Three−dimensional Seismic Waves in Fault Structures with Material Interfaces and Depth−dependent Properties

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Summary

We perform three−dimensional numerical calculations of wave propagation in seismic fault zones in order to understand the influence of variable velocity structure on the recorded waveforms of trapped and head waves.

The method is based on a high−order staggered−grid finite−difference scheme. The accuracy of the modelling is tested against analytical solutions for waves generated by a point−dislocation along a material interface [Ben−Zion, 1990, 1999].

To understand the complicated structure of the wavefield we present seismograms for models with increasing complexity.

The next step will be to implement models derived from real data e.g. for the Parkfield segment of the San Andreas fault and to check the quality of models based on algorithms which invert fault zone seismic waveforms.

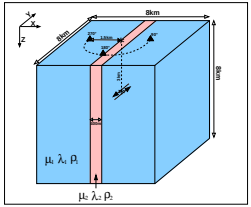

Figure 3:
Sketch of the basic fault model. Inside the fault the material parameters are 30% reduced w.r.t. the surrounding medium. For the three simulations shown on the right the model is discretized with a grid consisting of 201^3 gridpoints, a grid spacing of 40m and a time step of about 2ms.

Testing against Analytical Solutions

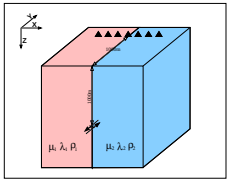

Figure 1:
Model of two halfspaces with a receiver array shifted 1km upwards and 1km backwards with respect to the source (from Ben-Zion, 1990). The receiver spacing is app. 25m.

The source is a double couple in the horizontal plane ($M_{xy} = M_{yx} = M_0$) and can be interpreted as a horizontal slip of one halfspace with a constant velocity and 0.1 s duration.

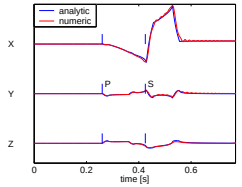

Figure 2:
Comparison of the X, Y, and Z components of analytical solutions after Ben-Zion, 1990, with numerical seismograms from our FD program for the geometry shown in Figure 1.

Displayed are the Greens functions of the numerical seismograms for the receiver right above the discontinuity which is most sensitive to the contrast.

Homogeneous Model

Figure 4:
Velocity seismograms for a homogeneous model and the receiver geometry shown in Figure 3. The source is a double couple in the horizontal plane and the source time function is a delta impulse. The traces are filtered to obtain a dominant frequency of about 10Hz.

Figure 5:
Snapshot of the XZ cross section through the center of the model, shown is the Y component of velocity at time $t = 0.85s$. In this plane only SH motion is excited.

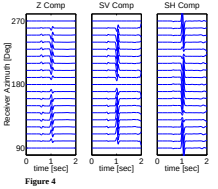

Figure 4

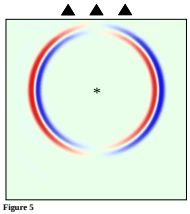

Figure 5

Basic Fault Model

Figure 6:
Seismograms for a basic fault model and the receiver geometry shown in Figure 3. The source time function, source radiation and trace filtering are the same as in the homogeneous model.

In addition to the direct waves large amplitudes especially on the SH and SV components occur due to trapped waves inside the fault.

Figure 7:
Snapshot of the XZ cross section through the center of the model, shown is the Y component of velocity at time $t = 0.85s$. Large amplitudes develop in the fault zone.

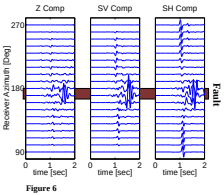

Figure 6

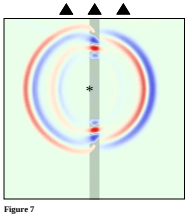

Figure 7

Fault with horizontal low velocity layer

Figure 8:
Seismograms for a fault model with a horizontal low velocity layer and the receiver geometry from Figure 3. The source time function, source radiation and trace filtering are the same as in the homogeneous model.

Again trapped waves appear but with weaker amplitudes due to diffraction at the bottom of the horizontal low velocity layer.

Figure 9:
Snapshot of the XZ cross section through the center of the model, shown is the Y component of velocity at time $t = 1.14s$. The trapped waves diffract at the bottom of the horizontal low velocity layer.

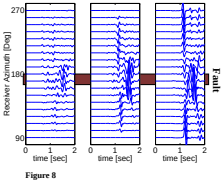

Figure 8

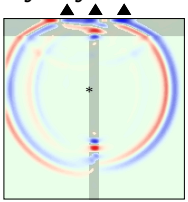

Figure 9