



# ETRS89 from the user perspective

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## EUREF SYMPOSIUM 2023, RESOLUTION 2

The IAG Reference Frame Sub-commission for Europe (EUREF)

noting the improved consistency between recent realisations of the ETRS89, especially between the ETRF2014 and the proposed ETRF2020

- and recognising the benefits of harmonising the reference frames used by the countries within Europe
- *and considering* the differences in coordinates between recent realisations of the ETRS89 and former realisations that have been adopted by European countries
- recommends that the EUREF Governing Board investigates the impacts of national adoption of recent ETRS89 realisations compared to previously adopted ETRS89 realisations, whilst considering the needs and expectations of the geodata community



#### BACKGROUND

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- The EUREFTN-I is updated and the ETRF2020 is published (thank you Zuheir!): http://etrs89.ensg.ign.fr/pub/EUREF-TN-I-Mar-04-2024.pdf
- I think that we can agree that the ETRS89 is one of the major success stories of EUREF
- It is recognized in official EU documents and regulations (including INSPIRE and the EU Radio Navigation Plan 2023)

https://joint-research-centre.ec.europa.eu/scientific-activities-z/complementary-and-alternative-pnt\_en#the-european-radionavigation-plan-ernp

- Almost all of the countries in Europe have a national realization of ETRS89, and most of these agree at the I-2 cm level in horizontal coordinate components
- Thus, we have succeeded to harmonize the reference frames in Europe at a level that correspond to the uncertainty level of the commonly used surveying methodology (Network-RTK)
- The ETRF2014 and ETRF2020 differ from previous ETRFs at the level of about 7 cm in the horizontal component.
- And an update of all national realizations of ETRS89 would be very costly.



#### CONSIDERATION

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- For geo-referencing purposes where agreement with realizations in neighboring countries is of concern, the only available option is to use the ETRF2000, and thus this is *for the moment* the recommendation from EUREF (EUREFTN-I)
- I think it would be beneficial if we some time in the future (or soon??) could leave the ETRF2000 when we publish our EUREF products, but then we need something else that supports the harmonization of horizontal coordinates for geo-referencing purpose
- Also noting the EUREF Symposia 2023 Resolution 2



#### Transformation formula from ITRF to ETRF (EUREFTN-I)

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For station position at any epoch t:

$$X^{E}(t_{c}) = X^{I}_{YY}(t_{c}) + T_{yy} + \begin{pmatrix} 0 & -\dot{R}3_{YY} & \dot{R}2_{YY} \\ \dot{R}3_{YY} & 0 & -\dot{R}1_{YY} \\ -\dot{R}2_{YY} & \dot{R}1_{YY} & 0 \end{pmatrix} \times X^{I}_{YY}(t_{c}) \cdot (t_{c} - 1989.0)$$

and for velocities:

$$\dot{X}^{E} = \dot{X}_{YY}^{I} + \begin{pmatrix} 0 & -\dot{R}3_{YY} & \dot{R}2_{YY} \\ \dot{R}3_{YY} & 0 & -\dot{R}1_{YY} \\ -\dot{R}2_{YY} & \dot{R}1_{YY} & 0 \end{pmatrix} \times X_{YY}^{I}$$





### Transformation parameters (EUREFTN-I)

Table 1: Transformation parameters from ITRF<sub>yy</sub> to ETRFyy at epoch 1989.0 and their rates/year

$\text{ETRF}_{yy}$	T1	T2	T3	D	<b>R</b> 1	R2	R3
	mm	mm	mm	$10^{-9}$	mas	mas	mas
ETDEO000	0.0	0.0	0.0	0.00	0 000	0 000	0 000

Table 2: Transformation parameters from ITRF<sub>yy</sub> to ETRF2020 at epoch 2015.0 and their rates/year

ITRF Solution	T1	T2	T3	D	R1	R2	R3
	mm	mm	mm	$10^{-9}$	mas	mas	mas

Table 4: Transformation	parameters from ITRF	y to ETRF2000 at e	epoch 2015.0 and	their rates/year
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ITRF Solution	T1	T2	T3	D	R1	R2	R3
	mm	mm	mm	$10^{-9}$	mas	mas	mas
ITRF2020	53.8	51.8	-82.2	2.25	2.106	12.740	-20.592
rates	0.1	0.0	-1.7	0.11	0.081	0.490	-0.792
ITRF2014	55.2	52.7	-83.6	2.67	2.106	12.740	-20.592
rates	0.1	0.1	-1.9	0.11	0.081	0.490	-0.792
ITRF2008	53.6	50.8	-85.5	2.54	2.106	12.740	-20.592
rates	0.1	0.1	-1.8	0.08	0.081	0.490	-0.792
ITRF2005	51.1	51.7	-80.8	1.60	2.106	12.740	-20.592
rates	-0.2	0.1	-1.8	0.08	0.081	0.490	-0.792
ITRF2000	54.0	51.0	-48.0	0.00	2.106	12.740	-20.592
rates	0.0	0.0	0.0	0.00	0.081	0.490	-0.792





## THE NATURE OF ETRF2020/2014 AND ETRF2000

#### ETRF2020

- Origin and scale identical to ITRF2020 (state-of-the-art terrestrial reference frame)
- Vertical positions identical to ITRF2020 (important for work on height and geoid)
- and vertical velocities identical to ITRF2020 (relevant for crustal deformation studies)
- Horizontal positions (latitude, longitude) differ ~7cm compared to the realizations of ETRS89 implemented at national level

#### ETRF2000

- Agree well at the coordinate level to what are implemented at national level today
- Origin and scale differ from resent ITRFs
- Vertical position differ from recent ITRFs. Also, an "apparent tilt" in vertical position
- Vertical velocities differ from recent ITRFs

So unfortunately, there are issues with booth options, especially regarding recommendations for national realization of the ETRS89.



Explanation: The translation in the transformation from ITRF to ETRF (applied in the ETRF2000 and previous ETRFs) cause an "apparent tilt" in the vertical





# On the ETRS89 and its realizations in the perspective of geoid models and IHRS (International Height Reference System and Frame)

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- The "apparent tilt" (and the height difference itself) in ETRF2000 compared to ITRFxx is annoying in the perspective of geoid modelling over large areas. E.g. while comparing the geoid model to "GPS-levelling", (i.e. ETRS89-EVRS and its realizations)
  - Also noting that global potential models are best related to recent ITRF (I presume..)
  - Should we use GNSS vertical positions in ETRFxx or in ITRFxx together with EVRS/F for geoid work in Europe? E.g. for the European Unified Height Reference
- This issue may be even more pronounced in the near future in the perspective of the IHRS and its realizations, where the relation between our realizations of EVRS and the future IHRF will be determined using GNSS and global geopotential modes (including local gravity etc)
- Therefore, identical vertical positions in ETRFs and ITRFs are beneficial.





### An alternative, (from presentation in Wroclaw 2017)

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

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

- The static rotation only effects the horizontal positions and leave the vertical position unchanged.
- To derive realization of ETRS89 this way is different in practice, but no change principles – we just adapt the new ETRS89 frame to previous conventional frame in order to minimize the changes at the coordinate level



#### ETRF2020 COMPARED TO ETRF2000 @ EPOCH 2010

#### ETRF2020 - ETRF2000

Maxium: 97 mm RMS: 60 mm

Here, ETRF2000 is used to represent the older ETRFs that national realizations of ETRS89 are based on

Epoch 2010 is chosen as a "mean epoch of relatively modern national realizations of the ETRS89"



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#### Results

# Number of common sites : 13
# RX = -1.6925 mas, sRX = 0.1185 mas
# RY = 2.2506 mas, sRY = 0.0634 mas
# RX = 0.1216 mas, sRZ = 0.1514 mas
# Statistics of residuals for the common points:
# m\_dn = 1.2 mm, RMS\_dn = 6.5 mm
# m\_de = -0.8 mm, RMS\_de = 5.4 mm
# m\_du = 8.2 mm, RMS\_du = 18.7 mm
#

Maximum: 17 mm RMS: 6 mm



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#### HEIGHT DIFFERENCE ETRF2000 – ETRF2020 @ EP 2010

Max: 35 mm RMS: 13 mm

"Small" in central Europe,

But a clear tilt.

This is an obstacle for using ETRF2000 in geoid work and GNSS-levelling.



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Do you consider the ~7 cm difference between ETRF2020 (also ETRF2014) and current national realizations of ETRS89 as an issue for "georeferencing" and cross national geodetic work in Europe? Majority YES!

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- Given the presented issues with the ETRS2000, would you like to see an alternative (to ETRF2000) to be recommended for geo-referencing as national realization of the ETRS89? <u>Majority YES!</u>
- Would you consider the presented alternative (basically an ETRF2020 with a static Euler pole to rotate horizontal positions to agree with current realizations of ETRS89) as an option? Majority YES!



## WHAT IS PROPOSED AND WHAT IS NOT PROPOSED ?!

- It is NOT proposed to change/replace the ETRF2020
- But in addition provide a modified version of ETRF2020 that better agree at the coordinate level to existing national realizations of the ETRS89
- It is NOT proposed that every country should replace their national ETRS89 realizations (considered very costly)
- But if you consider an update, EUREF provide an option based on a proper geodetic reference frame AND agree at the coordinate level to your neighbors
- EUREF accepts that every county will make their own decision based on own priorities
- EUREF may eventually phase out some of the products provided in the ETRF2000 frame.



### NEXT STEP

If you agree;

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- Finalize the proposed option for realization of ETRS89 (to be used for georeferencing and geodetic work within and between countries)
- Document and include in relevant EUREF Guidelines
- Possibly provide relevant EUREF products in this proposed version of the ETRF2020 (noting that horizontal velocities, vertical velocities, and vertical position is identical to ETRF2020, only the position in horizontal dimension differ but agrees to current national realizations)





# Thank You!

# Comments and questions?



## TACK! VI FINNS PÅ...

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