

Vertical multi-frequency FDEM loop-loop soundings for subsurface conductivity imaging: comparison of HCP and PERP configurations for different environments

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Description

Our primary goal is to efficiently sense the electrical conductivity within the first 50 meters of the subsurface with multi-frequency FDEM soundings using decametric coil spacing.

For this study, we tried to address the following questions:

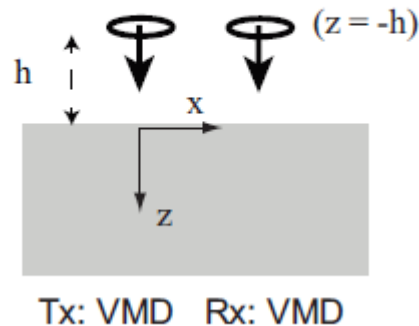
- What is the maximum lateral resolution we can obtain when assuming a layered medium?
- What is the effect of near-surface 2D/3D heterogeneities in practice?
- Is there an optimal acquisition strategy to make the 1D approximation more likely applicable? For example, the PERP configuration is expected to show less severe 2D effects than the HCP configuration.

Experiments:

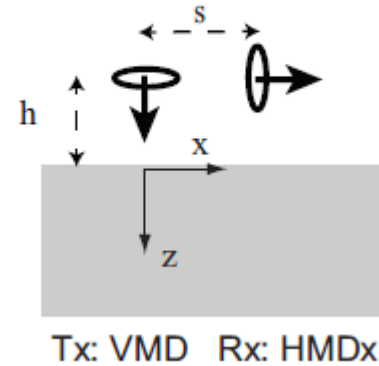
- We recorded dense HCP and PERP FDEM profiles in two different geological environments: one tabular setting in a coastal area and one laterally more complex setting on an alluvial fan in Braunsbach (Germany). In both sites, we compare the LCI 1D inversion of FDEM data to the 2D inversion of ERT data.
- We inverted several synthetic data sets computed for 2D distributions of subsurface conductivity.

Subsurface 2D sensitivities for a coil spacing of 30 m

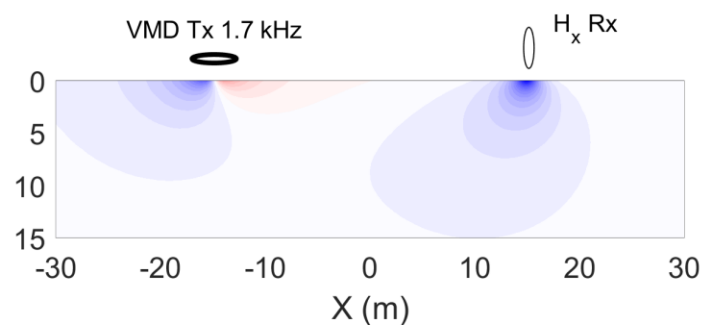
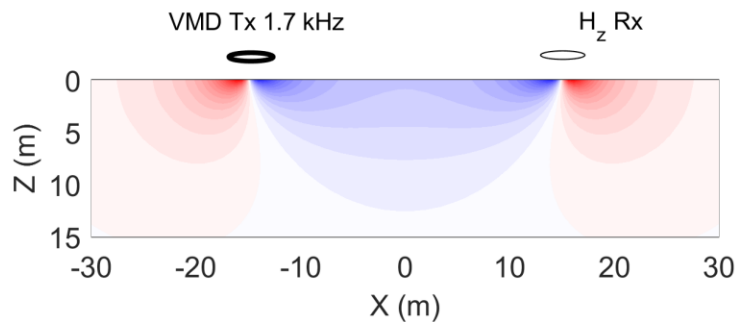
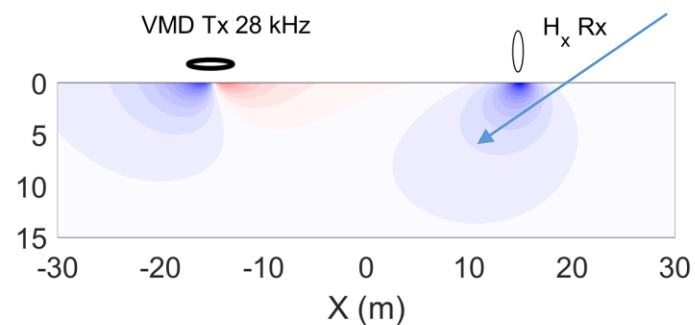
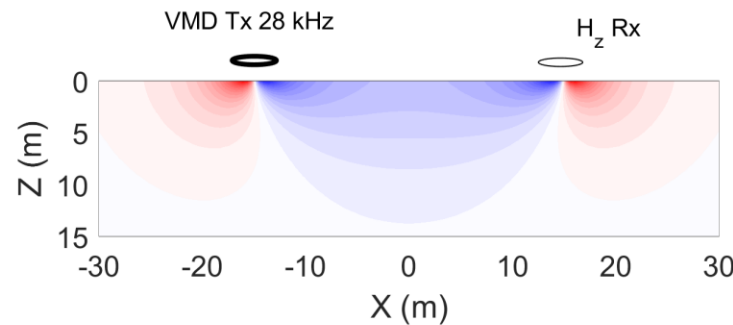
Horizontal coplanar (HCP)



PERP configuration

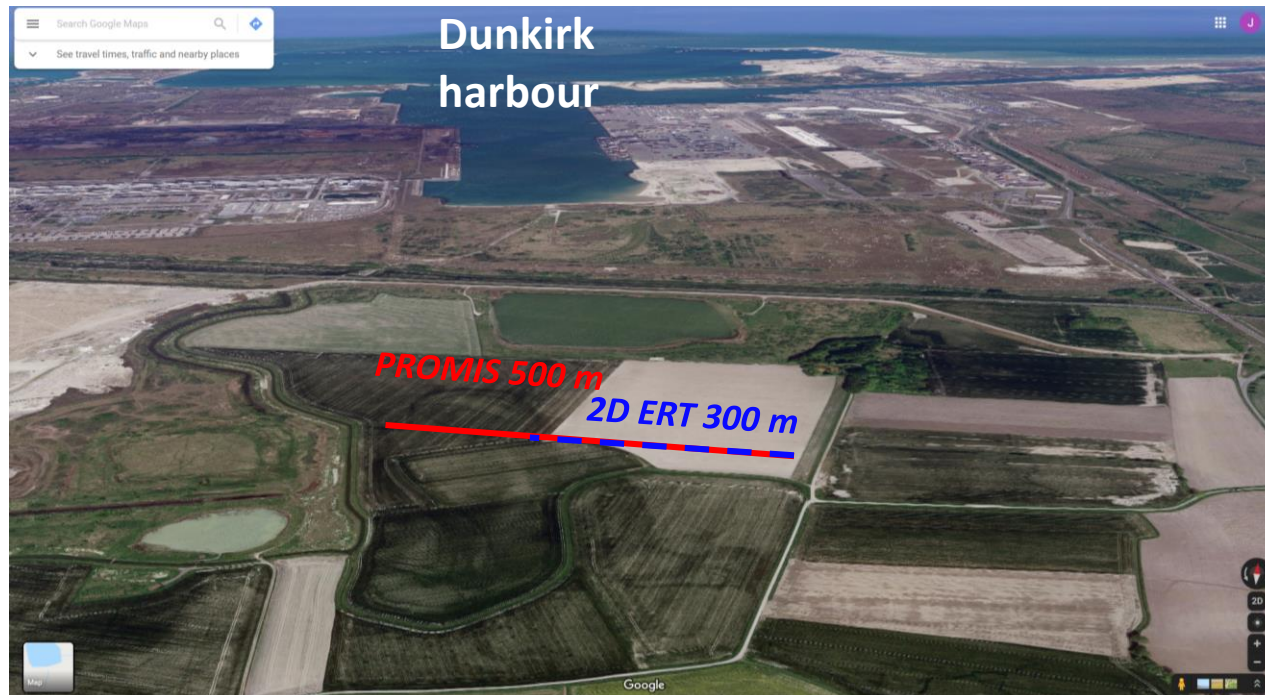
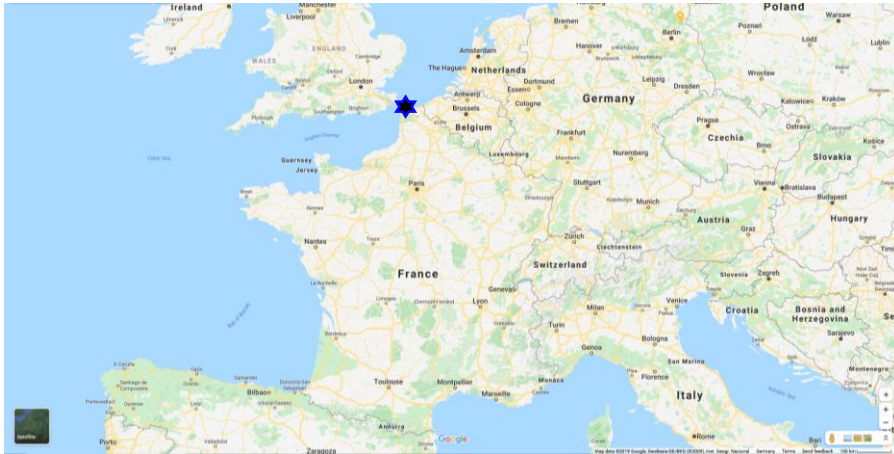


Preponderant sensitivity near the Rx receiver -> should we centre the 1D results near the Rx ?



First field experiment: Loon-Plage (France)

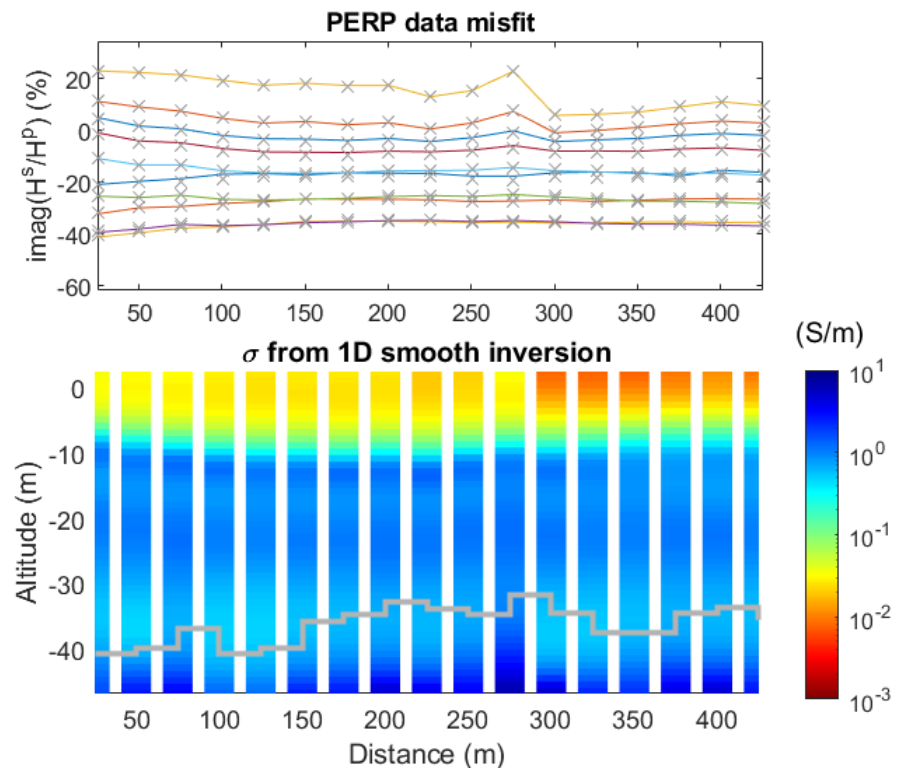
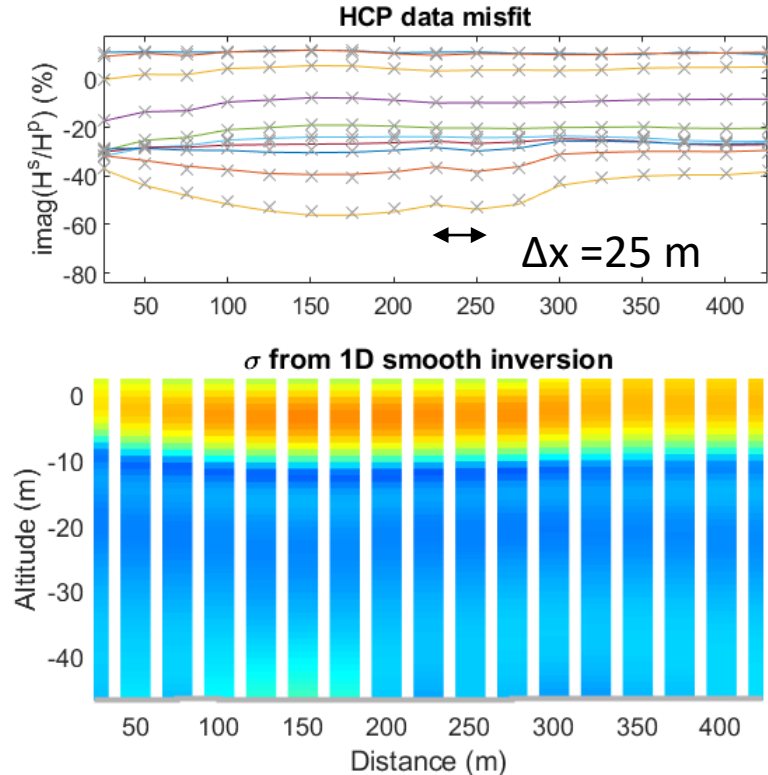
Context: preventive archaeological survey (INRAP) in the framework of the Dunkirk harbour extension.



First field experiment: Loon-Plage (France)

Multi-frequency source, dual component (HCP/PERP).

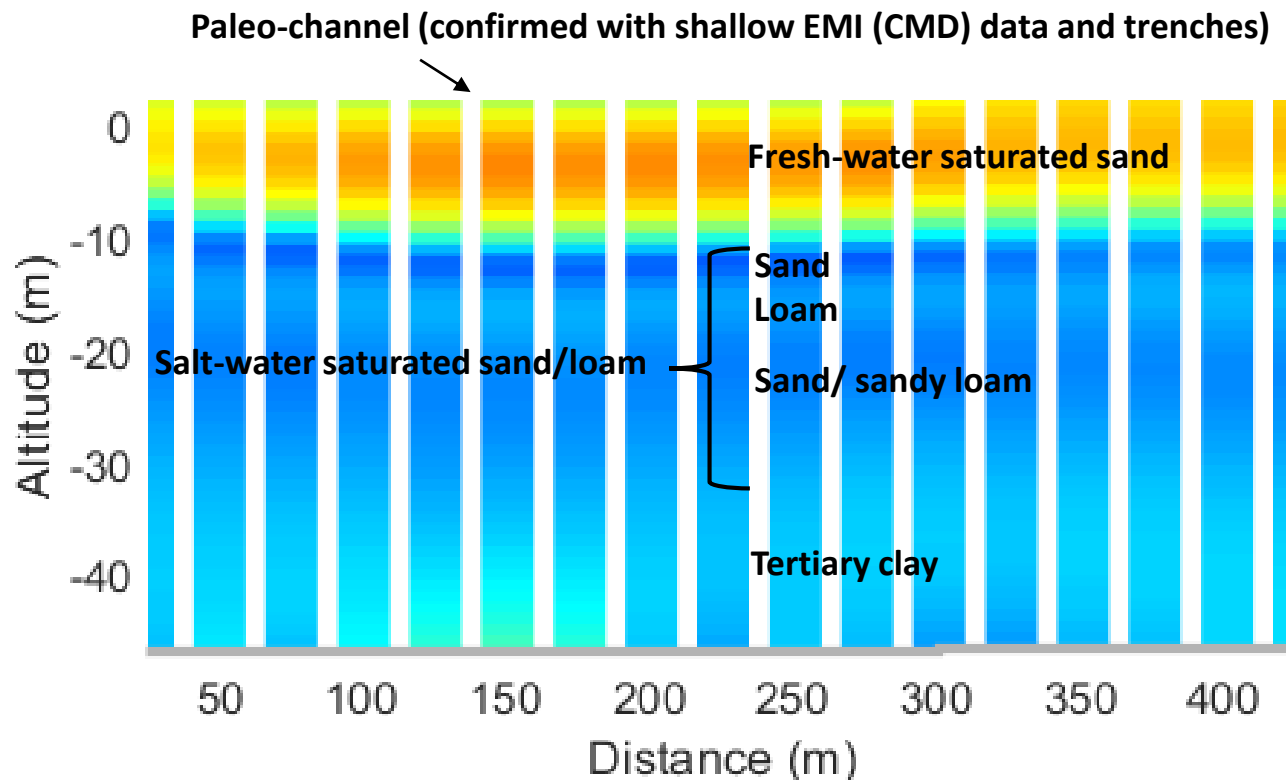
Coil spacing: $s = 50$ m, profile with $\Delta x = 25$ m.



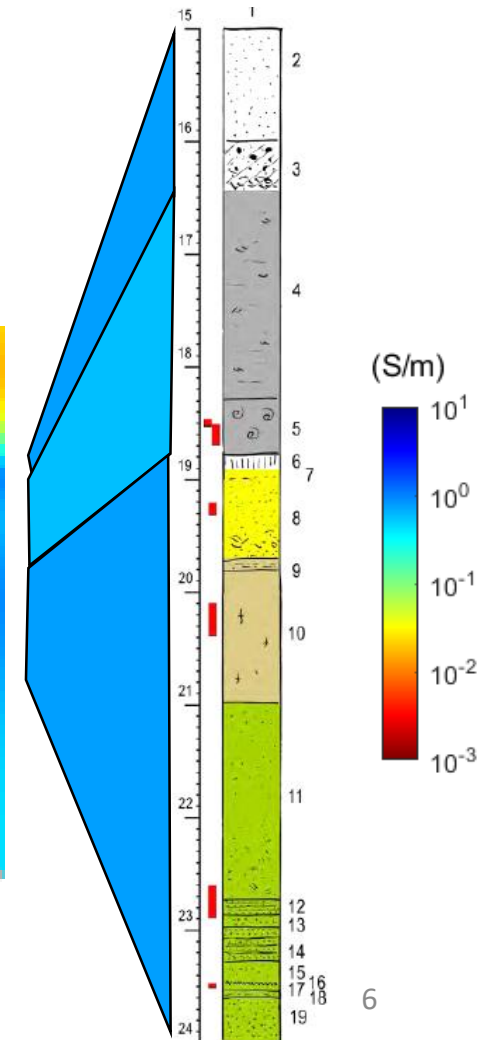
First field experiment: Loon-Plage (France)

Geological interpretation and comparison with borehole information.

n.b., the signal related to the loam layer within the area saturated with saltwater is slightly above the provided STD values.

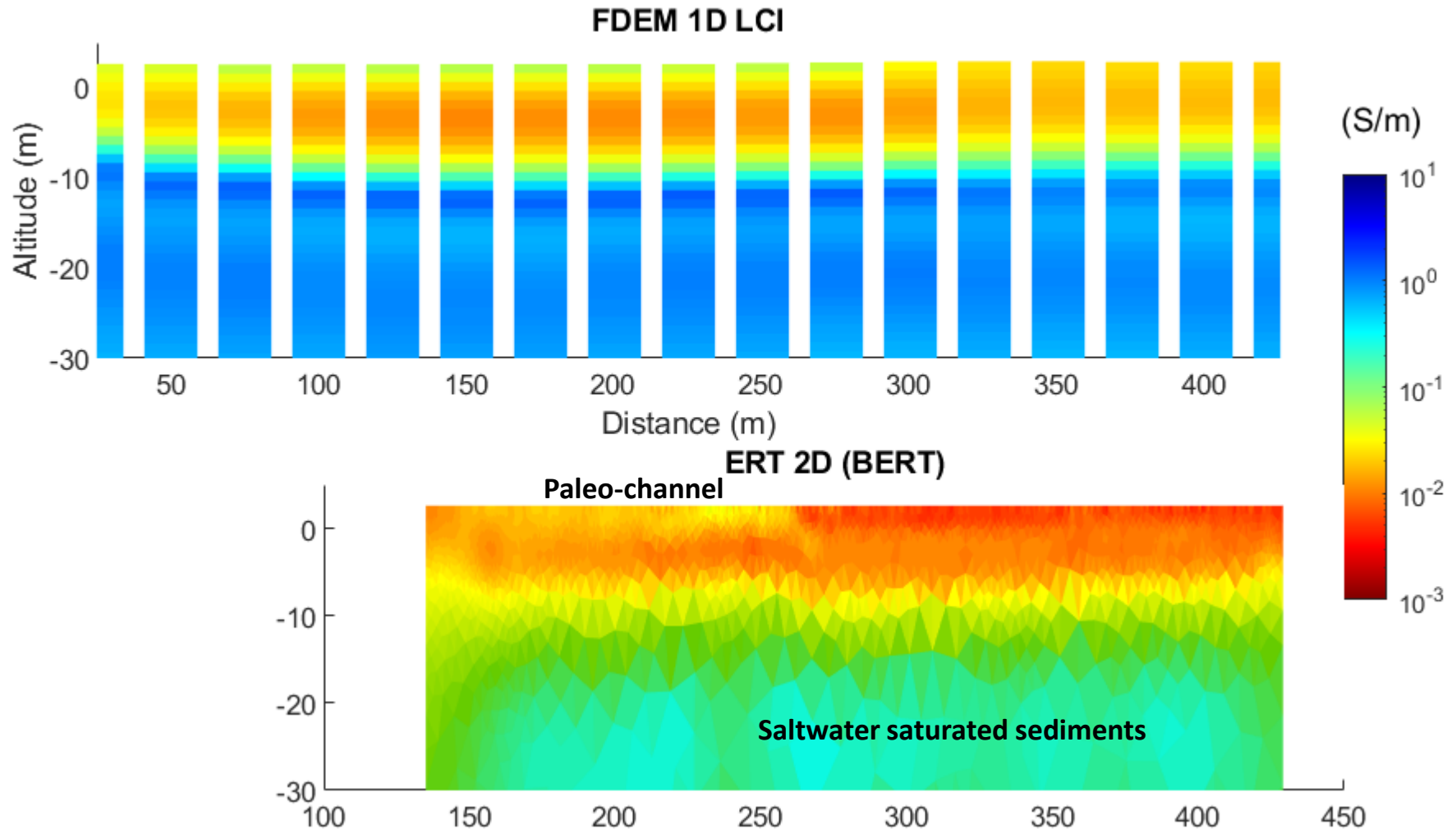


(Deschodt, 2020)



First field experiment: Loon-Plage (France)

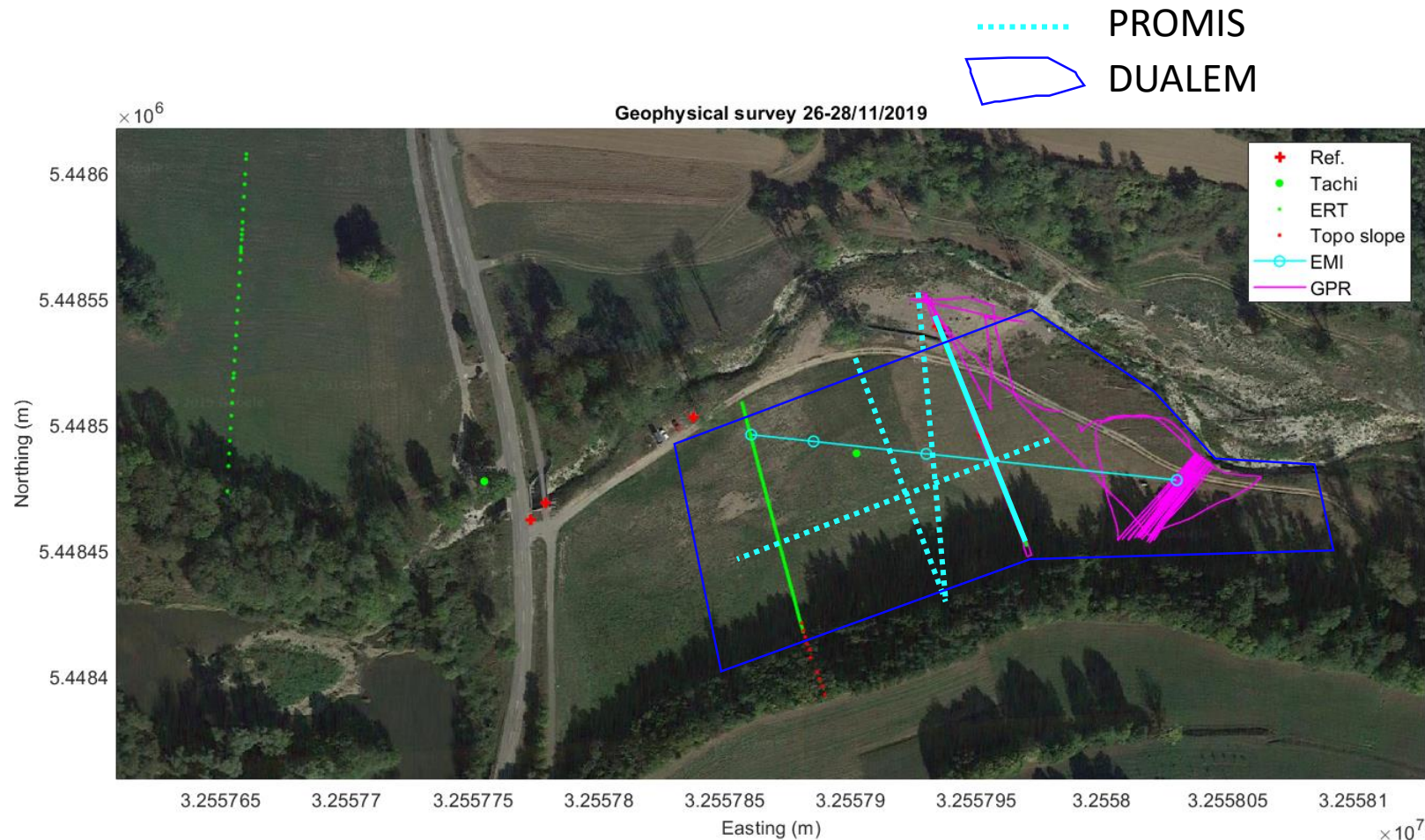
Comparison with ERT results: good structural agreement.
The loam layer is not visible in the DC results.



Second field experiment : Braunsbach (Germany)

Multi-frequency HCP/PERP, coil spacing: $s = 30$ m, profiles with $\Delta x = 5$ m

Geophysical survey in the Grimm bach alluvial fan. See project description [here](#)



Second field experiment : Braunsbach (Germany)

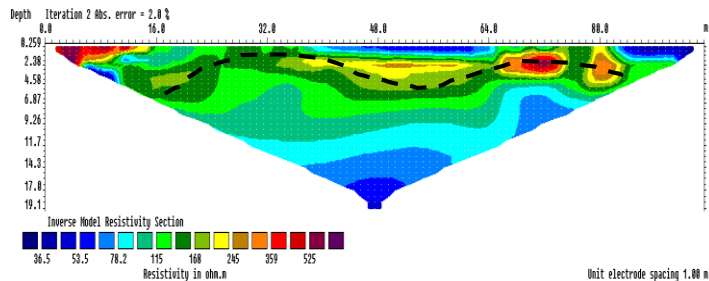
The inversion of PERP data shows a near-surface electrical conductivity distribution that is in a rather good agreement with the ERT results (see dashed line following the resistive maxima).

HCP data /results centred on the middle point between Tx and Rx.

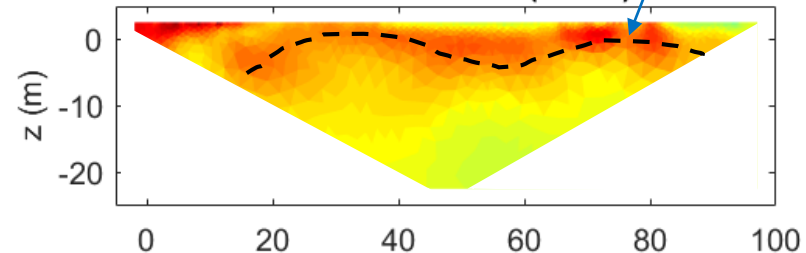
PERP data/results centred on the Rx position.

Line following the maxima of the resistive anomaly.

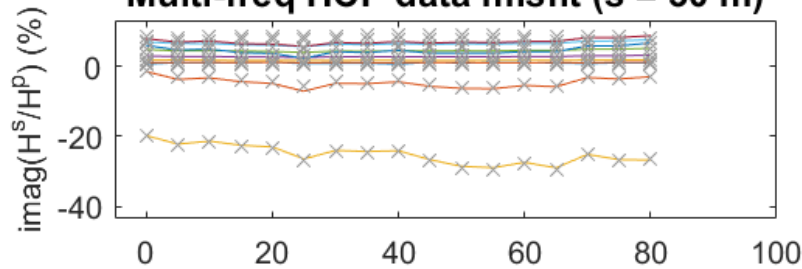
Res2Dinv result



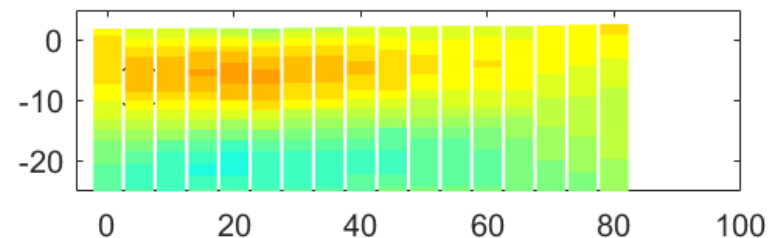
ERT 2D inversion (BERT)



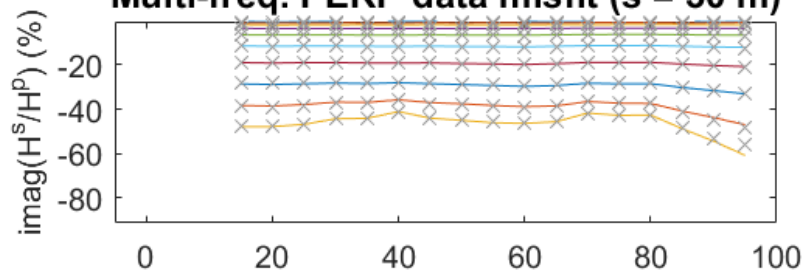
Multi-freq HCP data misfit (s = 30 m)



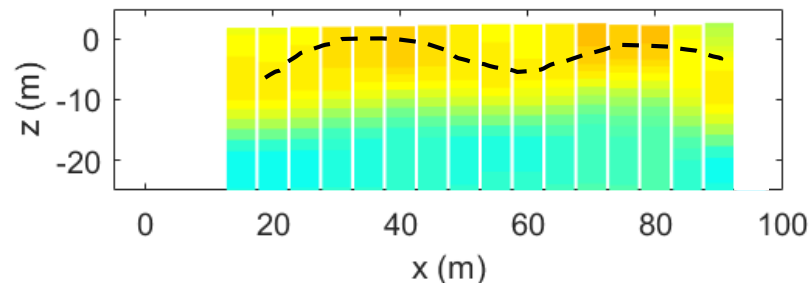
LCI 1D inversion of HCP data



Multi-freq. PERP data misfit (s = 30 m)



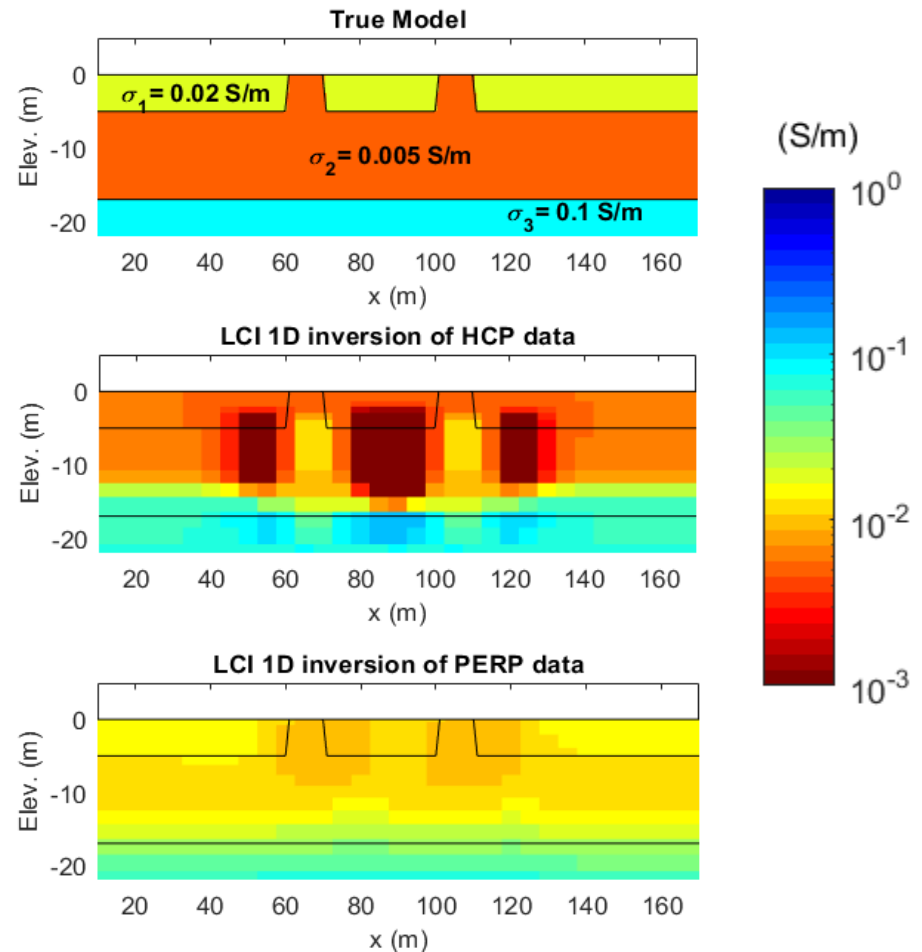
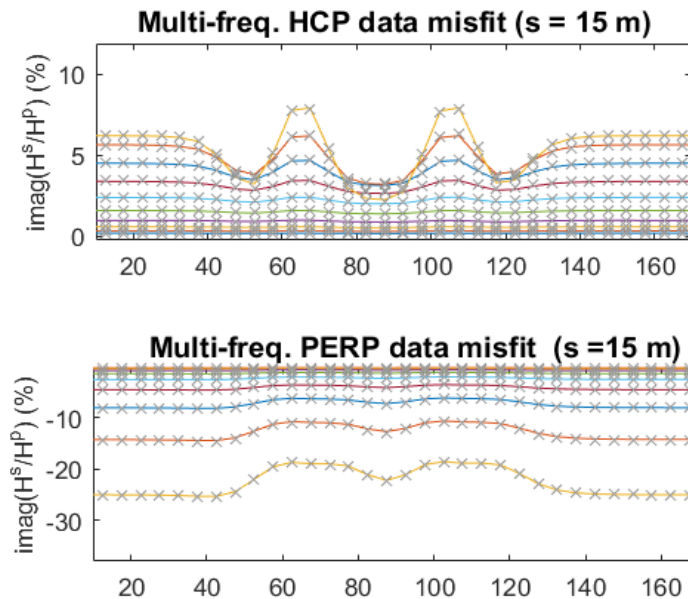
LCI 1D inversion of PERP data



Synthetics for a coil spacing : 15 m

The perp inversion shows near-surface electrical conductivity distribution which is in good agreement with true model.

n.b., the data were laterally smoothed with a Gaussian filter with variance proportional to the lateral sensitivity ($\text{var} = 1.5s$) in order to reduce the 2D signal.

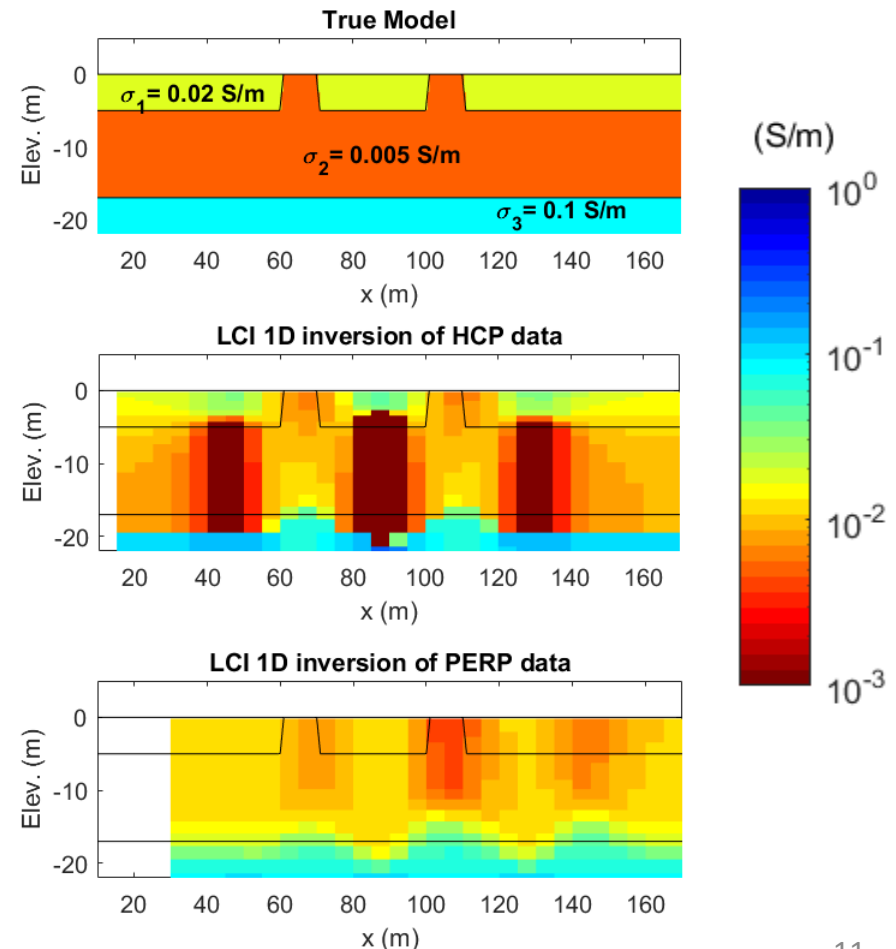
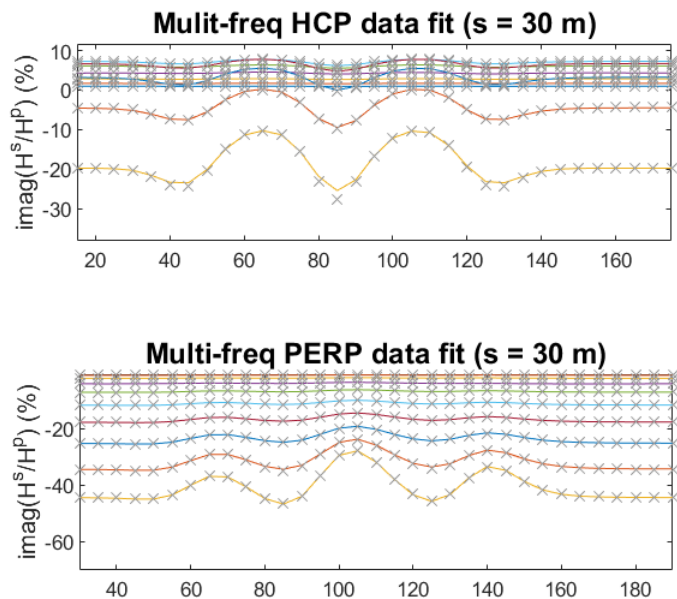


Synthetics for a coil spacing : 30 m

The 1D LCI inversion of PERP FDEM data shows a near-surface electrical conductivity distribution which is still in a better agreement with the ERT results than for the HCP case, however critical artefacts appear.

The first layer is no longer detected due to the larger coil spacing (due to a decrease in vertical resolution near the surface)

n.b., the data were laterally smoothed with a Gaussian filter with variance proportional to the lateral sensitivity (var = 1.5s) in order to reduce the 2D signal.



Conclusion

The lateral distribution of the electrical conductivity near the surface ($z < 10$ m) has a significant impact on the recorded multi-frequency FDEM data.

-> An acquisition with a sufficiently dense lateral sampling is needed to unveil the related 2D/3D effects. After that, one can better reduce or remove them (for 1D inversion) or exploit them (with 2D/3D inversion approaches).

The dense profile recorded in Braunsbach confirms our expectation regarding the better applicability of the 1D approximation with PERP data.

To limit the 2D/3D effects due to near surface heterogeneities, the synthetic tests suggest to use the PERP configurations with a coil spacing as small as possible.

Further work: 2D/3D inversion, and field acquisition test with $s = 15$ m.