SCEC WORKSHOP REPORT

Community Velocity Model Technical Activity Group Workshop

Convener: Cliff Thurber
Date: September 7, 2019
Location: Hilton Palm Springs
SCEC Award: 19080
Website: https://www.scec.org/workshops/2019/cvm

The first meeting of the SCEC Community Velocity Model Technical Activity Group (CVM TAG) was held on September 7, 2019, at the Hilton Palm Springs. The workshop goals, agenda, and participants are shown below. The workshop consisted of five sessions, (1) Overview, Desired Outcomes, Motivation, and Framework; (2) Improving SCEC CVMs; (3) CVM assessment and validation; (4) New Techniques and Related Efforts; and (5) Action Item Prioritization and Funding Opportunities. This report summarizes the key points of the presentations and associated discussions. Available public versions of the presentations are also posted on the CVM TAG web page:

https://www.scec.org/workshops/2019/cvm

(1) Overview, Desired Outcomes, Motivation, and Framework

C. Thurber (University of Wisconsin-Madison) welcomed the participants and spent a few minutes reviewing the workshop agenda. He emphasized the point that the SCEC CVMs either were controlled and updated by a very small group of people (CVM-H) or were "frozen" with no clear path for improvement (CVM-S). The expectation is that the CVM TAG will work towards making both CVM-H and CVM-S and the data used to construct them more accessible and more readily evaluated and improved.

Y. Ben-Zion (SCEC/USC) discussed his view of the importance of the SCEC CVMs and some of the key activities and capabilities needed to enable community efforts to improve them. He pointed out that the character of the two SCEC CVMs differs, with CVM-H focusing on basin structures controlled largely by industry data imbedded in a regional-scale tomographic model and CVM-S evolving through tomographic updating. In addition to improvements in methodology and expansion of model coverage (particularly to encompass Baja California and the southern end of the San Andreas Fault), he supported the idea of establishing new special projects involving dense seismic arrays, allowing for finer resolution using higher frequencies. He pointed to several recent tomographic studies spanning spatial resolutions of ~1 km to ~10 m. Ben-Zion made the key point that in order for such higher resolution models to be incorporated into SCEC CVMs, it is essential to develop an open method for merging models. He outlined a possible strategy for achieving merging that would result in an improved model. It was suggested that work being done at ETH-Zurich on a global scale model homogenization effort be examined as an example of how model merging can be accomplished.

In the final presentation of the first session, P. Maechling (SCEC/USC) provided an overview of the current CVMs hosted by SCEC within the UCVM software framework, which provides the means for accessing all the CVMs. He pointed out that the main demand for CVM access has been for the purpose of ground motion modeling. The CVMs vary in character and in size, from tiny 1D models to large “standard” models (CVM-H and CVM-s) to very large, custom 3D models, with or without a geotechnical layer (GTL). The latter consist of a standard model with embedded basins, with the discontinuities between them smoothed in a specified manner. The UCVM framework allows extraction of any catalogued model or a hybrid combination of models, for example to represent a larger region than any one model covers. Some planned new features and activities include Community Fault Model (CFM) and Geological Framework web-based viewers and submission of the SCEC CVM collection to the IRIS Earth Model Collaboration (EMC), which uses the common netCDF format.

Some comments from the audience included the issues of evaluating a new model and evaluating epistemic model uncertainty, whether compression techniques might be utilized for the larger models, and the importance of attenuation and anisotropy.

(2) Improving SCEC CVMs

The first presentation in this session was by A. Plesch (Harvard University), who provided a detailed description of the construction of CVM-H and plans for its improvement. Briefly, the key aspect of CVM-H is its foundation on knowledge of basement depths in the main Southern California basins. These depths were derived from a combination of geologic information, seismic reflection and refraction profiles, well, and potential field data. The seismic structure of the sediments in the basins was based on 100-m smoothed sonic logs and reflection stacking velocities where available, with kriging applied where data were sufficiently dense. Elsewhere, a rule-based structure was applied. An updated tomography model provides the velocity structure outside the basins. As new basin structures are imbedded in the future, tomographic updates will be necessary.

The next presentation was by C. Tape (University of Alaska-Fairbanks), who discussed past (briefly) and potential future full-waveform tomographic model development of CVMs. At present, there are two plausible academic community sources of code packages for such work: SALVUS and SeisFlows. It is encouraging that the latter package has been used successfully by people other than the developers. Tape described the suite of work a student in New Zealand (Bryant Chow) carried out in his use of SeisFlows: meshing, HPC job handling, optimization, data handling, misfit quantification, and visualization. He noted that they have found the L-BFGS optimization algorithm to perform better than other alternatives, such as LSQR. He showed a checkerboard test example, and explained how much more difficult it was to construct compared to a travel-time tomography checkerboard. Other current applications are to Southern California and south-central Alaska.

(3) CVM assessment and validation

R. Taborda (Universidad EAFIT, Colombia) presented findings on ground motion validations using different CVMs. A goodness-of-fit criterion derived from a comination of metrics is used to compare synthetic ground motions to observations. The results show the choice of velocity models influences the simulation performance significantly. He also presented the results of using machine learning to prioritize the validation metrics. With machine learning techniques, he is able to identify the most important metrics in the goodness-of-fit criteria.

A. Rogers (Lawrence Livermore National Laboratory) presented broadband (up to 5 Hz) ground-motion simulations of a magnitude 7.0 scenario earthquake on the Hayward fault. Taking advantage of computer cluster with Graphics processing units (GPUs), the simulation is 48 times faster than the Central processing unit (CPU) version. Simulations using one-dimensional and three-dimensional Earth models show the median ground motion intensity measurements agree well with Ground Motion Prediction Equations. Ground motion simulations associated with the 3D model show more heterogeneity than those with the 1D model, as expected.

K. Olsen (San Diego State University) used anelastic ground motion simulations to assess CVM-S5. He compared simulation results associated with a few different attenuations formula in respect to shear-wave velocity. The results show the choice of attenuation formula has a big influence on the differences between simulations and observations. Interestingly, he also found that a small change (0.1) in earthquake magnitude would affect the differences significantly.

(4) New Techniques and Related Efforts

R. Clayton presented several studies targeting the structure of basins in the greater LA region. Dense data coverage is essential to obtaining high-resolution models. Due to the modest number of permanent broadband stations in the area of interest (~40), industry data and other temporary dense array data are essential. Ambient noise cross-correlation between permanent network stations and four arrays of nodal instruments deployed by industry yields both surface waves and P waves. A suite of dense linear arrays are being deployed in WHICH BASIN. Finally, ~300 recently installed strong-motion instruments in schools recorded the Ridgecrest sequence.
M. Bianco described a machine-learning approach to tomography as applied to ambient noise data. In an iterative approach, “patches” with structural patterns are determined using dictionary learning in tandem with sparse inversion for the patch coefficients that adequately fit the observed data. The method was applied to the Long Beach dense nodal array. The resulting structure model was interpreted in terms of the extent of the shallow Silverado aquifer.

B. Aagaard reviewed the history of models of SF Bay area structure, starting with some basin studies and a number of 3D tomography studies. For the centennial anniversary of the 1906 San Francisco earthquake, the USGS developed a 3D geologic model, with lithologic blocks bounded by faults, with both a small, fine-scale model and a much larger coarse-scale model. Empirical relations were then used to construct 3D models (Vp, Vs, density, Qp, Qs) from the geologic model. Some modifications and updates have been done subsequently. The current focus is on the East Bay area, where discrepancies between simulated and observed waveforms have been identified. In addition, a model development plan for the SF Bay area has emerged from a 2018 workshop, which will be released as a USGS report soon.

B. Bradley reviewed the development of 3D models for New Zealand, motivated by the desire for realistic ground motion simulations, with the goal of predicting ground motion better than

GMPEs.. As in Southern California, a major emphasis is on basins. Basin structure is represented by surfaces with different forms of velocity parameterization in between. The structure below and surrounding the basins is based on tomographic models. The current nationwide model is NZVM 2.0. Some issues faced include treating basin edges, validating new models, and the limited density of broadband stations.

(5) Action Item Prioritization and Funding Opportunities

C. Thurber presented the action items that emerged from the 2018 CVM workshop, split into some goals that could potentially be completed within SCEC5 and other goals that could be initiated during SCEC5 but would likely not be completed. He asked for feedback on prioritization of the action items, revisions to their anticipated completion, and other possible goals that should be considered. The action items will be circulated again along with a draft report on this workshop.

Y. Ben-Zion discussed some existing, funded efforts and other pending and potential proposals. A project aimed at the shallow crust has been funded by DOE, which will provide some additional funds for SCEC-supported projects. A sustained special projects effort on CXMs should be proposed. He also mentioned a related Geoinformatics proposal, led by SCEC participants, that has been submitted. The SCEC community should consider developing other initiatives like the Geoinformatics proposal to provide further support for CVM development and broaden SCEC community participation in these efforts.