Effektiv bruk av EM-data: 3D vs. 2D

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Is it possible to use 2D EM data inversions in a 3D setting?

- Tools and method
- Arguments supporting 2D EM inversions
  - Diffusion vs. Wave propagation
  - Physical equivalent: heat conduction
- Examples of 2D inversions and comparison to 3D
  - Troll
  - Wisting
- Summary

Tools and method

- NGI 2D code (JIP)
  - Finite element frequency domain code
  - Developed by Malte Vöge & Joonsang Park

- Data preparation
  - Projection on 2D line & decomposition of fields
  - Move Rx to sea bed / adjust sea bed
  - Smoothing (filter) & interpolation for commen source resampling
  - Restrict offsets

- Start model
  - Simple constant resistivity or gradient models
  - Start model from coarse grid low frequency inversion + filter

- Levenberg Marquard inversion
  - Smoothness regularisation → minimal!

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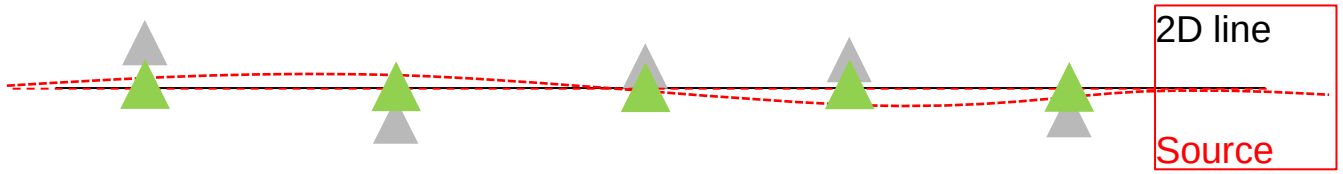

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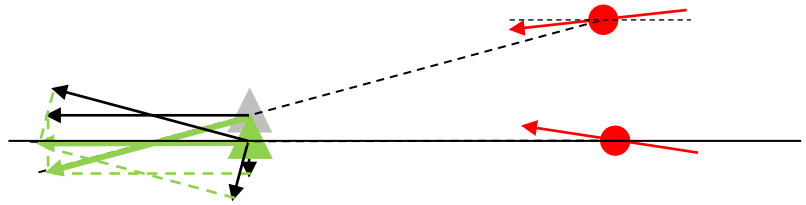

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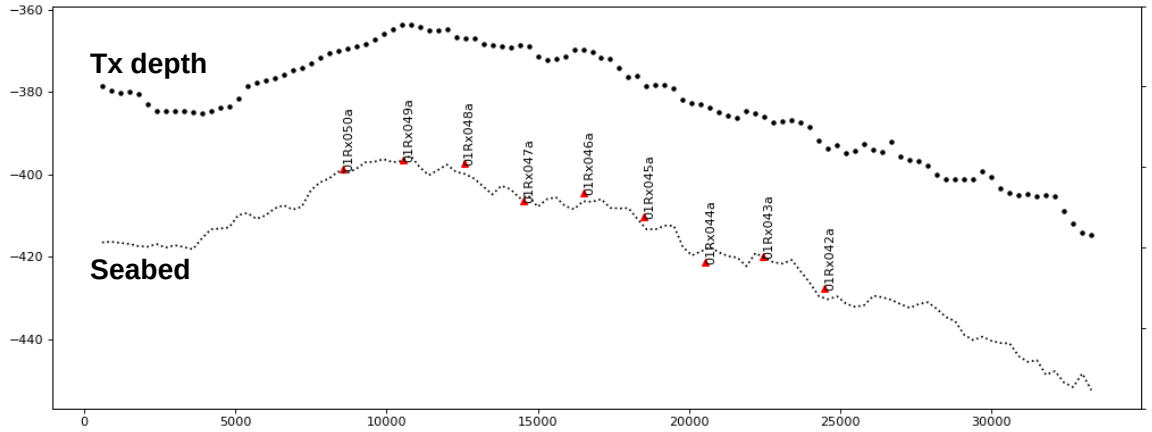

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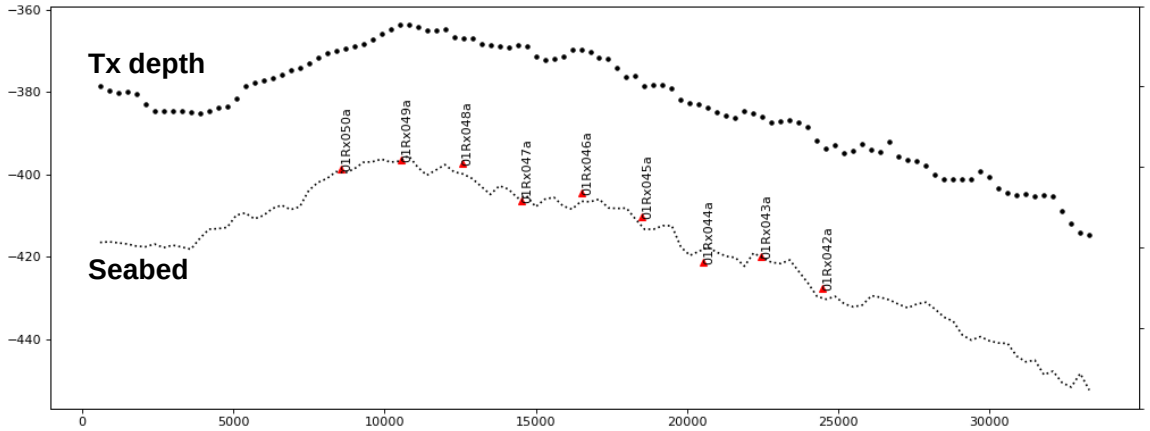

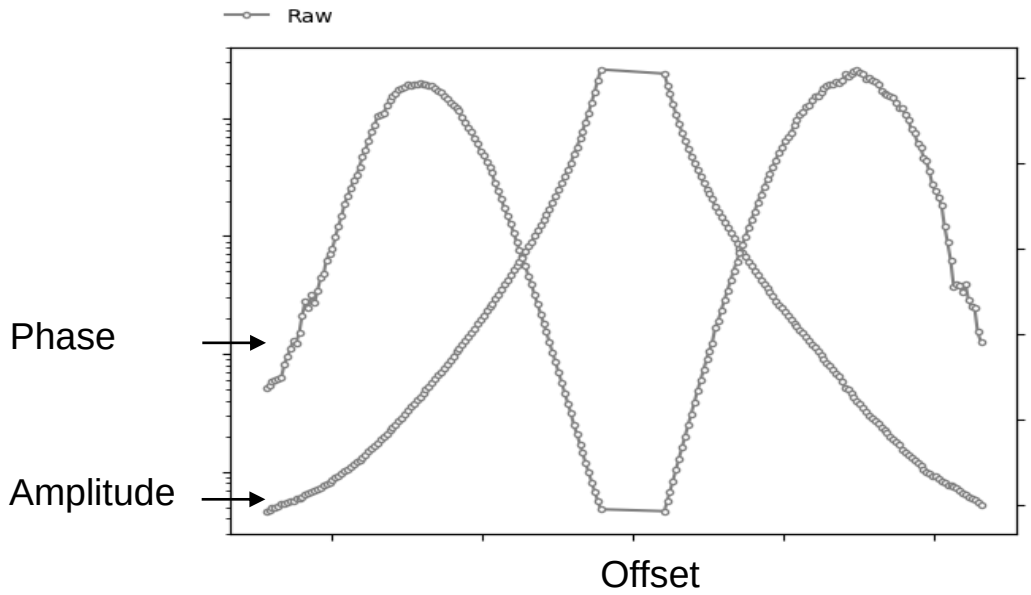

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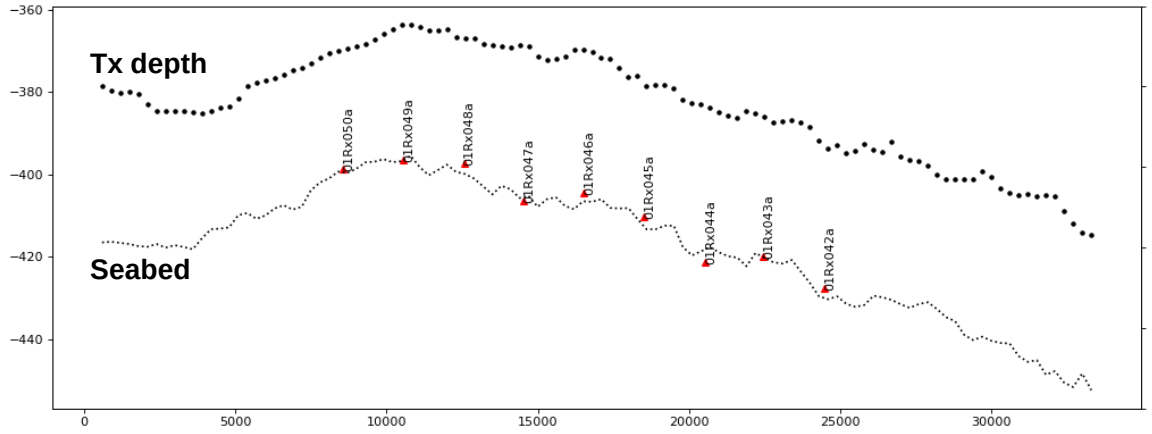

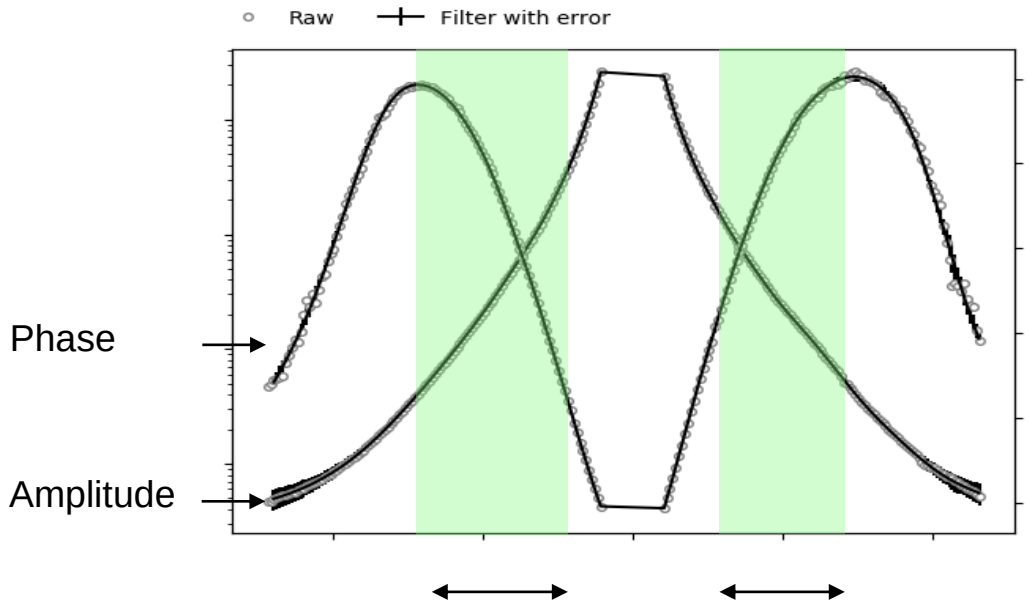

Selected offsets: avoid air wave

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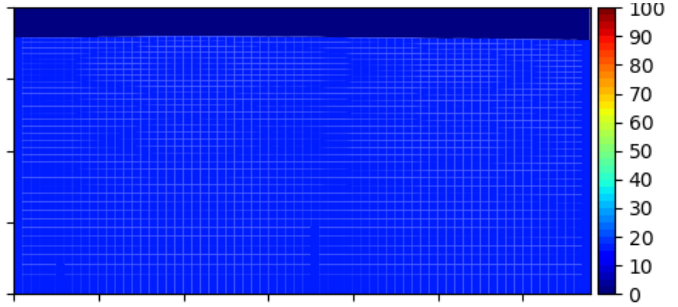
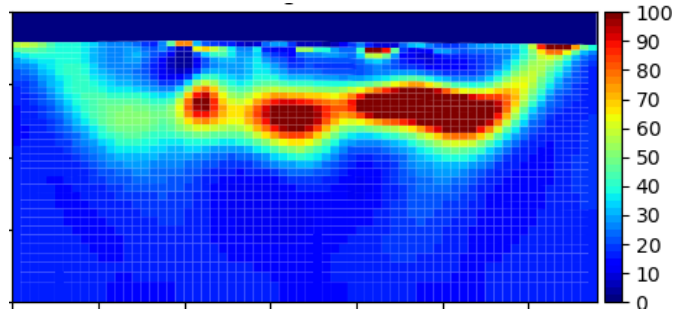
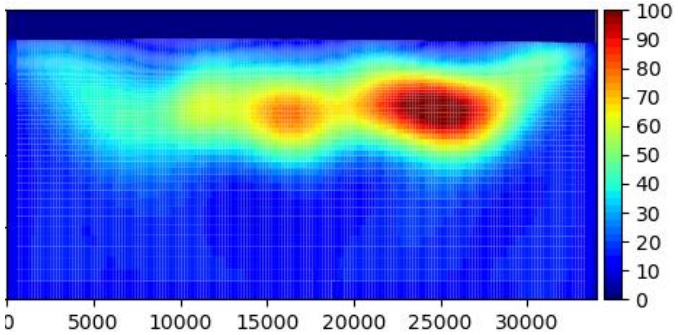


Low frequency inversion
Coarse grid



Smooth start model

Fine grid



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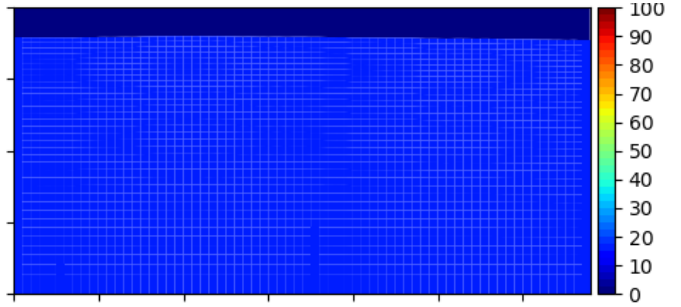

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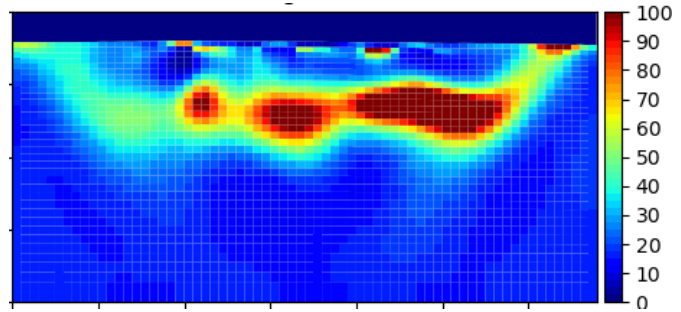

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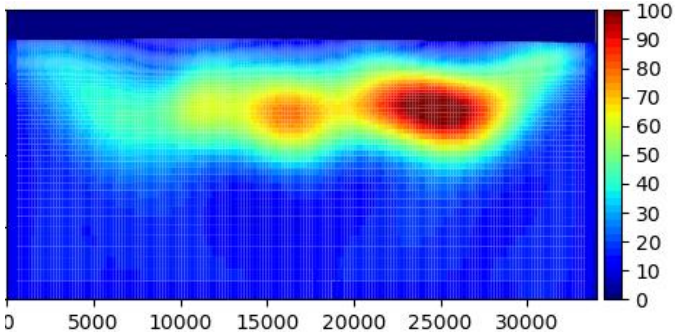


EM & diffusion

Maxwells Equations

→ Low frequency limit in conductive medium → Diffusion equation → $\frac{\partial \vec{J}}{\partial t} = \frac{1}{\mu\tilde{\sigma}} \nabla^2 \vec{J}$ $\vec{J}$ … Current density

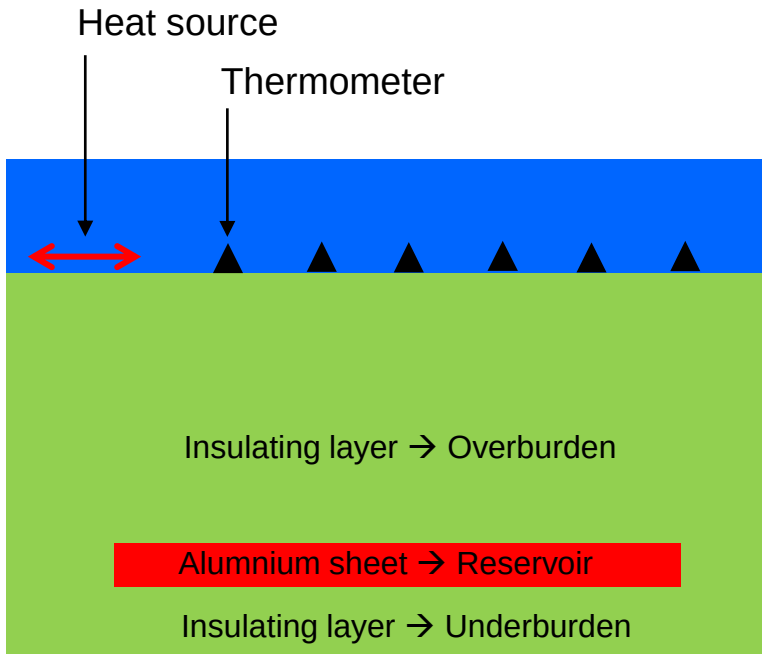
→Same equation describes conduction of heat → $\frac{\partial T}{\partial t} = \frac{\lambda}{c} \nabla^2 T$ T … Temperature

→ Can understand the behavoir of the EM response by heat conduction analogy

low conductivity σ → high resistivity → high heat conductivity λ

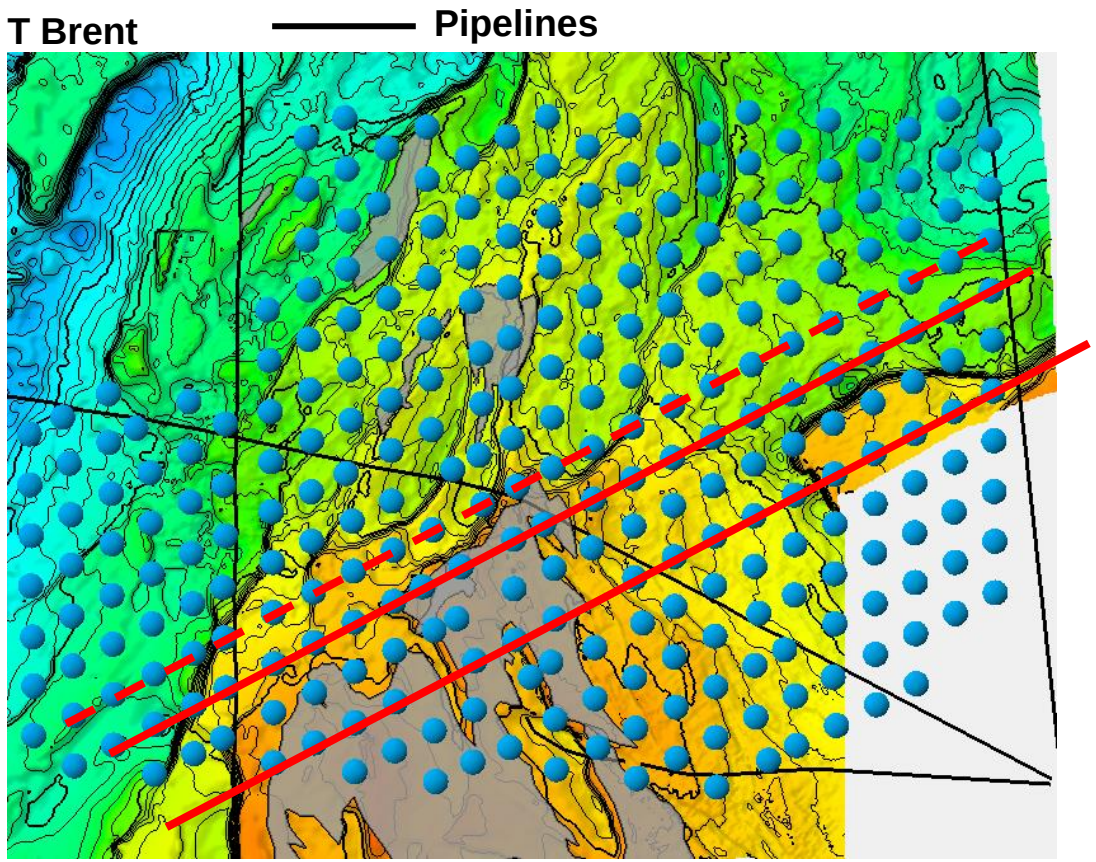
Based on the heat conduction analogy

- Volume method: The most important is the total transverse resistance, detailled distribution is less important
- Local: What happens at one position is not very sensitive to the properties far away → absorbing boundary conditions at short distance
- Dominated by the material between source (heating) and the receiver (thermometer)



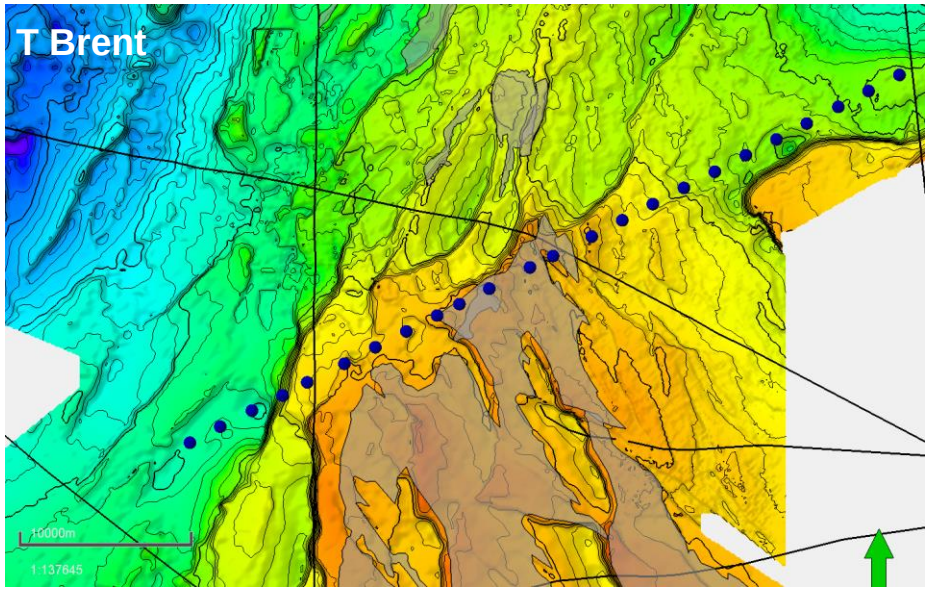
Troll

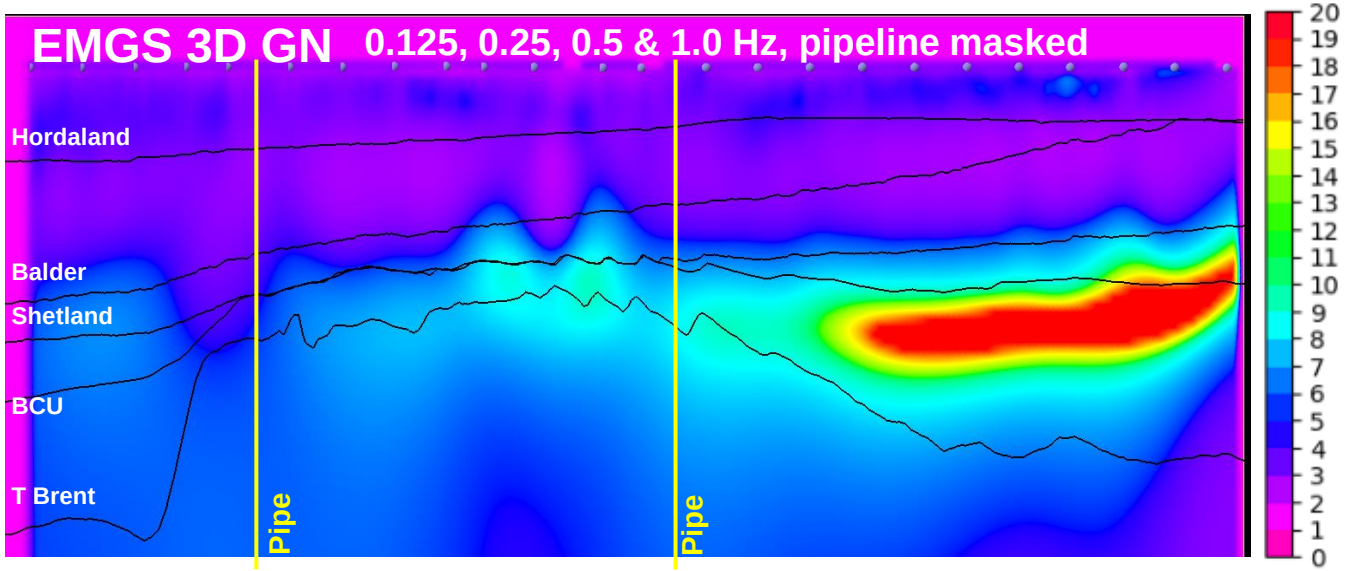
- Shelf express shallow tow → air wave
- ~350 m water depth!
- Top reservoir ca. 1850m → 1500 m overburden
- Pipelines
- 2014 data, base frequency 0.125 Hz, ca 2 km Rx spacing
- Very good data quality
- Moderate resistivities

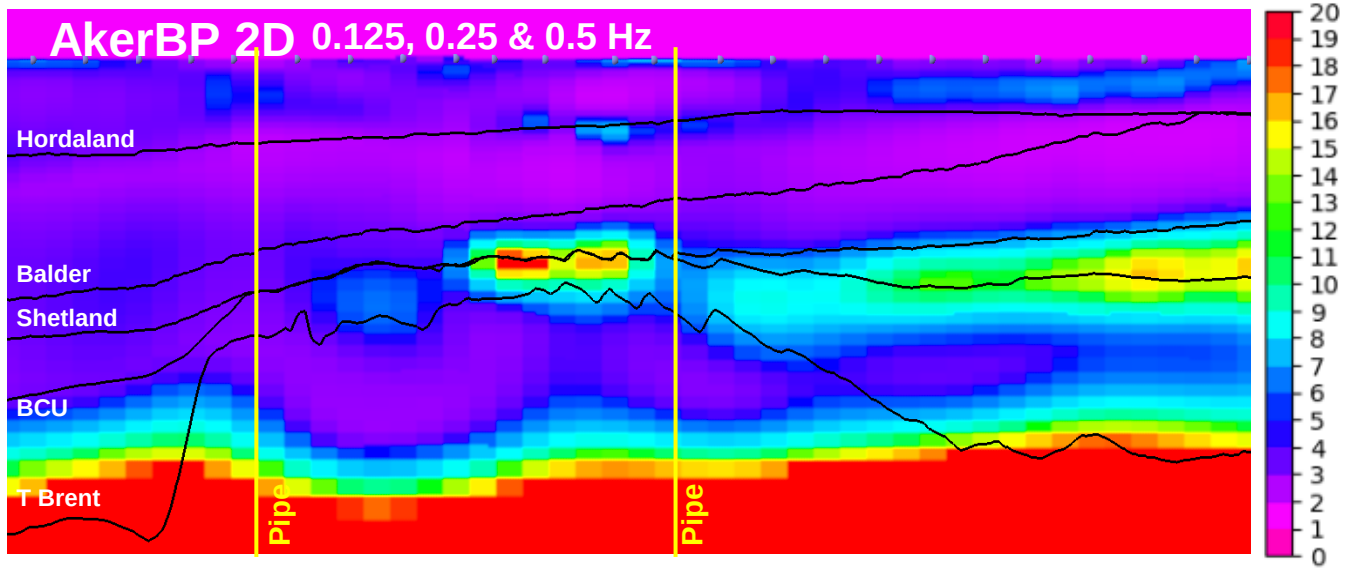


2D vs. 3D Inversion: Troll

- Tx013 only touches the Troll field
- Geometry perpendicular to line not 2D
- Pipelines are not crossed perpendicular
- Good 2D inversion result

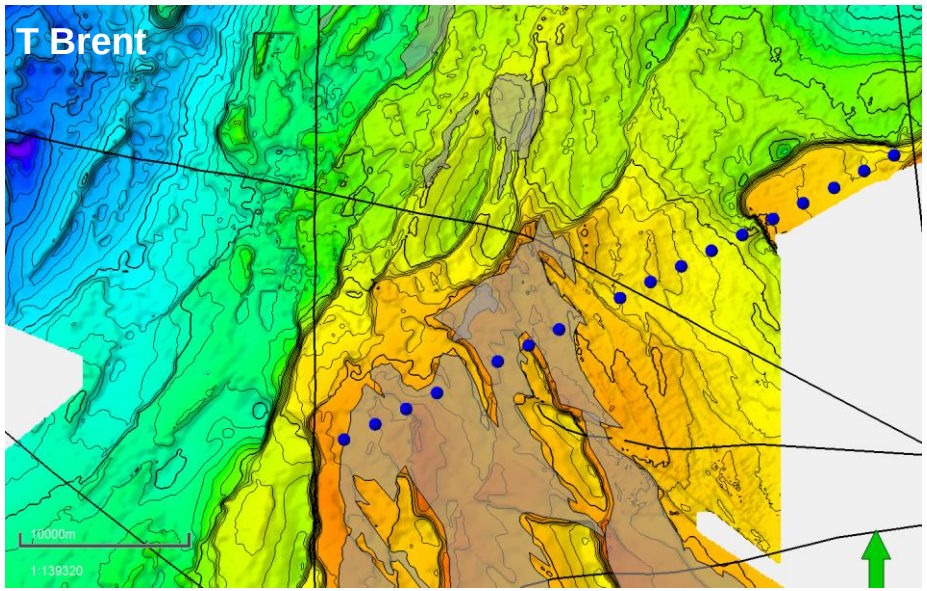


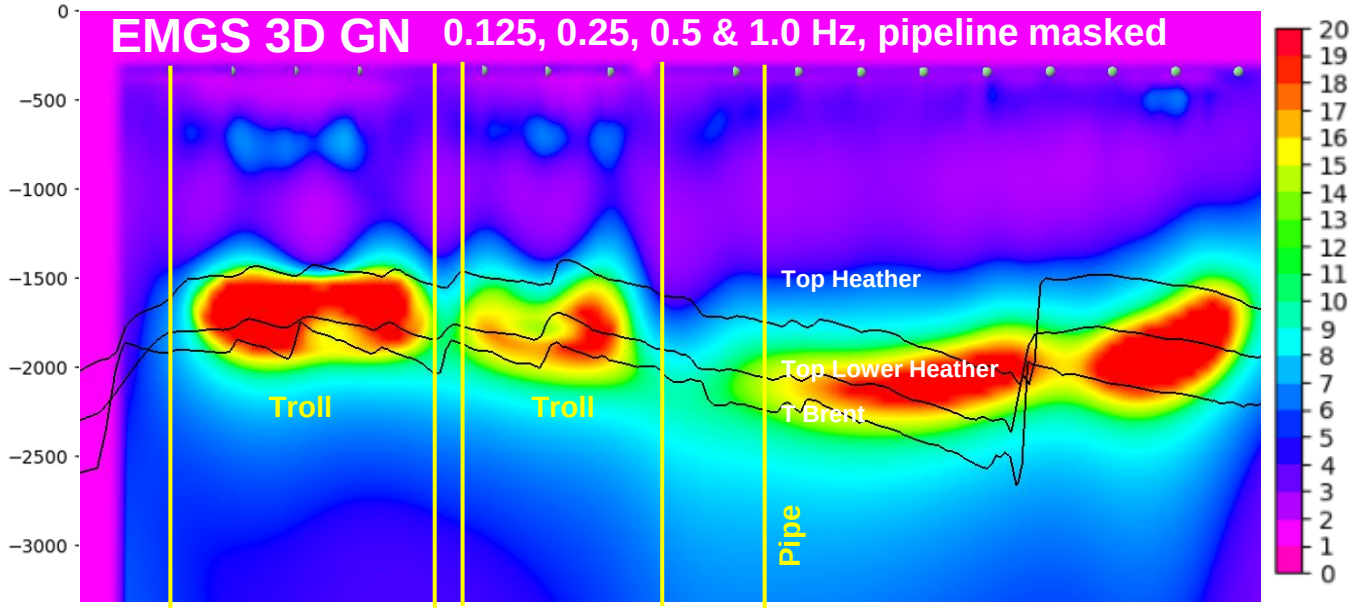


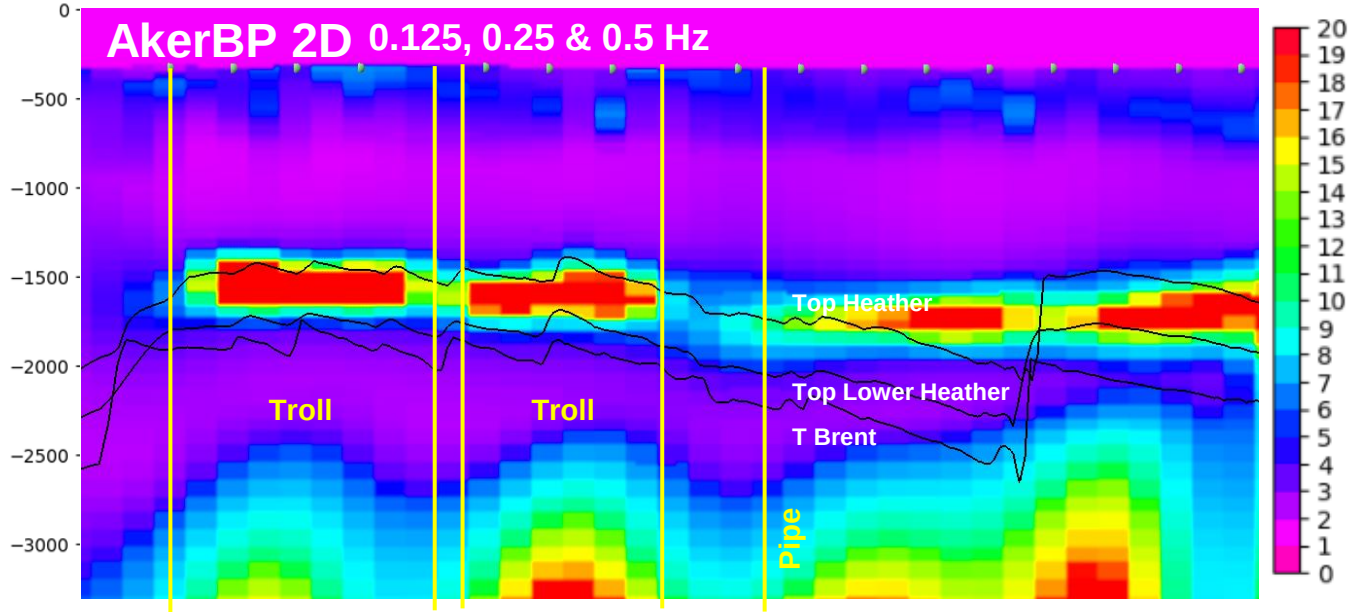


2D vs. 3D Inversion: Troll

- Tx015
- Expect 2D to be a good approximation
- Pipelines are not crossed perpendicular
- Good 2D inversion result







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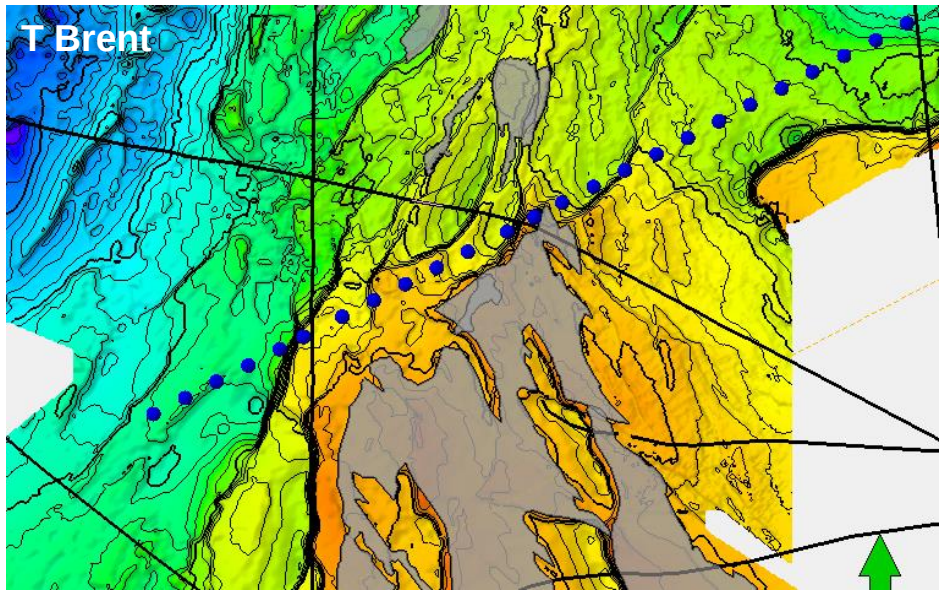
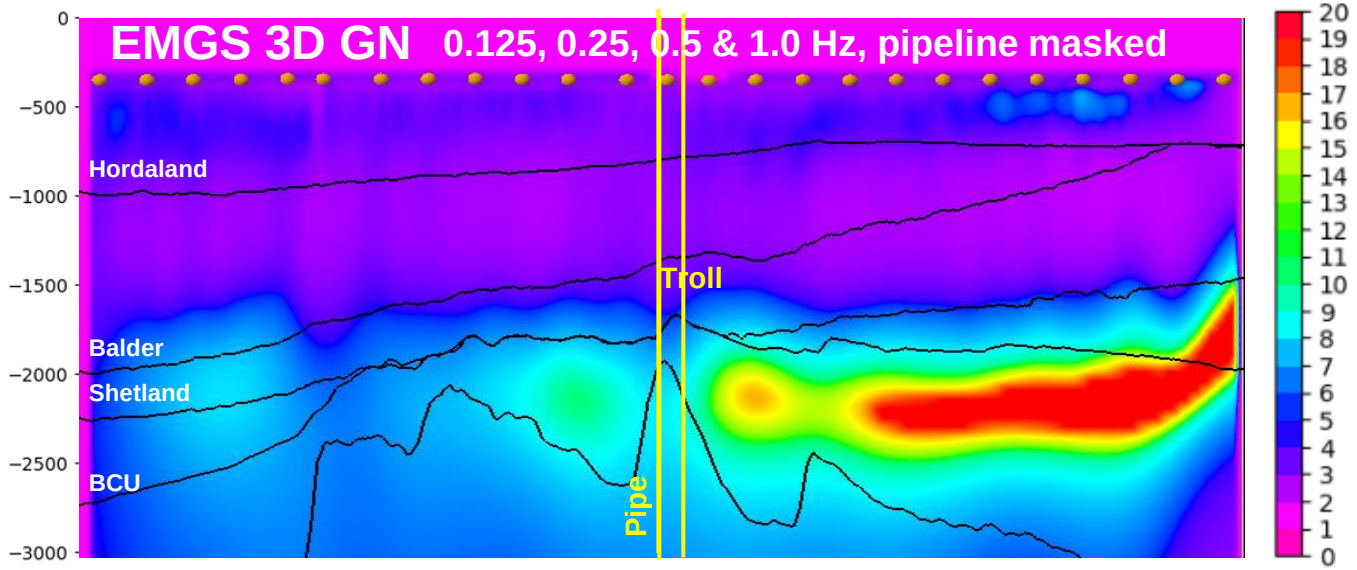
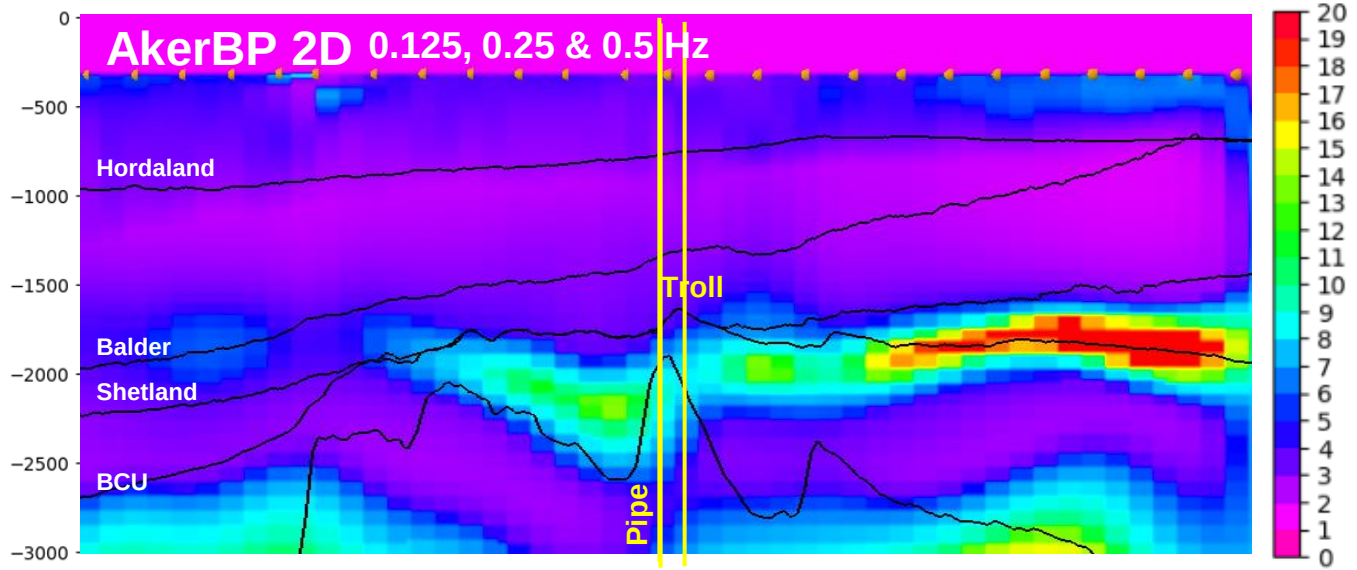
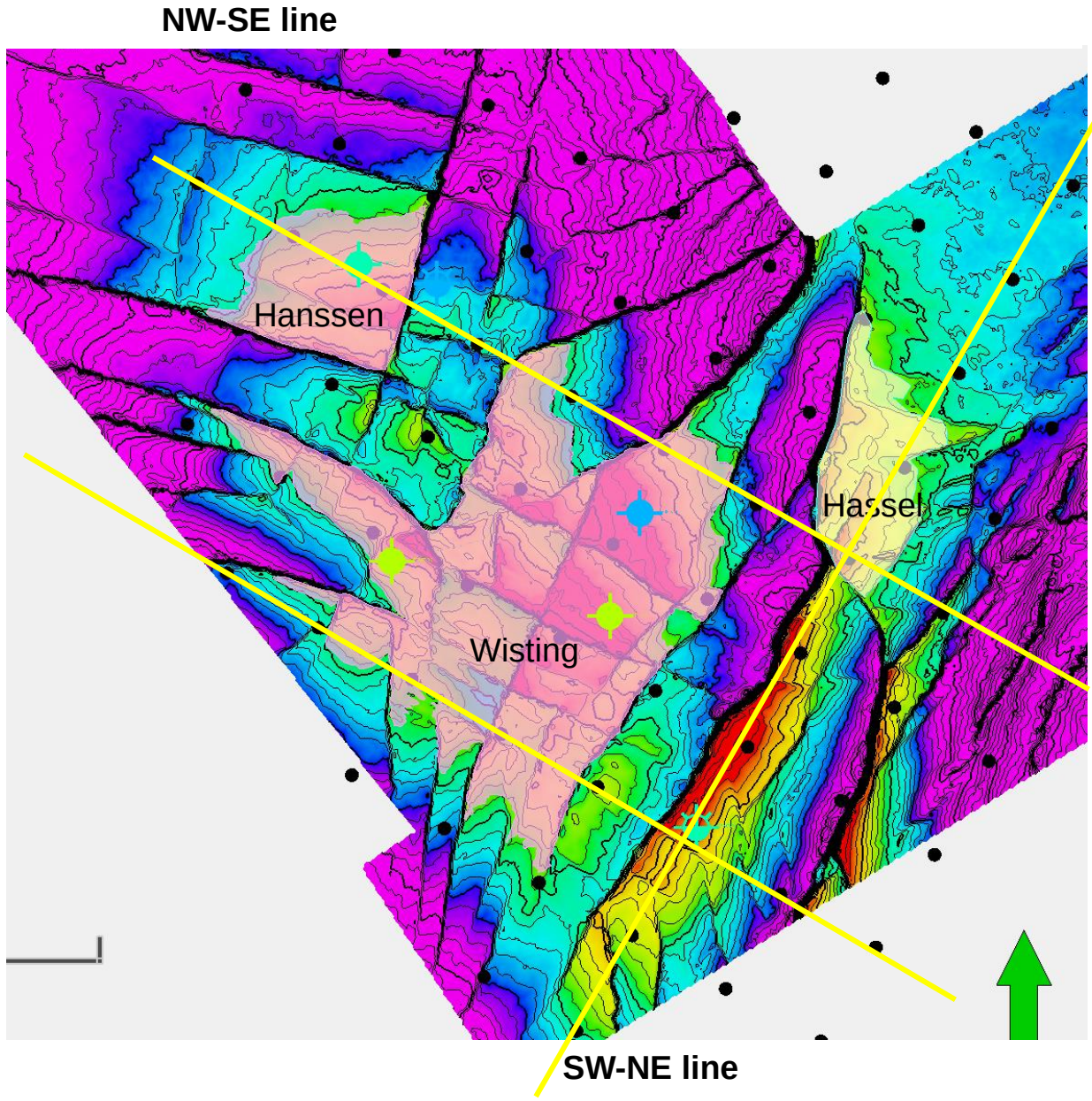






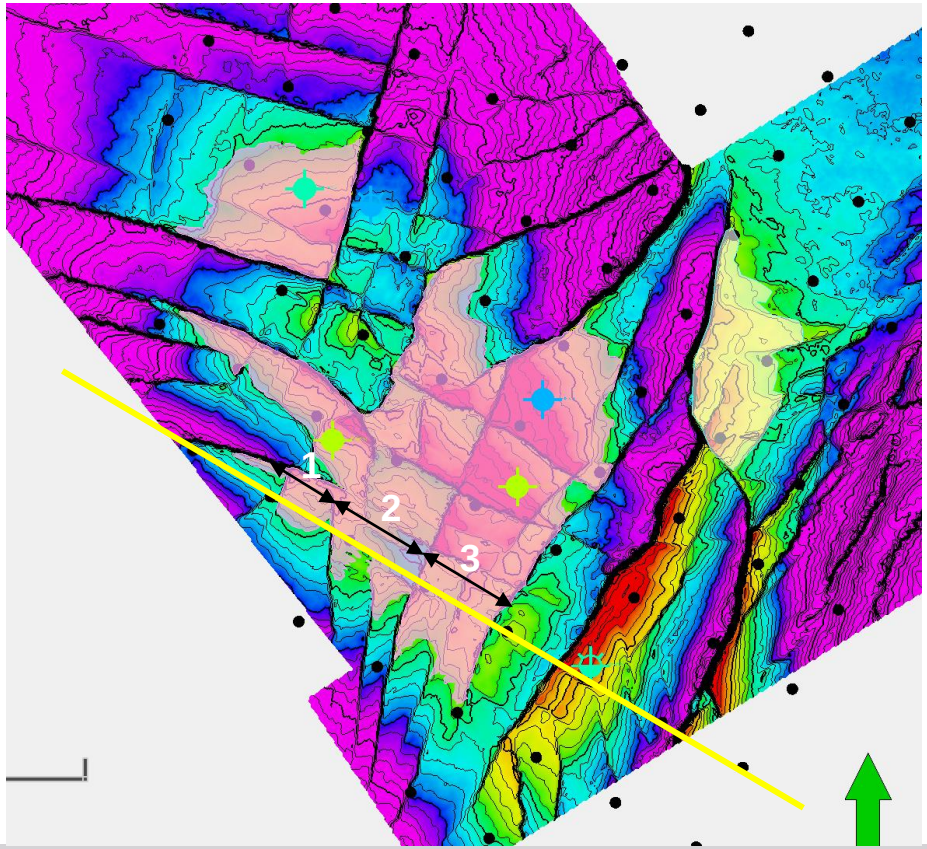
Wisting

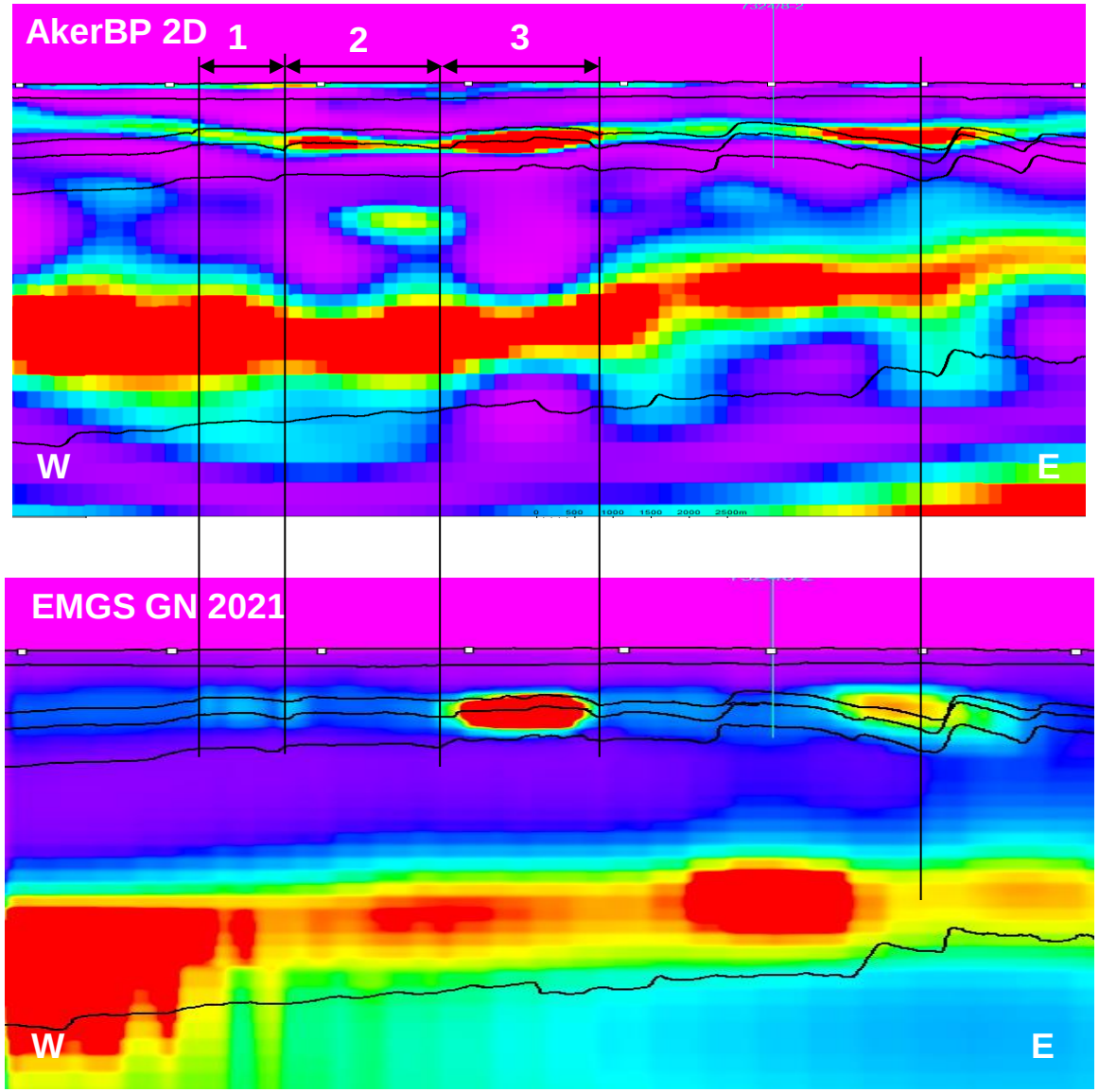
- 350 m water depth
- Top reservoar 650 m → 300 m overburden
- 2x2 km Rx spacing
- 2014 data, base frequency 1.0 Hz
- Extreme resistivity anomalies at shallow depth → challenging for 2D inversion
- NW-SE line acceptable for 2D, SW-NE line challenging



Tx007

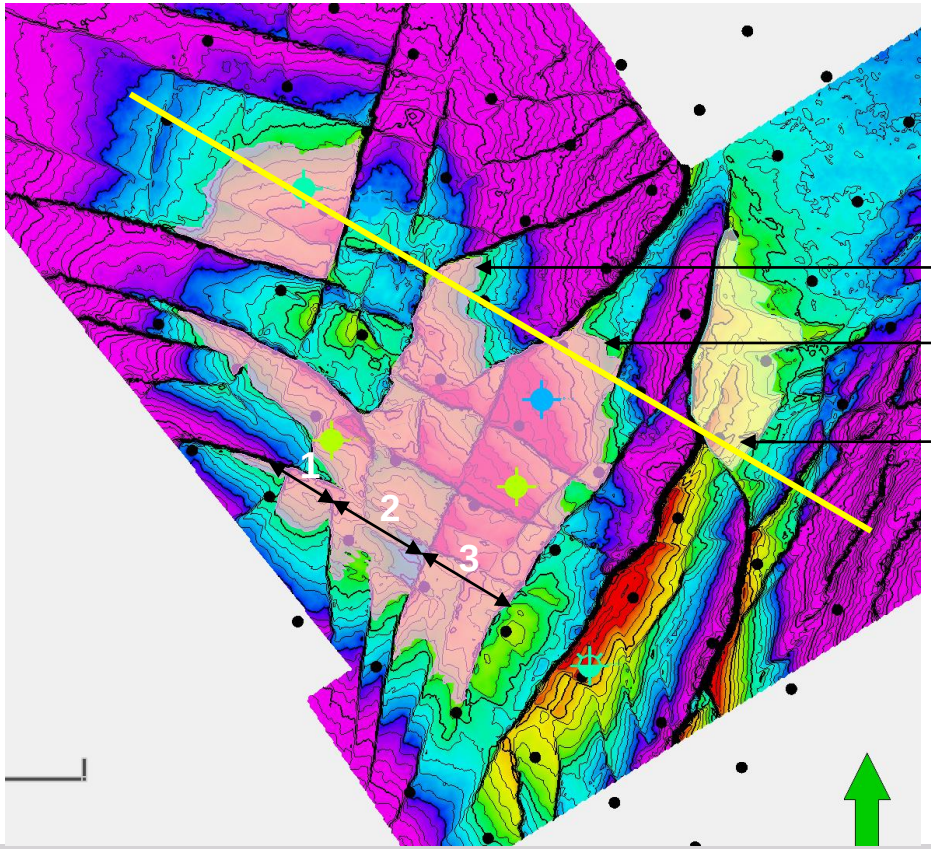
- 2D not a good approximation? Ok 2D inversion result





Tx013

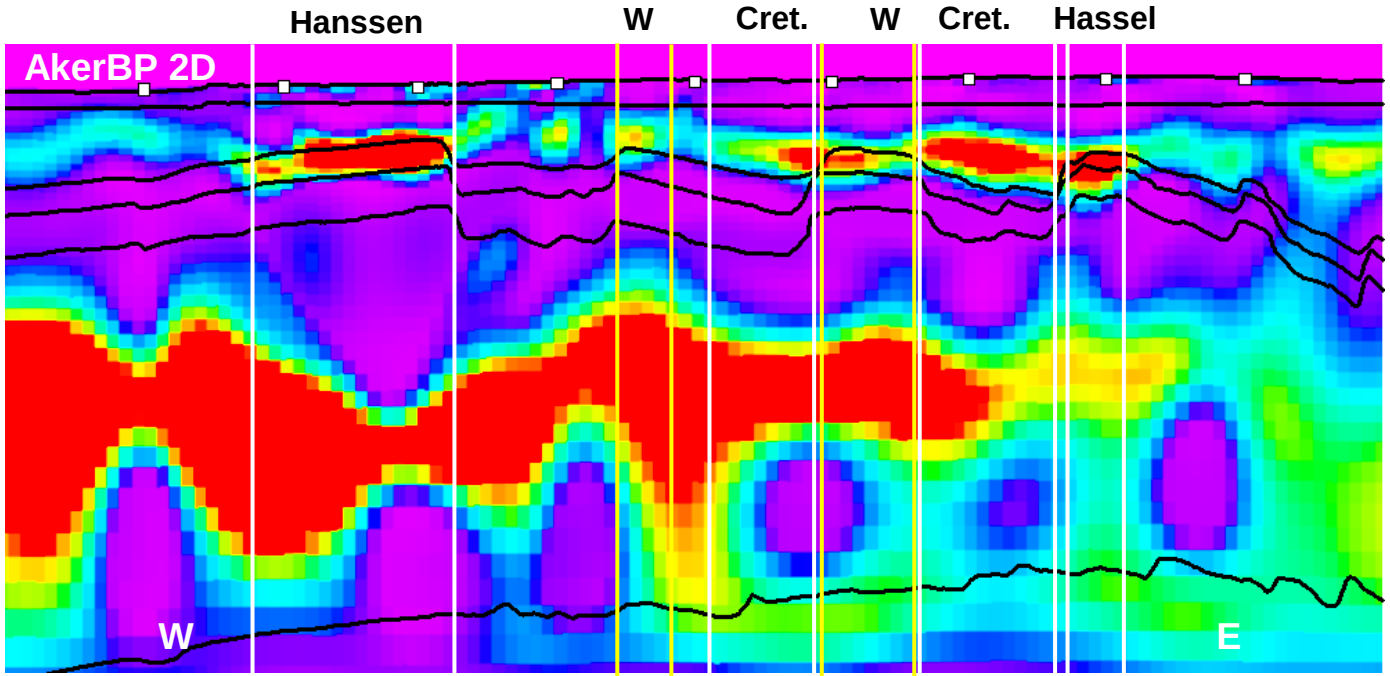
- 2D not a good approximation? Ok 2D inversion result
- Strong lateral regularisation in 2D inversion

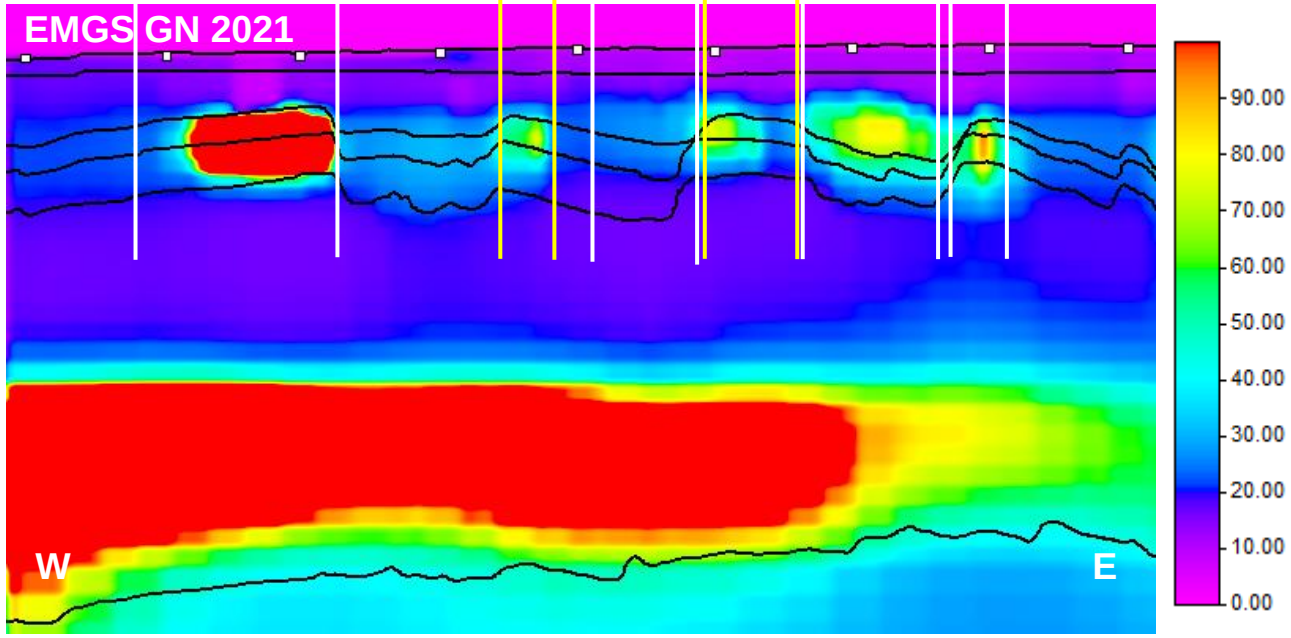


Wisting W

Wisting E

Hassel: 3D effects here?





Tx101

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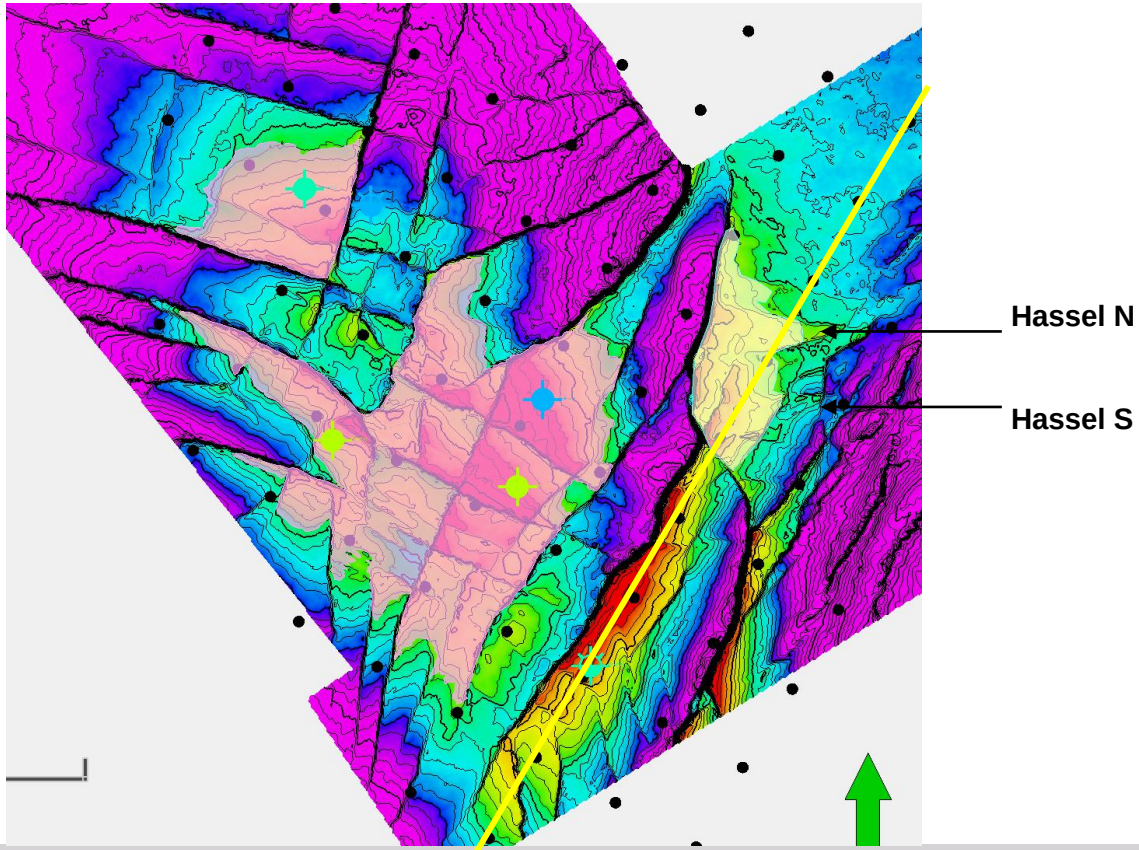

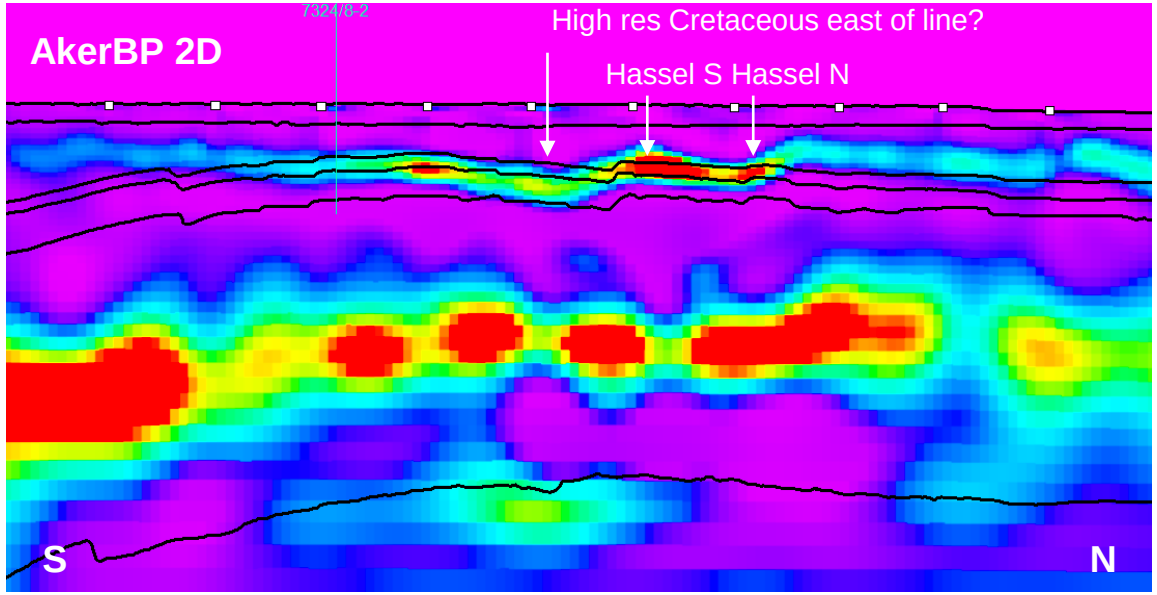

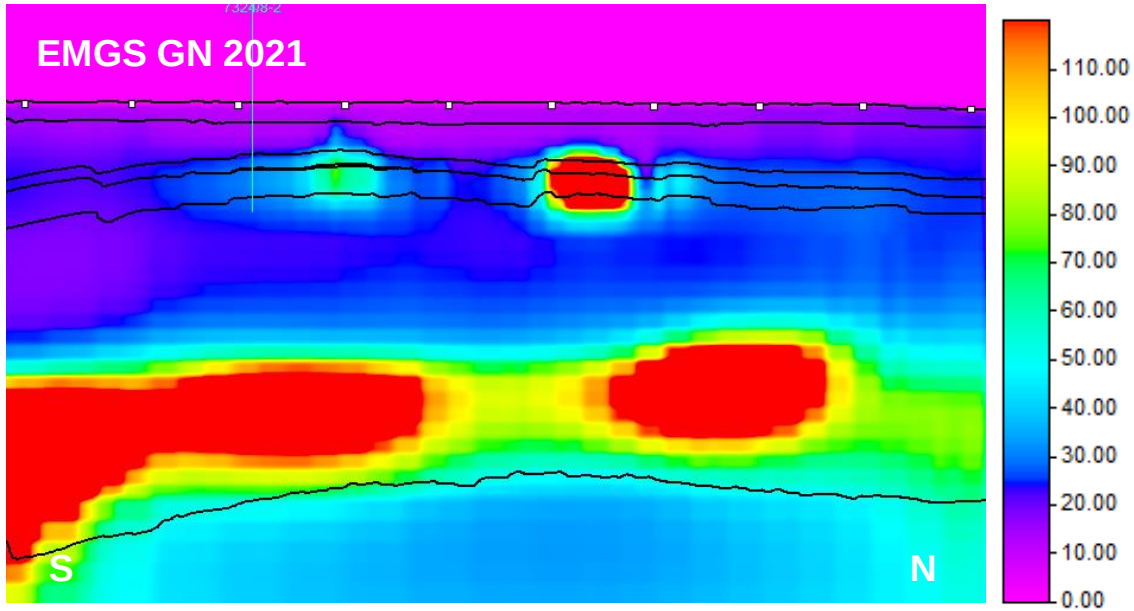

Summary

2D

- 2D inversions result often meaningful and good resistivity models
  - Relative sharp and structural conform resistivity section
  - No resistivity map, results only at 2D line
- Relative fast
  - Test of inversion paremeters
  - Many independent inversions → computational expensive
  - Fine inversion grid
- Independent 2D inversions
  - Real anomalies vs. Noise → consistency between lines
  - Many inversions: consistency and bookkeeping
  - More sensitiv to data errors / less statistics
- Remaining uncertainty due to 2D approximation
- Cost efficient 2D survey

3D

- 3D resistivity cube
  - Can present anomaly in map view: structural conformance
  - Arbitrary resistivity sections
- Computational expensive
- Explain all data with a single model
  - Better statistics, suppress noise
- Not very many vendors
  - Limited number of commercial 3D codes
  - Experience

Don’t be afraid: You can use 2D EM data and inversion!

Ja takk, begge deler!