Cybershake NZ v17.9: New Zealand simulation-based probabilistic seismic hazard analysis

QuakeCoRE FP1: Ground motion simulation and validation (GMSV) – Jan 25, 2018

Contributors:

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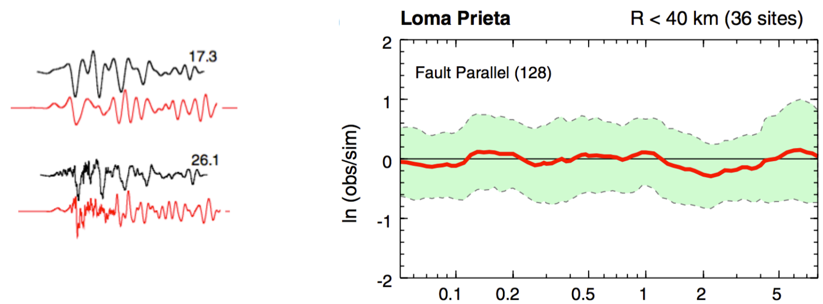
Te Whare Wānanga o Waitaha

Motivation – conventional approach in PSHA

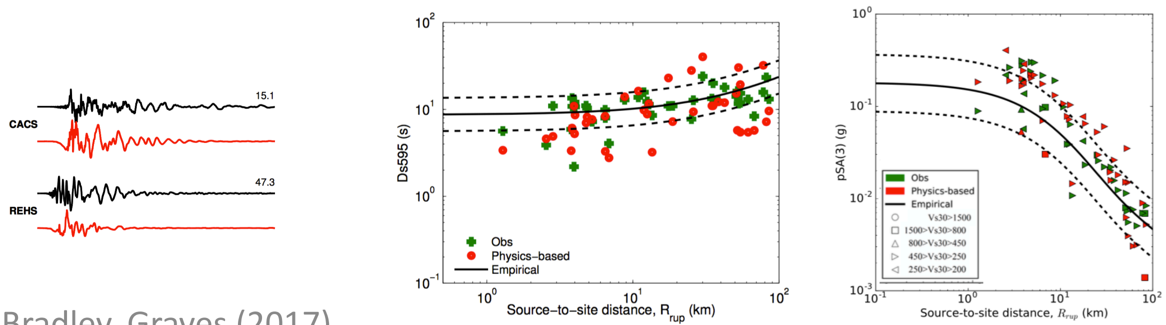
- Probabilistic seismic hazard analysis (PSHA) is a key component in seismic design and performance assessment of engineered systems.
- Conventionally, simplified models are used to represent rupture characteristics and resulting ground motions in PSHA.
- Paucity of ground motions recorded from large magnitude ruptures in the near-fault region.
- Ergodicity assumptions in empirical ground motion models
- Large aleatory variability and epistemic uncertainty in empirical ground motion models.

Motivation – capabilities of simulations for PSHA

- Validation of simulated ground motions against the observed ground motions in the past events demonstrates the capabilities of simulations for PSHA.



Graves and Pitarka (2010), BBSA

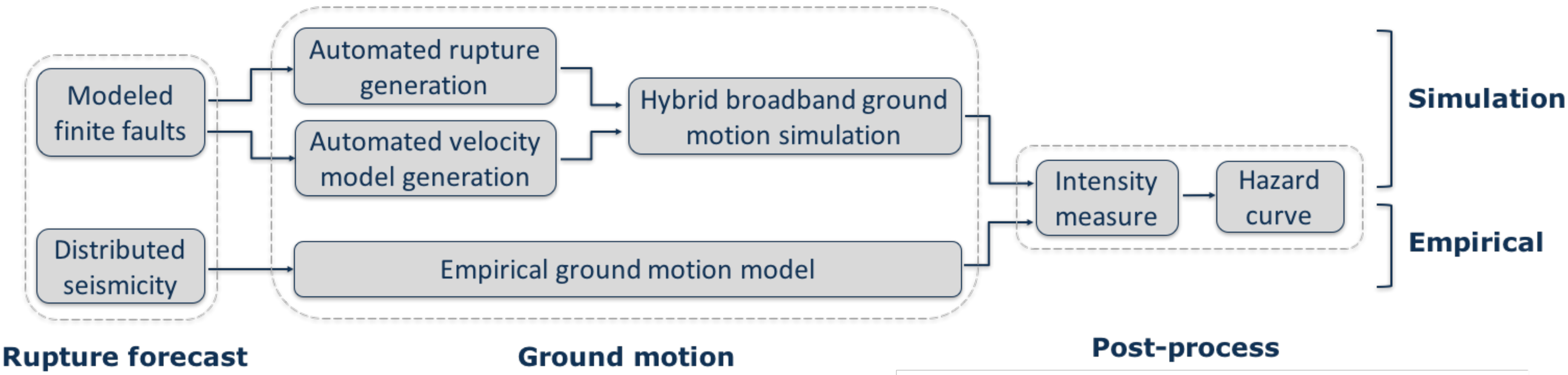


Razafindrakoto, Bradley, Graves (2017)

Motivation – explicit representation of source, path, and site effects via simulations

- Slip heterogeneity
- Stress drop
- Hypocentre location
- Rupture velocity
- Basin generated waves
- Nonlinear site effects
- Detailed characterization of the crust

Computational workflow implemented



$$\lambda_{Rup}(rup_n)$$

$$P_{IM|Rup}(IM > im|rup_n)$$

$$\lambda_{IM}(im) = \sum_{n=1}^{N_{rup}} P_{IM|Rup}(IM > im|rup_n)\,\lambda_{Rup}(rup_n)$$

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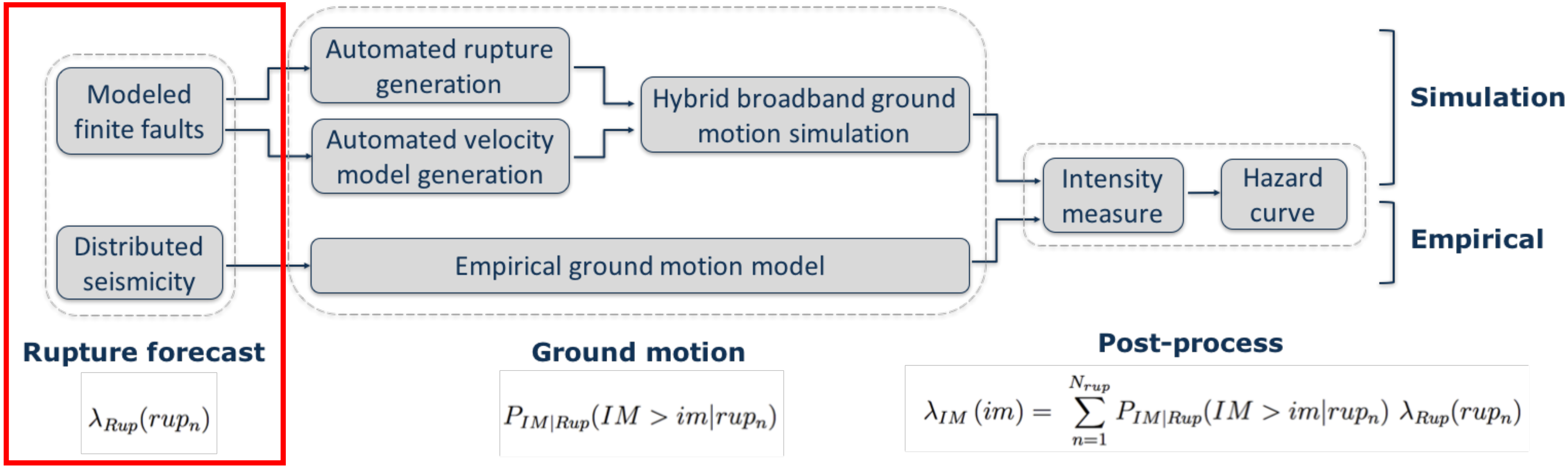

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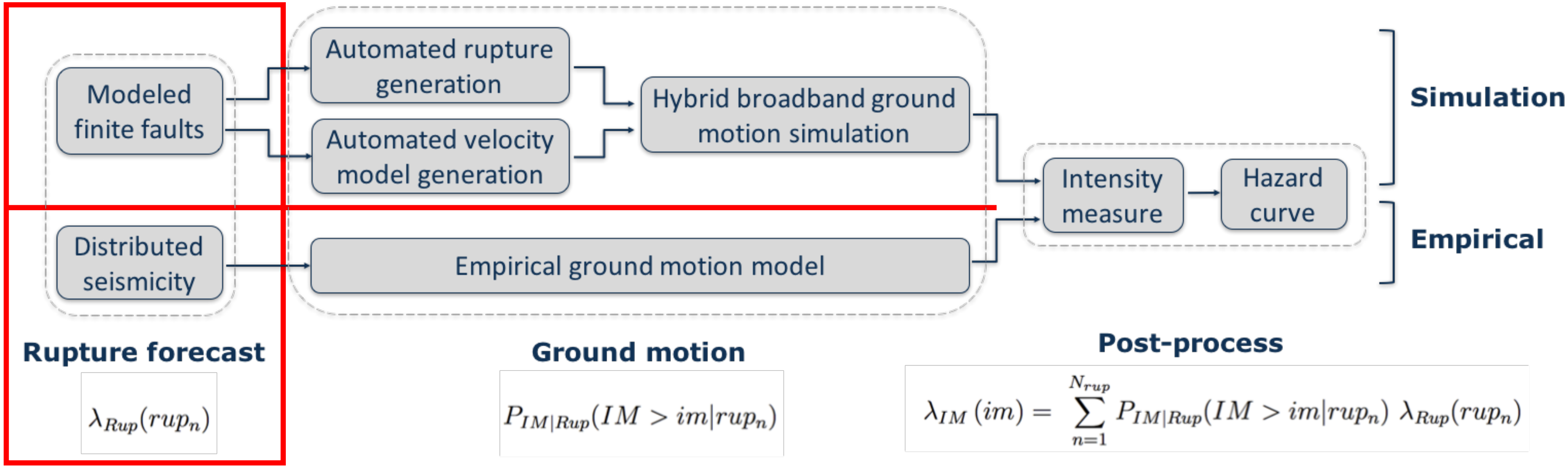

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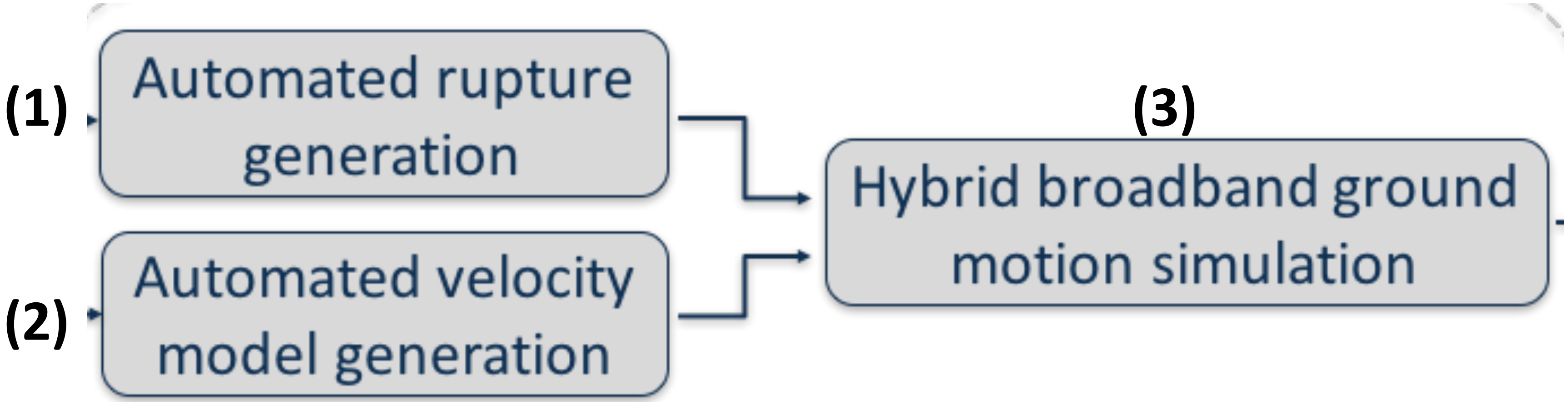
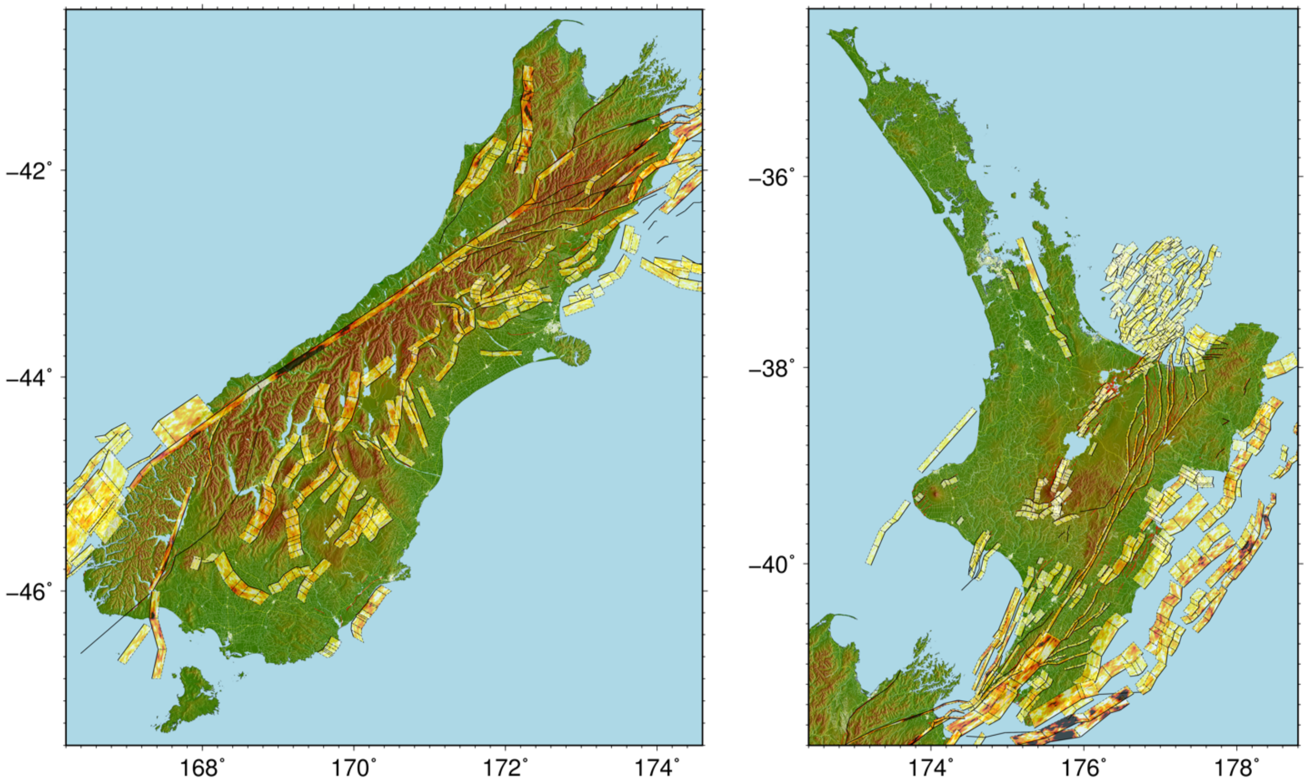


(1) Automated rupture generation

- 536 fault in Stirling et al. (2012)
- 160 and 250 faults are considered in the South and North Islands



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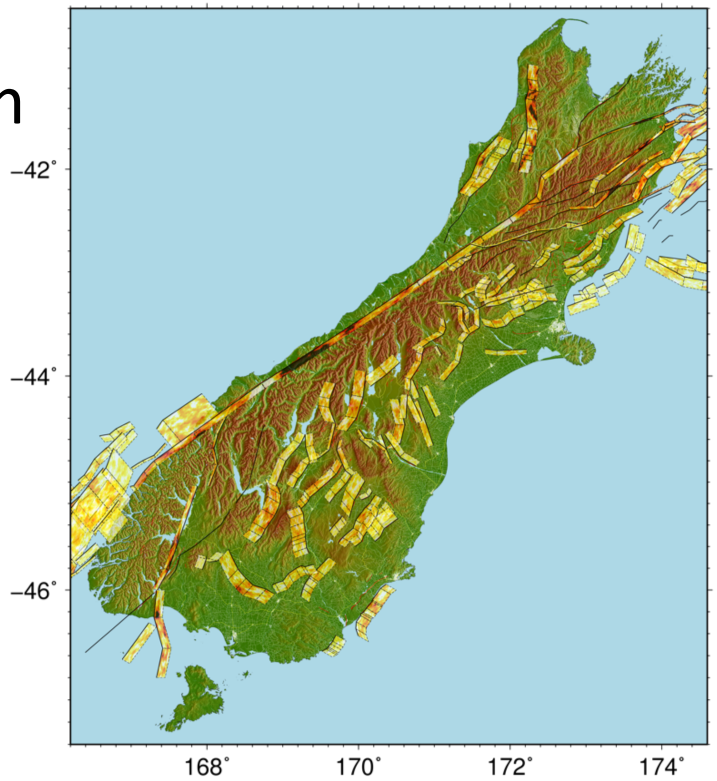
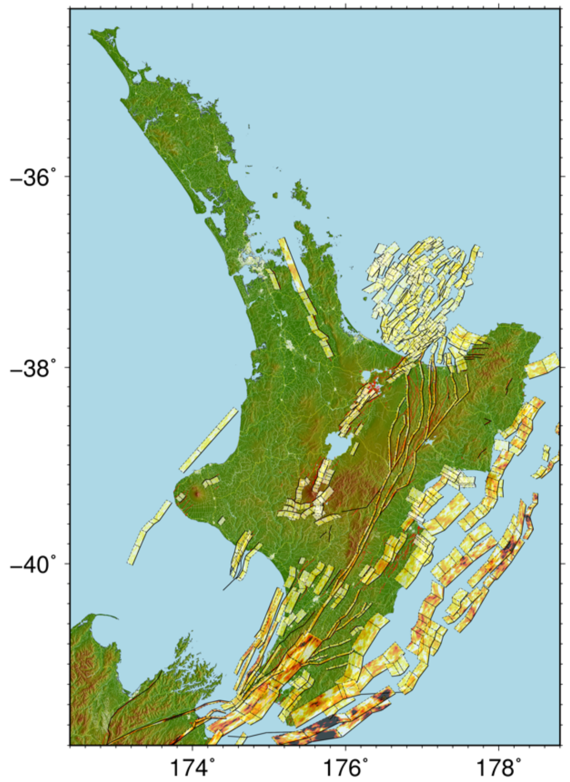
•Hypocentres every 20 km along the strike direction

•3 slip realizations per hypocentre





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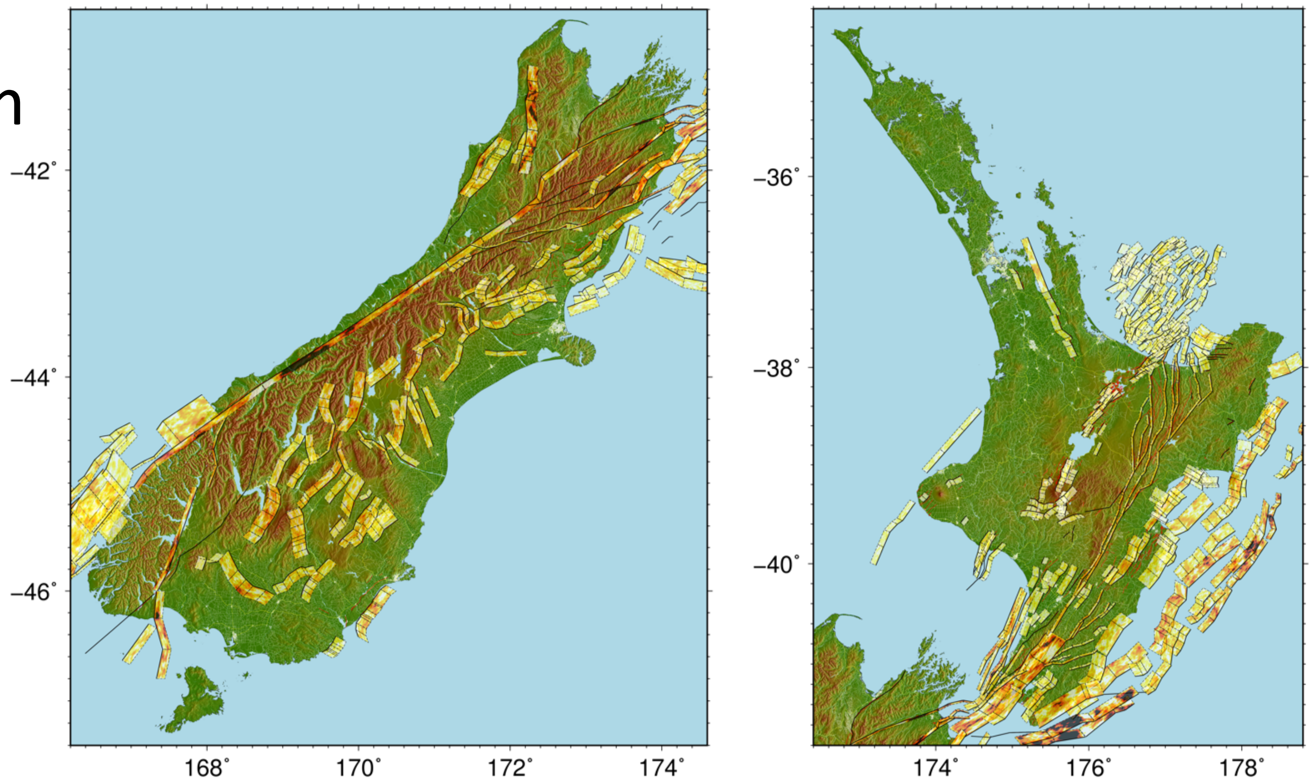
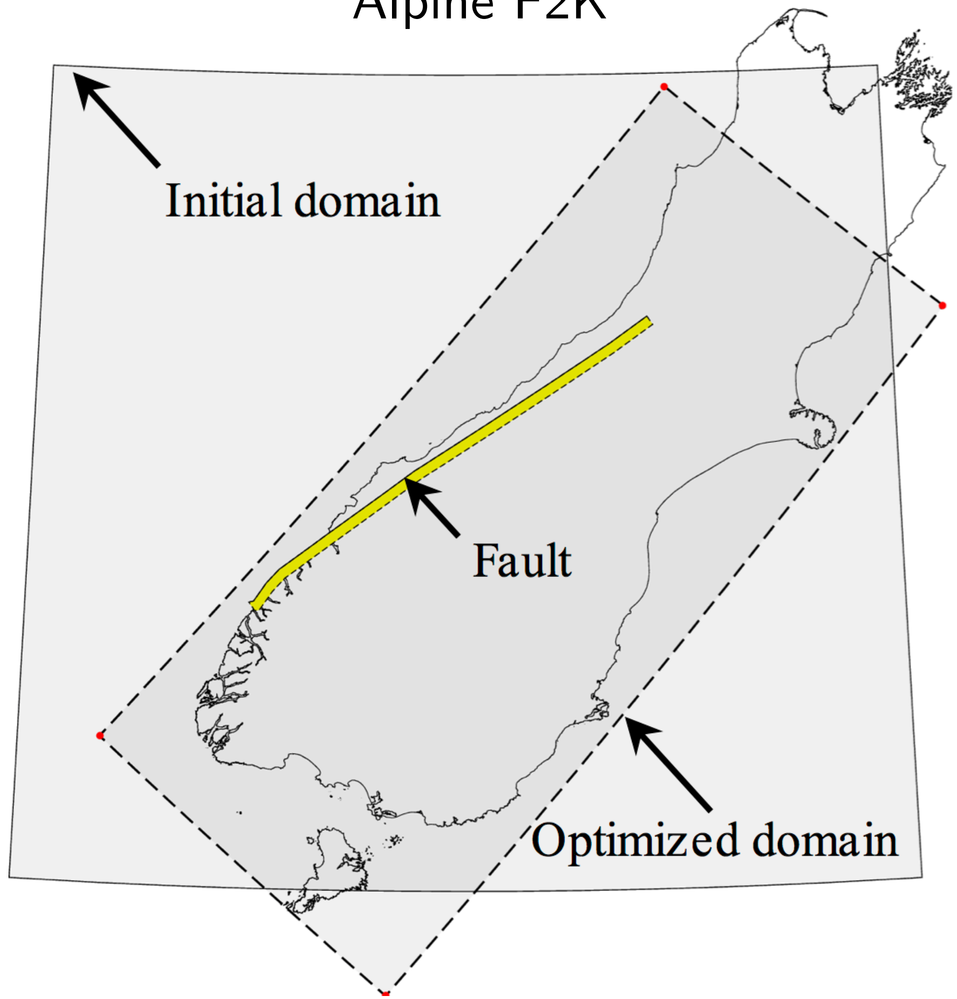
- 1566 ruptures in the SI
- 1656 ruptures in the NI



(2) Automated velocity model generation

- Build a initial boundary around the fault corresponding to PGV=5 cm/s.

Alpine F2K



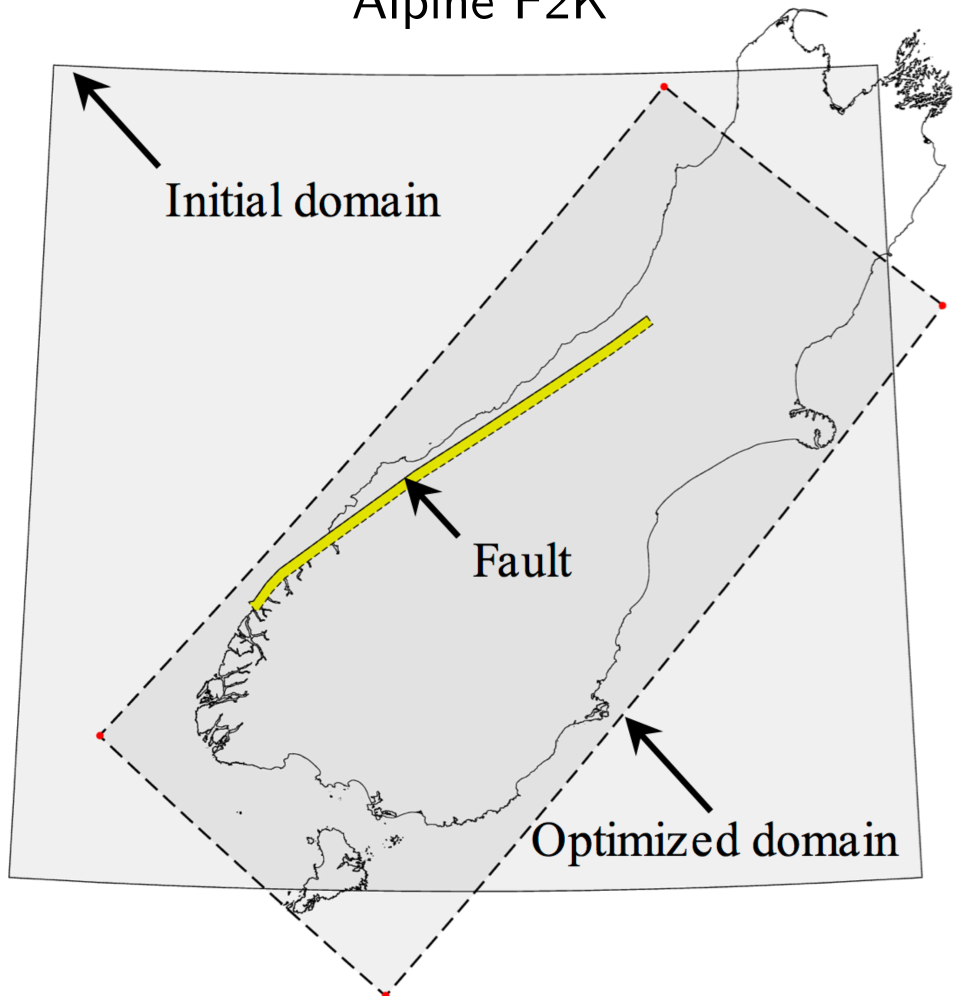
(2) Automated velocity model generation

- Build a initial boundary around the fault corresponding to PGV=5 cm/s.

⇩

- Rotate to align with the Island centreline.

Alpine F2K



(2) Automated velocity model generation

- Build a initial boundary around the fault corresponding to PGV=5 cm/s.

⇩

- Rotate to align with the Island centreline.

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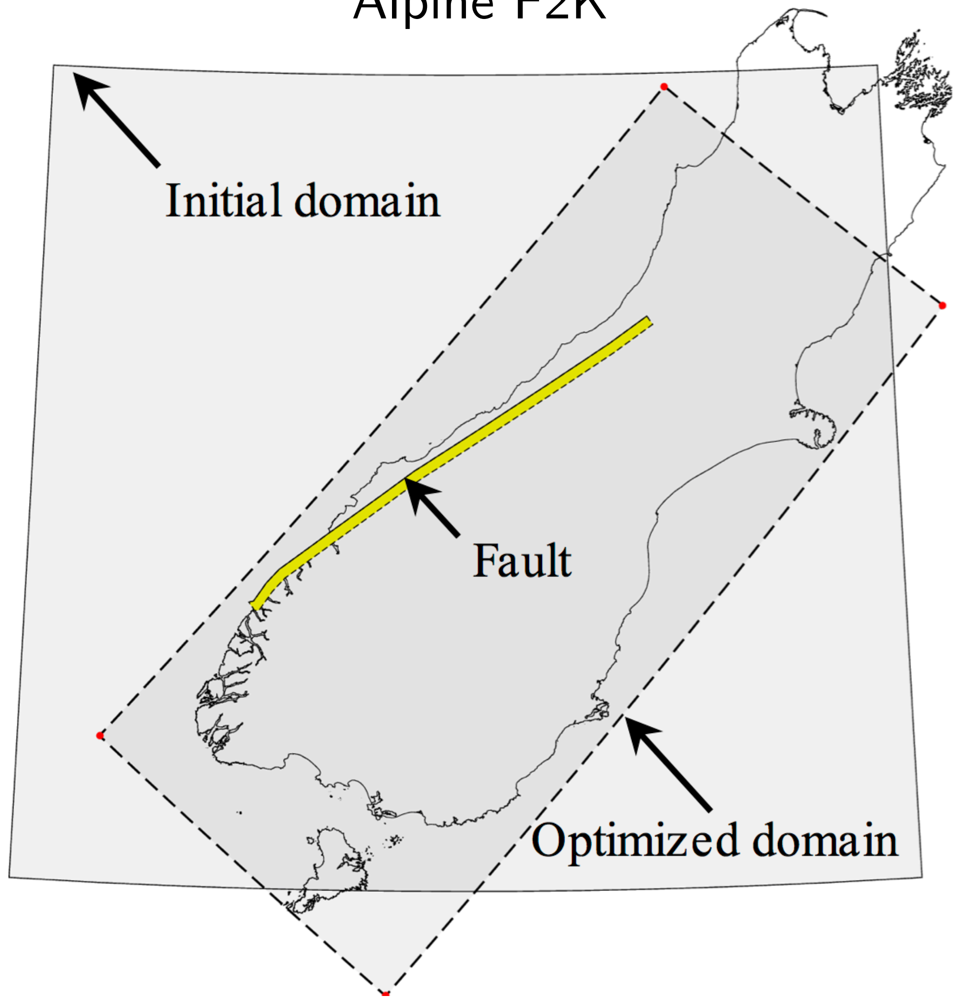
- Reduce the domain if it extends offshore. Keep the edges 15 km away from the fault and 5 km away from the shoreline.

Alpine F2K



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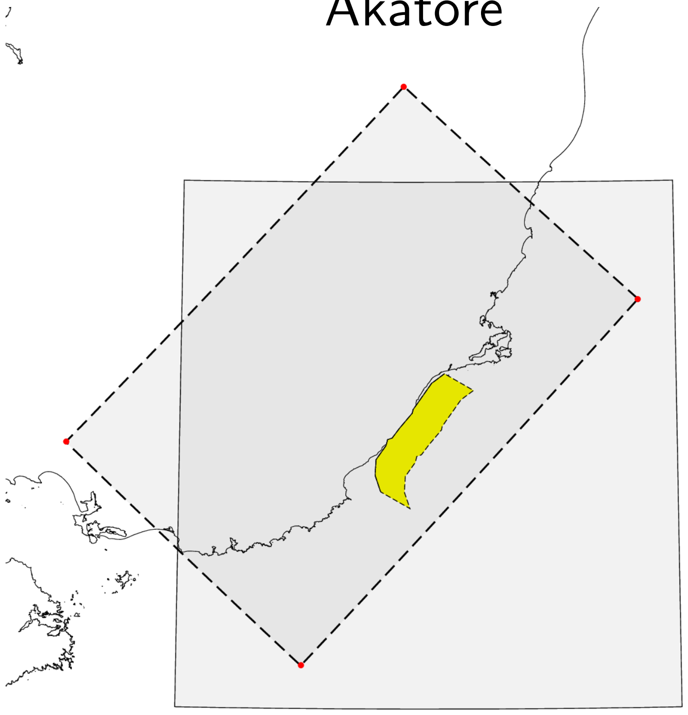
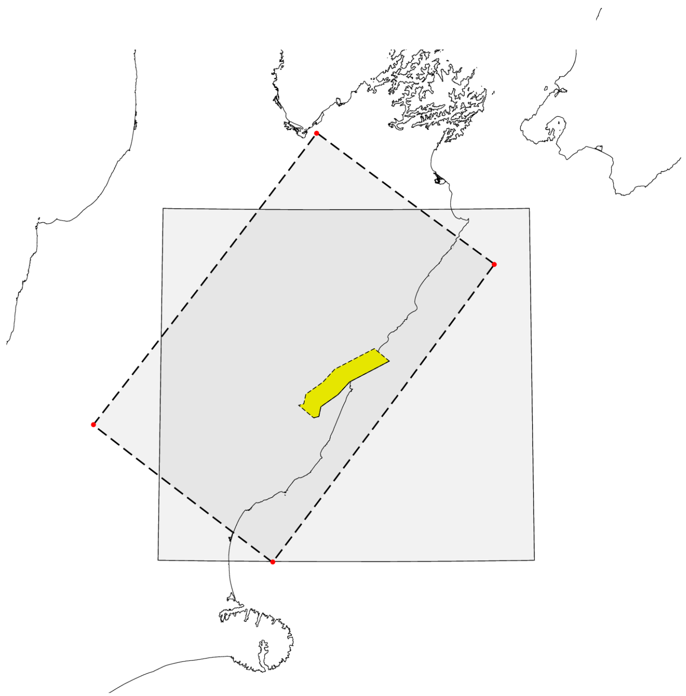
Akatore



Hundalee



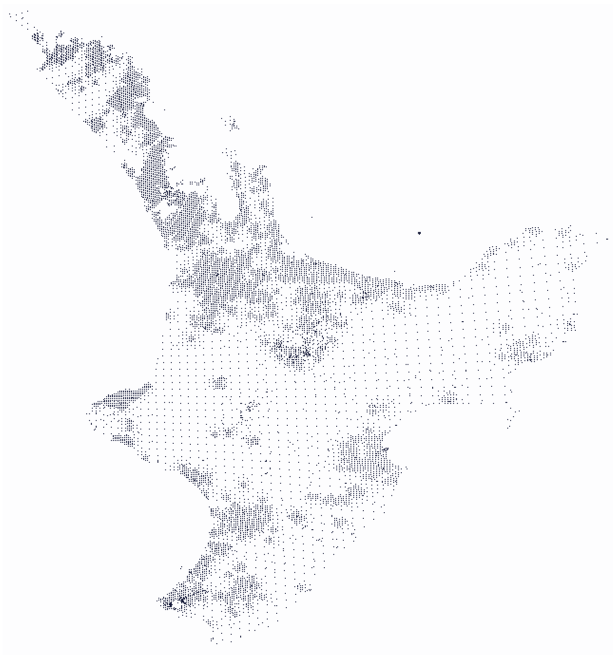
(3) Ground motion simulation

- Hybrid broadband simulation approach of Graves and Pitarka (2010, 2015) is utilized.
- A crustal model with a grid spacing of 0.4 km.
- Transition frequency of 0.25 Hz.
- Empirically-calibrated local site response model of Campbell and Bozorgnia (2014).

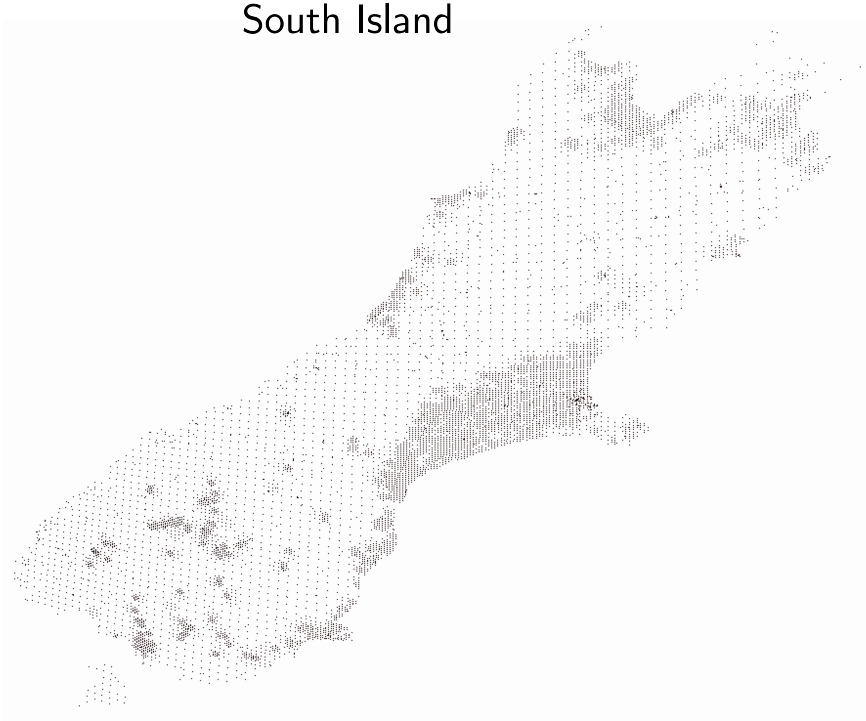
(3) Ground motion simulation

- A nation-wide grid of recording stations is generated to store ground motions based on population density and sub-surface soil condition.

North Island



South Island



Differences with SCEC Cybershake

- California Cybershake (Graves et al. 2011) utilizes reciprocity due to the larger number of considered sources (i.e., 10000, resulting in 415,000 ruptures) in comparison to the number of recording stations (250)

- NZ Cybershake uses a forward simulation approach as the total number of finite faults in Stirling et al. (2012) (i.e., 536, resulting in 3222 ruptures) is significantly less than the number of recording stations (19604 in the current recording station grid utilized).

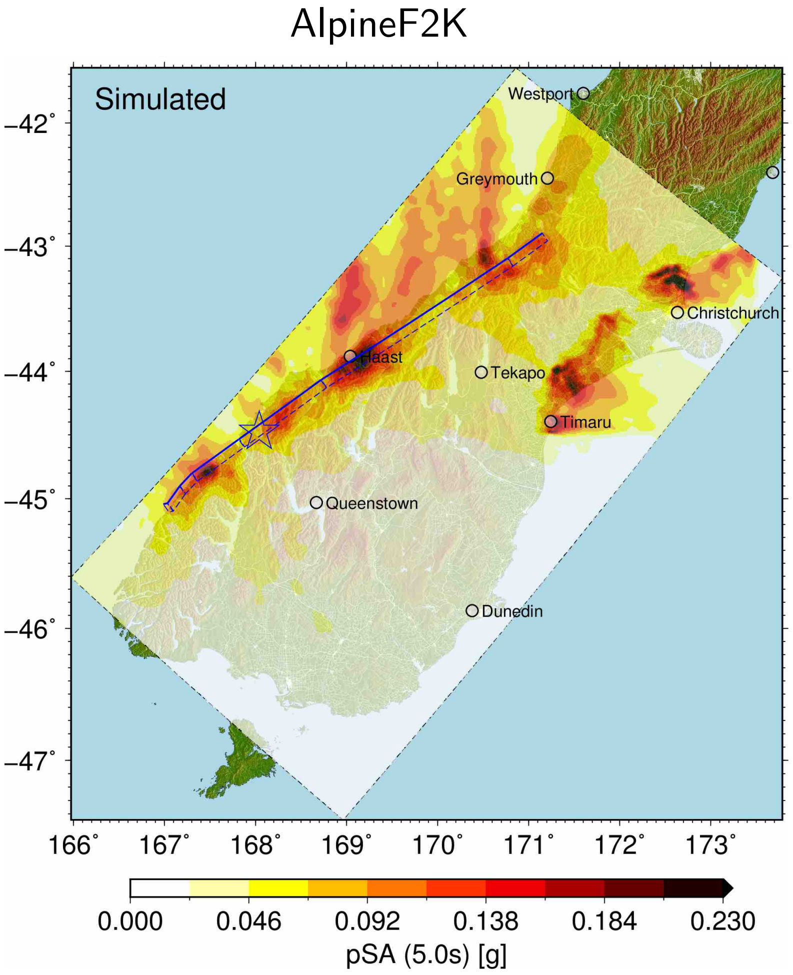
Differences with SCEC Cybershake

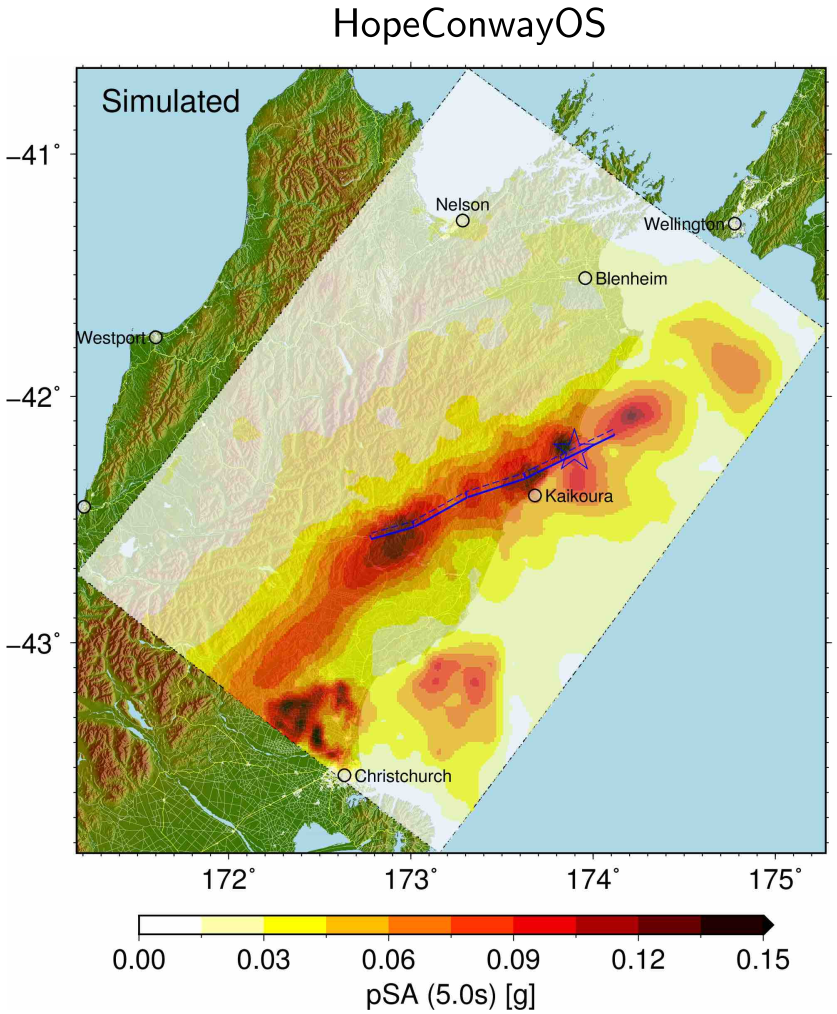
- Local site effects, i.e., empirical and/or simulation-based site response.

- Broadband simulation.

- Utilizing empirical ground motion models for distributed seismicity sources.

Scenario simulation results



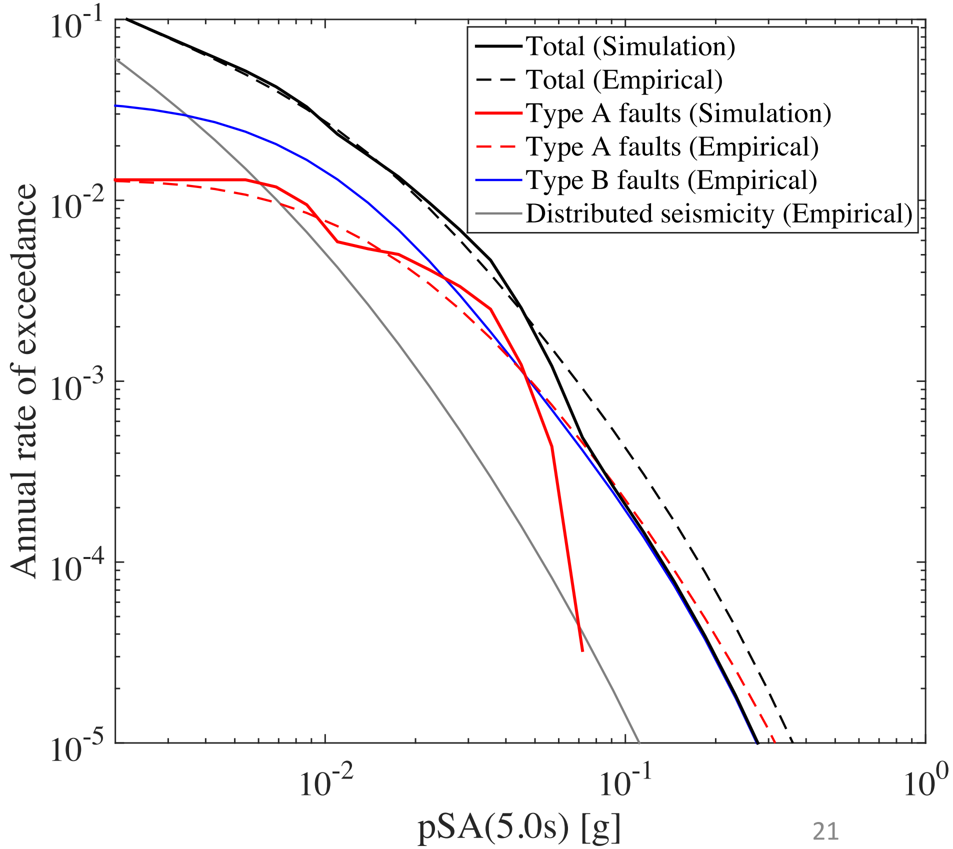


Seismic hazard curve

$$\lambda_{IM}(im) = \sum_{n=1}^{N_{rup}} P_{IM|Rup}(IM > im|rup_n)\lambda_{Rup}(rup_n)$$

Three types of sources:

- i) distributed seismicity sources.
- ii) finite faults with simulated ground motions, i.e., Type A Faults.
- iii) finite faults with no simulated ground motions to-date, i.e., Type B Faults.



Discussion

Considered variabilities: Slip distribution and hypocentre location

Considerations for future versions:

- Variability in: rupture magnitude, fault dimensions, rupture velocity, rise time, stress drop, anelastic attenuation.

- Finer spatial discretizations (e.g., 0.2 km)

- Different realizations of the utilized velocity model

- More slip realizations and hypocentres

Discussion

- Simulation-based PSHA can be considered as one of the alternative approaches within the considered logic tree branches to address PSHA epistemic uncertainty.

- The weight on the simulation-based PSHA can be assigned based on the validity of simulations in different regions of the country (considering the detailed analyses conducted to examine the validity of simulated ground motions with respect to the observed ground motions).

Thank you for your attention

Further discussion ...