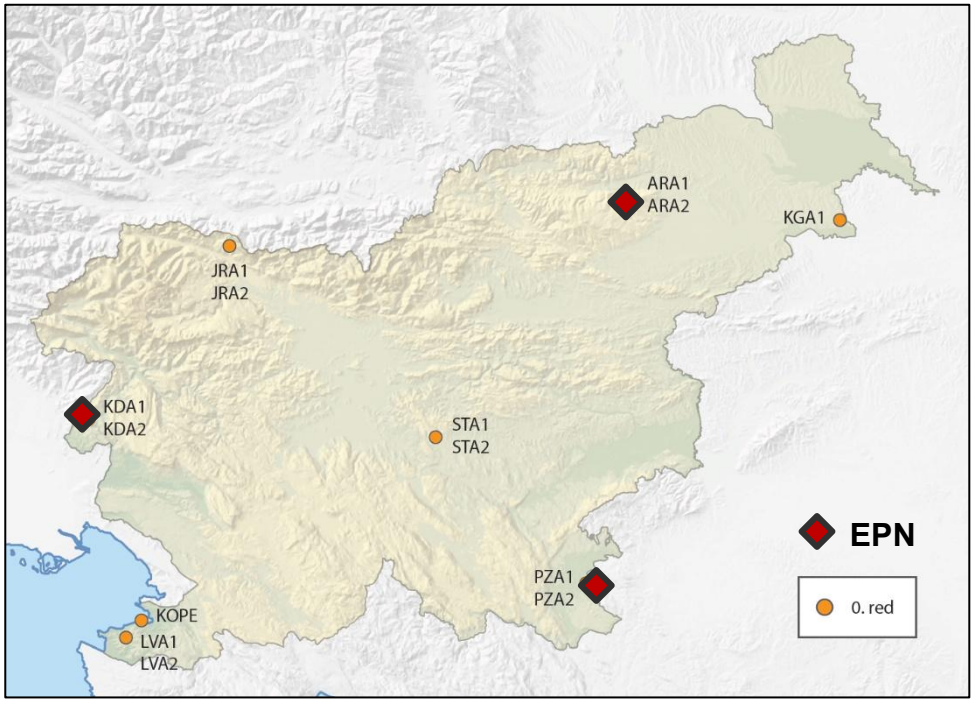
- **16** continuously operating GNSS stations in Slovenia (9 ***Trimble*** + 7 ***Leica***)
- **+14** continuously operating GNSS stations in Austria, Croatia, Hungary & Italy
- ***Trimble*** *Pivot Platform* + ***Alberding*** *Quality Control*

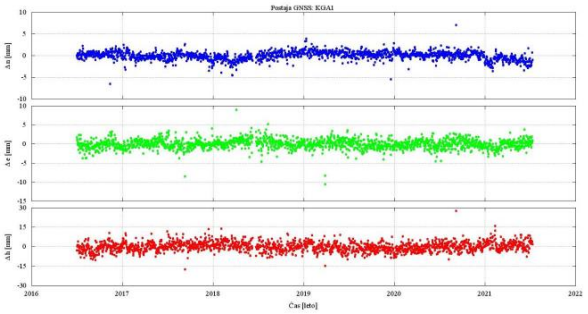




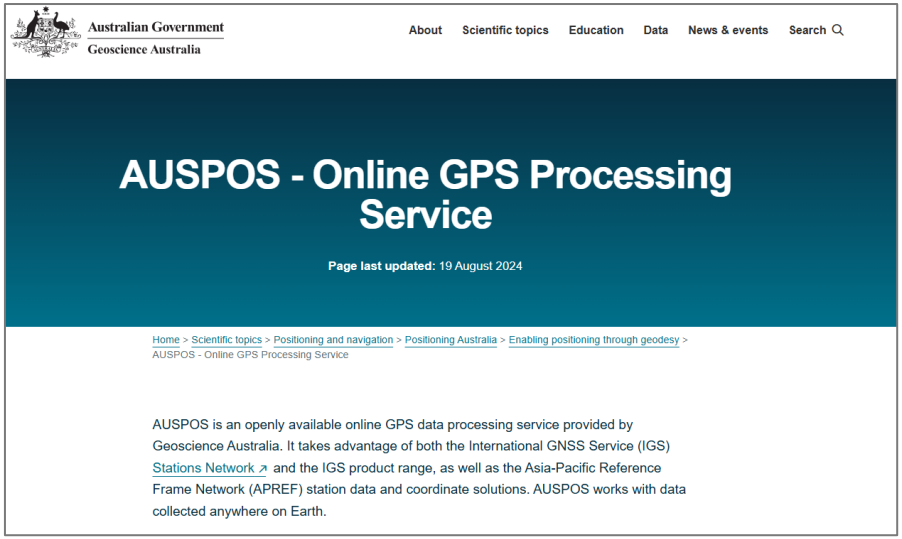
Zero-Order Geodetic Network (as a Reference)

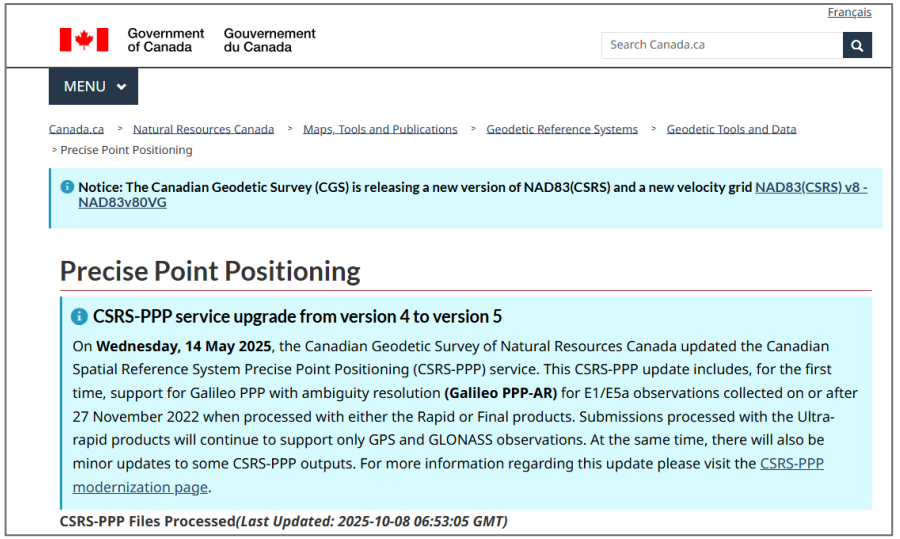
- **7** continuously operating GNSS stations in Slovenia (***Leica*** equipment)
- **6** of them are **twin stations**, **1** collocated with a **seizmic station**,
  1 near an old **triangulation point**, **1** near an **absolute gravimetric point**;
  all stations connected to the first order levelling network
- 3 EPN stations (ARA2, KDA2, PZA2)
- ***Alberding*** *GNSS Status Software*





AUSPOS and **CSRS-PPP** Free Online Services





- AUSPOS provides a network solution using a double-difference strategy (running on Bernese GNSS SW)
- Minimal constraints alignment using 10 nearest IGS stations
- GPS satellites only
- MAX 20 RINEX files in one package
- Results in the ITRF2020 at the epoch of observations

- CSRS-PPP provides precise point positioning solution
- No reference stations required
- GPS, GLONASS, and Galileo satellites
- Simultaneous processing;
  MAX 300 MB ZIP of RINEX files in one package
- Results in the ITRF2020 at the epoch of observations

Examples of Reports from AUSPOS and CSRS-PPP

3 Computed Coordinates, ITRF2020

All coordinates are based on the IGS realisation of the ITRF2020 reference frame. All the given ITRF2020 coordinates refer to a mean epoch of the site observation data. All coordinates refer to the Ground Mark.

3.1 Cartesian ITRF2020

Station	X (m)	Y (m)	Z (m)	ITRF2020 @
V099	4303423.707	1075444.454	4568317.572	11/06/2025
V100	4297163.810	1099650.304	4568543.980	11/06/2025
V101	4290871.332	1123849.372	4568735.941	11/06/2025
V102	4284519.654	1148034.353	4568864.800	11/06/2025
V103	4277827.372	1172127.454	4568627.859	11/06/2025
V104	4271170.515	1196228.195	4568428.439	11/06/2025
V105	4326895.113	1055855.091	4550554.475	11/06/2025
V106	4321186.973	1080196.702	4551363.596	11/06/2025
V107	4314657.576	1104336.045	4551302.690	11/06/2025
V108	4308291.513	1128516.691	4551415.117	11/06/2025
V109	4301630.321	1152619.132	4551213.407	11/06/2025
V110	4295055.480	1176742.959	4551103.208	11/06/2025
V111	4288508.616	1200873.764	4551022.659	11/06/2025
V112	4350203.536	1036227.465	4532625.829	11/06/2025
V113	4344032.299	1060450.479	4532940.669	11/06/2025
V114	4338256.165	1084774.269	4533671.711	11/06/2025
V115	4332330.517	1109066.871	4534247.086	11/06/2025
V116	4325429.477	1133109.684	4533794.710	11/06/2025
V117	4319207.368	1157328.888	4534058.383	11/06/2025
V118	4312276.668	1181356.961	4533572.869	11/06/2025
BOR1	3738358.111	1148174.031	5021815.946	11/06/2025
BRUX	4027881.303	306998.840	4919499.070	11/06/2025
BUCU	4093760.512	2007794.165	4445130.178	11/06/2025
GANP	3929181.193	1455237.049	4793654.093	11/06/2025
GRAC	4581708.067	556133.020	4389341.501	11/06/2025
GRAZ	4194423.475	1162703.062	4647245.625	11/06/2025
JOZ2	3664880.202	1409190.909	5009618.643	11/06/2025
MATE	4641949.185	1393045.814	4133287.764	11/06/2025
MEDI	4461400.374	919593.967	4449505.001	11/06/2025
POTS	3800689.312	882077.713	5028791.513	11/06/2025
WSRT	3828735.557	443305.286	5064884.909	11/06/2025
WTZR	4075580.219	931854.146	4801568.330	11/06/2025
ZIM2	4331299.593	567537.692	4633133.952	11/06/2025

CSRS-PPP 5.14.0 (2025-08-07)

GSR1161A.25o
GSR1

Data Start	Data End	Duration of Observations
2025-06-10 00:00:00.00	2025-06-10 23:58:30.00	23:58:30
Processing Time	**Mode**	**Product Type**
14:31:44 UTC 2025/09/26	Static	Final

Observations

GPS : C1 C2 L1 L2 | GLONASS : C1 C2 L1 L2 | Galileo : C1 C5 L1 L5

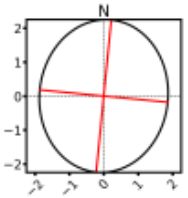
Elevation Cut-Off	Rejected Epochs	Fixed Ambiguities	Estimation Steps
7.5 degrees	0.00 %	93.85 %	30.00 sec
Antenna Model	**APC to ARP**		**ARP to Marker**
LEIAR20 LEIM	REF PCO : GPS GLONASS Galileo		H:0.065m / E:0.000m / N:0.000m

(APC = antenna phase center; ARP = antenna reference point; REF PCO = reference phase center offset)

Estimated Position for GSR1161A.25o

	Latitude (+n)	Longitude (+e)	Ell. Height
ITRF20 (2025.4)	46° 2' 53.29229"	14° 32' 37.39627"	351.670 m
Sigmas(95%)	0.002 m	0.002 m	0.006 m
A priori*	46° 2' 53.27029"	14° 32' 37.36219"	351.672 m
Estimated – A priori	0.679 m	0.733 m	-0.002 m

95% Error Ellipse (mm)
semi-major: 2 mm
semi-minor: 2 mm
semi-major azimuth: 5° 35' 5.33"

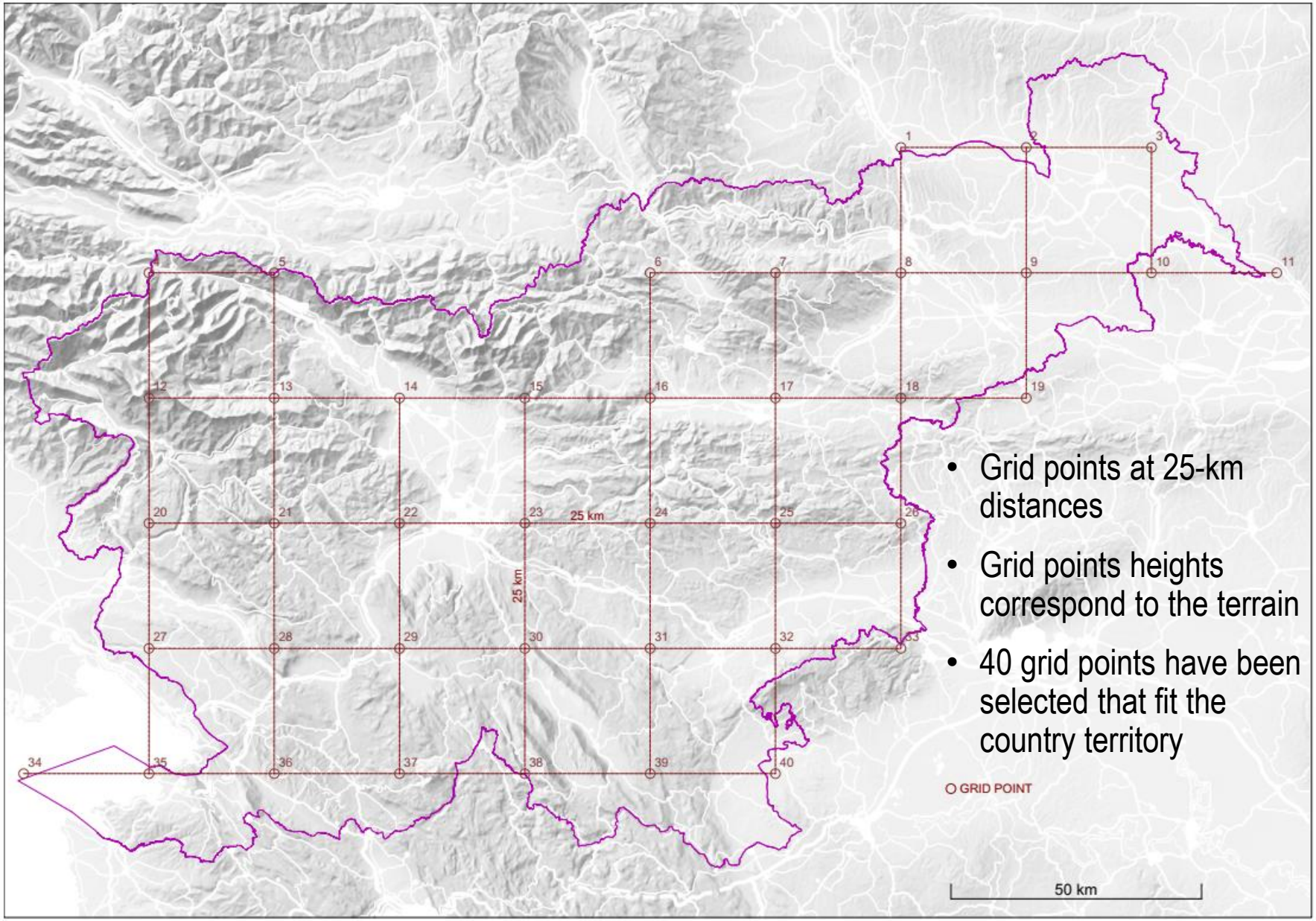


UTM (North)
Zone 33

5099497.029 m (N)
464699.939 m (E)

Scale Factors
0.99961532 (point)
0.99956021 (combined)

Creation of a Grid in the Projected CRS (D96-17/TM)

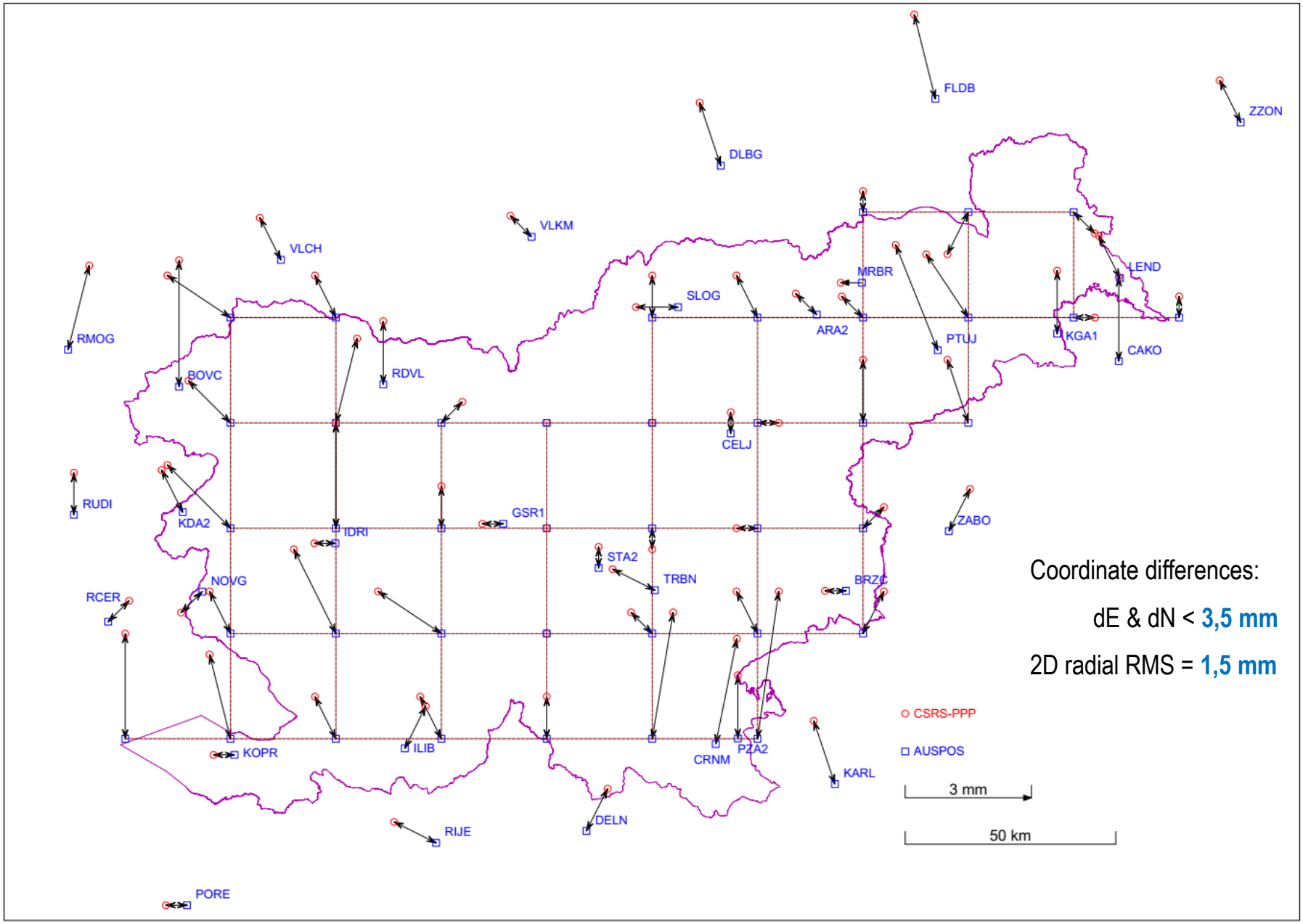


- Grid points at 25-km distances
- Grid points heights correspond to the terrain
- 40 grid points have been selected that fit the country territory

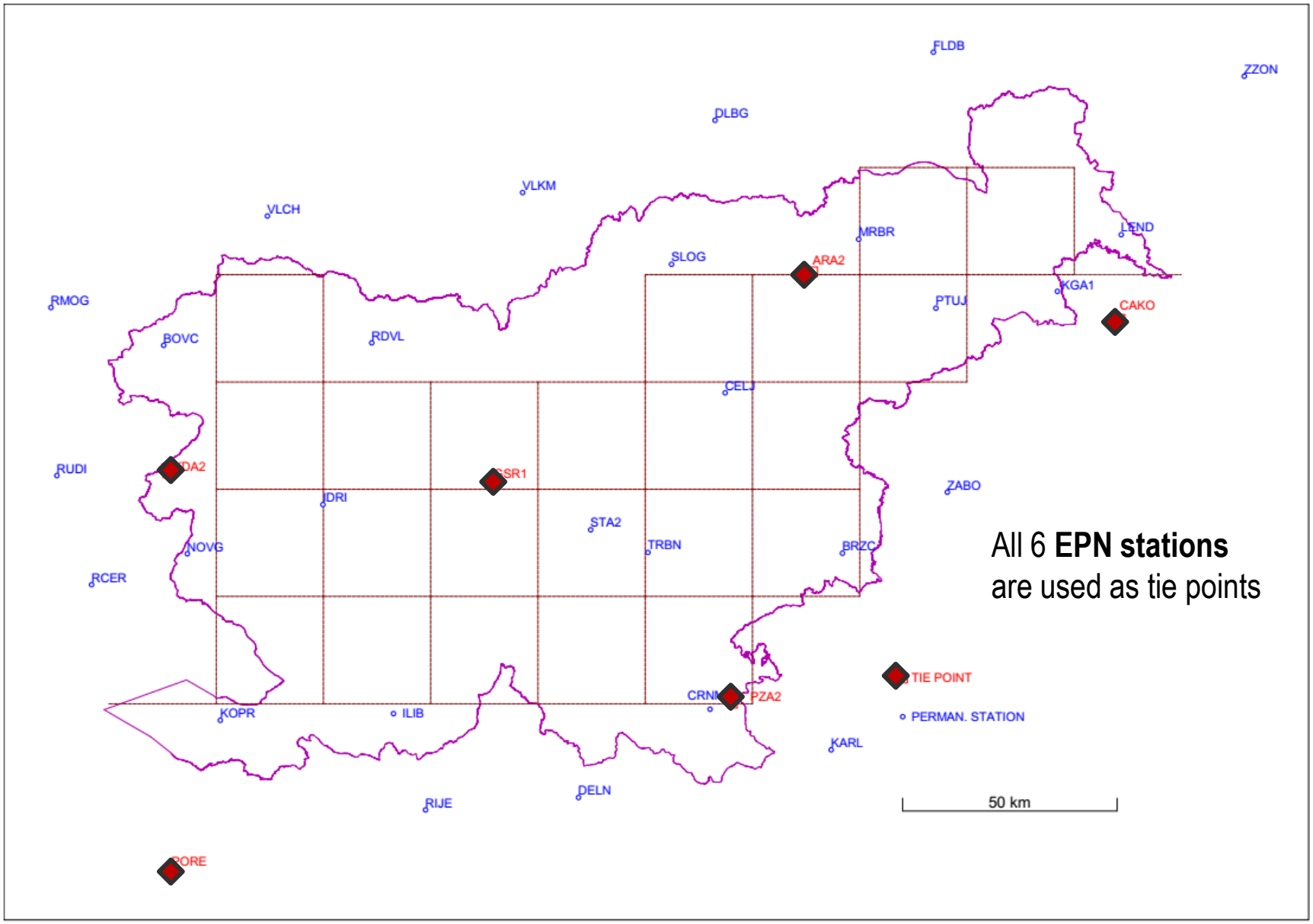
Data Acquisition and Processing

- RINEX 3.04 data for 29 SIGNAL Network stations and 5 Zero-Order Network stations
- RINEX 3.04 data for 40 virtual reference stations (VRS) – the grid points
- Two consecutive daily sessions (separate files, 2 × 24 hours, 30 s interval) – 10 & 11 June 2025 (2025.4)
- RINEX data uploaded to AUSPOS and CSRS-PPP online services:
  2 packages for CORS networks and 2 packages for grid points
- Results/coordinates obtained the ITRF2020 at the mean epoch (12:00) for each day; average coordinates calculated from both daily sessions
- Best-fit similarity transformation from ITRF2020@2025.4 into D96-17 4 (Leica Infinity 4.1) using 6 EPN stations from both CORS networks
- Comparison of the reference and computed coordinates for CORS and GRID points

Comparison of Hz-Coordinates **AUSPOS** vs. **CSRS-PP**



Tie Points Used for the Reference Frame Alignment



Best-Fit Transformation of AUSPOS Coordinates from the ITRF2020@2025.4 into the National CRS (D96-17)

Transformation: Molodensky - Classical 3D

Parameters

Height Mode:	Ellipsoidal		
Model:	Molodensky		
Common Points:	6		
Δx:	0,6559 m	RMS Δx:	0,0016 m
Δy:	-0,5897 m	RMS Δy:	0,0016 m
Δz:	-0,4682 m	RMS Δz:	0,0016 m
Rx:	-0,01648 "	RMS Rx:	0,00573 "
Ry:	-0,01550 "	RMS Ry:	0,00773 "
Rz:	-0,01605 "	RMS Rz:	0,00442 "
Scale:	1,000000010643	RMS Scale:	0,000000017190
x0:	4.292.742,0693 m		
y0:	1.135.242,2120 m		
z0:	4.563.051,3702 m		

#	Point Id (A)	Point Id (B)	Use	Residual E [m]	Residual N [m]	Residual Height [m]
1	ARA2	ARA2	Position & Height	0,0033	-0,0061	-0,0007
2	CAKO	CAKO	Position & Height	0,0014	-0,0004	0,0005
3	GSR1	GSR1	Position & Height	-0,0040	0,0017	-0,0007
4	KDA2	KDA2	Position & Height	-0,0036	-0,0049	0,0008
5	PORE	PORE	Position & Height	-0,0001	0,0025	-0,0003
6	PZA2	PZA2	Position & Height	0,0031	0,0070	0,0003

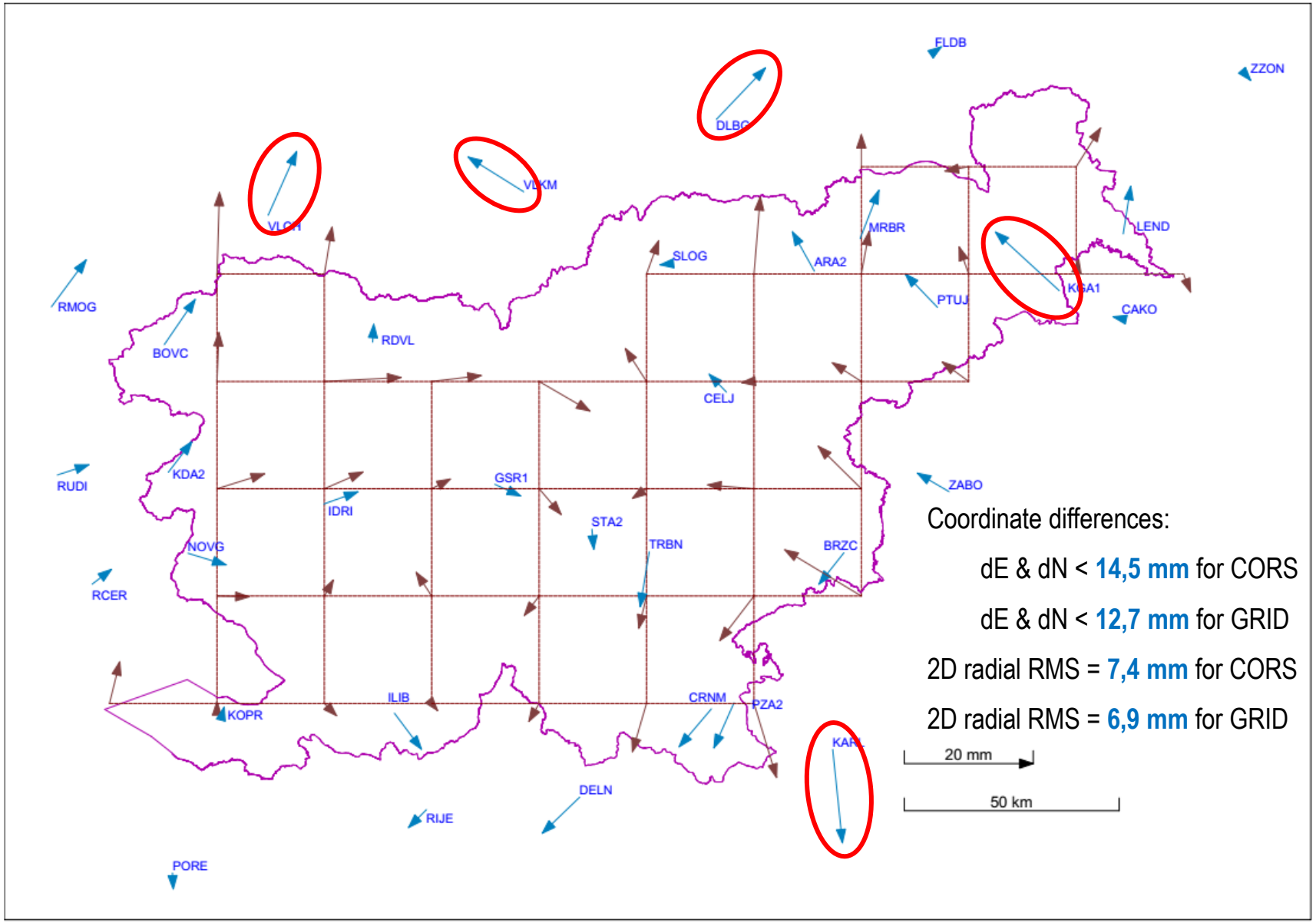
Similar results (transformed coordinates up to ±2 mm) obtained:

- with additional tie point GRAZ north-east of the country or
- using 6-parameter (rigid) transformation (with the same set of tie points)

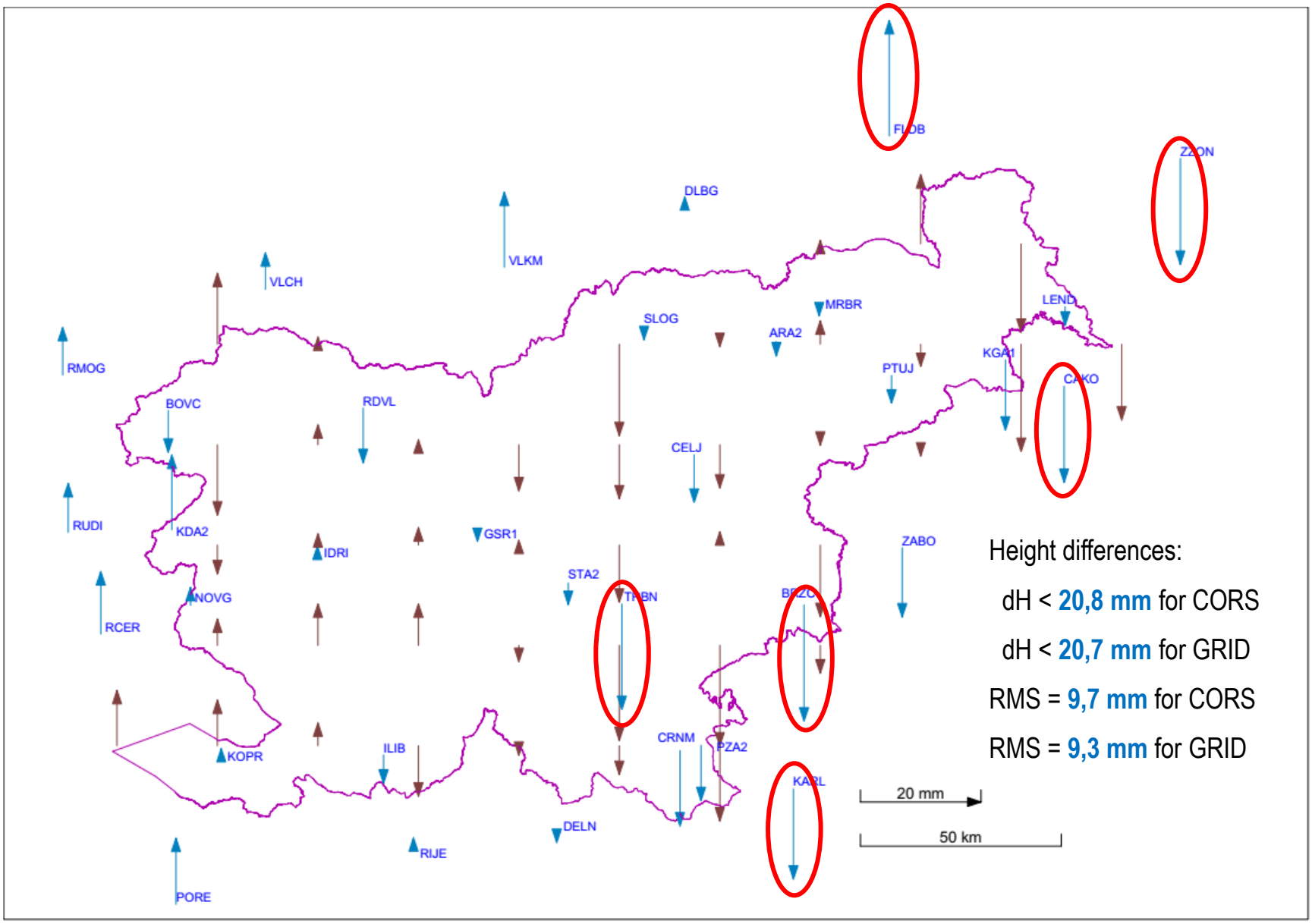
Coordinate residuals:

dE & dN < **7,0 mm**
dH < **0,8 mm**

Comparison of the Reference and Computed Hz Coordinates in the National CRS (D96-17)



Comparison of the Reference and Computed Ellipsoidal Heights in the National CRS (D96-17)



Conclusions

- The Grid Check method can validate:
  - the quality of the CORS network coordinates and
  - the quality of the CORS network positioning services.
- Free online services such as AUSPOS or CSRS-PPP are easy to use and provide good results.
- Majority of the work is done with the acquisition of CORS RINEX data and VRS RINEX data for the grid.
- Decline in the quality may arrise from:
  - intraplate deformations and earthquakes,
  - construction works and local deformations,
  - GNSS signal interference (solar activity, jamming & spoofing),
  - GNSS signal multipath (eg. new obstacles),
  - GNSS equipment changes (especially antenna changes),
  - receiver settings or firmware upgrades.

Acknowledgement

The **GRID CHECK** presented here is carried out following the example of the Netherlands, presented in 2021 at the 30th EUREF Symposium in Ljubljana: http://www.euref.eu/sites/default/files/symposia/2021Online-from-Ljubljana/03-06-Huisman.pdf.

Detailed explanations and support from **Lennard Huisman** are highly appreciated.

Thank you for your attention

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