2021 SCEC Proposal FINAL REPORT

A workflow for homogenization of seismic velocity models in Southern California

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Summary

Knowledge of the subsurface geological structure and the seismic velocities of rocks and soils is essential to model seismic wavefields and predict the ground motions during an earthquake. Thus, accurate knowledge of the seismic velocity structure combined with three-dimensional (3D) wave propagation simulations can significantly improve seismic hazard models (e.g., Graves et al., 2011). One of the most significant limitations of 3D wavefield simulations is modeling very low seismic velocities in the shallow subsurface. The computational requirements increase exponentially by increasing mesh resolution (maximum wavelengths and frequencies desired) and, therefore, by modeling low material speeds. This project aims to implement the 3D seismic velocity fast-Fourier homogenization (FFH) technique of Capdeville et al. (2015) coupled with the SCEC Unified Community Velocity Model (UCVM; Small et al., 2017) software to facilitate efficient high-performance computers (HPC). The goal is to make effective-medium velocity models easily accessible to researchers. Towards this aim, during the past year, we had the following accomplishments:

1. We installed the 2D homogenization program of Capdeville et al. (2010) in a high-performance computer and ran 2D homogenizations in parallel in 8, 16, and 24 cores. To test the simulations, we used simple models, including a 1D layered model and a model of circular inclusion on a homogeneous half-space. The input models were isotropic, meaning that three parameters characterize every point in the domain: density (ρ) and P- and S-wave velocities (Vp, and Vs, respectively). Runs are performed using the multistage setup. The number of samples necessary to compute the effective media makes the required memory too large to fit a single computer shared memory node in the RAM. Thus, multistage runs divide the domain into smaller sections that can run in parallel on multi-node machines or one by one in a single node machine.
2. The outputs of FFH are the anisotropic elastic constant tensor and density properties at any domain location. These values should be adapted to the input needed to be read by the wave equation solvers. As such, we are working on installing and testing the spectral element wave-propagation software code package SEM46 (Trinh et al., 2018; Cao et al., 2020) to be able to run parallel wavefield simulations using effective media velocity models from FFH.

One difficulty that we encountered is designing an experiment to verify the software toolchain, e.g., we might require implementing other homogenization techniques such as Backus (1962) and Krief-Gassman (Ciz and Shapiro, 2007) averaging methods and comparing simulation outputs. We started to verify the parameter selection and the code output files by using simple velocity models for which numerical simulations of wavefields can be run in HPC and compared. We already performed tests for 1D isotropic layered models. We now plan to compare outputs from the techniques of additional cases, including parameters such as lower and upper bounds of the velocities, and a good match to the data.

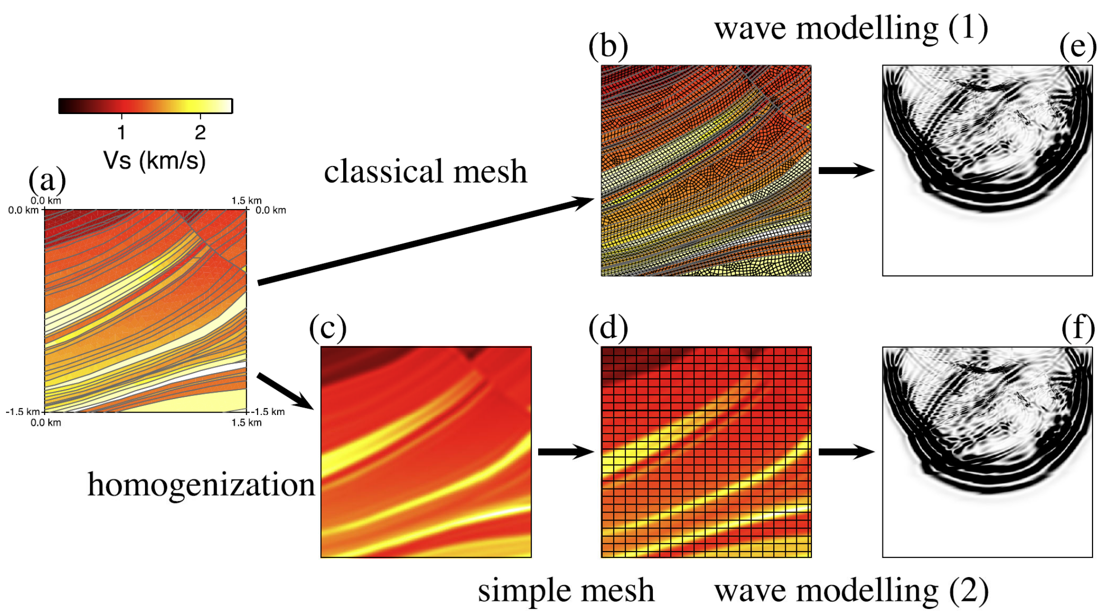

Fig. 1. Illustration of the homogenization procedure for a complex 2D velocity model [After Capdeville and Cance (2015)].

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Intellectual Merit

The research contributes to development of techniques for homogenizing multi-scale 3D velocity models with strong gradients near the surface and large faults. The homogenization process is an important step for developing integrated multi-scale velocity models in southern California. The developed methodology will allow rigorous down sampling of velocity models that retain the information on larger scales. The homogenized version of the multi-scale models will allow efficient large-scale computations.

Broader impact

The project contributes to the development of integrated multi-scale community velocity models. The developed workflow will be made available with easy access to SCEC researchers. The resulting velocity models can be used in many different studies by multiple SCEC groups and will contribute directly and indirectly to most SCEC5 science questions. The project contributes to the education and research experience of a PhD student.

Publications supported by the project

The project has no publication. The research was delayed by the pandemic. We anticipate submitting results for publication in the coming year.