Community Benchmarks for Code Verification

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Computational Infrastructure for Geodynamics

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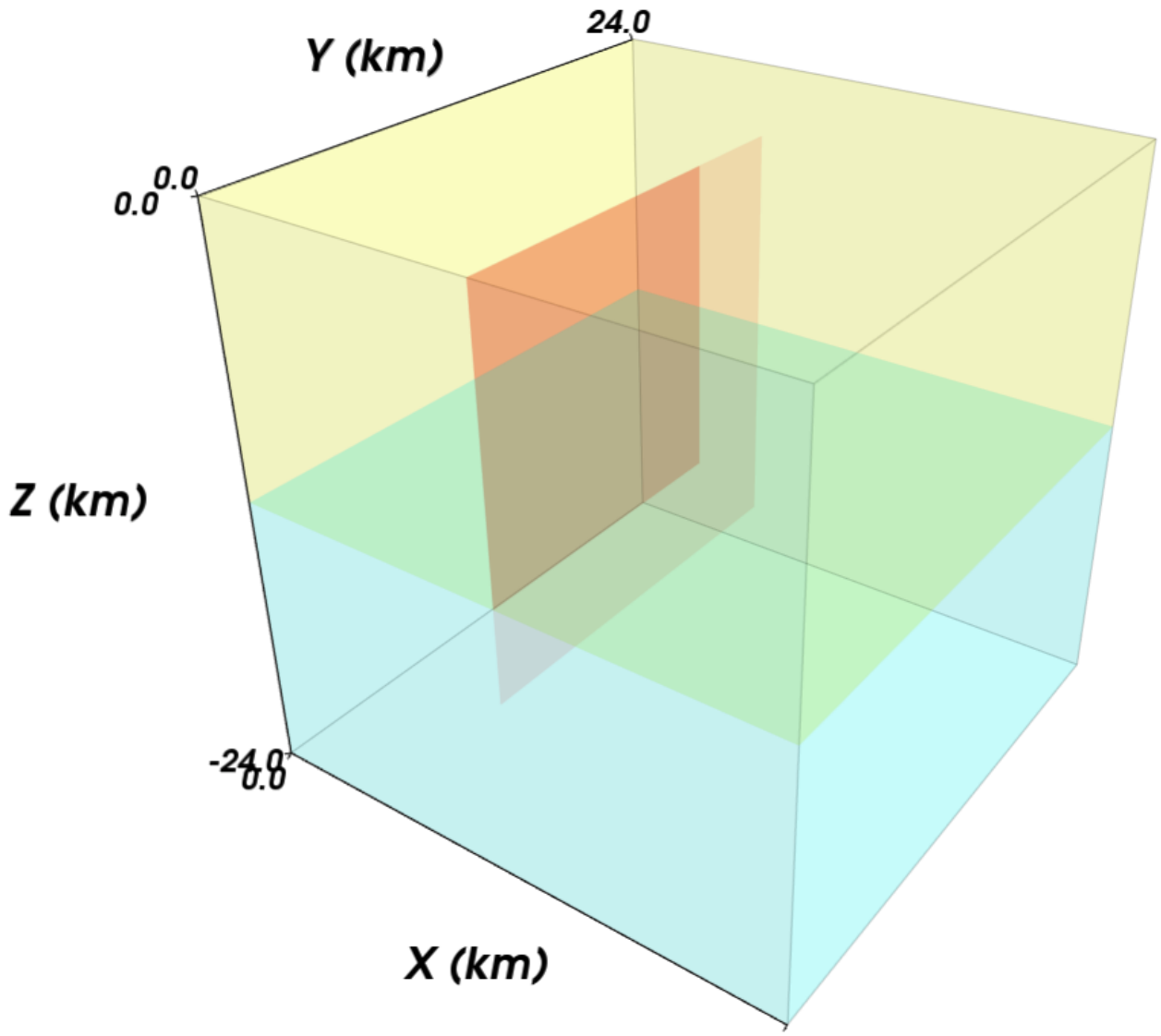
Community Benchmarking Efforts

- SCEC Crustal Deformation Modeling (quasi-static)
  - Focus on geometry, viscoelastic rheology, quantifying error
  - Very few codes (PyLith and GeoFEST)
  - Large benchmark suite $\Rightarrow$ small benchmark suite
- SCEC Earthquake Source Physics (dynamic)
  - Focus on geometry, elastic/elastoplastic, qualitative comparison
  - More than a dozen codes
  - 1–2 benchmark problems per year

Summary of Community Benchmarks

Category	Rheology	Fault geometry	Fault model
SCEC Crustal Deformation Modeling	Maxwell viscoelastic	vertical, strike slip	kinematic
		dipping, reverse slip	
	w/gravity	dipping, reverse slip	
		vertical, strike slip	eq cycle
SCEC Eq Source Physics	elastic	vertical, strike slip	slip weakening
	w/bi-material	vertical, strike slip	slip weakening
		vertical, strike slip	overburden press.
		dipping, normal slip	subshear
		dipping, normal slip	supershear
	Drucker-Prager	dipping, normal slip	overburden press.
	elastic	vertical, strike slip	rate and state

Quasi-static: Strike-Slip Benchmark



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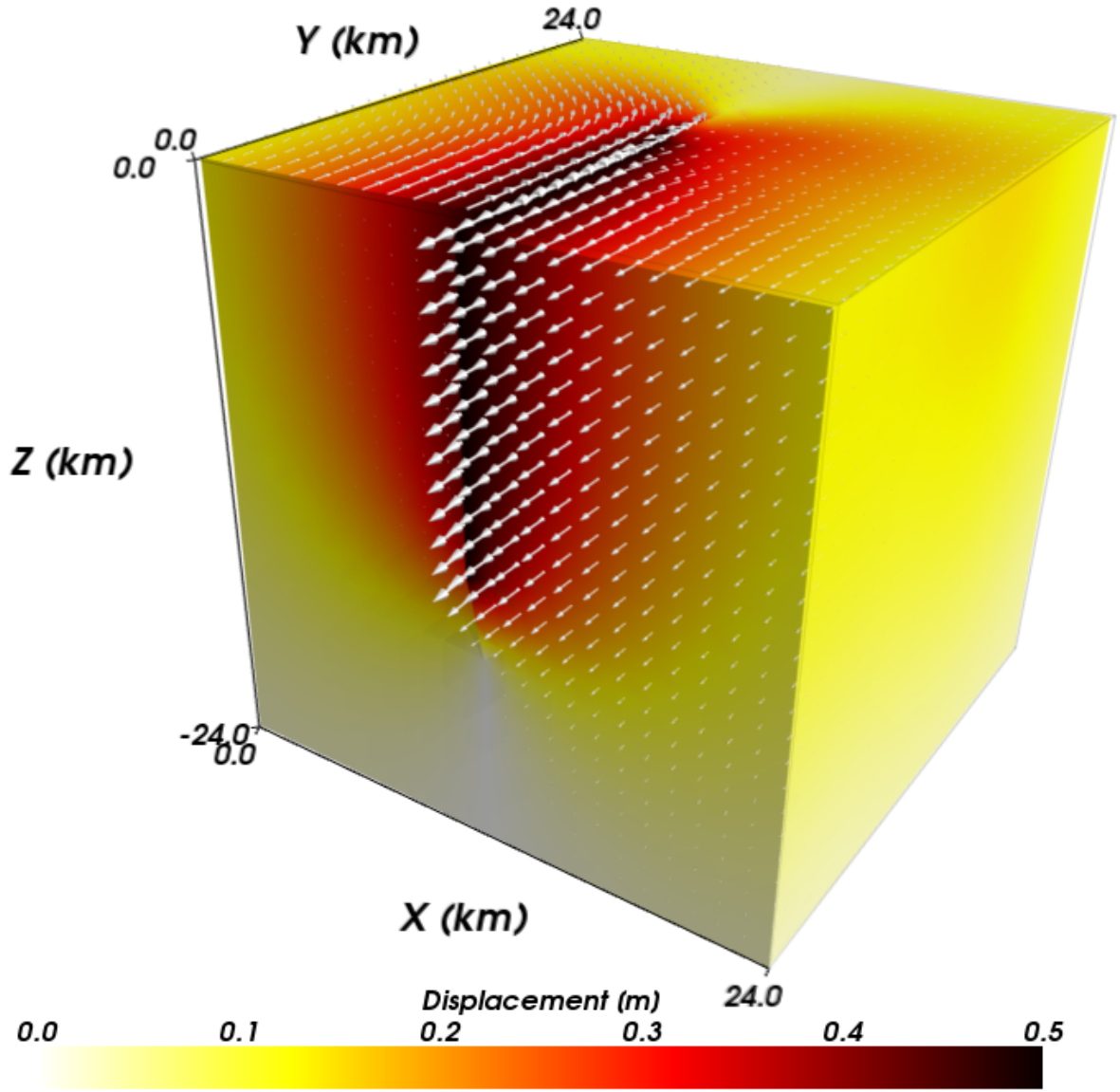
Quasi-static: Strike-Slip Benchmark



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Quasi-static: Strike-Slip Benchmark

Error metric

- Local error

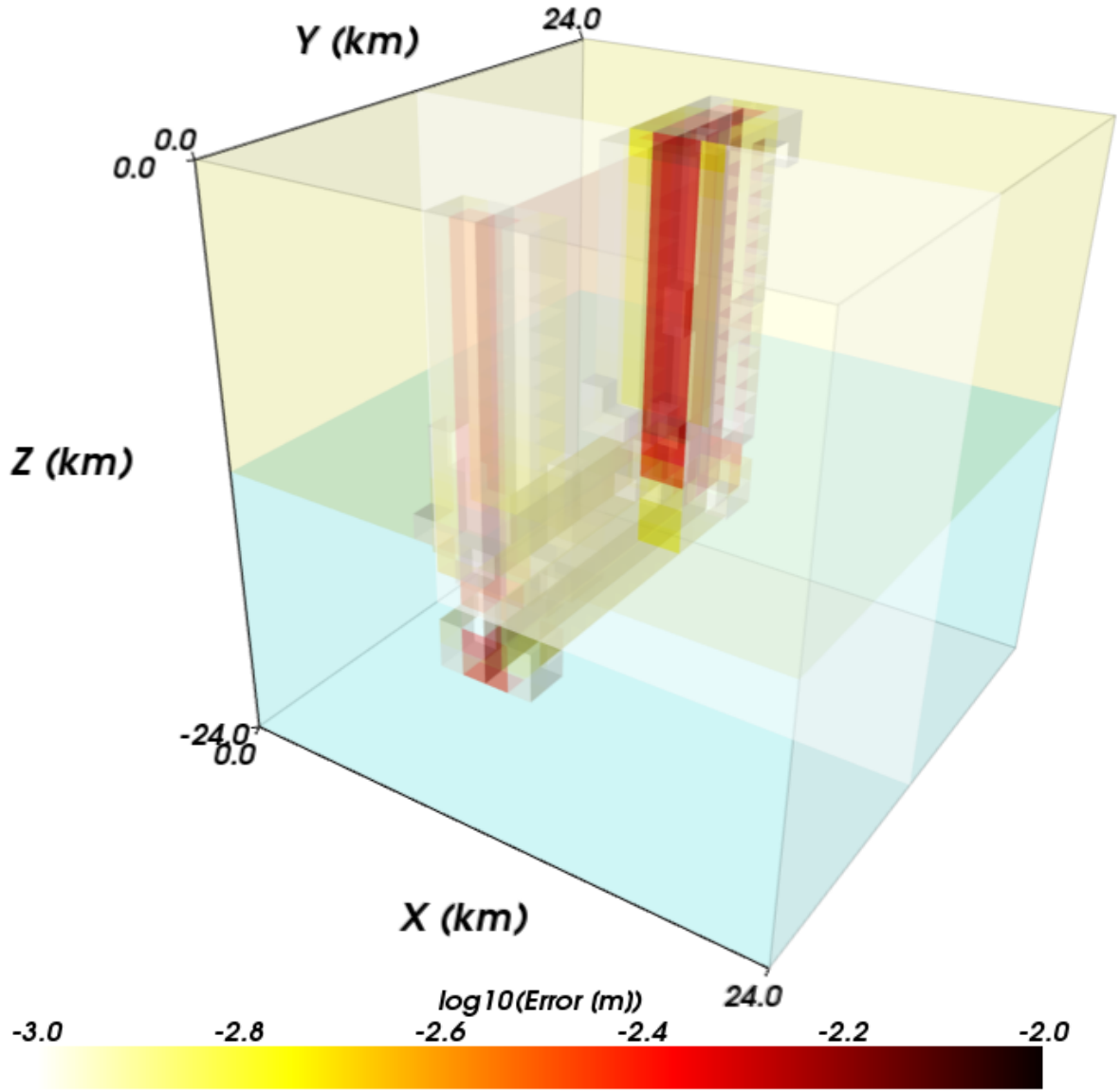
$$E_{local} = \frac{1}{V_{cell}} \sqrt{\int_{cell} \left(u_i^A - u_i^B\right)^2 \, dV} \tag{1}$$

- Global error

$$E_{domain} = \frac{1}{V_{domain}} \sqrt{\int_{domain} \left(u_i^A - u_i^B\right)^2 \, dV} \tag{2}$$

Quasi-static: Strike-Slip Benchmark

Error for Hex8, 1000m resolution



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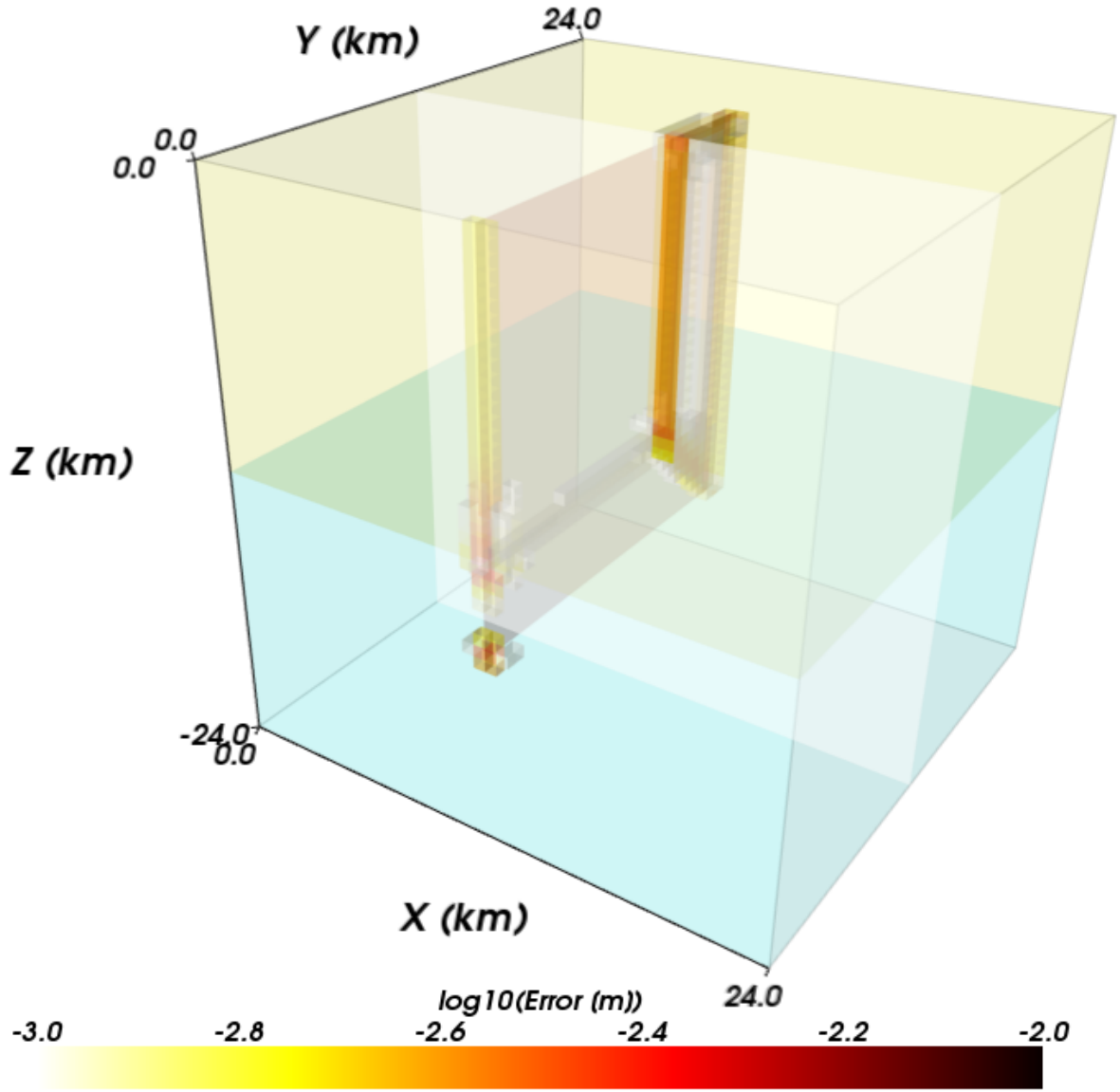
Quasi-static: Strike-Slip Benchmark

Error for Hex8, 500m resolution



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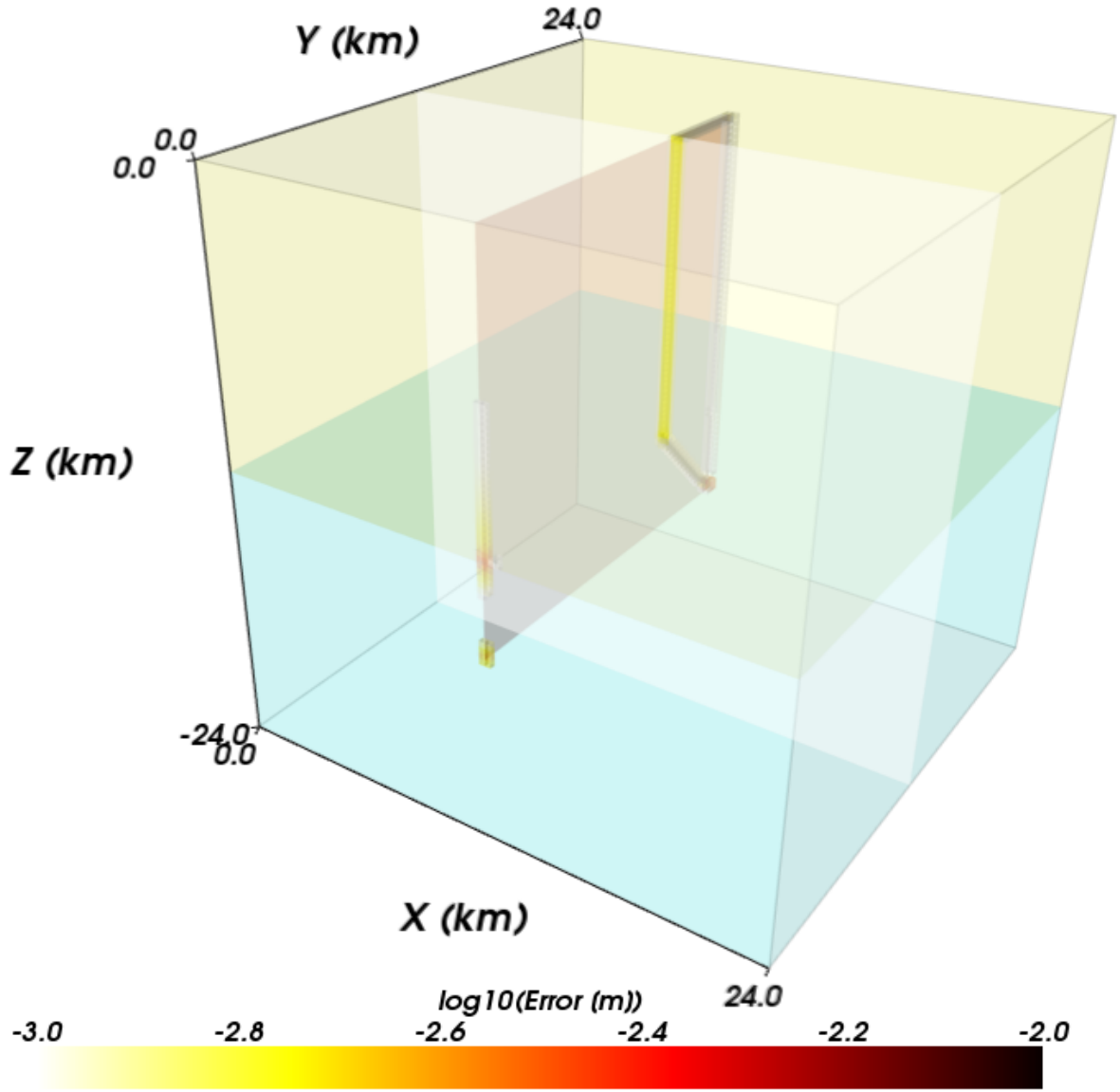
Quasi-static: Strike-Slip Benchmark

Error for Hex8, 250m resolution



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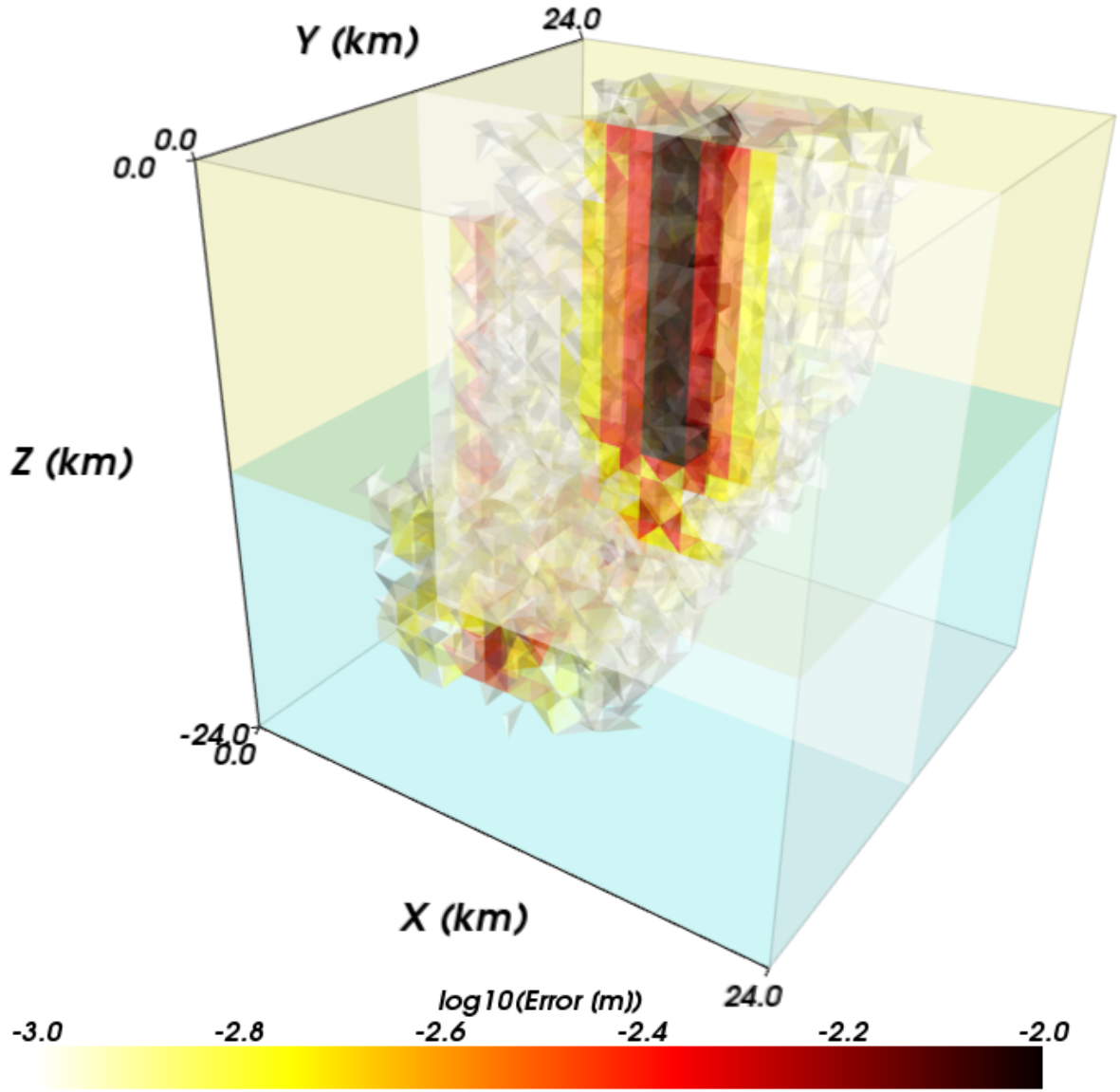
Quasi-static: Strike-Slip Benchmark

Error for Tet4, 1000m resolution



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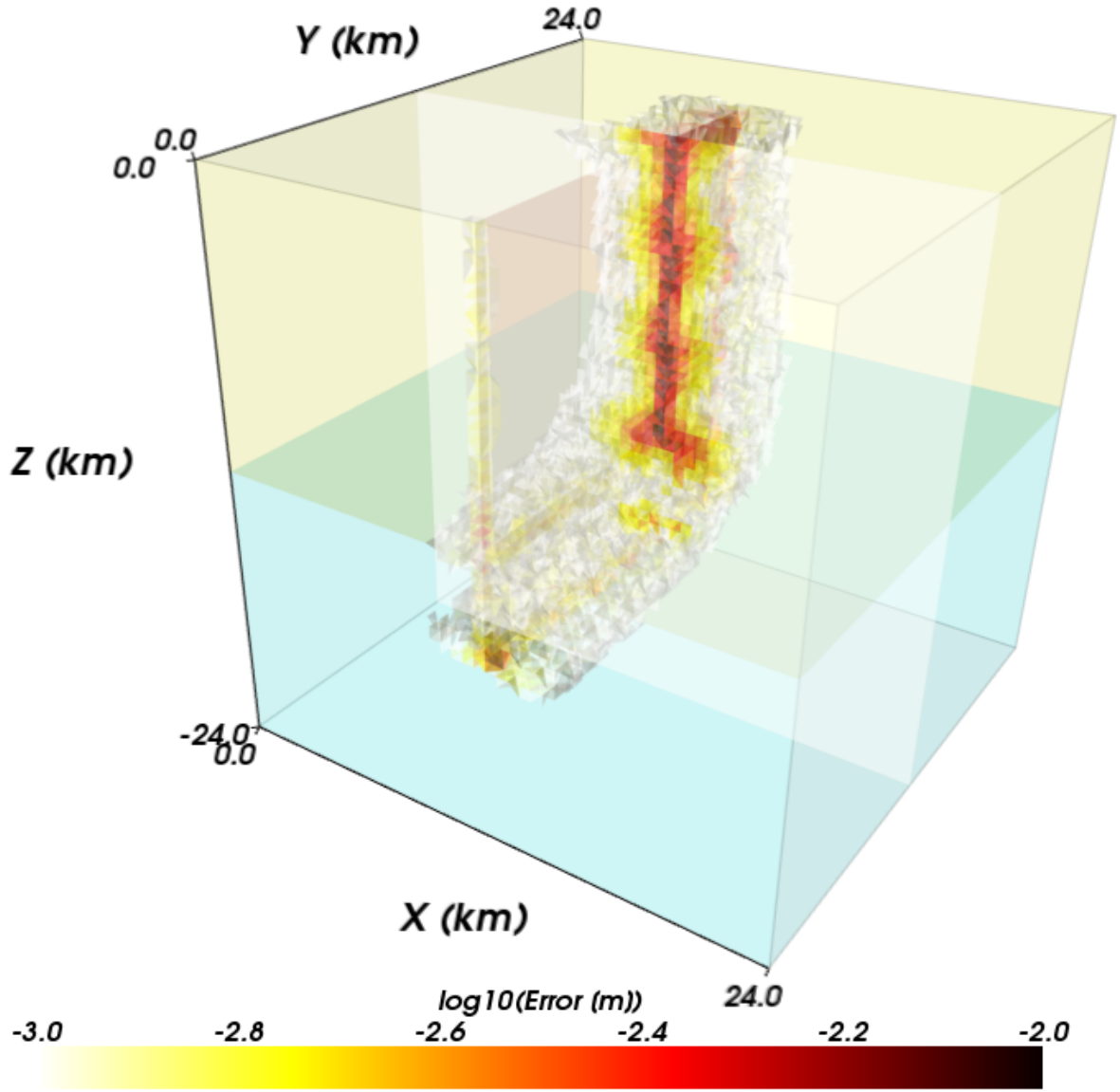
Quasi-static: Strike-Slip Benchmark

Error for Tet4, 500m resolution



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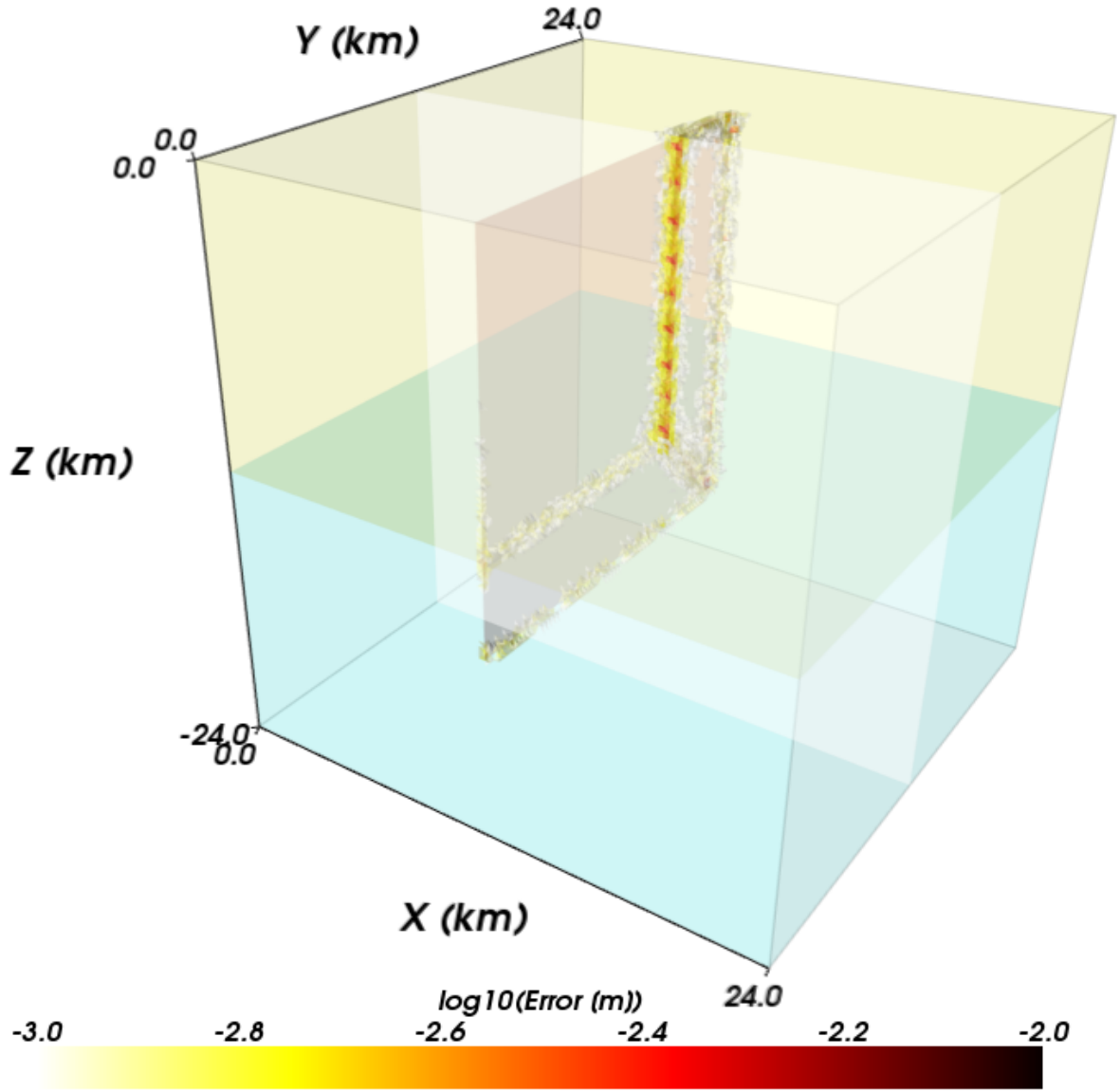
Quasi-static: Strike-Slip Benchmark

Error for Tet4, 250m resolution



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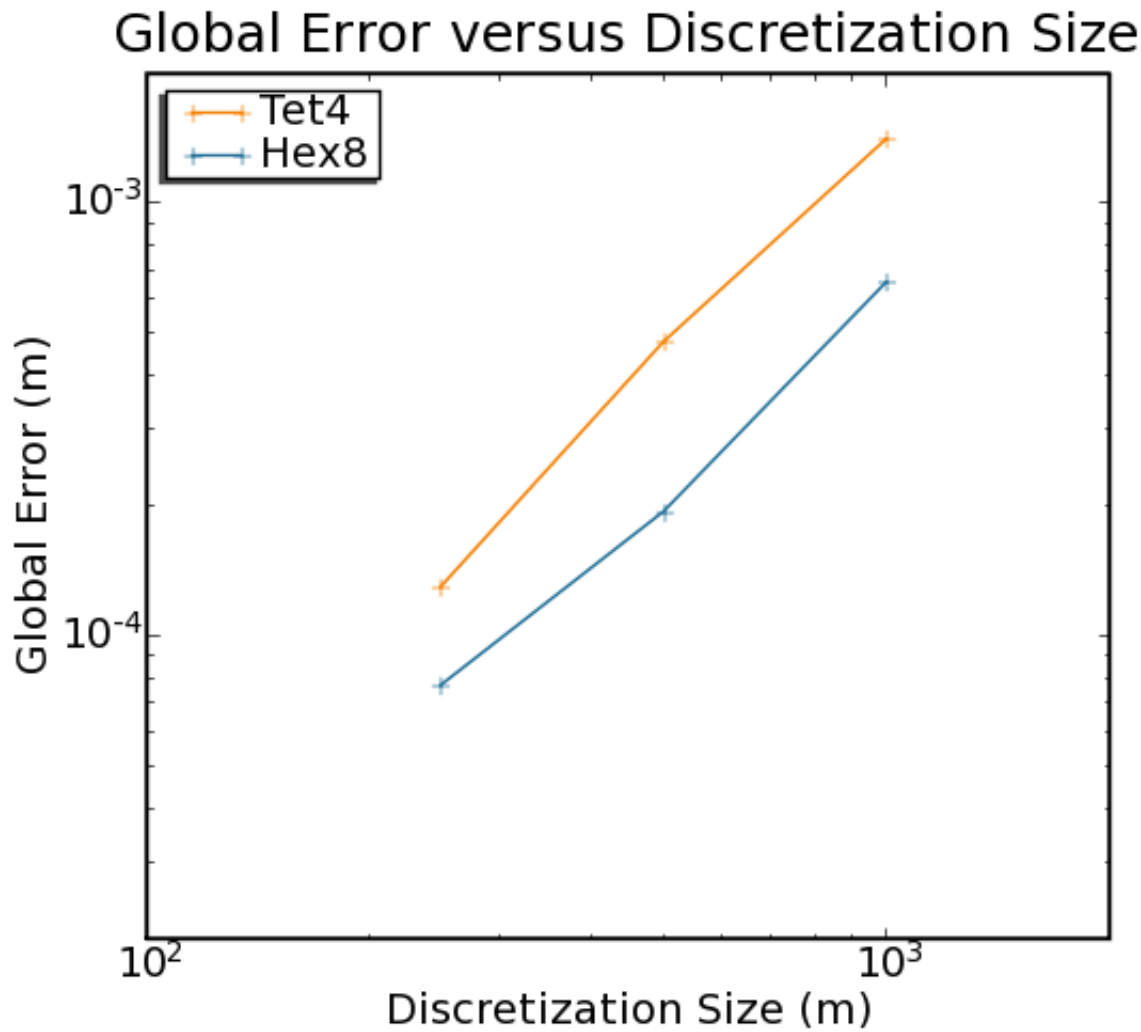
Quasi-static: Strike-Slip Benchmark

Hex8 outperforms Tet4



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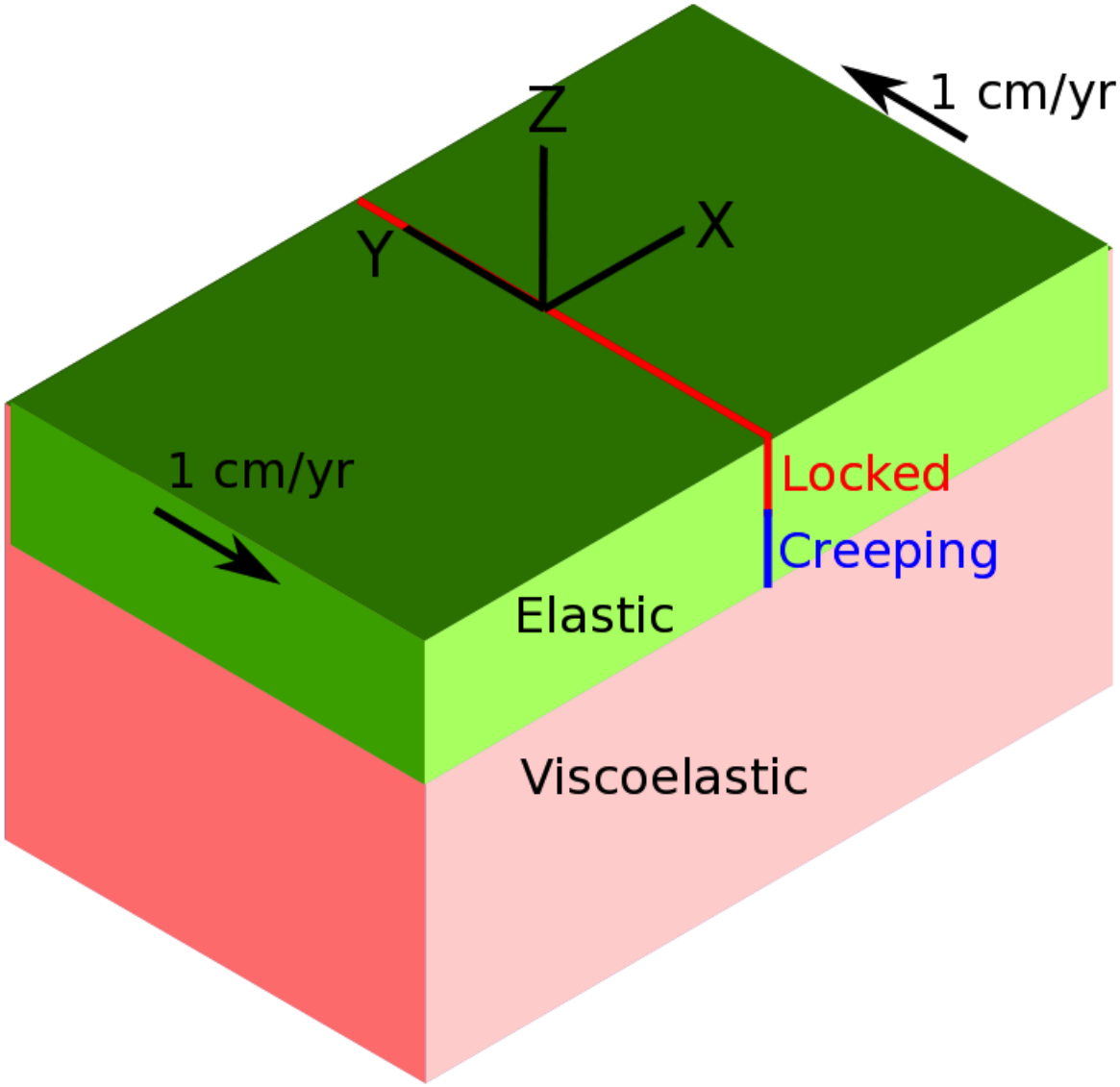
Quasi-static: Savage-Prescott Benchmark



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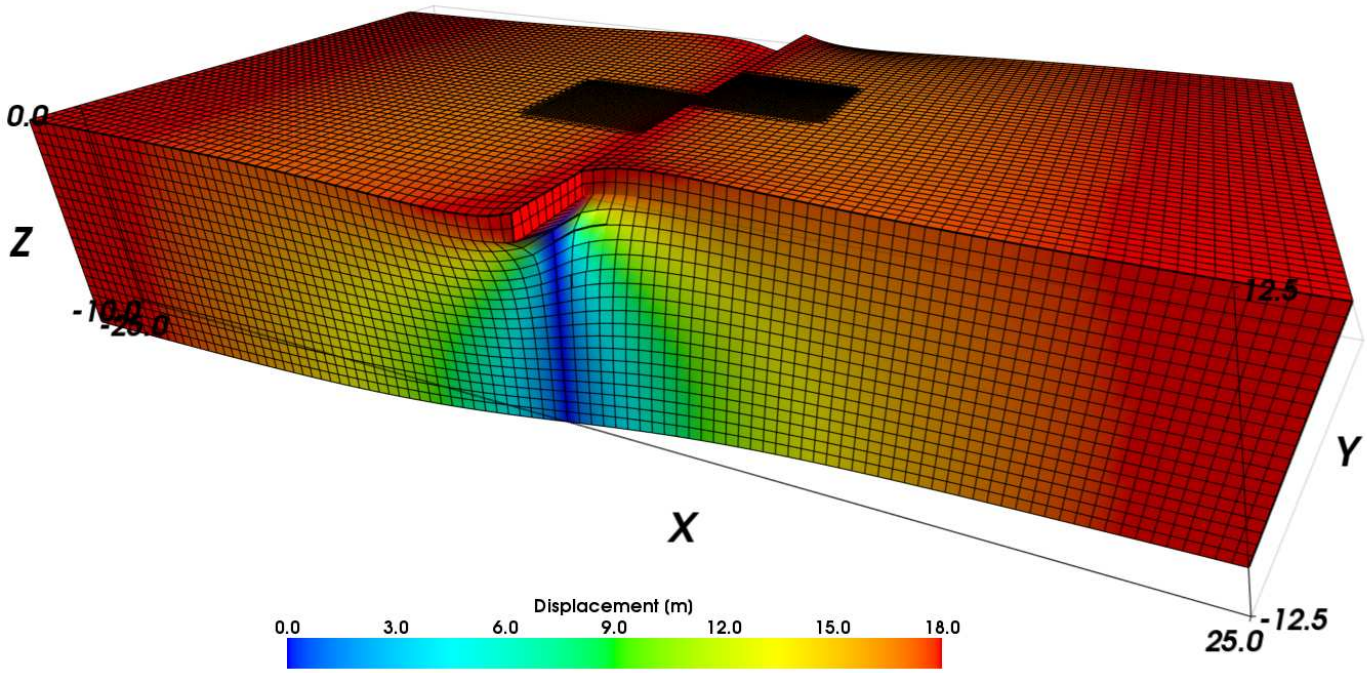
Quasi-static: Savage-Prescott Benchmark



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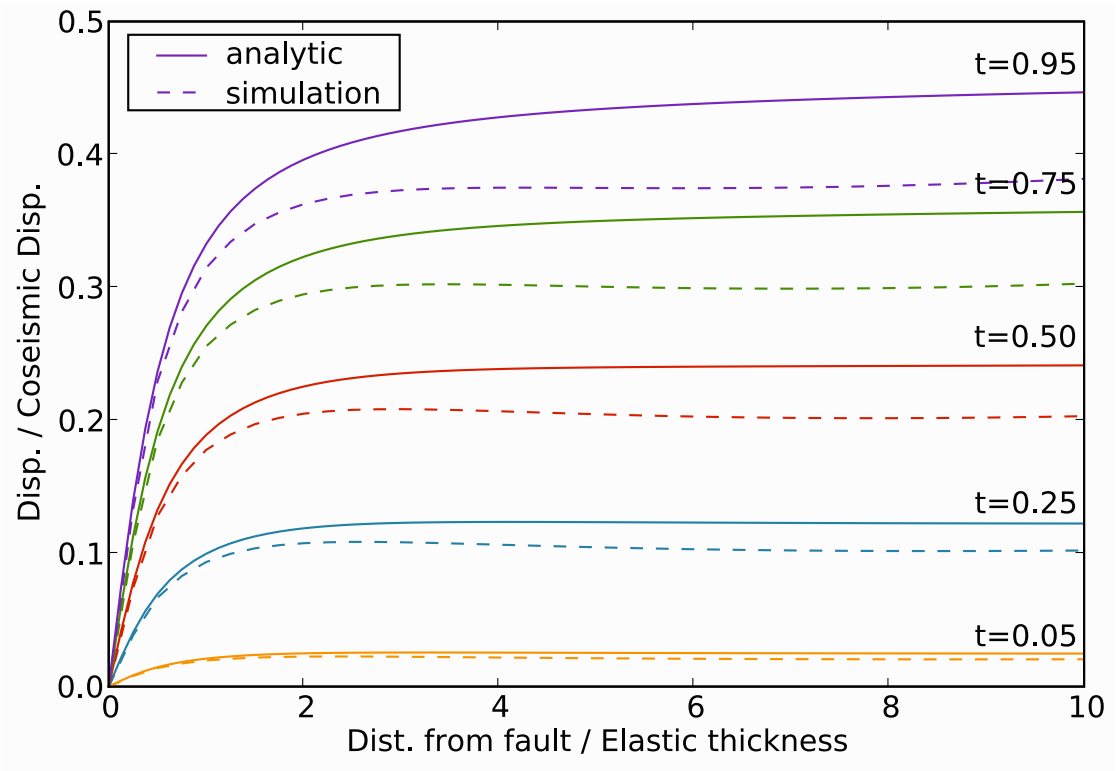
Quasi-static: Savage-Prescott Benchmark

Analytic versus PyLith: Earthquake cycle 3

Model has not yet spun-up to steady-state solution.



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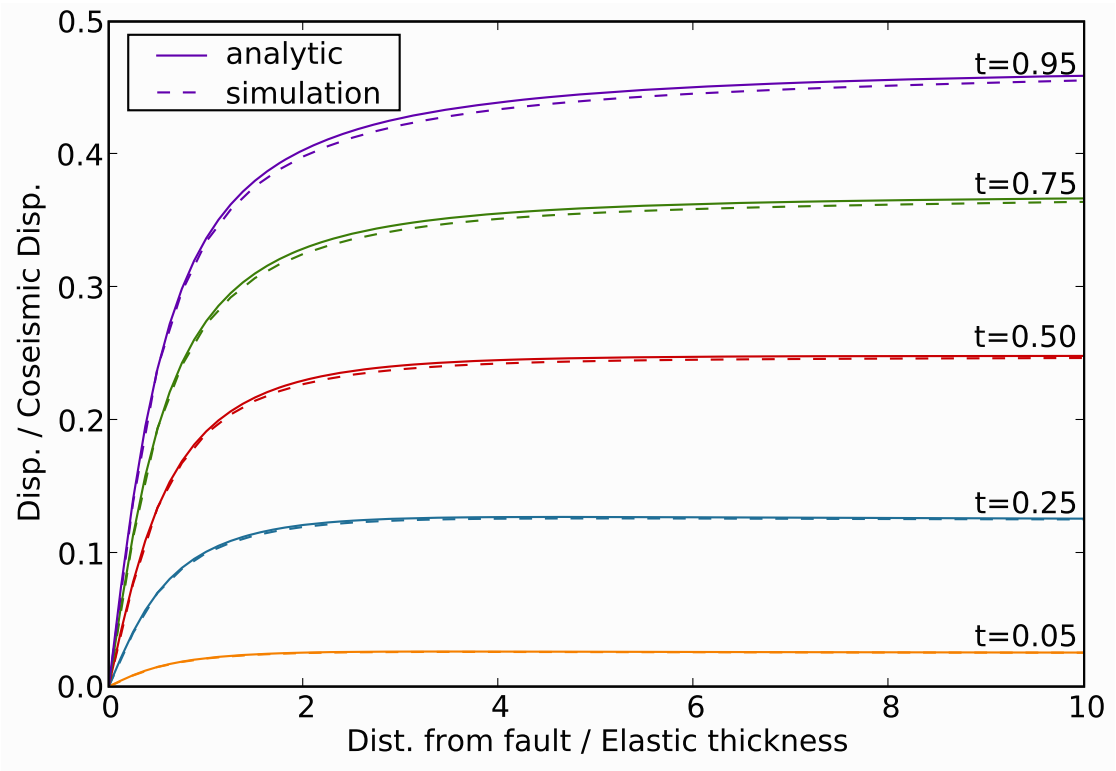
Quasi-static: Savage-Prescott Benchmark

Analytic versus PyLith: Earthquake cycle 10

Model is very close to steady-state solution.



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Quasi-static Benchmarks: What is missing?

Need benchmarks for new features

- PyLith features not tested by benchmarks
  - Power-law quasi-static
  - Small strain (have full-scale tests for rigid body motion)
  - Drucker-Prager quasi-static
  - Generalized Maxwell
  - Quasi-static w/friction

- New benchmarks
  - Code comparison based on current benchmarks for new features
    - Strike-slip benchmark w/power-law rheology?
    - Savage-Prescott benchmark w/power-law rheology?
  - Verification w/analytical and semi-analytical solutions