FAST 3D HYBRID SEISMIC MODELING: RAY-FD APPROACH FOR ELASTIC MODELS WITH LOCALLY COMPLEX STRUCTURES

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Hybrid approaches may find broad applications wherever full source, path,and site effects modeling methods are too expensive. A new efficient hybrid method allowing to compute seismic wavefield in large 3D elastic models containing a complex local structure embedded in a large, but considerably simpler, structure is designed. This hybrid method combines the ray approach in the large simple structure with the finite difference (FD) approach in the local complex structure.

The hybrid method is based on two successive steps. In the 1st one, the source and path information is carried by wavefield propagating in the large simple structure. This wavefield, calculated by the ray method, is incident at the points along a two-fold formal boundary (excitation box, EB) surrounding that part of the model which is to be replaced by the complex medium in the 2nd step. 3D rays are necessary due to arbitrary source-EB configuration, even in case the 1st step structure is less dimensional (2D, 1D, homogeneous). Along EB, the ray endpoints may be distributed sparsely thanks to relative simplicity of the structure. This reduces computer time requirements and also the size of the excitation file saved on the disk.

The ray wavefield along EB provides (after interpolation in space and time) the input for the second step consisting in calculating the complete wavefield by the 3D FD method on irregular grids. The FD computational domain contains the EB and its close vicinity. The 2nd step model differs from the 1st step model only inside the EB where the local complex structure is inserted. To verify the consistency between the 1st and the 2nd step binding, the 2nd step computation can be performed on (unchanged) 1st step model ('replication test'). This should give the same wavefield as the 1st step inside, and zero wavefield outside the EB. The EB remains fully permeable for all waves propagating within the FD domain.

Provided the 1st step structure does not contain too many layers and the number of the excitation gridpoints in the 1st step is not too large, the asymptotic high-frequency solution makes the hybrid approach very efficient in comparison with full FD computation for the large structure model with the local structure inserted.

The 3D ray-FD method is tested on several models in which the locally complex structure represents the well-known Volvi lake basin. It is excited by the point source situated outside the basin. The 1st step model is either 1D layered structure or 2D layered structure containing inclined or curved interfaces. The 1D case allows the method to be compared with the alternative hybrid DWN-FD results (replacing the ray method in the 1st step by DWN method). The DWN-FD method was used even to verify, at least partly, the RAY-FD results in 2D structures provided they depart from 1D case only slightly.

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