Testing different metrics for 3D conductivity model comparison

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ABSTRACT

Background

Geomagnetically Induced Currents (GICs) result from rapid fluctuations in the Earth's geomagnetic field, driven by intense solar wind activity. These induced currents flow within the Earth's subsurface and along conductive human-made infrastructures (e.g.: transport power lines). Calculating GICs is crucial today due to their potential for catastrophic impacts, including blackouts. Accuracy demands understanding factors like geomagnetic variations, Earth's conductivity, and power grid parameters.

Question

Different conductivity models, with varying levels of spatial resolution, have an impact on the GIC simulations. Can we define metrics to best characterize those differences in the conductivity models through the induced electric field (E-filed)?

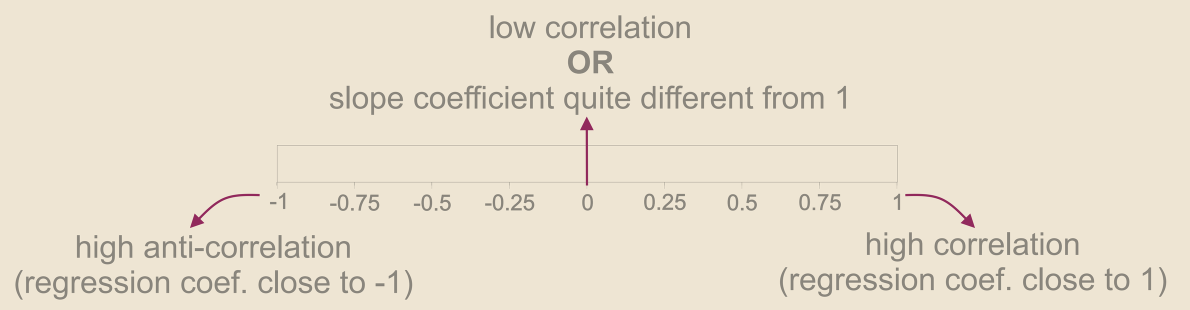
Research Design and Methods

3D Conductivity model + Geomagnetic Storm → Induced Electric Field (Uniform grid)

Compare conductivity models with different resolution

Correlation-Regression Ratio (CRR) it's a single normalized coefficient (-1 < CRR < 1) which provides joint information from Pearson correlation (r) and slope regression coefficient (m).

$$CRR = \begin{cases} \frac{r}{|m|}, & \text{if } |m| > 1 \\ r \times |m|, & \text{if } |m| < 1 \end{cases}$$



Conclusions

- CRR, as the Pearson coefficient, is symmetric relative to the two models under consideration.
- Preliminary results of the CRR metric reveal the potential to identify regions with relevant differences between the conductivity models.
- The CRR is the closest parameter to the complement of the relative SD (GIC) difference between the models.

Acknowledgements

- Collaboration with REN (Rede Eletrica Nacional) was most important for the setup of the power network model
- CITEUC is funded by National Funds through FCT - Foundation for Science and Technology (UIDB/00611/2020 and UIDP/00611/2020)

RESULTS

1 Coductivity models

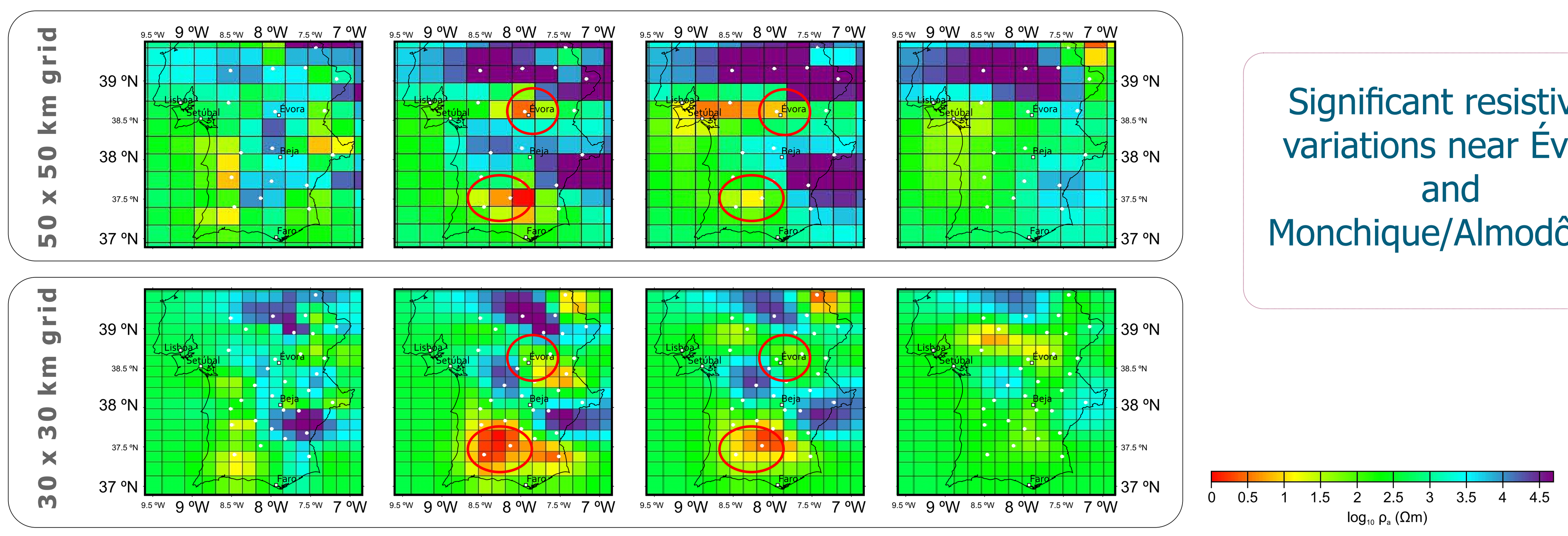


Fig.1: Horizontal slices of resistivity models for the South of Portugal. White dots represent the location of the MT soundings

Significant resistivity variations near Évora and Monchique/Almodôvar.

2 Comparing the Induced Electric Field

(geomagnetic storm 17.03.2015)

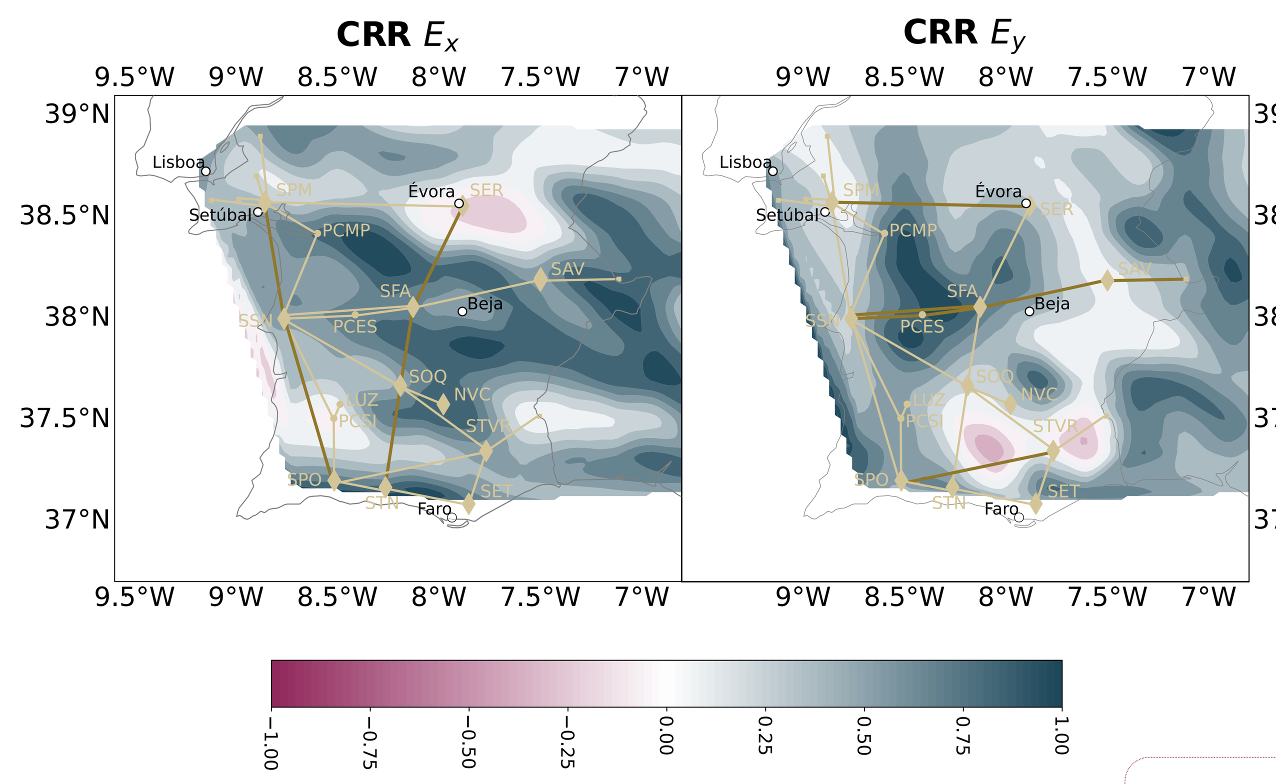


Fig. 2: Comparison of E_x and E_y CRR for the two conductivity models. Golden Symbols and Lines indicate substations and power lines.

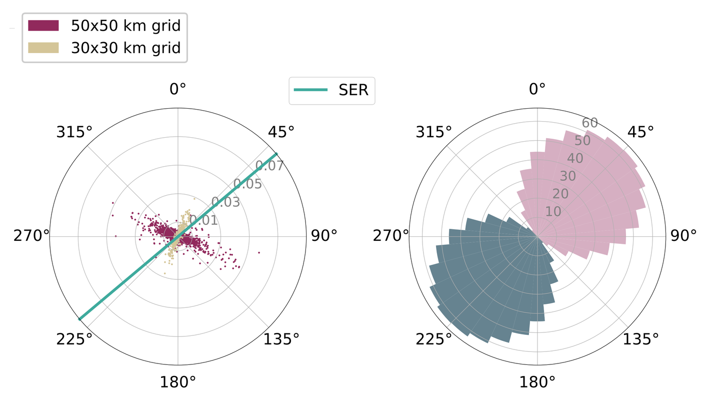


Fig. 3: Left: electric field polar charts for the two conductivity models at substation SER. Darkcyan represents substation SER's Peak GIC orientation or an electric field magnitude of 1V/km; Right: Directional sensitivity of GIC in the substation SER for an electric field magnitde of 1V/km

Areas with negative and close to zero CRR in the E-field, are located in regions with more relevant differences in the conductivity models.

3 GICs Simulations

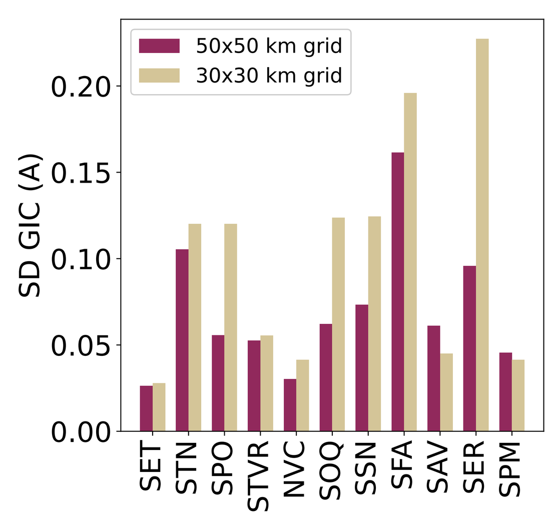


Fig. 4: GIC standard deviation (SD(GIC)) for two conductivity models

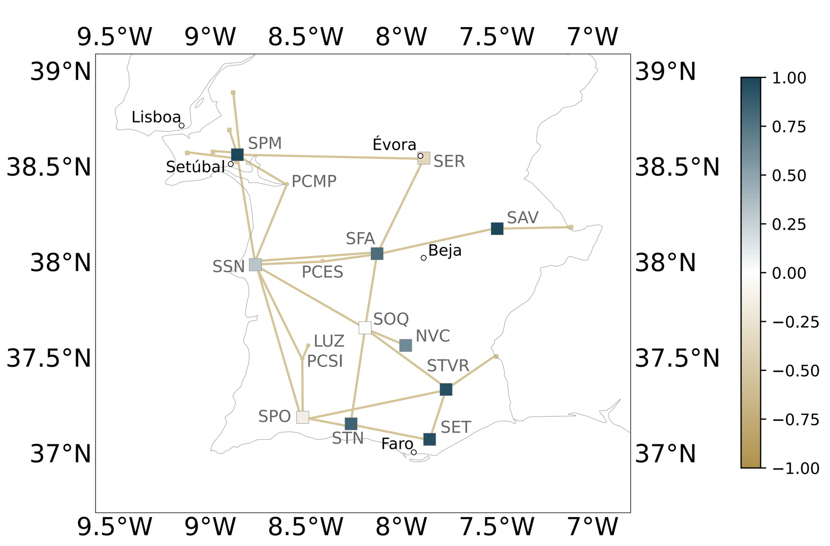


Fig. 5: Complement of the SD(GIC) relative difference between the two conductivity models

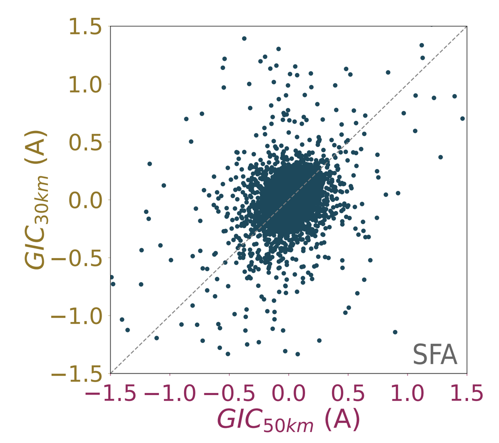


Fig. 6: GIC Scatterplot for the substation SFA. The dispersion is due to the grid's topology. SFA is crossed by N-S line (SFA-SER) where the Ex-field is badly correlated, and an ≈ E-W line (SFA-SAV) where the Ey-field is poorly correlated.

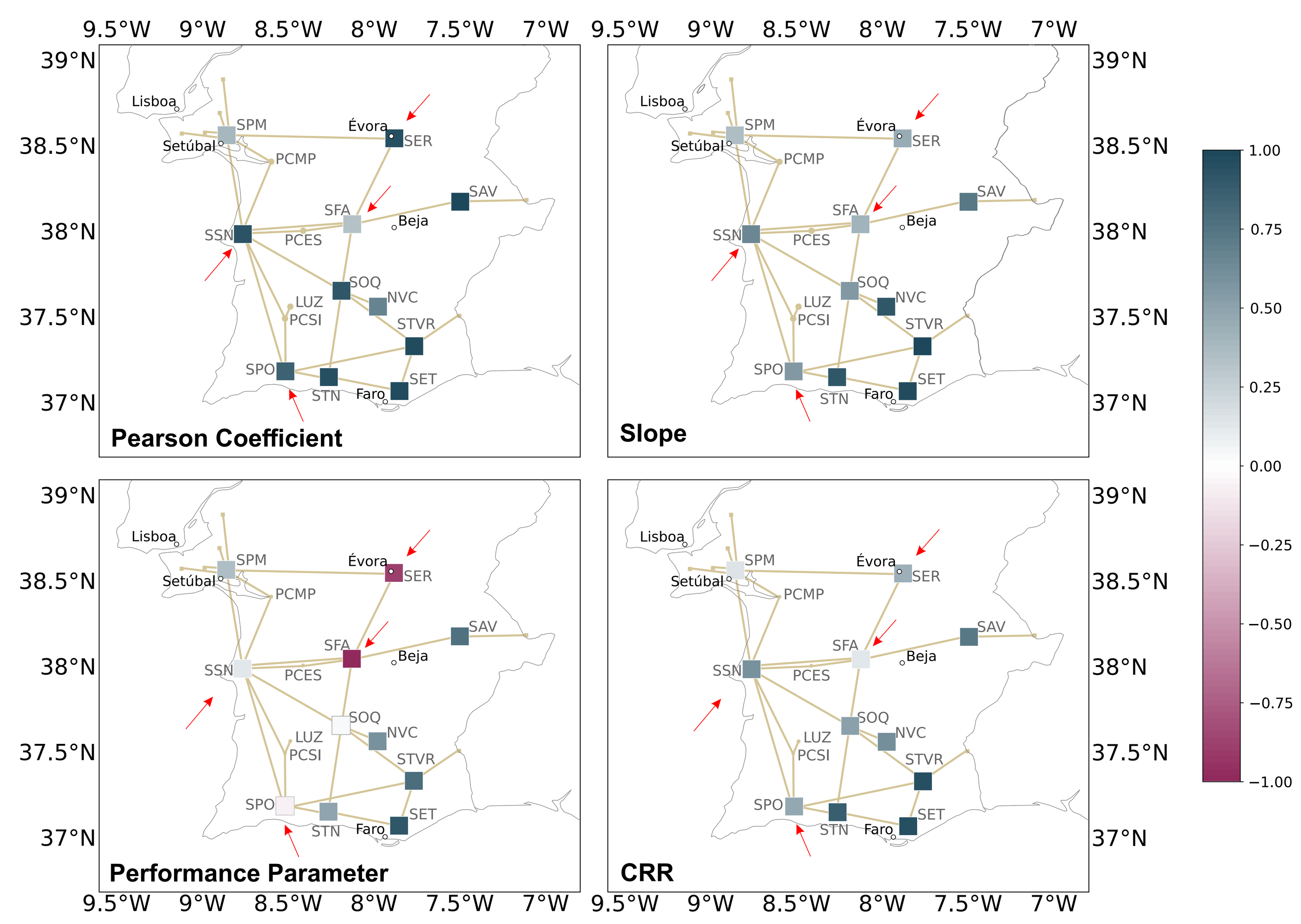


Fig. 7: Comparison four different metrics to identify major GIC differences due to two different conductivity models

- A CRR parameter < 0 always indicates an anti-correlation.
- A CRR value around 0 may be due to either a low correlation degree or a slope coefficient very different from 1.
- A CRR value close to 1 indicates good agreement between the two models.
- CRR compares well with the complement of the relative SD(GIC) difference.

European Space Weather Week 2023
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