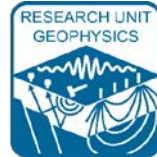




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# Geophysical characterization of an industrial landfill to quantify raw materials and detect possible leakages

Lukas Aigner and Adrián Flores Orozco

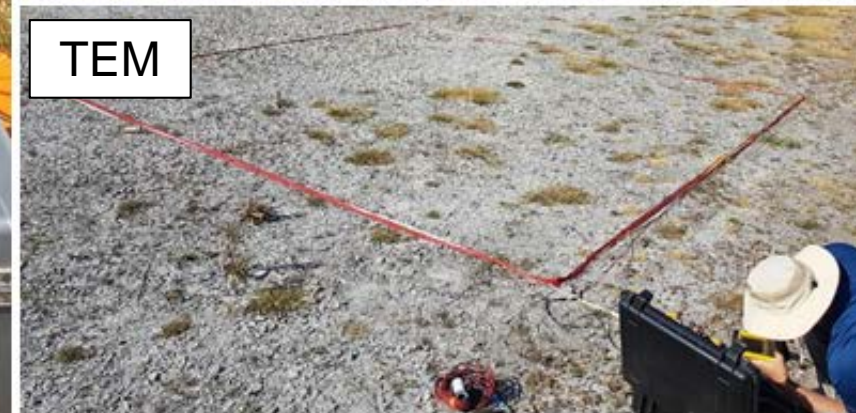
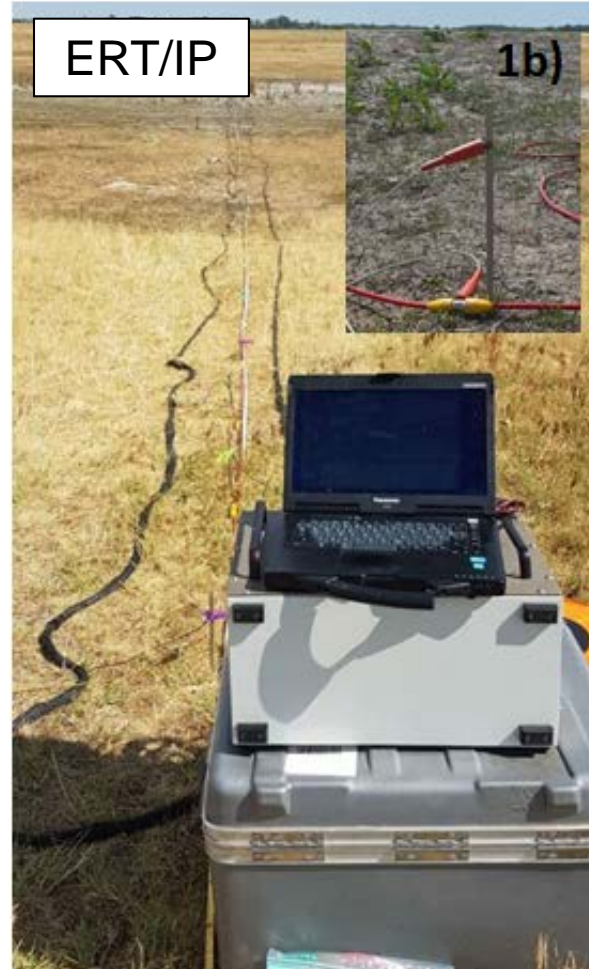
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- Objectives
- Electrical methods in landfills capped with a PVC liner
- Why electromagnetic methods?
- Virtual boreholes
- Results
- Outlook

- Investigation of a landfill capped with a PVC liner using electrical and electromagnetic geophysical methods
- Characterize landfill geometry and changes in waste composition
- Identify wet areas in the landfill and the underlying materials.

- These methods are sensitive to the electrical conductivity ( $\sigma$ )
- The electrical conductivity increases with
  - Increasing salinity ( $\sigma_w$ )
  - Increasing the soil moisture ( $S^n$ )
  - Increasing interconnected porosity ( $\Phi^m$ )
  - Increasing organic and metallic content ( $\sigma_s$ )

$$\sigma = \Phi^m S^n \sigma_w + \sigma_s$$



Use of conductivity and polarization properties for an improved interpretation

- The electrical conductivity ( $\sigma'$ )
- The polarization effect ( $\sigma''$ )

$$\sigma^*(\omega) = \sigma'(\omega) + i\sigma''(\omega)$$

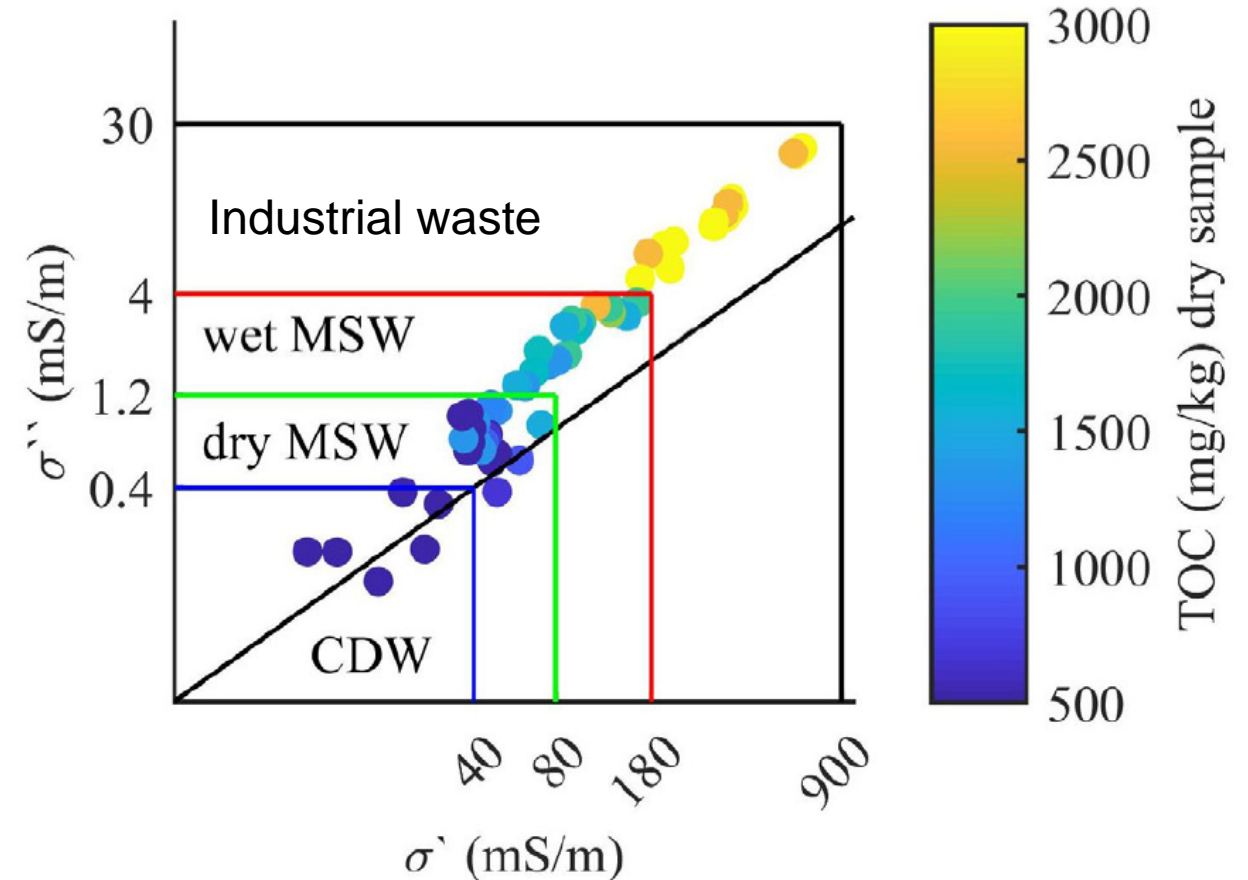


Figure modified from Flores Orozco et al., 2020 in Waste Management  
<https://doi.org/10.1016/j.wasman.2020.04.001>

- Measurements of the electrical conductivity – from the voltage-to-current ratio
- Measurements of the capacitive properties (or polarization) as the delay between voltage and current

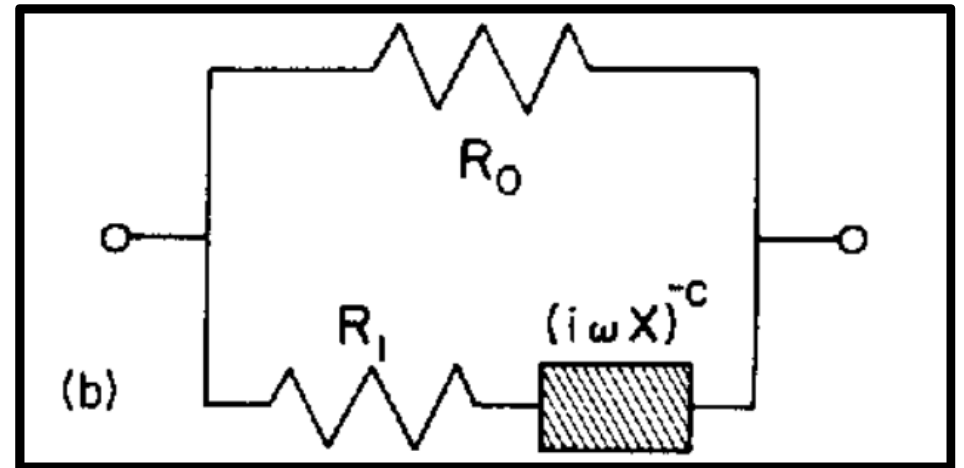
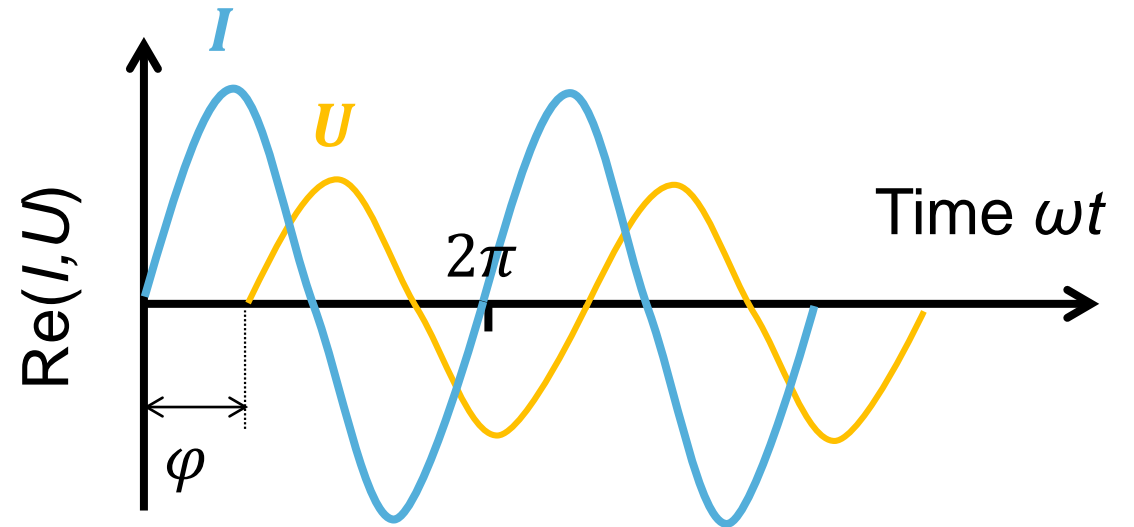
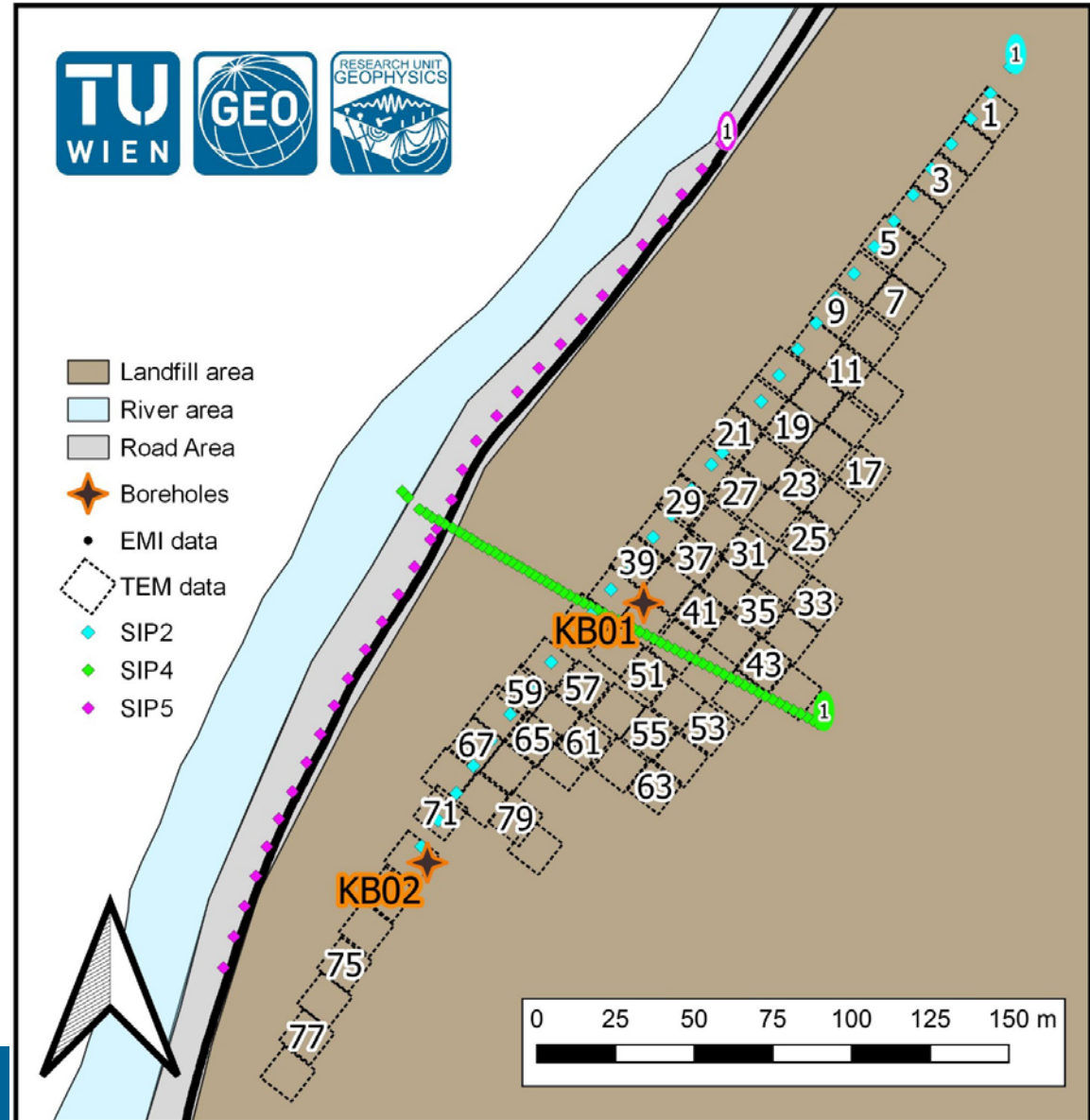


Figure from: Pelton et al., (1978). Geophysics

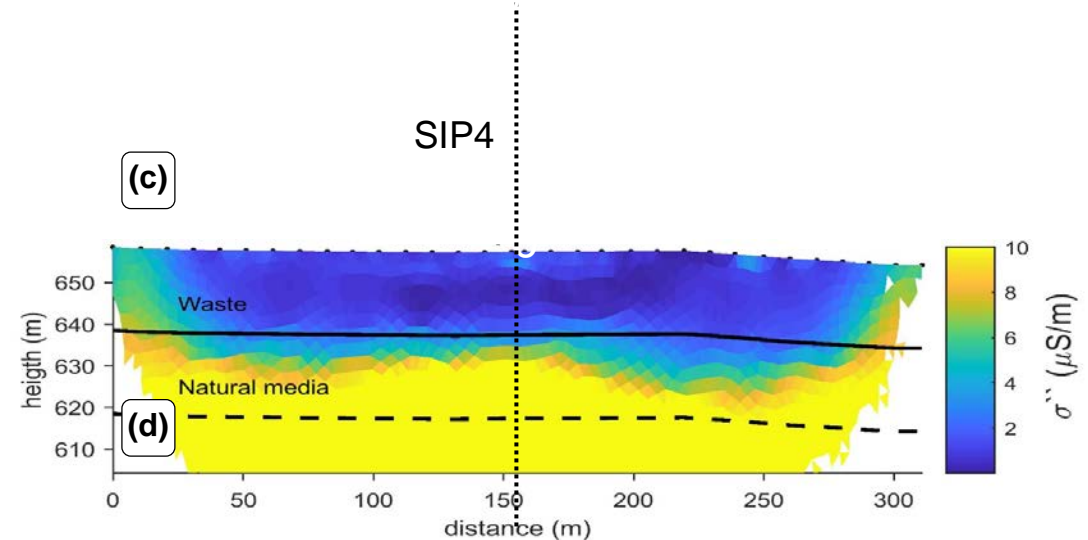
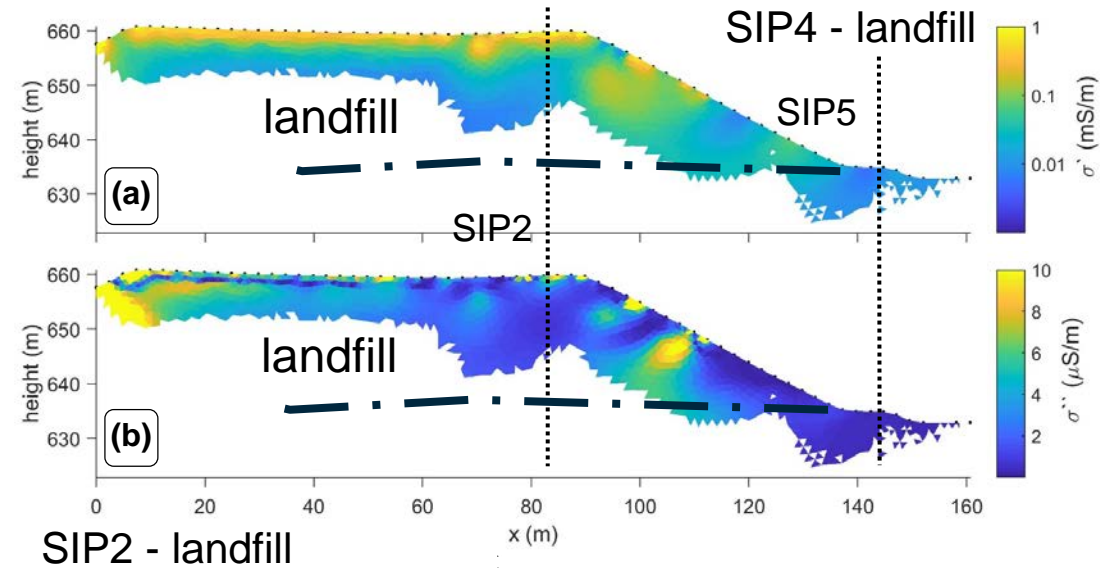
# Geophysical measurements at the industrial landfill

- 3 electrical SIP profiles
  - DAS1 system (by MPT-IRIS corp.)
  
- 81 TEM soundings
  - TEM-FAST 48 system (AEMR corp.)
  - 12.5 m loop
  - 4 A current
  
- Ground conductivity meter (EMI) profiling
  - CMD Explorer
  - Shallow conductivity mapping



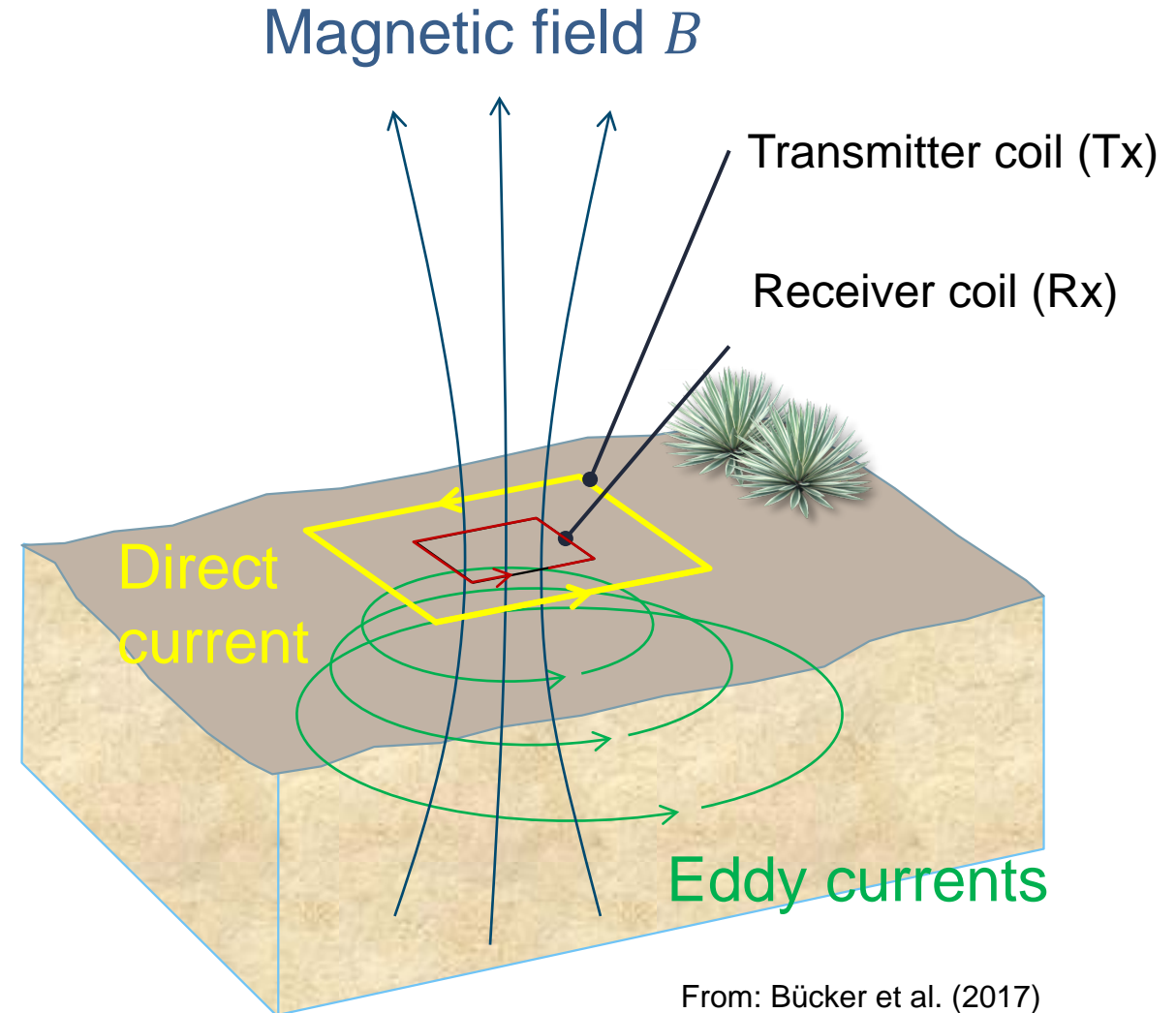
- SIP4 – crossing landfill
  - 2.5 m electrode separation
  - Low current density within landfill
  
- SIP2 – on top of landfill
  - 10 m electrode separation
  - Low current flow within the landfill

→ Electrical methods may be biased due to the PVC liner hindering current injection into the landfill!





- TEM does not require galvanic contact, only uses a wire laying on the ground
- TEM is based on the generation of an electromagnetic (EM) wave in a transmitter coil (Tx)
- Voltage measurements in a receiver coil (Rx) due to a secondary EM field induced in the subsurface



- Requires only a single copper cable as antenna
- Measurement device fits into a backpack
- Up to 100 soundings per day with 2 people
- TEM depth of investigation depends on loop size

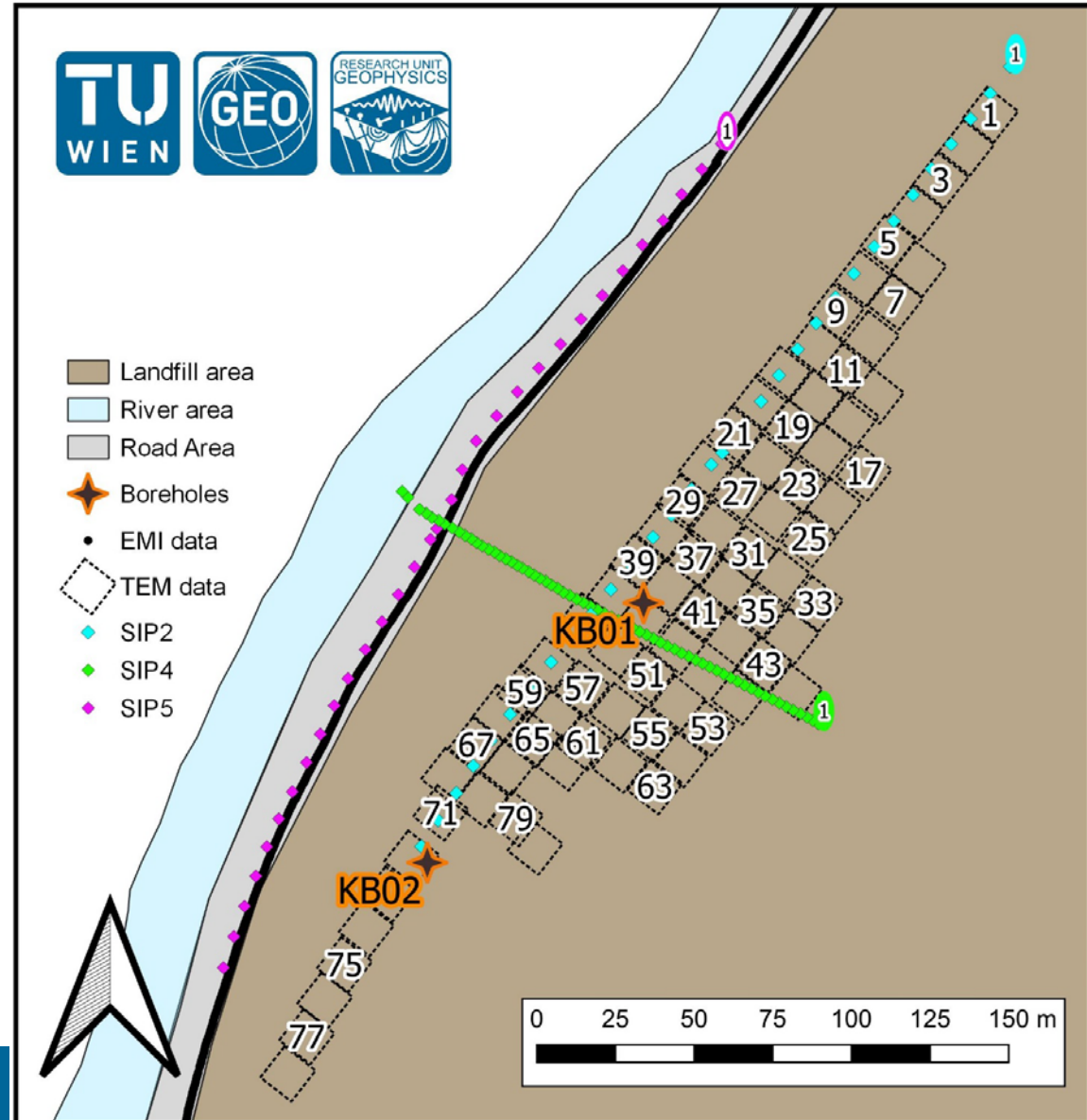


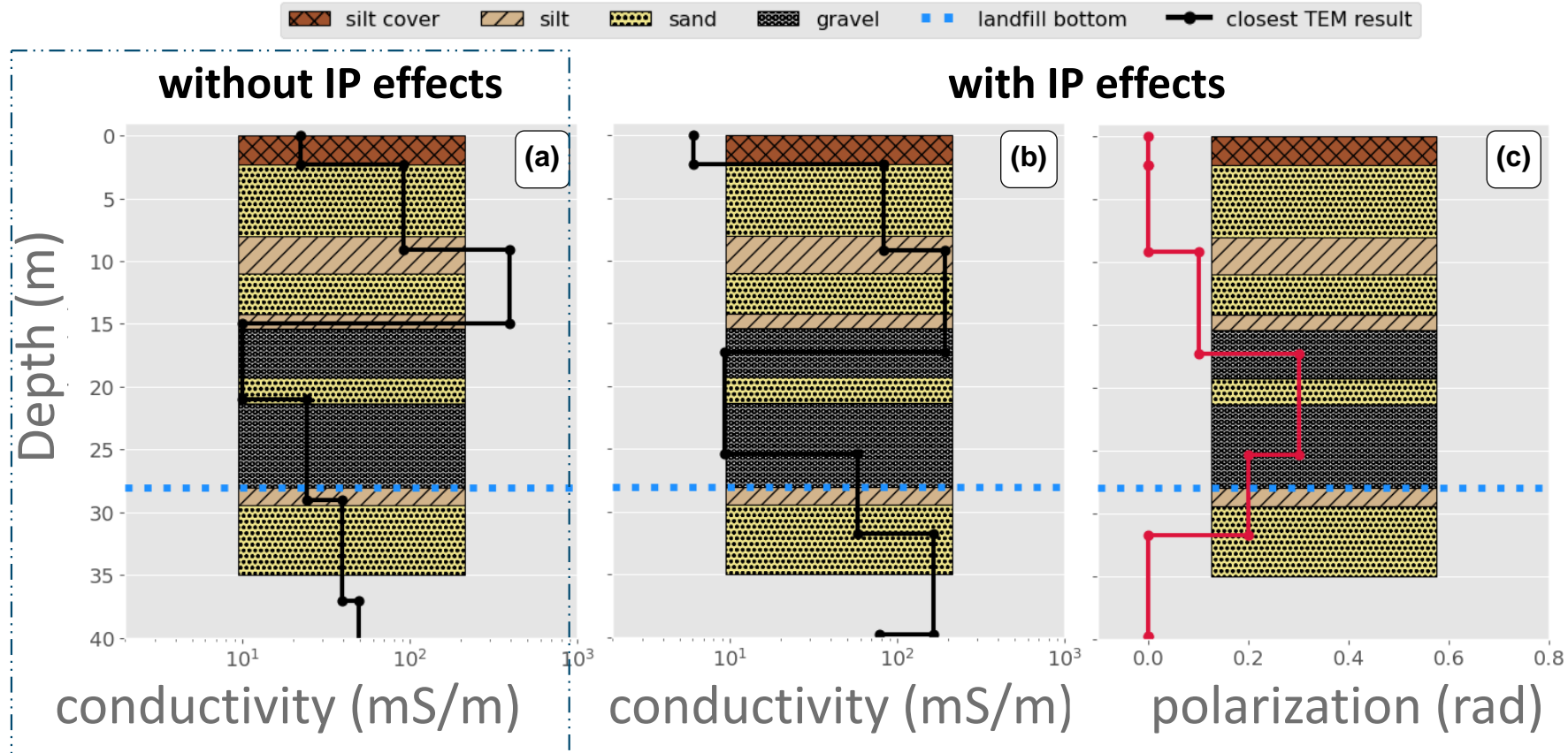
- Modeling frequency dependance of complex conductivity
  - Conductivity at low frequencies ( $\sigma_0$ )
  - Maximum polarization response ( $\phi_{max}$ )

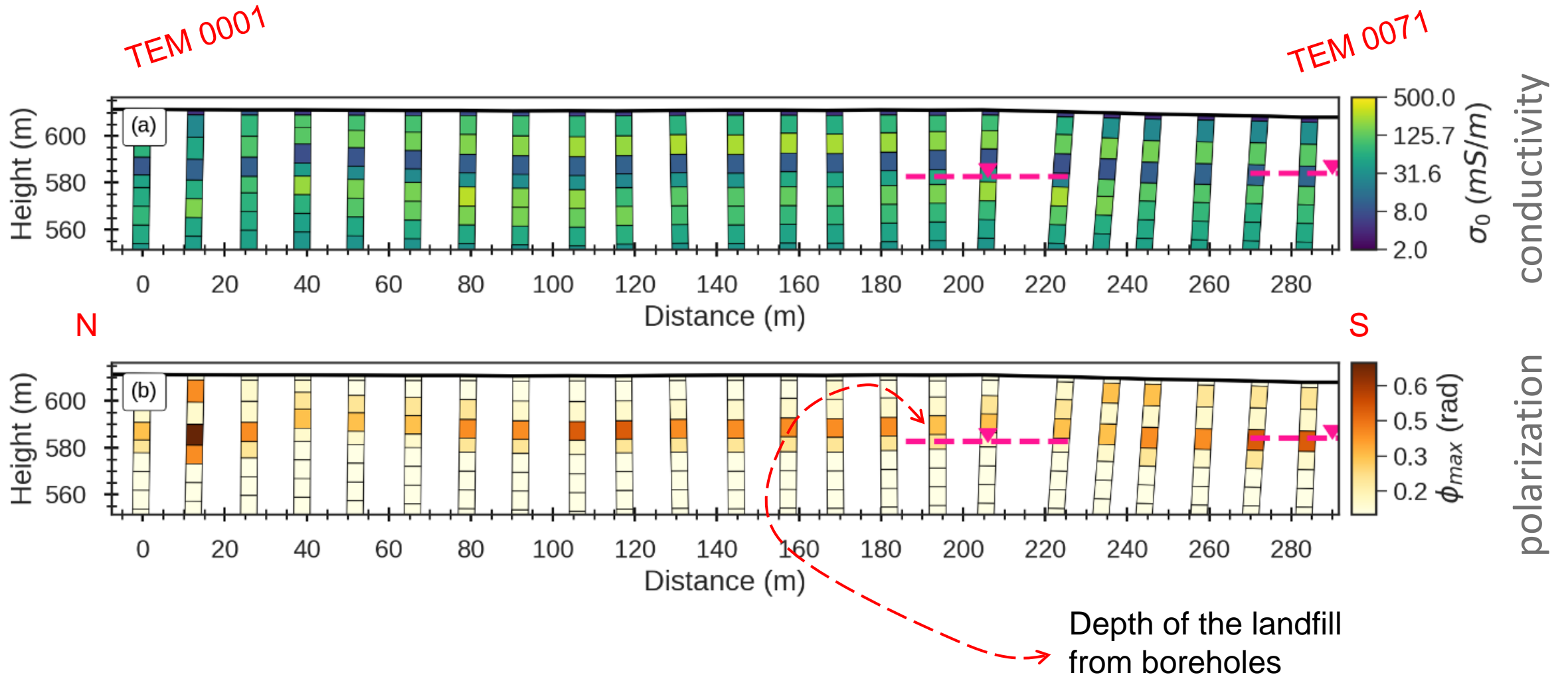
Figure from: Aigner et al., 2024. Journal of Applied Geophysics

# Geophysical measurements at the industrial landfill

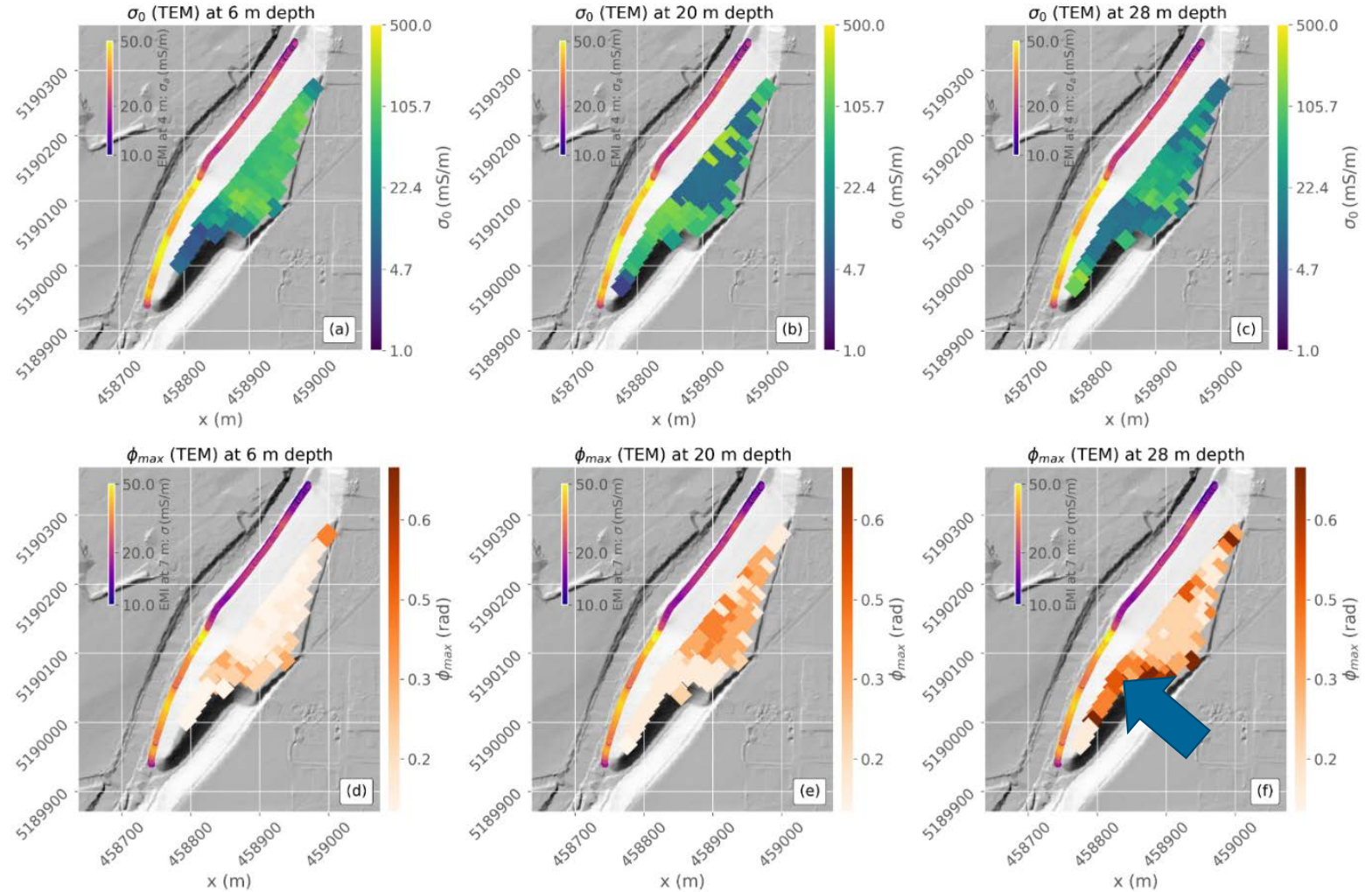
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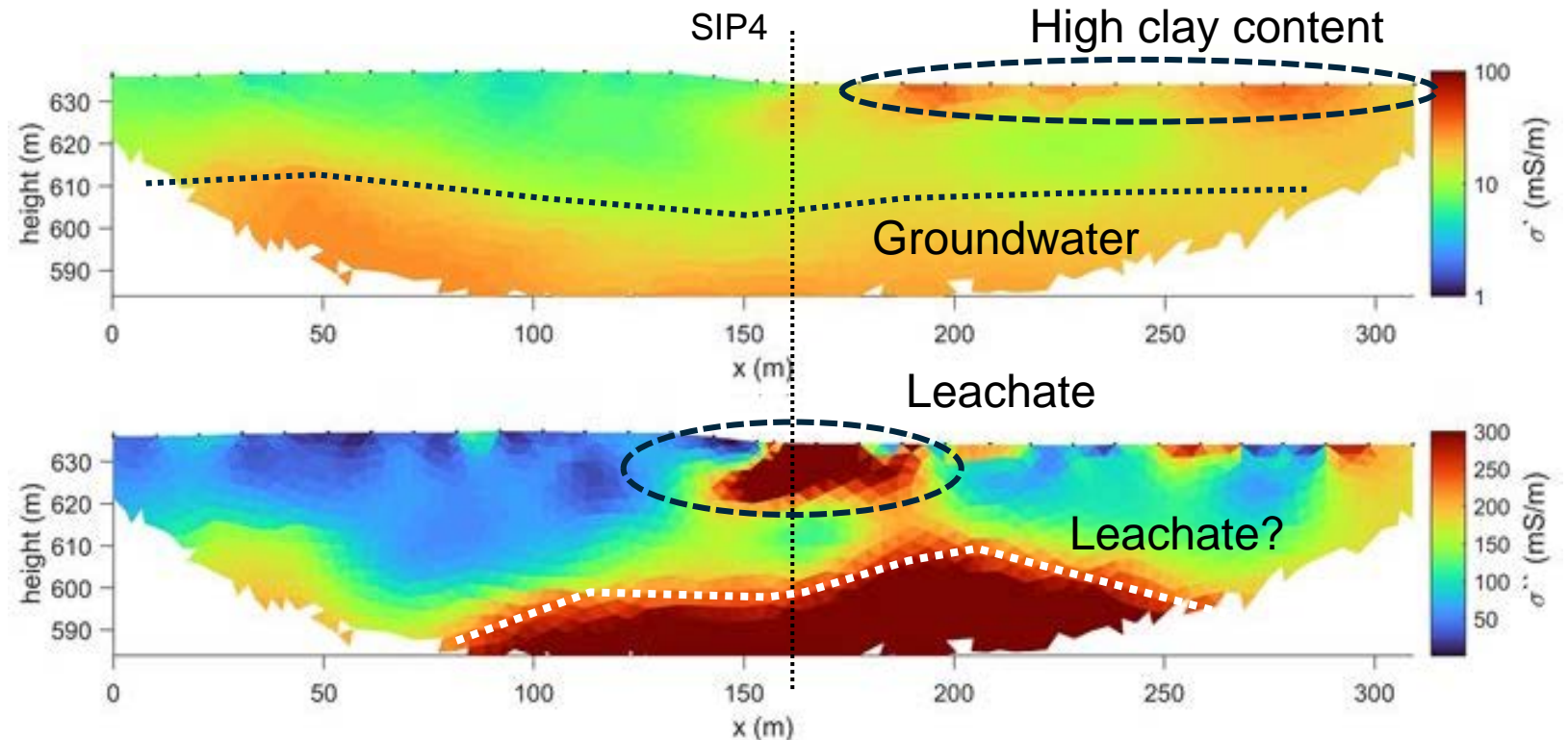
- Depth slices within the landfill  
→ changes in water saturation and waste composition
- Depth slice below the landfill:  
→ possible leachates



conductivity

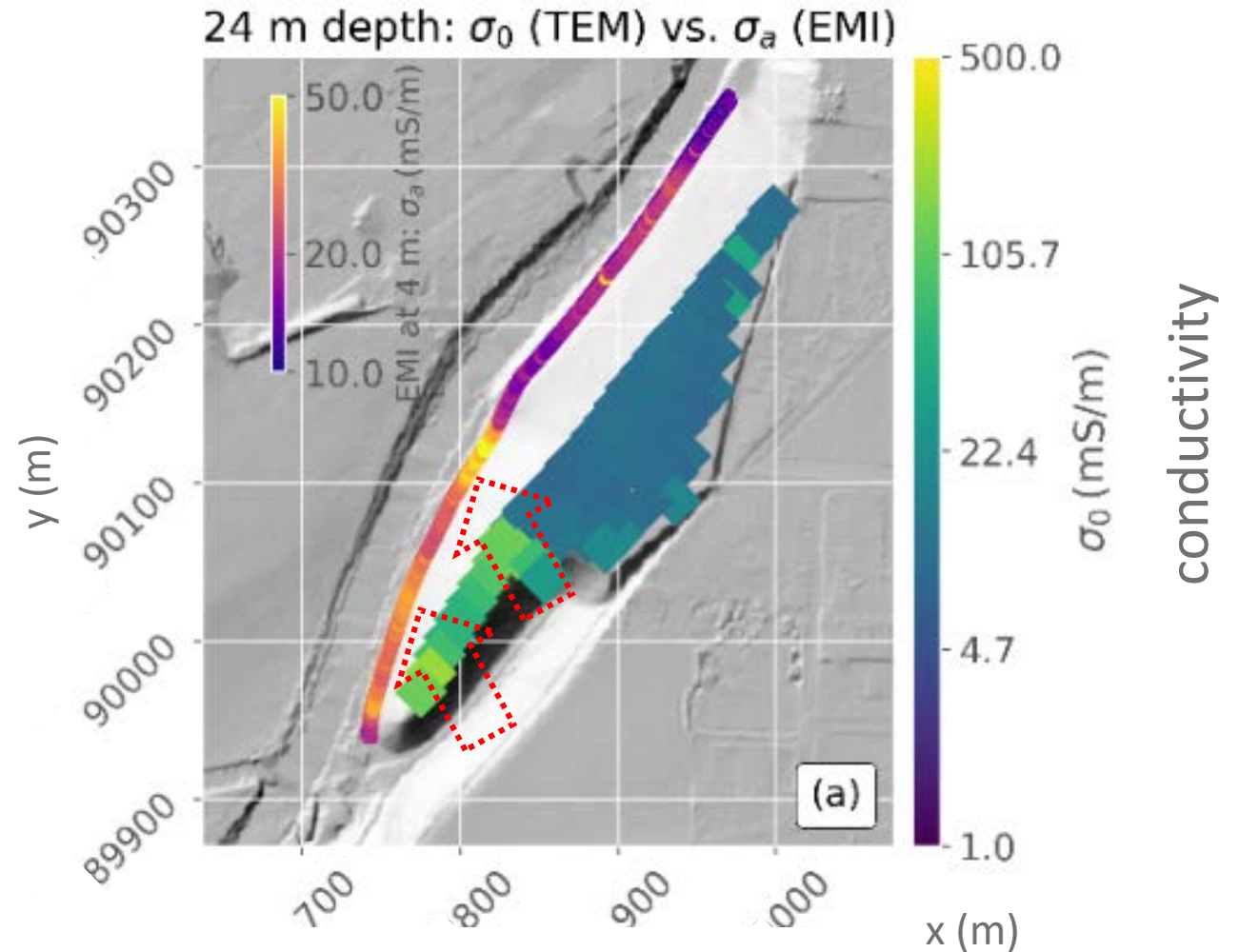
polarization

- SIP5 – outside of the landfill
  - High current density
  - High signal-to-noise ratio
  
- High values of  $\sigma''$  indicate leachates at the bottom of the landfill

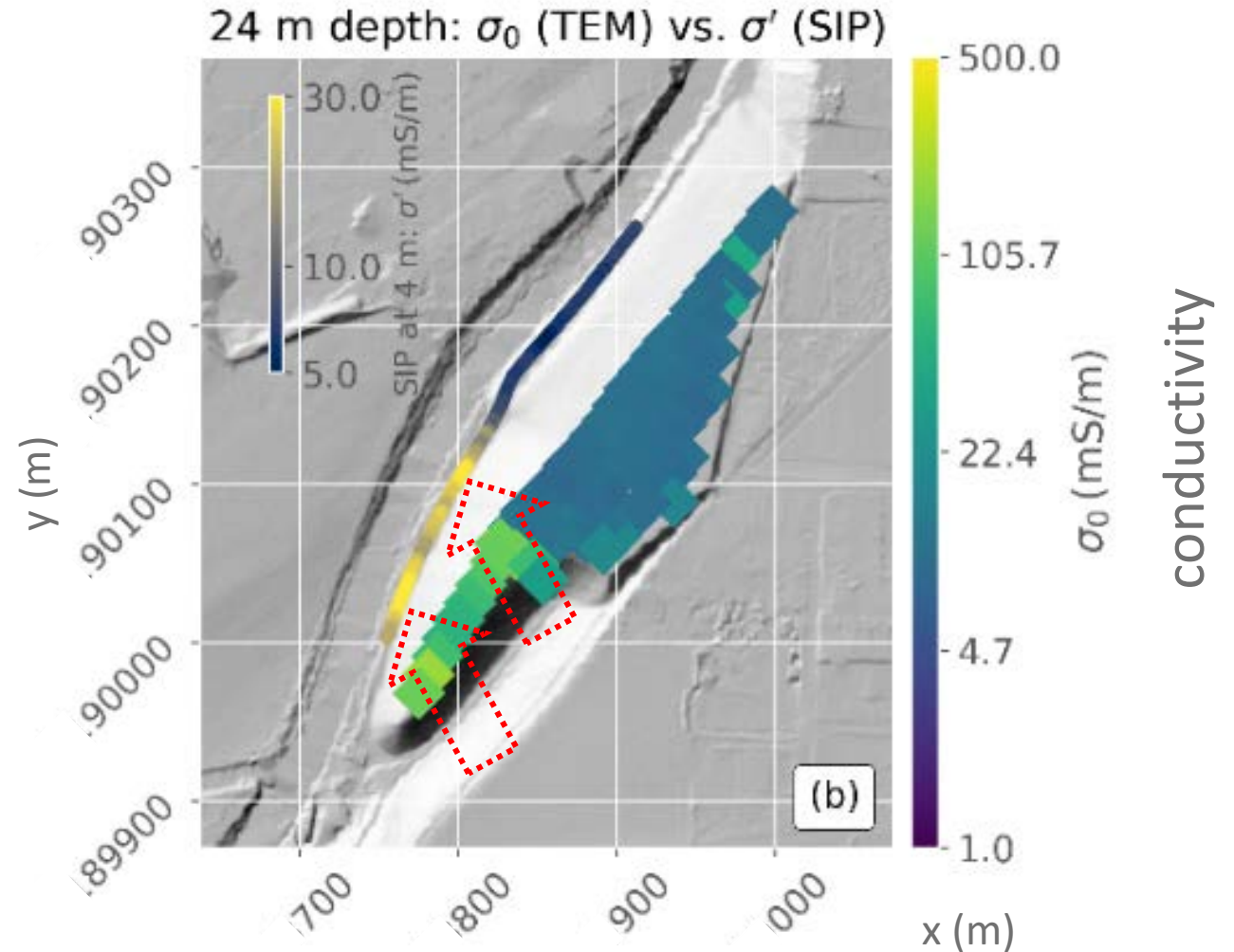




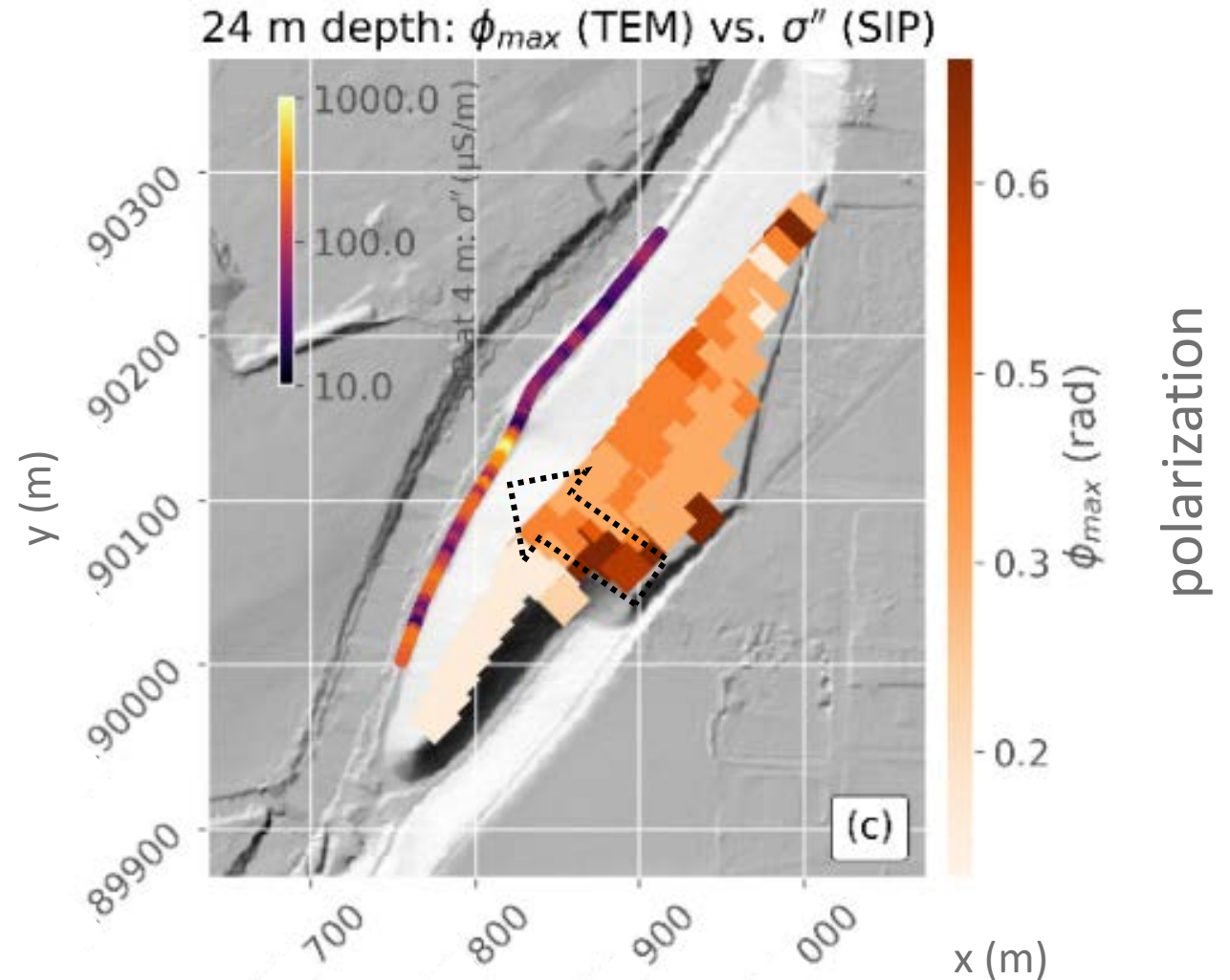
- Ground conductivity meter next to landfill base
- Indicates possible leachate migration
- EMI and TEM anomalies are in good agreement



- Real part of complex conductivity from SIP5
- Increase of  $\sigma'$  24 m below the landfill
- SIP and TEM anomalies are in good agreement



- Imaginary part of complex conductivity  $\rightarrow$  represents polarization
- Increase of  $\sigma''$  below the landfill
- SIP and TEM anomalies are in good agreement



- Limited information from electrical measurements at the landfill due to the capping PVC liner
- Transient electromagnetic (TEM) soundings can be used as virtual boreholes to investigate landfills capped with a PVC liner
- Good agreement between TEM at the landfill and electrical methods in natural media next to the landfill
- Delineation of possible leachates