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Quantitative analysis of accuracy of seismic wave-propagation codes in 3D random scattering media

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Several recent verification studies (e.g. Day et al., 2001; Bielak et al., 2010, Chaljub et al., 2010) have demonstrated the importance of assessing the accuracy of available numerical tools at low frequency in presence of large-scale features (basins, topography, etc.). The fast progress in high-performance computing, including efficient optimization of numerical codes on petascale supercomputers, has permitted the simulation of 3D seismic wave propagation at frequencies of engineering interest (up to 10Hz) in highly heterogeneous media (e.g. Hartzell et al, 2010; Imperatori and Mai, 2013). However, high frequency numerical simulations involving random scattering media, characterized by small-scale heterogeneities, are much more challenging for most numerical methods, and their verification may therefore be even more crucial than in the low-frequency case.

Our goal is to quantitatively compare the accuracy and the behavior of three different numerical codes for seismic wave propagation in 3D random scattering media at high frequency. We deploy a point source with omega-squared spectrum, and focus on the near-source region, being of great interest in strong motion seismology. We use two codes based on finite-difference method (FD1 and FD2) and one code based on support-operator method (SO). Both FD1 and FD2 are 4-th order staggered-grid finite-difference codes (for FD1 see Olsen et al., 2009; for FD2 see Moczo et al., 2007). The FD1 and FD2 codes are characterized by slightly different medium representations, since FD1 uses point values of material parameters in each FD-cell, while FD2 uses the effective material parameters at each grid-point (Moczo et al., 2002). SO is 2-nd order support-operator method (Ely et al., 2008). We considered models with random velocity perturbations described by van Karman correlation function with different correlation lengths and different standard deviations. Our results show significant variability in both phase and amplitude as the standard deviation of velocity perturbations increases, suggesting that the numerical representation of material heterogeneity in different codes exerts non-negligible effects on ground-motion simulations in heterogeneous media. The detailed quantification of these effects may need to be included into the epistemic uncertainty of ground-motion prediction.