2020 SCEC Report

Enhancements to the Community Fault Model (CFM) and its IT infrastructure to support SCEC science

SCEC Award 20081

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1. Summary

This past year, we made significant progress in improving SCEC's Community Fault Model (CFM) and enhancing the recently developed website and associated database that allows users to access and query the model and its associated metadata. The CFM (Plesch et al., 2007) is one of SCEC's most established and widely used community resources, with applications in many aspects of SCEC science, including crustal deformation modeling, wave propagation simulations, and probabilistic seismic hazards assessment (e.g., UCERF3). The CFM also directly contributes to other community modeling efforts, such as the Geological Framework (GFM), Community Rheologic (CRM), and Community Velocity (CVM-H) Models.

This project represents a collaboration between the SCEC CXM co-chair (Marshall), Associate Director for IT (Maechling), CXM software developer (Mei-Hui Su), and the primary Community Fault Model (CFM) developers (Plesch and Shaw). This group has worked closely with SCEC staff (Tran Huyn and Edric Pauk) to make our results available to the research community through enhancements in the SCEC CXM website (https://www.scec.org/research/CXM).

Results of this past year's efforts include:

1) Developing and releasing a new model version, CFM5.3, and its associated products, including faults traces (now also provided in .kml) and surface meshes at a range of resolutions. CFM5.3 includes more than 60 newly represented faults, and refinements to many other fault representations.
2) Major enhancements to the CFM metadata, including addition of area-weighted average fault strike and dip, surface area, and the population of data fields that define primary fault slip sense and references used to define the fault geometry.
3) Enhancements to the CFM web-viewer, including the ability to search by region and fault orientation, and the addition of a new advanced capability to render and view fault representations in 3D.

2. CFM Improvements

2020 was a productive year for the CFM, highlighted by numerous additions to the CFM fault representations, significant refinement of the associated metadata, the addition of semi-automated consistency checks, and development of the CFM website and 3D fault viewer. These efforts are summarized below.

CFM Model Development

A new version of the CFM (5.3) was developed and released as part of this research project. The new model includes improvements to more than 60 fault representations provided by SCEC investigators (Plesch et al., 2019, 2020; Nicholson et al., 2020). Additions to the CFM were led by the development of detailed representations of the source faults and surrounding structures for the 2018 Ridgecrest earthquake sequence. These fault models were developed using an objective, reproducible workflow (Riesner et al., 2017) that applies formal weights to the data constraints, including fault traces, hypocenter catalogs, and focal mechanisms. These new representations are based on relocated hypocenter catalogs expanded by template matching (Ross et al., 2019a, 2019b), focal mechanisms for M4 and larger events provided by the SCEDC, as well as detailed rupture traces (Kendrick et al., 2019; Hudnut et al., 2020). This resulted in a much-refined representation of the complete Little Lake Fault zone (LLFZ, Plesch et al., 2020), responsible for the M6.4 and M7.1 2019 Ridgecrest sequence (Fig. 1), new representations of faults situated between the LLFZ and the Owens Valley fault (OVF) including the Rose Valley fault, Coso Junction fault zone, and the southern extension of the OVF (Figure 1). The new fault representations are generally smooth and dip steeply, but are nonplanar. The Ridgecrest rupture zone consists of three main branches, two smaller cross faults, and three additional branches at the northern termination of the fault. As a result, the eastern and southern faults intersect each other at nearly right angles. The base of the faults is defined by the regional seismogenic thickness surface in the CFM. Early versions of these new 3D fault representations were made available for download as part of SCEC's earthquake response effort and on the CFM webpage. Revised and improved version of these faults are now formally integrated into version 5.3 with complete metadata and are accessible through the web-viewer and CFM website.

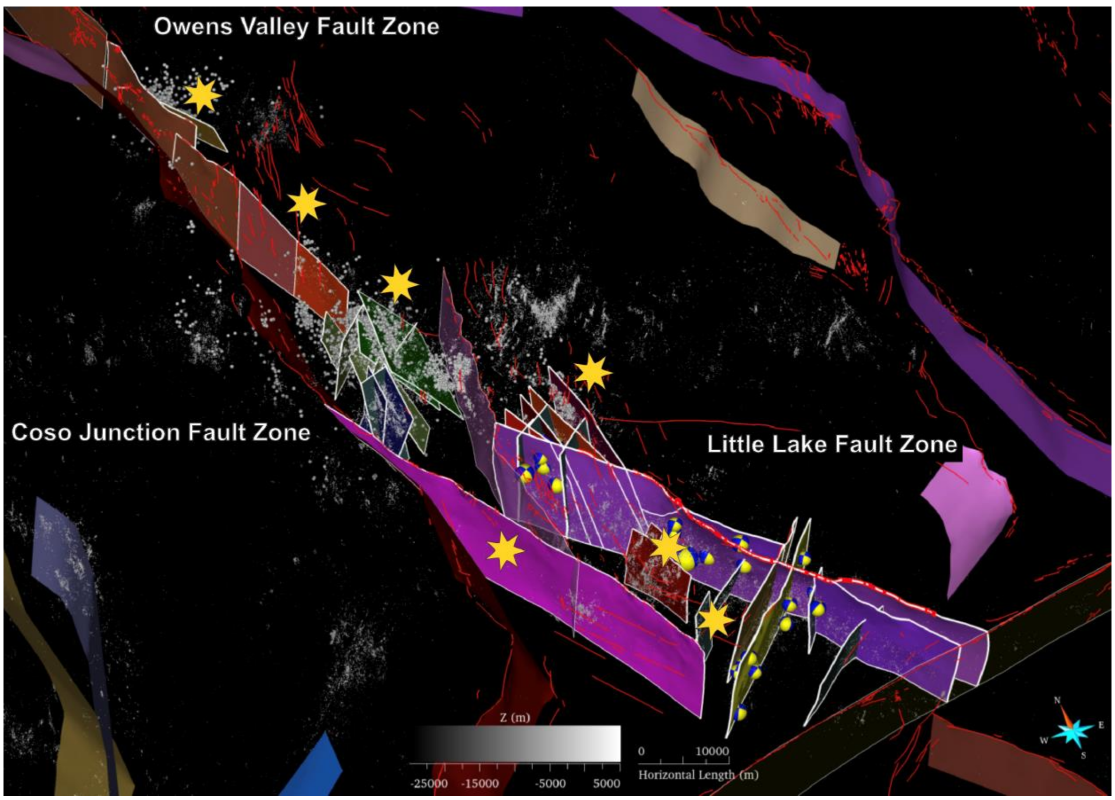

Figure 1: Perspective view of updates and additions to the CFM for version 5.3, in the area of the 2019 Ridgecrest sequence, in the Coso Junction area to the north, and to southern end of the Owens Valley Fault zone. Stars note areas of new fault representations.

Updates to the CFM5.3 also include ~30 new/revised faults based on coordination with Craig Nicholson (UCSB), who was supported by another SCEC grant to refine CFM faults in other areas of southern California and input from other SCEC investigators.

CFM Metadata Improvements

Historically, the CFM has been built manually, one fault and datafile at a time. The CFM5.3 model has grown to contain more than 400 surfaces, just in the preferred model. Each fault object has numerous components including: metadata (information about the fault, geometry, and references), several different 3D surface representations (each in different files), and fault trace data (in several different file formats). This results in a volume of data that cannot be manually managed. We have therefore developed a set of semi-automated scripts that test various components of the model for accuracy and self-consistency including:

1) All CFM faults now have a listed reference that indicates what each surface is based on.
2) Hierarchical object names now conform to a consistent naming convention. This allows users to write code that can easily parse the fault names from the various files.
3) Hierarchical object names are now checked with the various metadata columns for self-consistency.
4) We now provide direct automated calculations of fault surface area and average strike/dip. Average strike/dip calculations are weighted by element area, to represent a true average orientation of the fault surface regardless of mesh variations.
5) All fault objects are verified to exist with consistent names as t-surf files in the native, 500m, 1000m, and 2000m mesh resolutions. Similar checks are made for the fault trace data files.
6) All fault surfaces are provided as a single patch (in GOCAD files) instead of various grouped surfaces. The same is true for fault traces.

These enhancements are implemented as part of the database system that supports the CFM web-viewer and metadata files are also available as an Excel spreadsheet that can be downloaded from the site. Complete and self-consistent metadata is required for greater use of the CFM, so while these metadata and self-consistency improvements may not be apparent, they are critical.

CFM Website and 3D Fault Viewer
Our collaboration also resulted in the creation of the new CFM 3D viewer and enhanced capabilities for the CFM website (https://www.scec.org/research/cfm-viewer/). While the CFM is one of SCEC's most established models, the main hurdle for potential users was the previous requirement for specialized software that can render the model in 3D. Now, any user can go to the interactive CFM website, select faults of interest, and interactively view the 2D (Fig. 2) or full 3D geometry (Fig. 3). This new software will greatly aid users in using and understanding the CFM.

We anticipate that these software tools will have a major impact in facilitating peer-review of the community models within the next year. The CFM contains a number of alternative representations for major faults, with preferred fault versions defined by peer review and quality rankling. Previous CFM reviews have been conducted virtually, where the need to download and work with specialized software has made it difficult for many to fully participate in this process. Now with a web-based viewer, we anticipate that all those who are interested can readily access CFM fault representations and view them in 3D to facilitate their assessment and rankings. We anticipate that the formal evaluation of CFM5.3 will lead to the development and release of CFM6.0.

We believe this software development effort is required for SCEC to obtain the full benefit of the extensive collaborative scientific work that has gone into the development of the SCEC CFMs. Looking ahead, experience and product implementations derived from this effort are already serving as valuable catalysts to other SCEC community models looking to solve data organization, visualization, storage and retrieval challenges.

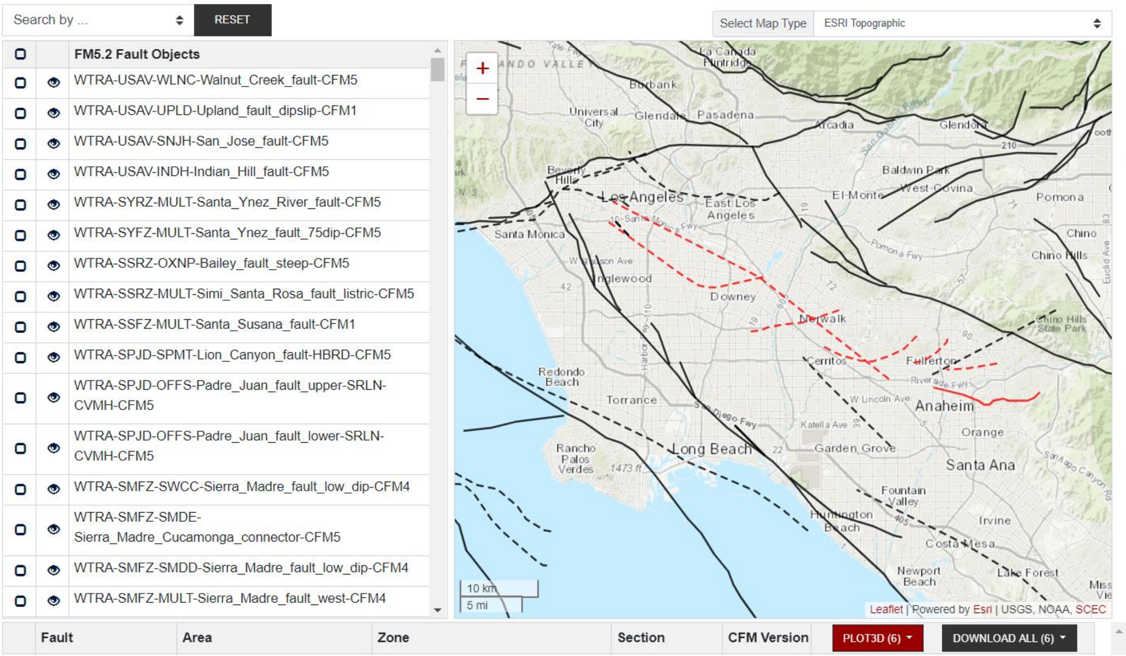

Figure 2. Screenshot of the CFM map-based search tool showing the greater Los Angeles region and the Puente Hills and Lower Elysian Park faults (highlighted in red). In map-view, these faults misleadingly appear to intersect.

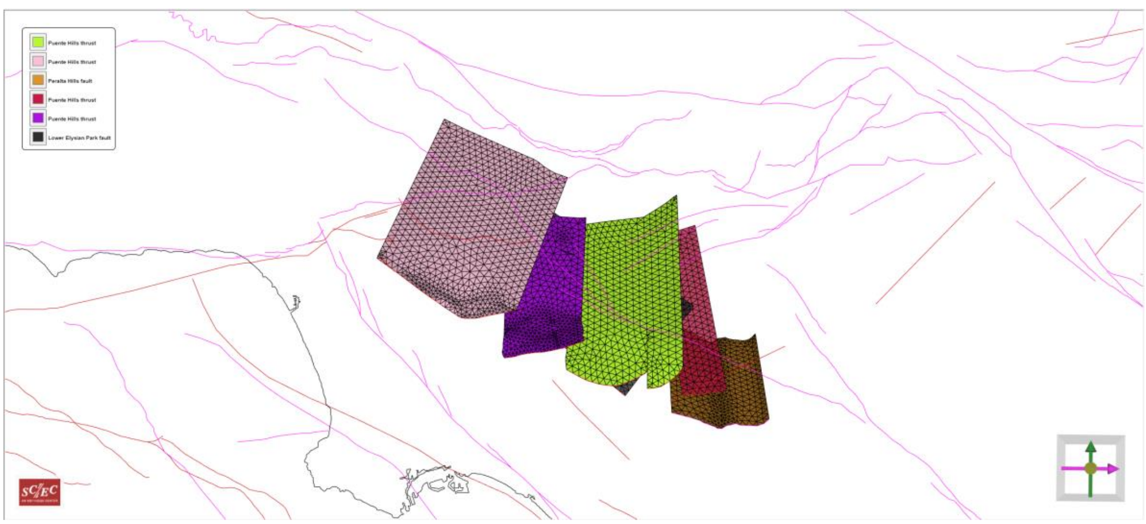

Figure 3. Screenshot of the new interactive 3D CFM viewer. In this web-based tool, the true 3D geometry can be visualized showing that the Puente Hills faults are shallower than the Lower Elysian Park fault.

3. Application to SCEC5 Goals

This research represents a primary effort to address the following SCEC priority:
P3.a. Refine the geometry of active faults across the full range of seismogenic depths, including structures that link and transfer deformation between faults.
Moreover, through the development and delivery of the CFM this project contributes to the CXM modeling effort and a range of other SCEC goals.

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