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Preface

Special Issue on "Computational Geophysics"

Computational geophysics is vitally important for improving our understanding of the Earth and Earth processes; however solutions to most problems in computational geophysics have been unapproachable due to limited computing capacity. With increasing computer speed, memory, storage capacity, and input/output capability, solving these problems is becoming feasible. Computational geophysics can include not only forward modeling to predict what will happen in a given situation but inverse modeling or inversion, in which data are interpreted in terms of a model. Such inversion can be even more computationally intensive than forward modeling as it can require several iterations of forward modeling. This Special Issue contains 13 papers and encompasses several different and important computational geophysical problems, including seismic-wave modeling using different methods, electromagnetic modeling/inversion, and tsunami simulation.

Large-scale computational methods for seismic wave modeling and inversion are expected to greatly improve the understanding of the Earth's interior structure. The paper by Tromp, Komatitsch and Liu, "Spectral-Element and Adjoint Methods in Seismology," gives an overview of the spectral element method with applications particularly in global seismology. After covering the essential relations from linear elasticity theory, the weak formulation of the elastic wave equation is given. A more detailed description of the discretization of a general three-dimensional volume with tensor-product spectral elements follows. The assembling of the stiffness matrix and the source term is carried out explicitly, concluding with the respective discrete expressions. The last section describes a computational optimization approach to inversion of material or source parameters. A cost functional is introduced, whose first-order extremality conditions are subsequently derived. This leads to the identification of an adjoint variable.

On the other hand, computational methods for seismic wave propagation on a smaller scale and at higher frequency are critical to the understanding of details of underground structures and rock properties. Cheng and Blanch's paper titled "Numerical Modeling of Elastic Wave Propagation in a Fluid-Filled Borehole" provides a review of two frequently used elastic-wave modeling methods: the quasi-analytic method known as the discrete wavenumber summation method and the finite-difference wave-equation method. Some numerical difficulties for the special geometry of the borehole and in cylindrical coordinates, and the advantages and disadvantages of the methods are discussed.

The paper titled "Boundary Integral Modelling of Elastic Wave Propagation in Multi-Layered 2D Media with Irregular Interfaces" by Enru Liu, Zhongjie Zhang, Jianghua Yue and Andy Dobson, extends the well known indirect boundary element method to irregular layered media. It is a semi-analytic method based on the propagation matrix for each layer and uses a recursive solution strategy to compute responses of elastic (and acoustic) waves in multi-layered media. The method adapts an absorbing boundary condition used in the finite-difference wave-equation method to suppress artificial boundary reflections.

The paper by Tatsuhiko Saito, Haruo Sato and Tsutomu Takahashi, "Direct Simulation Methods for Scalar-Wave Envelopes in Two-Dimensional Layered Random Media Based on the Small-Angle Scattering Approximation," extends previous works on the use of the Markov approximation for scalar-wave envelope simulation for uniform random media to layered random media. Saito et al. also investigate applications of Williamson's stochastic ray-path method to random media. The methods are validated using finite-difference modeling and results demonstrate that these two methods give practically the same results.

The next paper titled "MoSST_DAS: The First Generation Geomagnetic Data Assimilation Framework" by Weijia Kuang, Andrew Tangborn, Weiyuan Jiang, Don Liu, Zhibin Sun, Jeremy Bloxham and Zigang Wei, attempts to connect dynamo models more closely with geomagnetic data. It gives the overall architecture, mathematical formulation, numerical algorithms, and computational techniques of the geomagnetic data assimilation framework. It shows that sequential filtering using observational data can improve the predictive capabilities of the current generation of geodynamo models.

The paper on "Theoretical and Experimental Studies of Seismoelectric Conversions in Boreholes" by Zhenya Zhu, Shihong Chi, Xin Zhan and M. Nafi Toksöz, gives theoretical formulations for seismoelectric effects in boreholes, presents simulations of electric fields in boreholes penetrating formations with different permeability and porosities, and studies the sensitivity of converted electric fields to formation permeability and porosity. The theory and numerical simulations are verified by experimental results. The work can shed a light on the practical applications of using seismoelectric/seismomagnetic logging for determining formation properties, such as porosity and permeability.

Kazuya Shiraishi and Toshifumi Matsuoka's paper on "Wave Propagation Simulation Using the CIP Method of Characteristic Equations" describes the application of a Cubic Interpolated Profile (CIP) scheme for acoustic-wave modeling. The directional splitting and diagonalization of the coefficient matrix are used to derive the characteristic equations for acoustic wave propagation. The CIP modeling method can accurately simulate acoustic-wave propagation in highly inhomogeneous media with complex topography.

Adriana Citlali Ramírez and Einar Otnes's paper titled "Forward Scattering Series for 2-Parameter Acoustic Media: Analysis and Implications to the Inverse Scattering Task Specific Subseries," describes the scattering theory approach to wavefield modeling and geophysical imaging/inversion. It gives a forward scattering description of acoustic wave propagation through a 1D medium, and discusses how the forward and inverse scattering series are connected. A conceptual framework for the multiparameter Born series provides an insightful analysis that can be mapped and applied to the concepts and algorithms of the inverse scattering series.