EUREF Study Group on alternatives to ETRS89. Status of work

Xavier Collilieux, Zuheir Altamimi, Dimitrios Ampatzidis, Andrzej Araszkiewicz, Karoline Arnfinnsdatter Skaar, Esther Azcue Infanzón, Carine Bruyninx, Alessandro Caporali, Rolf Dach, Chris Danezis, Michail Gianniou, Ambrus Kenyeres, Karin Kollo, Christopher Kotsakis, Pasi Häkli, Lennard Huisman, Juliette Legrand, Gunter Liebsch, Martin Lidberg, Ivars Liepiņš, Tomasz Liwosz, Benjamin Männel, Rosa Pacione, Markku Poutanen, Lars Prange, Martina Sacher, Joachim Schwabe, Wolfgang Söhne, João Agria Torres, Jeffrey Verbeurgt, Brice Virly, Christof Völksen, Anastasiia Walenta, Lin Wang, Joachim Zurutuza

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Current ETRS89 (1/2)

The ETRS89 definition implies the following two conditions (Altamimi and Collilieux, 2024):

"1. **The ETRS89 coincides with the ITRS at epoch 1989.0.** This condition leads to consider that the 7 transformation parameters between ITRS and ETRS89 are all zeros at epoch 1989.0.

2. **The ETRS89 is fixed to the stable part of the Eurasian tectonic plate.** This condition implies that the ETRS89 is co-moving with the Eurasian tectonic plate, hence defining its time evolution. Therefore the time derivatives of the 7 parameters between ITRS and ETRS89 are zeros, except the three rotation rates. The three rotation rates are in fact the three components of the Eurasia angular velocity in the ITRFyy frames."

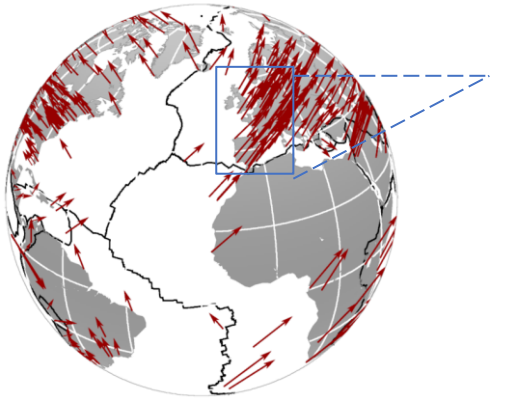
Every time a new ITRF is published, the corresponding ETRF is computed (with the exception of ITRF2008)

- Differences between ETRFxx

  ~8 cm between ETRF2000 and ETRF2014/ETRF2020

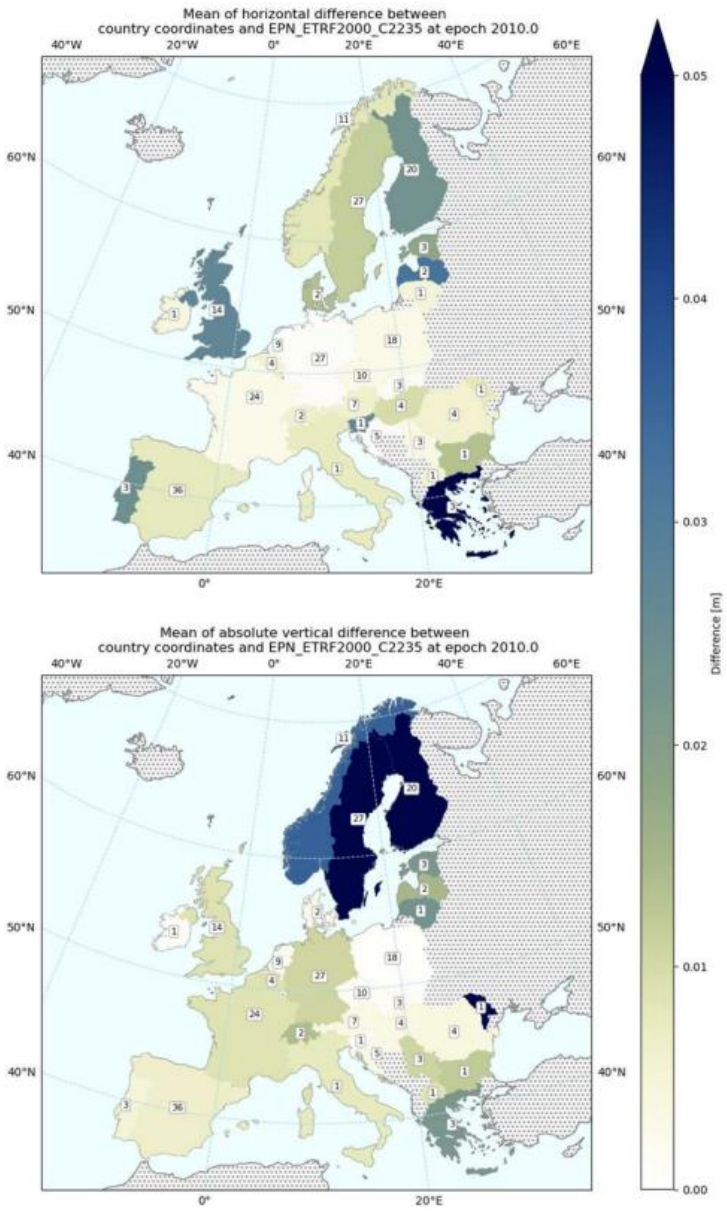
- Differences between ETRFxx and ITRFxx close to 1 m

  - ITRF2020 vs ETRF2020 ~ 0.86 m in 2025 (ex: Western Europe)
  - ITRF2020 vs ETRF2020 ~ 1.10 m in 2035



about 25 cm every 10 years

Current ETRS89 (2/2)



One system but various frames:

- ETRFxx are **kinematic frames** = coordinates can be exchanged at any epoch.
  Coordinates published at a primary network of points only (common with ITRFs and densified network via the EPN network)

- National realizations are derived from ETRFxx but are **static**.

- Differences between national coordinates better than 10 cm (differences with ETRF2000@2010 within 5 cm for all countries, except for Greece and Moldavia)

Questions:

- Should the consistency between national ref. frames be improved further?
- How to move to up-to-date reference frames? ETRF2000 height velocities are known to be biased

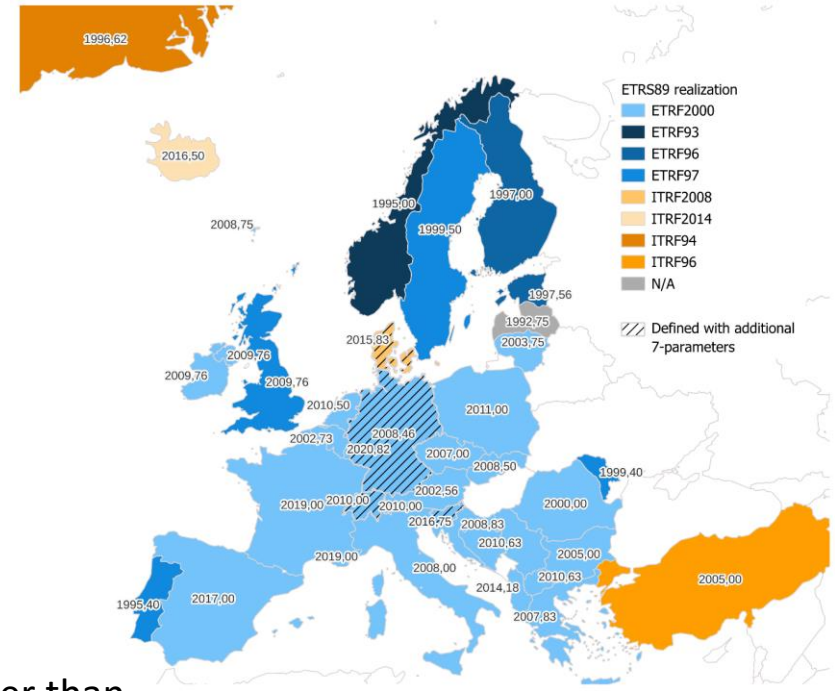


Fig. ETRS89 realizations currently in use with their reference epochs. For countries where additional 7-parameters are used, the transformation may be restricted to 3 parameters. Based on the version 1.0a of Schwabe and Sacher (2024) inventory.

Map by Nascimento et al.
Differences between national coordinates (preliminary dataset) and ETRF2000 @ 2010.0

Study group methodology

- ☑ Review the Strategies used in other countries to define their reference frame.
- ☑ Establish a list of needs regarding TRS (from an expert perspective).
- ☑ Consolidate needs thanks to a survey to be sent to the authorities in charge of national reference frames. They will be accountable for gathering, analysing, and translating user needs into requirements.
  A copy of the questionnaire, which will be widely available on the EUREF website, will ensure that no opinions are overlooked.
- ☑ List scenarios of ETRS89 alternatives and write pro and cons. Eliminate and consolidate scenarios according to their ease of implementation (level of complexity), their alignment with needs, their accuracy, and their lifetime.
- ☐ Give some recommendations in a white paper according to the needs for a selected set of scenarios
- ☐ Review the result of the survey regarding needs.

Any decision must be approved by an EUREF resolution.

Study group methodology

☑ List of needs regarding TRS (from an expert perspective).

- Minimized displacements
- Displacement known everywhere at any time
- Small changes with current national coordinates
- Same geoid grid to be used with ITRS and ETRS89 alternative (= same height coordinates)
- Small scale difference with ITRS for unbiased transformation of ITRS-based GNSS orbits and clocks to ETRS89
- Easy use of ITRS coordinates
- 1 cm accuracy for coordinates

Two choices for harmonizing further coordinates:

- Build on what has already been established, i.e. stay as close as possible to the old coordinates
- Take the opportunity to establish a new standard

Handling deformation (1/3)

Significant deformation noticed in many countries but various approaches used. Some examples :

- **Greece**. Deformation measured but not fully modelled in RTK real-time network.
- **Spain**. Small deformation in South of Spain, can be handled by an additional rotation pole.
- **Italy**. RTK base station coordinates updated every month.
- **Nordic countries**. A deformation model is provided to transform ITRF coordinates to an intermediate frame at epoch 2000.0 (Häkli et al., 2023). The deformation model also used to transform coordinates from the intermediate frame to the national frames.

Problem to be solved: how to compare coordinates acquired in a deformation zone at two different epochs?
A deformation model that predicts coordinate variations in time and space is required.

Model availability: deformation model EuVeM2022 by Steffen et al. (2025) proposed as official EUREF product by the EUREF governing board in oct 2025.

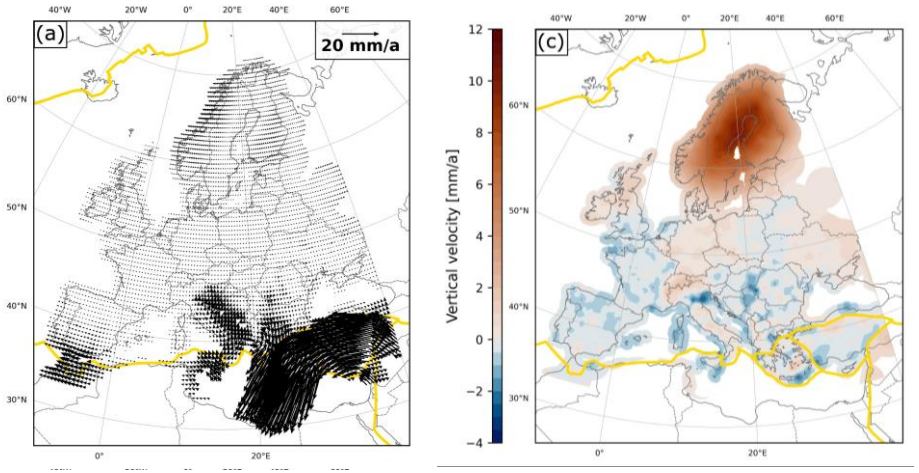


Fig. 2D and Up interpolated velocity field (Steffen et al. 2025)

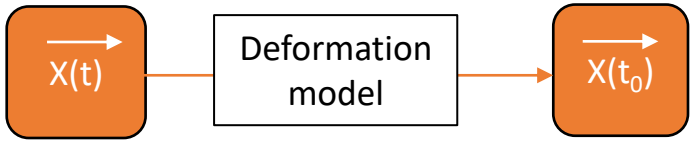
Note: the deformation model can be ignored in stable zone. ETRFxx@t = ETRFxx@t'

Handling deformation (2/3)

How to use a deformation model in reference frame applications ?

- Kinematic (dynamic) frame = optimal solutions. Coordinates can be published at any epoch.
  Still experimental in GIS, may require high computational cost with large datasets (vector, raster)
  (Evers, 2025; Himle, 2025).

- Static frame : coordinates published at a reference epoch t_0 + a deformation model which can be used for transforming ETRS89 coordinates @t to ETRS89 coordinates @t_0



Handling deformation (3/3)

When updating the deformation model ?

- Improvement of the interpolated velocity model
- Earthquakes

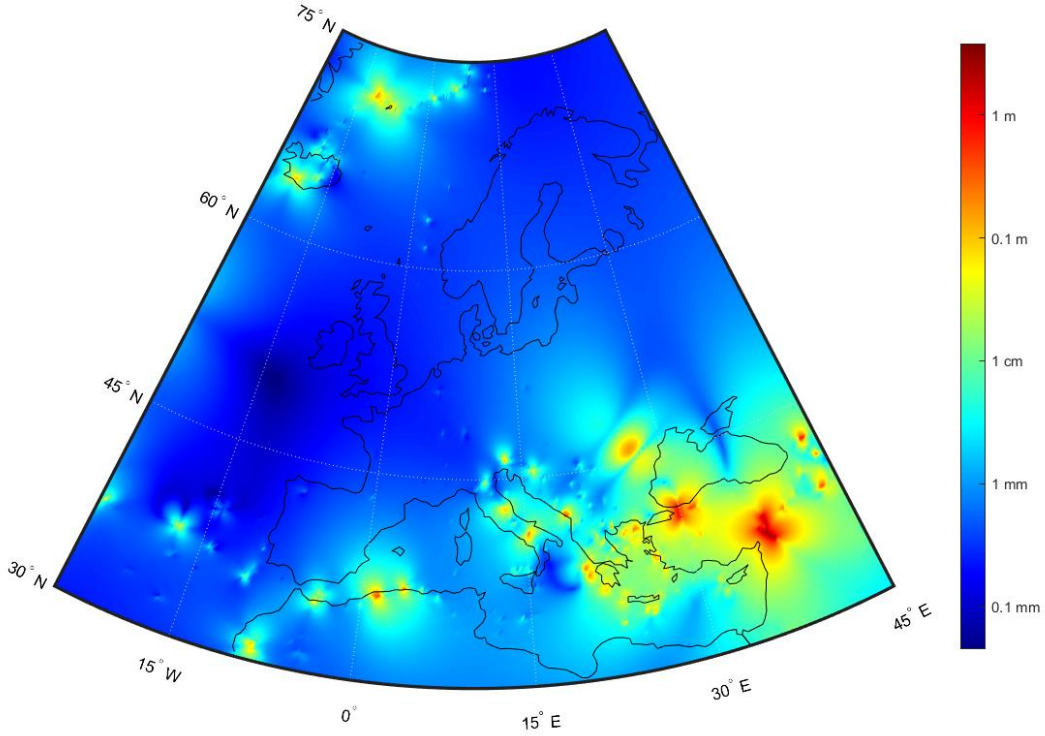


Fig. Cumulative co-seismic deformations (1976-2025). Map by L. Métivier

Conclusions:

- Study group members agreed that a deformation model can be used and recommand it to be part of any scenario of ETRS89 alternative.
- The deformation model can be ignored in stable zone. To be use if necessary only.

Scenarios

List of scenarios currently under study (preliminary)

- Scenarios that require slight evolutions of ETRS89 specifications:
  - Scenario 1 keep ETRS89
  - Scenario 2 keep ETRS89 but add guidelines to make future national coordinate updates more consistent

Presented today

- Scenarios that require a system change with legal consequences:
  - Scenario 3 Create ETRS35 that coincides with ITRS at epoch 2035.0
  - Scenario 4 Change ETRS89 orientation to minimize coordinate differences with current national coordinates.
  - Scenario 5 One plate-fixed system per tectonic plate
  - ✗ Scenario 6 Any ETRS89 alternative and legal use of ITRS coordinates

Already eliminated

Scenario 1 : ETRS89

Preliminary

- No change in ETRS89 definition.

  A deformation model [*no recommended specifically*] can be used to transform ETRFxx@t to ETRFxx@t'.

Pros	Cons
Long history, well established governance, adopted by law	
Countries can retain their own approach	Countries have not adopted recent ETRS89 realizations
Country free to keep their current realization	Country free to keep their current realization and do not adopt unbiased frame (ETRF2020)
14-parameters are now standard	Past ETRS89 realizations have shown large differences
Same scale than and same geoid grid to be used with ITRS if new ETRS89 realizations are used by countries	
A deformation model provide a solution in deformation zones (or other tectonic plate) even if the deformation is not totally minimized	

Scenario 2 : ETRS89 with guidelines to compute realizations

Preliminary

- 2A : Future national static coordinates can be provided at a conventional reference epoch. Ex: 2020.0

- 2B : Propose a correction term to be applied to ETRFxx coordinates (ETRF2020 and future) to improve their fit with ETRF2000 in horizontal components while maintaining a rigorous relationship between the resulting frame and any ITRFyy/ETRFyy.

  Description of the correction: a rotation term that minimizes the difference of coordinates between ETRF2020 (or ETRFxx) and ETRF2000 as proposed by Lidberg (2024). The horizontal coordinate residuals are smaller than 2 cm.

Pros	Cons
Keep a 14-parameter relationships between corrected ETRFxx and ITRFxx	Maintain continuity with an old frame
Ensure smaller coordinate variations between ETRS89 next realizations and current national coordinates	
Same geoid grid for ITRFxx and corrected ETRFxx in the future	
Unbiased “corrected ETRF20xx” vertical velocities	

Scenario 3 : ETRS35

Preliminary

- ETRS35 coincides with the ITRS **at epoch 2035.0** (or another epoch) to ensure a close agreement between ITRS and ETRS35 coordinates over a longer time span (as done by Geoscience Australia for GDA2020).
- ETRS35 fixed to the stable part of the Eurasian tectonic plate
- Static frames derived from this system to be provided at **a conventional reference epoch 2035.0**
- A deformation model [*no recommended specifically*] can be used to transform ETRFxx@t to ETRFxx@t'.

Pros	Cons
Transparent use of ETRS35 and ITRS even with more accurate positioning devices (~20 cm = Galileo HAS accuracy)	Agreement between ETRS35 and ITRS limited on time (~16 years at maximum 20 cm level)
Large difference so less confusion possible between ETRS89 and ETRS35 coordinates	Large coordinate difference with current ETRFxx and national coordinates (~1m)

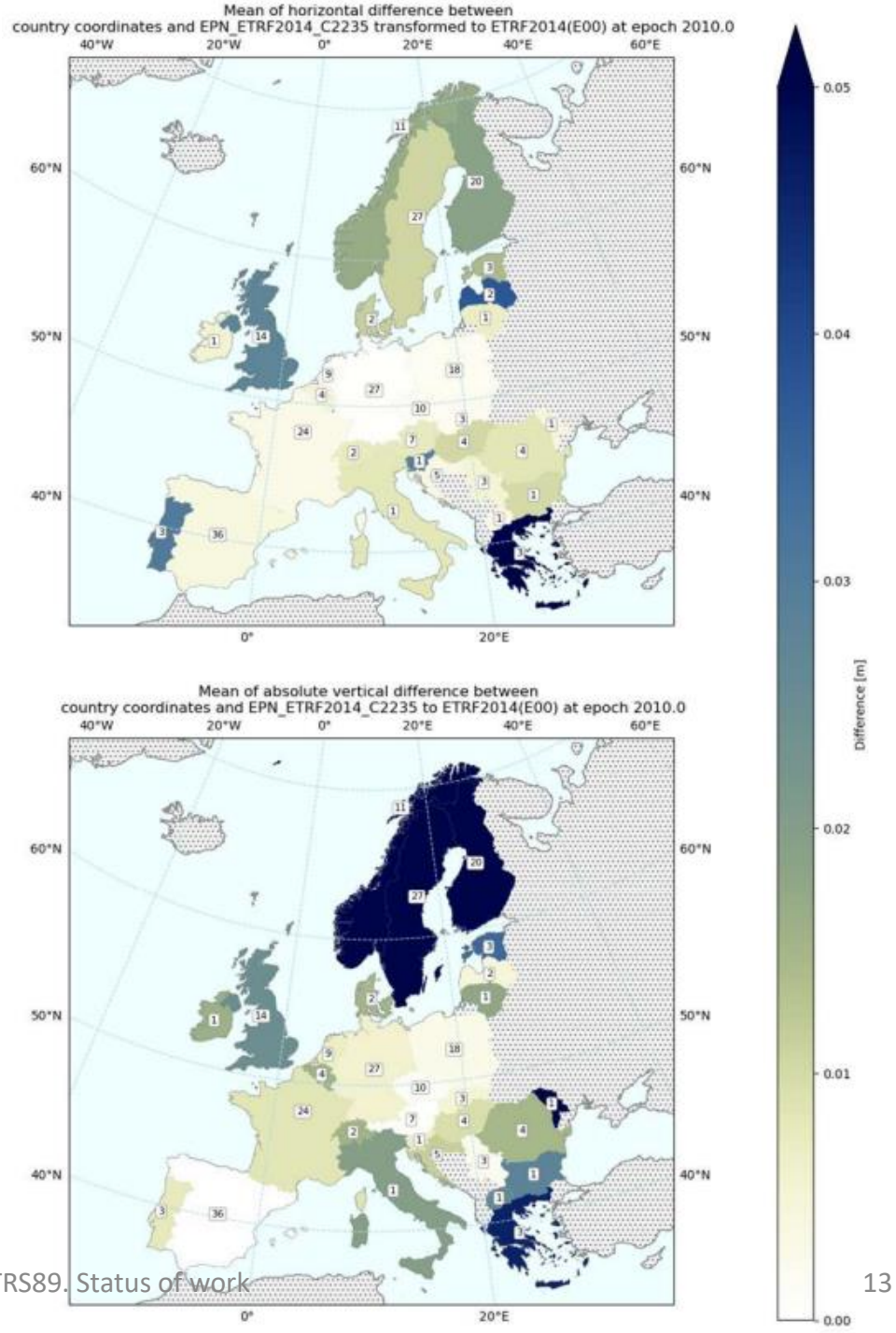
Such a change would be significant (coordinate change magnitude and legal implication) and should be clearly justified.

Need to work more on the advantages of such scenario.

Difference with current national coordinates

- Official national coordinates are still being collected by the Study Group.
- Differences between simulated coordinates and national coordinates to be computed

  Ex: - Scenario 2B : Right figure



Map by Nascimento et al.
Differences between national coordinates (preliminary dataset) and ETRF2014@ 2010.0 corrected by a rotation term

Don’t hesitate to exchange with study group members

https://euref2026.sciencesconf.org

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