EUREF Study Group on alternatives to ETRS89

X. Collilieux (chair), Altamimi Z., Anastasiia W., Araszkiewicz A., Arnfinnsdatter Skar K., Bruyninx C., Caporali A., Dach R., Danezis C., Gianniou M., Kenyeres A., Kollo K., Kotsakis C., Häkli P., Huisman L., Legrand J., Liebsch G., Lidberg M., Liwosz T., Männel B., Pacione R., Poutanen M., Prange L., Sacher M., Schwabe J., Söhne W. , Torres J. A. , Verbeurgt J., Virly B., Völksen C., Zurutuza J.

Context

- The European Terrestrial Reference System 89 (ETRS89) was adopted in 1990 in Firenze. It is defined in such a way that it coincides with ITRS at epoch 1989.0 and is fixed to the stable part of the Eurasian tectonic plate.

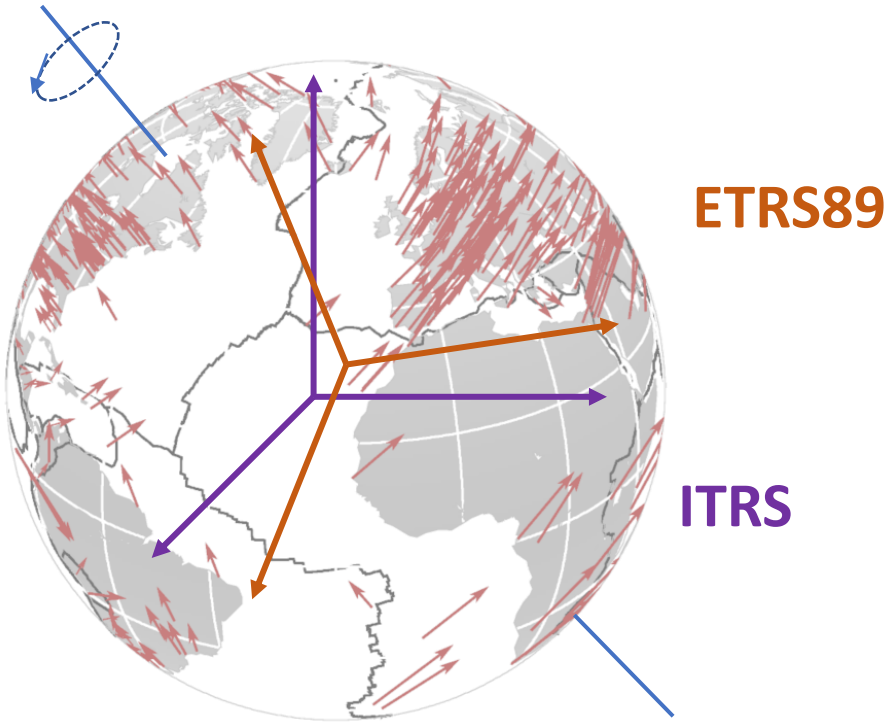


Fig. The ETRS89 continuously rotates with respect to ITRS

Context

- 12 realizations have been published so far, the most recent being ETRF2020.
- European countries have aligned their national reference frame with respect to an ETRS89 realization. Most of the countries have chosen **ETRF2000** but at various epochs.
- The most recent version, **ETRF2020**, has coordinate differences of around 7 cm with ETRF2000 which is also known to be affected by origin artificial drifts. However, only a few countries have adopted the recent unbiased updates

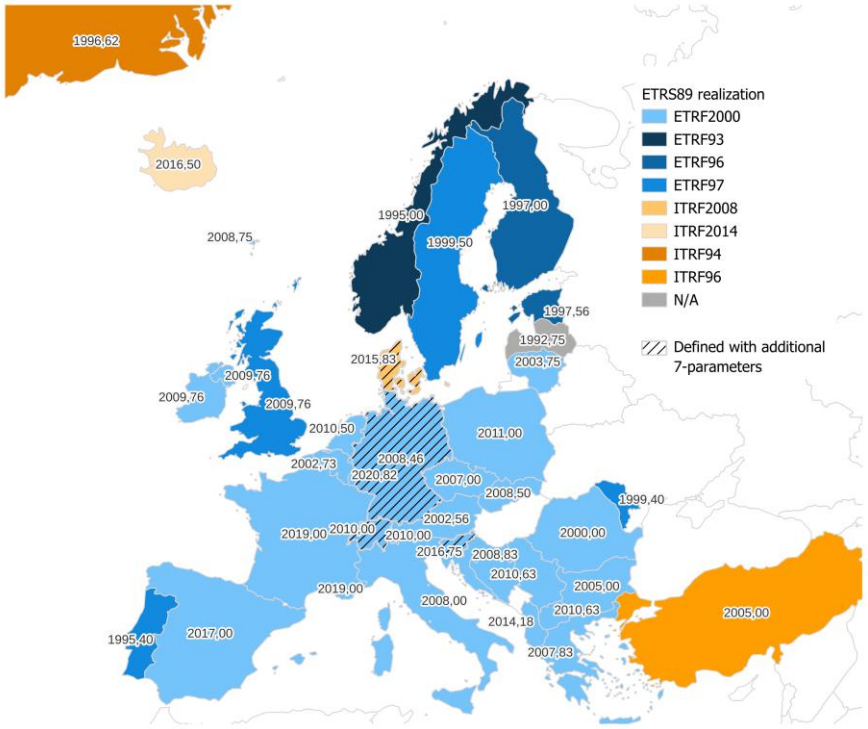


Fig. ETRS89 realizations currently in use with their reference epochs. For countries where additionnal 7-parameters are used, the transformation may be restricted to 3 parameters

Data source:
Schwabe, J.; Sacher, M. (2024): Overview of national realizations of the integrated geodetic reference in Europe, https://10.71603/NatRefEurope

Acknowledgment: J. Schwabe

Question: is ETRS89 still in line with user needs?

A study group created by the regional Reference Frame sub-commission for Europe of the International Association of Geodesy (EUREF) governing board in October 2024.

Objectives:

- Investigate if ETRS89 is still in line with user needs.
- Propose an alternative definition of the system if it is relevant.

Tasks:

- List advantages and drawbacks of current ETRS89 and its realizations with respect to user needs.
- Make an inventory of the strategies adopted in other regions of the world.
- List alternatives to ETRS89 as well as their strength and weaknesses.
- Evaluate the order of magnitude of coordinate differences in these systems and the impact on national realizations.

Study group

- 16 members, 16 correspondent members from 17 countries in total
- Planned duration of the study group: one year
- Expected deliverable: a white paper with recommendations

Status of the work

- 3 web meetings have been organized (01-28 ; 03-25; 05-05)
- 7 presentations by study group members + discussions

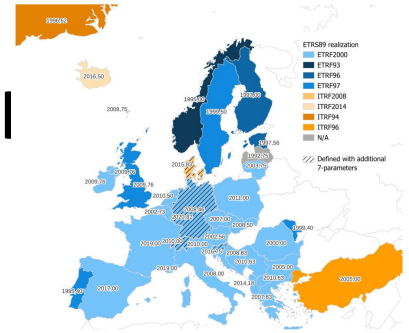
Tasks	Status	Comment
List advantages and drawbacks of current ETRS89 and its realizations with respect to user needs	**Done**	See next slides
Make an inventory of the strategies adopted in other regions of the world	**Started**	
List alternatives to ETRS89 as well as their strengths and weaknesses	**Started**	
Evaluate the order of magnitude of coordinate differences in these systems and the impact on national realizations.	**Started**	See next slides

Task : list advantages and drawbacks of current ETRS89 and its realizations with respect to user needs

PROS

- For many countries in the stable part of the tectonic plate, no need to have point velocities in the national realizations (static frames).
- ETRS89 realizations, as ITRFxx, are kinematic frames. NB: national frames are static.
- Many ETRFxx realizations but 14-parameters transformations have become standard (ex: *proj* library)
- ETRS89 is widely adopted (by law), INSPIRE directive. Adopted by practically all countries. Well accepted by end users at national level for most countries.
- Long history.
- Well established governance.
- Roadmap to introduction of a new system will take many years and might add confusion

Task : list advantages and drawbacks of current ETRS89 and its real respect to user needs



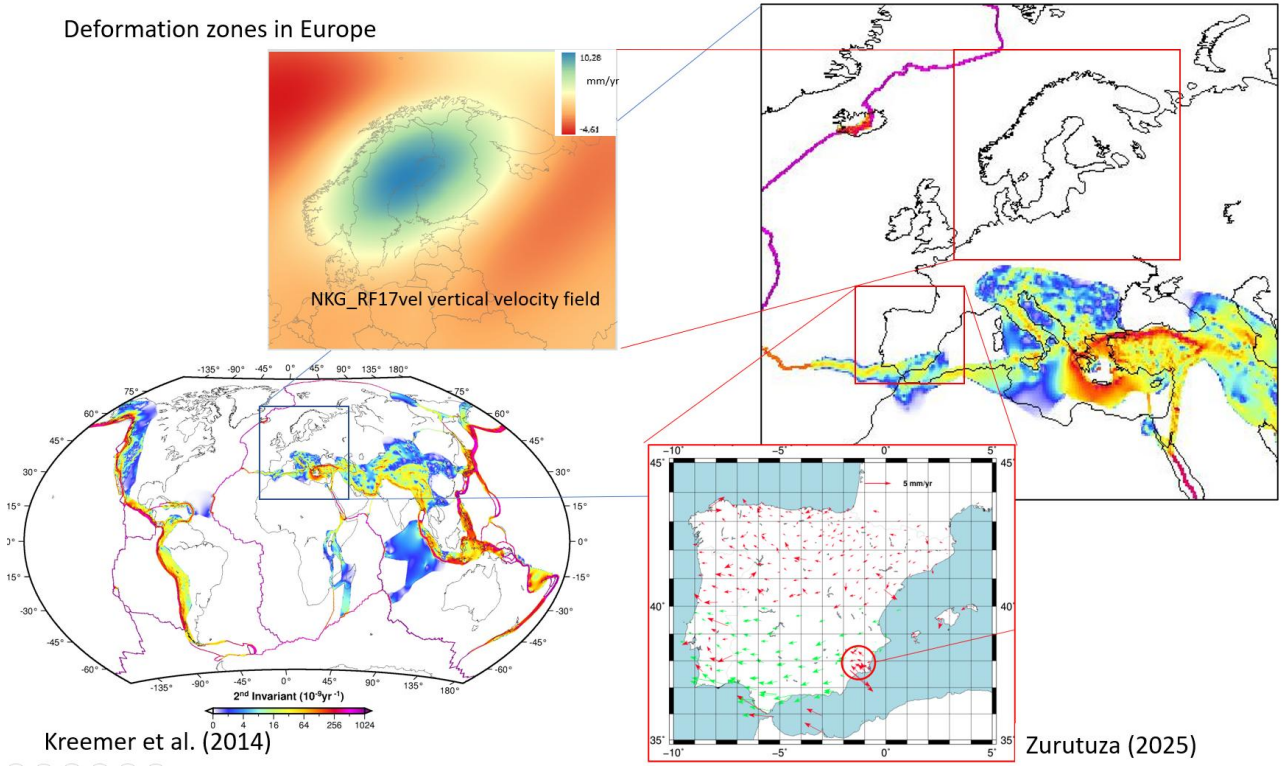
CONS (1/3)

- Already mentioned. Most countries still use old realizations. Moreover there is a ~7 cm difference between horizontal coordinates in ETRF2000 and ETRF2014/ETRF2020.
- The additional TZ/Scale drift causes differences in height and **vertical velocities** (this creates a dependency to the epoch).
- Previous realizations included a translation that causes an apparent tilt in the vertical coordinate between some realizations.
- The cross product $\vec{\Omega} \Lambda \vec{X}$ that models the rotation rate of the ETRFxx w.r.t. ITRFxx (including the 14-parameter transformation between ETRFxx and ITRFxx) causes a small difference in the vertical velocities.
- ETRF2000/ITRF2020 scale difference impact PPP users who wish to get coordinates in ETRF2000. Indeed, transformation of real-time orbit and clock products causes bias in height of ~2 cm in 2025 when using EUREF real-time PPP-product due to scale difference between ETRF2000 (ITRF2000) and ITRF2020.
- Regulations need to be changed if ETRS89 is replaced.

Task : list advantages and drawbacks of current ETRS89 and its realizations with respect to user needs

CONS (2/3)

- Displacements are likely not minimized at the continental scale. Minimized for Eurasian plate only.
- In some countries (like Greece), coordinate changes <u>in average</u> for the whole country in ITRFxx are smaller than in ETRFxx.
- Current realizations provide point coordinates (position, velocities). Dense velocity field are separate products. No operational solutions at the European scale for extracting point velocities. + non steady deformations in some areas (seimic activity): no coordinate update.



Kreemer et al. (2014)

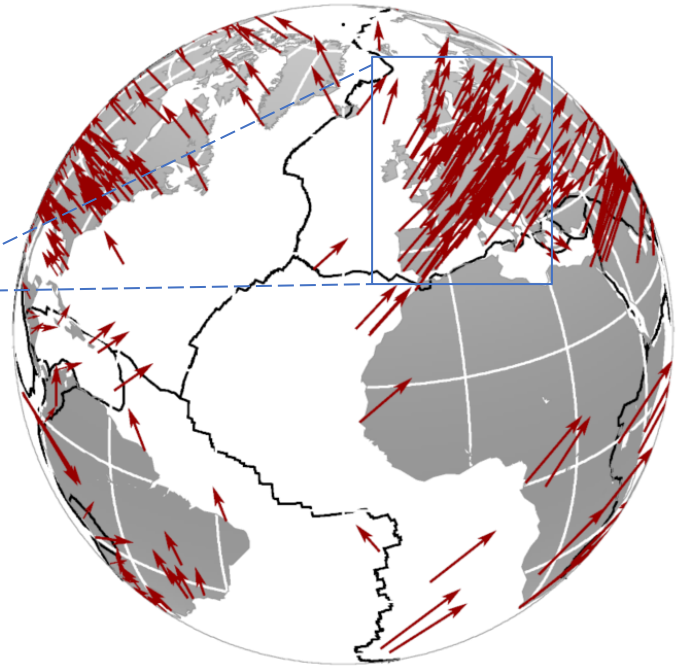
Zurutuza (2025)

Task : list advantages and drawbacks of current ETRS89 and its realizations with respect to user needs

CONS (3/3)

- Reference epoch. ETRF2020 differs with ITRF2020 (WGS84) by ~86 cm in 2020.0, ~1.1 m in 2035.
- Reference epoch. Defining a frame in 1989.0 causes the alignment to be sensitive to Euler pole random errors. ~6 mm in 2020.0 (Collilieux et al., 2025).

about 25 cm every 10 years



Task : list advantages and drawbacks of current ETRS89 and its realizations with respect to user needs

User needs

- Consistency of ETRS89 realizations with ITRFxx?
- Minimized displacements for all areas/plates. One TRS per tectonic plate?
- New needs: Displacements everywhere at any time (deformation model)?
- What precision requirement for the frame ? 1 cm at reference points at any time? -> Precision of RTK/NRTK
- Consistency (few cm?) with adopted national realizations? For a convenient use at country boundaries.
- Same geoid (so same vertical position) and same vertical motion models (velocities) usable in ITRFxx and European TRFxx (height (velocity) ITRFxx=European TRFxx)?
- Bias free transformation of ITRFxx satellite orbits and clocks for EUREF products ?
- Two-frame approach: unchanged TRF for geospatial data (now: ETRS89/ETRF2000), additional TRF (few year validity) close to ITRS @ current epoch for navigation and webmapping?

Future work

- Investigate what strategies are adopted in other regions of the world.
  Countries to be studied :
  - Australia
  - Canada
  - New Zeland
  - USA

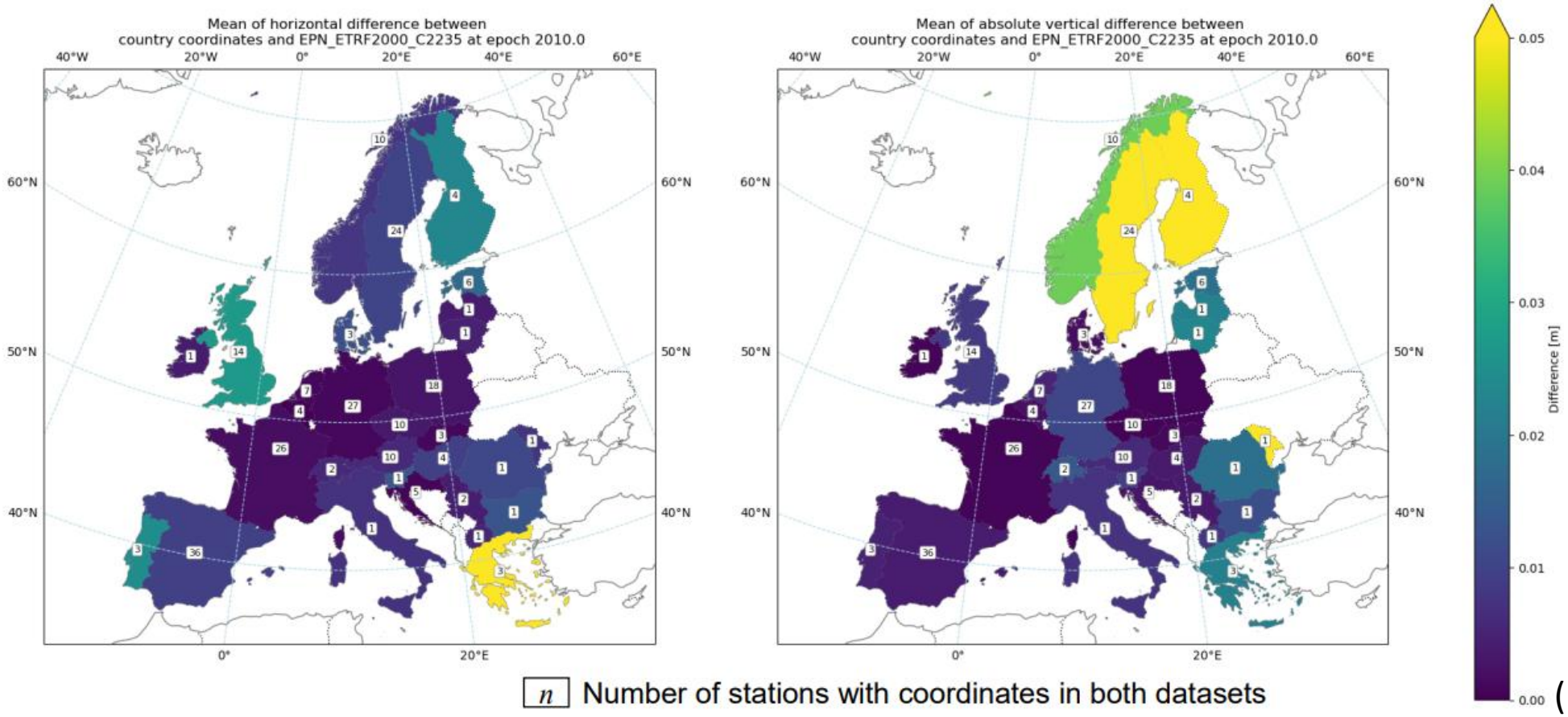
- List alternatives to ETRS89 to be studied and quote which needs are met by specific proposed alternatives

- Derive a reference dataset : country-specific coordinates of reference points in national reference frames. Will be used to assess the coordinate differences of studied ETRS89 alternatives w.r.t. national coordinates (next slides).

Discussions planned at meeting #4

Task: Evaluate the order of magnitude of coordinate differences in these systems and the impact on national realizations

Differences between available national reference coordinates and ETRF2000 (ETRF2000_C2235 solution)



(Huisman, 2025)

Some of available national coordinates are old and require an update. **Decision: task =** update national coordinates

Conclusion

- Work is ongoing. More will be available later
- Thank you

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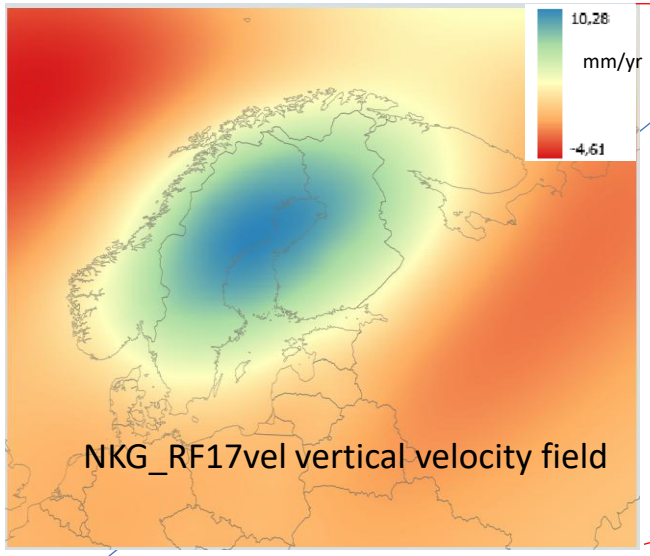
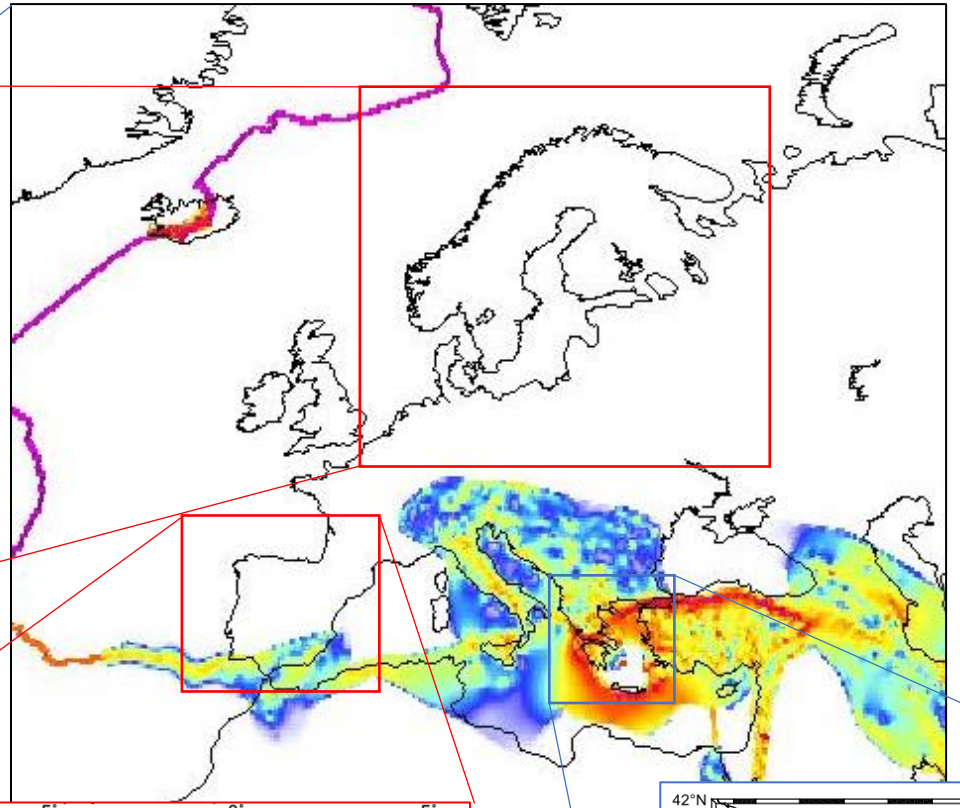
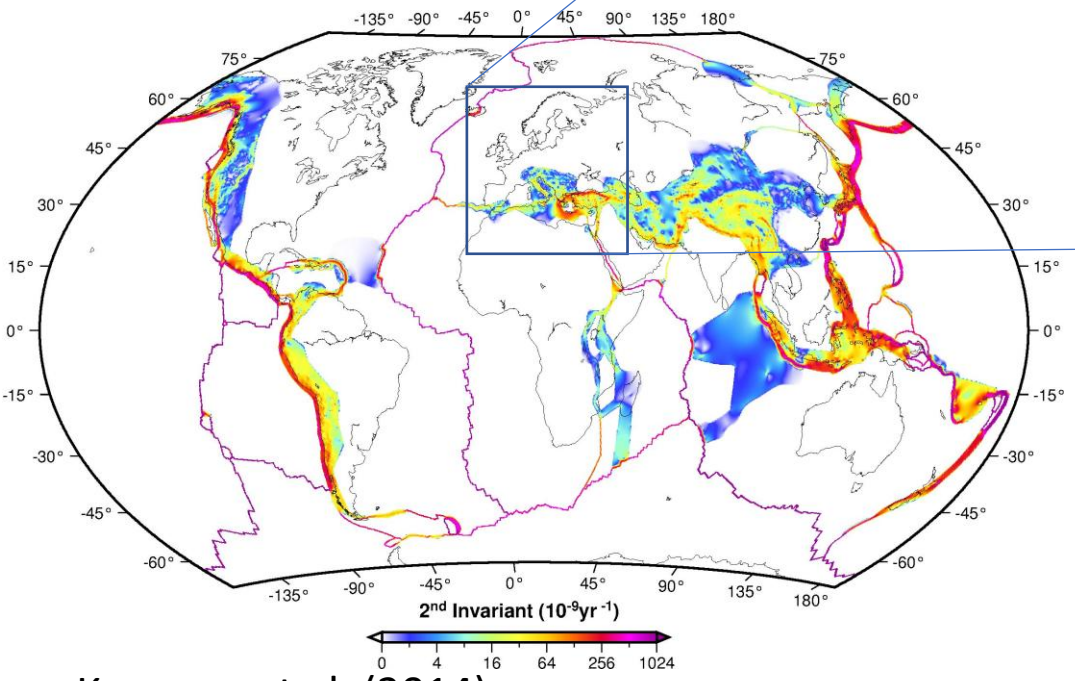
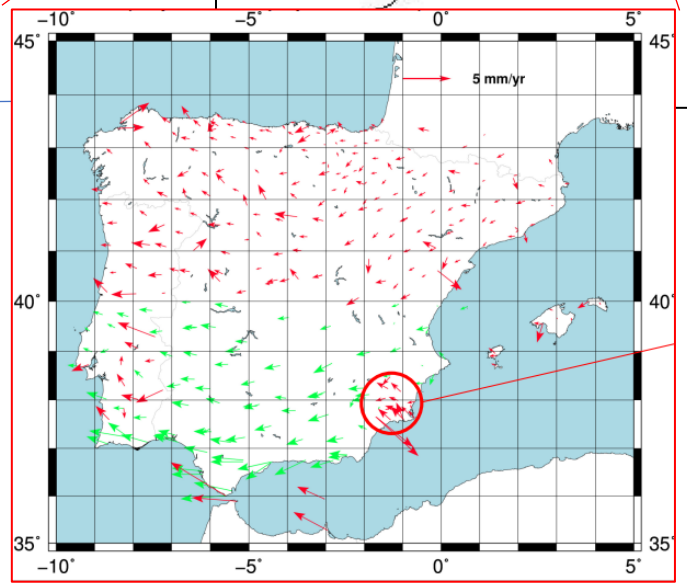
Deformation zones in Europe







Kreemer et al. (2014)



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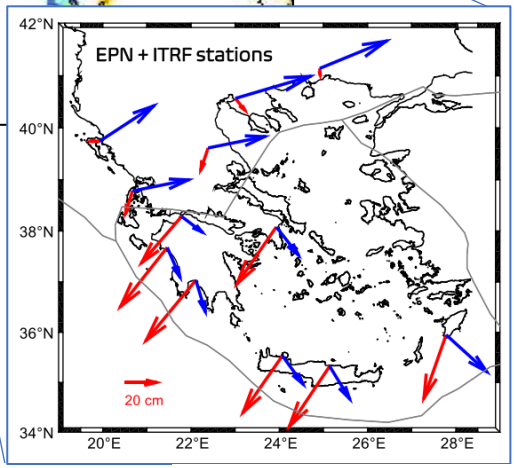

Kotsakis (2025)