



HAL
open science

Editorial: Applications of wave propagation simulation in complex geological media

Paul Cupillard, Jonas D de Basabe

► **To cite this version:**

Paul Cupillard, Jonas D de Basabe. Editorial: Applications of wave propagation simulation in complex geological media. *Frontiers in Earth Science*, 2023, 11, pp.1168678. 10.3389/feart.2023.1168678 . hal-04154135

HAL Id: hal-04154135

<https://hal.science/hal-04154135>

Submitted on 7 Jul 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License



OPEN ACCESS

EDITED AND REVIEWED BY
Jeroen Van Hunen,
Durham University, United Kingdom

*CORRESPONDENCE
Paul Cupillard,
✉ paul.cupillard@univ-lorraine.fr

SPECIALTY SECTION
This article was submitted to Solid Earth
Geophysics, a section of the journal
Frontiers in Earth Science

RECEIVED 17 February 2023
ACCEPTED 23 February 2023
PUBLISHED 09 March 2023

CITATION
Cupillard P and De Basabe JD (2023),
Editorial: Applications of wave
propagation simulation in complex
geological media.
Front. Earth Sci. 11:1168678.
doi: 10.3389/feart.2023.1168678

COPYRIGHT
© 2023 Cupillard and De Basabe. This is
an open-access article distributed under
the terms of the [Creative Commons
Attribution License \(CC BY\)](https://creativecommons.org/licenses/by/4.0/). The use,
distribution or reproduction in other
forums is permitted, provided the
original author(s) and the copyright
owner(s) are credited and that the
original publication in this journal is
cited, in accordance with accepted
academic practice. No use, distribution
or reproduction is permitted which does
not comply with these terms.

Editorial: Applications of wave propagation simulation in complex geological media

Paul Cupillard^{1*} and Jonas D. De Basabe²

¹GeoRessources, Université de Lorraine/CNRS, Nancy, France, ²Center for Scientific Research and Higher Education of Ensenada (CICESE), Seismology Department, Ensenada, Baja California, Mexico

KEYWORDS

computational seismology, seismic hazard, random media, thermoelastic wave, acoustic wave, elastic wave

Editorial on the Research Topic

Applications of wave propagation simulation in complex geological media

Earth models and seismic sources models can be inferred from waves recorded at the surface of the Earth or at depth in wells. Whatever the method used for this, it is necessary, at a recurring stage of the process, to model these waves, i.e., to solve a wave equation for a given source and a given medium. In some very simple cases, analytical solutions exist, but these cases rarely correspond to the geological complexity that we want to take into account in practice. Geological environments are indeed heterogeneous and 3D. Moreover, they can present behaviors much more complex than the simple linear elasticity. For lack of analytical solutions in such media, the resolution of the corresponding wave equation is done using numerical methods.

In addition to their implication in the construction of models, the numerical methods for modeling seismic wave propagation are essential to the evaluation of the seismic hazard, in particular the site effects which can amplify the energy of the waves on the surface and cause significant damage. These methods are also involved in seismic survey design in order to monitor or better image a given geological medium.

Whatever the application, most numerical modeling methods require a mesh, i.e., a discretization of the geometry of the medium. However, we have seen that geological environments are complex by nature: they are heterogeneous, 3D, multi-physics, and above all, they are multi-scale and discontinuous. These last two features pose major issues when modeling waves numerically, because the required mesh can be very difficult to generate and the computational cost of the simulation can increase dramatically. In many applications, these two features are set aside. This is the case in full waveform inversion (FWI) for instance. To remain above the seismic resolution and mitigate the non-uniqueness of the problem, FWI results are restricted to smooth models without any small scales. Nevertheless, geological environments contain some, and geological complexity should remain one of the guidelines of seismological research.

Forgetting the geological complexity, some seismologists say that the resolution of the seismic wave equation no longer is a problem. When claiming this, they probably also set aside the ambition to process the ever-increasing quantity of data at our disposal. Despite

the development of artificial intelligence algorithms and the increasing computational power, these data would benefit from innovative simulation methods in order to investigate deeper and extract further information on geological environments and seismic sources. There is an increasing amount of seismic data because of 1) new acquisition technologies such as distributed acoustic sensing and 2) new types of data such as rotational motion of particles, noise correlations and tremors from non-volcanic sources. Better using and understanding these data, with the help of better simulation methods and tools, is another guideline of seismological research.

The papers in this Research Topic cover a wide variety of aspects of numerical wave propagation and tackle some of the current challenges. [Hou et al.](#) analyze a multi-physics issue related to the exploration of geothermal reservoirs; namely, the effects of a temperature field in the elastic waves. They use a thermoelastic model based on the Biot and extended Lord-Schulman theories, and obtain the reflection and transmission coefficients for the P- and S-waves and an additional T-wave predicted by this model. [Yang et al.](#) propose a new finite-difference method for acoustoelastic wave propagation in prestressed media. Their method is based on the rotated staggered-grid finite-difference method and was developed with a particular interest in the exploration of deep oil- and gas-bearing formations. [Ajala et al.](#) are concerned with the application of numerical wave propagation to seismic hazard analysis. They perform numerical simulations using realistic rupture scenarios in the San Andreas fault in southern California, and analyze the effects of topography, near-surface layers and attenuation in the wavefield. Also with a keen interest in earthquake simulations, [Lehmann et al.](#) use state-of-the-art machine-learning techniques to investigate the variability in seismic response associated to random geological fluctuations. As a result, they show how condensing these fluctuations into a few components can help in performing uncertainty analyses. In a very similar context, [Celorio et al.](#) compare spectral element simulations and radiative transfer predictions of SH-waves in 2D random media. Relying on an

unprecedentedly large number of von Karman realizations, the authors find an excellent agreement between the two approaches for both the scattering mean free path and the mean intensities. In particular, they show how the ballistic peak evolves with propagation distance, which is crucial in seismic hazard evaluation. Finally, [Shen et al.](#) propose a method to improve hybrid simulations, i.e., when a wavefield computed in a large domain using a given simulation feeds another simulation in a more local domain. The improvement consists in a relevant space and time interpolation of the hybrid inputs. When the global and local meshing differs, the proposed interpolation method appreciably reduces the error of the hybrid waveforms caused by inaccurate hybrid inputs.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.