External Grant Award Number 06HQGR0055

FRAMEWORK FOR A CALIFORNIA-WIDE THREE-DIMENSIONAL SEISMIC WAVESPEED MODEL

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Abstract

Our project has taken the first steps towards the development of a state-wide California 3-D seismic wavespeed (Vp) model. We have undertaken several key preliminary tasks that are critical to laying the framework for the 3-D model construction process. We build upon work that has been or is being carried out by external and internal NEHRP program investigators, which previously were mainly limited to separate northern or southern California efforts. The specific tasks the UW group has pursued this year include (A) holding a state-wide workshop, (B) developing quality-control procedures, and (C) developing and testing essential software. We report on our progress in each of these areas in some detail in this report.

Project Results

Our project has taken the first steps towards the development of a state-wide California 3-D seismic wavespeed model. When complete, the model can be used for a variety of purposes, such as improving earthquake locations, calculating 3-D finite-fault wave-propagation effects, modeling source mechanisms, and interpreting tectonic structures. There are other valuable aspects to consider as well, including providing a 3-D structural framework for facilitating statewide hazard estimates, and research using data from the USArray stations deployed in California. We have undertaken several key preliminary tasks that are critical to laying the framework for the 3-D model construction process. We build upon work that has been or is being carried out by external and internal NEHRP program investigators, which previously were mainly limited to separate northern or southern California efforts. The specific tasks the UW group has pursued this year include holding a state-wide workshop, developing quality-control procedures, and developing and testing essential software.

One of the major accomplishments of this project was the organization and realization of a major workshop on California 3-D seismic velocity models. The workshop was co-sponsored by the USGS and the Southern California Earthquake Center (SCEC), was held the day before the annual SCEC meeting in Palm Springs (September 9, 2006), and involved 65 participants. The goal of the workshop was to bring together interested scientists to develop a plan for the construction of California-wide 3-D seismic velocity models. A workshop report, to be submitted to SCEC and the USGS, is nearing completion; a brief review of the workshop organization and presentation highlights is included herein.

The workshop was divided into four parts:

"Vision" for the statewide model – construction and utilization,
New methods that will be required to assemble a statewide model,
State of the art of existing 3-D velocity models for northern and southern California,
Plans for building statewide models, including Vp, Vs, and density

About 25 "mini-presentations" were made during the 7-hour workshop, accompanied by extensive discussion.

The first set of presentations (Thurber, Clayton, Okaya, Plesch, Davis) focused on relatively practical but overarching issues of how a state-wide model can be assembled, what data and modeling techniques to use, how such a model can be efficiently represented, stored, and accessed, how it can be tied to other models such as statewide 3-D fault models, and how the upper mantle should be incorporated into the model. The second set of presentations (Suess, Clayton, Brocher, and Zhang) presented some of the details of existing 3-D models for southern and northern California. The third set of presentations (Lin, Hardebeck, Fuis, Murphy, Clayton, Liu, Tape, Chen, and Ritzwoller) focused on specific techniques and datasets that are relevant to and/or can provide constraints on various aspects of a state-wide model. Following a lunch break, the fourth and final set of presentations (Catchings, Langenheim, Waldhauser, Shearer (for Fialko), Aagaard, Humphreys, and Clayton) provided some perspective on state-of-the-art techniques and their applications, including those that would utilize a state-wide model in the future. The workshop closed with a brief discussion of organizational strategies and initial goals.

Our quality-control efforts have concentrated on developing tools for assessing absolute and relative arrival time data accuracy. Although relatively simple in concept, such tools are essential for assuring veracity of the data. For refraction data, time-distance plots are effective at identifying outliers and data with reduced travel times, etc., given the generally short interstation

spacing and resulting coherence in arrival times. For earthquake data, the equivalent plots are not particularly useful due to 3-D effects. Instead, we have developed a multi-event relative arrival time assessment tool that evaluates consistency among arrival times or differential times to a given station from nearby events.

We have made substantial progress in developing and testing software essential for regional-scale model development. The two main areas of our effort have been in improved regional-scale tomography and efficient resolution matrix calculation. We have benchmarked a new spherical-Earth finite difference travel time code developed by Steve Roecker and have integrated it into the tomoDD algorithm (Zhang and Thurber, 2003). Our work on efficient resolution matrix calculation takes advantage of the recent development of a package called PROPACK that can accurately estimate the singular values and vectors for sparse matrices was developed by Larsen (1998). The PROPACK package is based on the Lanczos bidiagonalization process, similar to LSQR, but it is able to estimate the larger singular values and vectors more accurately. This method is shown to be very efficient for estimating the full model resolution matrix for inverse problems having hundreds of thousands of observations and tens of thousands of model parameters. Using this method, estimating the full model resolution matrix is no longer a significant challenge for large inverse problems. We have been able to incorporate the PROPACK package into the double-difference seismic tomography code tomoDD and estimate the model resolution matrix for large seismic tomography problems. Compared to previous LSQR-based methods for estimating the model resolution matrix, the PROPACK-based method calculates the full resolution matrix and thus gives a complete description of how well the model is resolved.

Finally, we have continued our efforts to improve and interpret our existing San Francisco Bay area and northern California 3-D models, and have collaborated with UCSD and Caltech scientists on a southern California 3-D model, as part of the preparation process for extending to a state-wide model. A manuscript on the San Francisco Bay study is now in press in the Journal of Geophysical Research (Thurber et al., 2007), a paper on the updated southern California model is in review (Lin et al., 2007), and a paper on the northern California model is in preparation. Presentations related to this project were also made at the SSA and fall AGU meetings, and a presentation was also made at the NEHRP Northern California workshop.

The 3-D San Francisco Bay Area and Northern California models have been shared with our USGS collaborators and numerous other investigators. Electronic supplements to the related publications will be established to facilitate broad dissemination.

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