



EUREF densification campaign in Republic of Serbia

F. Kostadinović, J. Matić Varenica



REPUBLIC GEODETIC AUTHORITY
OF SERBIA



Background

- The official reference system of the Republic of Serbia is **ETRS89**, implemented through the conventional reference frame **ETRF2000** (epoch 2010.631)
- The **EUREF Serbia 2010 campaign** established the official geodetic reference system of the Republic of Serbia
- This campaign was **validated by EUREF** as a **Class B densification** of the EUREF network
- It ensured alignment of the national GNSS infrastructure with European standards and provided a high-precision reference for geodetic activities

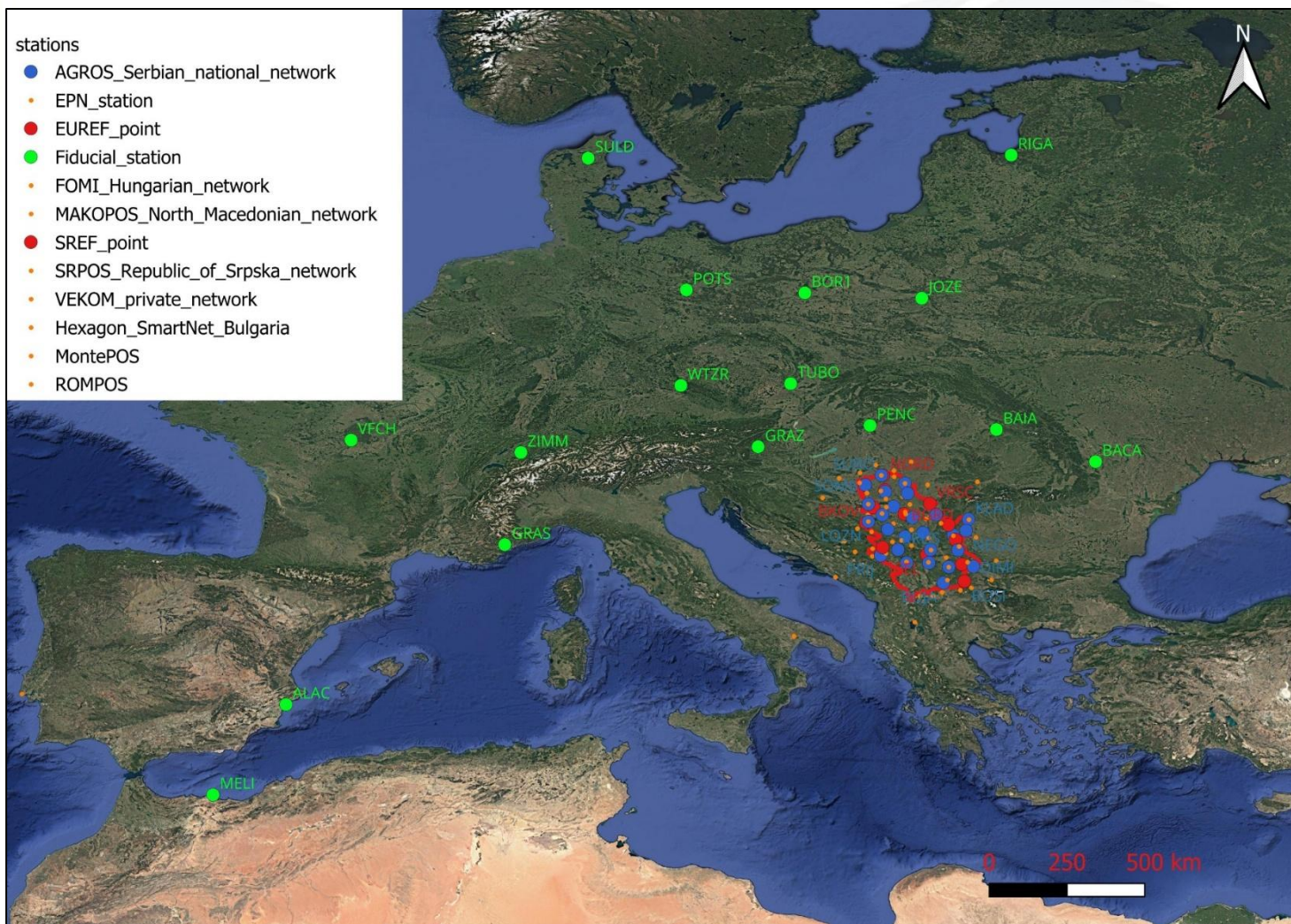


Purposes of the campaign in 2023

- **Maintain** and **monitor** the densification of the European Terrestrial Reference Frame (ETRF) within the territory of the Republic of Serbia
- Ensure the **integrity** and **stability** of the existing national ETRS89 realization, established by previous EUREF densification campaigns
- Compute the **coordinates** of geodetic points in the **ITRF2020/IGS20 reference frame**
- Further densify the European Terrestrial Reference Frame within Serbia
- Strengthen Serbia's integration into the European geodetic framework



Description of the campaign



Carried out from **July 16** to **August 19, 2023**

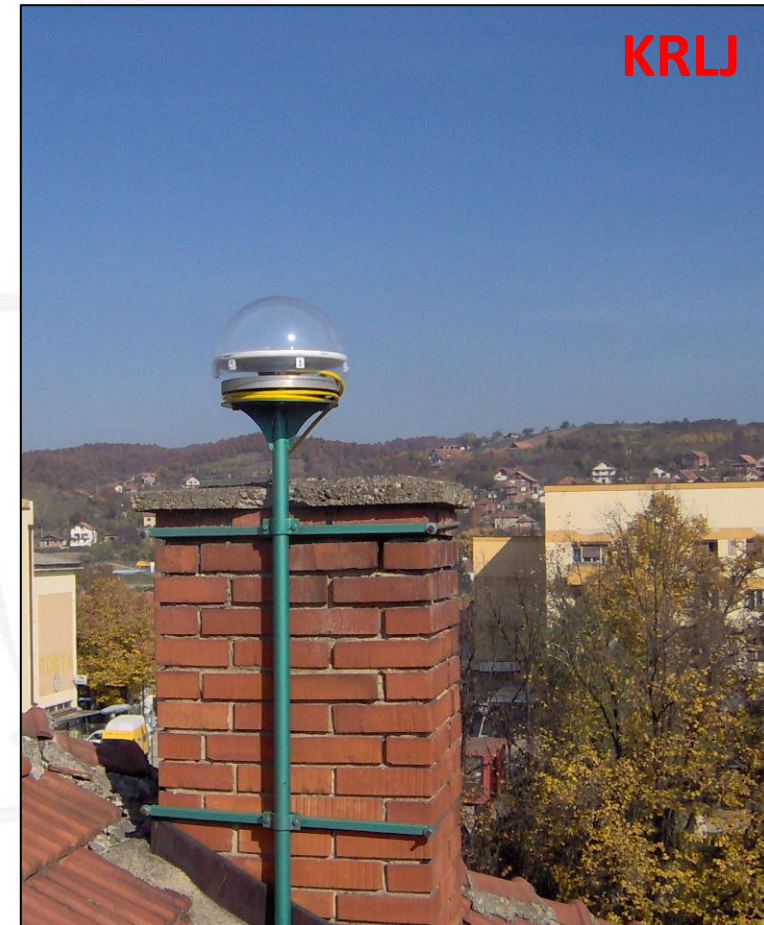
The campaign included a total of **118 points**:

- **25 EPN station**
- **18 stations** from national permanent networks of surrounding country
- **7 stations** from EUREF Serbia 2010 campaign
- **5 stations** from the geodetic reference basis of Serbia (SREF)
- **27 permanent GNSS stations** from the national reference network of permanent GNSS stations (AGROS)
- **36 permanent GNSS stations** from VEKOM private network.



Description of the campaign

Monument type of AGROS station





Description of the campaign

Monument type field points





Description of the campaign

Other data used
in the processing

Products	Sources
Final, precise GPS orbits	http://ftp.aiub.unibe.ch/CODE/yyyy/, COD0OPSFIN_yyyyddd0000_01D_05M_ORB.SP3.gz
Earth rotation parameters	http://ftp.aiub.unibe.ch/CODE/yyyy/, COD0OPSFIN_yyyyddd0000_01D_01D_ERP.ERP.gz
Satellite and reference (station) clock corrections	http://ftp.aiub.unibe.ch/CODE/yyyy/, COD0OPSFIN_yyyyddd0000_01D_30S_CLK.CLK.gz
Global Ionosphere maps	http://ftp.aiub.unibe.ch/CODE/yyyy/, COD0OPSFIN_yyyyddd0000_01D_01H_GIM.ION.gz
Code/phase biases	http://ftp.aiub.unibe.ch/CODE/yyyy/, COD0OPSFIN_yyyyddd0000_01D_01D_OSB.BIA.gz
Antenna correction model	http://ftp.aiub.unibe.ch/BSWUSER54/REF/I20.ATX https://gnpcvdb.geopp.de/gpppcvdb/125
Special cases of antenna correction model used in EPN	https://epncb.oma.be/pub/station/general/epnc_20.atx
Ocean tides loading	http://holt.oso.chalmers.se/loading/ , Ocean tide model FES2004b, without correction for the center of mass motion of the Earth, BLQ format
RINEX files for EPN stations	https://igs.bkg.bund.de/root_ftp/%site% (%site% is the marker name) All RINEX files for EPN stations are downloaded from the ftp server of the Bundesamt für Kartographie und Geodäsie (Agency acronym: BKG)
Coordinates and velocities of EPN fiducial station	http://ftp.aiub.unibe.ch/BSWUSER54/REF/IGS20.CRD http://ftp.aiub.unibe.ch/BSWUSER54/REF/IGS20.VEL ftp://itrf-ftp.ign.fr/pub/itrf/itrf2020/ITRF2020-IGS-TRF.SNX.gz
EPN daily SINEX solutions	https://igs.bkg.bund.de/root_ftp/EUREF//products/www/, EUR0OPSSNX_YYYYDDD0000_01D_01D_SOL.SNX files



Description of the campaign

Fiducial stations

4-char ID	DOMES number	FULL NAME	Solution
ALAC	13433M001	ALICANTE	ITRF2020
BACA	11405M001	BACAU	ITRF2020
BAIA	11406M001	BAIA MARE	ITRF2020
BOR1	12205M002	BOROWIEC	IGS20
GRAS	10002M006	CAUSSOLS	IGS20
GRAZ	11001M002	GRAZ	IGS20
JOZE	12204M001	JOZEFOSLAV	IGS20
MELI	19379M001	MELILLA	IGS20
PENC	11206M006	PENC	IGS20
POTS	14106M003	POTSDAM	IGS20
RIGA	12302M002	RIGA	IGS20
SULD	10113M001	SULDRUP	ITRF2020
TUBO	11503M001	TUBO	ITRF2020
VFCH	10046M001	VILLEFRANCHE-SUR-CHER	ITRF2020
WTZR	14201M010	BAD KOETZTING	IGS20
ZIMM	14001M004	ZIMMERWALD	IGS20



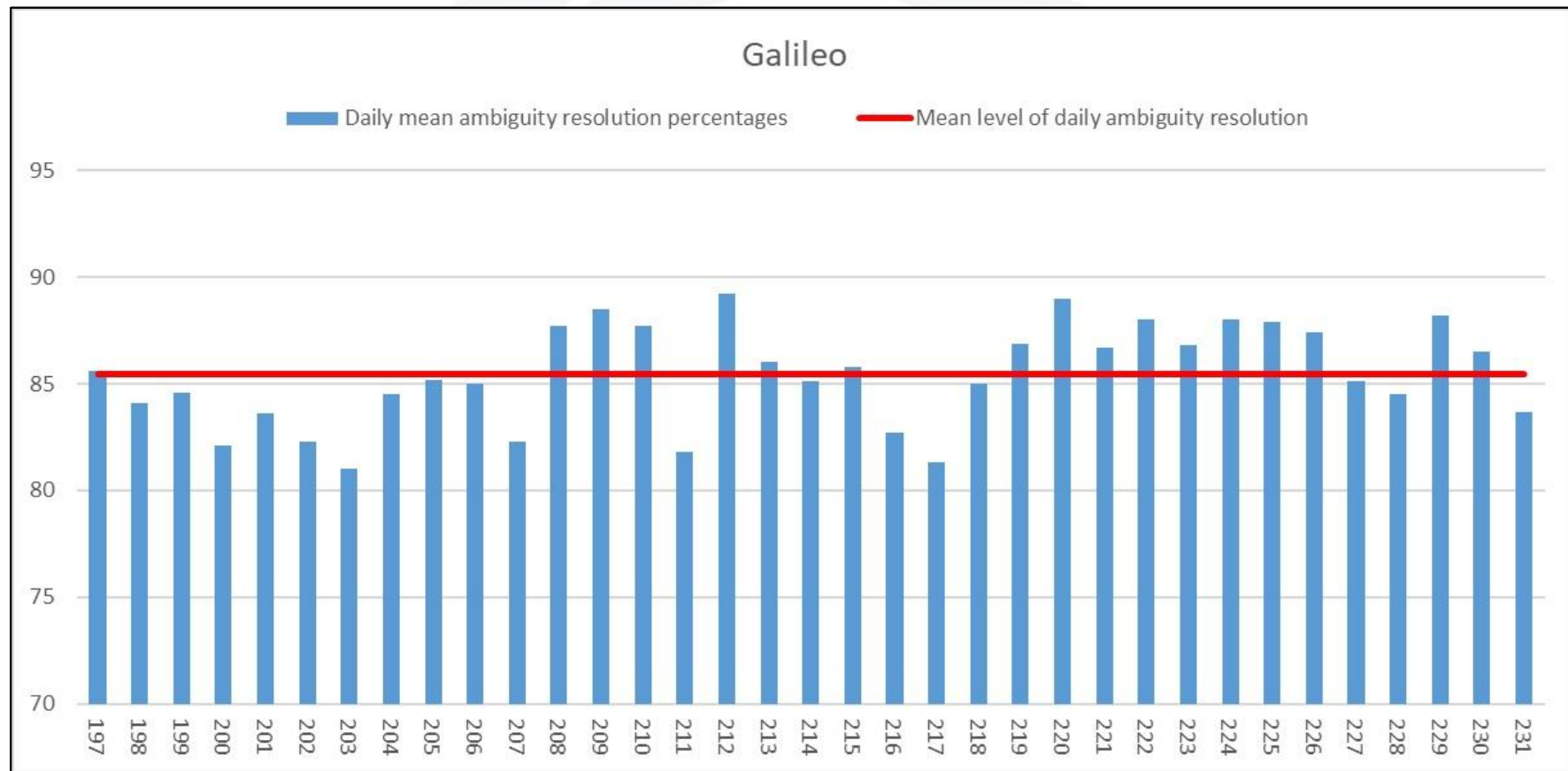
Processing

- Processing was conducted from **July to November 2024** by the Republic Geodetic Authority
- Following the “Guidelines for the EPN Analysis Centres”
- **Bernese GPS Software**, version 5.4, update October 16, 2023
- Datum definition type: **Minimum constraint solution with no-net translation condition**



Results

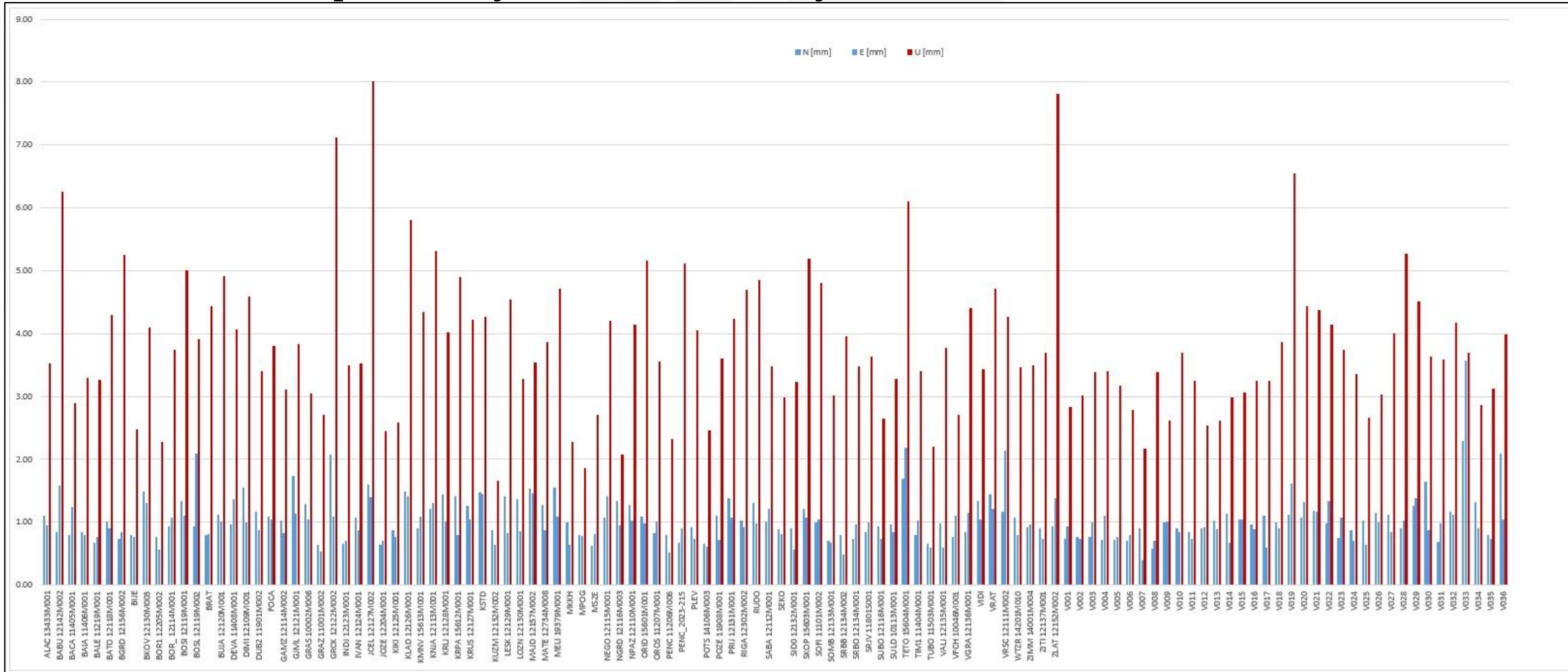
Daily mean ambiguity resolution percentages





Results

Coordinate repeatability based on the daily solutions





Results

Elevation cut – off test

- A test solution with a 25° cut-off angle was produced and compared to the final network solution

	RMS of differences		
	N	E	U
	[mm]	[mm]	[mm]
Total	1.53	1.80	21.71

- The stations where site-dependent effects are most evident include SID0, KLAD, IVAN, VGRAD, and PENC_2023-215



Results

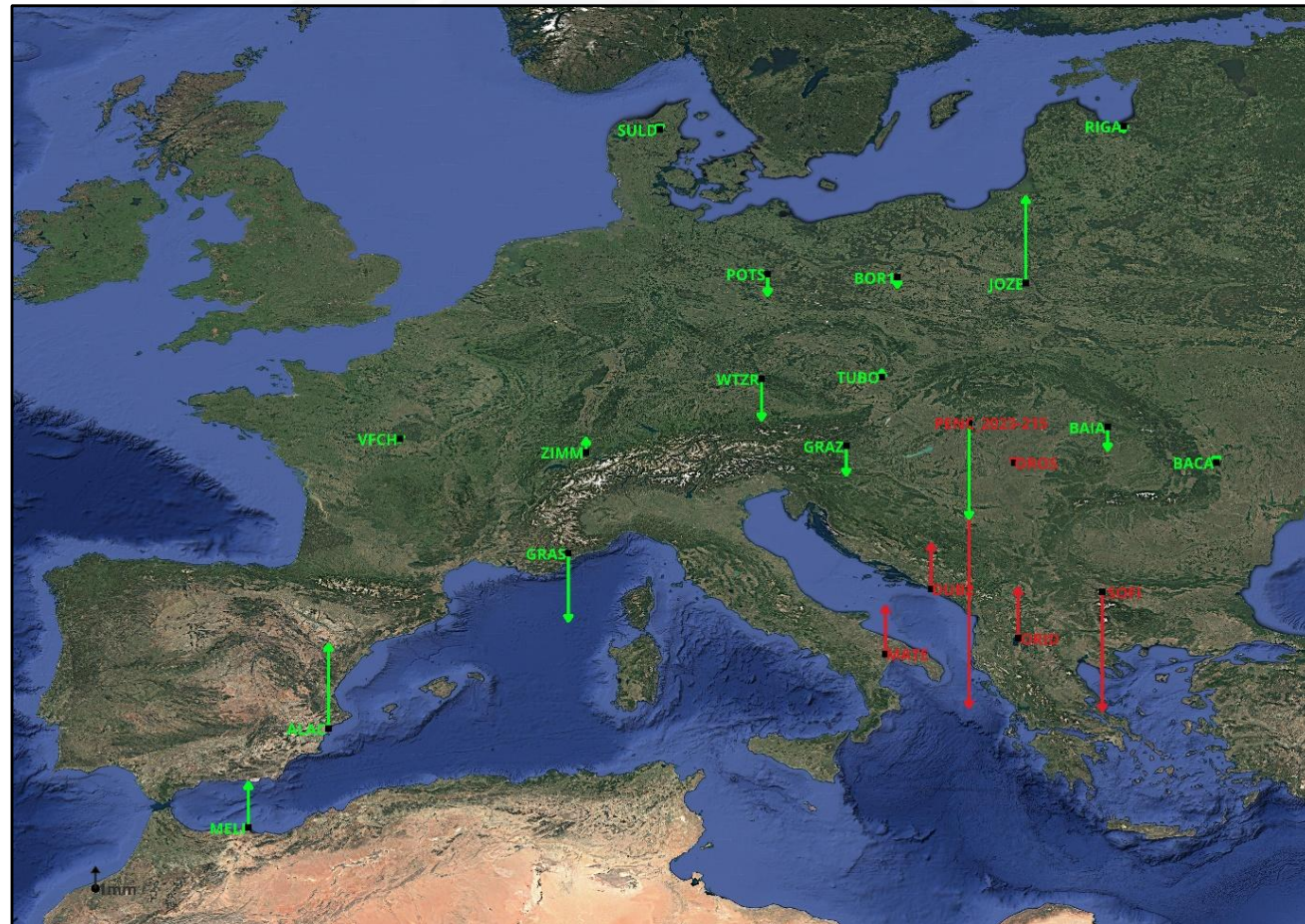
Comparison between the final network solution and ITRF2020/IGS20 coordinates

Station	a plain comparison		
	N	E	U
	[mm]	[mm]	[mm]
ALAC 13433M001	3.02	1.23	3.88
BACA 11405M001	-0.73	-0.34	-0.06
BAIA 11406M001	-0.36	-1.13	-1.08
BOR1 12205M002	-0.40	-0.71	-0.50
DUB2 11901M002	-0.07	-2.68	2.09
GRAS 10002M006	2.39	1.32	-3.13
GRAZ 11001M002	0.09	-0.40	-1.36
JOZE 12204M001	-1.96	-2.02	3.97
MATE 12734M008	0.17	1.55	2.20
MELI 19379M001	4.31	-0.06	2.09
ORID 15601M001	1.11	0.58	2.32
OROS 11207M001	1.21	-3.25	-0.13
PENC 11206M006	-1.24	0.45	-4.40
POTS 14106M003	-0.92	-0.49	-1.01
RIGA 12302M002	-1.01	-0.18	-0.30
SOFI 11101M002	-0.41	1.44	-5.44
SULD 10113M001	-1.73	-0.74	-0.11
TUBO 11503M001	0.83	-0.32	0.34
VFCH 10046M001	0.78	1.12	-0.18
WTZR 14201M010	-0.96	1.31	-1.91
ZIMM 14001M004	-0.27	0.38	0.66
PENC_2023-215	-0.43	2.68	-13.04
RMS	1.71	0.92	2.14



Results

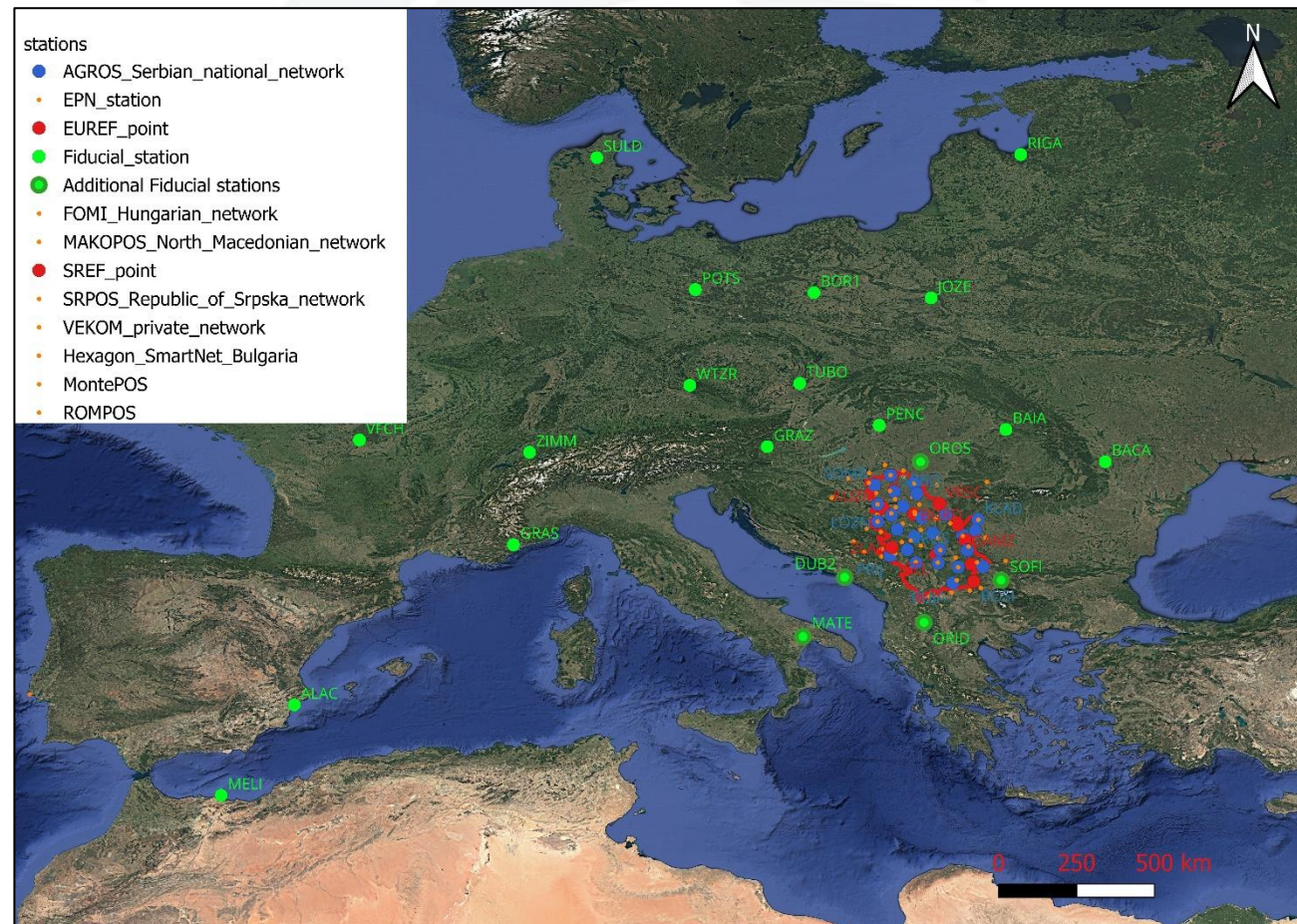
Comparison between the final network solution and ITRF2020/IGS20 coordinates





Results

Additional fiducial stations





Results

Comparison between the originally submitted solution and the EUREF GB recommended solution incorporating additional fiducial stations

a plain comparison	RMS of differences		
	N	E	U
	[mm]	[mm]	[mm]
Total	0.09	0.13	0.04

3 translation parameters	RMS of differences		
	N	E	U
	[mm]	[mm]	[mm]
Total	0.00	0.00	0.01

PARAMETERS:	[mm]
TRANSLATION IN X	-0.01
TRANSLATION IN Y	0.14
TRANSLATION IN Z	-0.09



Results

- An alternative campaign solution was produced
- The difference from the final network solution lies in the type of datum definition used
- The daily campaign solutions were combined with the corresponding daily EPN solutions

Station	a plain comparison		
	N	E	U
	[mm]	[mm]	[mm]
ALAC 13433M001	-0.28	0.83	0.88
BACA 11405M001	-0.53	0.05	1.34
BAIA 11406M001	-0.55	0.35	0.87
BOR1 12205M002	-0.67	0.22	0.76
DEVA 11408M001	-0.61	0.39	1.39
DUB2 11901M002	-0.58	0.13	1.64
GJML 12121M001	-0.46	0.18	1.24
GRAS 10002M006	-0.37	0.38	-0.01
GRAZ 11001M002	-0.43	0.28	1.26
JOZE 12204M001	-0.72	0.17	1.84
KNJA 12113M001	-0.61	0.26	3.85
MATE 12734M008	-0.34	0.28	2.19
MELI 19379M001	-0.26	0.92	0.23
NPAZ 12110M001	-0.47	0.24	1.22
ORID 15601M001	-0.26	0.04	1.89
OROS 11207M001	-0.63	0.22	1.31
PENC 11206M006	-0.65	-0.12	0.08
POTS 14106M003	-0.62	0.35	0.17
POZE 11908M001	-0.52	0.14	1.76
RIGA 12302M002	-0.39	0.45	0.16
SABA 12112M001	-0.50	0.26	0.87
SID0 12132M001	-0.70	0.15	1.37
SOFI 11101M002	-0.31	-0.08	0.50
SRJV 11801S001	-0.50	0.33	1.52
SUBO 12116M001	-0.60	0.17	3.71
SULD 10113M001	-0.45	0.34	-0.16
TUBO 11503M001	-0.51	0.25	1.50
VFCH 10046M001	-0.44	0.64	0.43
WTZR 14201M010	-0.65	0.31	1.32
ZIMM 14001M004	-0.82	-0.12	0.68
RMS	0.53	0.35	1.51



Results

Transformation to ETRS89

- Transformation to the ETRS89 is done by tools and services available on the **EPN website**
- The coordinates were propagated from epoch **2023.586** to epoch **2010.631** using the EuVeM2022_HV-LSC-ex_LSC-ex2_ETRF2000 model



Results

Comparison with previous ETRS89 densification

Station	a plain comparison		
	N [mm]	E [mm]	U [mm]
BABU 12142M002	-28.65	-19.04	-23.02
BOR_ 12114M001	6.08	-2.05	-3.52
DIMI 12109M001	-4.34	-0.17	-6.22
IVAN 12124M001	-4.28	-3.49	10.32
JCEL 12127M002	-22.34	-1.76	18.93
KIKI 12125M001	-3.01	7.65	6.24
KLAD 12126M001	8.03	9.80	-8.79
KNJA 12113M001	-4.20	-2.26	17.59
KRLJ 12128M001	0.76	-4.08	-6.77
KRUS 12127M001	-8.36	-0.07	-4.54
KUZM 12132M002	-1.03	-1.38	-10.06
LESK 12129M001	-0.90	1.48	32.57
LOZN 12130M001	-5.80	-5.96	20.95
MAJD 12157M002	-12.18	-18.01	6.00
NEGO 12115M001	-1.00	0.04	-8.70
NGRD 12116M003	-8.95	12.03	-7.87
NPAZ 12110M001	2.38	0.66	-24.28
PRIJ 12131M001	6.84	15.79	-2.22
SABA 12112M001	-2.13	2.63	15.79
SOMB 12133M001	-1.92	0.47	-0.59
SRBB 12134M002	-9.46	-20.61	-11.23
SUBO 12116M001	-3.96	1.53	-7.07
VALJ 12135M001	-7.24	-3.30	33.74
VGRA 12136M001	-8.36	-3.60	7.22
ZITI 12137M001	-1.22	4.08	-5.98
ZLAT 12152M002	-6.93	2.67	14.00
RMS	9.11	8.32	14.88

Non-geodetic antennas
(TRM39105.00 NONE) were
used in the previous campaign

Station	a plain comparison		
	N [mm]	E [mm]	U [mm]
BOSI 12119M001	7.57	-1.69	-109.03
GJML 12121M001	5.07	-12.97	-16.25
INDJ 12123M001	-4.67	-1.79	15.95
SID0 12132M001	-9.05	8.49	-99.19
SRBO 12134M001	4.25	30.76	-15.07
RMS	6.40	15.44	67.04

Station with issues

Station	a plain comparison		
	N [mm]	E [mm]	U [mm]
BUJA 12120M001	-4.31	-1.49	198.66



Results

Alternative Transformation to ETRS89

- During the EUREF Symposium 2024, Dr. Martin Lidberg, proposed an alternative transformation approach to ETRS89 that aims to better **align** with existing national realizations while maintaining **consistency** with recent reference frame updates
- The proposed transformation preserves the vertical positions and velocities from ETRF2020 to ensure consistency with ITRF2020, while applying a static Euler pole rotation to derive a version of ETRF2000
- Transformation from **ITRF2020/IGS20 2023.586** to **ETRF2020rot 2010.631** is done by an in-house Python-based program
- The coordinates were propagated from epoch 2023.586 to epoch 2010.631 using the EuVeM2022_HV-LSC-ex_LSC-ex2_ETRF2014 model, implemented with **bilinear interpolation** within the same Python tool



Results

Comparison with previous ETRS89 densification

Station	a plain comparison		
	N	E	U
	[mm]	[mm]	[mm]
BABU 12142M002	-25.26	-9.84	-35.44
BOR_ 12114M001	9.49	6.82	-14.15
DIMI 12109M001	-0.93	9.10	-18.80
IVAN 12124M001	-0.98	5.43	-0.35
JCEL 12127M002	-18.95	7.25	7.54
KIKI 12125M001	0.09	16.07	-0.70
KLAD 12126M001	11.48	18.51	-18.58
KNJA 12113M001	-0.78	6.71	6.14
KRLJ 12128M001	4.10	5.08	-18.65
KRUS 12127M001	-5.06	8.85	-15.60
KUZM 12132M002	2.10	7.28	-18.07
LESK 12129M001	2.40	10.75	20.12
LOZN 12130M001	-2.71	2.66	12.11
MAJD 12157M002	-8.87	-9.28	-3.81
NEGO 12115M001	2.40	8.91	-19.18
NGRD 12116M003	-5.91	20.20	-14.12
NPAZ 12110M001	5.71	9.60	-35.92
PRIJ 12131M001	9.98	24.71	-13.08
SABA 12112M001	0.99	11.33	7.22
SOMB 12133M001	1.16	8.84	-7.10
SRBB 12134M002	-6.24	-12.25	-18.34
SUBO 12116M001	-0.92	9.88	-13.29
VALJ 12135M001	-4.08	5.36	24.29
VGRA 12136M001	-5.04	5.05	-1.99
ZITI 12137M001	1.92	12.45	-13.57
ZLAT 12152M002	-3.67	11.56	3.51
RMS	7.93	11.28	16.60



Conclusions

- The internal quality of the EUREF Serbia 2023 solution is typically around **1 to 2 mm** in **N** and **E** and around **3 to 5 mm** in **U**
- The coordinate recoveries of fiducial stations indicate that ITRF2020/IGS20 for EUREF Serbia 2023 is realized to around **2 mm** in all three components
- The comparison with the EUREF Serbia 2010 campaign shows an RMS agreement within **10 mm** in the horizontal components and **15 mm** in the vertical component
- A separate analysis was conducted for the stations BOSI, GJML, INDJ, SID0, and SRBO, as non-geodetic antennas were used in the previous campaign. The results show that the new campaign agrees with the previous one, with RMS residuals of approximately **15 mm** in the horizontal and **50 mm** in the vertical components
- A significant height anomaly of **20 cm** was detected at station BUJA. Despite comparisons with AGROS processing and analysis of all available data, the cause of the height jump remains unexplained



Conclusions

- When comparing the results of the alternative transformation, an RMS agreement of approximately **10 mm** in the horizontal components and **15 mm** in the vertical component was obtained at the reference epoch 2010.63
- These results are on the same level as those obtained using the standard ETRF2000 transformation
- The EUREF Serbia 2023 campaign, with the exclusion of the VEKOM network, is proposed for EUREF validation



Thank you for your attention

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www.rgz.gov.rs

Email:

office@rgz.gov.rs

gs@rgz.gov.rs