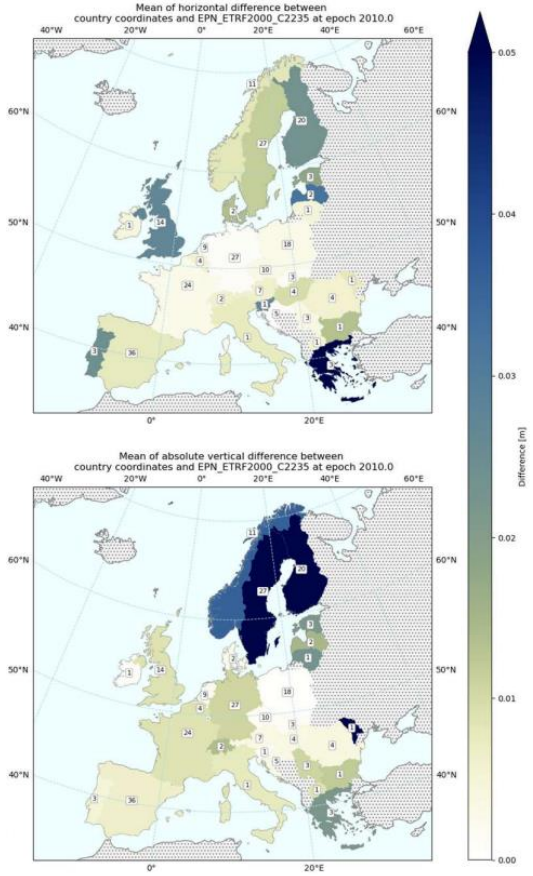
EUREF Study Group on alternatives to ETRS89

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Acknowledgment: R. Nacimento



Study group activity



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

Context:

- ~8 cm between ETRF2000 and ETRF2014/ETRF2020
- Differences between ETRFxx and ITRFxx close to 90 cm in 2026
- Differences between national coordinates better than 10 cm (differences with ETRF2000@2010 within 5 cm for all countries, except for Greece and Moldavia)
- The deformation model EuVeM2022 by Steffen et al. (2025) was proposed as official EUREF product by the EUREF governing board in oct 2025.

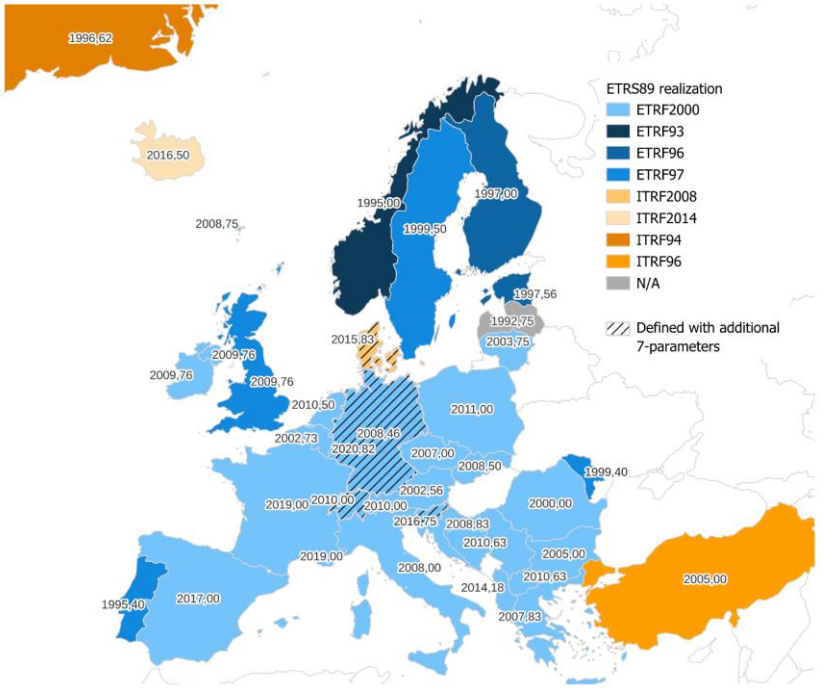


Fig. ETRS89 realizations currently in use with their reference epochs.
For countries where additional 7-parameters are used, the transformation may be restricted to 3 parameters. Based on the version 1.0a of Schwabe and Sacher (2024) inventory.

Goal:

Is ETRS89 still in line with user needs ?

Can we propose any alternative definition of the terrestrial reference system ?

Study group activity

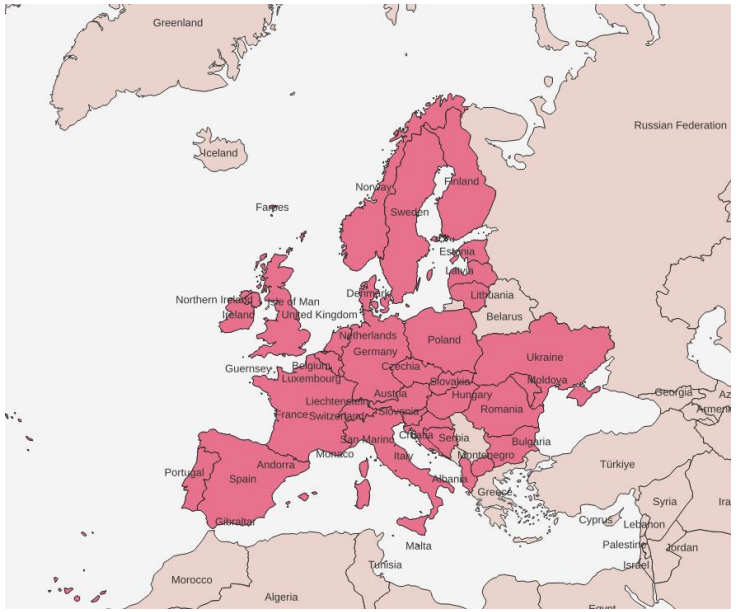
- ☑ Review the Strategies used in other countries to define their reference frame.
- ☑ Establish a list of needs regarding TRS (from an expert perspective).
- ☑ Consolidate needs thanks to a survey sent to the authorities in charge of national reference frames (deadline 2026 June 10th). They are accountable for gathering, analysing, and translating user needs into requirements.
  A copy of the questionnaire, which available on the EUREF website, ensures that no opinions are overlooked.
- ☑ Review the result of the survey regarding needs.
- ☑ 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

NB: Any decision must be approved by an EUREF resolution.

User needs : result of the survey

Restricted questionnaire
37 answers

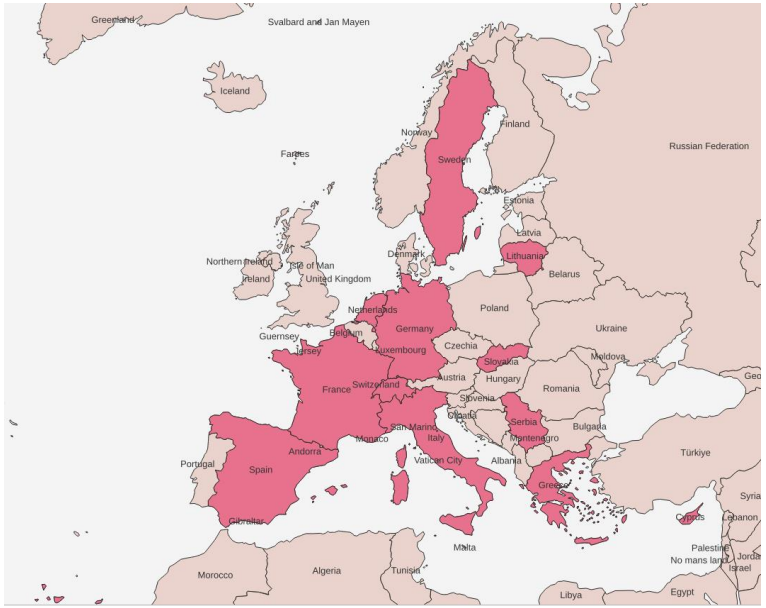
Sent to NMAs or Institutes in charge of the national reference frames on March 31st



NB: 2 answers from North Macedonia : only one considered.
Provisional answer from Italy

Public questionnaire
24 answers

Posted on the EUREF website, sent to council of European geodetic surveyors, EuroSDR on Apr 17, EuroSDR mailing list on May 11, EUREFmail June 1st



- 15 public (3 from NMA)
- 6 private companies
- 3 others

➢ No real disagreement between NMA and public questionnaire answers

Duplicated answers with the public questionnaires were removed

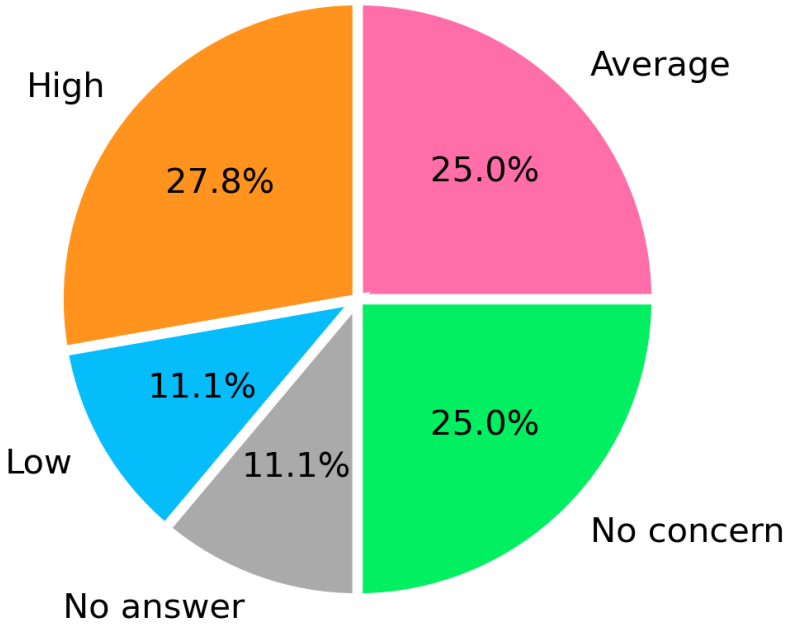
User needs : result of the survey

Example of answers

The following needs are important to meet in my country

Stay consistent with previous national reference system despite the INSPIRE directive

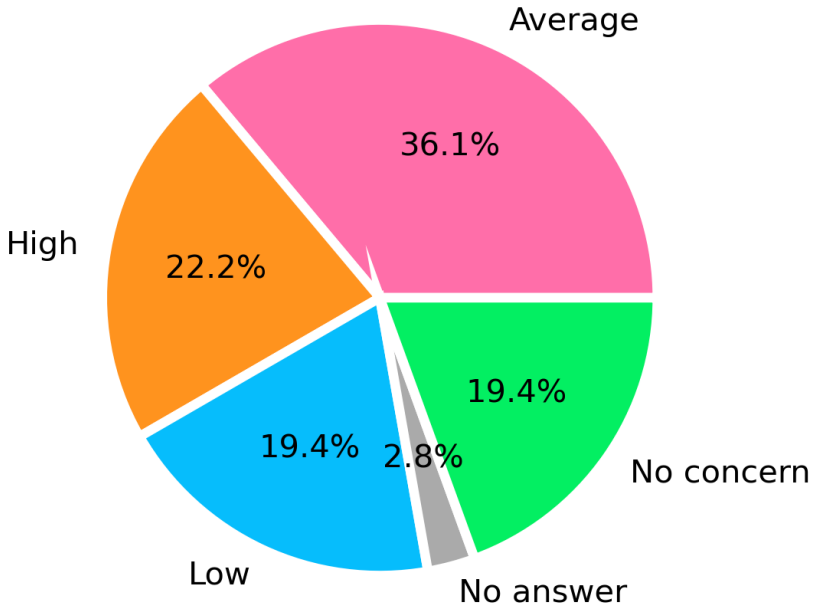
Average + high = 53%



The following issues are of concern to your country

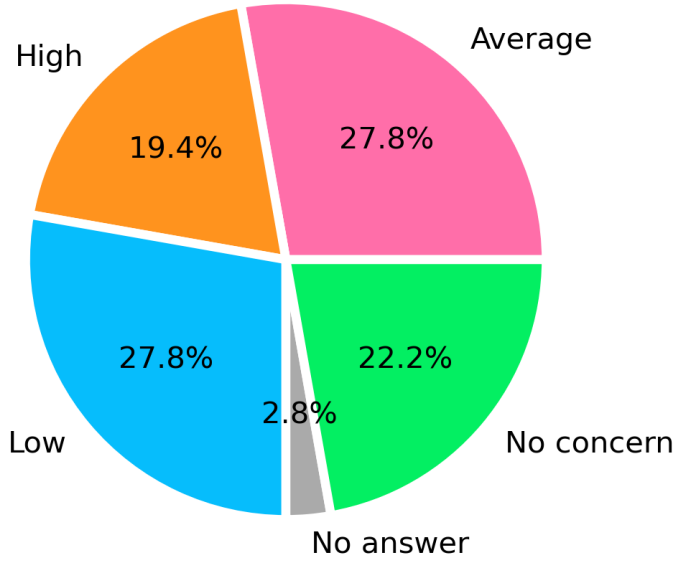
The differences between our national realization and recent ETRFxx (ETRF2014 and ETRF2020) are too large

Average + high = 58%



The difference between national realization and ITRS realizations (ex: ITRF2020) is too large today (~90 cm)

Average + high = 47%



User needs : result of the survey

Some needs/concerns are mutually exclusive :

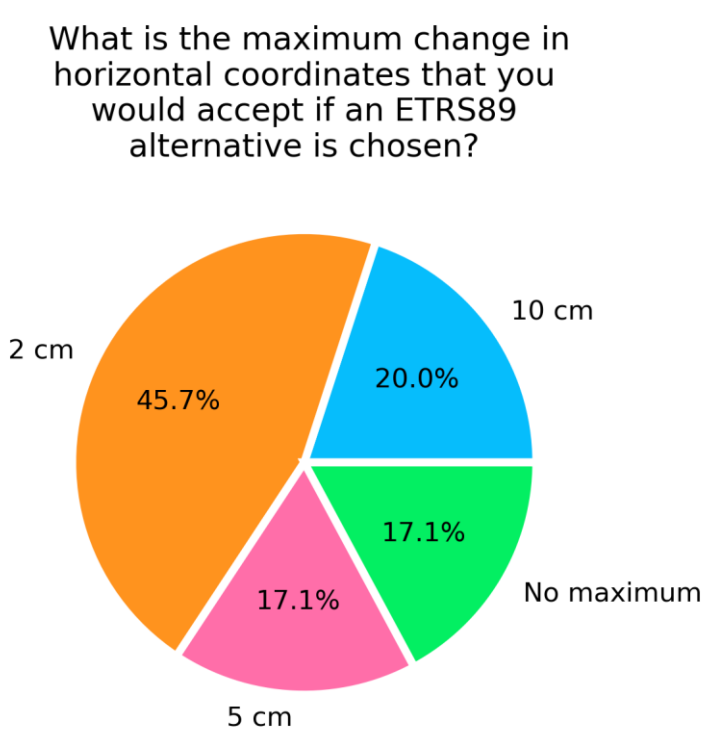
- Staying consistent with previous national reference system (53%)
- Differences between national coordinates and ETRF2020 are too large (58%)
- Differences between national coordinates and ITRFyy are too large (47%)
  - The use of two different geoid grids for ETRFxx/ITRFyy is of concern for 39% of the NMAs (larger considering Greece and Cyprus)
  - Allow users to work in ITRF is wanted by for 36% of the NMAs (larger considering Greece and Cyprus)

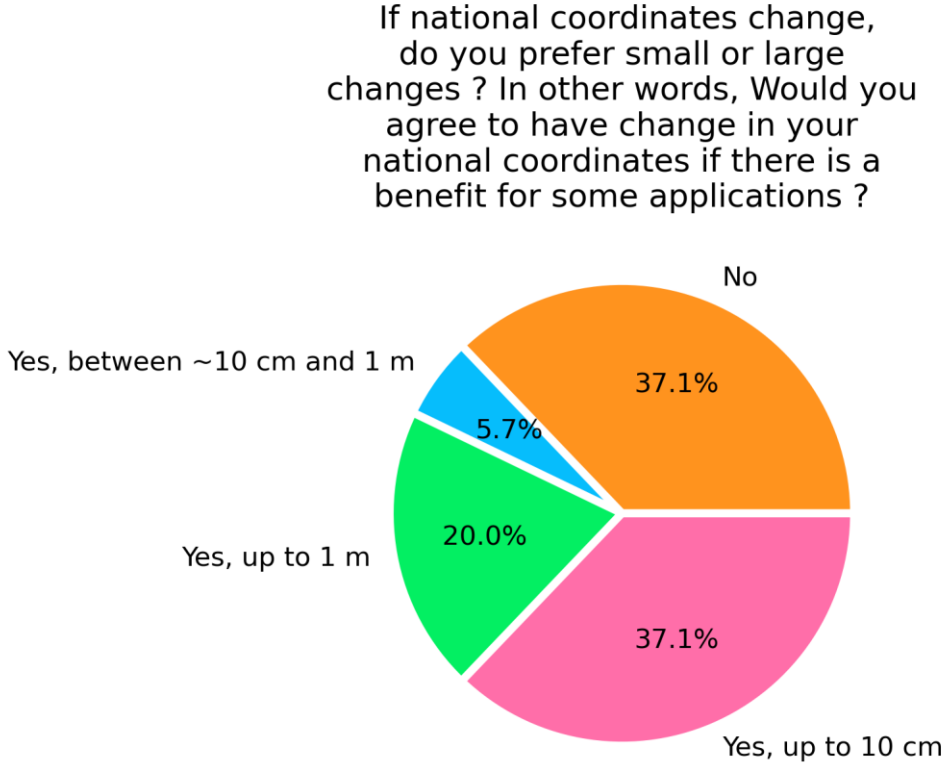
But most agreed upon others:

- National coordinates consistency at the level of 1-2 centimeter (75% of the NMAs)
- Minimum deformation at country level is required by 64% of the NMAs
- Most countries want to keep a static frame (69% of the NMAs)
- An accurate Pan-European deformation model is needed.
  NB: can be ignored if no deformation.
- Official transformations between different national TRFs, ETRFs, ITRFs at any epochs are required

User needs : result of the survey

- For the majority of NMAs (54%), a 2D coordinate change of 5 cm is possible, maximum 2 cm for 46%, possibly 10 cm for 37%
- But some countries may agree to move up to 10 cm if there is a benefit for some applications (63%), or larger (26%)
- Minimal acceptable time to change the national reference frame is larger than 10 years for 54% of the NMAs





ETRS89 alternatives

For all of these scenarios :

- Consider a deformation model with associated uncertainty for coordinate transformation (and variance propagation). To be used to transform coordinates (or static coordinates) at t_0 to ITRFyy at any epoch t (preferred operational solution) or kinematic frame at the national level (that could be experimental or not).

  - Scenario 1 : no change in ETRS89
    But continue to improve metadata description, and give more visibility to transformations between national frames and ETRFxx

  - Scenario 2 : no change in ETRS89
    But guidelines added to document how to compute national realizations of ETRS89. The recommendation would include a conventional epoch (ex: 2025.0). With two alternatives :
    - 2a Transition to ETRF2020 (resulting in a ~7 cm change) or any future ETRFXX since recent ITRS realizations are being stabilized.
    - 2b Same as before but apply an additional rotation to approximate ETRF2000 horizontal coordinates by keeping ETRF2020 height quality (or next ETRFXX) (=>smallest coordinate change from most countries in any scenario other than scenario 1) (Lidberg, 2024)

  - Scenario 3 : anticipate plate motion to create ETRS35 and increase fit between ETRFxx and ITRFyy (=> 1 m change)

  - Other possible scenario : adopt fixed-epoch ITRS with regular updates (every five years).

← 65% would agree to accept such coordinate change if there is a benefit

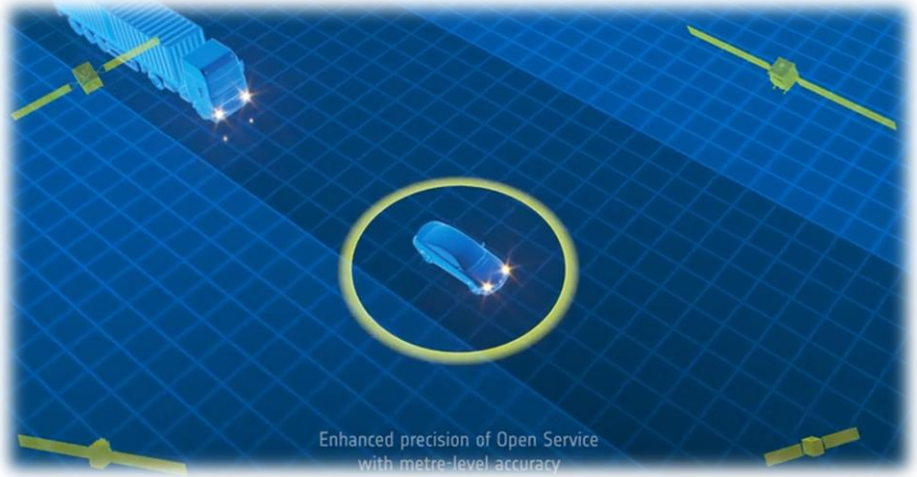
← Acceptable to all in terms of 2D coordinate change

← 19% would agree to accept such coordinate change

Positioning in the future?

What accuracy for future mass-market positioning sensors ?

- Enhanced precision of open services (ex: Galileo second generation (G2G), first launches targeted for 2027) (ESA, 2025;2026), higher power level (ESA, 2026)
- Multi-frequency of mass market sensors?
- EGNOS v3 (dual-frequency + Galileo) accuracy could reach 50 cm or better in 2D. Dual-frequency planned for 2029.
- A democratized use of HAS technology? Enhanced HAS planned for G2G (ESA, 2025)). Better than 20 cm in 2D?
- Smaller convergence time?
- Sensor Fusion ? (IMU, vision)



Source: figure extracted from ESA (2025)

Is the difference in coordinates between ETRS89 and ITRS something positive or negative ?
Can EGNOS/HAS receivers implement the transformation or ESA provide a stream in ETRS89?

References:
- ESA 2025, https://www.esa.int/esatv/Videos/2025/05/Galileo_Second_Generation_-_Animation/May_2025_-_Galileo_Second_Generation
- ESA 2026, EU Space Market Report, EU_Space_Market_Report_2026.pdf
- Gutierrez 2025, Airbus Tests Dual-Frequency, Multi-Constellation EGNOS V3, https://insidegnss.com/airbus-tests-dual-frequency-multi-constellation-egnos-v3/
- Madrazo 2024, EGNOS Programme Status, https://egnos.gsc-europa.eu/sites/default/files/2024-03/1.%20EUSPA%20AMA%20-%20EGNOS%20programme%20status.pdf

Next step

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

Next steps :

- Study the benefit and drawbacks of each scenario, but also their costs, to support the decision -> white paper
- Compute coordinate differences in scenario 2a, 2b (done already) and 3

Conclusion :

- ETRS89 will be replaced only if there theoretical or practical benefits
- If it is not replaced, a better operational framework is required : metadata, official transformations with velocities, enhanced documentation

References

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- Schwabe J. and Sacher M. (2024) Overview of national realizations of the integrated geodetic reference in Europe, https://10.71603/NatRefEurope
- Steffen, R., Steffen, H., Kenyeres, A., Nilsson, T., & Lidberg, M. (2025). EuVeM2022—a European three-dimensional GNSS velocity model based on least-squares collocation. Geophysical Journal International, 241(1), 437-453, https://doi.org/10.1093/gji/ggaf052