Time-lapse cross-hole electrical resistivity tomography (CHERT) for monitoring seawater intrusion dynamics in a Mediterranean aquifer

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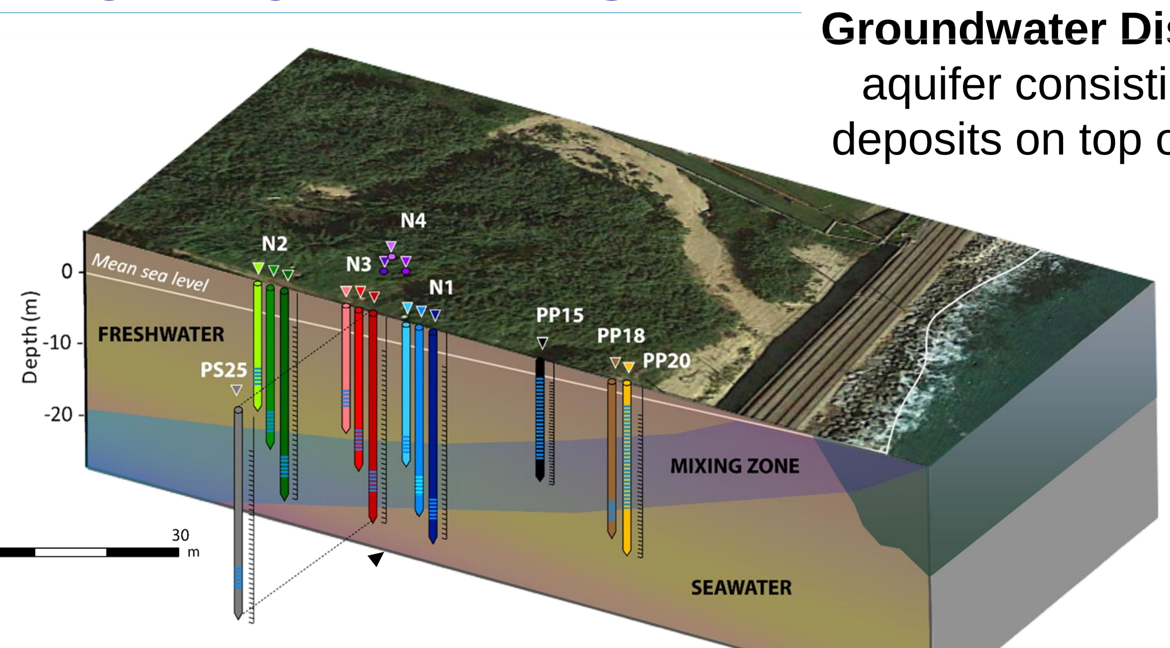
1. INTRODUCTION

Electrical Resistivity Tomography is a common practice for studying freshwater-seawater interface due to the positive correlation between salinity and electrical conductivity (EC). Nevertheless, not many studies have been presented about passive monitoring of a coastal aquifer using CHERT with real field datasets.

With this work, we aim to provide a suitable experimental setup for imaging seawater intrusion and studying the natural and induced dynamic processes that occur in coastal aquifers.

2. ARGENTONA FIELD SITE

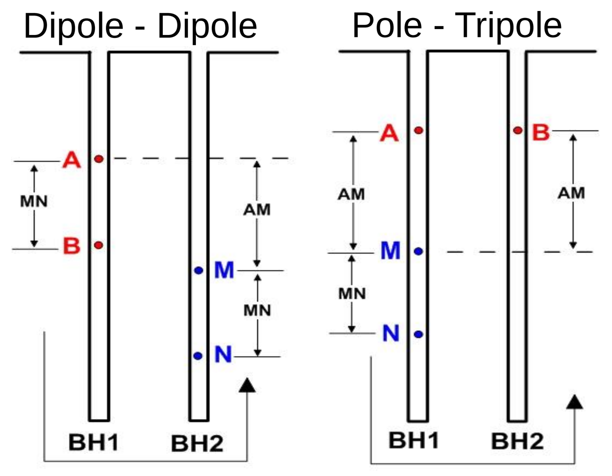
Seawater Intrusion and **Submarine Groundwater Discharge** in a coastal aquifer consisting of layered alluvial deposits on top of weathered granite.



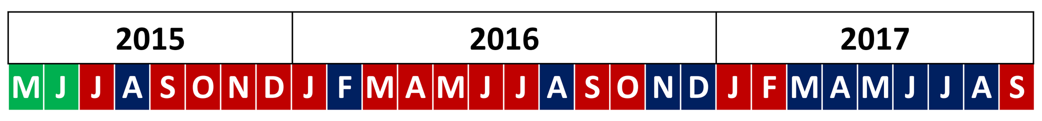
3. EXPERIMENTAL SETUP

- Imaging of the **transect perpendicular to the coastline**.
- 36 electrodes in **5 piezometers (PP20, PP15, N1, N2, N3)** with electrode spacing from 40 to 70 cm.
- Acquisition time: 30 minutes per CHERT, more than 5000 data.
- 16 CHERT in two years.

Electrodes Configuration



(Bellmunt et al., 2012)



4. INVERSION METHOD

- Deterministic time-lapse inversion (using PyGimli framework).
- Reference model created inverting surface ERT and CHERT datasets.
- Geostatistical regularization operator.
- Data error floor set at 3%.
- Occam type inversion (i.e., looking for the most smoothly varying model that fits the data).

Results are presented in terms of changes in EC (σ) because it tells us about Water Quality.

Time-lapse Inversion Strategy: Ratio Method (Daily et al., 1992)

$$\widetilde{d_i} = \frac{d_i}{d_o} g(m_{ref})$$

$\widetilde{d_i}$ = input data for inversion
d_i = data from time t_i
d_o = data from baseline time t_o
$g(m_{ref})$ = response from a reference model

Formation Electrical Conductivity (EC) (Waxman and Smits, 1968)

$$\sigma = \frac{\sigma_w}{F} + \sigma_S$$

σ_w: Pore water EC
σ_S: Pore surface EC (assumed constant)
F: Formation Electrical Factor (assumed constant)

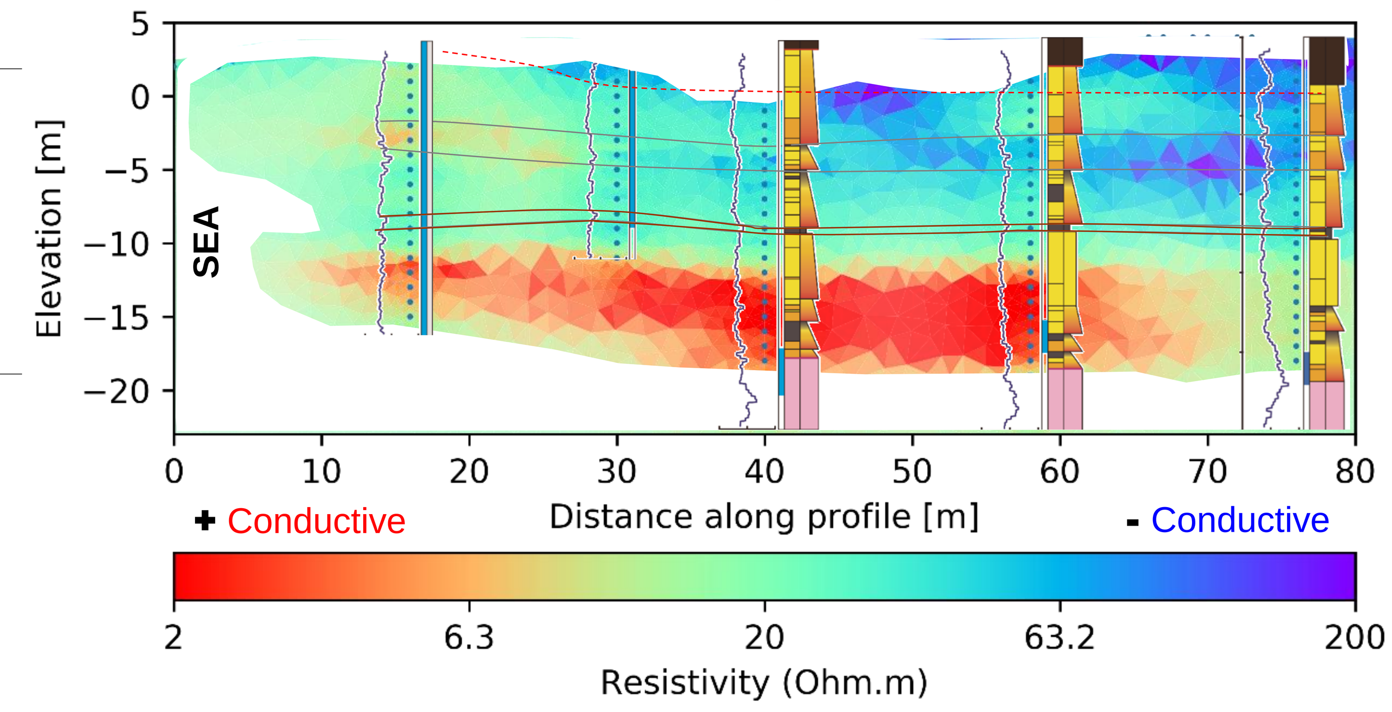
5. TIME-LAPSE RESULTS

Reference Model: Inversion of Surface and Crosshole ERT datasets from September 2015

*"Fresh"-water-bearing sequences (**unconfined** aquifer)*

Silt Layer

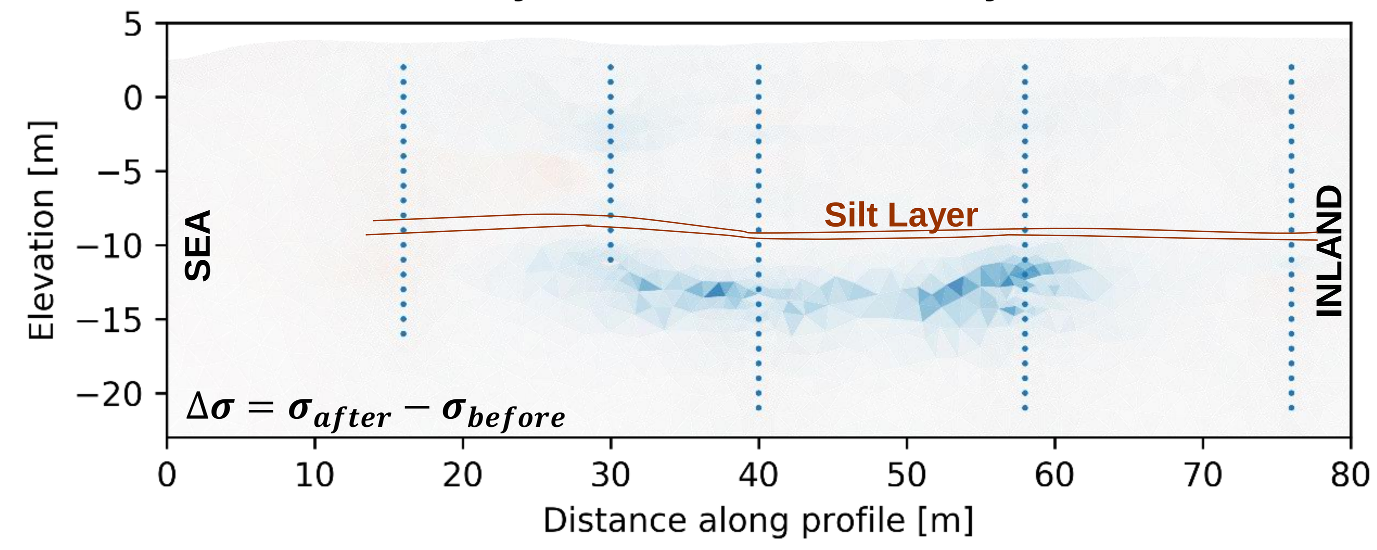
*Saltwater-bearing sands (**semi-confined** aquifer)*



Heavy Rain Events Decrease Conductivity

In October 2016, 250mm of precipitation in a few hours. The salinity in the saline wedge decreased thanks to fresh water infiltration.

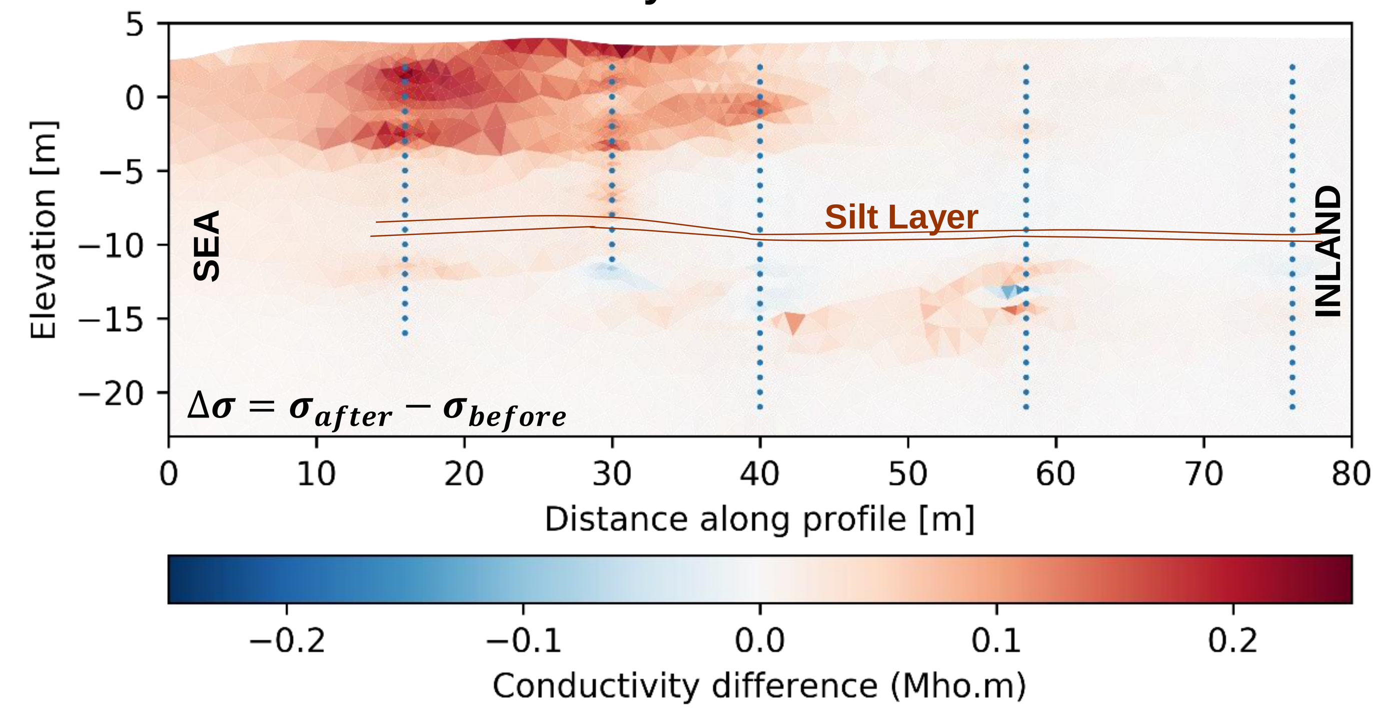
Conductivity variation after a Heavy Rain event



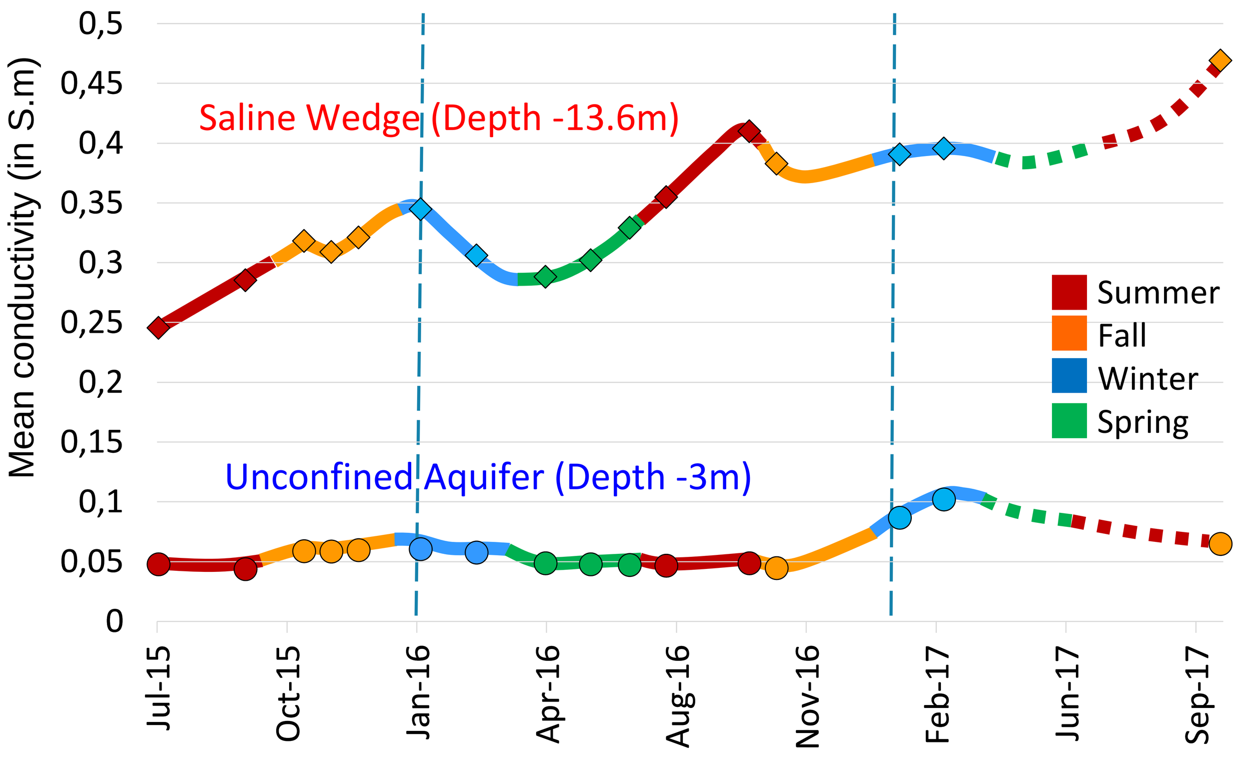
Storm Surges Increase Conductivity

Early 2017, strong winds increased sea level and wave activity, affecting the upper part of the unconfined aquifer.

Conductivity variation after Storms



Seasonal variations and Salinization of the wedge



- Conductivity of the unconfined aquifer did not significantly vary, except during and after storm period.
- Mean conductivity variations in the semi-confined aquifer show a response with respect to seasons and an overall increase of salinity.

6. CONCLUSION

CHERT experiment improved our understanding of the SWI dynamics in the Argentona field site and captured the aquifer and saline wedge responses to important yearly events such as heavy rains and storms.

7. REFERENCES

- Bellmunt, F., Marcuello, A., Ledo, J., Queralt, P., Falgàs, E., Benjumea, B., Velasco, V., Vázquez-Suñé, E., 2012. Time-lapse cross-hole electrical resistivity tomography monitoring effects of an urban tunnel. J. Appl. Geophys. 87, 60–70. https://doi.org/https://doi.org/10.1016/j.jappgeo.2012.09.003
- Daily, W., Ramirez, A., 1992. Electrical resistivity tomography of vadose water movement. Water Resour. Res. 28, 1429–1442. https://doi.org/10.1029/91WR03087
- Jordi, C., Doetsch, J., Günther, T., Schmelzbach, C., Robertsson, J.O.A., 2018. Geostatistical regularization operators for geophysical inverse problems on irregular meshes. Geophys. J. Int. 213, 1374–1386. https://doi.org/10.1093/gji/ggy055
- Rücker, C., Günther, T., Wagner, F.M., 2017. pyGIMLi: An open-source library for modelling and inversion in geophysics. Comput. Geosci. 109, 106–123. https://doi.org/10.1016/j.cageo.2017.07.011
- Waxman, M.H., Smits, L.M., 1968. Electrical Conductivities in Oil-Bearing Shaly Sands. Soc. Pet. Eng. J. 8, 107–122.

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