Geophysical Wave Propagation

The propagation of shear (S) and compression (P) waves within the earth represents a critically important phenomenon for geologists. For many years, geologists have developed specialized computational programs to calculate wave propagation within complex geophysical regions. These programs have been instrumental in determining the location and characteristics of natural phenomena (e.g., earthquakes) and man-made activity (e.g., nuclear-blast tests). Since these waves typically travel long distances prior to detection, these programs typically require large computational models and significant computational resources. Newer applications for this technology include border security and exploration for natural resources. The length scales of these applications are much smaller than for typical applications. Thus, the *P* and *S* waves decay less than in applications with longer length scales and therefore cannot be ignored. As these industries apply existing technology to meet today's challenges, they are finding that new methods of solving these problems have significant advantages over traditional methods.

New methods of solving geophysical wave propagation problems are being developed by AltaSim Technologies to provide practical solutions to the Department of Homeland Security, the Department of Defense, and the energy industry. These industries, as well as many others, are being served by the application of the computational methods in COMSOL Multiphysics. By using new commercially available numerical software, geologists have reduced their need for large computational resources and can now conduct in-field calculations to improve signal processes. These improvements increase the sensitivity for detecting underground activities on our borders and in hostile foreign countries. In the energy industry, operators can use this technology to better understand how existing well are functioning.

To implement this technology, AltaSim solved the equilibrium equations for a time-varying system using the finite element method. Although these methods have been used by many industries, these applications have traditionally been analyzed using finite-difference based algorithms. Applying the finite element method provides greater flexibility by eliminating the need for regular computational grids inherent in the finite difference method. The finite element mesh more easily represents a typical geological domain that includes local inhomogeneities.

The example in Figure 1 shows the velocity distribution in a half-space subjected to a dynamic excitation near the Earth's surface. The Cartesian plots show the surface and subsurface response. For the simplified case of a homogeneous half-space, the engineers at AltaSim implemented closed-form solutions for a wide range of loadings against which to compare the computational results. The solution for a sinusoidal forcing function was implemented directly into the analysis software to facilitate rapid comparison of computational results with the analytical solutions. The sinusoidal forcing function analyzed in this work represents an impact loading with a total duration of 10 ms. These results show the magnitude of the subsurface wave at 50 meters from the source still have a significant magnitude relative to the surface waves. Thus, the ability to resolve both wave types improves the understanding the signals measured from near-surface sensors.

As part of this work, AltaSim considered the effects of mesh and time step size to develop models that provide accurate solutions while minimizing computational resources. The mesh necessary to solve this problem included 11,000 elements and 90,000 degrees-of-freedom. To limit memory requirements for meshes of this size to be solved on in-field computational resources, the analyses used a PARDISO sparse solver.

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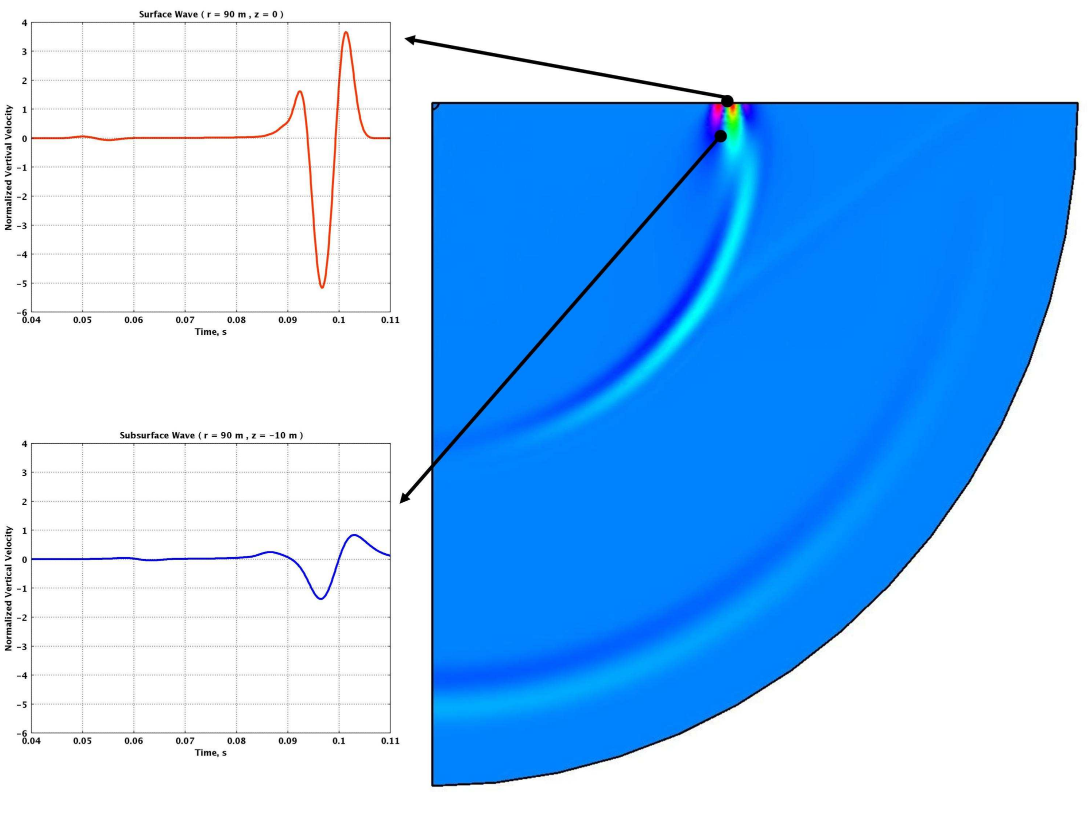

Figure 1. Seismic wave propagating through geological domain.