Effects of subsurface heterogeneity on ground motion amplification in Groningen, the Netherlands

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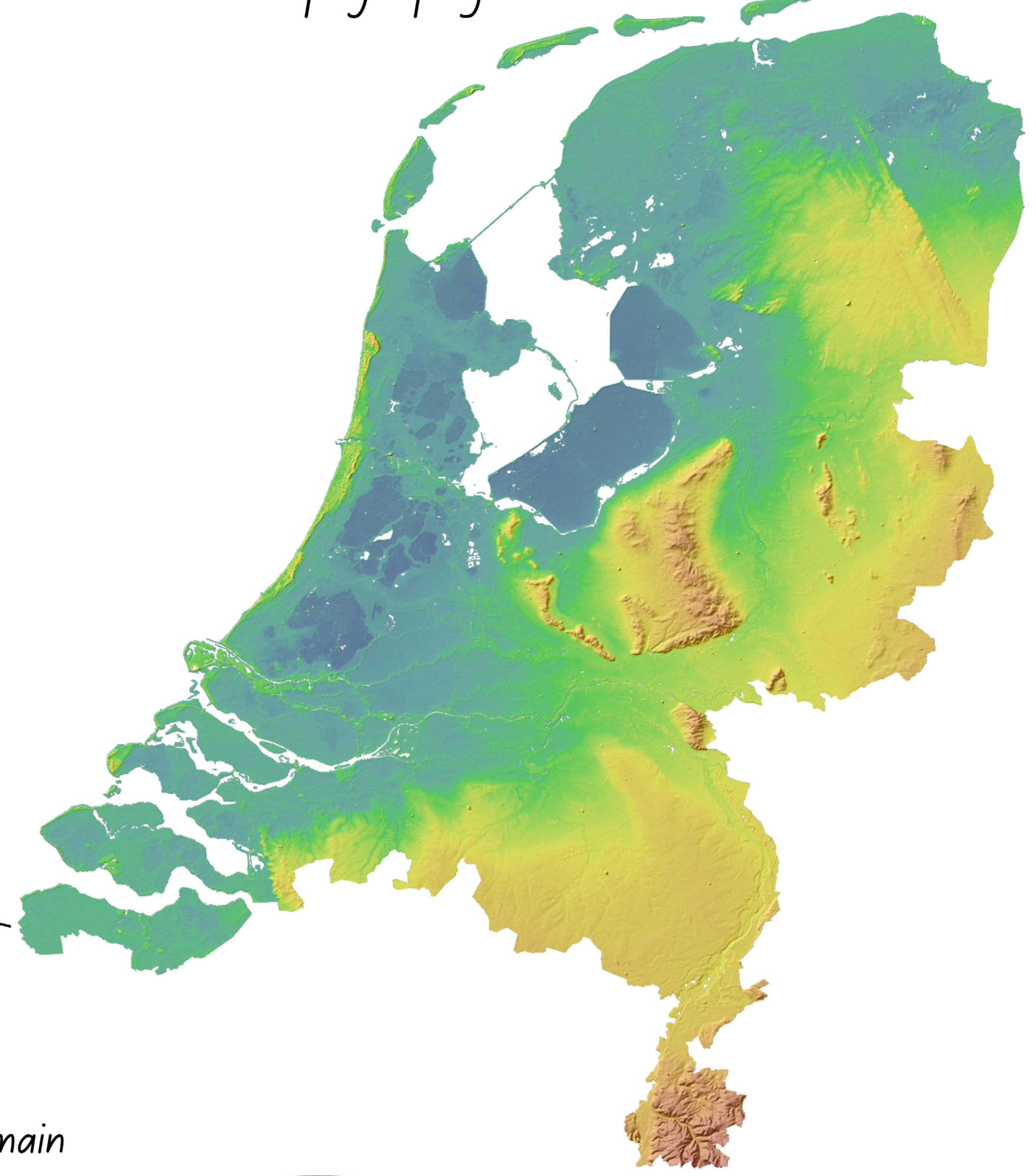
1 MOTIVATION

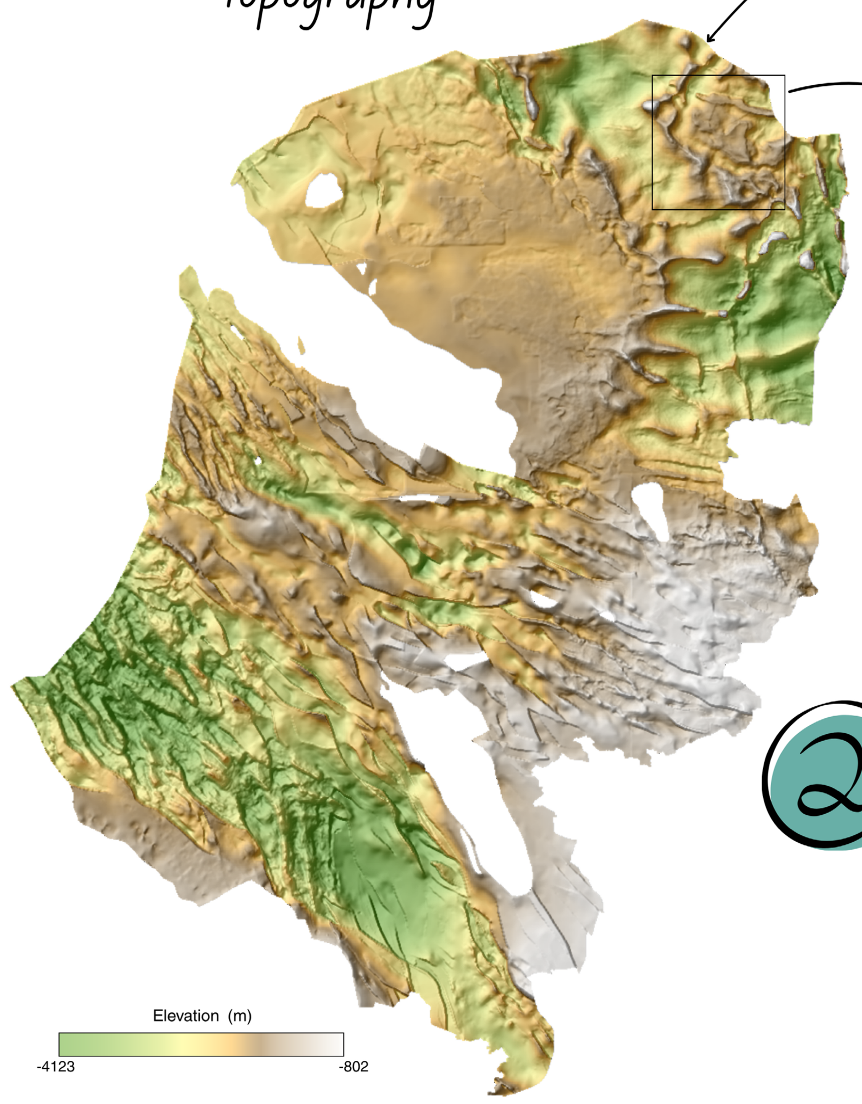
Subsurface exploitation in Groningen has caused a substantial number of induced earthquakes, which can result in ground motions at the surface that significantly impact society and infrastructure. Ground motion simulation is therefore essential for understanding and mitigating seismic risks in the region. While the Netherlands is characterized by low surface topography, its subsurface is considerably more complex, including the pronounced topography of the Zechstein salt layer, create significant heterogeneity that can strongly influence how seismic waves propagate and how ground motion is distributed at the surface. Previous studies have highlighted the strong influence of near-surface unconsolidated layers on ground motion amplification, yet the role of deeper structural heterogeneity has received less attention.

Surface topography

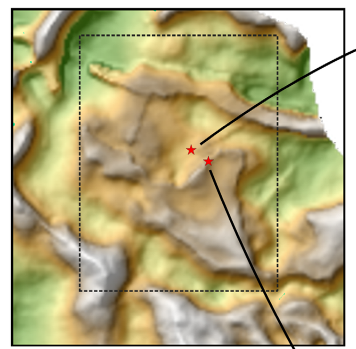


~1.8 km below

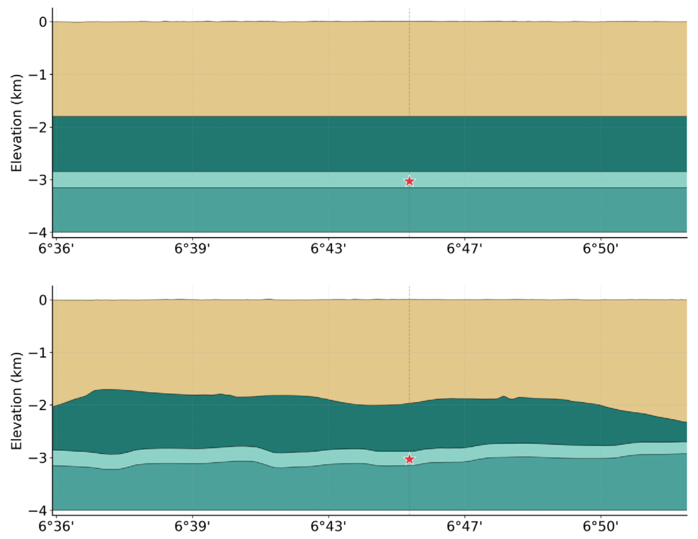
Zechstein layer topography



Simulation domain



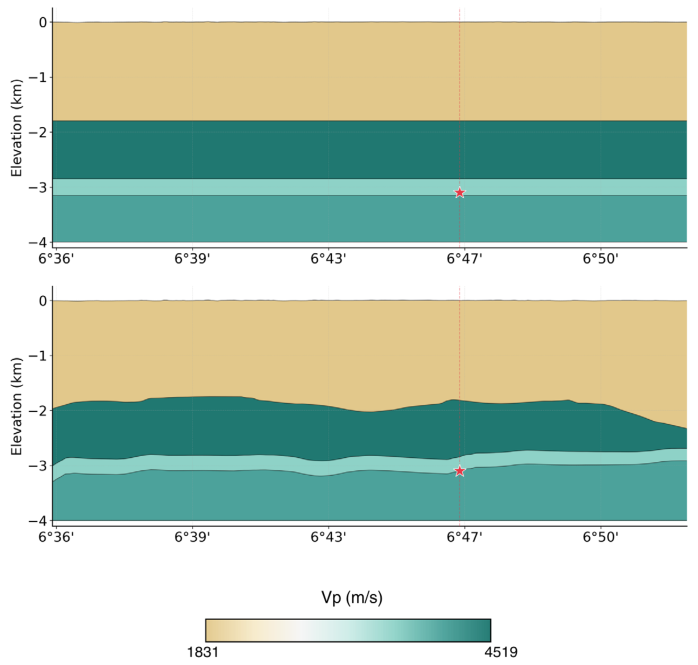
Zeerijp 2018



2 AIM

In this study, we investigate how subsurface heterogeneity, both shallow and deep, affects seismic wave propagation in the Groningen gas field. We employ 3D full waveform modeling using the spectral element method to examine how subsurface structure shapes observed ground motion patterns.

Zeerijp 2025



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References

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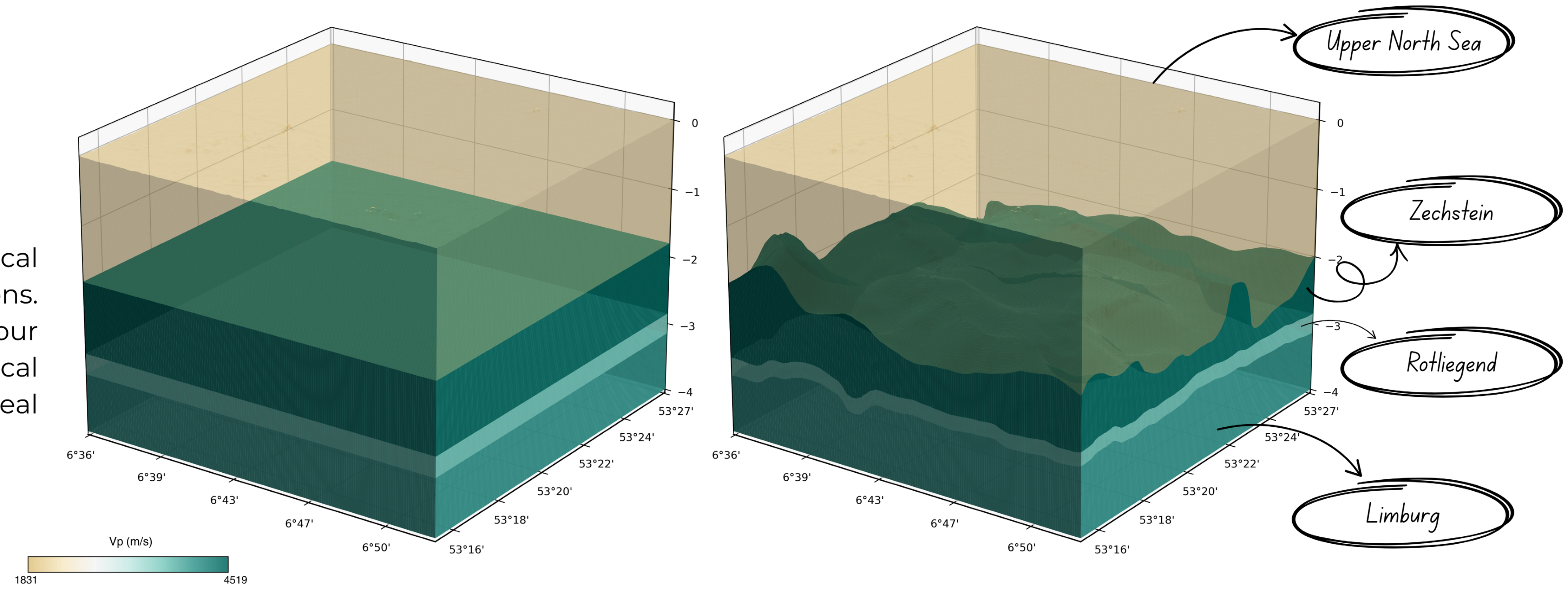
3 MODEL

Three-dimensional geological models used in the simulations. Both models represent four geological units with identical velocity parameters and real GMRT surface topography.

Flat layer model

Subsurface topographic model



4

(PGV topo - PGV flat)/ PGV flat x 100

PGV flat model

PGV topographic model

PGV difference

Topographic amplification