

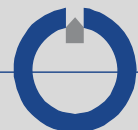
# Terrænnær højopløselig geofysik

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HydroGeophysics Group  
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# Motivation

- **Electromagnetic induction (EMI) instruments**
  - High resolution, small footprint
- **EMI instrumentation dramatically improved**
  - More robust instruments — better data quality
  - More coil geometries — larger depth of exploration (DOE)
- **Tool developed for airborne electromagnetic**
  - Automatic processing
  - Robust, fast, full non-linear inversion
  - Approximations are no-go



# Applications

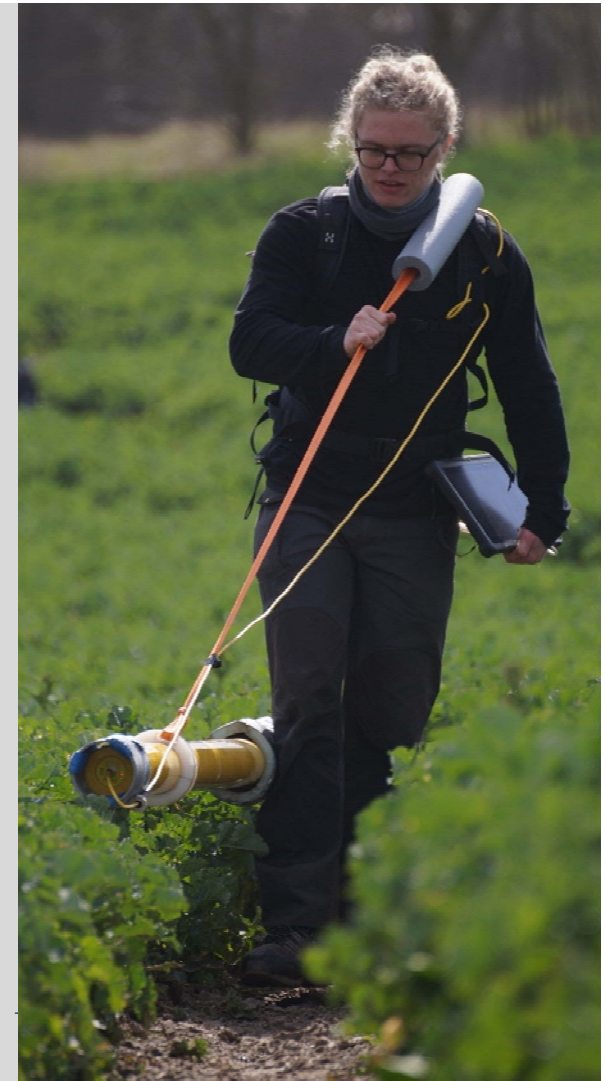
- **Soil mapping**
- **Geotechnical engineering**
- **Pre-housing development (LAR)**
- **Archeology**
- **Dike construction**

**Any application involving shallow geology**



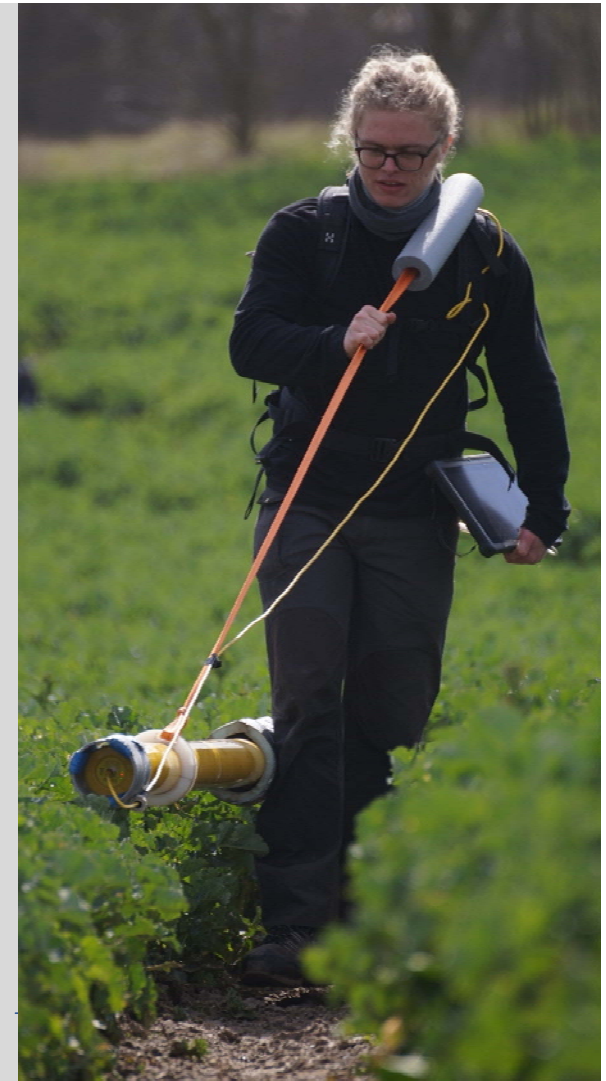
# Outline

- **Methodology**
- **Processing & Inversion scheme**
- **Results – The Pillemark (Samsø) case study**
- **New transient electromagnetic system in the pot**



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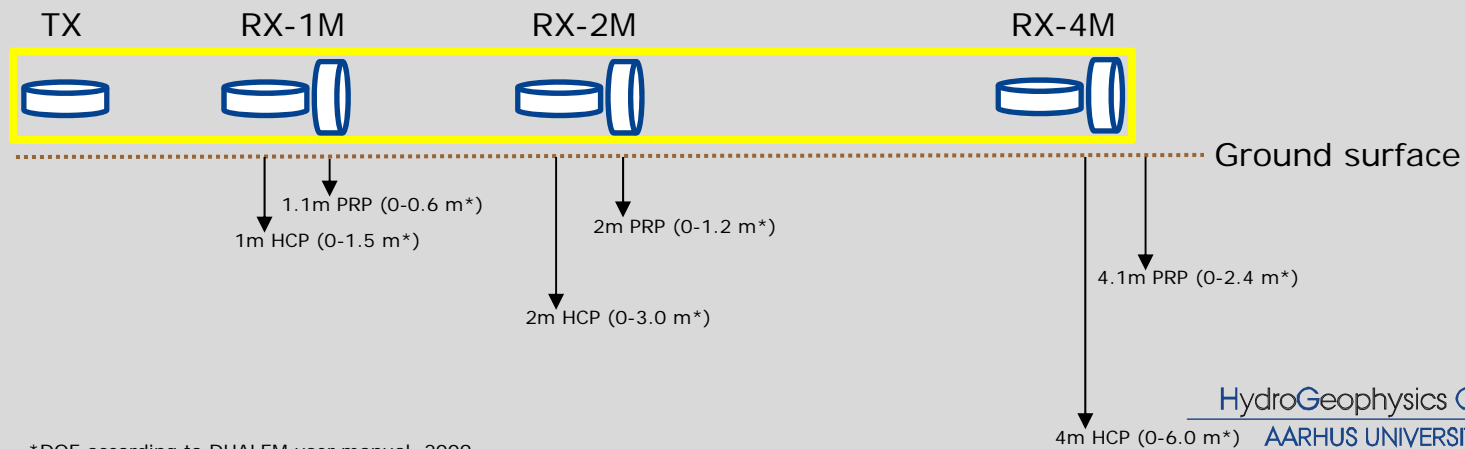
# Electromagnetic Induction



- DUALEM-421S
- Frequency domain, 9000 Hz
- Sampling rate, 10 Hz
- 6 coils, providing apparent resistivity information of the soil



# Electromagnetic Induction



\*DOE according to DUALEM user manual, 2009.  
Assuming low frequency-approximation (LIN condition)

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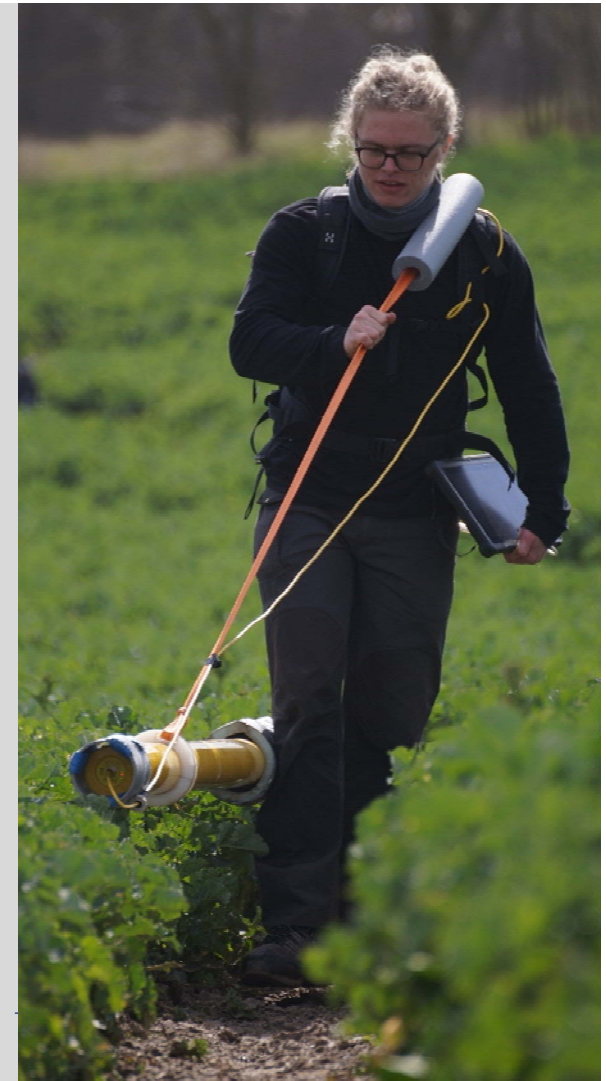
# Electromagnetic Induction





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# Processing in the Aarhus Workbench

## 1. Alignment of sounding data

- Shift of GPS position

## 2. Automatic processing

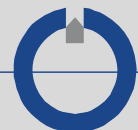
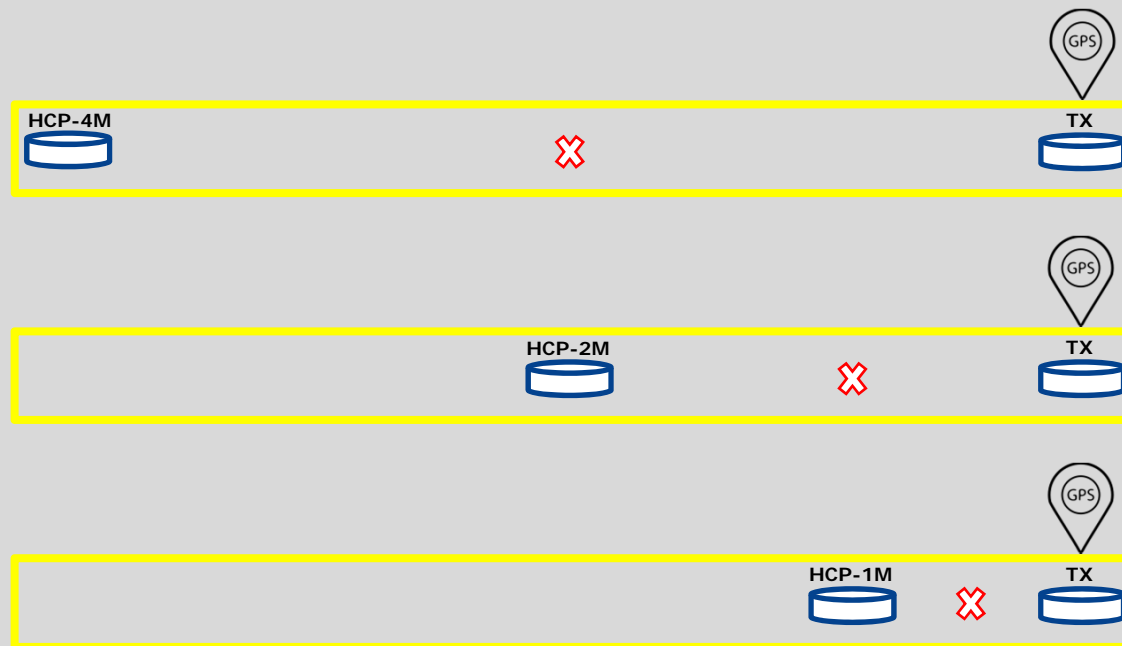
- Averaging (increase S/N ratio due to motion induced and background noise)

## 3. Manual processing

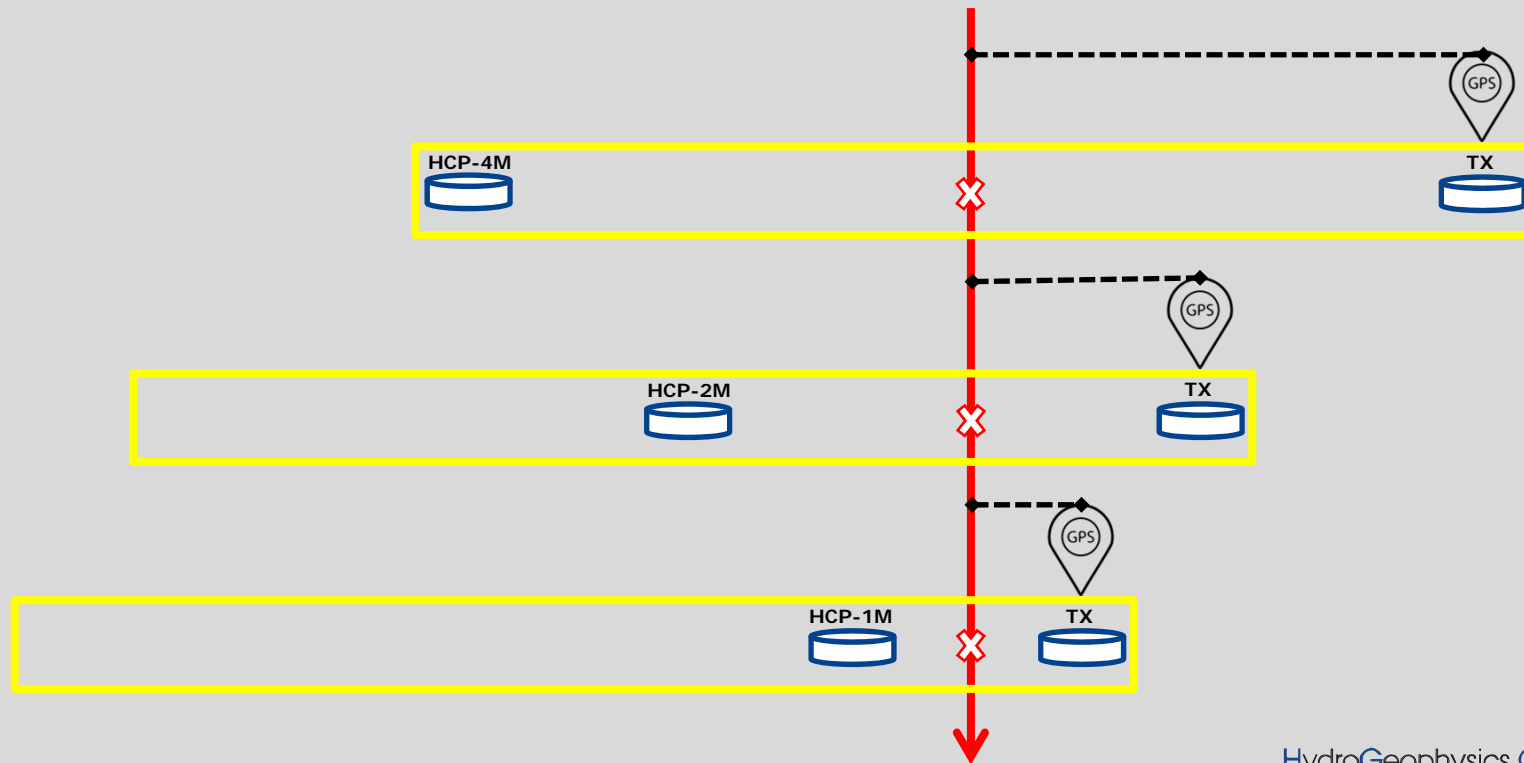
- Removal of signals from man-made installations



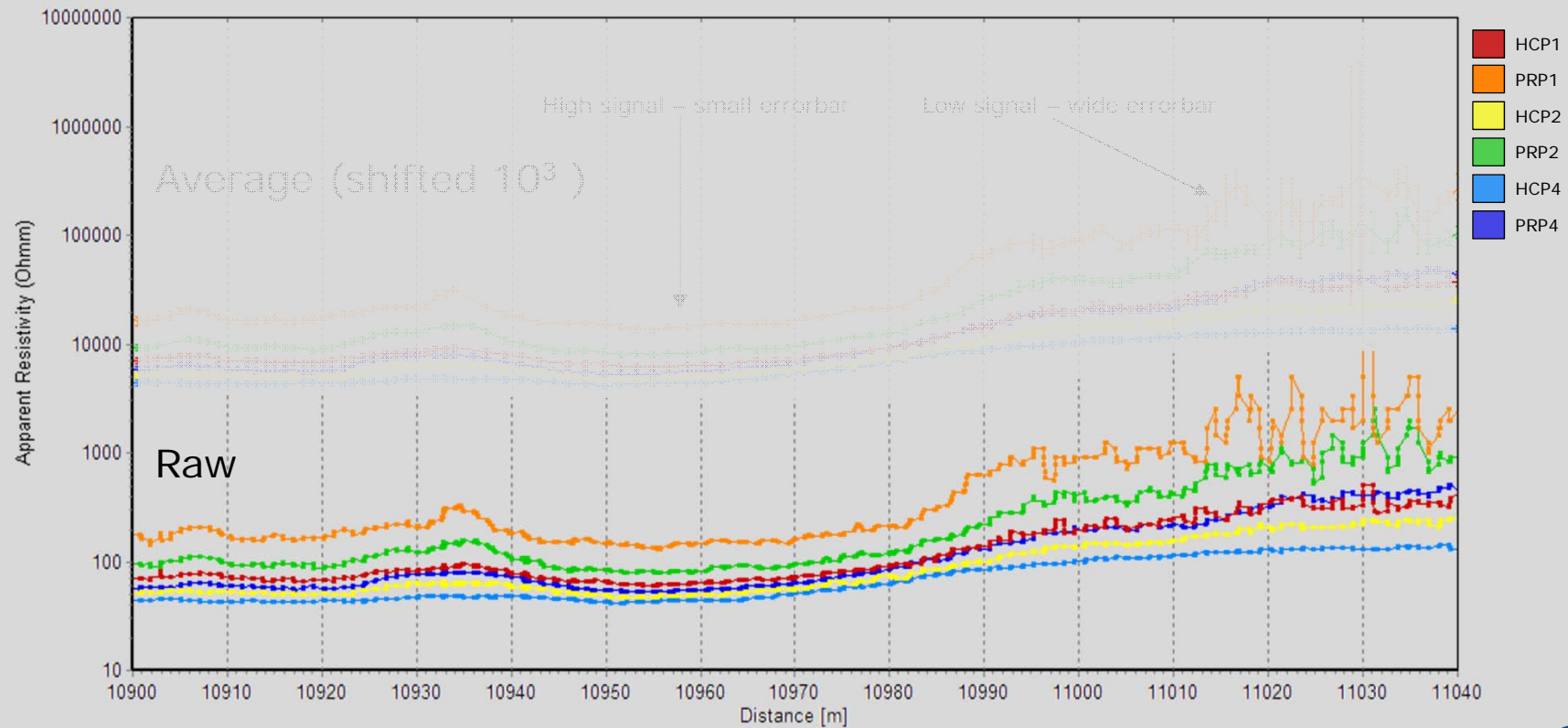
# Processing - alignment of sounding data



# Processing - alignment of sounding data

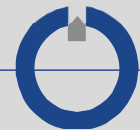
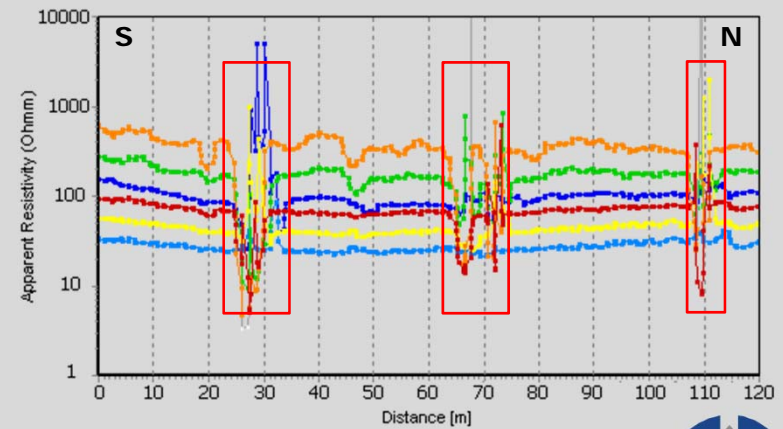
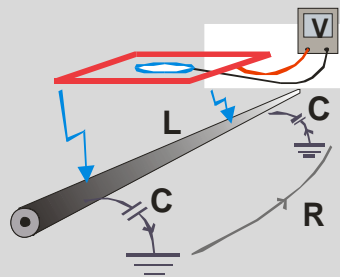


# Processing - automatic



# Processing - manual

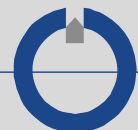
- Capacitive coupling LCR - circuit with oscillating decay
- Insulated conductor, telephone cables, buried electrical cables
- Easily recognizable in the data



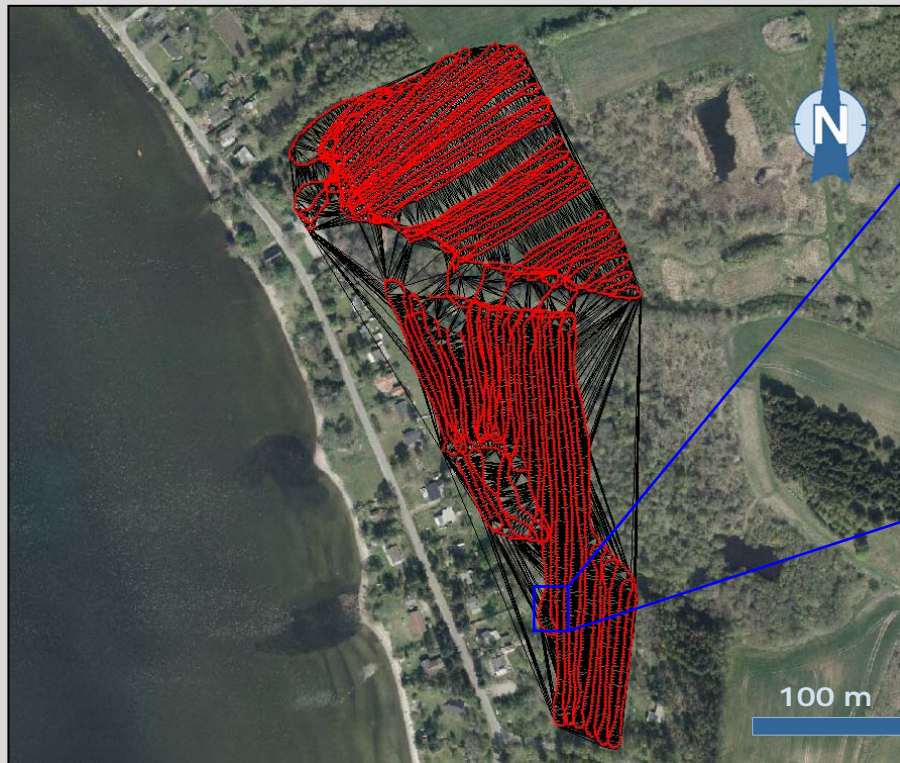
# Inversion

- Aarhus Workbench inversion code
  - Least squares, full non-linear solution
  - 1D - spatially constrained inversion
- Production code for AEM, ERT, IP and EMI data
  - More than 500.000 line km of AEM data interpreted in worldwide mappings

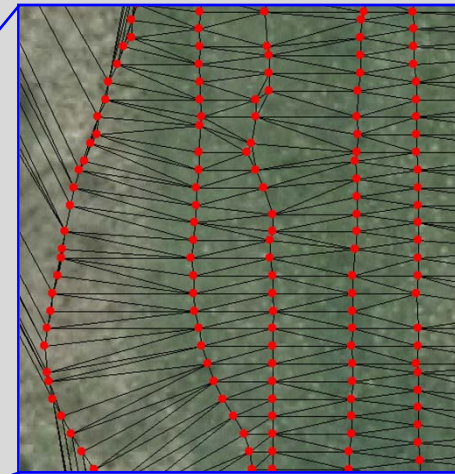
**Auken, E. et al.**, 2015, An overview of a highly versatile forward and stable inverse algorithm for airborne, ground-based and borehole electromagnetic and electric data, **46** exploration geophysics.



# Inversion – spatially constrained



● Model — Constraint



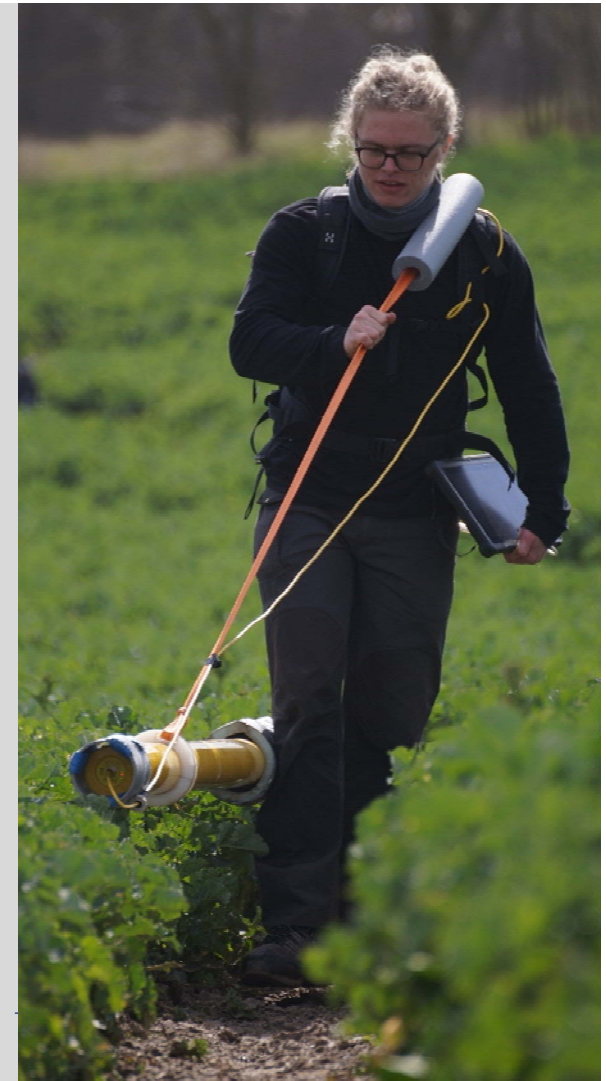
- **Inline and crossline constraints**
  - Ensure lateral consistency
  - No striping in maps
  - Sedimentary environment





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# Results – Pillemark study

## Mapping soil heterogeneity

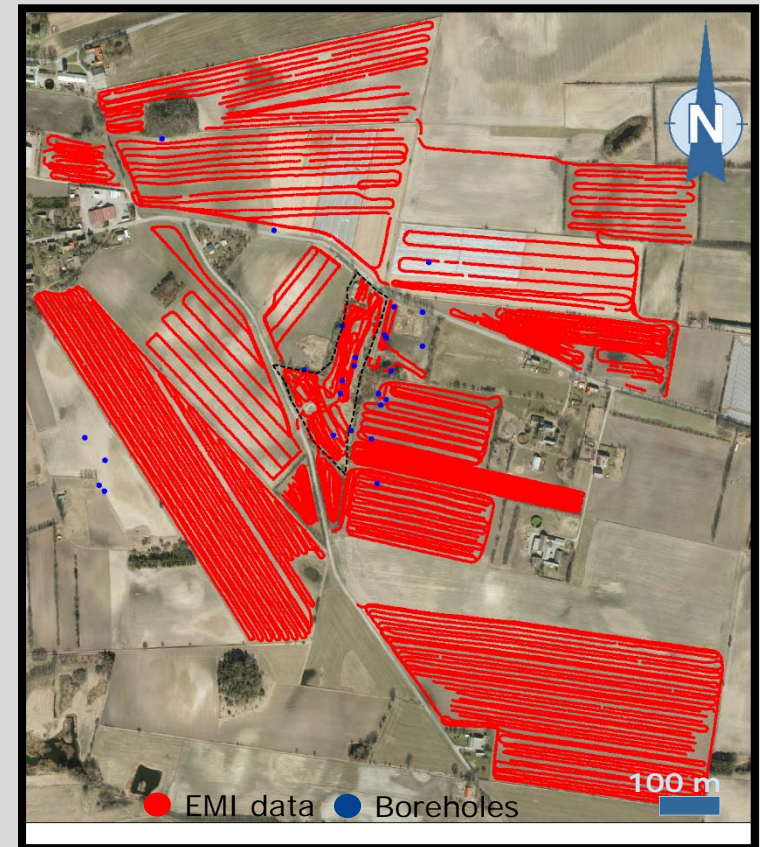
- Soil maps
- Resolve small scale geological structures i.e. paleo stream channels
- Resolve continuity of shallow sand layers

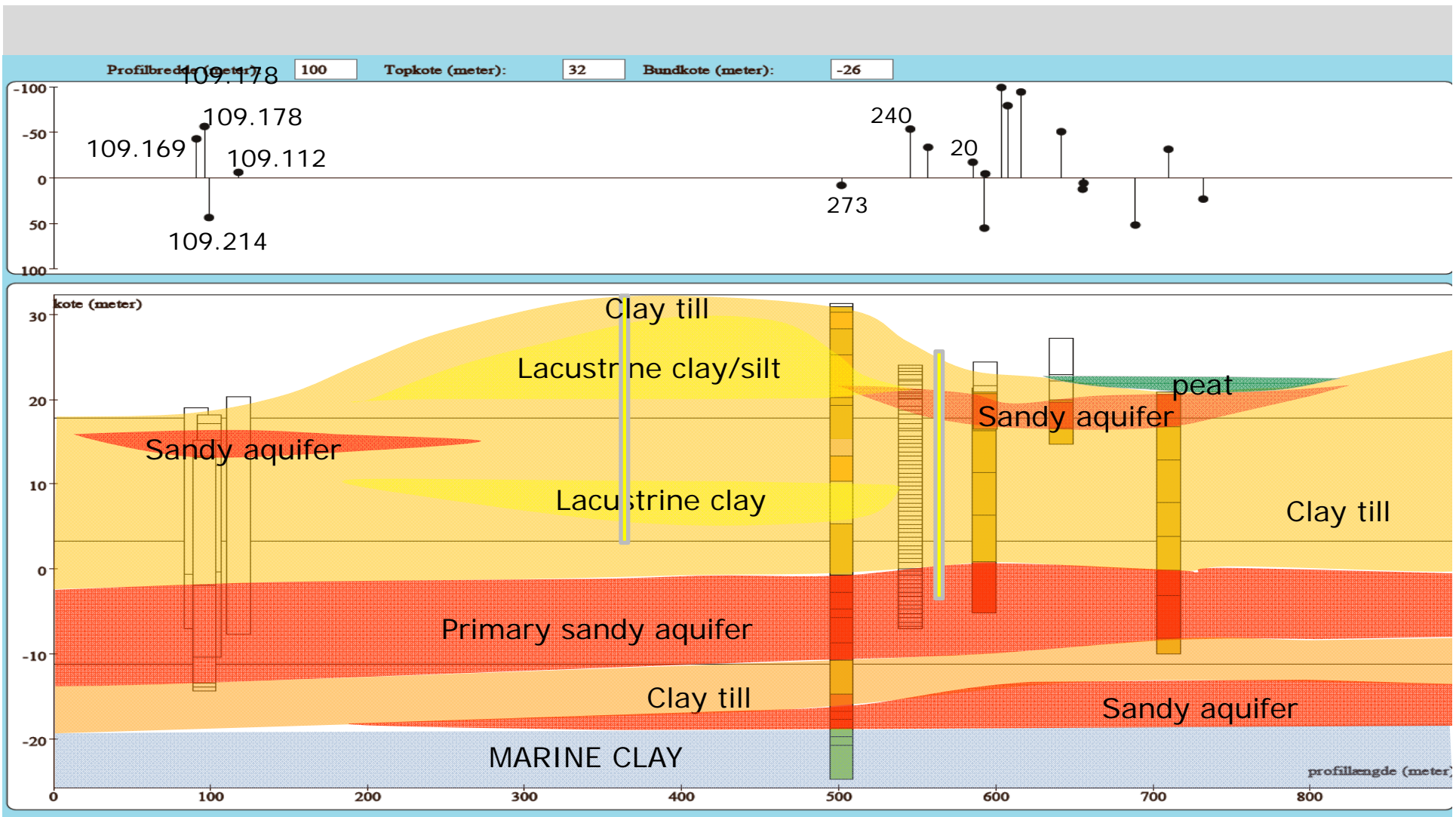
## Mapping campaign

- 2 days of acquisition time
- 5 – 25 m line distance, 0.5 m sample density
- 93 km of data, 42 950 unique measurements

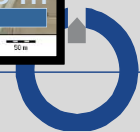
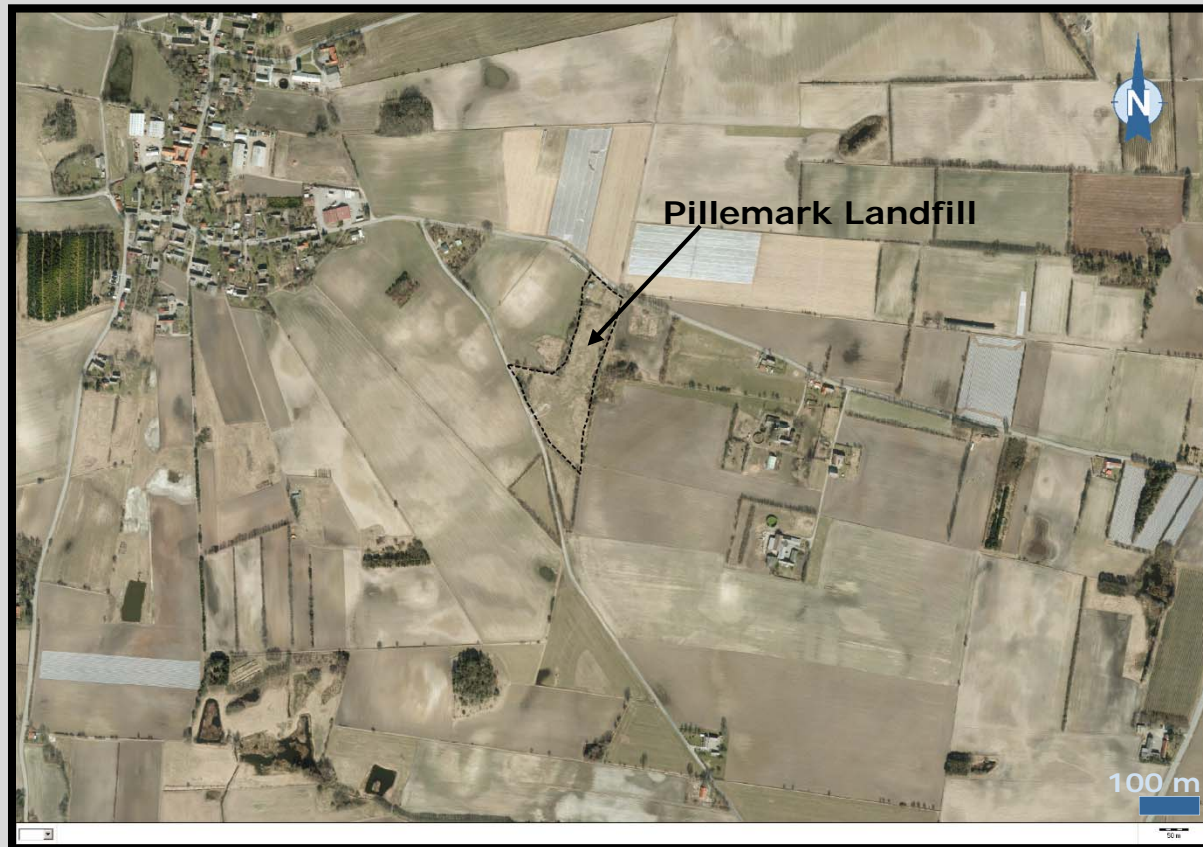
## Processing & inversion

- 10 hour processing
- Runtime of ~20 minutes for full non-linear inversion



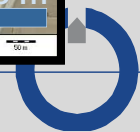
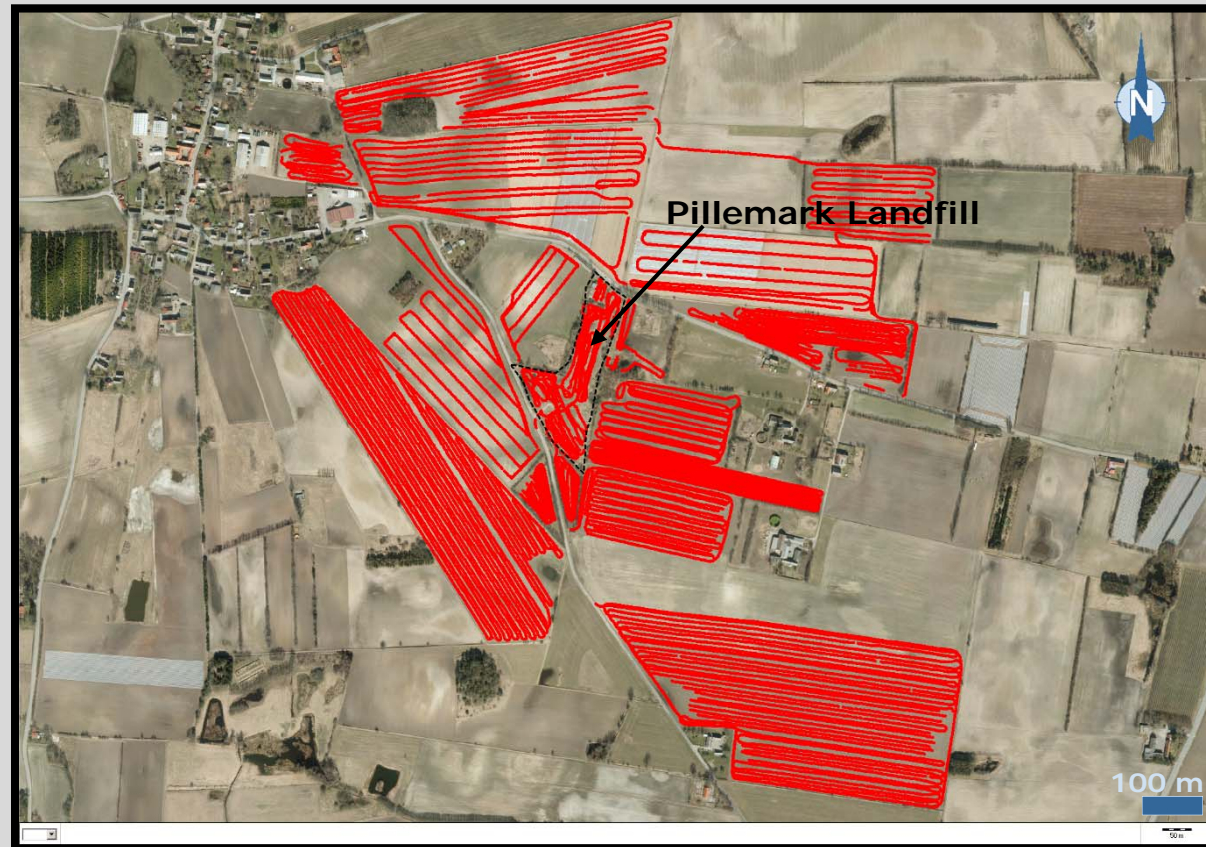


# The area



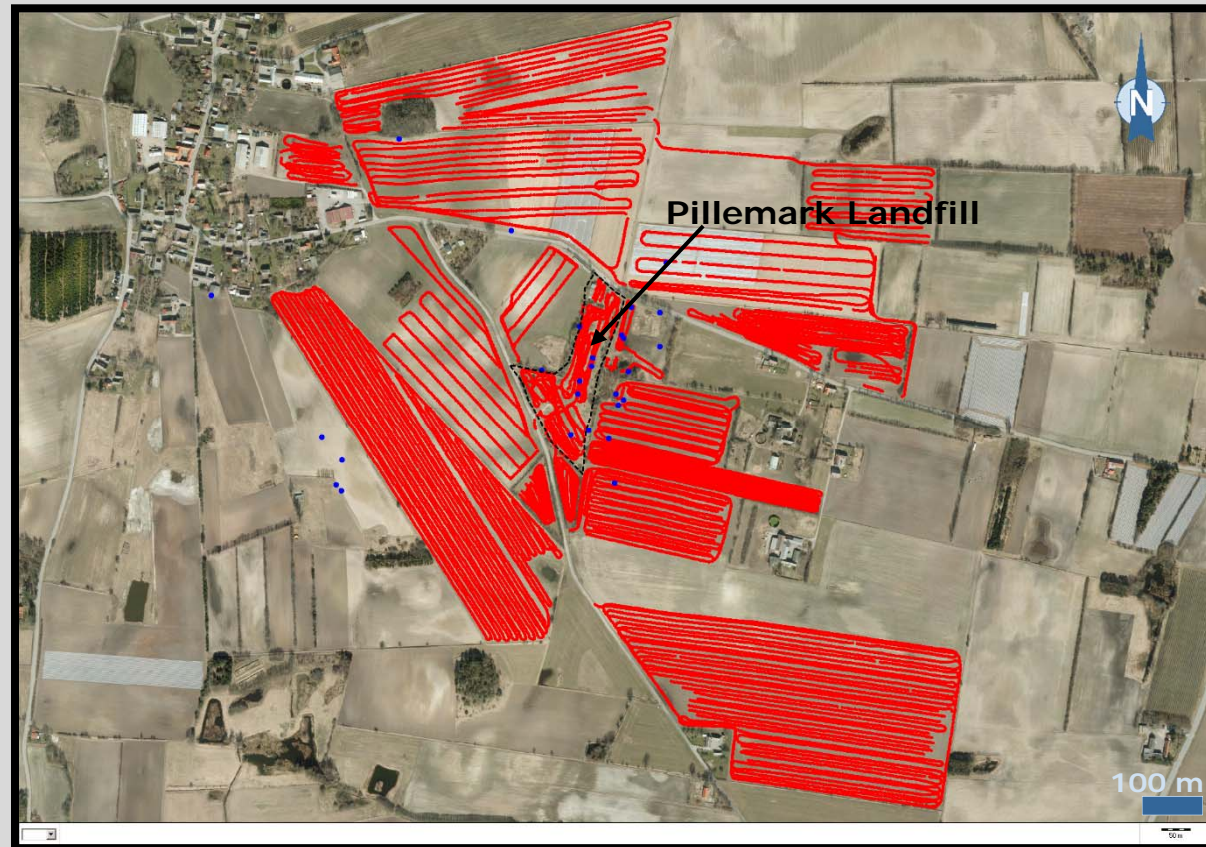
# The area

- GCM soundings

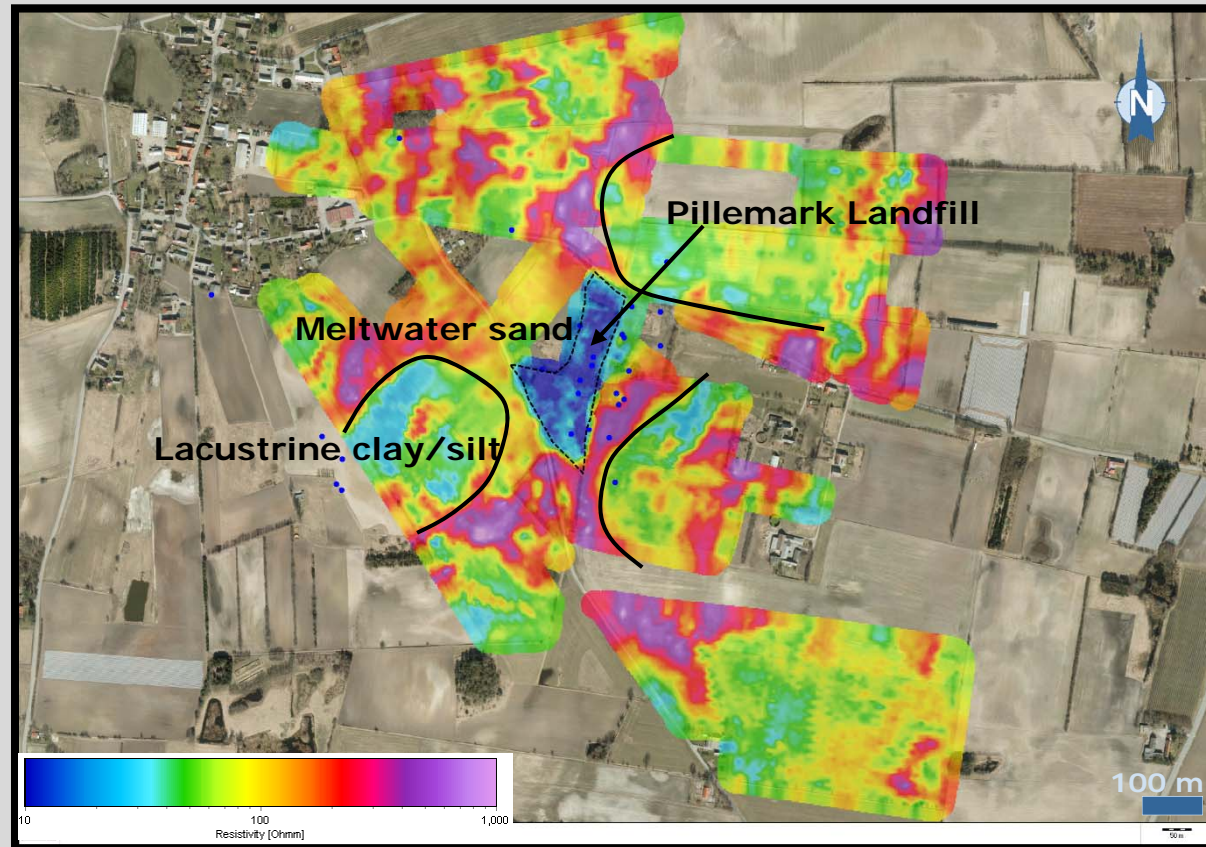


# The area

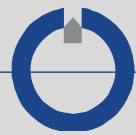
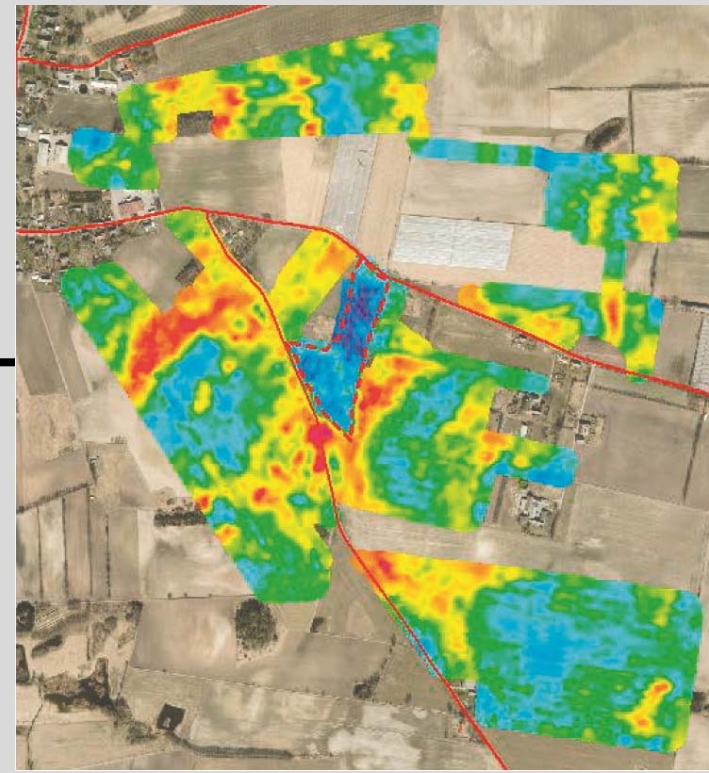
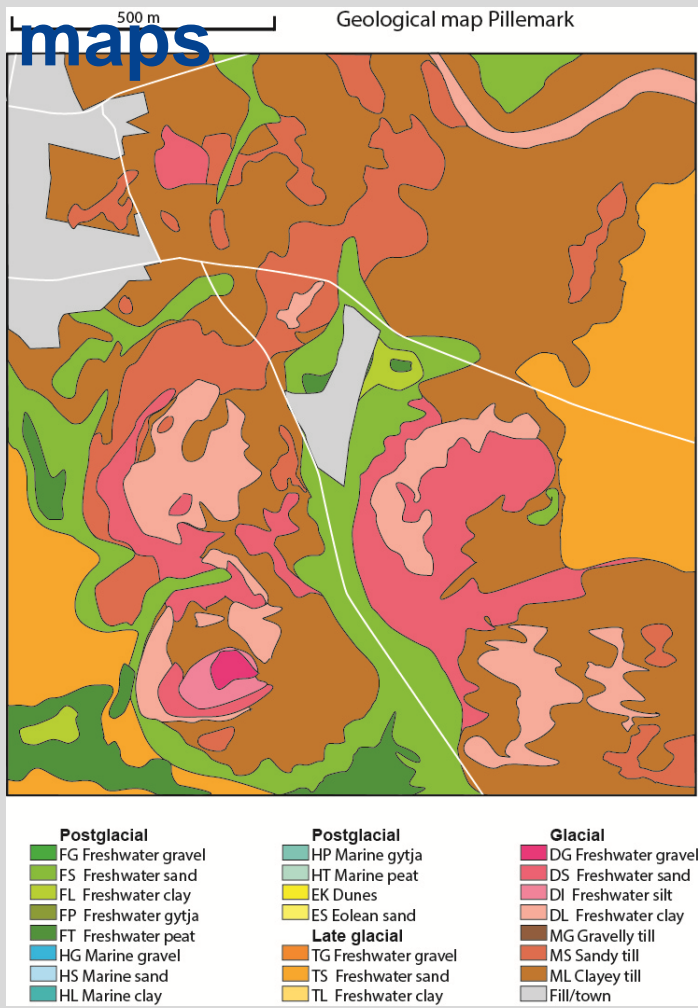
- GCM soundings
- Boreholes



# Average resistivity 0 – 1 mbs

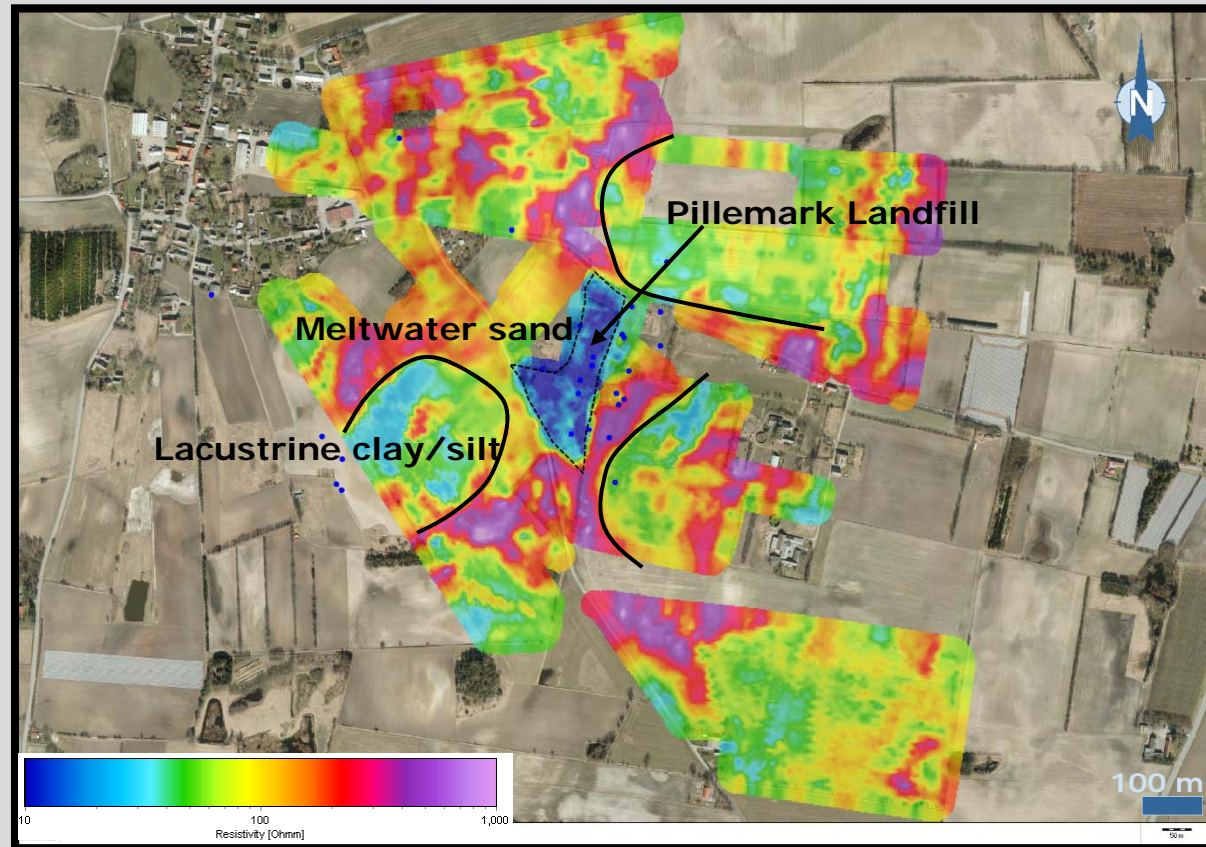


# Soil maps



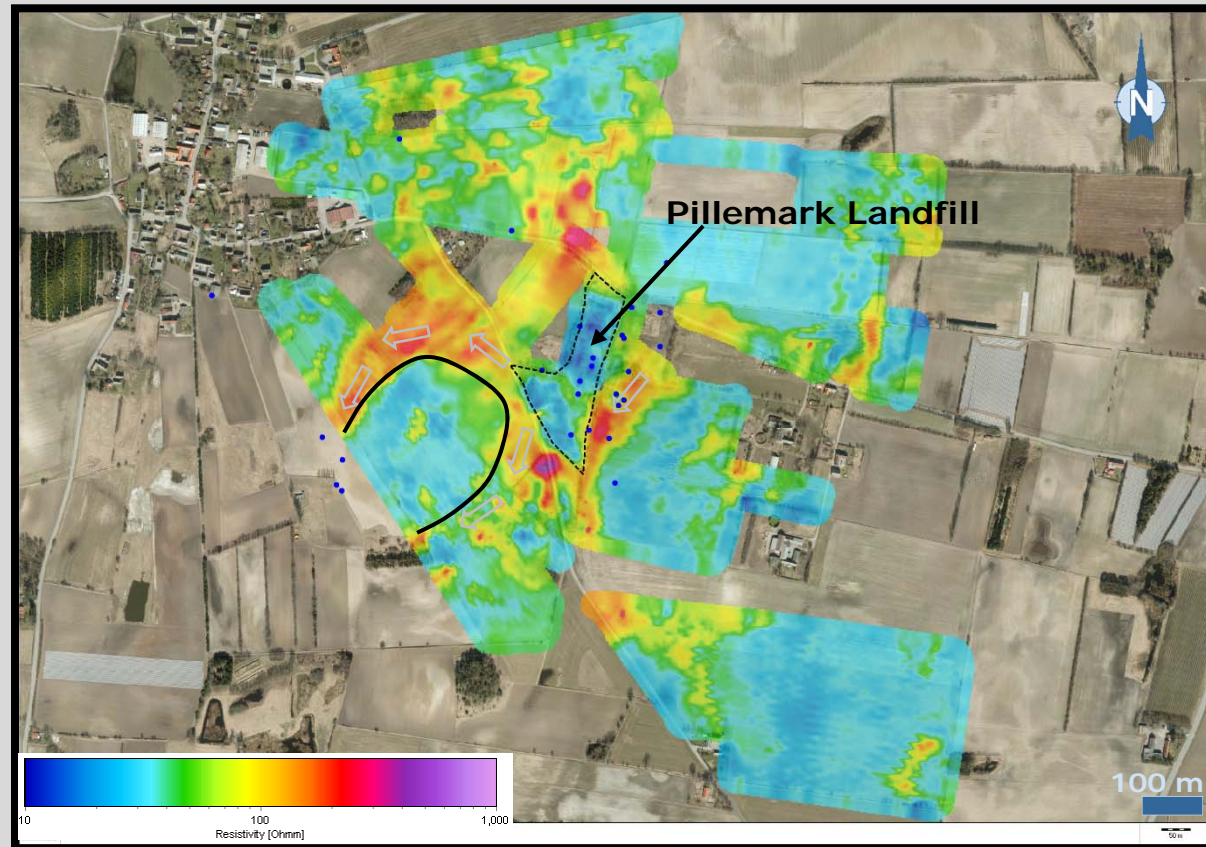


# Average resistivity 0 – 1 mbs

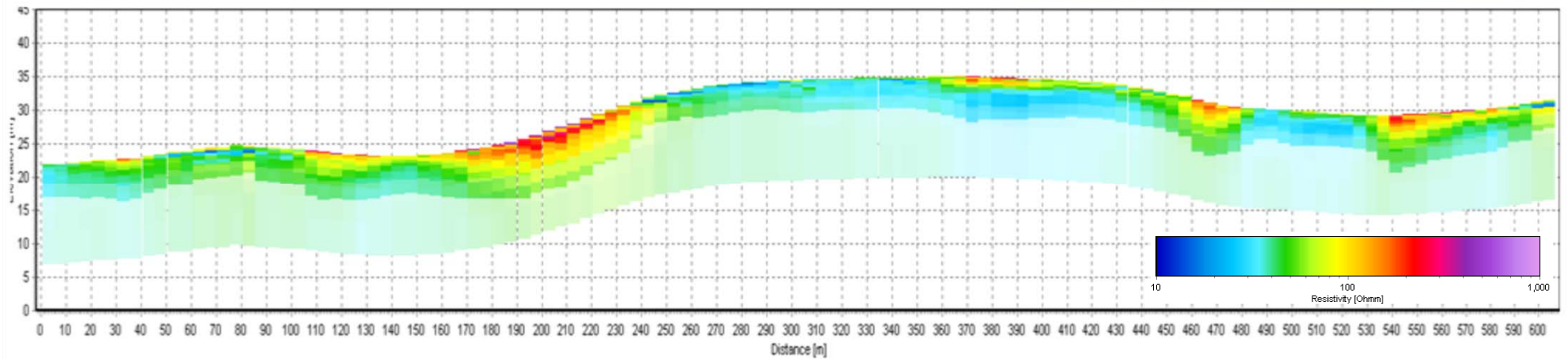
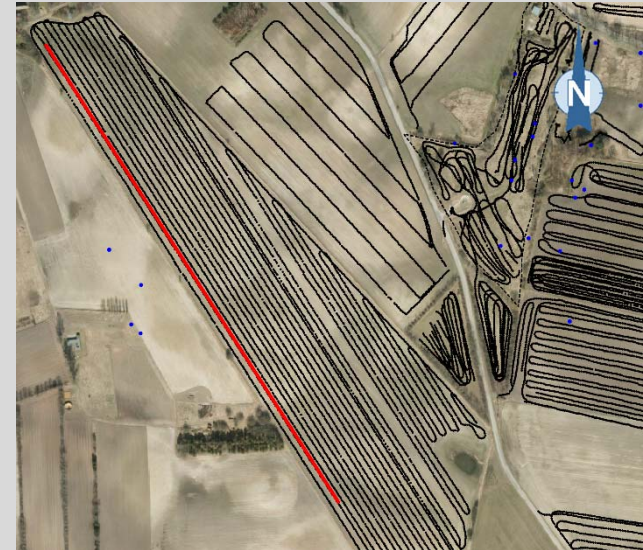


# Average resistivity 1 – 2 mbs

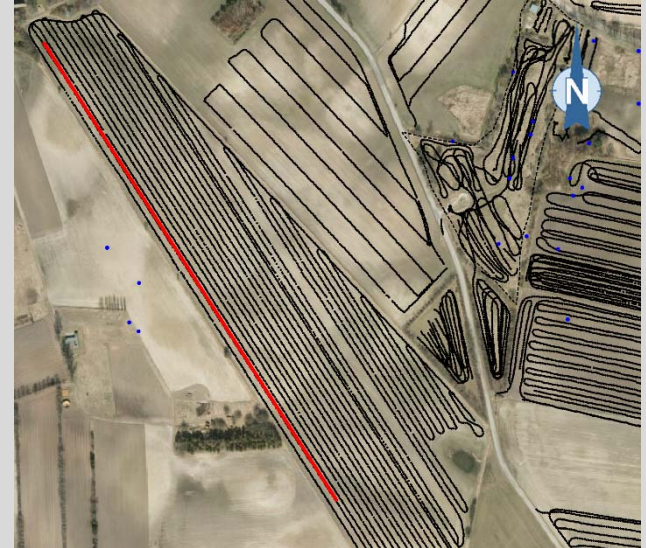
- Deeper structure



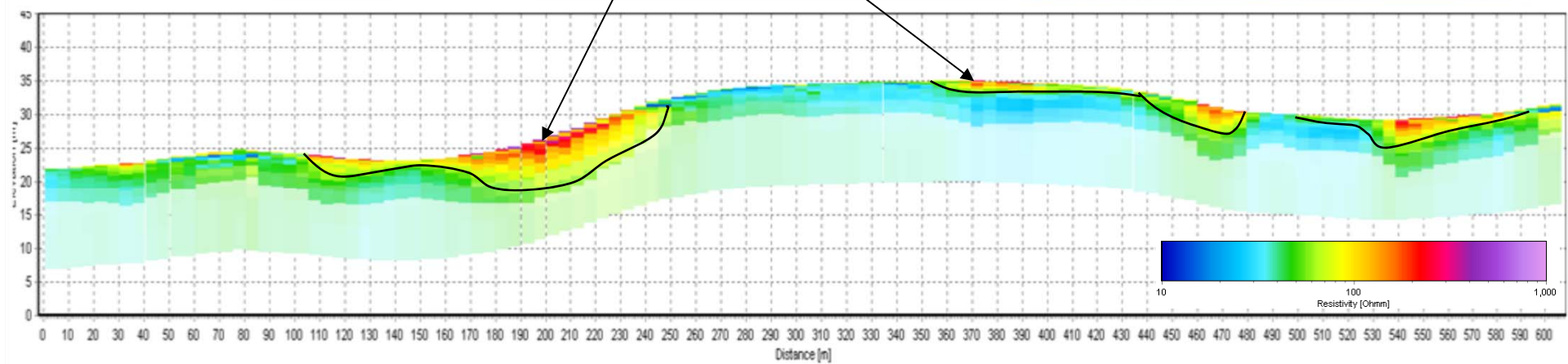
# Cross section



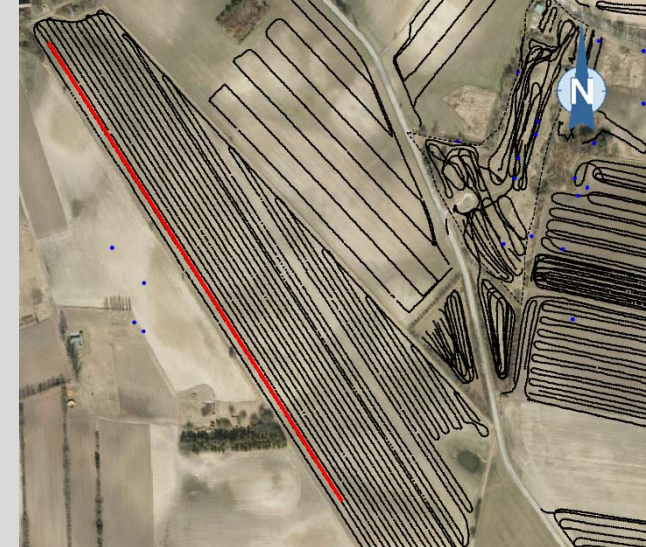
# Cross section



Meltwater sand

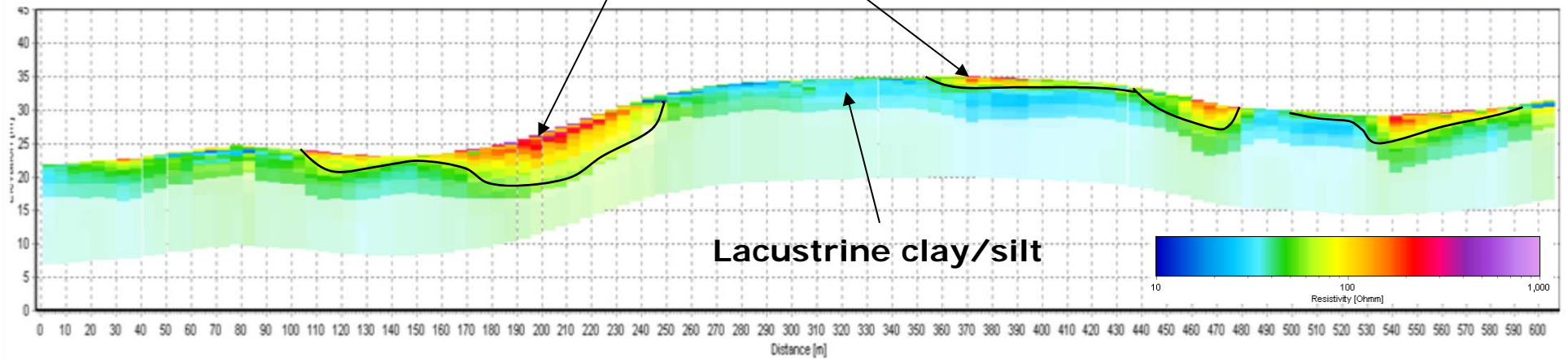


# Cross section

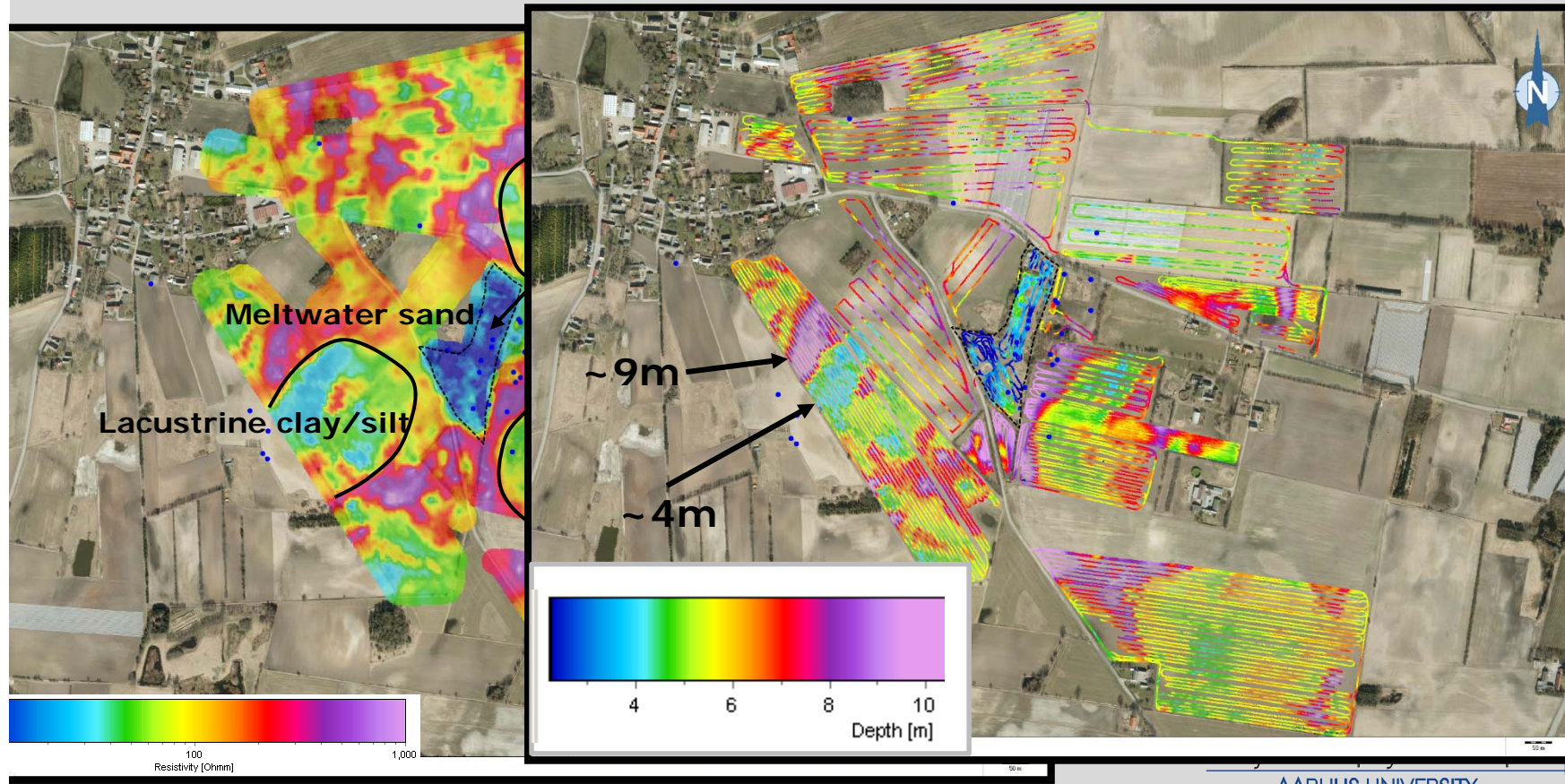


Meltwater sand

Lacustrine clay/silt

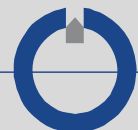


# Depth of Investigation (DOI)



# Outlook

- **Basis for the hydrostratigraphic input for GW modelling in the unsaturated zone**
- **Operational methodology to address effects of**
  - **Extreme rain events,**
  - **LAR design,**
  - **Shallow groundwater tables**
  - **Nitrate infiltration**
  - **ect.**



## Conclusion

- **Small and efficient system to deployed on the hectare scale**
- **Detailed processing and full non-linear inversion gives:**
  - True resistivity information with depth
  - Resolution of small scale shallow geological layers
- **Very good correlation with boreholes and soil maps**



## Acknowledgement

- GEOCON – [www.geocon.env.dtu.dk](http://www.geocon.env.dtu.dk)
- HyGEM – [www.hygem.dk](http://www.hygem.dk)

**Thank you for your attention!**

**Remember the HyGEM day April  
6<sup>th</sup> in Aarhus**

