Geophysical survey in a coastal aquifer for monitoring saltwater intrusion dynamics

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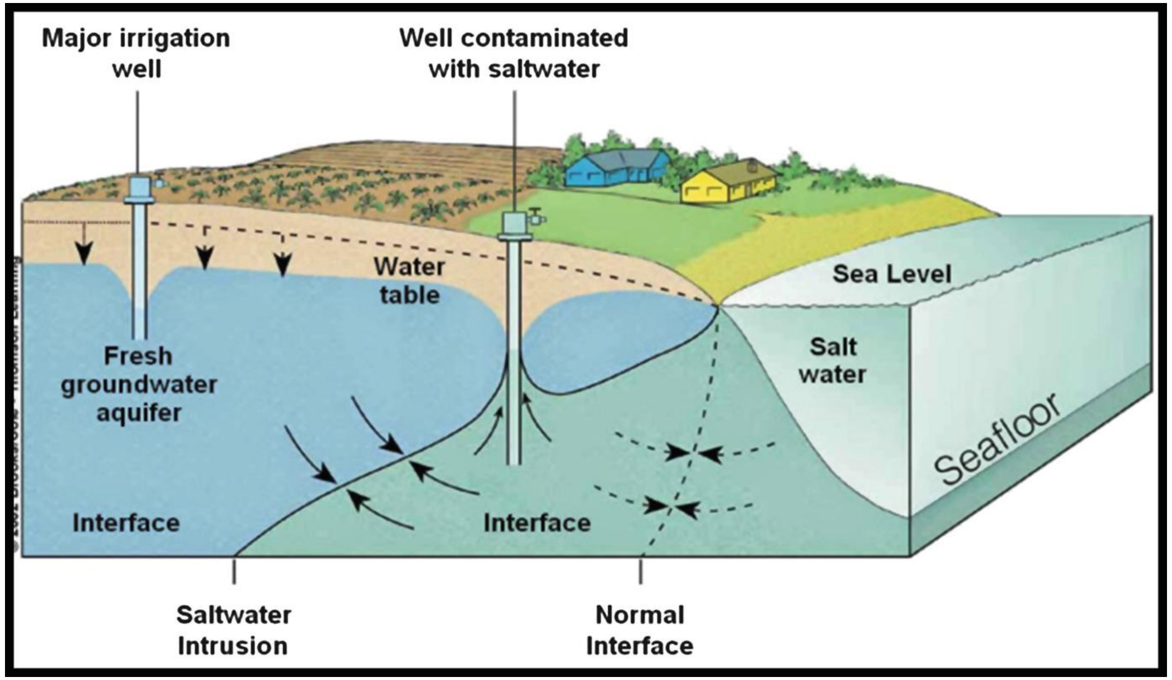
Motivation and goal

Saltwater intrusion causes a depletion of the resource by reducing potable and irrigation freshwater supplies and causing severe deterioration of groundwater quality.

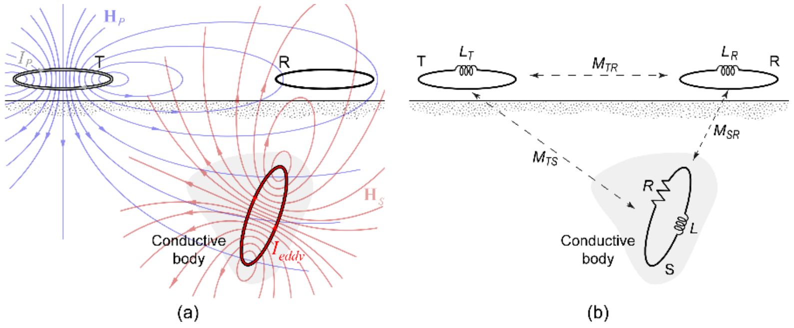


Traditional techniques that rely on measurements in pumping wells often fail to provide accurate and detailed information due to the uneven distribution of wells and the limited ability to collect synchronous data at various depths.

Presentation Outline

1. Study area

2. Methodology



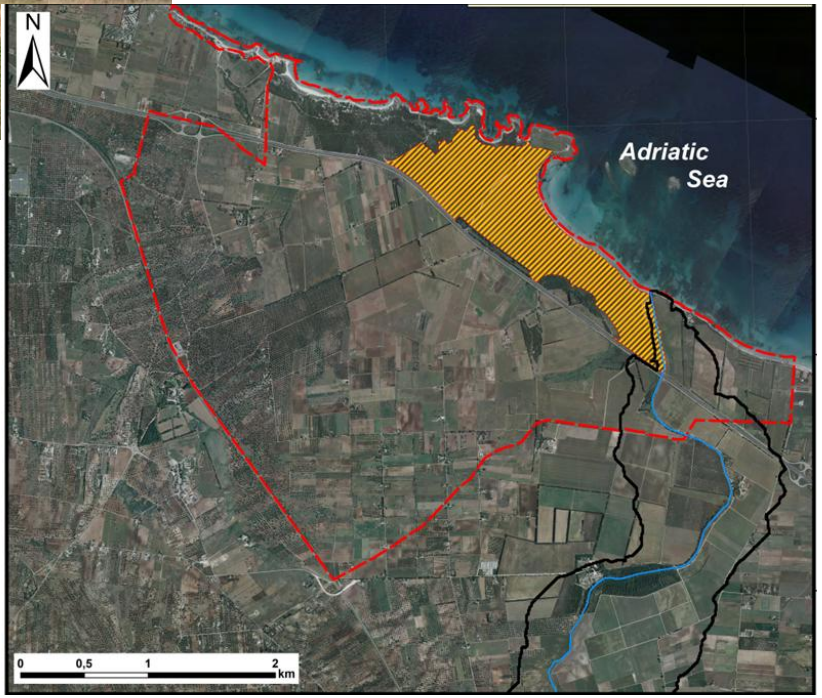
3. Data collection

4. Results

1. Study area

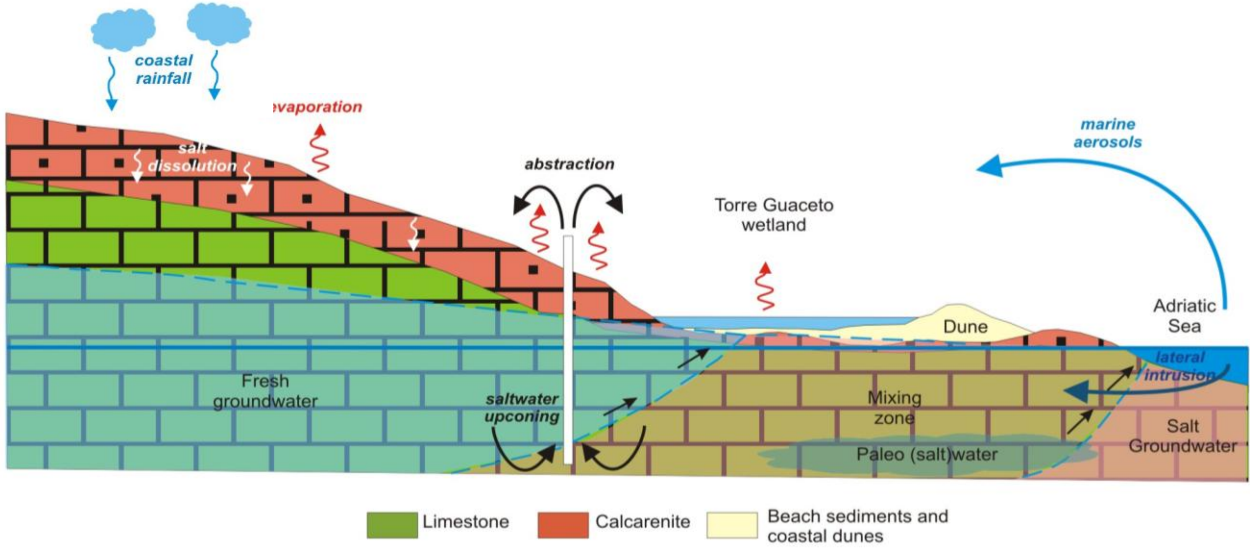
TORRE GUACETO WETLAND

A Natural State Reserve hosting a coastal wetland surrounded by an intensive agricultural landscape in the southeastern part of the Apulia region (Southern Italy)



- ✓ The Natural State Reserve of Torre Guaceto is a 1.120 ha area, for 8 km of coastal length;
- ✓ Ramsar Convention on Wetlands Ramsar as site no. 215;
- ✓ It is a WWF Nature Reserves.
- ✓ The name "GUACETO" comes from the Arabic terms "GAW SIT" that means "freshwater site".
- ✓ At present, the reserve is administrated by Consorzio di Gestione di Torre Guaceto.

1. Study area



CONCEPTUAL MODEL

- ✓ A thick karstified carbonate aquifer;
- ✓ Transition (mixing) zone - freshwater floats over intruded saltwater;
- ✓ Upconing zone – rising of the SW-FW interface due to overexploitation;
- ✓ Marine aerosol and intensive irrigation practices

GOAL OF THE PROPOSED STUDY

- ✓ define a schematic hydrogeological setting of the area through a geophysical survey;
- ✓ identify a highly conductive plume associated to the saltwater and define its extension;
- ✓ monitor the variation of such plume over time;
- ✓ merge geophysical and hydrological data into a predictive model

2. Methodology: ELECTROMAGNETIC INDUCTION (EMI) TECHNIQUE

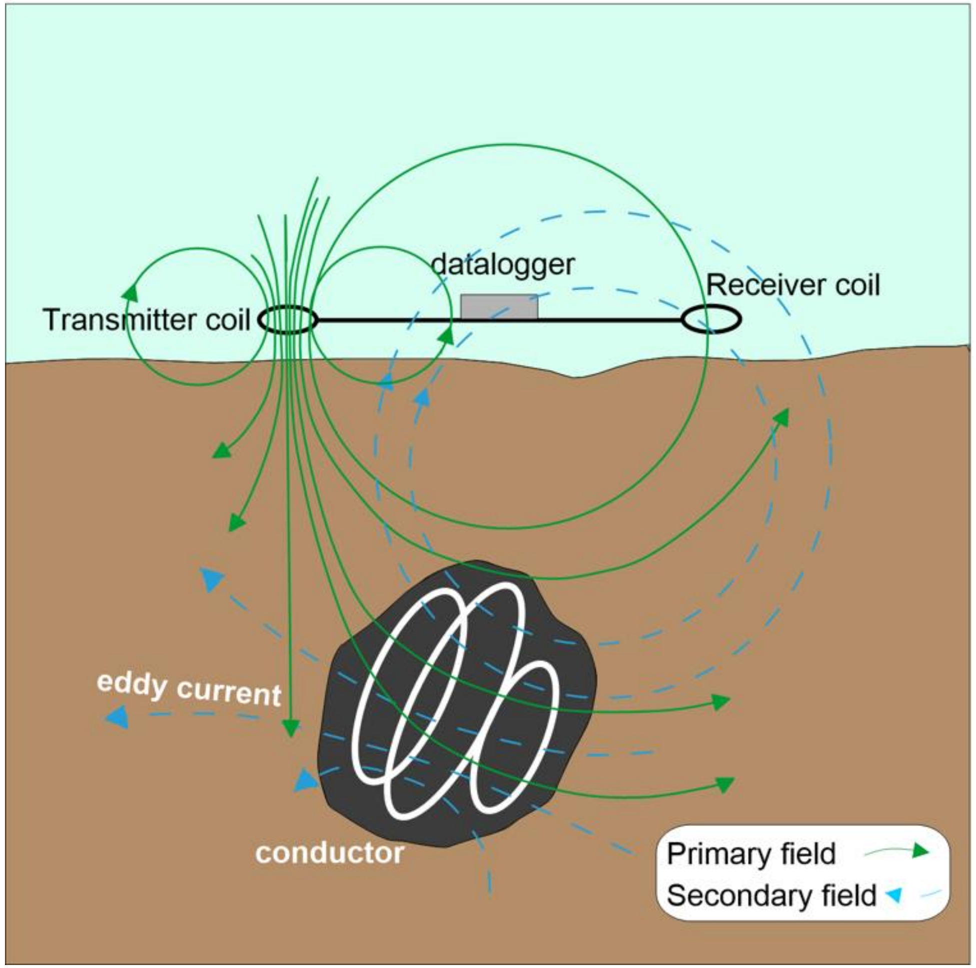
Advantages

- ✓ Noninvasive measurements with limited costs;
- ✓ High spatial data coverage with variable resolution;
- ✓ Identification of 2D-3D subsurface structures;
- ✓ Monitoring flow and transport processes.

Limitations

- ✓ Require calibration with traditional data (sampling, drilling);
- ✓ EC depends on several factors;
- ✓ Limited investigation depth.

2. Methodology: ELECTROMAGNETIC INDUCTION (EMI) TECHNIQUE



- ✓ An alternating sinusoidal current in the transmitter produces a primary magnetic field HP, which induces small eddy currents in the subsurface.
- ✓ These currents produce, in turn, a secondary magnetic field HS, which is sensed by the receiver.
- ✓ The ratio HS/HP of the secondary to the primary magnetic fields is measured by the device, providing information about the amplitude and the phase of the signal.
- ✓ The imaginary part, also called the out-of-phase or quadrature component, mainly by the electrical conductivity.
- ✓ The real part, or the in-phase component, of the measured signal is mainly affected by the magnetic permeability of the subsoil.

3. Data collection - EMI campaigns

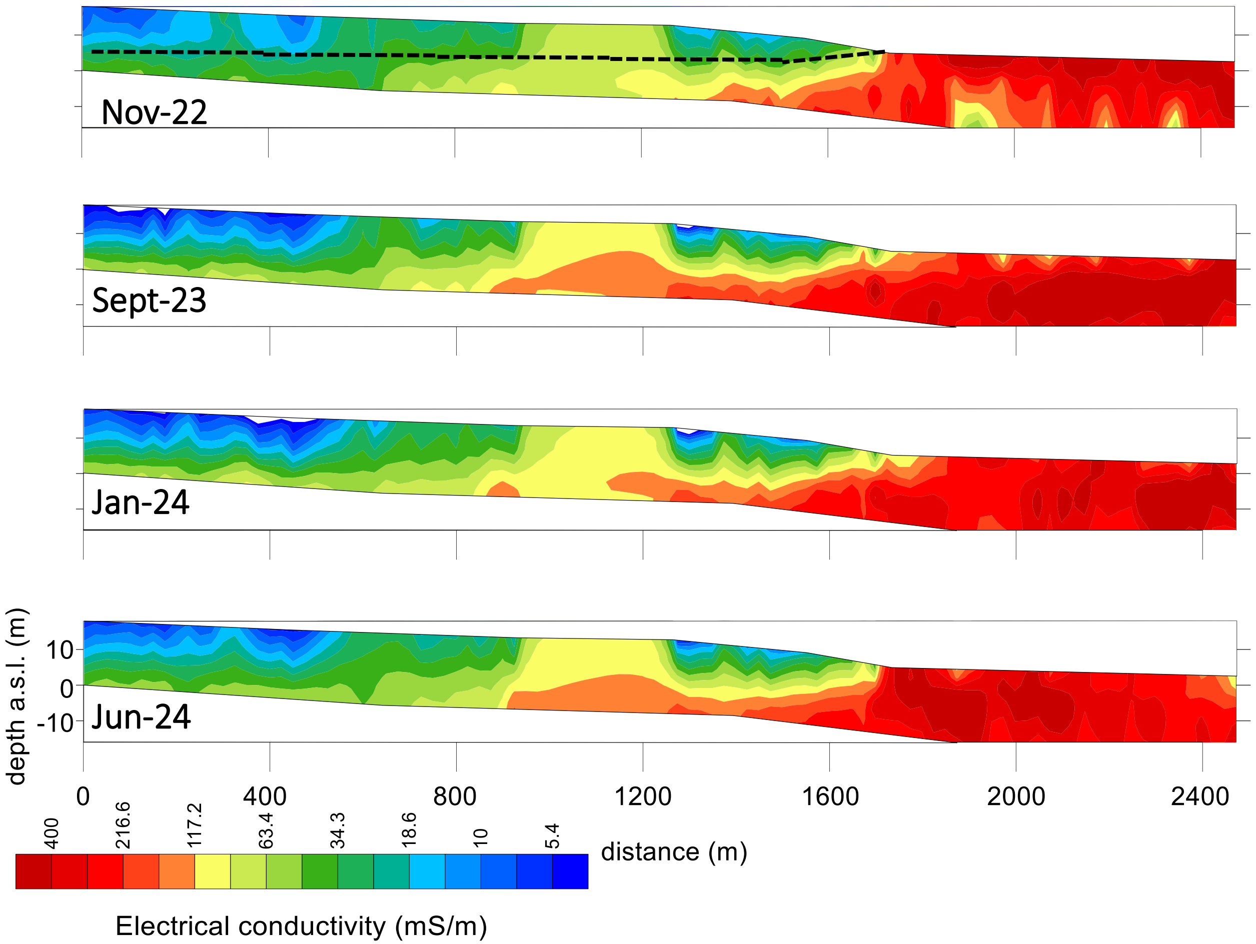
- ✓ EMI campaigns were performed between November 2022 and June 2024;
- ✓ Transect 2.5 Km long, located about perpendicular to the coastline;
- ✓ The CMD DUO sensor (GF Instruments s.r.o., Czech Republic) collected electromagnetic data;
- ✓ On-the-go ECa measurements collected along the transect

- ✓ A combination of three different cables (10 m, 20 m, and 40 m long) and coils configuration (VCP and HCP) was used to deepen the investigation to the maximum depth;
- ✓ More than 5000 data collected in 2 hours

3. Data collection - Hydrogeological monitoring

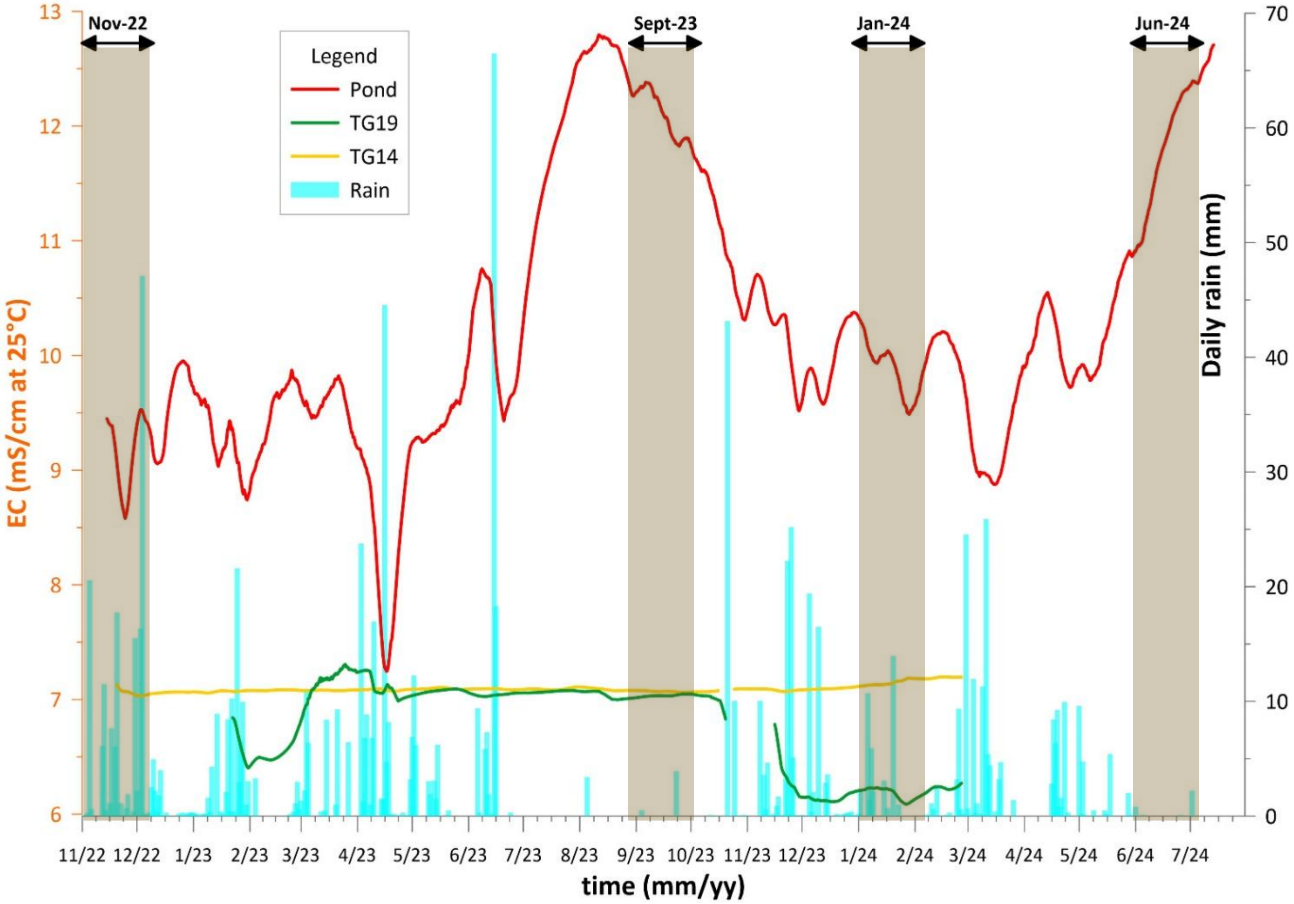
- ✓ Three monitoring points (TG14, TG19, and PND00);
- ✓ Electrical conductivity (EC), temperature (T), and water pressure (CTD-Diver®, Van Essen Instruments B.V.);
- ✓ A barometer (BARO) to compensate for the variations in atmospheric pressure
- ✓ High frequency data collection every 3 hours;

4. Geophysical results



- ✓ Layered model upstream of the cross-section: an upper resistive body (EC < 20 mS/m) overlaying a lower conductive one (20 < EC < 70 mS/m);
- ✓ A sloping discontinuity surface (black dotted line) marks the transition between the resistive unsaturated zone and the conductive groundwater;
- ✓ The upper resistive layer thins and eventually disappears at approximately 1700 m from the start of the cross-section.
- ✓ The electrical conductivity of the bottom layer increases as we move towards the sea, about 1250 m from the start of the section, due to groundwater salinity rising (EC>10 mS/m up to 200 mS/m).

5. EC monitoring



- ✓ Salinity influence from inland to the coast.
- ✓ In well TG14 EC remains almost constant;
- ✓ In well TG19 EC increases consistently during the irrigation period;
- ✓ In the pond EC is strongly affected by precipitation.

Future work

- ✓ Keeping long-term geophysical monitoring. This involves periodical observation of the bulk electrical conductivity over time.
- ✓ Identifying seasonal variations in the bulk electrical resistivity. This refers to tracking changes related to the movement of the saline plume with different weather conditions;
- ✓ Recording high-frequency fluctuations of the upper groundwater.
- ✓ Predicting future scenarios with a numerical model that merges geophysical and hydrological data