

Workshop: California Statewide Geologic Framework and Community Thermal Models (GFM/CTM)

Conveners: Michael Oskin, Sierra Rack, Andrew Zuza, Terry Lee, Laurent Montesi, Oliver Boyd, and Yuehua Zeng

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Location: UC Davis, Davis, CA

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Website: <https://www.scec.org/events/2025-scec-gfm-ctm-workshop/>

Workshop summary

Developing Community Earth Models (CEMs) constitutes a major Statewide California Earthquake Center (SCEC) activity. With the expansion of SCEC *Statewide*, there is an urgent need to extend the geographical scope of these models as well. Among the CEM components, the Geological Framework Model (GFM, Oskin et al., 2017) and Community Thermal Model (CTM, Thatcher et al., 2020) are foundational products on which other models like the Community Rheology Model (CRM, Hearn et al., 2020) are built and constitute a crucial framework for the interpretation of velocity, geodetic, and stress models and measurements. With this in mind, we convened a joint Geological Framework (GFM) and Community Thermal Model (CTM) workshop at UC Davis, CA, to identify critical datasets and organize the community of volunteers working to update and extend these models to the entirety of California. The choice of UC Davis as a venue was motivated by its central location in Northern California, with easy access from major institutions with geologists actively studying Northern California geology, such as those in San Francisco, CA, Sacramento, CA, and Reno, NV.

The SCEC5 geological framework is a model of the distribution of major lithotectonic provinces in Southern California, largely inherited from pre-San Andreas convergent-margin processes (Crouch & Suppe, 1993). The framework for Northern California is broadly similar to that of Southern California, but with a greater contribution of accretionary tectonics to constructing the crust of the west-facing continental margin (Day et al., 1985; Ernst, 2017). Workshop discussion of the GFM centered on (1) extending existing lithotectonic provinces and defining additional lithotectonic provinces for Northern California, (2) incorporating major three-dimensional features such as dipping boundaries, deep sedimentary basins, and sub-province scale variations in crustal structure, and (3) developing upper mantle models that are consistent with tomographic and thermal constraints. Contributions were solicited from allied efforts at the USGS (San Francisco Bay Area 3-D model— Hiramakawa & Aagaard, 2022, and National Crustal Model— Boyd, 2019a) and CGS (3-D geological modeling effort).

Over 50 years of thermal modeling developments accompanied by continuing accumulation of observations and improved computational power allow higher resolution and better-constrained temperature estimation of the continental crust. Further, several thermal models have been developed in the United States, ranging from national to regional models, and comprise the entirety of the Pacific-North American plate transform boundary in California (Boyd, 2019b; Lee et al., 2024; Shinevar et al., 2018; Thatcher et al., 2020). For this workshop, community members were invited to discuss and assess available observations and constraints, diverse modeling techniques, existing CTMs, and their relevance for evaluating seismicity and related applications. The current state of the CTM was discussed, as well as ways that the existing suite of CTMs can be accessed. Community participation in and discussion of CTM development seeded new ideas and suggestions for future CTM updates and generated feedback on the role of the CTM in relation to the broader Community Earth Models (CEM) framework.

The workshop was organized by eight PIs, including two early-career PhD students.

Summary of findings and discussions for the future

Geologic Framework Model

- Developing the Statewide GFM is an urgent need for the planned expansion of the Community Rheology Model (CRM). The attendees provided extensive feedback on proposed lithotectonic block boundaries for the Northern California and northwest Nevada GFM. Completion of a statewide model is a high priority for the coming year.
- Detailed 3D geologic framework models exist for parts of Northern California, including the Bay Area 3D model, and detailed, structurally based models for parts of the Coast Ranges and Central Valley. There is a need to develop a mechanism to embed detailed models, as well as the national depth-to-basement map (Boyd et al., 2019a), into the statewide GFM.
- Dipping three-dimensional boundaries should be defined at the outset, if possible, rather than implemented retroactively, as for the Southern California GFM.
- Some regions of Northern California have very poorly known compositions (e.g., the mid- to lower crust of the Modoc Plateau and western Sierra Nevada). Such areas may be better represented as an unknown lithology with seismic velocity constraints.
- Lithotectonic block boundaries may not be precisely known or exist as discrete features. This uncertainty should be represented within the GFM.
- Shear zones form persistent weaknesses throughout the lithosphere that localize deformation. At present, the GFM and CRM do not adequately represent the width and composition of these important features.
- Validation strategies should be prioritized for testing and refining the GFM. Comparison with regionalized seismic velocity models (e.g., Eymold and Jordan, 2019; Hirakawa and Aagard, 2022; Furlong et al., 2024) was identified as a promising approach.

Community Thermal Model

- Thermal models are critical inputs to many SCEC-derived products, most directly including the Community Rheology Model (CRM).
- Previous SCEC thermal models were reviewed for the group, such as Shinever et al. (2018) and Thatcher et al. (2020), which were both focused on Southern California.
- There are two methods to develop a crustal or lithosphere-scale thermal model. One group projects surface heat flow observations to depth, integrating knowledge of heat production and its distribution in the upper crust. A second approach is to use and fit geophysically derived temperature proxies through different crust levels.
- The new Lee et al. (2025) California-Nevada statewide thermal model was introduced.
- Oliver Boyd summarized four thermal models of the contemporaneous US (Blackwell et al., 2011; Boyd, 2019; Aljubran and Horne, 2024; Sui et al., 2025), each with different lateral and vertical resolutions, depth extents, and open accessibility. Most models are spatially similar, which is due to ultimately similar inputs.
- One issue is the assumption of steady-state conditions and how to treat non-steady-state processes. We can individually examine and model provinces of magmatism, lithospheric delamination, hydrothermal circulation, and use low-temperature thermochronology to determine vertical crustal advection.
- An important goal for future work is to determine methods to validate any thermal model with external proxies that were not used as inputs. Some potential options include integrating quartz alpha–beta phase transitions detected with seismic velocities, Curie depth, or examining whether signals of partial melting correlate with observations of hot temperatures above solidus conditions. Examination of thermal spring geochemistry and well temperature profiles may be ways to test the upper-crust thermal profile, and correlations with the Lithosphere–Asthenosphere Boundary may be ways to test for non-steady state conditions in the lower lithosphere.
- Ángela Maria Gómez Garcia introduced a new Southern California thermal model that utilizes the GFM as a proxy for lithology to infer the lateral and vertical distribution of radiogenic heat production.
- Kevin Furlong discussed the evolving thermal structure within three tectonic domains in Northern California, including Salinian Corridor, Pioneer Corridor, and the Mendocino Crustal Conveyor Corridor. He also emphasized the importance of integrating non-steady-state thermal modeling with surface heat flow observations and low-temperature thermochronology to evaluate tectono-thermal processes.
- Yuehua Zeng summarized how crustal thermal models can be used to constrain the brittle–ductile transition and estimate the lower seismogenic rupture depth.

Workshop Agenda

Thursday August 14th, 2025

09:00 - 09:15	Session 1: Introduction, logistics, and objectives	
09:15 - 10:15	Session 2: GFM/CTM reviews, comparison, and validation	
09:15 - 09:35	A statewide geological framework	Mike Oskin & Sierra Rack (UC Davis)
09:35 - 09:45	Discussion	
09:45 - 10:05	Ongoing 3D geologic mapping from the Valley to the Coast	Russ Graymer (USGS)
10:05 - 10:15	Discussion	
10:15 - 10:30	Break	
10:30 - 10:50	Updates on the CTM (PDF)	Terry Lee (UNR)
10:50 - 11:10	Conterminous United States thermal models (PDF)	Oliver Boyd (USGS)
11:10 - 11:30	Community models: From geology to rheology (PDF)	Laurent Montesi (U. Maryland)
11:20 - 11:30	Discussion	

11:30 - 12:00	General Discussion	
12:00 - 13:00	Lunch Break	
13:00 - 15:45	Session 3: Contributed talks	
13:00 - 13:06	A geologically-consistent 3D thermal model of central and southern California	Ángela Maria Gómez Garcia
13:06 - 13:12	Integrating 3D geologic framework information into Macrostrat's descriptive Earth model	Daven Quinn (UW– Madison)
13:12 - 13:18	The geologic framework in the USGS National Crustal Model for seismic hazard studies (PDF)	Oliver Boyd (USGS)
13:18 - 13:24	1:24:000 scale geologic mapping in the northern Walker Lane, NW Nevada.	Ryan Goldsby (UNR / Nevada Bureau of Mines and Geology)
13:24 - 13:30	Coupling diverse datasets to develop a 3D structural model of the San Joaquin Fold-and-Thrust Belt	Robert Welch (Loyola Marymount University/Harvard)
13:30 - 13:36	Do borehole breakouts tell us about regional stress or local structures?	Sarah Titus (Carleton College)

13:36 - 13:42	Work toward multiscale statewide CVM (PDF)	Yehuda Ben-Zion (USC)
13:42 - 13:48	Characterization of heat flow and fault zone properties in eastern California	Zachary Smith (UC Berkeley)
13:48 - 13:54	Lower seismogenic depth model for western US earthquake ruptures (PDF)	Yuehua Zeng (USGS)
13:54 - 14:15	General discussion	
14:15 - 14:30	Break	
14:30 - 15:45	Contributed talks continued	
14:30 - 14:42	Active tectonics in Northern California and the evolving lithospheric thermal structure (PDF)	Kevin Furlong (Penn State)
14:42 - 14:54	Geochemistry-strength evolution in silicate crust during post-seismic healing	Christie Rowe (UNR)
14:54 - 15:00	Low-frequency earthquakes track the evolution of a captured slab fragment	Amanda Thomas (UC Davis)
15:06 - 15:12	A rock-centric framework for earthquake dynamics and its applications in southern California	Binhao Wang (USC)

15:12 - 15:18	Near-surface (<1-km depth) location and characterization of faulting with 30-minute surveys (PDF)	John Louie (Terēan)
15:18 - 15:24	ShakeAlert in the Age of AI: Using DL to Predict Station Failure using State of Health Data	Fabia Terra (UC Berkeley)
15:24 - 15:30	A compilation of velocity models for central California	Gary Fuis (USGS)
15:30 - 15:45	General discussion	
15:45 - 16:00	Break	
16:00 - 17:30	Session 4: Breakouts	
	Breakout #1: Discussion of major lithotectonic units of Northern CA	
	Breakout #2: Discussion of CTM methods and comparisons	

Friday August 15th, 2025

08:30 - 09:00	Session 1: Introduction and recap of Day 1	
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09:00 - 10:00	Session 2: Invited overview CFM	
09:00 - 09:25	CFM and CEM (PDF)	Scott Marshall (Appalachian State)
09:25 - 09:50	Crescent community models	Becky Fildes (Western Washington University)
09:50 - 10:15	The San Francisco Bay Area CVM	Evan Hirakawa (USGS)
10:00 - 11:30	Session 3: Breakout discussions on either GFM or CTM	
	Breakout #1: Moving forward with GFM	
	Breakout #2: Moving forward with CTM	
11:30 - 12:00	Wrap up	
12:00	Workshop Adjourns	

Workshop Participants

Last Name	First Name	Organization
Aguilar	Brian	CSU Bakersfield
Arnold	Alec	UC Davis student
Ben-Zion	Yehuda	USC/SCEC
Boyd	Daniel	California Geological Survey
Boyd	Oliver	USGS
*Boyd	Sierra	Berkeley Seismological Laboratory
*Dunham	Eric	Stanford University
Elbanna	Ahmed	University of Southern California
Fildes	Becky	Western Washington
Furlong	Kevin	Penn State University
Goldsby	Ryan	UNR
*Gómez Garcia	Ángela Maria	CSIC/GFZ
*Graymer	Russell	USGS
Hirakawa	Evan	USGS
Hwang	Lorraine	UC Davis CIG
*Langenheim	Victoria	USGS
Lee	Wai Ho (Terry)	University of Nevada, Reno
Louie	John	Terēan

*Marshall	Scott	Appalachian State
Martin	Hannah	Nevada Seismological Laboratory, UNR
Montesi	Laurent	University of Maryland
Oskin	Michael	UC Davis
Quinn	Daven	UW–Madison
Rack	Sierra	UC Davis
Rowe	Christie	UNR - Nevada Seismo Lab
Smith	Zachary	University of California Berkeley
Terra	Fabia	UC Berkeley
Thomas	Amanda	UC Davis
Tian	Xiaochuan	UC Davis
Titus	Sarah	Carleton College
Wang	Binhao	University of Southern California
Welch	Robert	Loyola Marymount University/Harvard University
Young	Elaine	California Geological Survey
Zeng	Yuehua	USGS
Zuza	Andrew	University of Nevada, Reno

*Attended remotely

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