EDITORIAL
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Editorial: Reverse Time Imaging in Solid Earth and Exploration Geophysics

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Editorial on the Research Topic

Reverse Time Imaging in Solid Earth and Exploration Geophysics

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BACKGROUND

Our knowledge of Earth's interior structures and properties has been based, for a significant portion, on findings in solid Earth and exploration geophysics. As likely the most popular geophysical tool, seismic imaging has been providing evidences for revealing the nature of Earth structure and geodynamics, for exploring natural resources such as water, petroleum, coal, and minerals, and for mitigating geohazards including land subsidence, landslides, earthquakes, volcanic eruptions, and tsunamis. To better live with the nature, we must balance human activities between taking natural resources and minimizing human impacts on the environment. High fidelity seismic images of Earth's interior are useful to all of these efforts.

MOTIVATION FOR THE TOPIC

Reverse time imaging (RTI) was conceptualized in 1980s as reverse time migration (RTM), to map reflectivity structures and seismic sources *via* modeling time reversed seismic waveforms. Constrained by the limited computing power in the past, RTI has not become a leading way of seismic imaging until this century. With the growing demands for high-fidelity seismic images, it is timely that we present some of the latest advances in RTI.

SUMMARY OF THE PAPERS

The modeling approach enables RTI to map a multitude of seismic sources that were excited in the same time span and at nearby locations, and allows RTM to take multiple scattering wavefields as signals rather than noises. Zhang et al. present here a least-squares RTM (LSRTM) using multiples of OBN data and suppressing crosstalk of multiple wavefields with numerical examples. Zheng et al. take surface multiples in a field walkaway VSP data as the input signal to RTM for monitoring CO_2 injection in NW China, *via* wavefield decomposition and an inverse scattering imaging condition. He et al. propose a P-SV converted-wave RTM *via* 1st-order velocity-dilatation rotation of multicomponent data without the source information, and verify their approach *via* numerical simulations.

The versatility of RTI is demonstrated in several case studies of a variety of targets. Huang et al. apply an anisotropic LSRTM to map complex subsurface structures for accurate fault interpretation in geothermal exploration at the Pirouette Mountain and Eleven-Mile Canyon in Nevada. Wang et al. show vertical cable RTM images of hydrate-bearing sediments in South China Sea. Kim et al. present a new way of velocity model building *via* frequency-domain common image gather, and demonstrate it with field data from offshore SW Africa.

Most papers on this Research Topic have an element of improving RTI methodology, especially those focused on numerical studies. After verifying the Kirchhoff modeling is better than the Born modeling in LSRTM, Zhang et al. present an RTM with staggered-grid finite-difference velocity-stress wave equation in pseudo-space domain, to reduce the modeling error of finite-difference meshing. Xu et al. implement a Kirchhoff approximation in LSRTM with L_1 sparse constraint, using a 2D numerical demonstration. Du et al. show a pseudo-Laplace filter to reduce image artifact from using the dot-product scalar imaging condition in vector elastic RTM. Rong and Jia apply deep-learning to reduce the cost of computing the illumination of single-shot RTM, and show some 2D numerical test results. Xie et al. suggest a precondition of LSRTM *via* transmitted wave energy gradient, and test it with the Marmousi and Pluto models. In a second paper, these authors demonstrate an angle-weighted RTM using 2D numerical test and a marine seismic line in the East China Sea.

STATUS OF THE TOPIC

The common occurrence of imaging artifacts and position errors in seismic images based on field data inspires seismic imaging research toward high fidelity, which specifies how accurately each imaging target is resolved at the correct location. To achieve this goal, researchers are making low-frequency vibroseis sources, deploying dense and broadband seismic arrays, developing more advanced and effective numerical simulation algorithms to model seismic wave propagation under more realistic physical conditions, proposing more robust inversion and imaging methods for large volume datasets, and adapting artificial intelligent techniques into seismic imaging. Clearly, the expansion of seismic imaging from high resolution toward high fidelity is an exciting and challenging process. The challenges usually include limited quality and quantity of field data, and more importantly the lack of evidence for verifying imaged features. We expect more interdisciplinary studies to bring in independent evidences for cross checking and corroborating seismic images at processing and interpretation stages.

FUTURE PERSPECTIVES

The desire to better live with our mother Earth demands new ways to overcome the challenges for exploring its interior, and assessing the intricate relationship between our activities of extracting natural resources and the impacts on the environment. We hope the exemplary studies presented here can motivate new research in reverse time imaging, toward providing higher fidelity seismic images for a wider spectrum of applications.

AUTHOR CONTRIBUTIONS

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