Report of Transnational Access Projects

Project ID: C2-TA2-541-9-1

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Project title: Seismic hazards from joint ruptures of crustal and subduction earthquakes

Project acronym: *SHARE*

Hosting installation: *Ludwig-Maximilians University (LMU)*; *Barcelona Supercomputing Center (BSC-CNS)*

Hosting team: *Alice-Agnes Gabriel (LMU, Scripps), Claudia Abril (LMU), Josep de la Puente (BSC-CNS), Natalia Zamora (BSC), Iris Christadler (LMU)*

Period of visit: *26 April – 12 May 2026*

Report of activities:

This project is part of a broader research effort aimed at improving the characterisation of seismic hazard in New Zealand (NZ) through physics-based ground motion simulations[1]. New Zealand sits on the boundary between the Pacific and Indo-Australian plates and is exposed to complex earthquake processes, including multi-fault ruptures and interactions between crustal and subduction systems. Understanding the impact of these processes on near-source ground shaking is a key challenge for seismic hazard assessment.

In this project, we adapt the updated, nationally consistent representation of fault geometries and rupture sets from the New Zealand National Seismic Hazard Model (NSHM) [1], exploring the ground motion characterization from *Cybershake*-simulated kinematic ruptures and associated wave propagation. This project leverages recent developments of the CyberShake platform, deployed at the Barcelona Supercomputing Center (BSC) and adapted for use beyond California through the *UnifiedCSWFlow* workflow [3]. Building on this, Geo-INQUIRE has enabled the deployment of *CyberShake* on the *MareNostrum 5* supercomputer, supporting simulations of complex earthquake scenarios in diverse tectonic environments [2].

In this report, we summarize the rupture scenarios that we have tested. We focused our research on major upper plate fault ruptures and selected five rupture sets from the central NZ datasets with a cut-off long-term slip rate of 10^{-5} m/s corresponding to a potential M7 earthquake every 80 years (Figure 1). The ruptures range in moment magnitude from 7.06 to 7.58, given their likely frequent occurrence in geological records [3]. The fault geometries from the NSHM Source Rupture Model (SRM) are mainly constrained by geological data, particularly given the sparsity of instrumental records. While the original NZ rupture sets consider segmented planes for spatial variations in faulting mechanisms (e.g., strike, dip, and rake), in its current implementation,

the Graves-Pitarka rupture generator can only handle planar faults. We therefore modify the original rupture sets by 1) taking the straight lines between starting and ending points of the segments as surface fault traces (Figure 1a) and 2) averaging the dip and rake of all segments to represent a homogeneous rupture direction. We leave the exploration of multi-segment rupture sets in *Cybershake* as future research. We assume that the 1-D seismic velocity model for the domain is derived from a 3D nation-scale velocity model [6], considering the limited domain size (Figure 1). No shallow low-shear velocity (e.g., Vs30) is included. The model domain is spatially discretized to resolve the minimum seismic wavelength corresponding to 1 Hz. We conduct the numerical simulations with *CyberShake* installed on *MareNostrum 5,* following the *UnifiedCSWFlow* workflow [3].

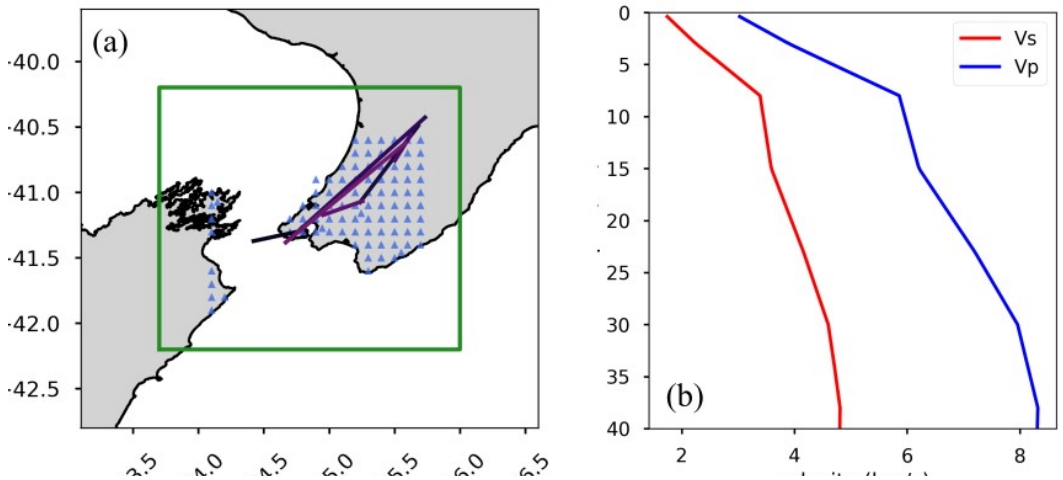

Figure 1. (a) Mapview of research domain, selected fault surface trace, and synthetic seismic stations in this study. (b) 1D seismic velocity profile extracted from NZ national-scale velocity model [6].

Figure 2a shows example kinematic ruptures on the Wellington Fault for two selected events, including fault slip and rupture-front arrival times. A range of kinematic rupture scenarios for a given magnitude and fault geometry was generated using the Graves–Pitarka (GP) pseudo-dynamic rupture model [5], producing variability in ground-motion intensity at a fixed distance. We generated five realizations for earthquakes with magnitudes 7.06<Mw<7.58, for stochastic models of slip distribution and randomly selected hypocentre locations. Variability in intensity ground motions simulated at the synthetic stations is illustrated in Figure 2b, which compares the peak pseudo-acceleration (PSA) at 1.0 s from the simulations with an empirical ground motion model for upper-plate earthquakes in New Zealand [7].

The general alignment between numerical simulations and empirical predictions suggests that advanced numerical simulations can provide complementary data for characterizing ground motion in seismically active regions. This is important for seismically active regions like central NZ, where the sparsity of instrumental records of larger events has significantly hindered the analysis of seismic hazard uncertainties. However, we observe an overestimation of spectral acceleration in simulations, particularly given the clear variability associated with the kinematic rupture sets (Figure 2b). This mismatch suggests that further calibration of the seismic source characteristics is required. Furthermore, a detailed description of the crustal structure with a 3D velocity model may also improve the simulation results.

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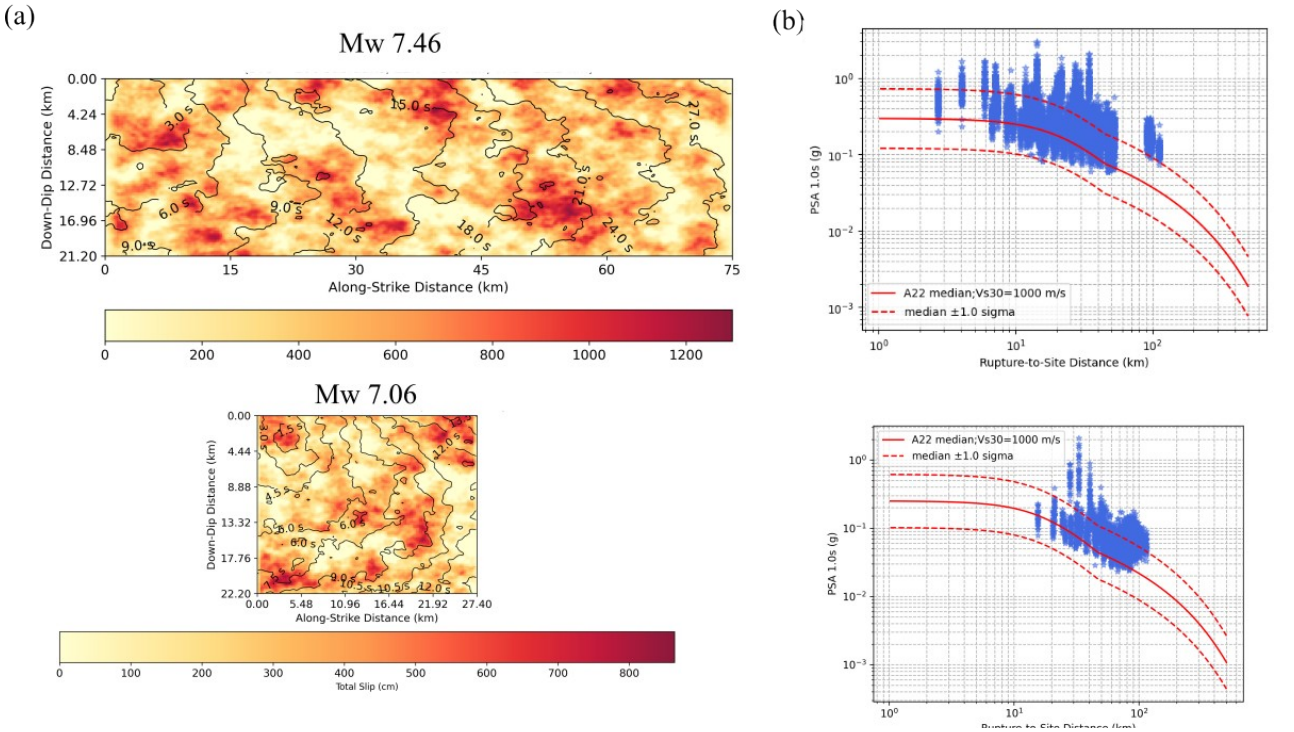

Figure 2. Summary of *CyberShake* model results. (a) Kinematic rupture sets of two selected events (Mw 7.46 and Mw 7.06). (b) Corresponding peak pseudo-accelerations (SA) at 1.0s are compared with the New Zealand-specific ground motion model [6] for the same magnitudes, assuming Vs30=1000m/s. Simulated ground intensities at 81 synthetic inland stations are included.

References:

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Project outcomes:

https://sdl.hpc.cineca.it/app/experiments/479/summary

Note: Data, products, software and publications resulting from TA activities must be publicly accessible under a CC-BY 4.0, GPLv3 or equivalent open license. No embargos beyond June 2026 are allowed. They must cite Geo-INQUIRE as the source of funding. Minimal citation: "*Geo-INQUIRE is funded by the European Union (GA 101058518)*".