EGU2020 -2257

EGU General Assembly 2020

What if a larger earthquake would occur at the causative fault of the Gyeongju earthquake with M_L 5.8 on September 11, 2016 in South Korea?

Hoseon Choi[1]
[1] Korea Institute of Nuclear Safety, Daejeon, South Korea (hoseon@kins.re.kr)

Abstract

A seismic source can be a capable tectonic source or a seismogenic source. A capable tectonic source is a tectonic structure that can generate both vibratory ground motion and tectonic surface deformation at or near the earth's surface in the present seismotectonic regime. On the other hand, A seismogenic source generates vibratory ground motion but is assumed to not cause surface displacement, covering wide range of seismotectonic conditions, from a well-defined tectonic structure to simply a large region of diffuse seismicity.

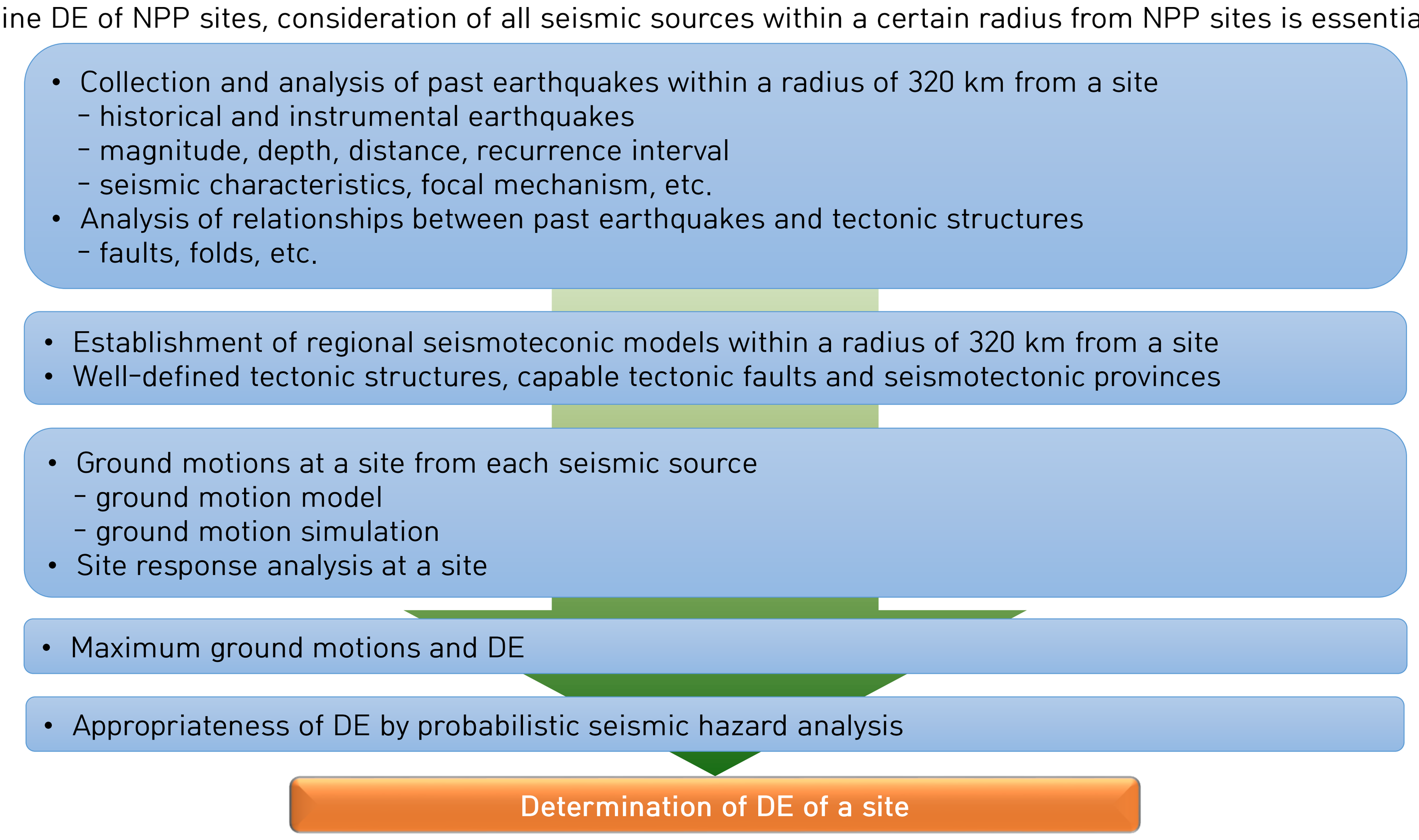
The M_L 5.8 Gyeongju earthquake on September 11, 2016 in South Korea is the largest instrumental one since 1978 that occurred in buried fault not exposed to the surface area. So to speak, there is no evidence of surface faulting till now. On the other hand, the geometry of the causative fault of the Gyeongju earthquake was revealed in detail from the distribution of foreshocks and aftershocks. Therefore, the causative fault of the Gyeongju earthquake can be treated as a seismogenic source corresponding to a well-defined tectonic structure as mentioned above.

What level of ground motions would occur at the site of interest if a larger earthquake would occur at the causative fault of the Gyeongju earthquake? To make a rough estimate of that question, we carried out a simple study of modeling the causative fault with the data available, and simulating strong ground motions with the stochastic and empirical Green's function techniques. The magnitude of the maximum earthquake potential on the causative fault is in the range of 6.0 to 7.0 and increased by 0.5. We do not claim the possibility of such a large earthquake in the region, but have a goal to evaluate the seismic safety evaluation of the site of interest from such an earthquake potential. This type of study may help us elucidate the seismic hazard in a low seismicity area such as South Korea and review the seismic safety of the site of interest.

Seismic Safety Evaluation Procedure for NPP sites in South Korea

◆ Seismic source
- Capable tectonic source : capable fault
- Seismogenic source : a well-defined tectonic structure or simply a large region of diffuse seismicity
  → The causative fault of the Gyeongju earthquake can be regarded as a well-defined tectonic structure.

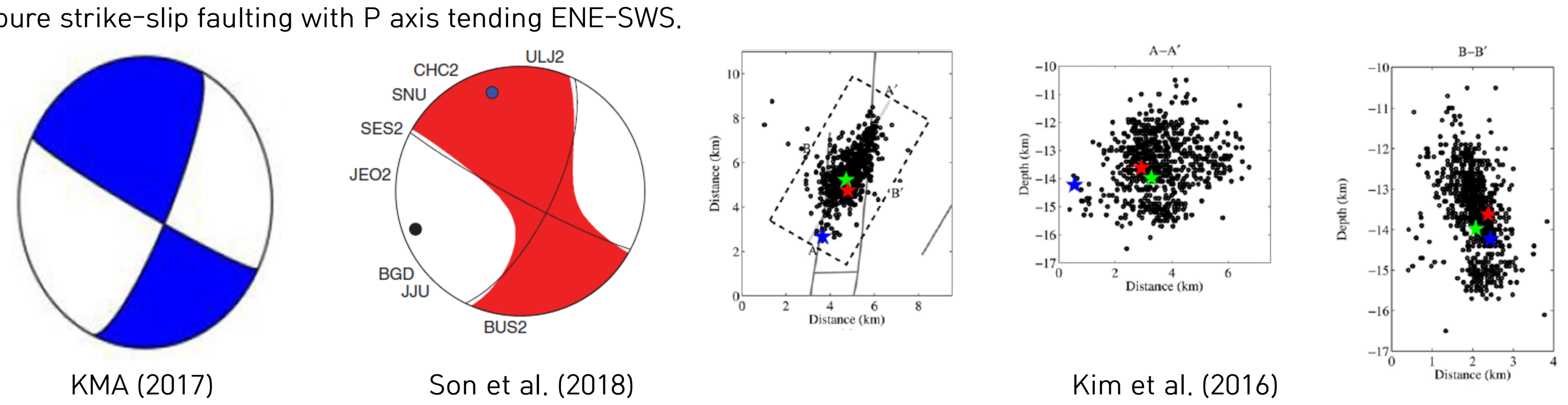
◆ Procedure for determining design earthquake (DE) in NPP sites in South Korea
- To determine DE of NPP sites, consideration of all seismic sources within a certain radius from NPP sites is essential.



The Gyeongju Earthquake

◆ Status
- At 19:44 on September 12, 2016, an earthquake with M_L 5.1 occurred in the Gyeongju area, South Korea. The mainshock with M_L 5.8 occurred at 20:32 in succession.
- The Gyeongju earthquake is the largest instrumental one since the Korea Meteorological Administration started its formal earthquake reporting around the Korean Peninsula in 1978.
- After a week, the largest aftershock with M_L 4.5 occurred.

◆ Geometry of the Causative Fault of the Gyeongju Earthquake
- The geometry of the causative fault of the Gyeongju earthquake could be inferred in detail from the distribution of aftershocks.
- The Gyeongju earthquake is an event that occurred in buried fault not exposed to surface area, and the fault plane solution shows a pure strike-slip faulting with P axis tending ENE-SWS.



KMA (2017) Son et al. (2018) Kim et al. (2016)

Stochastic Method

◆ Acceleration amplitude spectrum model
- The model amplitude spectrum is given by $A(M_0,R,f)=C \cdot E(M_0,f) \cdot D(R,f) \cdot P(f) \cdot I(f) \cdot S(f)$
  → C(scaling factor), E(amplitude source spectrum), D(diminution function), P(high cut filter), I(shaping filter), S(site response)
- We also considered duration model and shaping window for windowing of Gaussian noise.

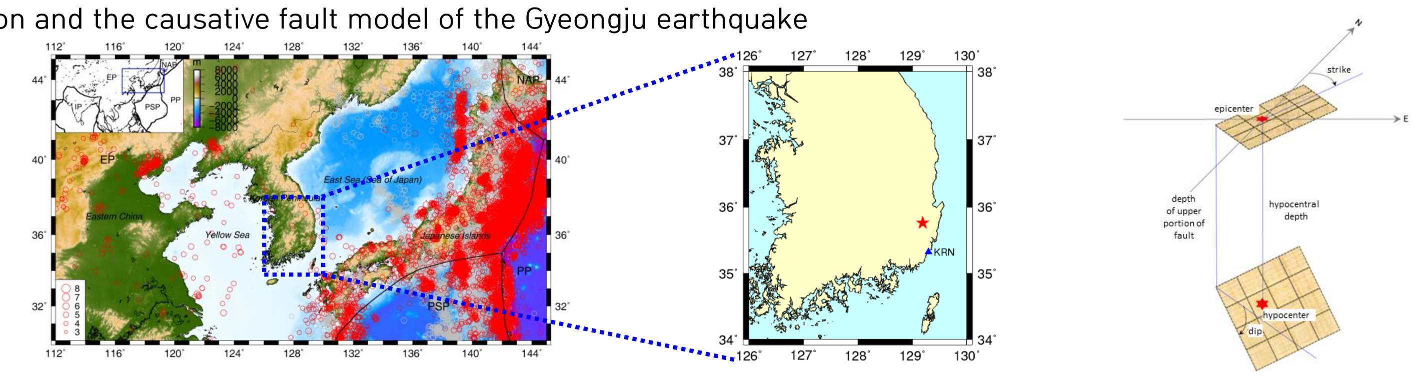
◆ EXSIM
- An open source stochastic finite fault simulation algorithm written in FORTRAN, that generates time histories of earthquake ground motions (Motazedian and Atkinson, 2005)
- EXSIM is adopted to simulate ground motions by the maximum potential earthquake that may occur on the causative fault of the Gyeongju earthquake for its usefulness and conciseness from an engineering view.

Ground Motion Simulation Considering the Causative Fault of the Gyeongju Eq. using EXSIM

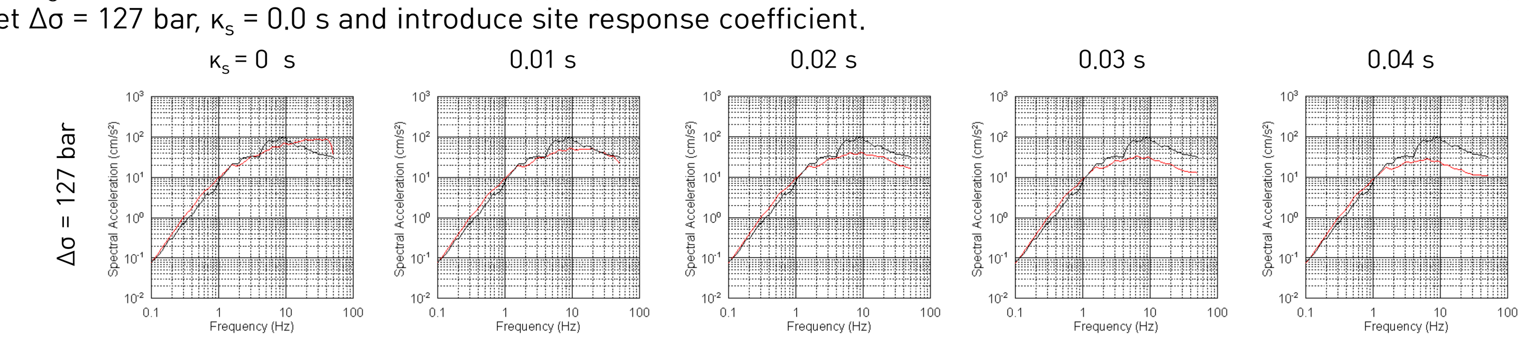
◆ Input parameters

	Value	Remark
hypocenter	35.7621 N 129.1903 E 12.8 km	Son et al. (2018)
fault length and width	4 km × 4 km	
fault type	strike slip	
magnitude	M_W 5.5	
stress drop	127 bar	
geometrical spreading	1/R (R ≦ 50 km), $(50R)^{0.5}$ (R > 50km)	Rhee (2018)
anelastic attenuation	$229.2f^{0.73}$	Kim (2007)
duration	0 (R ≦ 10 km), 0.16(R-10) (10 < R ≦ 70 km) 9.6-0.03(R-70) (70 < R ≦ 130 km), 7.8+0.04(R-130) (130 km < R)	Atkinson and Assatourians (2015)
κ_s	0, 0.01, 0.02, 0.03, 0.04 sec	for test
V_S and density	3.5 km/s, 2.7 g/cm³	Junn et al. (2002)
radiation pattern	0.55	EXSIM
free surface amplification	2	-

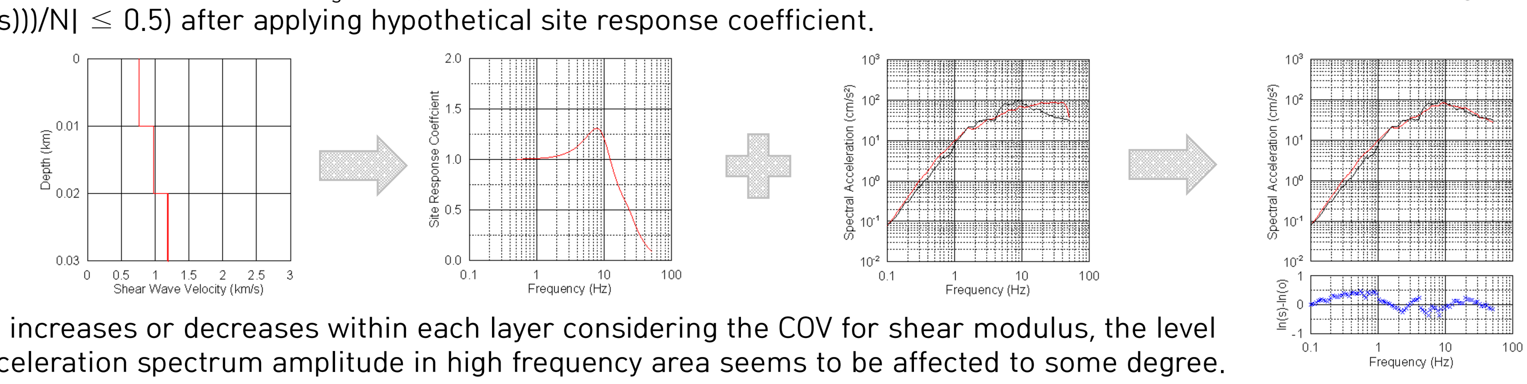
◆ Site location and the causative fault model of the Gyeongju earthquake



◆ Response spectrum comparison of simulated and observed ground motion
- $\Delta\sigma$ and κ_S are factors that greatly affect simulating the level of acceleration amplitude spectrum in high frequency ranges.
- We set $\Delta\sigma$ = 127 bar, κ_S = 0.0 s and introduce site response coefficient.

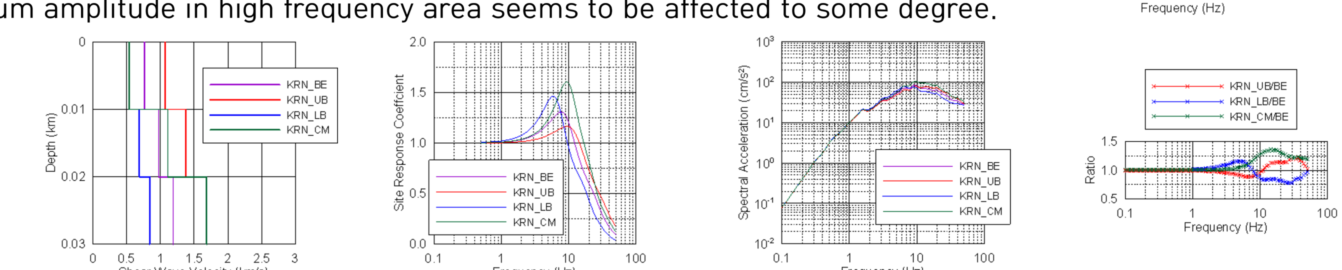


◆ Site response coefficient
- There is no data on V_S and density profile at KRN station. But the base-rock shear wave velocity around KRN is known as 1,190 m/sec, so we regard V_S at surface area as 760 m/s considering the medium rock of V_{S30} and V_S at the depth of 30 m as 1,190 m/s with 3 layers.
- In case of $\Delta\sigma$ = 127 bar and κ_s = 0 s, the fitness between observed (black) and simulated (red) data seems to be good ($|(\Sigma(\ln(syn)-\ln(obs)))/N| \leq 0.5$) after applying hypothetical site response coefficient.

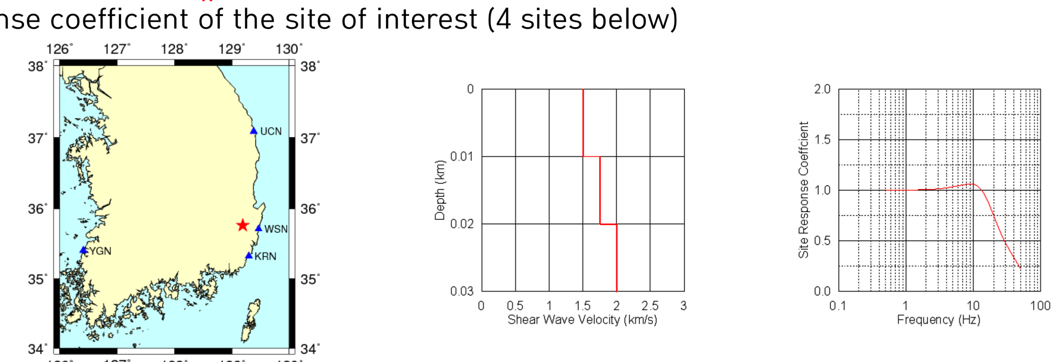


- As V_S increases or decreases within each layer considering the COV for shear modulus, the level of acceleration spectrum amplitude in high frequency area seems to be affected to some degree.

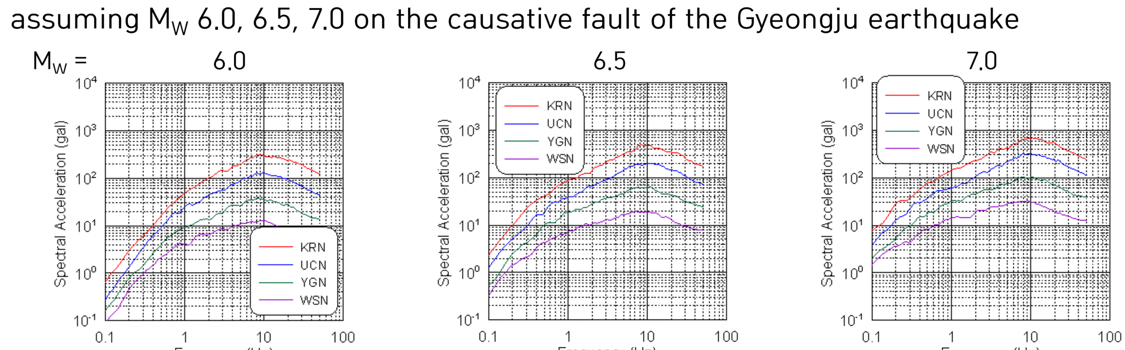
$V_{UB} = V_S \times \mathrm{sqrt}(1+COV)$
$V_{LB} = V_S / \mathrm{sqrt}(1+COV)$
V_{CM} : combination of V_{UB} and V_{LB}



◆ Ground Motion Simulation Assuming M_W 6.0, 6.5, 7.0 on the Causative Fault of Gyeongju EQ. by EXSIM
- Hypothetical site response coefficient of the site of interest (4 sites below)



- Response spectrum assuming M_W 6.0, 6.5, 7.0 on the causative fault of the Gyeongju earthquake



Empirical Green's Function Method

◆ Empirical Green's Function (EGF)
- Theoretically, Green's functions are the impulse response of the medium, and EGFs are recordings used to provide this impulse response.
- The waveform for a large event is synthesized by summing the records of small events with corrections for the difference in the slip velocity time function between the large and small events considering scaling laws.

◆ EGFM
- An open source written in FORTRAN for simulating large events with empirical Green's function method (Irikura, 1986)
- Thanks to various magnitude values of foreshocks, mainshock and aftershocks, and abundant seismic data of the Gyeongju earthquake, EGFM can be applied to simulate ground motions by the maximum potential earthquake that may occur on the causative fault of the Gyeongju earthquake.

Ground Motion Simulation Considering the Causative Fault of the Gyeongju EQ. using EGFM

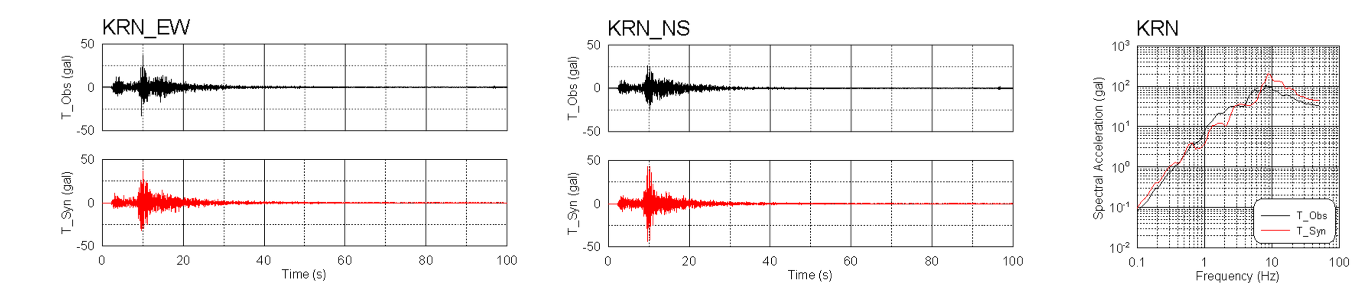
◆ Source parameters

	latitude (°N)	longitude (°E)	depth (km)	mag. (M_W)	strike (°)	dip (°)	rake (°)
foreshock	35.7698	129.1911	13.9	5.0	29	73	178
mainshock	35.7621	129.1903	12.8	5.5	26	68	175

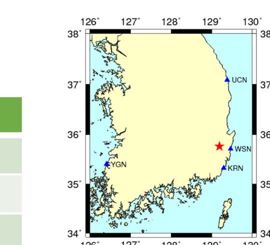
◆ EGFM parameters

	l (km)	w (km)	N	subfault	C	V_S (km/s)	V_r (km/s)
mainshock/ foreshock	2	2	2	2×2	1	3.5	2.8

◆ Comparison observed waveforms with simulated waveforms at KRN station



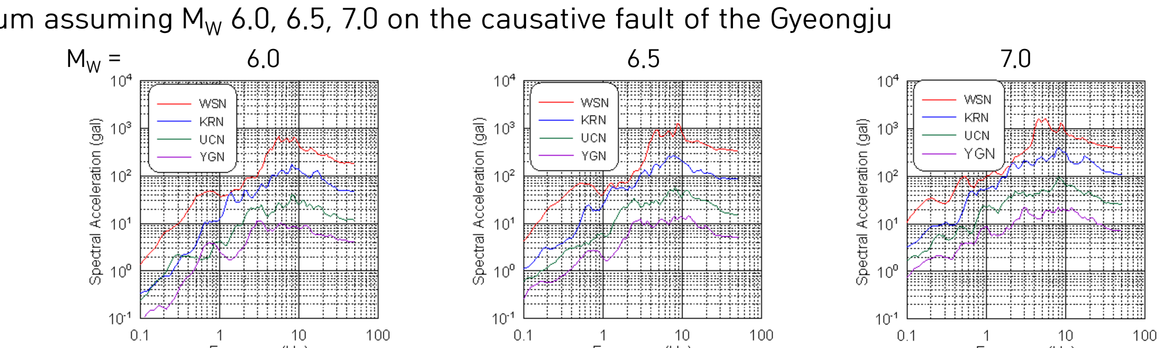
◆ Ground Motion Simulation Assuming M_W 6.0, 6.5, 7.0 on the Causative Fault of Gyeongju EQ. by EGFM



- EGFM parameters

M_W	l (km)	w (km)	N	subfault	C	V_S (km/s)	V_r (km/s)
6.0	4	4	2	2×2	1	3.5	2.8
6.5	4	4	3	3×3	1	3.5	2.8
7.0	4	4	5	5×5	1	3.5	2.8

- Response spectrum assuming M_W 6.0, 6.5, 7.0 on the causative fault of the Gyeongju



Conclusion, Application, Limitation, and Reference

◆ Conclusion
- We modeled the causative fault of the Gyeongju earthquake, and simulated strong ground motions at the site of interest by the stochastic and empirical Green's function methods assuming M_W 6.0, 6.5, 7.0 of the maximum earthquake potential on the causative fault.
- But further in-depth study including sensitivity analysis for various parameters should be conducted using more recorded data.

◆ Application
- Derivation of preliminary ground motion evaluation result of the site of interest considering causative faults of significant earthquakes in South Korea
- Establishment of a basis for deriving related research items for future updates

◆ Limitation
- The hypothetical site response coefficient should be replaced with the measured one.
- Due to the nature of the stochastic method, three components of seismic waves and directivity effects cannot be simulated.
- The discrepancies between seismic source models used in two methods should be described in a reasonable way, and so on.

◆ Reference

- Atkinson, G. M. and K. Assatourians (2015). Implementation and validation of EXSIM (a stochastic finite-fault ground-motion simulation algorithm) on the SCEC broadband platform. Seismological Research Letters, 86, 48-60.
- Irikura, K. (1986). Prediction of strong acceleration motions using empirical Green's function. 7thJapan Earthquake Engineering Symposium, 151-156.
- Junn, J.-G., N.-D. Jo and C.-E. Baag (2002). Stochastic prediction of ground motions in southern Korea. Geosciences Journal, 6, 203-214.
- Kim, K.-H, T.-S. Kang, J. Rhie, Y.H. Kim, Y. Park, S. Y. Kang, M. Han, J. Kim, J. Park, M. Kim, C.H. Kong, D. Heo, H. Lee, E. Park, H. Park, S.-J. Lee, S. Cho, J.-U. Woo, S.-H. Lee and J. Kim (2016b). The 12 September 2016 Gyeongju earthquakes: 2. Temporary seismic network for monitoring aftershocks. Geosciences Journal, 20, 753-757.
- Kim, S. K. (2007). Seismic wave attenuation in the southern Korea Peninsula: comparison by the applied method and used data. Journal of Korean Geological Society of Korea, 43, 207-217. (in Korean with English abstract)
- Korea Meteorological Administration. (2017). 2016 Earthquake Annual Report.
- Motazedian, D. and G. M. Atkinson (2005). Stochastic finite-fault modeling based on a dynamic corner frequency. Bulletin of the Seismological Society of America, 95, 995-1010.
- Rhee, H.-M. (2018). Analysis of seismic source parameters of earthquakes in the Korean Peninsula and characteristics of strong ground motions. Thesis for the Degree of Ph.D. in Jeonnam National University. (in Korean with English abstract)
- Son, M., C. S. Cho, J. S. Shin, H.-M. Rhee, and D.-H. Sheen (2018). Spatiotemporal distribution of events during the first three months of the 2016 Gyeongju, Korea, earthquake sequence. Bulletin of the Seismological Society of America, 108, 210-217.