Congresso SGI-SIMP
«Geology for a sustainable management of our Planet»

# Geoelectromagnetic map for central Italy: preliminary results of the MARGE project

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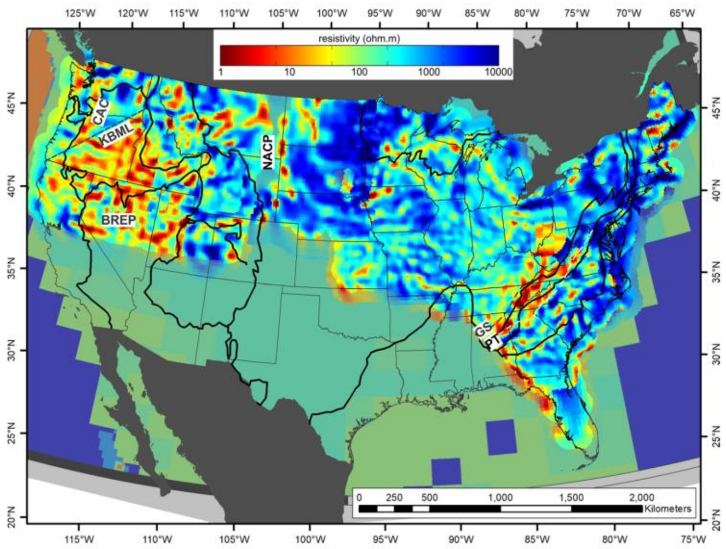
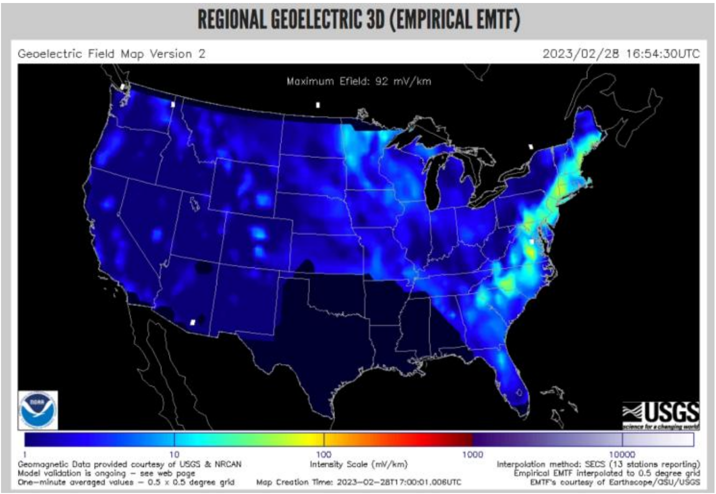
# AIMS


Apparent resistivity model of the large-scale lithospheric structure of central Italy

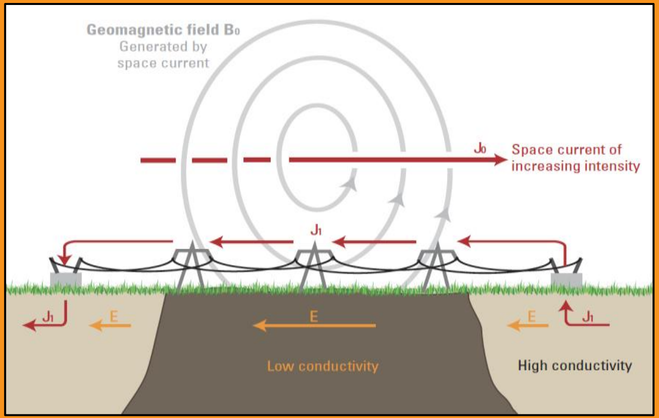



*A.Kelbert, 2019*

Real-time monitoring of ground effects related to space weather events (GIC)

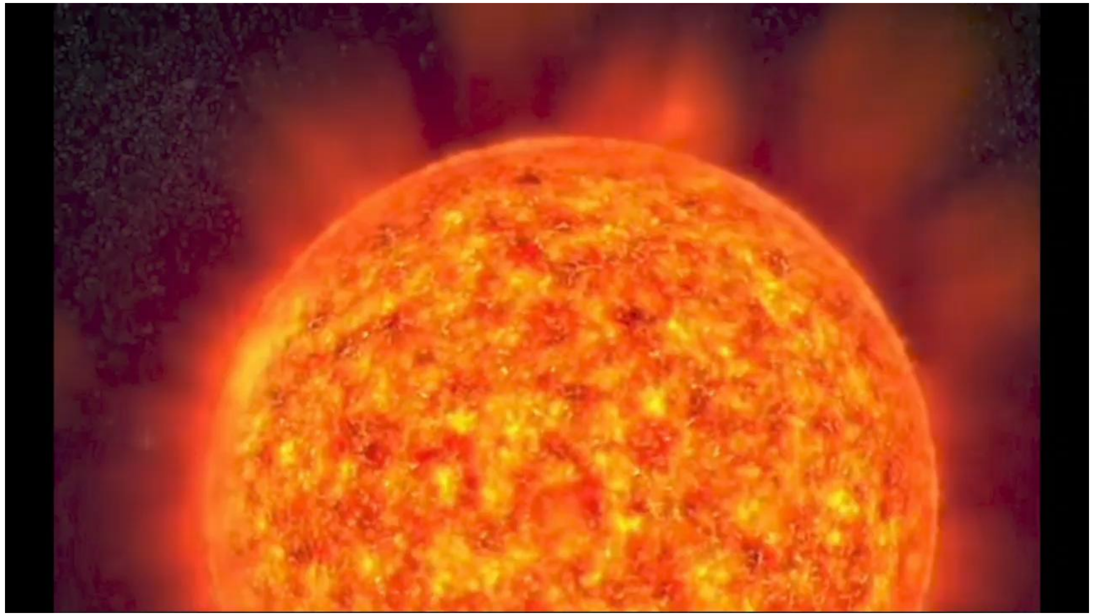


# WHAT IS THE DANGER?



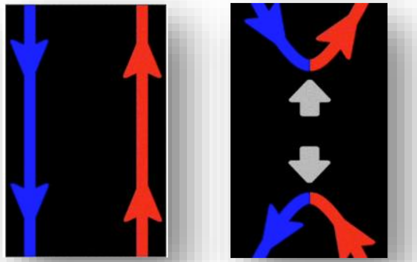

*Geomagnetic disturbances induce horizontal geoelectric fields in the ground and generate low-frequency currents called geomagnetically induced currents (GIC*


# PHENOMENOLOGY: GEOMAGNETIC STORMS



## *Open Magnetosphere*

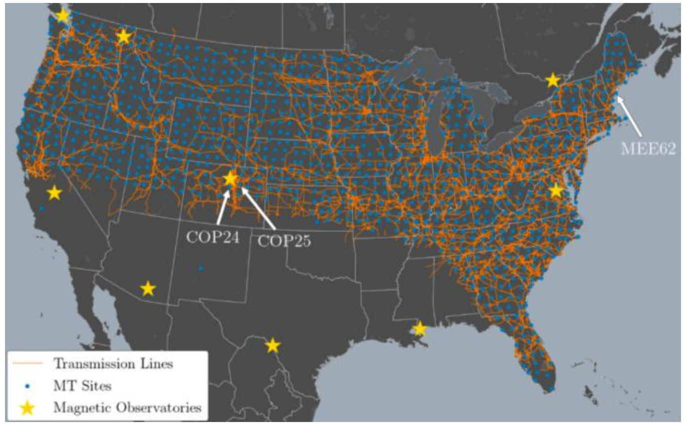
*The lines of force of the Earth's magnetic field and those of the magnetic field carried by the solar wind have opposite directions causing the Earth to lose its natural magnetic shield*



Earth's Magnetic Field
Magnetic Field Carried by Solar Wind

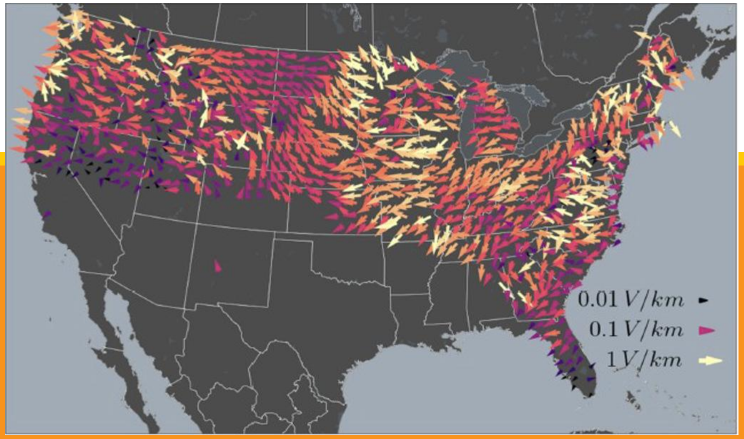
# Estimation of GICs

*Electric power grids*




*Lucas et al. (2020)*

*Estimated geoelectric field*




*Lucas et al. (2020)*

$$\boxed{GIC(f) = aE_x(f) + bE_y(f)}$$

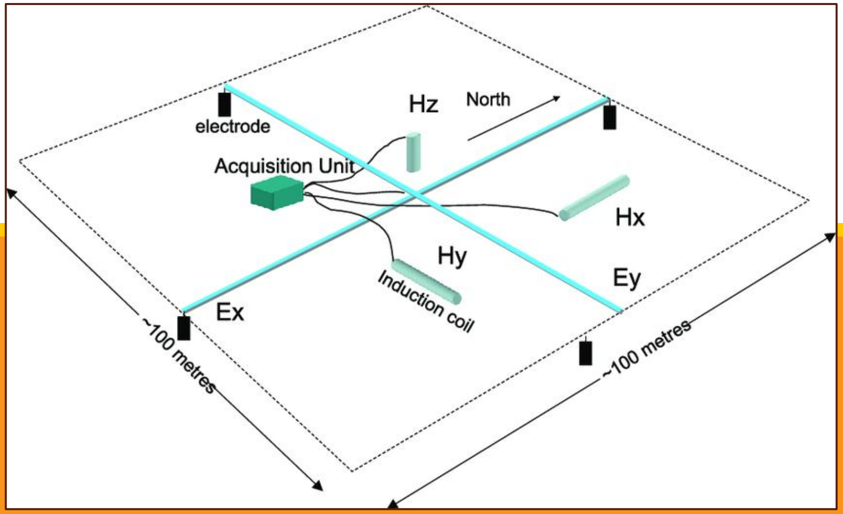
⬇

$$E_x(f) = Z_{xx}(f)\,B_x(f) + Z_{xy}(f)\,B_y(f)$$

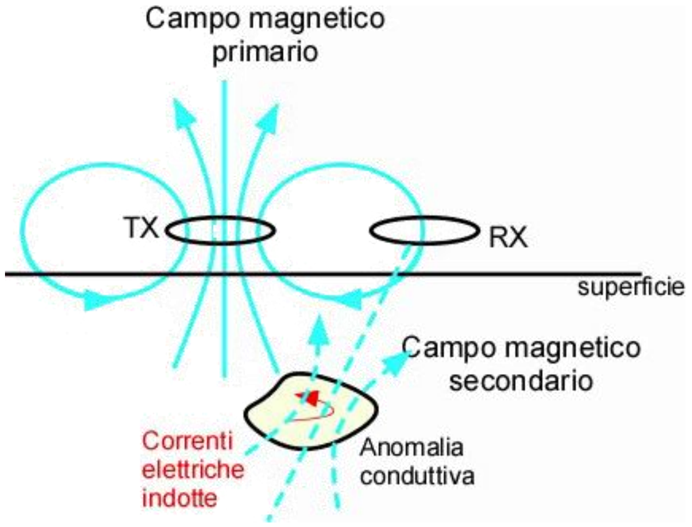
$$E_y(f) = Z_{yx}(f)\,B_x(f) + Z_{yy}(f)\,B_y(f)$$

⬇

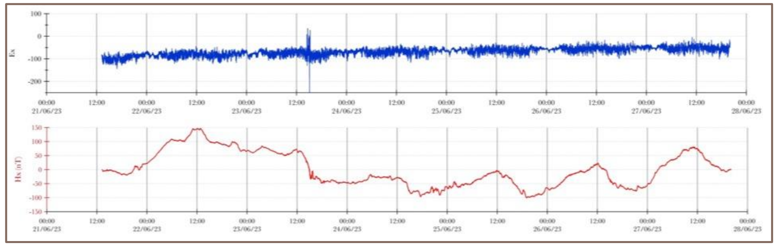
**MAGNETOTELLURIC**




***MT Survey***




***EM time series***



⬇

***Impedance tensor***

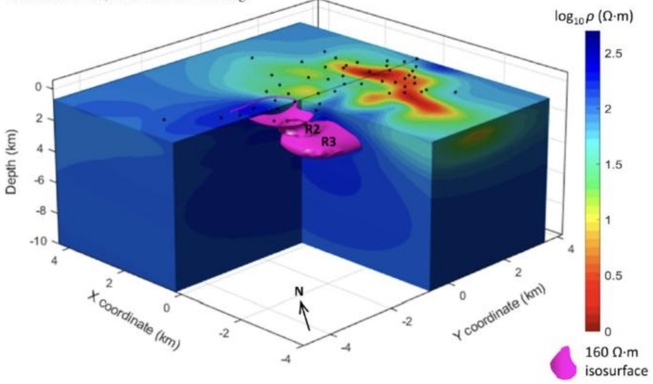
$$\boxed{Z_{ij} = \frac{E_i\ (w)}{H_j\ (w)}}$$

# MAGNETOTELLURIC

Grid of MT measurement sites
with spacing of 50-70 km

## 3D Resistivity model

from Pace et alii, 2022. Remote Sensing




## *PROCESSING MT*

### *Impedance tensor*

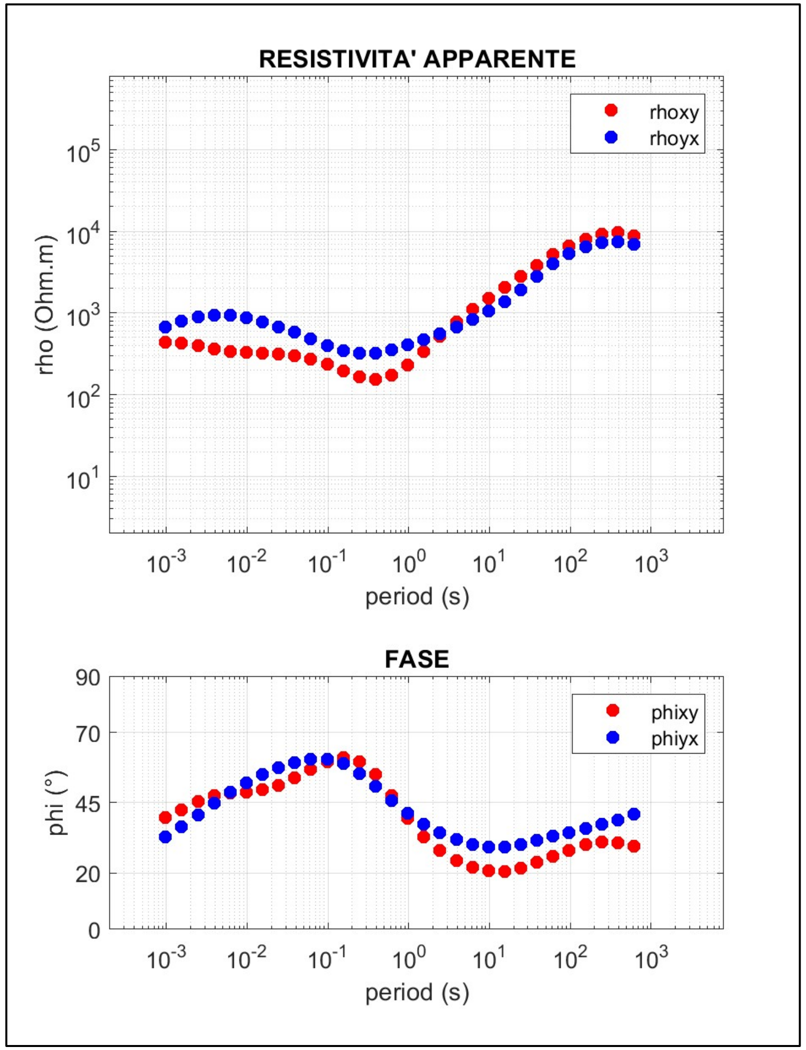
$$Z_{ij} = \frac{E_i\ (w)}{H_j\ (w)}$$

### *Apparent resistivity*

$$\rho_{a_{ij}} = \frac{1}{\omega\mu_0}|Z_{ij}|^2 = \frac{1}{\omega\mu_0}\left(\frac{E}{H}\right)^2$$

### *Phase*

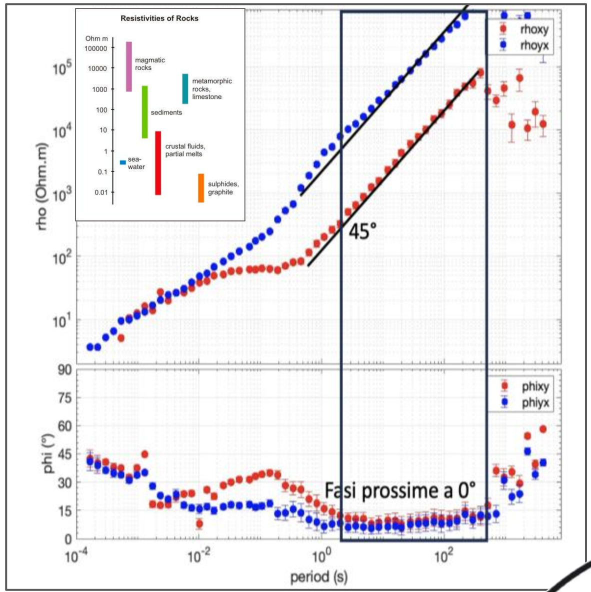
$$\phi_{ij} = \tan^{-1}(Z_{ij})$$




*Apparent resistivity and phase curves*

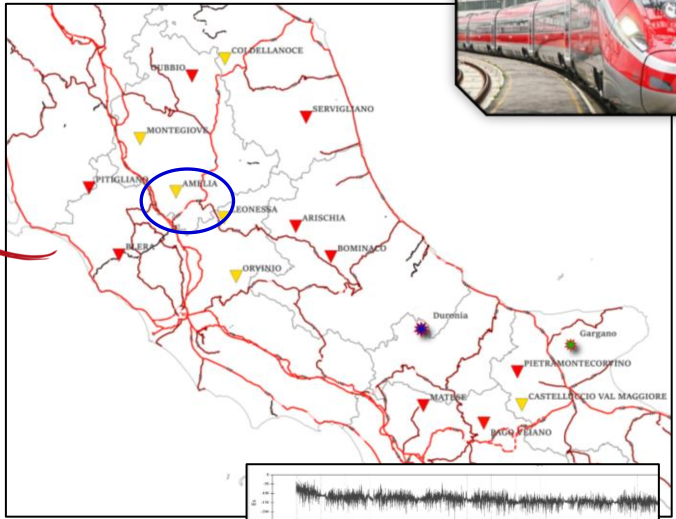
# MT survey campaign

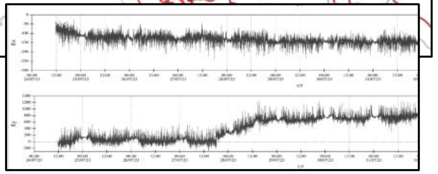
## NOISE IN DATA




*Apparent resistivity and phase curves (Amelia)*

Electrified railway networks



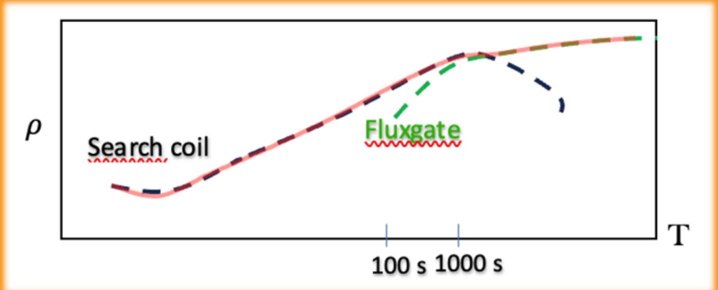



*Heavily perturbed electric field components*


Search-coil

Fluxgate

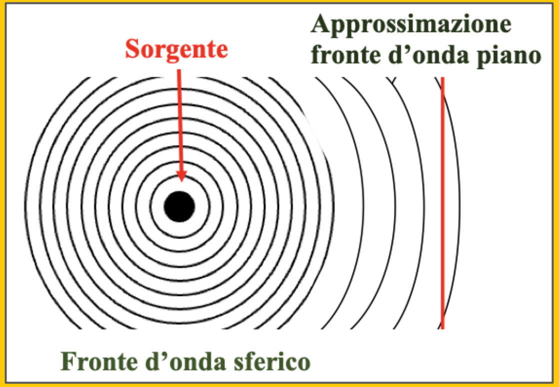
## MT instrumentation



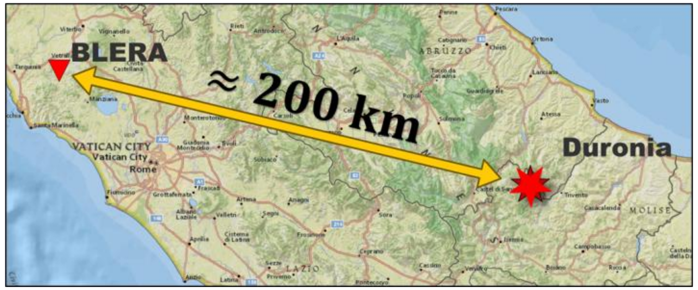

*Schematic example of the combination of apparent resistivity curves obtained with the two types of magnetometers*

# PLANE WAVE ASSUMPTION

The external electromagnetic field affects the earth's surface with a plane wavefront in the MT frequency range from $10^{-4}$ Hz to $10^{4}$ Hz




**Long-period uniform magnetic field over 200-300 km**




***Continuous wavelet spectrogram of the magnetic signal in the N-S direction acquired simultaneously at the MT site in Blera (VT, Italy) and at the geomagnetic observatory in Duronia (CB, Italy)***

# MT survey campaign

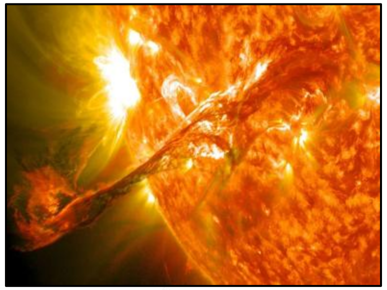
## NOISE IN DATA

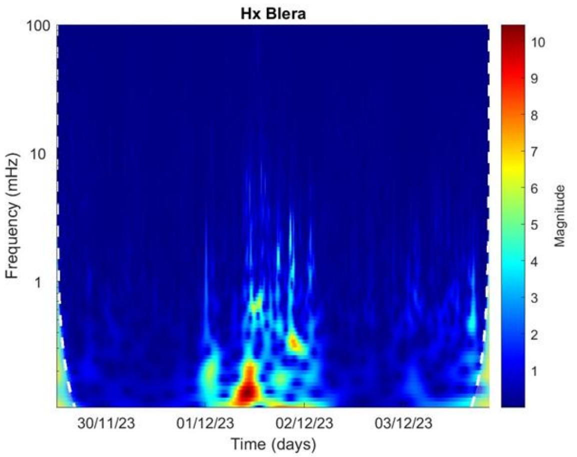
**REMOTE REFERENCE**

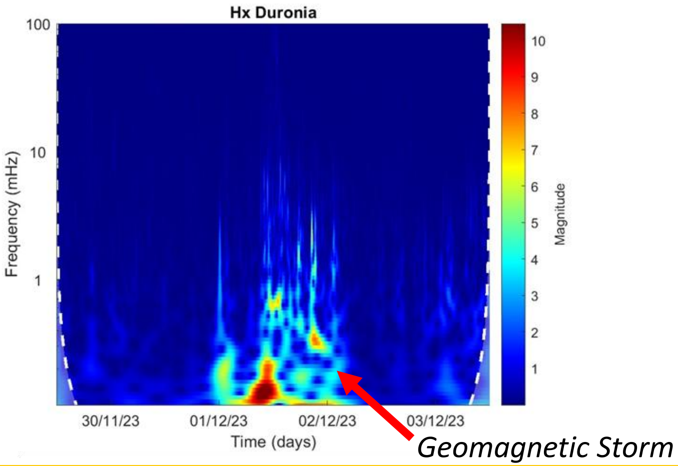
***Smis(w)= S(w)+N(w)***

*S(w): real magnetotelluric signal*

*N(w): electromagnetic noise in the MT signal*

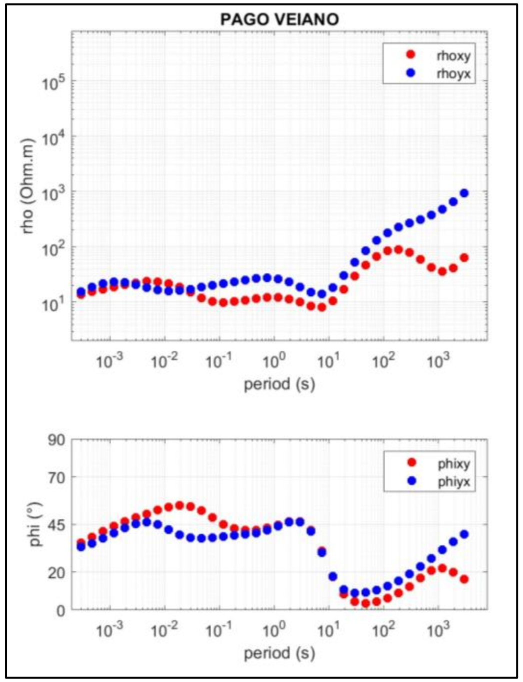


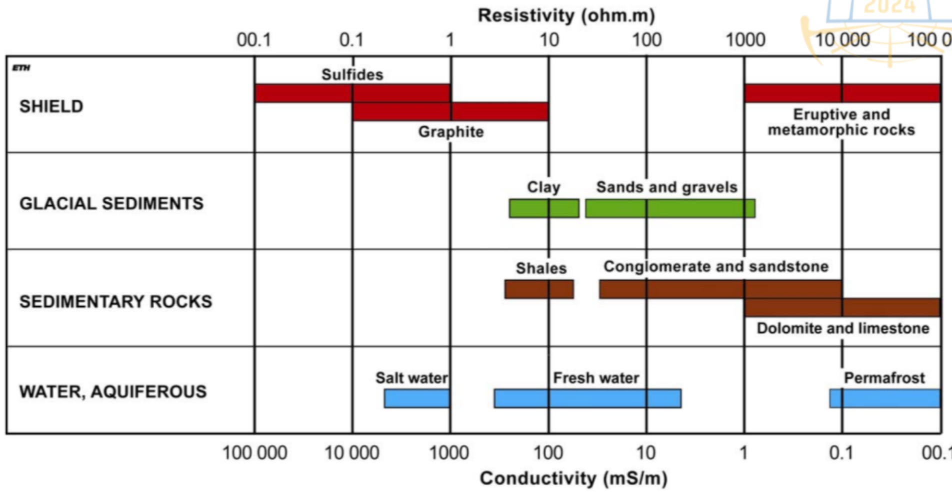


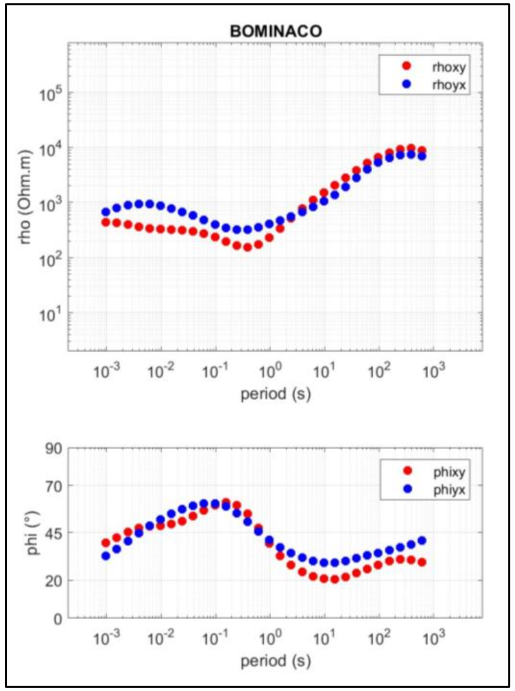
# Preliminary results:

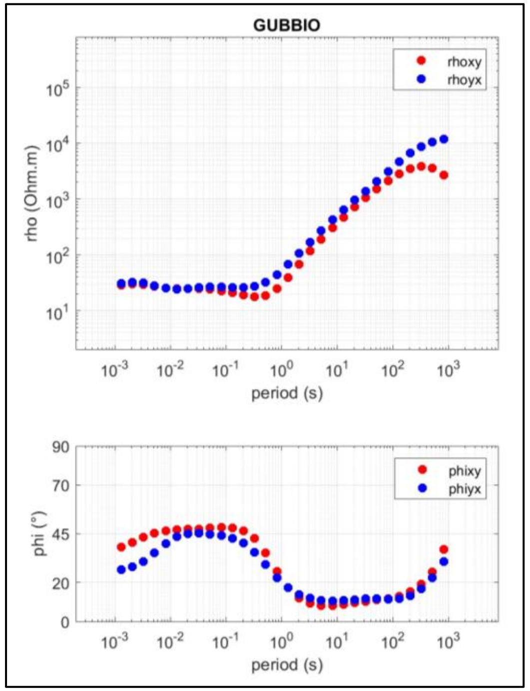
## Apparent resistivity and phase curves

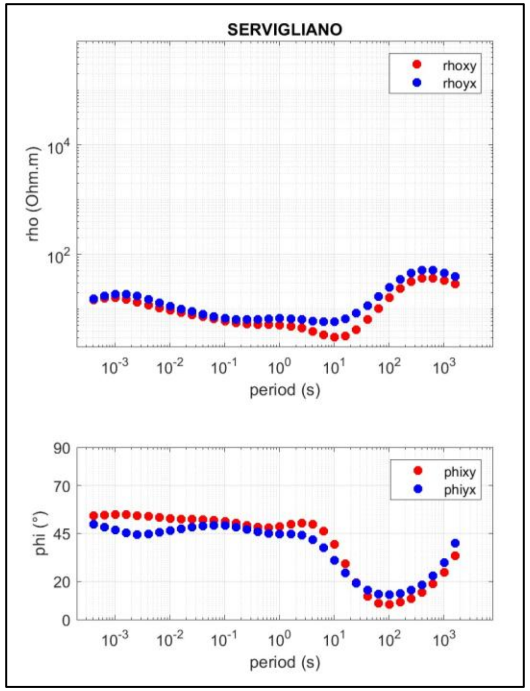




*Apparent resistivity and phase curves*

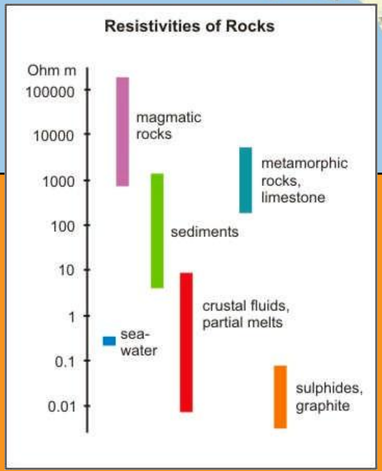


# Preliminary results:

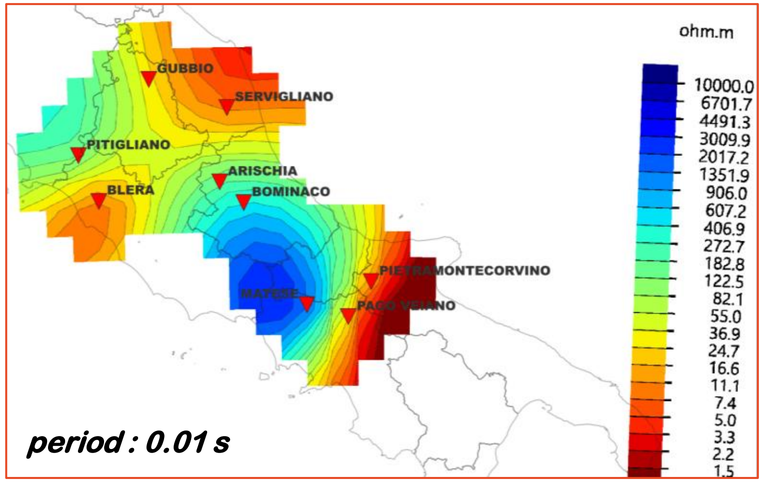
## Apparent resistivity maps

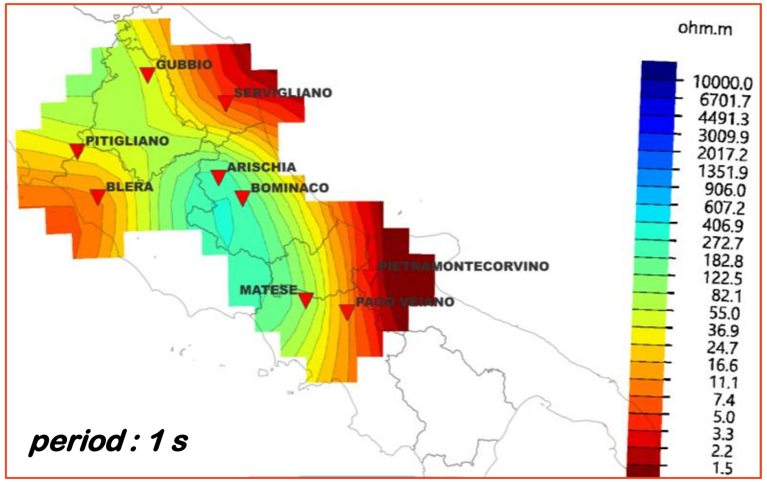

**SKIN DEPTH**

$$\delta \cong 503\sqrt{\rho \cdot T}$$

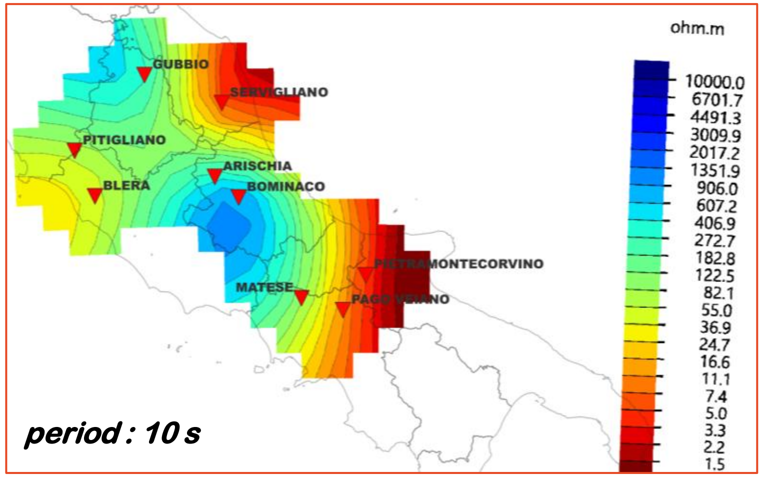
# 1D MT model



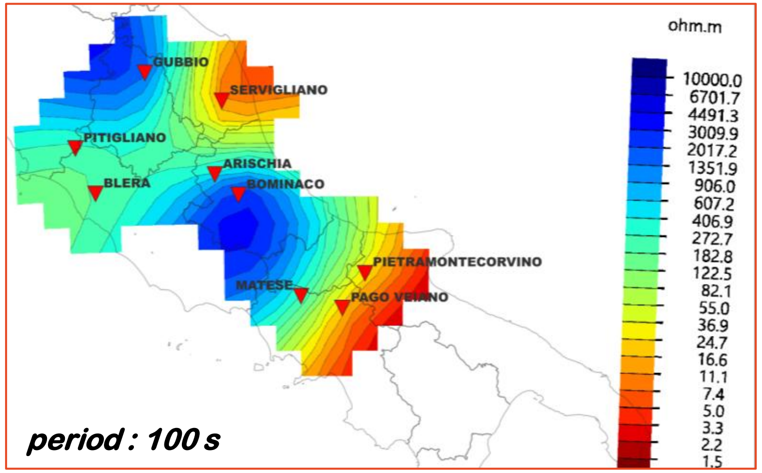

*period : 0.01 s*




*period : 1 s*



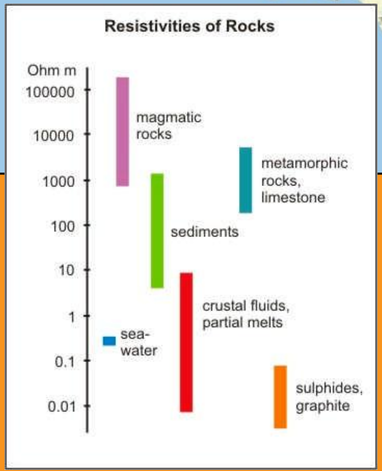

*period : 10 s*




*period : 100 s*

# Preliminary results:

## Apparent resistivity maps


**SKIN DEPTH**

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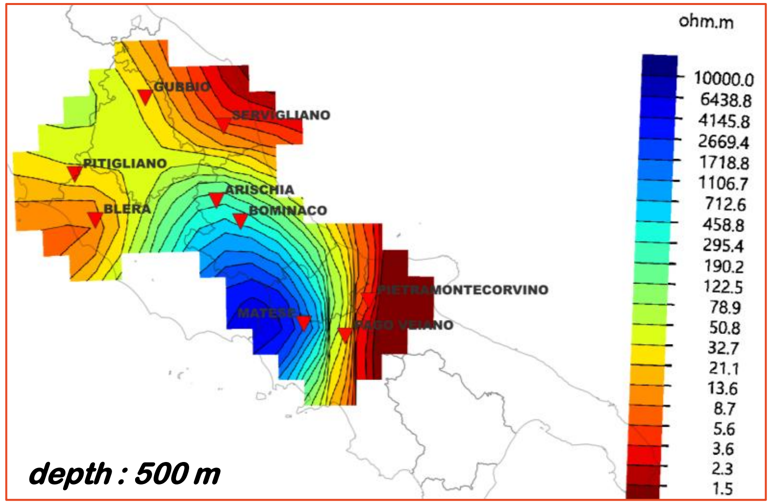
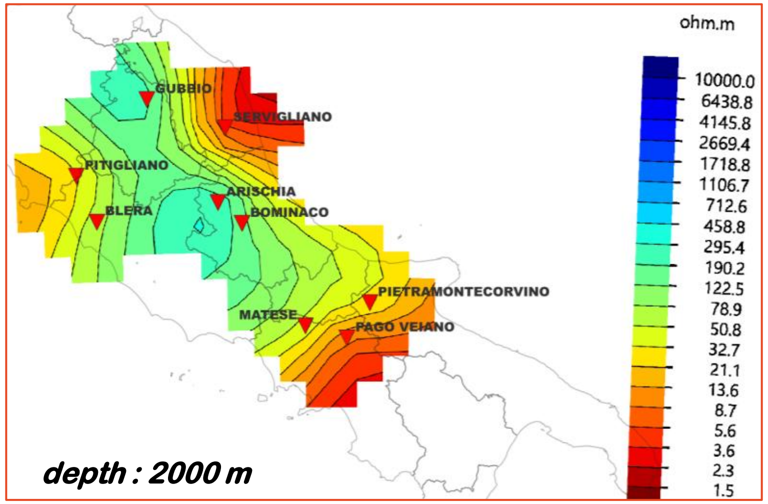
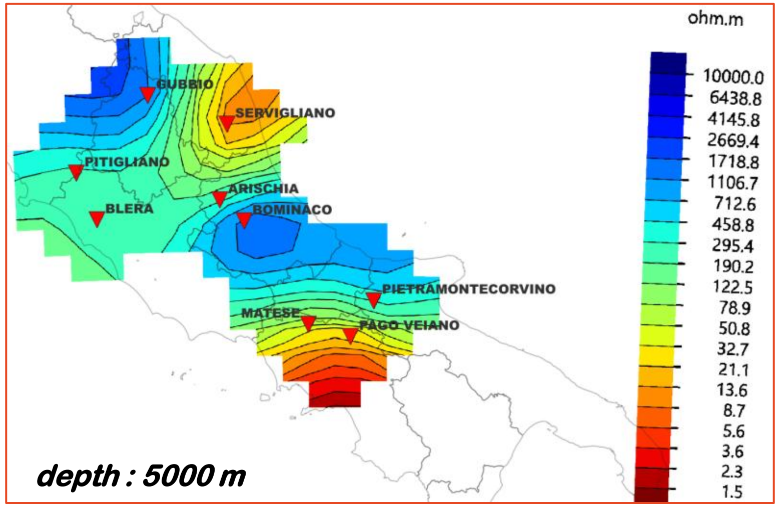
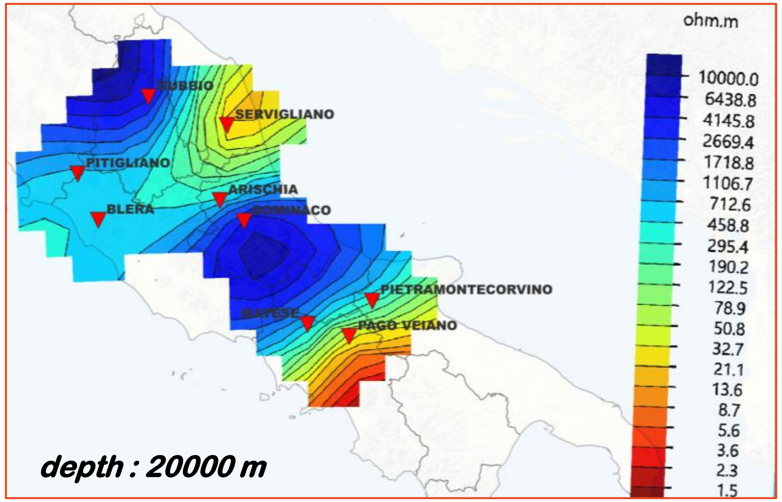
# 1D MT model



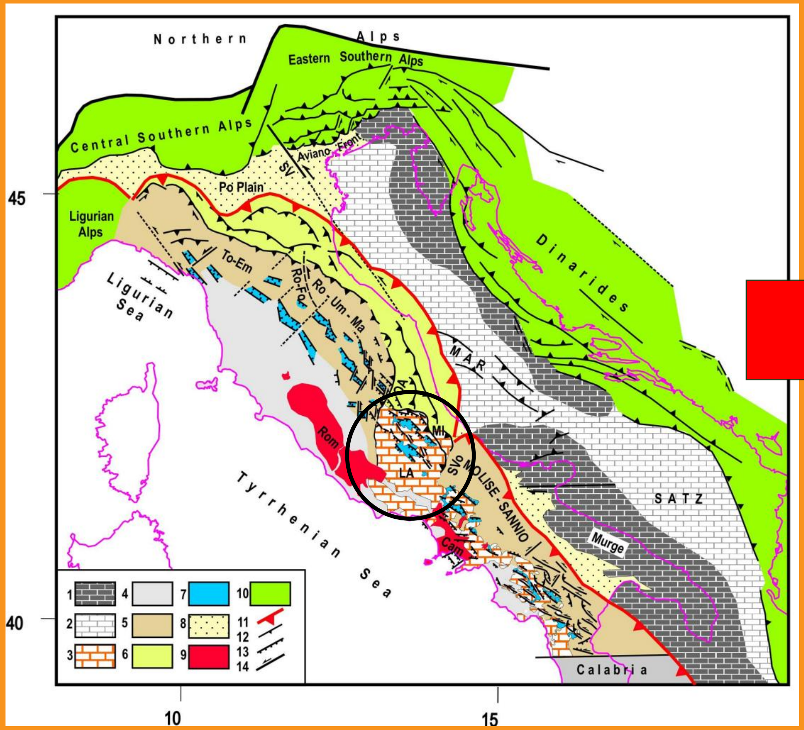



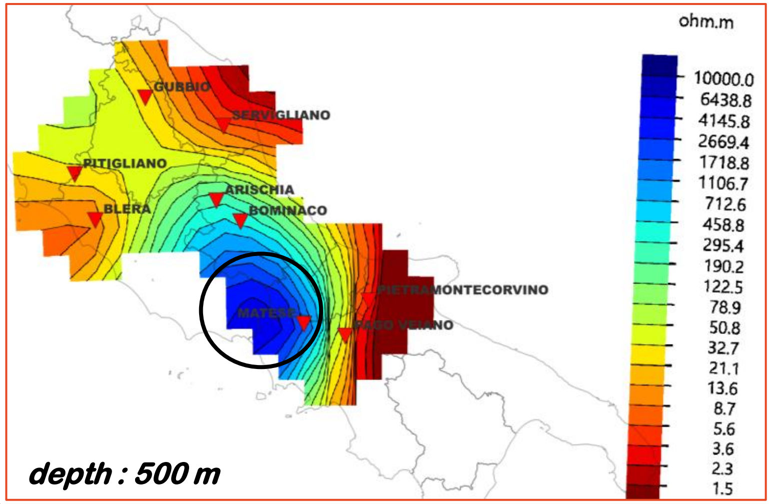
# Preliminary results:

## Apparent resistivity maps

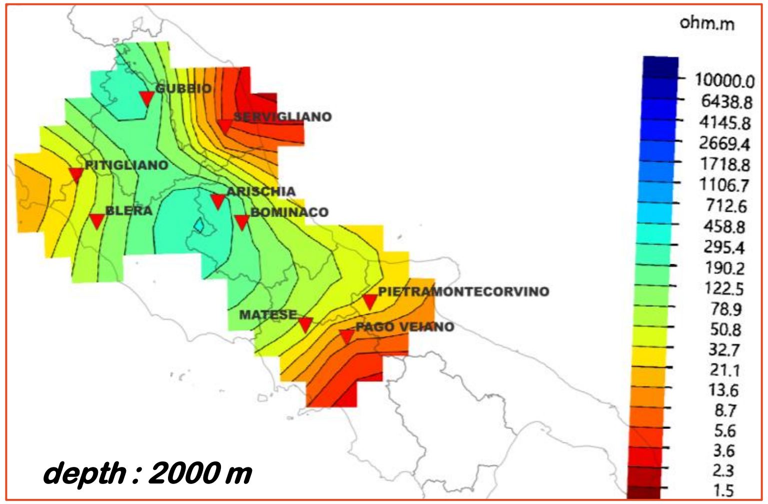



*Mantovani E, 2024*

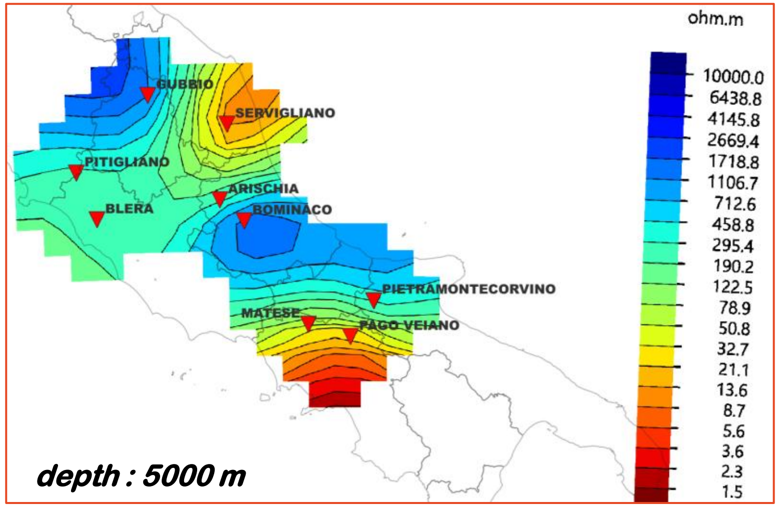
# 1D MT model



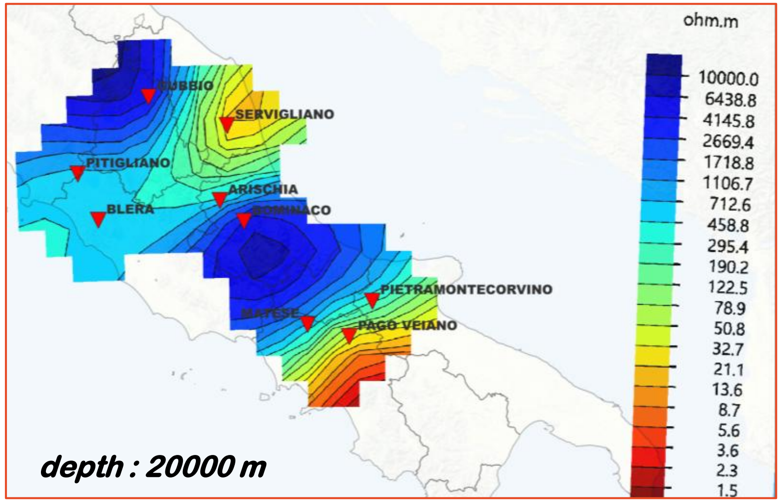

*depth : 500 m*




*depth : 2000 m*




*depth : 5000 m*

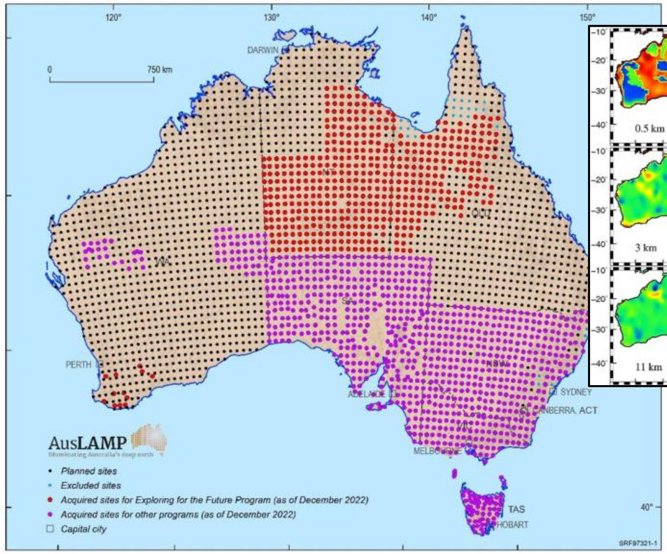



*depth : 20000 m*

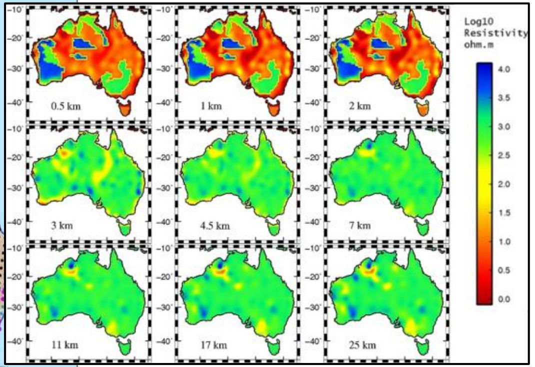
# *Next MT survey campaign*

**Construction of a 2D electrical resistivity model in the area of central Italy to define large-scale crustal structures**

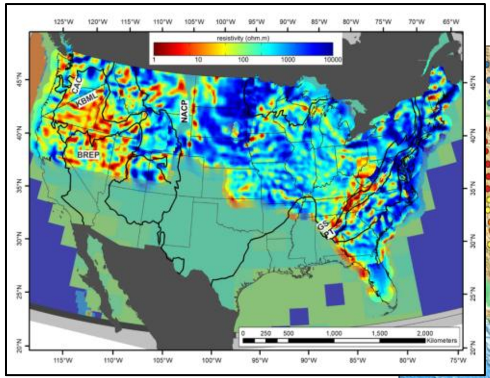
*MT survey campaign and resistivity model (Australia)*



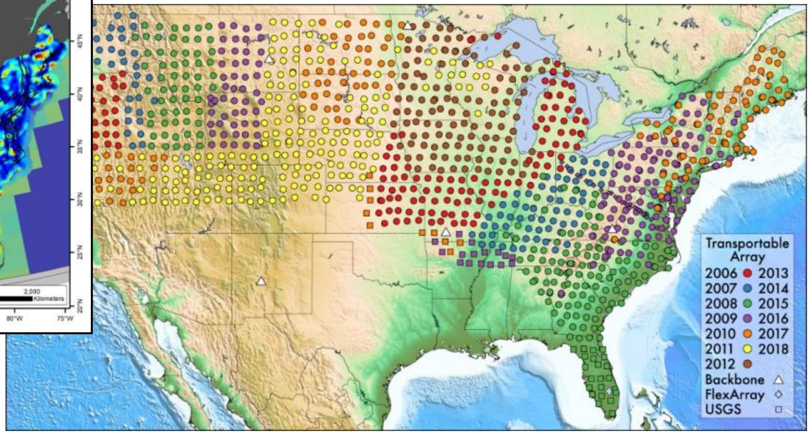

*AusLAMP, 2023*



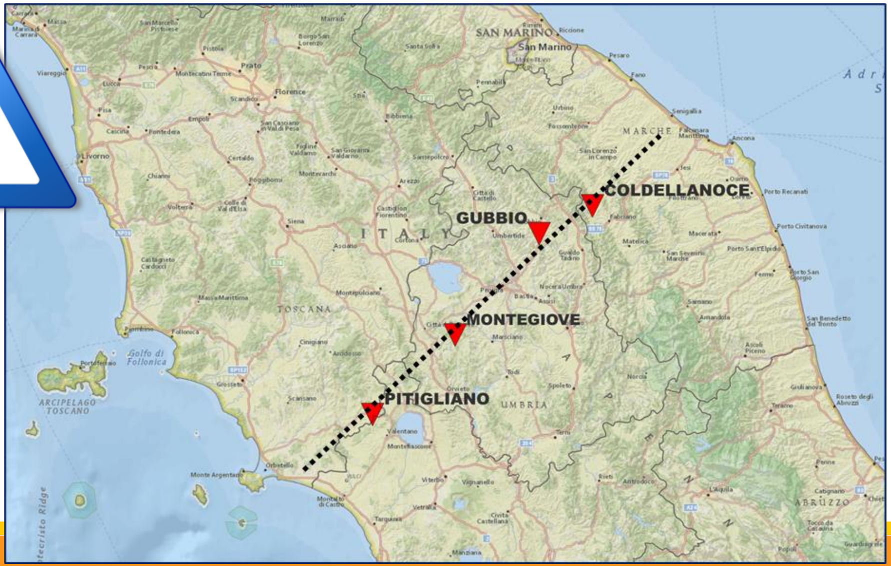

*R. A. Marshall, 2019*




*MT survey campaign and resistivity model (USA)*




**Distribution of survey sites on a grid with a regular mesh size of about 50-70 km**



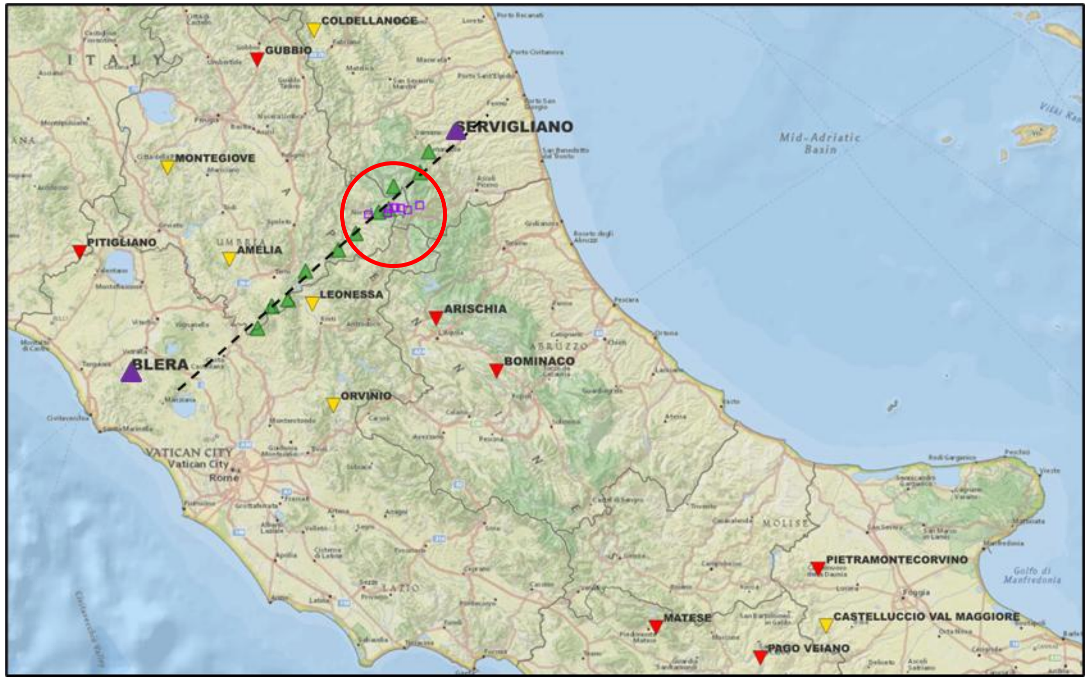

*MT survey campaign (Italia)*

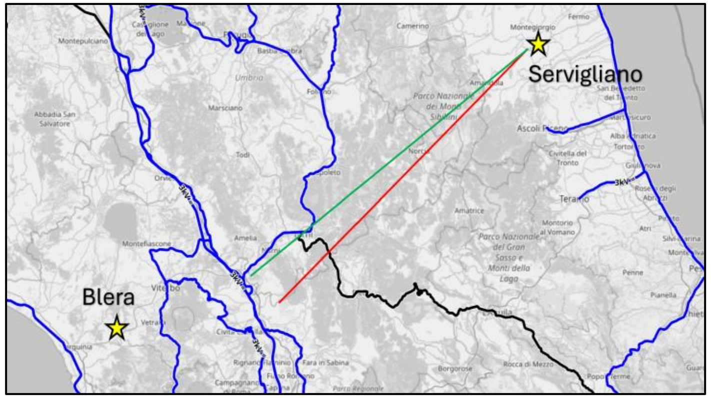
# Next MT survey campaign

*Extend MT surveys with 50 km grid spacing in Saredegna and Croatia*


*10-15 additional MT surveys*
*10 km spacing*
*3 days of acquisition*

*Thickening MT surveys with a 10-km interdistance in the Apennine area of central Italy*




*Map of electrified railway networks (in blue) in the survey area. The red line represents the transect selected for the measurement campaign, the green line represents the transect between Servigliano and Blera (discarded)*

- *Good surveys*
- *Surveys with problems*
- *Transect surveys acquired in the MARGE project*
- *Data acquired in another project*

**The aim of the campaign is to build an electrical resistivity model of the Apennine region of central Italy in order to define large-scale crustal structures in the central Apennines.**

# NEXT STEPS OF THE MARGE PROJECT

- *New campaign of shorter period MT surveys to obtain crustal electrical resistivity models*
- *Continuation of the campaign of longer period and high spatial resolution MT surveys*
- *Data processing and estimation of the impedance tensor Z*
- *Inversion of MT data and 3D conductivity models and interpretation*
- *Estimation of expected electric fields and GICs*

# CONCLUSION

*Importance of research for risk assessment of space weather events to predict and avoid global catastrophes*