

3D electromagnetic modeling and inversion

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Geological Survey of Finland

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European Union



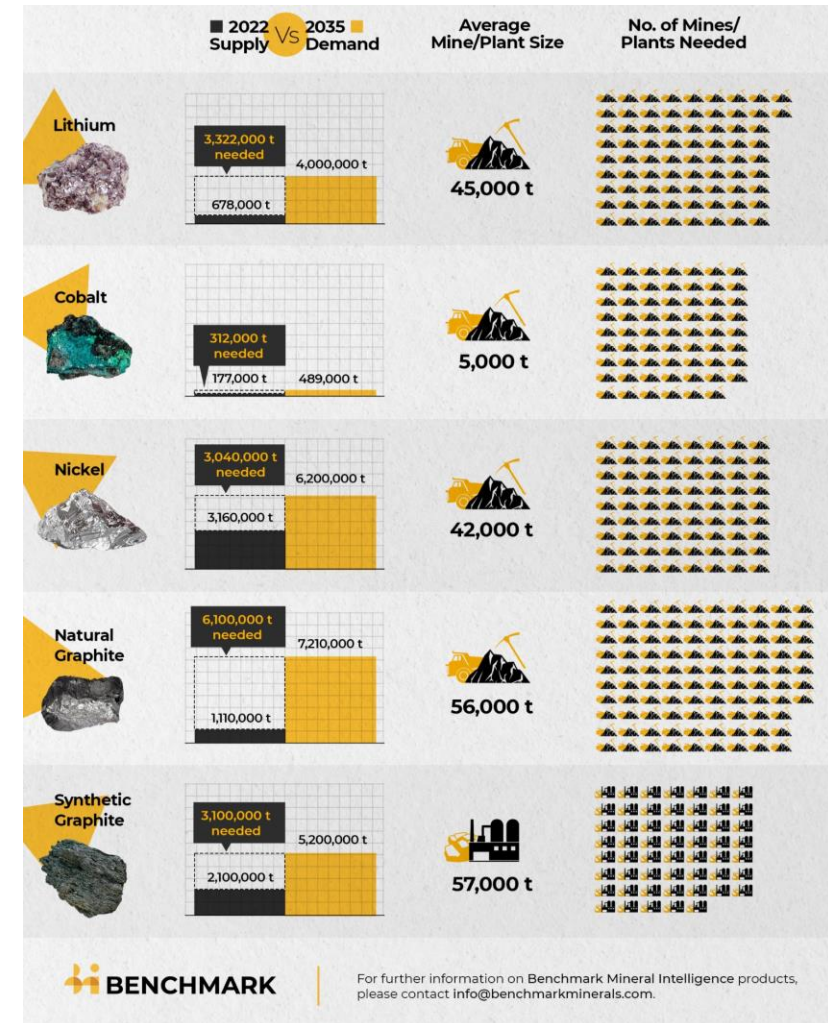
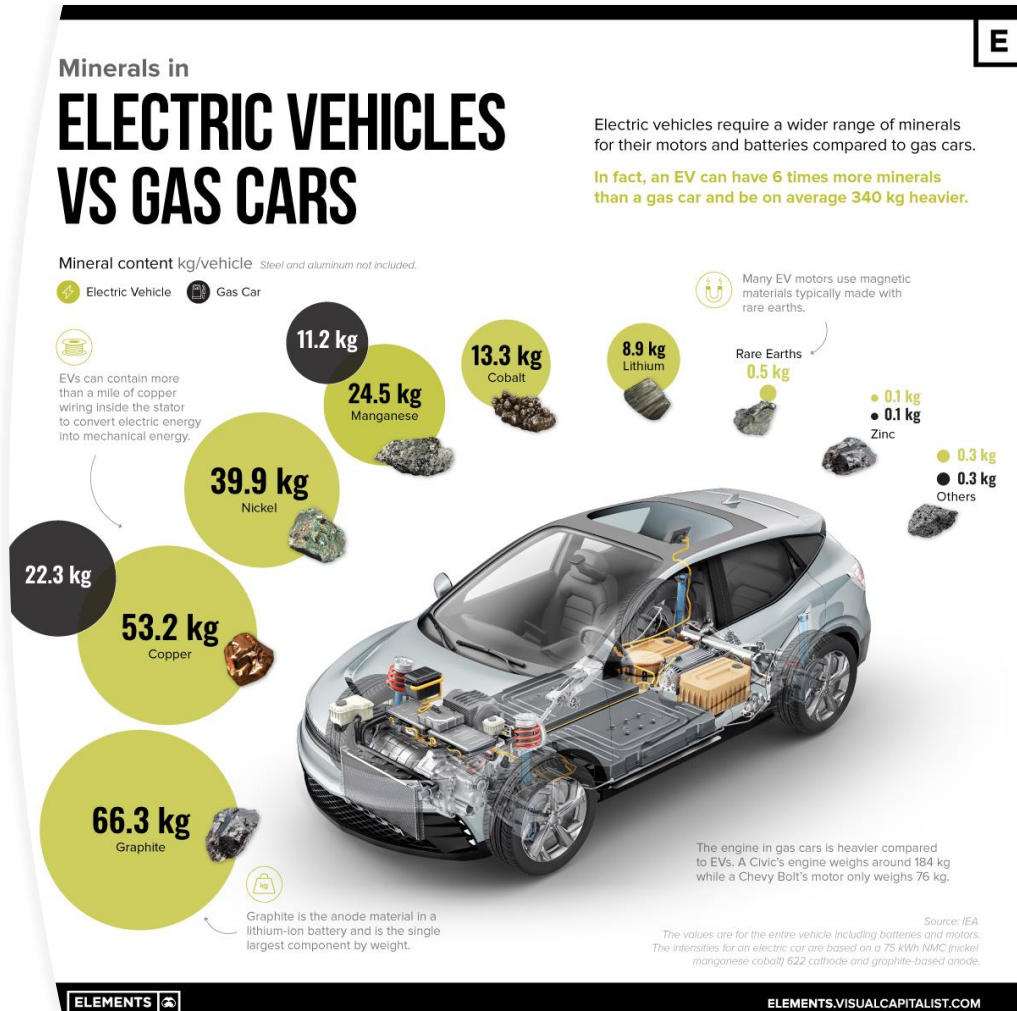
Outline

- Background
- Methods
- Preliminary results
- Conclusion and outlook

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How much do we need ?



What can we contribute as geo-scientists?

- Improving the technology (-)
- Looking for the resources (+)

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What we want ...

- Lower cost
- More speed
- Higher accuracy

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Aim

To deliver a 3D inversion software of electromagnetic (EM) data.

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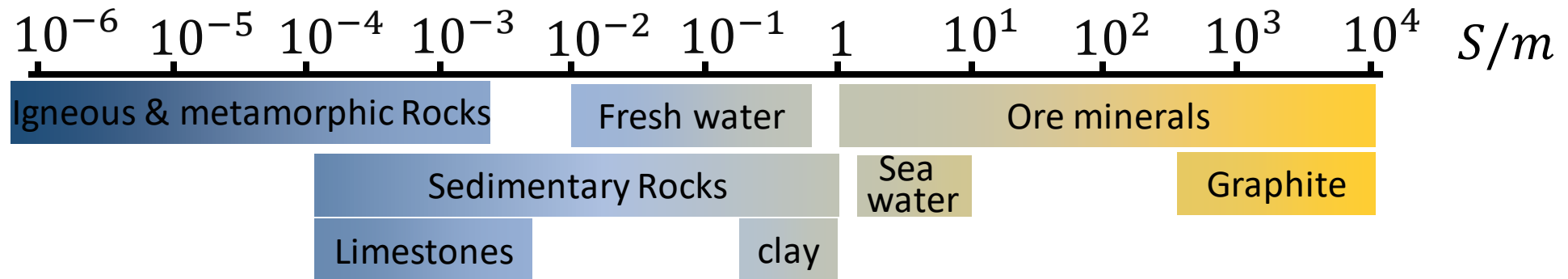
Aim

To deliver a 3D inversion software of electromagnetic (EM) data

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Electrical conductivity & Minerals



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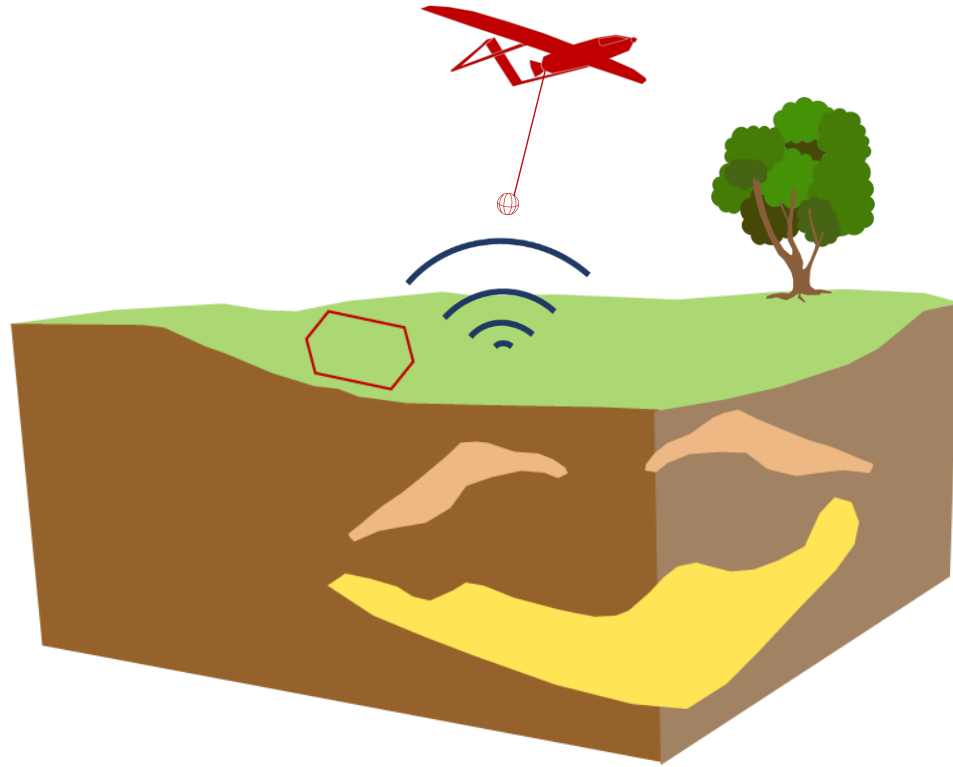
Aim

To deliver a 3D **inversion** software of electromagnetic (EM) data.

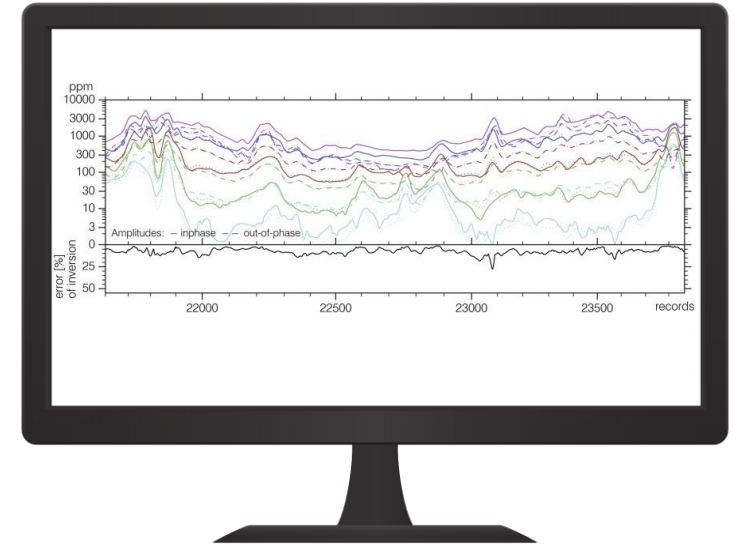
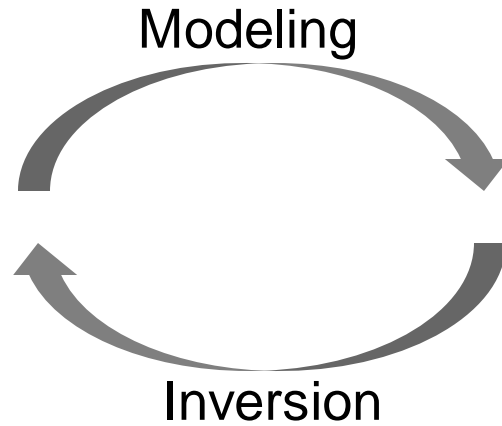
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Modeling and inversion



Model space (conductivity)



Data space
(electric/magnetic field)

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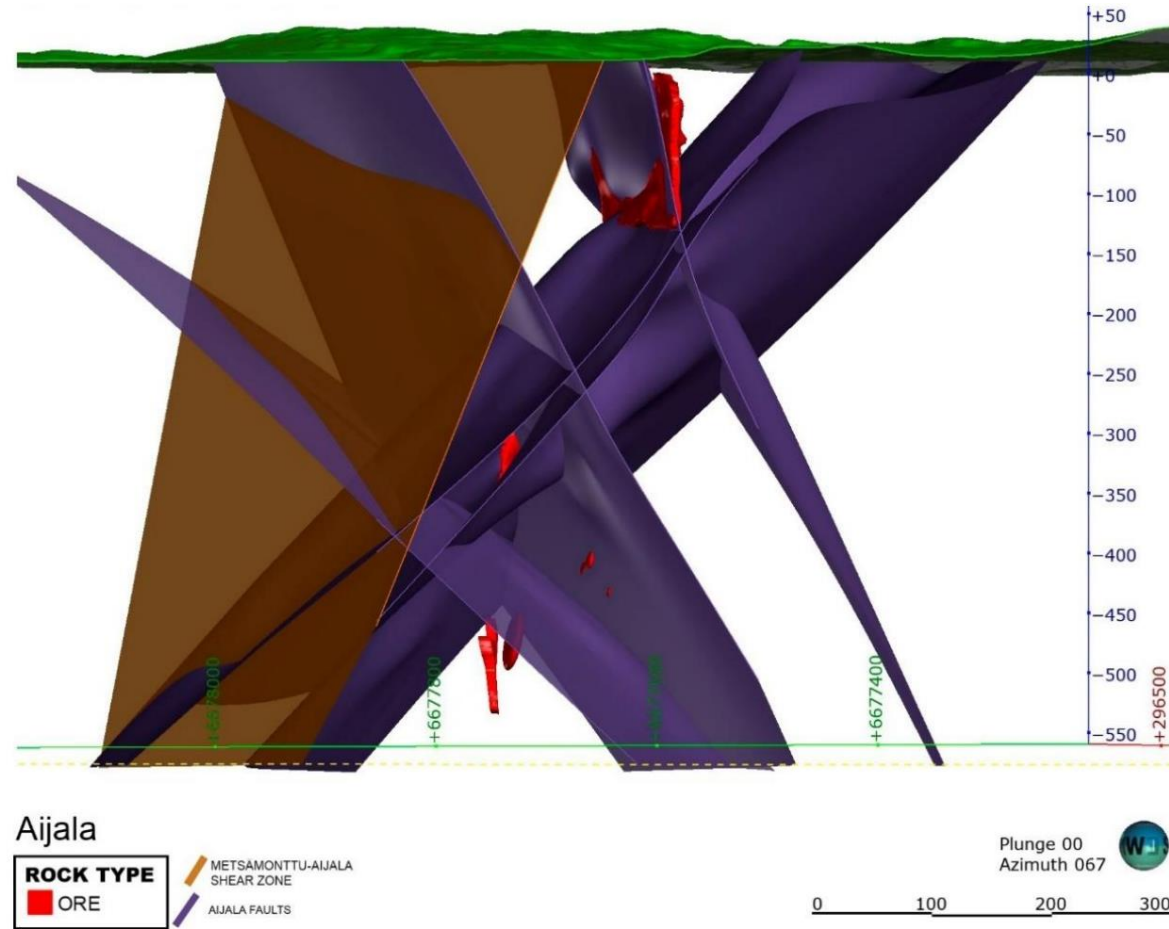
Aim

To deliver a **3D** inversion software of electromagnetic (EM) data.

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Geological 3D model of Aijala

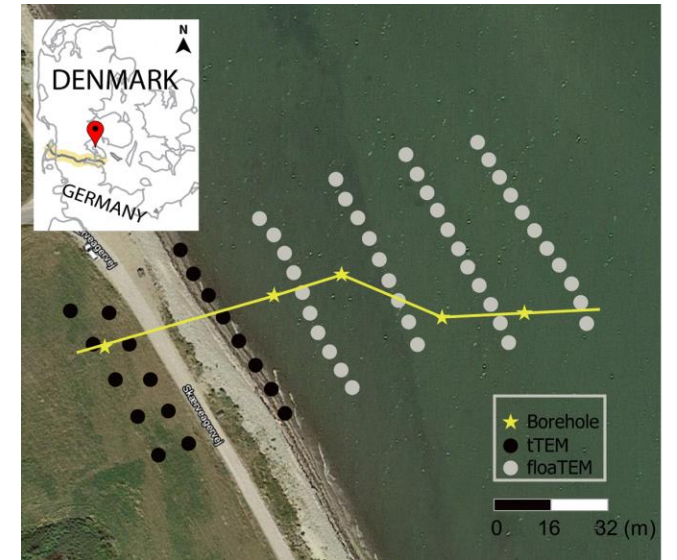
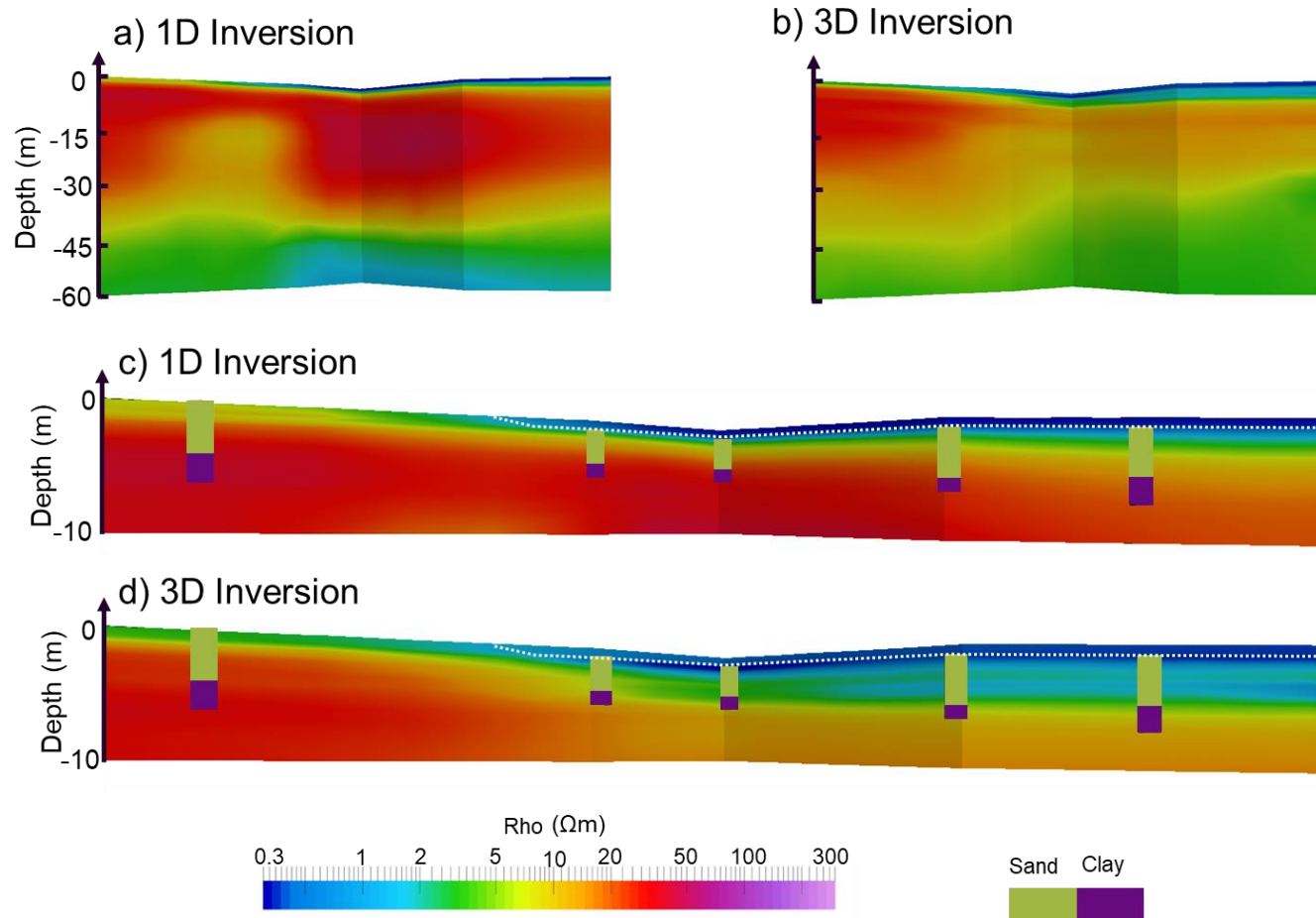


(J. Sandström, 2021)

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3D vs 1D inversion



(Xiao L. et al. ,2021)

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Outline

- Background
- **Methods**
- Preliminary results
- Outlook

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Method highlight

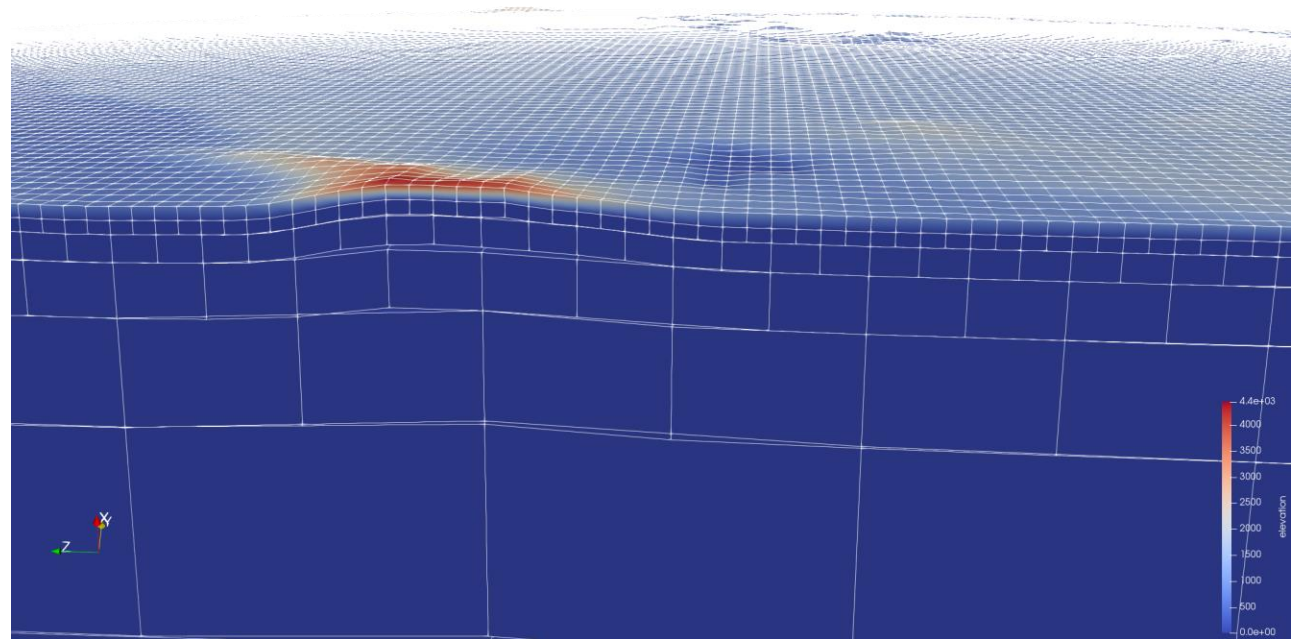
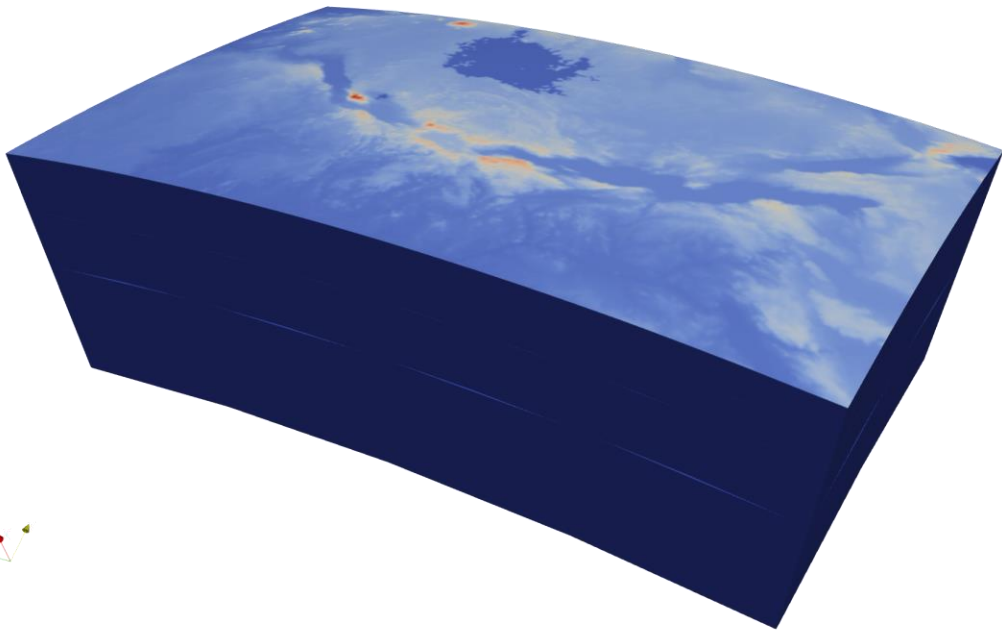
- Finite element method
- Octree mesh
- Dual-grid inversion
- Parallelization

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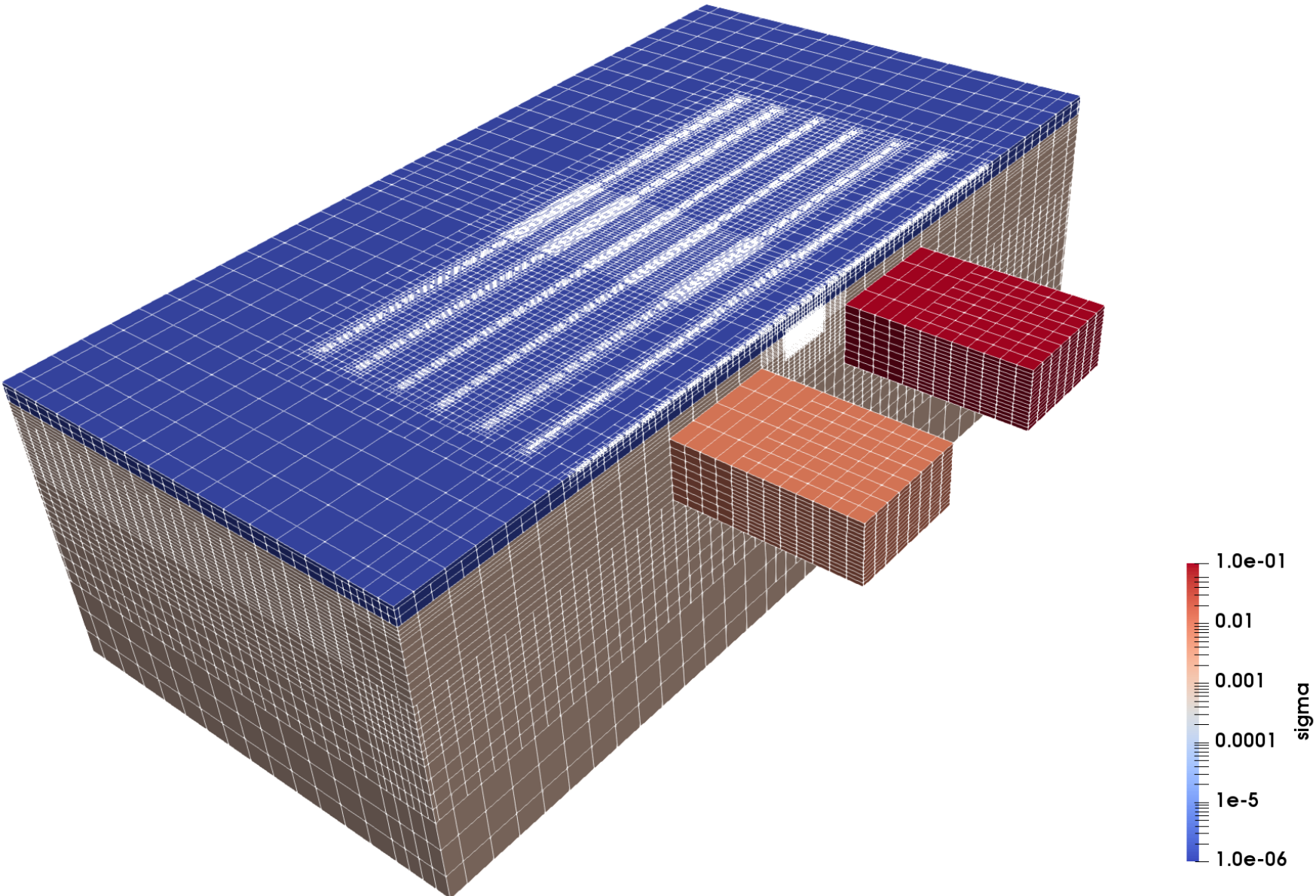


Finite element method

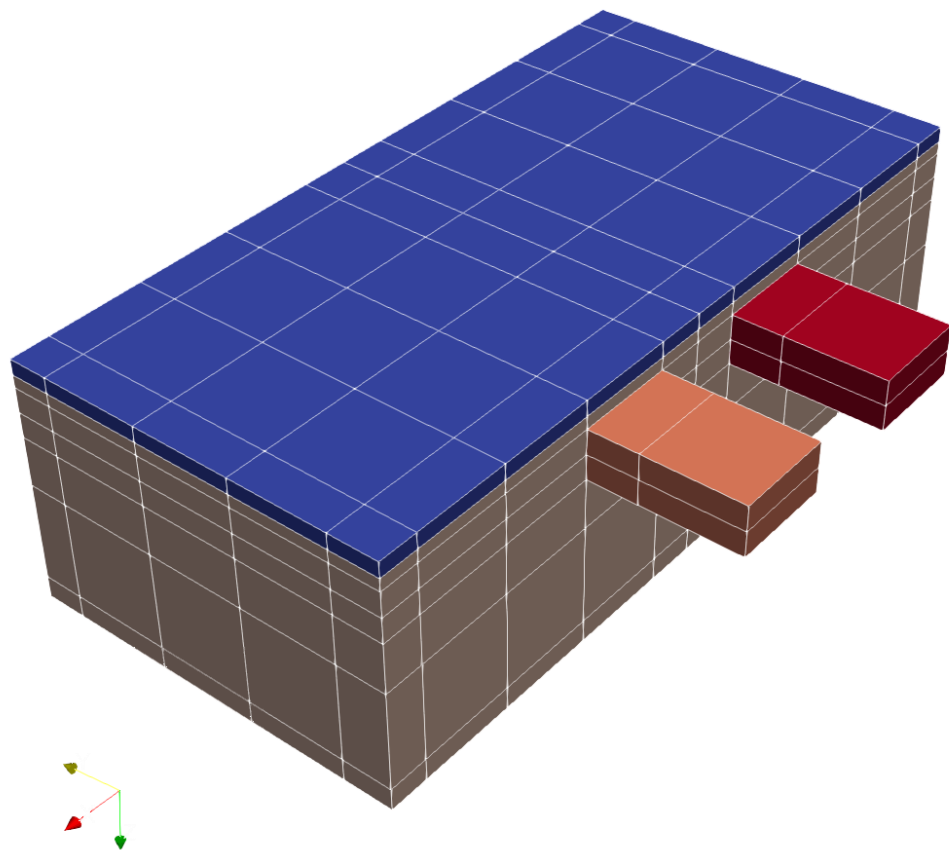
- Allow complex geometry
- Local refinement



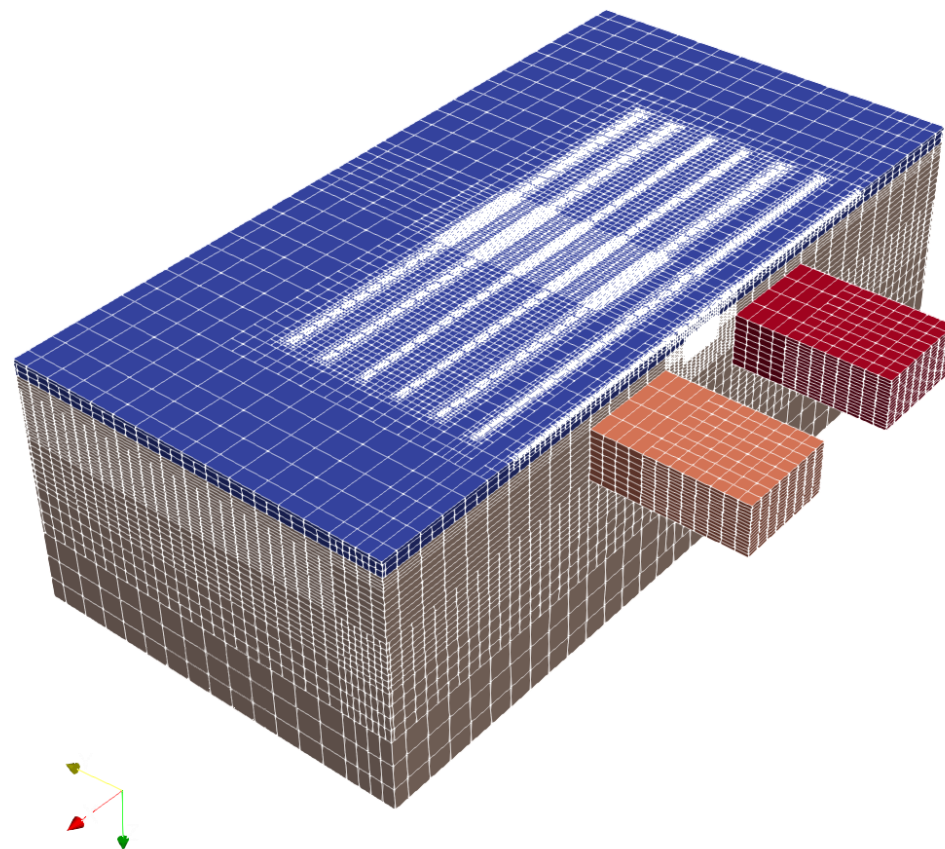
Octree mesh



Dual-grid inversion

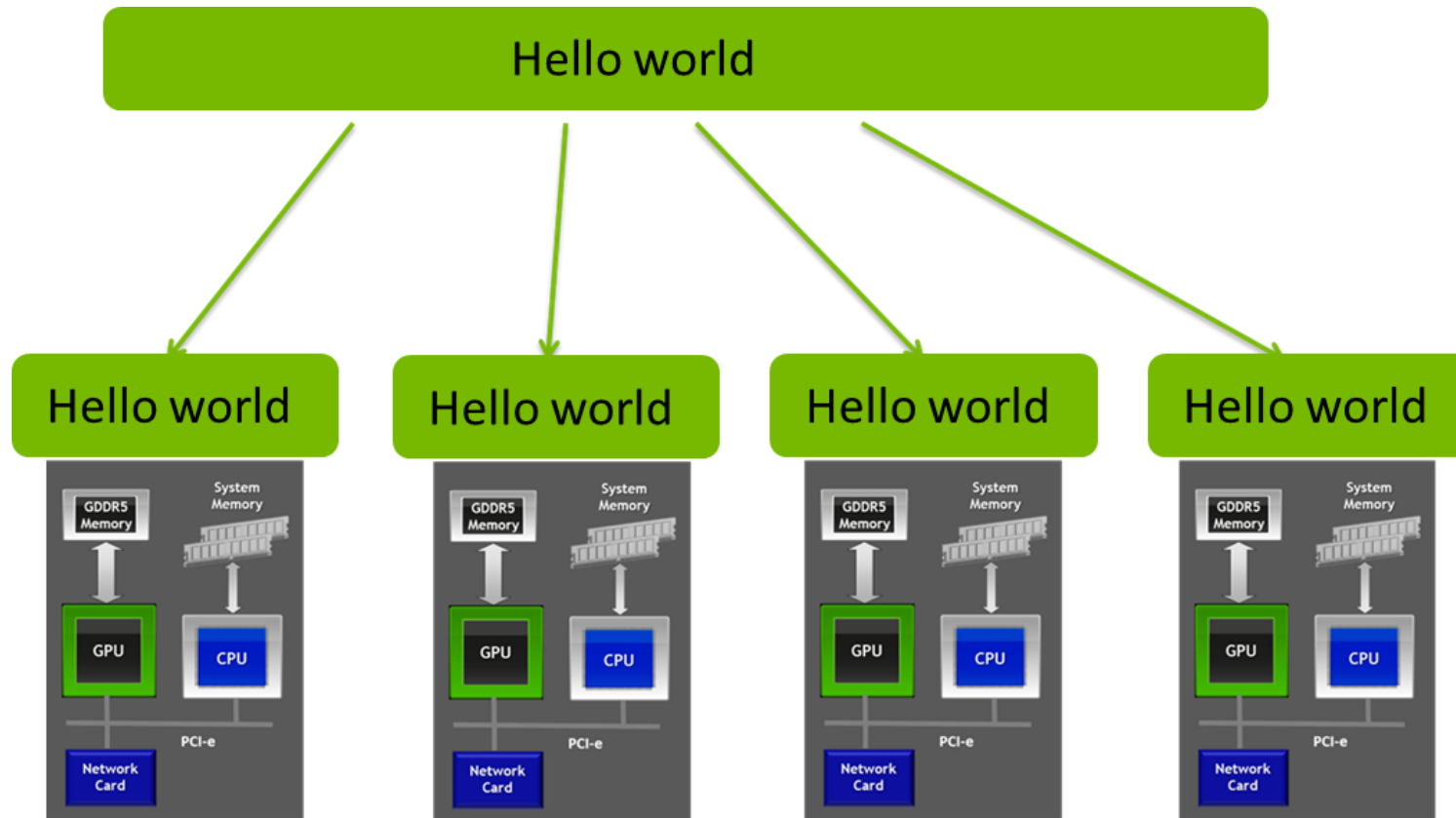


Inversion mesh



Forward mesh

Parallelization (MPI, OpenMP)



Method highlight

- Finite element method -> accuracy
- Octree mesh -> speed
- Dual-grid inversion -> speed
- Parallelization -> speed

What we want ...

- Lower cost
- More speed
- Higher accuracy

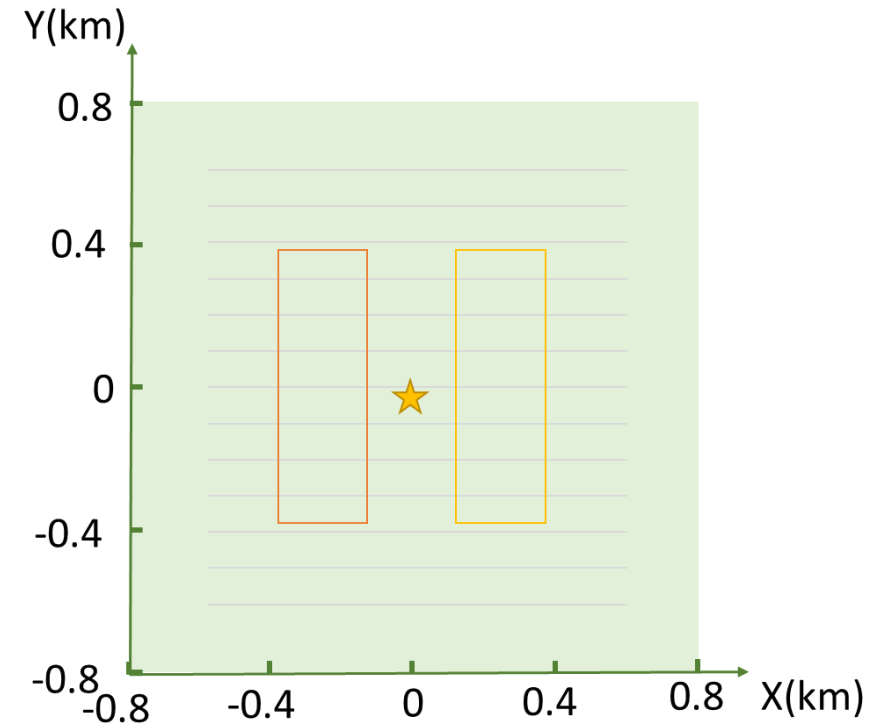
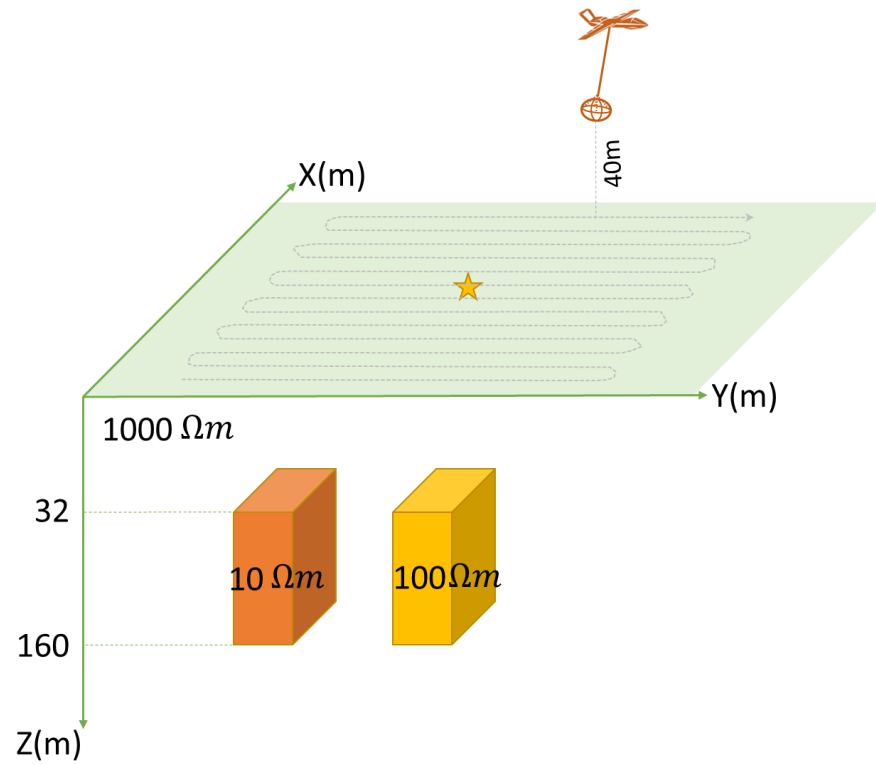
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Outline

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- Methods
- **Preliminary results**
- Outlook

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Frequency: 960 - 10600 Hz

Receiver height: 40m in the air

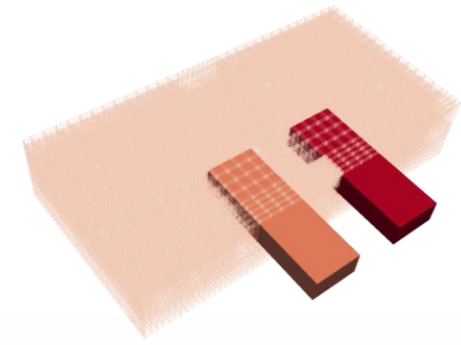
Line space: 50 m

Sounding space: 20 m

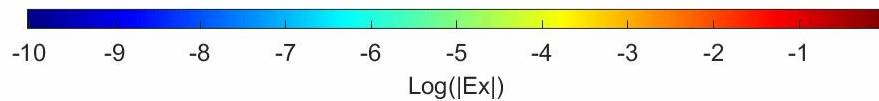
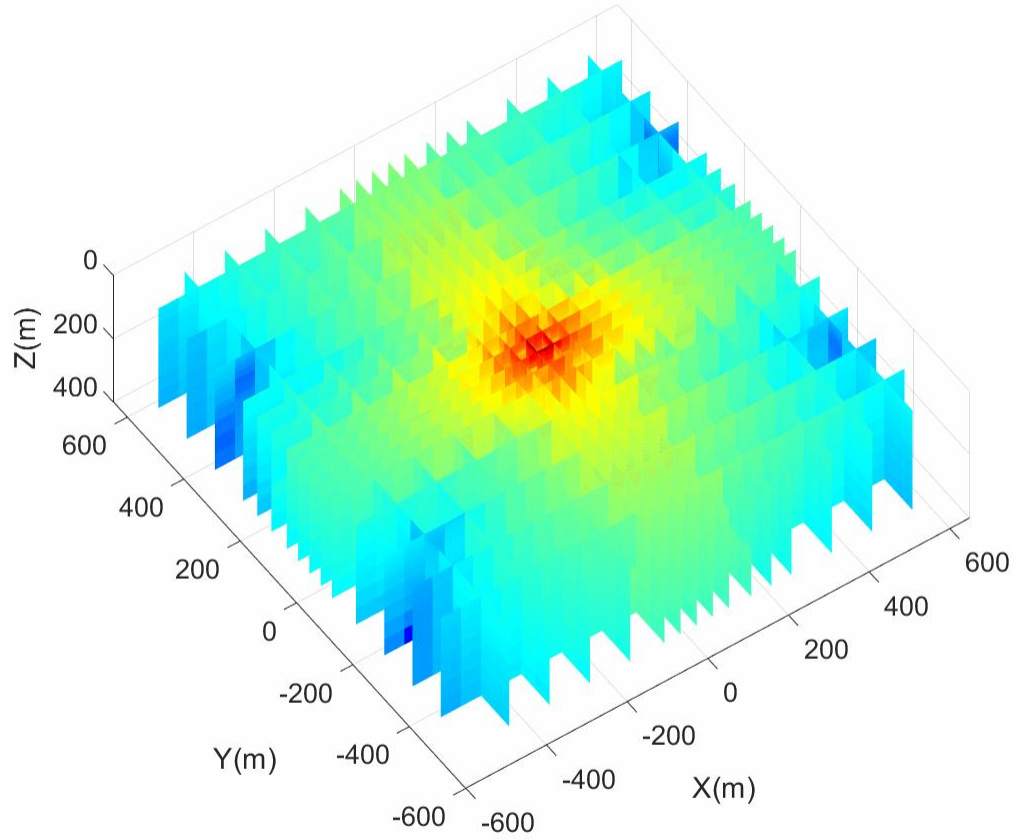
Coverage: 1.2 km * 1.2 km

Sounding: 1440 = 24 lines * 60 soundings

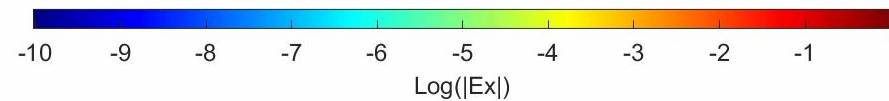
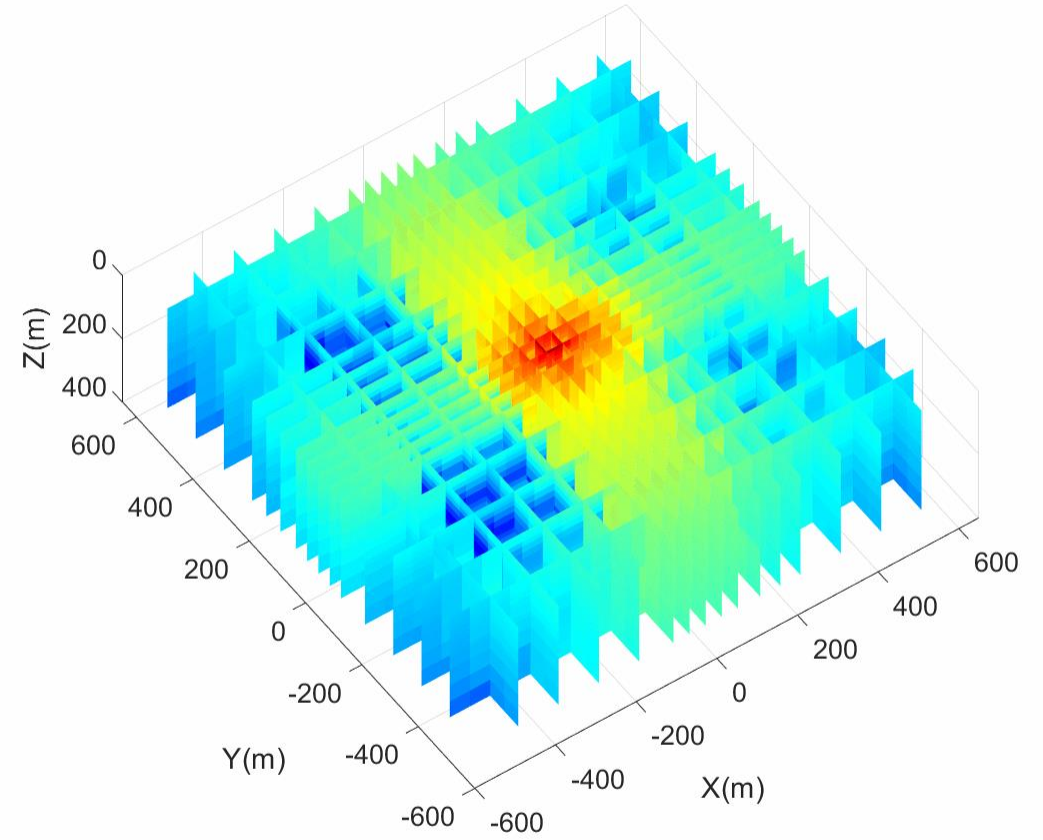
Ex-field propagation (of transmitter Jx)



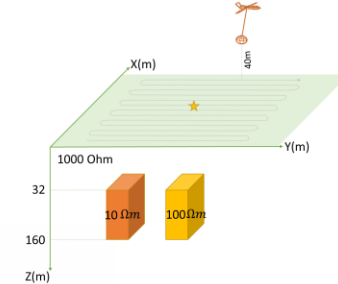
Halfspace - 10600 Hz



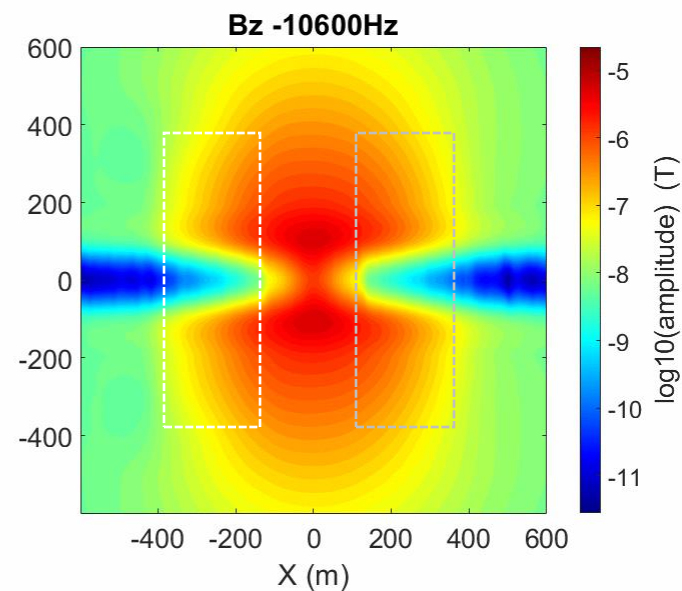
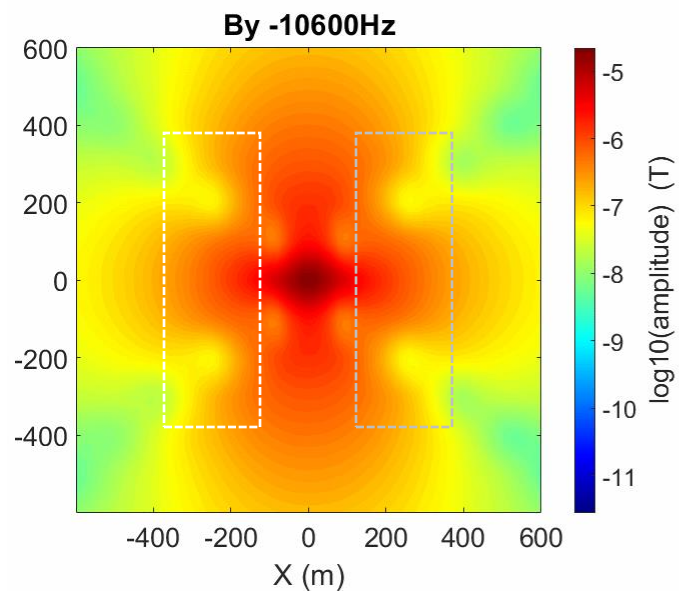
3D model - 10600 Hz



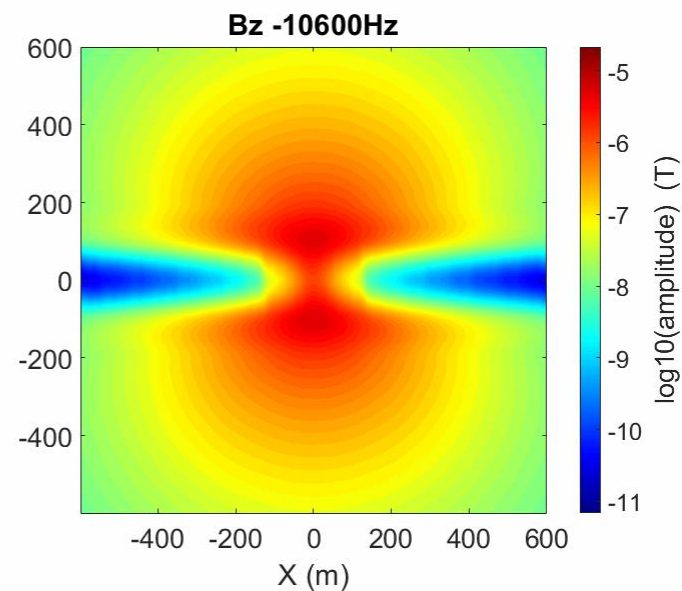
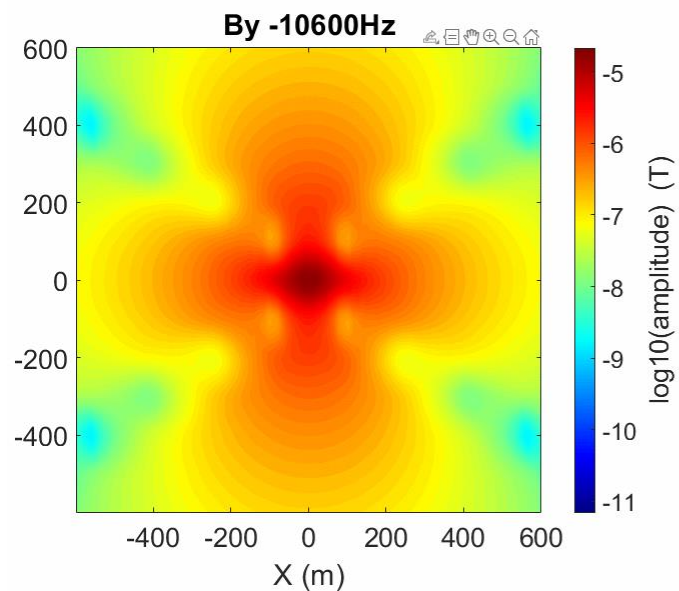
Responses at receivers



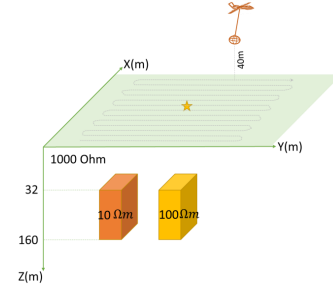
With anomaly



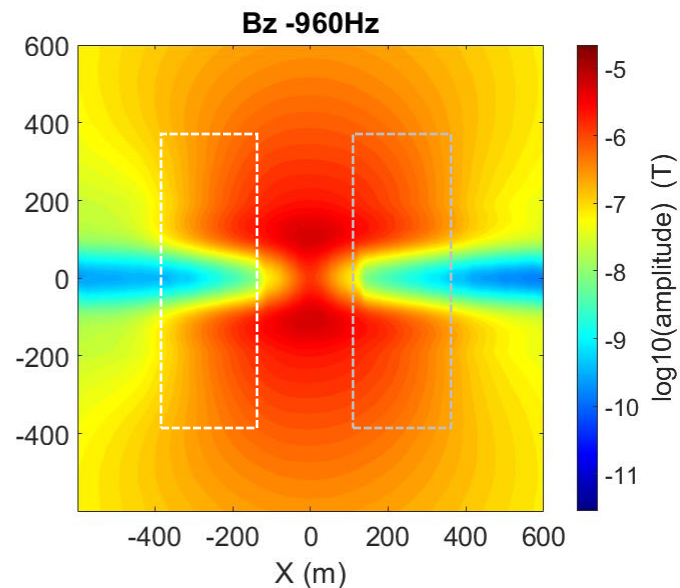
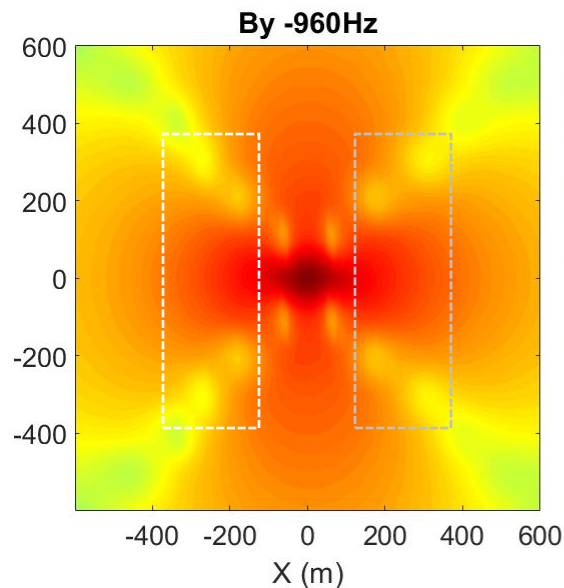
Halfspace



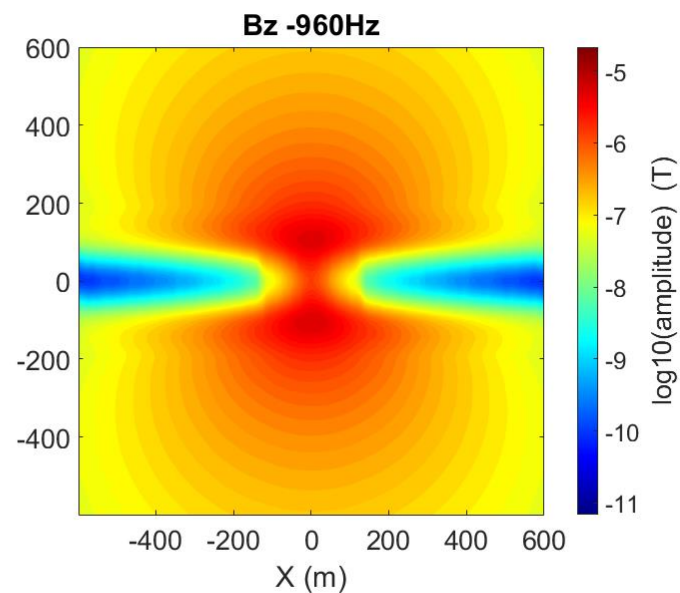
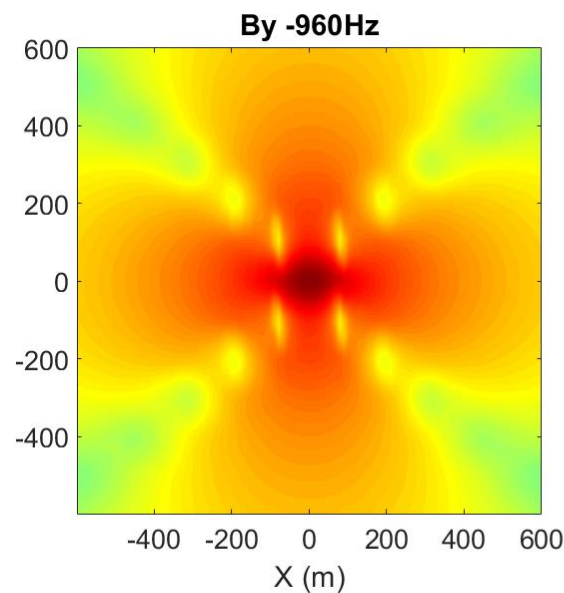
Responses at receivers



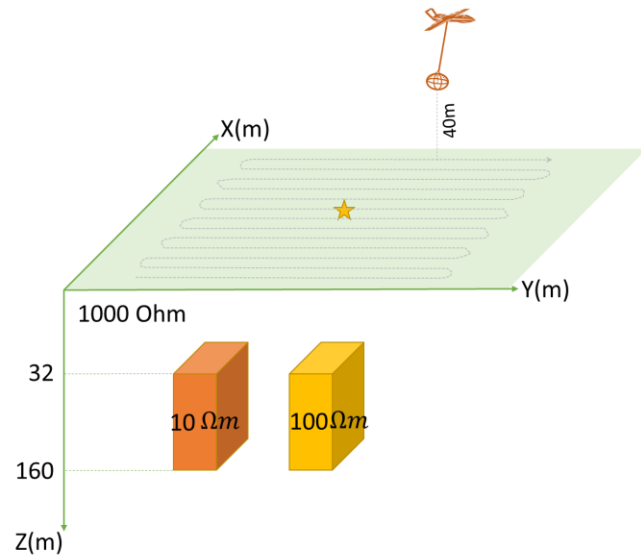
With anomaly



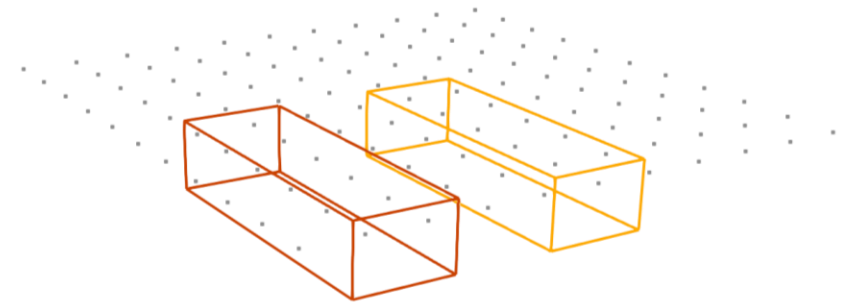
Halfspace



Inversion



Sampling



Sounding space: 20 m

24 line * 60 soundings/line = **1440** soundings

Sounding space: 50 m

11 line * 11 soundings/line = **121** soundings

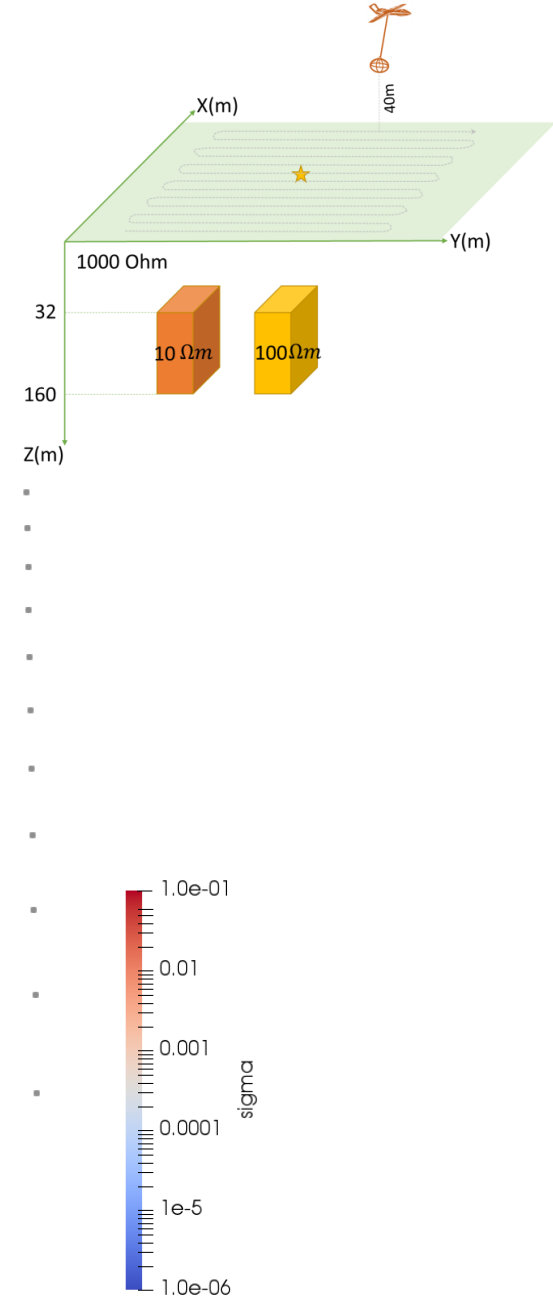
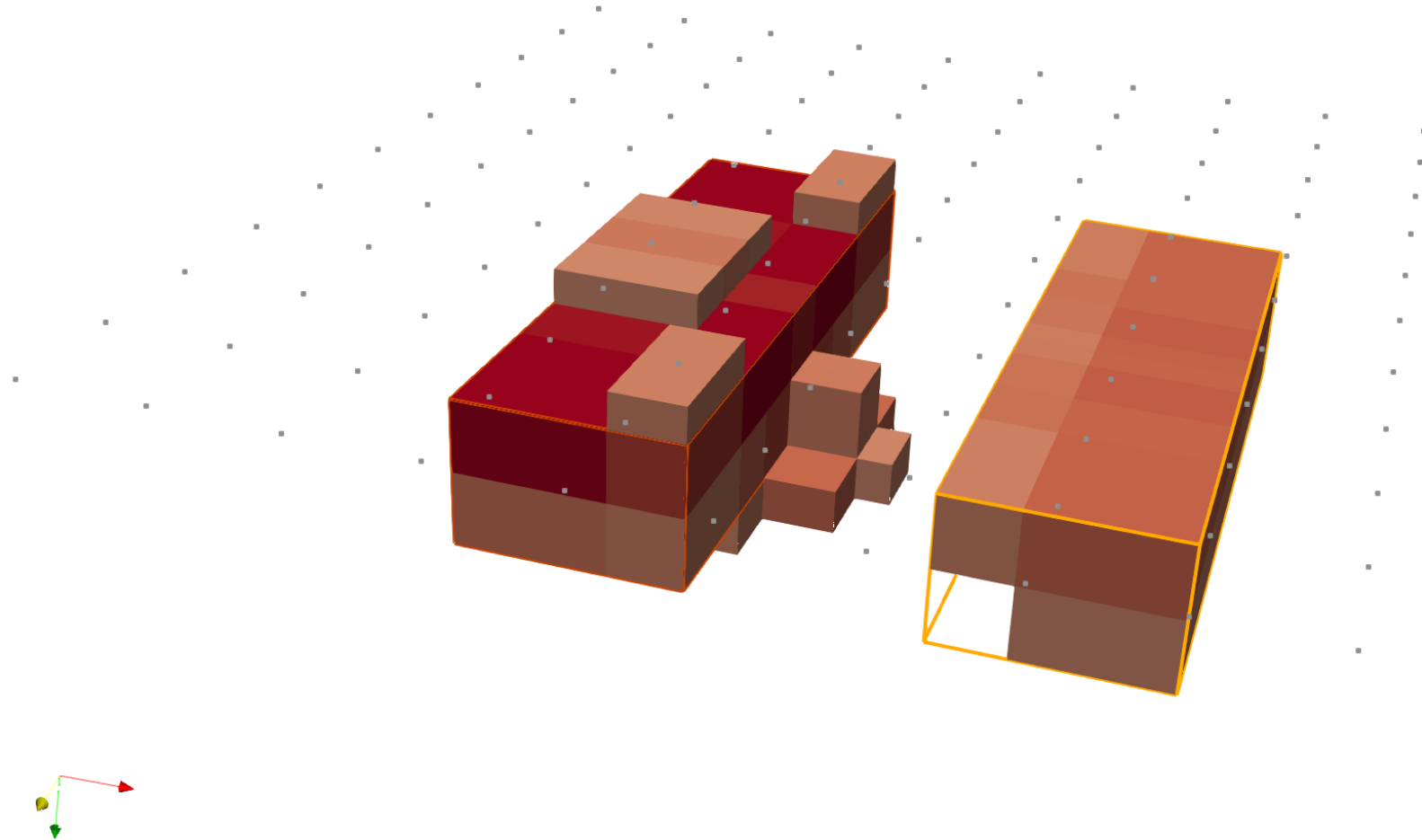
Inversion numbers

- Method: Occam
- Forward elements: 601,787
- Inversion elements: 7200 (980)
- **2178** data points = **121**(rec) * 3(comp) * 3 (freq) * 2 (src)

Source: Csx, Csy
Frequency: 2300/4600/9600 Hz
Components: Bx, By, Bz
Receiver: 121

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Inversion result



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Conclusion

- The 3D inversion frame for frequency-domain drone EM data is in place
 - Forward modeling
 - Jacobian computation
 - Inversion scheme
 - ...
- The algorithm is built on open-source libraries Deal.II and PETSc, allowing
 - In-place optimized finite element solution
 - Iterative solvers
 - MPI parallelization
 - ...

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Outlook

- Massive tests: Drone data inversion for different synthetic models
- Improving performance: optimization for large-scale dataset inversion
- Incorporating topography
- Better user friendliness

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Thank you

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