Electric Fields Estimation from the Solar Storm of May 2024 Using an Updated Lithospheric Resistivity Model of the Iberian Peninsula

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Outline

- Overview of the May 2024 solar storm and its significance.
- Electrical Resistivity Model of the Iberian Lithosphere (ERMIL).

New MT data acquisition to refine the previous model.

- Hazard Map of Electric Fields induced in Iberia During the Storm.

Steps and methodology used to generate the hazard map for induced electric fields during the storm.

- Identifying the Most Vulnerable Zones in Iberia

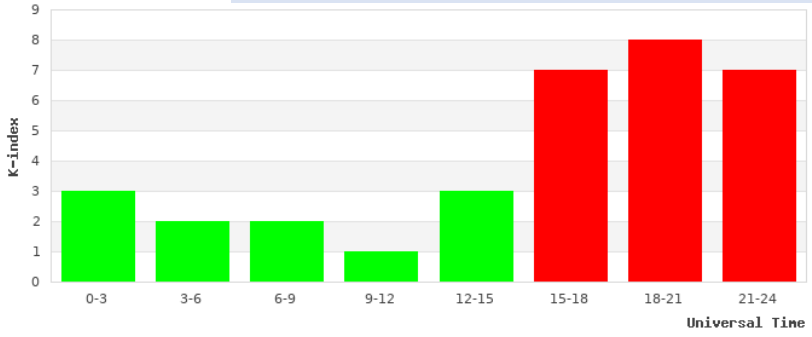
Analysis of the areas at the greatest risk and why these zones are particularly susceptible during geomagnetic events.

Solar storm May 2024

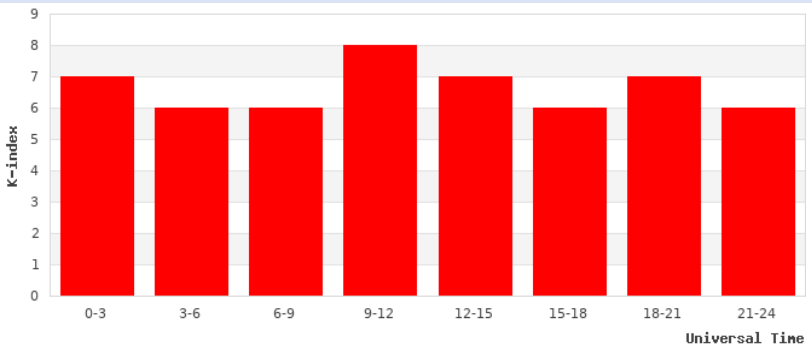
- According to NOAA geomagnetic scale, this storm has been classified as G5 (extreme).

Northern lights visible in the A: Catalonia (Lat~ 41 N) and B: Canary Islands (Lat~ 28 N). Spain

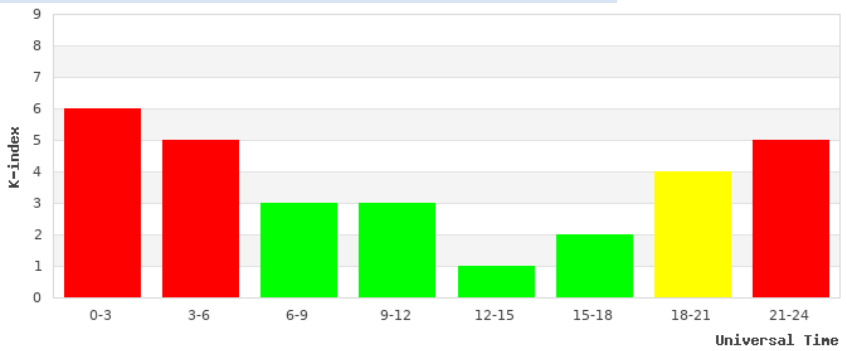
K index preliminary values



10/05/2024



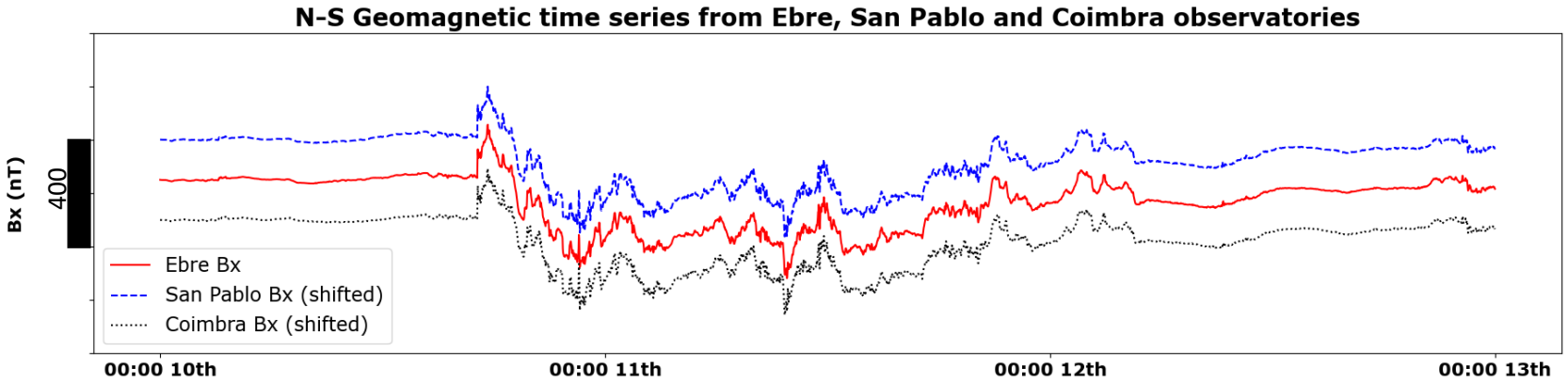
11/05/2024

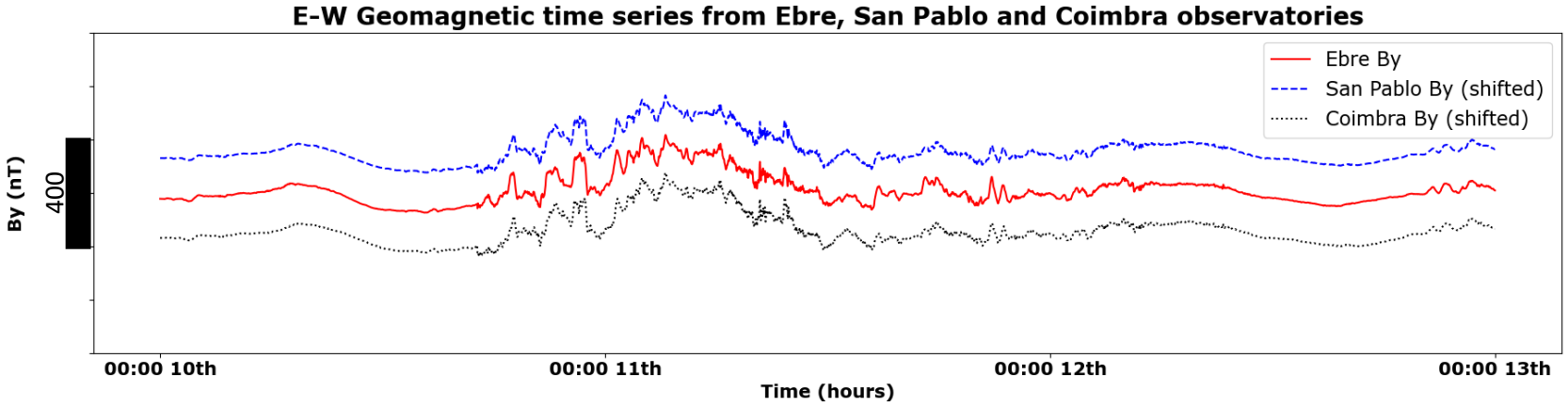


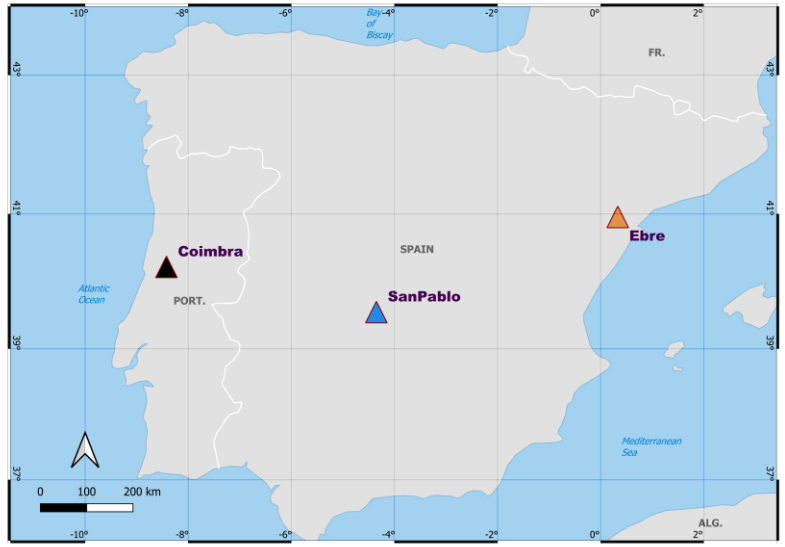
12/05/2024

Credit: Ebre observatory website

Geomagnetic data from three observatories in Iberia



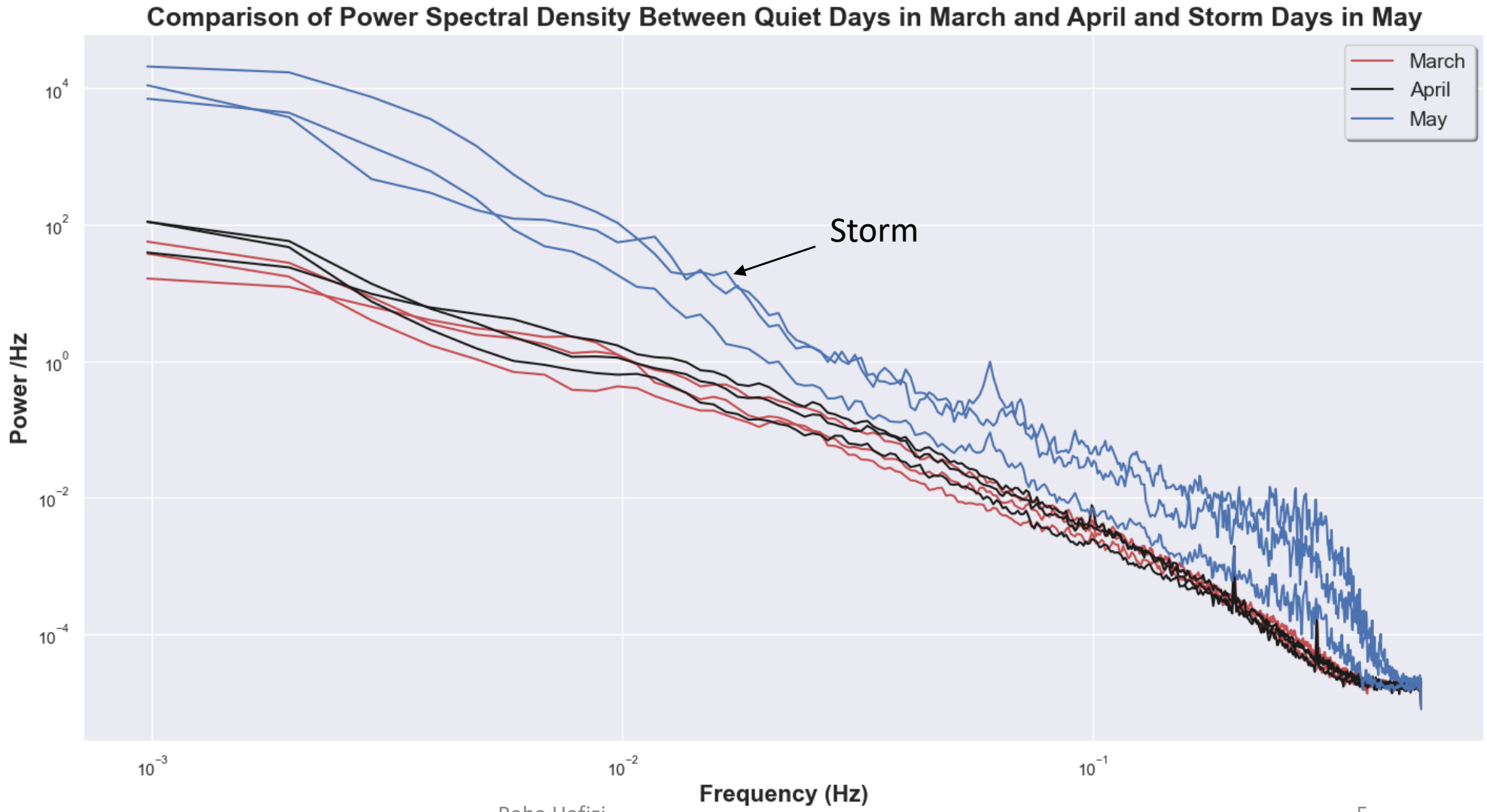




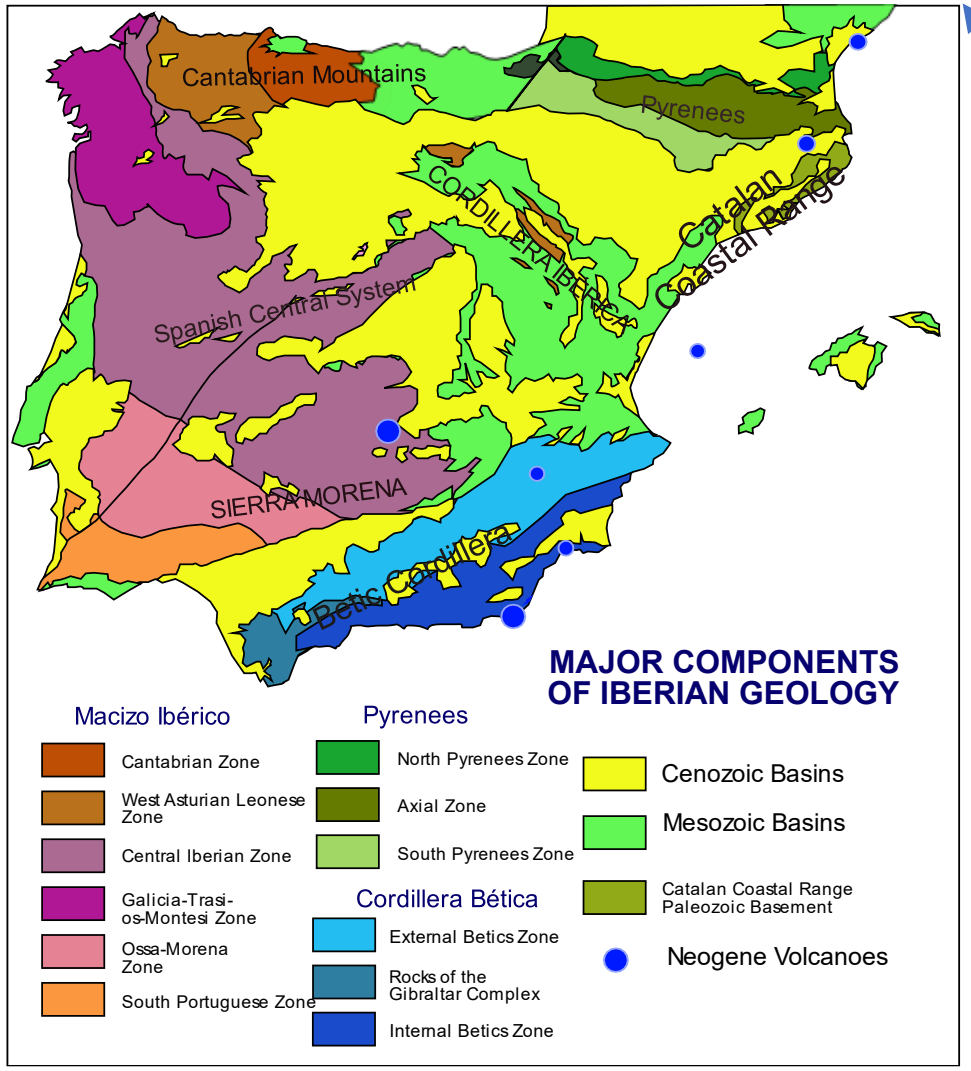
- Ebre obs., intermagnet
- 1 minute data sampling
- Detrended data

Power Spectral Density (PSD) of geomagnetic fields

- The geomagnetic data is from Ebre Observatory
- 1 second sampling data (preliminary)
- 10-12th of March and April *(quiet days)*
  10-12th of May *(storm days)*



Study area: Iberian Peninsula

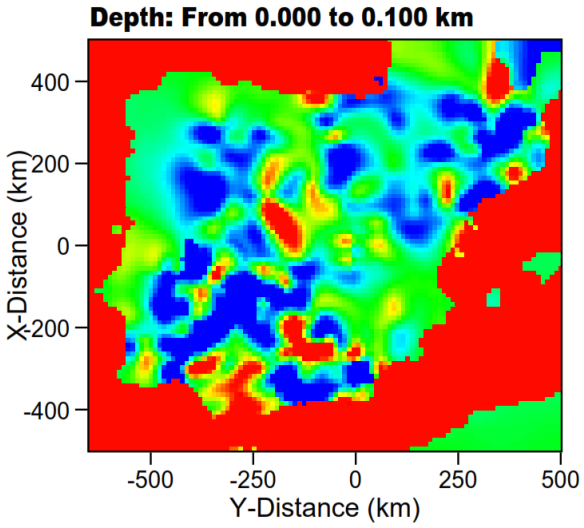


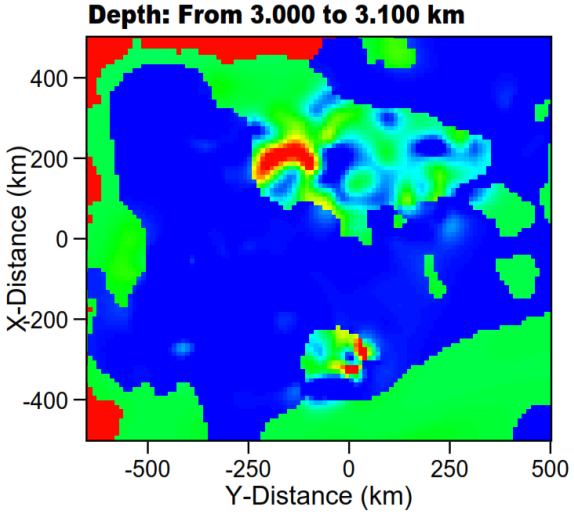
Credit: PePeEfe, translated by Graeme Bartlett and Joutbis – derivative of File:Geological units of the Iberian Peninsula ES.svg changing Spanish names to English

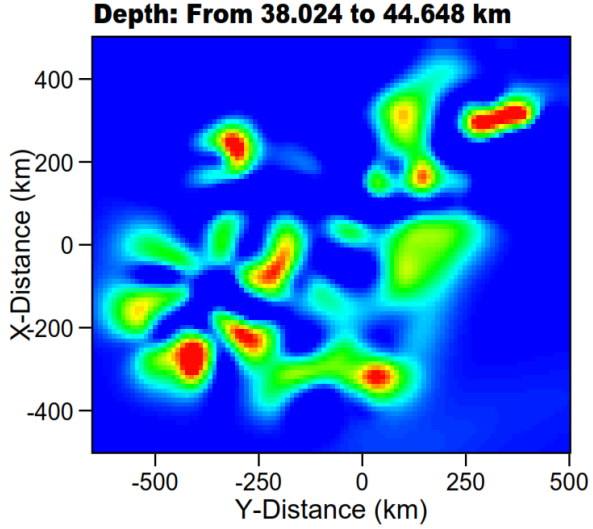
Electrical Resistivity Model of the Iberian Lithosphere (ERMIL)

- 112 MT sites
- ModEM

Map developed by QGIS

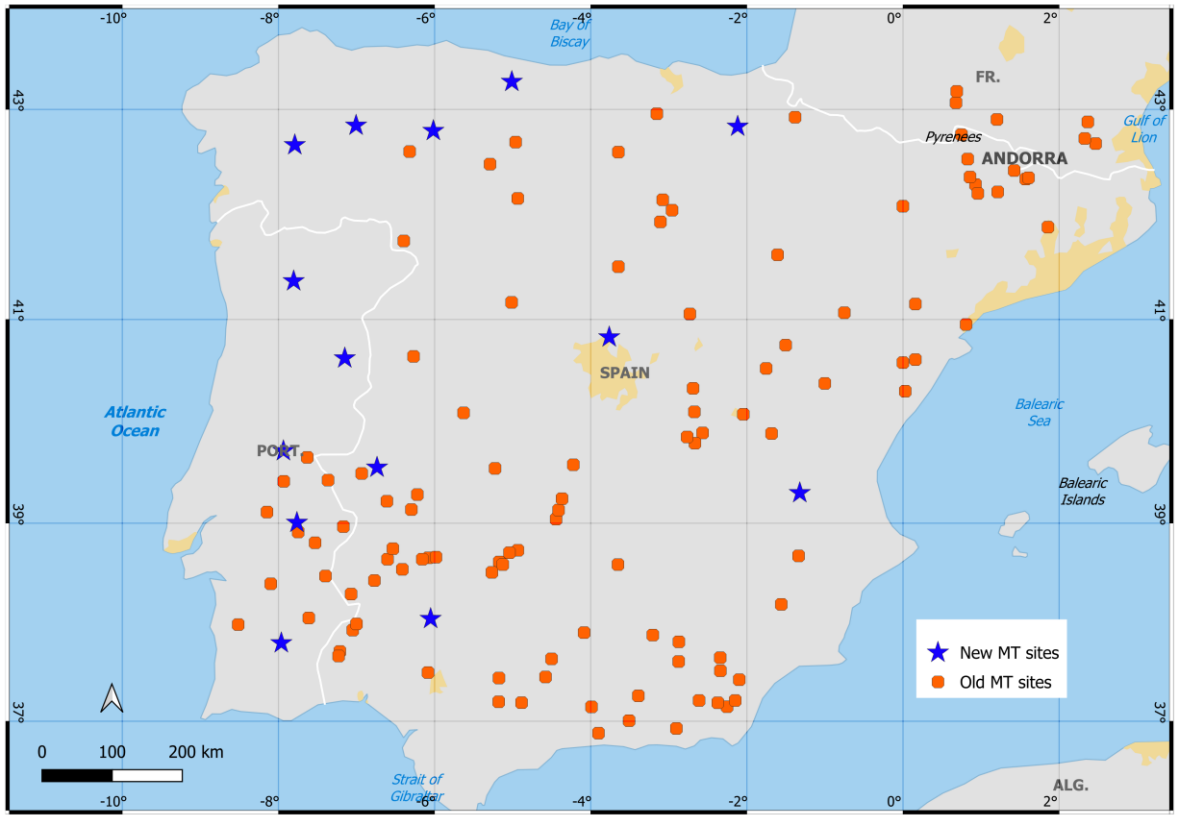






New data acquisition

- Long period MT data, recording time > 10 days
- Different Lemi instrument
- To refine the model and fill the gaps



Raw Data from 14 sites

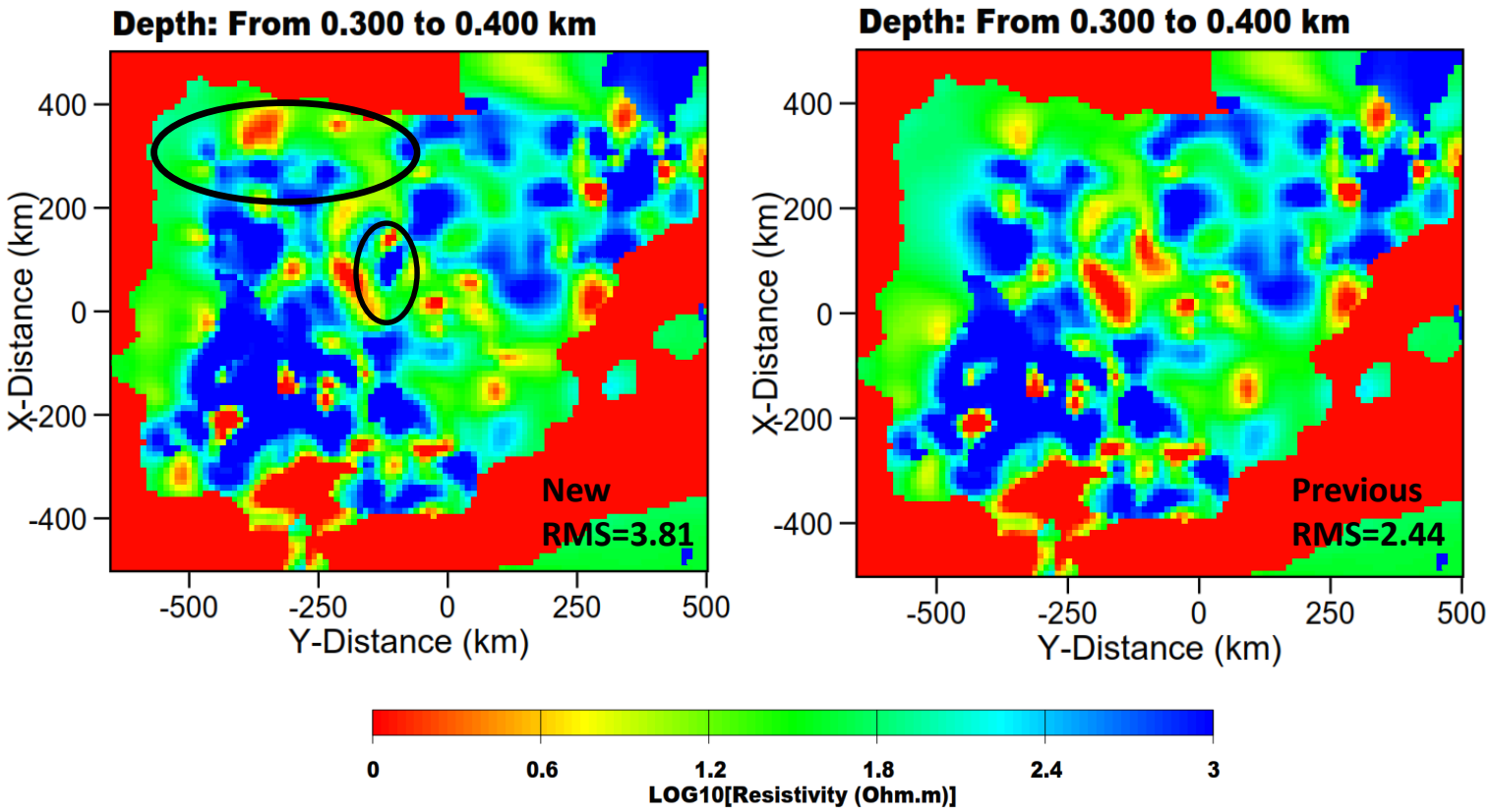
↓

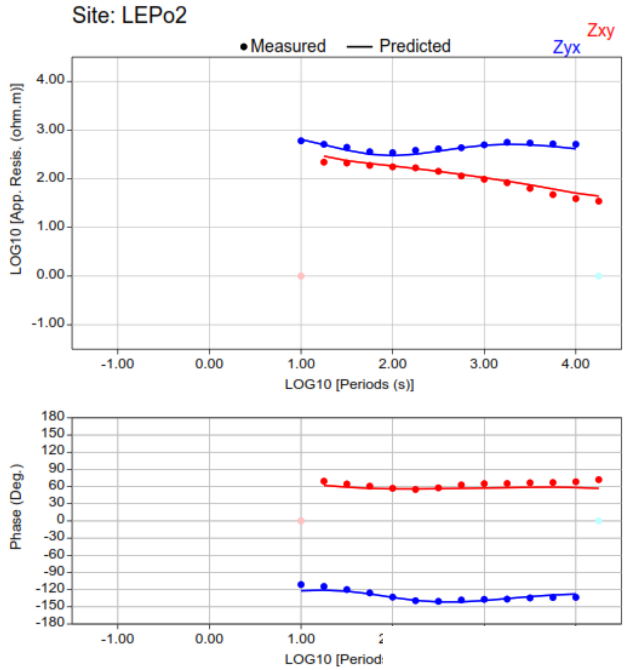
Different processing programs

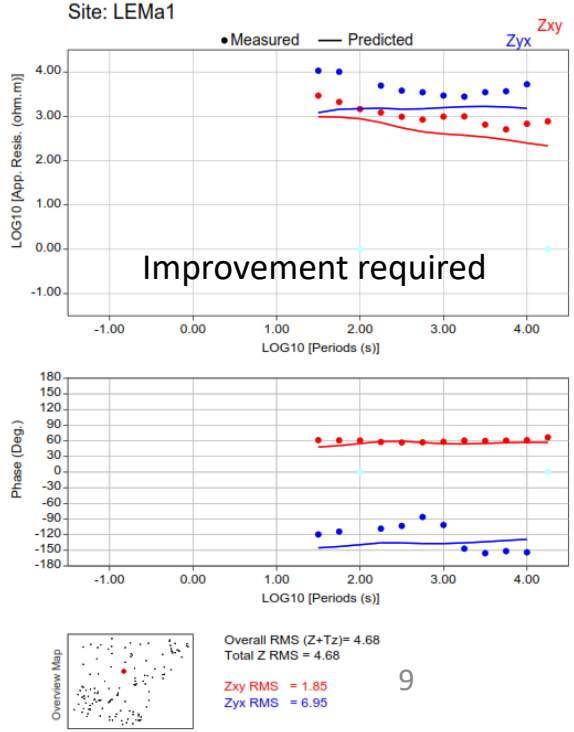
↓

Edi data ready for the inversion

Inversion



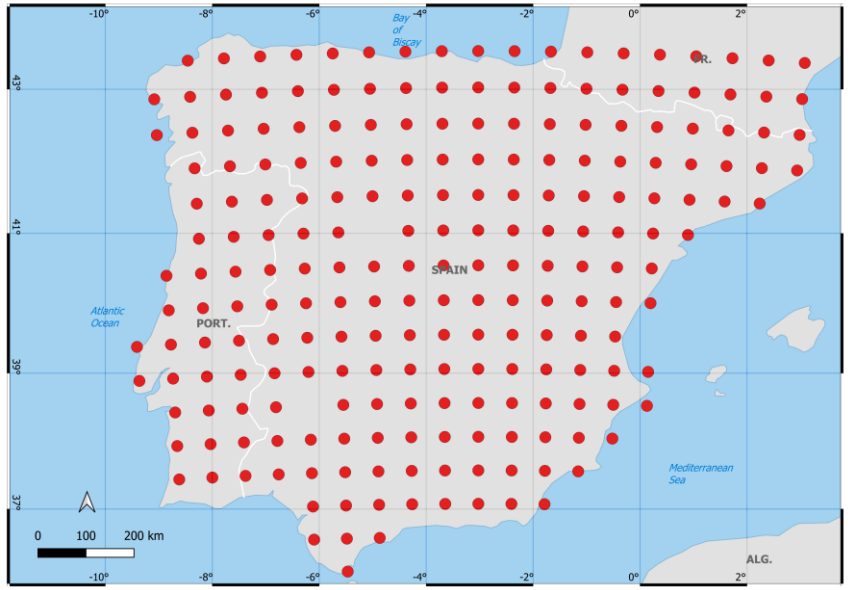




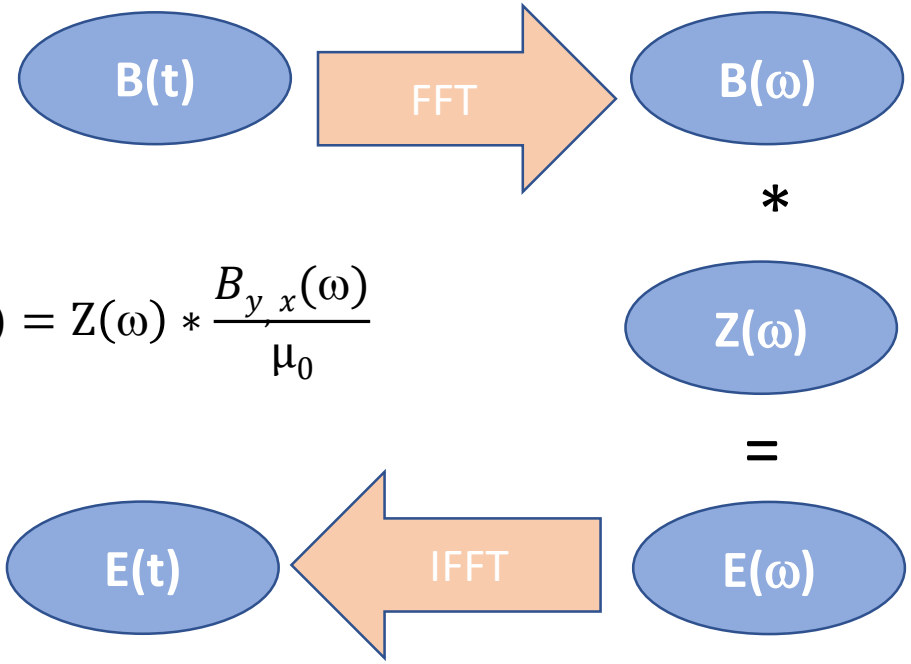
The error floors chosen: 15% for Zxx & Zyy
10% for Zxy & Zyx

Modeling induced electric fields

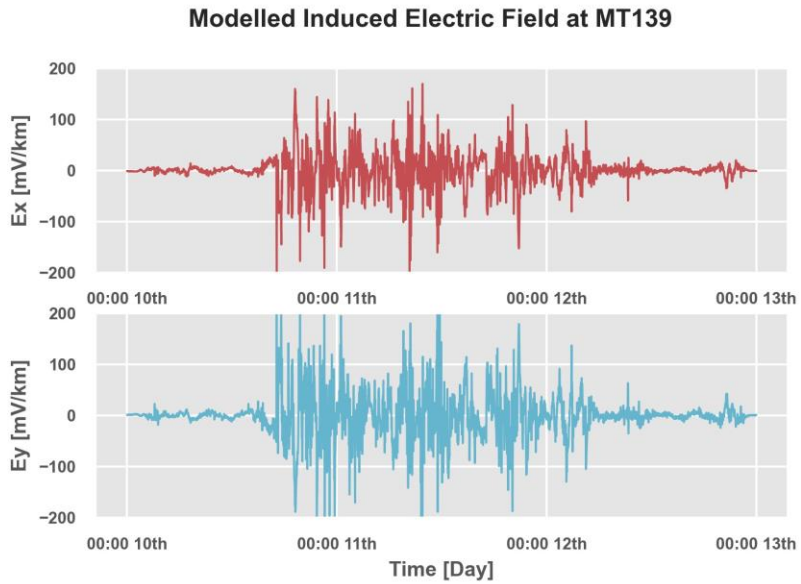
- Impedances (Z) by applying a forward modeling on the latest version of ERMIL
- Electric fields modeling by Campanyà et al 2019 code
- B is extrapolated by Spherical Elementary Currents Systems (SECS) method



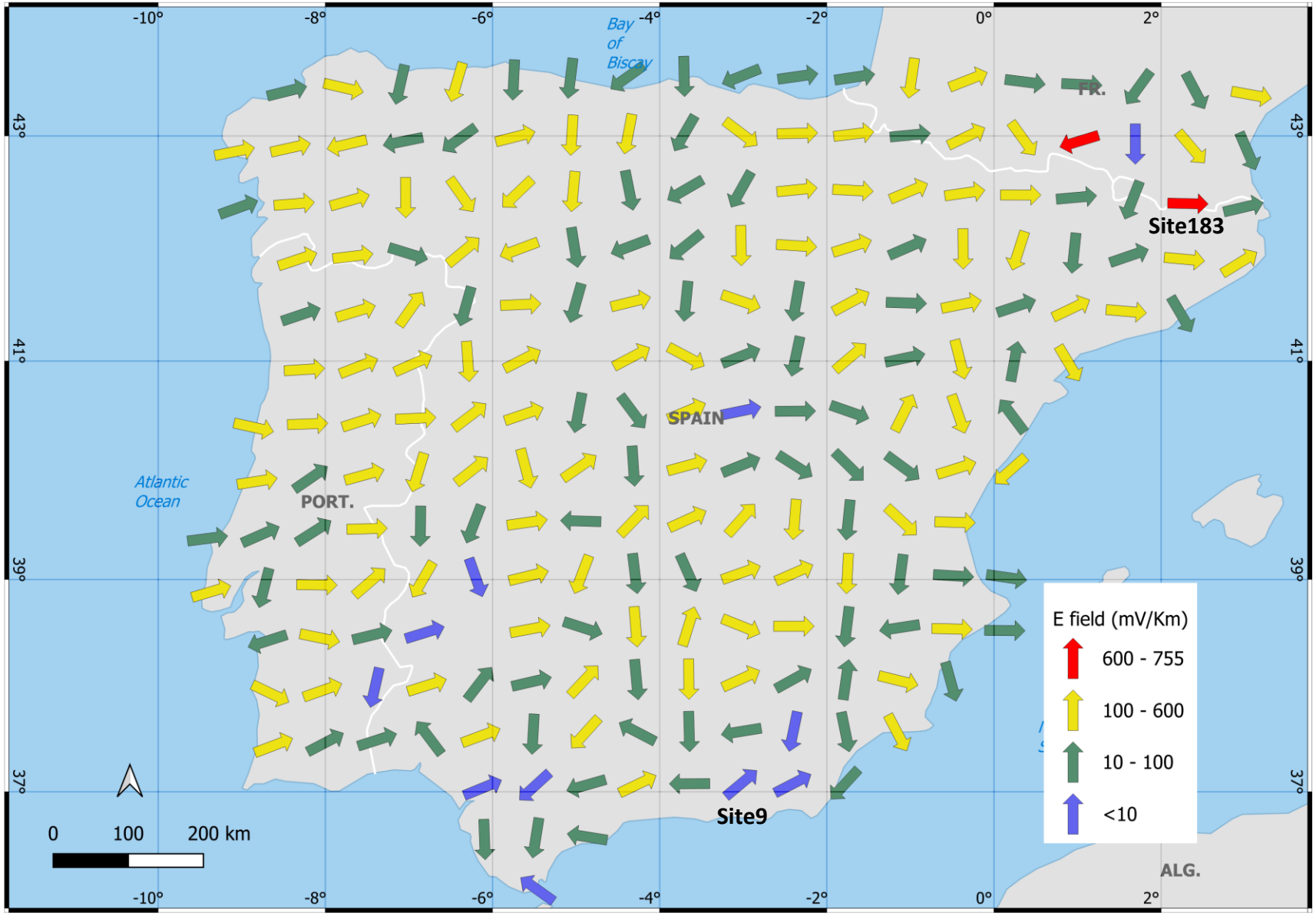
Regular grid of 222 sites at a distance of 55 km in x and Y directions



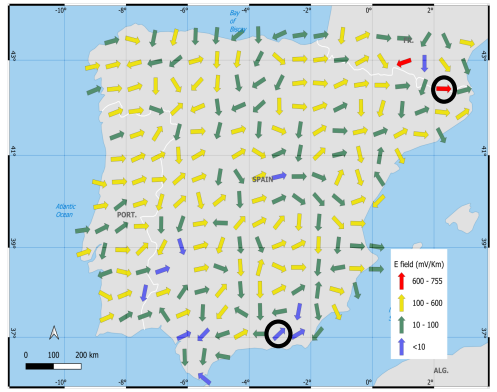
$$E_{x,y}(\omega) = \mathrm{Z}(\omega) * \frac{B_{y,x}(\omega)}{\mu_0}$$



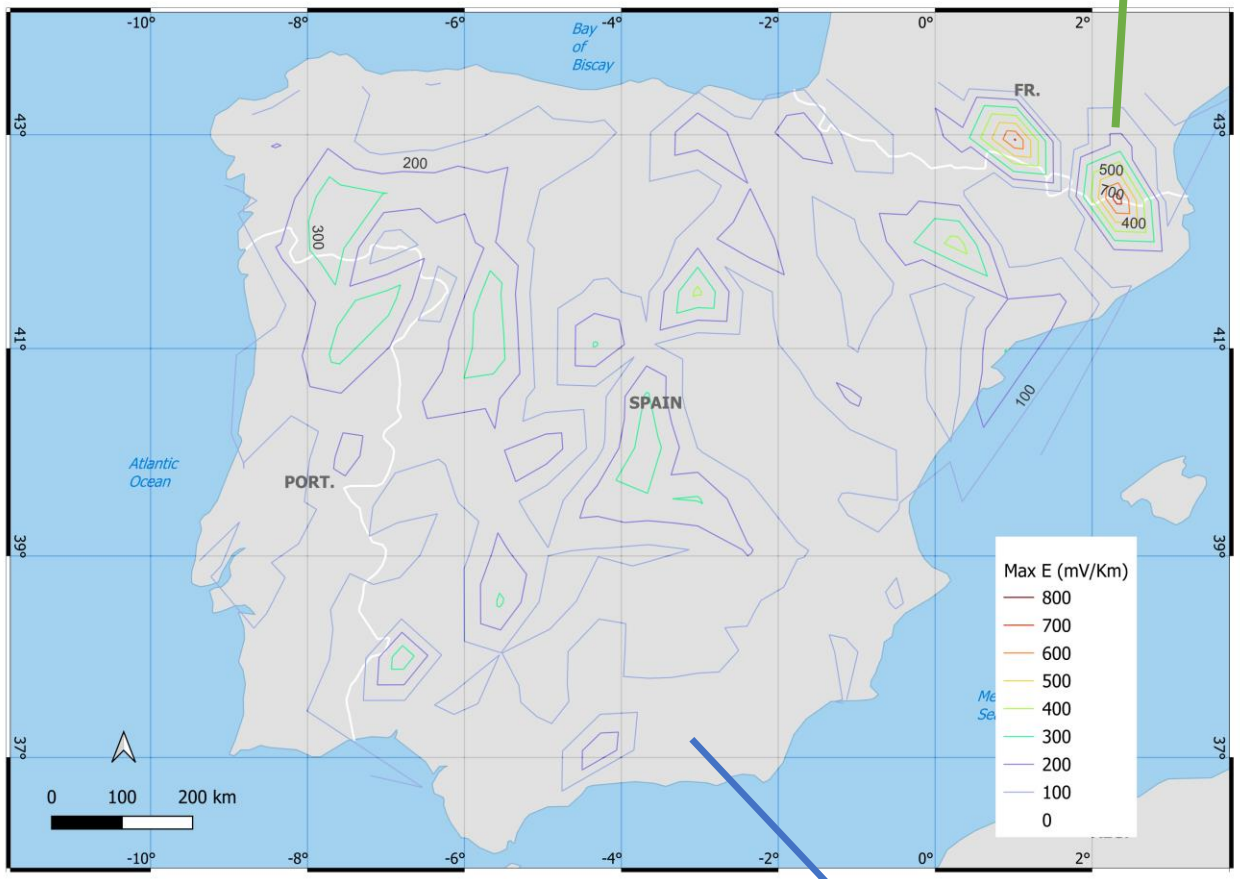
Map showing the maximum electric field in each sites

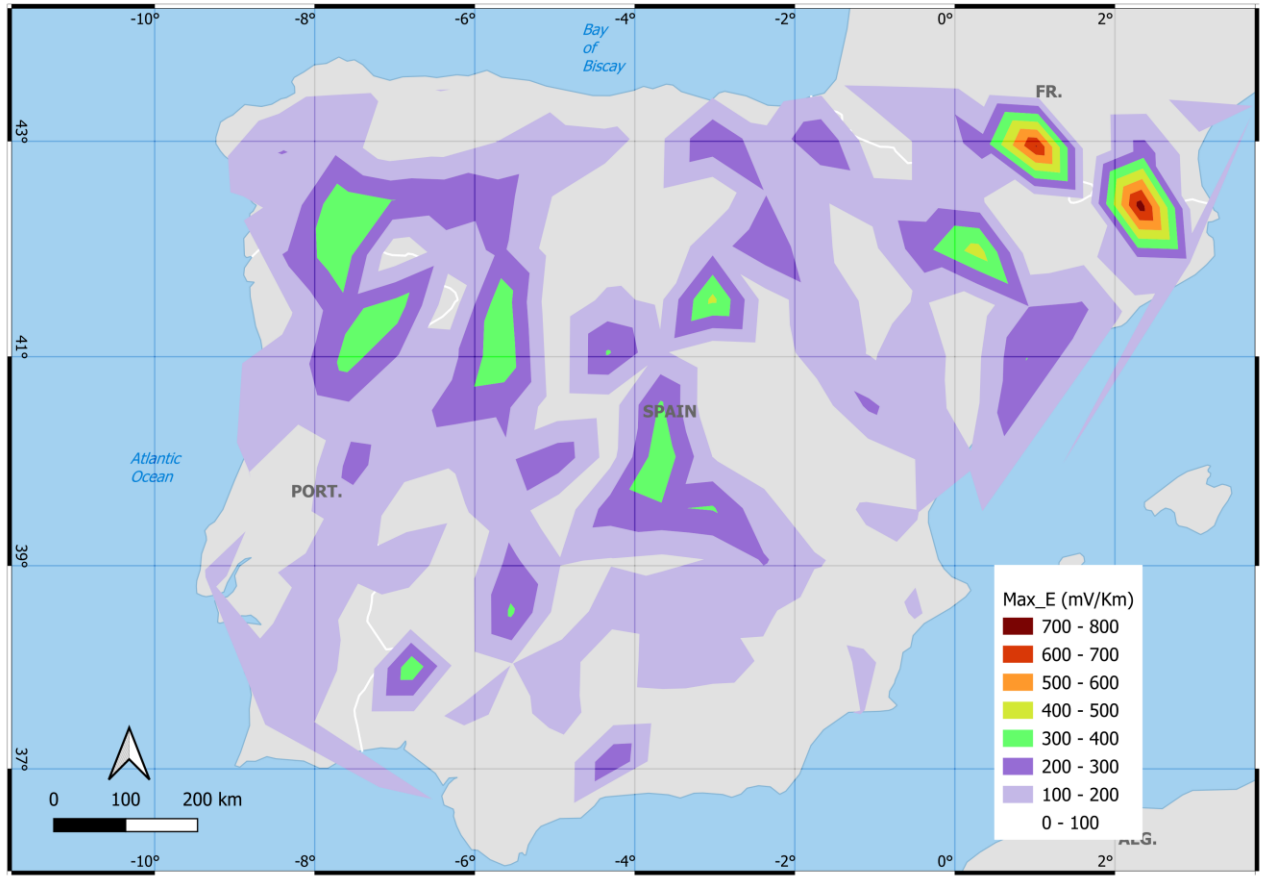


Contour maps of maximum electric fields



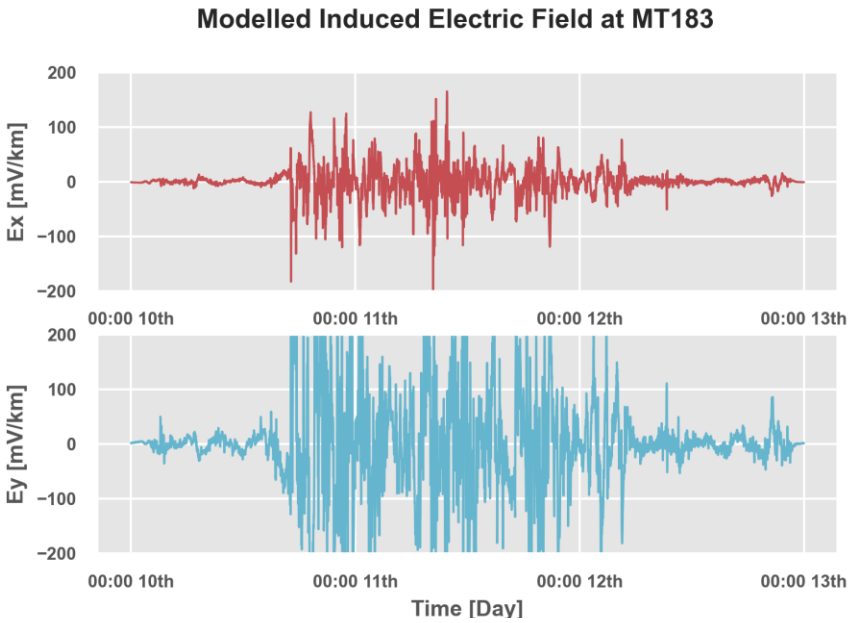
Site 183

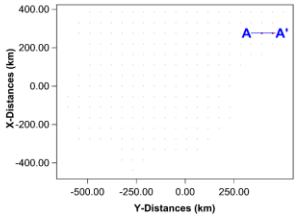




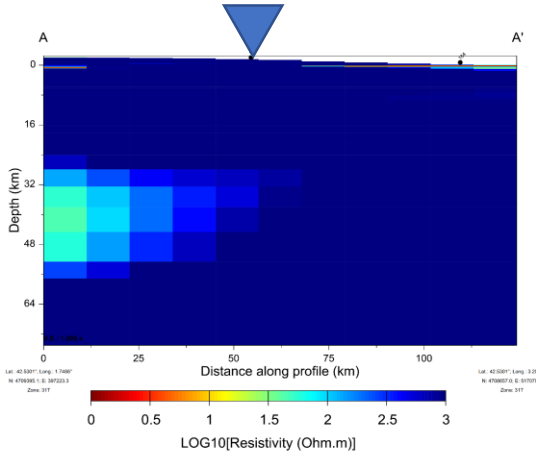
Site 9

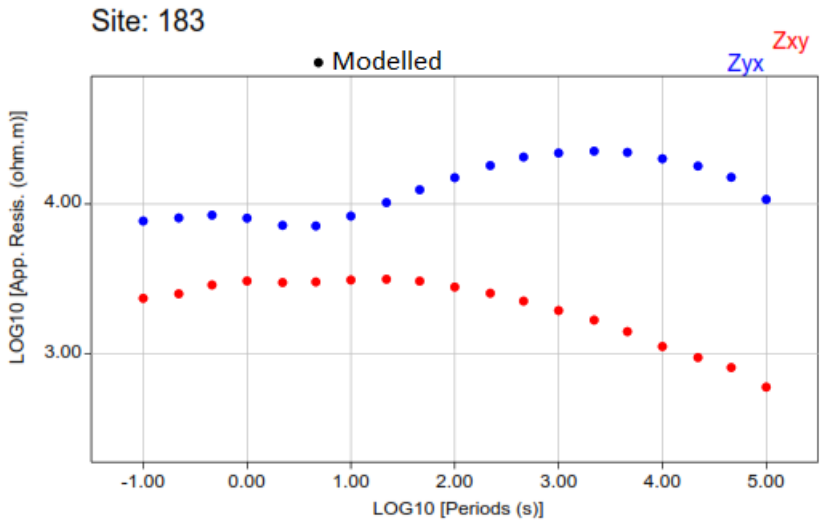
High E value in site 183

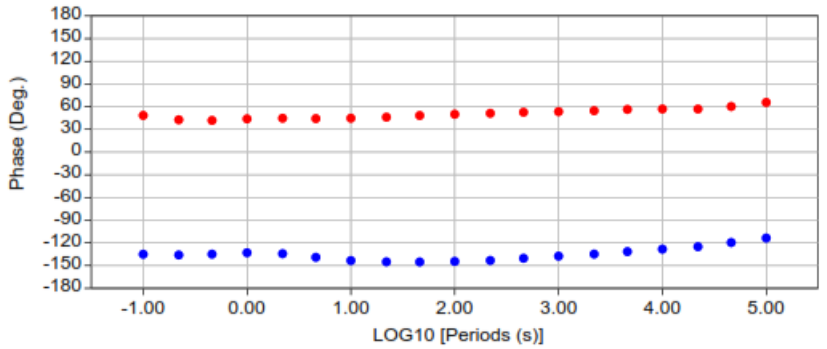


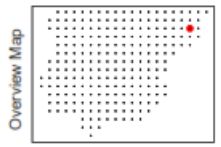


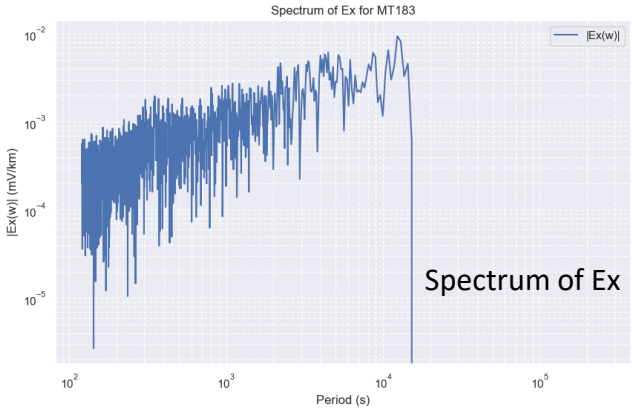
Site 183

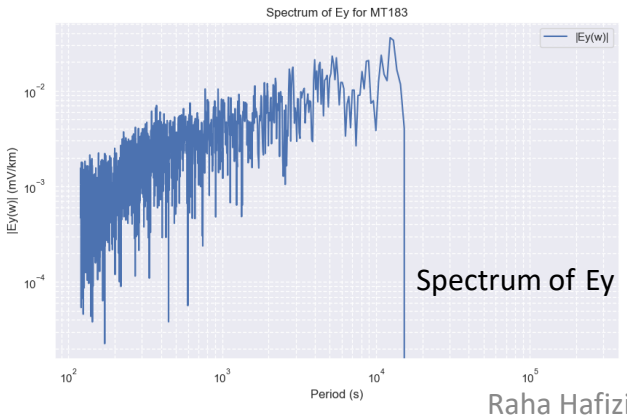






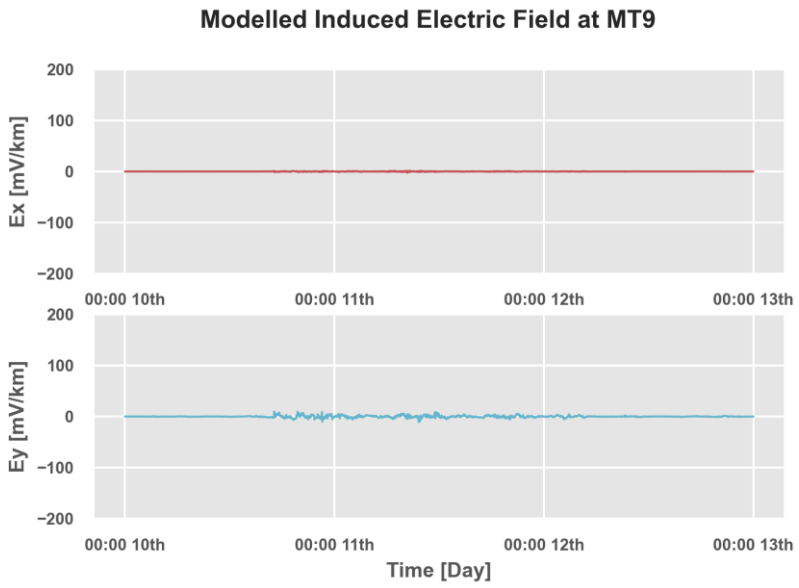


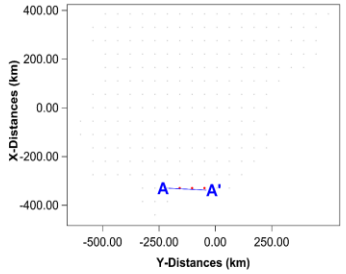


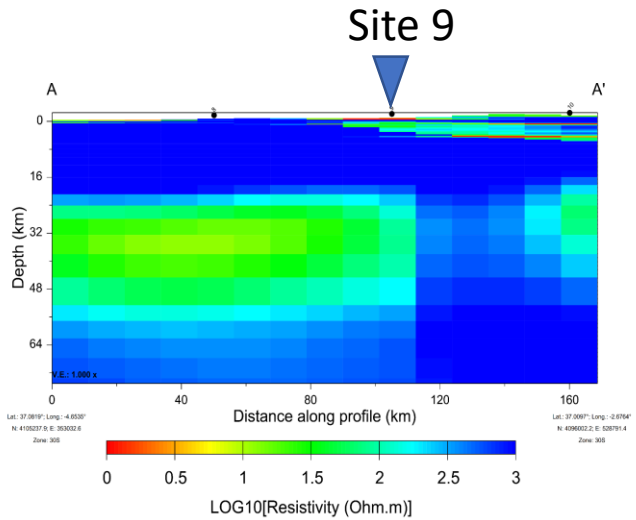


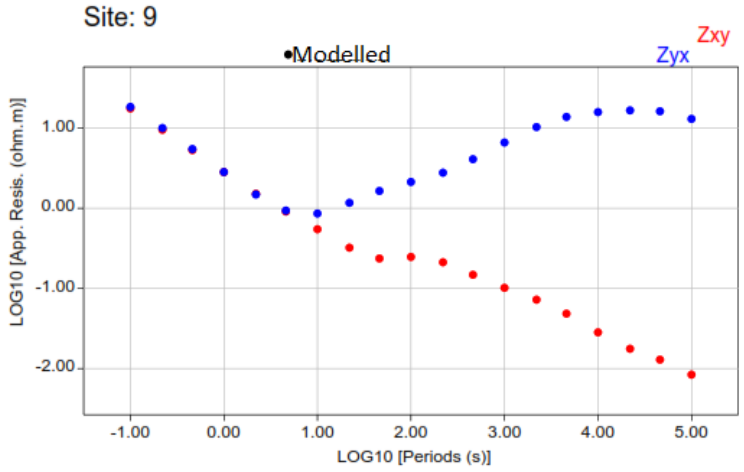
E magnitude range: 0.035 – 754.8 mV/Km

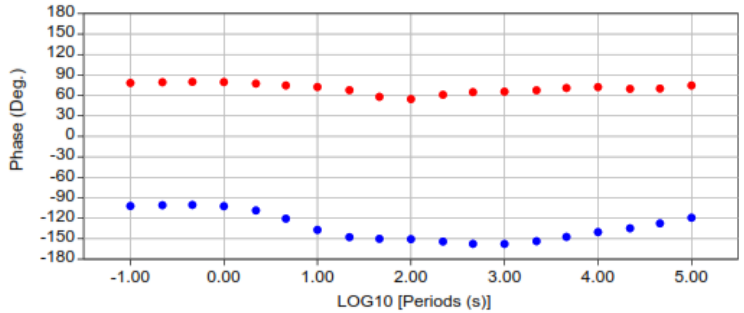
Low E value in site 9

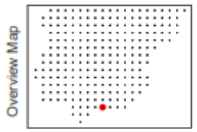


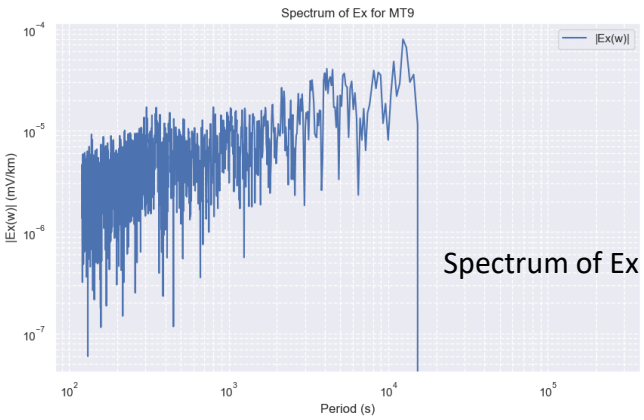


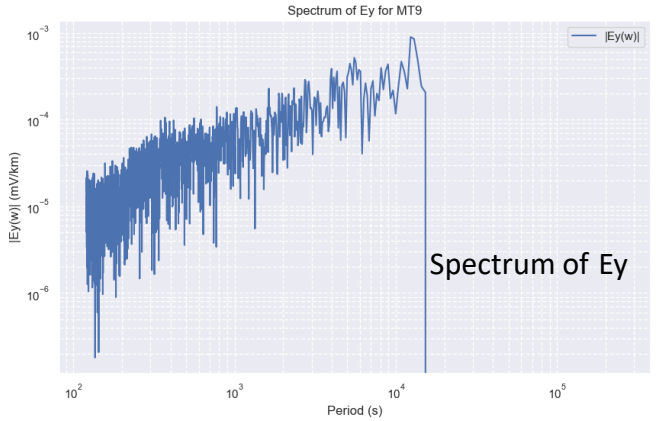








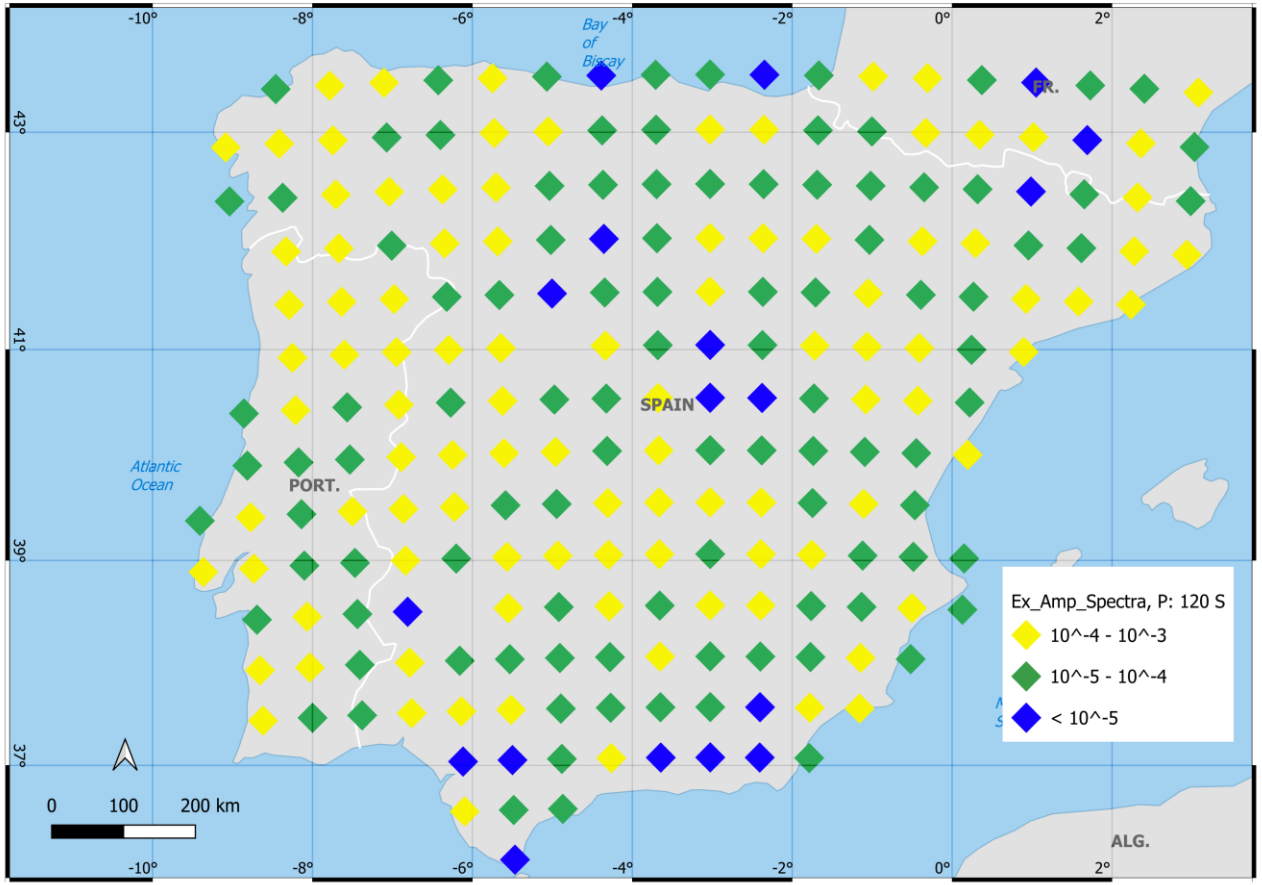




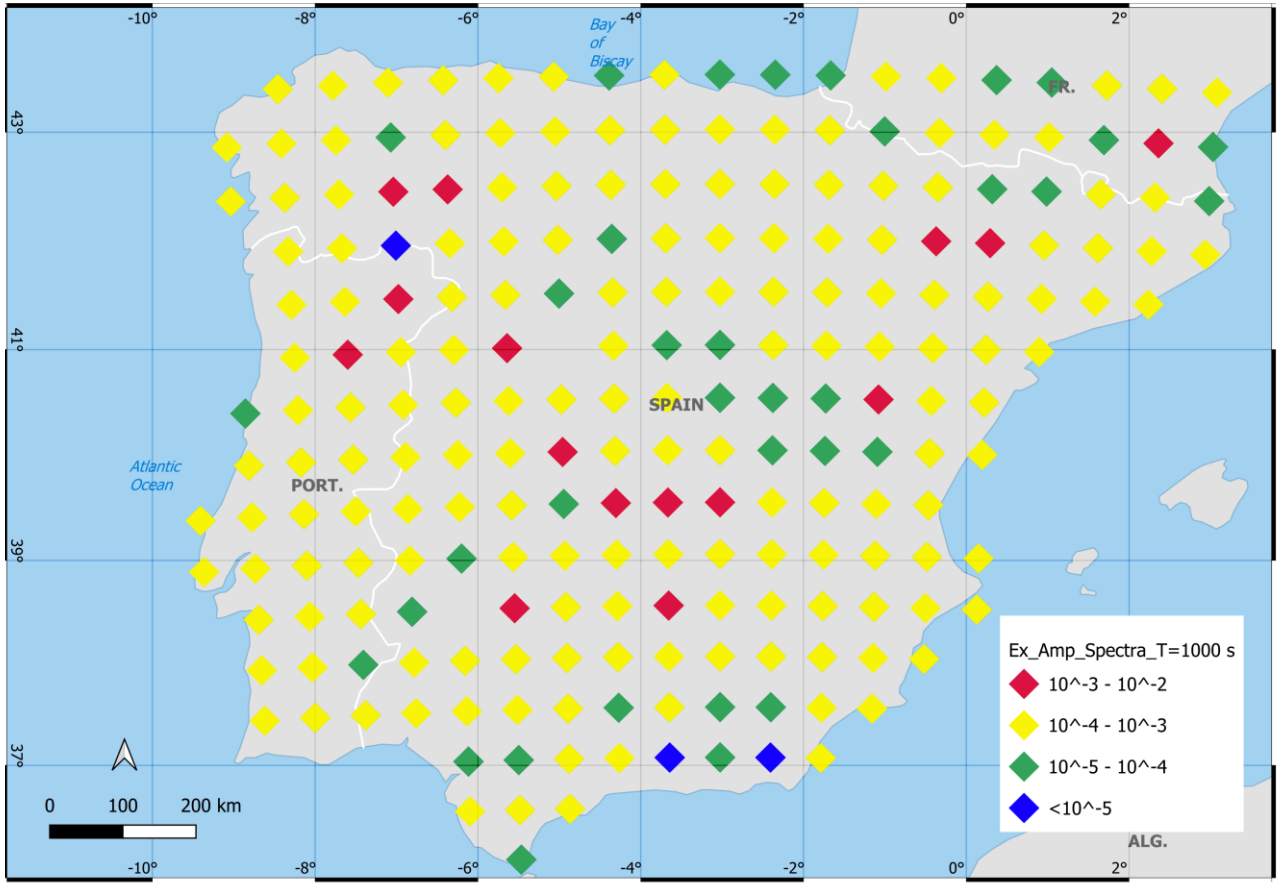
E magnitude range: 0.0026 - 10.75 mV/Km

Amplitude spectra of Ex for two periods

Ex spectra T=120 s

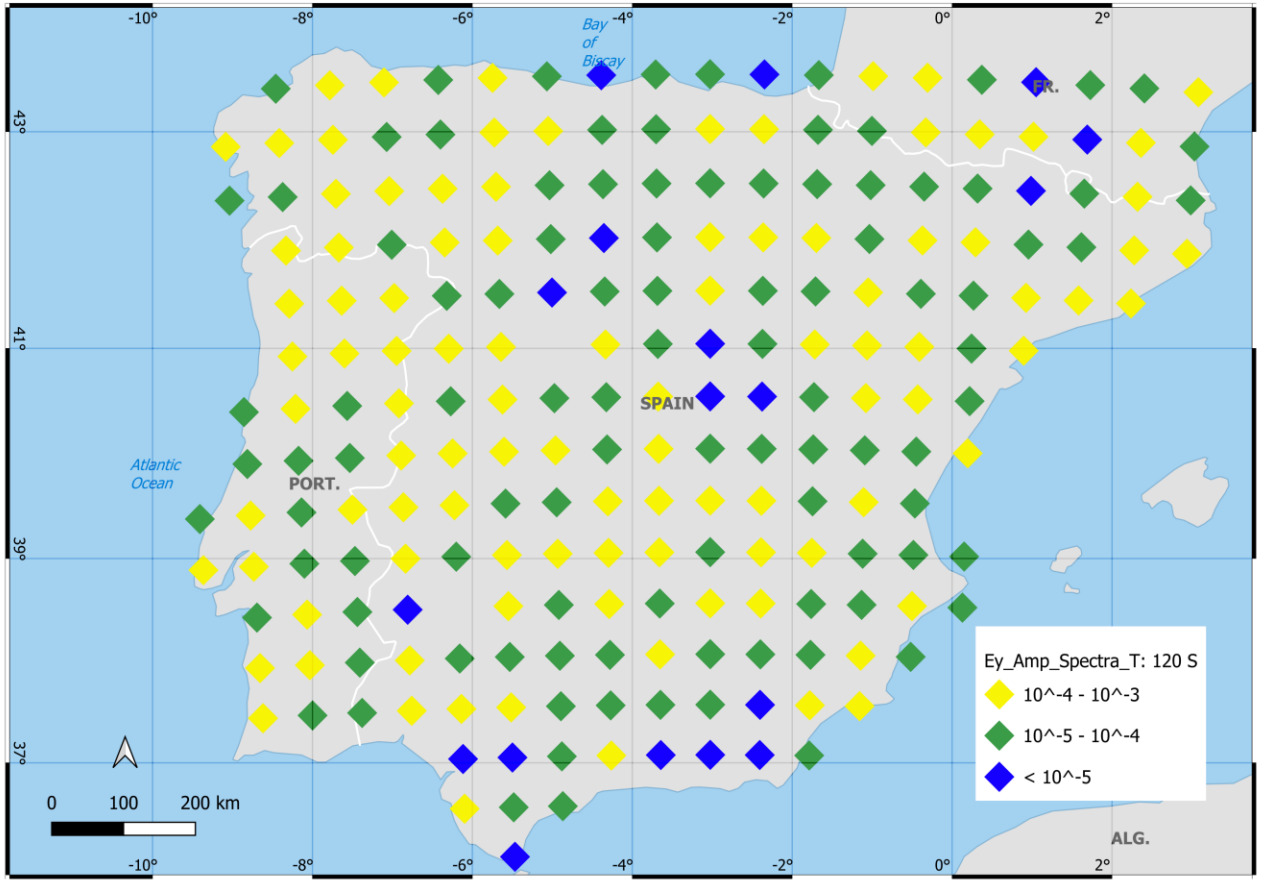


Ex spectra T=1000 s

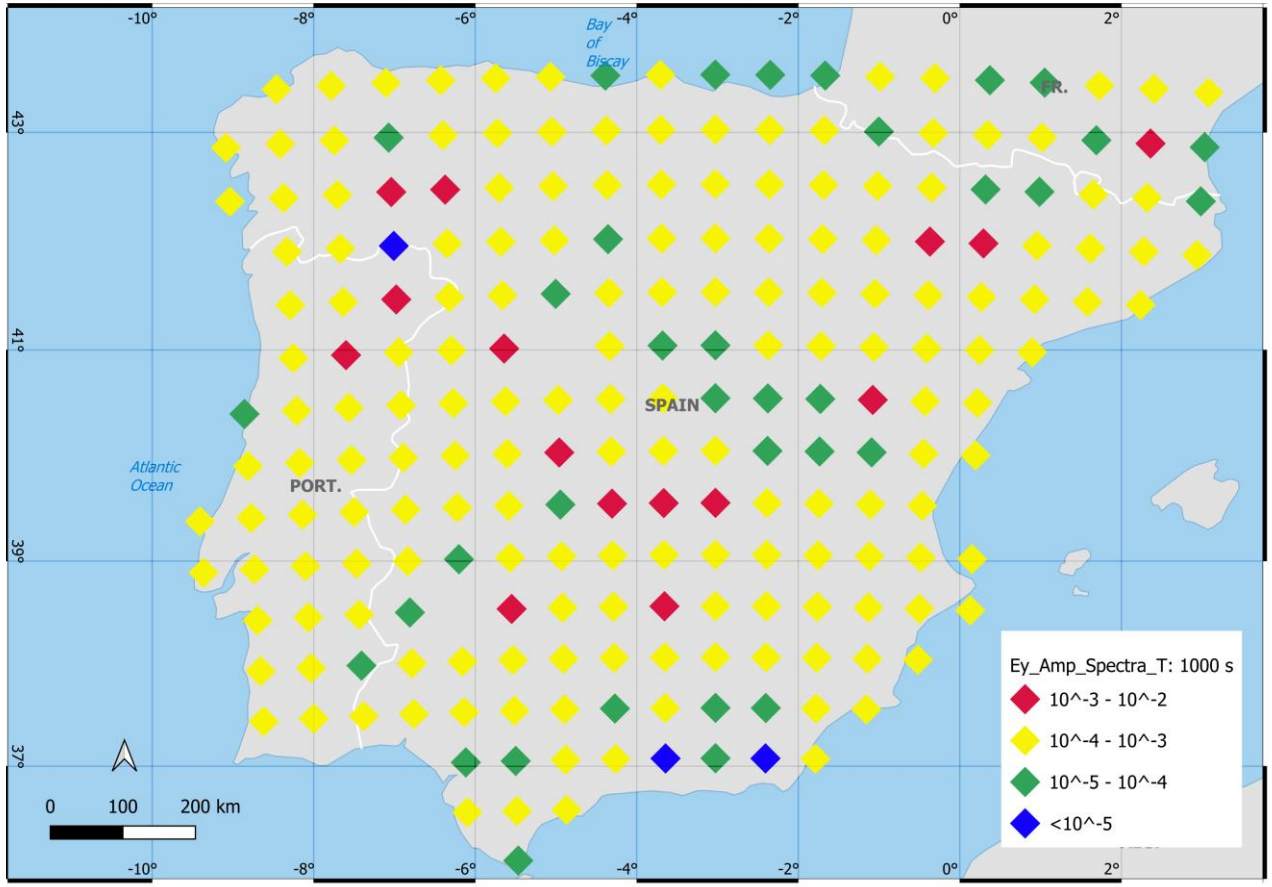


Amplitude spectra of Ey for two periods

Ey spectra T=120 s



Ey spectra T=1000 s



Conclusion

- New MT data improves lithospheric resistivity distribution accuracy in the model.
- Maximum induced electric fields during May 2024 storm reaches to the value 755 mV/km.
- Regionally the Pyrenees area in NE of Peninsula shows higher values of induced electric fields due to its high-resistivity structures.
- The modelled electric fields can be used in calculation of GICs in Iberia.

Acknowledgment

- This work is part of the IBERGIC CAST project, funded by the Ministry of Science and Innovation of Spain. (PID2020-113135RB-C31)
- I am also grateful for the financial support from the Generalitat de Catalunya during my PhD career.
- I extend my gratitude to Gary Egbert and co-authors for generously sharing the ModEM code, and to Naser Meqbel for the 3D-Grid.
- I thank the Ebre, San Pablo, and Coimbra observatories for sharing their data with me.
- Lastly, I thank the EMIW2024 workshop for providing the financial support.