

EUREF 2025 SYMPOSIUM



Scientific Sessions Posters



INSTITUTO
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ESTIMATION OF GNSS STATION COORDINATES IN THE HITECHNIQUES NETWORK

ABSTRACT: This study presents the results of a 10-day GNSS data processing campaign conducted on a dense network of stations operated by Hitechniques Ltd. in Ireland. The observations were processed using the GAMIT/GLOBK software suite, with GPS and Galileo signals and precise products from the IGS20 reference frame. The quality of the estimated coordinates was evaluated through residual analysis and comparison with a set of reference and control stations from the SmartNet Ireland network. The results confirm the consistency and reliability of the Hitechniques network for precise geodesy applications. Analyses have also shown that the coordinates align with the Irish realization, which, however, deviates from the latest EUREF solutions.

The analyzed network consisted of a total of 56 stations (Table 1). In addition to the Hitechniques stations, the network included selected OSI (Ordnance Survey Ireland) and EPN (EUREF Permanent GNSS Network) stations used as reference stations for coordinate estimation, as well as a separate subset of OSI stations incorporated for the purpose of independent quality control (Figure below). The analyses were performed using the GAMIT/GLOBK software package, following the processing strategy adopted by the IUPAC Center for regional GNSS solutions (Table 2).

Table 2. Processing strategy:

Group	Parameter Notes
Software	GAMIT v.10.7.1
Observations	GPS+Galileo, ionosphere-free code and phase combination
Orbits	CODE (IGS20)
Antennas/models	EC501 (p20, 2342, 24)
Clocks	IGS20
Troposphere	GPT3n as prior, 1x ZTD estimated and 2x gradient
Tide	ERS0204, FES2014b
Reduction	
Period	01.12.2024 – 10.12.2024 (10 days)
Frame realization	9 fiducial stations belonging to SmartNet Ireland (Tab. 3).

Table 3. Phase ambiguity resolution [s]

	0117	0118	0117	0117	0117	0117	0117	0117	0117	0117	0117
WLS	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8
WLS	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8
WLS	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8
WLS	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8

▲ Stations used in analysis ▲

The coordinates of the Hitechniques network were estimated using two different sets of reference stations (Table 4). In the first approach, a subset of nine OSI stations was used – those from a formal realization of ETRF09. In the second, selected stations from the EPN (EUREF Permanent GNSS Network) were employed. Some stations were common to both reference station sets; however, the resulting coordinate differences between the two solutions were significant. Given that the Hitechniques network must remain consistent with the OSI framework, the solution based on OSI stations was ultimately chosen, despite the resulting greater discrepancies when compared to EUREF-based coordinates.

Table 4. Reference coordinates in ETRF2000 epoch 2009.756.

Station ID	X [m]	Y [m]	Z [m]	Station ID	X [m]	Y [m]	Z [m]
OSI1	377205.407	-523932.360	5099435.229	OSI2	-	-	-
OSI3	3488499.550	-387026.598	5159122.227	OSI4	-	-	-
OSI5	3101435.676	-551369.404	4996476.556	OSI6	-	-	-
OSI7	3726882.427	-481739.865	5136439.136	OSI8	-	-	-
OSI9	3760851.362	-454417.513	5191371.982	OSI10	-	-	-
OSI11	3405893.837	-464045.278	5225307.333	OSI12	-	-	-
OSI13	3472322.046	-476578.557	5129496.052	OSI14	-	-	-
OSI15	3797203.484	-423484.665	5190128.446	OSI16	-	-	-
OSI17	3877520.012	-700589.992	4996722.365	OSI18	-	-	-

* not reduced for the epoch (no velocities available)

The main coordinate differences with respect to the catalog values were -0.3 mm in the north component, 0.7 mm in the east component, and 2.3 mm in the up component (Figures on the right). The corresponding standard deviations were 3.2 mm, 3.6 mm, and 13.1 mm, respectively. These results indicate a high consistency of the adjusted network with the reference system, with residual discrepancies remaining within the expected range for high-precision GNSS processing.

Residuals from reference stations coordinates (OSI) ►

for horizontal (left) component and height (right) ►

▲ Residuals from control stations coordinates for

horizontal (left) component and height (right) ►

A comparison between the estimated coordinates and the catalog values at the control stations belonging to the OSI network yielded mean coordinate differences of -0.3 mm (East), -0.9 mm (North), and 6.5 mm (Up) (Figures on the left). Horizontal coordinate differences at most stations remained within 120 mm, while vertical differences were generally below 120 mm. However, a few stations showed larger discrepancies (up to 105.8 mm), and one station (MFLT) showed a discrepancy of 105.8 mm, which may indicate local site instabilities or outdated reference values.

These results confirm that the adjusted GNSS Hitechniques network is consistent with the official realization of the reference frame used in Ireland, as maintained by OSI.

Hitechniques: High-Availability RTK Network for Ireland: Coarsely positioned, target density (40-60 km) reference stations network enables full coverage. Features: GCPs - CHIRAS for processing and Nematico GCPDS for casting, supporting GPS, GLONASS, Galileo, and BeiDou. Custom hardware enhances reliability.



Table 1. List of used stations and their equipment.

Station ID	Type	Receiver	Antenna
OSI1	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI2	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI3	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI4	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI5	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI6	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI7	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI8	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI9	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI10	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI11	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI12	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI13	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI14	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI15	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI16	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI17	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI18	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI19	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI20	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI21	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI22	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI23	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI24	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI25	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI26	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI27	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI28	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI29	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI30	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI31	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI32	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI33	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI34	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI35	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI36	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI37	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI38	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI39	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI40	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI41	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI42	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI43	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI44	Hitechniques	COMNAV 4010 PRO	OSI010101
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OSI46	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI47	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI48	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI49	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI50	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI51	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI52	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI53	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI54	Hitechniques	COMNAV 4010 PRO	OSI010101
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OSI56	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI57	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI58	Hitechniques	COMNAV 4010 PRO	OSI010101
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OSI60	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI61	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI62	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI63	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI64	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI65	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI66	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI67	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI68	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI69	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI70	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI71	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI72	Hitechniques	COMNAV 4010 PRO	OSI010101
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OSI85	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI86	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI87	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI88	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI89	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI90	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI91	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI92	Hitechniques	COMNAV 4010 PRO	OSI010101
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OSI94	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI95	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI96	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI97	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI98	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI99	Hitechniques	COMNAV 4010 PRO	OSI010101
OSI100	Hitechniques	COMNAV 4010 PRO	OSI010101

Table 5. Estimated coordinates in ETRF2000 epoch 2009.756.

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OSI17	3877520.012	-700589.992	4996722.365	OSI18	-	-	-

* Stations that were included after the initial network adjustment were subsequently included using the same GNSS processing and adjustment scheme.

Estimation of GNSS station coordinates in the Hitechniques network

Andrzej Araszkiewicz^a, Dariusz Liszka^b

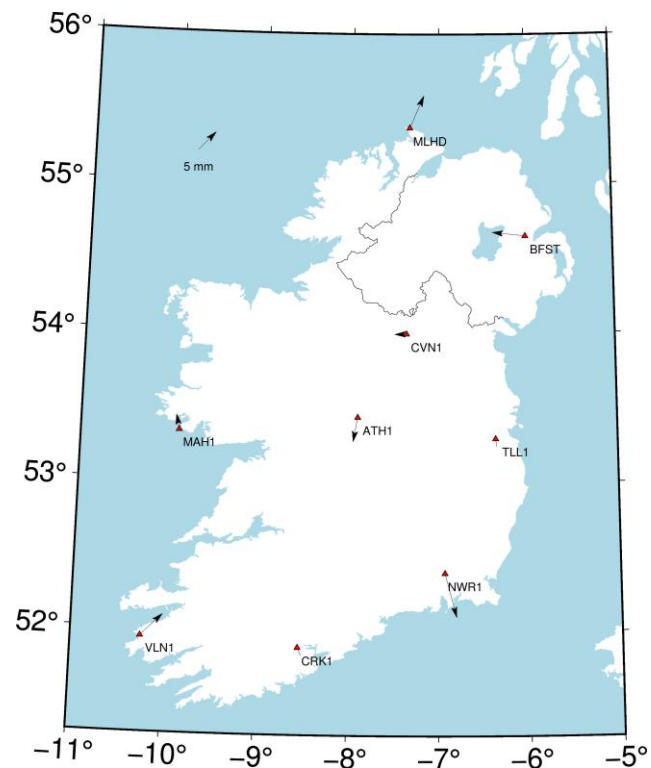
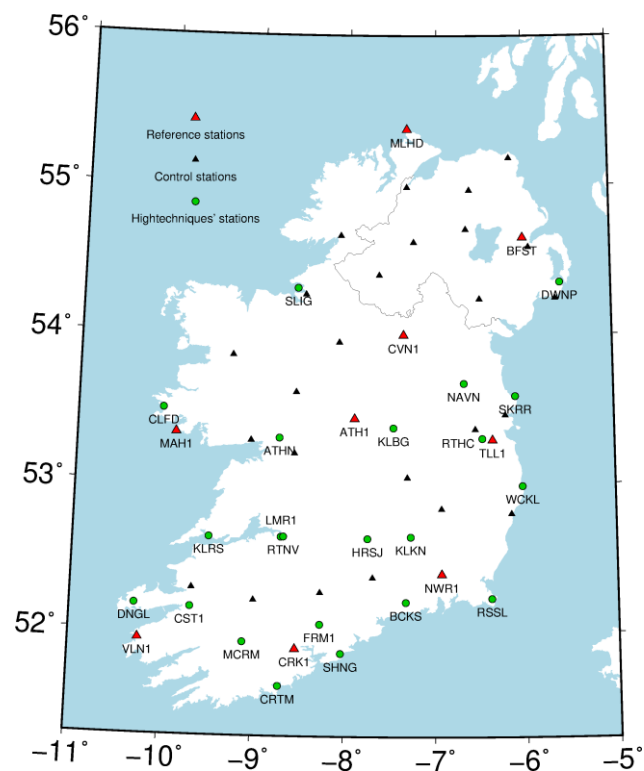
^a) Military University of Technology, Poland

^b) Hitechniques Ltd., Ireland



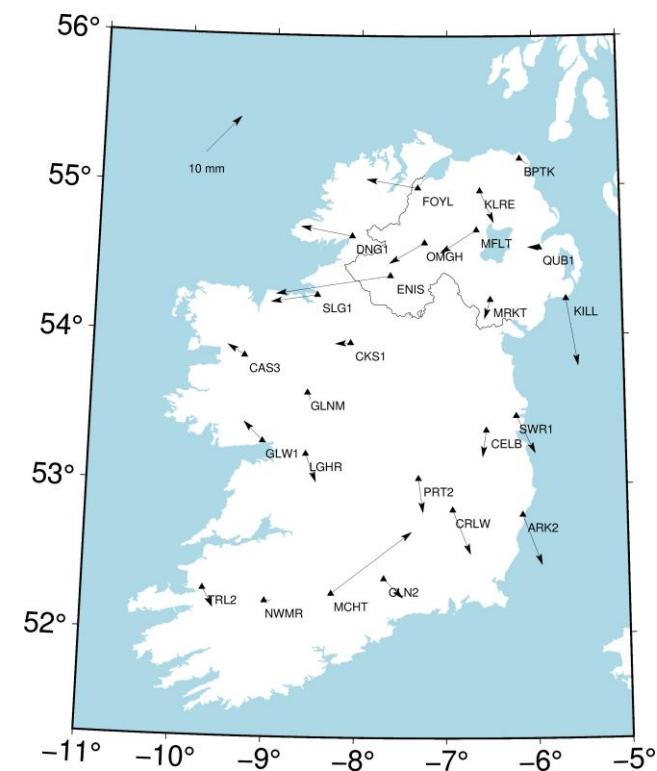
- 10-day GNSS campaign on a new dense Irish network (Hitechniques Ltd.).
- Processed using GAMIT/GLOBK with GPS, Galileo, and IGS20 products.
- Quality checked via residuals and SmartNet Ireland stations.
- Hitechniques network proven reliable for precise geodesy.
- Coordinates match Irish realization, but differ from latest EUREF.

Stations used in analysis



Residuals from reference stations coordinates

Residuals from control stations coordinates



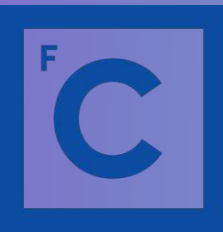
The new Portuguese National Geodetic Network adjustment

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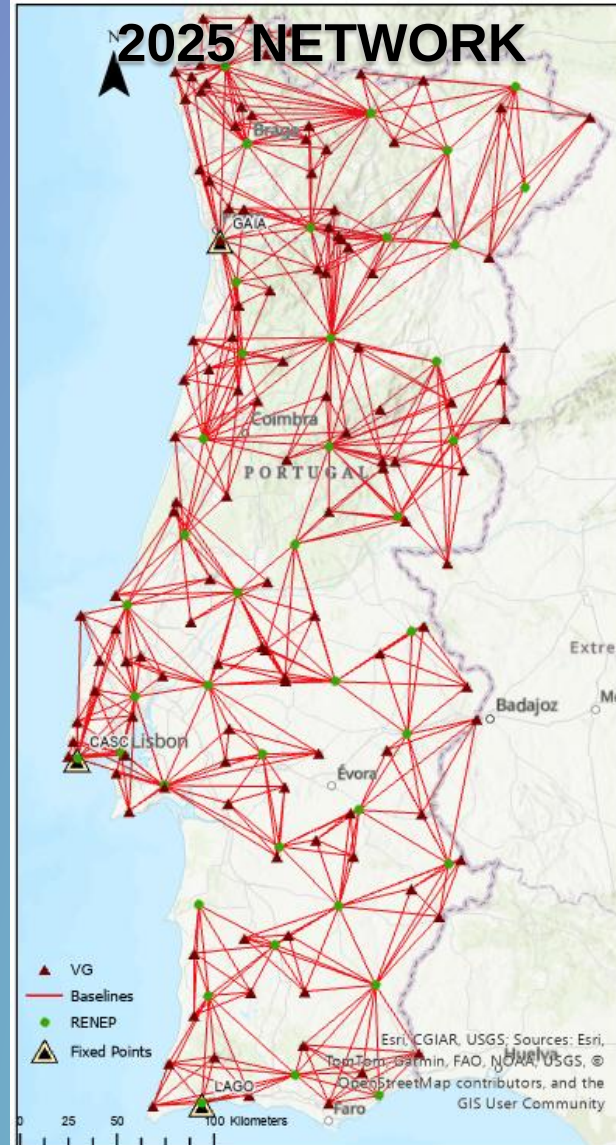


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1997-2005 NETWORK



2025 NETWORK



OBSERVATION CAMPAIGNS

1997-2005

- 127 first-order and 520 second-order vertices observed in mainland Portugal as part of the ETRS89 implementation
- GPS-only receivers
- Only one permanent GNSS station in 1997 (CASC, Cascais)
- Observation files in proprietary Trimble® format with inconsistent metadata

2025

- 130 geodetic landmarks are being re-observed using modern GNSS technologies
- Multi-GNSS (GPS, GLONASS, Galileo and BeiDou)
- Supported by ReNEP, the National CORS Network, which has 42 permanent GNSS stations across Portugal mainland
- Observation files in RINEX format that include comprehensive metadata

ADJUSTMENT STRATEGY

Using Leica Infinity 4.2.0, a two-stage network adjustment was performed:

1. Minimally Constrained Adjustment

Identify gross errors, significant residuals, and evaluate internal inconsistency of the network;

2. Constrained Adjustment

Fix at least three control points to official coordinates from DGT (*Direção-Geral do Território*) to ensure alignment with the national reference frame PT-TM06/ETRS89.

PRELIMINARY RESULTS

• Despite historical data limitations, the adjusted coordinates showed high consistency, with planimetric deviations < 2 mm and vertical deviations ~ 3 mm (orthometric) and ~ 6 mm (ellipsoidal), relative to the official coordinates of the RGN, after excluding problematic baselines;

• However, the F-test value was 4.74 (critical value: 0.97), still suggesting residual inconsistencies;

• The initial 2025 adjustment, performed without baseline removal or error filtering, resulted in a significantly high variance ratio (F-test);

• Ongoing analysis includes outlier detection and baseline validation using the W-test and the T-test.



THANK YOU



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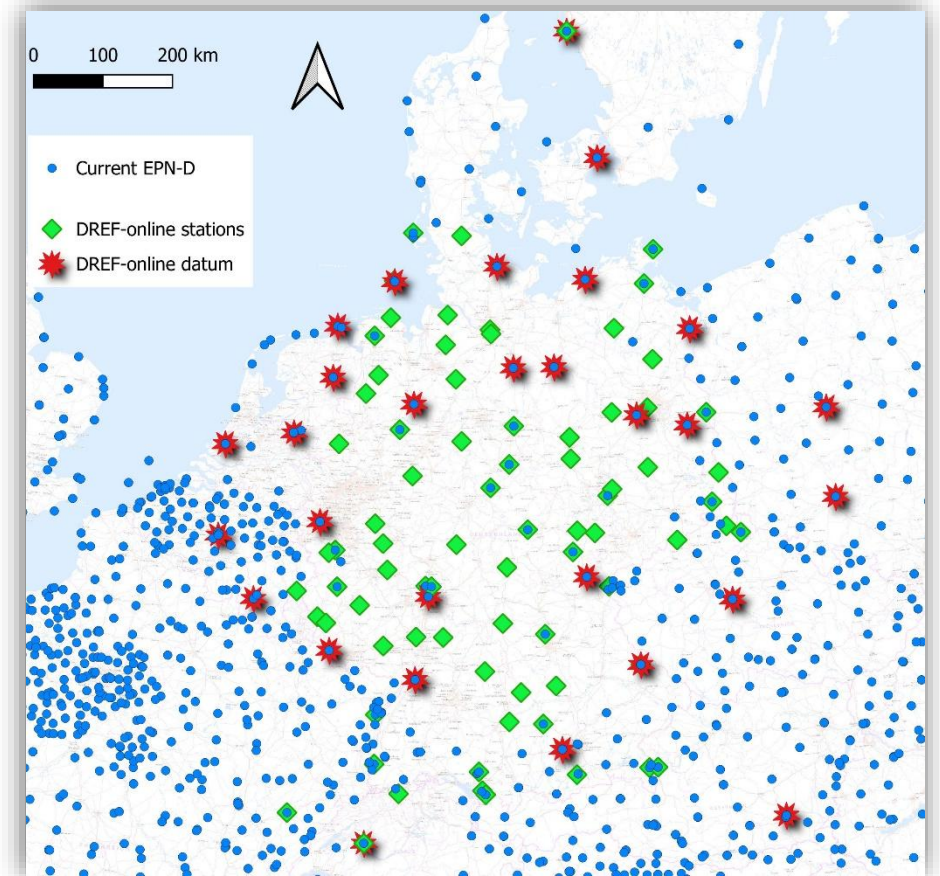
**INSTITUTO
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A permanent GNSS network in Germany joins the EPN-Densification Working Group

Current EPN-D (image from <https://epnd.sgo-penc.hu/station-distribution/>)



After inclusion of DREF-Online network



What does DREF-Online contribute?

- Best quality stations and best possible reference frame products with a low latency.
- 53 new permanent stations for EPN-D.
- Significant improvements of station coverage in Germany.
- Daily and weekly products with CODMOPSRAP orbit.
- ...
- For more details: talk to us!



Federal Agency for
Cartography and Geodesy

A permanent GNSS network in Germany joins the EPN-Densification Working Group

Lin Wang¹, Tetyana Romanyuk¹, Christian Rentsch², Hans-Georg Dick³, Irene Feldmeth³, Huishu Li³, Uwe Hense⁴, Falko John⁵, Sebastian Knappel⁶, Marco Brockmeyer⁷, Martin Freitag⁸, Ole Roggenbuck⁹, Wolfgang Sohne¹, Axel Rülle¹

¹ Federal Agency for Cartography and Geodesy, ² Senatsverwaltung für Stadtentwicklung, Bauen und Wohnen Berlin, ³ Landesamt für Geoinformation und Landentwicklung Baden-Württemberg, ⁴ Landesamt für Geobasisinformation Sachsen, ⁵ Landesamt für Geoinformation und Landesvermessung Niedersachsen, ⁶ Landesamt für Digitalisierung, Breitband und Vermessung Bayern

DREF-Online GNSS Network

- DREF-Online:** Combined network of the Integrated Geodetic Reference Network of Germany (IGREF) and selected SAPOS[®] reference stations
- It links the German reference frame with the European reference system on behalf of the Working Committee of the Surveying Authorities of the Laender of the Federal Republic of Germany (Adv).
 - The main task of DREF-Online is to produce, validate and monitor the German reference frame product.
 - DREF-Online provides the datum in the International Reference Frame to other Analysis Centers in Germany and to support the combination at the federal level.
 - After including the DREF-Online network into the EPN-D, the distribution around German region can be significantly improved and more homogenous in spatial distribution, see Fig. 1.
 - DREF-Online includes the highest quality of German GNSS stations from BKG and federal states to ensure the best quality of the GNSS observation and best possible reference frame products, see Fig. 2.
 - DREF-Online network was initially launched in 2007 and the first operational product was published for the GPS week 1406 (17-23.12.2006). The very first solution includes 47 stations, including 29 IGREF, 10 SAPOS[®] and 8 IGS/EPN stations.

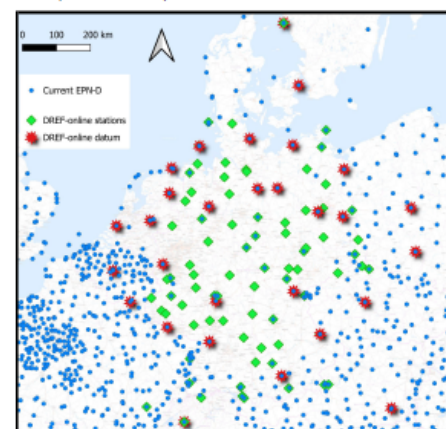


Fig. 1: DREF-Online network distribution (green) and the datum (red) for the process. The current EPN-D network in blue dots.

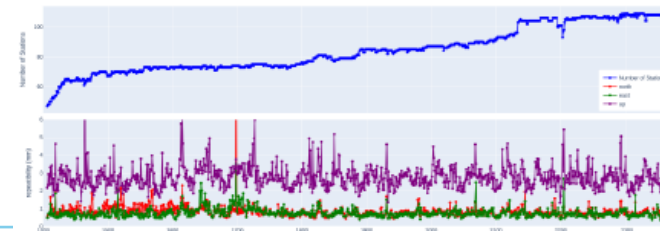


Fig. 2: Number of stations in DREF-Online operational products and the repeatability of the estimated weekly coordinates.

Processing Configurations and Strategy

DREF-Online mainly follows the latest IGS and EPN standard to ensure the consistency to the international datum definition.

Items	Modelling
Software	Bernese GNSS Software v5.3 CODE IGS development branch
Operating System	Red Hat Enterprise Linux 8 in VMware Hypervisor
Mode	Daily Double-Difference network process and weekly Normal Equation stacking process
Station	109 active multi-GNSS Stations 33 new to EPN-D (see Fig. 1) • 38 SAPOS[®] • 26 IGREF
Observable	4G (GPS+GLONASS+Galileo+Beldou) code and phase observations in RINEX 3/ RINEX 4 format with 30s sampling rate, recorded and uploaded to datacenter from receiver
Satellite Orbit/clock	Middle day orbit from Rapid orbit product CODMOPSRAP
A prior TRF	IGS20 with velocity and post-seismic deformation corrections, seasonal variations omitted
Tropospheric delay	VMF3 grid (1 degree X 1 degree), zenith tropospheric wet delay with 1 hourly piece wise linear parameter, horizontal gradient daily estimated. Tropospheric parameters are combined at the day boundaries for weekly stacking process
Carrier phase ambiguities	3G (GPS+GLONASS+Galileo) • L1&L2 combination for baseline < 30 km • L1&L3 combination for baseline < 200 km • Q1F combination for baseline < 2000 km • Melbourne-Wübbena combination for baseline < 6000 km
Antenna phase center	Satellite PCV from IGS20.txt Station PCV from IGS20.txt [*]
Station displacements	IGRS 2010 Conventions, atmospheric tidal and non-tidal loading omitted

^{*} Expected to be changed in 2025.

- Access: similarly to IGREF products (open access), DREF-Online product (credential required) is hosted in BKG IGS Datacenter (igs.bkg.bund.de), and it is ready to be submitted to data server of EPN-D.
- Product: Free-net and No-Net-Transition constrained Normal Equation in SINEX format^{*}, estimated coordinates in multiple reference system^{*}, statistical report^{*}.
- Computation effort: ~ 1.5 hour per day.
- Latency: typically 2.8-3.5 days, due to the waiting for CODE CODMOPSRAP Products and computation time. Rather than waiting for the Final products for the better precision, a small trade-off of the orbit precision for a significant lower latency.
- Average distance to the closest station: 43 km (IGREF: 160 km).
- The postprocessing analysis is a certified process in BKG according to ISO 9001:2015.
- Disaster-proof: Metadata prepared for the postprocess analysis and the corresponding source codes are managed by version control system and backed up routinely.
- Contact: Operational process of DREF-Online is computed by postprocessing team (Email: postpro_igs@bkg.bund.de) in Satellite Navigation Group (unit G2) of BKG.

Remarks and future works

- For EPN-D, a new German network is ready to contribute.
- After including DREF-Online network, a significant coverage improvement can be expected, reducing the average distance from 160 km to 43 km in the German region.
- DREF-Online is consist of the best quality stations in German region and its product is consistent, robust and carefully monitored.
- Reprocessing of last 5 to 10 years of DREF-Online is planned and expected to start by the end of 2025.
- Due to the changes of the technical standard in Germany, configuration changes are expected later in 2025, more details will be documented and explained within our products.

Presented in EUREF 2025 Symposium, 24-26 June 2025, Covilhã, Portugal

Further information

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Thank you for your kind attention!

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34th EUREF Symposium

Covilhã, Portugal, June 25–26, 2025

Towards a 4D National Spatial Reference System (National Report of Slovenia)

Poster

[Sandi Berk](#)¹, [Niko Fabiani](#)³, [Klemen Medved](#)¹, [Natalija Novak](#)³,
[Polona Pavlovčič Prešeren](#)², [Peter Prešeren](#)¹, [Klemen Ritlop](#)²,
[Oskar Sterle](#)², [Bojan Stopar](#)²

1  REPUBLIC OF SLOVENIA
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2  **FGG** UNIVERSITY OF LJUBLJANA
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3  Federal Agency for
GEODETIC INSTITUTE OF SLOVENIA

ng L. et. al.: A permanent GNSS network in Germany joins the EPN-Densification Wo



34th EUREF Symposium
Covilhã, Portugal, June 25–26, 2025



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UNIVERSITY OF LJUBLJANA
Faculty of Civil and Geodetic Engineering



GEODETIC INSTITUTE OF SLOVENIA

Towards a 4D National Spatial Reference System (National Report of Slovenia)

S. Berk¹, N. Fabiani³, K. Medved¹, N. Novak³, P. Pavlovčič Prešeren², P. Prešeren¹, K. Ritlop², O. Sterle², B. Stopar²

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Abstract

The territory of Slovenia with its western part situated at the Adriatic microplate is tectonically active. Surface deformations reach few millimeters per year which has an impact on the quality of the national spatial reference system. Static realizations of the system become out of date in a decade, and we are facing the challenge of how to introduce the fourth dimension (time) into the national spatial reference system. The main aspects to be considered are the quality of the reference system itself and the impact of the proposed solution on various spatial databases and services. In order to provide a conceptual framework of the future realization of the spatial reference system in Slovenia, we started the so-called SLO4D Project.

A Brief History

The first realization of ETRS89 in Slovenia is based on GPS campaigns in years 1994–1996. The combined solution with the mean epoch 1995.55 is referred to as the **ETRS89/D96**. The computation presented at the EUREF 2003 Symposium [1] was accepted as Class B standard (EUREF 2003 Resolution No. 1).



Passive GNSS sites for reference system realization

The second realization of ETRS89 is based on a GNSS campaign with the mean epoch 2016.75. The solution referred to as **ETRS89/D17** was presented at the EUREF 2018 Symposium [2]. It was also accepted as Class B standard (EUREF 2018 Resolution No. 3).

Due to substantial coordinate differences between both static realizations of ETRS89 in Slovenia (exceeding **8 cm**), a pragmatic approach is employed that attempted to keep changes of coordinates as small as possible. This is achieved with a rigid (6-parameter) transformation from ETRS89/D17 into ETRS89/D96, which is based on carefully selected 56 GNSS sites included in both realizations. This solution is referred to as the **ETRS89/D96-17** and is used in Slovenia since 1st January 2020 [3].

Connection between ETRS89/D96-17 and ITRS

The transformation from a realization of ITRS (e.g., ITRF2020) at a given epoch (t) to ETRS89/D96-17 consists of four steps as follows [4]:

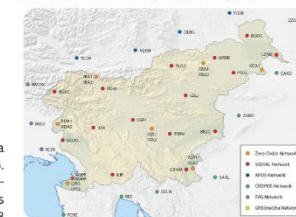
1. ITRF2020@t → ITRF2020@2016.75
2. ITRF2020@2016.75 → ITRF2000@2016.75
3. ITRF2000@2016.75 → ITRF2000@2016.75
4. ITRF2000@2016.75 → ETRS89/D96-17

Step 1 requires estimated velocity that can be provided by a geokinematic model. Step 4 is a non-standard solution; a special reference frame for Slovenia (ETRS89-D96-17) is added to Trimble Coordinate System Database v2022.10 which is now supported by Trimble software solutions.

CORS Networks and Time Series Analysis

The first Slovenian permanent GNSS station dates back to the year 2000. Later on, two national CORS networks were built [5, 6]:

- **SIGNAL Network** (operational since 2006) and
 - **Zero-Order Network** (operational since 2016).
- At present, the SIGNAL Network consists of 16 GNSS stations and is expanded with 14 GNSS stations from neighbouring countries. The Zero-Order Network consists of 7 mostly twin stations (2 new stations in 2025). Four Slovenian GNSS stations are EPN stations: ARA2, GSR1, KDA2, and PZA2.



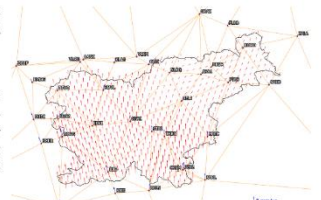
National CORS networks

Trimble Pivot Platform and Alberding Software are used in operational and data centers to manage both national CORS networks. An analytical center was established in 2016. *Bernese GNSS Software* and a self-developed PPP software are used for daily coordinate time series analysis.

Tectonic Issues and National Geokinematic Model

Tectonics of the Adriatic region is not negligible. With respect to stable part of Europe, the country territory moves with velocities of up to **few mm/yr** which causes problems in a long-term maintenance of the national spatial reference system [7, 8].

A permanent activity of the analytical center [9] combined with a multidisciplinary research project [10] resulted in a preliminary national geokinematic model which is based on estimated velocities in the EPN and both national CORS networks. A continuous 3D geodetic velocity field interpolation based on the ellipsoidal Earth model and DeLaunay triangulation is developed [11] and implemented in a freeware tool for time-dependent coordinate transformation between ETRS89/D96-17 and international terrestrial reference frames [12]. Such transformation is needed to support PPP survey, precise navigation services etc.



A preliminary national geokinematic model, Hz part (ETRF2000)

The SLO4D Project and plans for the future

A project aiming to introduce the fourth dimension (time) to the national spatial reference system started in 2022 and is referred to as the **SLO4D Project**. The main project activities are:

- densification of the zero-order network,
 - providing a national geokinematic model, v1.0,
 - proposing a solution for a 4D national spatial reference system, and
 - providing support for the users of this system.
- The proposed solution will be implemented in the upcoming years. The main challenge of the project is how to appropriately handle tectonic issues without causing inconvenience to the users.



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Towards a 4D National Spatial Reference System (National Report of Slovenia)

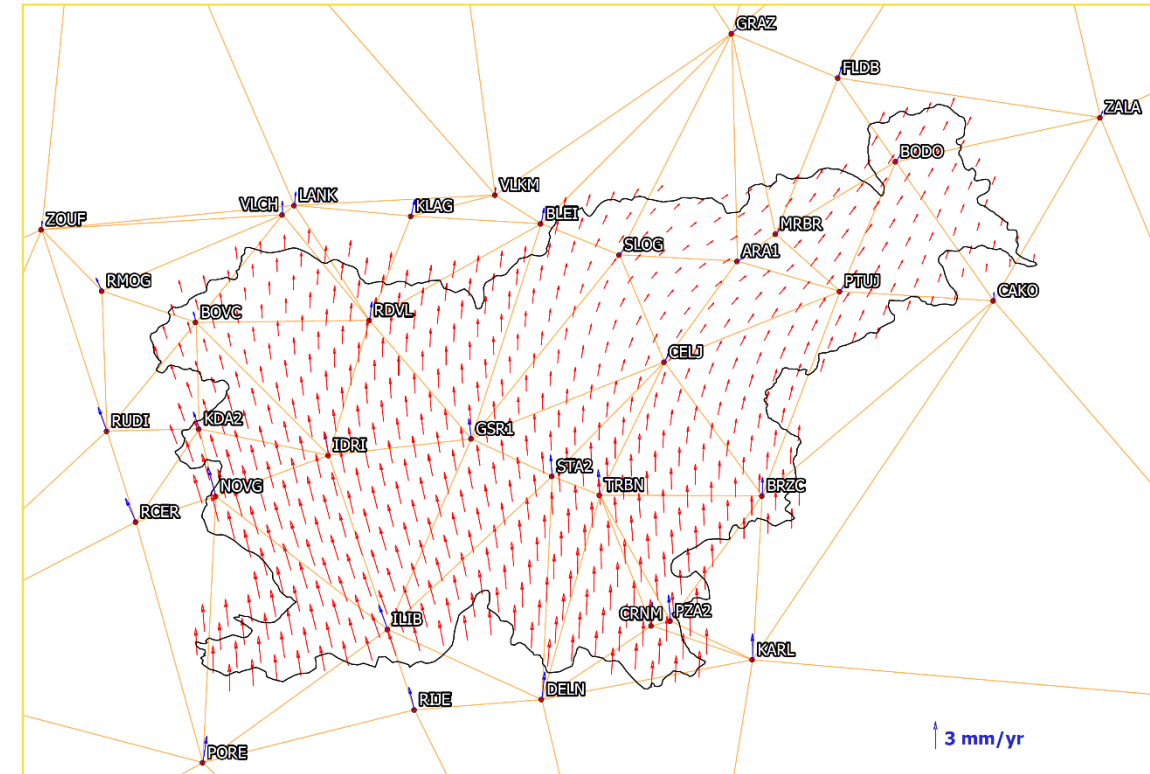
Why do we need to consider the fourth (time) dimension in the national SRS? What is an optimal solution:

- *to keep the required quality of the system over time*
- *without causing inconvenience to the users?*

The poster covers:

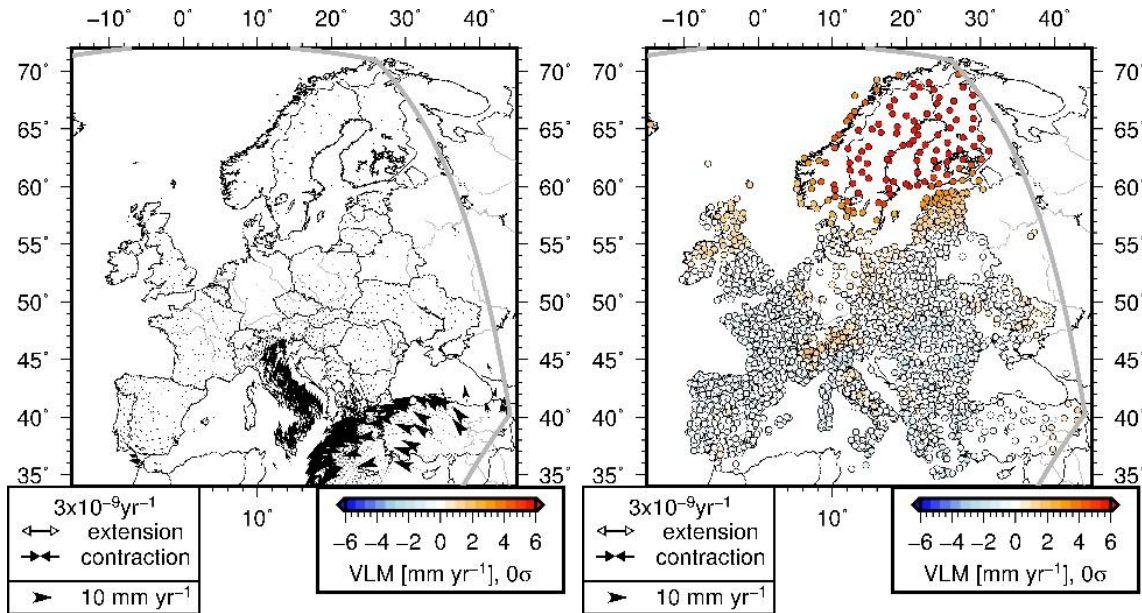
- A BRIEF HISTORY OF REALIZATIONS OF ETRS89 IN SLOVENIA
- CONNECTION BETWEEN ETRS89/D96-17 AND ITRS
- CORS NETWORKS AND TIME SERIES ANALYSIS IN SLOVENIA
- TECTONIC ISSUES AND NATIONAL GEOKINEMATIC MODEL

*The **SLO4D Project** (in progress) will address these issues.*



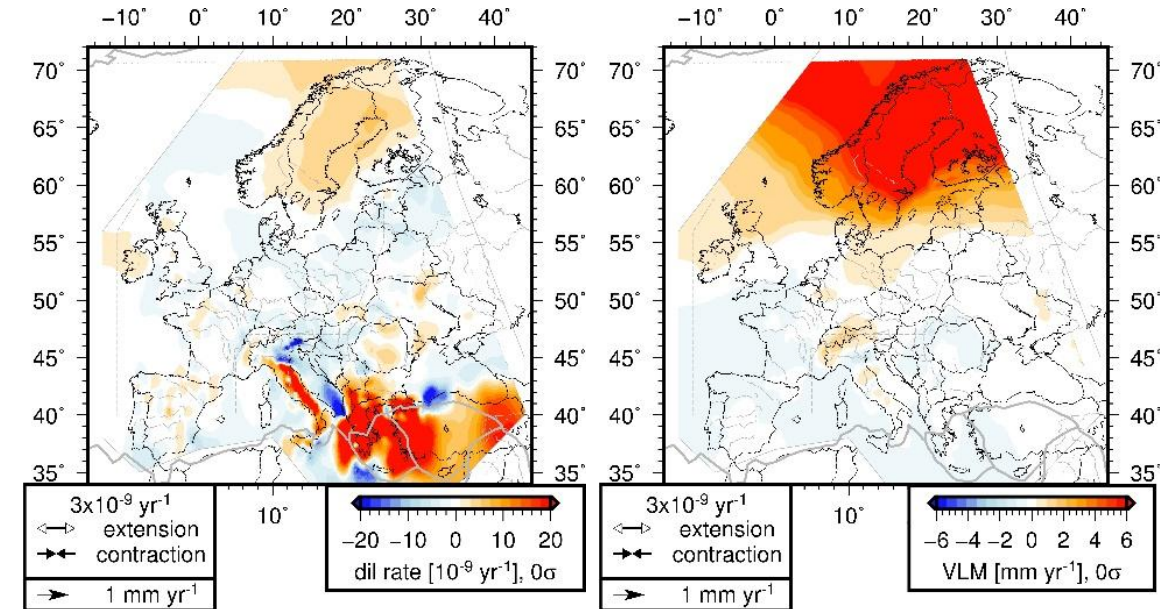
A preliminary national geokinematic model, Hz part (ETRF2000)

Assessing small-scale Surface Deformation Zones in Europe



RD3I

- Horizontal strain map
- Vertical imaging



- EPND velocity field
- NGL velocity field



ON THE STABILITY OF ETRS89

A comparison between recent observations and earlier national realisations in
Serbia and Sweden
– using **different ETRFs** and the **EuVeM2022** velocity model

ITRF2020/IGS20 transformed to:

 ETRF2020  "ETRF2020rot"  ETRF2000  ETRF97  NKG2020

Lotti Jivall, Filip Kostadinović, Dragana Popović, Rebekka Steffen



REPUBLIC GEODETIC AUTHORITY OF SERBIA



ON THE STABILITY OF ETRS89

A COMPARISON BETWEEN RECENT OBSERVATIONS AND EARLIER NATIONAL REALISATIONS IN SERBIA AND SWEDEN – USING DIFFERENT ETRFs AND THE EuVeM2022 VELOCITY MODEL

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Introduction

The common European reference system ETRS89, with its ETRFyyyy realisations, has provided stable geodetic frames over the recent decades. Most national realisations agree within a few centimetres in the horizontal components, especially those based on the “conventional frame” ETRF2000.

However, the time-dependent translation in the transformation from ITRS up to ETRF2000 introduced a bias in vertical velocities. Starting with ETRF2014, this translation was removed, leaving only the plate rotation. As a result, a horizontal offset of approximately 7 cm was introduced compared to previous ETRFs.

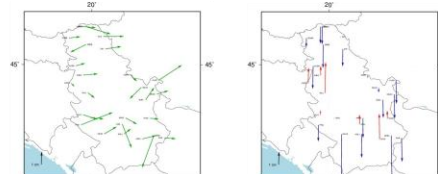
ETRF2020rot

To improve consistency with older realisations, Dr. Martin Lidberg proposed adding a static rotation to the ITRF–ETRF transformation. This method, tested here as ETRF2020rot (not an official name), preserves horizontal agreement with ETRF2000 while retaining vertical components from ITRF2020. [EUREF Symposium 2024]

Serbia

The EUREF Serbia 2023 campaign was processed in ITRF2020 (epoch 2023-08-02) and compared to the national realisation based on EUREF Serbia 2010 in ETRF2000 (epoch 2010-08-18).

Differences between EUREF Serbia 2023 transformed to different ETRS89 frames and the Serbian ETRS89 realisation based on ETRF2000 epoch 2010-08-18												
EUREF Serbia 2023		RMS (mm)			Mean (mm)			Abs Max (mm)				
Frame	Epoch	N	E	U	N	E	U	N	E	U		
ETRF2020	2023-08-02	79	11	22	77	-6	-16	106	30	43		
ETRF2020rot	2023-08-02	16	17	22	-6	14	-16	45	32	43		
ETRF2000	2023-08-02	20	10	20	-13	4	-13	53	23	37		
ETRF2020	2010-08-18	82	14	16	82	-12	-7	96	33	36		
ETRF2020rot	2010-08-18	8	11	17	-1	8	-8	25	25	36		
ETRF2000	2010-08-18	9	8	15	-5	-1	2	29	21	34		

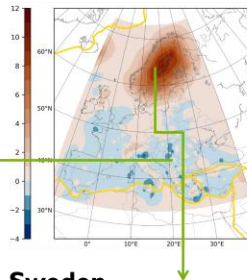


EUREF Serbia 2023 transformed to ETRF2020rot epoch 2010, minus EUREF Serbia 2010. EuVeM2022 was used for correction of 13 years of deformation.

Conclusions

- The ETRF2020rot performs almost as well as ETRF2000 in the comparison to the two examples of national ETRS89 realisations
- Using this approach for future national ETRS89 realisations would ensure a good agreement with present realisations
- ETRF2020rot provides a practical solution without the need for costly updates of national ETRS89 realisations
- Using EuVeM2022 improves the agreement with earlier ETRS89 realisations, especially if large velocities and a long time span

EuVeM2022



The European velocity model EuVeM2022 (including both horizontal and vertical components) was used to correct for the deformation since the national realisation epoch. Comparisons were made both with and without this correction.

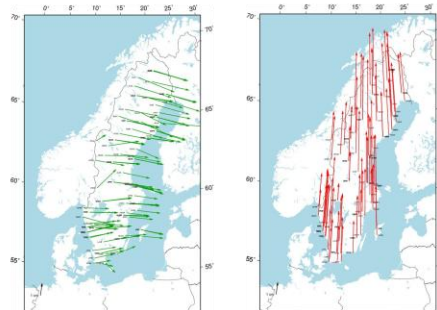
EuVeM2022 vertical velocities in ETRF2000.

Sweden

For Sweden, the recent weekly EPND solution SWE_2365 (week 2365, ITRF2020, epoch 2025-05-07) was transformed and compared to the official national ETRS 89 realization, SWREF 99, based on ETRF97 (epoch 1999-07-01).

In addition to the ETRFs tested for Serbia, transformations to ETRF97 and directly to SWREF 99, using the NKG2020 transformation, were tested.

Differences between the weekly EPND solution SWE23657 transformed to different ETRS89 frames and the Swedish ETRS89 realisation based on ETRF97 epoch 1999-07-01												
SWE_EPND GW2365		RMS (mm)			Mean (mm)			Abs Max (mm)				
Frame	Epoch	N	E	U	N	E	U	N	E	U		
ETRF2020	2025-05-07	69	25	207	68	-23	193	83	45	300		
ETRF2020rot	2025-05-07	15	8	207	-13	5	192	27	16	300		
ETRF2000	2025-05-07	13	8	175	-9	2	159	25	20	263		
ETRF97	2025-05-07	16	46	134	-9	-42	123	32	72	216		
ETRF2020	1999-07-01	79	10	36	79	-7	35	95	26	55		
ETRF2020rot	1999-07-01	6	22	36	-2	21	35	16	36	55		
ETRF2000	1999-07-01	5	16	26	-2	15	25	15	31	44		
ETRF97	1999-07-01	10	33	22	6	-32	-21	22	57	45		
SWREF 99	1999-07-01	1	2	3	1	-1	1	4	5	7		



SWE_2365 transformed to ETRF2020rot epoch 1999, minus SWREF 99. EuVeM2022 was used for correction of 26 years of deformation.

”ETRF2020rot” – presented with formulas and parameters in Barcelona 2024 by Martin Lidberg:

$$X^E(t_c) = X_{YY}^I(t_c) + R_{E20} \times X_{YY}^I(t_c) + \begin{pmatrix} 0 & -\dot{R}_{3YY} & \dot{R}_{2YY} \\ \dot{R}_{3YY} & 0 & -\dot{R}_{1YY} \\ -\dot{R}_{2YY} & \dot{R}_{1YY} & 0 \end{pmatrix} \times X_{YY}^I(t_c) \cdot (t_c - 1989.0)$$

”ETRF2020rot” is aligned to ETRF2000 with a static Euler pole rotation. Heights and vertical velocities are retained from ITRF2020.

- The ”ETRF2020rot” performs almost as well as ETRF2000 in the comparison to the two examples of national ETRS89 realisations
- Using this approach for future national ETRS89 realisations would ensure a good agreement with present realisations
- To facilitate the use of this approach, we propose to include also this type of transformation in future versions of EUREF Technical Note I.