# Real-Time Ground Motion Simulation Workflow

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## 1. Background and Objective

QuakeCoRE developed the Ground Motion (GM) simulation workflow based on the Graves and Pitarka (2010, 2015) methodology, we have strived to deliver the simulation result in timely manner to increase the research throughput.

Our effort has been made in two directions. Firstly we utilized high-performance computing (HPC) facility in partnership with New Zealand eScience Infrastructure (NeSI) to improve the computational capacity. Secondly we have incrementally refined the overall workflow, hence improved the computational efficiency. The importance of such an effort was highlighted by the 2016 Mw7.8 Kaikoura earthquake.

While the timely simulation result obtained in the immediate aftermath of an event can be of tremendous value for scientific reconnaissance and civil defence response, our delivery was not responsive, taking 7 hours just to produce the inputs, followed by 2 days of actual computation. This motivated to acquire "Near Real-time" GM simulation capability. In this poster, we present how we carried out the comprehensive overhaul of the computational workflow to achieve this goal.

**Figure 1: Researchers preparing for the GM simulation of the Mw7.8 Kaikoura earthquake in the morning following the event.**

## 2. What took so long? : Reasons for the Delay

Researchers analyse the raw data from multiple sources (GeoNet, USGS) and extract data to feed to programs that generate the inputs. The inputs are verified, transferred to HPC and a job is packaged for submission to the job scheduler, which will launch the GM simulation based on the hardware availability.

The following blocking factors were identified during the Kaikoura earthquake simulation.

1. Low level of automation : Most steps largely depended on manual user interaction as shown in Figure 2. Proceeding to the next step sometimes involved repeated parameter settings due to lack of shared configuration files.
2. Complexity of workflow : Overall workflow was too complex
3. Human factors : Time pressure and psychological insecurity means an error-prone environment. User input error also causes computation time wastage.
4. Scale of the event: The size of earthquake made it inherently more complex and longer to compute inputs.
5. HPC availability: Hardware was not immediately available

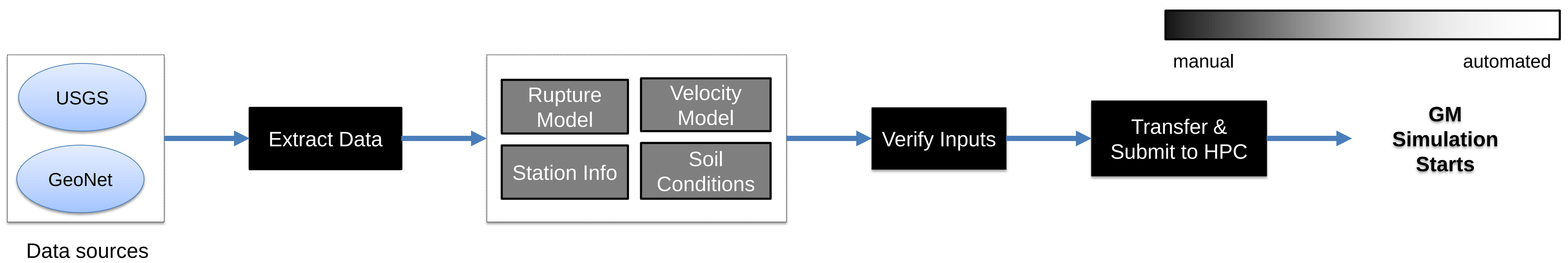



**Figure 2: Preparation pipeline of a GM simulation and the level of automation available for the Kaikoura earthquake simulation. (Shading of a box indicating level of automation)**

## 3. Streamlined Workflow

We have rectified the identified issues and greatly reduced the preparation time by streamlining the workflow, whose current status is illustrated by Figure 3. The workflow still relies on the user to extract data from the data sources, and to approve the generated inputs to proceed. The remaining is however mostly automated, and it also effectively enforced consistent file structure.

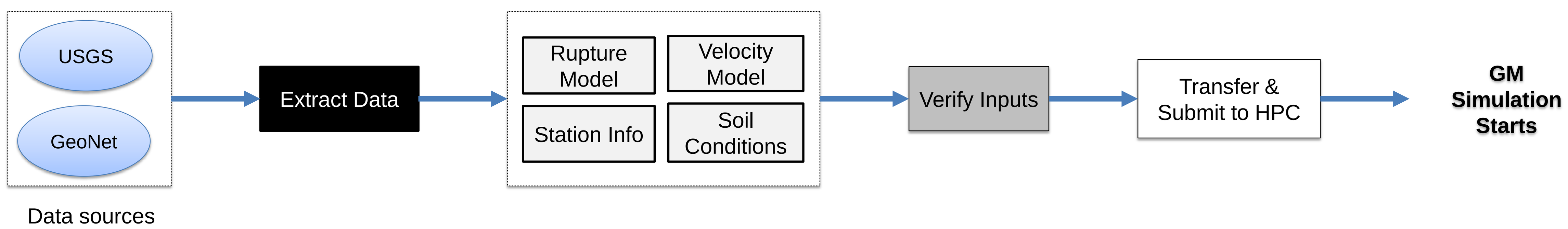



**Figure 3: Preparation pipeline of a GM simulation and the current level of automation**

## 4. Monthly Drill : Continual Incremental Improvement

We adopted a continual improvement development approach to streamline the workflow making a number of small incremental improvements each iteration.

Once a month we picked a historic event and ran the entire GM simulation pipeline testing new automation codes, having the time taken for each step logged. This *monthly drill* ended with discussion to identify new bottlenecks and prioritize automation and streamlining projects for the next month.

Figure 4 illustrates the time spent on the simulation preparation during each monthly drill, starting from Nov2016 for the Kaikoura earthquake simulation. The blue line is the total preparation time and the red line indicates the compute time only, where the difference between two represents the manual interaction time, whose significant reduction is evident in comparison to Nov2016.

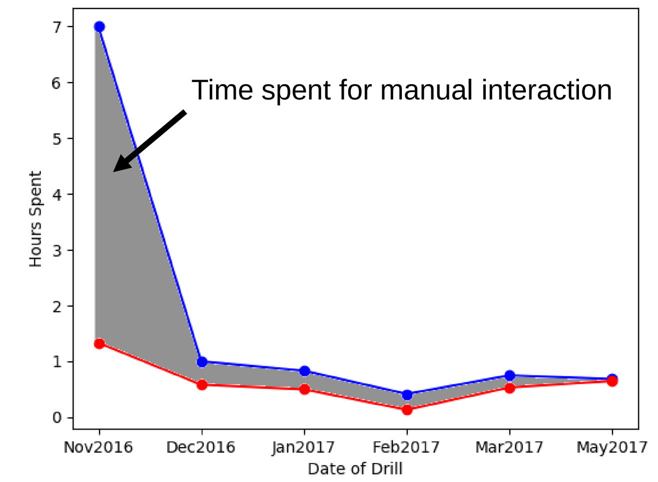
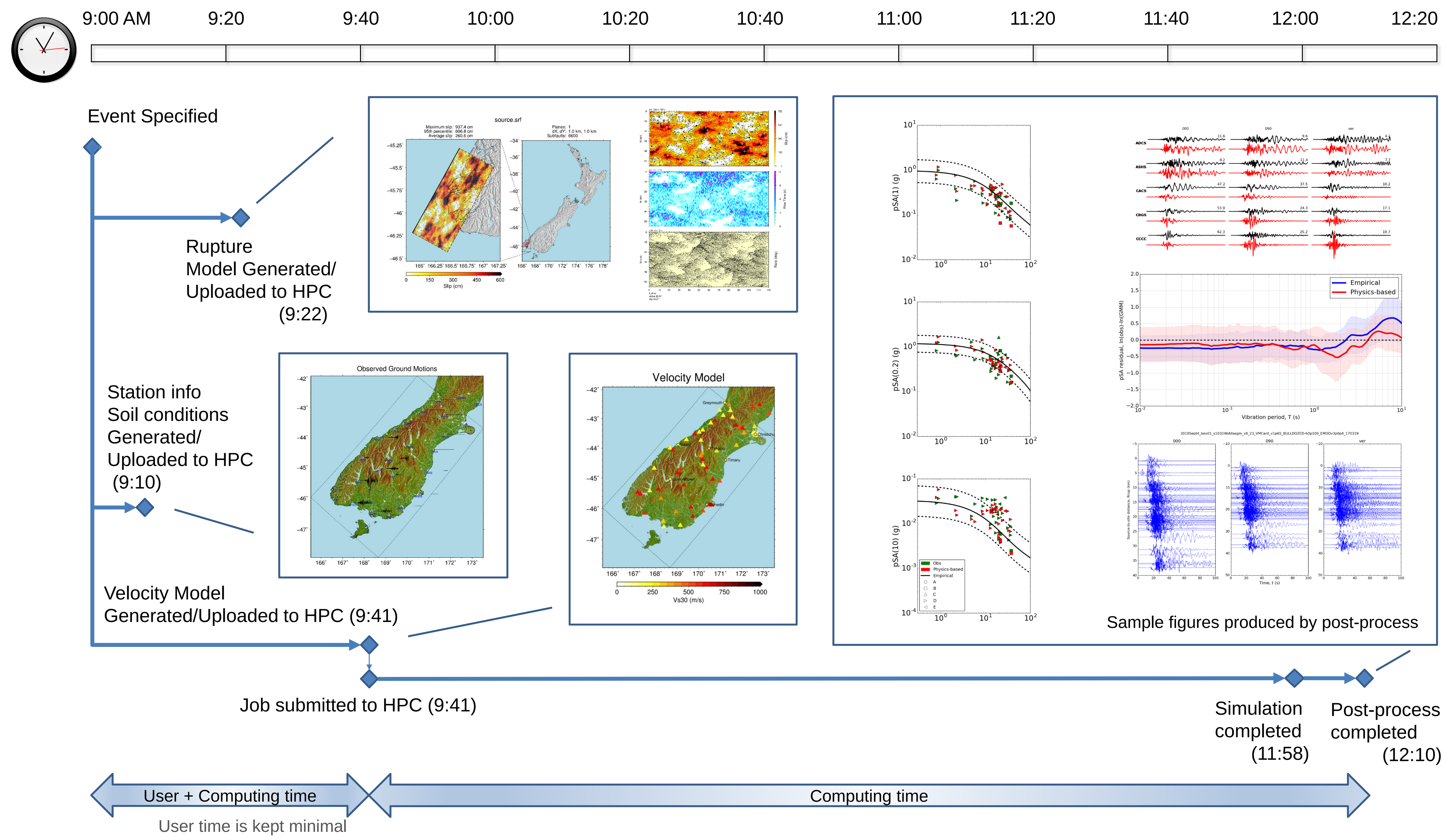



**Figure 4: Time spent for preparing the GM Simulation (Blue line is the total time and red line is the compute time only)**

## 5. Example Workflow Execution




## 6. Future Developments

We plan to have a fully-automated system that can trigger itself in the event of a major event, and run every step of the pipeline with no (or minimal if inevitable) human interaction. The next phase of workflow automation will undertake the following tasks.

- A server monitoring the GeoNet alerts and parses/extracts the data
- GeoNet alert message to contain moment tensor
- Automatic configuration for inputs generation
- Automated verification of the generated inputs

NeSI's next generation HPC cluster (expected Q1 2018) will open lots of new opportunities and some challenges. Our GM simulation workflow will be migrated to the new HPC cluster, and its extra computational resource is expected to further improve our "Near Real-time" simulation capability.