QuakeCoRE Ground Motion Simulation Computational Workflow

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1. Background and Objectives

Significant portions of QuakeCoRE research require large-scale computationally-intensive numerical ground motion (GM) simulations.
The amount of data and complexity of computation make the large-scale simulation practically impossible to run on a researcher's workstation. QuakeCoRE started collaboration with New Zealand eScience Infrastructure(NeSI), the national high performance computing (HPC) provider to gain the necessary computational capacity and execution speed.

2. Ground Motion (GM) Simulation

Our GM simulation is based on the Graves and Pitarka (2010,2015) methodology that is composed of computationally-intensive low-frequency and less computationally-demanding high-frequency modelling (due to stochastic nature) to produce broadband simulations. Figure 1 compares the simulated velocity time series with those observed in the 4th September 2010 Darfield earthquake.

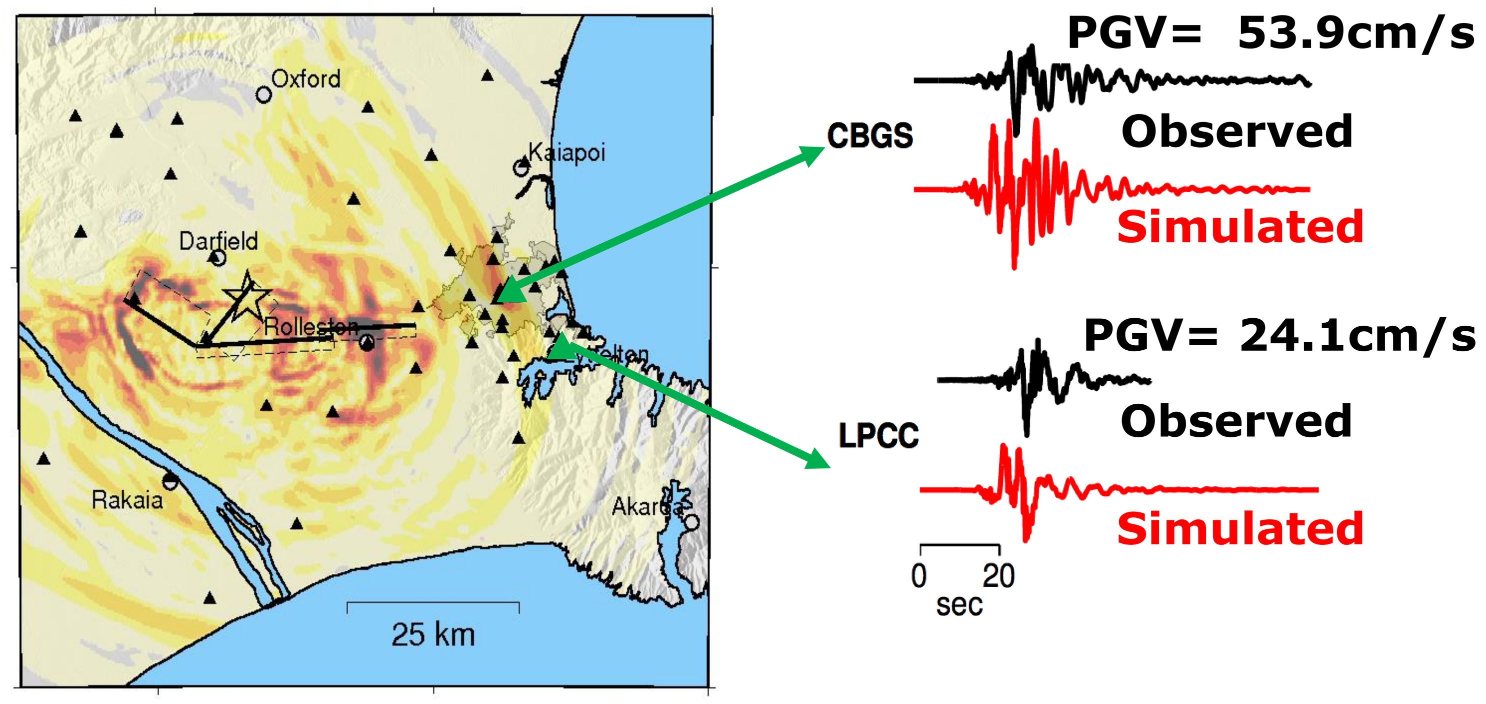

Figure 1: Numerical simulation of the 4 September 2010 Darfield earthquake (left), and comparison of the observed (black) and simulated (red) velocity time series in the North-South orientation for the CBGS and LPCC strong motion stations.

3. Computational Challenge

Figure 2: NeSI's Fitzroy cluster at NIWA, Wellington

- Graves and Pitarka's hybrid broadband code is scalable and easily deployed on various HPC environments.
- 2010 Darfield earthquake GM modelling would have taken 4 years on a researcher's workstation, which only takes 4 hours using 512 CPU cores of NeSI's BlueGene/P. Recent Alpine Fault simulation (h0.1km) takes 4.5 days using 8192 CPU cores of BlueGene/P.
- All the workflow has been ported to NeSI's Fitzroy cluster in NIWA (Figure 2) due to decommissioning of BlueGene/P.

- Fitzroy is a POWER6 based AIX cluster, housing 106 × POWER6, 32 way 4.7 GHz nodes, for a total of 3392 processors and 8.1 terabytes of memory.
- QuakeCoRE secured 1.2 million core hours.
- QuakeCoRE's GM simulation was selected as one of the benchmark tests for NeSI's new HPC system procurement process in 2017
- NeSI provides data storage and backup, and high-speed data transfer is enabled by Research and Education Advanced Network New Zealand (REANNZ)'s network.

4. Current Workflow

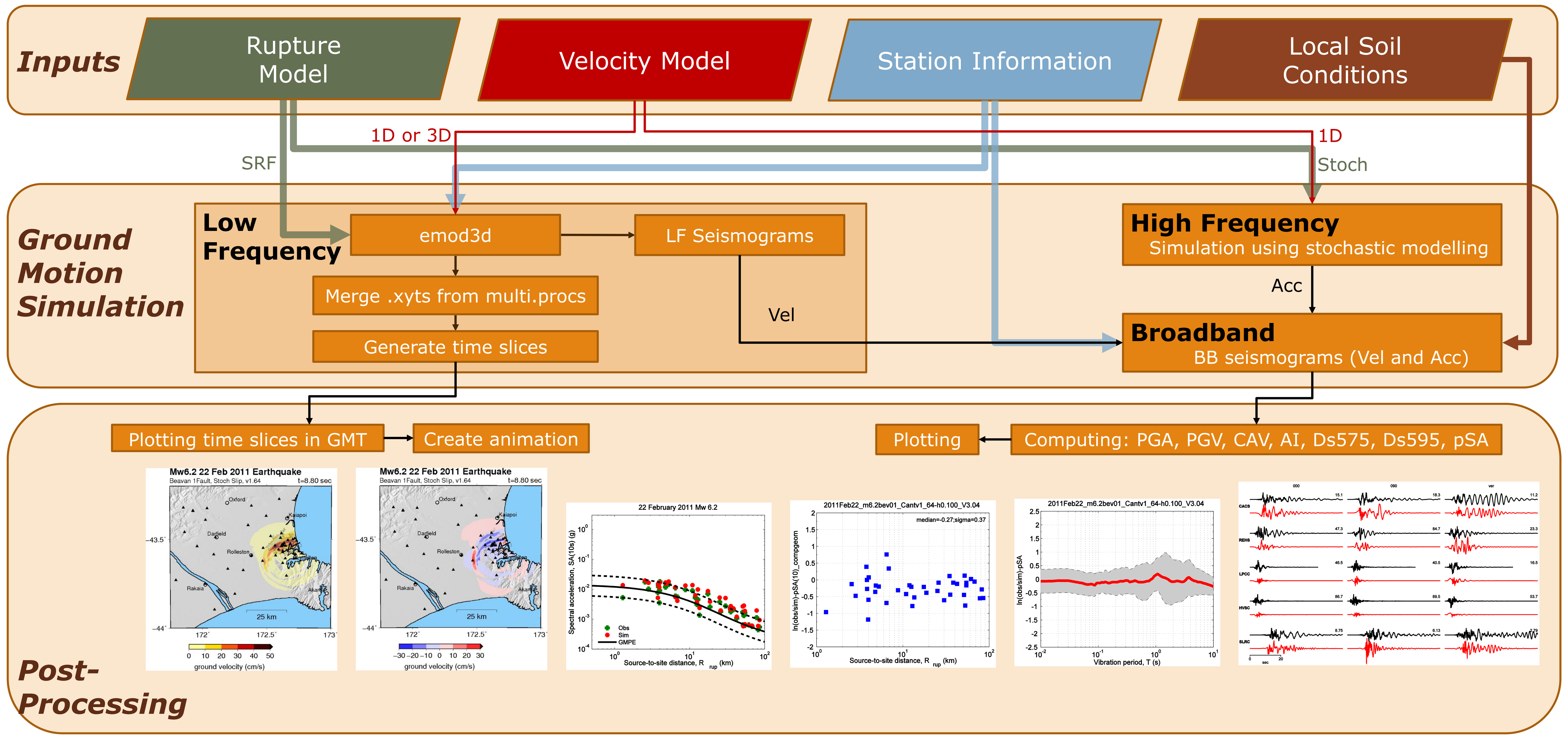

Figure 3: QuakeCoRE's GM Simulation workflow based on the Graves and Pitarka methodology(2010,2015)

The workflow in Figure 3 has been streamlined and automated to minimize the need for user interaction, improving modelling productivity making the workflow easier for new users to learn.

For efficient research collaboration and workflow integrity, we have also implemented
- Centralized scientific programming support
- Version control system for source code and input/output data
- Data management policy - directory structure and file name standard

5. Future Developments

We are automating ground motion simulations for moderate-to-large magnitude earthquakes (Mw>4.5). This will provide useable ground motion information in the immediate aftermath of an event for scientific reconnaissance and civil defence response, and allow us to undertake prospective validation testing of our implemented simulation methodology in an attempt to understand the regional variation in ground motion simulation predictive capability in NZ.

In the event of a significant earthquake, our server (Figure 4) will receive an earthquake moment tensor alert from GeoNet, and automatically start a simulation. Inputs will be prepared on the fly based on the moment tensor solution and magnitude scaling relationships. The spatial dimensions of the velocity model domain is a function of the earthquake magnitude.

After the workflow, we compare ensemble simulations (with different modelling assumptions) with observed ground motion seismograms and Bayesian updating to estimate the ground motion intensity over the region of interest.

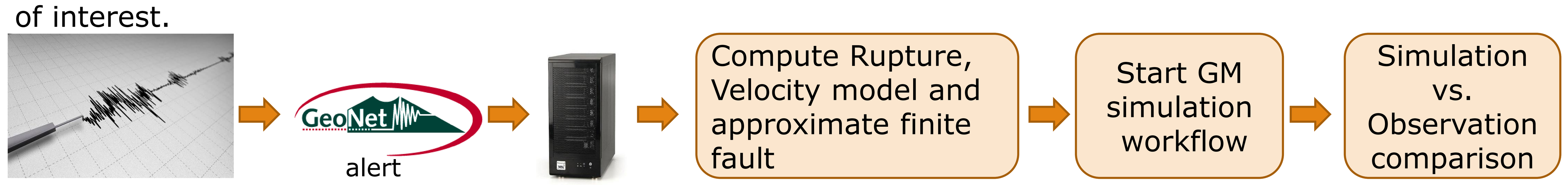

Figure 4: Automated GM simulation upon a major earthquake