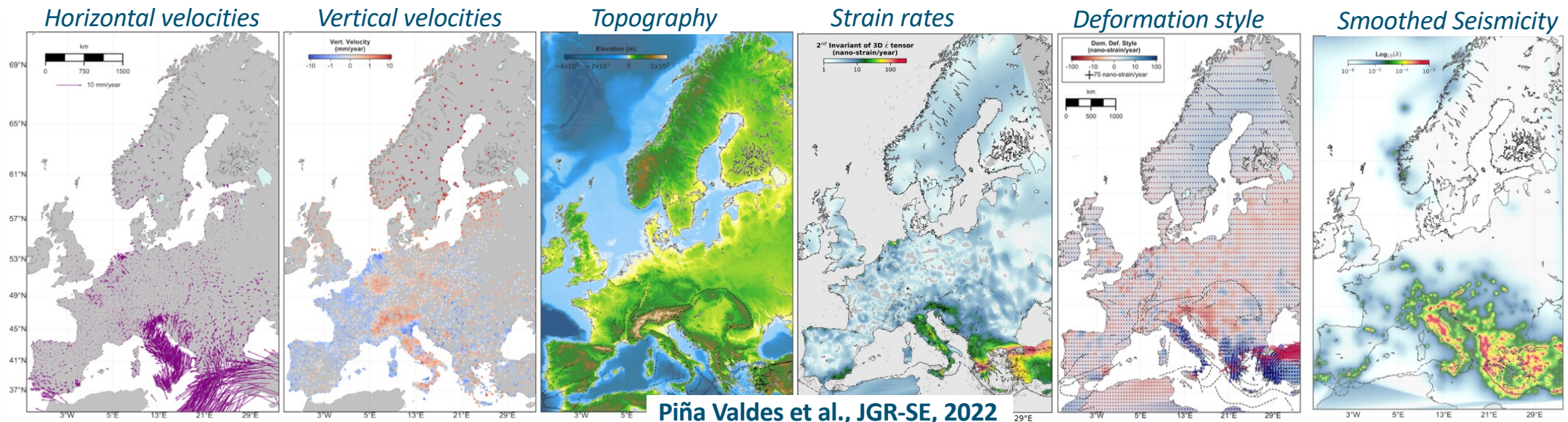


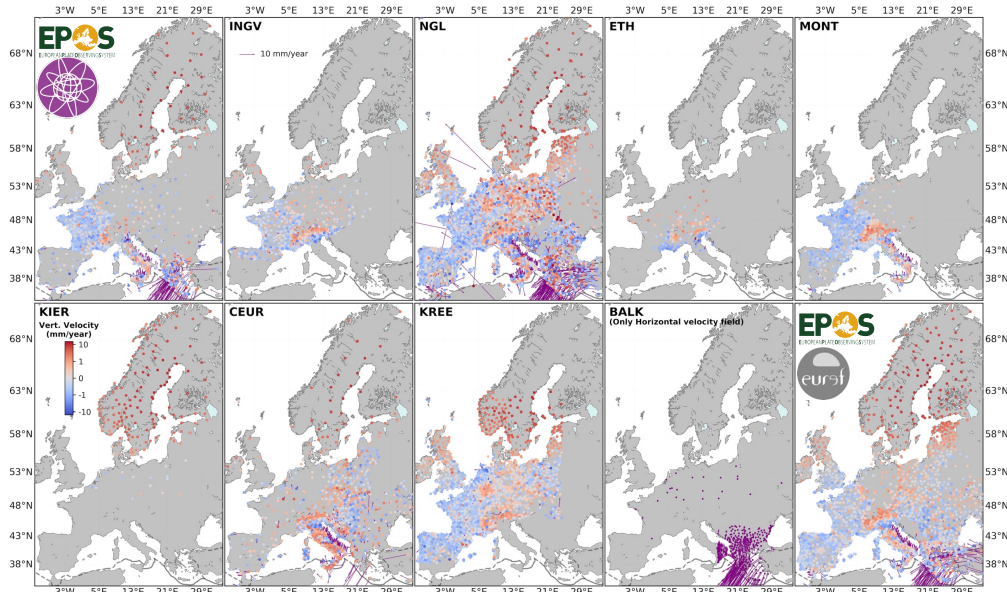
3D GNSS Velocity Field and strain rates in Europe, & link with the seismic potential

Anne Socquet

Bénédicte Donniol, Jesus Piña Valdes, Céline Beauval

Jesus Piña Valdes Bénédicte Donniol

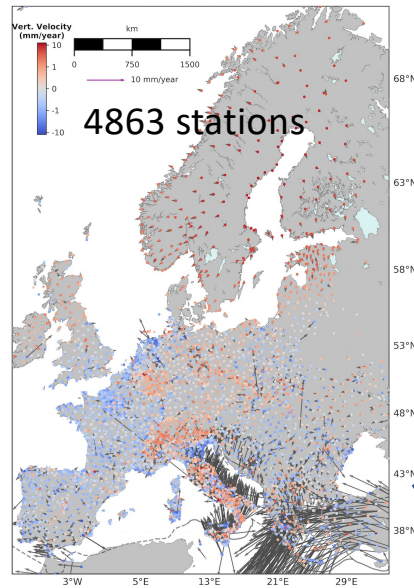




10 solutions

Combination at velocity level

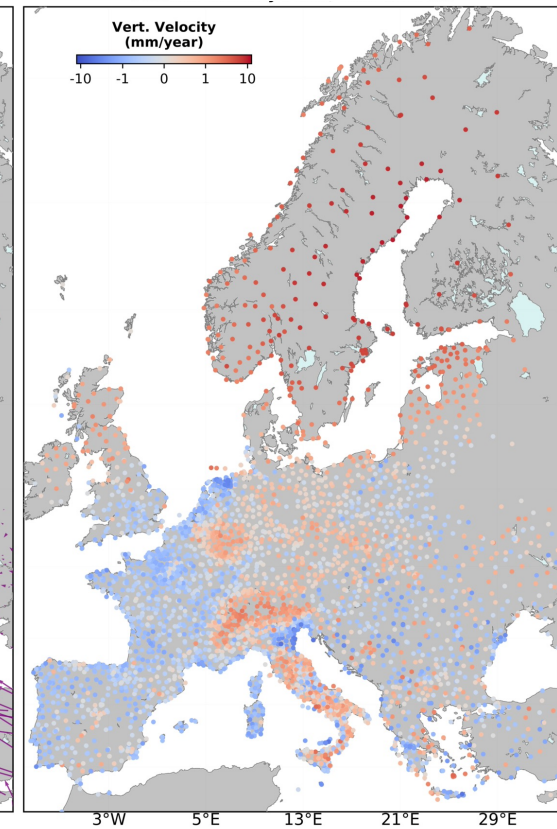
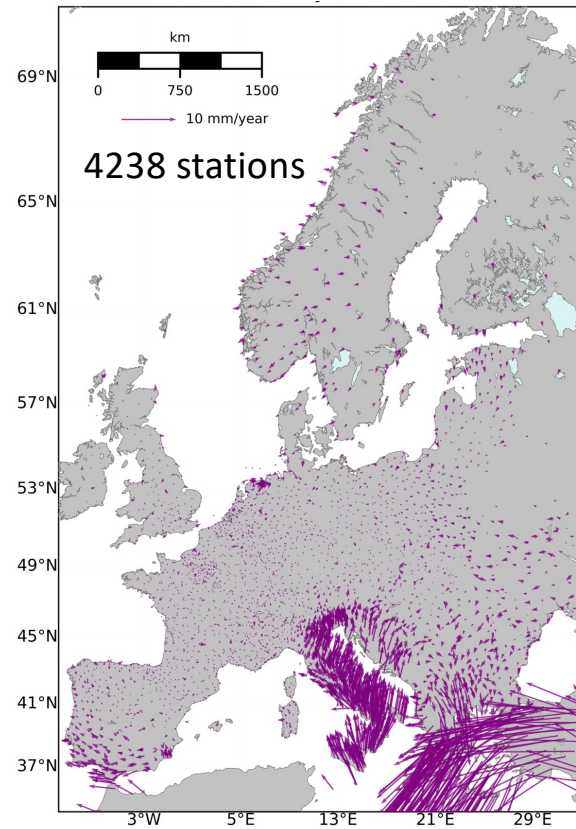
Uncertainty harmonization
6 param Helmert transform
ITRF2014 reference frame
Rotation wrt stable Eurasia



Combined Velocity Field

Horizontal velocities

Vertical velocities

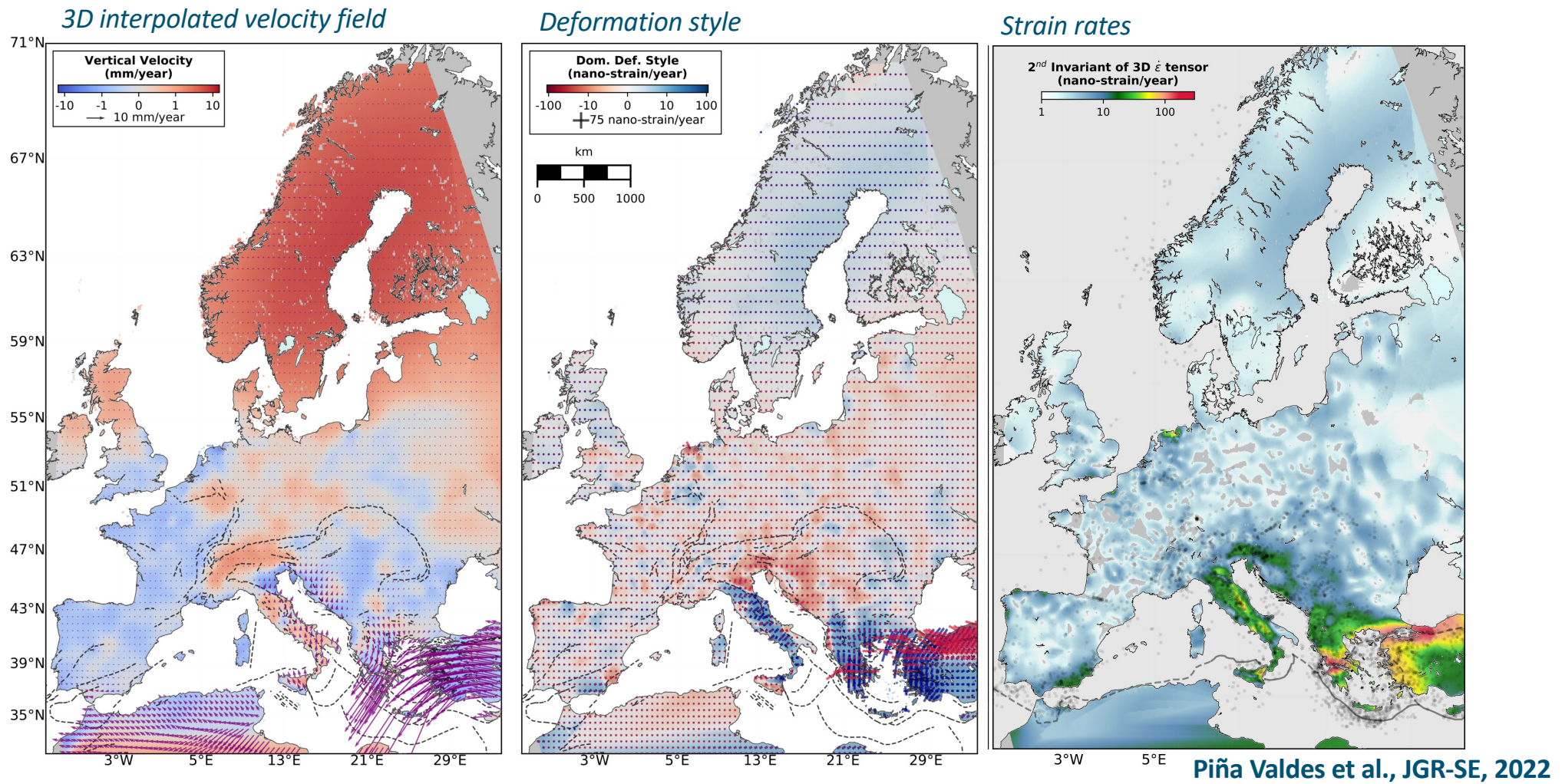


Filtering

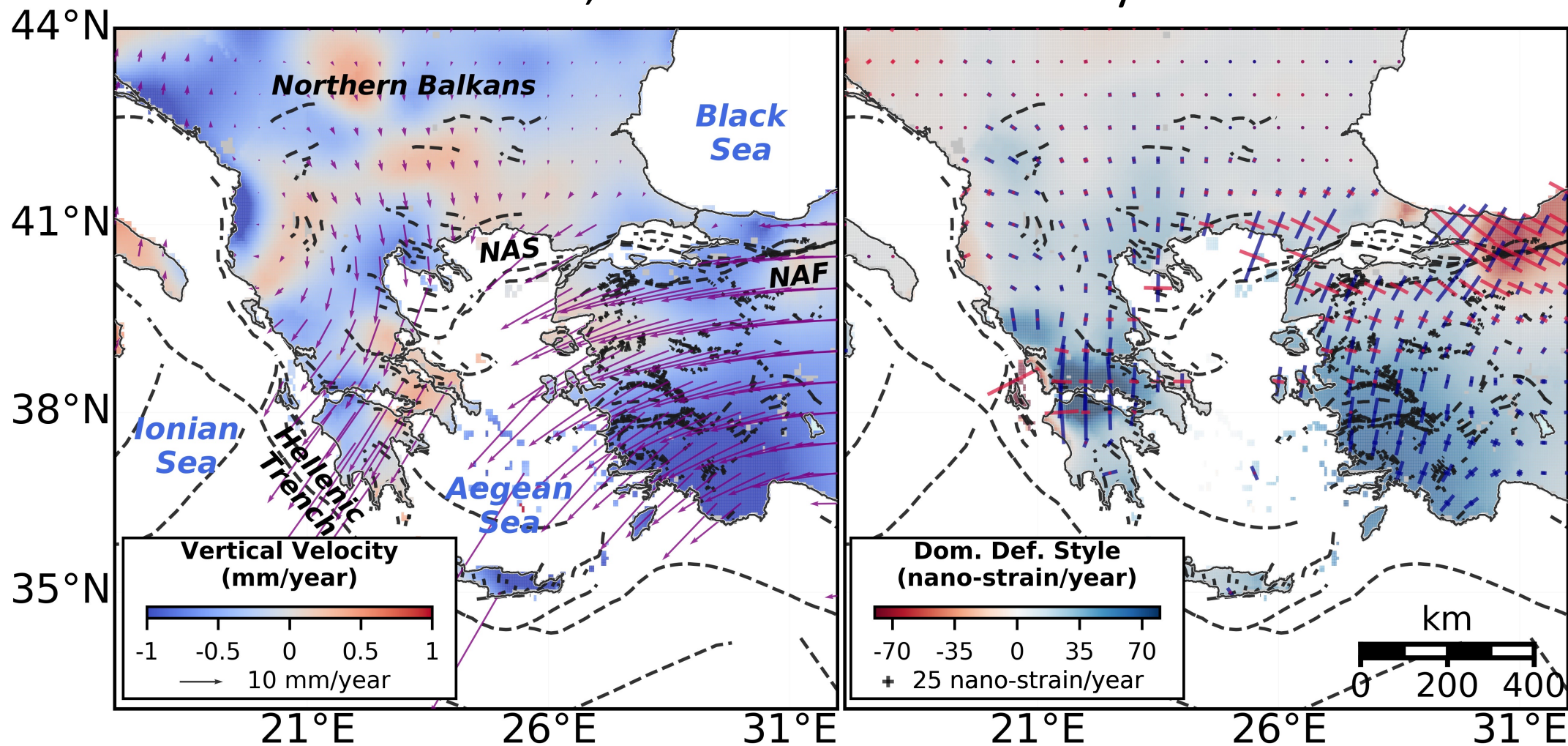
Outlier identification

Piña Valdes et al., JGR-SE, 2022

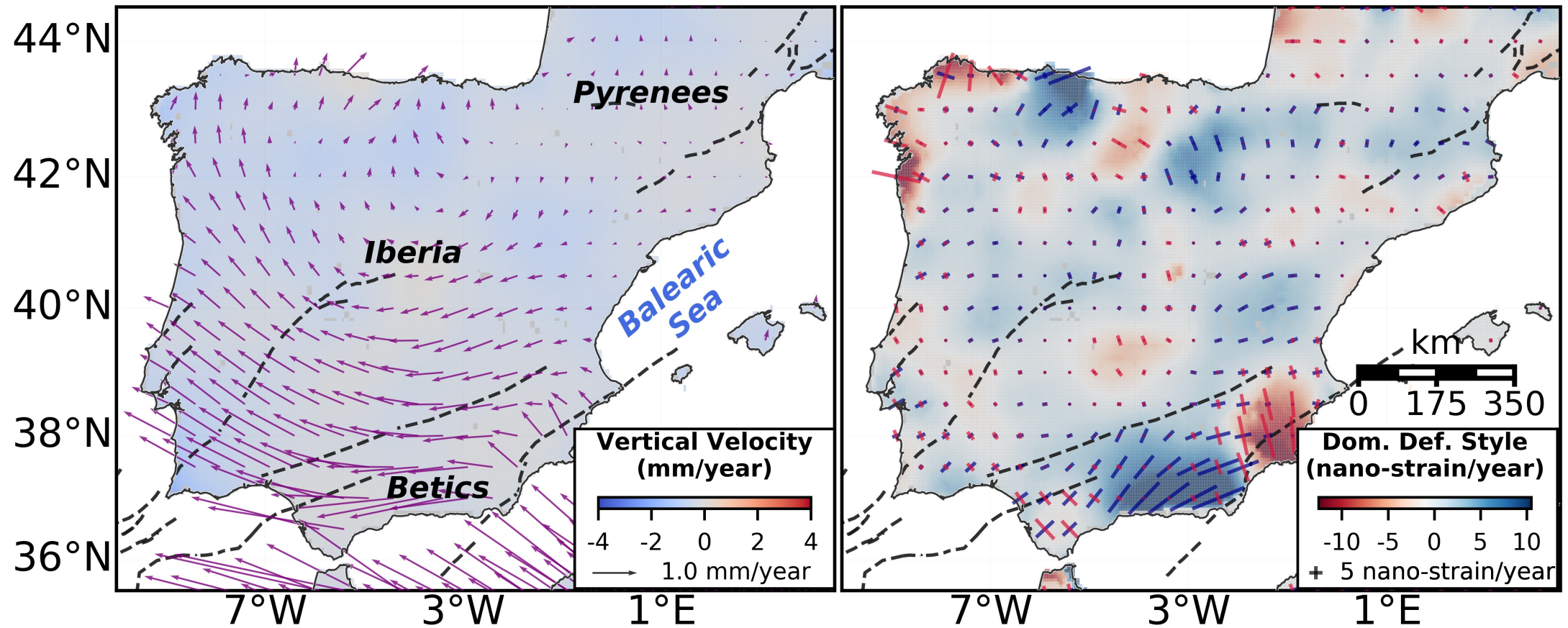
3D velocities, deformation style and strain



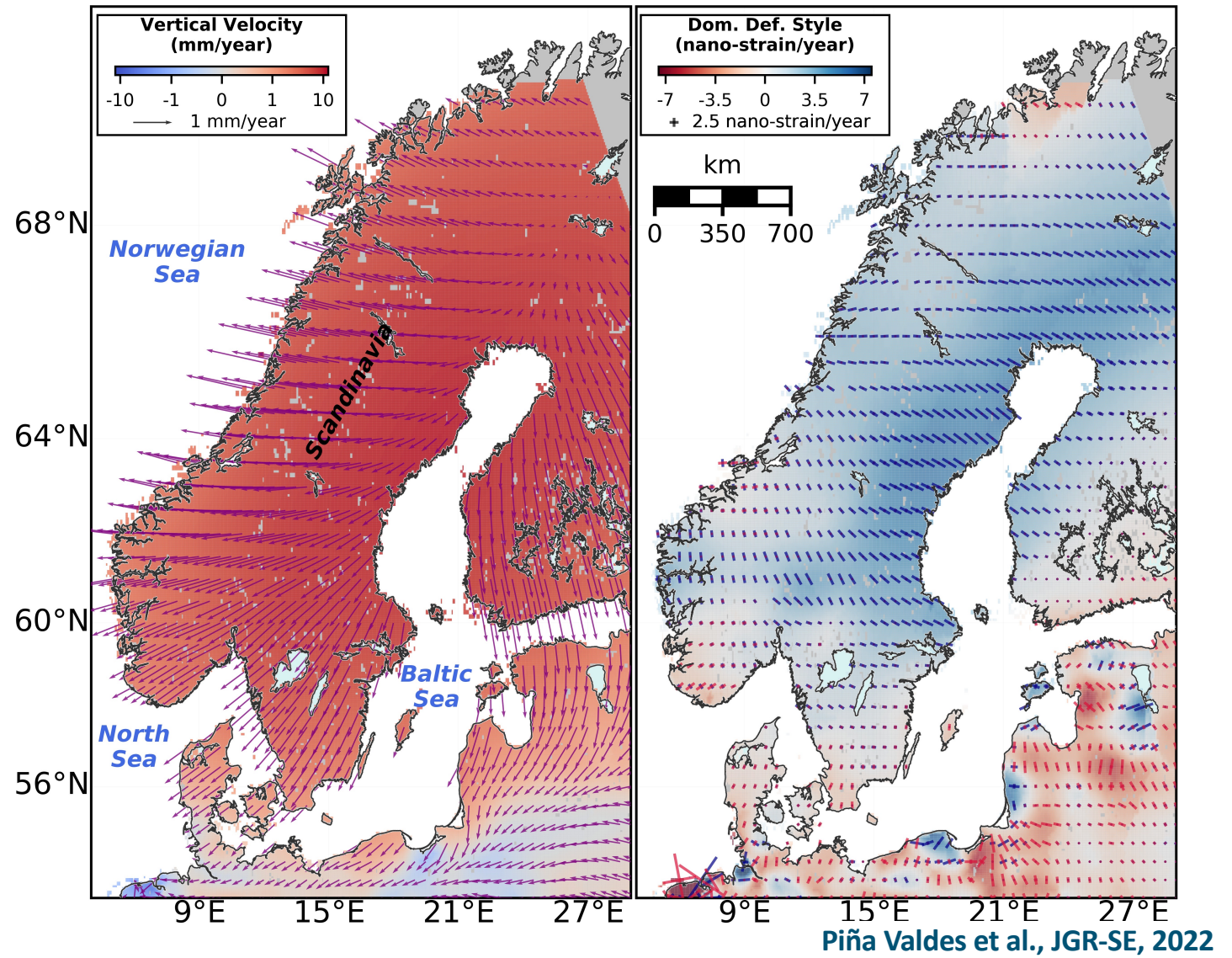
Zoom on Greece, Balkans and Türkiye



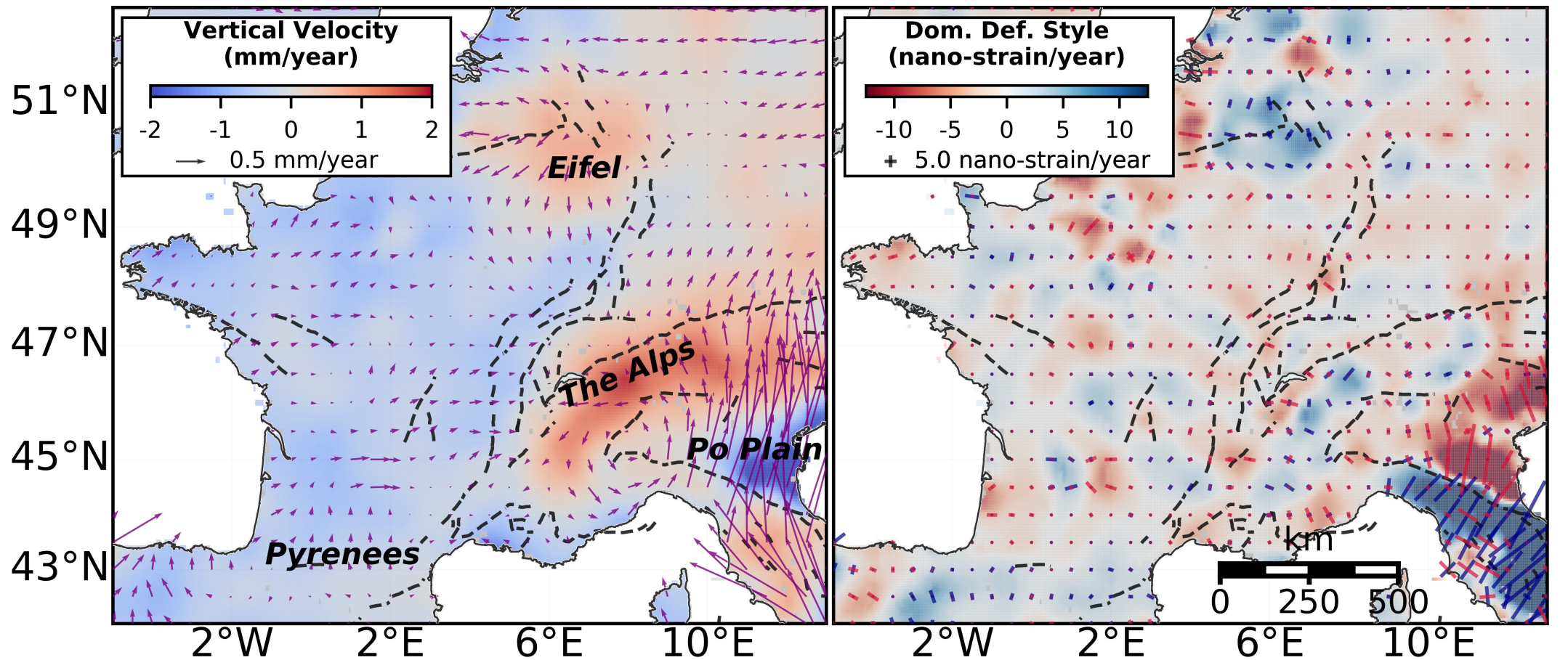
Zoom on Iberia



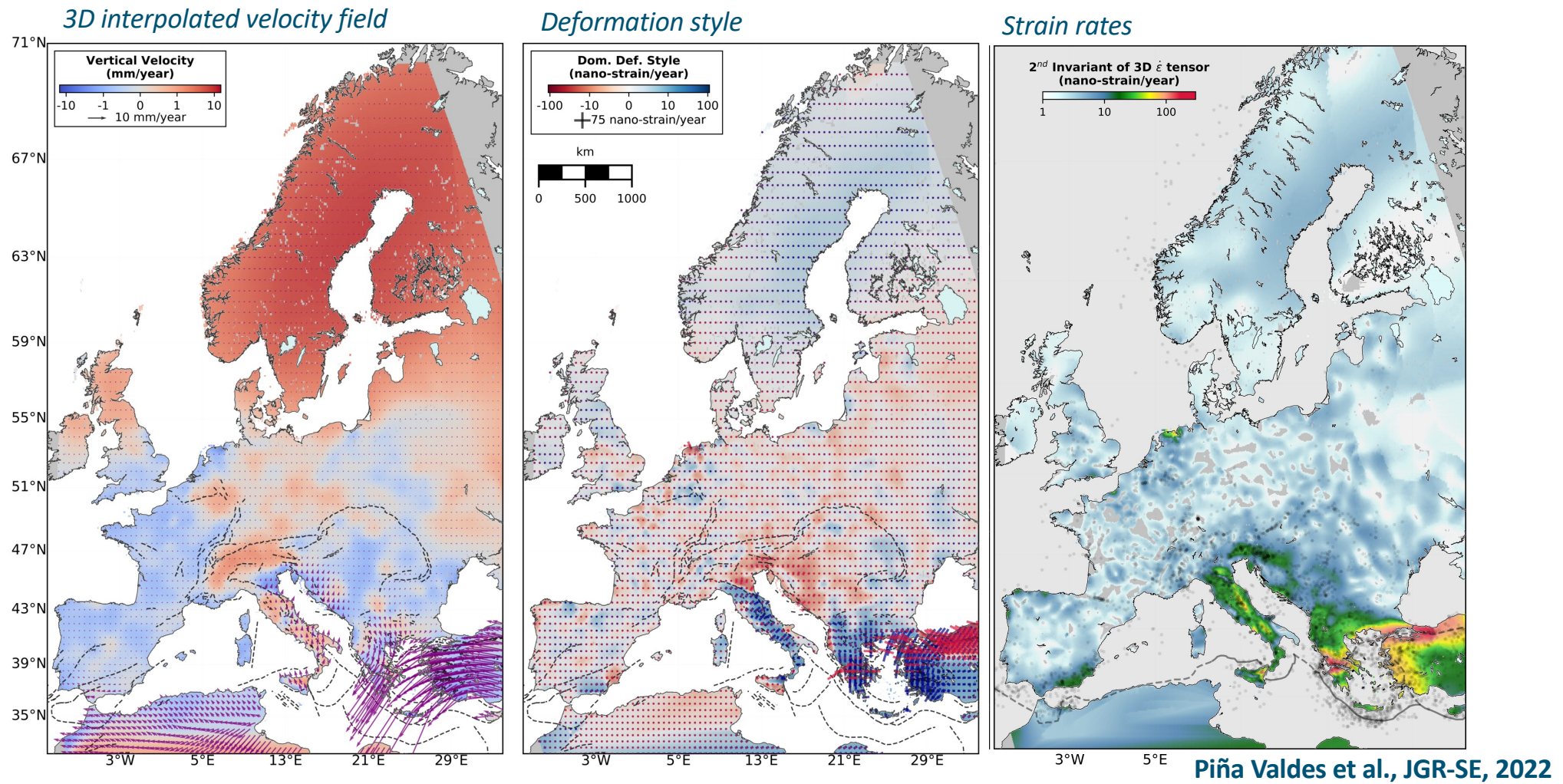
Zoom on Fenoscandia



Zoom on France



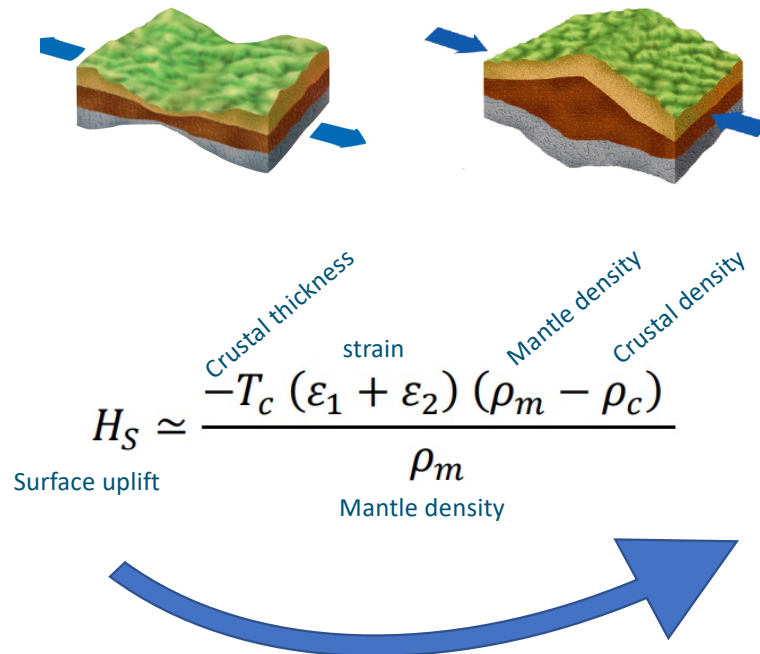
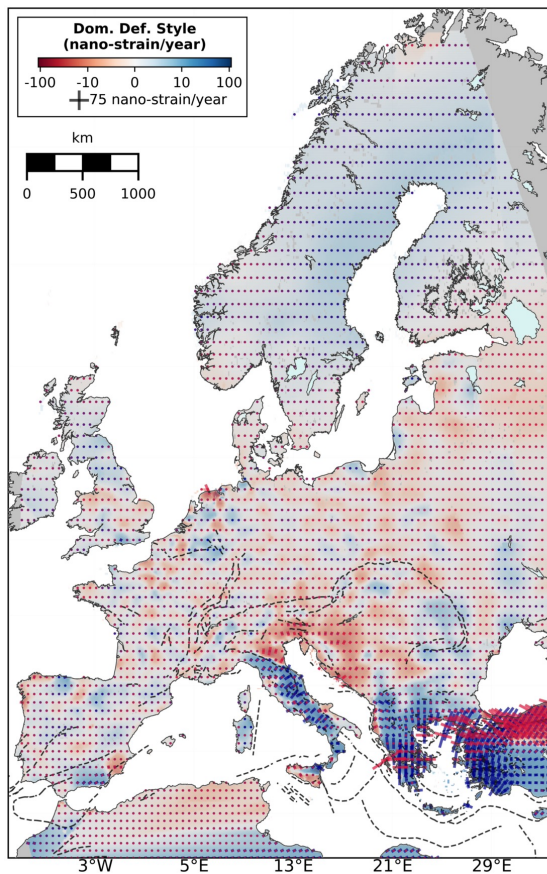
Consistency between strain and vertical?



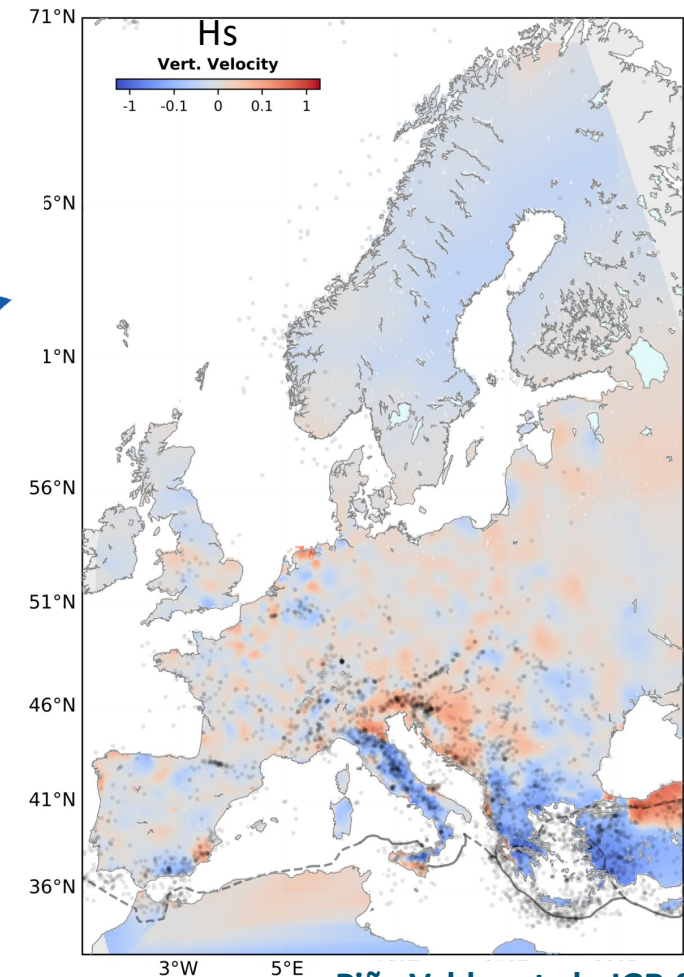
Predicting vertical velocities from horizontal strain

Assumption : conservation of strain + isostasy

Deformation style



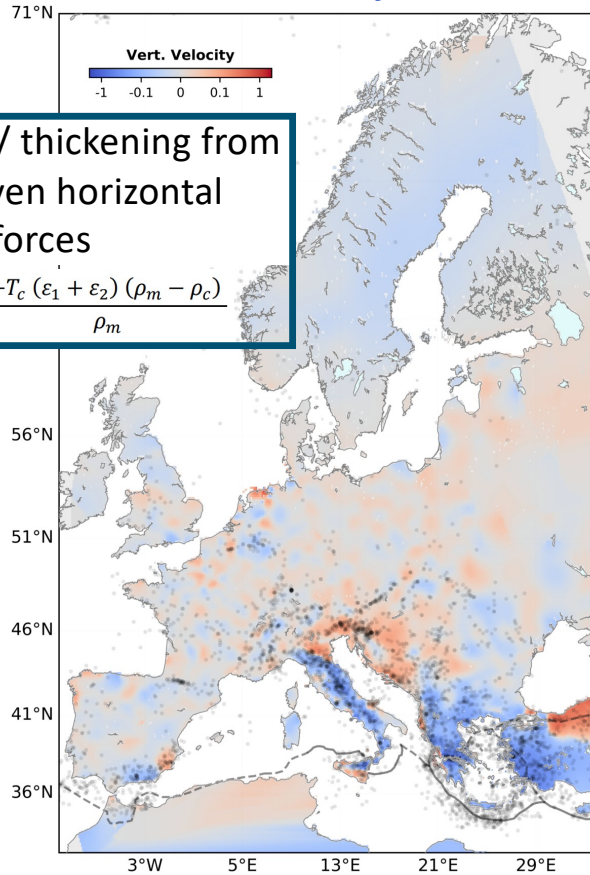
Theoretical vertical velocities from horizontal strain



Piña Valdes et al., JGR-SE, 2022

What contributes to vertical velocity field ?

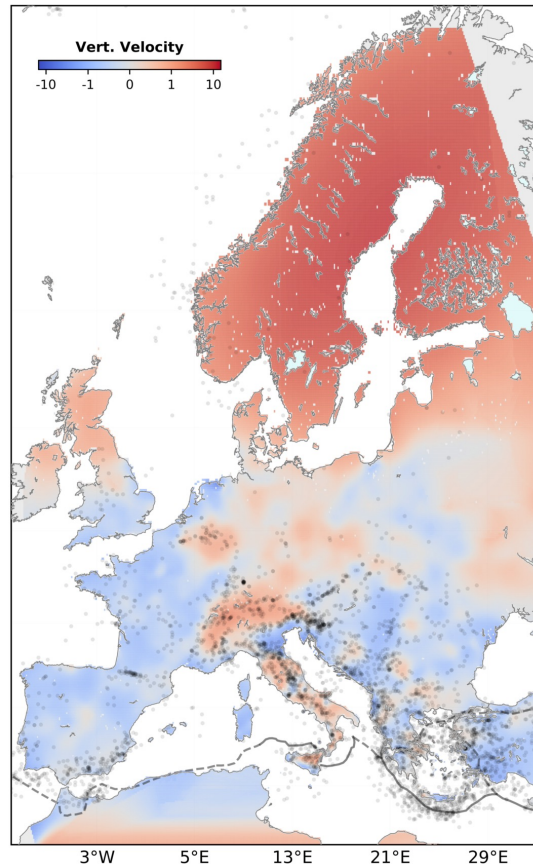
Theoretical vertical velocities from horizontal



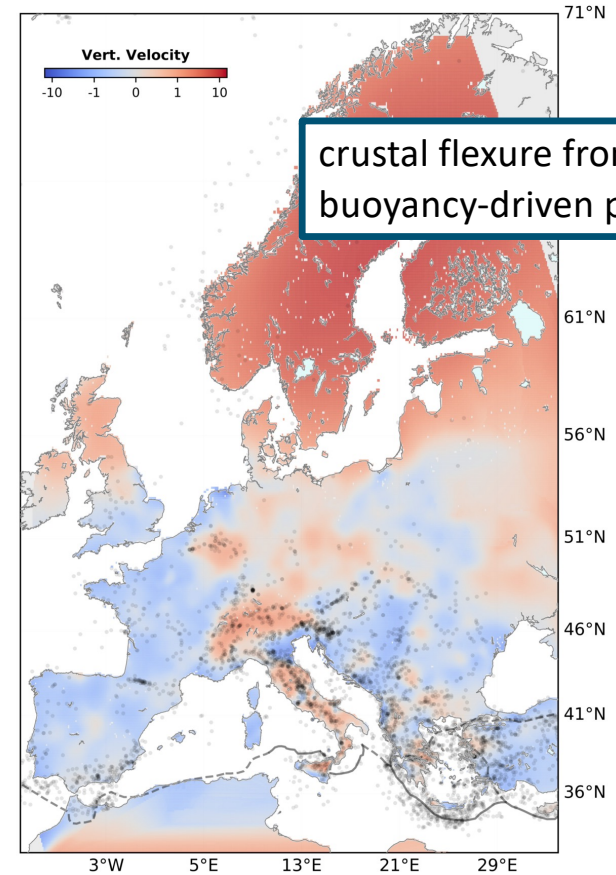
thinning / thickening from
edge-driven horizontal
tectonic forces

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

Observed vertical velocities



Difference : vertical velocities due to flexure ?

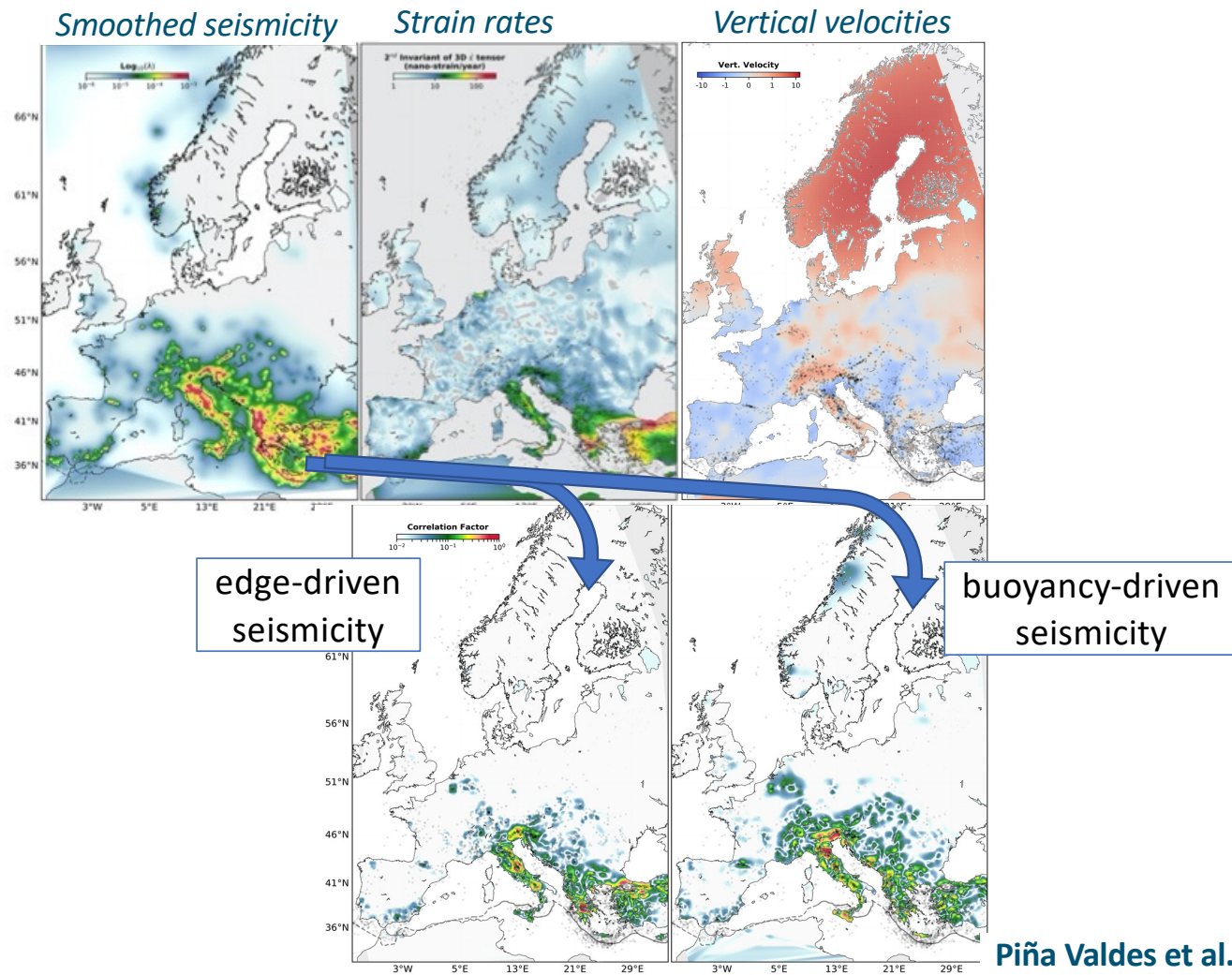


crustal flexure from
buoyancy-driven processes

Link seismicity deformation ?

Correlation

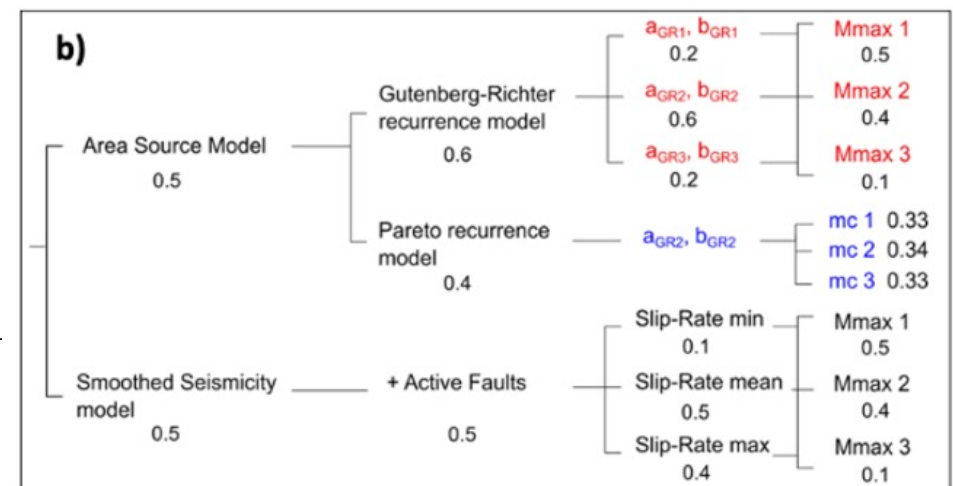
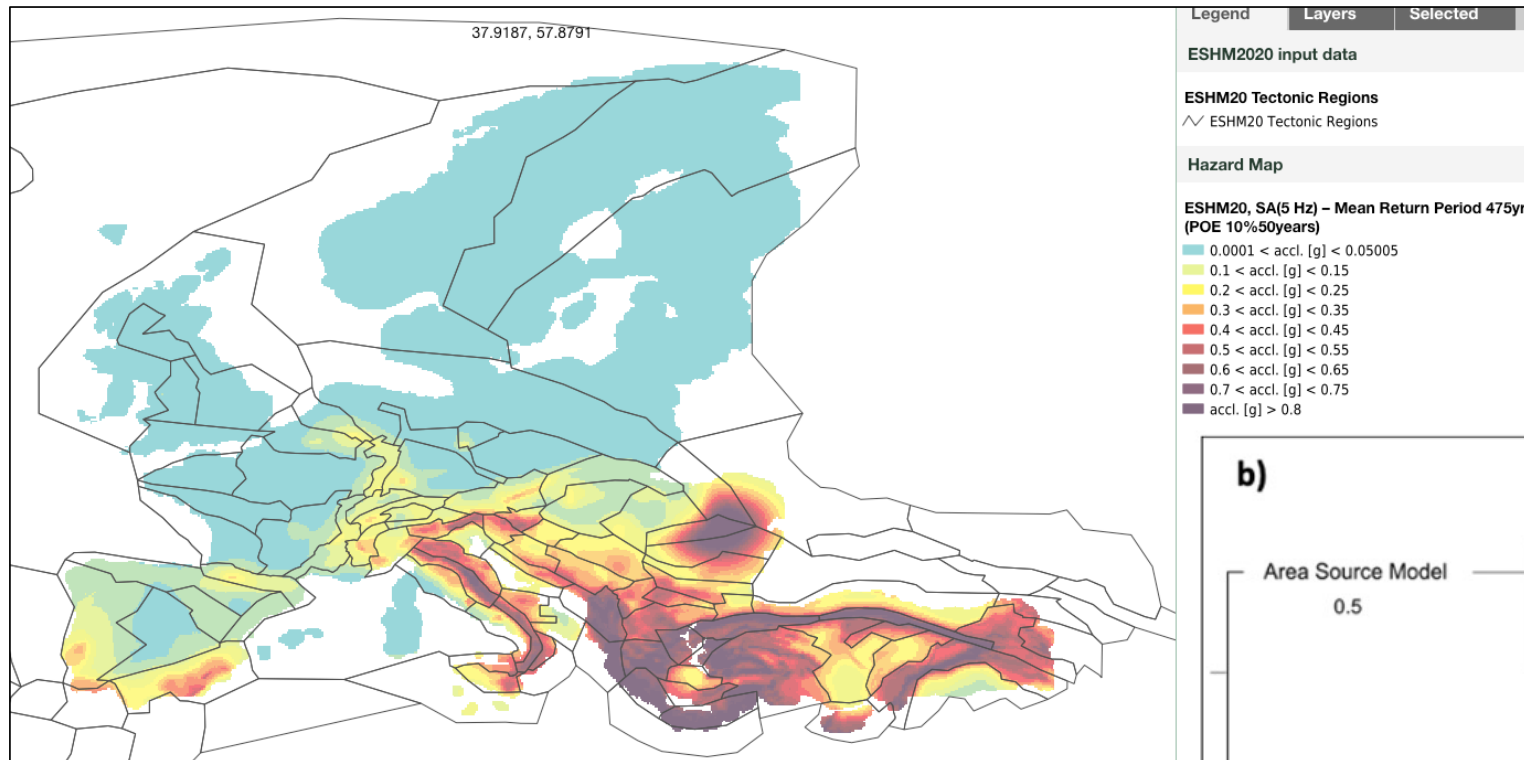
Between deformation
and smoothed seismicity
On sliding windows



Piña Valdes et al., JGR-SE, 2022

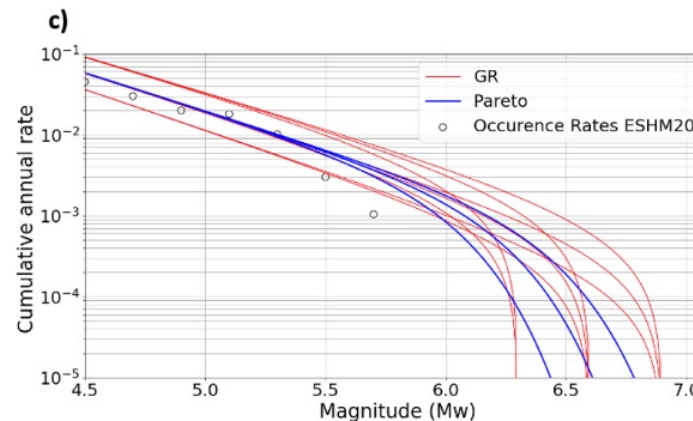
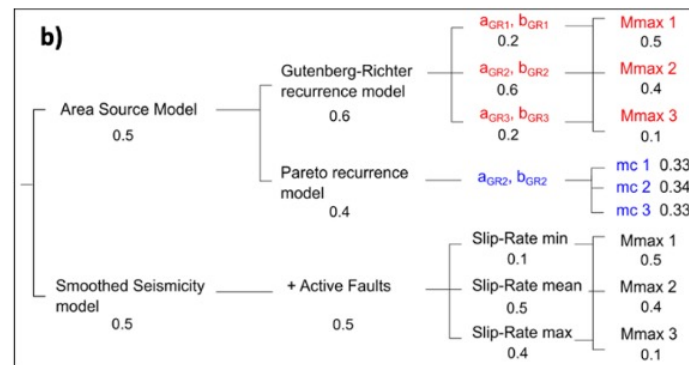
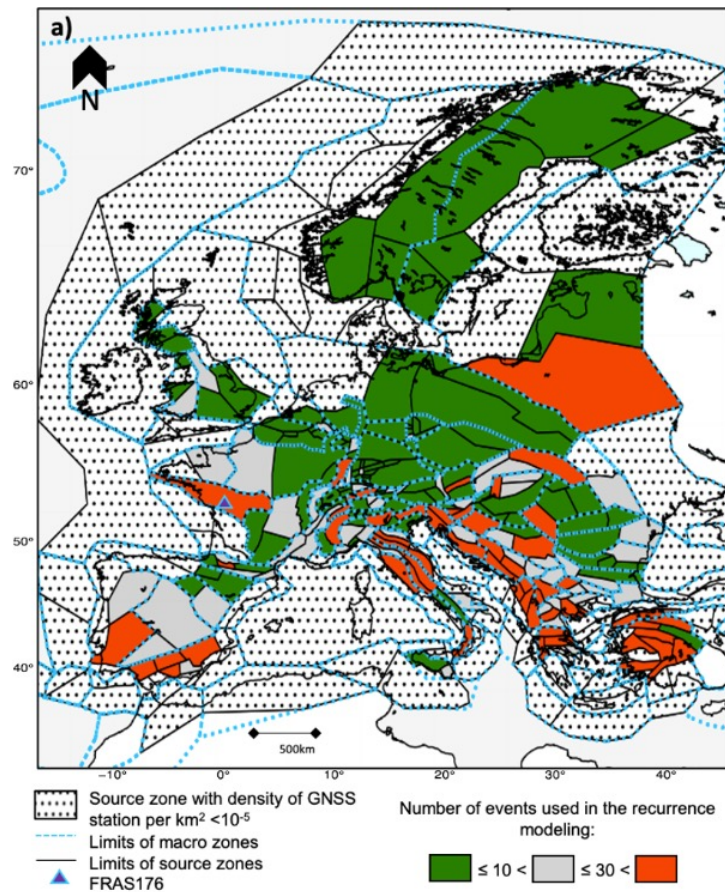
Can geodesy provide relevant information to constrain European Seismic Hazard Models?

ESHM20 (Danciu et al. 2021)

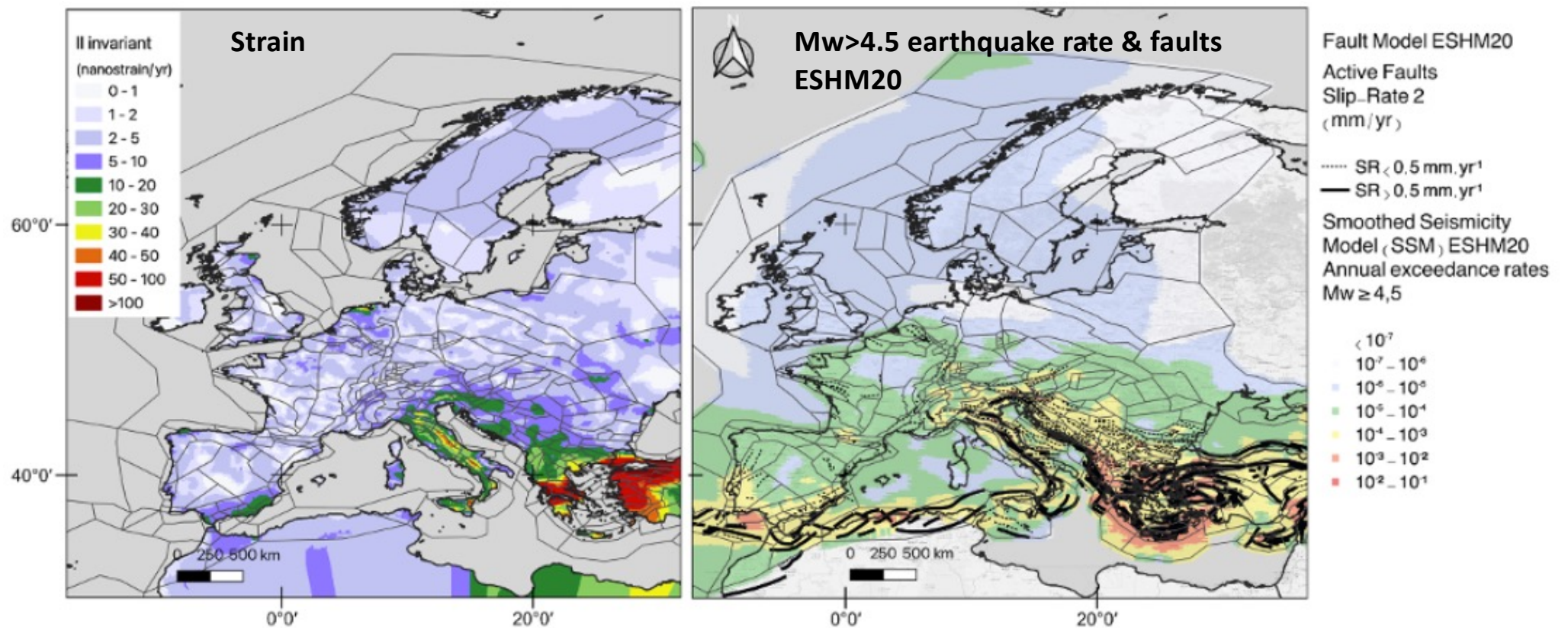


Can geodesy provide relevant information to constrain European Seismic Hazard Models?

ESHM20 (Danciu et al. 2021)

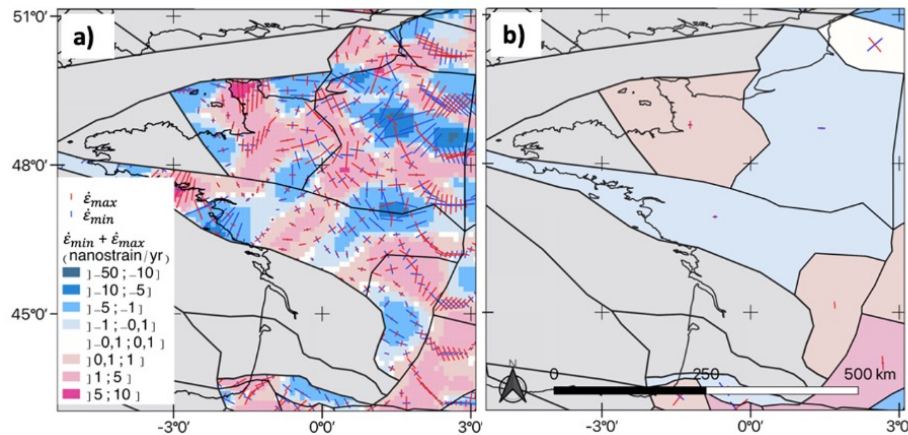


Compare geodetic moment and seismic moment from *ESHM20* (Danciu et al. 2021)



Computation of geodetic moment in ESHM20 source zones

1- Integrate Strain rate tensor in Source area



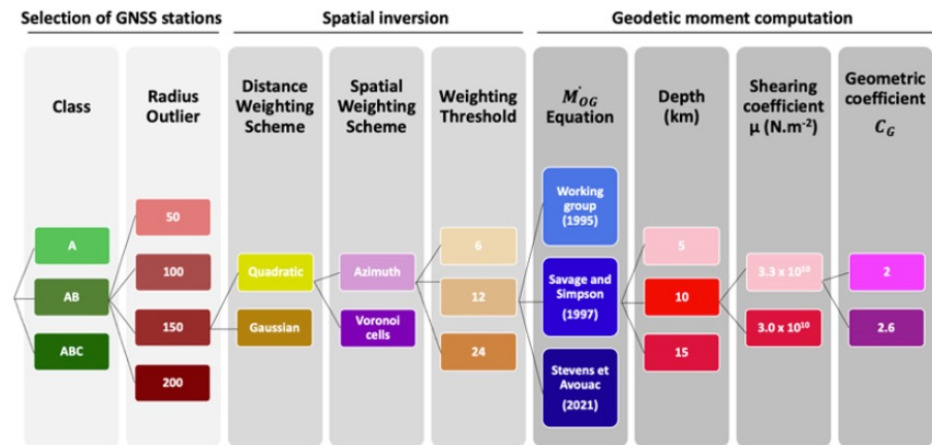
2- Compute geodetic moment (3 possible equations)

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

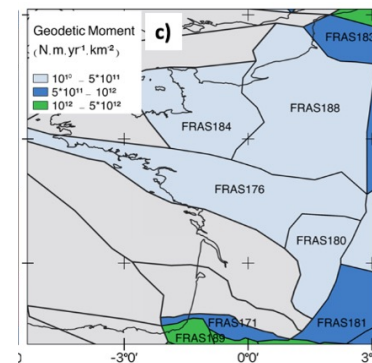
$$\dot{M}_{OG} = 2 * \mu * A * H * MAX(|\overline{\dot{\epsilon}_{max}}|, |\overline{\dot{\epsilon}_{min}}|, |\overline{\dot{\epsilon}_{max}} - \overline{\dot{\epsilon}_{min}}|)$$

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

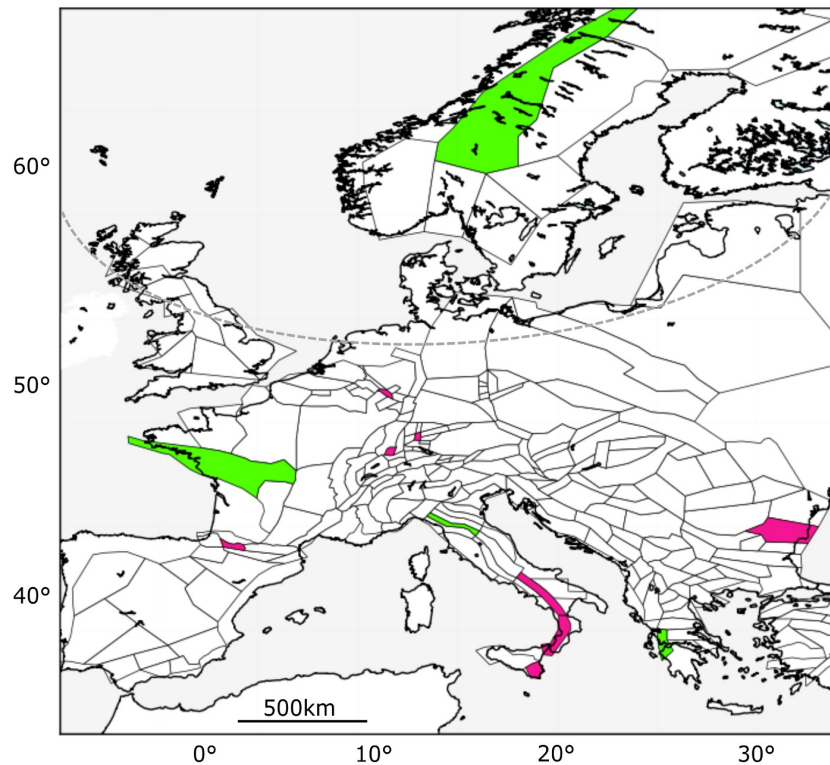
3- Explore uncertainties



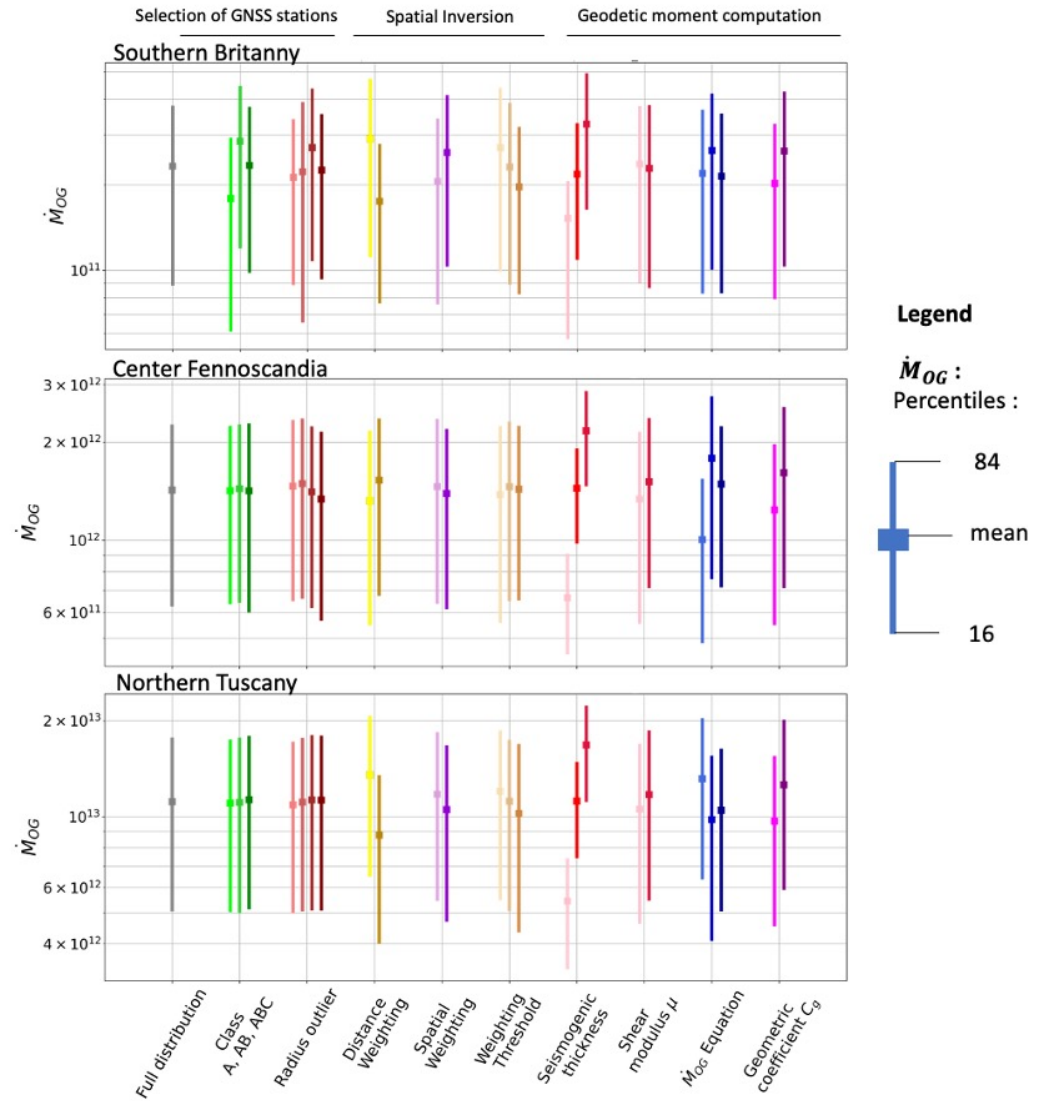
4- Compute the mean geodetic moment



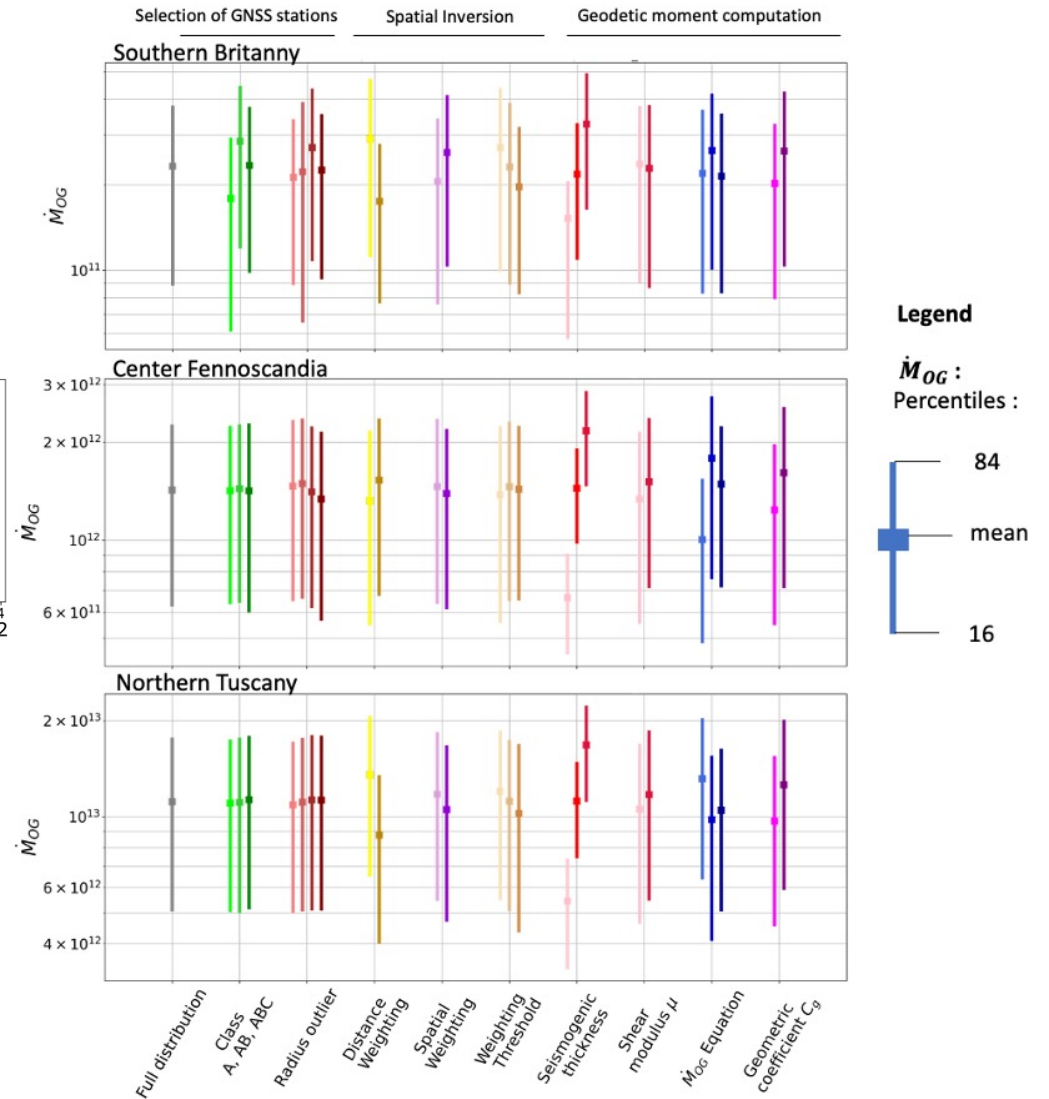
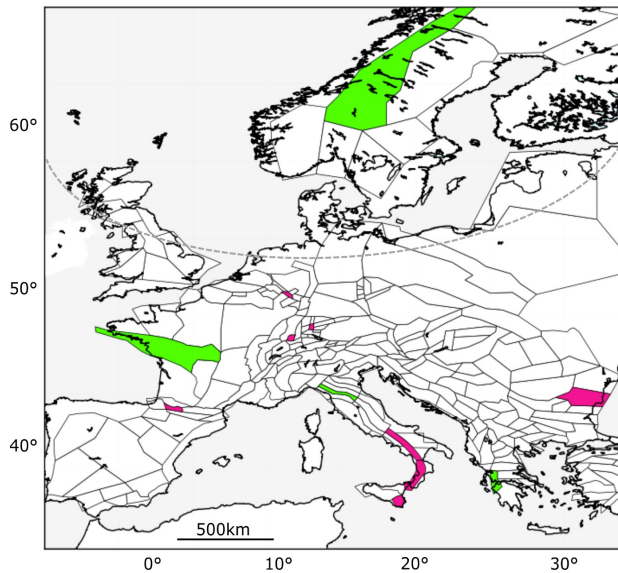
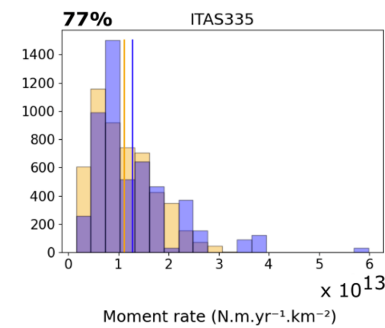
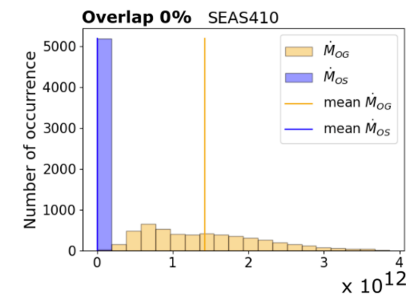
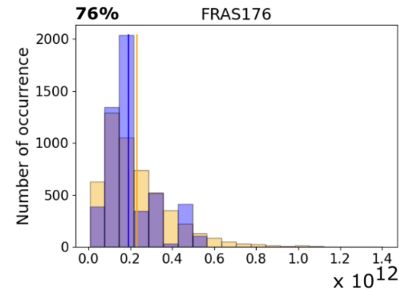
Geodetic M_o uncertainty exploration



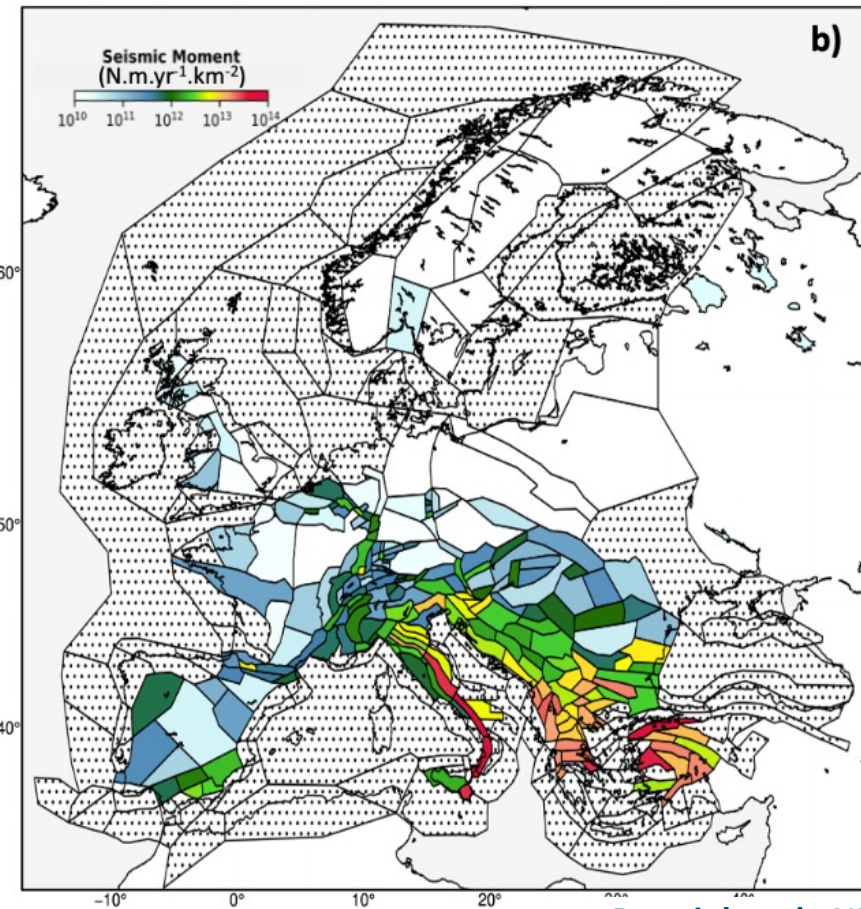
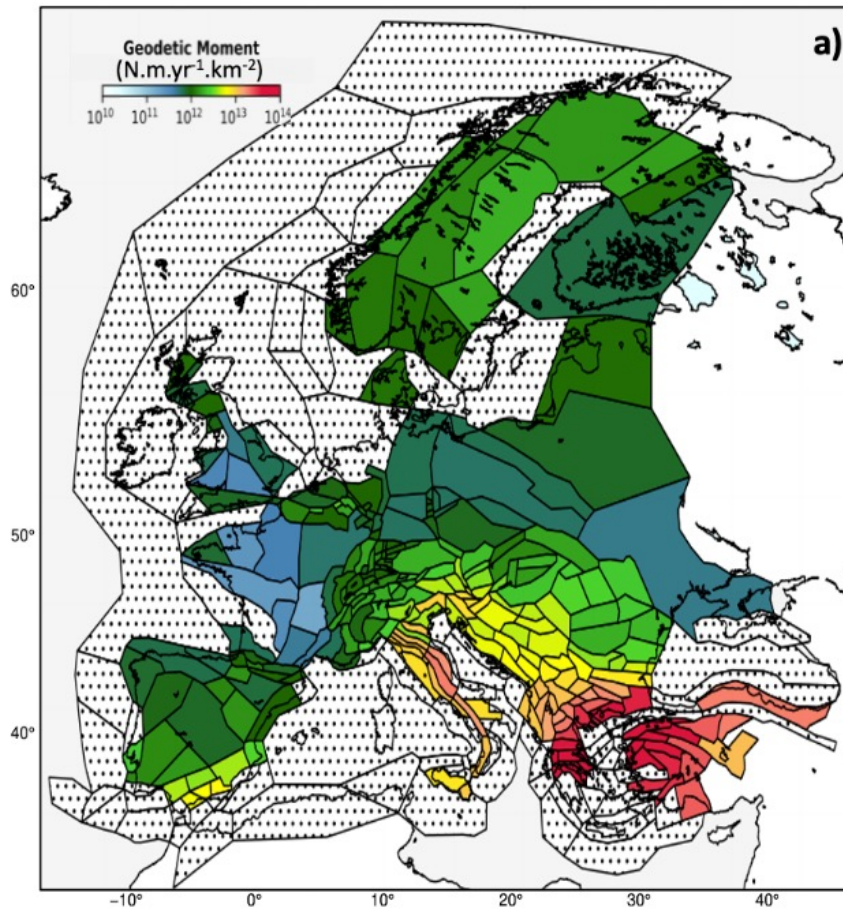
Donniol et al., NHESS 2024



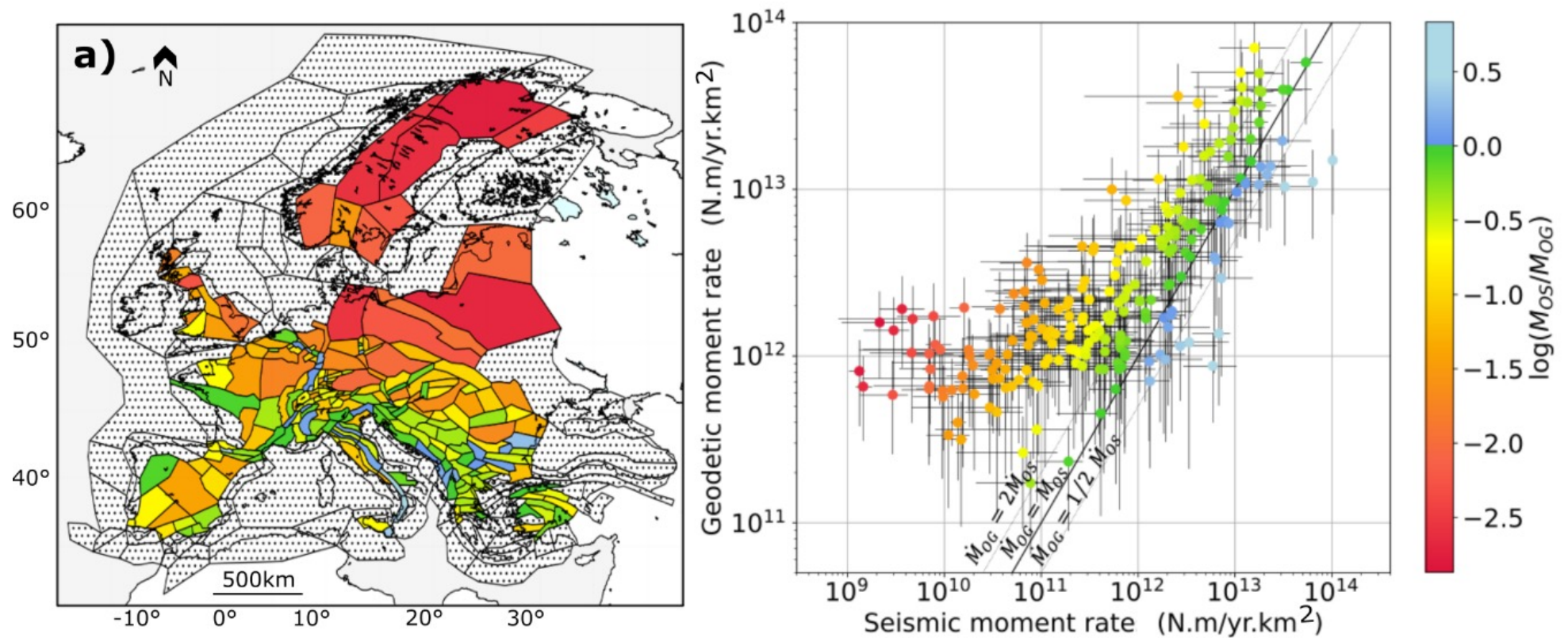
Overlap Geodetic Mo Seismic Mo



Geodetic versus seismic moment (mean values)

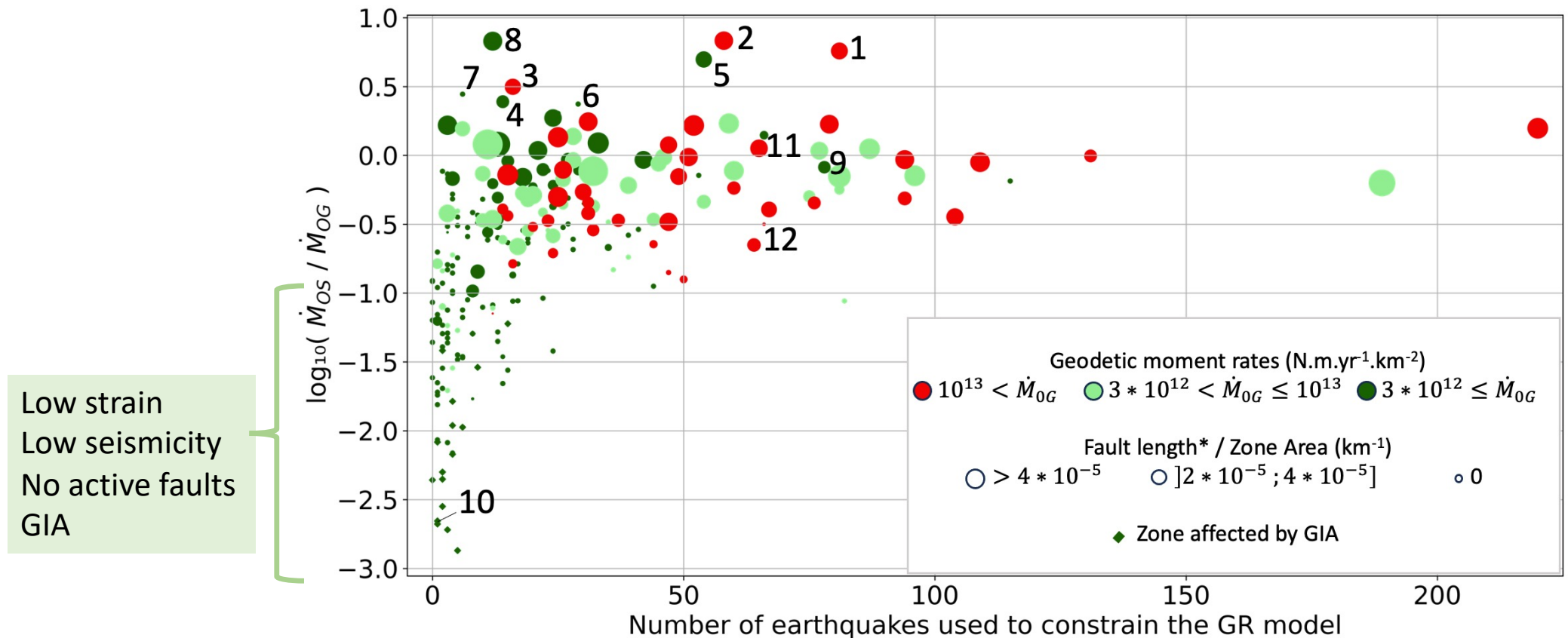


Ratio Seismic / Geodetic moment (mean values)



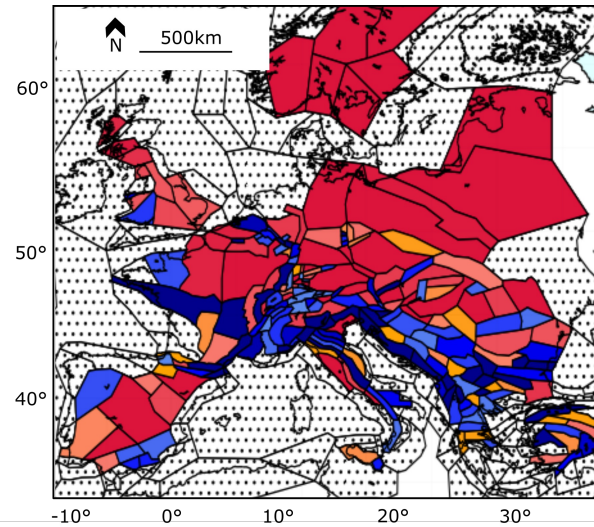
When do geodetic & seismic moment (dis)agree ?

f(seismicity rate, strain rate, fault activity, GIA)

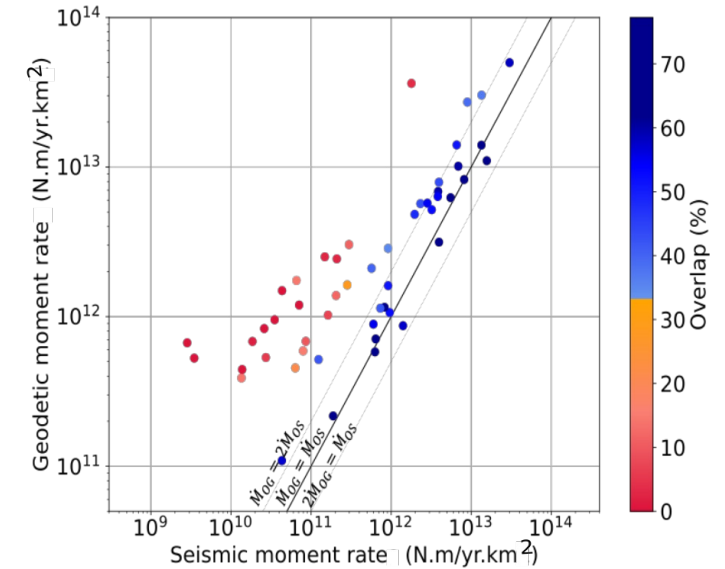
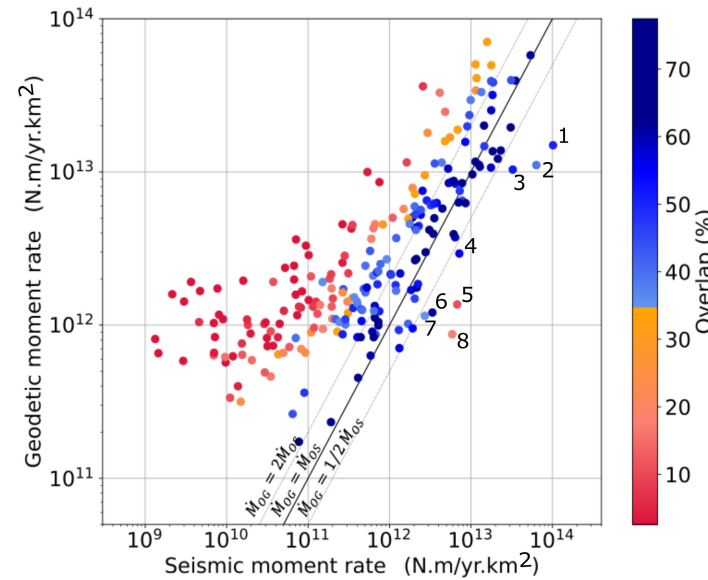
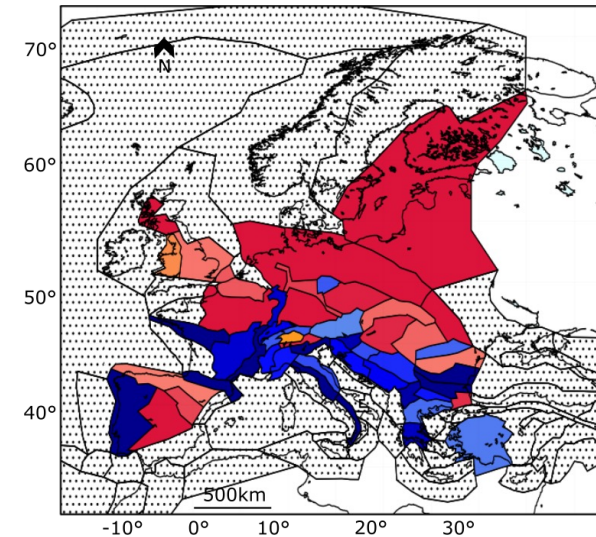


Overlap Geodetic Mo Seismic Mo

ESHM20 source zones

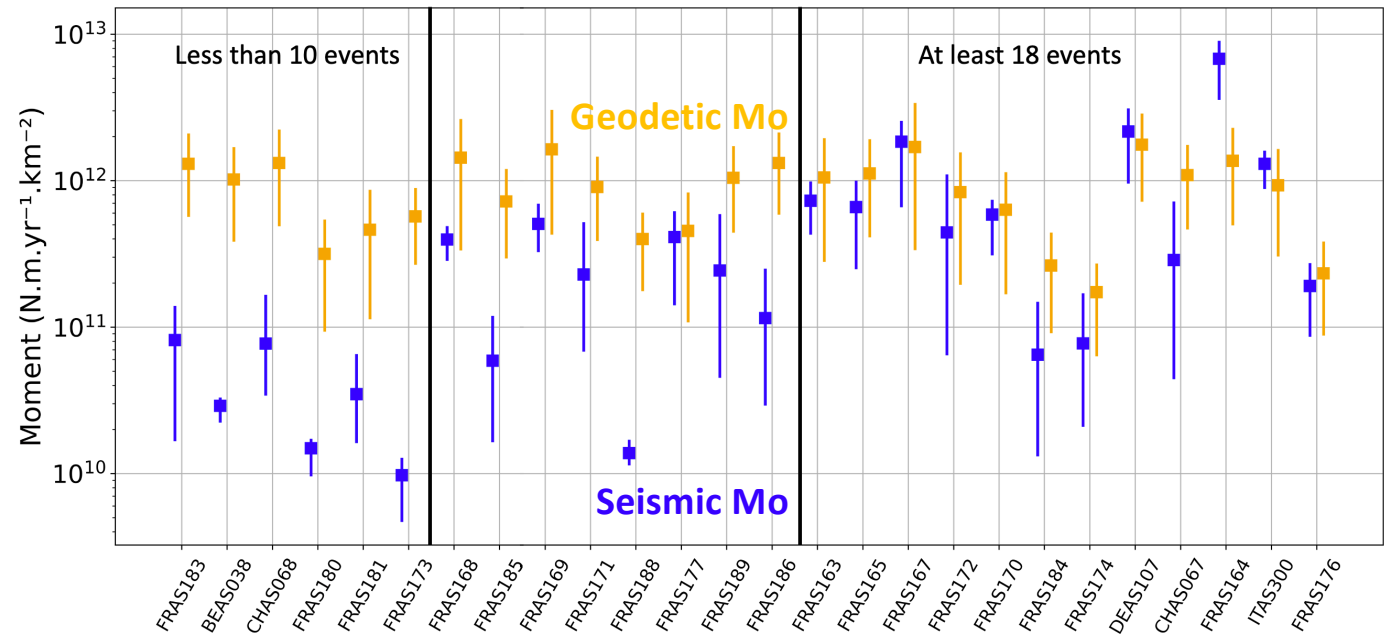
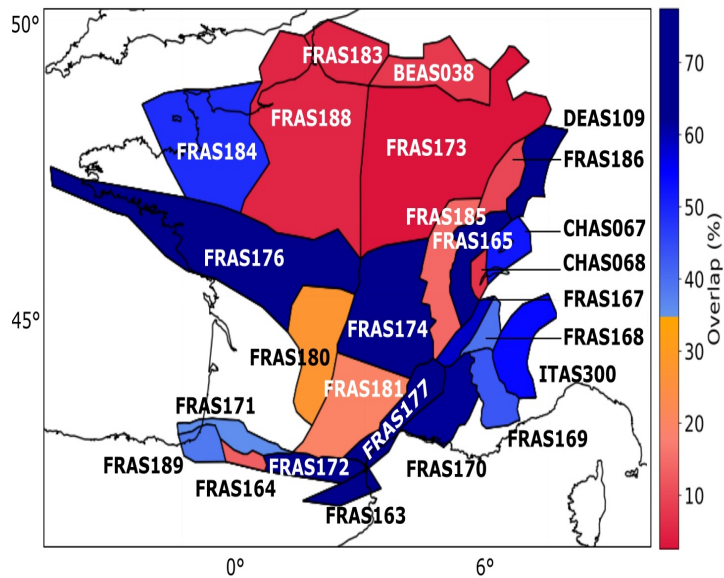


ESHM20 'tecto' zones (GIA excluded)



Focus on France

When enough seismic events constrain the Gutenberg Richter, the agreement is better



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



- (Still) need for methodology and benchmark work !!