



Kortlægning af potentielle grundvandsressourcer under Ringkøbing Fjord med luftbårne geofysiske metoder

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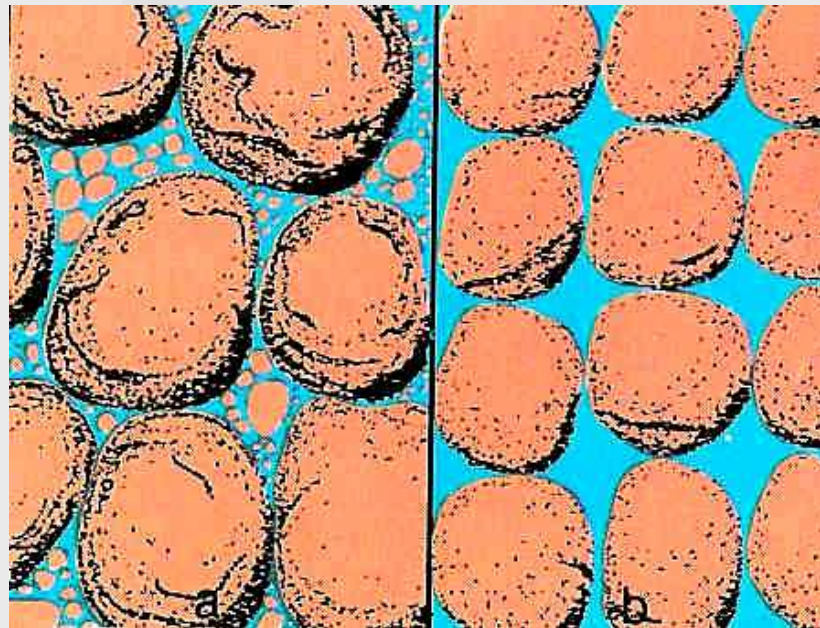
Presentation layout

- The airborne SkyTEM system
 - physics of the method
 - data processing
 - inversion
- The Ringkøbing fjord survey
- Concluding remarks



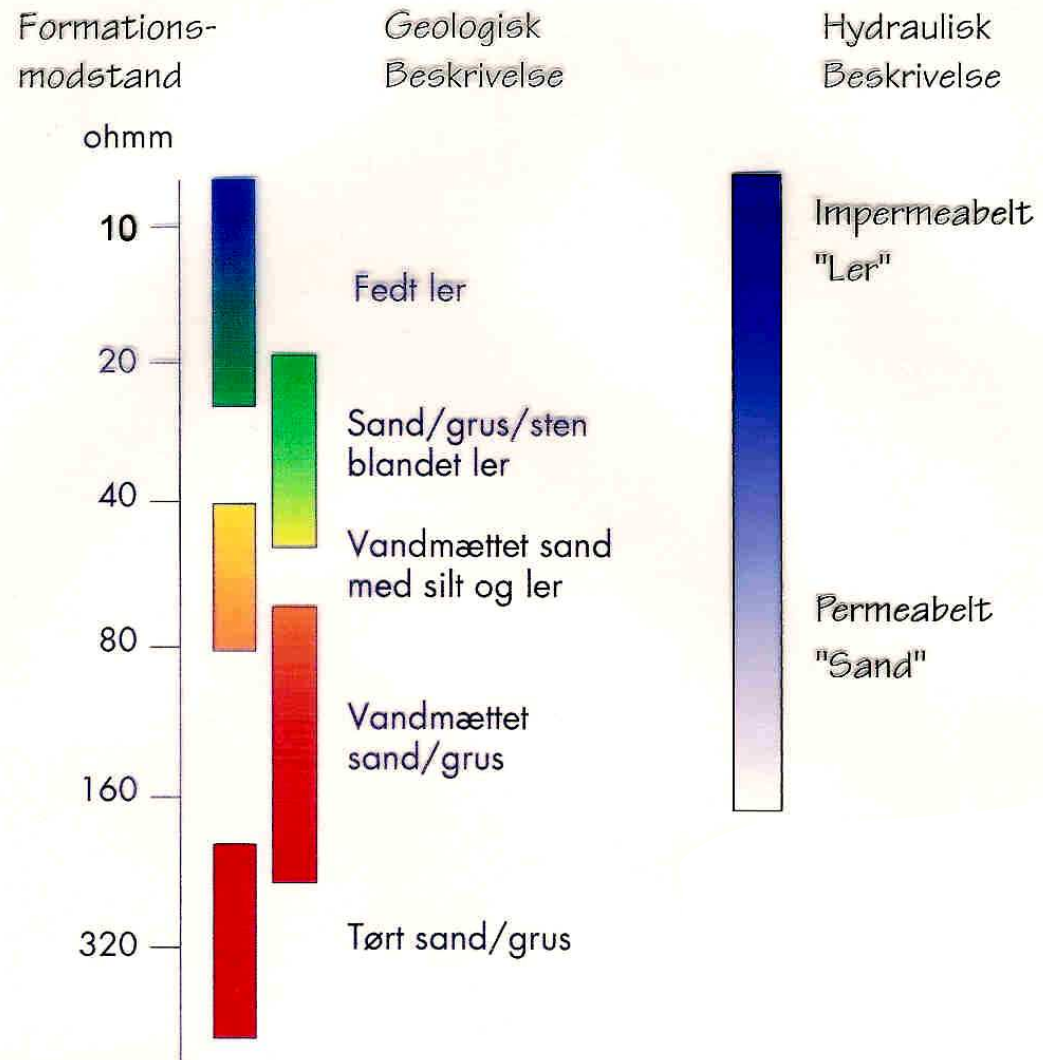
Governing factors for the formation resistivity

- Sediment type – sand and/or clay
- Ion content of the pore water
- Porosity – the space between the sediment pores



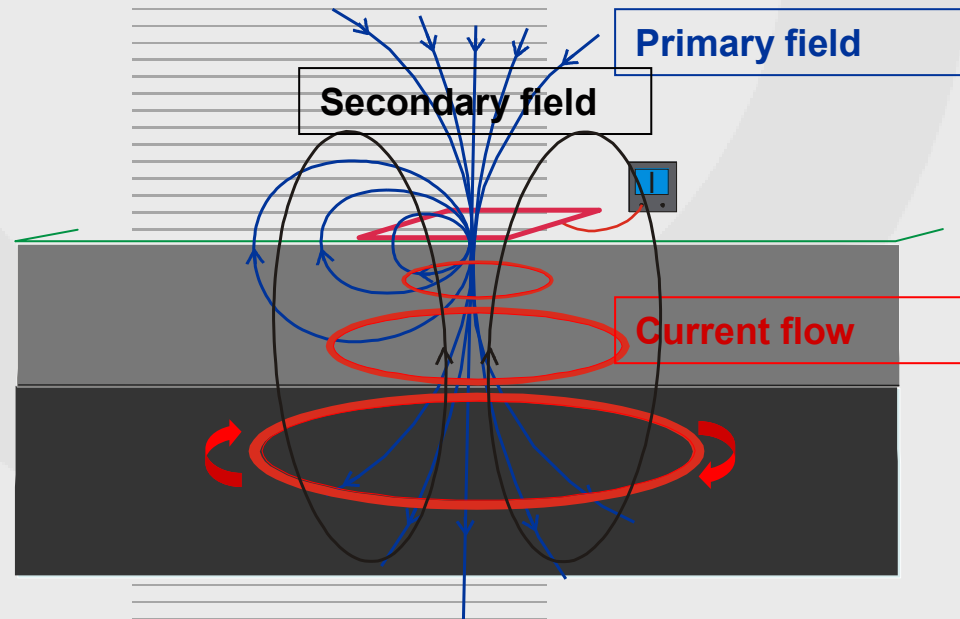
Geology - hydrology and formation resistivity

- **Low resistivities - clay dominated sediments - impermeable**
- **High resistivities - sandy sediments - permeable**
- **Resistivity is highly dependent on the ion content of the porewater and the porosity**



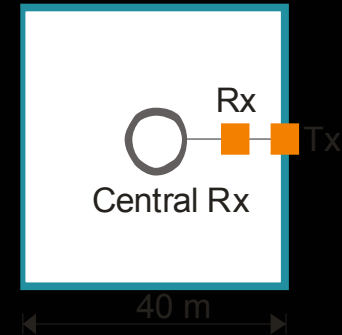
Transient EM - how does it work?

- Stationary current sets up a primary magnetic field
- Current is shut off and secondary currents is induced in the ground
- Secondary currents decay and generates a secondary magnetic field



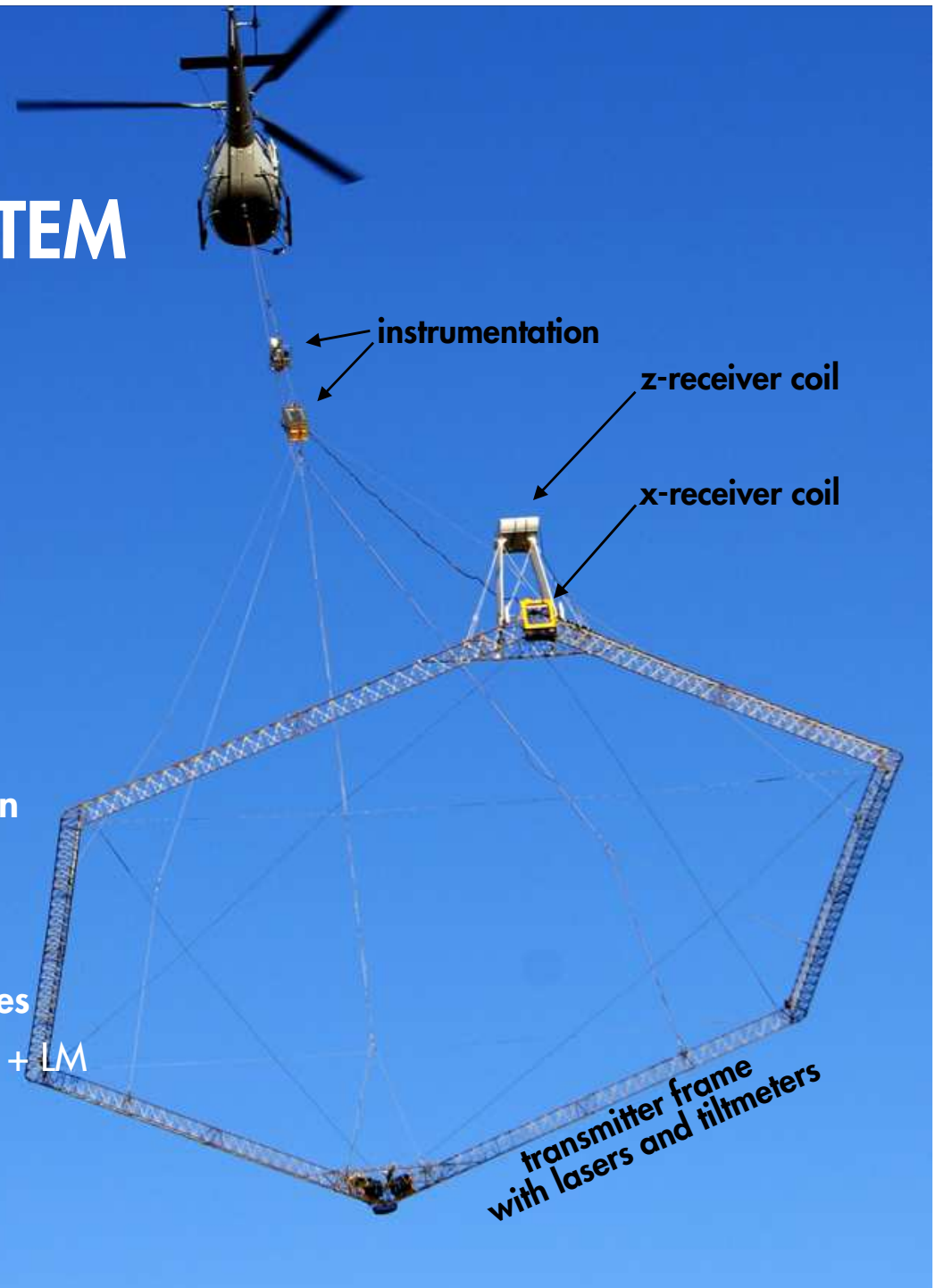
Traditional 40 x 40 m TEM

- Magnetisk moment of 4800 Am²
- 16 sonderinger pr. dag covering approx. 1 km²

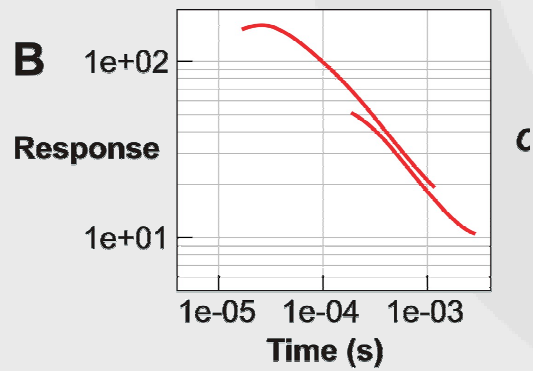
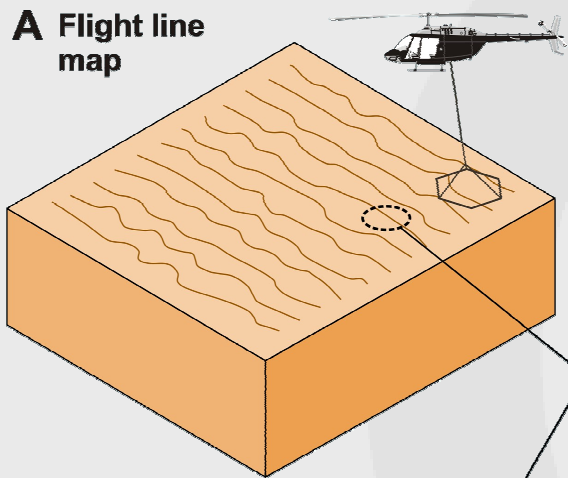


SkyTEM – airborne TEM

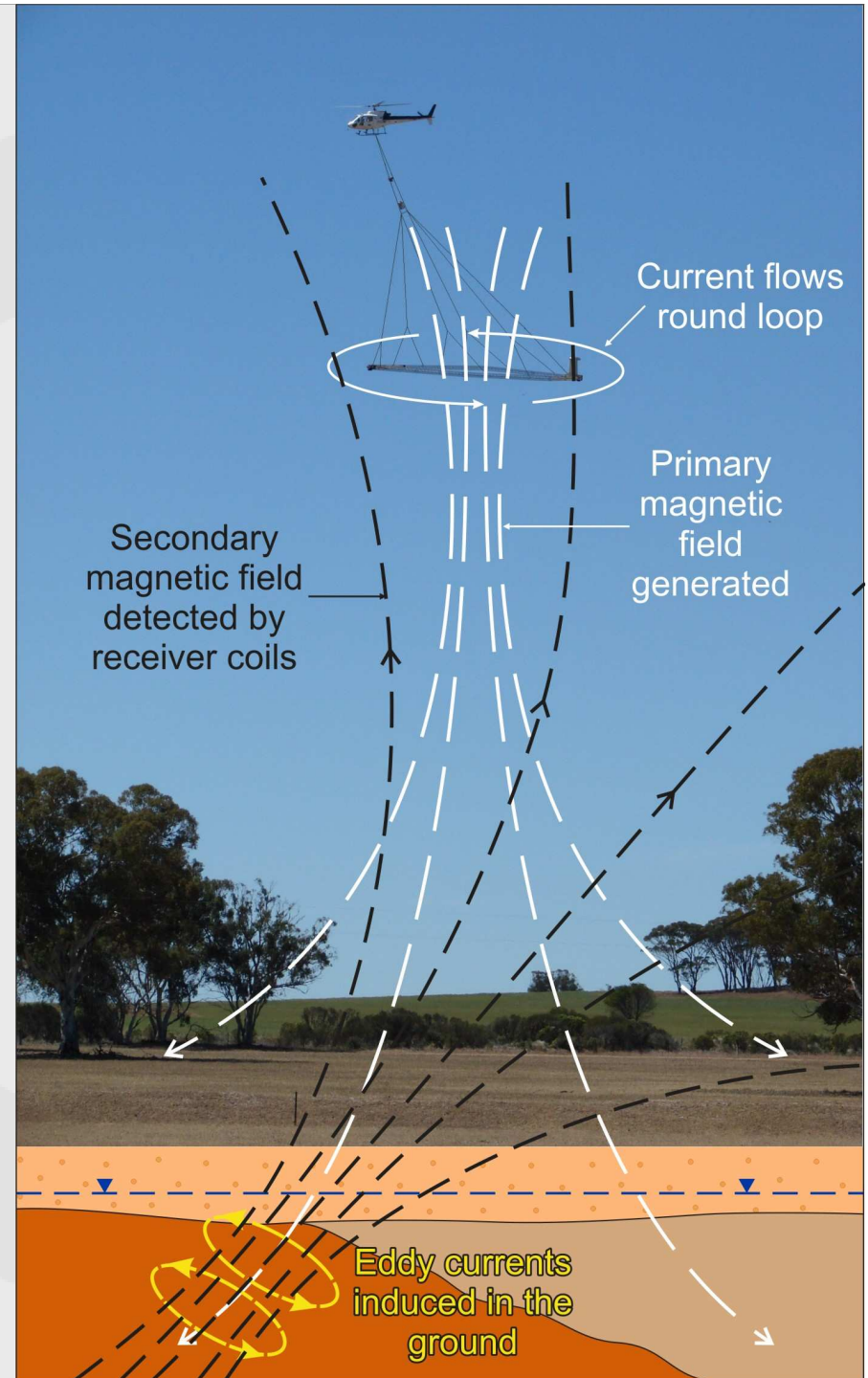
- **Super low moment (SLM)**
 - first unbiased gate in $10 \mu\text{s}$
 - 2 ms on-off
- **Low moment (LM)**
 - first unbiased gate in $17 \mu\text{s}$
 - $\cong 12\,000 \text{ Am}^2$
 - 2 ms on-off
- **High moment (HM) – large penetration**
 - $100\,000 - 160\,000 \text{ Am}^2$
 - 20 ms on-off
- **Moments used in alternating sequences**
 - Super near-surface resolution: SLM + LM
 - Deep resolution: LM + HM or HM



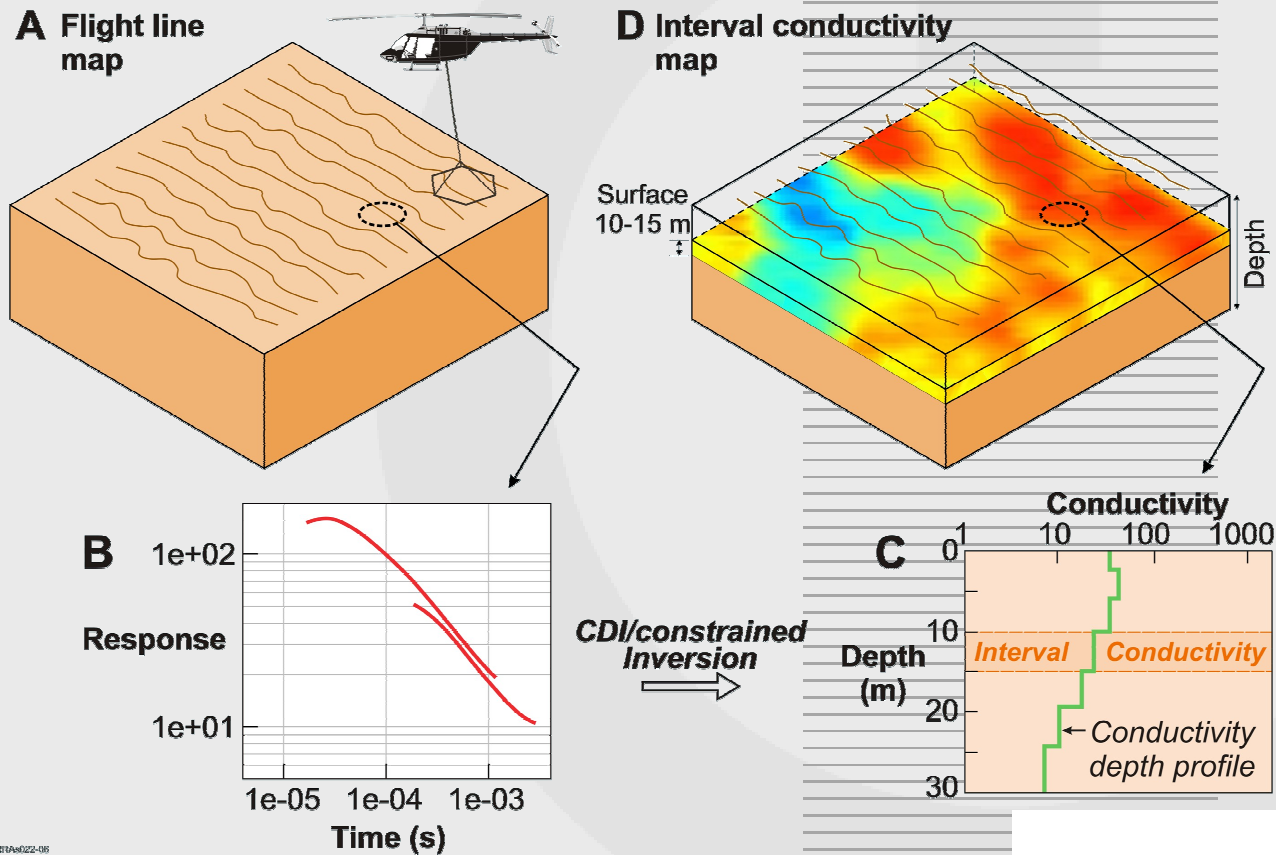
Data Acquisition



RFA/022-06

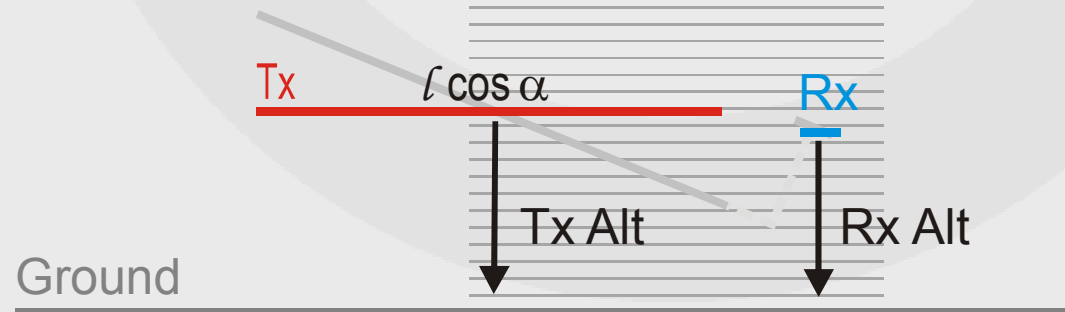


Modelling Field Data - inversion



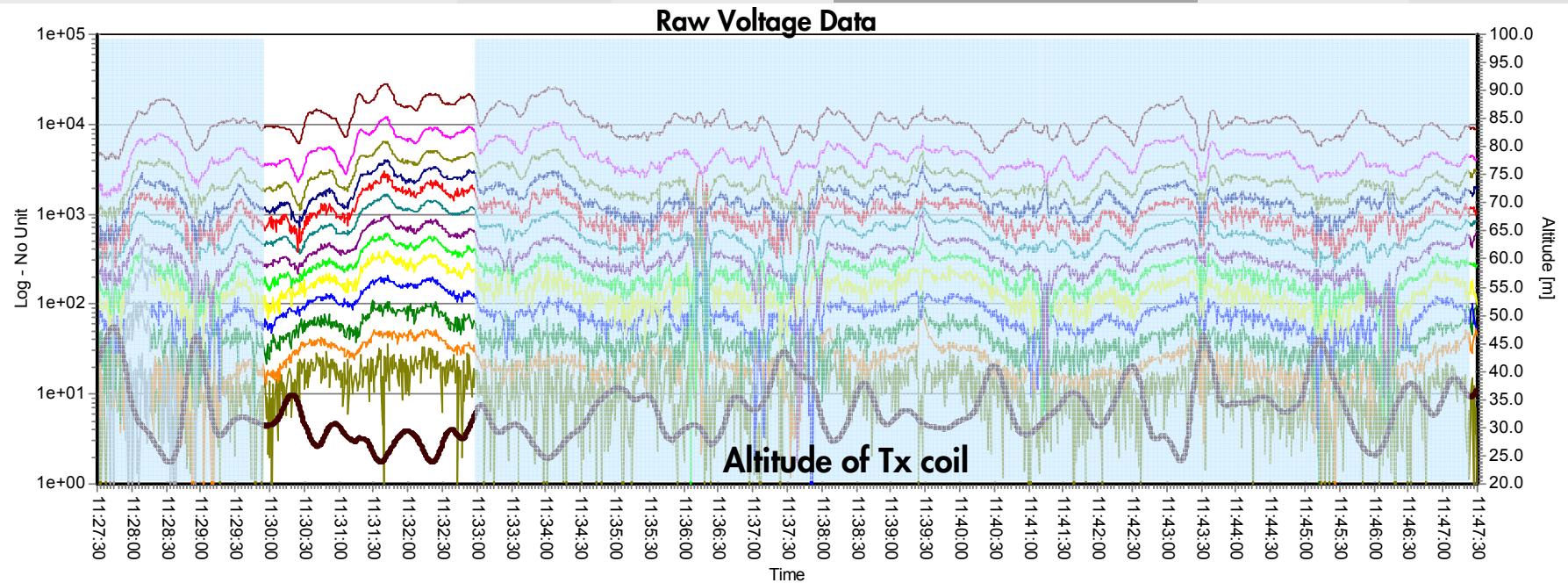
The data from the system

- **Navigation data**
 - GPS – 2 per sec.
 - Pitch and roll of transmitter frame – 1.5 per sec. from three devices
 - Laser altitude – 20 per sec. from two devices
 - Transmitter current – 1 per dataset or approx. 1 per sec.
- **Voltage - decays**
 - Single decays from 2 or more receiver channels – 40-120 Mb per hour
- **Voltage data and altitudes are corrected with respect to pitch and roll of the frame**



Raw Voltage Data

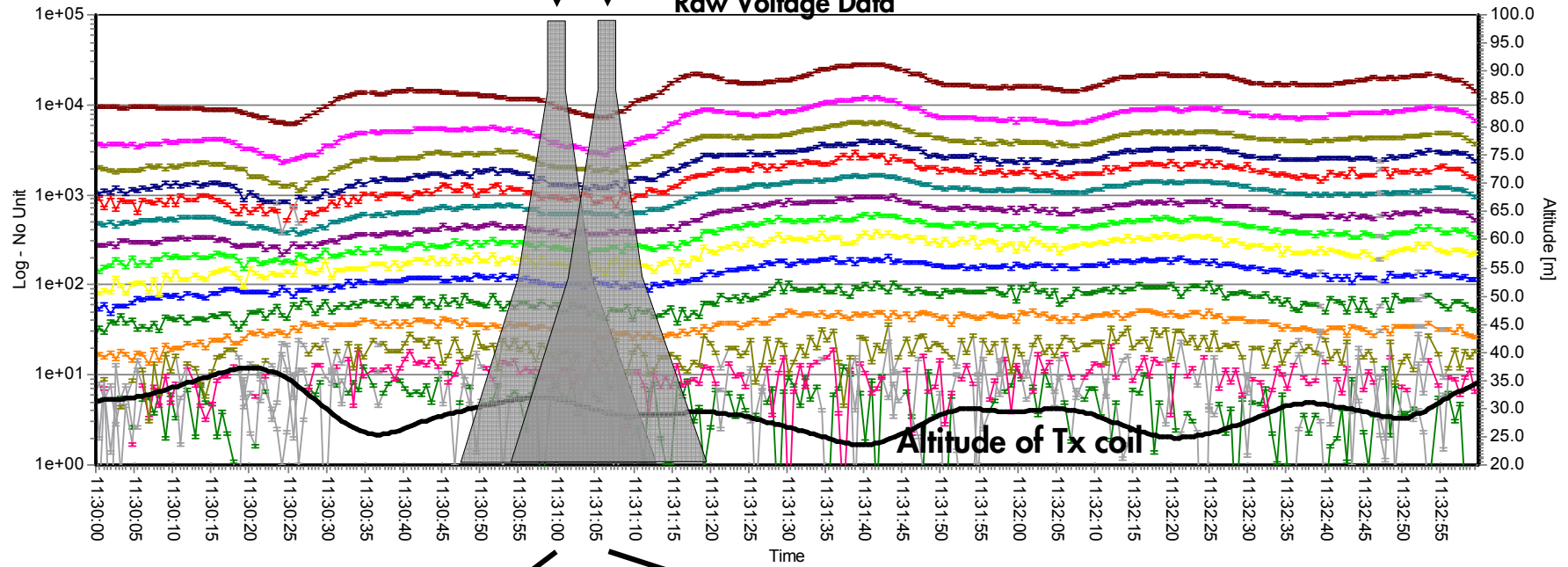
- 10 min \approx 7 line km
- Tx altitudes in the range 25 – 45 m
- Strong correlation between Tx altitude and voltage level



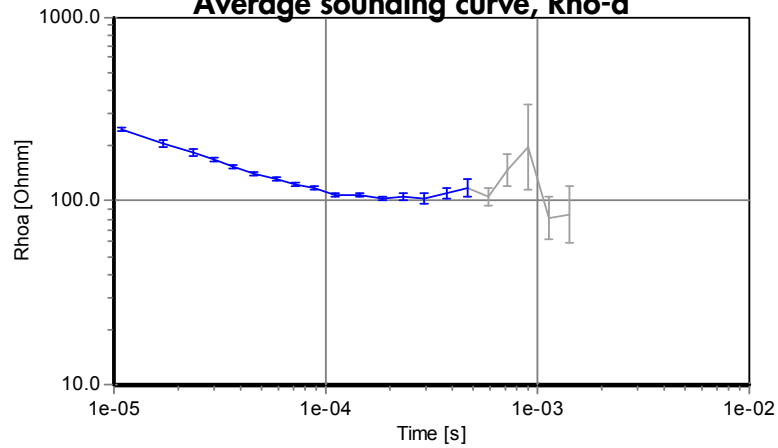
3 min \approx 2 line km

Average point

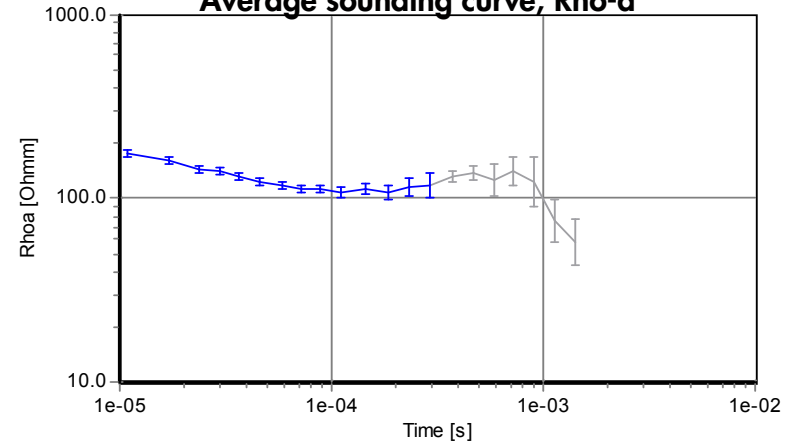
Raw Voltage Data



Average sounding curve, Rho-a



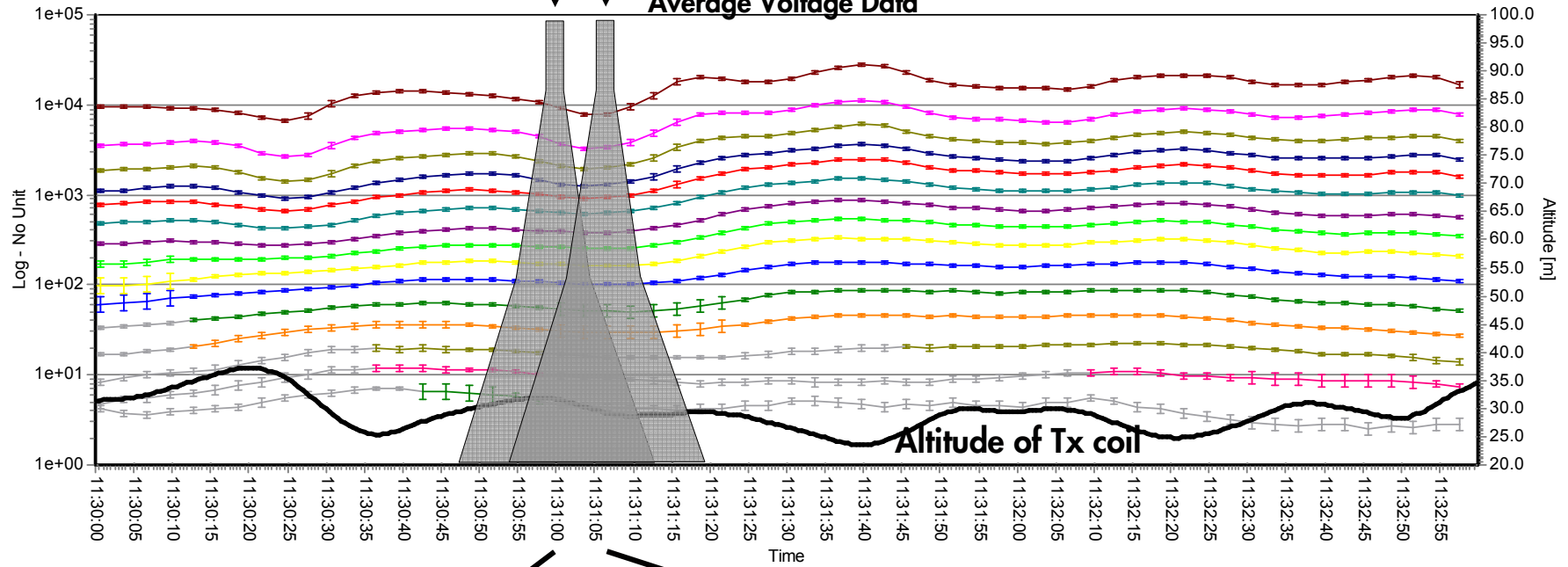
Average sounding curve, Rho-a



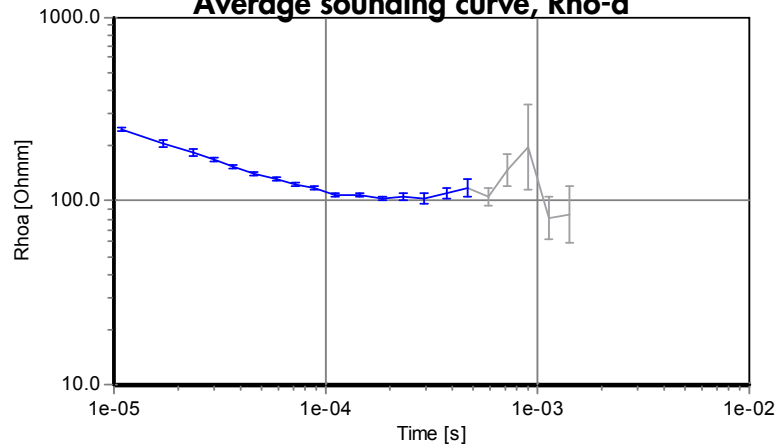
3 min \approx 2 line km

Average center point

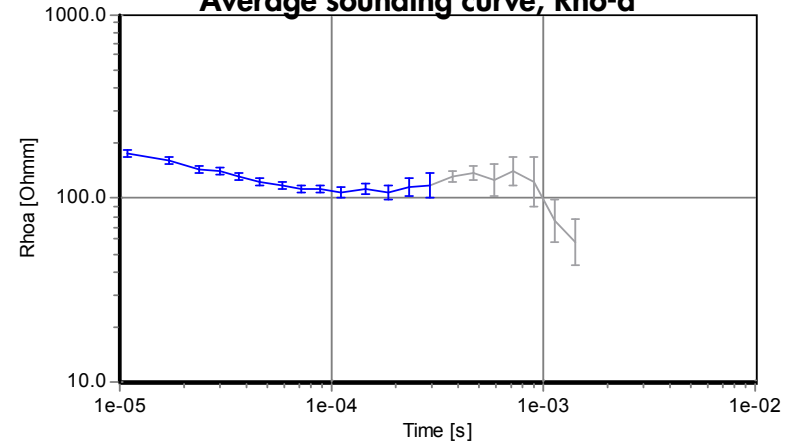
Average Voltage Data



Average sounding curve, Rho-a



Average sounding curve, Rho-a



Constrained inversion

- **Quasi 2D/3D - 2D/3D model with a local 1D forward solution**
- **Conceptual the coherency of the geology is used as a proxy for the inversion model**
- **Damped least squares scheme, modeling of system transfer function**
 - Low pass filters, turn-on and turn-off exponential ramps etc.
- **Regularization fixed through data noise estimates, parameter variances and horizontal constraints**

Presentation layout

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Ringkøbing Fjord survey

- **Aims**

- Mapping potential groundwater resources
- Estimate the outflow of groundwater to the North Sea.
- 3 dimensional description of the geology as input to a hydraulic model

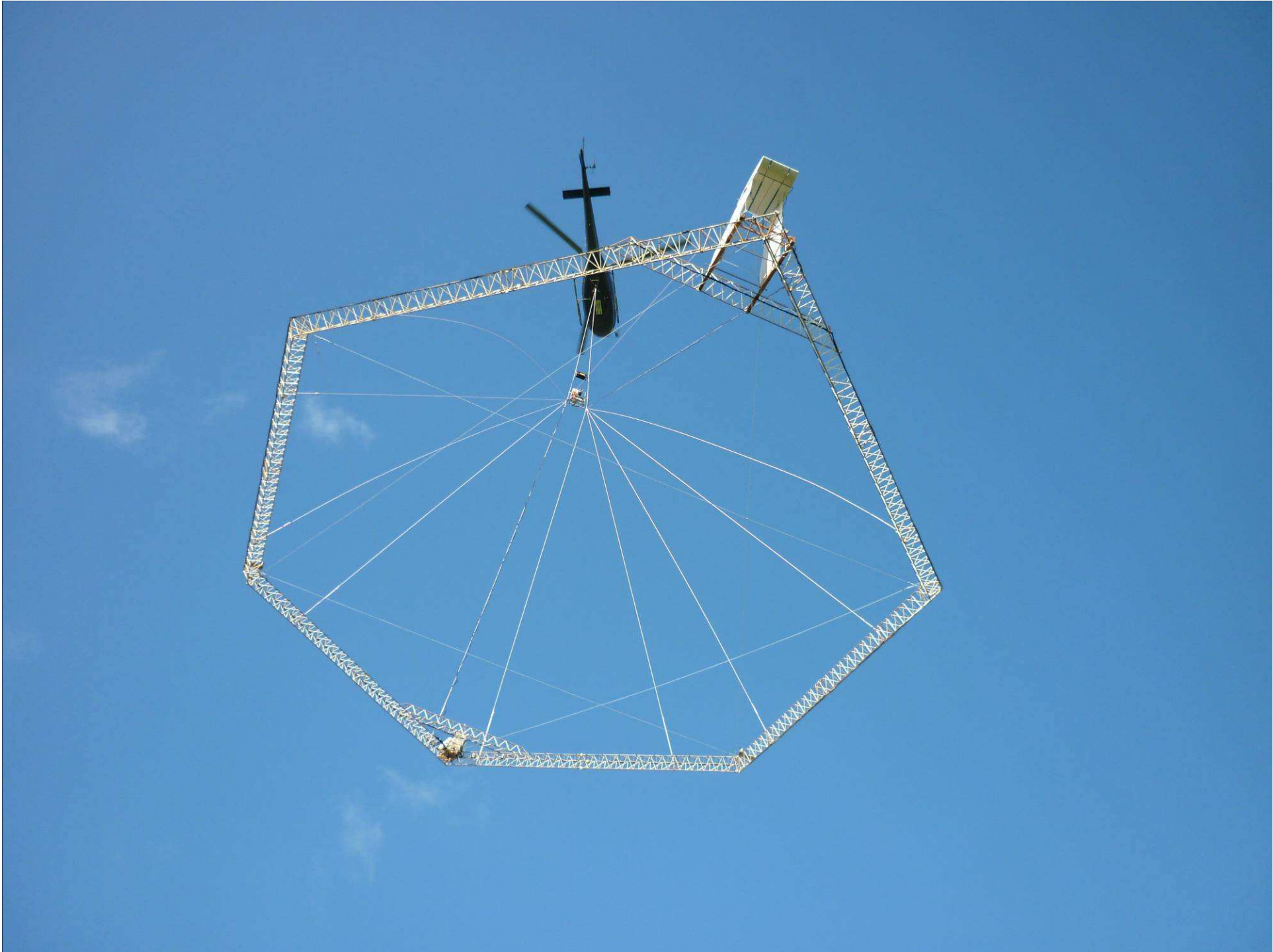
- **A few facts on the survey**

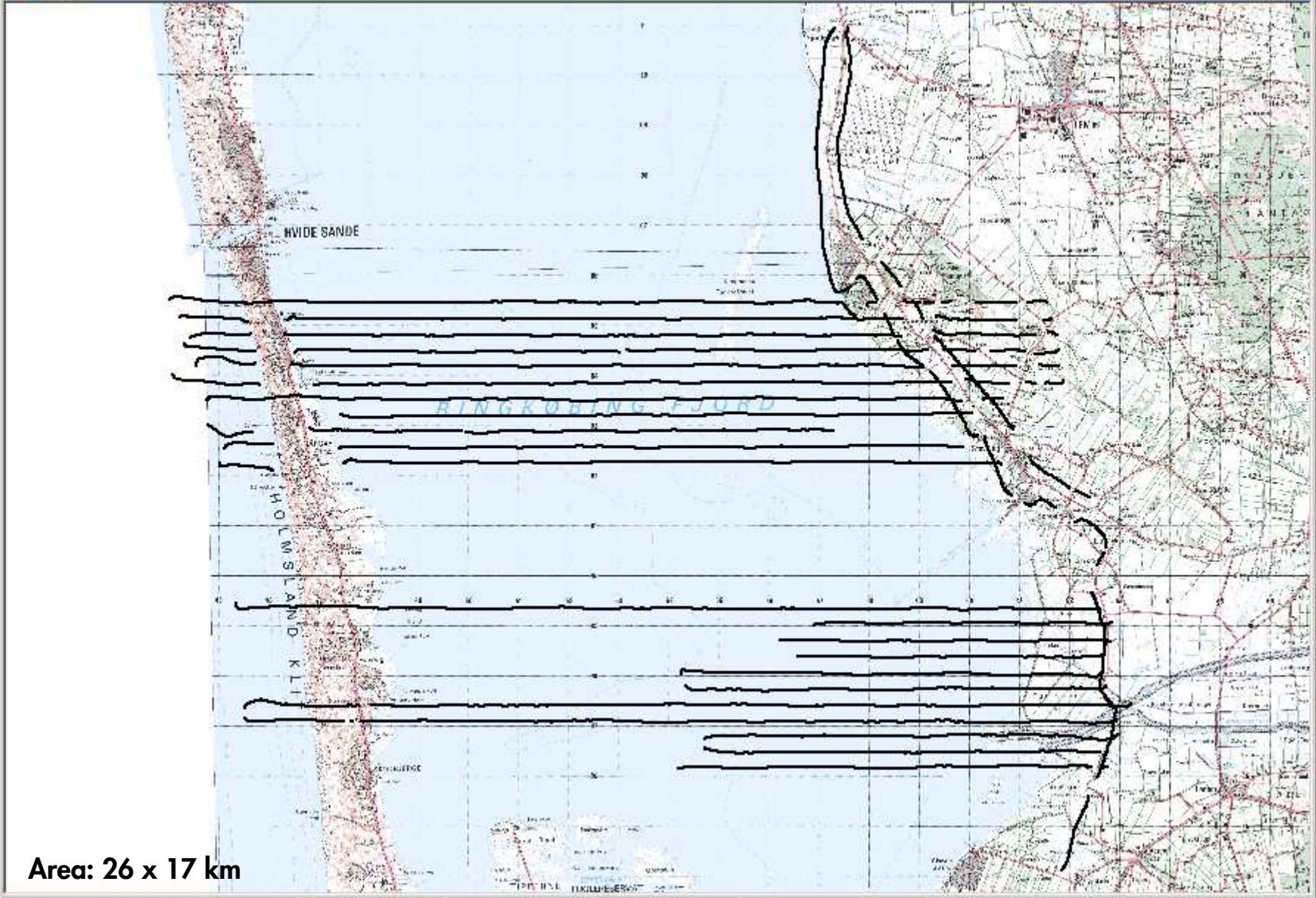
- 4 flights on the 18th and 19th of August
- SkyTEM with a maximum transmitter moment of approx. 1 60 000 Am²
- 350 km of data
- 20 000 soundings





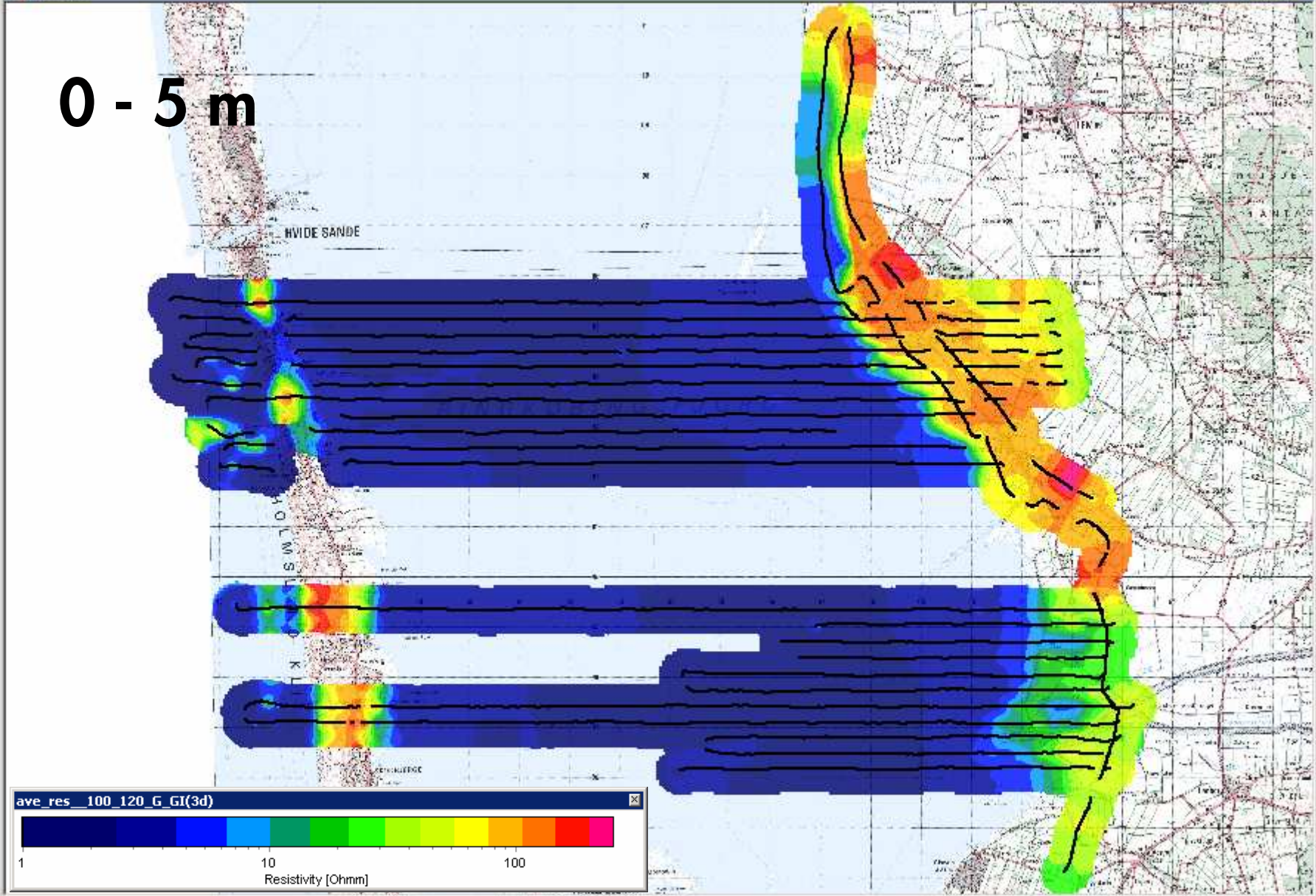




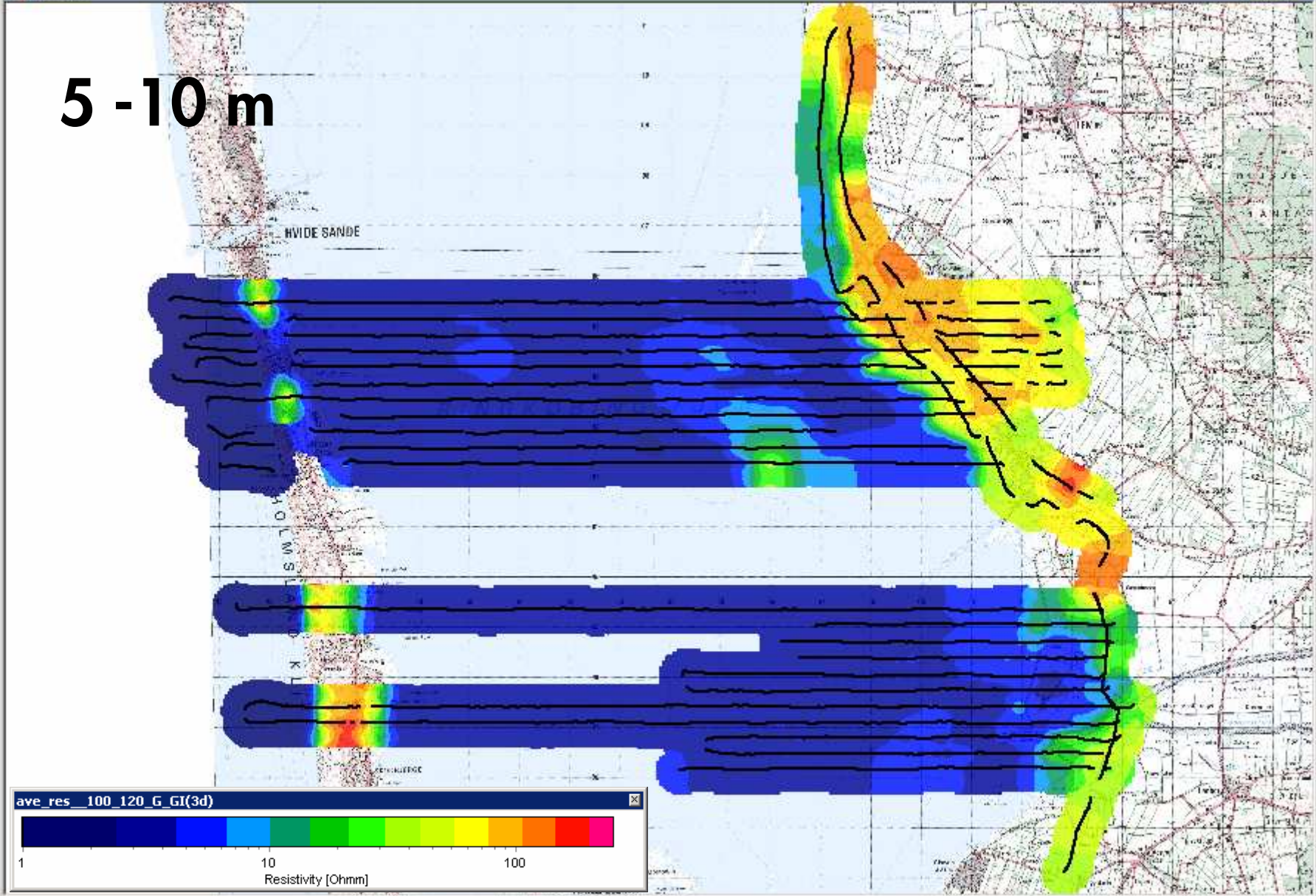


Area: 26 x 17 km

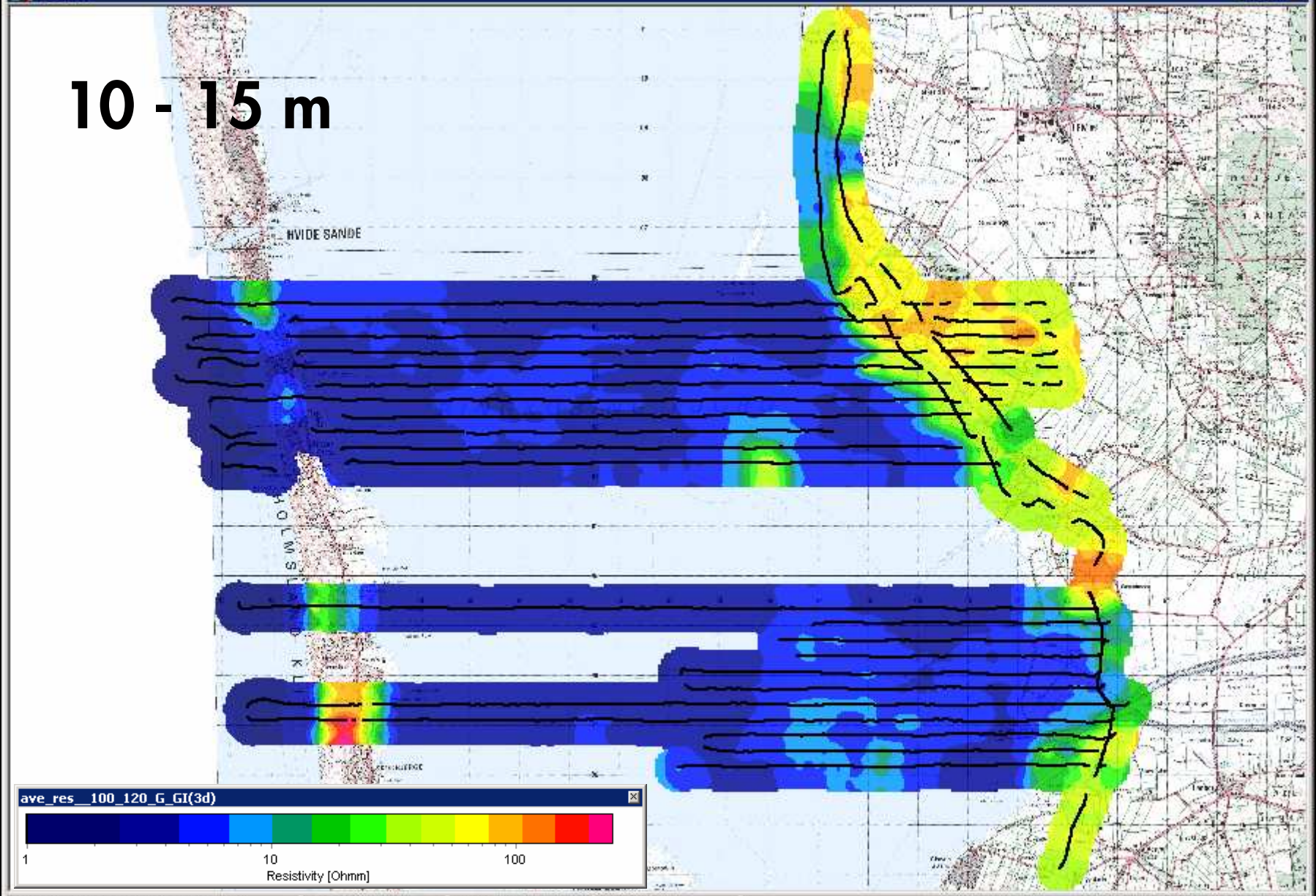
0 - 5 m



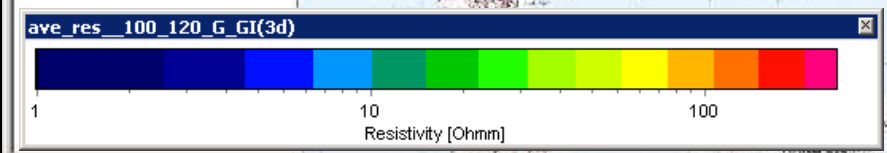
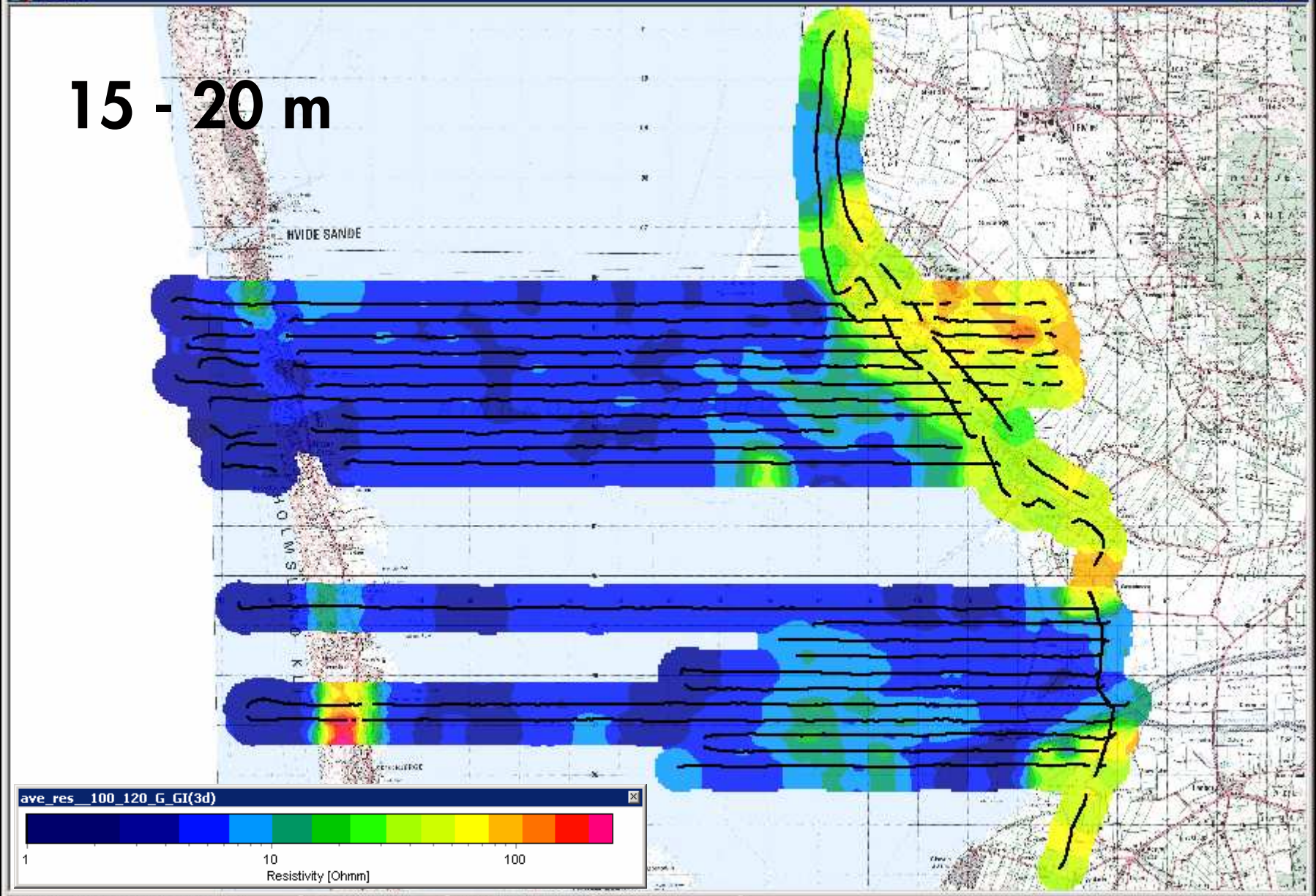
5 - 10 m



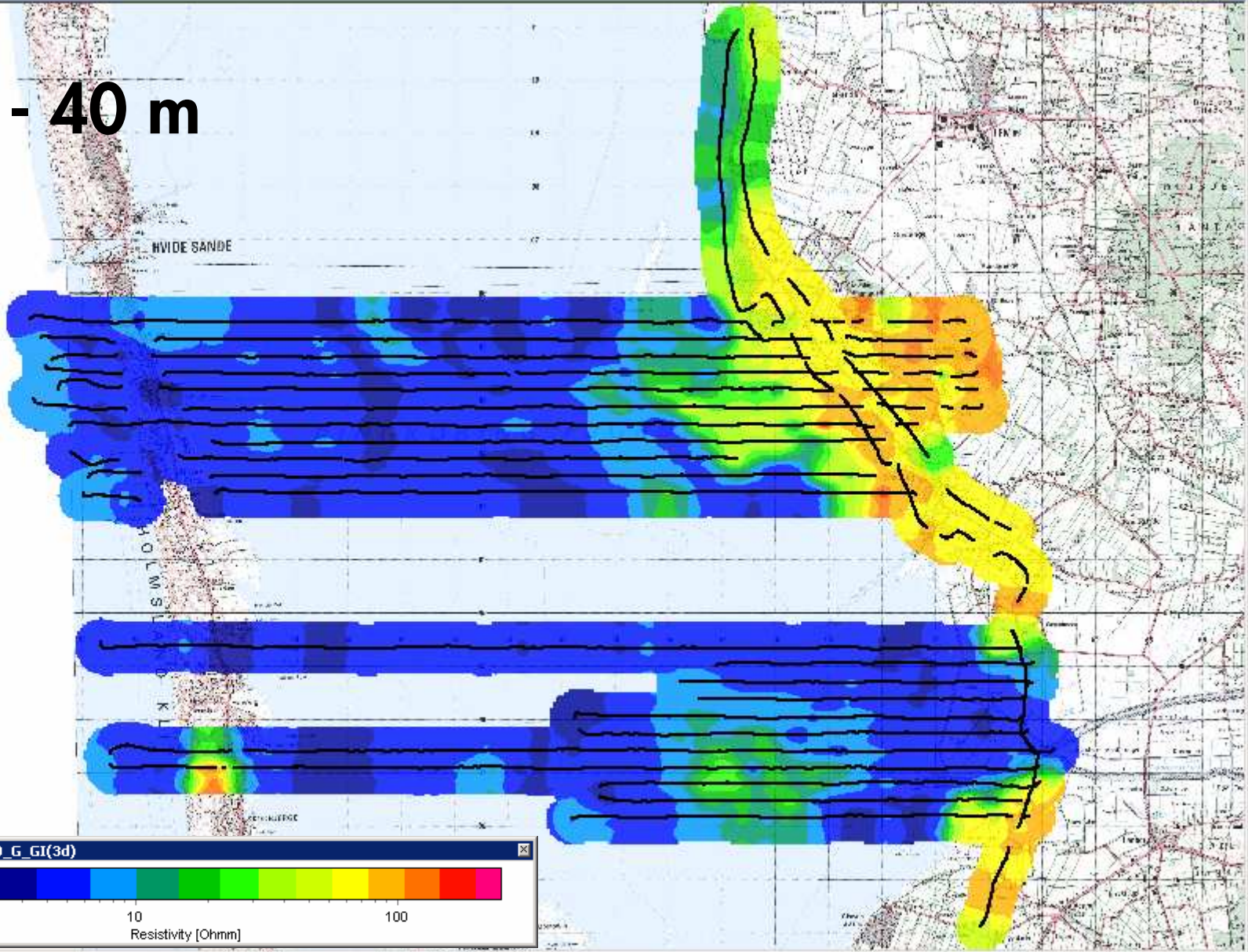
10 - 15 m



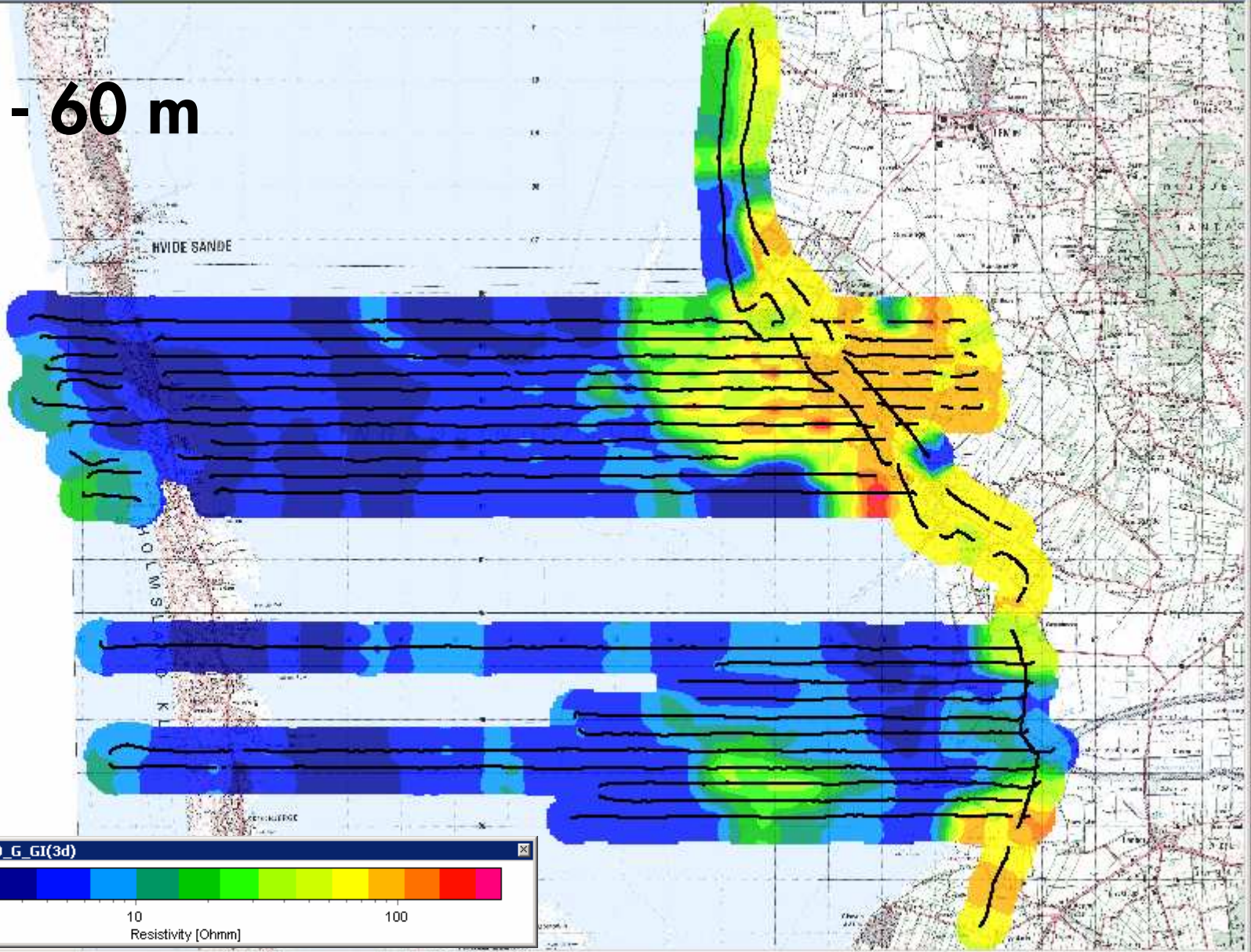
15 - 20 m



20 - 40 m



40 - 60 m

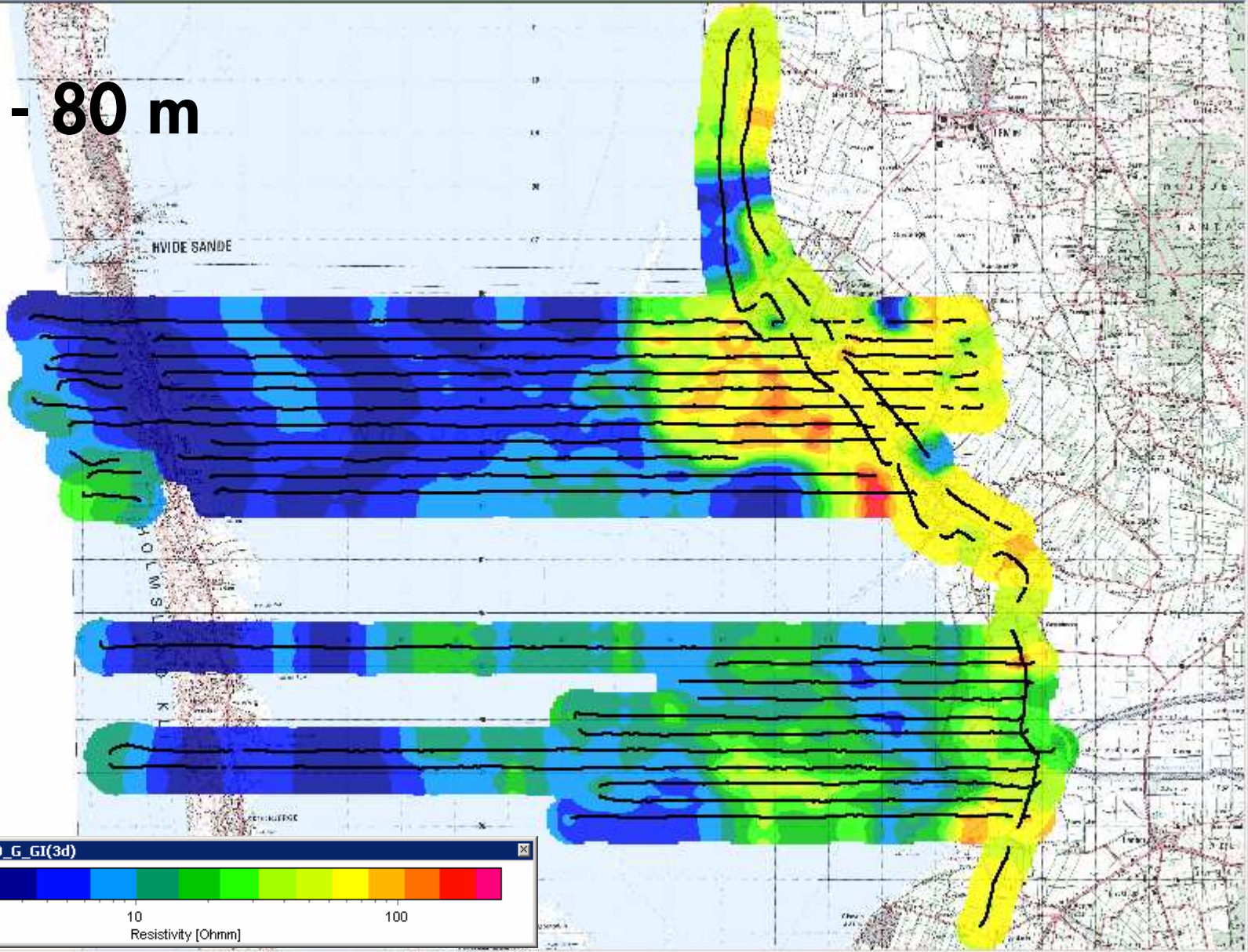


ave_res_100_120_G_GI(3d)

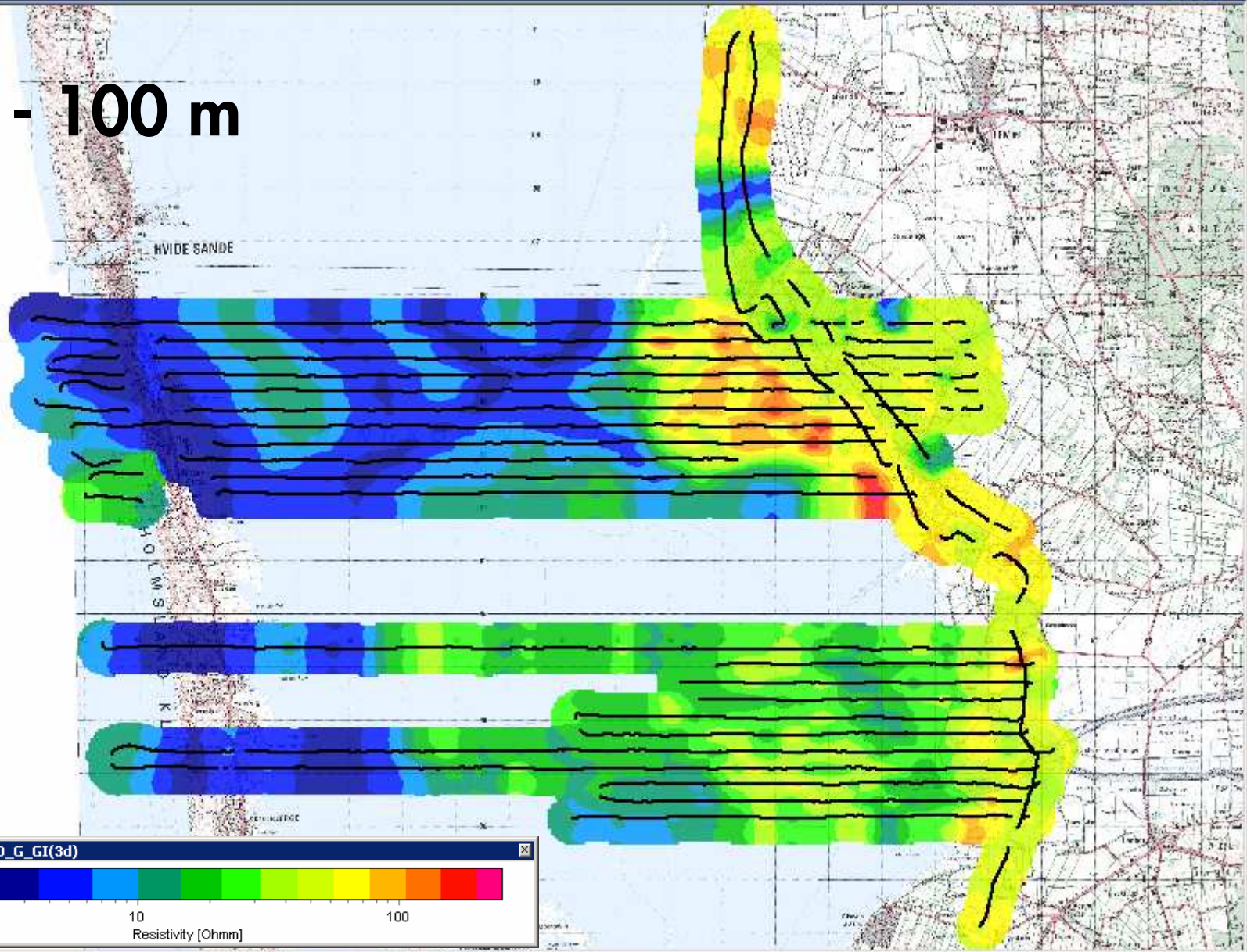


1 10 100
Resistivity [Ohm-m]

60 - 80 m



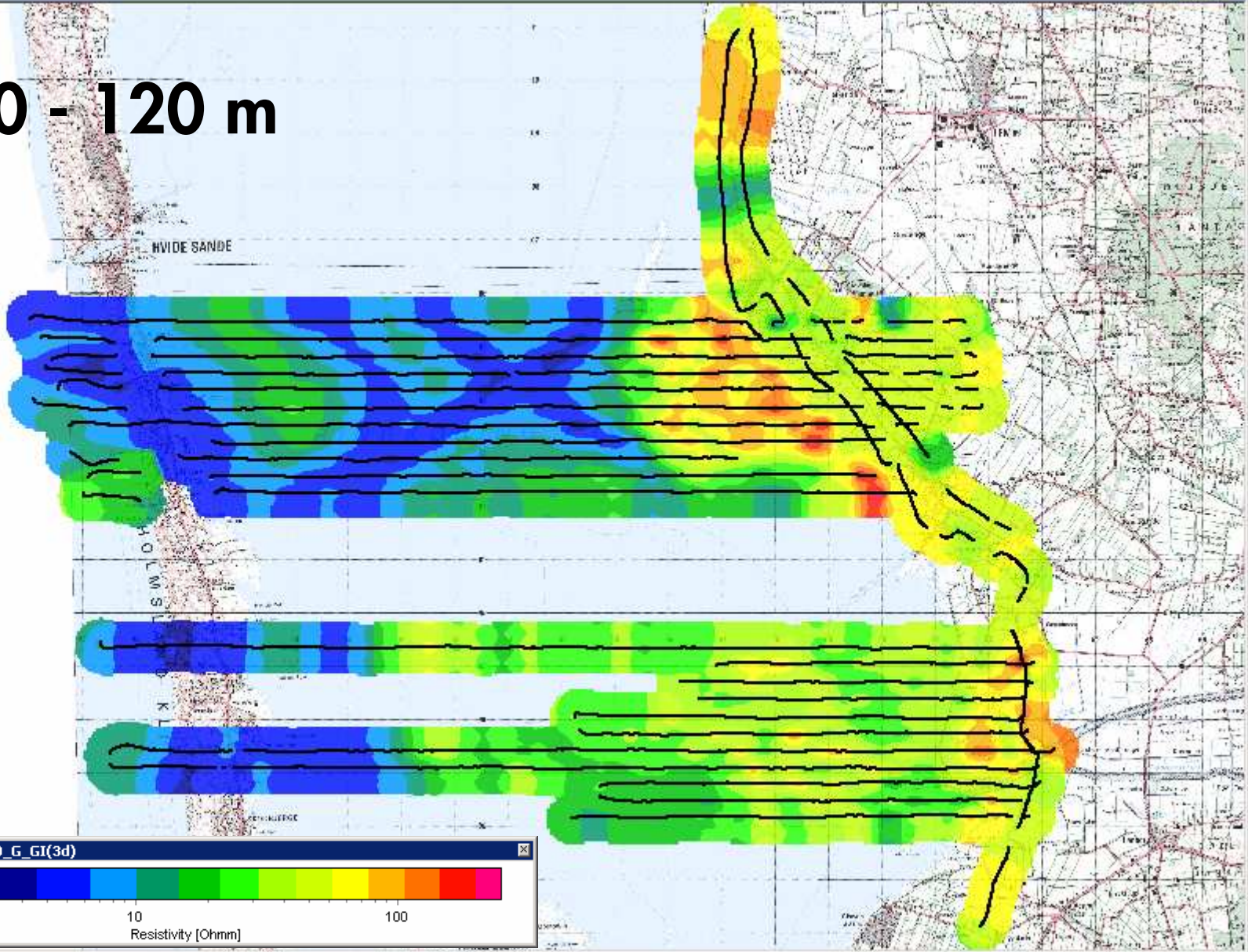
80 - 100 m



ave_res_100_120_G_GI(3d)



100 - 120 m



ave_res_100_120_G_GI(3d)



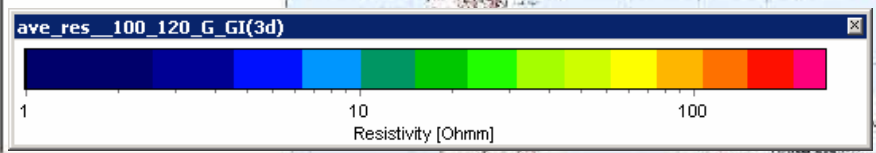
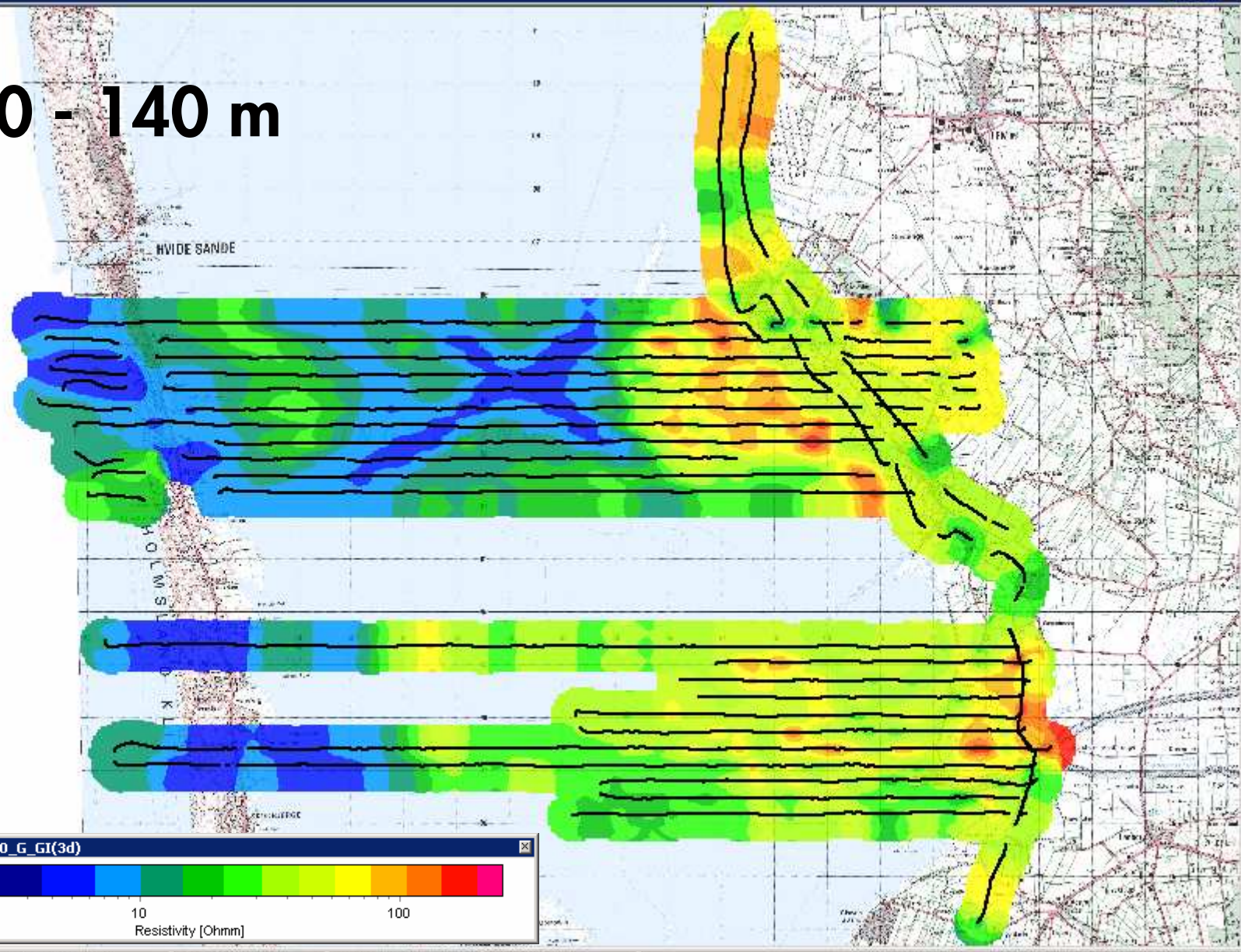
1

10

100

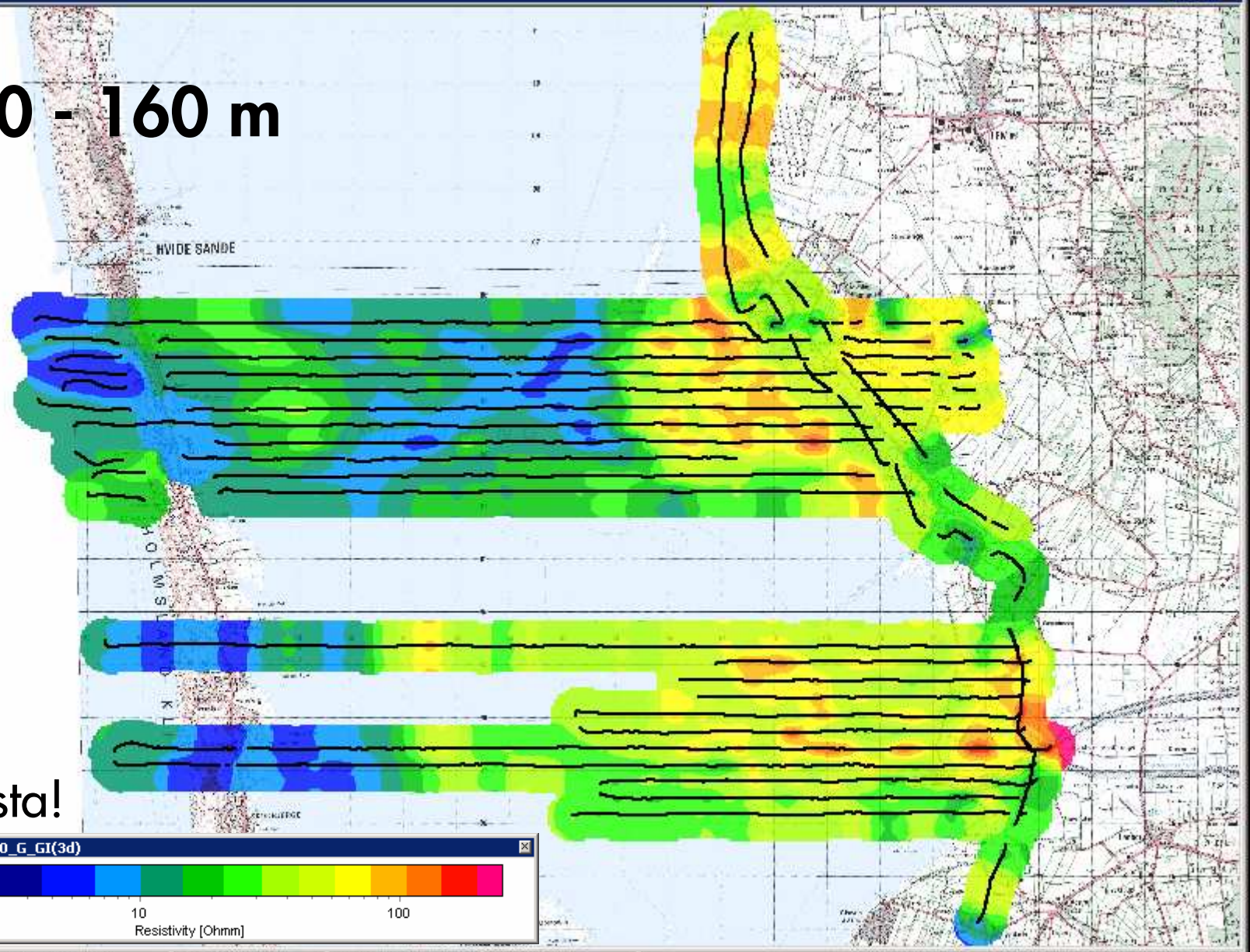
Resistivity [Ohm]

120 - 140 m

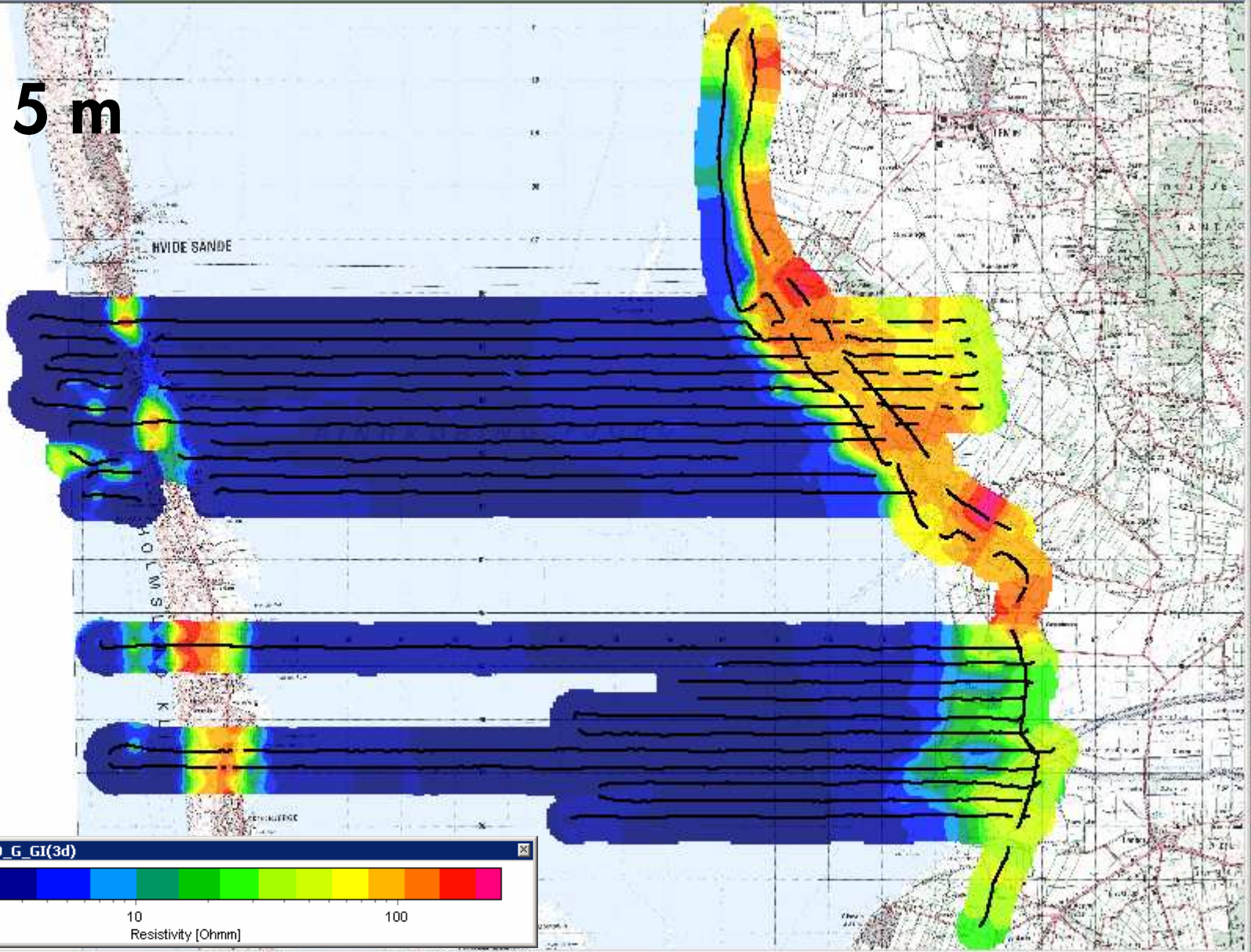


140 - 160 m

Basta!



0 - 5 m



ave_res_100_120_G_GI(3d)



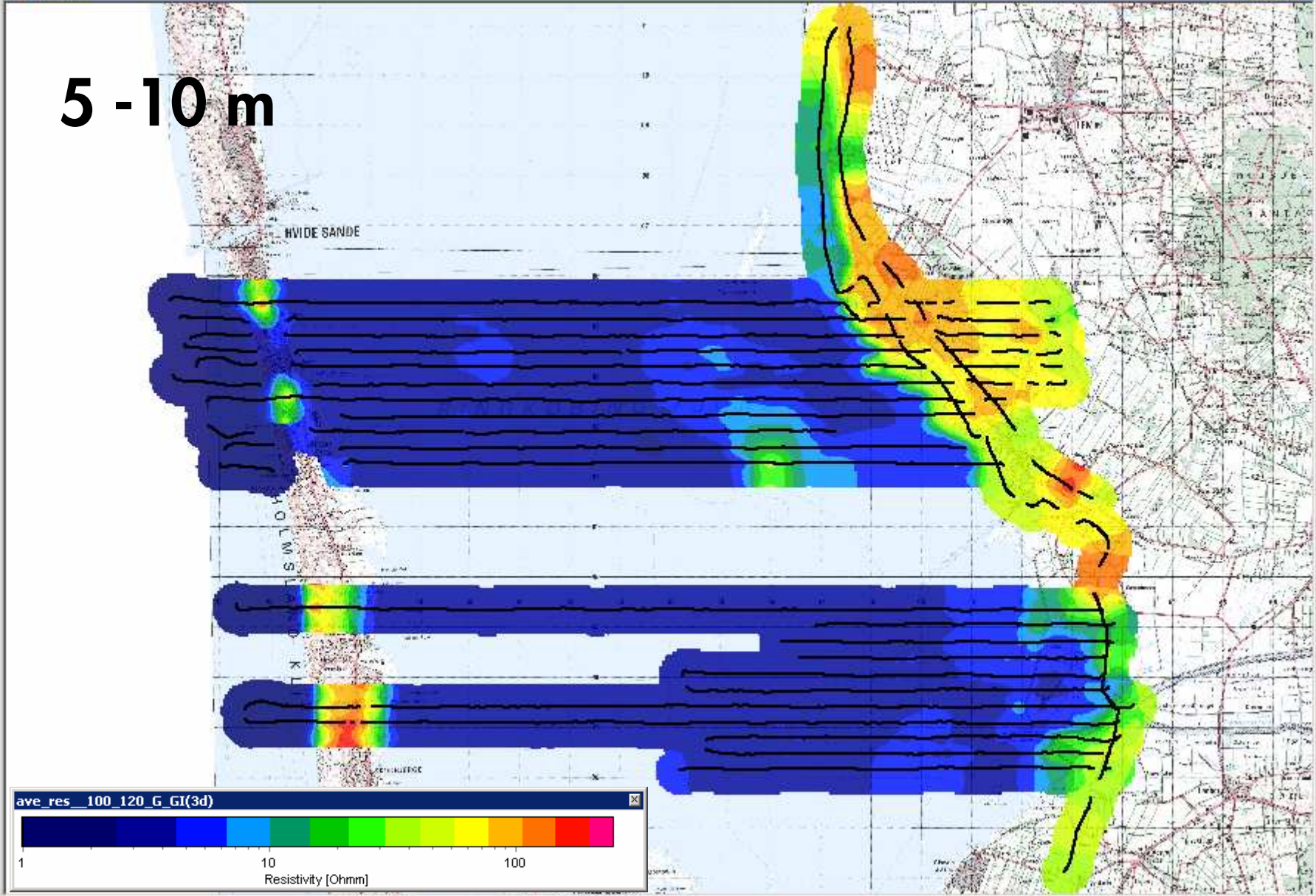
1

10

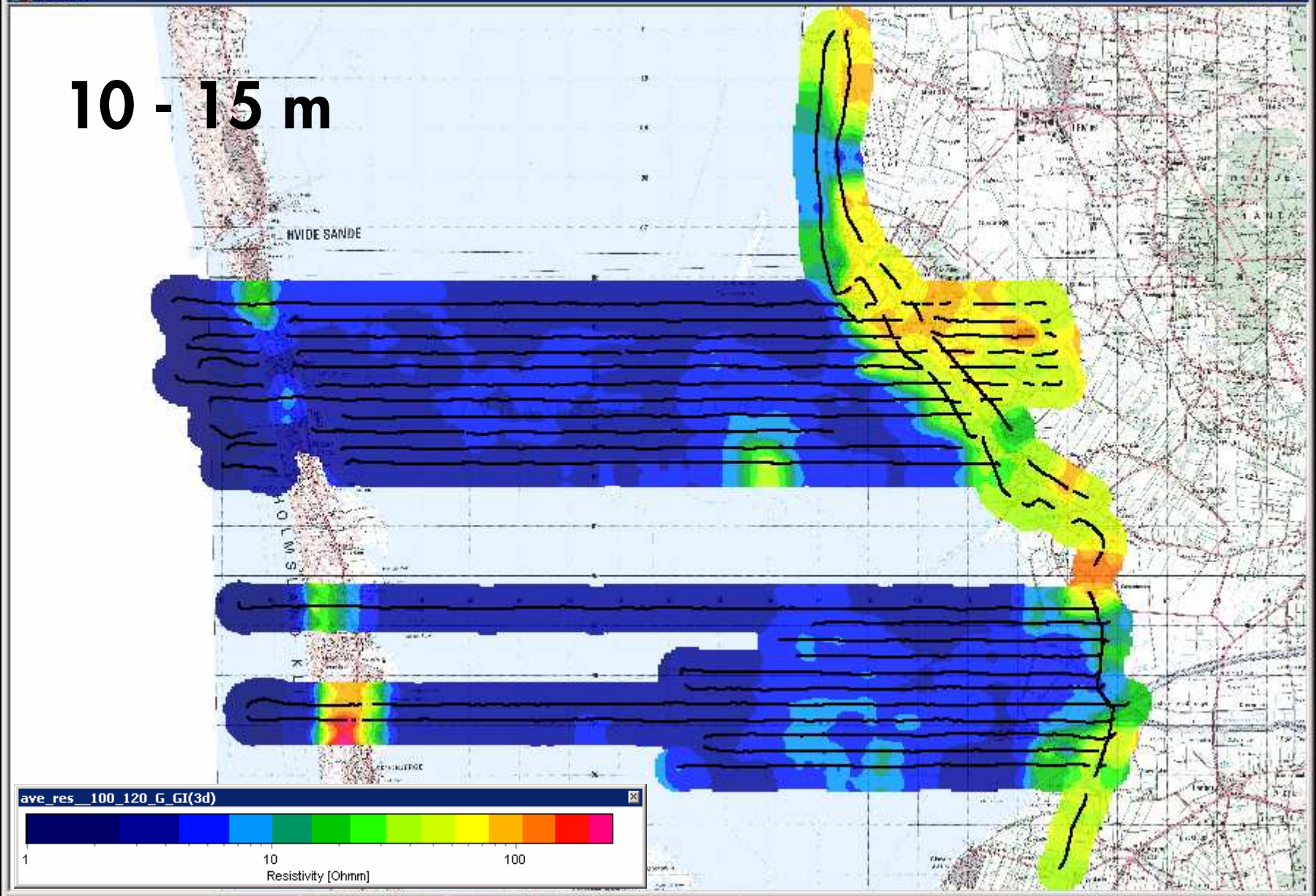
100

Resistivity [Ohm]

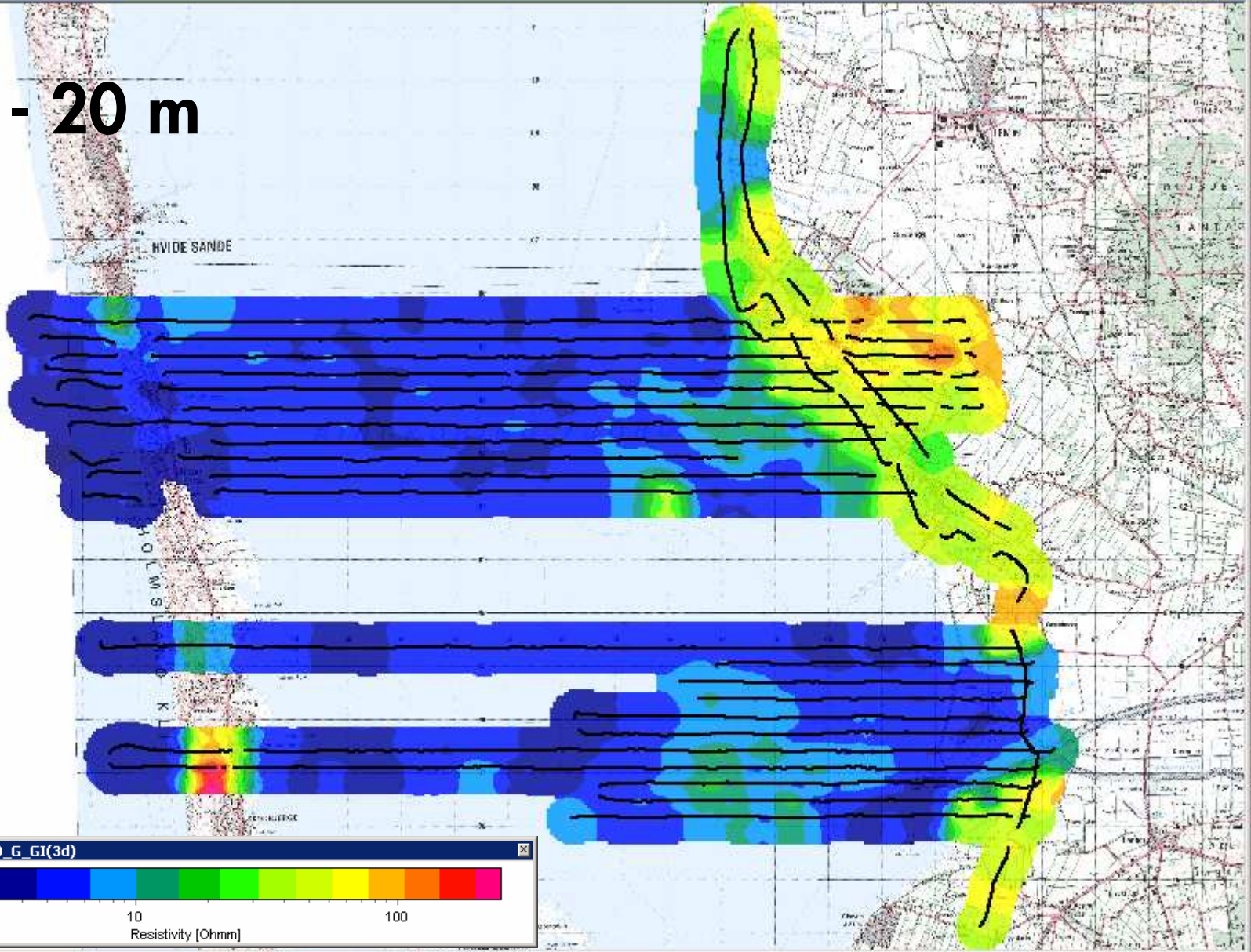
5 - 10 m



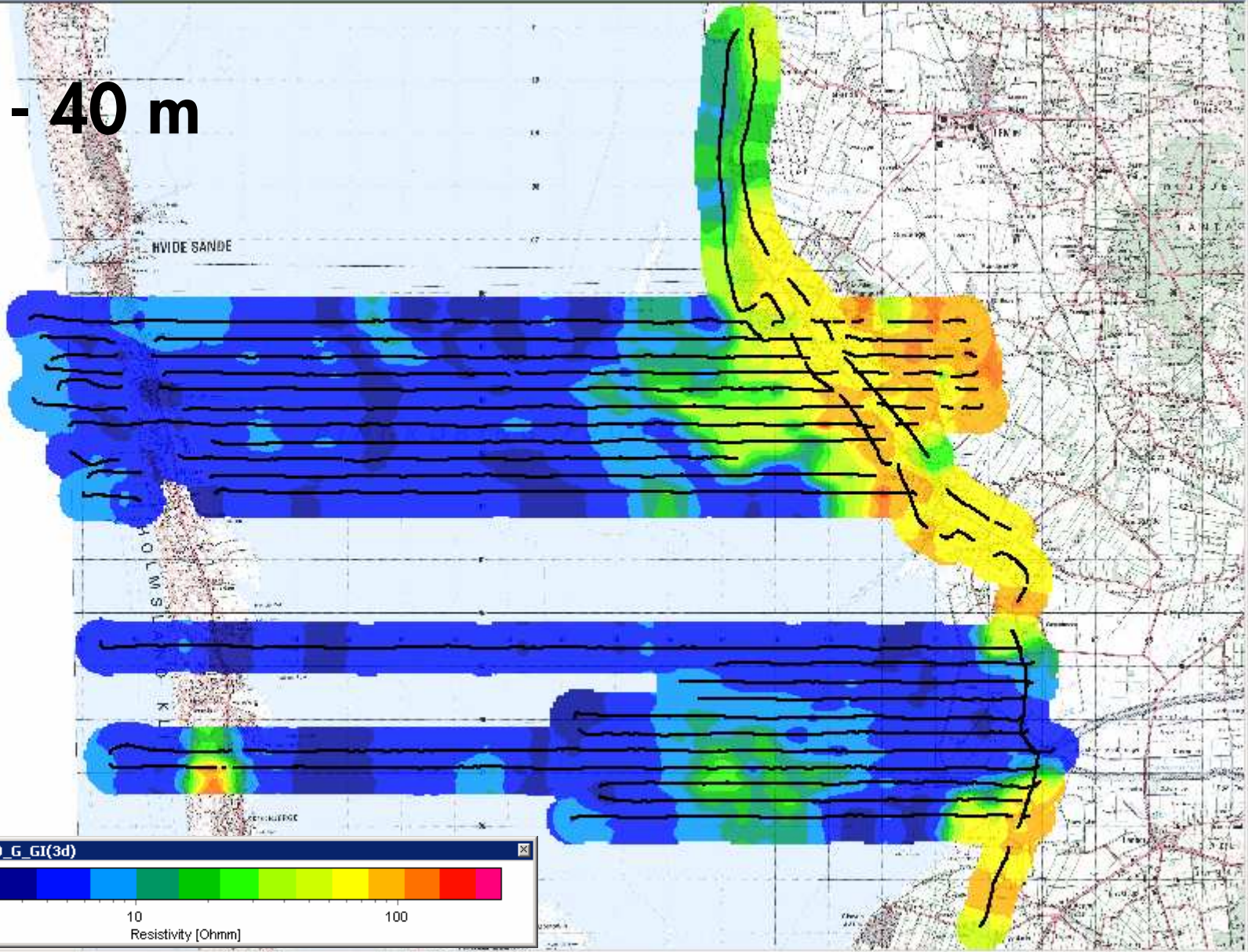
10 - 15 m



15 - 20 m



20 - 40 m



ave_res_100_120_G_GI(3d)



1

10

100

Resistivity [Ohm]

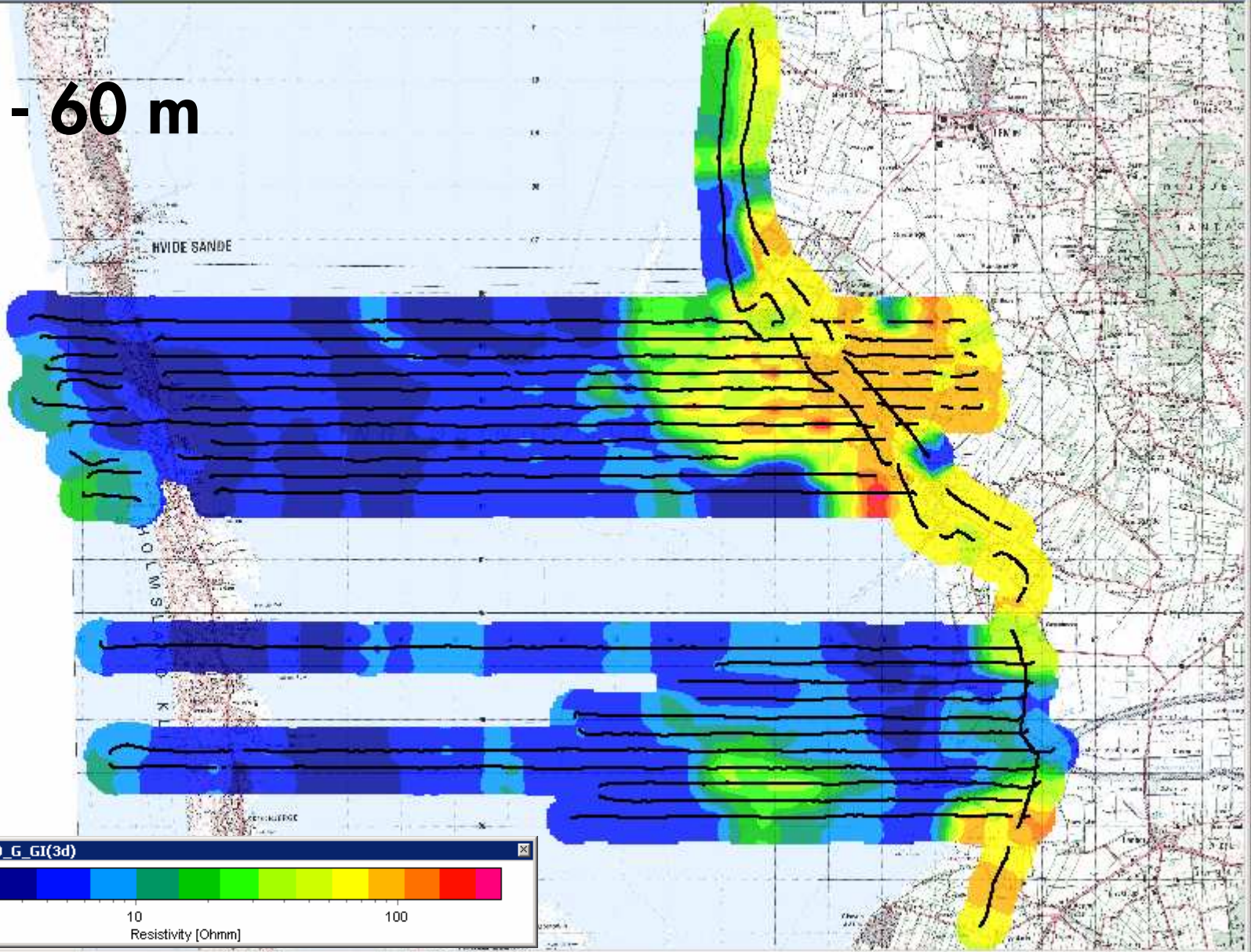
UTM Zone 32N (WGS 84)|p32632

X: 449025

Y: 6201201

I: 111310

40 - 60 m

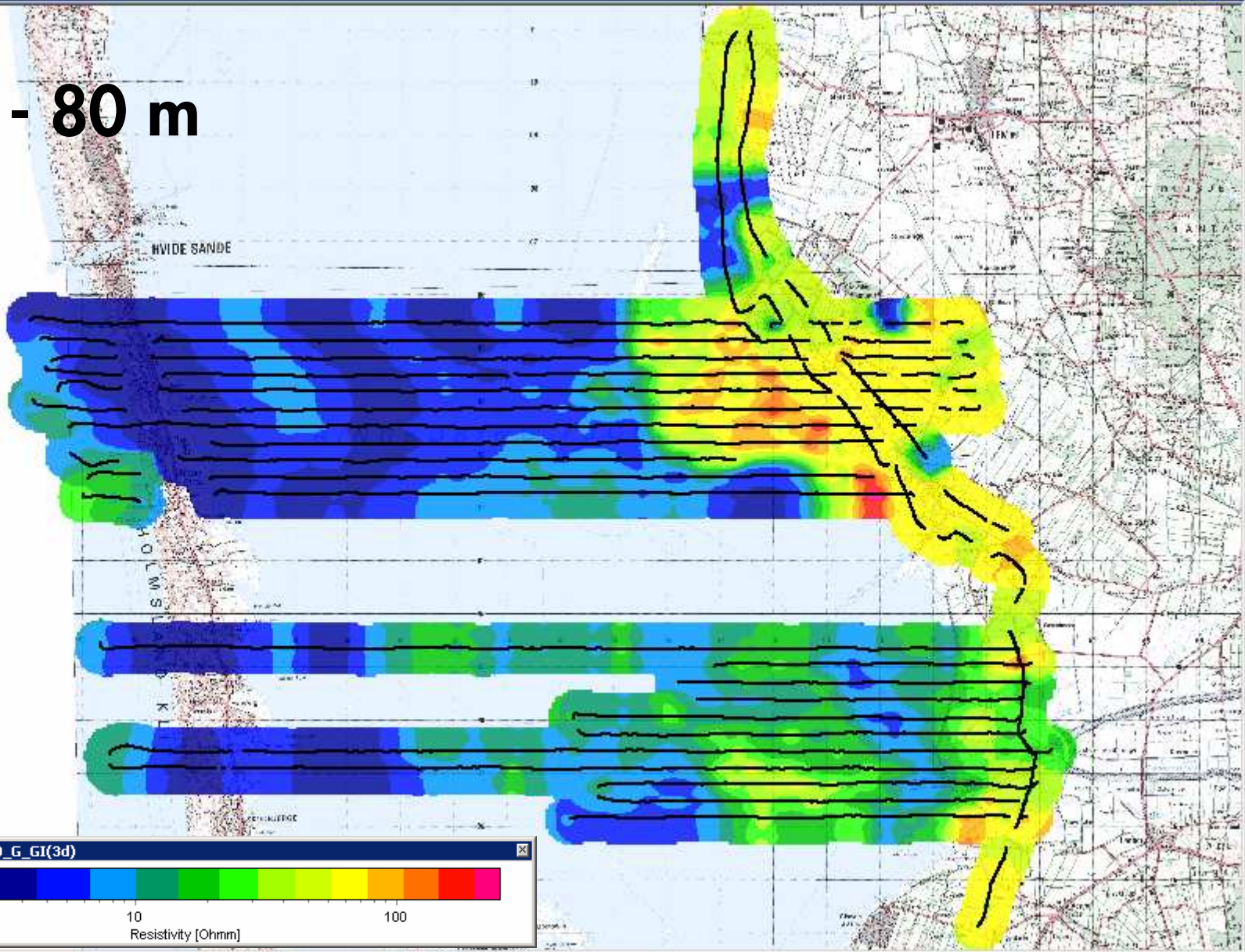


ave_res_100_120_G_GI(3d)

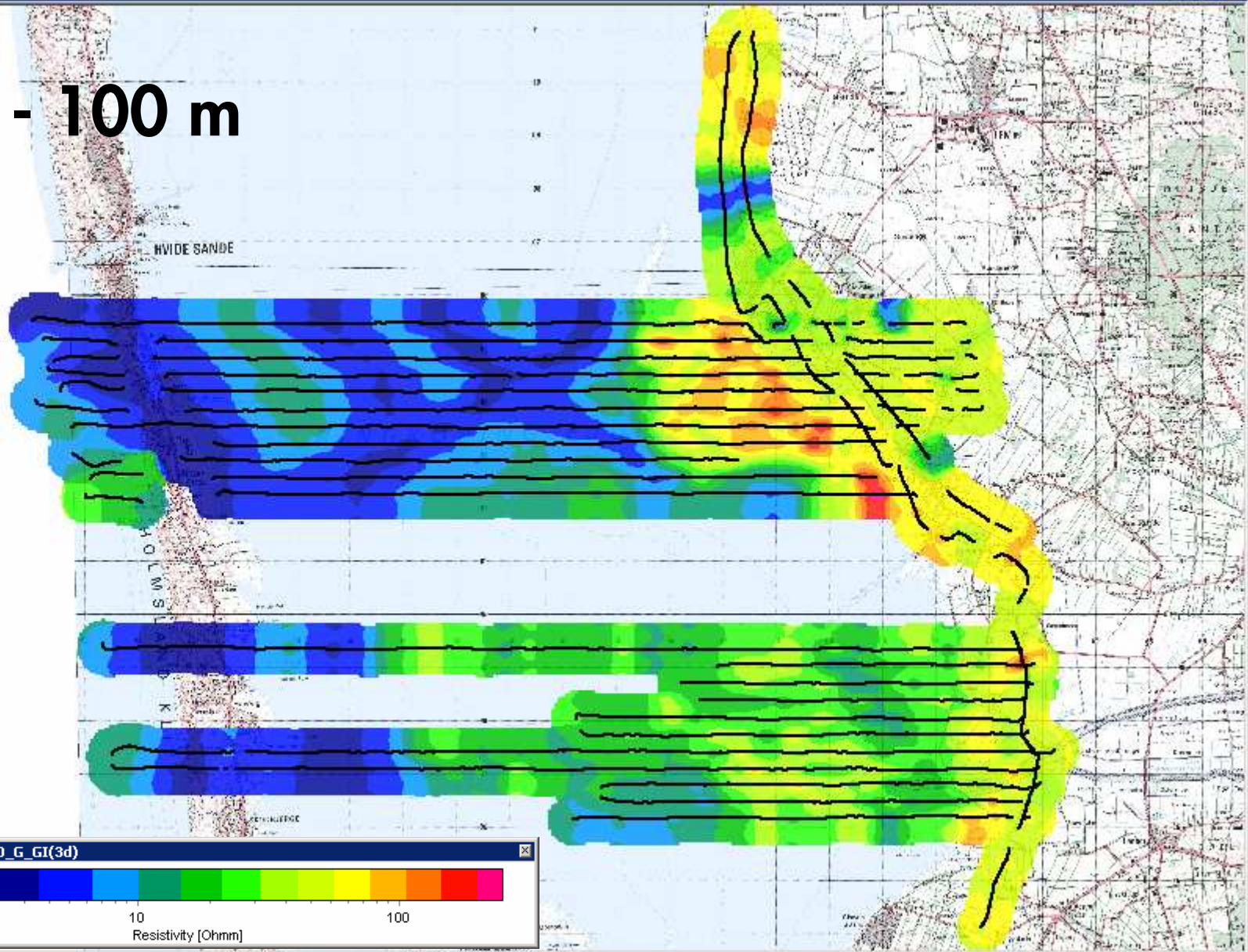


1 10 100
Resistivity [Ohm-m]

60 - 80 m



80 - 100 m



ave_res_100_120_G_GI(3d)



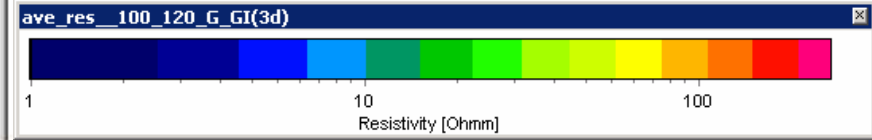
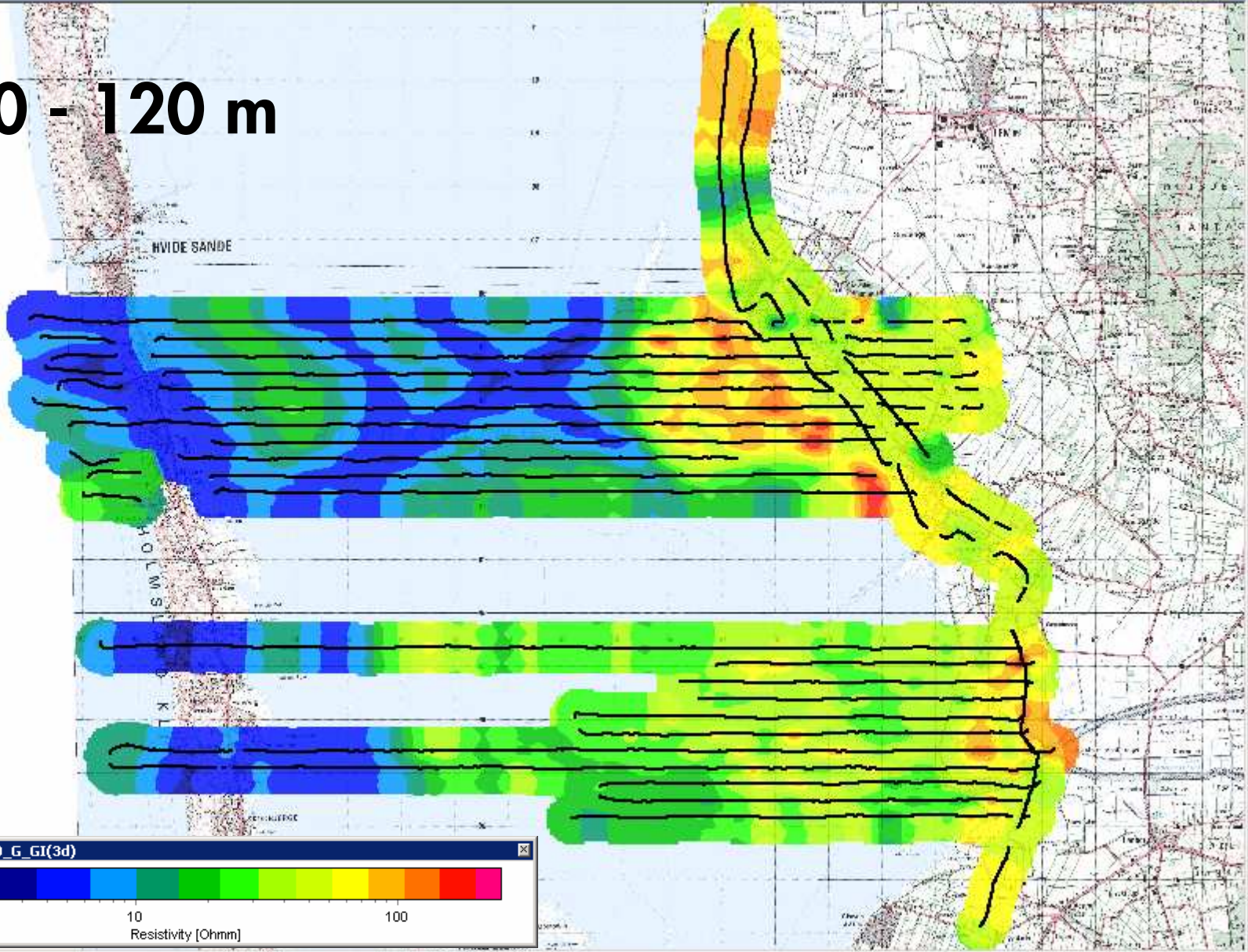
1

10

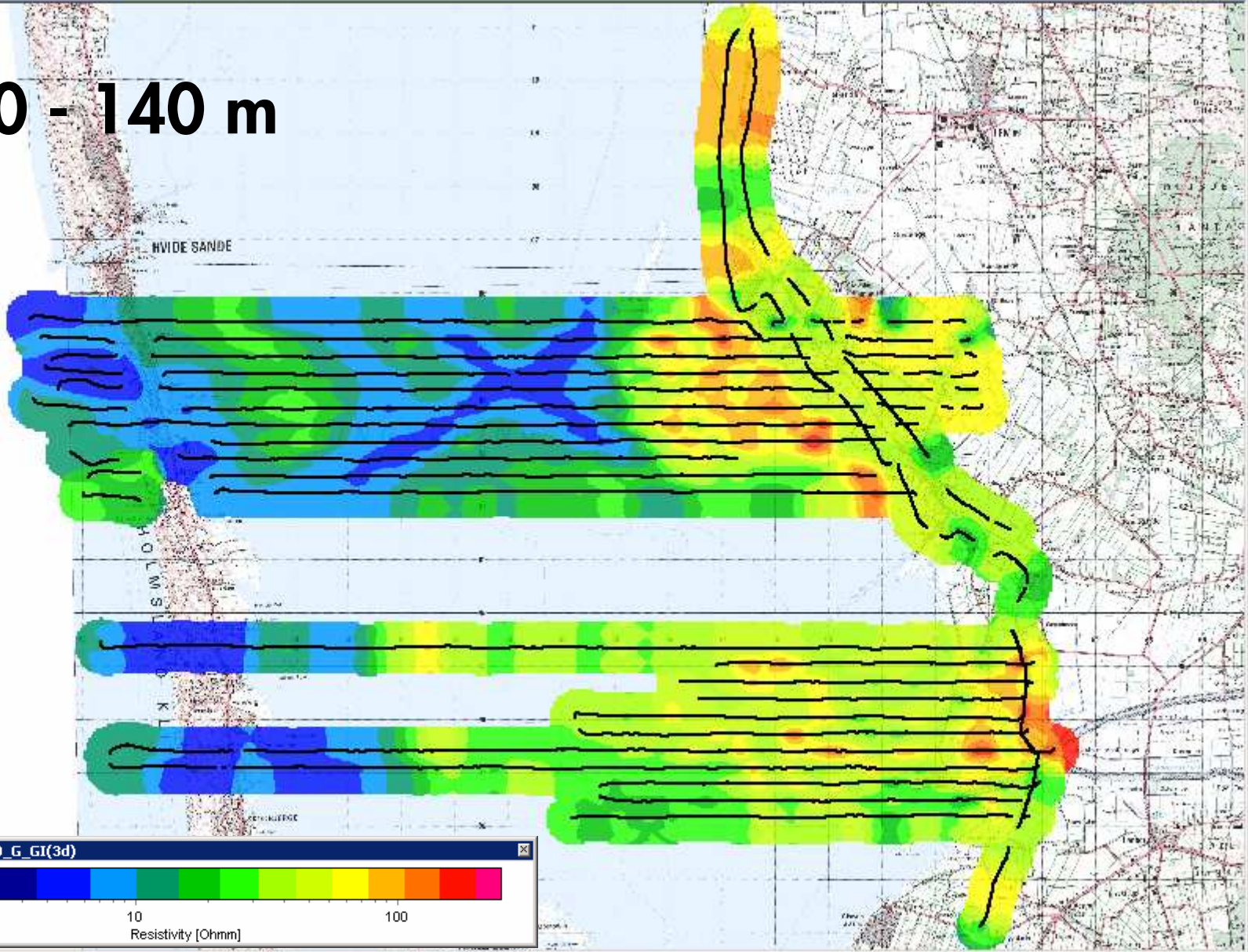
100

Resistivity [Ohm-m]

100 - 120 m

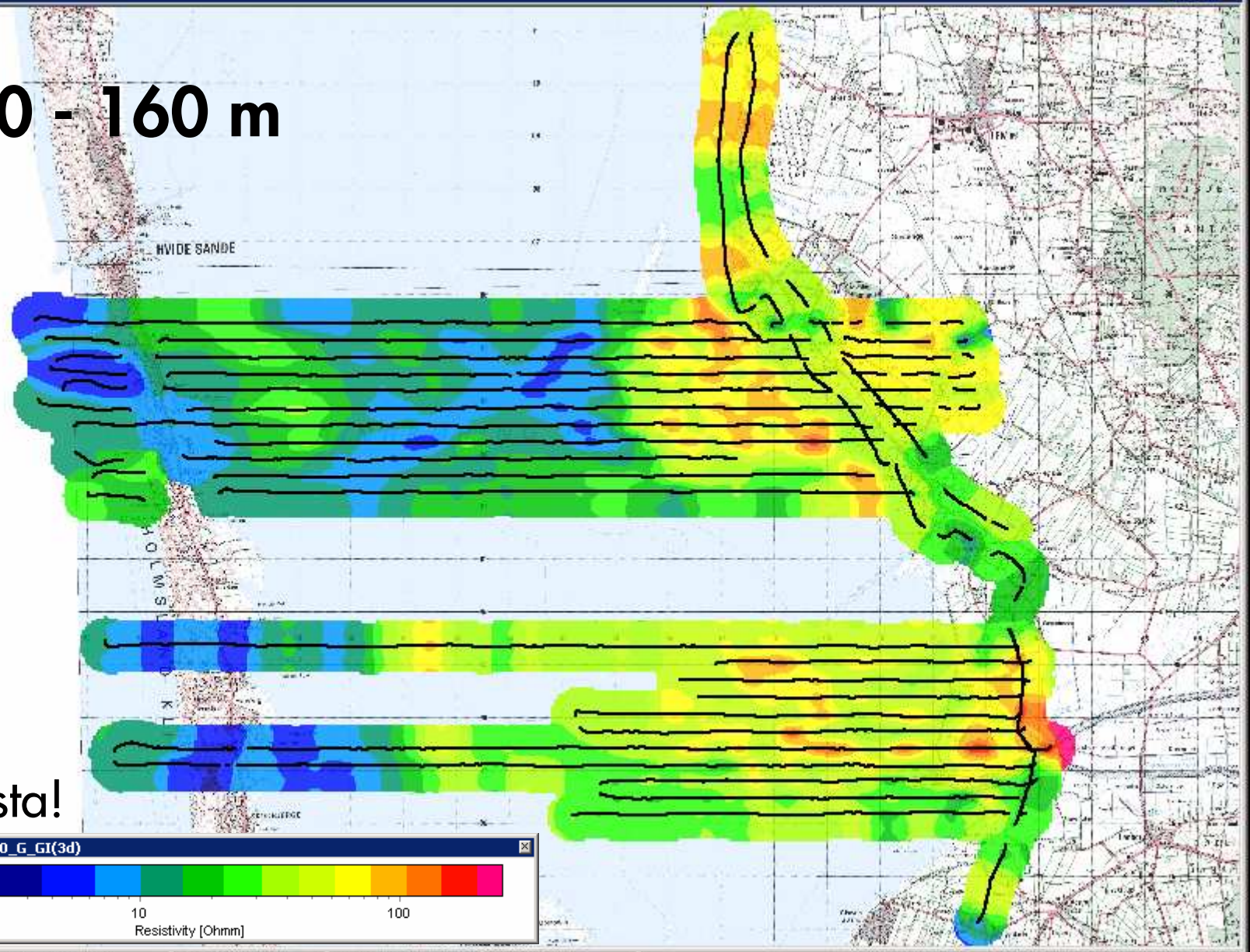
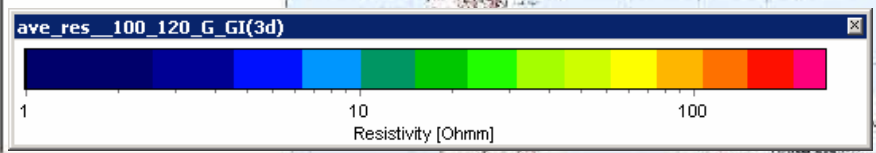


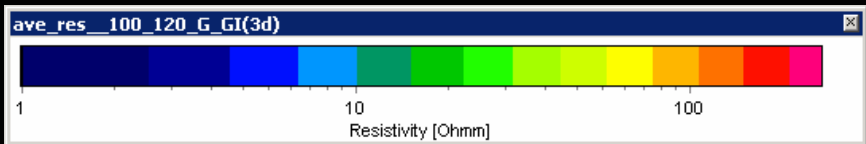
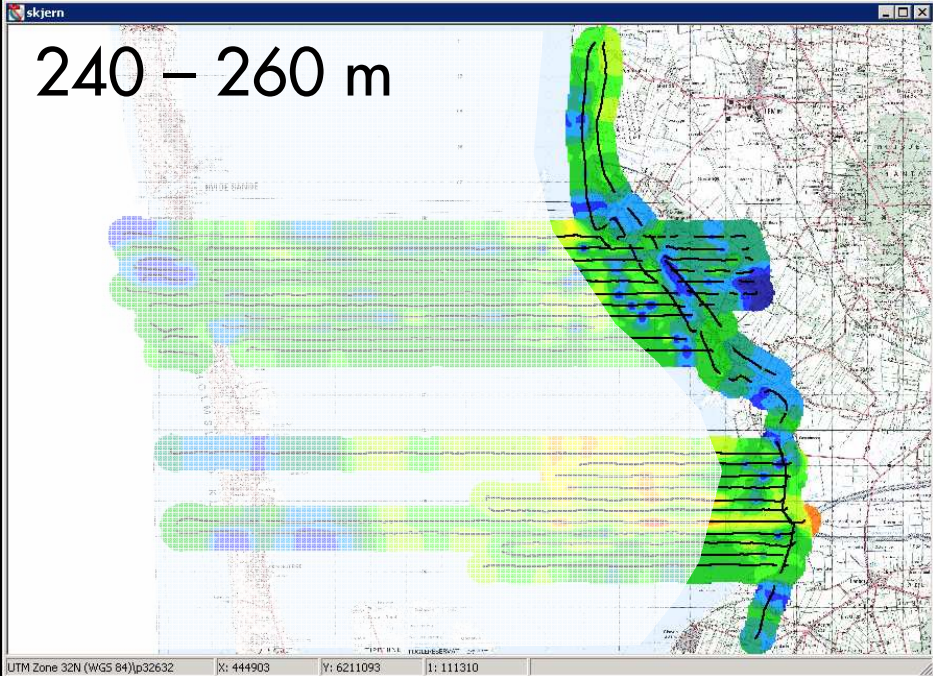
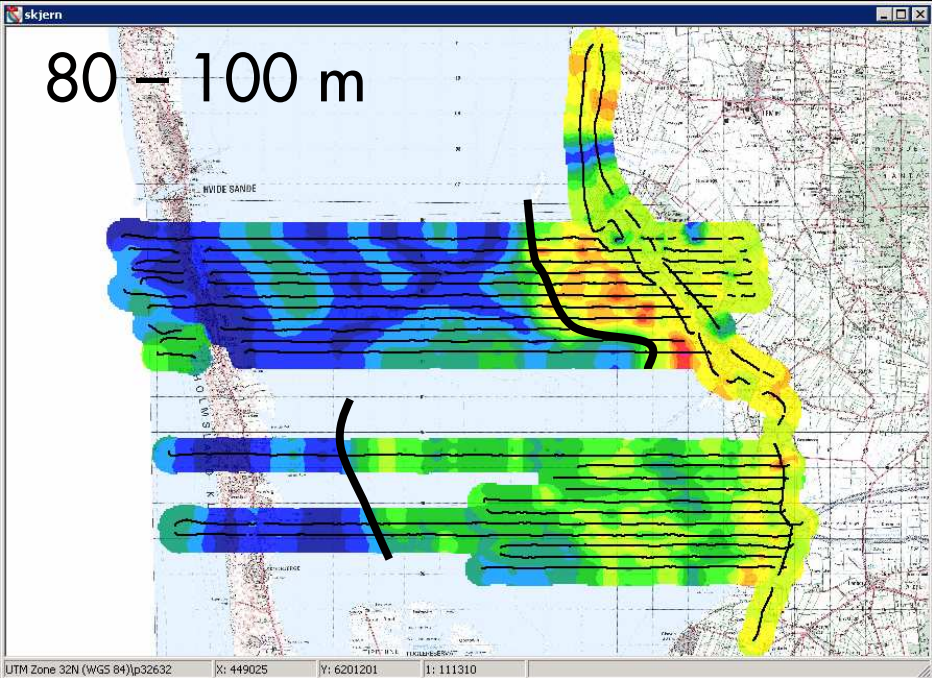
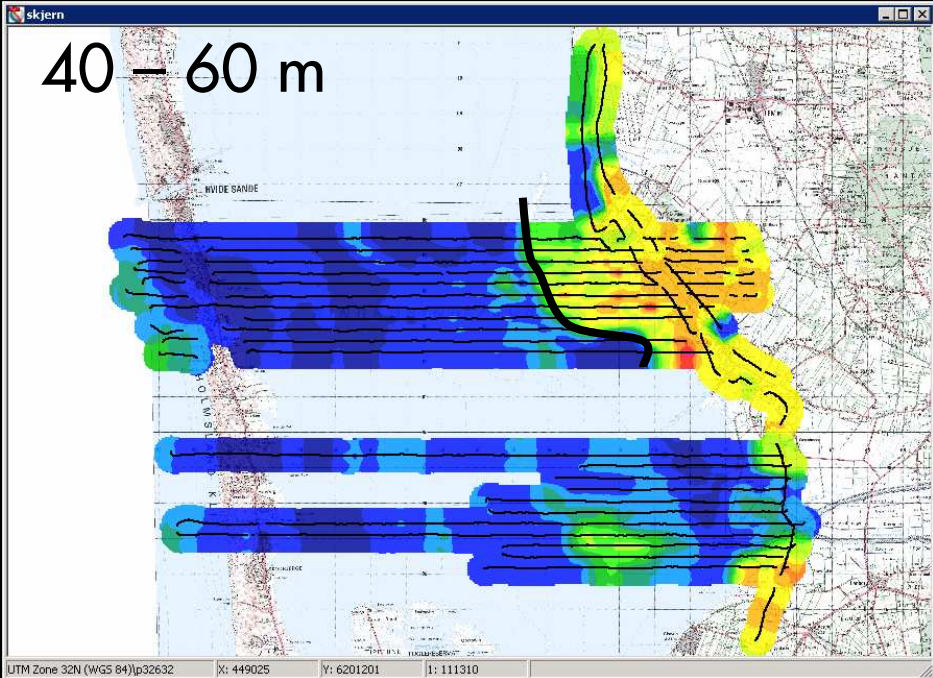
120 - 140 m



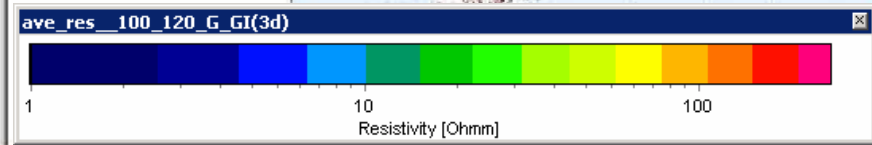
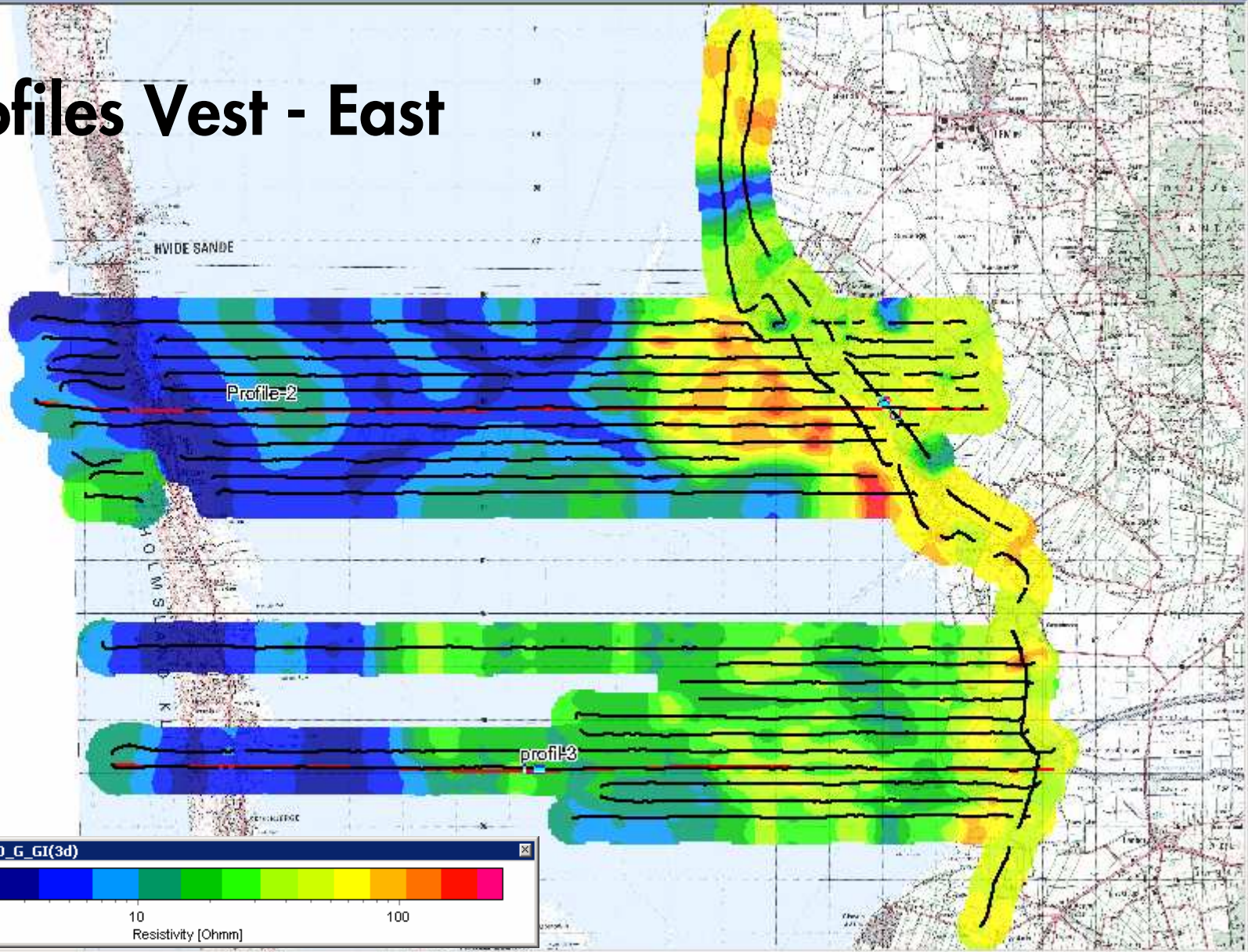
140 - 160 m

Basta!

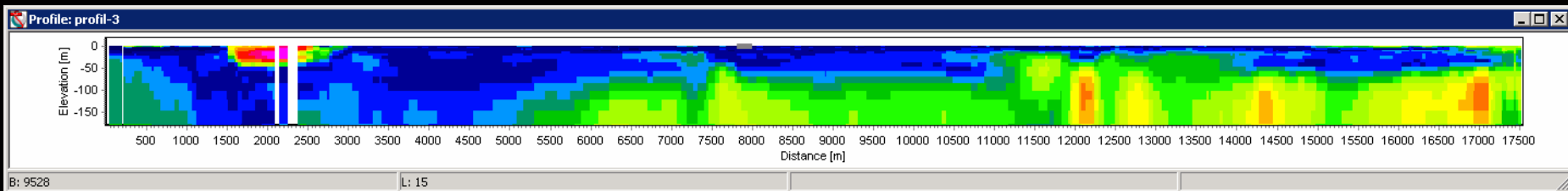
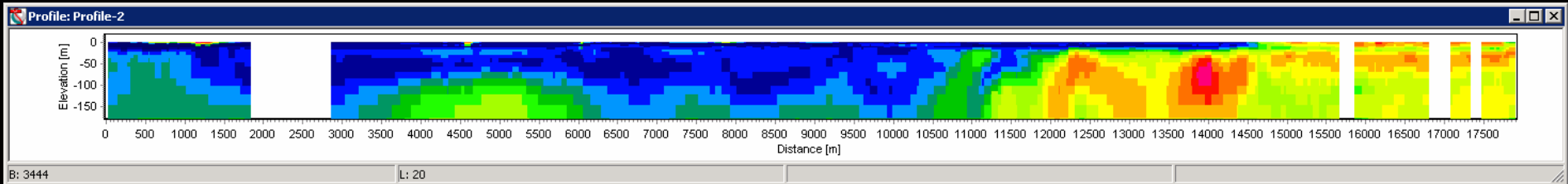
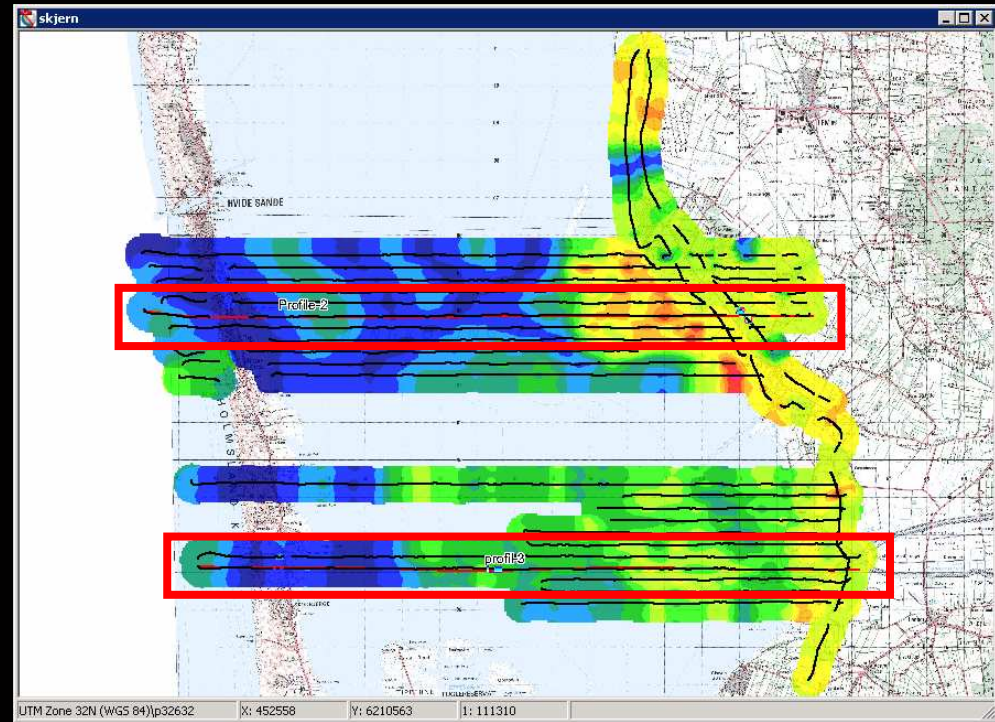




Profiles Vest - East

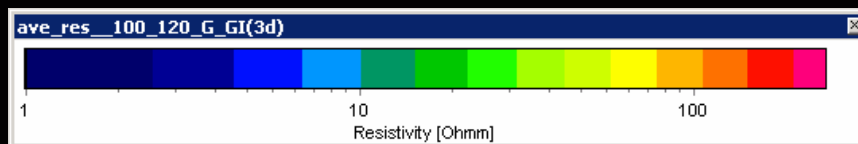


Profile 2 and 3

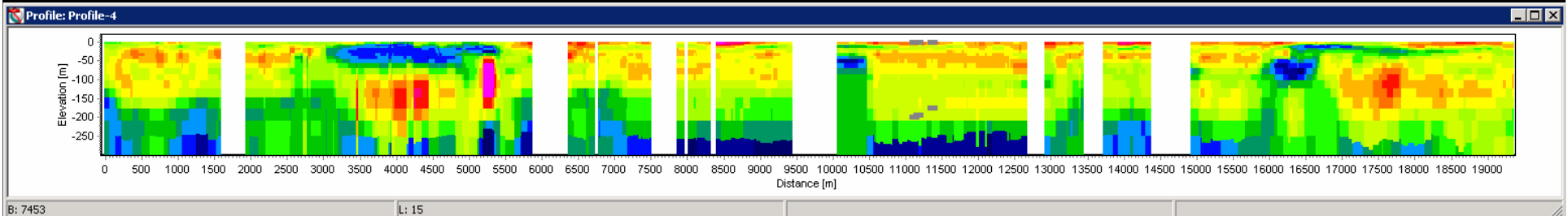
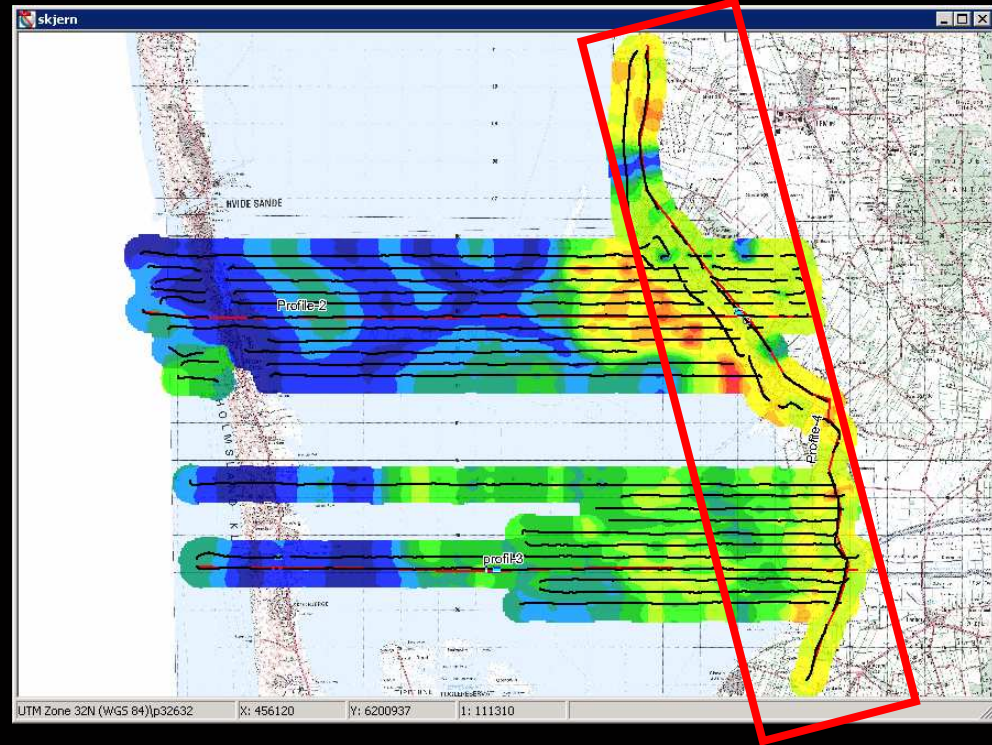


West

East

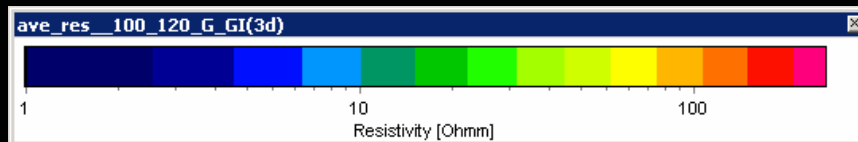


Profile 4



South

North



Concluding remarks

- **The initial results of the SkyTEM survey shows**
 - Sediments with high resistivity below the Ringkøbing Fjord – probably fresh water saturated
 - Surprisingly large spatial variability over the survey area
- **Work to be done**
 - In depth data processing and SCI inversion
 - Coupling to the conceptual geological model, the seismic line and the deep borehole
 - Integrated hydrological modeling

