APPLICATION OF A HYBRID APPROACH FOR BROADBAND GROUND MOTION SIMULATIONS TO THE 2008 IWATE-MIYAGI NAIRIKU EARTHQUAKE

L. Moratto, A. Vuan, A. Saraò

Centro Ricerche Sismologiche, OGS (Istituto Nazionale di Oceanografia e di Geofisica Sperimentale), Trieste, Italy

Email: lmoratto@inogs.it

1. OVERVIEW

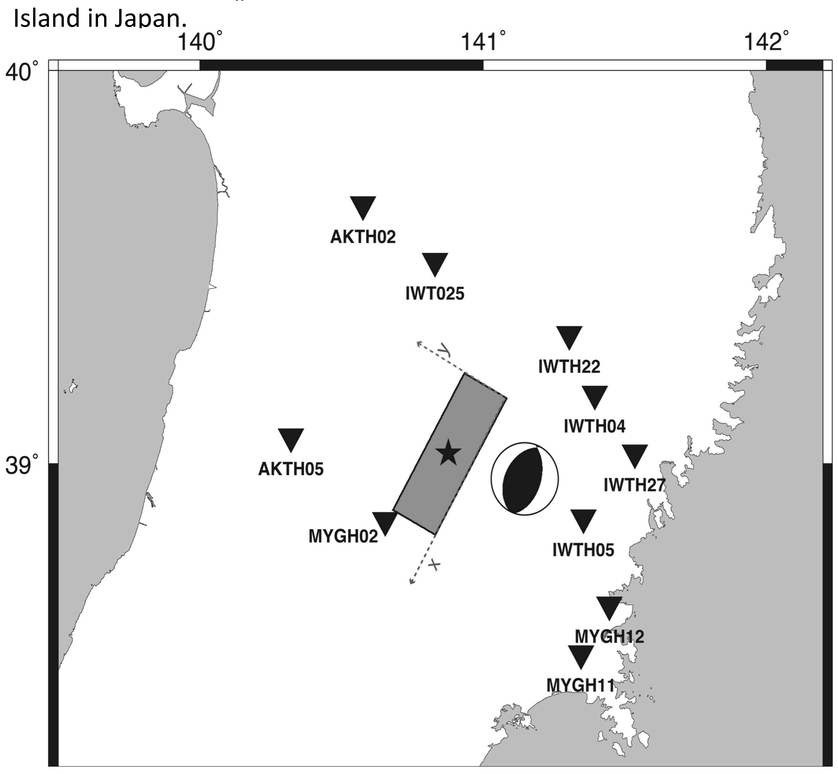
We developed a user-friendly hybridization code that merges the full-wave low-frequency signals with stochastic high-frequency synthetics to simulate broadband strong ground motion for engineering applications.

The approach is applied to reproduce, within the known source and structure constraints, the Kik-NET and K-net accelerometric data recorded during the 2008 Iwate-Miyagi Nairiku earthquake (M_w 7.0).

The results show that our approach is able to simulate satisfactorily the observed waveforms and the related response spectra over the broadband frequency range.

2. THE 2008 IWATE-MIYAGI NAIRIKU EARTHQUAKE

The earthquake (M_w 7.0) occurred on June 13, 2008 on the NE Honshu Island in Japan.

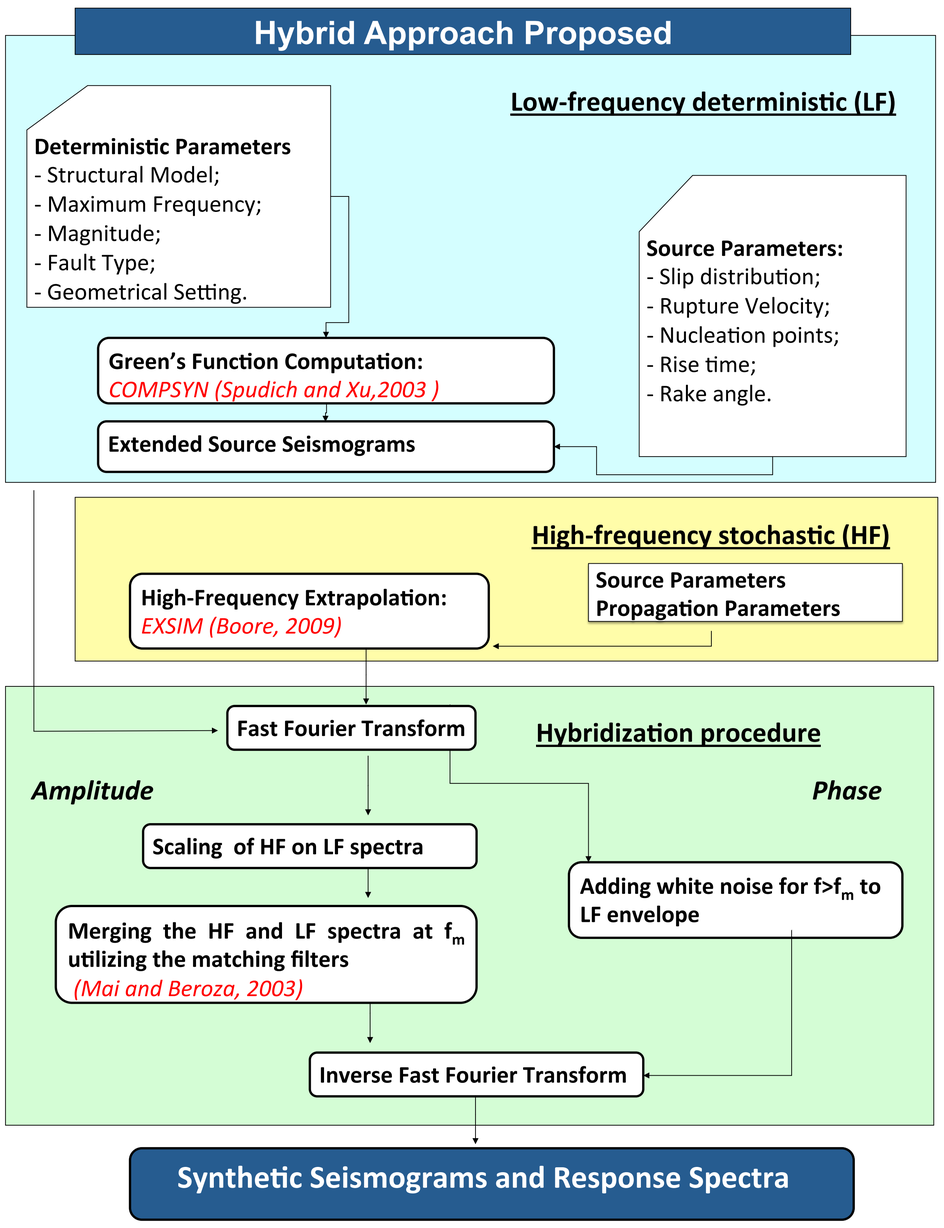


The hypocenter (39.027° N - 140.878° E) is at a depth of 6.5 km. Cultrera et al. (2013) proposed as source a rectangular fault (44.4 km x 19.0 km) with a reverse focal mechanism (str = 209°, dip = 40°, rake = 105°). The rupture propagates bilaterally. Two patches of slip distribution, the main concentrated in the southern shallow part of the fault with a maximum value of about 5.5 m were found through waveform inversion in the range 0.02-0.5 Hz.

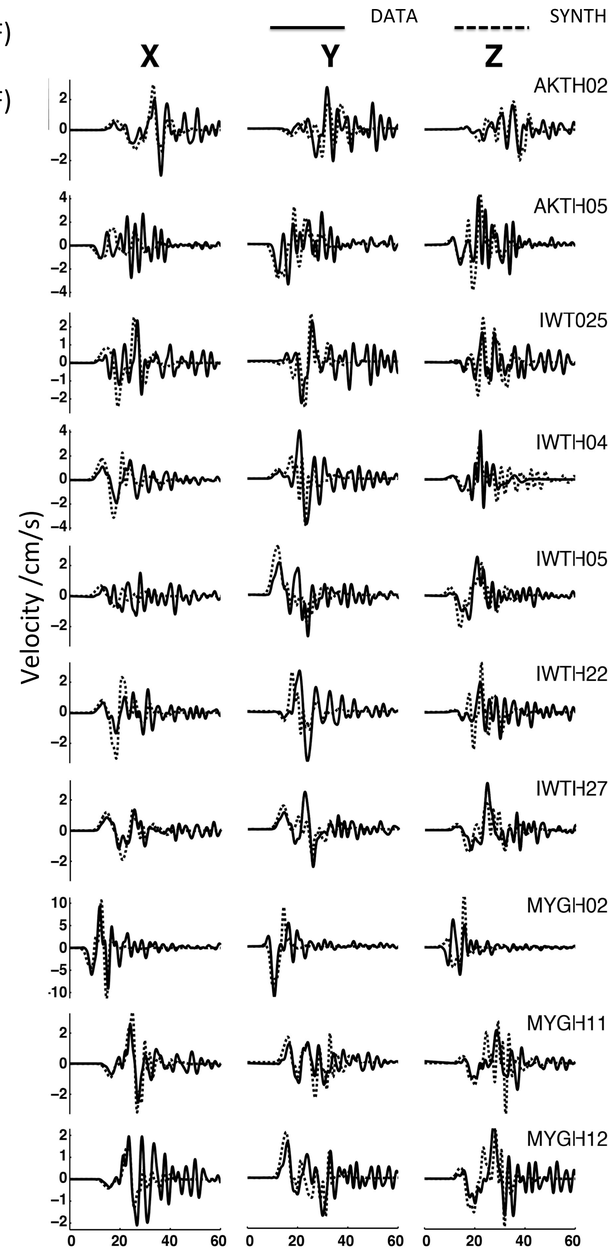
3. THE BROADBAND SYNTHETIC SEISMOGRAMS

The broadband seismograms are generated in three steps:

1. Deterministic computation of the synthetics in the low-frequency content (LF) using COMPSYN (Spudich and Xu, 2003).
2. Stochastic computation of the synthetics in the high-frequency content (HF) using EXSIM (Boore, 2009).
3. Merging of the LF and HF synthetics at f_m, a intermediate frequency of match.



LF synthetics vs. data (0.02-0.5 Hz)

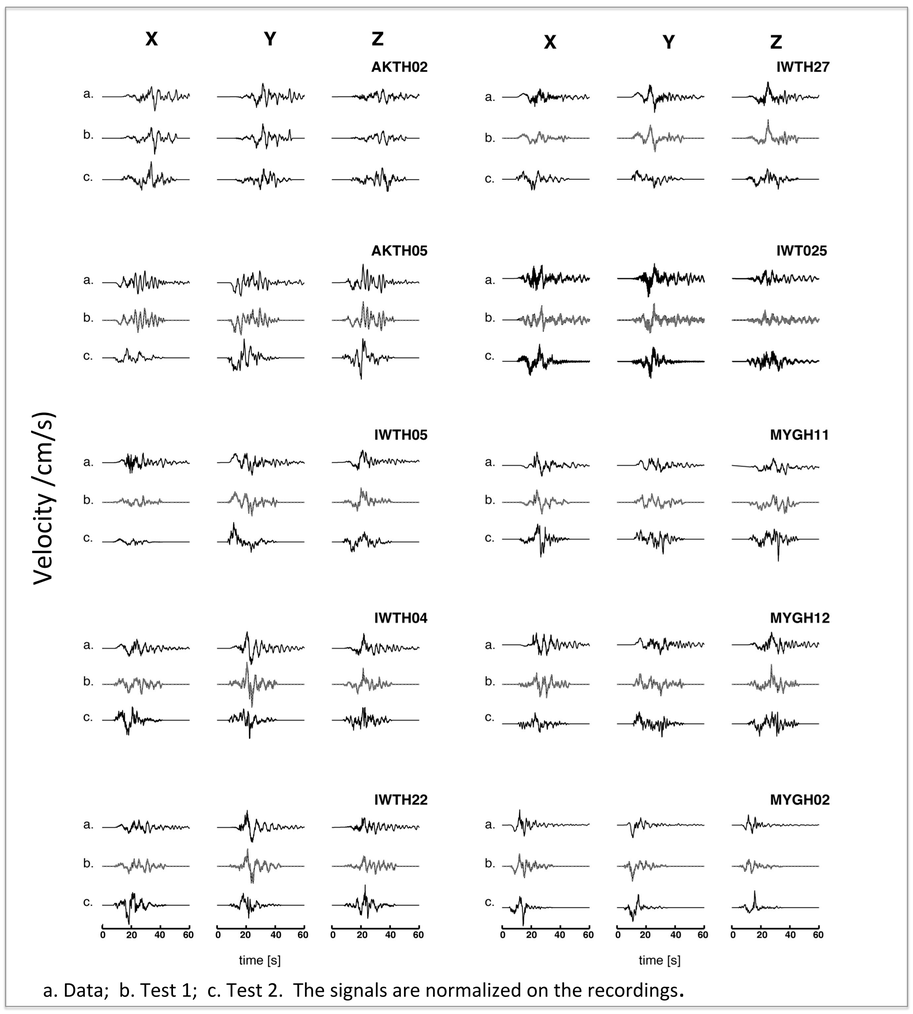


LF synthetic input:
source model by Cultrera et al. (2013), velocity model by Matsubara et al. (2008) and STF by Tinti et al. (2005).
HF synthetic input:
source model by Cultrera et al. (2013) and propagation parameter by Fujiwara et al. (2009).

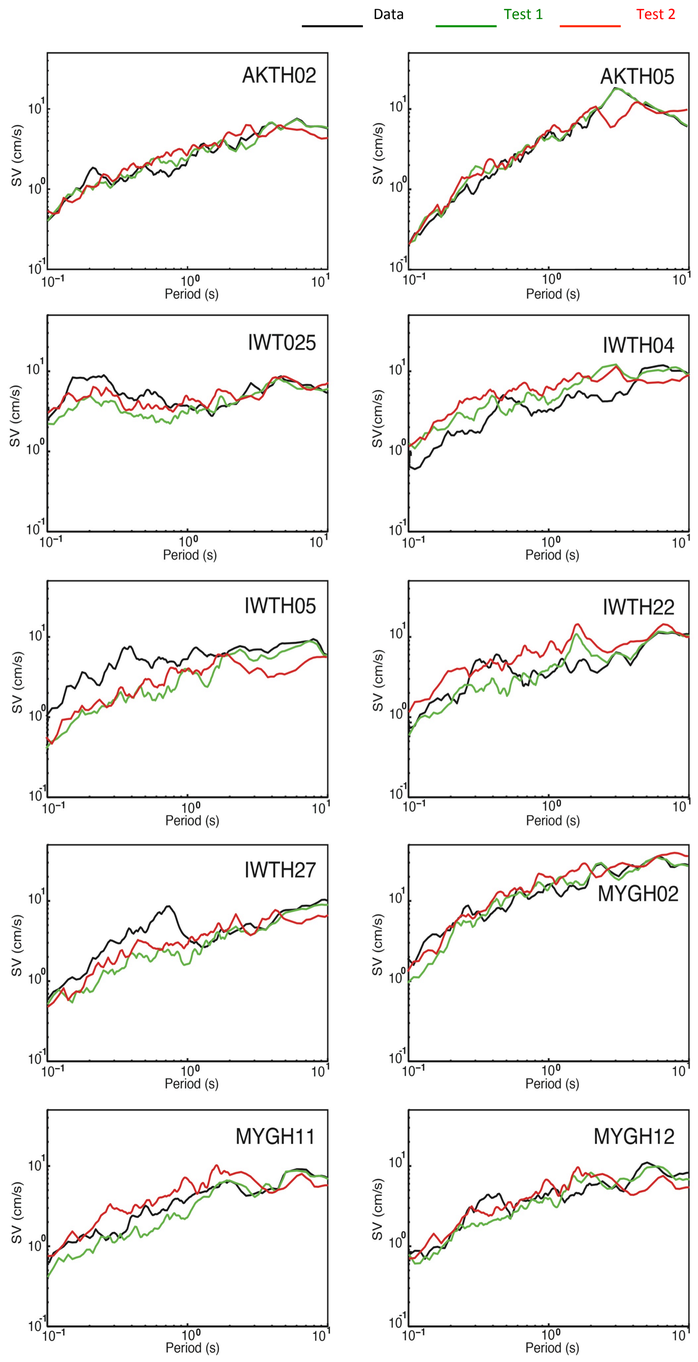
4. HYBRID SYNTHETIC SEISMOGRAMS OF THE 2008 IWATE-MIYAGI EARTHQUAKE (M_w=7.0)

We computed the ground motion by combining LF and HF signals. To test the sensitivity of our merging procedure we performed two different tests :

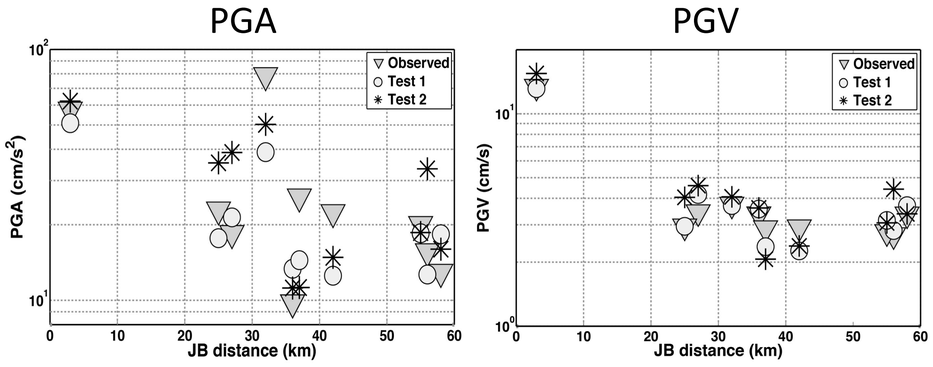
- TEST 1: merging HF synthetics with LF recordings
- TEST 2: COMPSYN-EXSIM merging



a. Data; b. Test 1; c. Test 2. The signals are normalized on the recordings.



Comparison between observed and synthetic velocity response spectra: the figure shows the vector addition of the horizontal components of the recordings (black lines) and the hybrid synthetics simulated in Test 1 (green lines) and in Test 2 (red lines).



The peak values are obtained from the geometrical mean of the horizontal components.

5. CONCLUSIVE REMARKS

The match between synthetics and the recorded data is fairly good and the strong ground motion is satisfactorily reproduced, thus validating our method.

- We estimated the effects of the hybridization in the peak and spectral parameters through the goodness of fit criteria - GOF (Olsen and Mayhew, 2010).
- In Test 1 the mean GOF values (100 stands for perfect fit) are around 70-80 (very good fit). In Test 2 the GOF range is 50-60 (fairly good fit). That means that is not possible to generate reliable broadband synthetics if the LF signals are not well constrained.
- If we disaggregate the GOF values related to different ground motion parameters, we observe that PGV is the most stable parameter, with a GOF ranging between 75 and 95 in Test 1 that decreases to 60-85 in Test 2; the most sensitive parameter is PGA with GOF ranging between 60 and 80 in Test 1 and decreasing to 40-60 in Test 2. The fit on the response spectra is slightly better than that obtained for the PGA values (the GOF is 60-90 Test 1 and 45-80 for Test 2).
- This hybridization process can be easily applied to generate broadband strong ground motion scenarios using different ground motion modeling techniques to calculate the LF and HF synthetics.

References:

- Boore, D.M., (2009). Comparing stochastic point-source and finite-source ground motion simulations: SMSIM and EXSIM. Bull. Seismol. Soc. Am. 99, 3202-3216.
- Cultrera, G., G. Ameri, A. Saraò, A. Cirella, and A. Emolo, (2013). Ground-motion simulations within ShakeMap methodology: application to the 2008 Iwate-Miyagi Nairiku (Japan) and1980 Irpinia (Italy) earthquakes. Geophys. J. Int. doi: 10.1093/gji/ggs074.
- Fujiwara, H., S. Kawai, S. Aoi, N. Morikawa, S. Senna, N. Kudo, M. Ooi, K.X. Hao, K. Wakamatsu, Y. Ishikawa, T. Okumura, T. Ishii, S. Matsushima, Y. Hayakawa, N. Toyama, and A. Narita, (2009). Technical Reports on National Seismic Hazard Maps for Japan. Technical Note of the National Research Institute for Earth Science and Disaster Prevention No. 336, 258 pp.
- Mai, P.M., and G.C. Beroza, (2003). A hybrid method for calculating near-source broadband seismograms: application to strong motion prediction. Phys. Earth Planet. Int. 137, 183-199.
- Olsen, K.B., and J.E. Mayhew (2010). Goodness-of-fit criteria for broadband synthetic seismograms, with application to the 2008 Mw 5.4 Chino Hills, California, earthquake. Seism. Res. Lett. 81, 715-723.
- Spudich, P., and L. Xu, (2003). Documentation of software package Compsyn sxv3.11: programs for earthquake ground motion calculation using complete 1-d green's functions, International Handbook of Earthquake and Engineering Seismology CD, Int. Ass. Of Seismology and Physics of Earth's Interior, Academic Press.
- Tinti, E., E., Fukuyama, A., Piatanesi, and M. Cocco, (2005). A kinematic source-time function compatible with the earthquake dynamics. Bull. Seism. Soc. Am. 95, 1211-1223.