DESING OF AN OPTIMAL SEISMIC NETWORK FOR MONITORING GEOTHERMAL FIELDS

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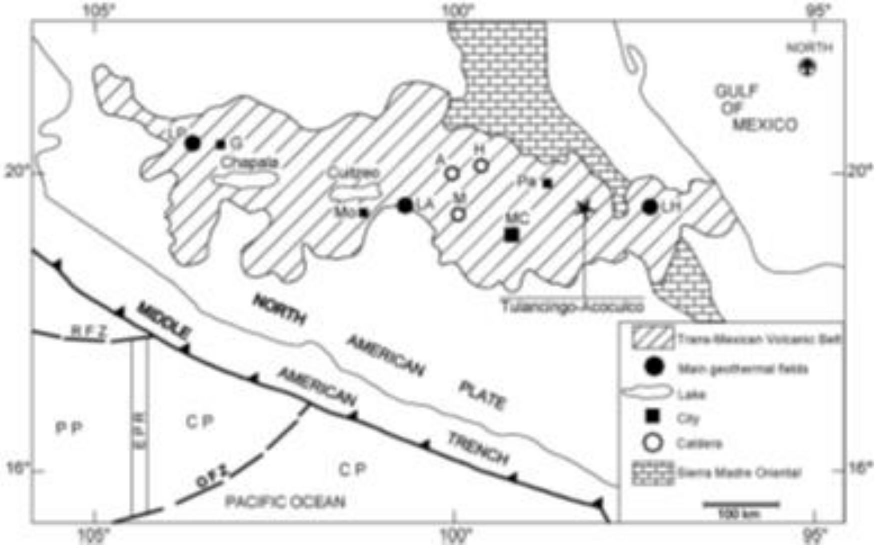
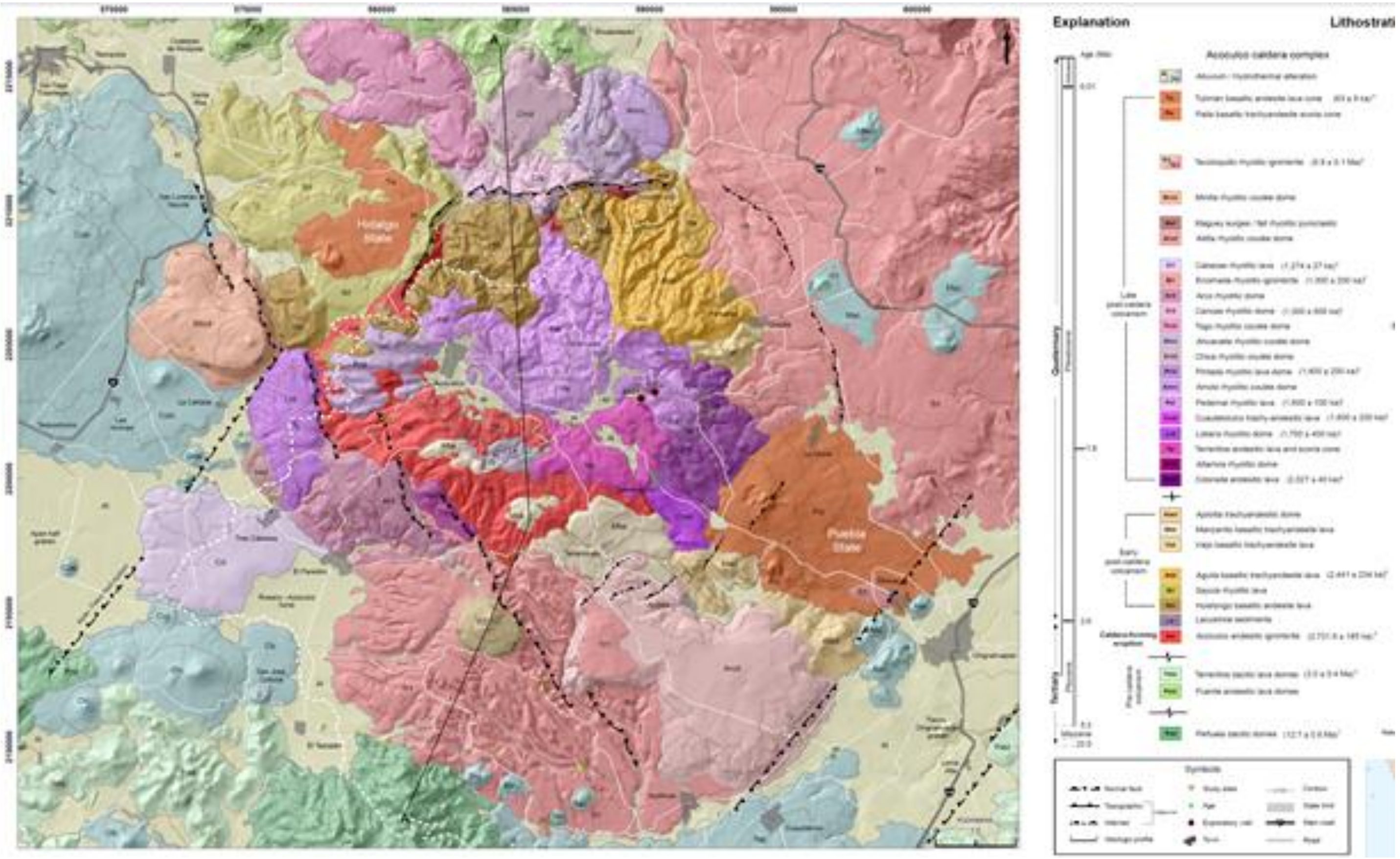
INTRODUCTION

The reliable monitoring and location of the seismic activity at a local and regional scale is a key factor for hazard assessment. The exploitation of a geothermal field can be affected by natural and induced seismicity, hence an optimal planning of a seismic network is of great interest for geothermal development.

Seismic monitoring depends on two main factors: 1) seismic network design and 2) location method. In this work, we attend the seismic network design to improve the resolution and network coverage in the region.

Acoculco geothermal field (Puebla, Mexico) has been considered a Hot Dry Rock geothermal system with only two exploratory boreholes. Since a borehole stimulation is planned in the site, the planning of an optimized seismic network is necessary to record and analyze properly the possible induced seismicity. Additionally, the complex volcanic history of the region resulted in a rugged topography. Thus, we added the topography gradient as a criterion for the network optimization.





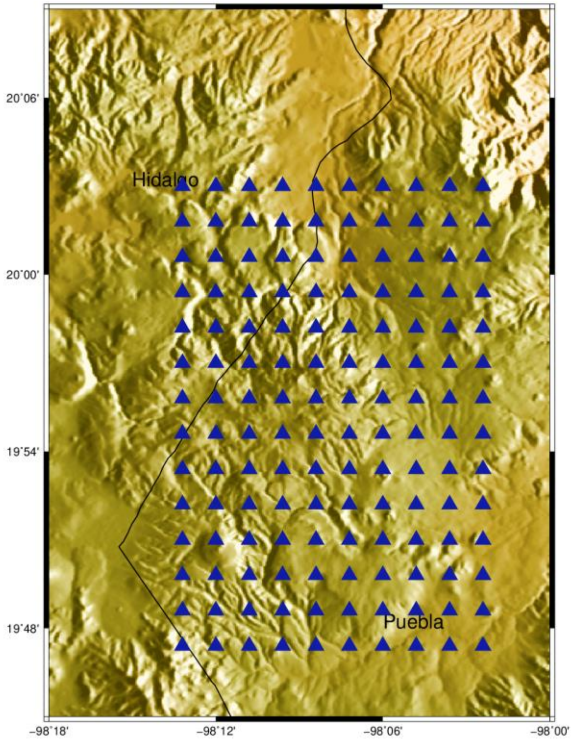
Avellán *et al.*, 2018.

METHOD

In this work, we show a modification of the seismic network optimization algorithm developed by Tramelli *et al*. (2013). The algorithm considers several parameters to make the optimization, e.g. the hypocenter location, magnitude, number of available sensors and some seismic properties of the medium as noise levels, stress drop, quality factor, density, S wave velocity, etc. The code computes, for every station combination, the determinant value of the matrix, whose inverse value is proportional to the error ellipsoid volume. The result is a list of all the combinations with a maximum of the determinant value, *i*. e. the results ensure a minimal location error. Finally, we added the topographic gradient as an optimization parameter that provides a set of combinations with minimal location error and avoiding regions with rugged topography. Therefore it allows a better planning of the installation campaigns.

METHOD

Initial network → **Detection capability** → **M matrix** → **Practical parameters**



- Synthetic data
  - Rupture Brune (1970) model

$$M_0 = 16.05 + 1.5M_w$$

$$A_f = \left(\frac{7}{16}\frac{M_0}{\Delta\sigma}\right)^{1/3}$$

  - Signal-to-noise ratio

- Partial derivarives of the arrival times at each station with respect to hypocenter.
- Optimal criterium

$$V \approx det(A^T A)^{-1/2}$$

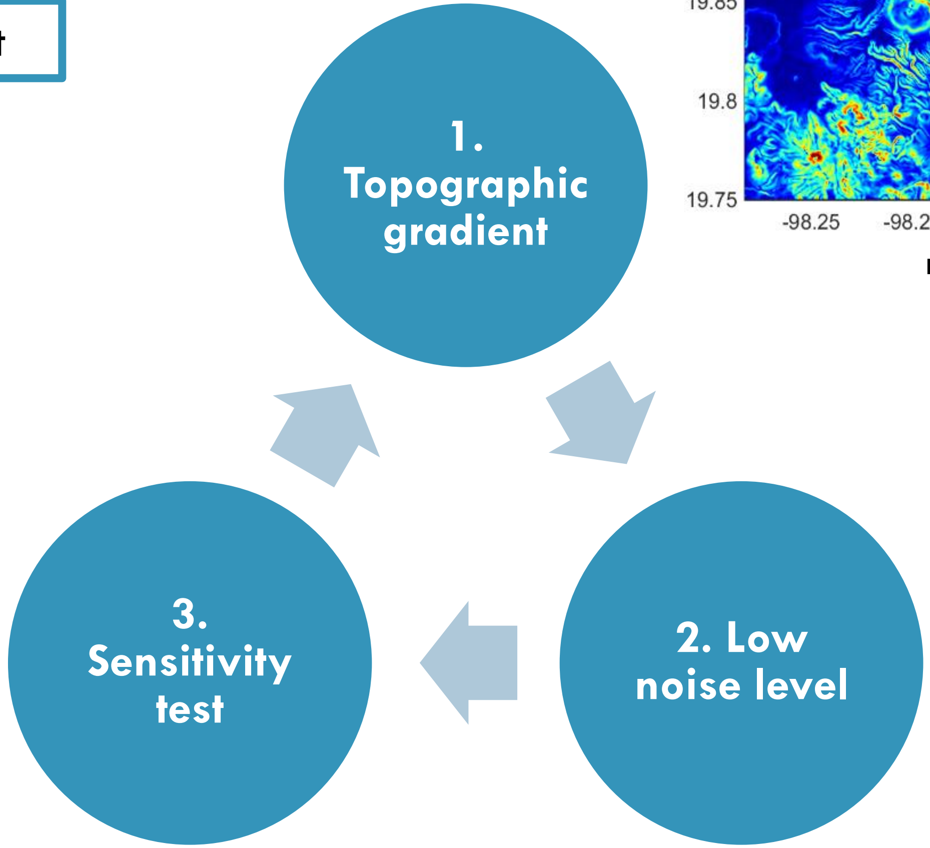
- Thus maximizes

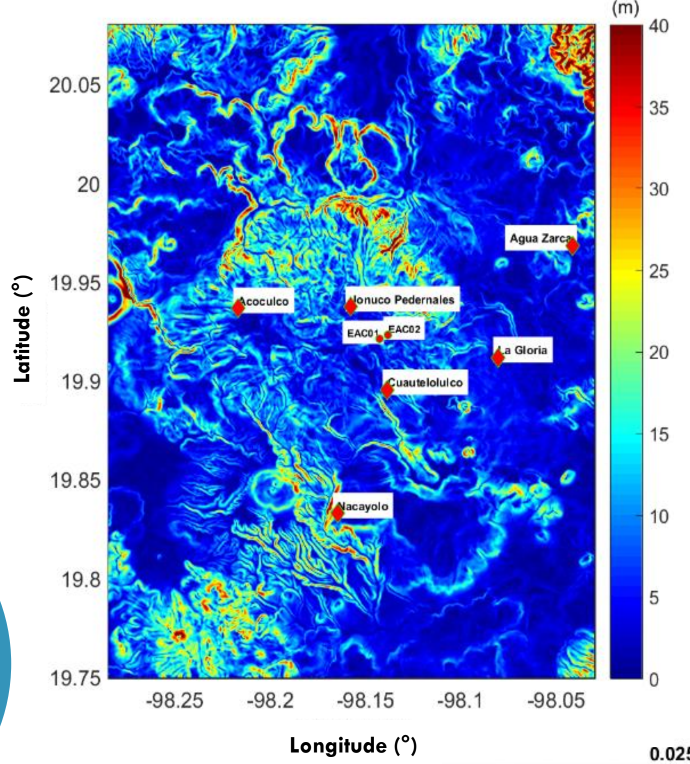
$$det(A^T A)$$

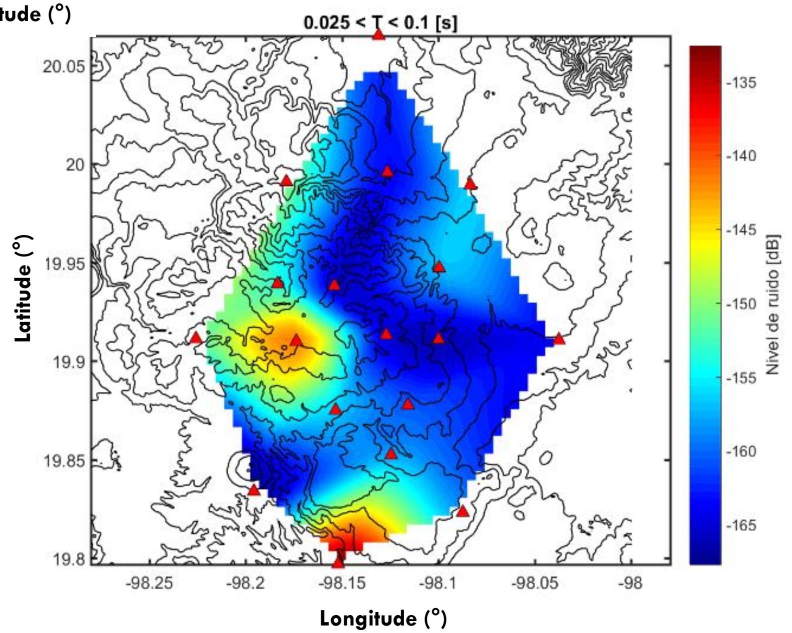
- Noise levels
- Topography
- Sensitivity

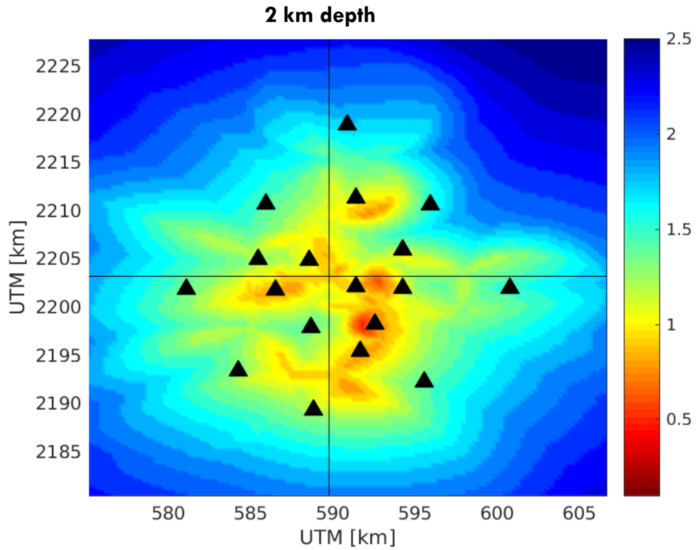
METHOD

Configuration set





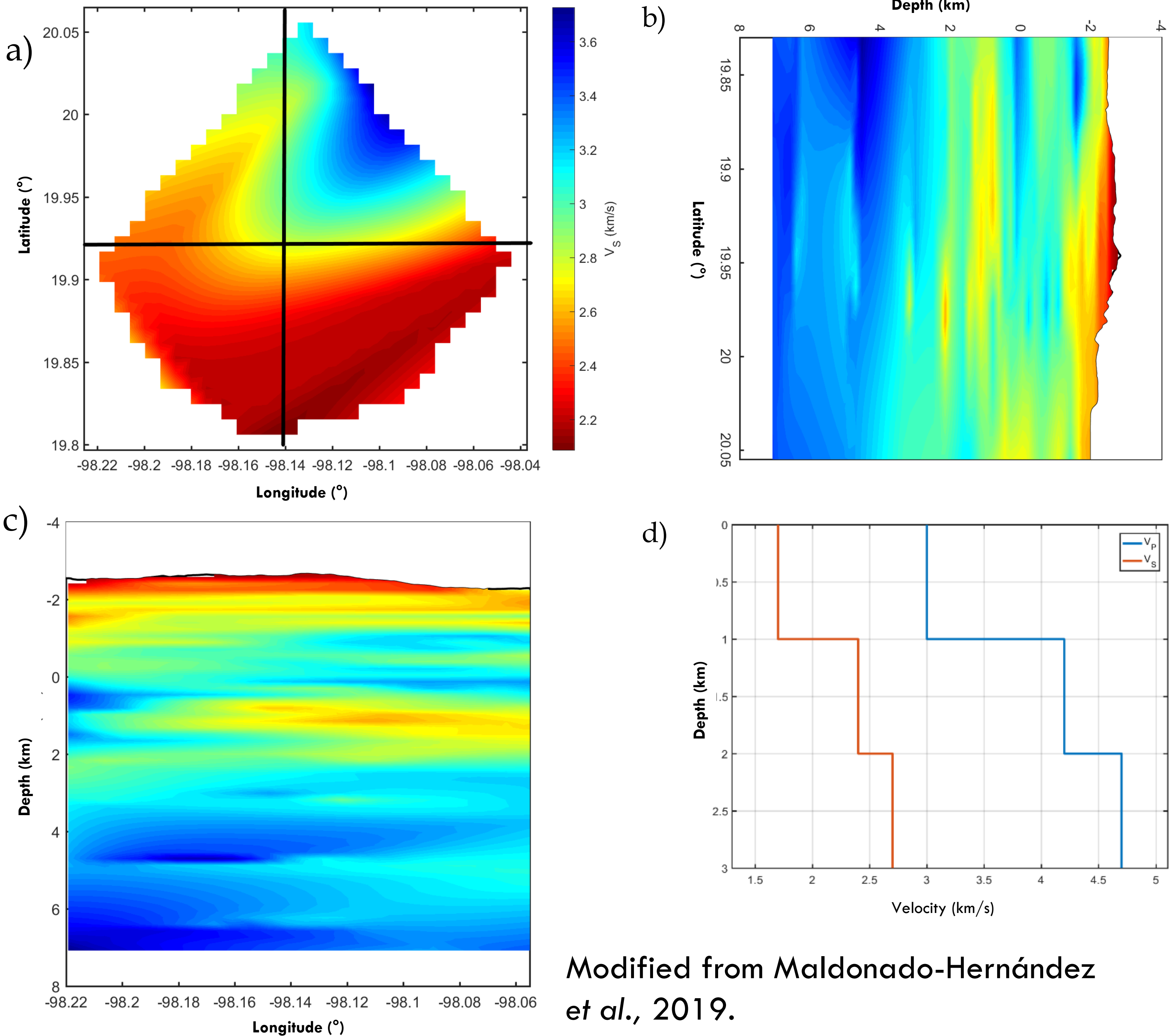




RESULTS

The algorithm was run using a different number of stations and velocity models. Indeed we assessed the influence of using a 1D pattern of a 3D velocity model of the region obtained using the ambient seismic noise method (Maldonado-Hernández et al., 2019).

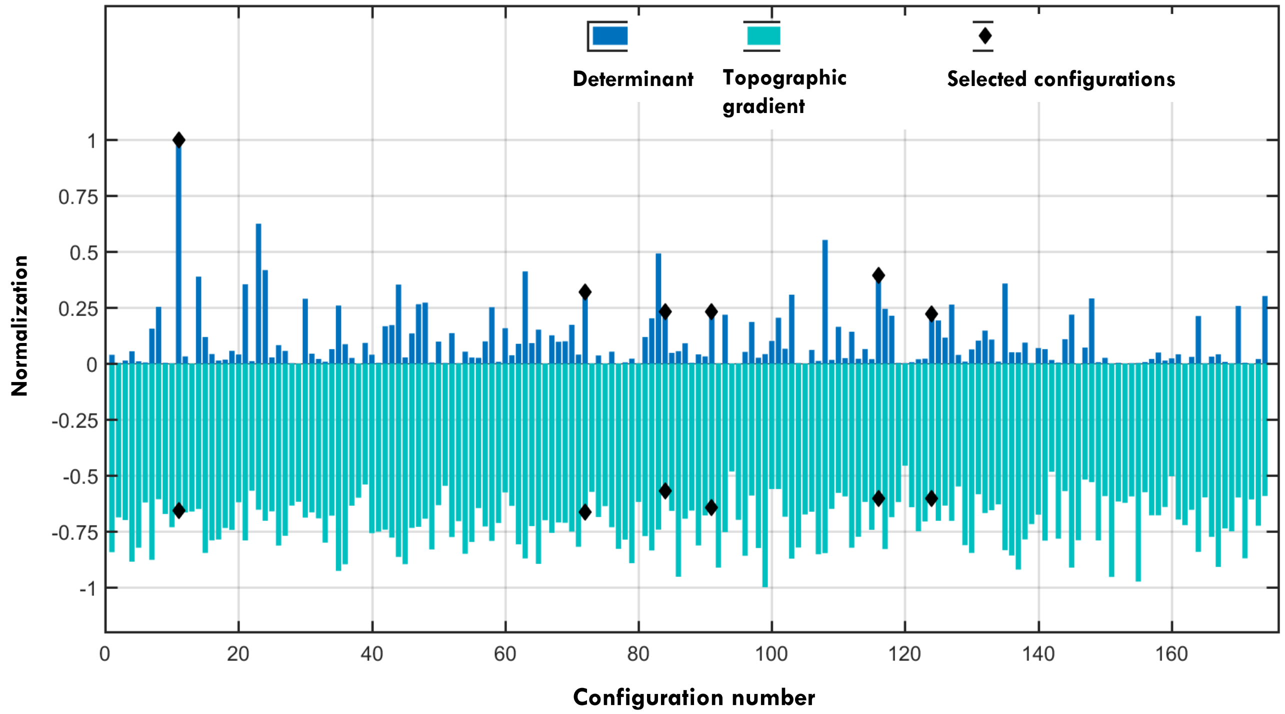
Velocity model
a) Plan view 2km depth
b) North-South section
c) East-West section
d) 1D velocity model



Modified from Maldonado-Hernández *et al.*, 2019.

RESULTS. 1D MODEL.

a)



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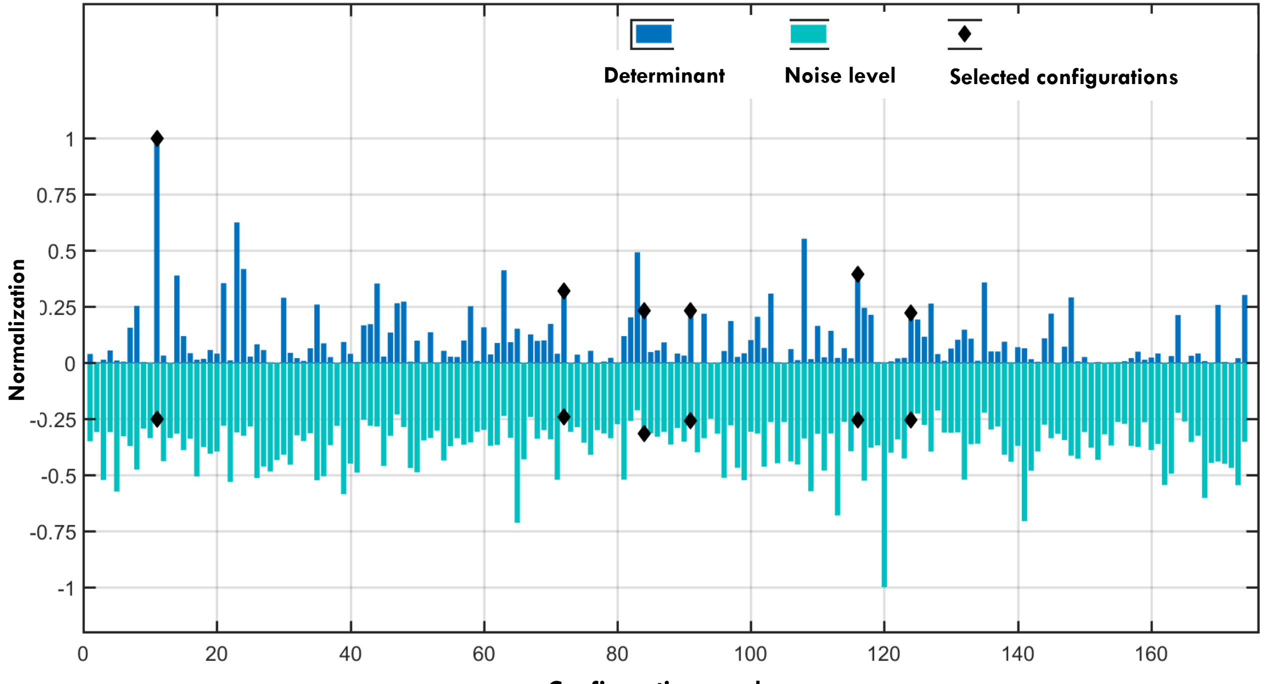
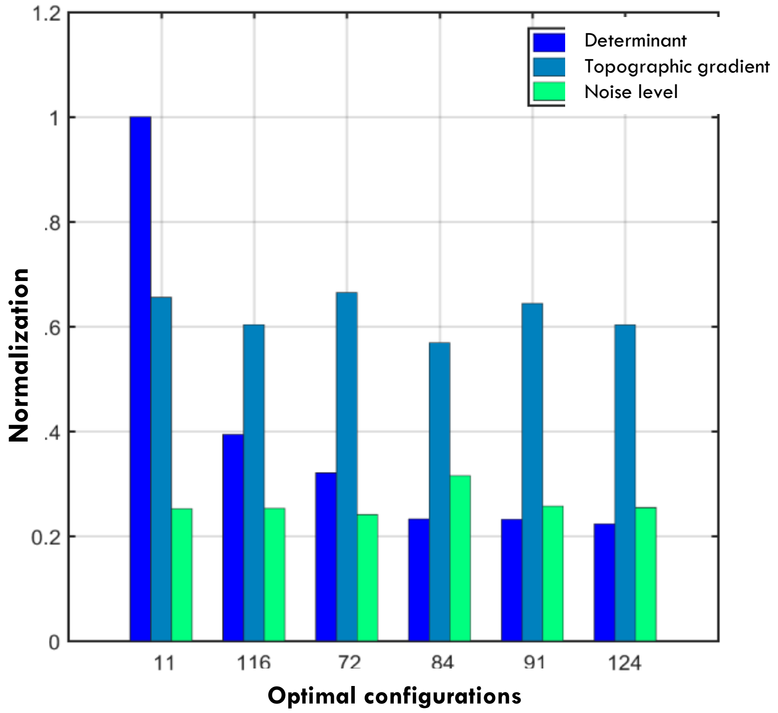


c)

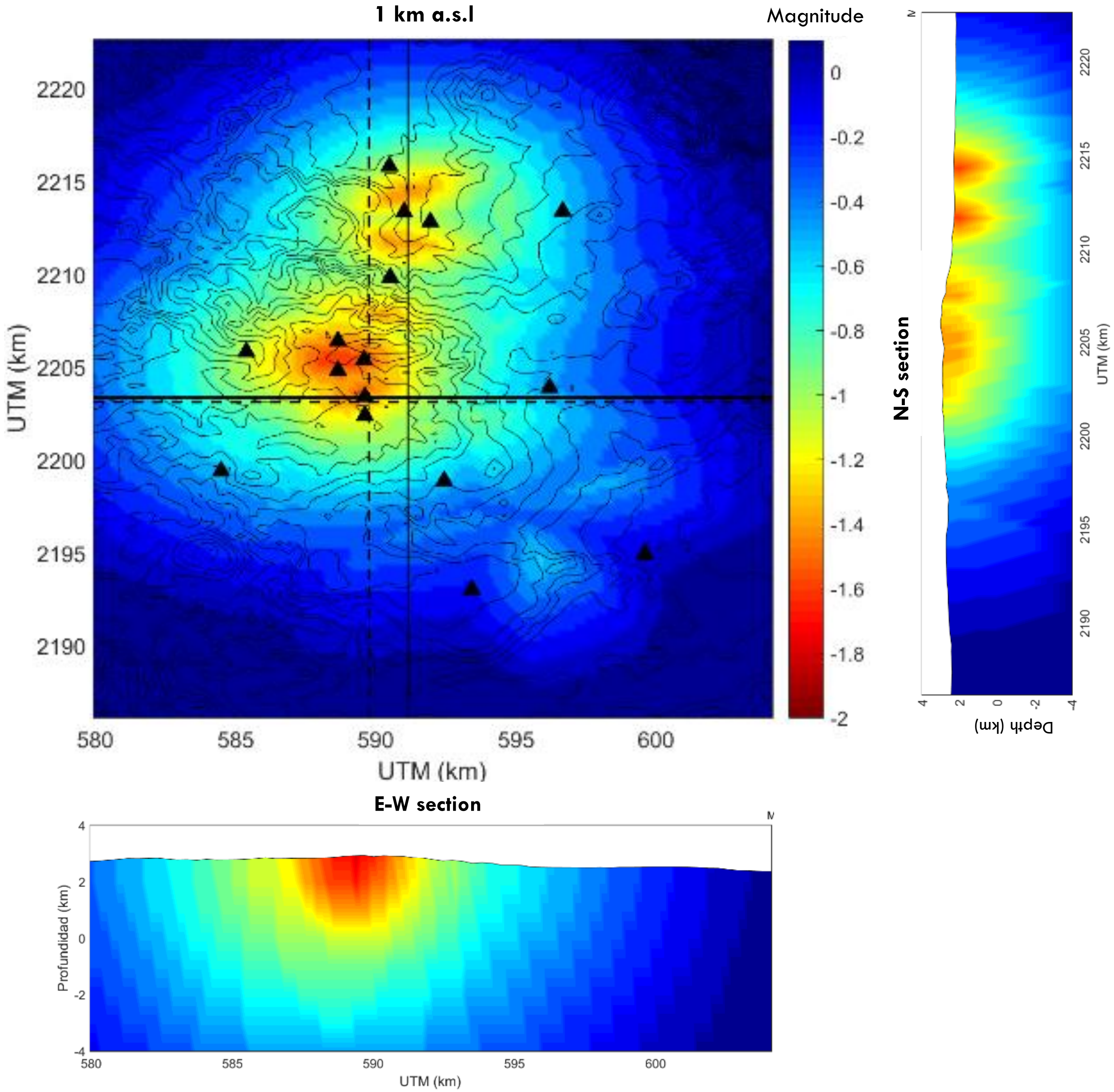


a) Variation of determinant, topographic gradient values for different configurations.
b) Variations of determinant and noise leves values for different configurations.
c) Comparation of determinant, topographic gradient and noise leves values for the best configurations.
* Black Diamonts indicate the best configurations.

RESULTS. 1D MODEL.

a)

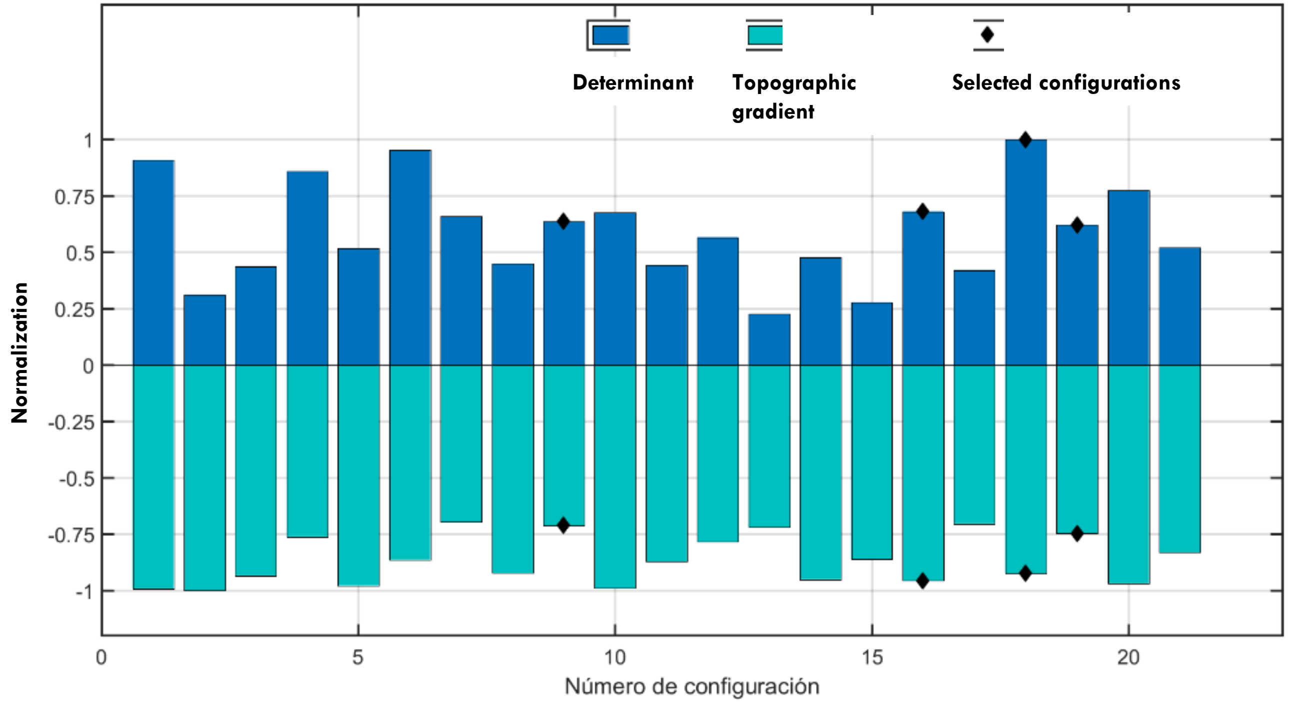
c)



A) Sensitivity of station arrangement number 116 at a depth of 2 km. Color bar indicate the range of coda magnitude capable to be detected by the array of stations. Black triangles represent the optimal network. Dashed lines indicate the location of the hypocenter. Solid vertical and horizontal lines indicate the North-South (b) and East-West (c) sections, respectively.

RESULTS. 3D MODEL.

a)



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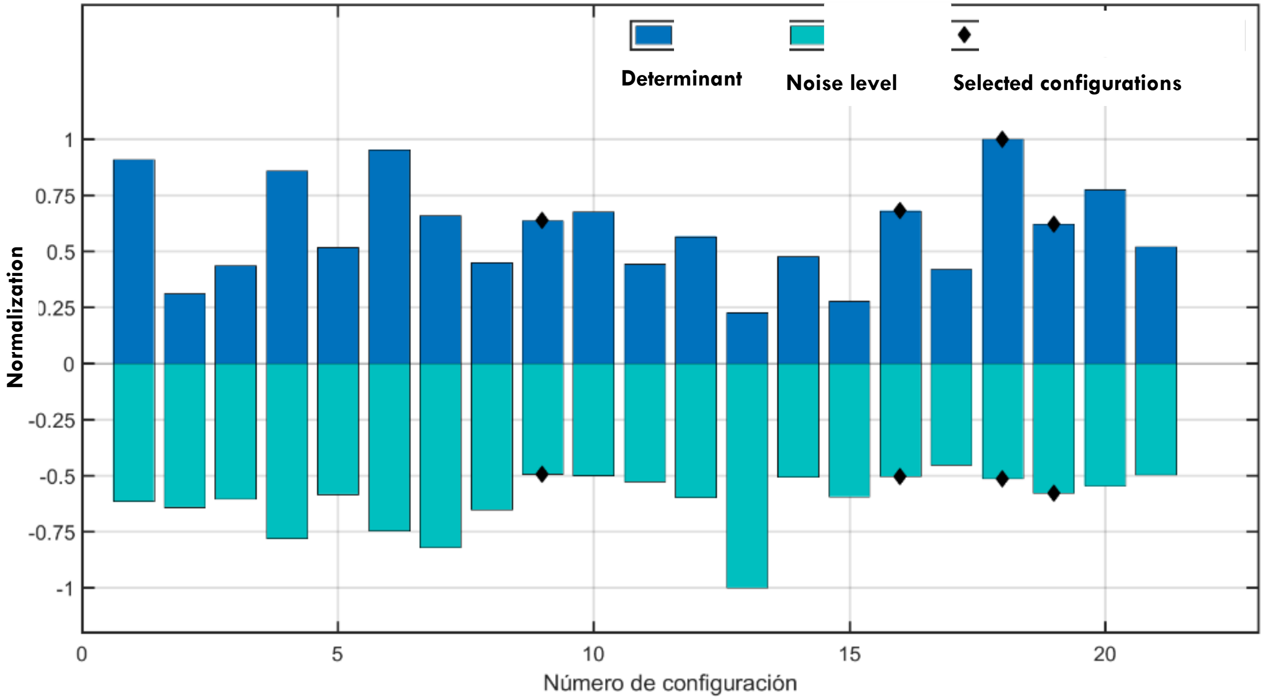

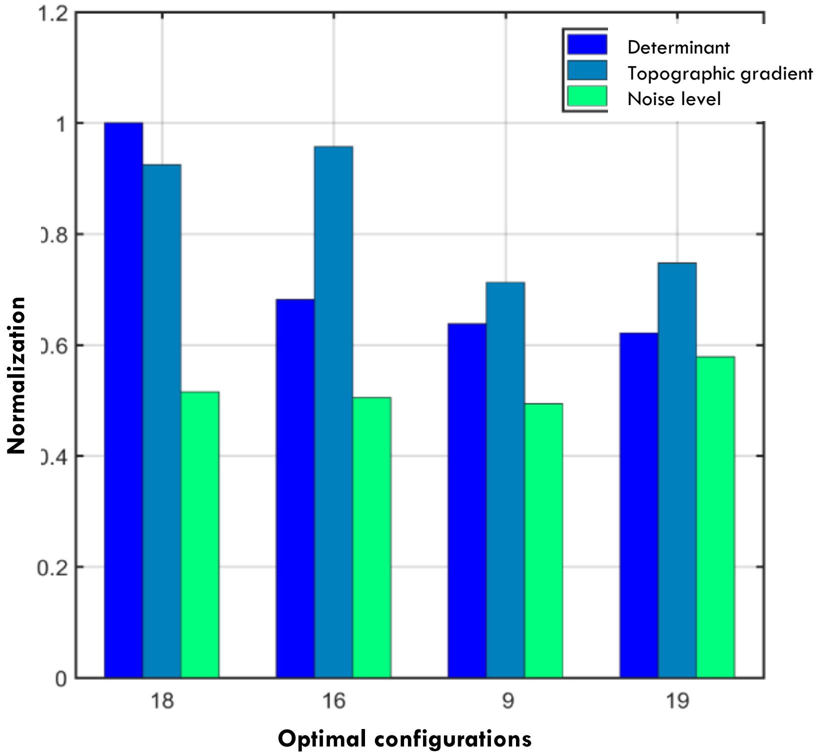

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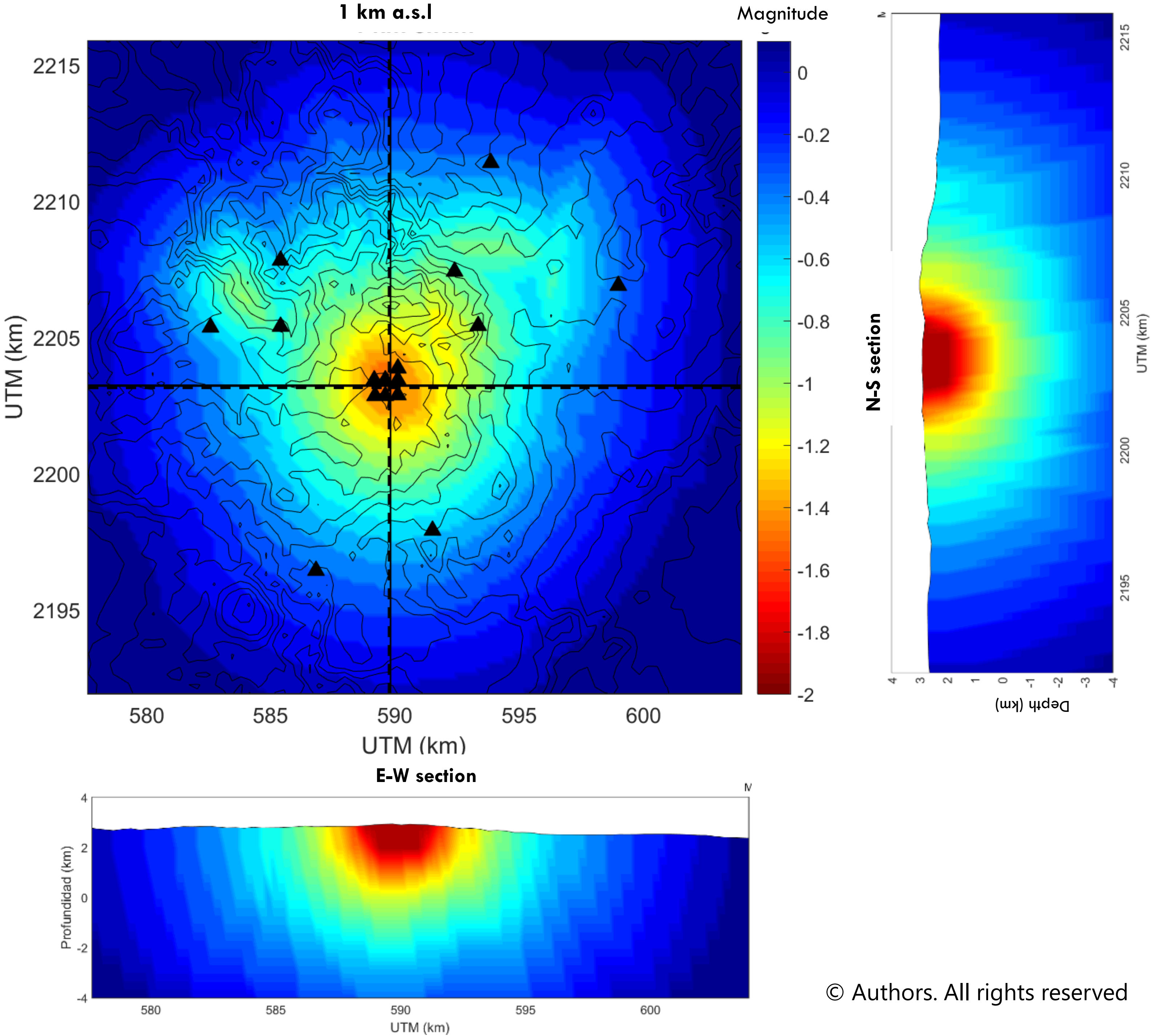

CONCLUSIONS

- The desing of an optimal network for monitoring the Acoculco geothermal field was improved using a large number of parameters as: error location, noise levels and topographic gradient; the last one is an important parameter to consider because Mexico has a rugged topography. Furthermore we found that the use of a proper velocity model is also a determinant variable to build an optimal network.

- The use of One-dimensional velocity model had the tendency to generate networks with stations clustered in several regions and more randomly distributed. This resulted in configurations suggesting position of the stations distributed in unwanted regions. Conversely, the use of an appropriated three-dimensional model of the region, led to propose networks where the stations were located in the target region ensuring a better azimuth coverage and a more suitable distribution of the expected resolution of the network.

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