Prediction of ground motion in South Korea based on physics-based broadband simulation

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Summary

- We implemented the physics-based hybrid broadband ground motion simulation method of Graves and Pitarka (2010, 2015), to simulate earthquakes in South Korea accounting for the crustal velocity structure and seismological characteristics of the Korean peninsula.
- For crustal velocity models, we implemented a three-dimensional velocity model by Kim et al. (2017) and a one-dimensional velocity model by Kim et al. (2011). To generate kinematic source models, we used a magnitude-area scaling relationship developed for stable continental regions (SCR) by Leonard (2010).
- Simulation of the 2016 **M**5.5 Gyeongju earthquake and the 2017 **M**5.4 Pohang earthquake demonstrated the potential of physics-based ground motion simulation in South Korea; at the same time, it also suggested the need for further validation of the simulation method for applications in South Korea.

Motivation

- In Korea, large earthquakes do not occur frequently. However, like many other countries in SCRs, Korea has suffered from infrequent yet damaging earthquakes in the past.
- For example, 2016 **M**5.5 (M_L5.8) Gyeongju EQ and 2017 **M**5.4 Pohang EQ generated strong ground shaking (up to PGA=0.4g) and caused significant damage (estimated at $80 million not including repair cost).
- Being in a SCR with a short history of instrumentation, Korea has not collected sufficient instrumental data for data-driven ground motion models, which leads to the need for simulation-based ground motion prediction.
- Most Korean ground motion models developed in the past were based on stochastic simulation methods, and recent developments in broadband ground motion simulation methods have not been extensively validated in Korea.
- High quality ground motion data obtained from recent damaging earthquakes, such as 2016 **M**5.5 Gyeongju EQ and 2017 **M**5.4 Pohang EQ, provide an opportunity for testing and validating broadband ground motion simulation methods.

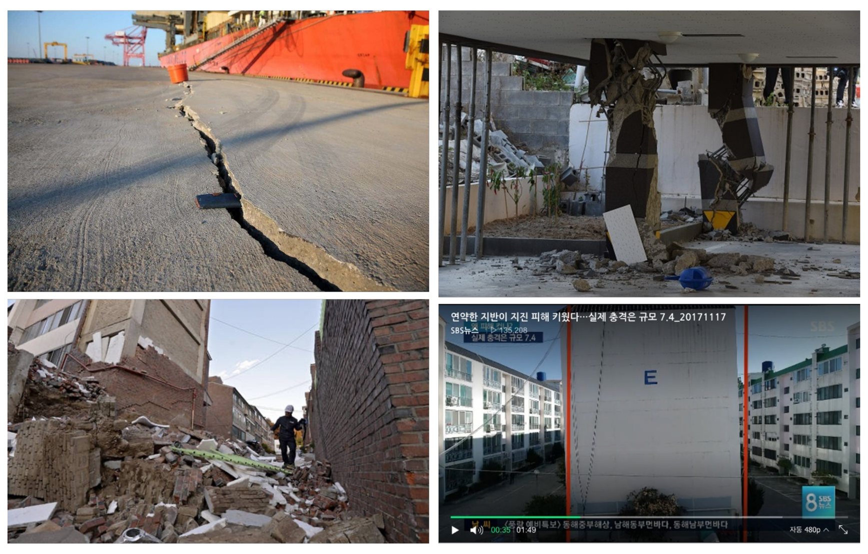

Figure: Examples of observed damage in the 2017 M5.4 Pohang earthquake, which was the second largest (**M**5.4) and the most damaging ($70 million).

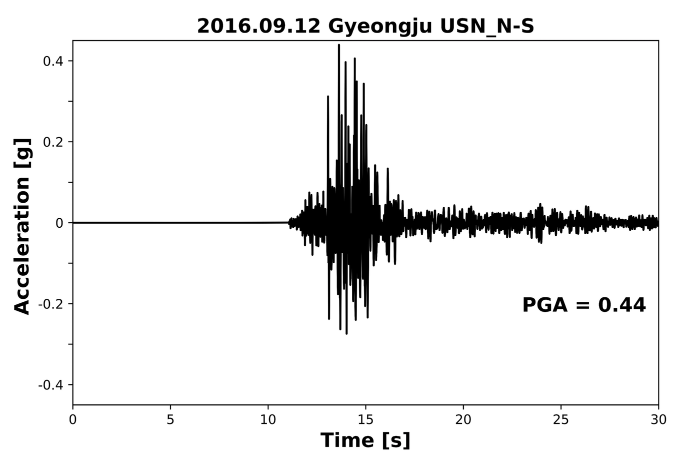

Figure: The recorded N-S component acceleration at USN during the 2016 **M**5.5 Gyeongju EQ.

Hybrid broadband ground motion simulation

Table: Source parameters of 2016 **M**5.5 Gyeongju and 2017 **M**5.4 Pohang events.

Event name	Origin time (KST)	Moment Magnitude	Epicenter latitude [degrees]	Epicenter longitude [degrees]	Depth [km]	Strike [degrees]	Dip [degrees]	Rake [degrees]
9.12 EQ	16-09-12 11:32:54	5.57	35.755	129.193	14	24	70	171
Pohang EQ	17-11-15 14:29:31	5.4	36.109	129.366	5	230	69	152

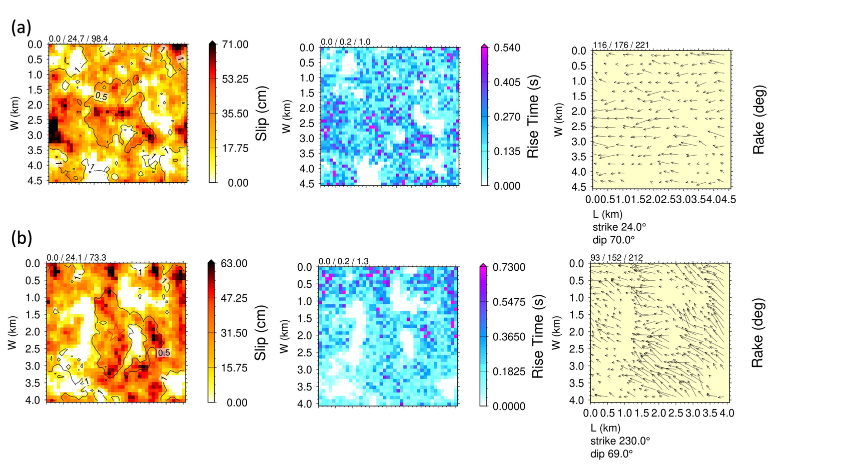

Figure: Kinematic rupture model of 2016 **M**5.5 Gyeongju and 2017 **M**5.4 Pohang events.

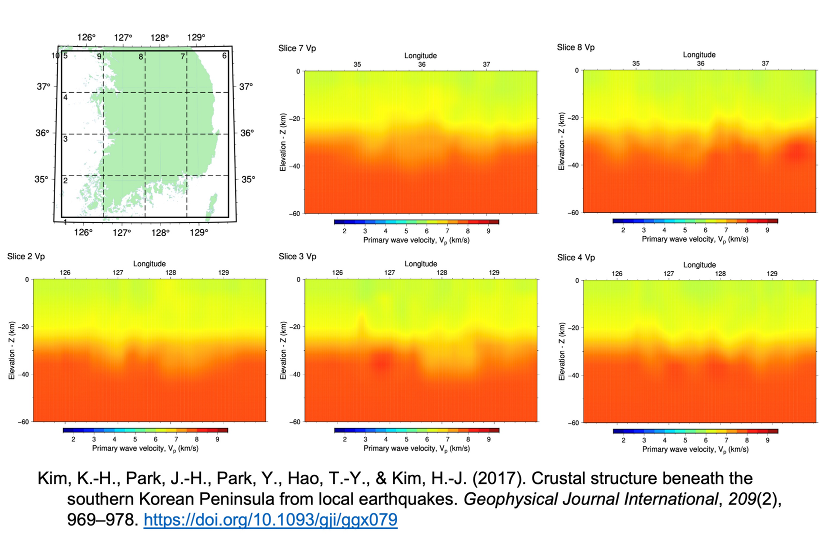

Figure: 3D velocity model of South Korea by Kim et al. (2017).

- We applied Vs30-based empirical site-effect correction based on Campbell and Bozorgnia (2014), using slope-Vs30 correlation by USGS.

- We implemented the hybrid simulation method of Graves and Pitarka (2010, 2015) on KISTI supercomputer Nurion, by modifying the simulation platform of QuakeCoRE.
- For crustal velocity models, we implemented a 3D velocity model by Kim et al. (2017) and a one-dimensional velocity model by Kim et al. (2011).
- For kinematic source models, we implemented Graves and Pitarka's rupture generator, with a magnitude-area scaling relationship developed for SCR by Leonard (2010, 2014).
- We used the following Brune stress parameter and spectral decay parameter: $\Delta\sigma$=5.0MPa and κ=0.016.

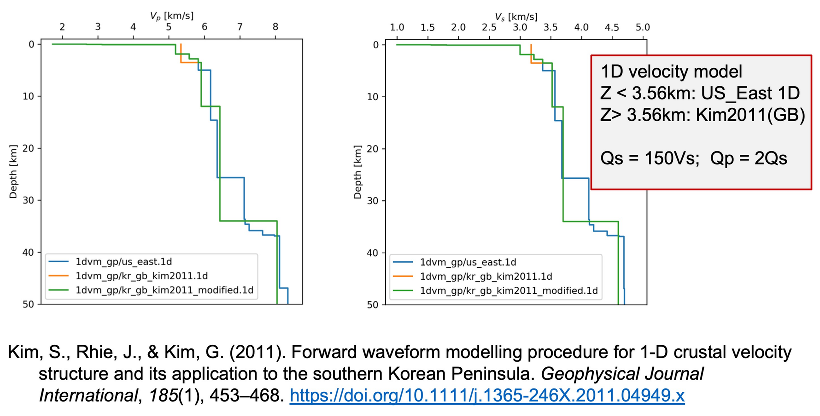

Figure: 1D velocity model implemented for this study, based on a Gyeongsang Basin model of Kim et al. (2011) and Eastern US model of SCEC Broadband Platform.

Studied region and strong motion stations

- We simulated ground motions of North and South Gyeongsang provinces.
- Ground motions are obatined at every 2km on the surface, and additionally at strong motion station sites.
- At every strong motion station, simulated motion is compared with recorded motion in terms of acceleration and velocity time series and response spectra.
- Maps of intensity measures are automatically generated after the completion of simulation.

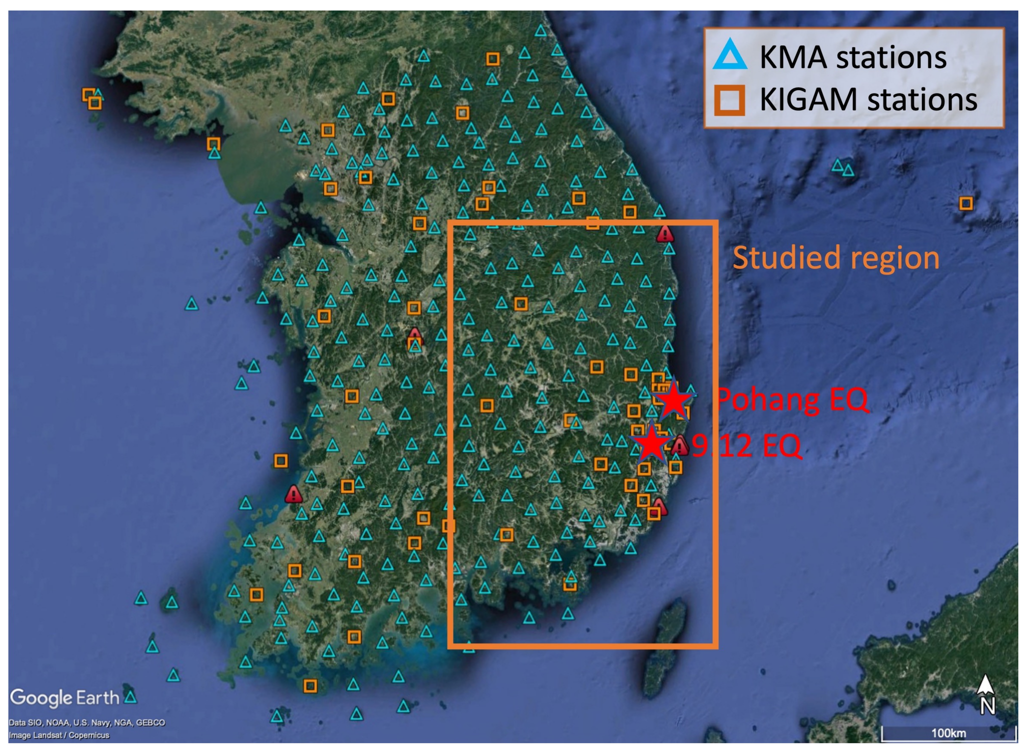

Figure: Map of the studied region. Markers show the locations of strong motion stations operated by Korean Meteorological Agency (KMA) and Korea Institute of Geoscience and Mineral Resources (KIGAM).

Results and validation

- Overall, simulation results were comparable with recorded motions.
- Some stations (e.g. JINA, HCNA, HACA) show much larger recorded motions with suspected site-specific effects in long periods.
- Current model is unable to predict the long-period surface waves of 2017 Pohang EQ, likely caused by the shallow rupture (hypocenter depth of 5km).
- Need further validation, including simulation of other smaller events, improvement of velocity models, investigation of site/basin effects, etc.

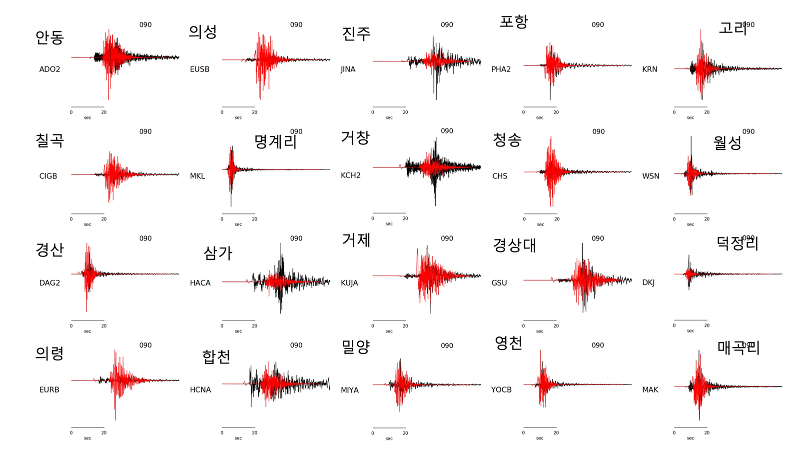

Figure: Comparison of simulated (red) and recorded (black) velocity time series from 2016 **M**5.5 Gyeongju EQ.

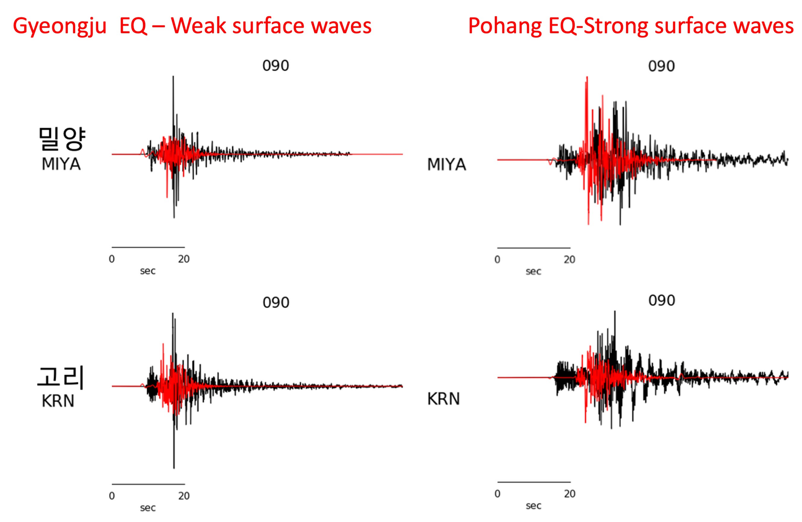

Figure: Comparison of velocity waveforms shows much stronger surface waves in case of 2017 **M**5.4 Pohang EQ.

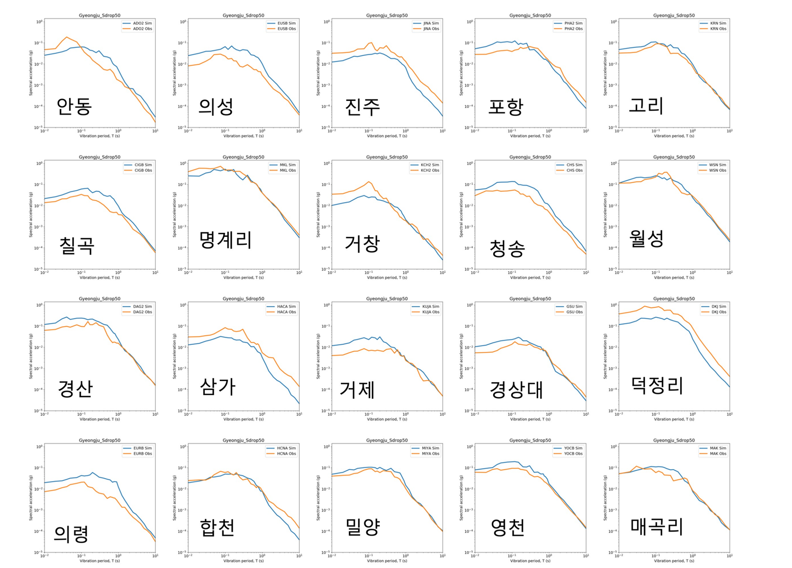

Figure: Comparison of simulated (blue) and recorded (orange) acceleration response spectra from 2016 **M**5.5 Gyeongju EQ.

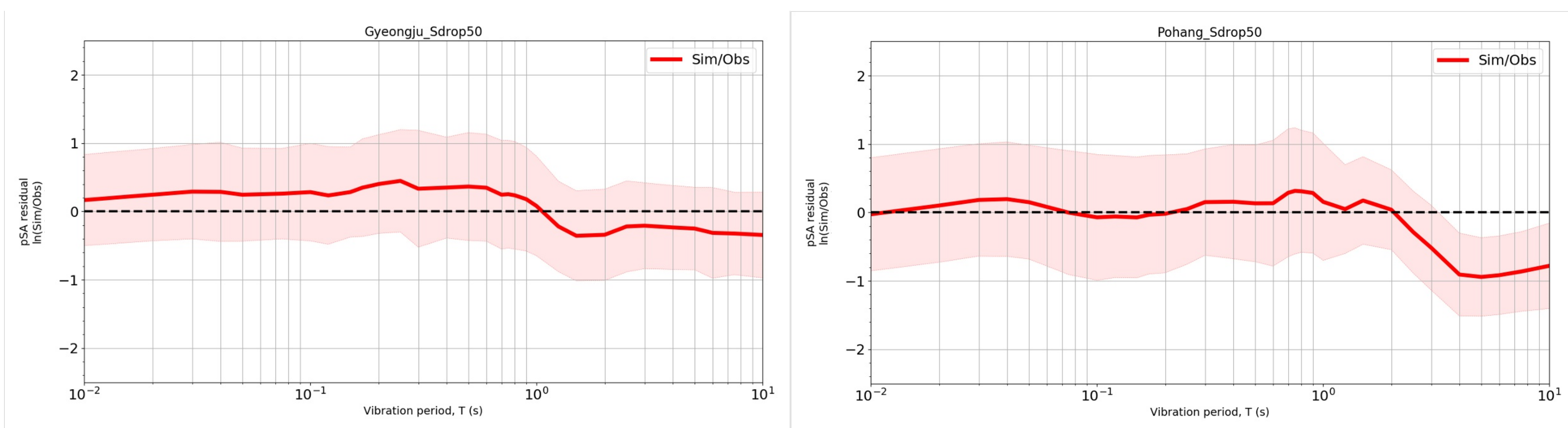

Figure: Residuals of acceleration response spectra from 2016 **M**5.5 Gyeongju EQ (left) and 2017 **M**5.4 Pohang EQ (right). Simulation significantly underestimated long-period motion in case of 2017 Pohang EQ.

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