3D GNSS Velocity Field and strain rates in Europe, & link with the seismic potential

Anne Socquet

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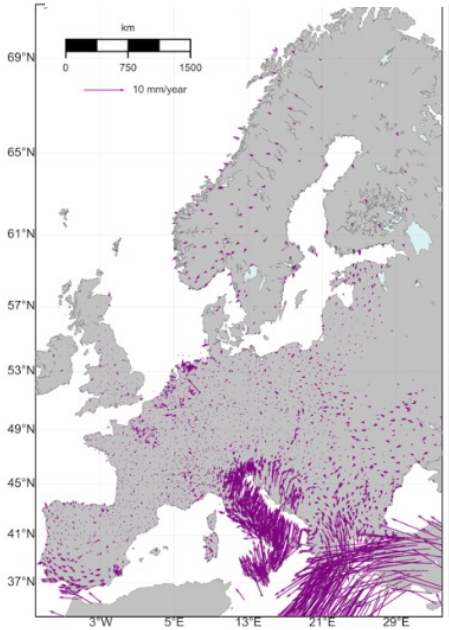
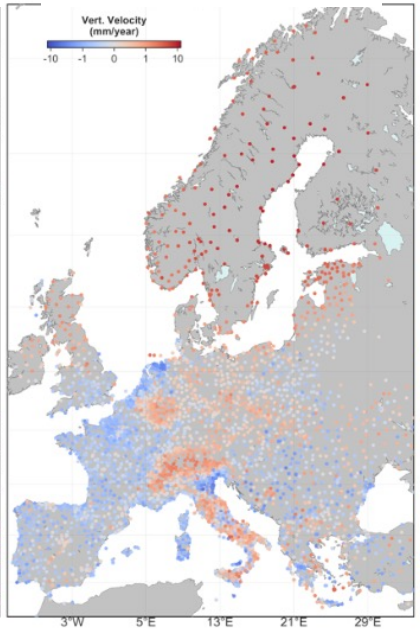
Horizontal velocities

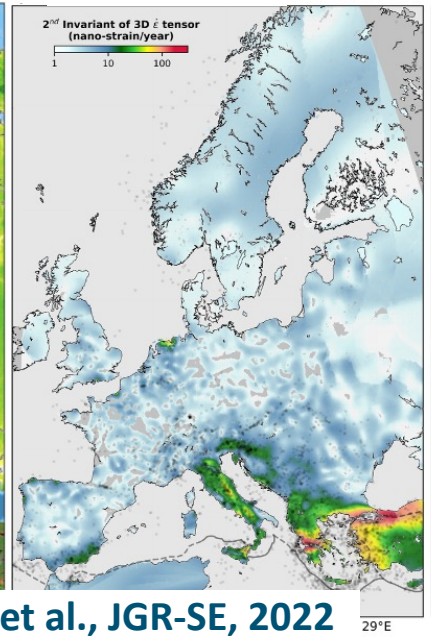


Vertical velocities

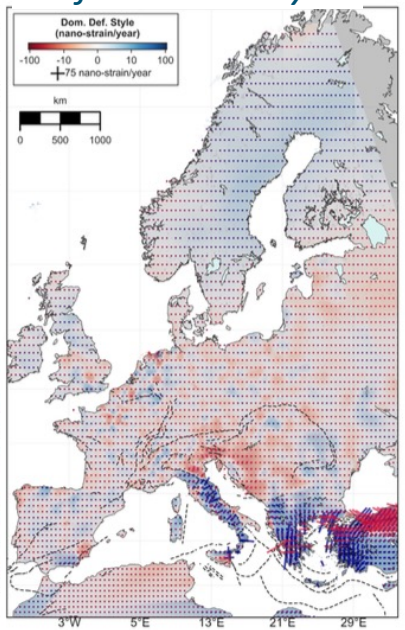


Topography

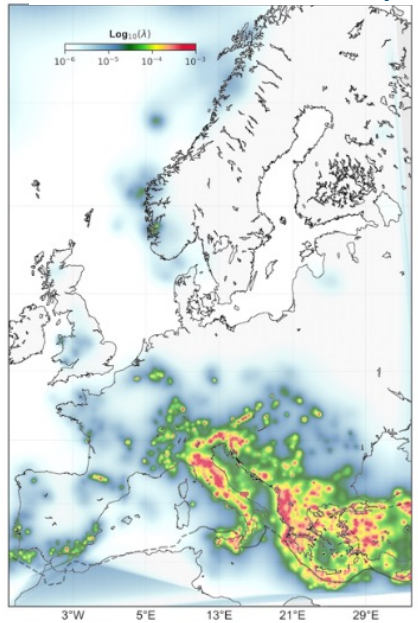
Strain rates



Deformation style



Smoothed Seismicity



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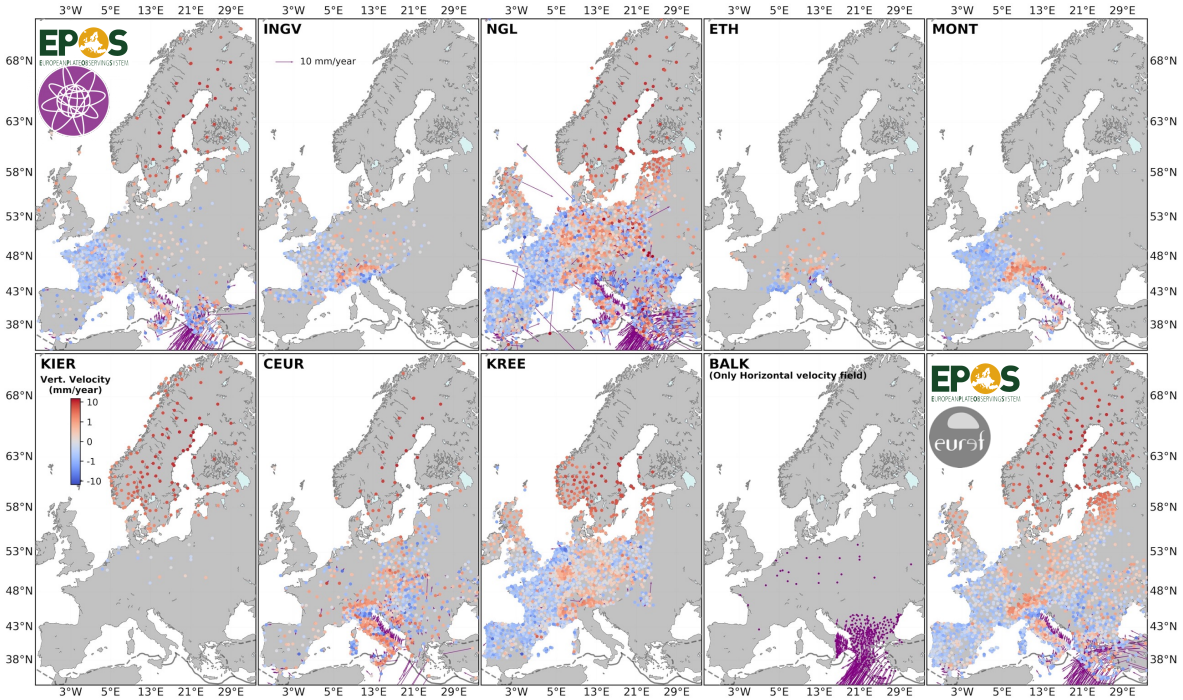
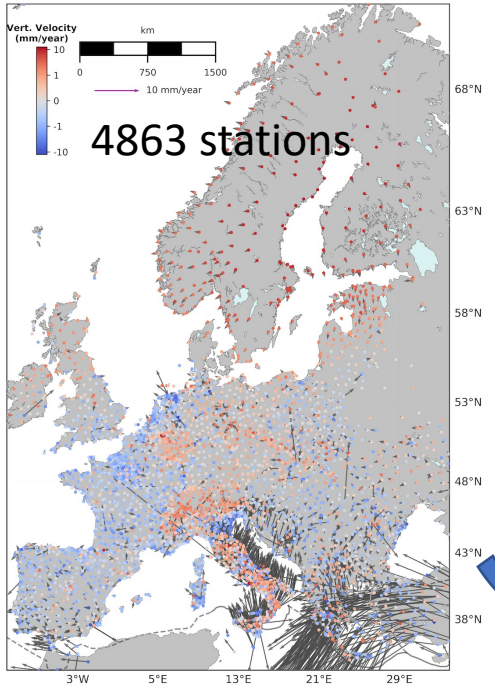
Combined Velocity Field



10 solutions

Combination at velocity level

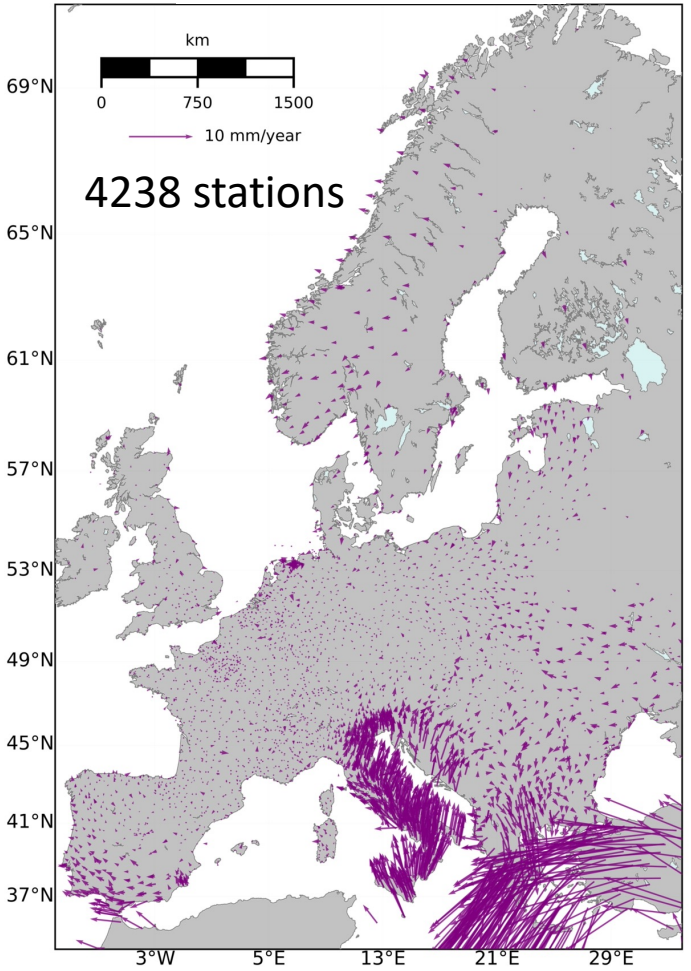
Uncertainty harmonization
6 param Helmert transform
ITRF2014 reference frame
Rotation wrt stable Eurasia



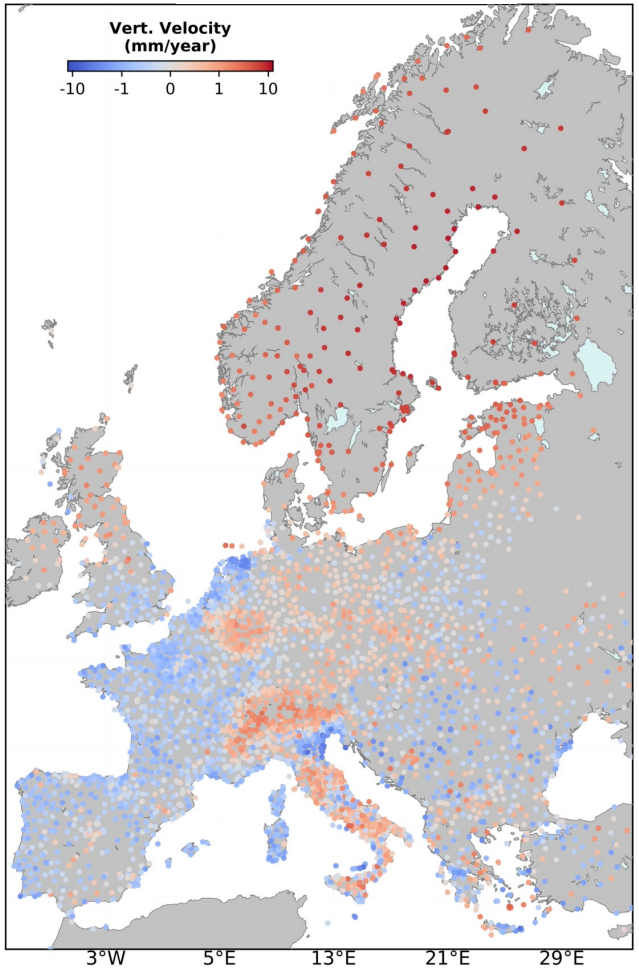
Filtering

Outlier identification

Horizontal velocities



Vertical velocities



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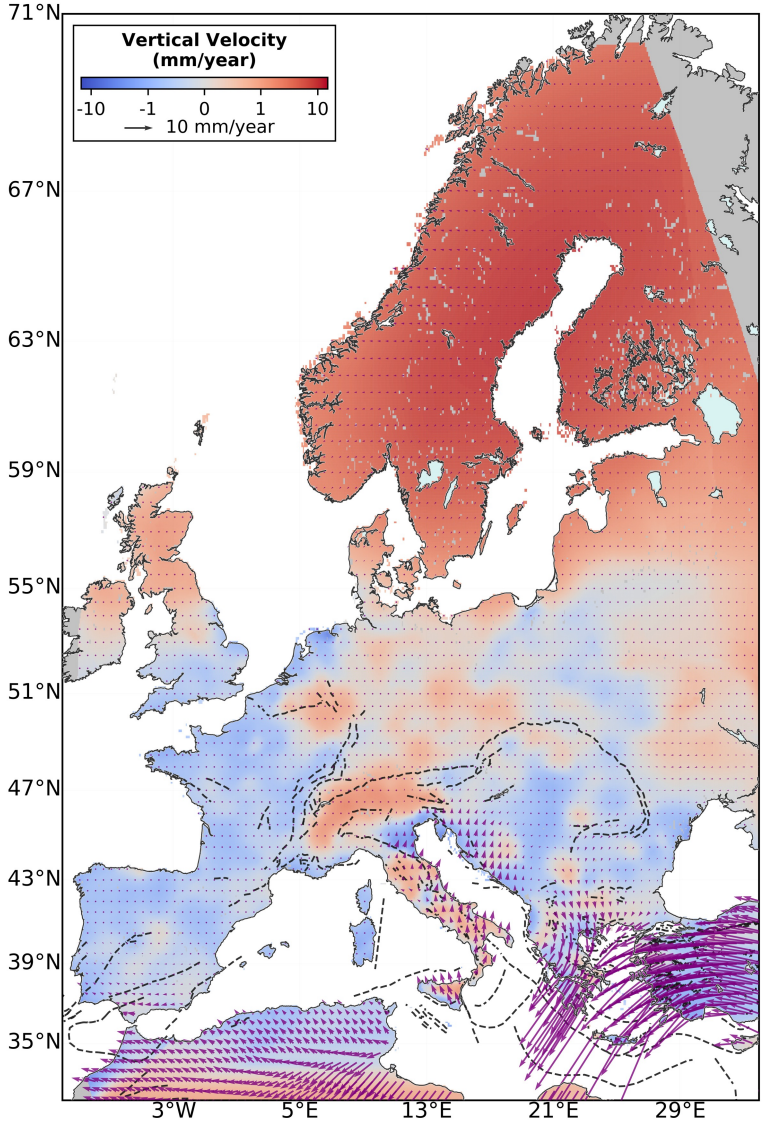
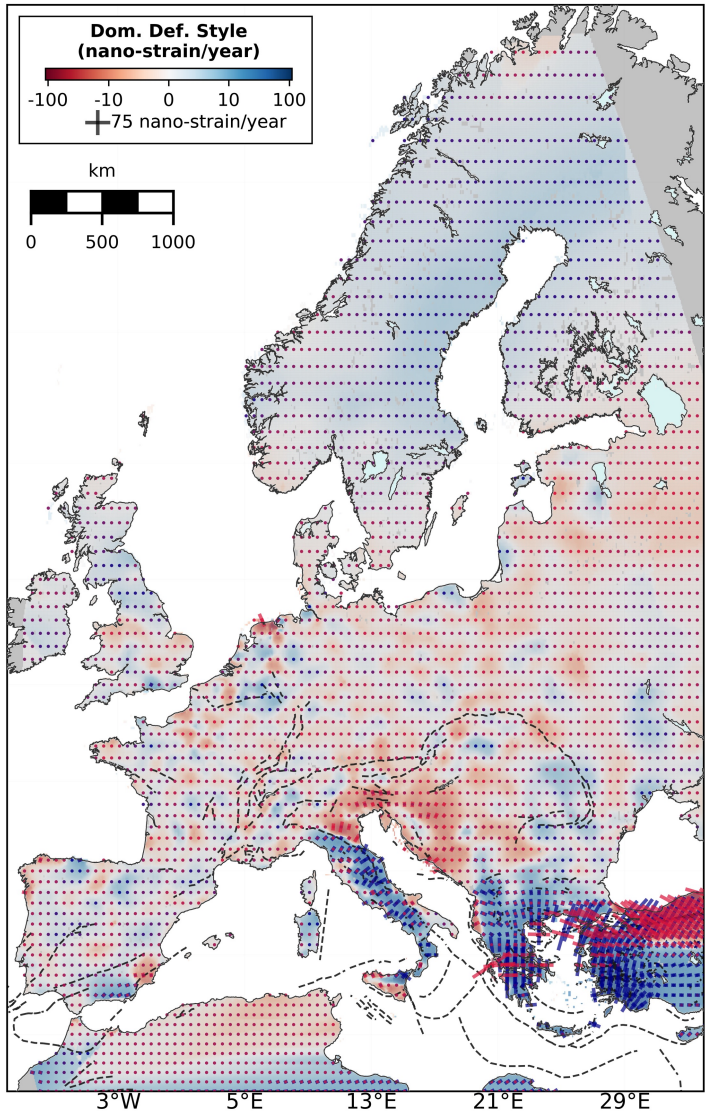
3D velocities, deformation style and strain

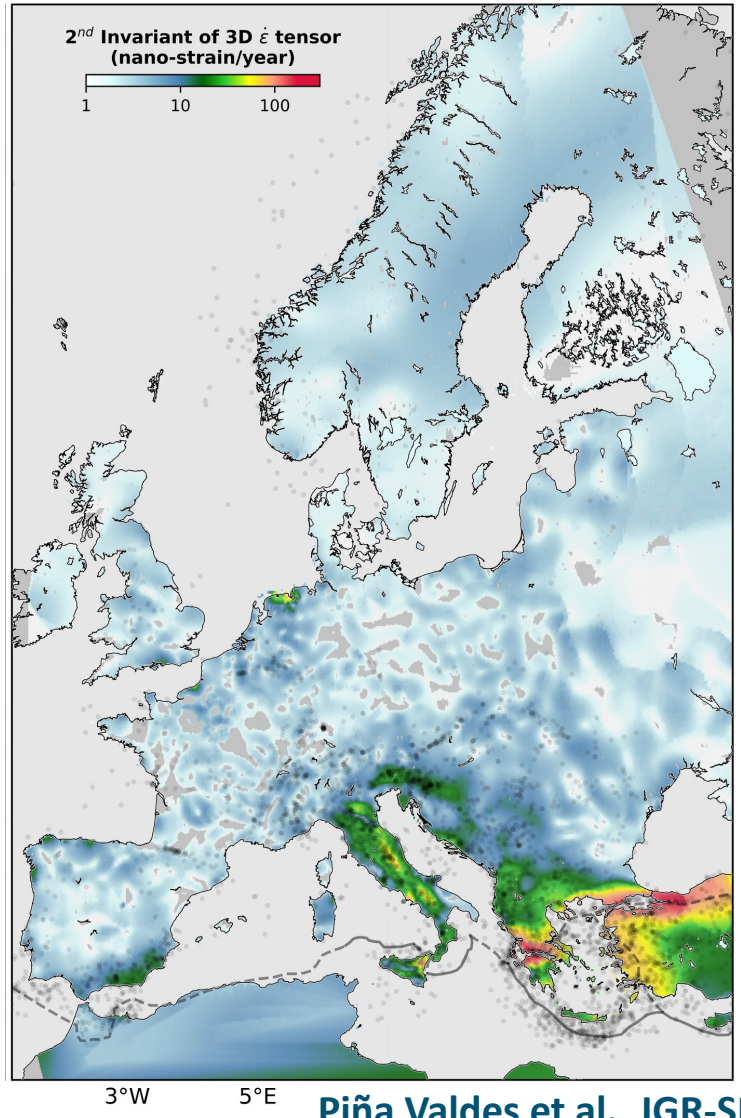
3D interpolated velocity field



Deformation style



Strain rates



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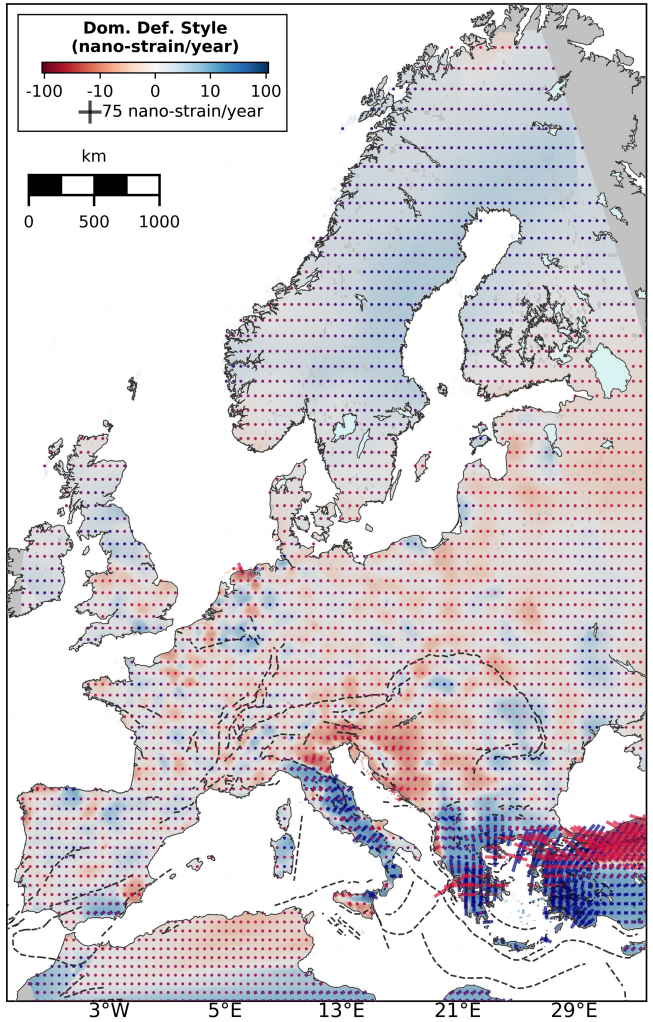
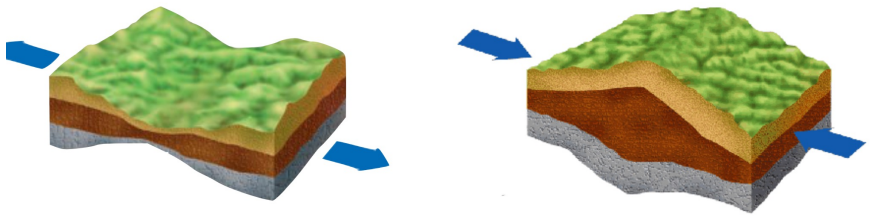
Predicting vertical velocities from horizontal strain

Assumption : conservation of strain + isostasy

Deformation style

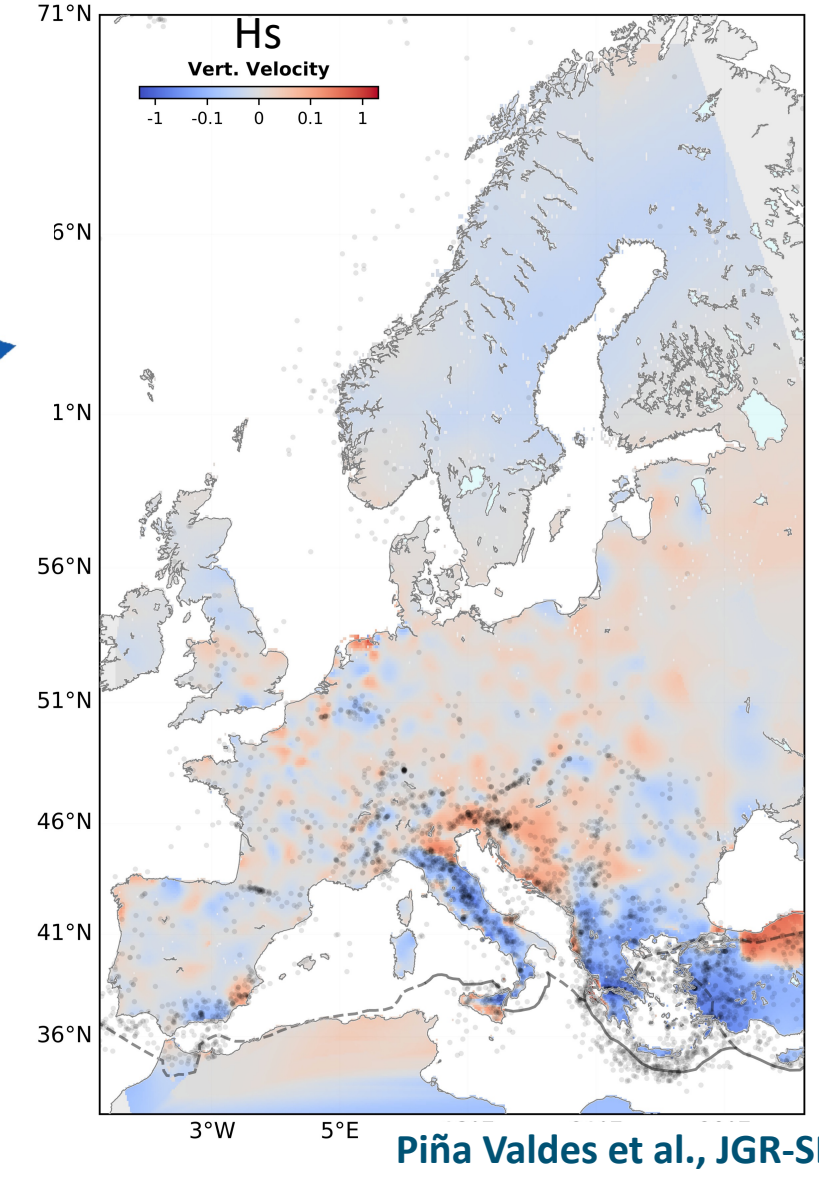




$$H_S \simeq \frac{-T_c\,(\varepsilon_1 + \varepsilon_2)\,(\rho_m - \rho_c)}{\rho_m}$$

Surface uplift — Crustal thickness — strain — Mantle density — Crustal density — Mantle density

Theoritical vertical velocities from horizontal strain



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What contributes to vertical velocity field ?

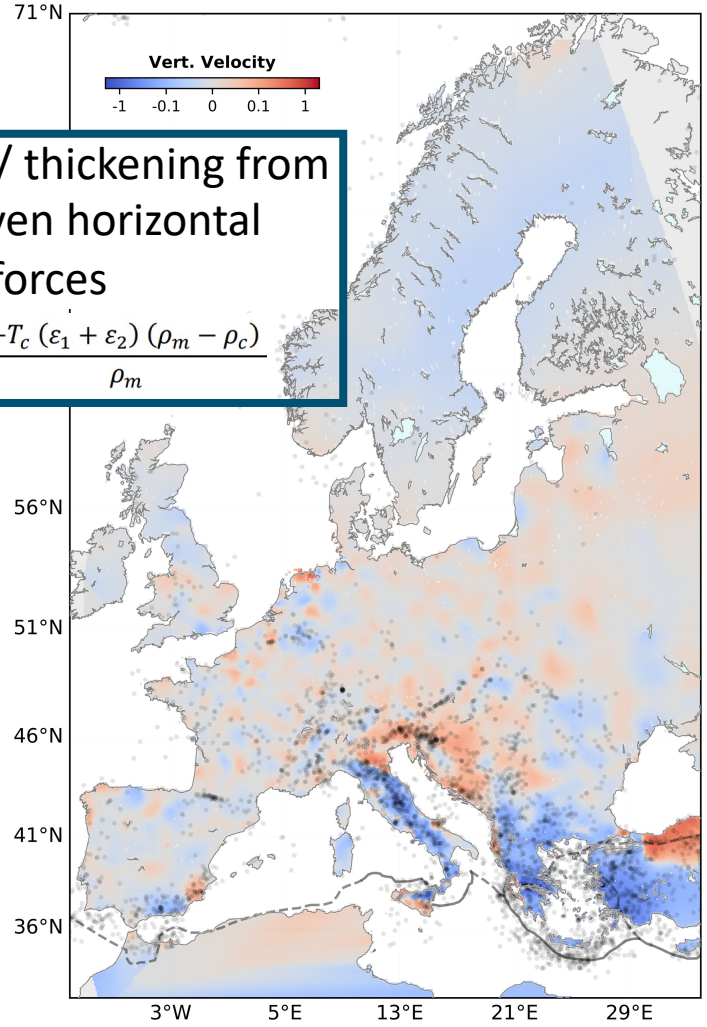
Theoritical vertical velocities from horizontal

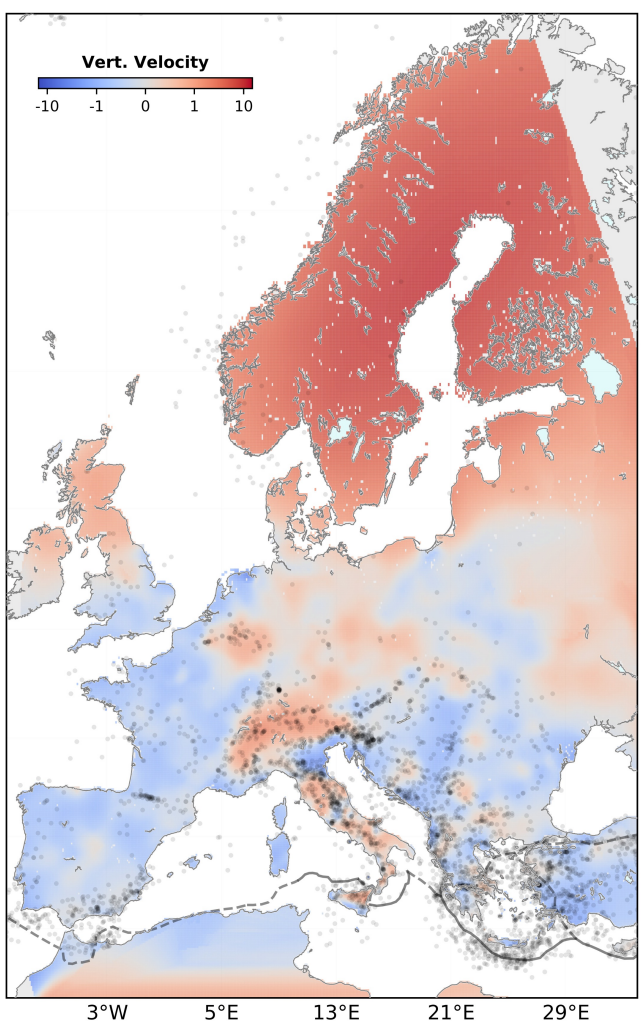
Observed vertical velocities

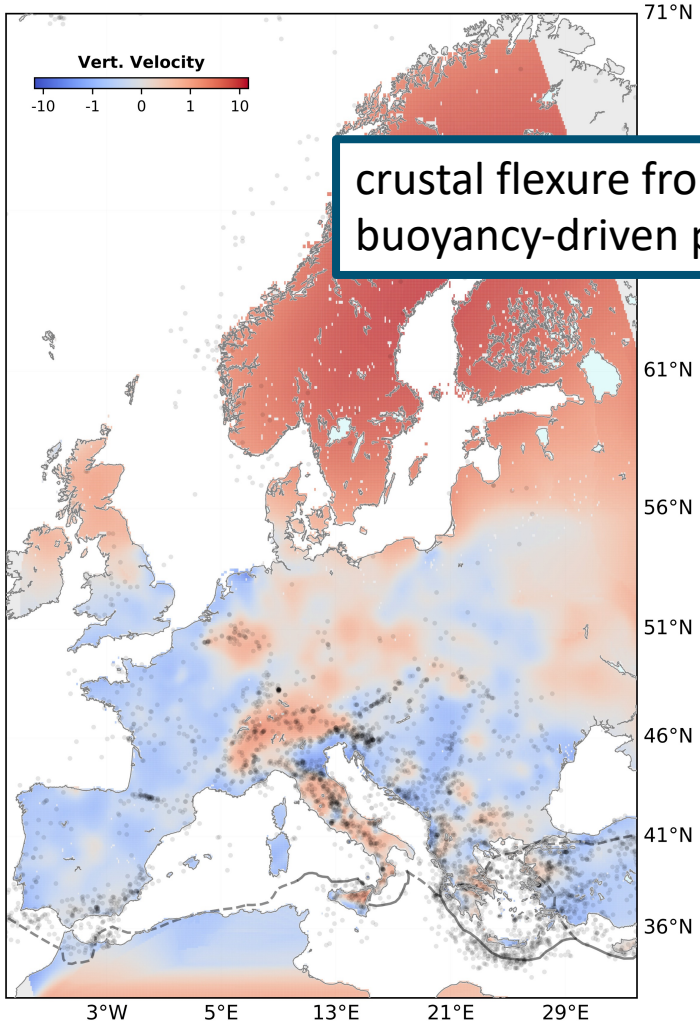
Difference : vertical velocities due to flexure ?

thinning / thickening from edge-driven horizontal tectonic forces

$$H_S \simeq \frac{-T_c\,(\varepsilon_1 + \varepsilon_2)\,(\rho_m - \rho_c)}{\rho_m}$$







crustal flexure from buoyancy-driven processes

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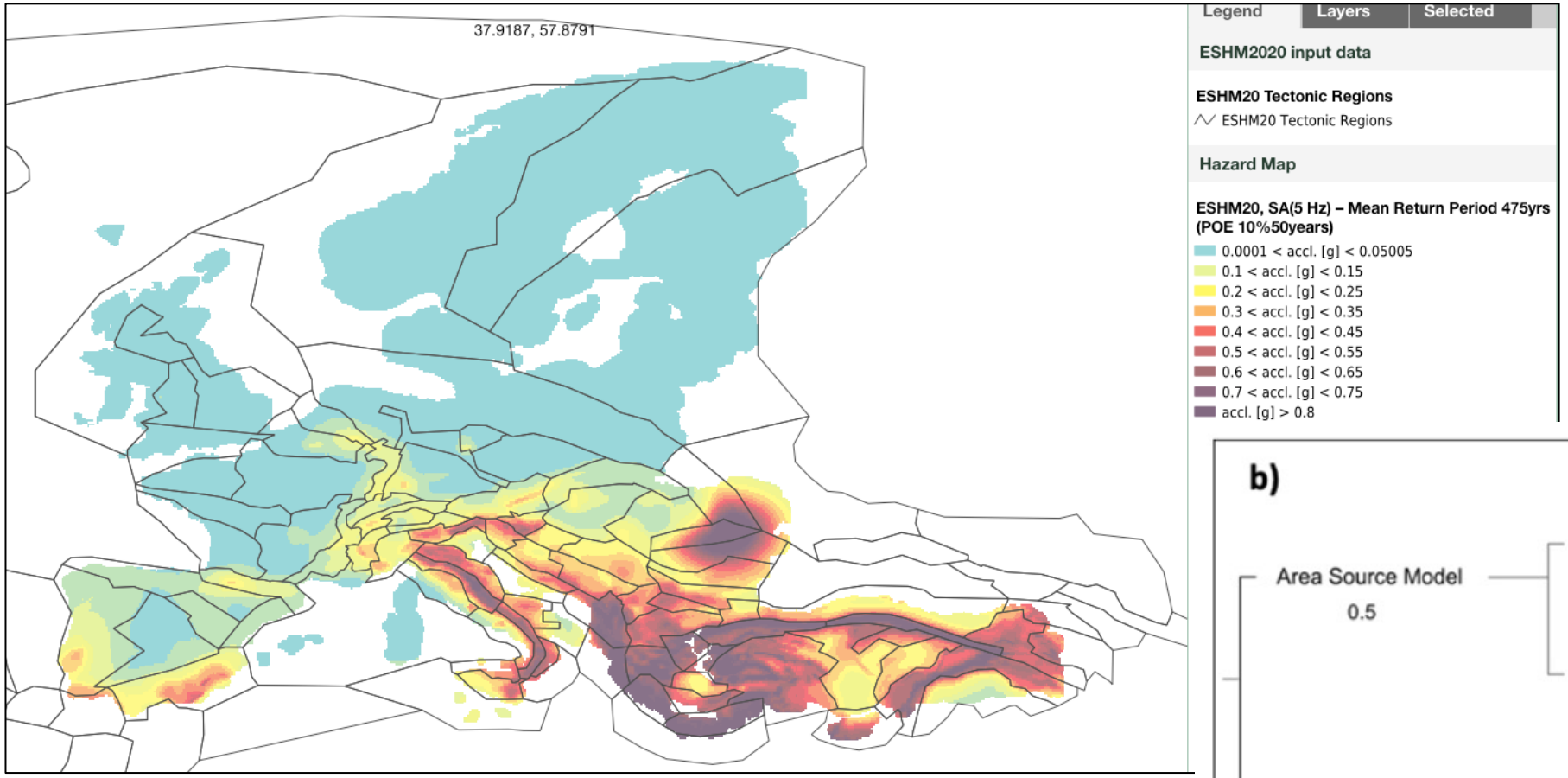
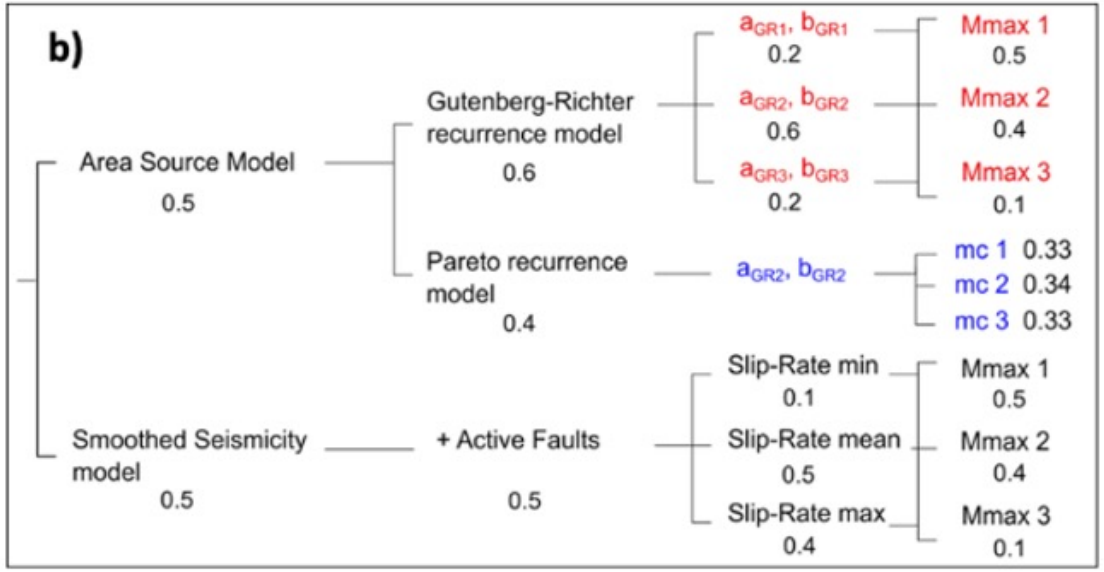
Can geodesy provide relevant information to constrain European Seismic Hazard Models?

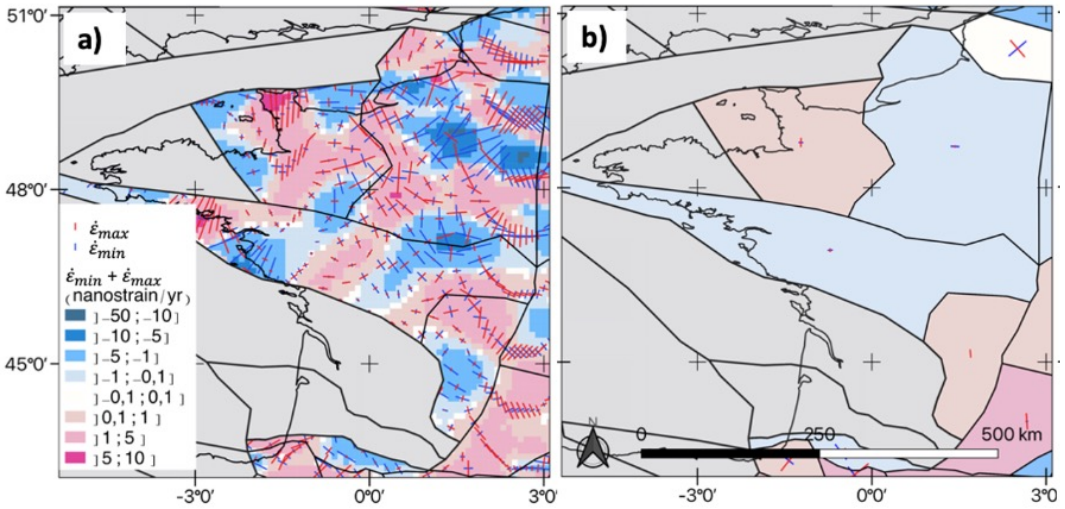
ESHM20 (Danciu et al. 2021)





Computation of geodetic moment in ESHM20 source zones

1- Integrate Strain rate tensor in Source area



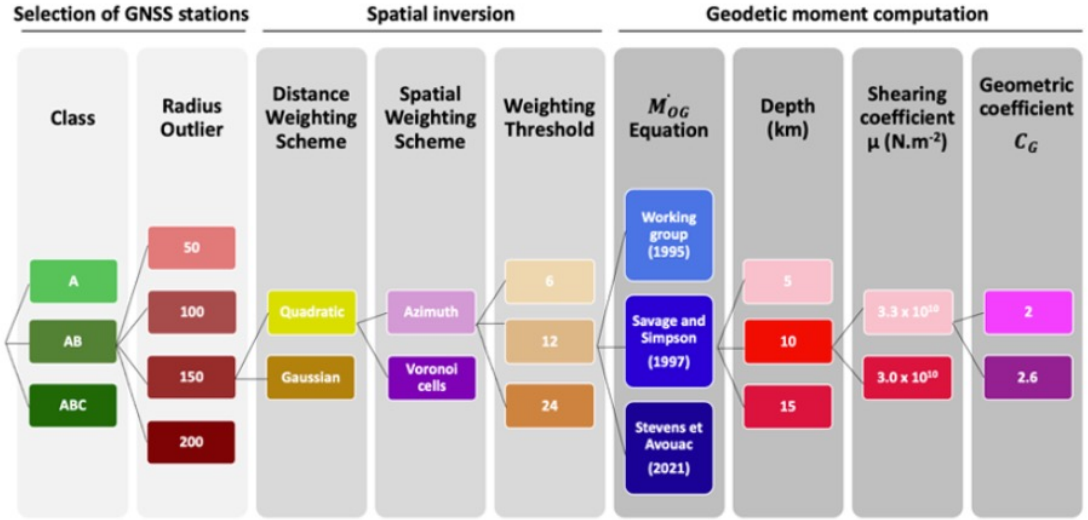
2- Compute geodetic moment (3 possible equations)

$$\dot{M}_{OG} = 2 * \mu * A * H * (\overline{\dot{\varepsilon}_{max}} - \overline{\dot{\varepsilon}_{min}})$$

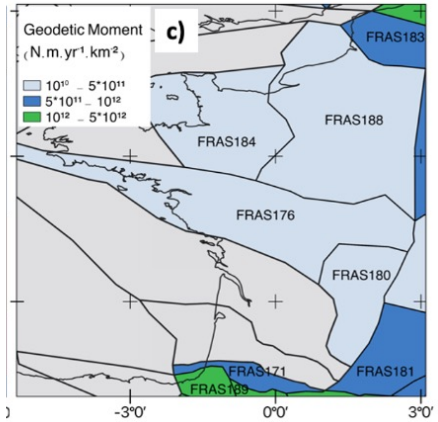
$$\dot{M}_{OG} = 2 * \mu * A * H * MAX(|\overline{\dot{\varepsilon}_{max}}|, |\overline{\dot{\varepsilon}_{min}}|, |\overline{\dot{\varepsilon}_{max}} - \overline{\dot{\varepsilon}_{min}}|)$$

$$\dot{M}_{OG} = C_g * \mu * A * H * \sqrt{\overline{\dot{\varepsilon}_{xx}}^2 + \overline{\dot{\varepsilon}_{yy}}^2 + 2 * \overline{\dot{\varepsilon}_{xy}}^2}$$

3- Explore uncertainties



4- Compute the mean



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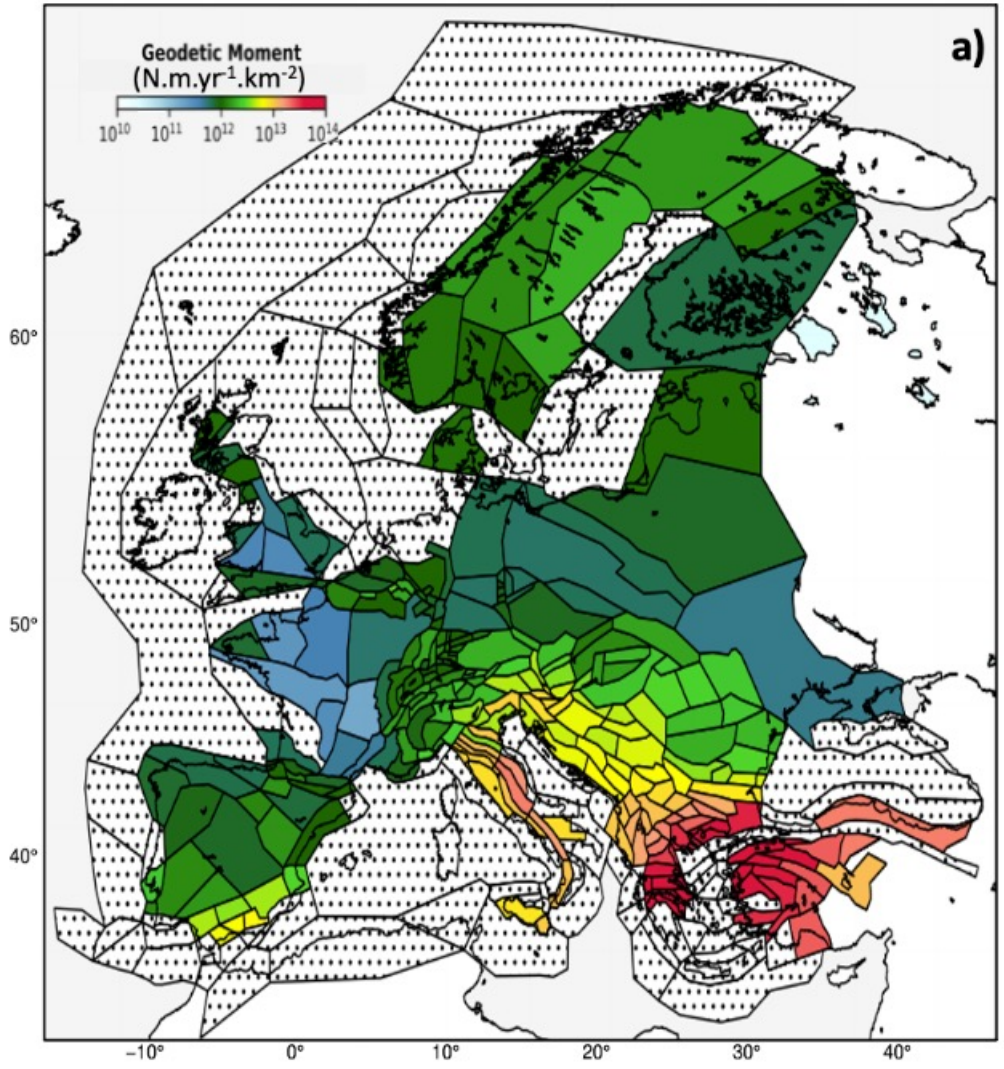
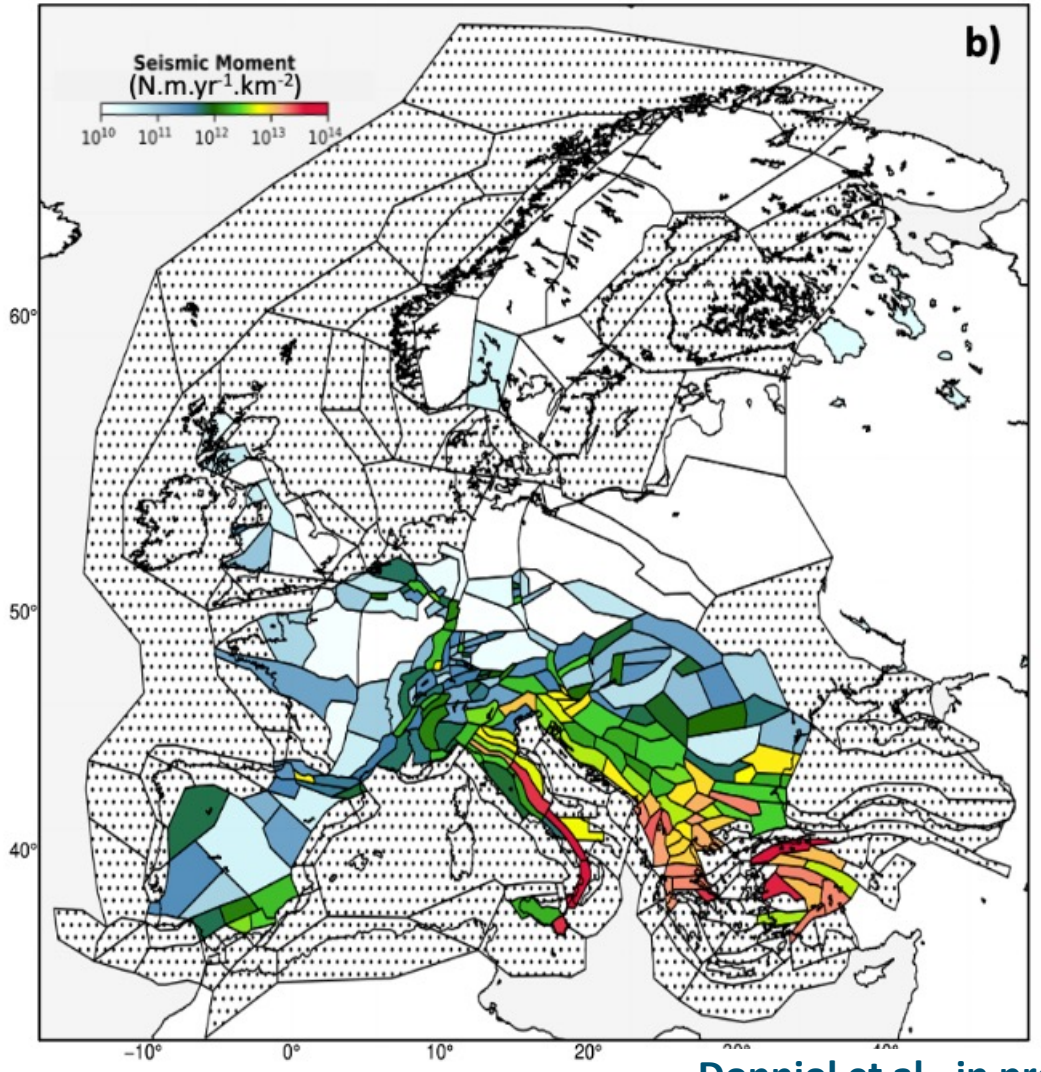
Geodetic versus seismic moment





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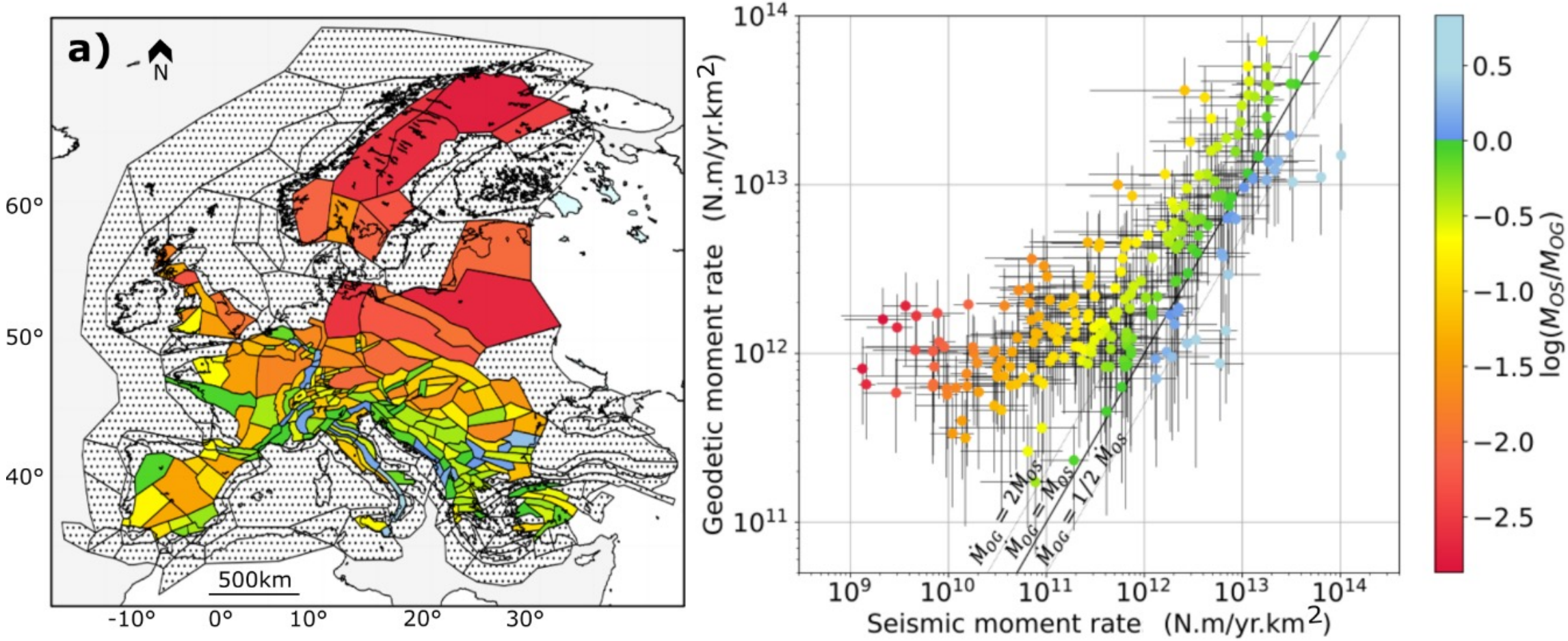
Ratio Seismic /Geodetic moment



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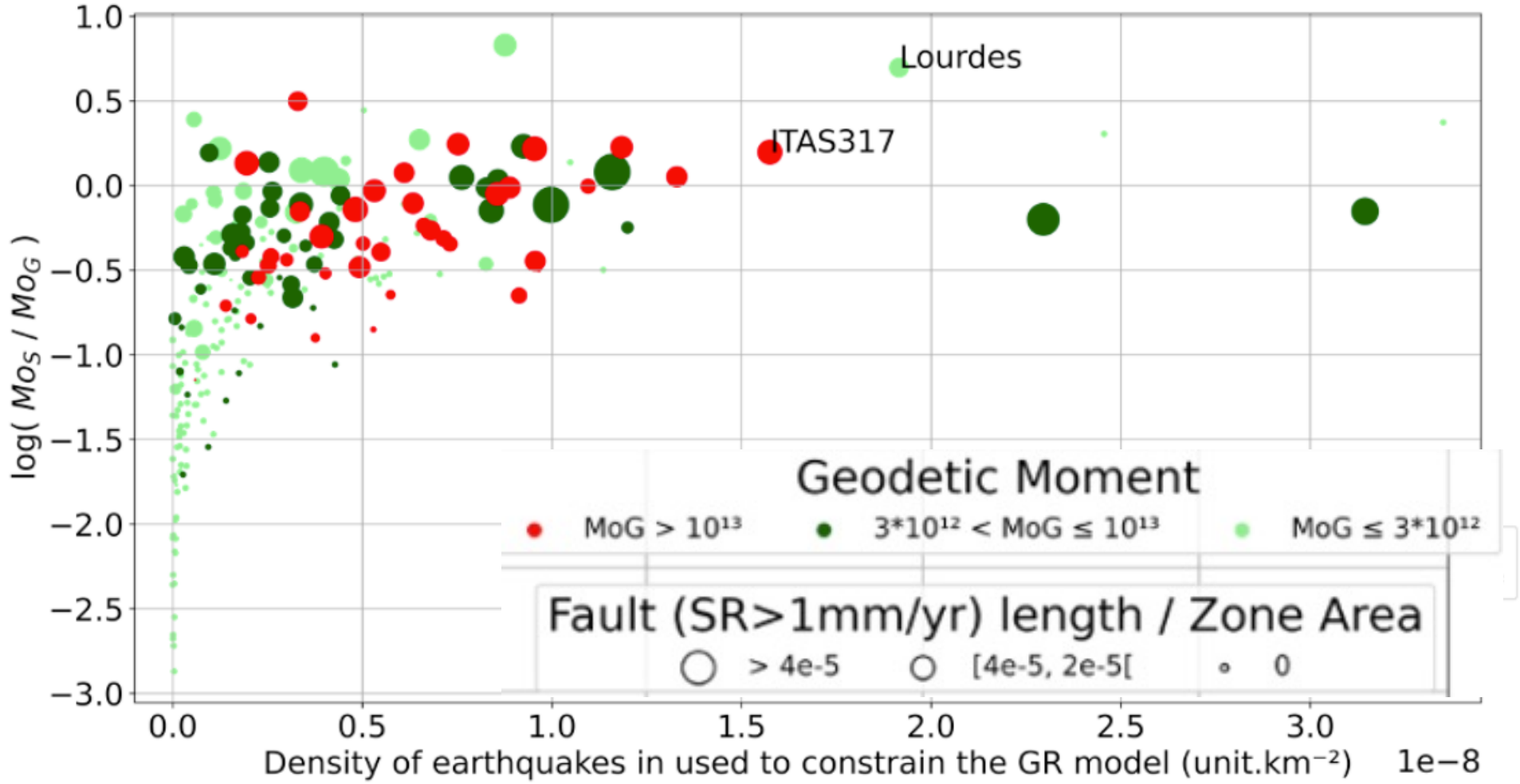
When do geodetic & seismic moment (dis)agree ?

f(seismicity rate, strain rate, fault activity)

Low strain
Low seismicity
No active faults



Donniol et al., in prep

Conclusion & take home messages

- Geodetic and seismic moment agree in high deformation areas
- In areas affected by GIA (Glacial Isostatic Adjustment)
  geodetic moment >> seismic moment
- In low seismic activity areas, geodesy can bring insights
  when strain rates or fault slips are large enough
- Need for dense data of quality and internally consistent geodetic solutions

  → EPOS EUROPEANPLATEOBSERVINGSYSTEM
- (Still) need for methodology and benchmark work