

# Nyeste udviklinger inden for geofysisk kortlægning

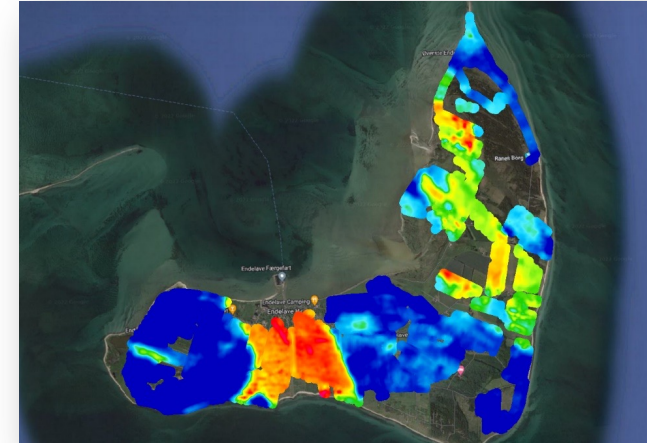
**Anders Vest Christiansen,**

HydroGeophysics Group, Department of Geoscience, Aarhus University, Denmark



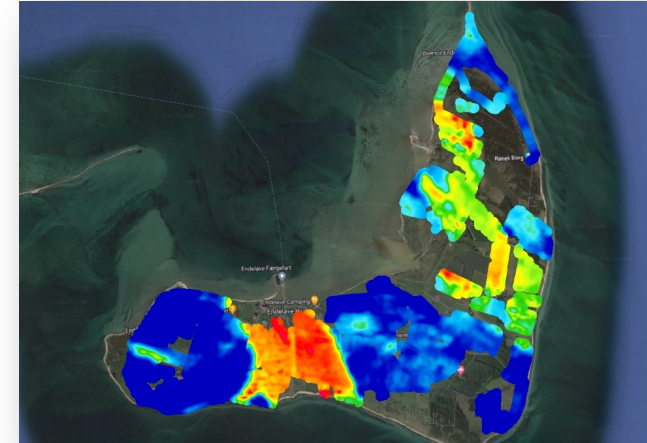
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  - Eksempler fra Albæk og Falster
- **Kortlægning af hav/sø – land**
  - FloaTEM



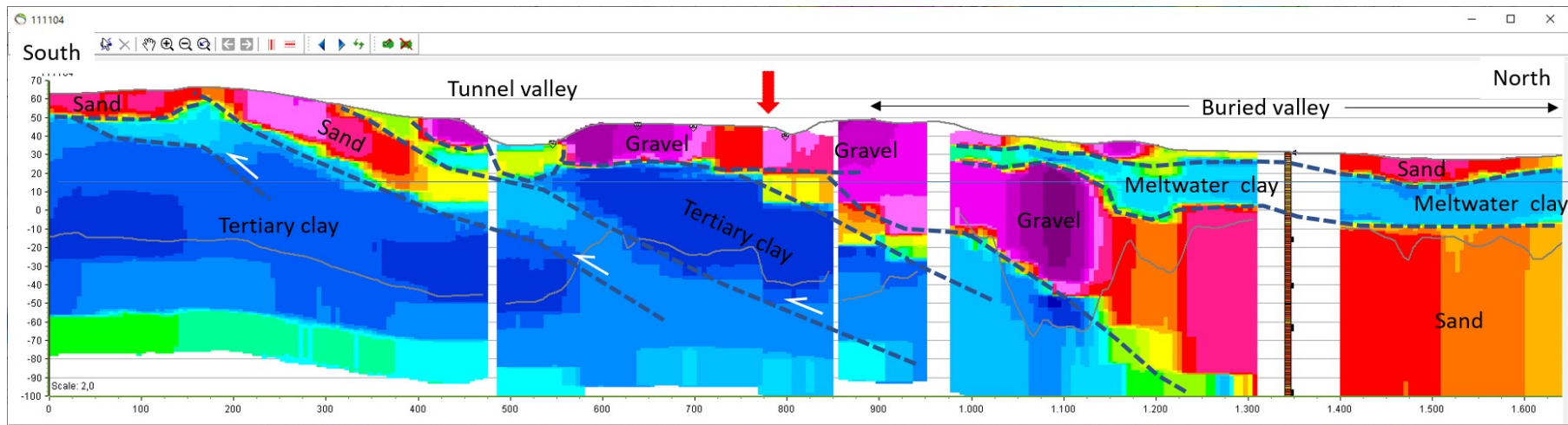
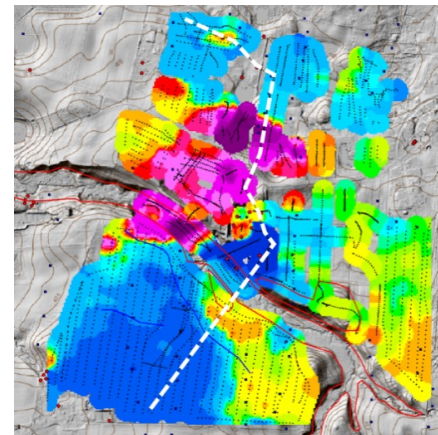
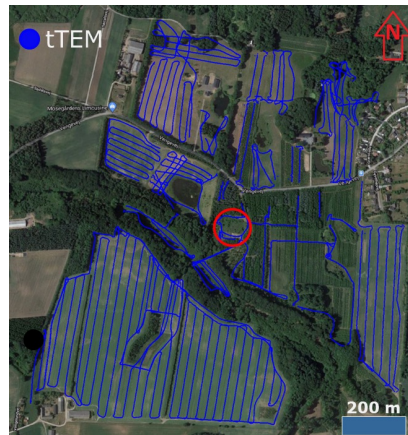
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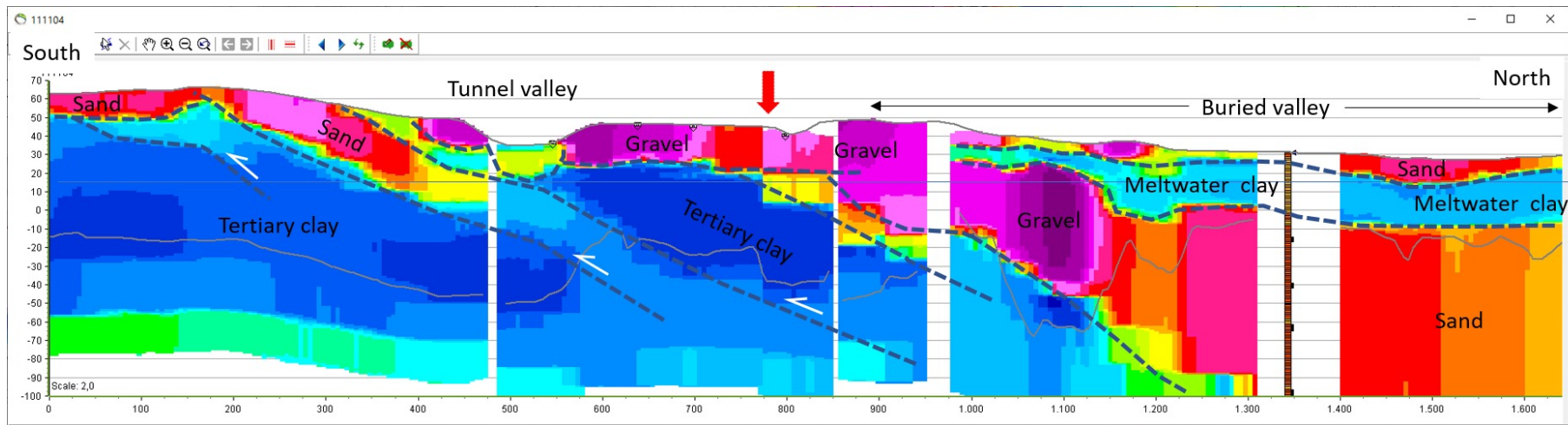
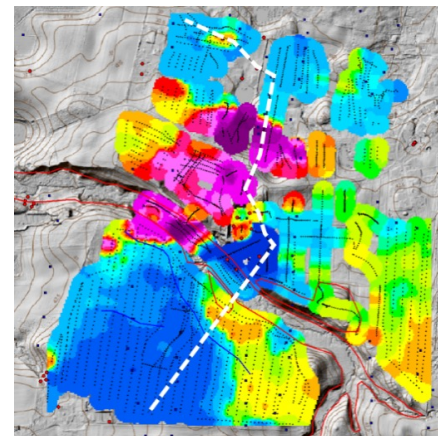
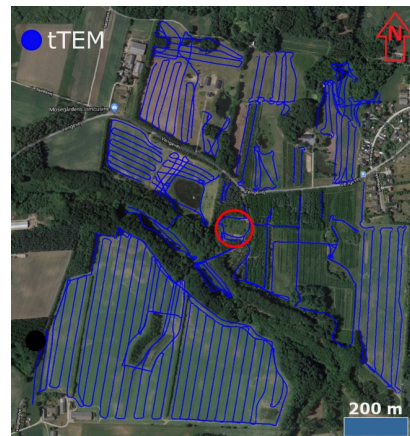
# Geofysikkens rolle

- tTEM mapping, Søballe
- Litologi (stratigrafi)



# Geofysikkens rolle

- tTEM mapping, Søballe
- Litologi (stratigrafi)
- → hydrologiske parametre?
- → tidslige variationer?
- → kortlægning på sø / til havs



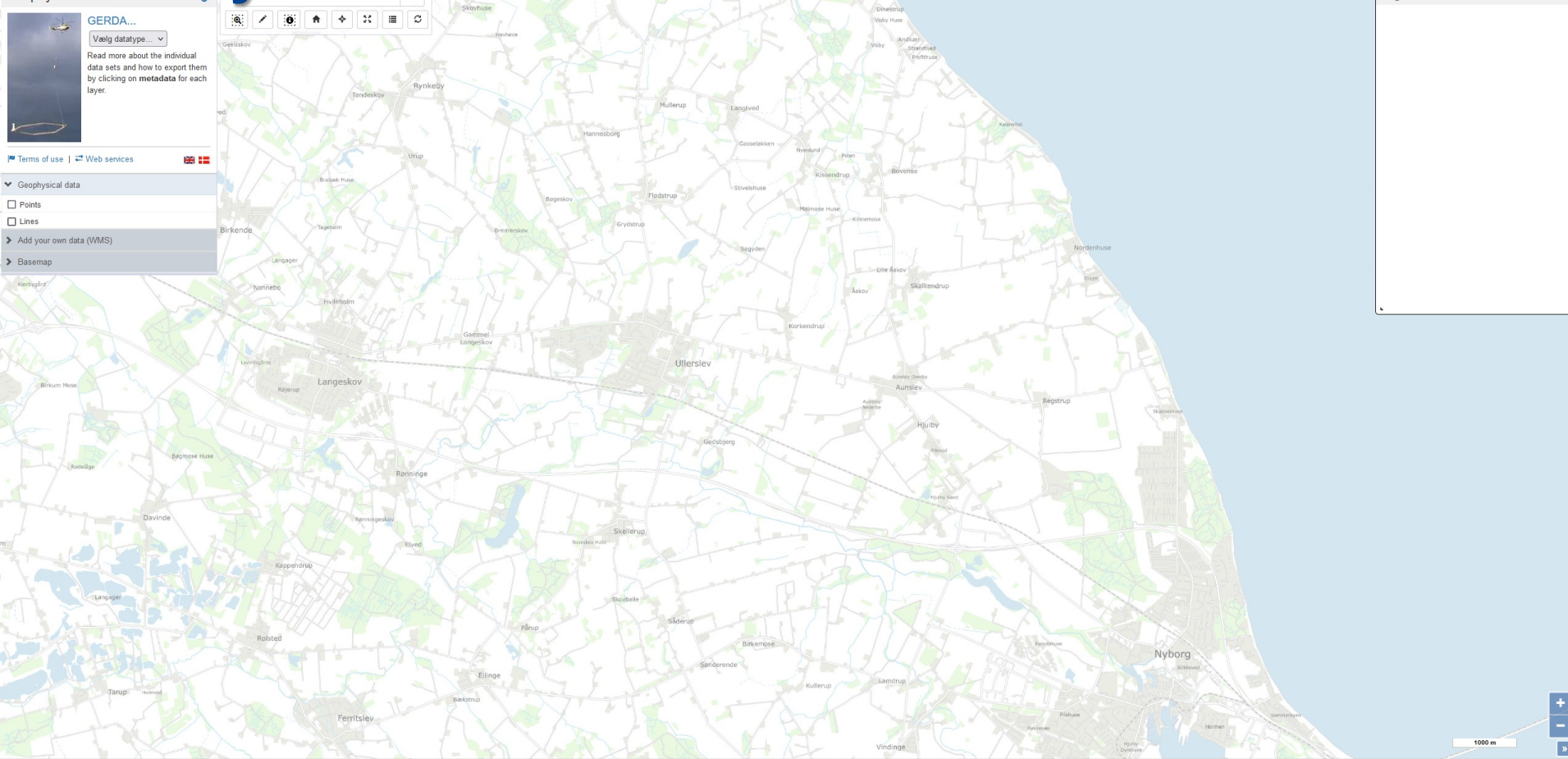
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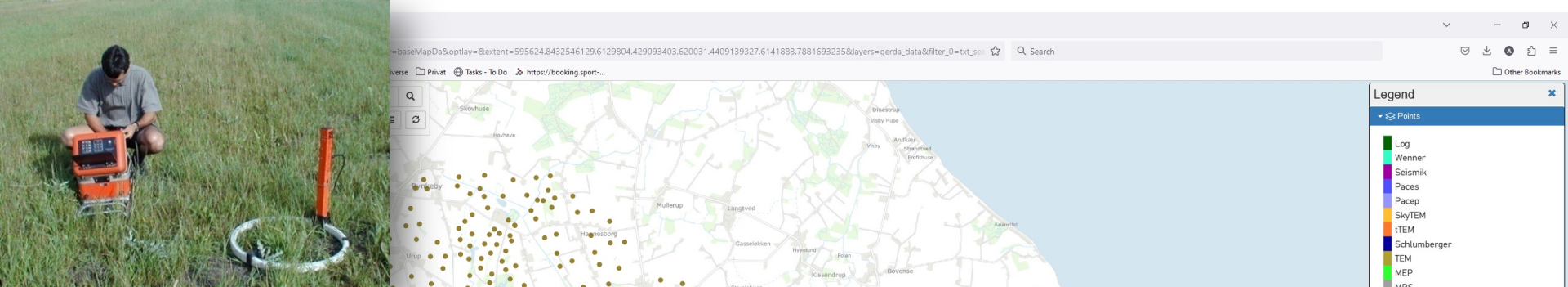
**Geophysical data**

GERDA...  
Vælg datatype...  
Read more about the individual data sets and how to export them by clicking on metadata for each layer.

Terms of use | Web services

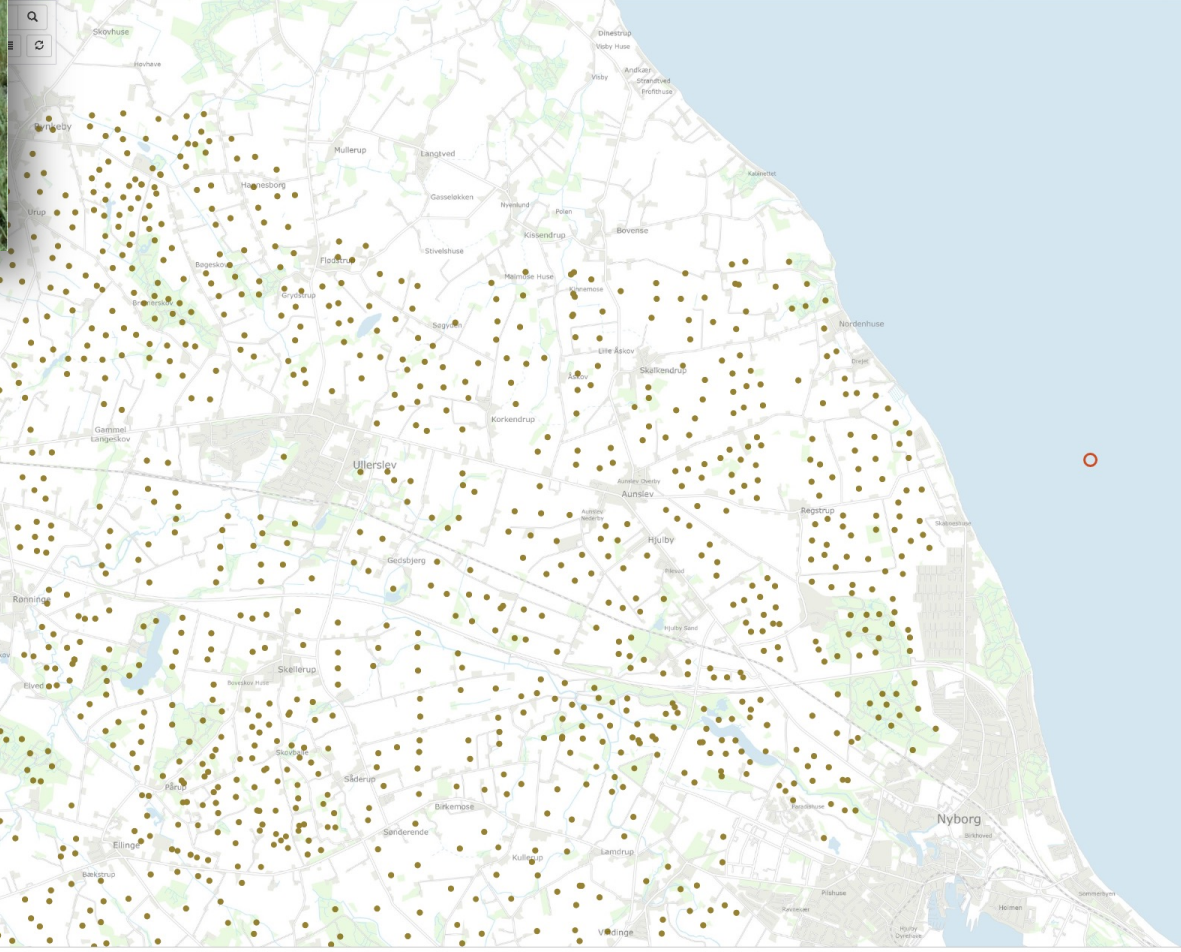
- Geophysical data
  - Points
  - Lines
  - Add your own data (WMS)
  - Basemap





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Private Tasks - To Do https://booking.sport...



### Legend

- Points
- Log
- Wenner
- Seismik
- Paces
- Pacep
- SkyTEM
- tTEM
- Schlumberger
- TEM
- MEP
- MRS

Points

Zoom to

Filter layer for the following criteria:

Text search

Data type

Dims

Layers

Acquired

Inserted

List X Reset

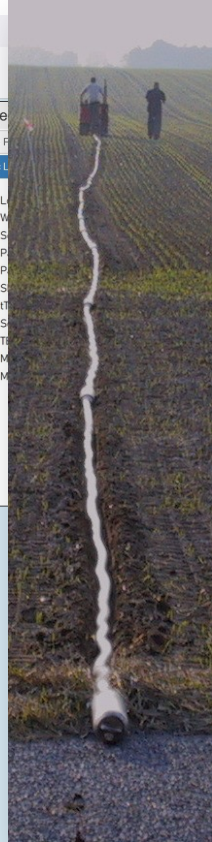
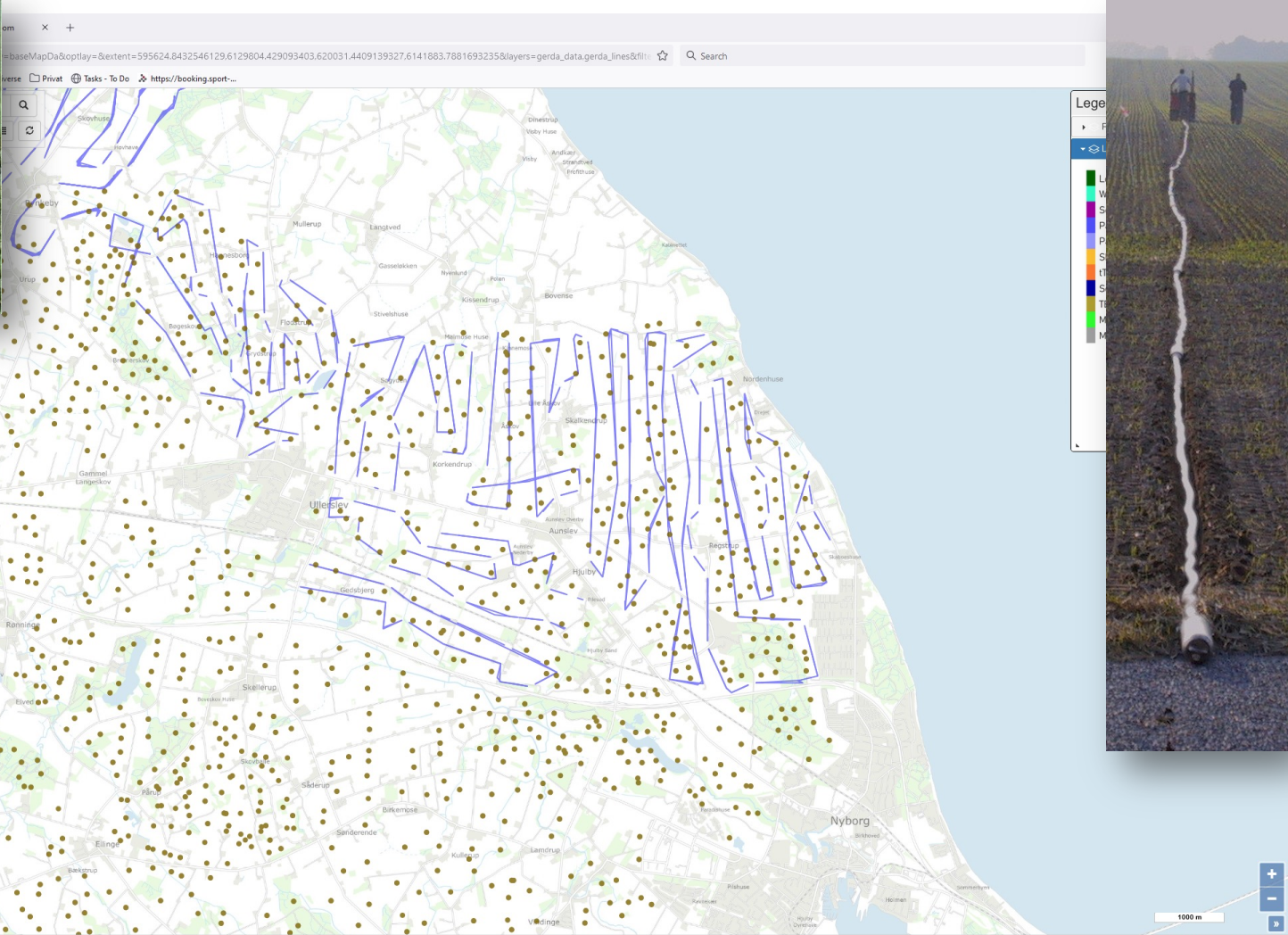
WMS | WFS | Export

Details

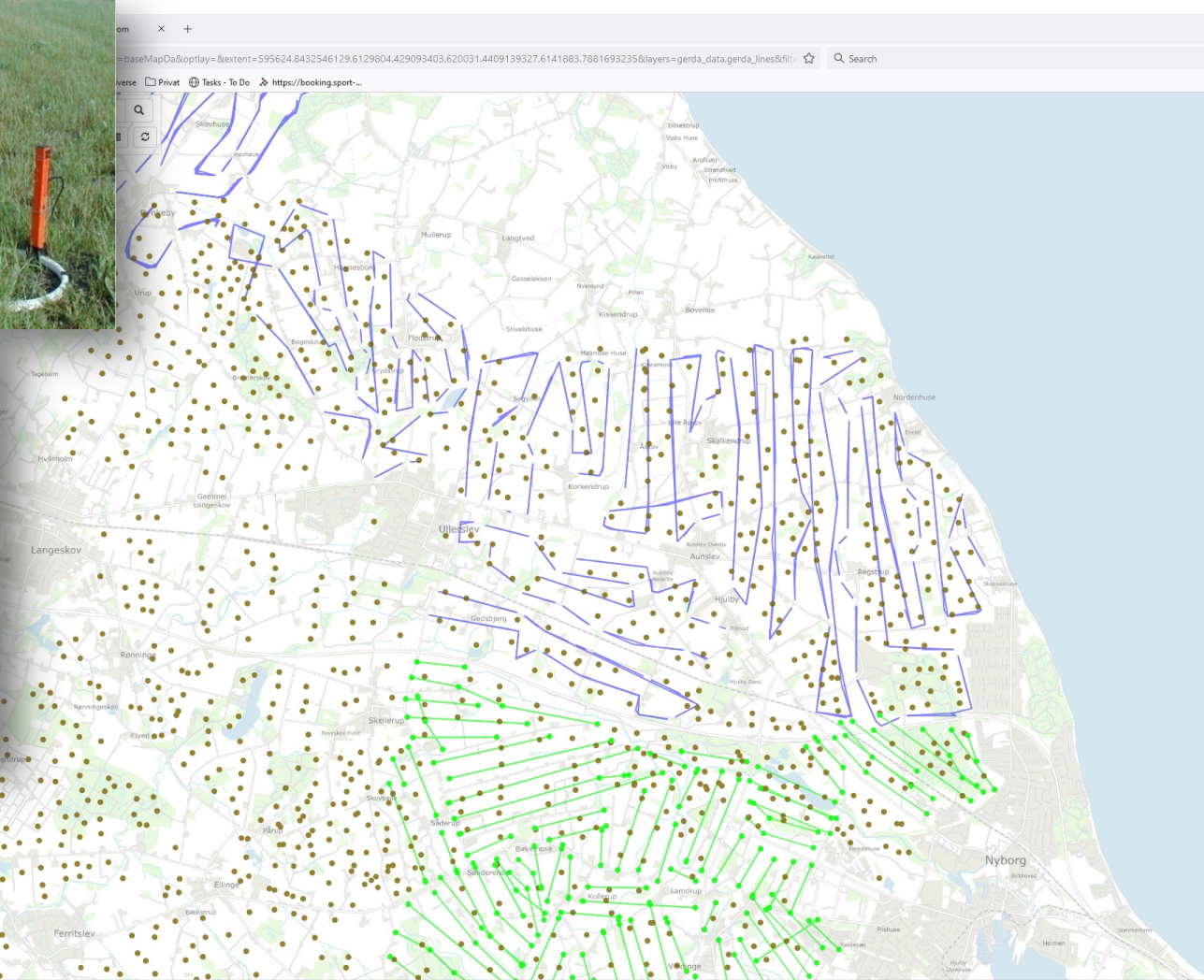
Points New window Excel

no records found

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6136020 484434761)







Legende

- U
- W
- S
- P
- P
- S
- T
- S
- T
- M



(CTRL+click)

Dims:

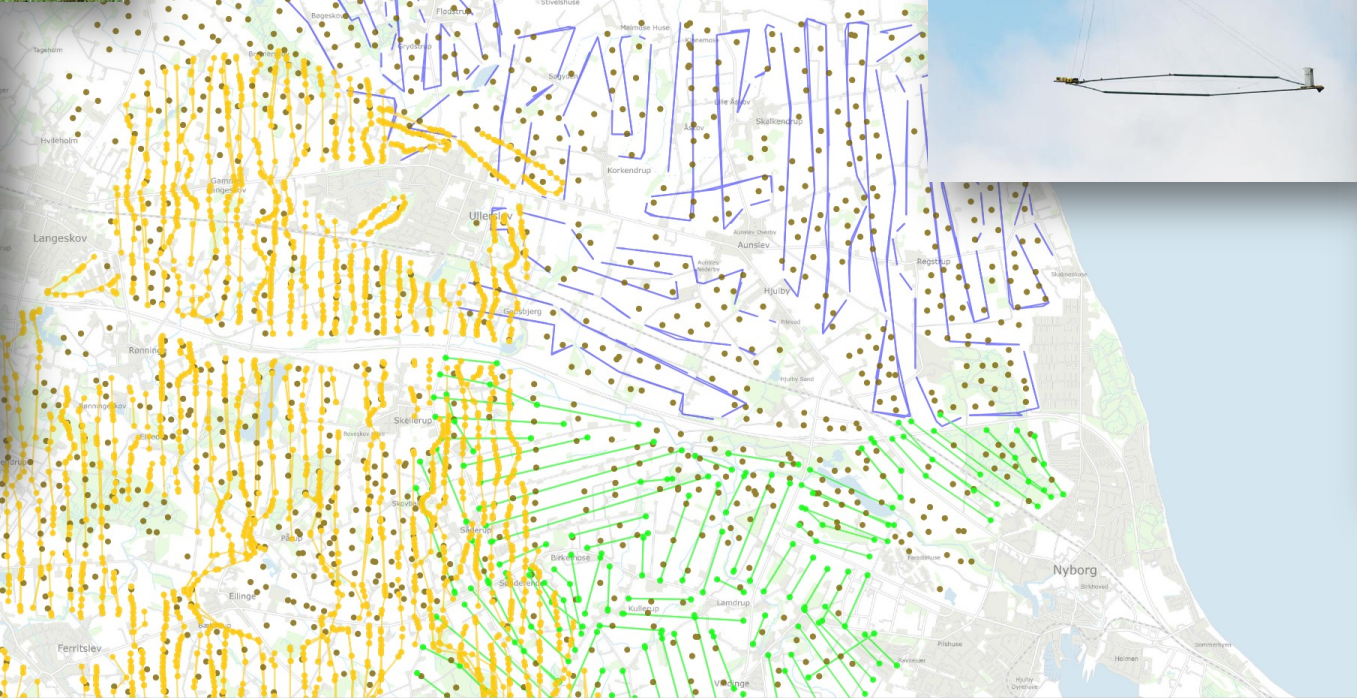
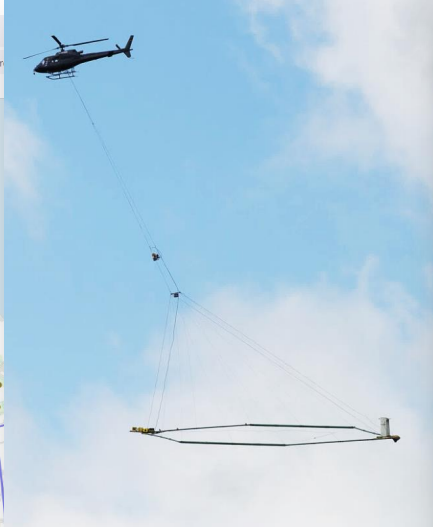
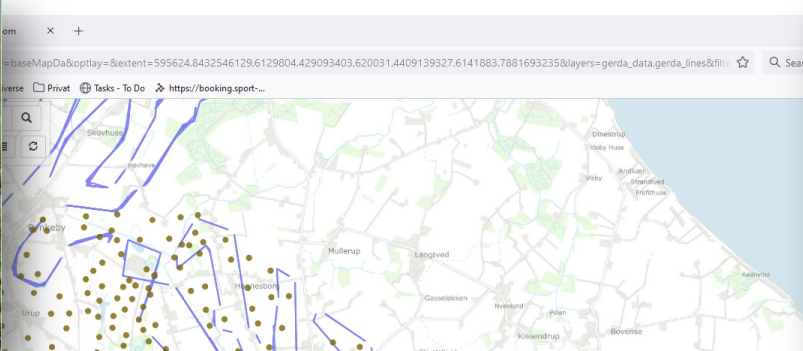
Layers:

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Inserted:

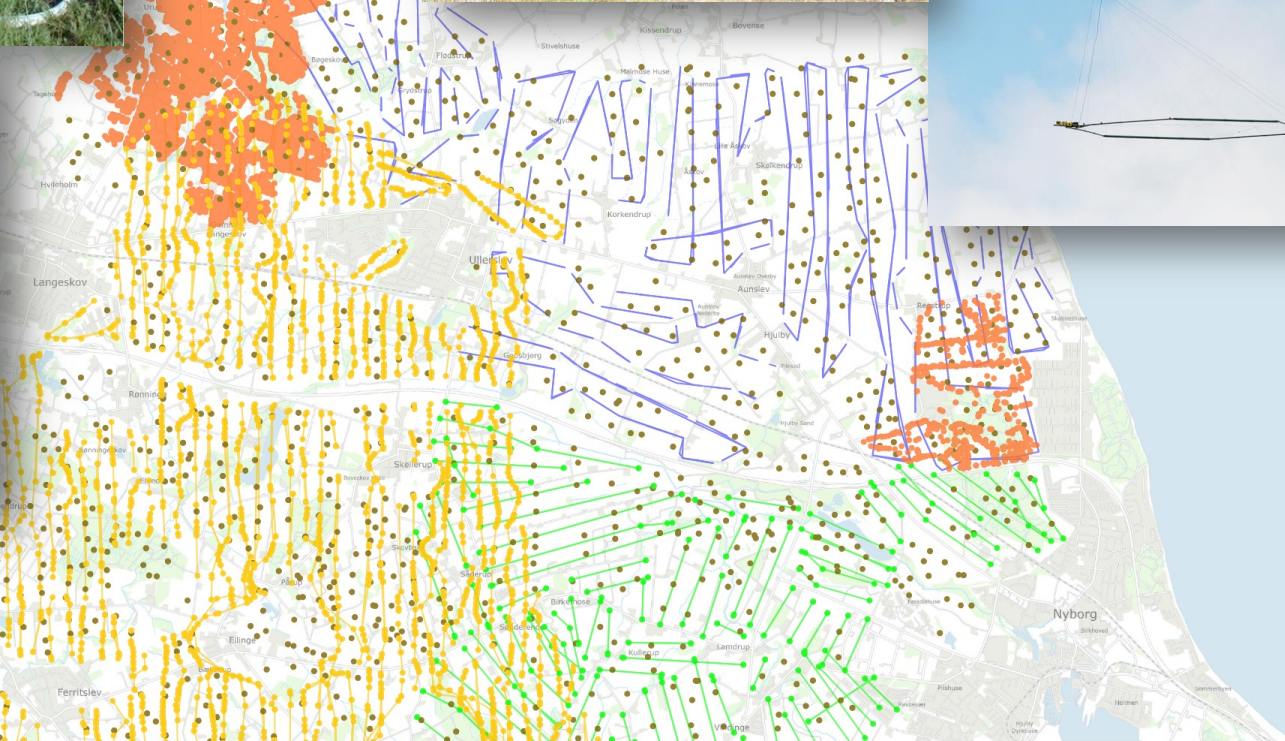
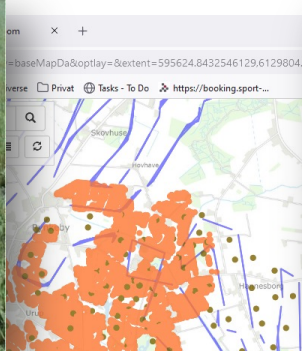
ZOOM IN: shift + Drag SELECT: ctrl + Drag

1000 m



(CTRL+click)  
Dims:   
Layers:   
Acquired:   
Inserted:   
   
WMS | WFS | Export  
Add your own data (WMS)  
Basemap

ZOOM IN: shift + Drag SELECT: ctrl + Drag

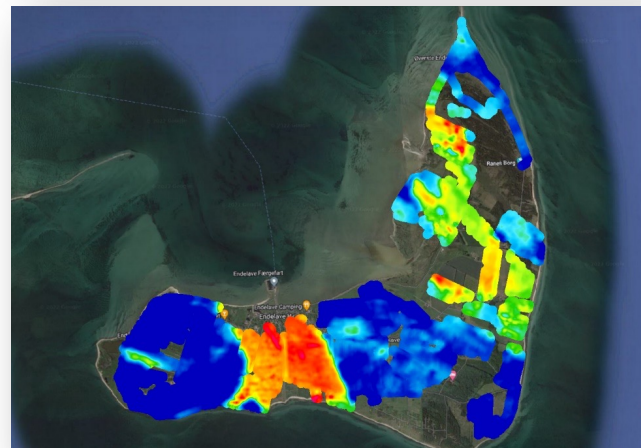


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Layers:   
Acquired:   
Inserted:   
   
WMS | WFS | Export  
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ZOOM IN: shift + Drag SELECT: ctrl + Drag

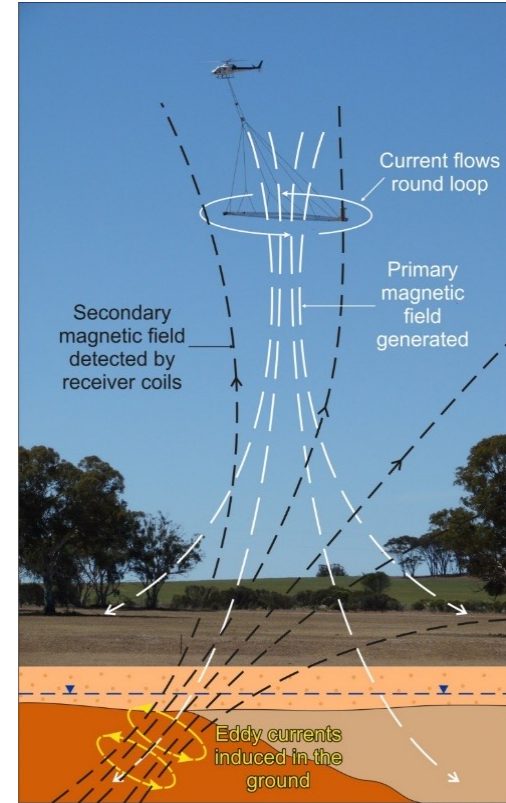
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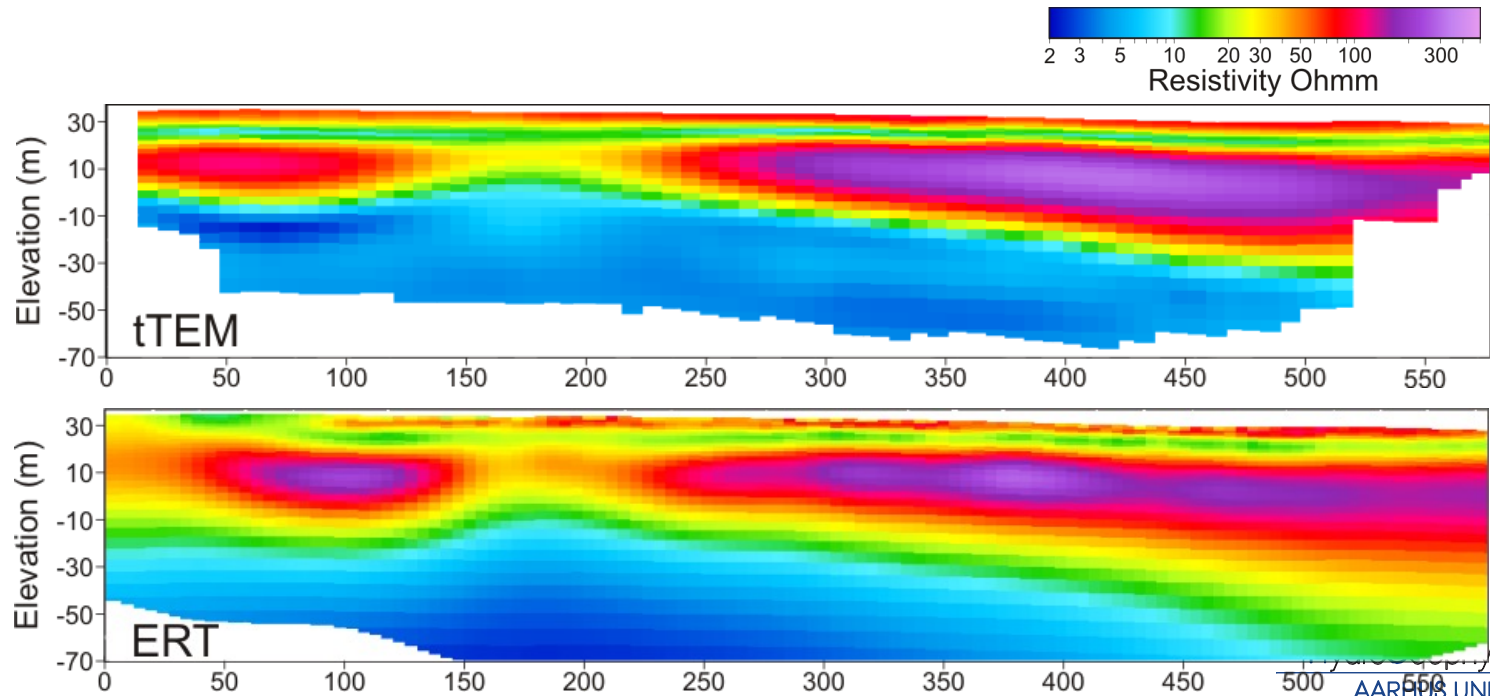
# Sammenligning

- **tTEM**
  - Towed transient electromagnetic
- **SkyTEM**
  - Airborne TEM
- **ERT / MEP**
  - Electrical resistivity tomography



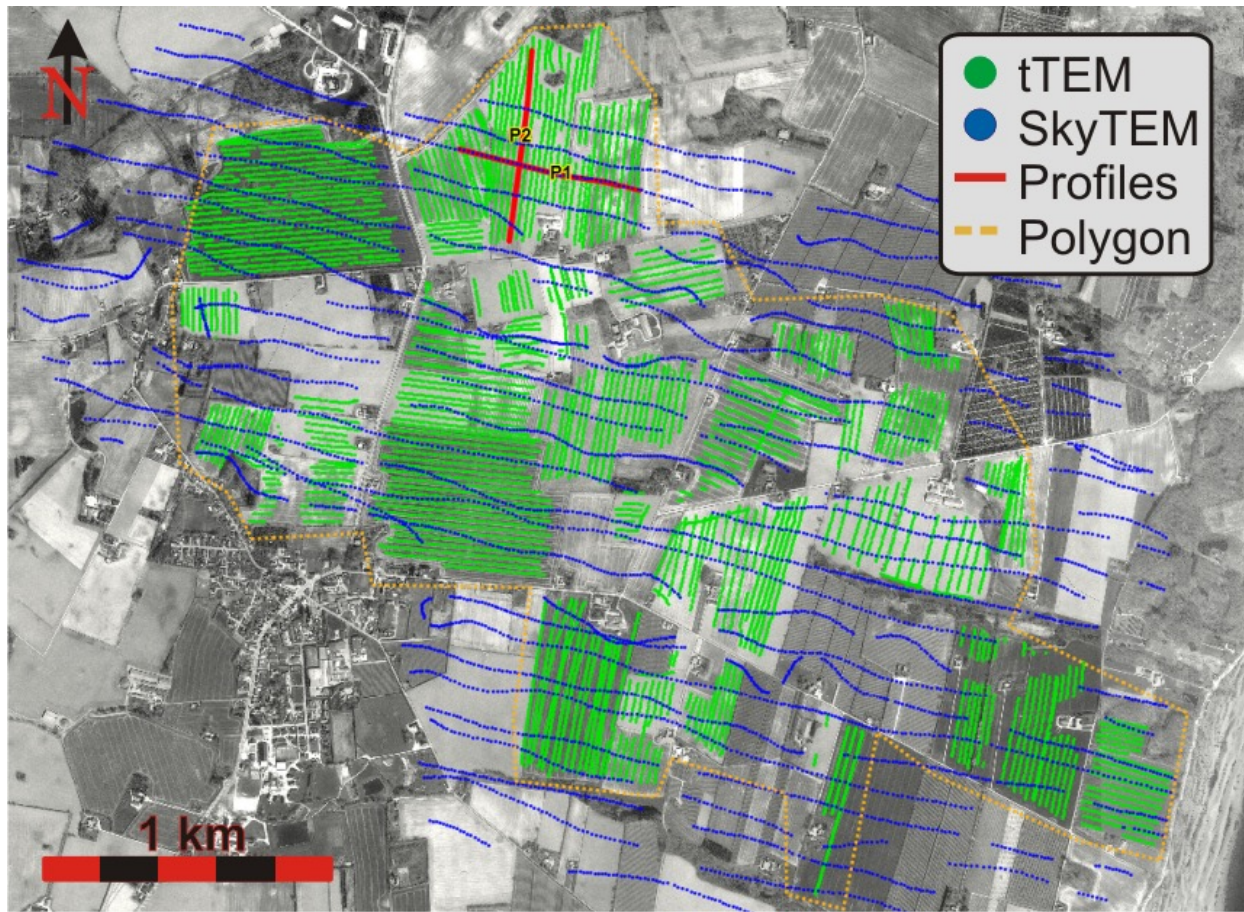
# Field example: ERT vs tTEM

- ERT: 2D-inversion, L2-norm (smooth)
- tTEM: 1D-LCI inversion, (smooth)

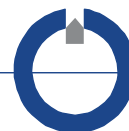
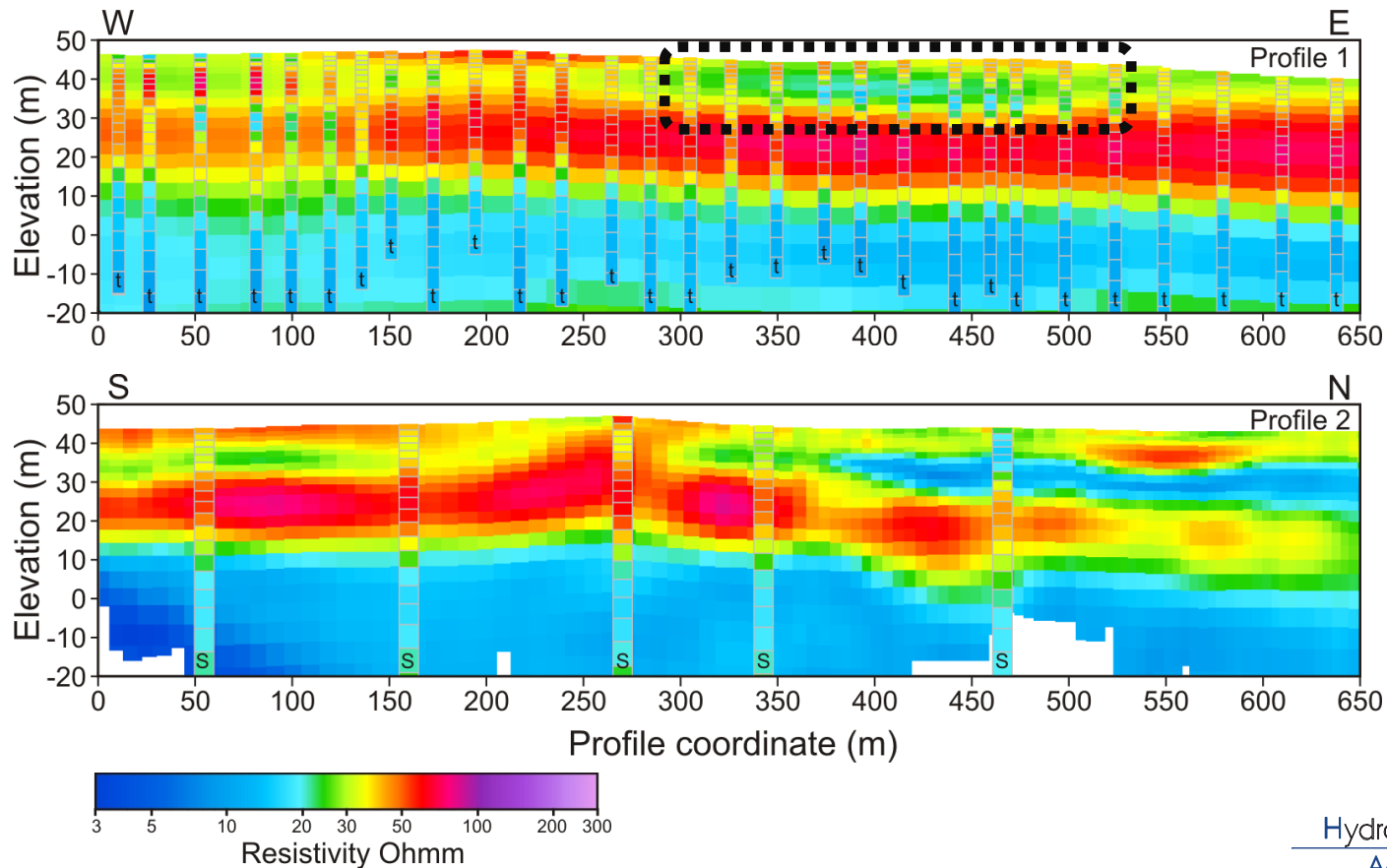


# Field example: tTEM vs SkyTEM

- SkyTEM line spacing <math><150\text{ m}</math>

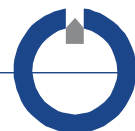
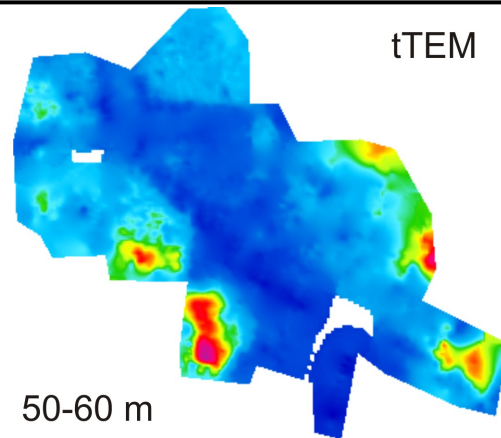
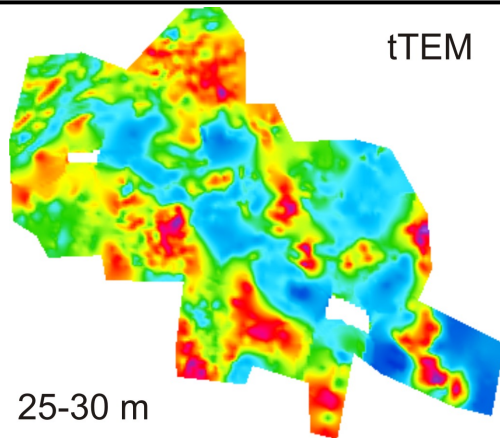
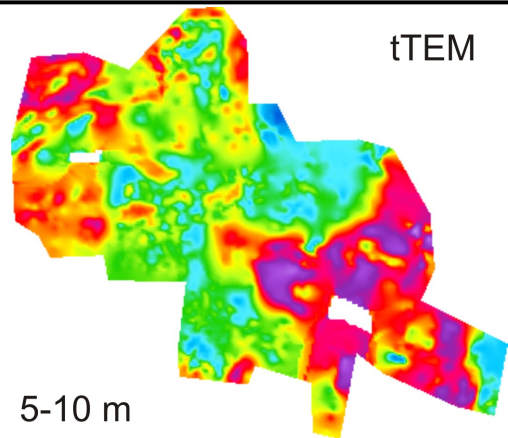
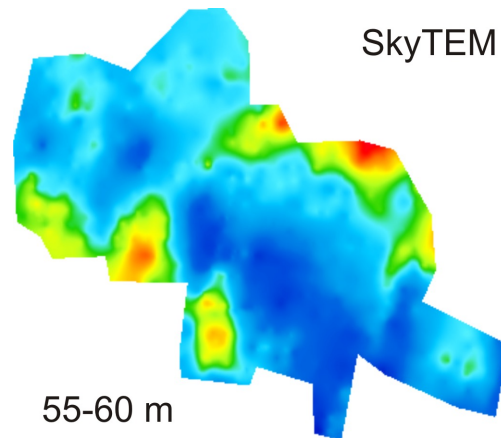
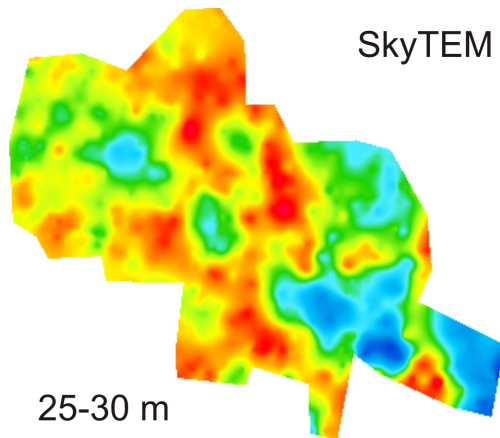
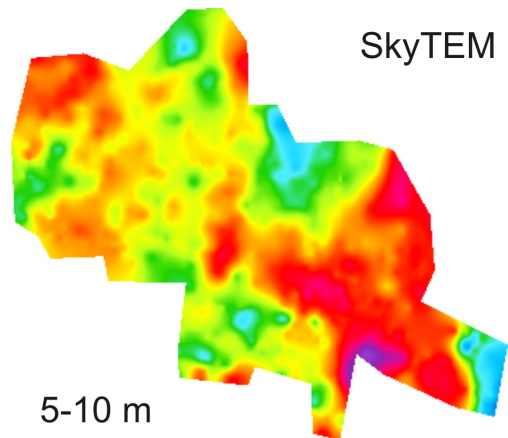


# Field example: tTEM vs SkyTEM



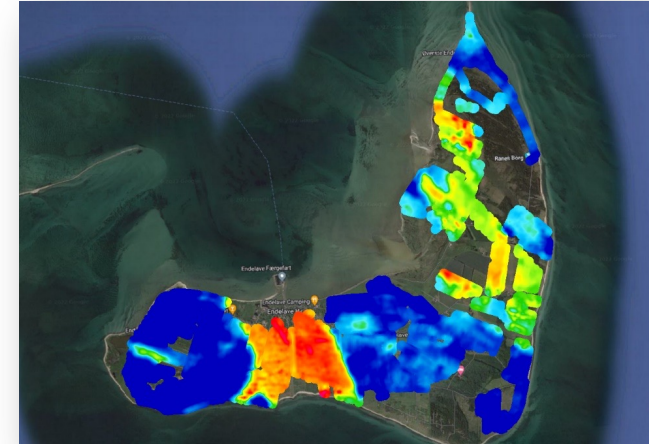


# Field example: tTEM vs SkyTEM - Horizontal slices

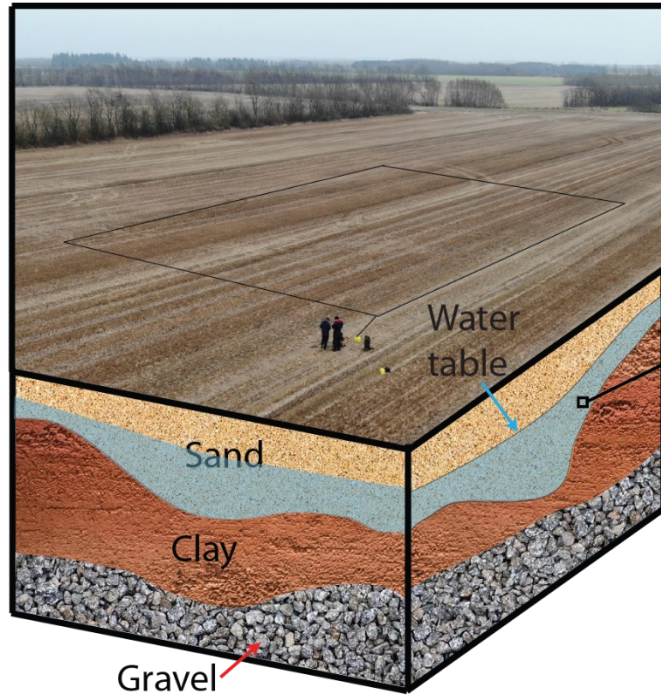


# Indhold

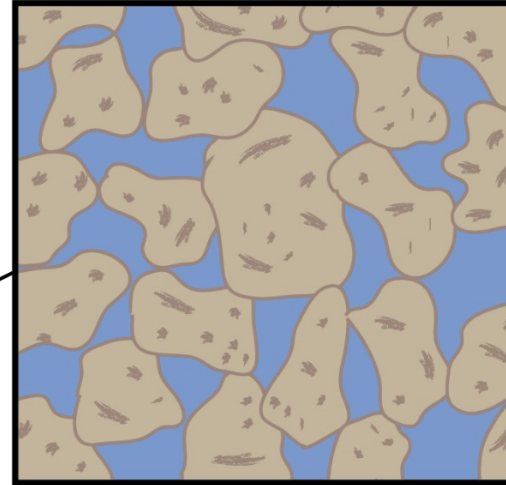
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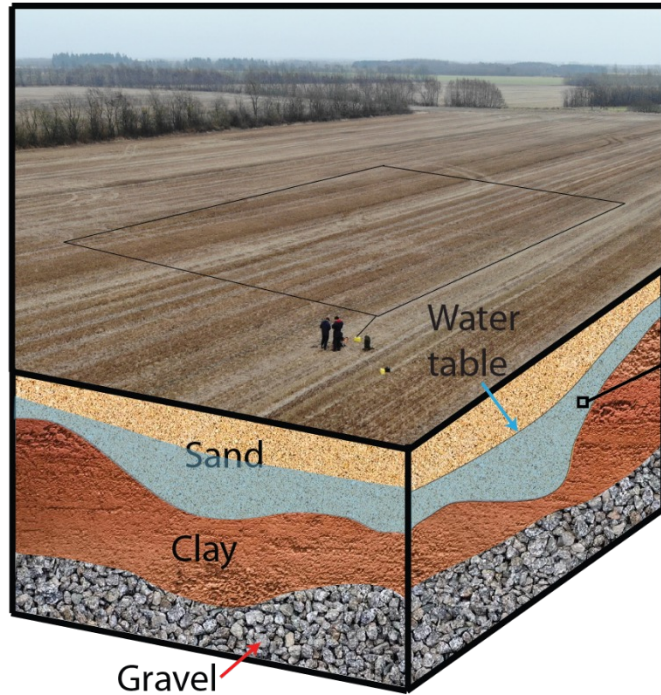
# Kortlægning af fysiske parametre - NMR



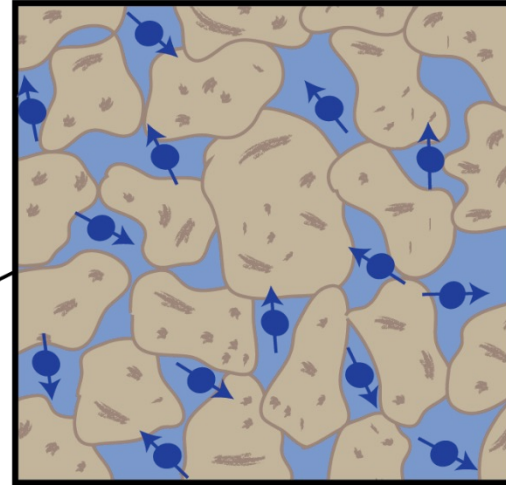
zoom in of pore space



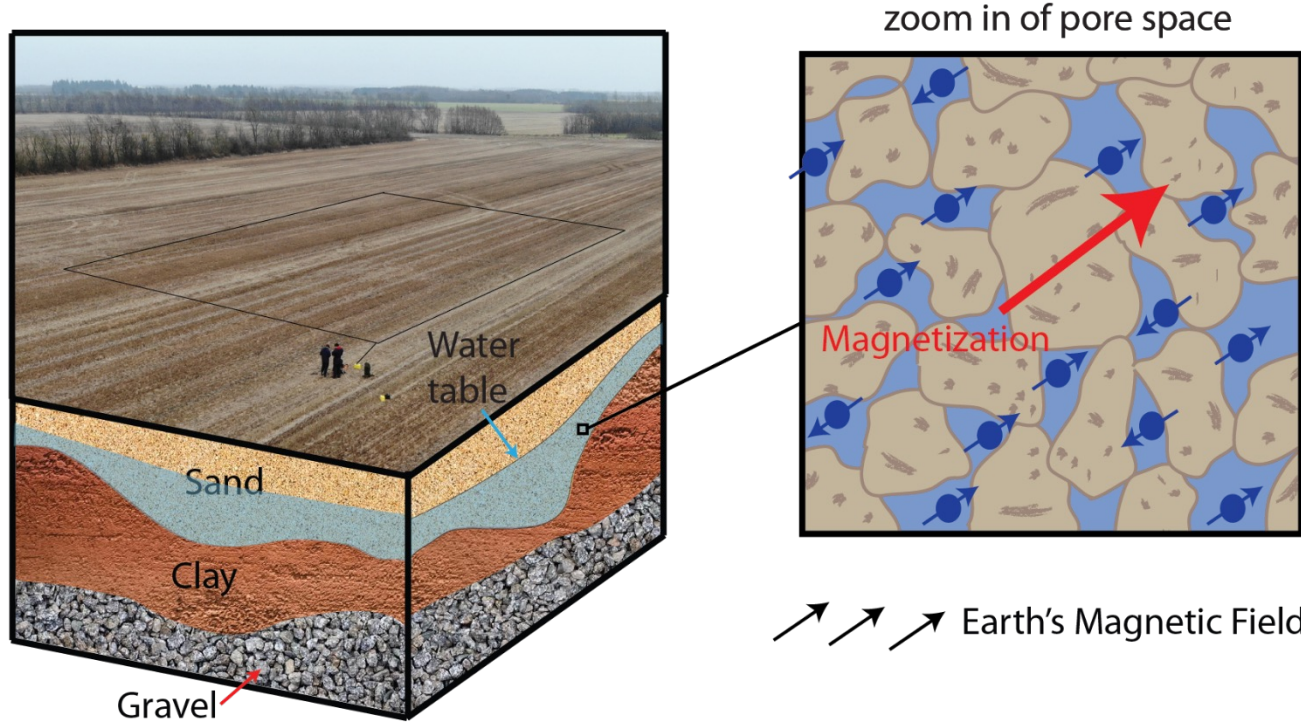
# Kortlægning af fysiske parametre - NMR



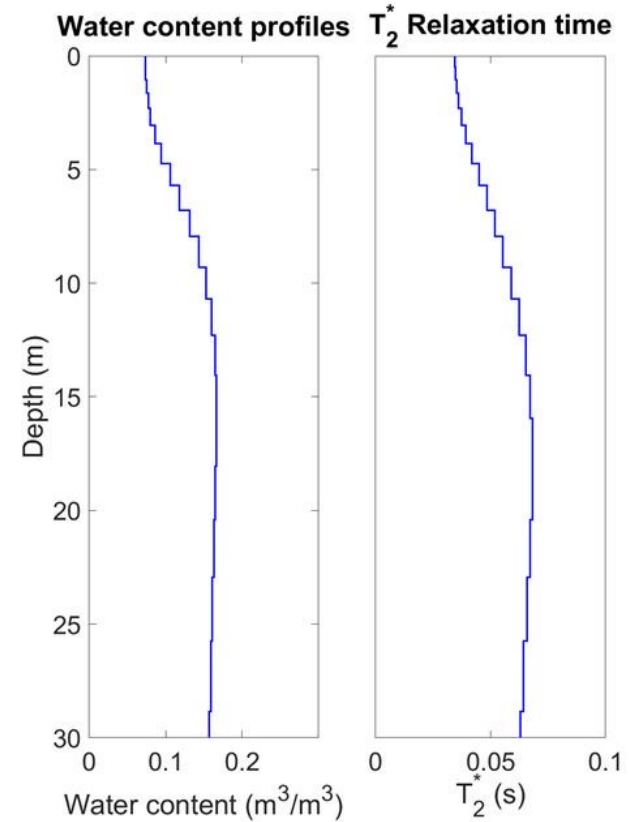
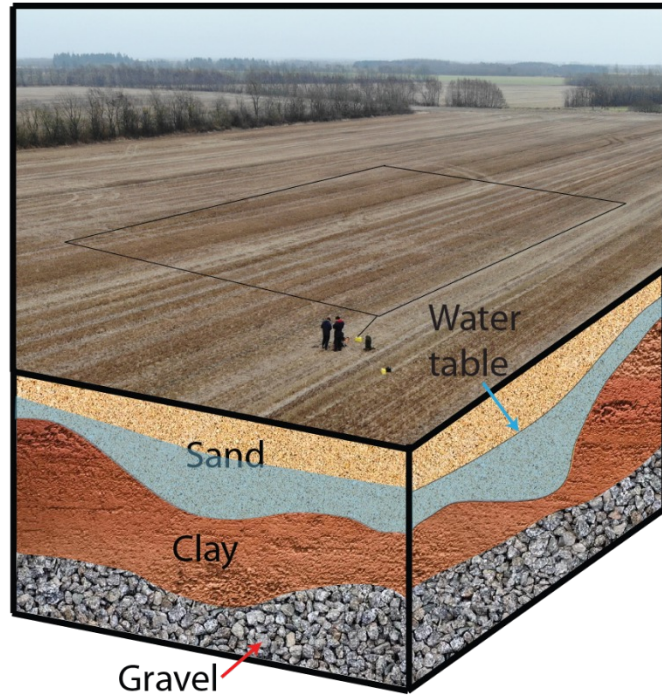
zoom in of pore space



# Kortlægning af fysiske parametre - NMR



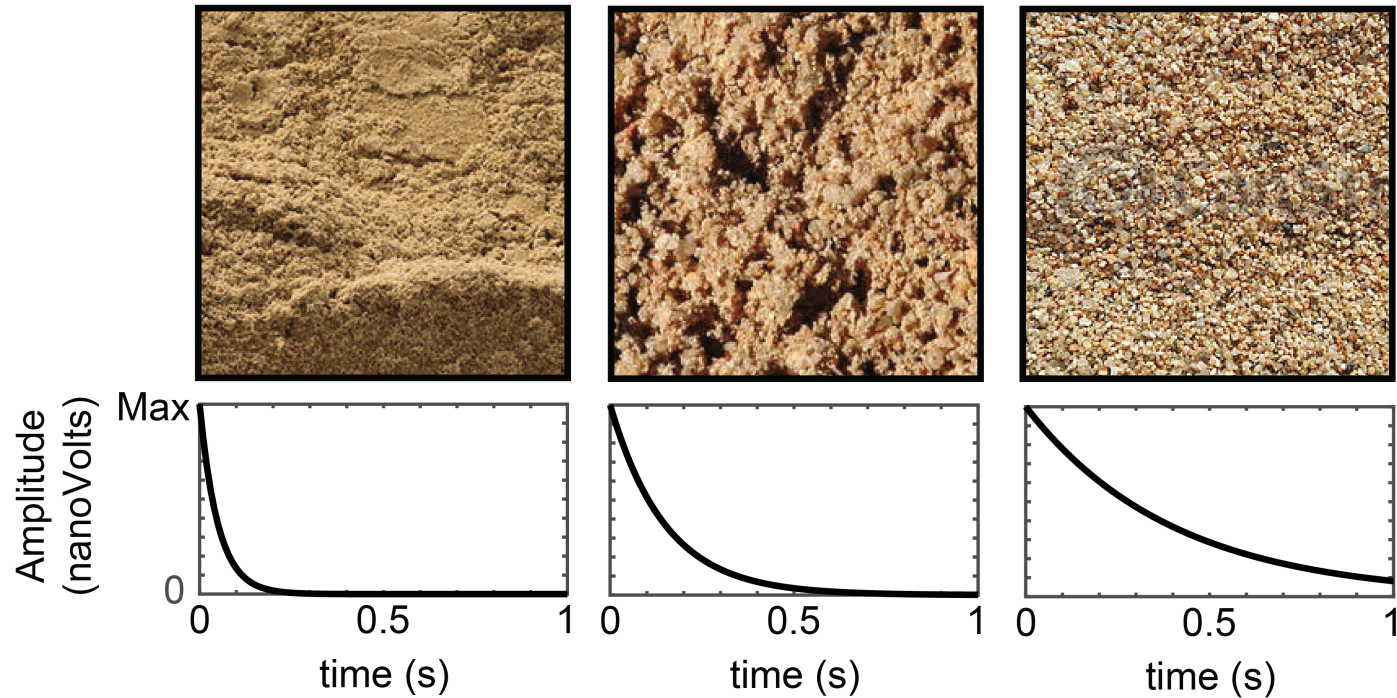
# Kortlægning af fysiske parametre - NMR



# Relaxation times

Increasing pore size →

Increasing  $T_2^*$  →



# Apsu



Transmitter

Power supply/cap bank

50 Ah Li Battery

Current Probe

Tx Controller/Receiver/PC

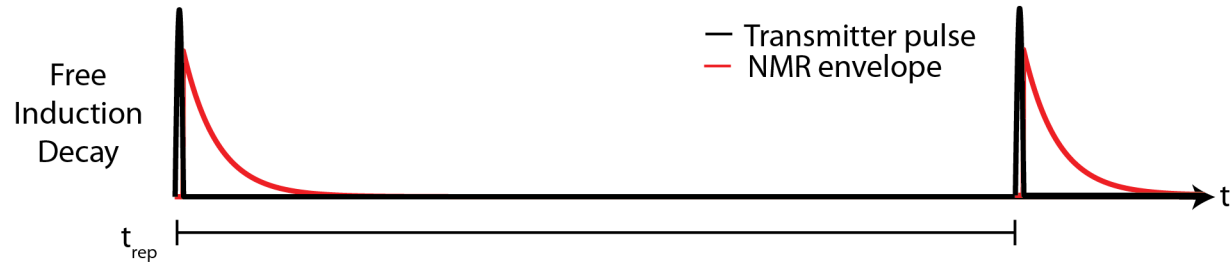
cables

50x50 m loop

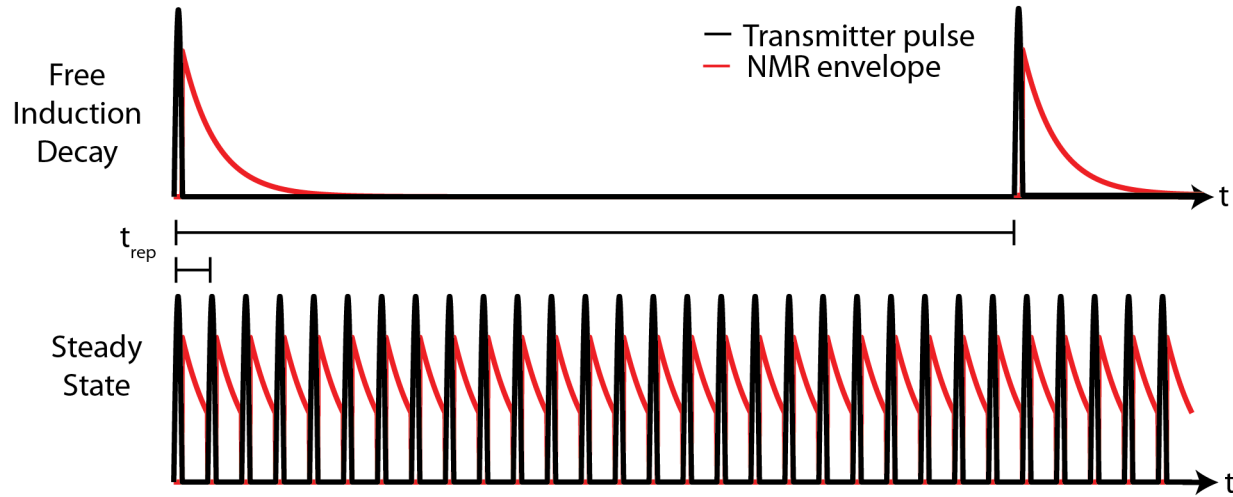
1 kWh generator



# Data acquisition

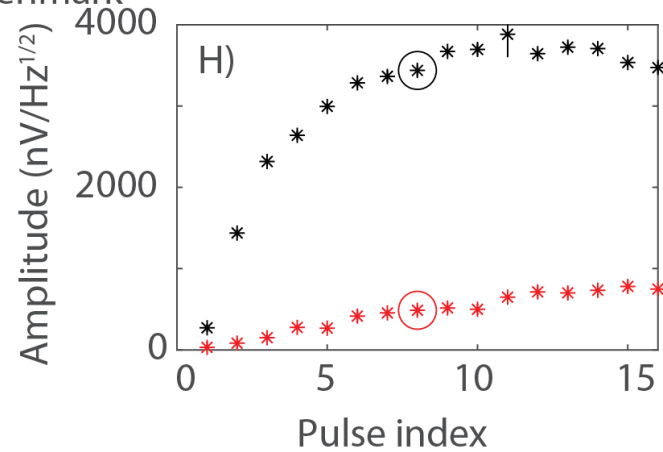
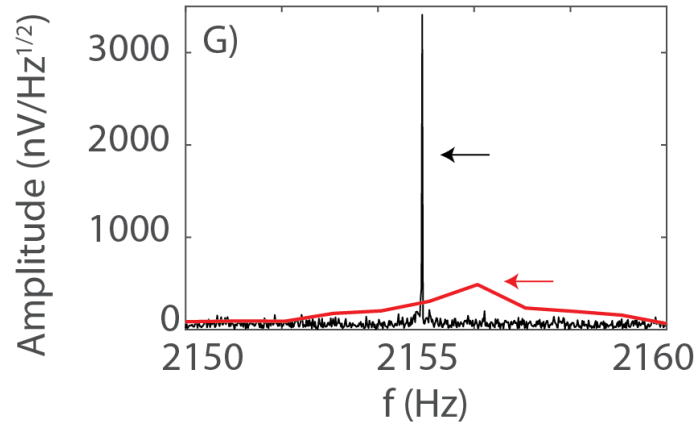


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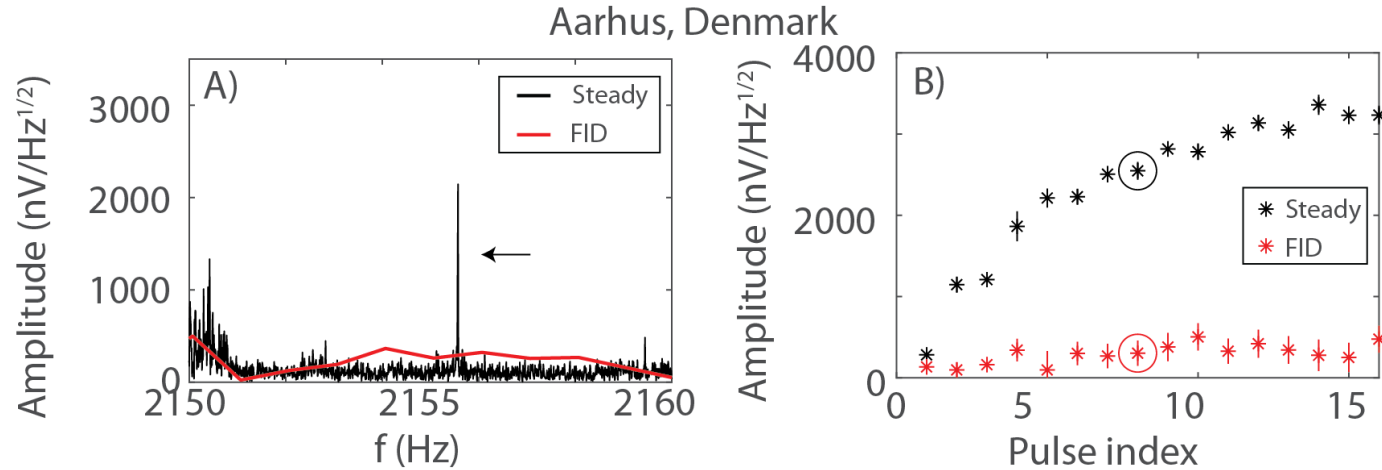


# Field data

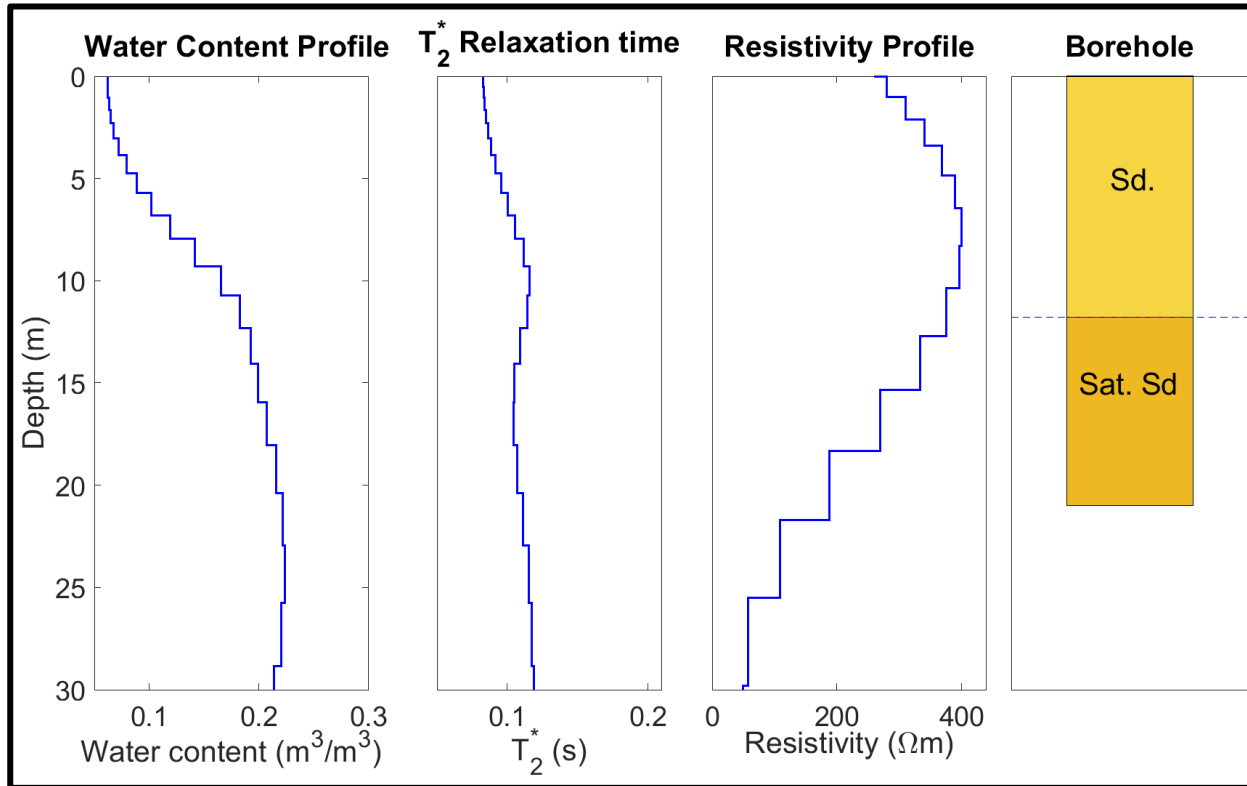
Silkeborg, Denmark



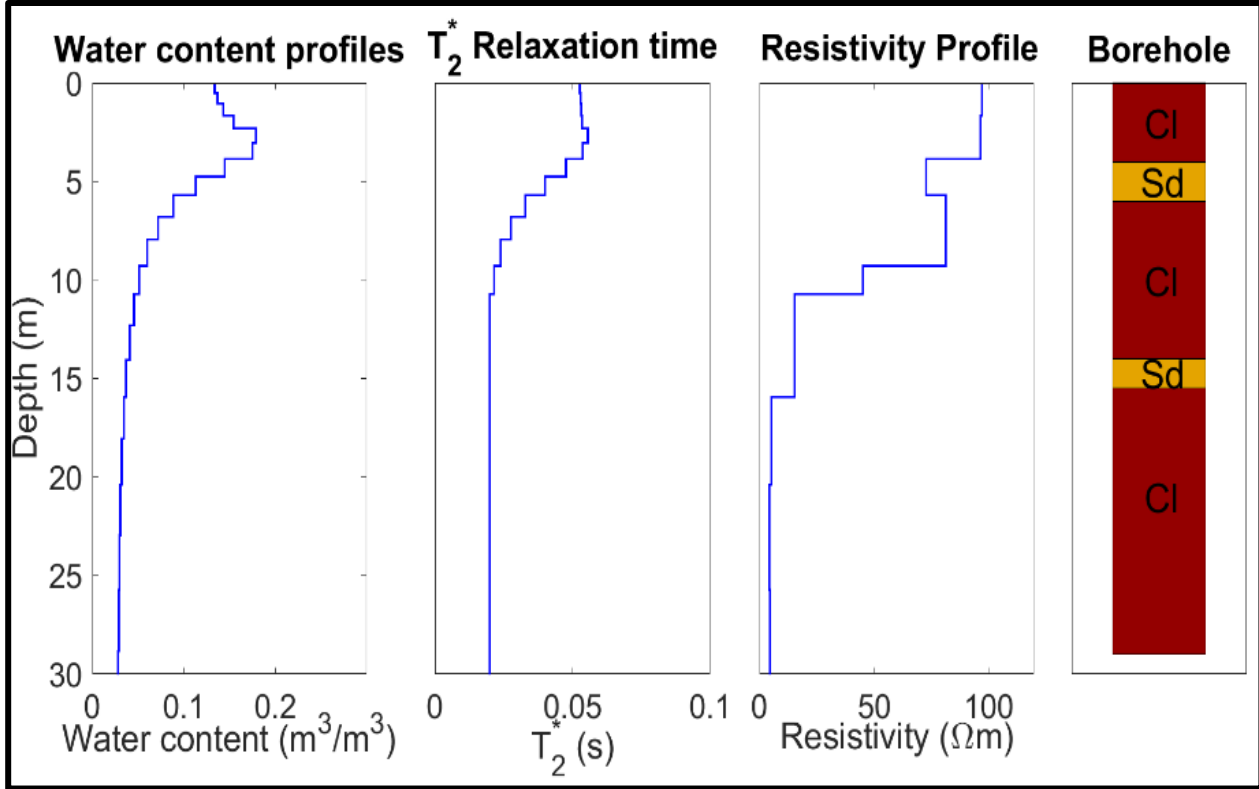
# Field data



# Apsu – depth profiles



# Apsu – depth profiles

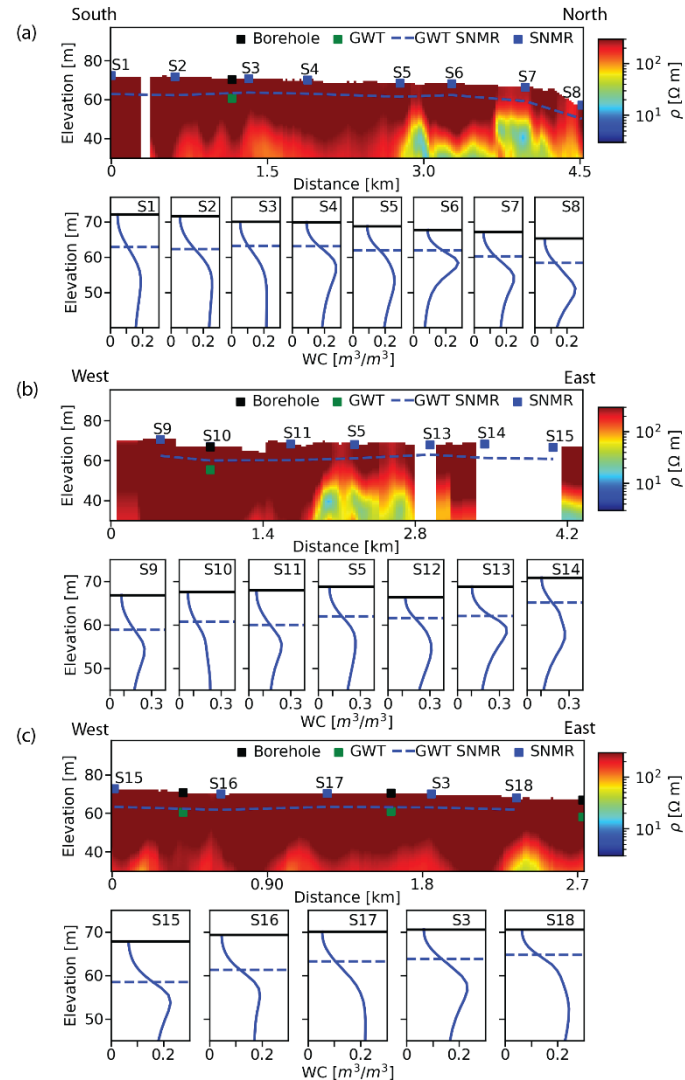
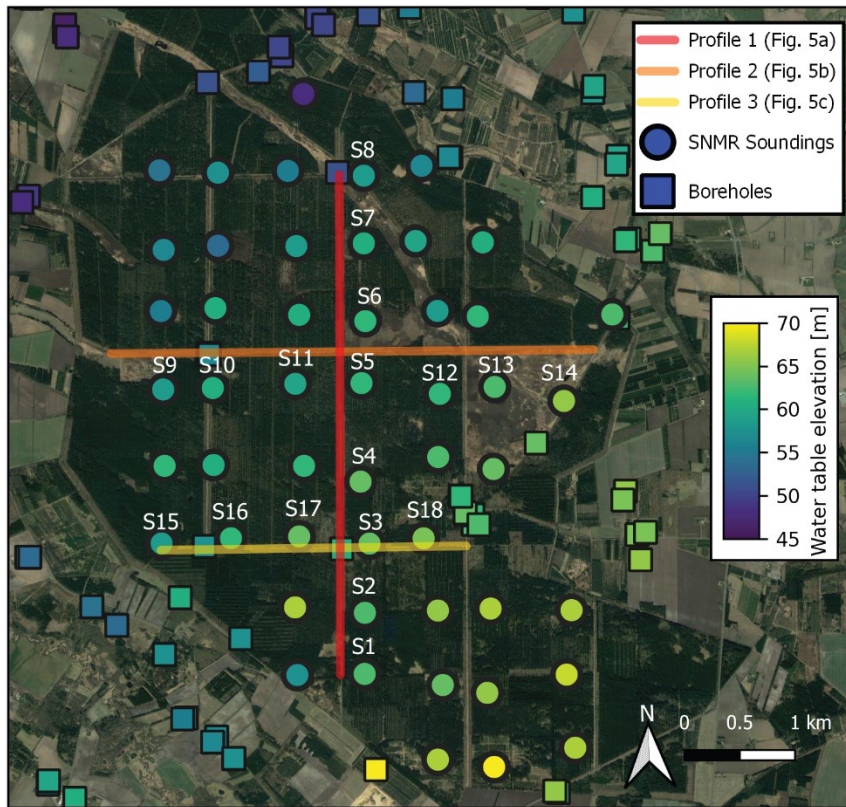


# Danish field examples

Rivers	No. Sites	Field days
Aars	29	10
Sunds	38	12
Kompedal	50	5
Endelave	50	6

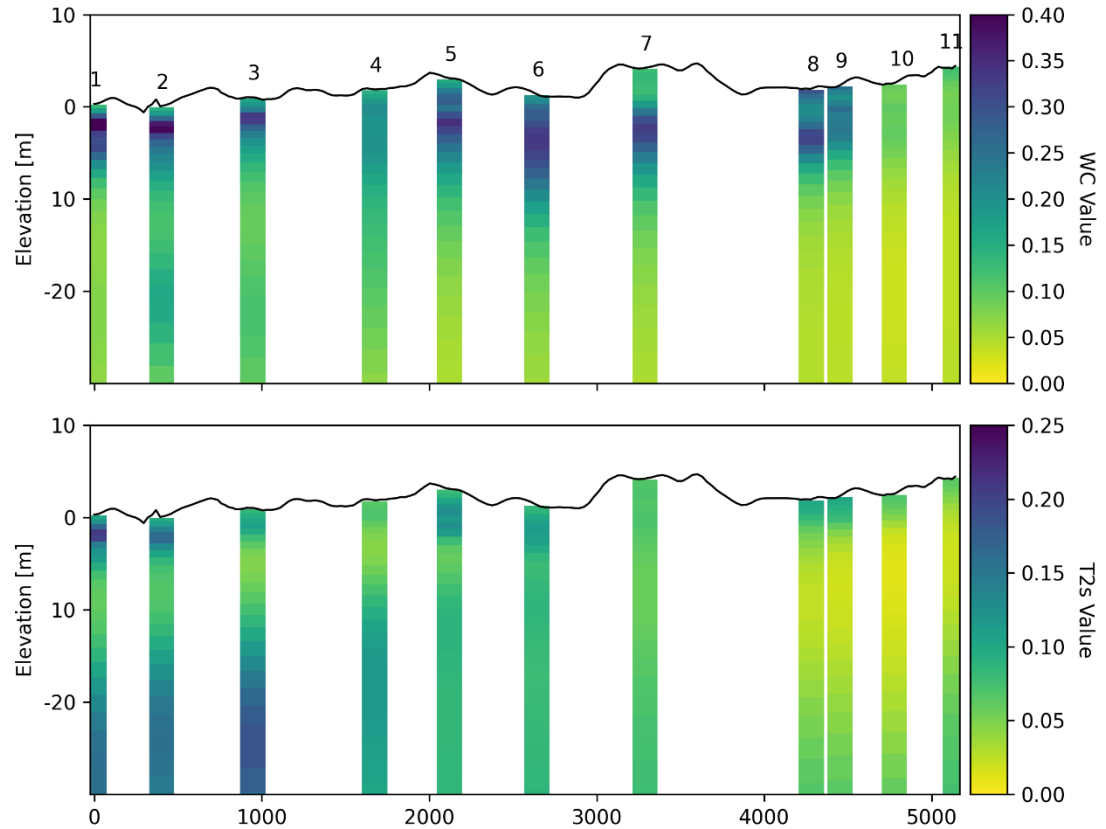
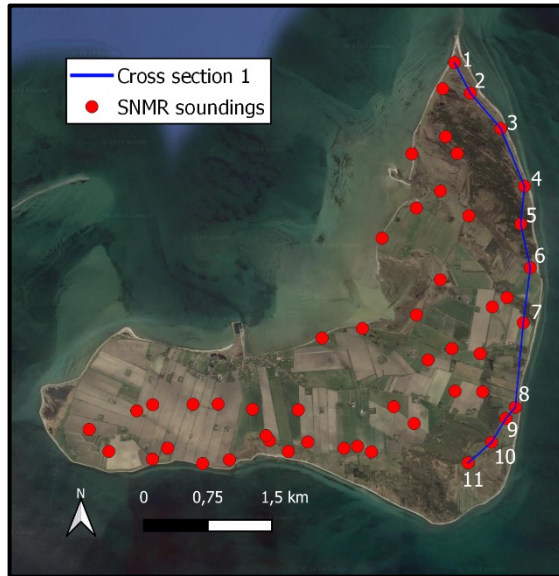


# Apsu – water table mapping

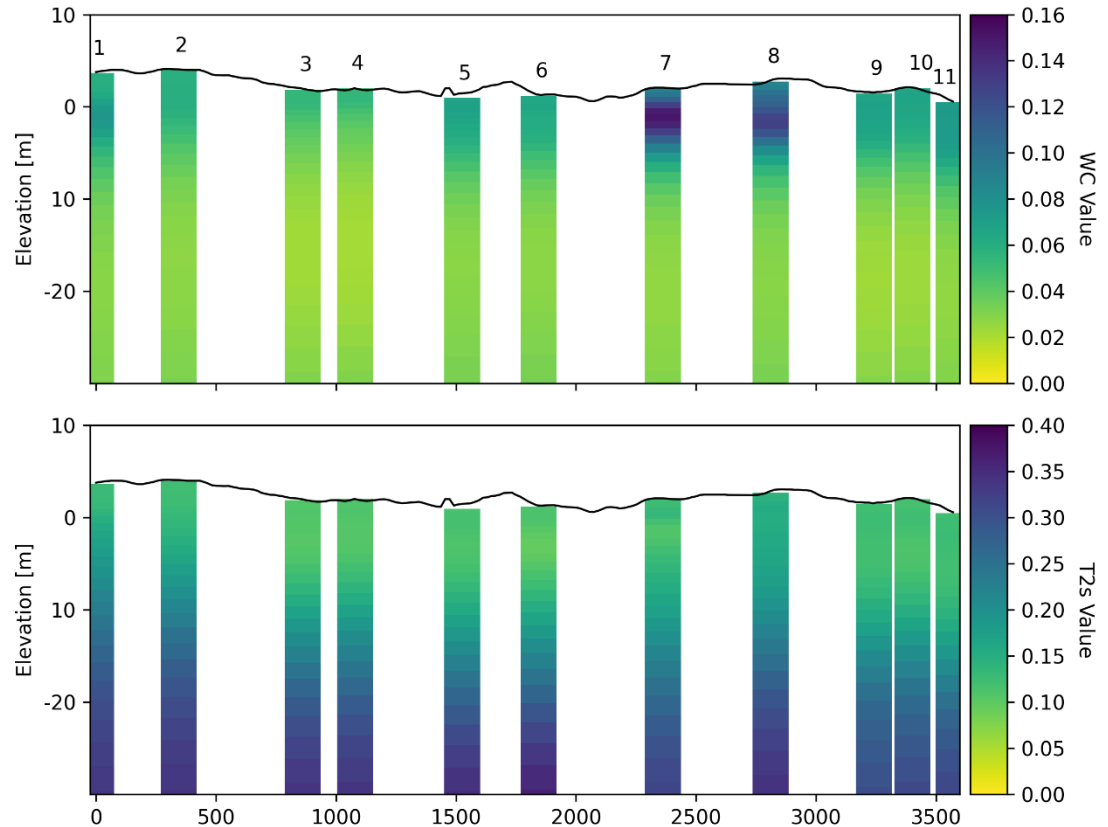
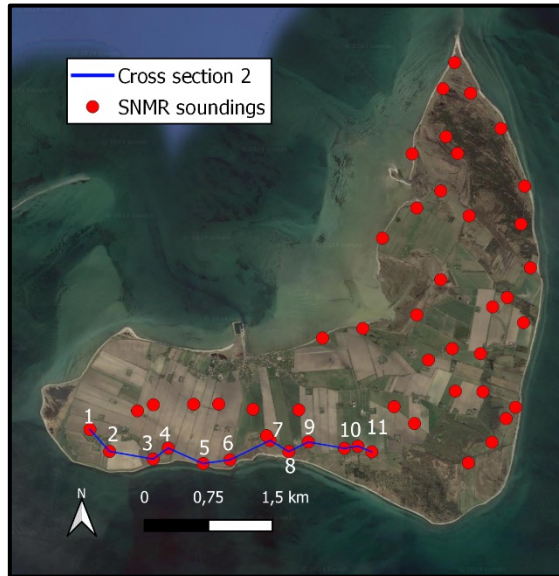




# Cross section 1

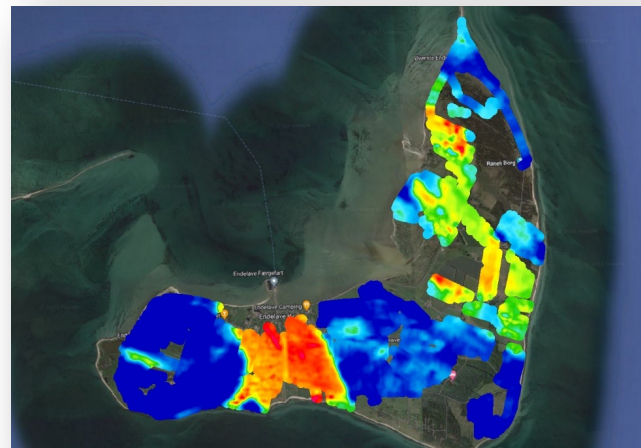


# Cross section 2



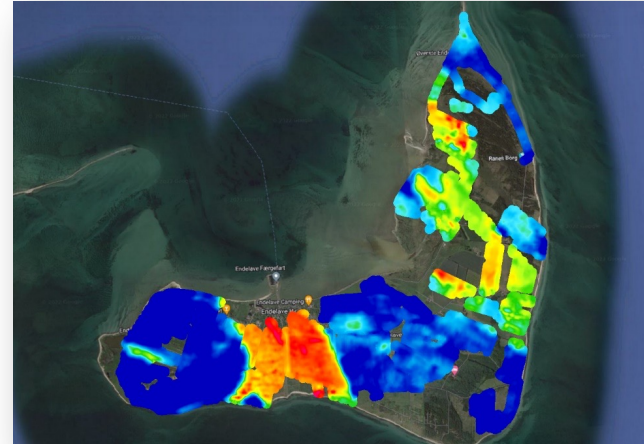
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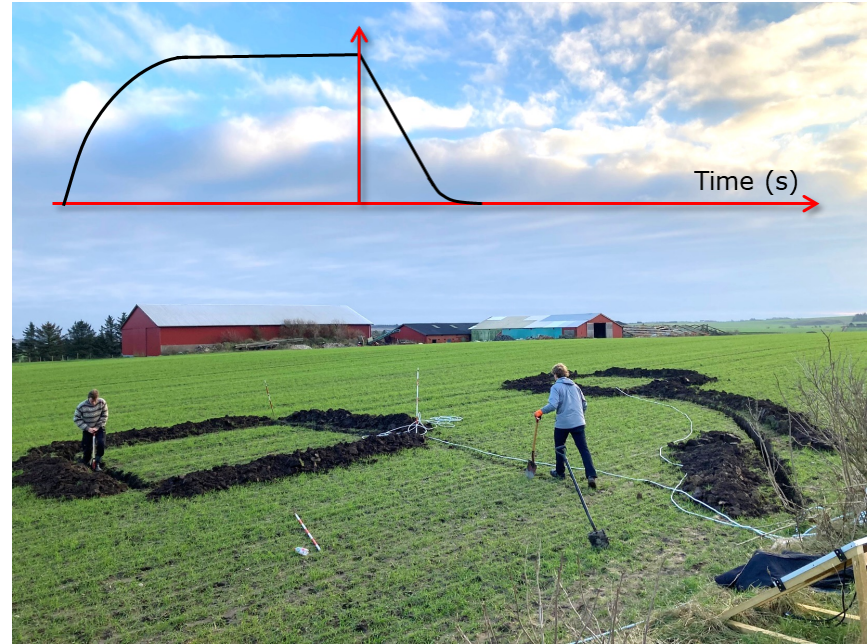
# Tidslige målinger

1. Salinity – e.g. saltwater intrusion or pollution
2. Groundwater level
3. Soil moisture / saturation
4. Temperature
5. Freeze-thaw processes

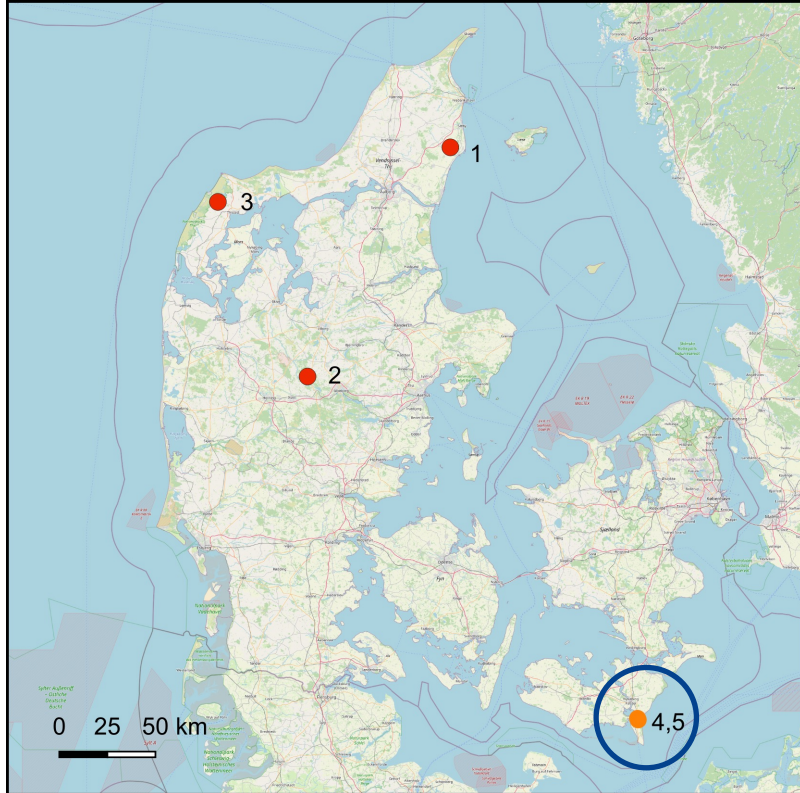


# System requirements

- **Low power**
  - Solar powered
  - Battery shift
- **Stability, no drift**
  - Transmitter waveform
  - Current level
- **Durability**
  - Animal protection
  - Weather-proofing
- **Accessibility**
  - Remote control and data upload
  - Autonomous measurements



# Installed monitoring systems



## Water table dynamics

### 1. Albæk

Monitoring started October 20<sup>th</sup>, 2022.

Goal: track water table in a shallow aquifer.

### 2. Kompedal

Monitoring started November 6<sup>th</sup>, 2022.

Goal: track water table in a high-resistive aquifer.

### 3. Thisted

Monitoring started April 8<sup>th</sup>, 2023.

Goal: coastal aquifer.

## Saltwater intrusion dynamics

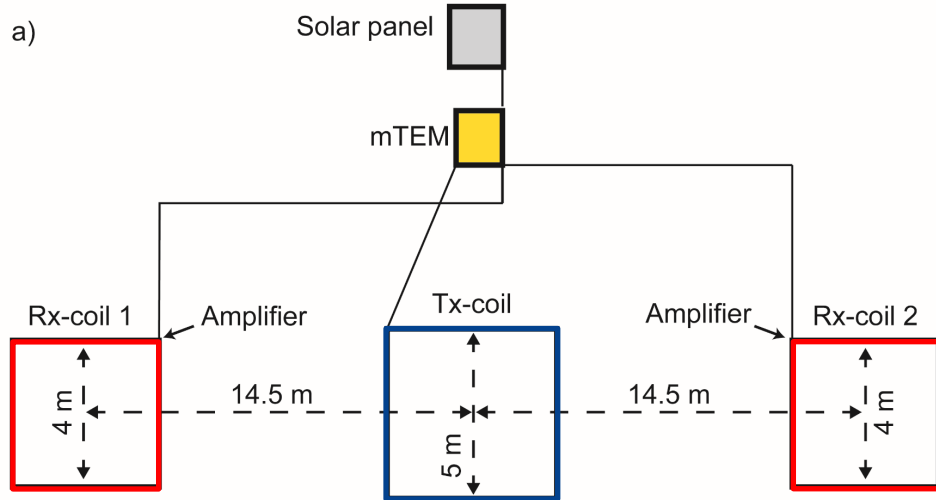
### 4-5. Falster

Two systems installed in Falster in November 2022 and January 2023.

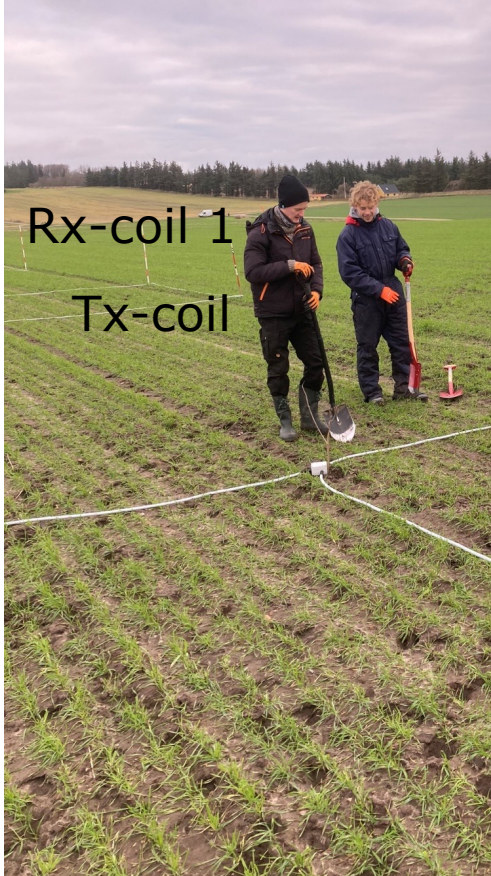
Goal: track seasonal change in saltwater intrusion.



# mTEM installation



# mTEM installation

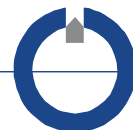
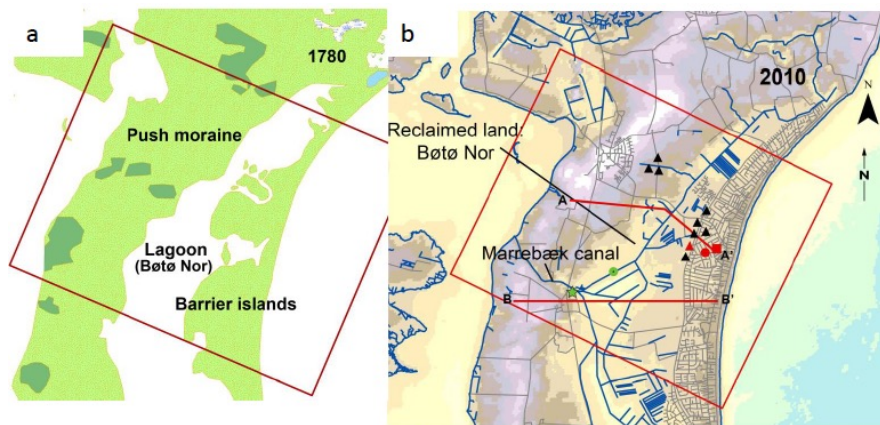




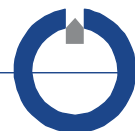
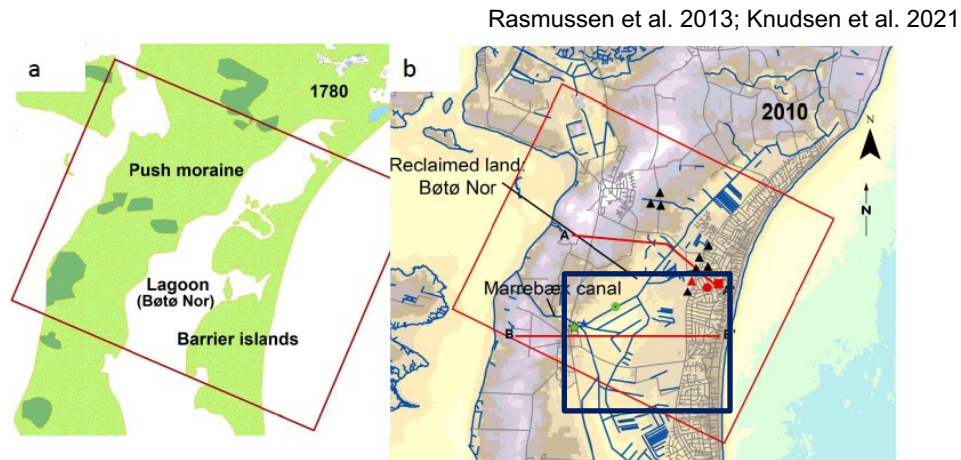
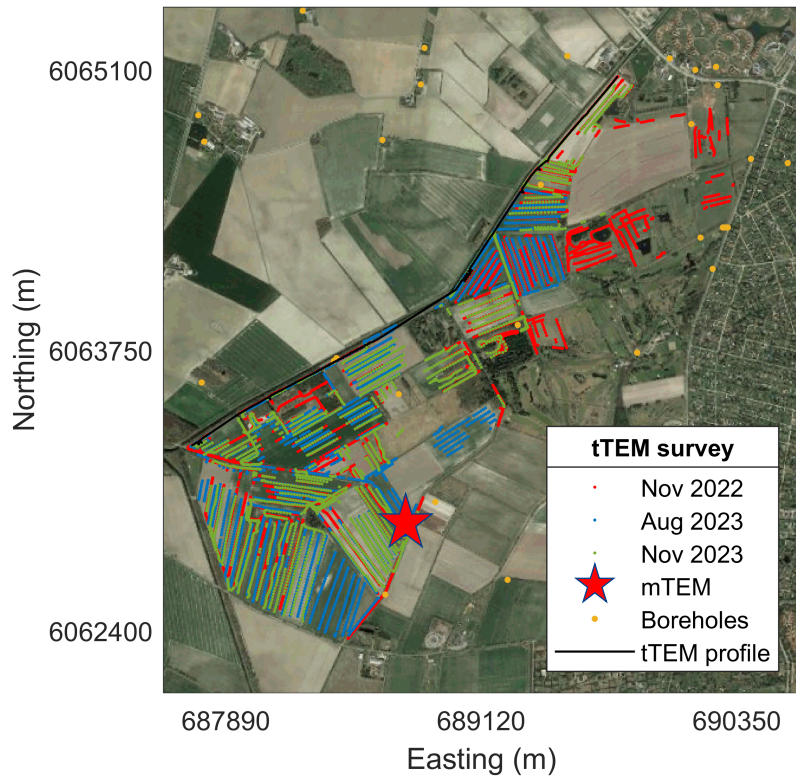
# Falster



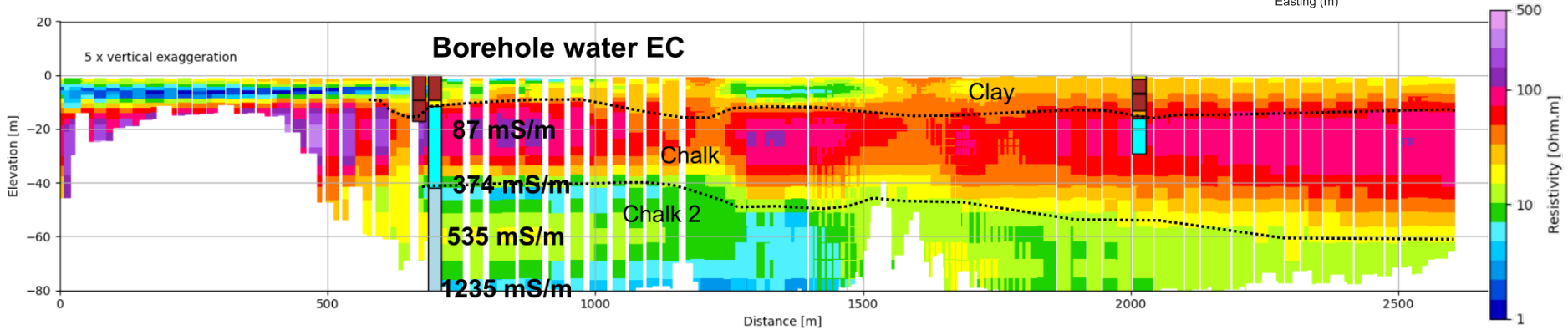
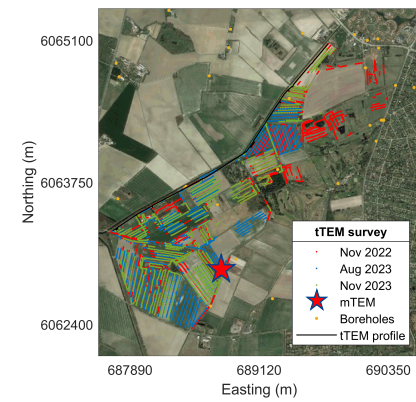
Rasmussen et al. 2013; Knudsen et al. 2021



# Falster



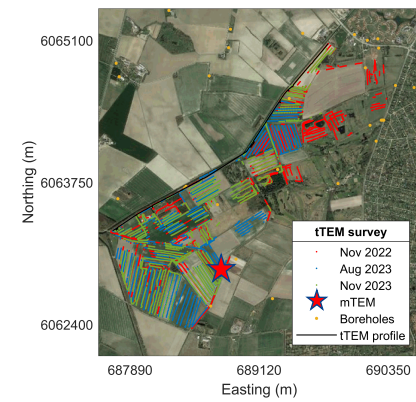
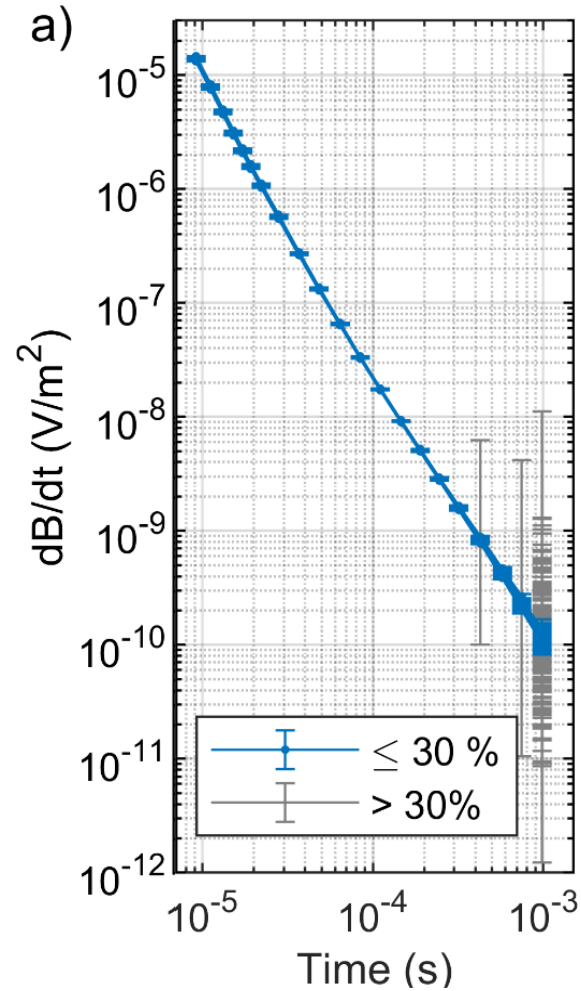
# Falster



- Simple geology; Clay and chalk
- Varying salinity in the chalk

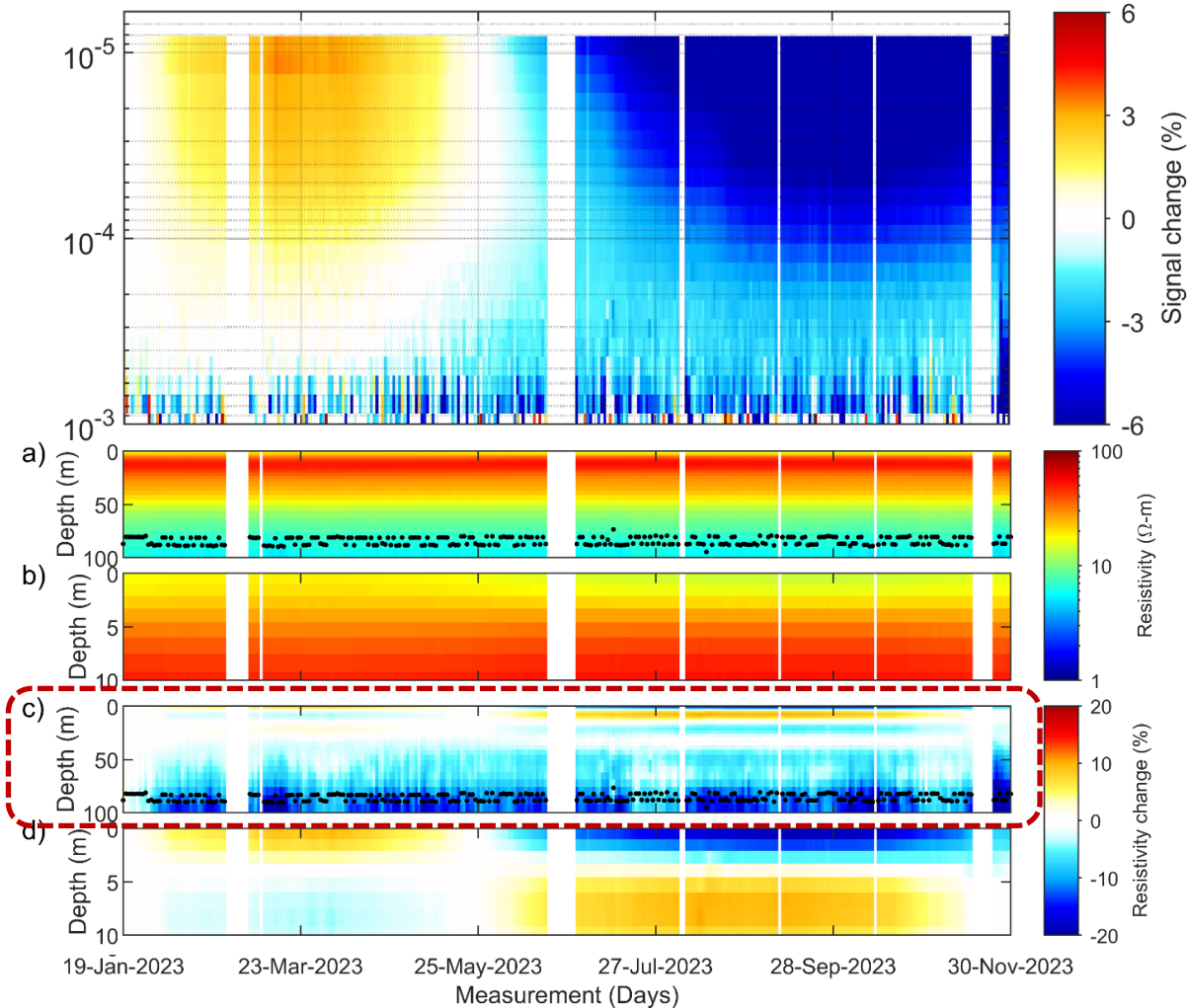


# Falster



# Falster

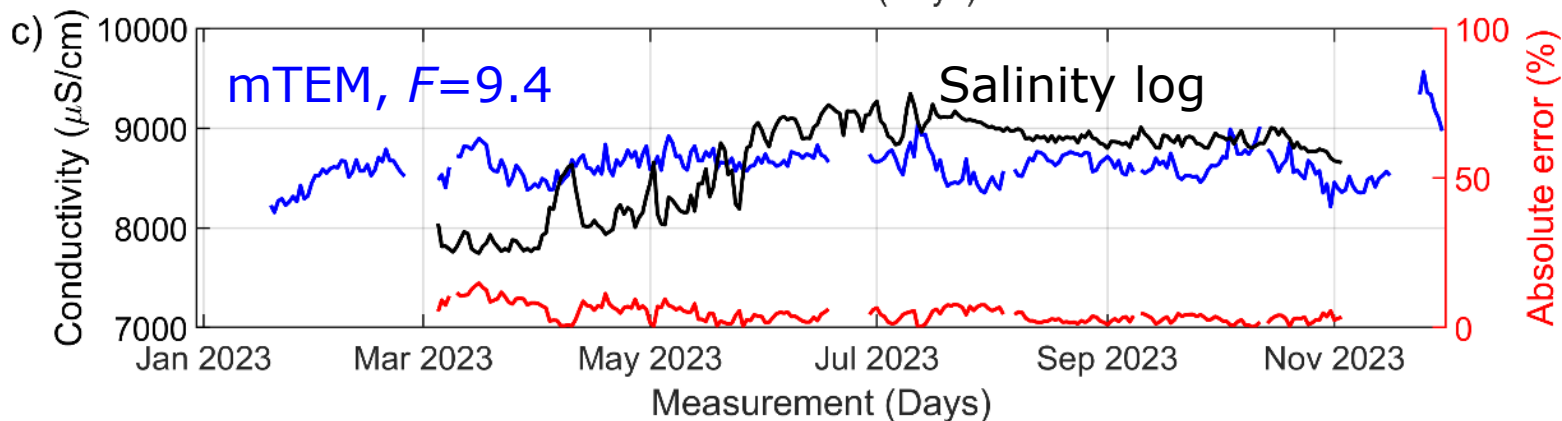
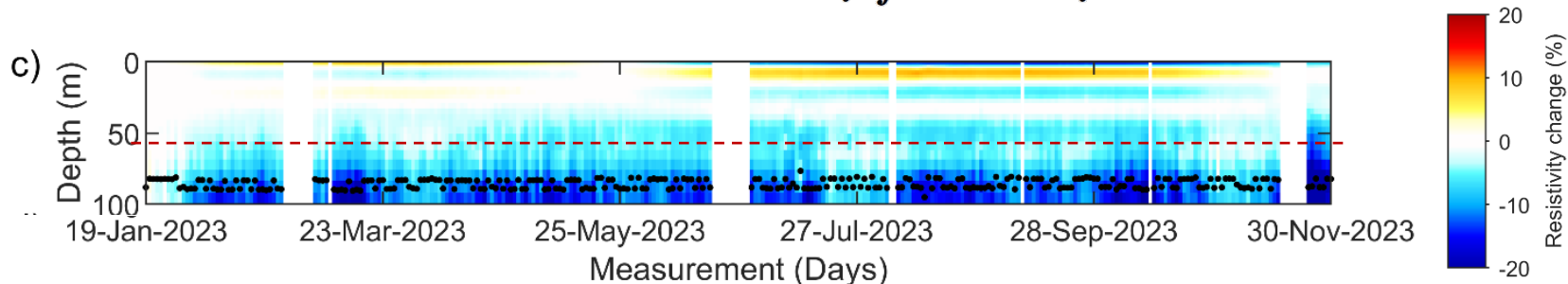
1. Saltwater intrusion
2. Fairly conductive
3. Smooth inversion with 30 layers
  - First layer at 1 m and last layer at 100 m
  - Time constraints



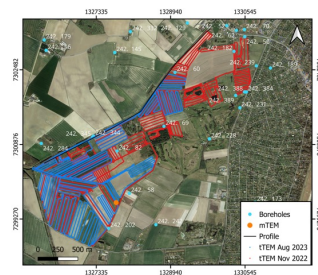
# Falster

- Data logger at 60 m in nearby (800 m) well
- Resistivity converted to conductivity using Archie's law

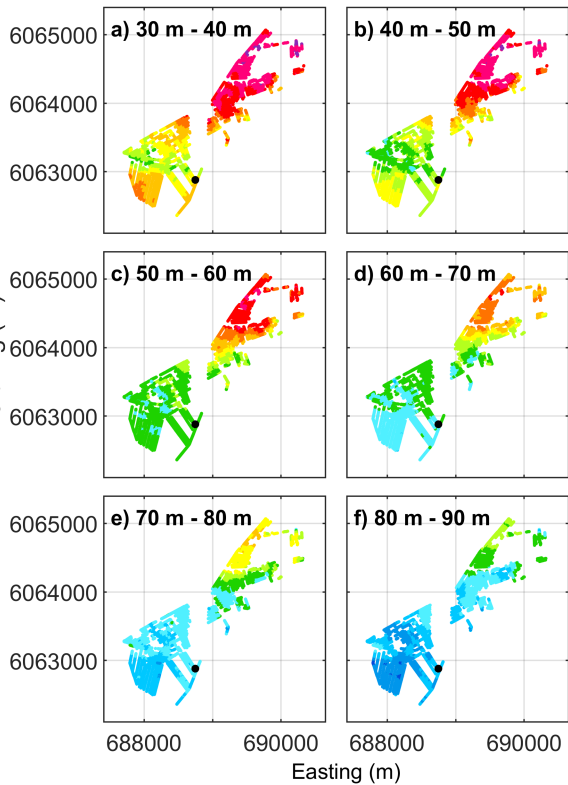
$$\rho_f = F \cdot \rho_w$$



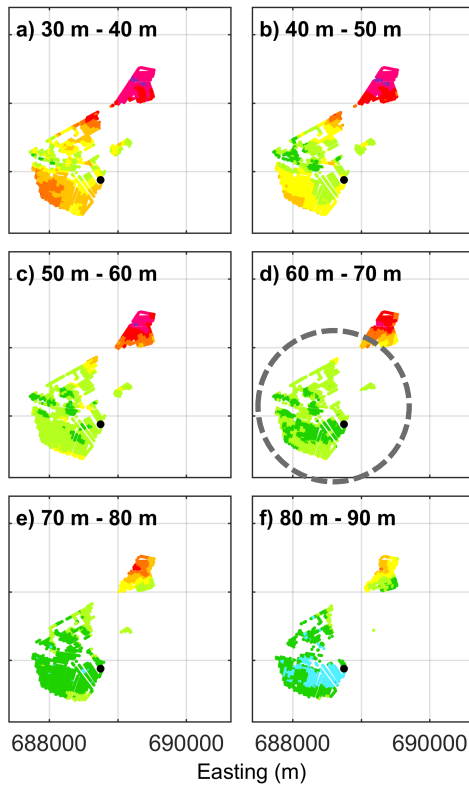
# Mean resistivity distribution with time



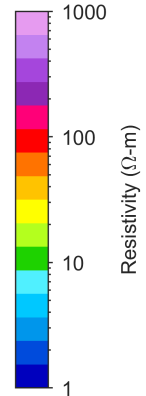
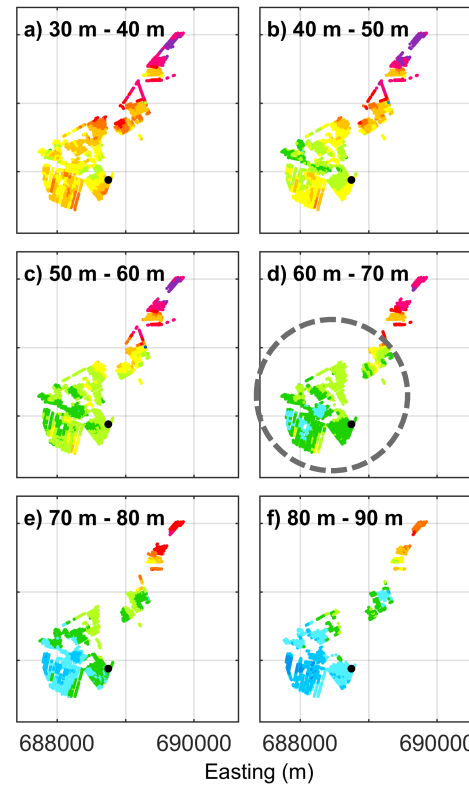
Nov 2022



Aug 2023

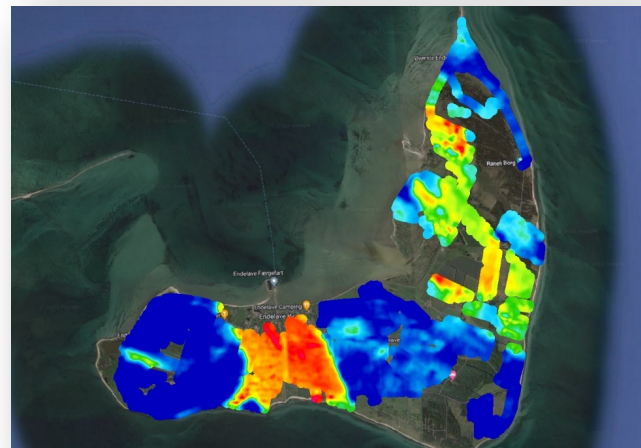


Nov 2023



# Indhold

- **Geofysikkens rolle**
  - Før: Rumlig struktur, litologi (sand, ler, kalk, ...)
  - Nu: Hydrologiske parametre, tidslige variationer, ...
- **Kortlægning af strukturer**
  - tTEM vs SkyTEM vs ERT/MEP
- **Kortlægning af fysiske parametre**
  - Nyt NMR-instrument, Apsu
  - Eksempler fra Kompedal og Endelave
- **Kortlægning af tidslige variationer**
  - Monitorering med TEM
  - Eksempler fra Albæk og Falster
- **Kortlægning af hav/sø – land**
  - FloaTEM





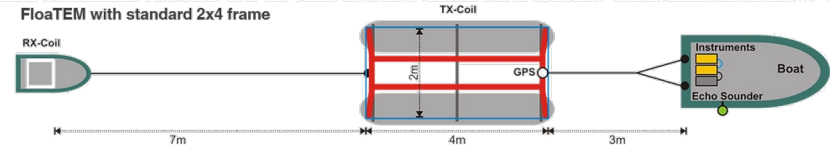
# FloaTEM



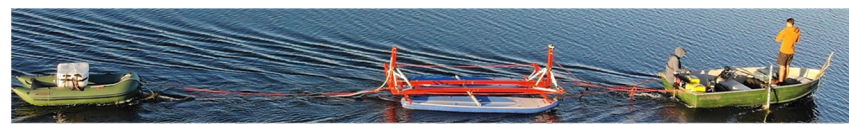
# FloaTEM Endelave



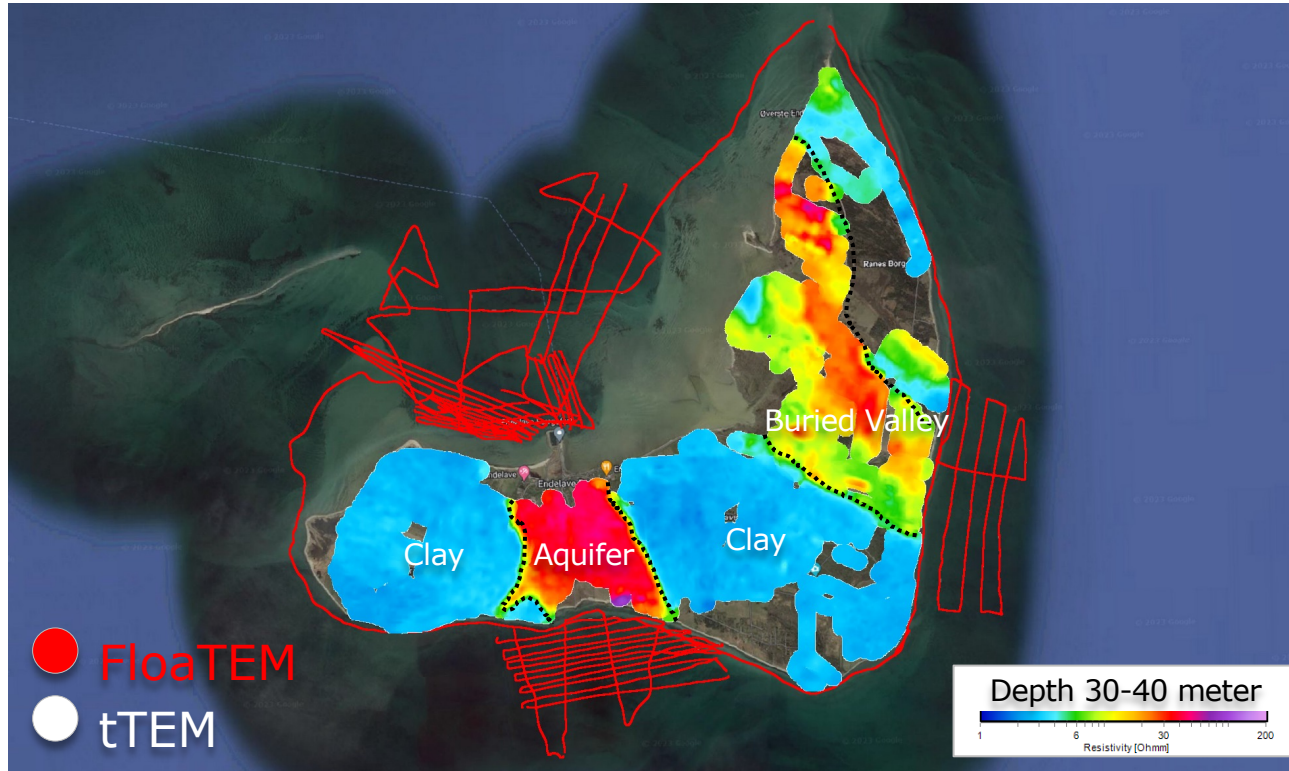
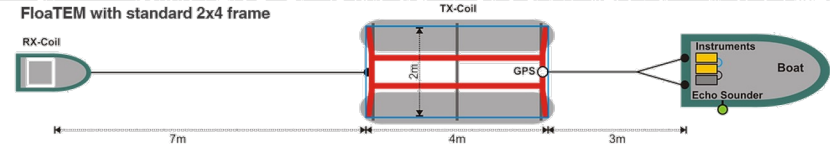
FloaTEM with standard 2x4 frame



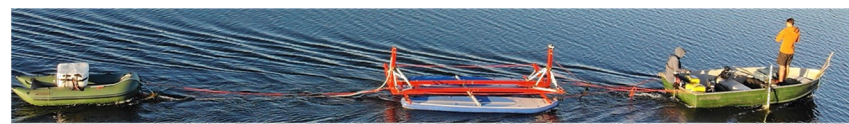
# FloaTEM Endelave



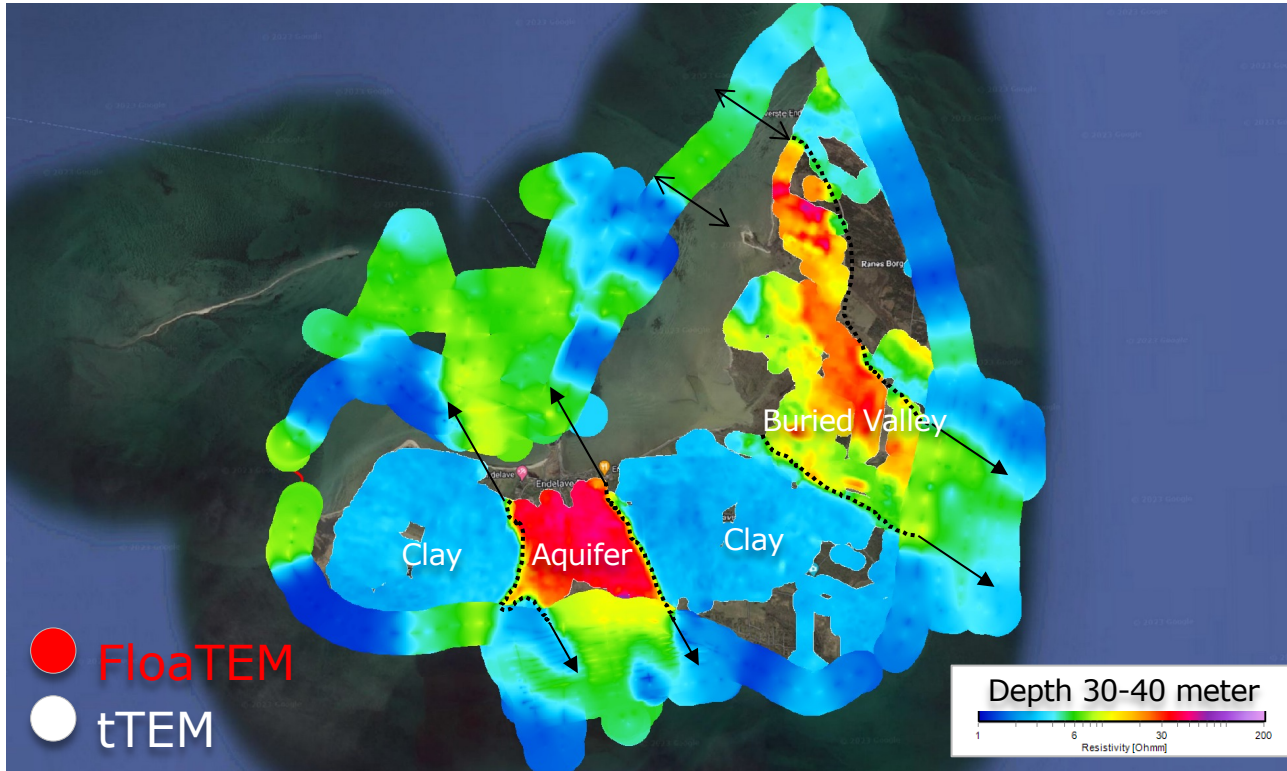
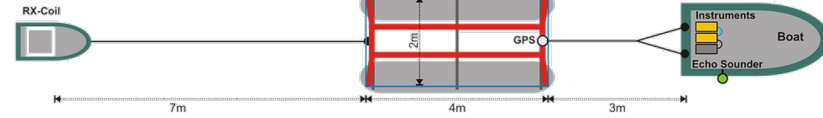
FloaTEM with standard 2x4 frame



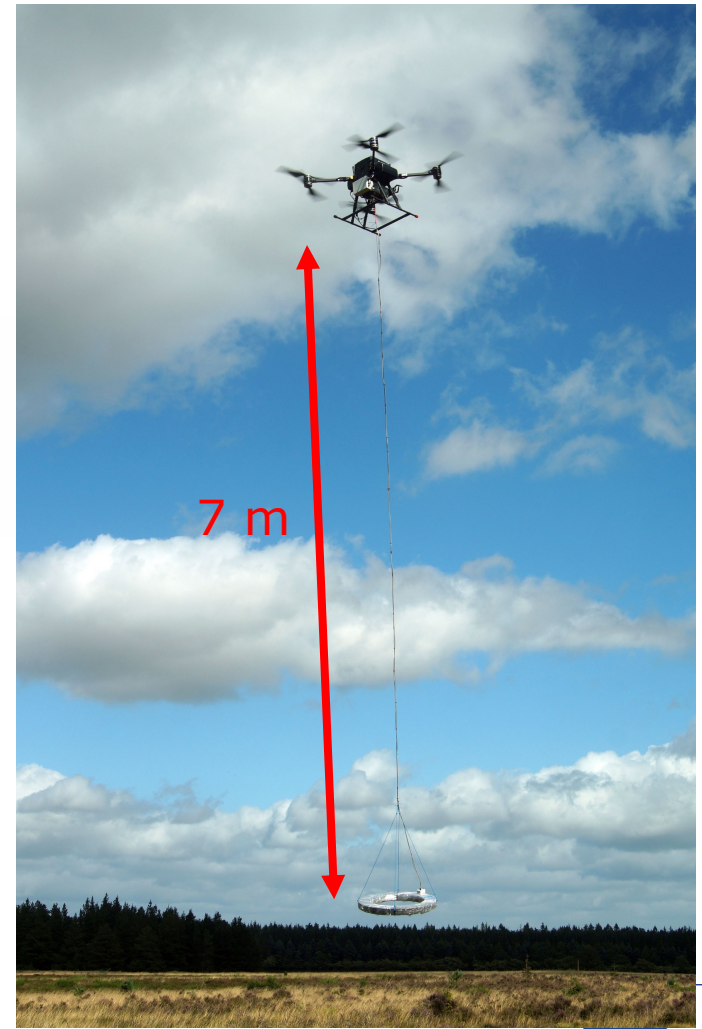
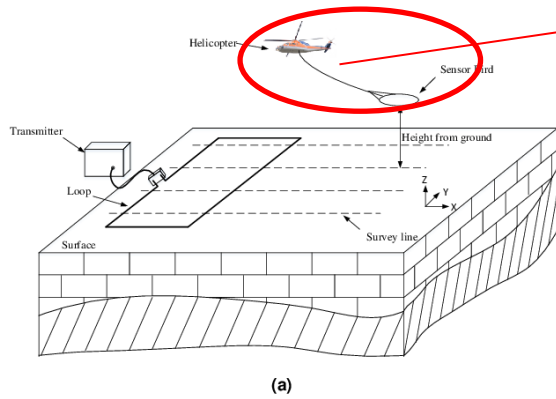
# FloaTEM Endelave



FloaTEM with standard 2x4 frame



# DroneTEM



# DroneTEM



# Field survey example-1



# Opsummering

- **Strukturel information**
  - Detalje-graden afhænger af systemvalg
- **Hydrologiske parametre med Apsu (NMR)**
  - >10 soundinger per dag
  - Information til 30-40 m
  - Vandindhold
  - Permeabilitet / porøsitet
  - *Kan kombineres med NMR i borehuller*
- **Tidslige variationer med TEM**
  - Små systemer, stor indtrængning
  - Stabile instrumenter
  - Monitorering af
    - Salinitet med dybde
    - Vandspejl
- **Andet**
  - FloaTEM kombineret med tTEM
  - DroneTEM

