Strong Ground Motion Simulations and Assessment of Influence of Model Parameters on the Waveforms

Ekaterina Zadonina(1)(ekaterina@uevora.pt), Bento Caldeira(1), Mourad Bezzeghoud(1), José Borges(1)

Abstrcts

Modeling near-field ground motion is an important and useful tool of modern seismology. In our work we use a finite difference algorithm to compute near-field ground motions from a real moderate event with pre-existing slip distribution model. Lately, synthetic seismograms are quantitatively compared with observed waveforms from near-field seismic stations in order to justify created model. Furthermore, we independently changed several source parameters (rupture velocity, source dimension and geometry), and structure (velocity model) in order to evaluate their influence on the waveforms. For the comparison of seismograms we applied quantitative misfit criteria based on wavelet transform.

Objectives

1. Study of existing metods and algorithms for ground motion simulations

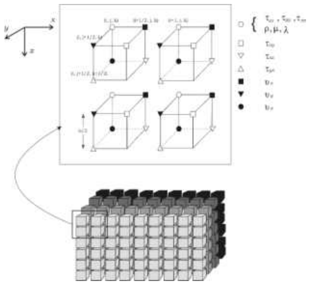
2. Strong ground motions simulations

3. Assess influence of different model parameters on waveforms

4. Find the way of quantitative evaluation of resulted waveforms

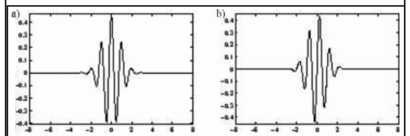
Methodology

Waveform modeling - Finite difference method (Pic.)



Pic. * The grid layout for staggered-grid formulation

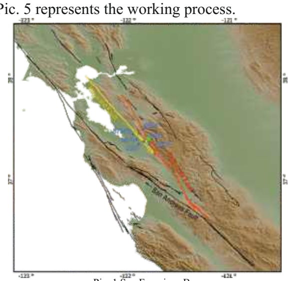
** Quantitative misfit criteria based on the time-frequency representation of the seismograms obtained as the continuous wavelet transform with the analyzing wavelet (Pic. **) (Kristeková et al, 2006)



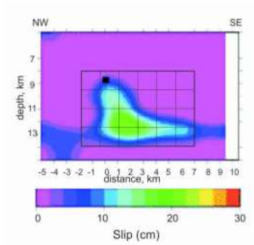
Pic. ** Real and imaginary part of the Complex Morlet Wavelet

Description and Processing of the Data

Theoretical knowledge and practical skills in seismic source modeling and waveform synthesis were applied for strong ground motion waveform synthesis of actual moderate event using its source geometry and slip distribution along with regional velocity structure as input parameters. As a moderate seismic event that could provide us with near-field strong-motion data we decide on using the Alum Rock earthquake that occurred near the junction of the Hayward and Calaveras faults in the San Francisco Bay, California, on October 31, 2007 at approximately 8:04 p.m. PDT (Pic.1). Slip distribution model and a velocity model were required for the region of interest in ordrer to creat an input model for simulations. They presented on the Pic. 2 and Pic. 3 respectively. In order to compare results of simulations with observed data we picked six broad-band strong ground motion stations that provided us with good azimuthal coverage and were located in the distance range from 5.4 to 14 km from the epicenter. Three components of one of these stations are presented on the Pic. 4. The chart on Pic. 5 represents the working process.



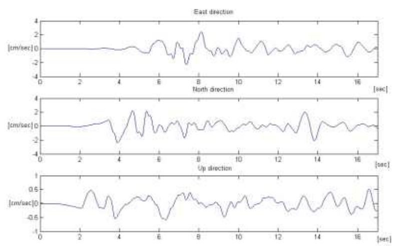
Pic. 1 San Francisco Bay. Blue triangles - broad-band near-field seismic stations. Green star - epicenter



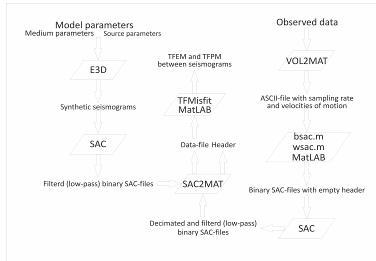
Pic. 2 Slip distribution (Hellweg et al., 2007). Black grid - the asperity where the maximum slip occurred. It was selected for simulations as finite fault slip model

Width of the layer, m	V_p, km/s	V_s, km/s	ρ, g/cm³
2	1.7	0.35	2
4	1.8	0.55	2.1
6	1.8	0.8	2.1
8	1.9	0.9	2.1
10	2	1	2.2
70	2.4	1.1	2.3
100	2.6	1.2	2.4
300	3	1.4	2.45
500	3.6	1.95	2.5
500	4.2	2.3	2.55
1000	4.8	2.8	2.6
500	5.25	3	2.62
2000	5.6	3.25	2.65
2000	5.9	3.41	2.7
2000	6.15	3.55	2.75
8000	6.35	3.62	2.85
8000	7	4.1	3
#######	8	4.5	3.3

Pic. 3 1D Velocity model by Aagaard (2008)



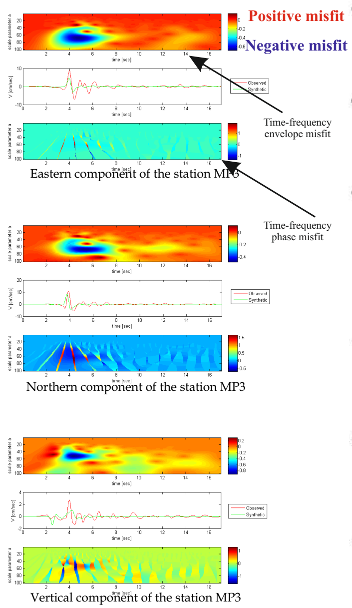
Pic. 4 Observed waveforms from the broad-band near-field seismic station MP3



Pic. 5 Data processing charts

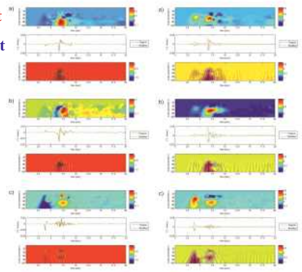
Obtained Results

Comparison of observed and synthetic waveforms

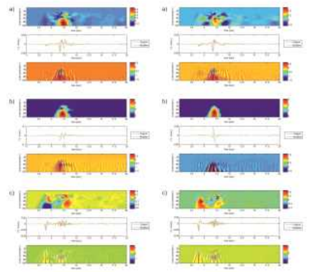


For the reason that presentation of all obtaine results would not fit in the frame of one poster it was decided to use one station as an example.

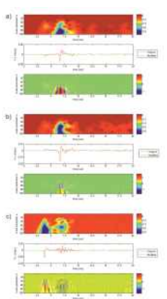
Comparison of originally synthesized waveforms with waveforms obtained using models with independently modified



i) ii)
Modification of dip angle (90 deg.). It was modified by 10 deg. in both directions: i) 80 deg. dipping NE, ii) 80 deg. dipping SW

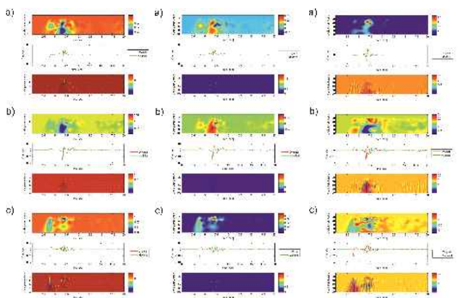


i) ii)
Modifications of strike angle (323 deg.): i) strike angle = 308 deg., ii) strike angle = 338 deg.



Fault plane length (9 km) enlarged by 50%

i) ii)
Modified velocity of rupture (3 km/sec): i) 2.8 km/sec, ii) 3.1 km/sec



Modified model: velocity model – Waldhauser& Ellsworth, 2002

Analysis and Conclusions

Results, obtained during this work, are very inspiring.

First of all, comparison of the results of simulations with observed waveforms for corresponding stations revealed that despite the high values of the misfit both in envelope and phase we obtained consistency on the polarity of the first motion for all presented stations. Moreover and most importantly, velocity peaks are generally in the same greatness order (Table 1). Generally, results of performed strong ground motion simulations could be considered as reasonable.

			Observed waveform		Synthetic waveform	
Station	Epicentral distance	Direction of motion	Maximum velocity (m/sec)	Minimum velocity (m/sec)	Maximum velocity (m/sec)	Minimum velocity (m/sec)
57950	14 km	East	0.015899	-0.014521	0.015169	-0.024246
		North	0.013926	-0.014721	0.003435	-0.011311
		Up	0.003987	-0.004843	0.013241	-0.006866
CHR	6.6 km	East	0.087013	-0.071132	0.046486	-0.031226
		North	0.105834	-0.05.6485	0.08.5103	-0.046711
		Up	0.027172	-0.013542	0.009690	-0.013867
MP3	10.3 km	East	0.024228	-0.022915	0.044063	-0.068273
		North	0.022084	-0.023885	0.046261	-0.028371
		Up	0.005209	-0.005908	0.015372	-0.007968
Q32	10.8 km	East	0.044501	-0.042279	0.047462	-0.072689
		North	0.040803	-0.040256	0.098770	-0.062763
		Up	0.006494	-0.007161	0.003506	-0.002213
ROC	5.4 km	East	0.029518	-0.058605	0.091114	-0.107964
		North	0.059710	-0.033989	0.098247	-0.059114
		Up	0.007456	-0.009603	0.003096	-0.002359
1684	10.4 km	East	0.017198	-0.015110	0.025219	-0.067559
		North	0.006597	-0.006842	0.000198	-0.000511
		Up	0.003140	-0.004489	0.001884	-0.003432

Table 1 Maximum and minimum velocities of observed and synthetic waveforms

The reasons that could have affected the results are for example unaccounted regional topography, lateral velocity variations and site effect. Rupture model could also be a source of inaccuracies because it was reconstructed by inversion method (Bersenev, 2003).

Inappropriate choice of parameters could also be a source of misfit.

In order to understand how dramatically variations on some model parameters (dip angle, strike angle, length of the fault plane, rupture velocity, and velocity model) could affect synthetic waveform we independently modified their values, simulated new waveforms, compared the results with data obtained using original model.

Results of the tests for model parameters influence on the waveform showed extreme importance of usage of appropriate and realistic input parameters. It is essential for simulation results. For example, variation in dip angle resulted in for some of the stations in misfit between waveforms up to 80 % from the original value. Often proposed cahnges in the original model even lead to changs in the polarity of motion.

Eventually, we achieved main goal of presented work and assess influence of some parameters of the model on upcoming result. But most importantly, priceless theoretical knowledge and practical skills were obtained in the process and they would be used and enriched in the future.

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