Geophysical Research Abstracts
Vol. 15, EGU2013-10399, 2013
EGU General Assembly 2013

Analytical computation of three-dimensional synthetic seismograms by Modal Summation: method, validation and applications

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In order to enable realistic and reliable earthquake hazard assessment and reliable estimation of the ground motion response to an earthquake, three-dimensional velocity models have to be considered. The propagation of seismic waves in complex laterally varying 3D layered structures is a complicated process. Analytical solutions of the elastodynamic equations for such types of media are not known. The most common approaches to the formal description of seismic wavefields in such complex structures are methods based on direct numerical solutions of the elastodynamic equations, e.g. finite-difference, finite-element method, and approximate asymptotic methods. In this work, we present an innovative methodology for computing synthetic seismograms, complete of the main direct, refracted, converted phases and surface waves in three-dimensional anelastic models based on the combination of the Modal Summation technique with the Asymptotic Ray Theory in the framework of the WKBJ – approximation. The three – dimensional models are constructed using a set of vertically heterogeneous sections (1D structures) that are juxtaposed on a regular grid. The distribution of these sections in the grid is done in such a way to fulfill the requirement of weak lateral inhomogeneity in order to satisfy the condition of applicability of the WKBJ – approximation, i.e. the lateral gradient of the parameters characterizing the 1D structure has to be small with respect to the prevailing wavelength. The new method has been validated comparing synthetic seismograms with the records available of three different earthquakes in three different regions: Kanto basin (Japan) triggered by the 1990 Odawara earthquake Mw= 5.1, Romanian territory triggered by the 30 May 1990 Vrancea intermediate-depth earthquake Mw= 6.9 and Iranian territory affected by the 26 December 2003 Bam earthquake Mw= 6.6. Besides the advantage of being a useful tool for assessment of seismic hazard and seismic risk reduction, it is characterized by high efficiency, in fact, once the study region is identified and the 3D model is constructed, the computation, at each station, of the three components of the synthetic signal (displacement, velocity, and acceleration) takes less than 3 hours on a 2 GHz CPU.