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Joint interpretation of geophysical data for evaluating the geothermal energy potential in the Romagna and Ferrara Folds (Italy)

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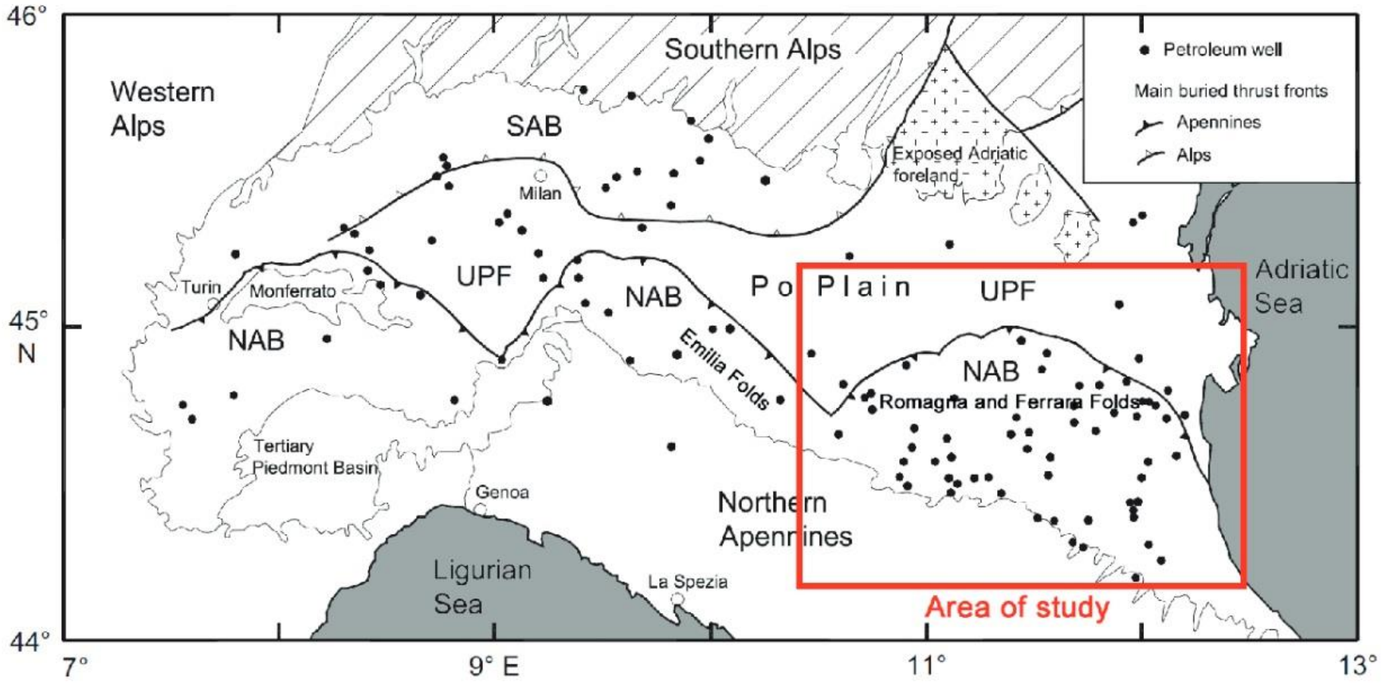
InGEO PRIN 2022 PNRR Project:

Innovation in geothermal resources and reserves potential assessment for the decarbonization of power/thermal sectors

Aim

Data Collection, analyses, and integration in a consistent petrophysical and structural model → **Thermal Modelling and geothermal potential assessment**

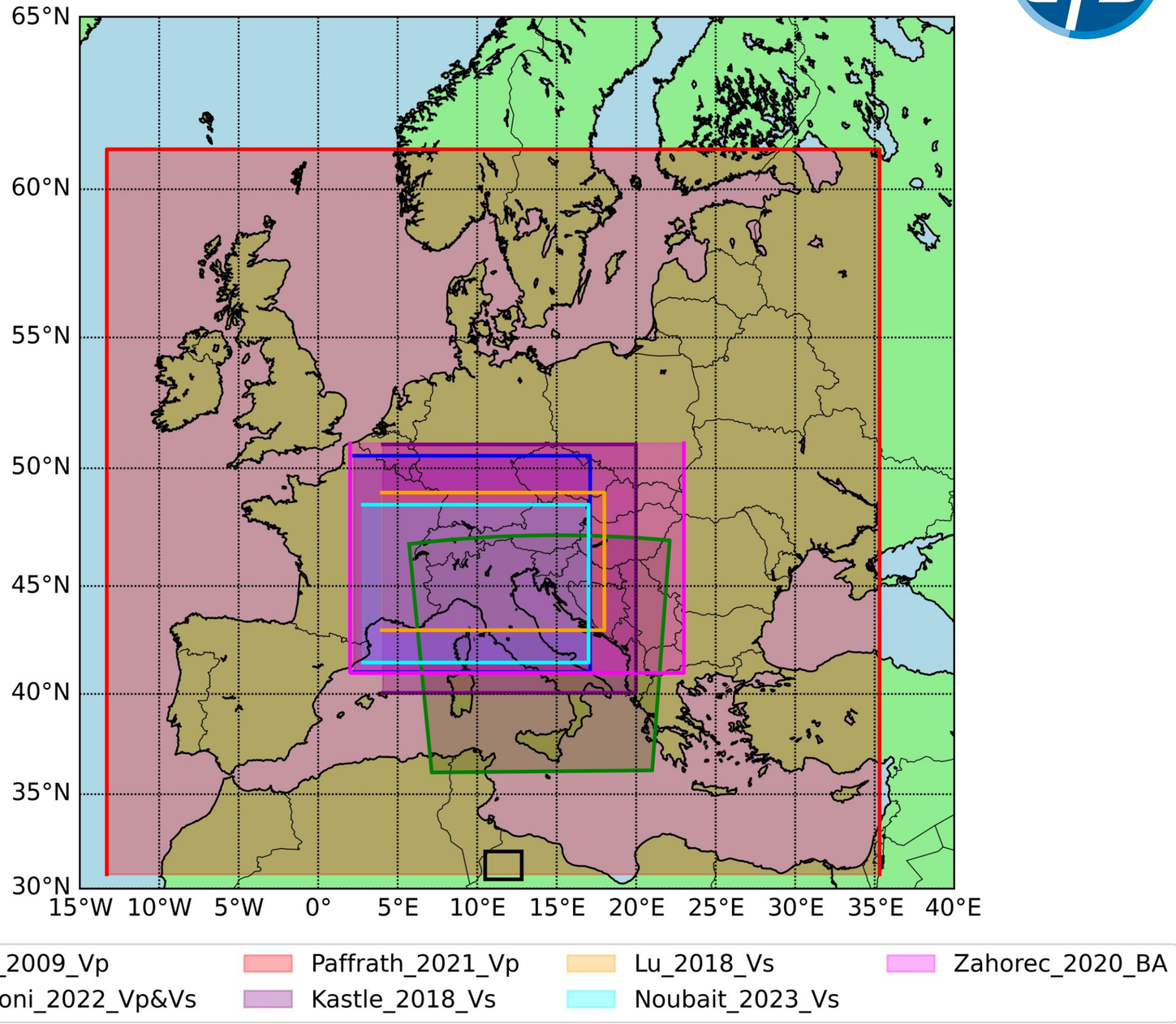
Study Area



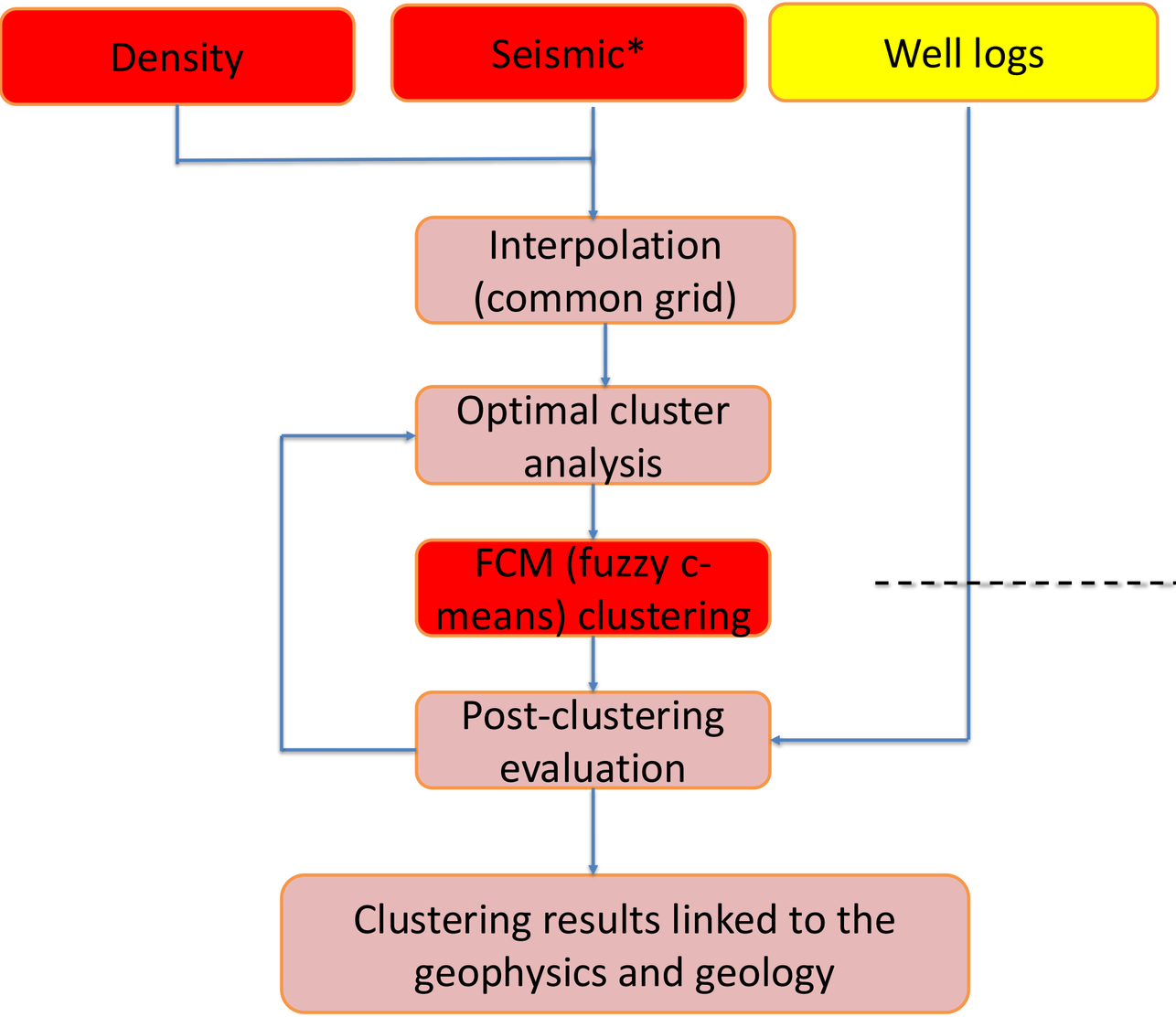
- Significant thermal gradients (on average 53 °C/km) in the impermeable formations overlying the deep carbonate units, in which convective fluid circulation occurs.
- In the Romagna and Ferrara Folds (RFF), near Ferrara, the average temperature recorded is about 85°- 95°C.

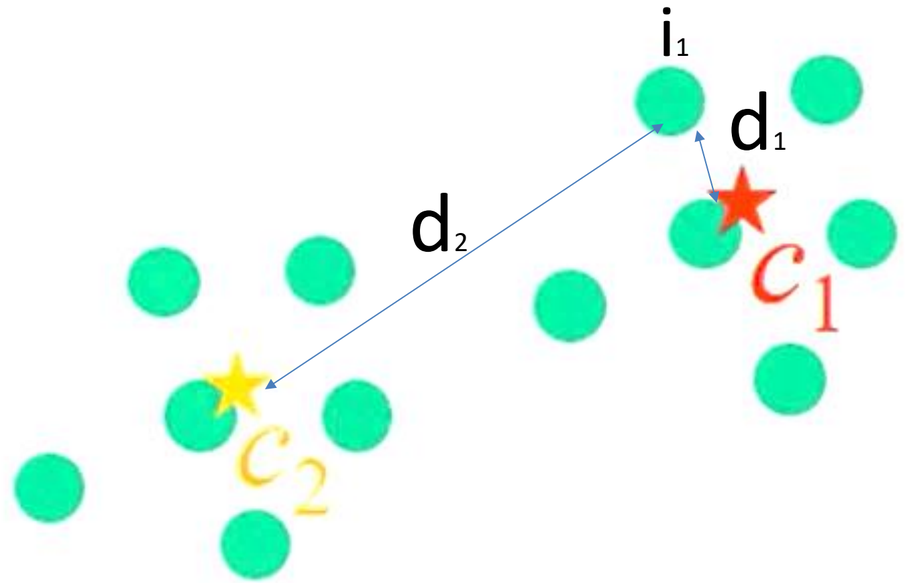
Multi-geophysical classification

- Geophysical Exploration in Romagna
- Benefits of using previous geophysical models
- Geographic outline shows seismic and gravity data can be used to re-interpret RFF region
- Focus on seismic tomography models



Joint Interpretation





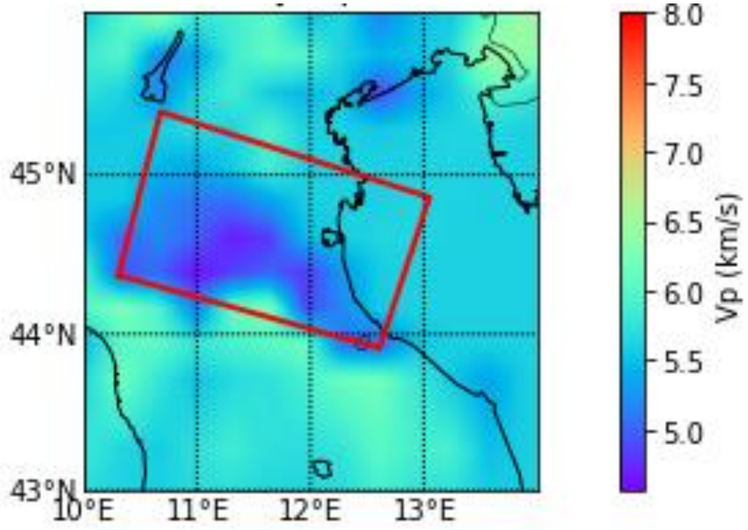
$$J_m(U,v) = \sum_{k=1}^{N}\sum_{i=1}^{c}(u_{ik})^m \ \| y_k - v_i \|^2$$

- d1 < d2 → i1 assigned to c1
- $u_{i1c1} > u_{i1c2}$
- $0 > u_{ik} > 1$

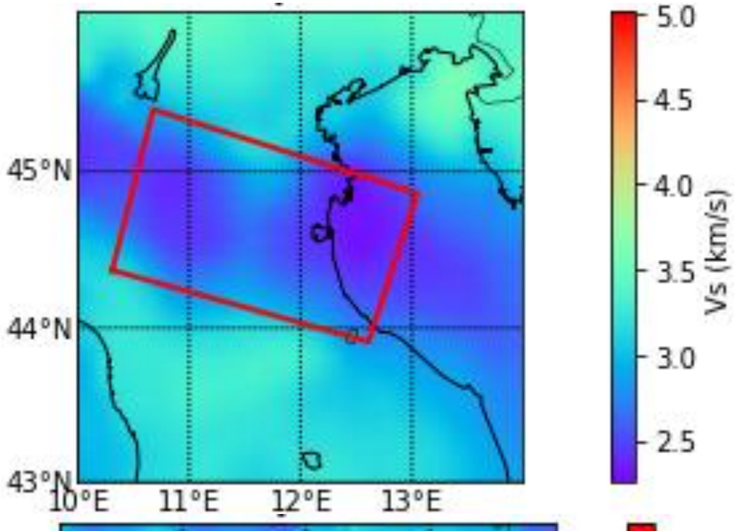
Bezdeck et al. (1984)

Seismic Tomography

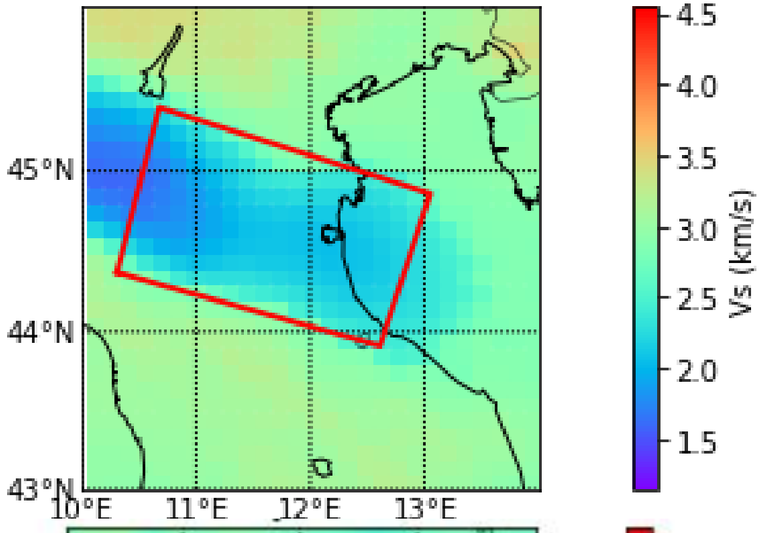
Diehl (2009) (3km)

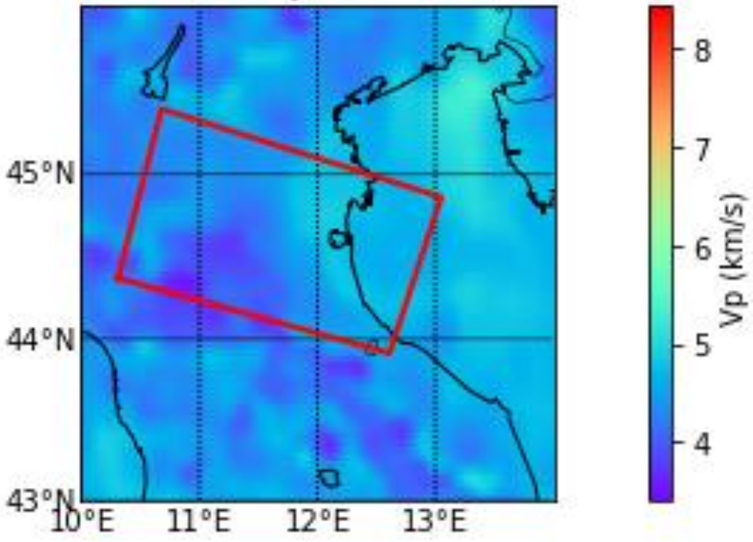


Nouibat(2023) (3km)

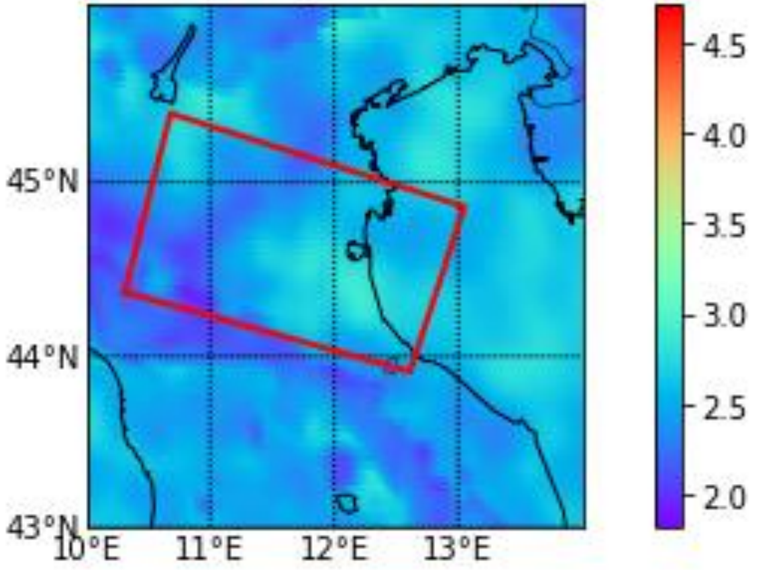


Kastle (2018) (3km)

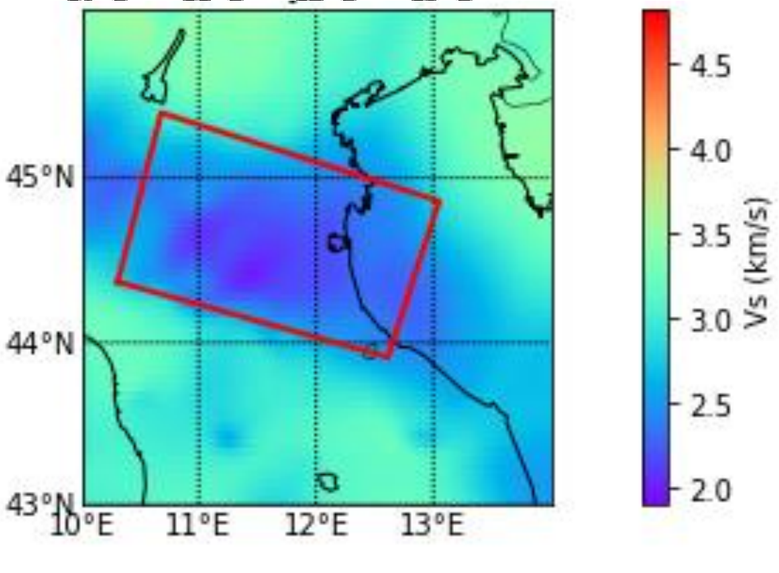




Magnoni (2022) (3km)

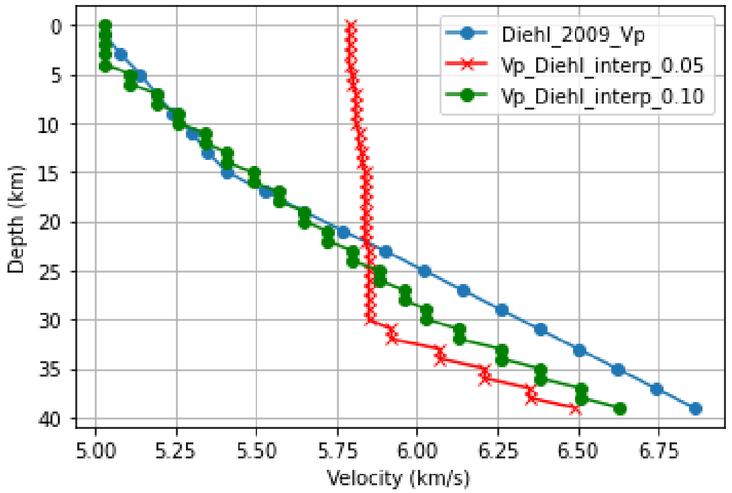


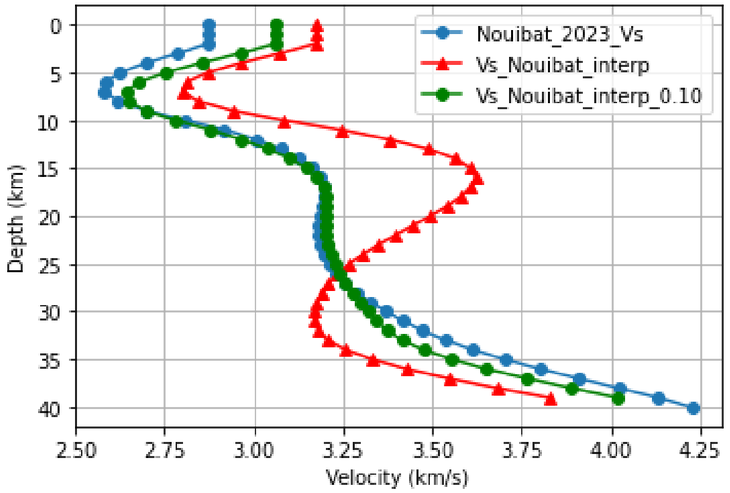
Magnoni (2022) (3km)

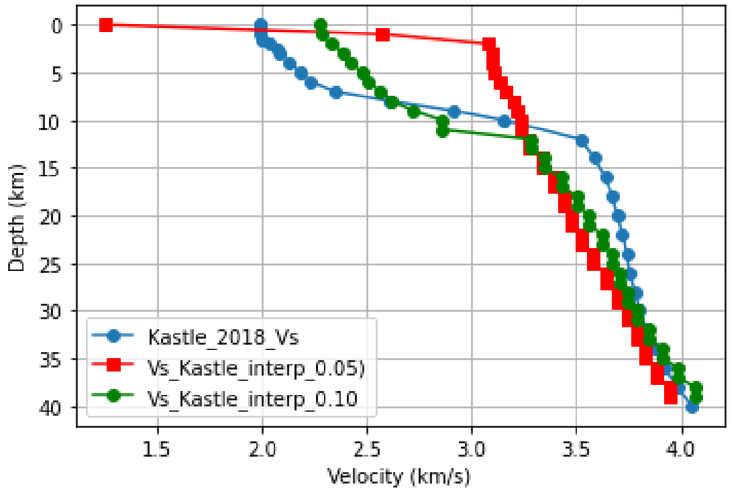


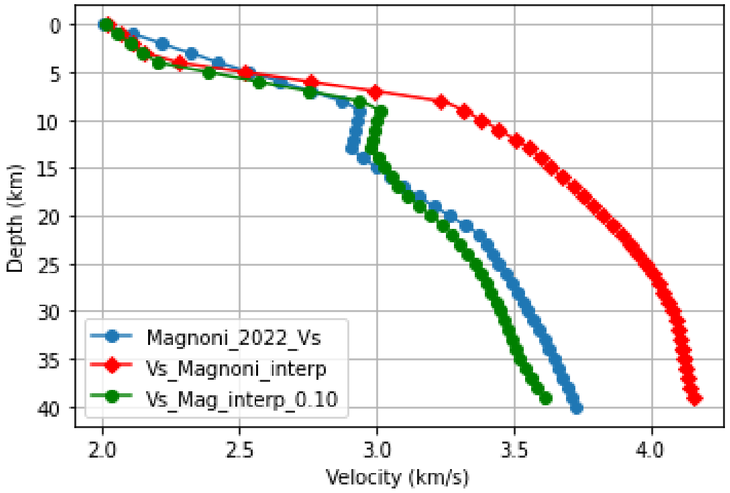
Lu (2020) (3km)

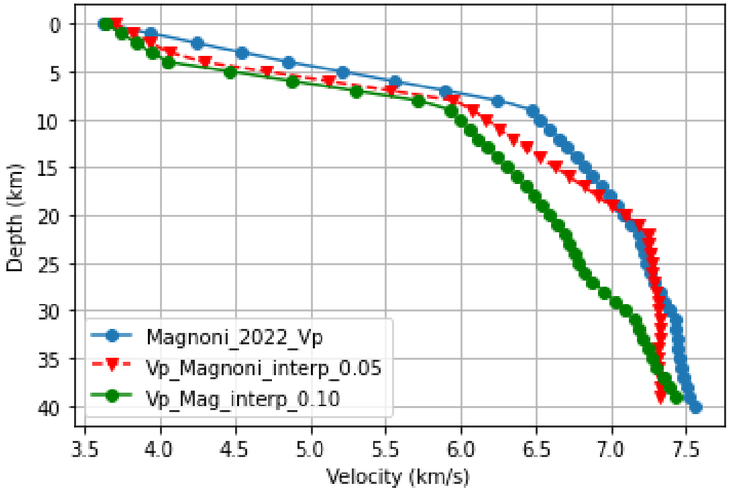
Interpolation onto common grid

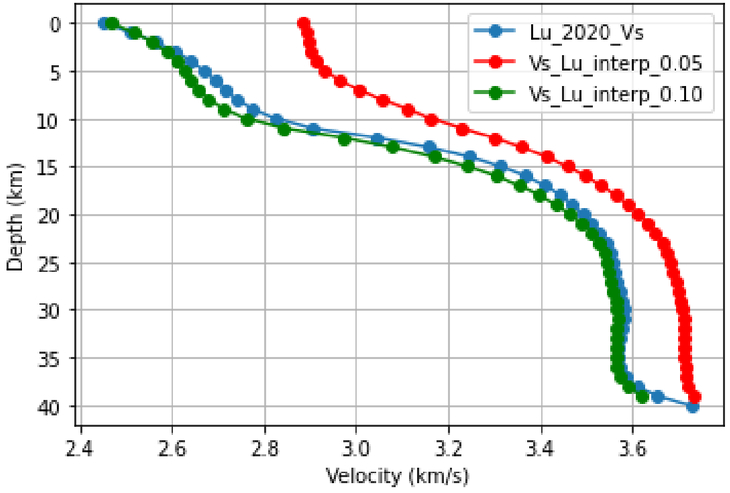






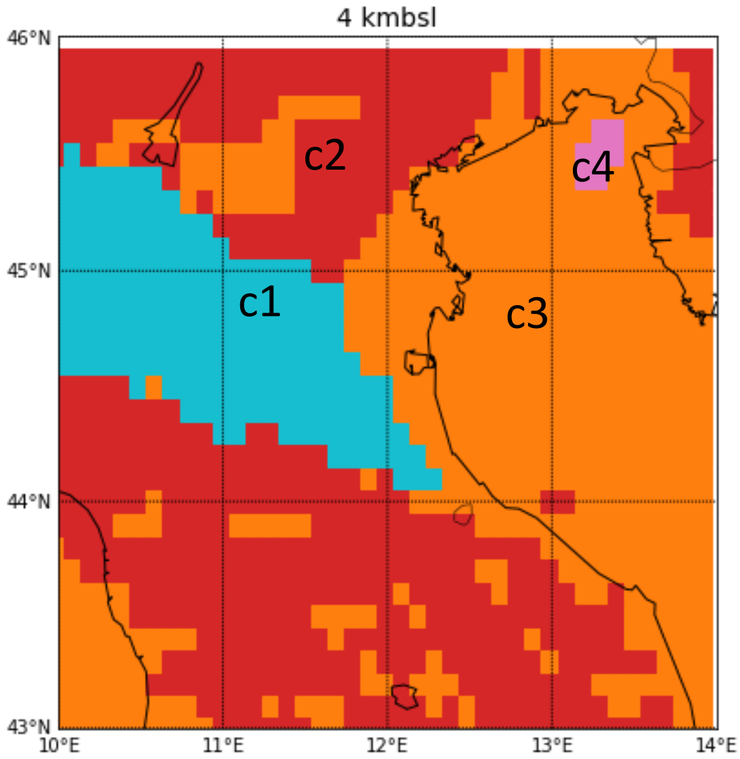




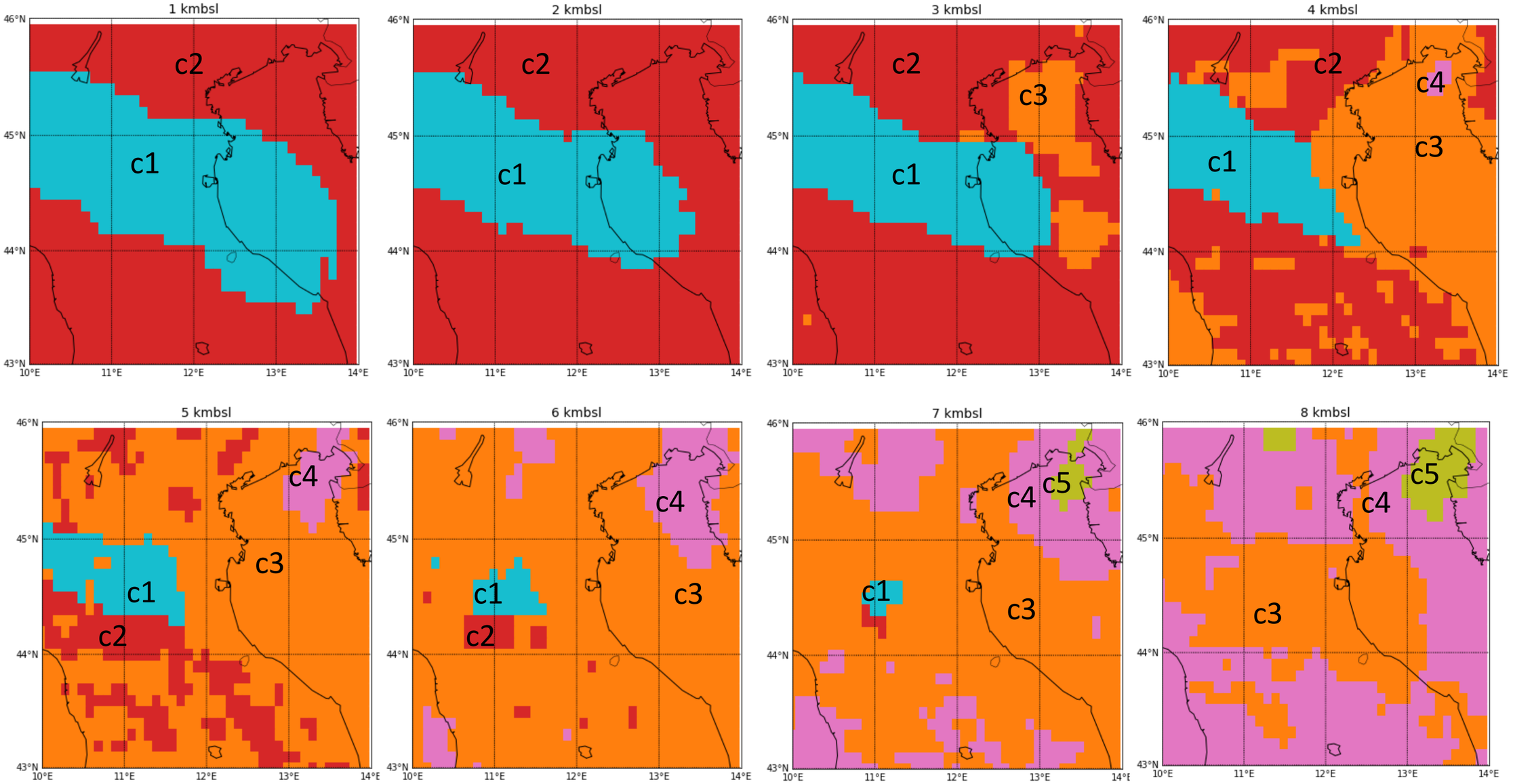


FCM Classification

	Lu_Vs	Kastle_Vs	Nouibat_Vs	Mag_Vs	Mag_Vp	Diehl_Vp	Density
c1	2.55	1.87	2.76	2.24	4.00	5.48	2.32
c2	2.99	2.94	3.10	2.40	4.33	5.69	2.37
c3	2.92	2.93	2.96	2.95	5.36	5.67	2.56
c4	3.20	3.22	3.24	3.29	6.11	5.81	2.73
c5	3.45	3.48	3.39	3.50	6.53	5.98	2.84

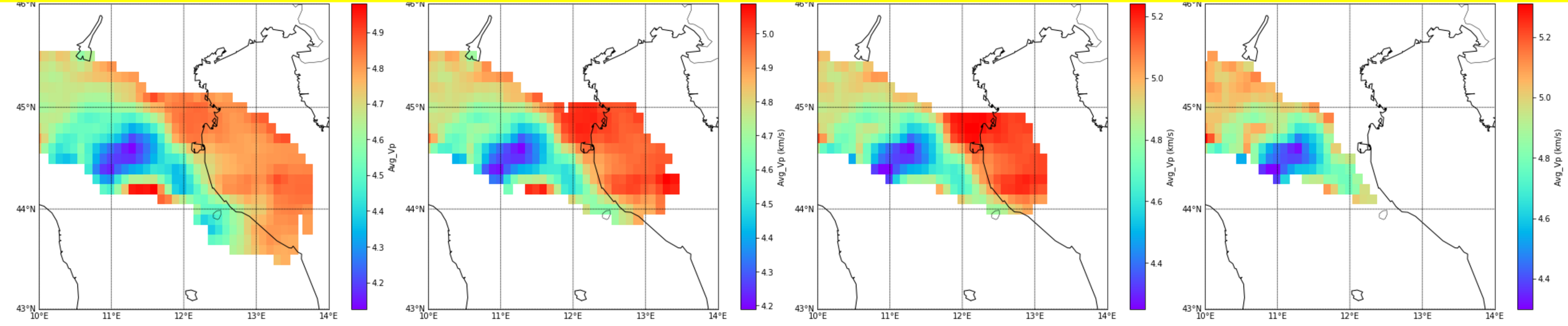


Cluster model variation up to 8 km depth

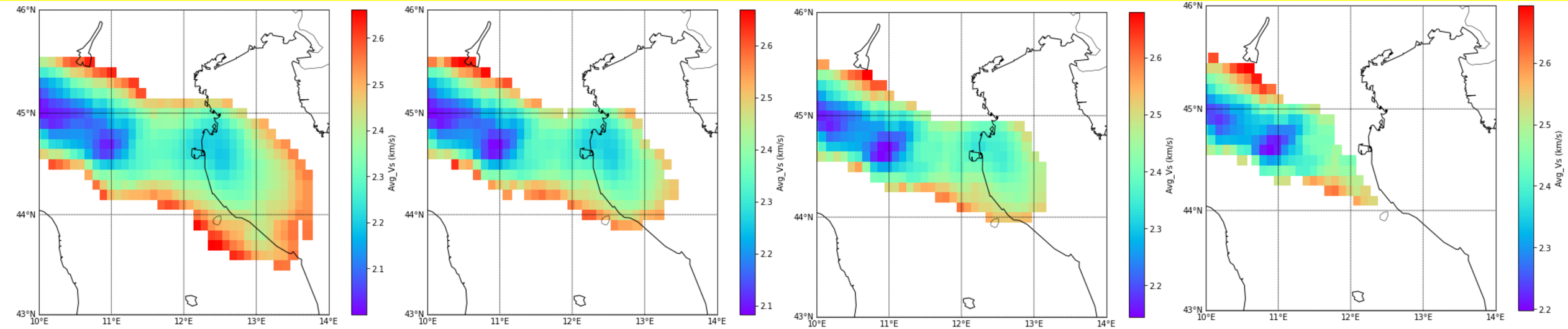


Seismic velocities

Avg_Vp



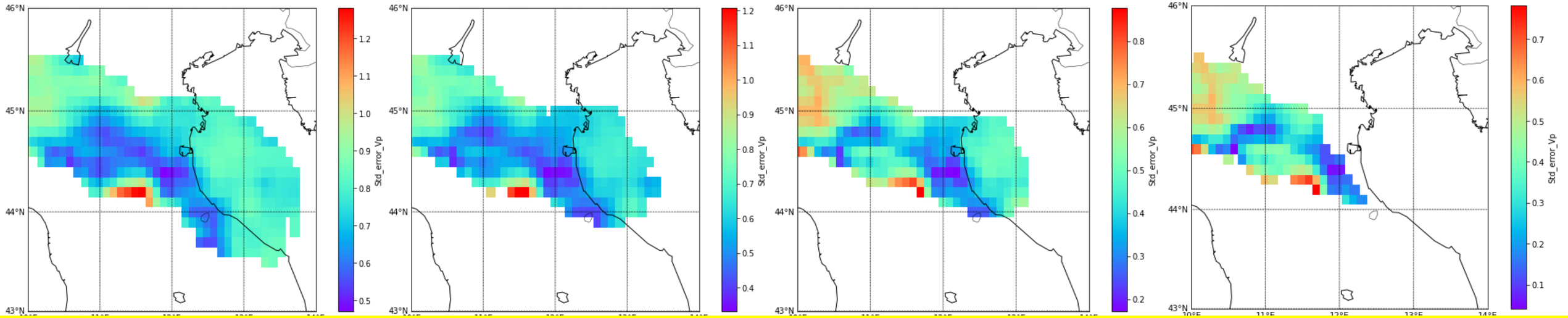
Avg_Vs



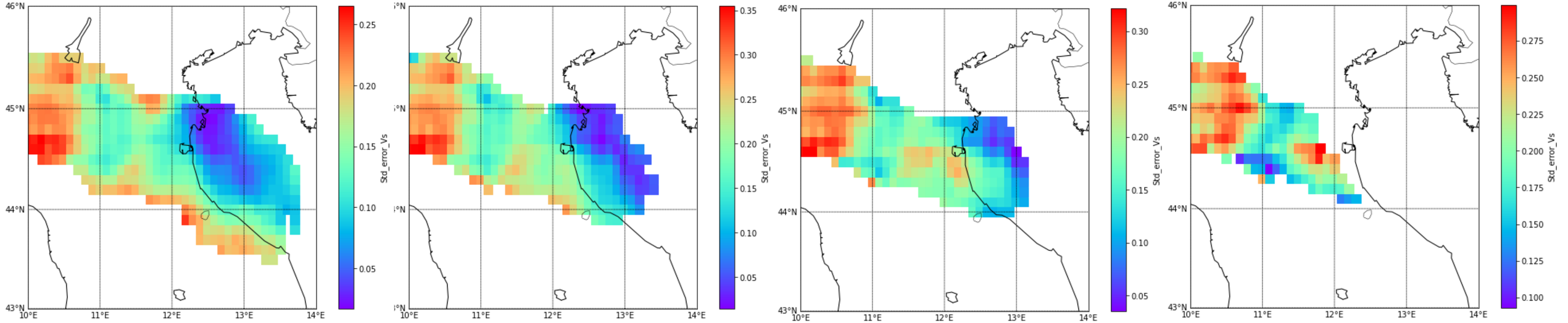
1 km 2 km 3 km 4 km

Uncertainty analysis

Vp

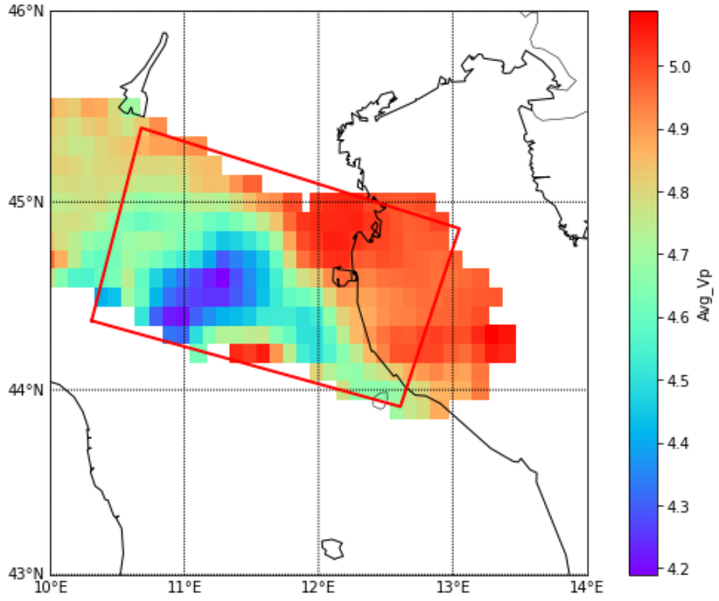


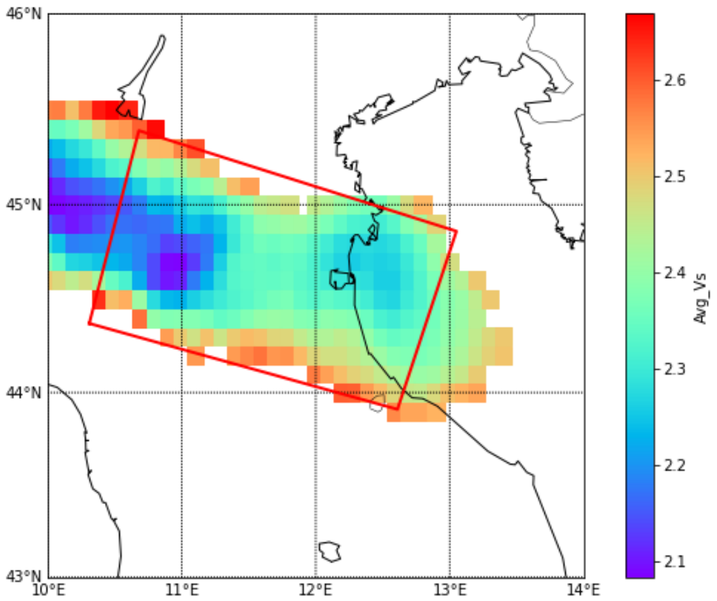
Vs

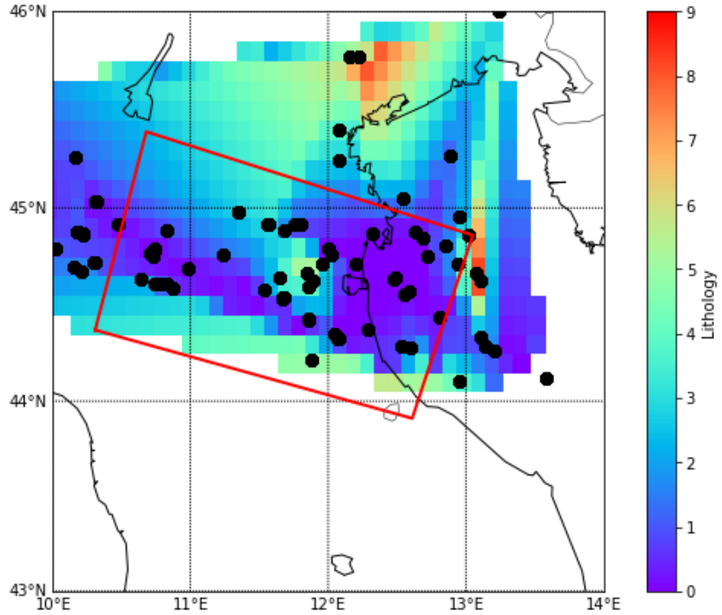


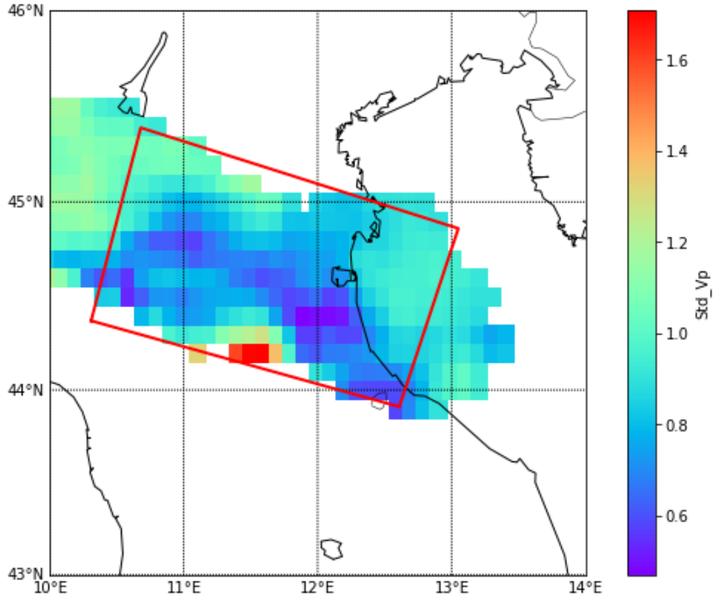
1 km 2 km 3 km 4 km

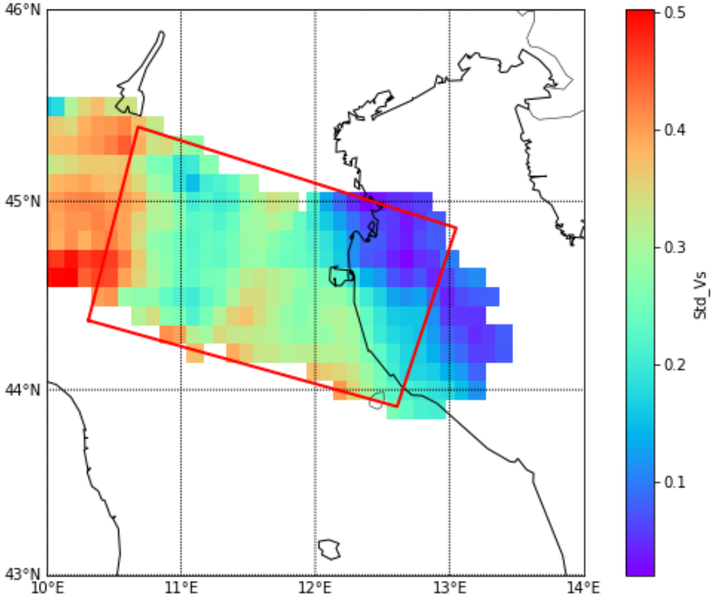
Comparison with well logs at 2km depth









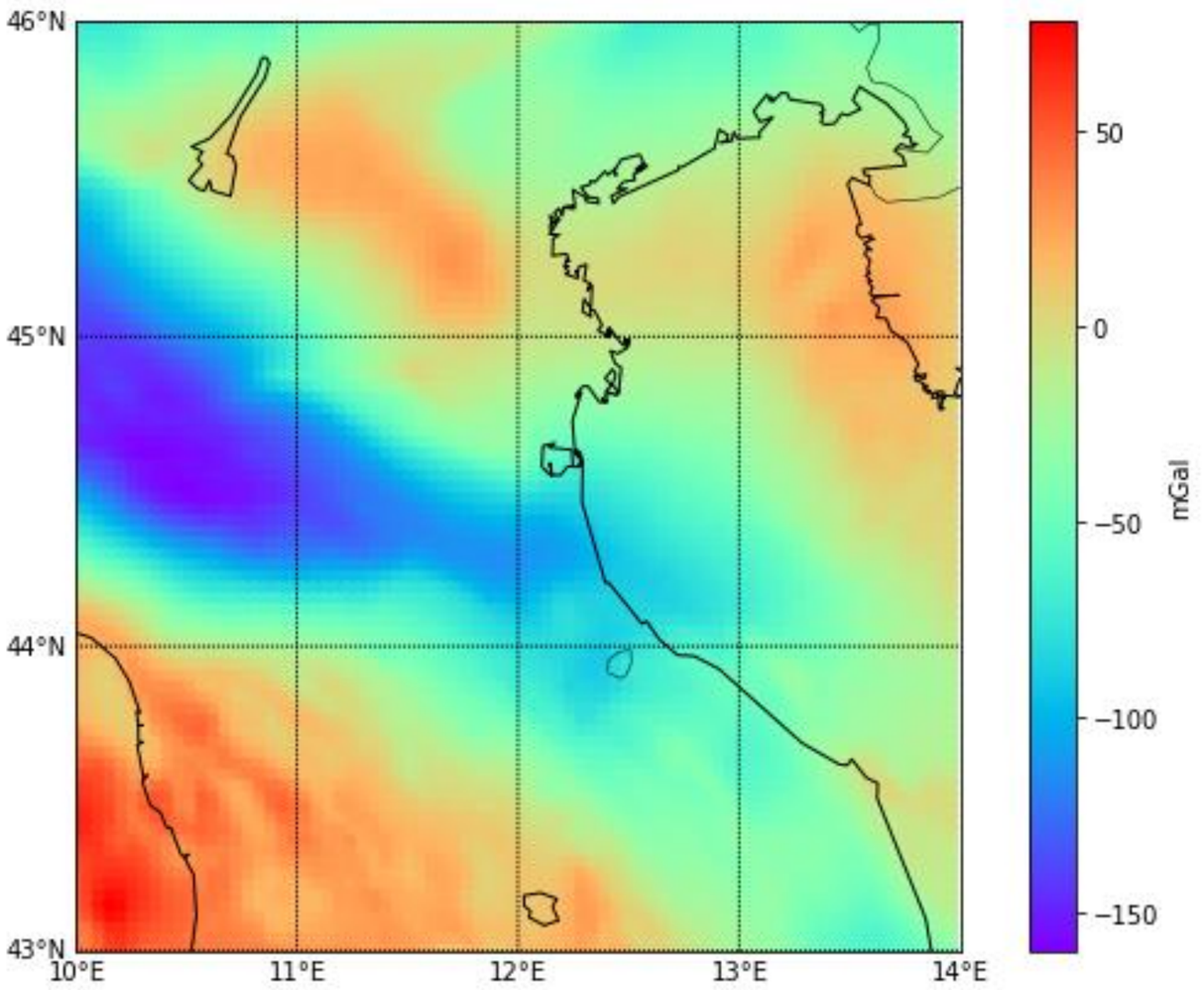


Livani et al (2023)

0-Sand
1-Shale
2-Alternances
3-Limestone
4-Conglomerate
5-Cry. basement
6-Marls
7-Dolomite
8-Gravel
9-Cem. Sand

Next Steps…

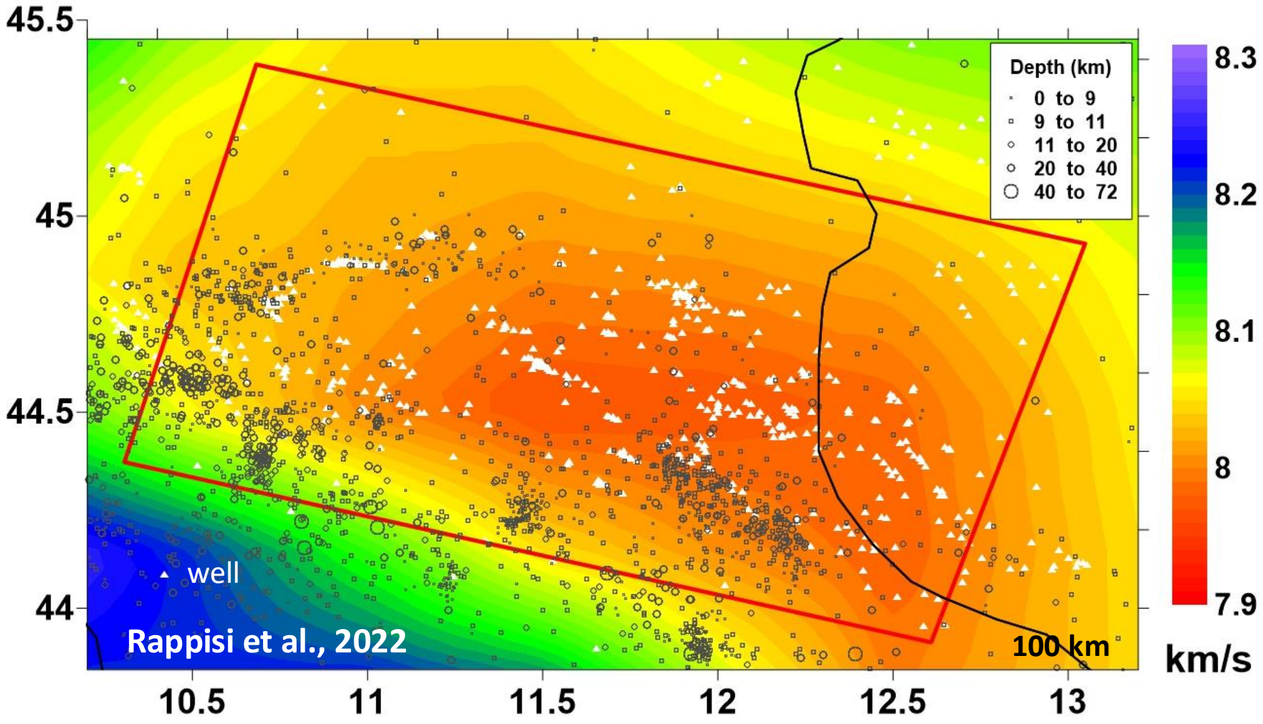
How much the seismic data are correlated with the gravity data?

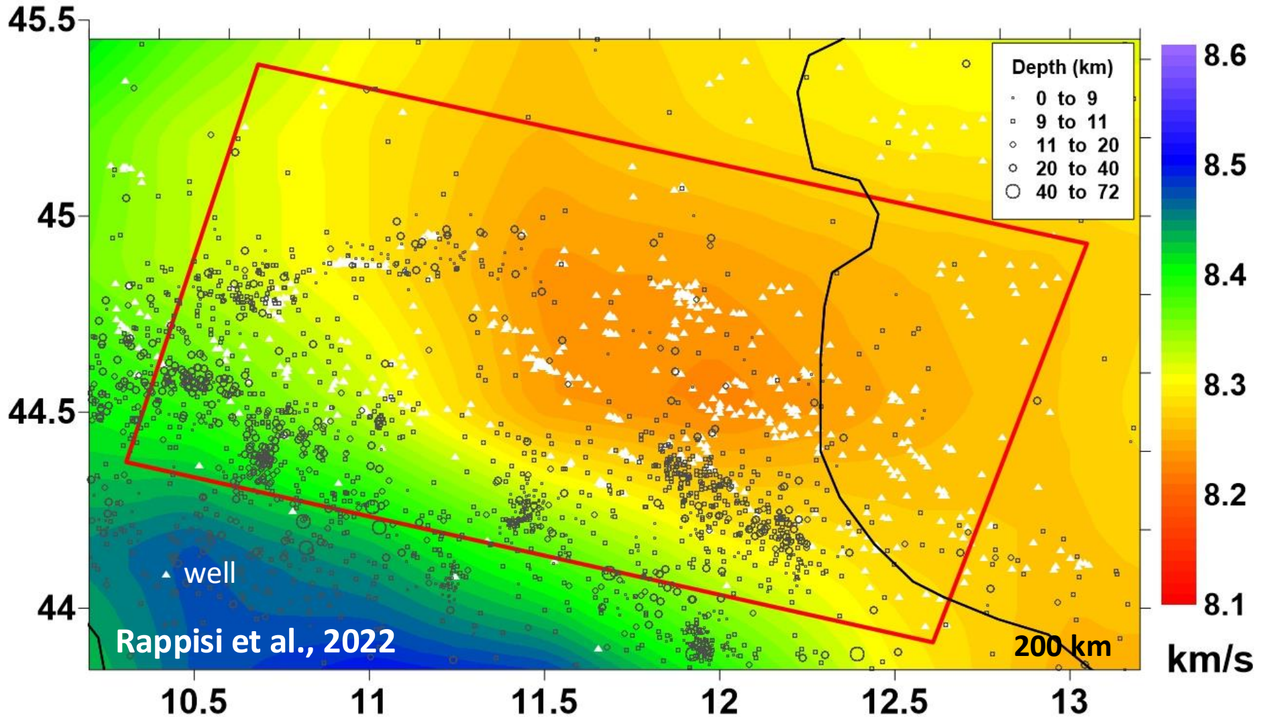


Zahorec et al. (2021)

Next Steps…

Is the thermal anomaly of the RFF related to the deep lithospheric structure?





- *A broad low Vs, which can reflect local asthenosphere uprising is observed in the uppermost mantle from seismic tomography data.*

Conclusions & Outlooks

- The first results of the cluster analyses allow us to constrain the geological features in 3D. In particular, we constrain the shape of the shallow low velocity anomaly and relate it to the sediments located above the carbonate reservoir.
- More consistency are shown among the Vs datasets (than Vp datasets) and well log data.

- We will validate the cluster model with petrological, well log data, and analyses of gravity data collected and perform a sensitivity analysis.
- Our results will contribute to implement a consistent geological/geophysical model to characterize the geothermal reservoir.
- Our general approach is transferable and can be taken as guideline for investigations of other geothermal systems worldwide.

Acknowledgements

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References

Bezdek J.C., et al., 1984. *FCM—the Fuzzy C-Means clustering-algorithm*. Computers & Geosciences· 10(2-3):191-203. DOI: 10.1016/0098-3004(84)90020-7.

Cortassa V., Tesauro M., Gola G., Nanni T, Galgaro A. and Manzella A.; 2025. *Integrated geological modelling for assessing geothermal potential in the Romagna and Ferrara Folds (Italy)*. Gruppo Nazionale per la Geofisica della Terra Solida (43° National Conference GNGTS), Bologna, 11-14 February 2025 (Abstract).

Diehl T., et al., 2009. High-resolution 3-D *P*-wave model of the Alpine crust, *Geophysical Journal International*, 179, Issue 2, 1133–1147. 10.1111/j.1365-246X.2009.04331.x.

Kästle E.D., et al., 2018. *Surface wave tomography of the Alps using ambient-noise and earthquake phase velocity measurements*, Journal of Geophysical Research: Solid Earth, 123, 1770–1792. https://doi.org/10.1002/2017JB014698.

Lu Y., et al., 2018. *High-resolution surface wave tomography of the European crust and uppermost mantle from ambient seismic noise*. Geophys. J. Int., 214, 1136–1150, https://doi.org/10.1093/gji/ggy188.

Magnoni F., et al., 2023. *Adjoint tomography of the Italian lithosphere. COMMUNICATIONS EARTH & ENVIRONMENT| (2022) 3:69.* https://doi.org/10.1038/s43247-022-00397-7.

Nouibat A., et al., 2023. *Ambient-noise wave- equation tomography of the Alps and Ligurian-Provence basin*. Journal of Geophysical Research: Solid Earth, 128, e2023JB026776.

Paffrath, M., et al., 2021. *Teleseismic P waves at the AlpArray seismic network: wave fronts, absolute travel times and travel-time residuals.* Solid Earth, 12, 1635 1660, https://doi.org/10.5194/se-12-1635-2021.

Rappisi F., et al., 2022. *Slab geometry and upper mantle flow patterns in the Central Mediterranean from 3D anisotropic P-wave tomograph*y. J. of Geophys. Res., 127, e2021JB023488. https://doi. org/10.1029/2021JB023488.

Zahorec P. et al., 2021. *The first pan-Alpine surface-gravity database, a modern compilation that crosses fro*ntiers. Earth Syst. Sci. Data, 13, 2165–2209, https://doi.org/10.5194/essd-13-2165-2021.

Thank you for your attention!

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Deadline for abstract submission: March 12, 2025

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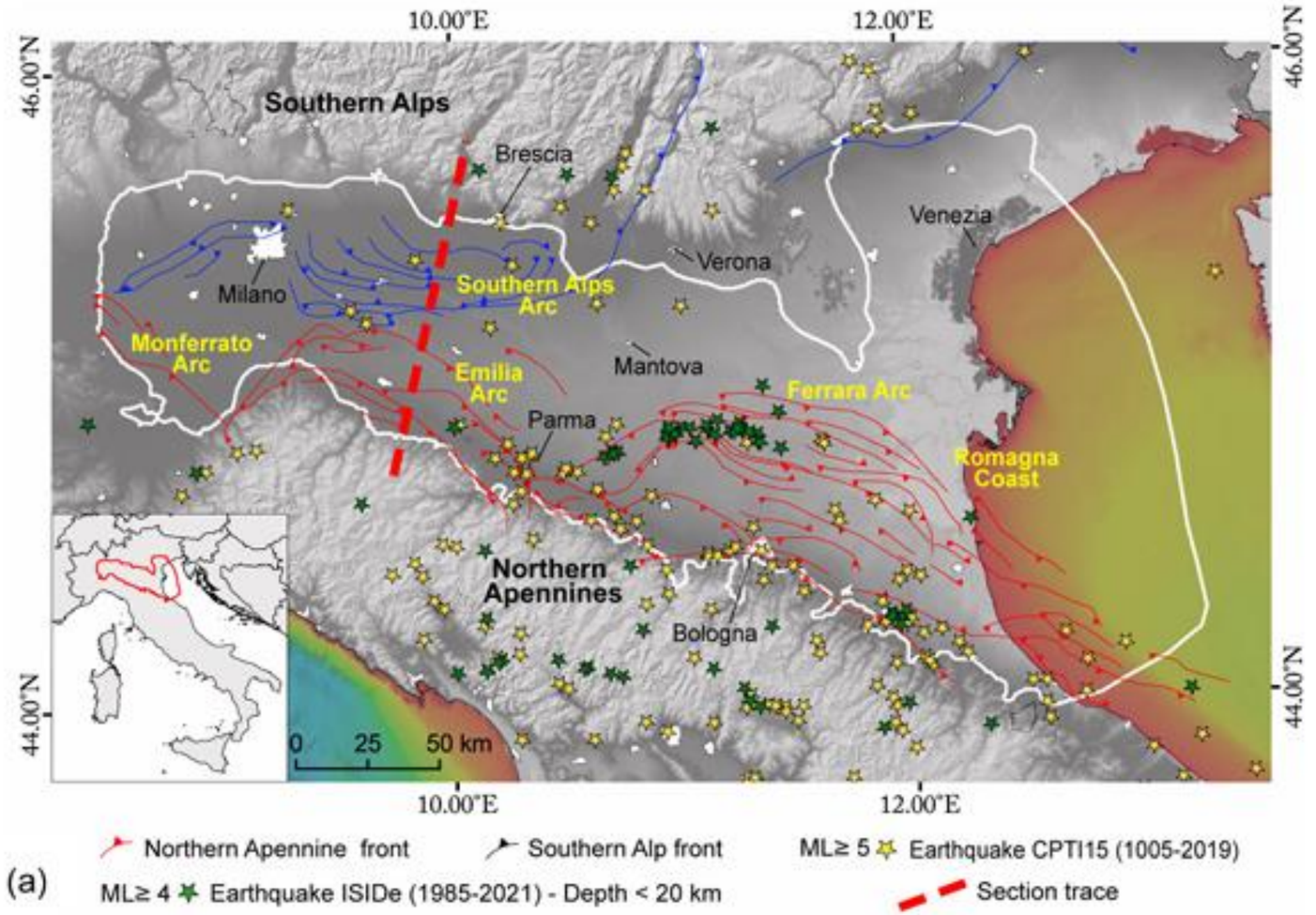
S19: Thermochemical Heterogeneities in the Crust and Upper Mantle from Geophysical Approaches

Conveners: *Magdala Tesauro, Fabio Cammarano, Juan Carlos Afonso, Javier Fullea*

InGEO: Innovation in geothermal resources and reserves potential assessment for the decarbonization of power/thermal sectors

- Advancing geothermal energy development in Italy
- Aims and benefits of InGEO Project
- Thermal anomaly in Romagna and Ferrara folds, Eastern Po Plain



Livani et al. (2023)