CRESCENT Tsunami Benchmark (TTPV1 and TTPV2):

3D fully coupled earthquake dynamic rupture and tsunami benchmarks with varying bathymetric complexity

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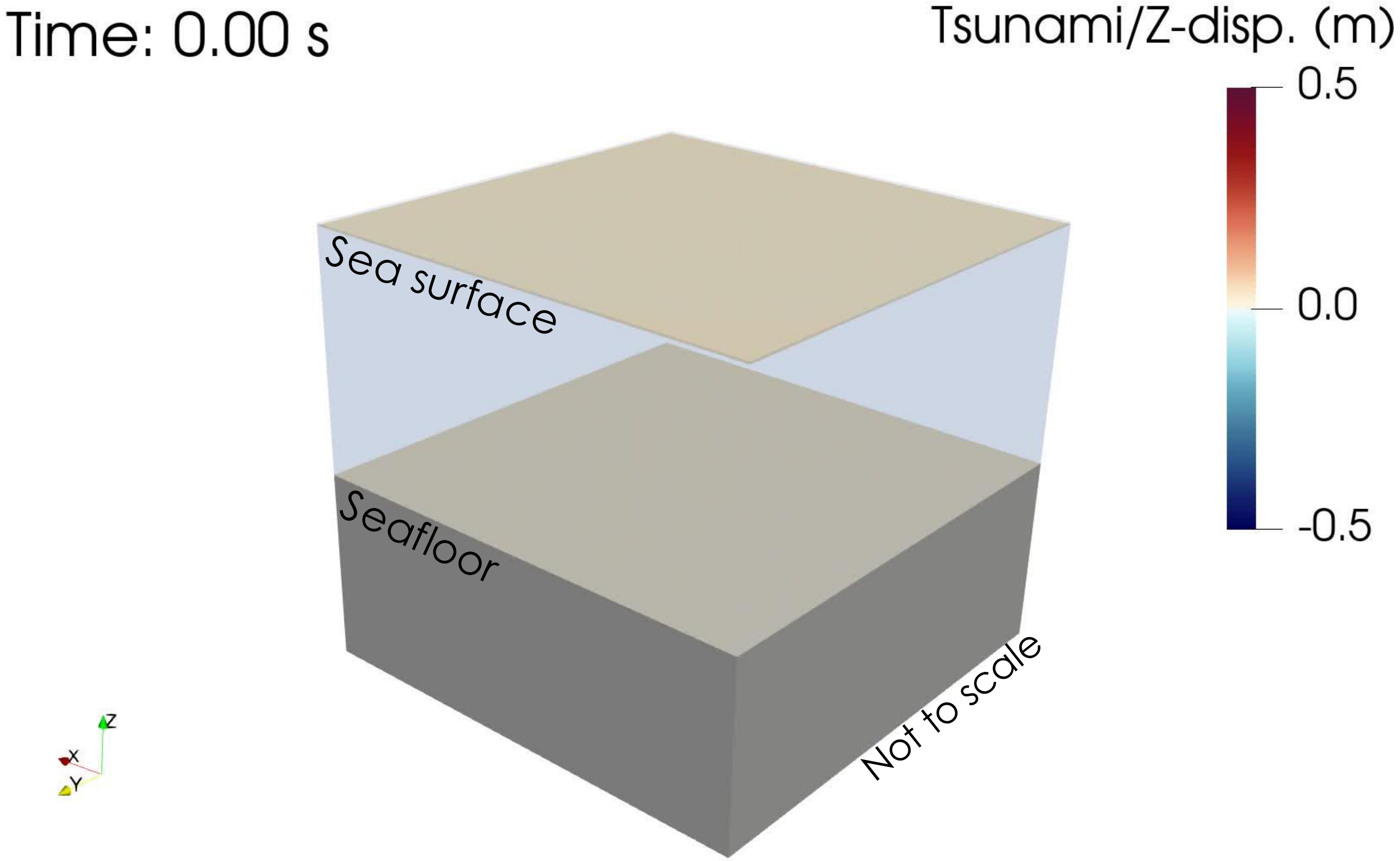
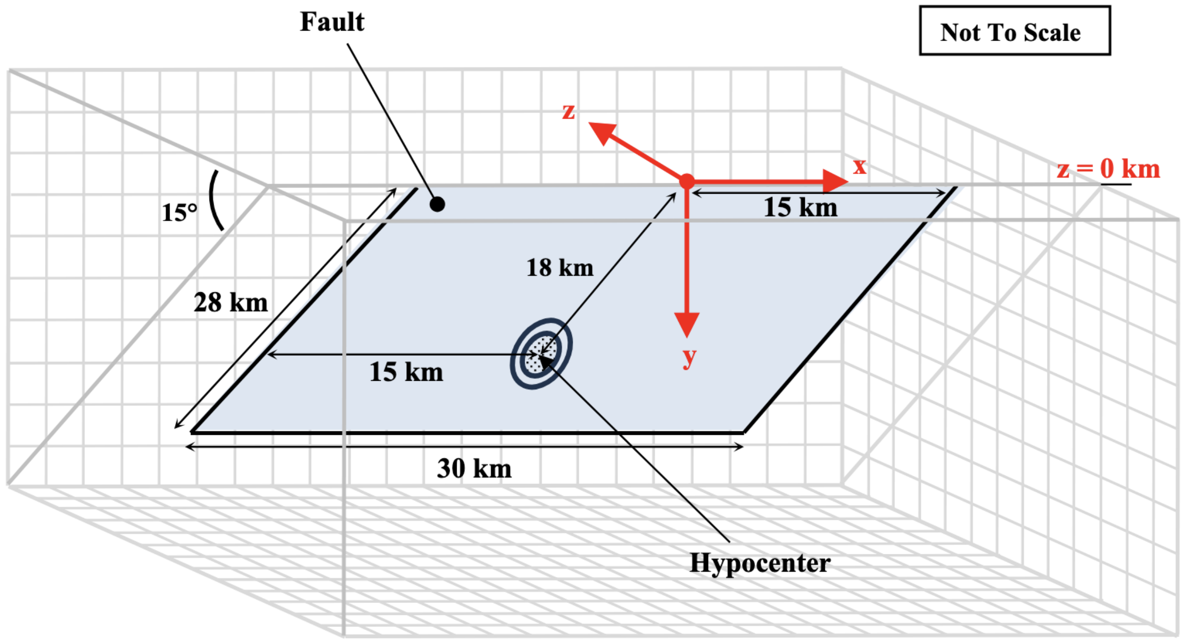


The Tsunami Problem Version 1 (TTPV1)

As model complexity increases, we need community benchmark exercises

The Problem Version 36 (TPV36; Harris et al., 2018)



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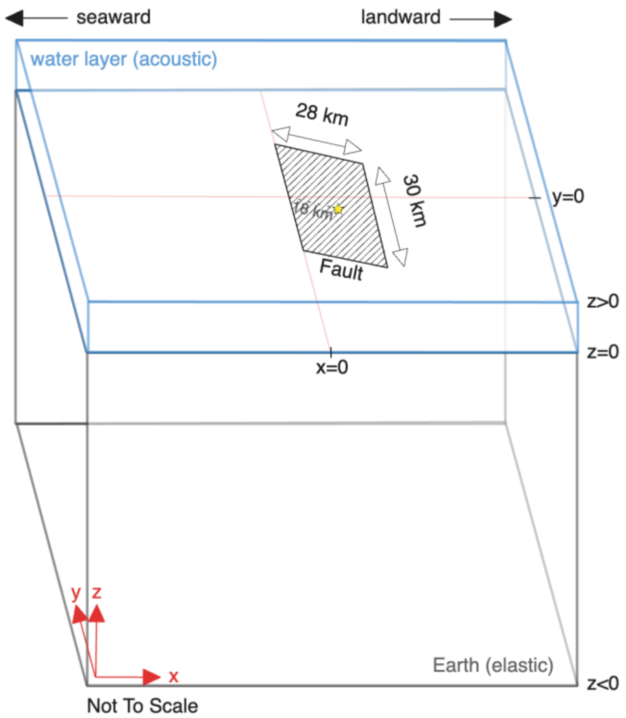
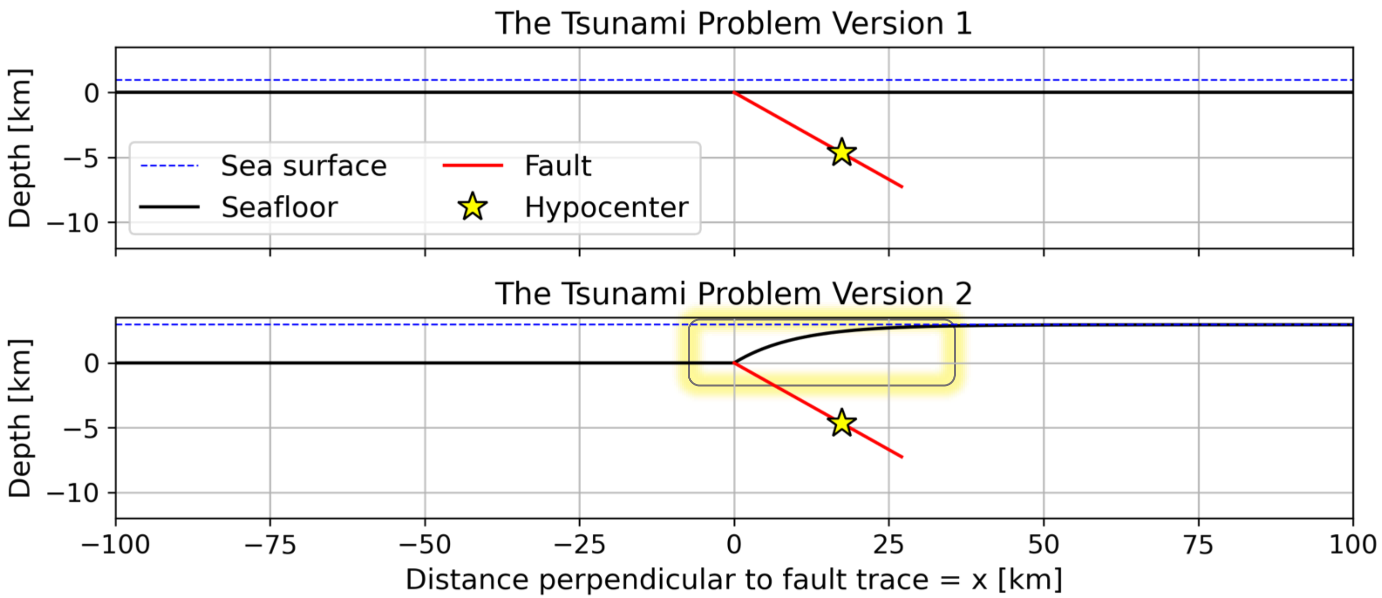


- Spontaneous 3D earthquake **dynamic rupture** on a 15° dipping thrust fault reaching the Earth's surface
- Rectangular planar fault measures 30 km along-strike and 28 km down-dip

- The **fully coupled** method combines earthquake dynamic rupture and tsunami generation into a **single simulation**
- We can capture 3D elastic, acoustic, and tsunami waves, including dispersion effects, **simultaneously** (e.g., Lotto & Dunham, 2015)

As model complexity increases, we need community benchmark exercises

Side view:



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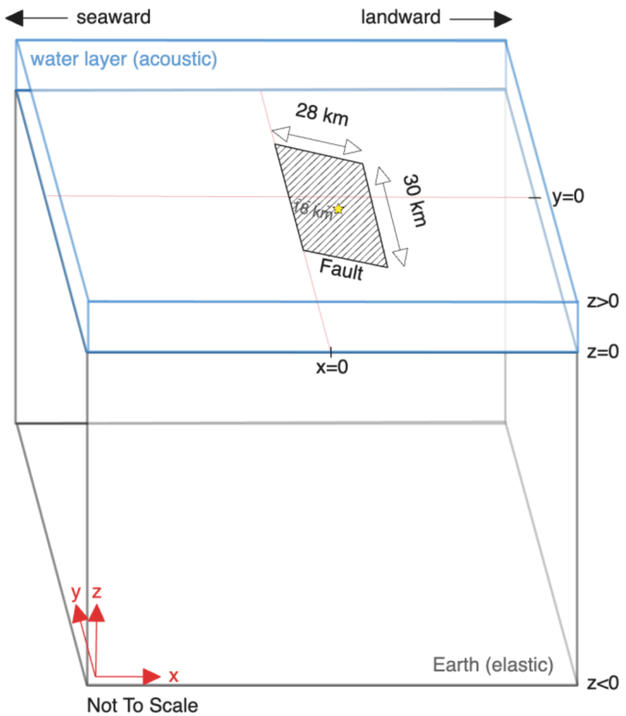
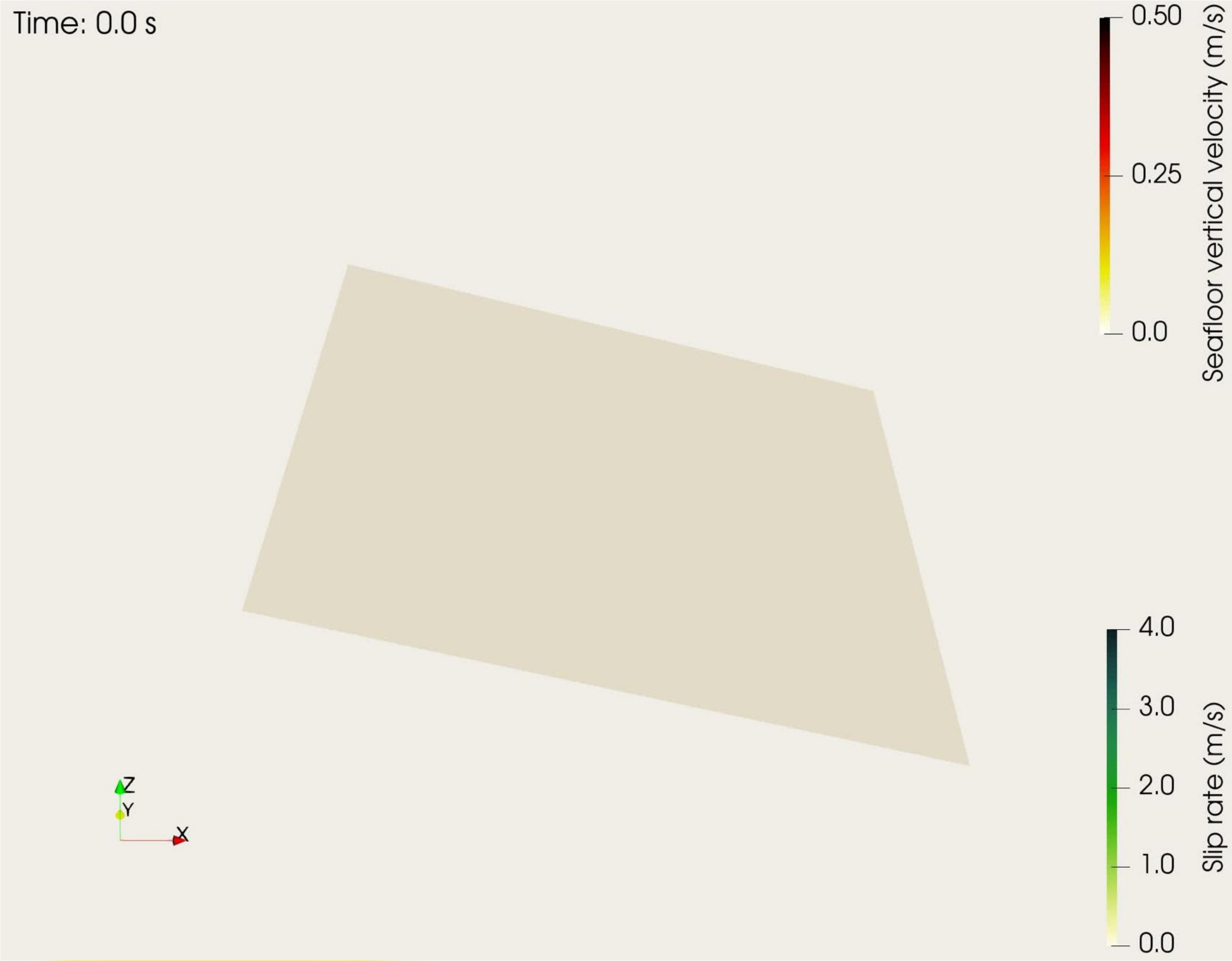


- In TTPV1, a 1 km thick uniform water layer is added atop the elastic medium
- A water layer with variable depth is atop the elastic Earth, with 3 km water depth on the seaward side, sloping to shallow depth (~50 m) landwards

- The **fully coupled** method combines earthquake dynamic rupture and tsunami generation into a **single simulation**
- We can capture 3D elastic, acoustic, and tsunami waves, including dispersion effects, **simultaneously** (e.g., Lotto & Dunham, 2015)

Spontaneous earthquake dynamic rupture



- Simulation of a M_W 7.1 earthquake with a peak fault slip of 3.4 m to test modeling capabilities
- Linear slip-weakening friction law with cohesion
- Initial normal stress and the initial shear stress are proportional to distance down-dip
- Simulation time of 4 minutes

Movie: First 30 s of spontaneous dynamic rupture with the seafloor vertical velocity for TTPV1

TTPV1: Comparison of the final seafloor displacement

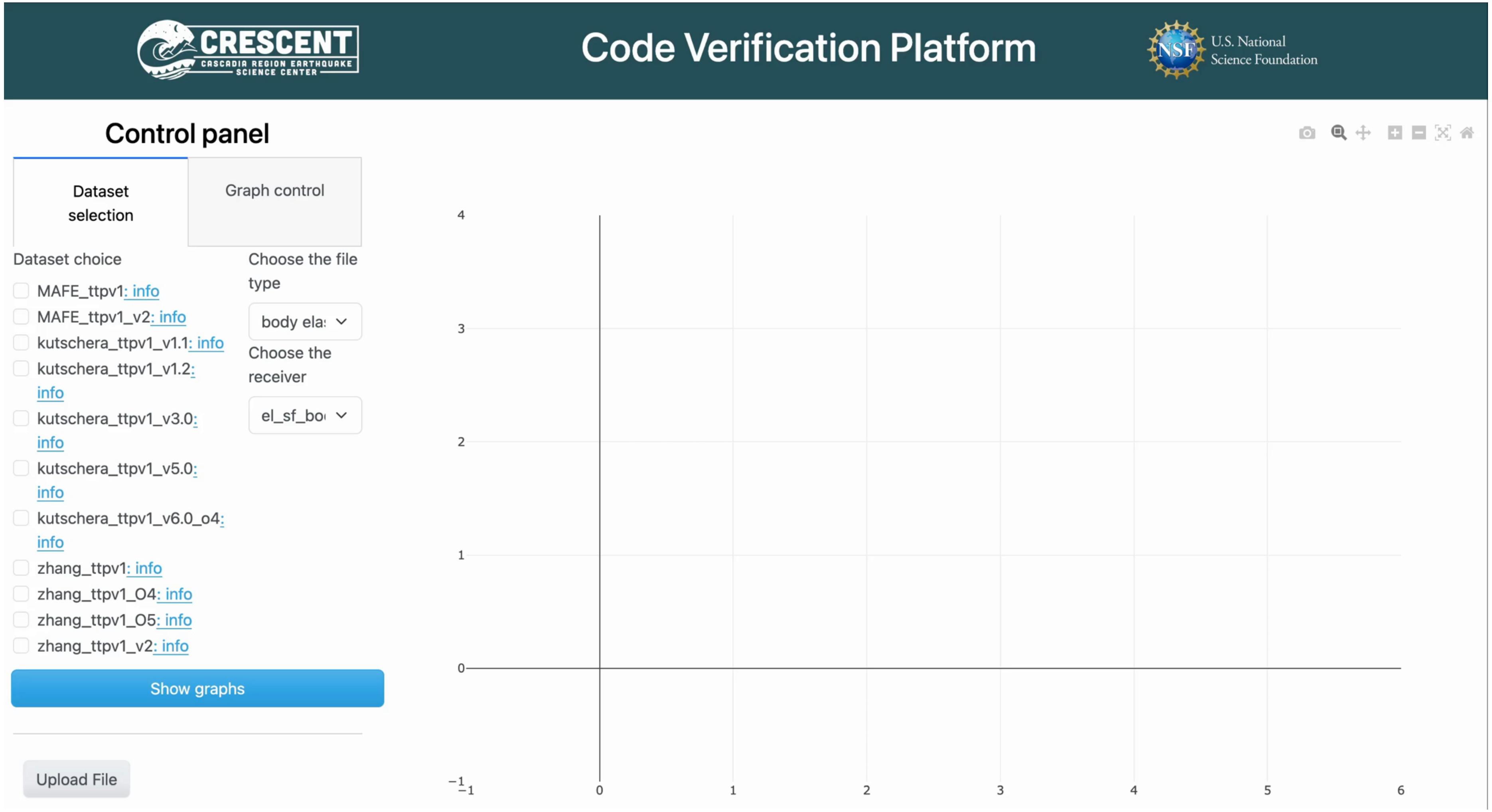
TTPV1 & 2 BENCHMARK DESCRIPTION

UPLOAD YOUR RESULTS

TTPV1 RESULTS

TTPV2 RESULTS

- Visualization based on the new code verification platform (https://cascadiaquakes.org/det)




Loïc Bachelot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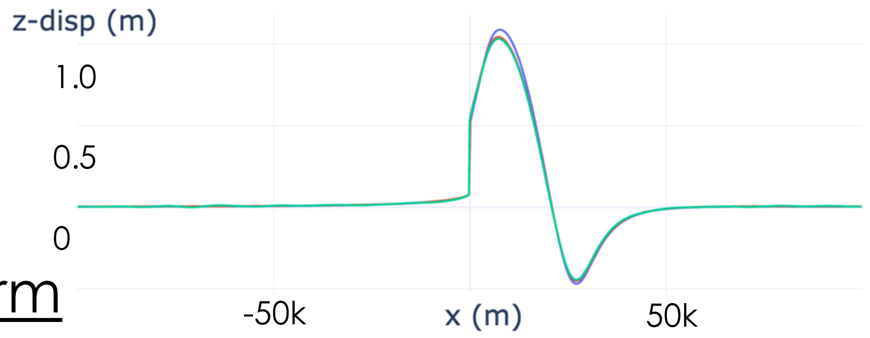
William Marfo

TTPV1: Comparison of the final seafloor displacement

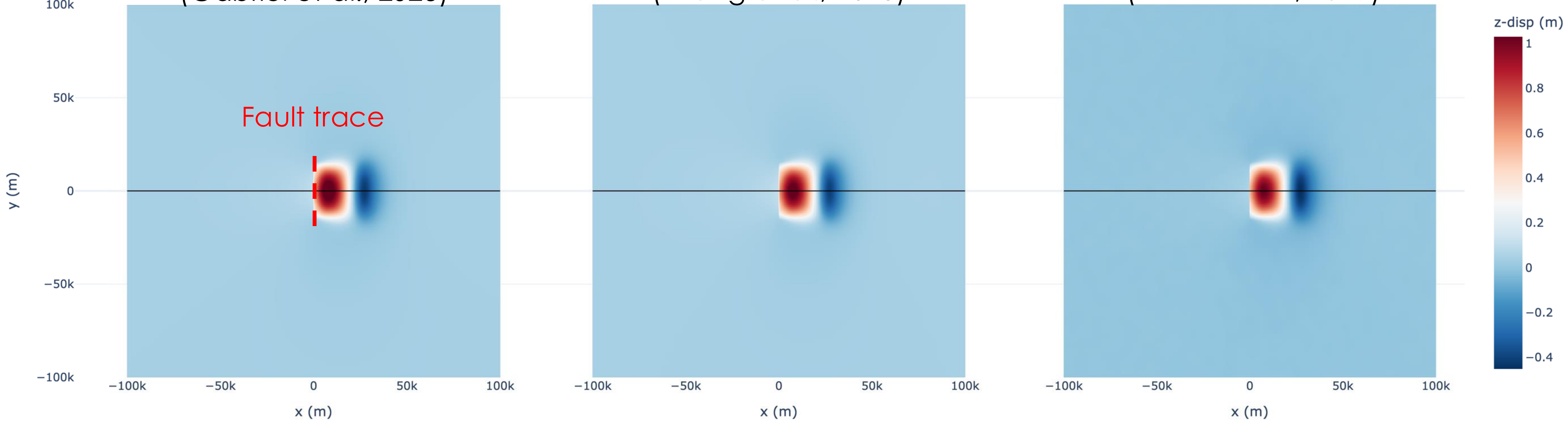


- Visualization based on the <u>new code verification platform</u>

SeisSol: arbitrary high-order derivatives discontinuous Galerkin finite element method (Gabriel et al., 2025)

drdg3d: mixed-flux-based discontinuous Galerkin finite element method (Zhang et al., 2023)

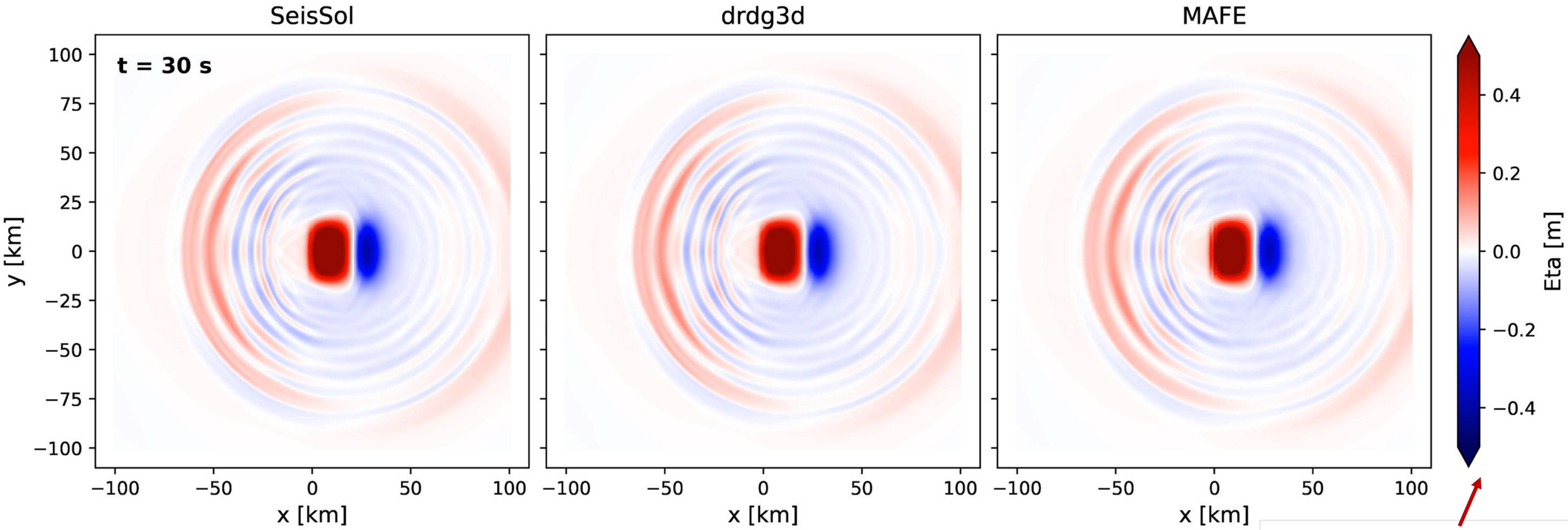
MAFE: velocity-stress-based finite element method with linear tetrahedral elements (Ma and Nie, 2019)



- Distribution of spatial seafloor displacement in good agreement, with peak uplift of 1.05 ± 0.02 m, and peak subsidence of -0.45 ± 0.01 m

TTPV1: Comparison of the time-dependent tsunami generation on the sea surface

- All simulations include transient seismo-acoustic waves (visible at 30 s)

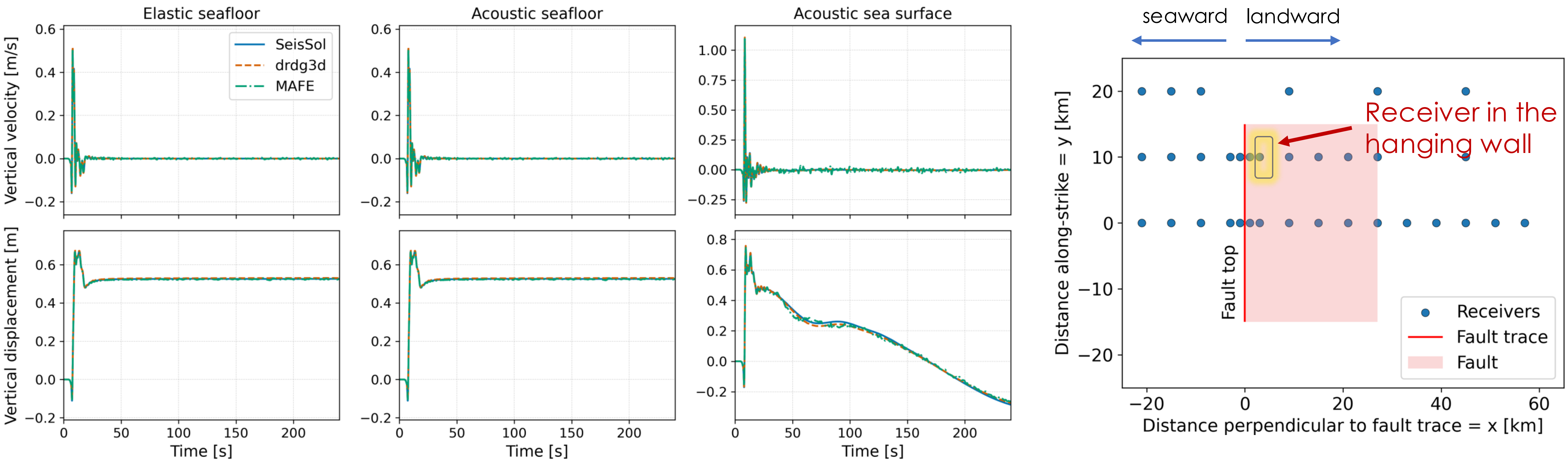


Eta = vertical displacement of the **sea surface** (tsunami + seismo-acoustic waves)

- Key features of the tsunami generation are in good agreement

TTPV1: Comparison of the receiver time-series

- Three-component velocities and displacements over time (elastic & acoustic)



TTPV1: Comparison of the receiver time-series

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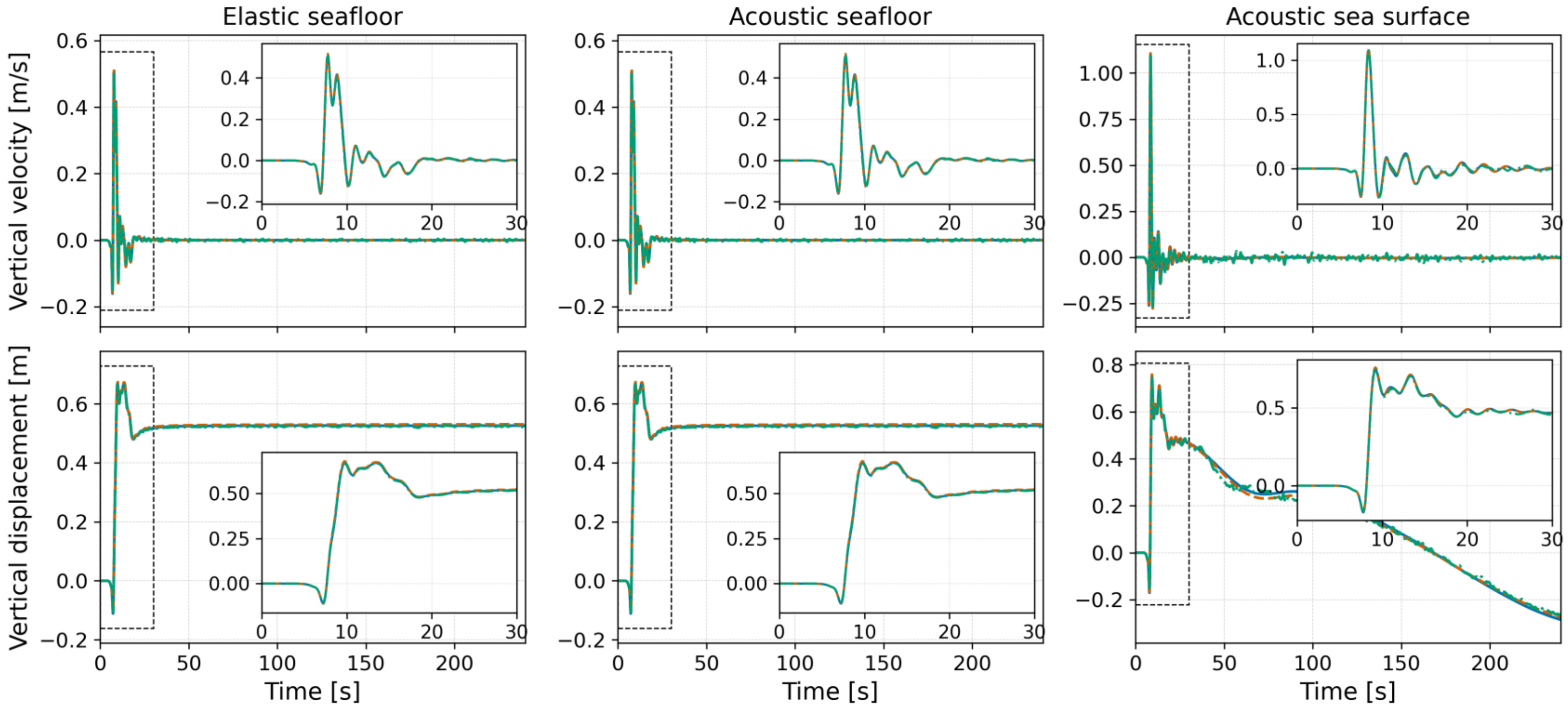
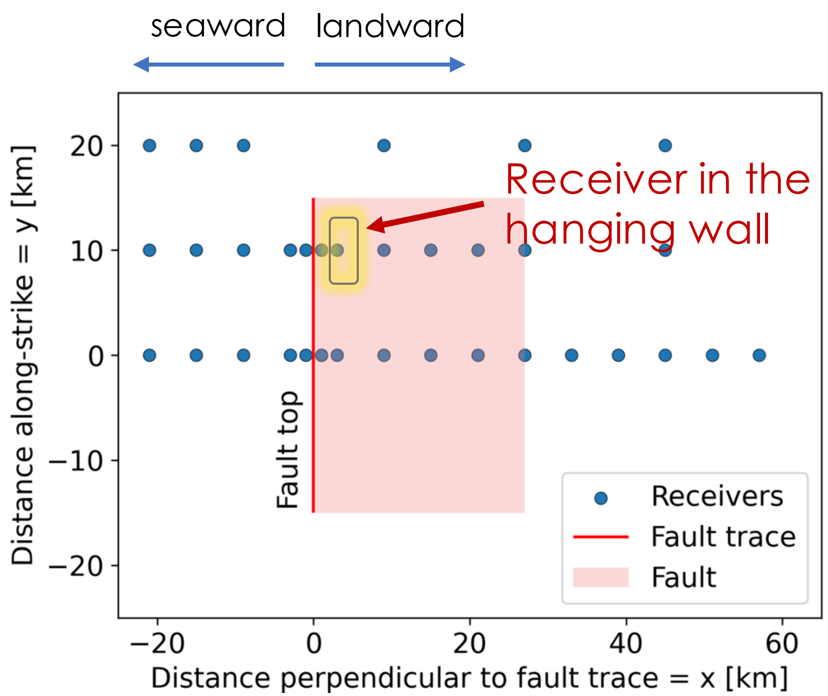


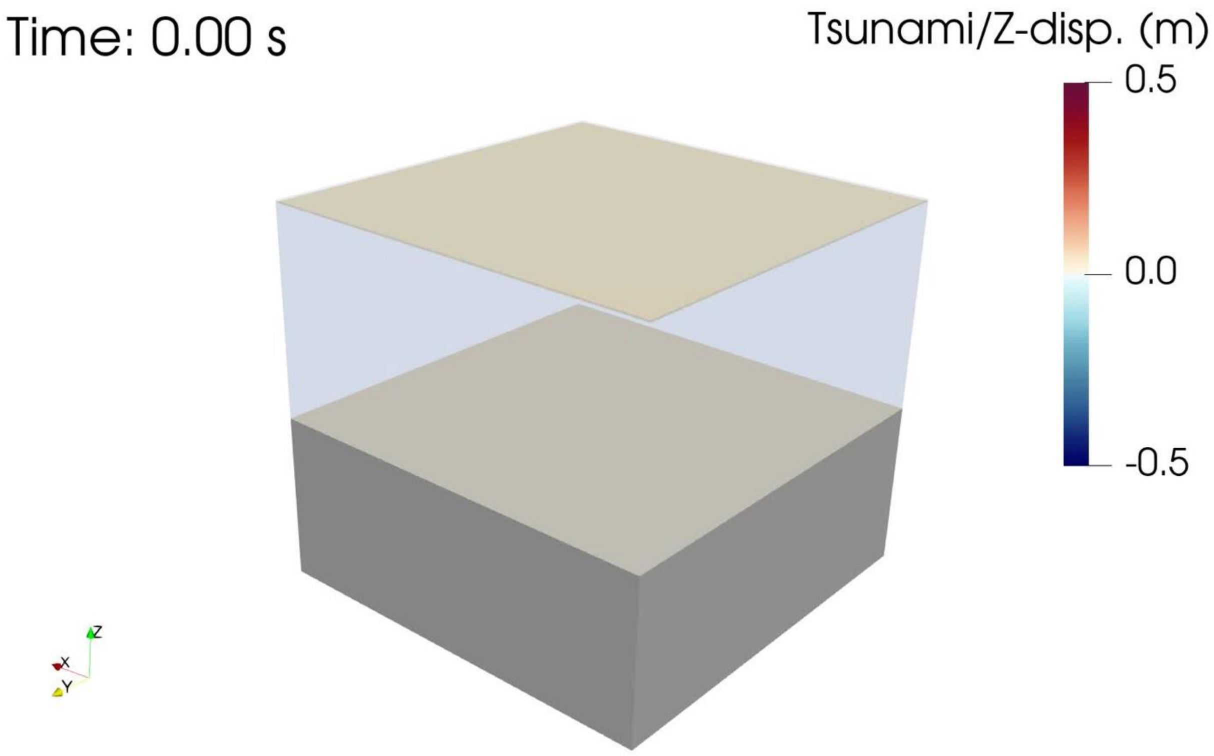


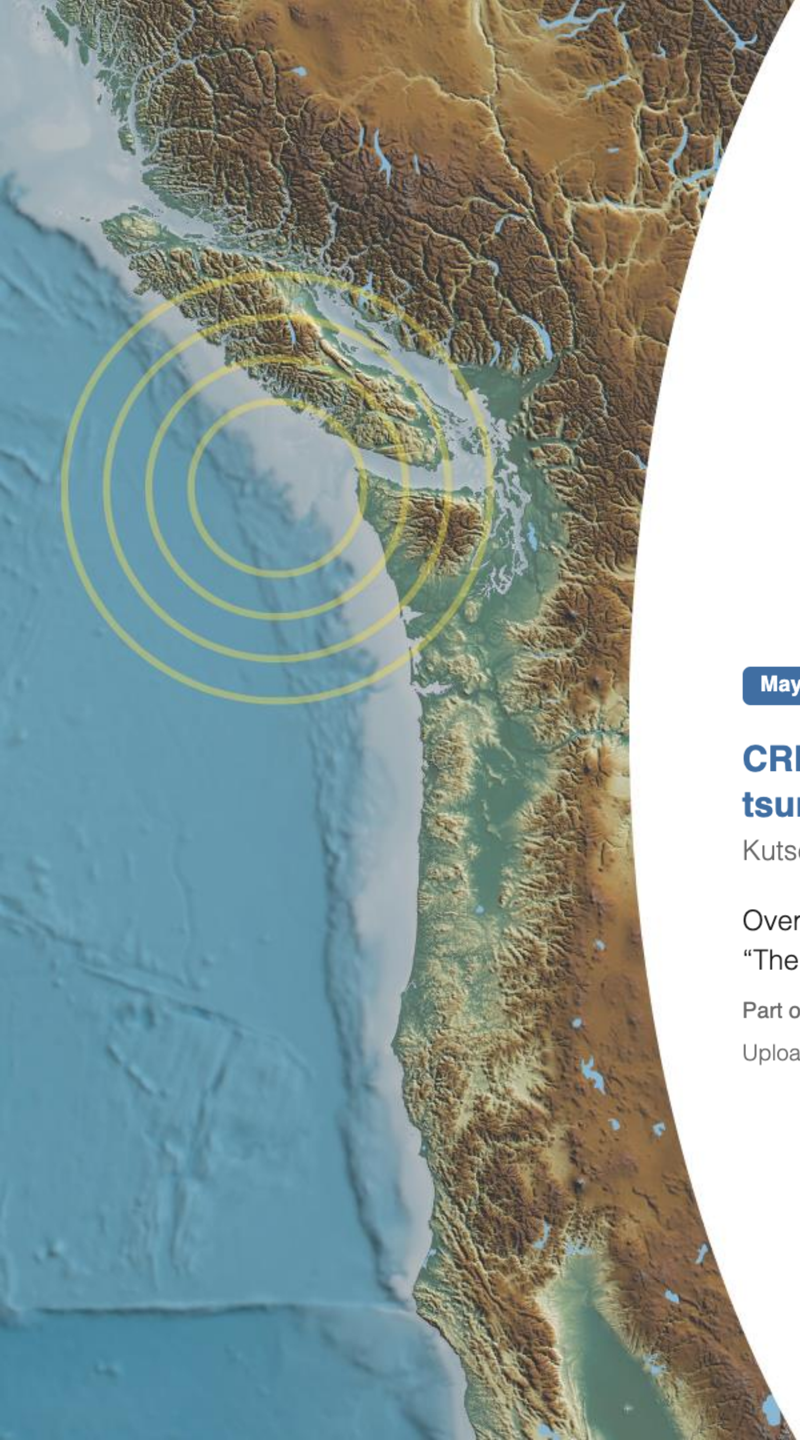
- Great agreement of the initial generation phase (first 30 s), clean of any numerical noise

Conclusions and outlook

Benchmark description: https://doi.org/10.5281/zenodo.15389414

- **3 codes were verified in 2 benchmarks** to model 3D fully coupled earthquake dynamic rupture and tsunami generation
- Good agreement of key features in the initial tsunami generation for both TTPV1 & TTPV2
- Differences in elastic-acoustic boundary condition implementations may affect horizontal synthetics
- Size matters → sufficiently large domain size is required for the benchmarks
- Future work:
    - Extend earthquake-tsunami benchmarks to numerical codes capable of simulating prolonged tsunami propagation
    - Incorporate additional complexity (off-fault plasticity, realistic bathymetry, etc.)





Backup

May 12, 2025 (v1) Other Open

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Kutschera, Fabian; Gabriel, Alice-Agnes; Dunham, Eric M.

OverviewThe two joint CRESCENT & SCEC/USGS benchmark problems TTPV1 and TTPV2 extend the SCEC/USGS dynamic rupture benchmark “The Problem Version 36” (TPV36, https://strike.scec.org/cvws/download/TPV36_37_Description_v12.pdf; last access May 12, 2025), a 3D…

Part of Cascadia Region Earthquake Science Center

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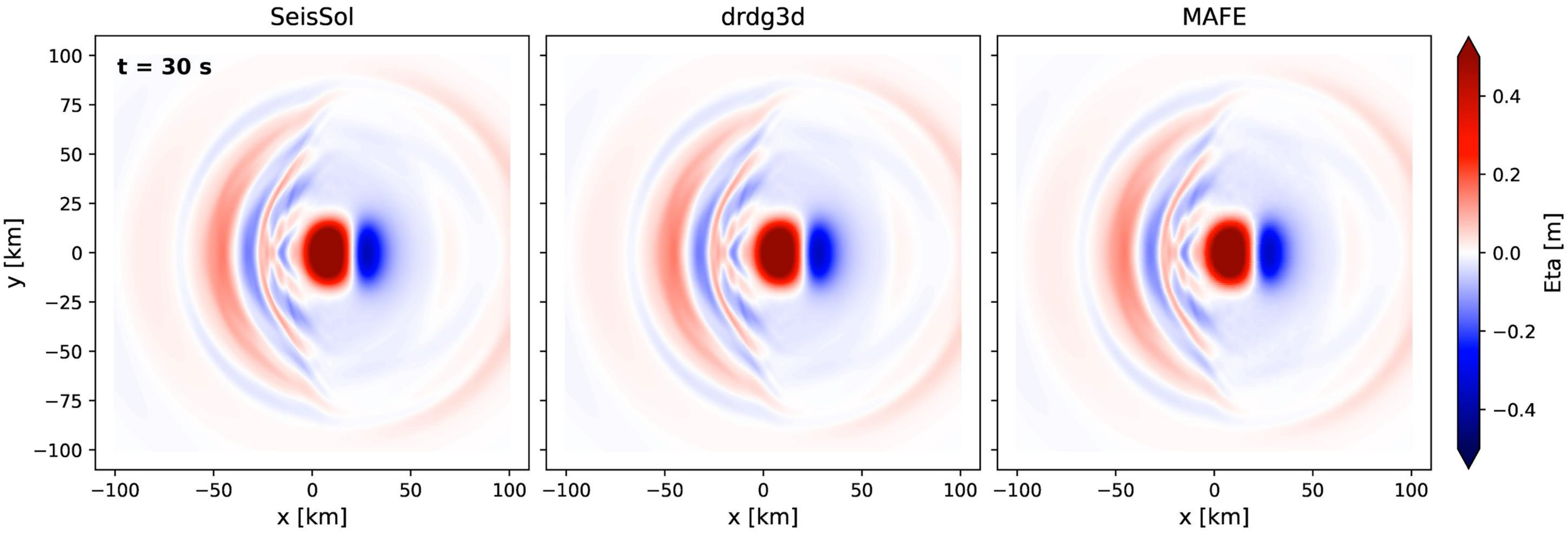
TTPV2: Comparison of the time-dependent tsunami generation on the sea surface

- All simulations include transient seismo-acoustic waves (visible at 30 s)
- Eta = vertical displacement of the sea surface (tsunami + seismo-acoustic waves)



- Key features of the tsunami generation are in good agreement