UNIVERSITY OF CALIFORNIA SAN DIEGO
SAN DIEGO STATE UNIVERSITY

Toward high-frequency determinstic simulations: source, path and site effects

A dissertation submitted in partial satisfaction of the
requirements for the degree
Doctor of Philosophy

in

Geophysics

by

Zhifeng Hu

Committee in charge:

University of California San Diego

Professor Joel Conte
Professor Peter Shearer

San Diego State University

Professor Kim Olsen, Chair
Professor Steven Day
Professor Samuel Shen
Doctor Daniel Roten

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The dissertation of Zhifeng Hu is approved, and it is acceptable in quality and form for publication on microfilm and electronically.

Chair

University of California San Diego

San Diego State University

2021

DEDICATION

To my family

Xiaoyang, Xiuhong and Fei

EPIGRAPH

You must know that a person's ability to discern the truth

is directly proportional to his knowledge.

— Cixin Liu, The Three-Body Problem

There are only the pursued, the pursuing, the busy and the tired.

— F. Scott Fitzgerald, The Great Gatsby

Never confuse education with intelligence,

you can have a PhD and still be an idiot.

— Richard P. Feynman

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VITA

2015	B.S. in Geophysics, Peking University
2015-2021	Graduate Teaching/Research Assistant, San Diego State University
2021	Ph.D. in Geophysics, University of California San Diego and San Diego State University

PUBLICATIONS

Hu, Z., Roten, D., Olsen, K.B., and Day, S.M. (2021) Kinematic Source Models for Earthquake Simulations with Fault-zone Plasticity. *In preparing*.

Hu, Z. and Olsen, K.B. (2021). 0-5 Hz Deterministic 3D Ground Motion Simulations for the 2014 Mw 5.1 LaHabra Earthquake. *To be submitted*.

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O'Reilly O., Yeh, T. Olsen, K.B., **Hu, Z.**, Breuer, A.N., Roten D., Goulet C. (2021). A High-order Finite Difference Method on Staggered Curvilinear Grids for Seismic Wave Propagation Applications with Topography, *Bulletin of the Seismological Society of America. Submitted*.

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ABSTRACT OF THE DISSERTATION

Toward high-frequency determinstic simulations: source, path and site effects

by

Zhifeng Hu

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Professor Kim Olsen, Chair

High-frequency (f_{max} > 1 Hz) ground motions are closely relevant to building response associated with small structures of the engineering interests. Gaining an deeper understanding of the propagation of seismic waves and characterisitc of ground motions, is therefore a principal goal for seismologists and earthquake engineers. Earthquake simulations, physcis-based deterministic simulations in particular, as a valuable complement to (often inadequate) recorded data, have drawn significant attention from the seismic community in the last decades. With the potential ability to accurately characterize broadband wavefield, numerical simulations have their own limitations, namely the difficulty in charaterizing the underlying physical parameters in fine scale

and accommodating regional-scale domains for risking earthquake study. The primary objective of this dissertations is to explore various model properties that impose high-frequency effects. Chapter 1 is an introduction, providing background and motivation for each of the following chapters. Chapter 2 studies nonlinear effects using dynamic simulations and propose an equivalent kinematic source generator to emulate near-source plasticity in terms of the resulting peak ground velocities. Chapter 3 and 4 focus on model characteristics that govern the high-frequency ground shaking. Chapter 3 proposes a calibration approach that enhances the near-surface velocity structure insufficiently resolved in community velocity models. In Chapter 4, we intensively simulate a series of models with topography, small-scale heterogeneities, frequency-dependent attenuation, low near-surface velocities to investigate their contributions in modulating wavefields and ground motions as the frequency extends up to 5 Hz. In Chapter 5, we incoporates surface topography in constraining the 3D subsurface structure to predicte site response.

Appendix

A Von Karmen Autocorrelation Function

The form of the Von Karman autocorrelation function (Frankel and Clayton, 1986) is

$$\Phi_{v,a}(r) = \sigma^2 \frac{2^{1-v}}{\Gamma(v)} \left(\frac{r}{a}\right)^v K_v\left(\frac{r}{a}\right) \tag{A1}$$

in which ν is the Hurst component, a is the correlation length, K_ν is the modified Bessel function of order ν, $\Gamma(\nu)$ is the gamma function, and σ^2 is the variance with Fourier transform:

$$P(k) = \frac{\sigma^2 (2\sqrt{\pi}a)^E \Gamma(v + E/2)^{v+E/2}}{\Gamma(v)\,(1 + k^2 a^2)} \tag{A2}$$

in which k is the wave number and E is the Euclidean dimension.

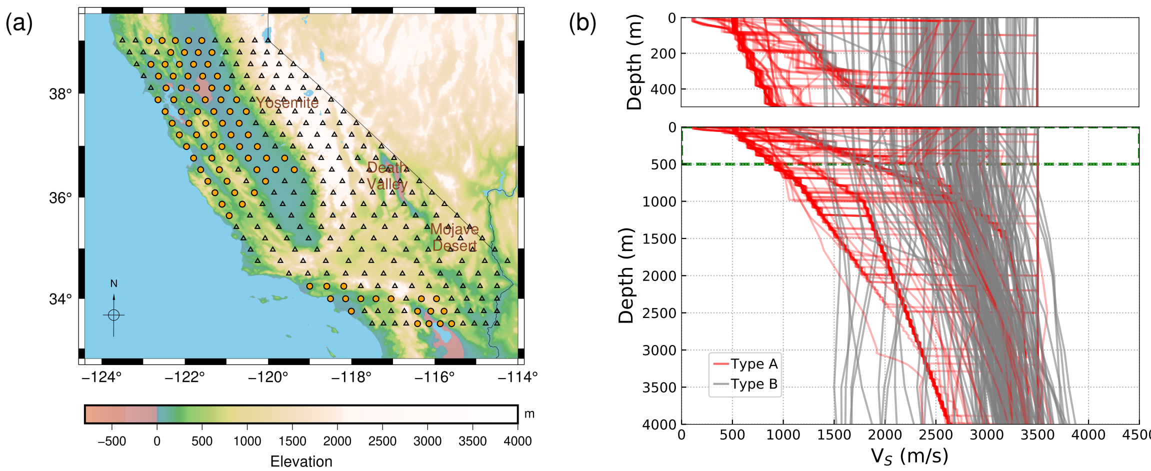

Figure A1: (a) V_S profile sample locations in California. Triangles denote rock sites and circles denote soil sites, and (b) extracted V_S profiles. The top panel zooms into the top 500 m.

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