Geodynamic modeling of the Southeastern United States: Associations between gravitational potential energy, modern tectonism, and inherited structures

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I - Abstract

- Geodynamic models quantify lithospheric gravitational potential energy (GPE) magnitudes in the Southeastern United States. Models incorporate recently published crustal thicknesses (Buehler et al., 2017) and a region of high seismic velocity beneath central West Virginia interpreted as delaminated, eclogitized crust (Biryol et al., 2016).
- Whereas in most locations recent seismicity is associated with higher magnitudes of GPE, inherited structures may explain regions in which earthquakes occur in areas with lower magnitudes of GPE.

II - Background

According to classic plate tectonic theory, deformation occurs primarily at plate boundaries. However, many earthquakes occur in plate interiors. Gravitational collapse of high topography is an important contributor to the force balance contributing to intraplate seismicity (e.g., Ghosh et al., 2019). We seek to analyze spatial relationships between GPE and ongoing seismic activity in the eastern United States.

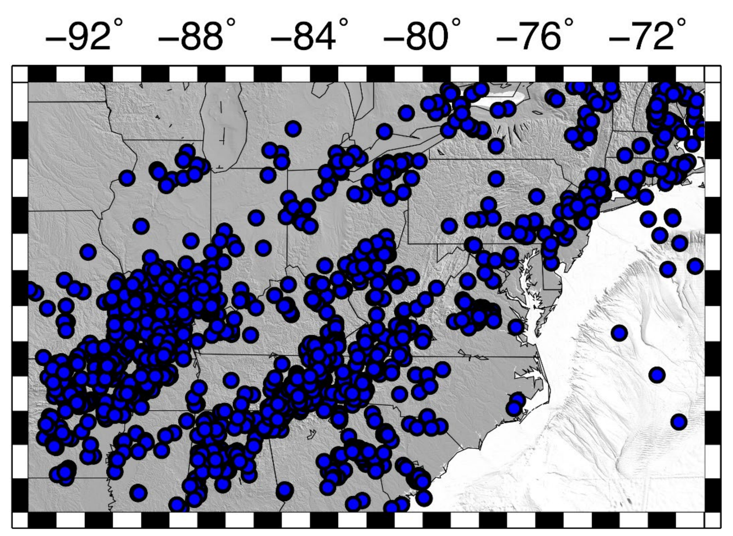


Figure 1 – Earthquake epicenters near the passive margin of the eastern U.S.

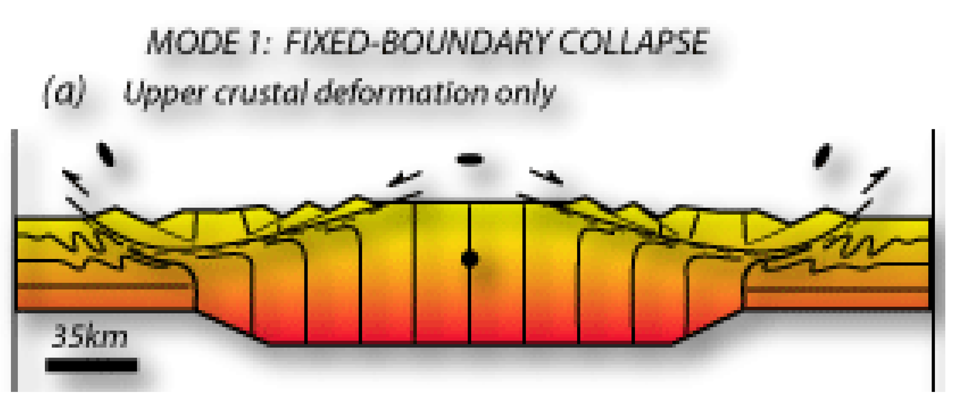


Figure 2 – From Rey et al. (2001): A cross-sectional depiction of fixed-boundary gravitational collapse

III - Methods

We first calculate GPE magnitudes using density and crustal thickness data from Crust 1.0 (Laske et al., 2013), which are integrated over the thickness of the lithosphere on a 0.5 by 0.5 degree grid (e.g., Flesch et al., 2001). The integral accounts for topography, rock density, and layer thicknesses. Crust1.0 models are compared to models that incorporate recent seismic observations (Biryol et al., 2016; Buehler et al., 2017). Mantle densities are calculated such that columns are in isostatic balance.

$$\bar{\sigma}_{zz} = -\frac{1}{L}\int_0^h \left(\int_0^z \rho z' g \mathrm{d}z'\right) \mathrm{d}z$$

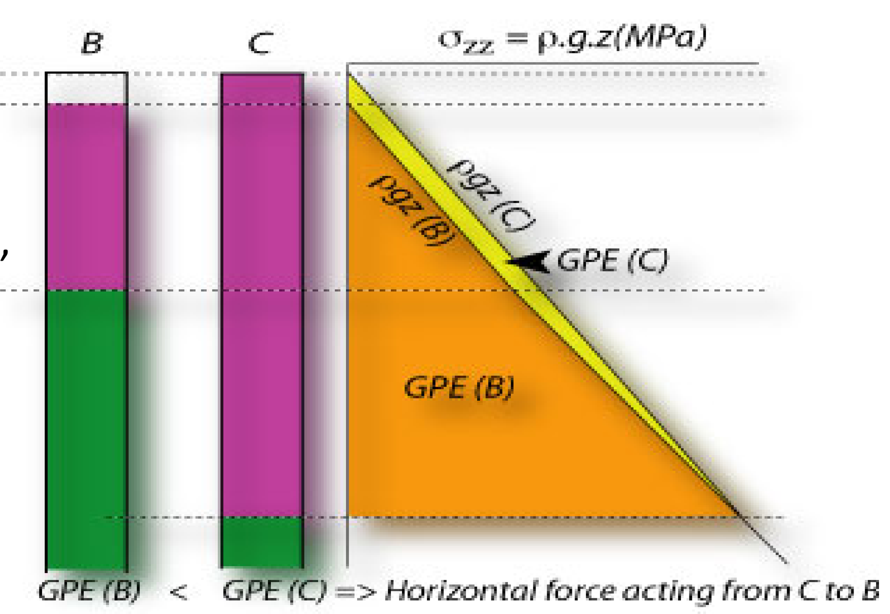


Figure 3 – From Rey (2019): 2-D depiction of GPE integral

IV - Results

Left: GPE magnitudes. Layer densities and thicknesses are from Crust1.0 (Laske et al., 2013). In Figures 5 and 6, Moho depths are from Buehler et al. (2017).
Right: GPE magnitudes plotted with earthquake epicenters (USGS).

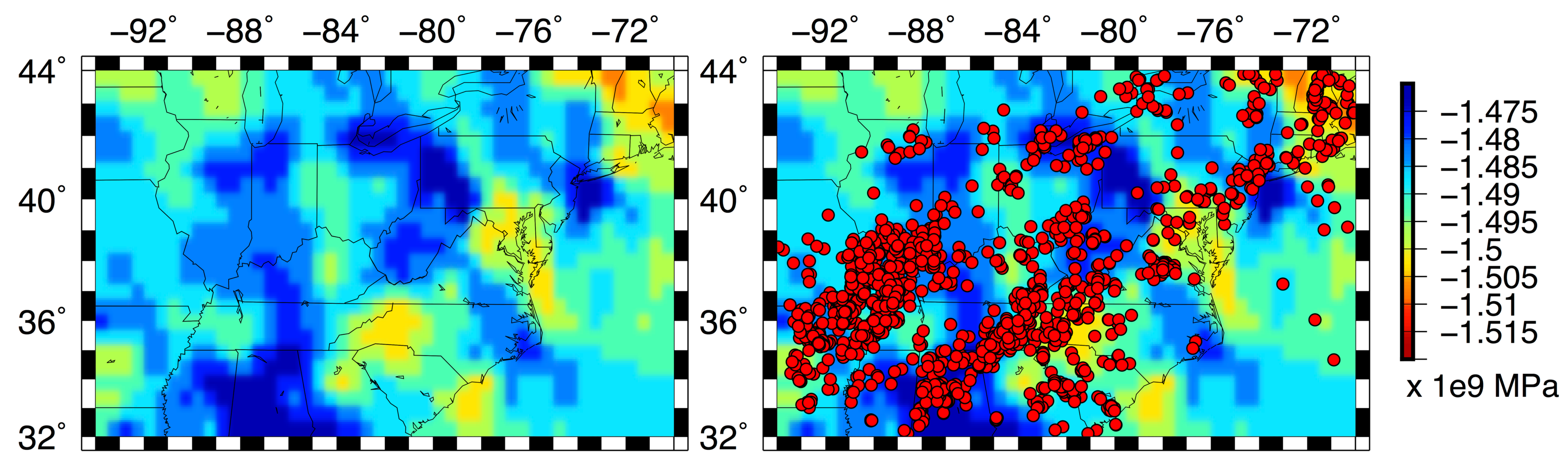


Figure 4 – GPE magnitudes calculated using density and Moho data from Crust 1.0 (Laske et al., 2013)

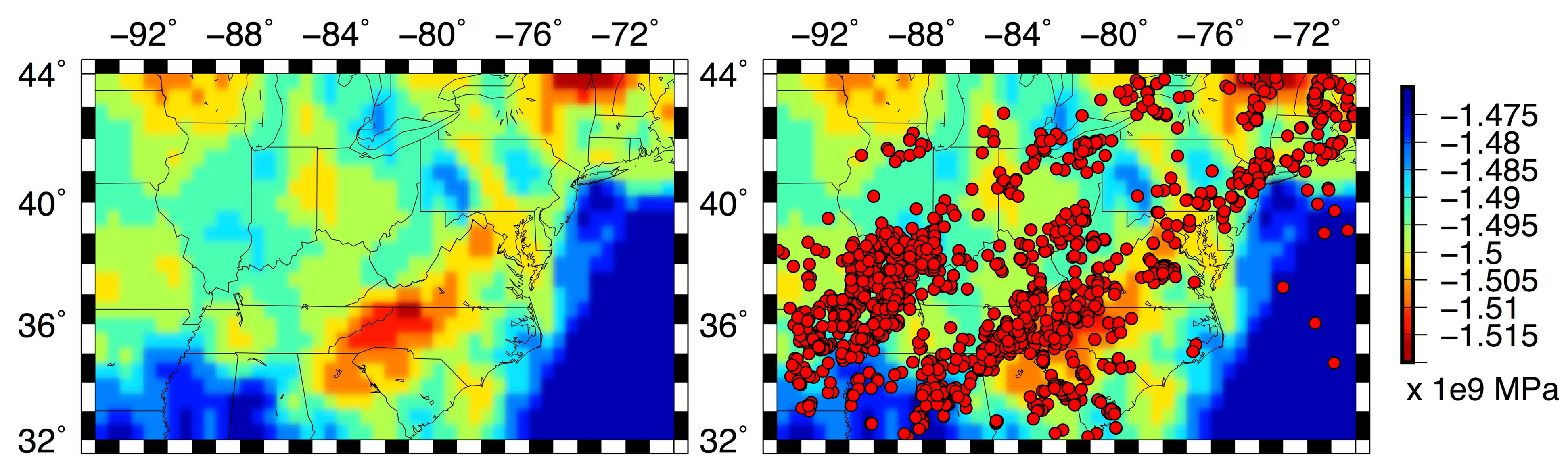


Figure 5 – GPE magnitudes calculated using density data from Crust 1.0 and continental Moho depths from Buehler et al. (2017)

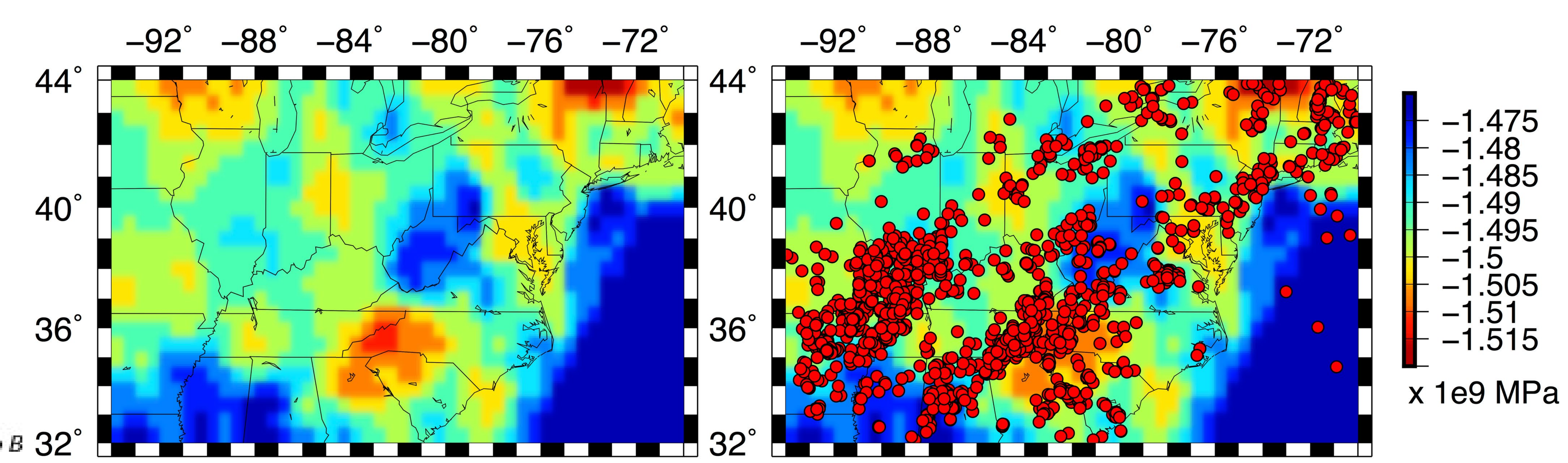
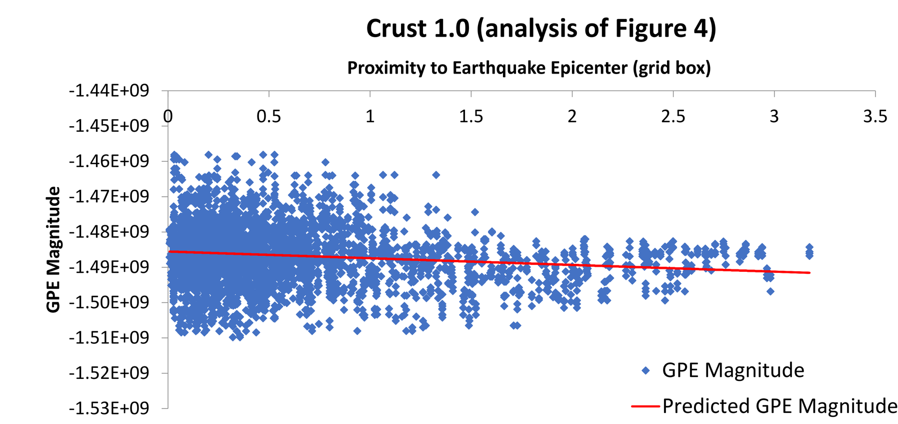
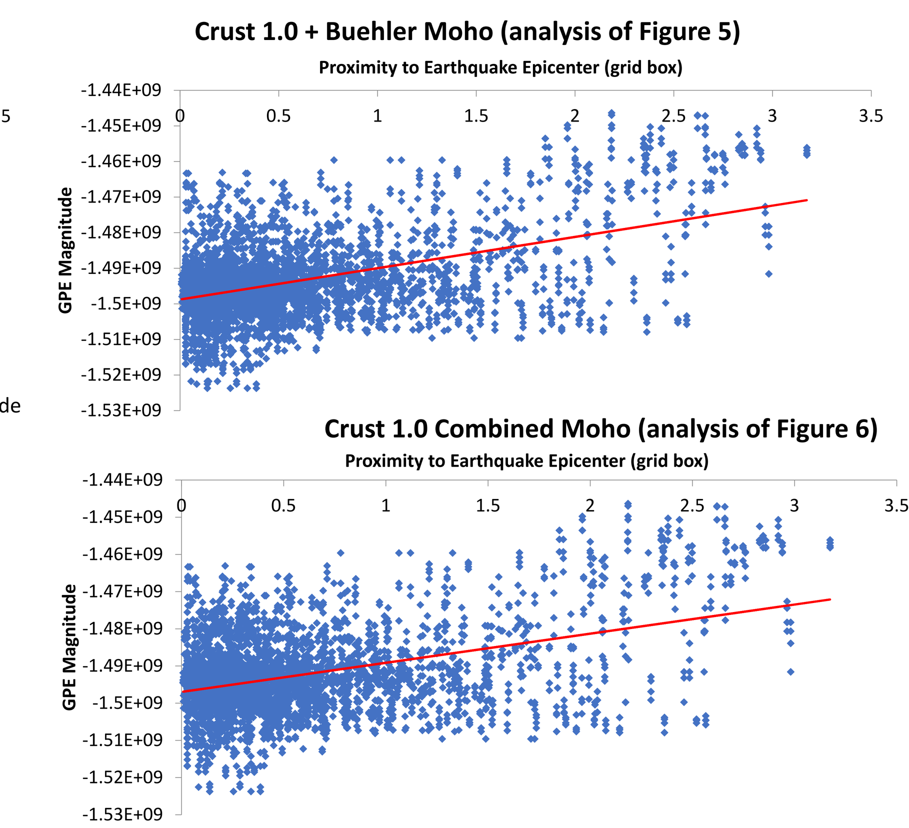


Figure 6 – GPE magnitudes calculated using density data from Crust 1.0, and combined continental Moho depths from Crust 1.0 and Buehler et al. (2017)

IV - Results, continued





	Crust 1.0	Crust 1.0 With Buehler Moho Depths	Crust 1.0 With Combined Moho Depths
Moran's I	0.028	0.475	0.424
R Square	0.019	0.223	0.17767
Slope	-1899300	8790909	7832053
P Value	5.63E-18	8.4E-205	2.60E-159

Figure 7 and Table 1 – Statistical analysis. A Bivariate Moran's I test and linear regression quantifies the relationship between GPE magnitude and proximity to nearest earthquake.

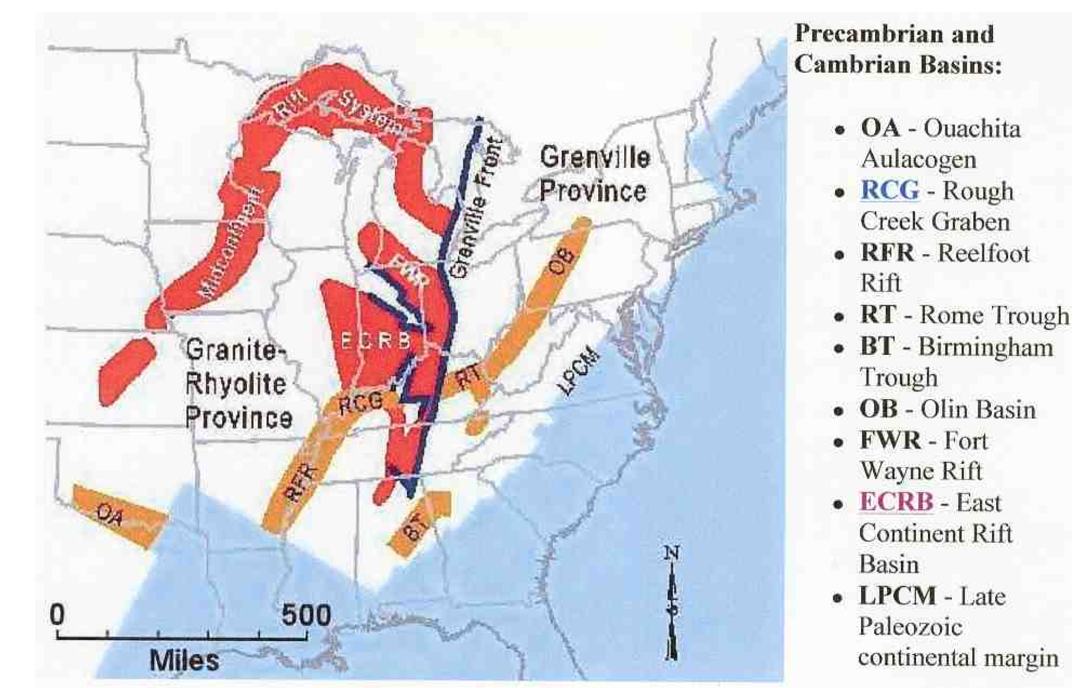


Figure 8 – From Harris (2000): Map of Precambrian rift basins in eastern North America. E.g., the Grenville Front and Reelfoot Rift align with seismic zones in areas with low GPE magnitude.

V - Conclusions

- In models that incorporate more precise Moho constraints (Figures 5 & 6), as GPE magnitude increases (becomes more negative), distance to earthquakes decreases (Figure 7, Table 1).
- There is a weak statistical correlation between high GPE magnitude and earthquake proximity. Spatial relationships with inherited features (Figure 8) suggest that inherited strength heterogeneities play a role in distribution of GPE and seismicity.

VI - Future Work

- Conduct further statistical analyses considering the spatial autocorrelation present in the models in Figures 5 and 6.
- Conversion of precise S-Wave tomography dataset (Parker et al., 2015; Wagner et al., 2018) to density data using empirical seismic velocity to density relationships as described in Abers et. al. (2016).
- Analyze interactions with inherited features, especially in areas with high concentrations of earthquake epicenters and lower GPE magnitude.

VII - Acknowledgments

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