

3D Hybrid Seismic Modeling: Ray-Fd or Dwn-Fd Approach for Elastic Models With Locally Complex Structures

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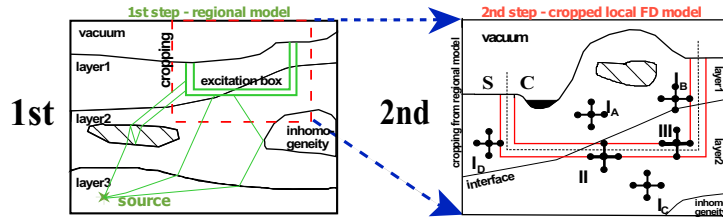
Why Hybrid Methods ?

- Source + path + site effects are to be considered
- "All in one" methods (e.g. FD) are too expensive



Two steps of the hybrid method:

- 1: source + path by DWN, Ray, FD or other 3D method
- 2: site by fine-grid FD



The 1st step: The particle motion at the double-planned excitation-box is saved on disc. The computation may be performed by any 3D-motion method as Discrete Wavenumber method (DWN or reflectivity), Ray method, Finite Difference method (FD) on a coarse grid, or it may be computed analytically. The structure and topography of the 1st step model are global or regional and they do not contain the local details. Thus the recorded excitation contains full source-path information without local effects.

The 2nd step: It is computed by FD method on a fine grid. The model contains the excitation box area from the 1st step. The local topography and complex structures are added inside the excitation box. The computation performs in three different areas (I,II,III) (see figure above) as introduced by Alterman and Karal (1968). For details concerning the computation at the excitation box points (see [4]).

Some of implications of the method:
for theory see [1,3]

-the excitation box represents all sources and source-path details from the 1st step model.

-the hybrid technique of the excitation in the 2nd step keeps the excitation box fully permeable for all the scattered waves created in the 2nd step model

-performing the 2nd step computation on (unchanged) 1st step model (so called 'REPLICATION TEST') should give the same wavefield as in the 1st step inside the box, while it should give 'zero' wavefield outside the box

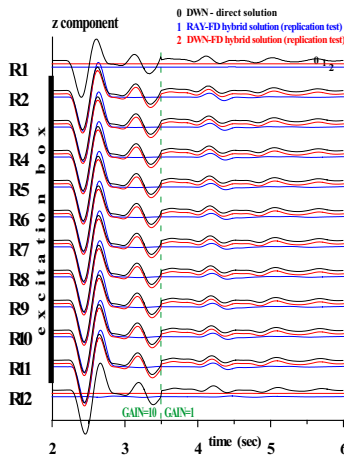
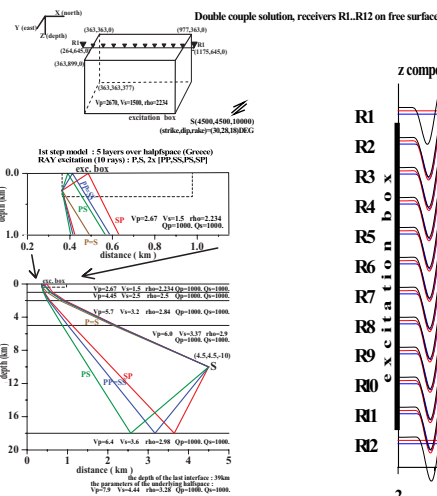
-thus the REPLICATION TEST is a measure of the consistency between the 1st and the 2nd step hybrid binding

-the frequency content of the computation may be relatively high even for cases of a distant source because the FD area is performed on a fraction of the original large all-in-one model

Numerical examples:

low velocity basin, embedded in layered crust; (fmax=5Hz)

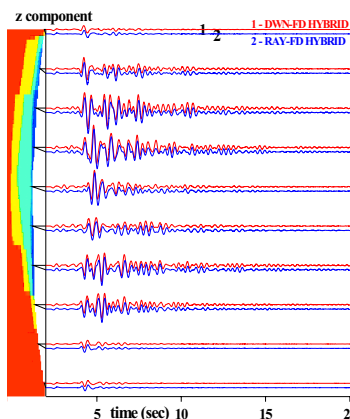
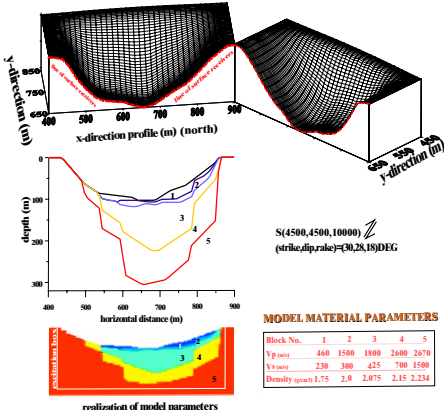
The 1st step: computation of the excitation and replication tests for two different methods - RAY and DWN:



The 2nd step: basin-model hybrid computations

The 2nd step local structure:
modified Volvi-lake model (see [4])

Comparison of the hybrid computations:
DWN-FD and RAY-FD :



Numerical methods:

1st step:

A double couple point source, $f = (0 \rightarrow 5.0)$ Hz

a) Ray method (see [2])

- zero-order ray solution (leading term of the ray series)
- local solution ("zero thickness" of the ray) - no Huygens' principle, infinite-frequency solution
- 3D particle motion in general 2D structures (thus 2.5D)

a) Discrete Wavenumber (or "reflectivity") method (DWN)

- 3D particle motion in general 1D structures
- all terms of representation theorem included

⇒ coarse 1st step excitation points are interpolated into the 2nd step excitation points ⇒

2nd step:

The PSI-3D FD SCHEME (see [3]); $f = (0 \rightarrow 5.0)$ Hz
the FD algorithm is easy to implement:

- one formula everywhere
- free surface by vacuum formalism
- Easy employment of topography
- Highly effective on irregular grids

Other features:

- (!) stable at high (v_p/v_s) contrasts
- (!) stable at high (v_p/v_s) ratio contrasts

A recipe :

- Calculate 3D wavefield due to source and crustal part
- Solve 3D site model by FD, thus you get combined source-path-site effects

Results:

1st step:

- source is a point double couple
- equivalent-forces time history is a pulse, fmax = 5Hz
- number of excitation box points: 2848
- Ray excitation realized by 10 rays: direct P and S, reflections and refractions from the free surface and from the 18km interface - 2 x [PP,PS,SP] waves
- computation of RAY excitation takes 10 minutes on PIII1.4GHz
- computation of DWN excitation - full-term solution - takes 10hrs on PIII1.4GHz

2nd FD step:

- complex local model with topography on an irregular grid (fmax=5Hz)
- the model is modified Volvi basin (from [4])
- computation of 25 sec history needs 12hrs on PII 500MHz

Hybrid results:

- DWN-FD and RAY-FD hybrid computations show a very good agreement, however, the RAY solution contains only 10 rays.
- in terms of computer time and memory, the whole FD model is only a fraction of all-in-one FD computation

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