SEAS BP8: Progress Report

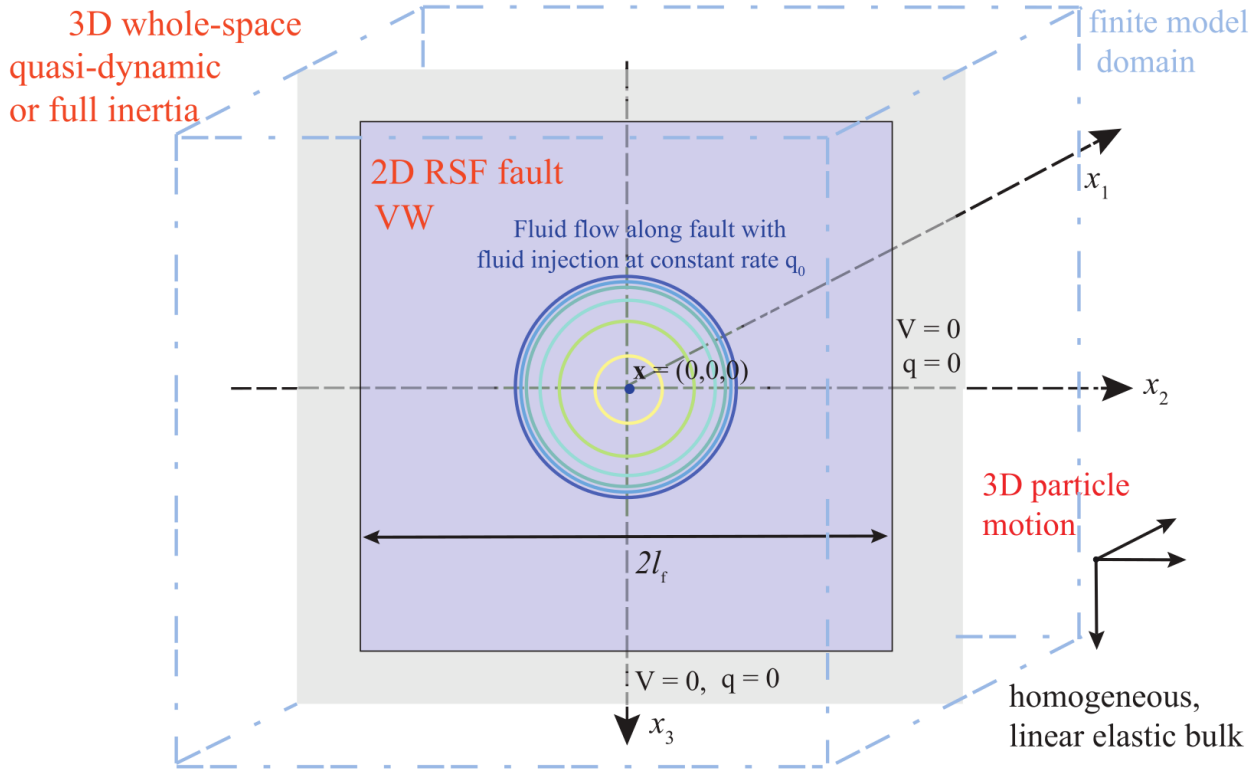
BP8 Problem Description

- 800 m x 800 m fault
- Quasi-dynamic
- Aging law
- a = 0.016, b = 0.010, D_RS = 0.5 mm
- Recommended cell size 10 m

- Diffusivity 0.05 m²/s
- no flux across the fault edges
- Inject for 100 h, simulate for 720 h

Two Versions

- GS: Gaussian-distributed source, Q0 = 0.003 m³/s
- PW: Peaceman well, Q0 = 0.0015 m³/s



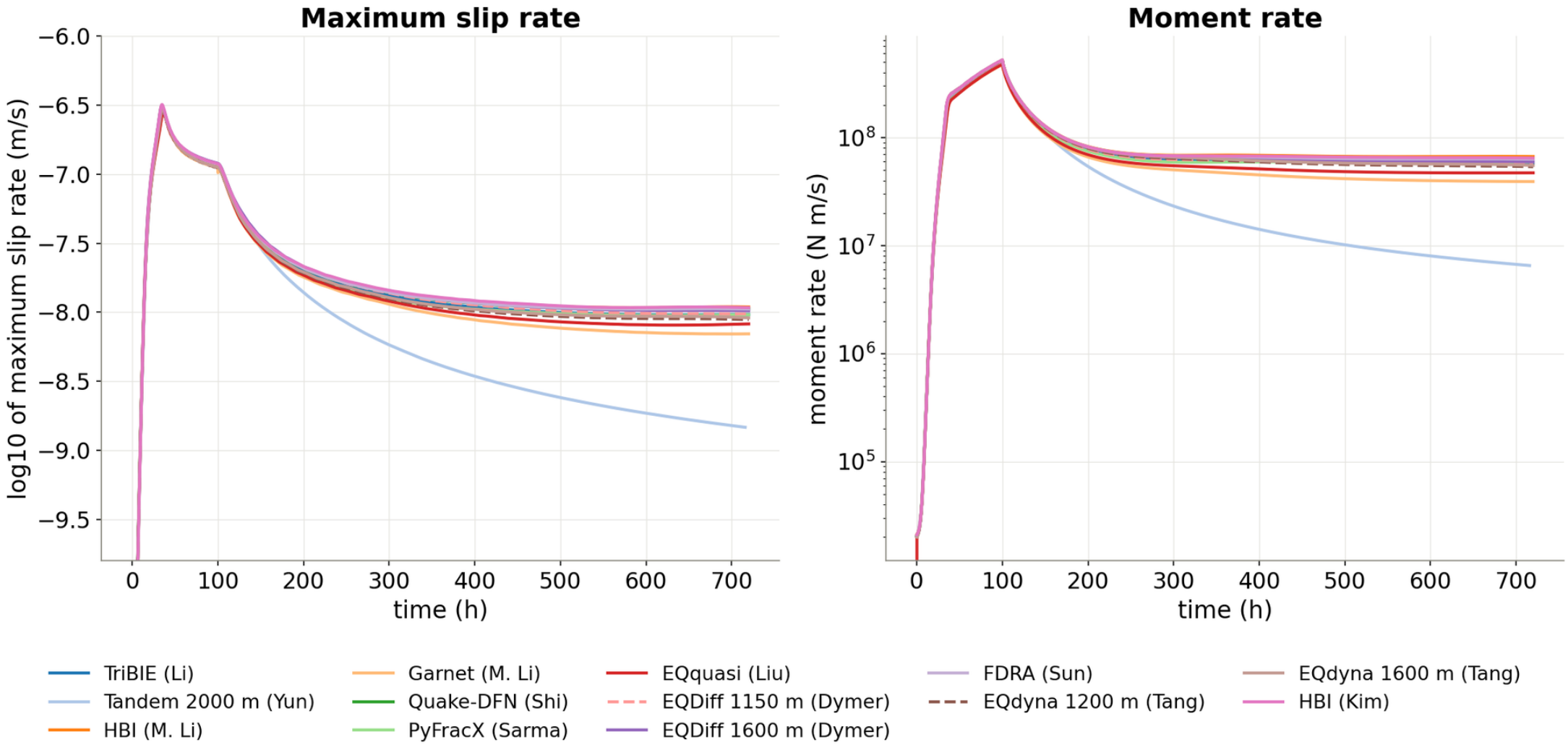
13 Gaussian-source submissions from 10 codes
4 Peaceman well submissions from 4 codes

Code (modeler)	Method	Domain	Rake	BP8-PW
TriBIE (Li)	Boundary	–	free	
HBI (M. Li)	Boundary	–	free	Y
HBI (Kim)	Boundary	–	fixed	Y
PyFracX (Sarma)	Boundary	–	free	Y
Quake-DFN (Shi)	Boundary	–	fixed	
FDRA (Sun)	Boundary	–	fixed	
EQDiff (Dymer)	Volume	1150 m	free	
EQdyna (Tang)	Volume	1200 m	free	
EQDiff (Dymer)	Volume	1600 m	free	
EQdyna (Tang)	Volume	1600 m	free	
Tandem (Yun)	Volume	2000 m	free	
EQquasi (Liu)	Volume	not reported	free	Y
Garnet (M. Li)	Volume	not reported	free	

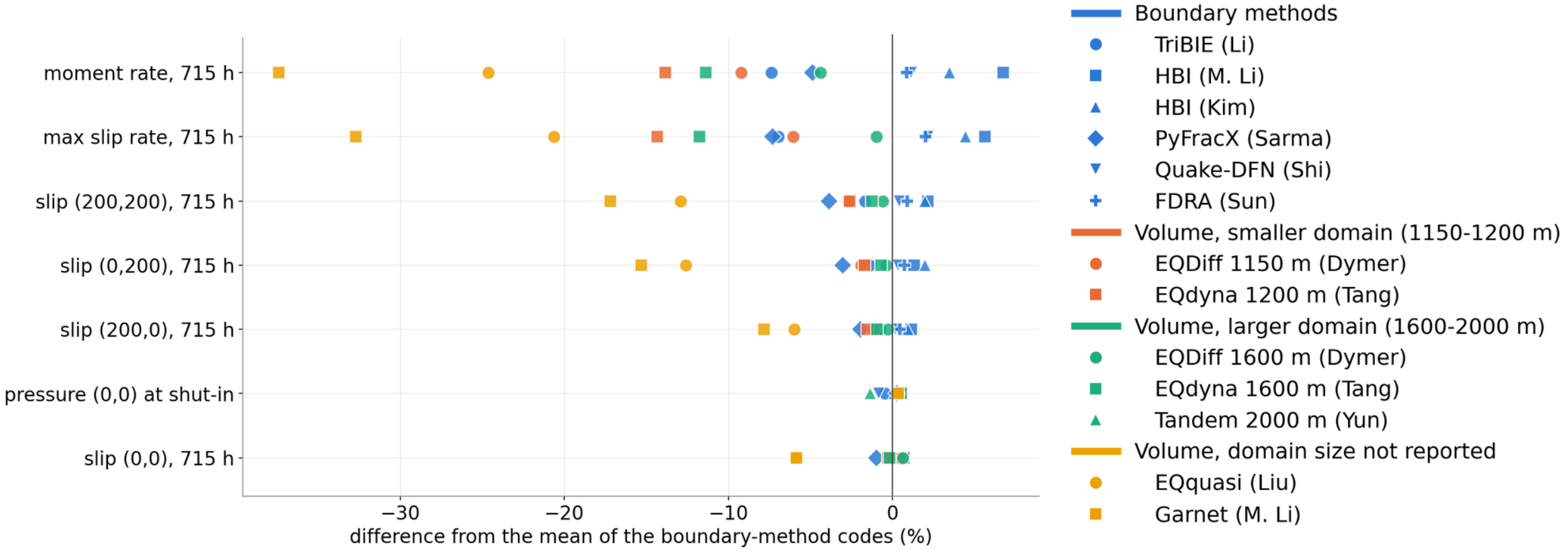
Color groups used in every figure

- Boundary methods (6)
- Volume, smaller domain: 1150–1200 m (2)
- Volume, larger domain: 1600–2000 m (3)
- Volume, domain size not reported (2)

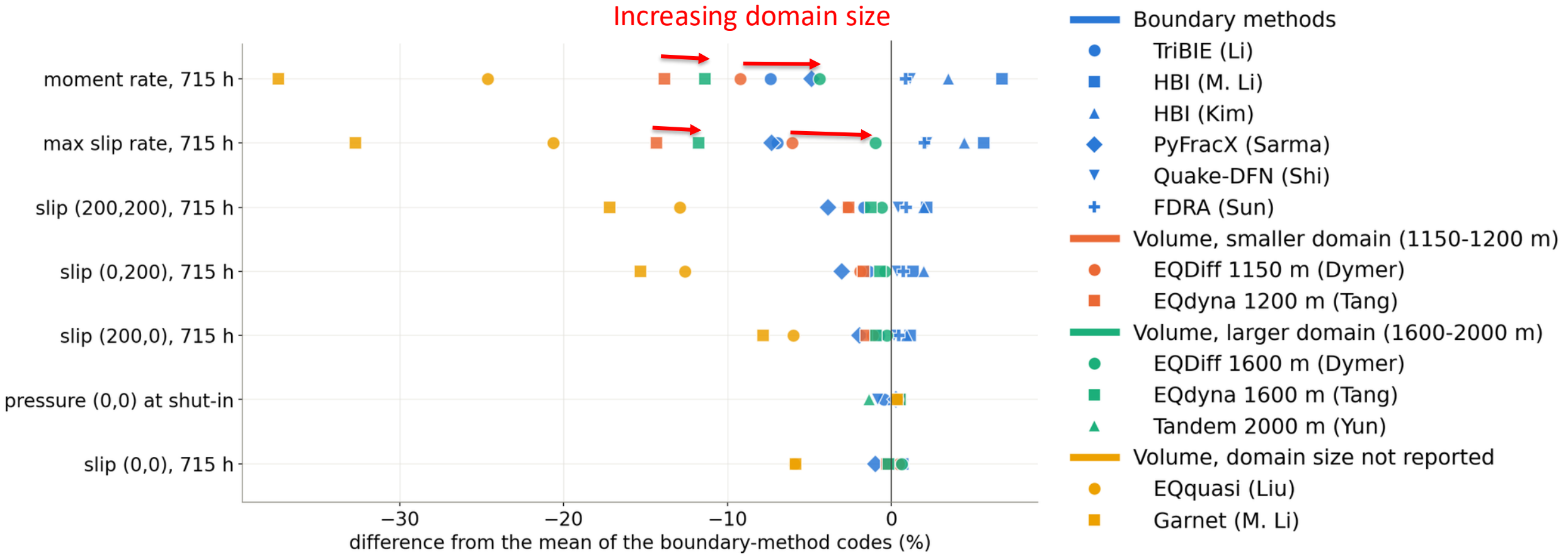
Global Output is Similar Across All Submissions



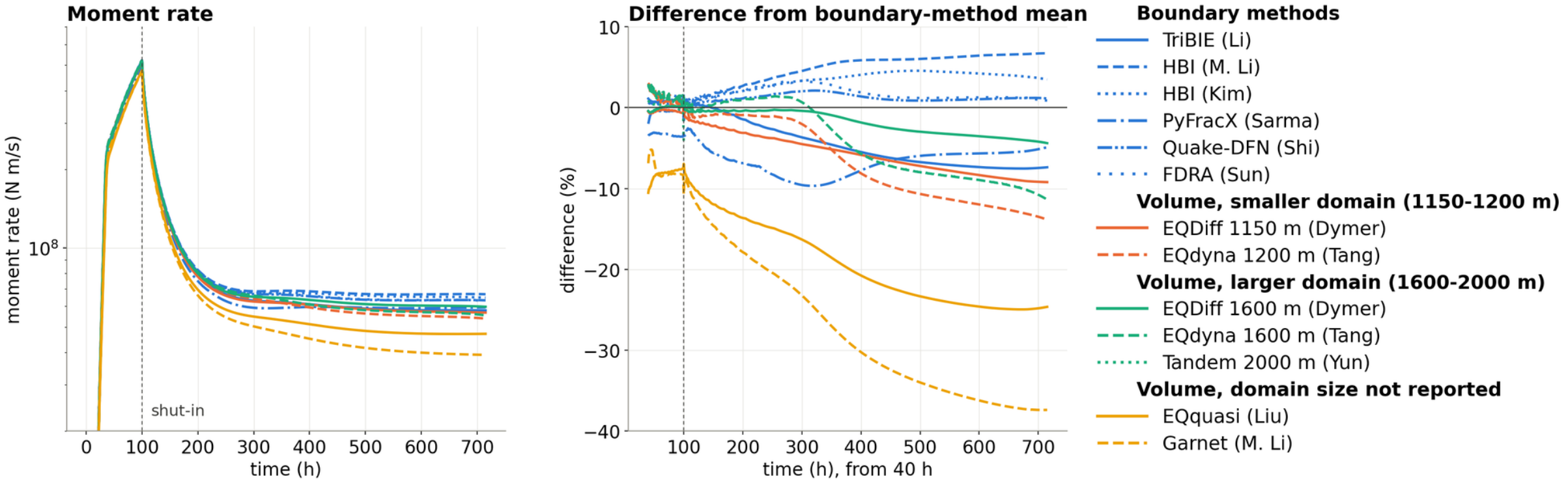
Agreement Decreases with Distance from Source
Disagreement Largest for Moment Rate and Maximum Slip Rate



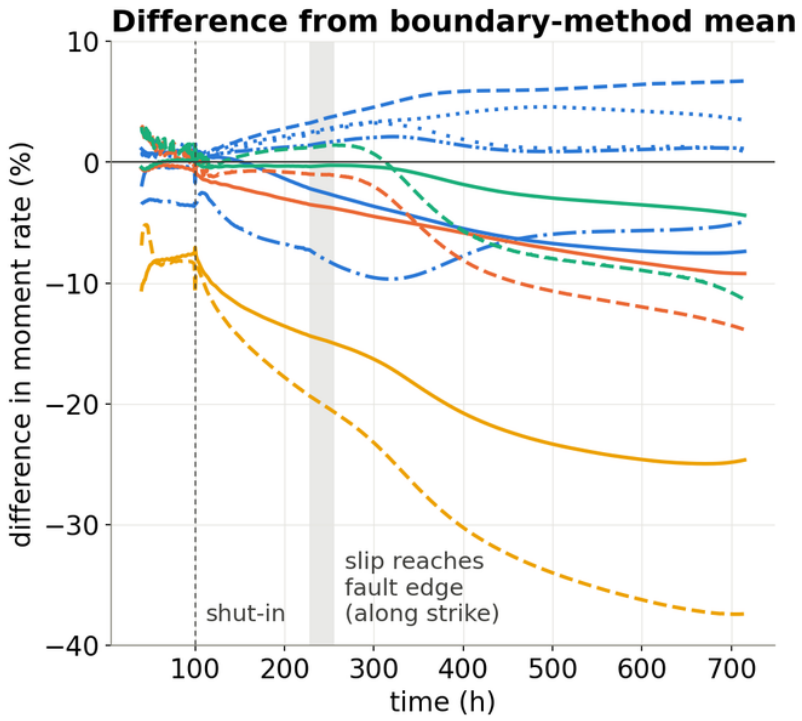
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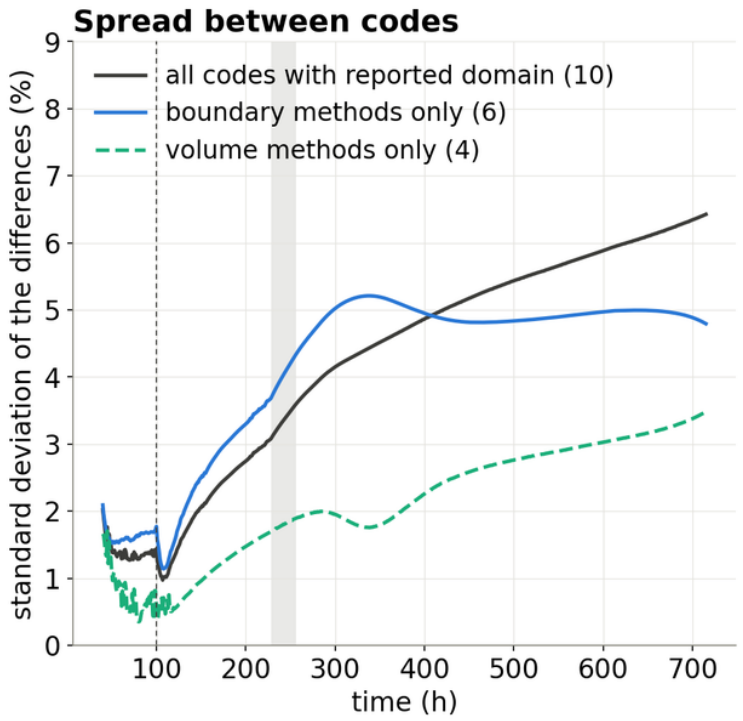


Zoomed-in Comparison of Moment Rate around Shut-in



Simulation Differences Increase after Shut-in





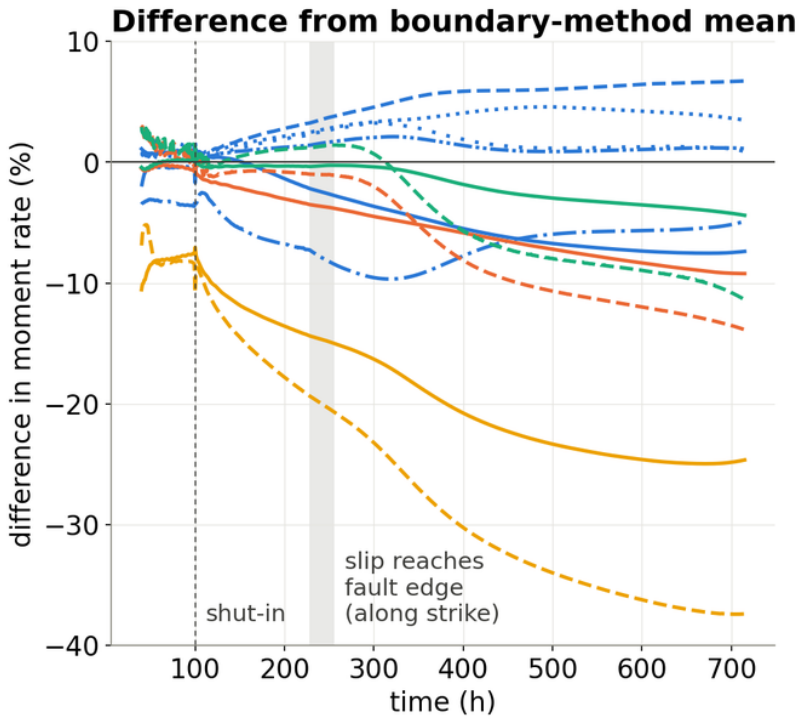
Boundary methods
- TriBIE (Li)
- HBI (M. Li)
- HBI (Kim)
- PyFracX (Sarma)
- Quake-DFN (Shi)
- FDRA (Sun)

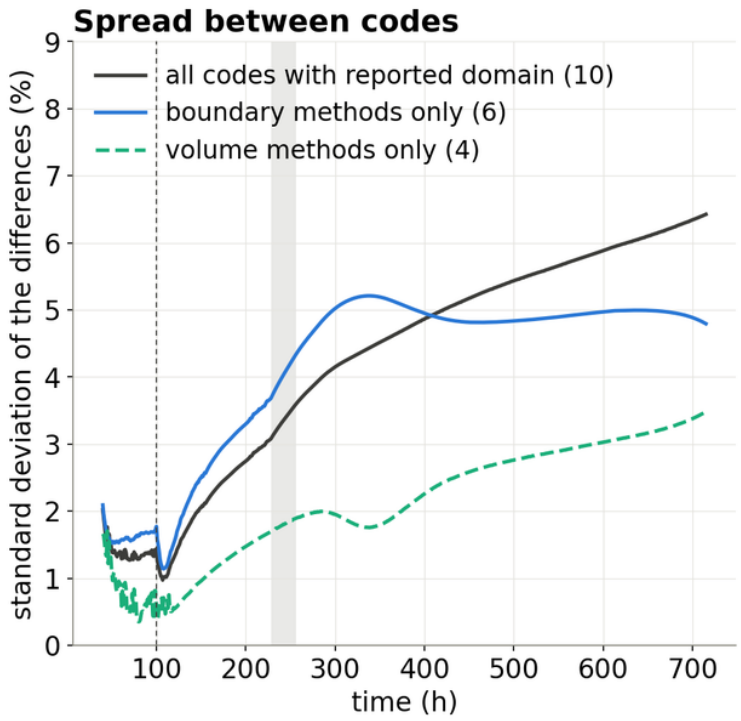
Volume, smaller domain (1150-1200 m)
- EQDiff 1150 m (Dymer)
- EQdyna 1200 m (Tang)

Volume, larger domain (1600-2000 m)
- EQDiff 1600 m (Dymer)
- EQdyna 1600 m (Tang)

Volume, domain size not reported
- EQquasi (Liu)
- Garnet (M. Li)

Simulation Differences Increase after Shut-in





Boundary methods
- TriBIE (Li)
- HBI (M. Li)
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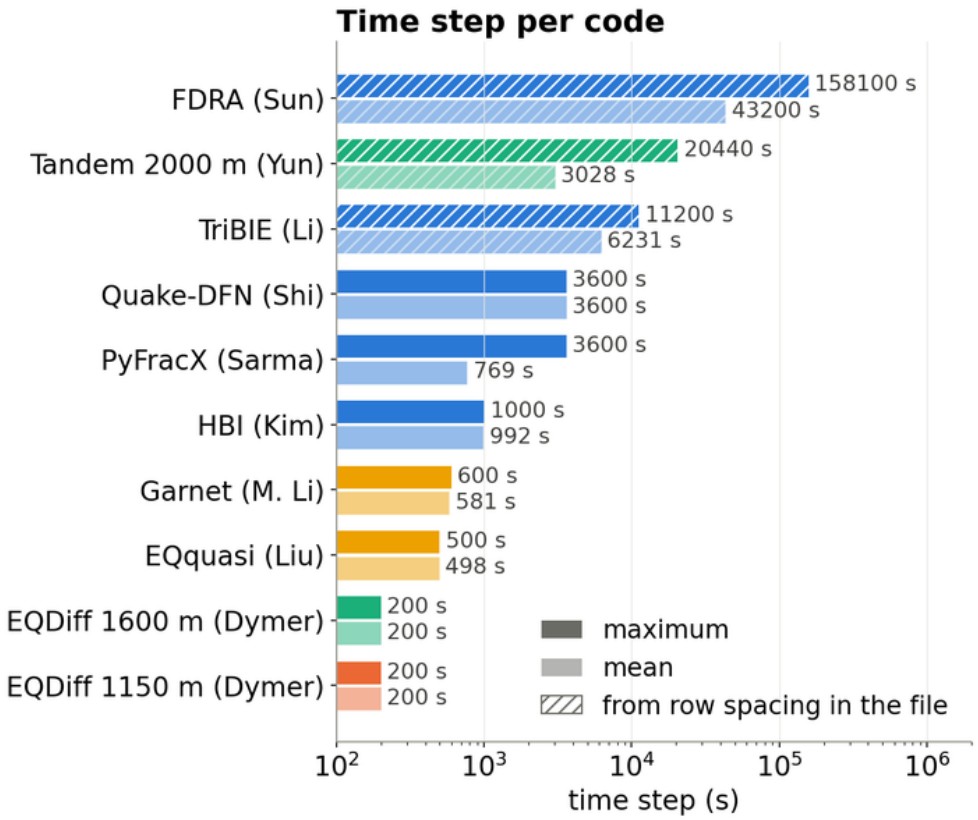
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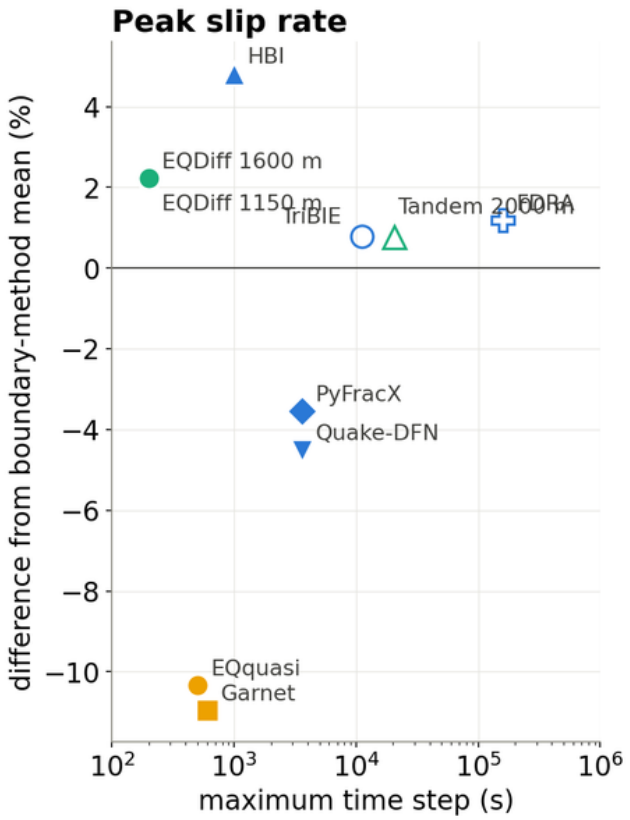
Volume, larger domain (1600-2000 m)
- EQDiff 1600 m (Dymer)
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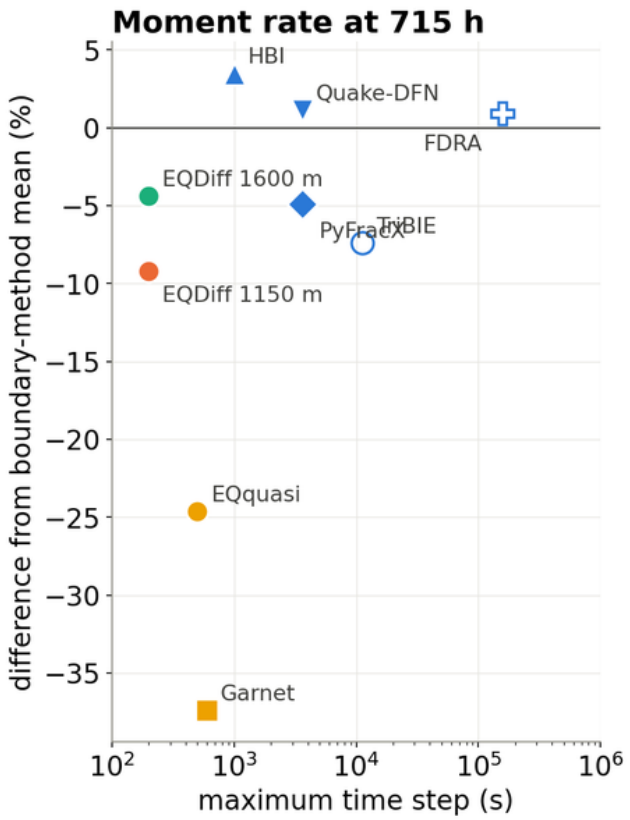
Volume, domain size not reported
- EQquasi (Liu)
- Garnet (M. Li)

Idea: Check volume balance after shut-in? (report mean pressure)

Time-step size doesn't seem to be controlling factor, although no one-to-one comparisons exist

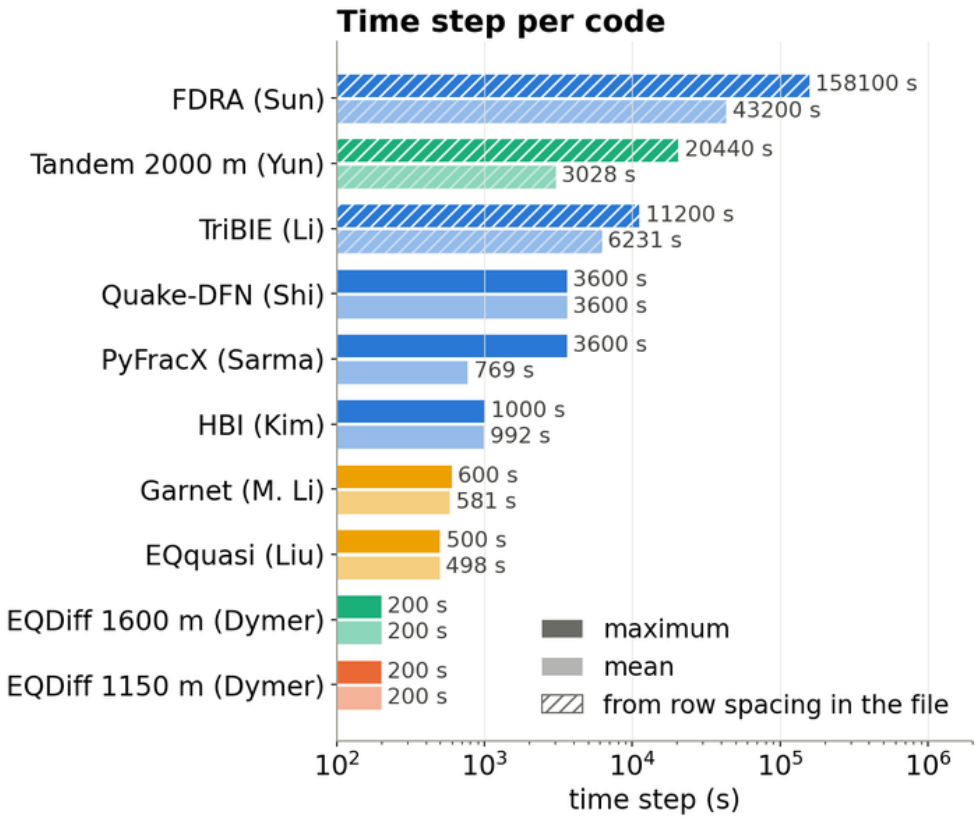






Boundary methods
Volume, smaller domain (1150-1200 m)
Volume, larger domain (1600-2000 m)
Volume, domain size not reported

Time-step size doesn't seem to be controlling factor, although no one-to-one comparisons exist



Community-Driven Code Comparisons for Simulations of Fluid-Induced Aseismic Slip

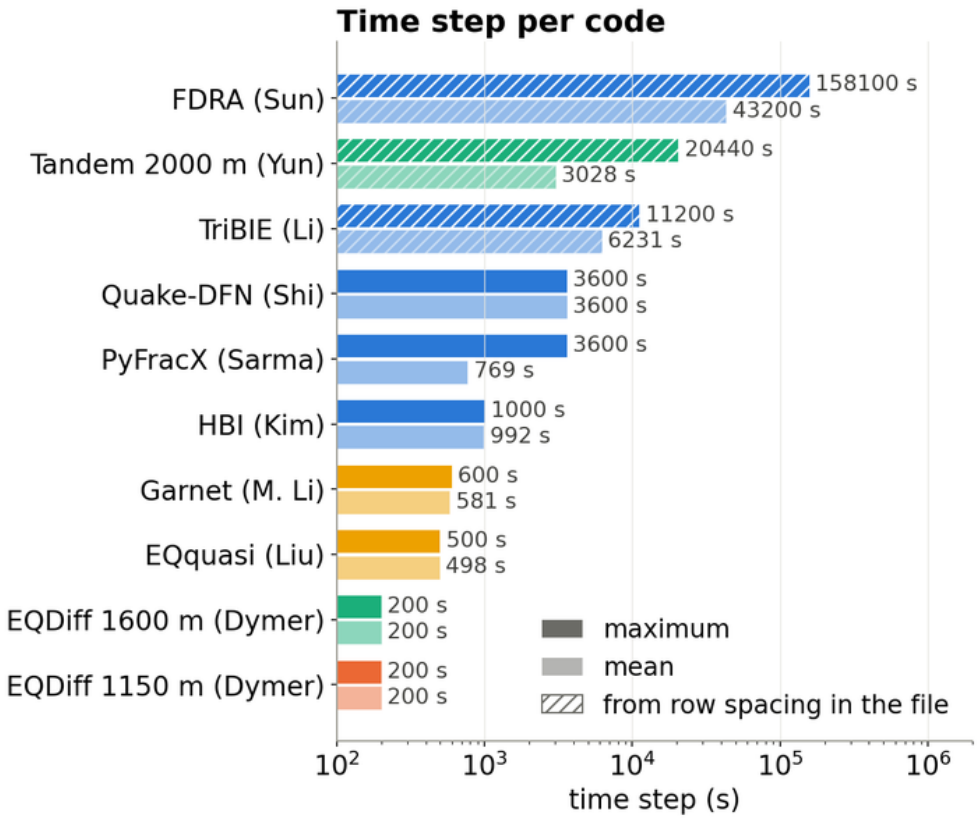
Valère R. Lambert[1], Brittany A. Erickson[2], Junle Jiang[3], Eric M. Dunham[4], Taeho Kim[5], Jean-Paul Ampuero[6], Ryosuke Ando[7], Frédéric Cappa[6], Pierre Dublanchet[8], Ahmed Elbanna[9], Yuri Fialko[10], Alice-Agnes Gabriel[10,11], Nadia Lapusta[5], Meng Li[12], Jasper Marcum[2], David May[10], Md Shumon Mia[9,13], So Ozawa[4], Casper Pranger[11], Pierre Romanet[6,14], Marco M. Scuderi[14], Ylona van Dinther[12], Yuyun Yang[15,16], and Jeena Yun[10]

Recommended maximum time step size

$$\Delta t_{\max} \leq \Lambda^2/\alpha$$

~ 32 hours (115,000 seconds)

Time-step size doesn't seem to be controlling factor, although no one-to-one comparisons exist



Community-Driven Code Comparisons for Simulations of Fluid-Induced Aseismic Slip

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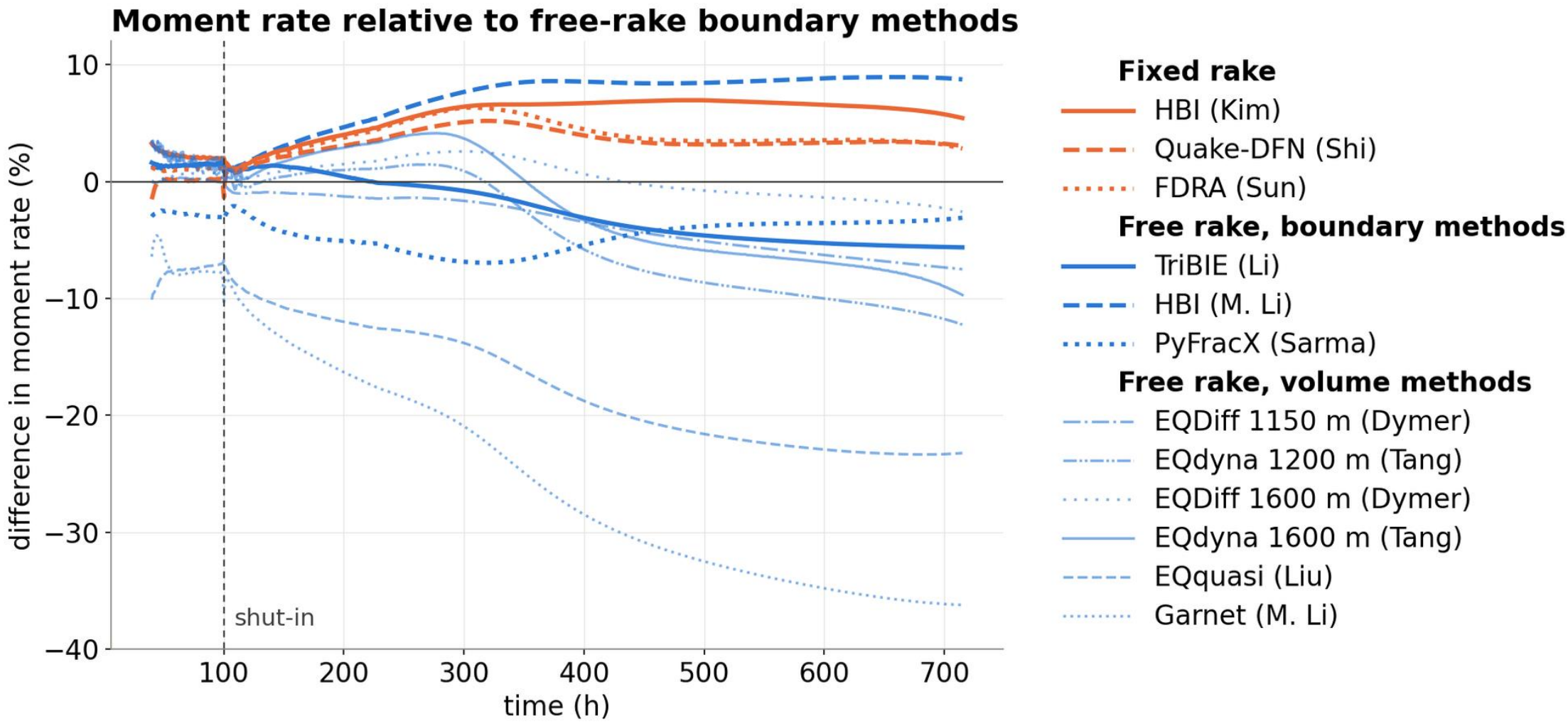
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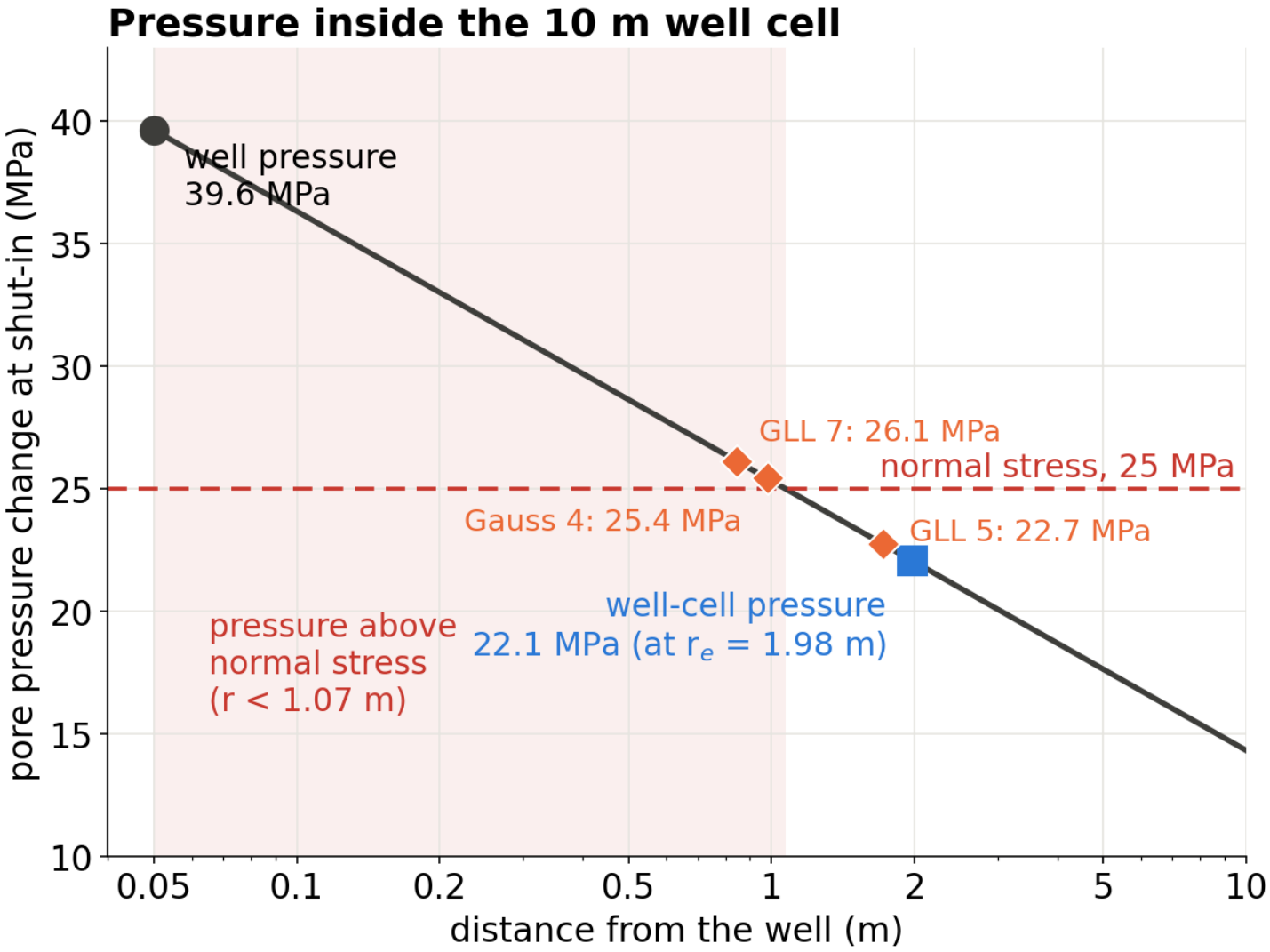
~ 32 hours (115,000 seconds)

Idea: Second submission with smaller maximum time steps

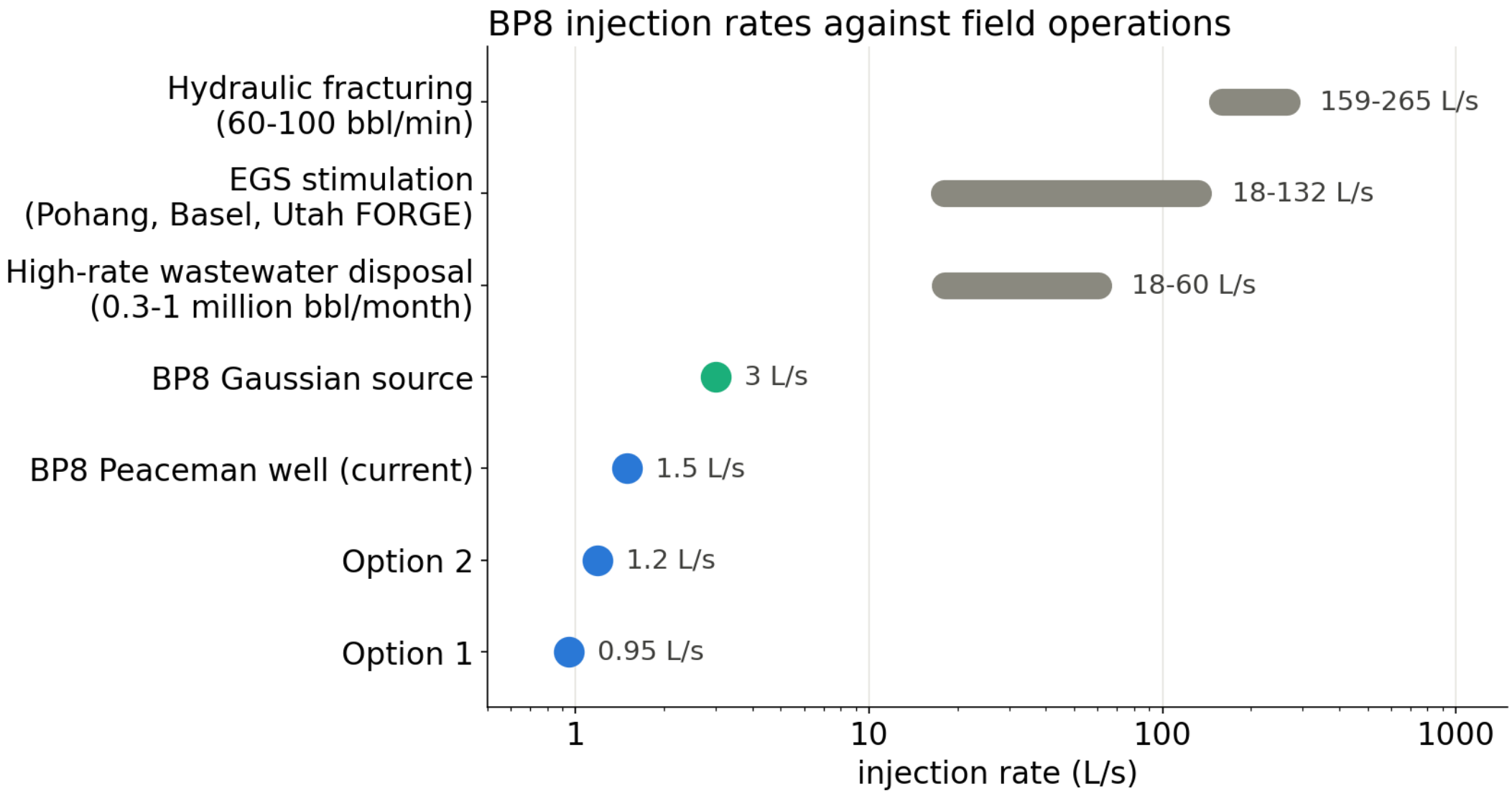
No systematic effect of accounting for rake on cumulative moment rate



Challenges with Peaceman well: Resolving High Well Cell Pressure



Keeping Injection Rates Realistic with Peaceman Well Model



Verifying the Peaceman well with a manufactured solution

1 **Choose the target pressure field**

$p(r, t) = (Q_f \eta / 4\pi kL) \cdot E_1(r^2 / 4\alpha t)$

Point source of strength Q_f; add image sources for the closed fault.

2 **Compute the flux through the well radius**

$Q_{wf}(t) = -2\pi\, r_w\, L\, (k/\eta)\, \partial p/\partial r = Q_f \cdot \exp(-r_w^2 / 4\alpha t)$

3 **Solve for the injection rate, with well storage**

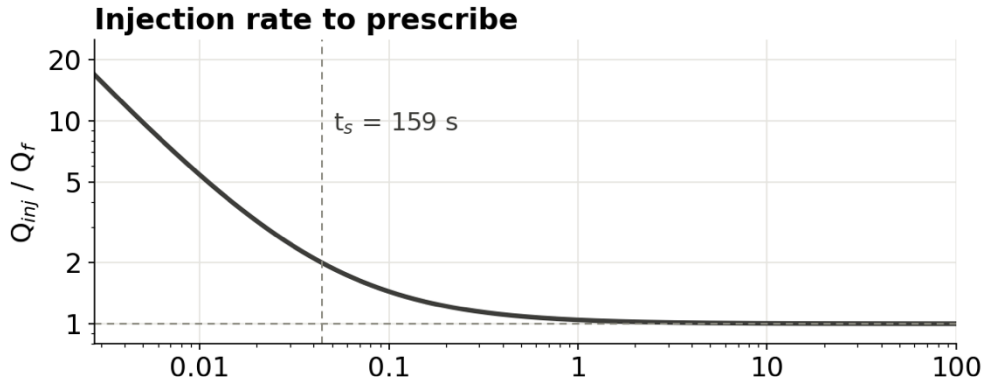
$p_{well}(t) = p(r_w, t)$

$Q_{inj}(t) = Q_{wf} + S_{well}\, dp_{well}/dt = Q_f \cdot \exp(-r_w^2 / 4\alpha t) \cdot (1 + t_s/t)$

$t_s = S_{well}\, \eta / 4\pi kL = 159$ s for the benchmark parameters.

4 **Run with $Q_{inj}(t)$ and compare with the target**

well → $p(r_w, t)$ well cell → $p(r_e, t)$ other cells → $p(r, t)$



Conclusions

Gaussian Source

- Biggest differences between solutions for Gaussian source (GS) are cumulative moment rate and maximum slip rate.
- Increasing domain size in volume-based code increases consistency with boundary element methods. Volume-based codes produce consistently lower moment rates.
- Simulation differences across all methods increase after shut-in. **Suggest submitting with mean pressure to check mass balance after shut-in.** Differences rise again after slip reaches boundaries.
- Maximum time steps are mostly below recommended size from BP6 results.
- Accounting for rake has minimal effect on moment rate calculations.

Peaceman Well

- High well cell pressure likely pushes codes into fault opening regimes with pressures higher than normal stress.
- Method of manufactured solutions provides a way to check implementation.