Groundwater Divides in a Fractured Crystalline Rock Setting

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Outline

- Background
- Modelling tools
- Surface lineaments
- Discrete Fracture Zone Networks
- Methodology
- Model properties
- Modelling results
- Summary and conclusions

Background

- For a groundwater modelling domain, lateral boundary conditions are commonly zero flux
  - Lateral extent is normally chosen based on topography and surface water divides
  - Groundwater divides are assumed to be coincident with surface water divides.
  - In fractured rock settings, fracture zones may cross surface water divides to permit groundwater flow across the divide.

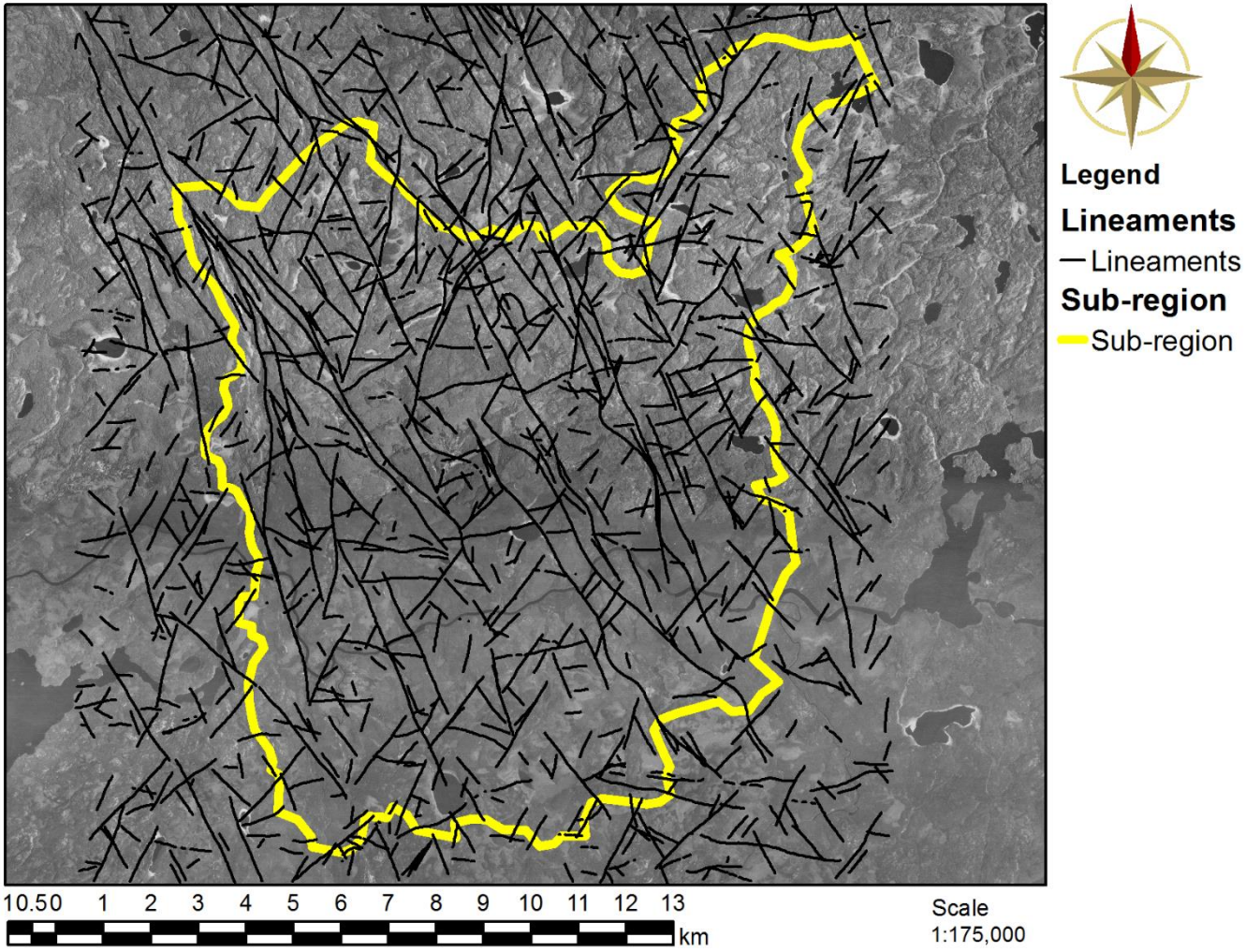
Background - Site

- Hypothetical site situated in the Canadian Shield
  - Approximately 100 km^2
  - Fractured crystalline rock setting
  - Surface lineament analysis from air photos
  - Generate 3D discrete fracture zone networks (DFZN) using MoFrac
  - Model groundwater flow with HydroGeoSphere

Background - Models

- MoFrac
  - Developed at Mirarco (based on work by Mohan Srivastava), a mining innovation research center in Canada
  - Generates 3D fracture network models for rock mass characterization
- HydroGeoSphere
  - HGS developed at the University of Waterloo and University of Laval
  - Currently developed and supported by Aquanty Inc.

Sub-regional Domain – Surface Lineaments



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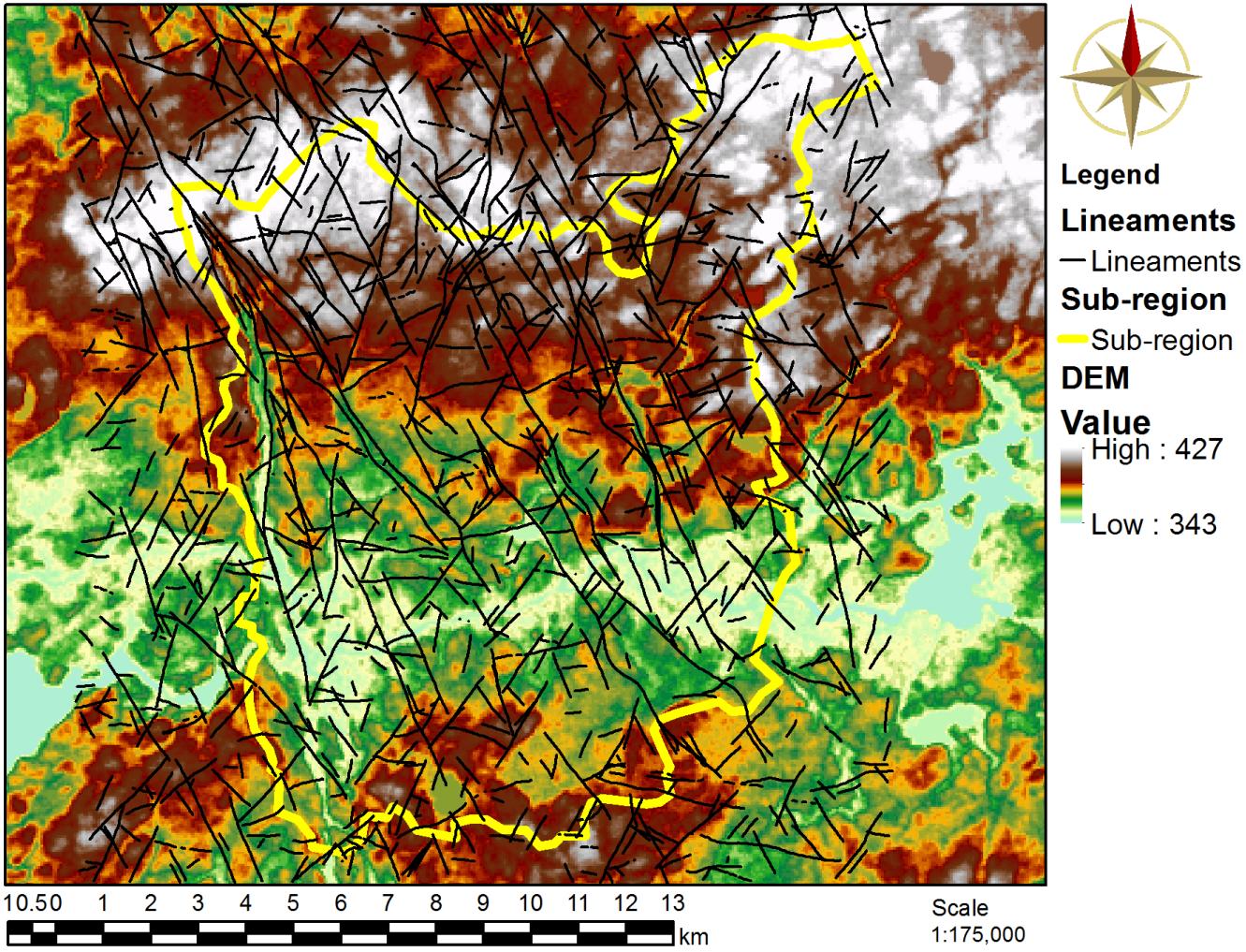
Sub-regional Domain



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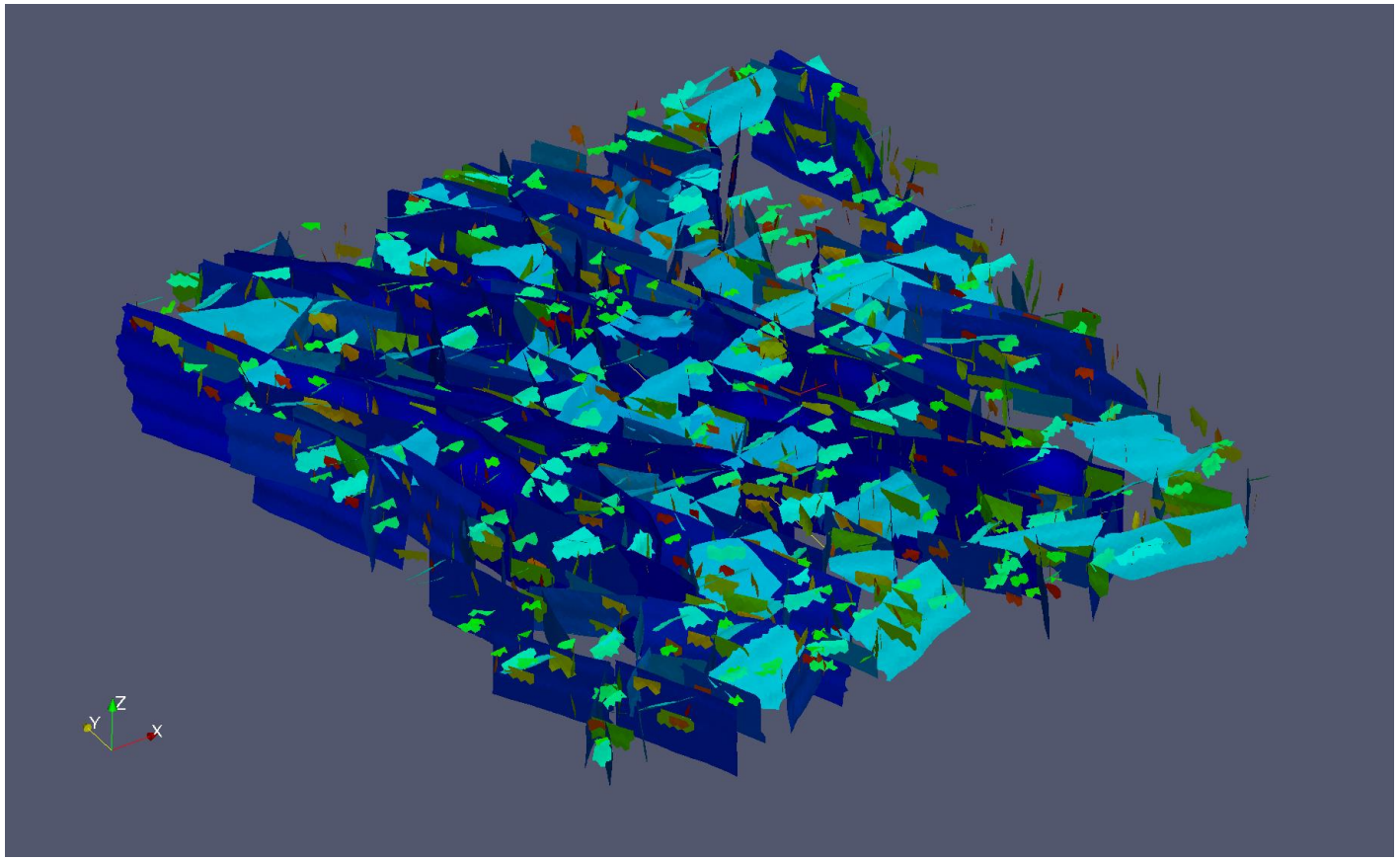
Discrete Fracture Zone Network

- 969 fracture zones



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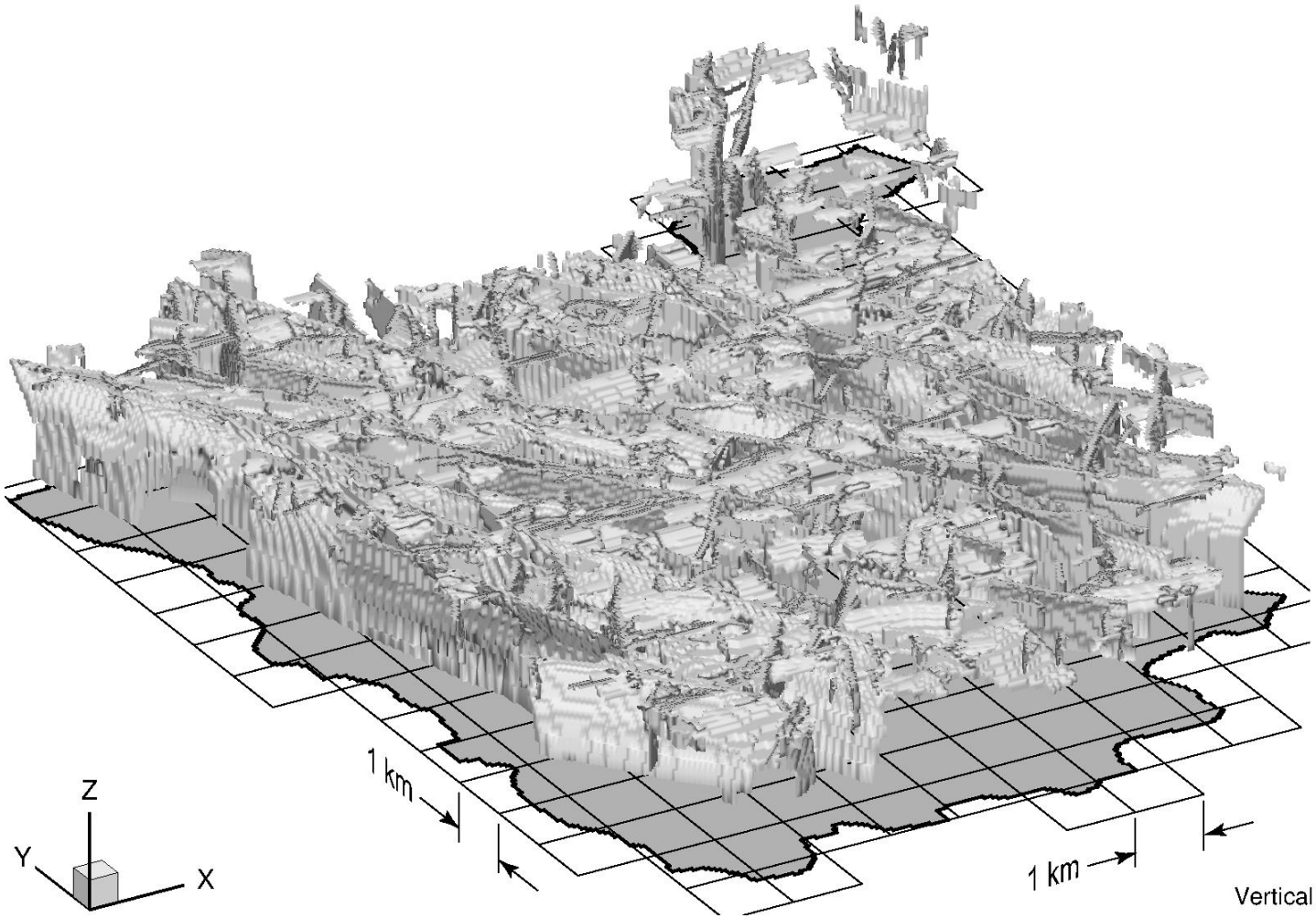
Discrete Fracture Zone Network



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Methodology

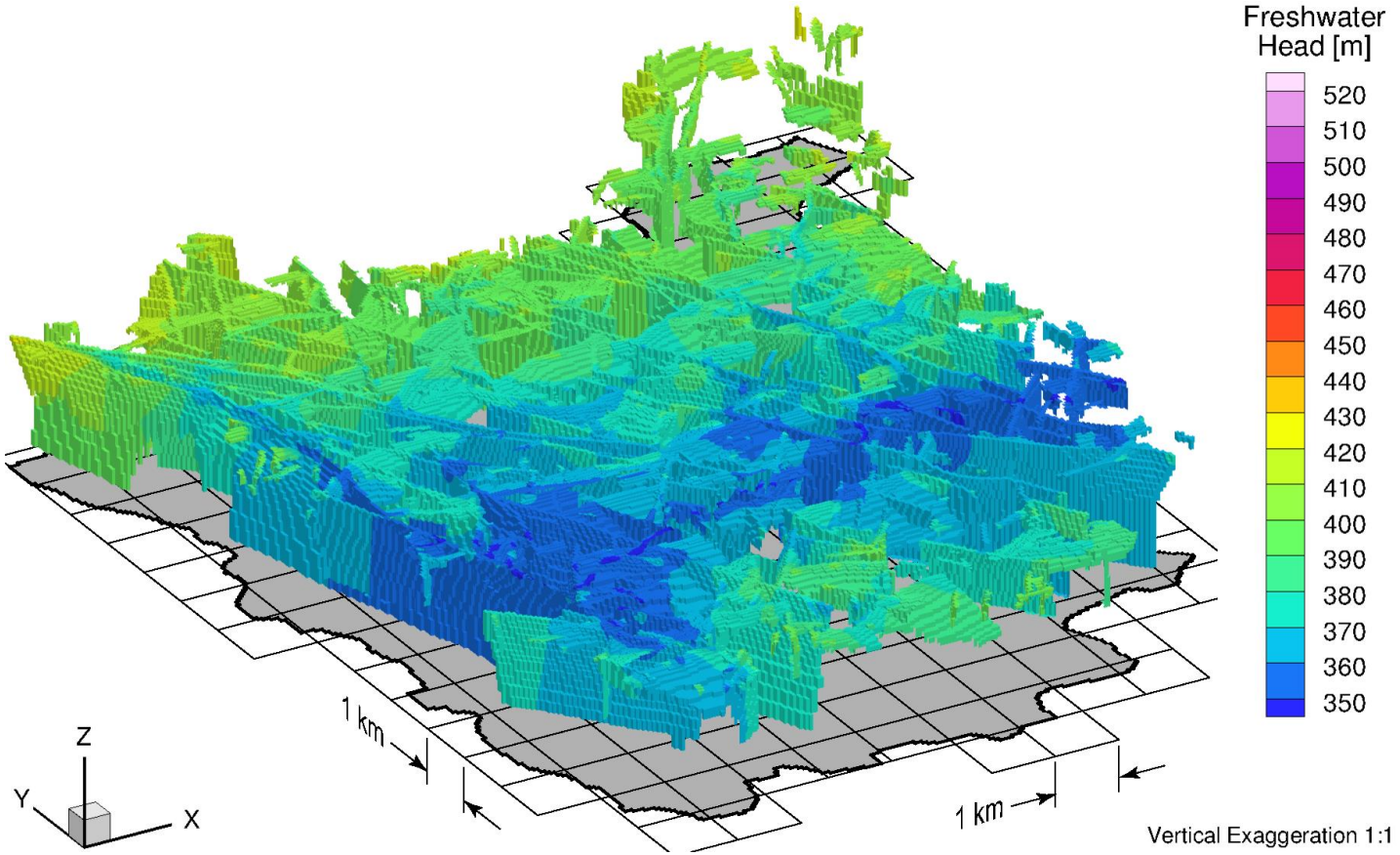
- Vary hydraulic conductivity of fracture zones
  - High conductivity 10^{-6} m/s (governed by safety case)
  - Low conductivity 10^{-9} m/s
- Vary surface hydraulic boundary condition
  - Dirichlet across entire surface
  - Dirichlet only at rivers, lakes, wetlands with Neumann recharge elsewhere
- Performance measures with steady-state models
  - Freshwater heads
  - Groundwater velocity magnitudes
  - Groundwater velocity magnitude ratios (V_z/V_{mag})
  - Mean Life Expectancy (MLE)

Model Properties

- Matrix
  - Hydraulic conductivity: 10^{-8} to 10^{-11} m/s
  - Porosity = 0.3%
- Fracture
  - Hydraulic conductivity = 10^{-6} m/s
  - Width = 1m (assumed for safety case)
  - Porosity = 10%

Base-case Freshwater Heads

- High fracture K, Dirichlet BC at surface



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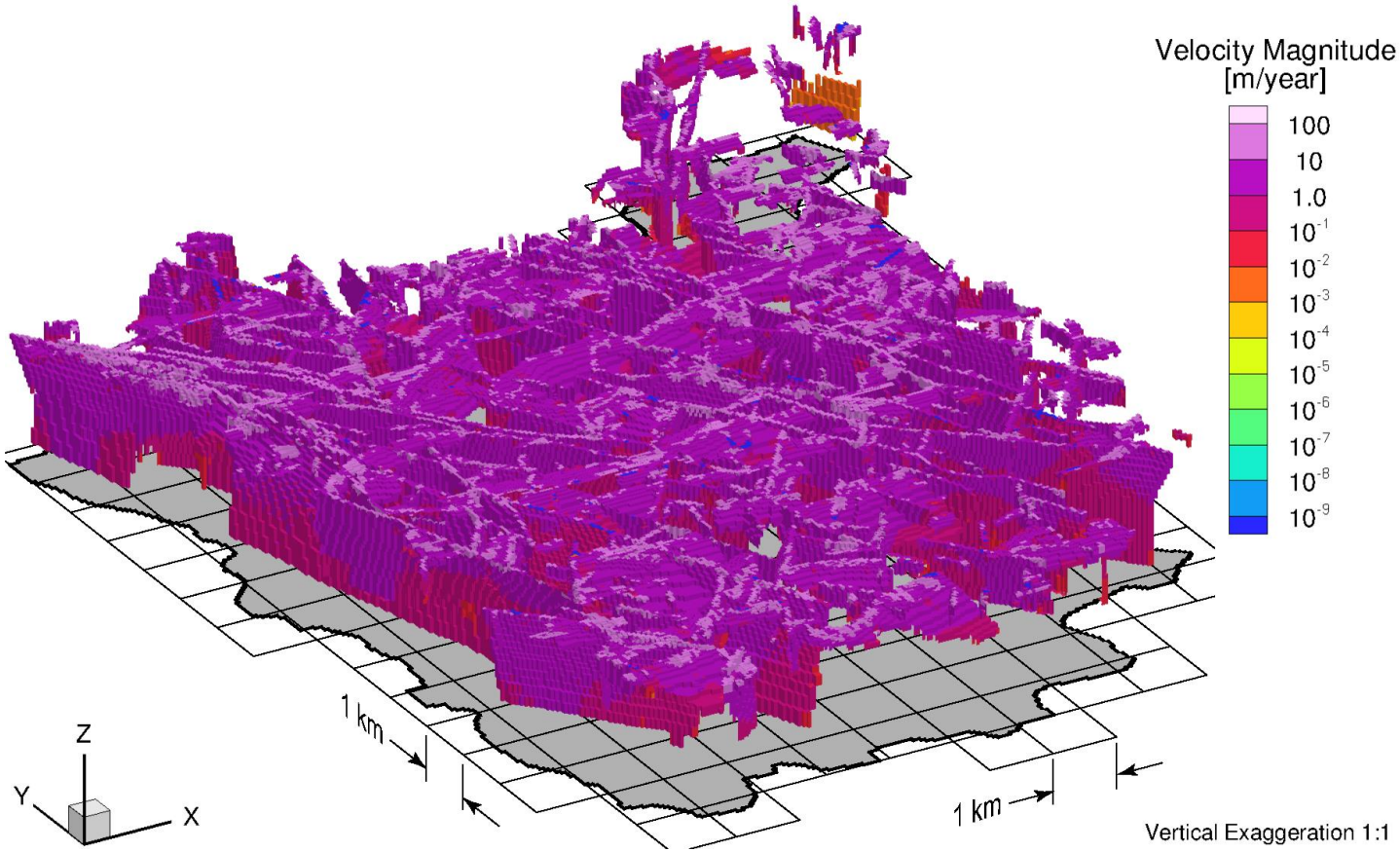
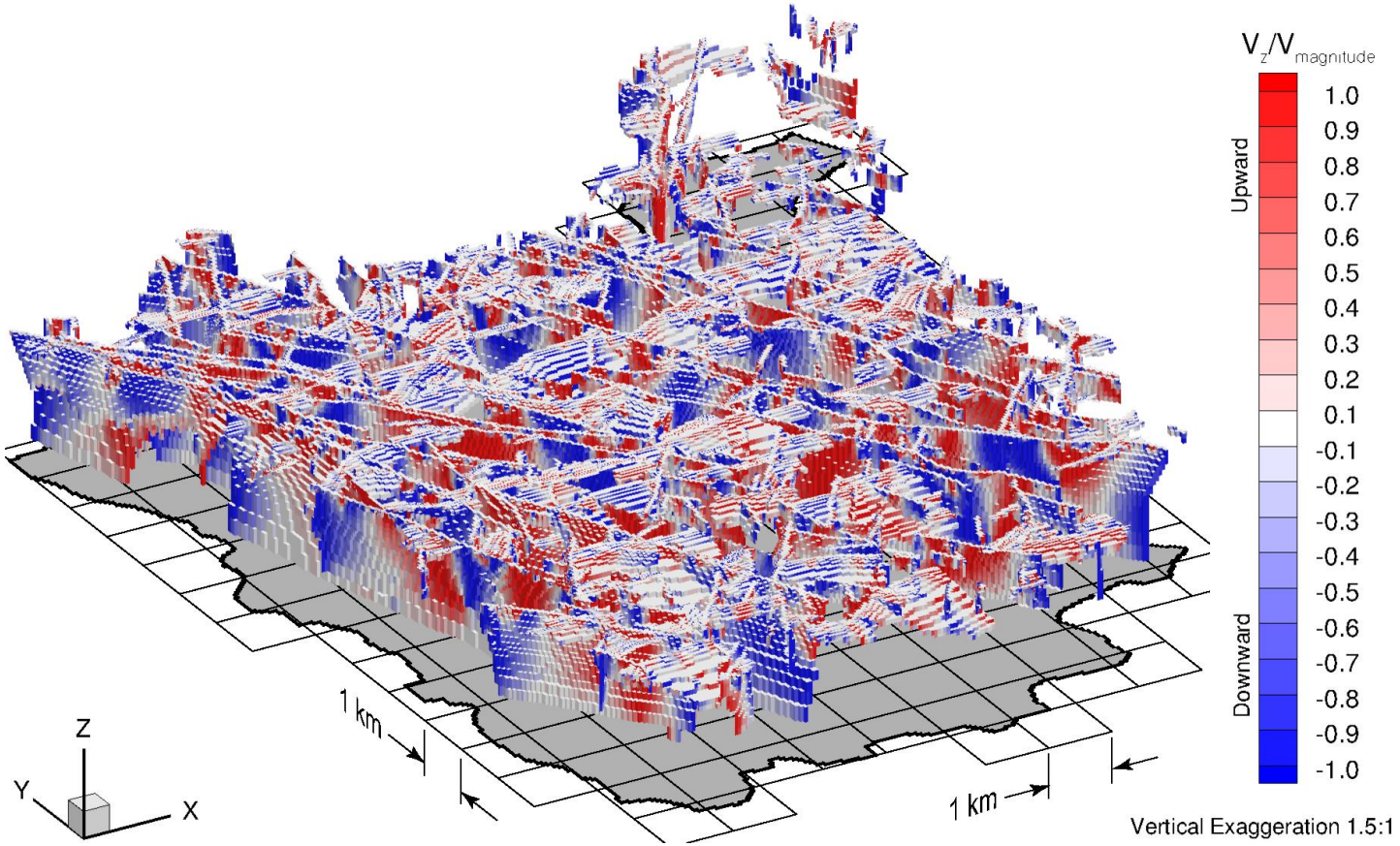
Base-case Velocity Magnitudes

- High fracture K, Dirichlet BC at surface



Base-case Velocity Magnitude Ratio

- High fracture K, Dirichlet BC at surface



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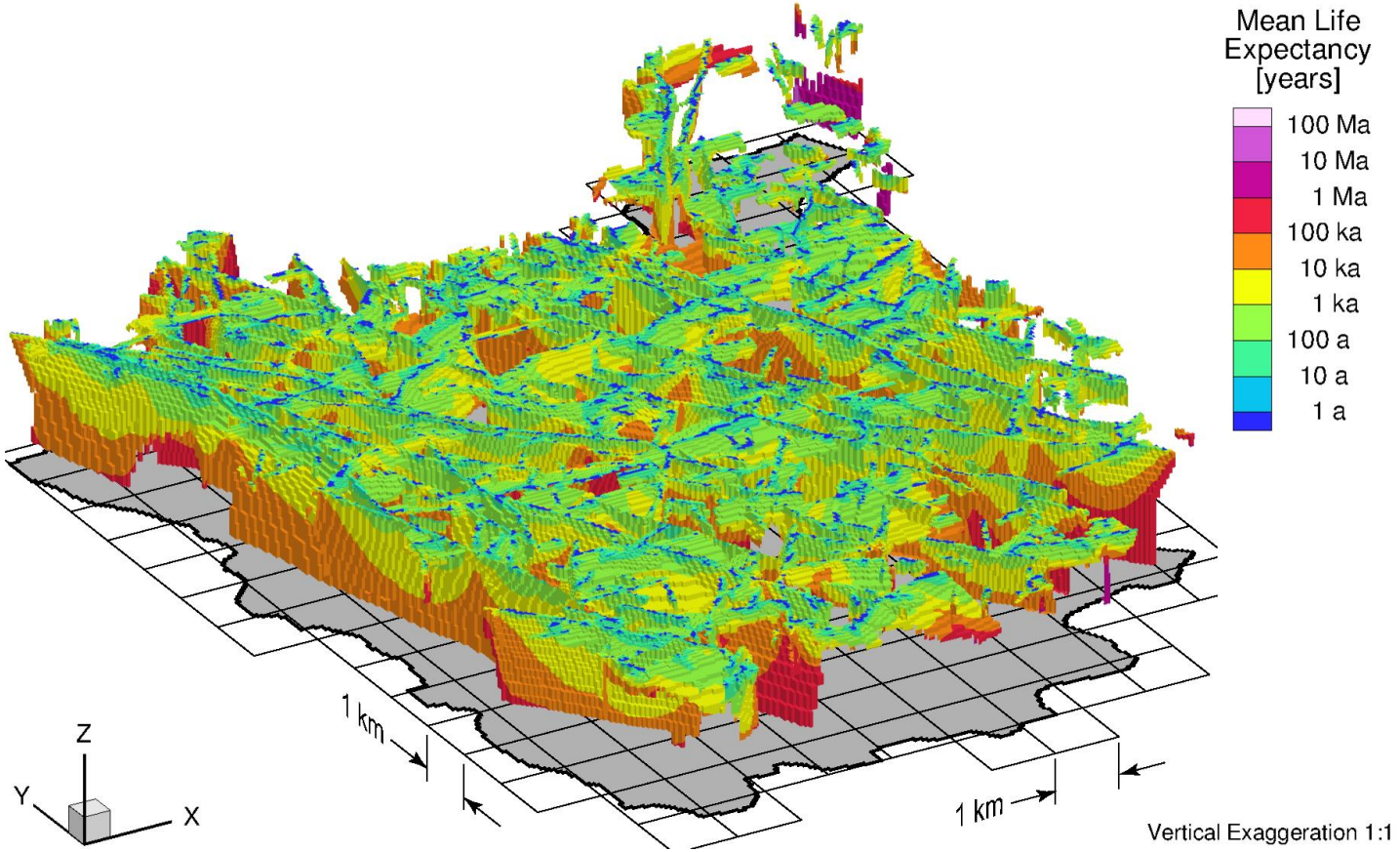
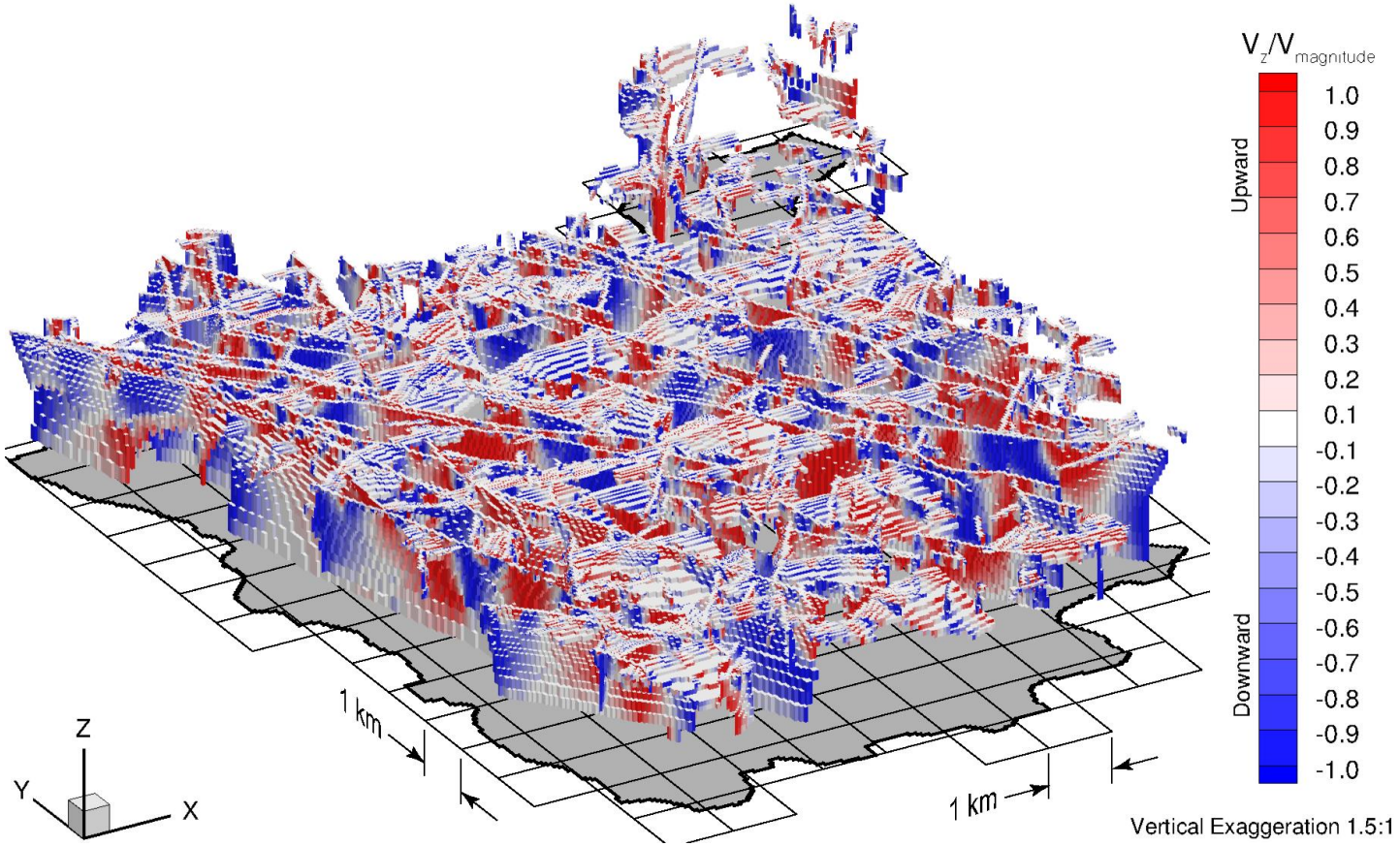
Base-case Mean Life Expectancy

- High fracture K, Dirichlet BC at surface



Velocity Magnitude Ratio

- High fracture K, Dirichlet BC at surface



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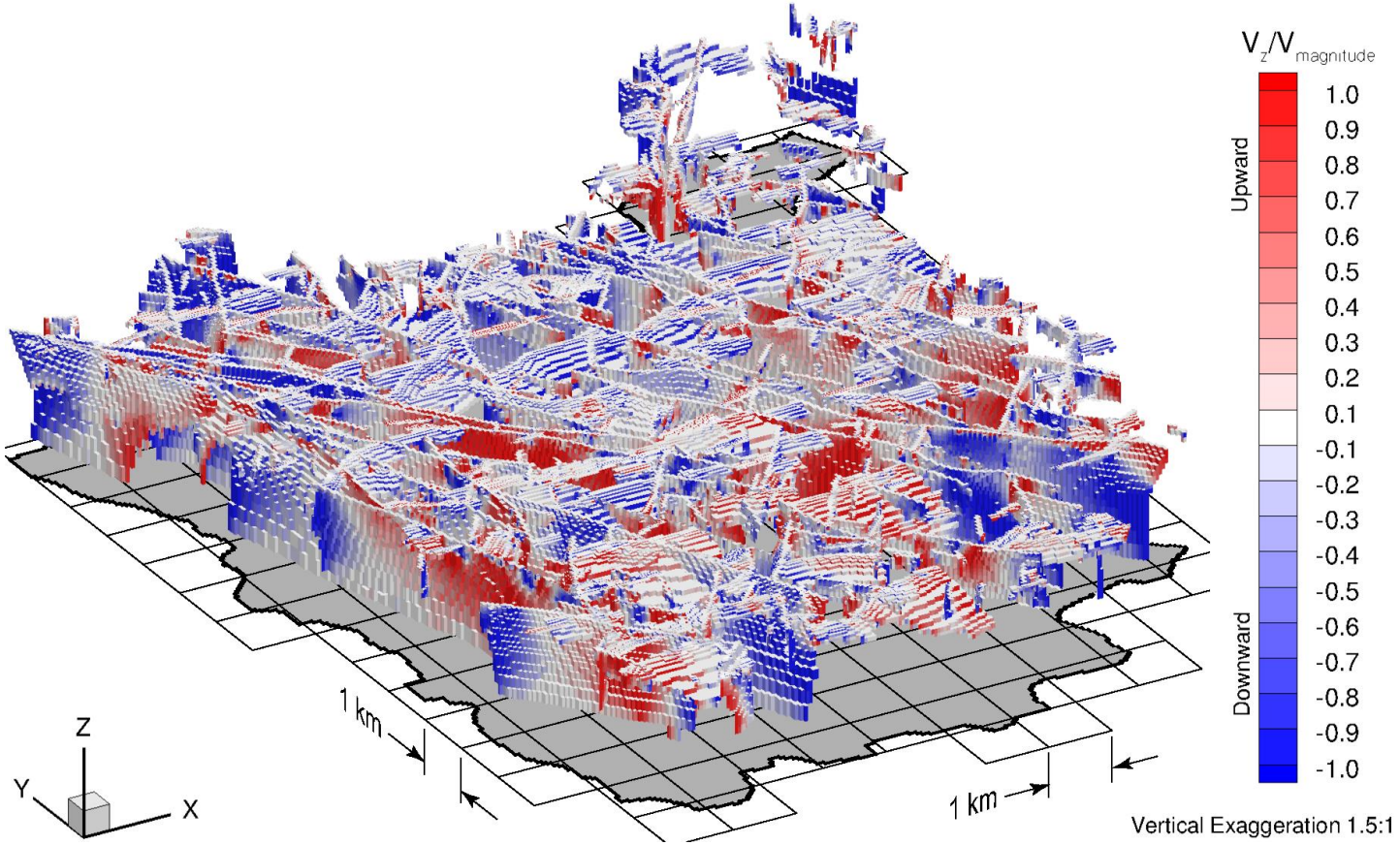
Velocity Magnitude Ratio

- High fracture K, Neumann BC at surface



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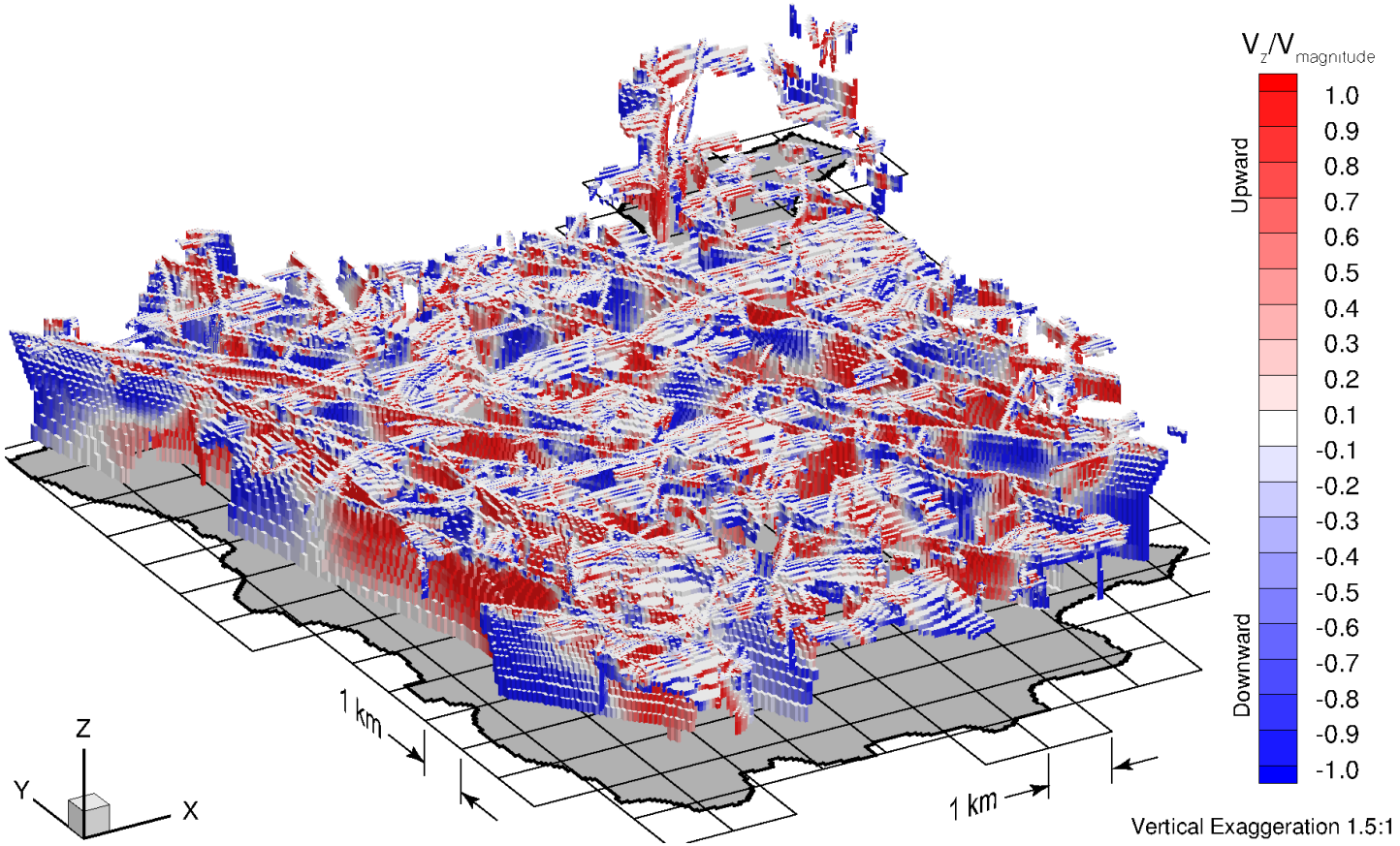
Velocity Magnitude Ratio

- Low fracture K, Dirichlet BC at surface



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Velocity Magnitude Ratio

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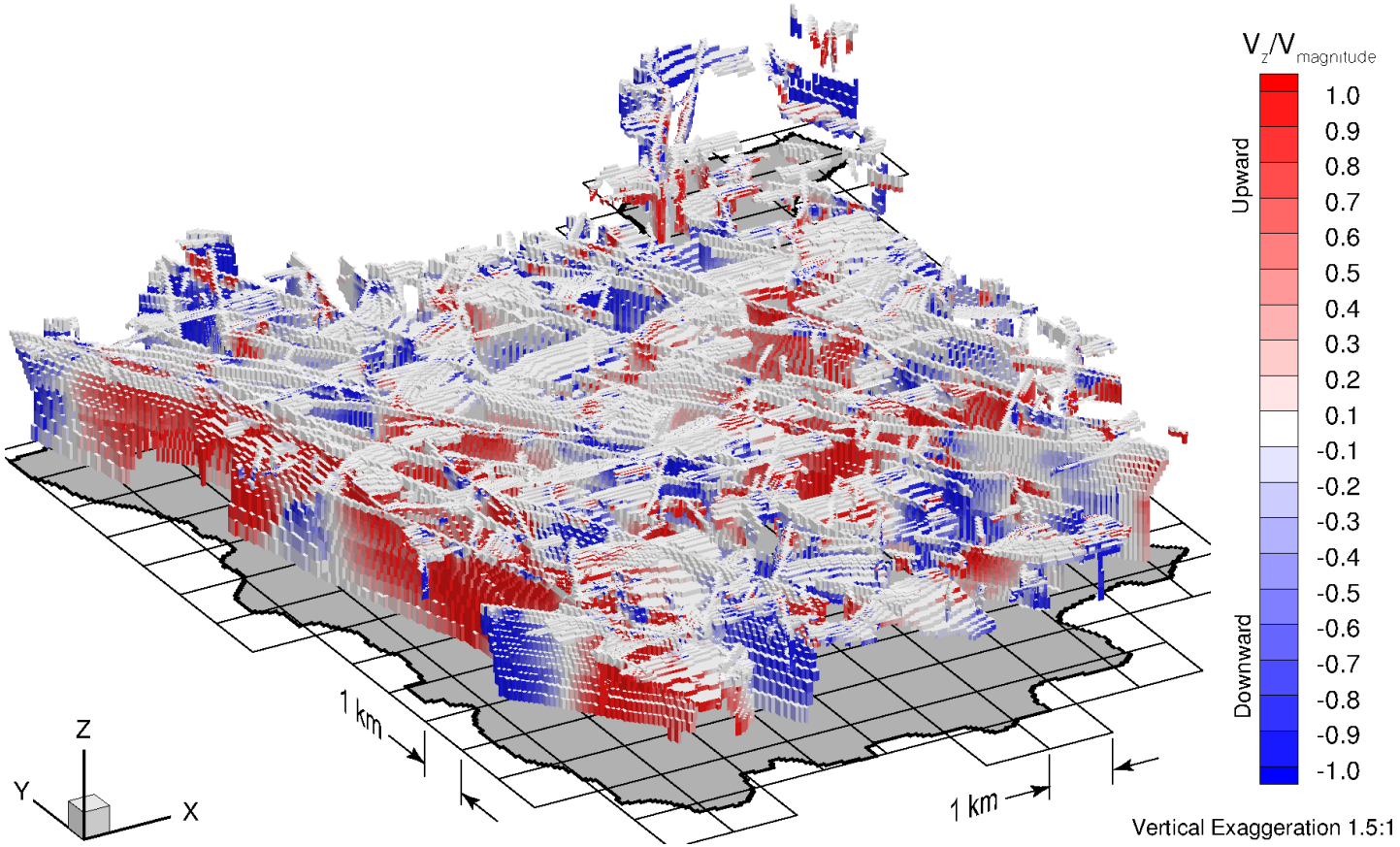

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Summary and Conclusions

- Zones of upward or downward groundwater flow
  - Identified using velocity magnitude ratios (Vz/Vmag)
  - Vary depending on the surface boundary condition
  - Vary depending on hydraulic connectivity across watersheds
  - Divides can occur at these zones
- Model boundaries may need to be extended to allow groundwater to flow across divides through permeable fracture zones

Acknowledgements

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Thank you!