The SCEC CSM v2024: a Statewide Community Model for Stress Orientation and Stressing Rate

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Statewide CSM v2024 fully released!

- We announce the full release of the first statewide version of the SCEC Community Stress Model (CSM), v2024.
- CSM v2024 includes both stresses and stressing rates. These are used to describe how faults are loaded, how faults interact, and as initial conditions in ground motion simulations.
- We expect that increasing the range and accessibility of CSM models will both expand the user community and facilitate novel research avenues.

What's included in CSM v2024?

- This latest CSM consists of 22 distinct models of stress or stressing rate, each based on different types of data, methodologies, and underlying assumptions (Figure 1).
- We have added eight new models of stress orientation from earthquake focal mechanism inversion, including six distinct models covering regions of the San Andreas system in central or northern California, in addition to one covering parts of Long Valley, and one covering the Ridgecrest region.
- With these additions CSM v2024 stress orientation models now cover the full extent of the main San Andreas fault.
- We have also developed three new stressing rate models based on strain rate estimates incorporated into the latest National Seismic Hazard Model release, assuming a uniform elastic material.
- These models cover the entire land area of California, and two have stress accumulation estimates that extend offshore to the full extent of CSM model grid space.

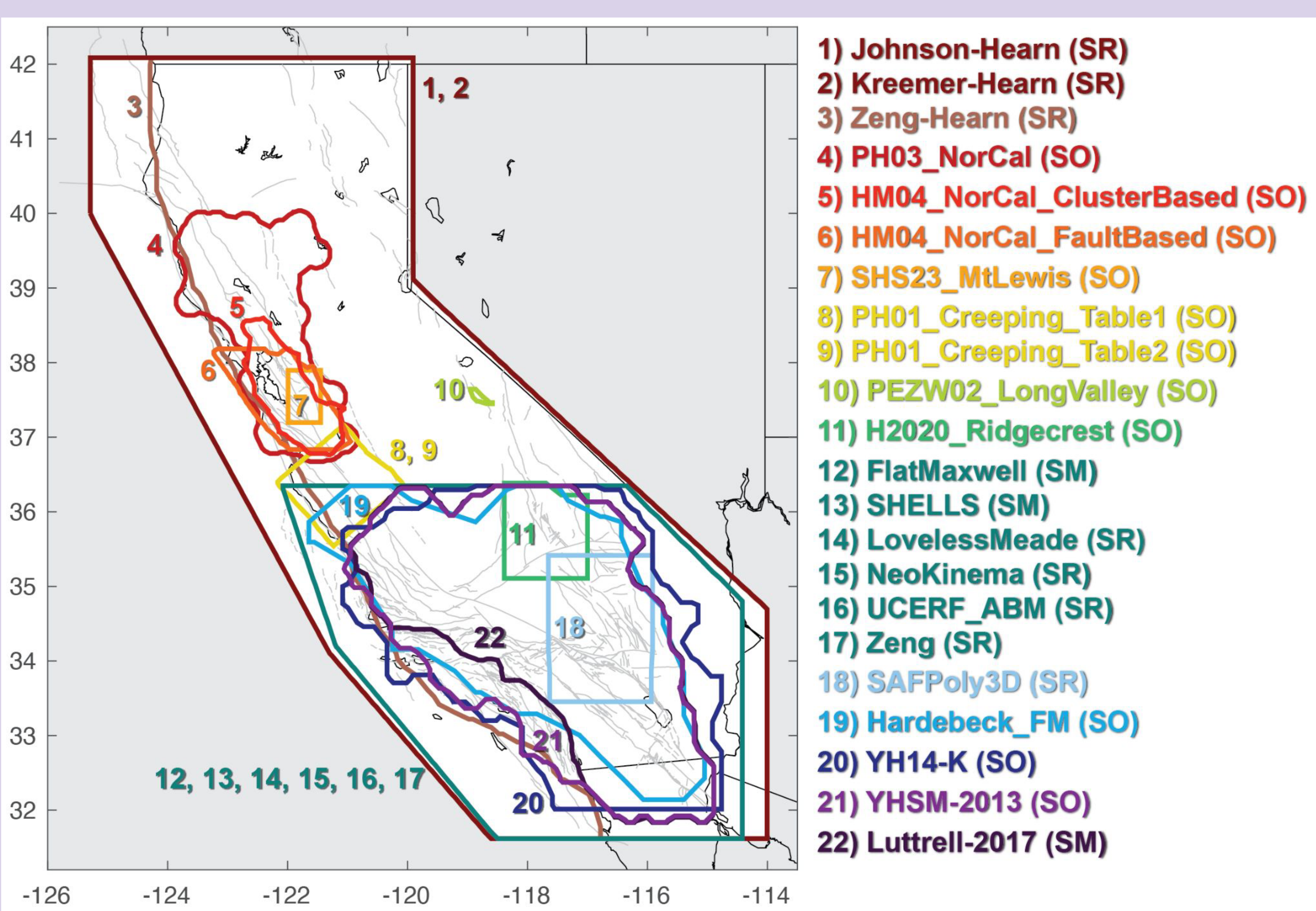

Figure 1: extent of models represented in the Community Stress Model v2024, with color and number corresponding to the list of models at right. Note, some models share extents. Models describing stressing rate (SR), stress orientation (SO), and stress magnitude (SM) are indicated by their name.

Comparing Models of Stress Orientation

- Of the 11 models of stress orientation derived from focal mechanism inversion, only one varies with depth. Therefore, we do not consider depth variation in this analysis and results instead represent seismogenic depths as a whole.
- Most areas of the SAF system are covered by 2 - 4 models (Figure 2a). (Note the PEZW02_LongValley model includes principal stress axes, but insufficient information to determine SHmax or Aphi definitively, so it is excluded here)
- Aphi values are fairly consistent throughout model space, with most areas in strike-slip or reverse faulting regime (Figure 2b). In most areas, RMS of model deviation from mean is < 0.37, indicating strong agreement in stress ratio (Figure 2d, 2f).
- SHmax values (Figure 1c) are fairly consistent between models, with RMS departure from the mean generally within 12º (Figure 1e, 1g).

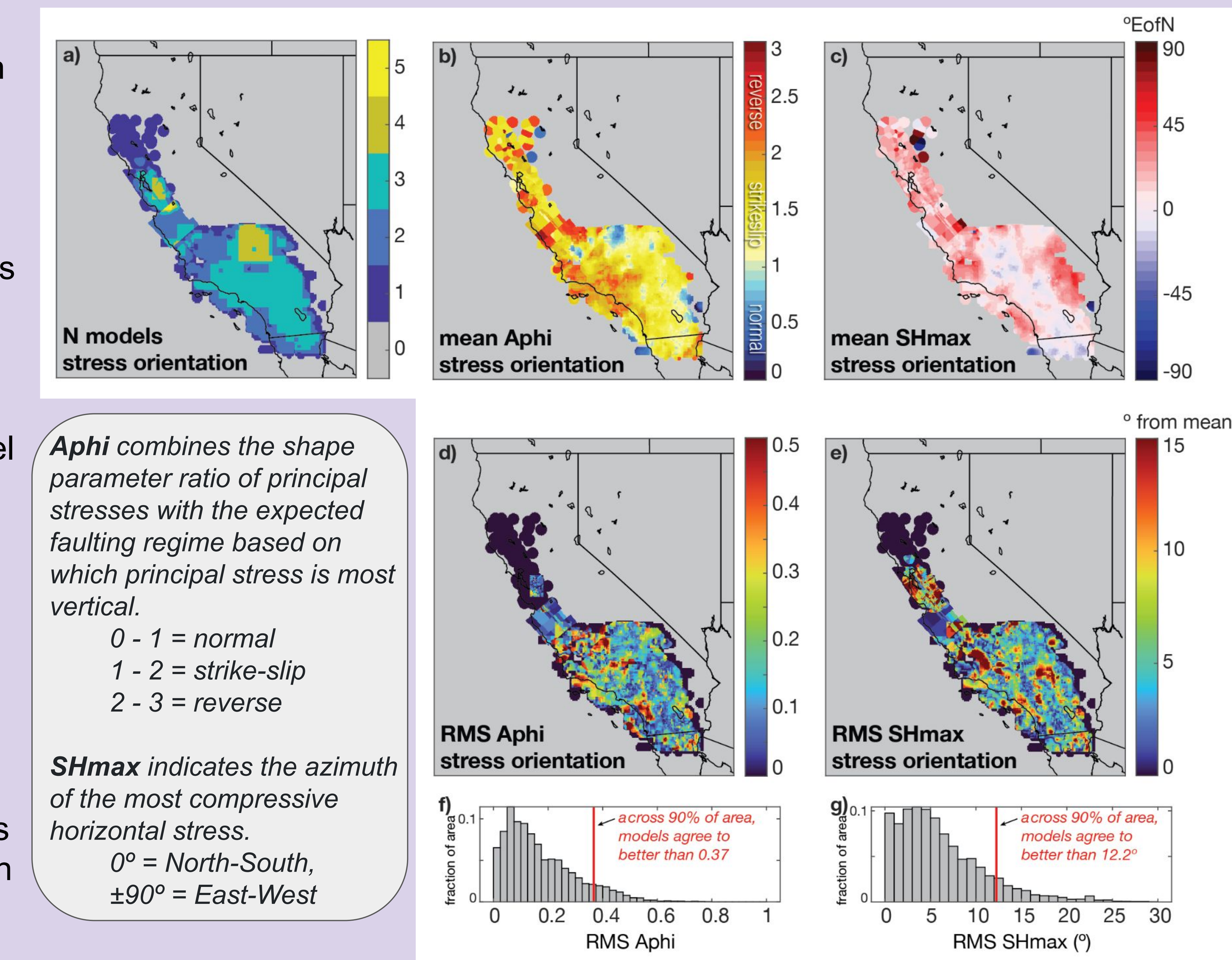

Figure 2: Summary of stress orientation models in CSM v2024: a) number of orientation models covering each region. Average model values for b) Aphi, and c) SHmax. RMS of model deviation from mean value for d) Aphi, and e) SHmax. Histogram of RMS values for f) Aphi, and g) SHmax

Comparing Models of Stressing Rate

- Of the 8 models of stressing rate, 4 vary with depth and 4 are depth independent. All stressing rate models have values that are valid at and above seismogenic depths (top ~15 km). One has values throughout the top 100 km, estimating the stressing rate at the base of shear zones. Here, showing results from 5 km depth.
- Most areas of northern California are covered by 3 models. Most areas of southern California are covered by 7 - 8 models. (Figure 3a)
- Rates of differential stress accumulation are typically ~20 - 50 kPa/yr along the main SAF (Figure 2b).
- Models agree well (to within ~20%) along the corridor of the main SAF segments. Disagreement is greater in the ECSZ and creeping SAF sections (~50%), and much greater toward the edges of model space (offshore, north of Mendocino, south of Cerro Prieto, etc.) (Figure 2f, 2j).
- Rates of isotropic stress accumulation are much smaller, generally < 5 kPa/yr (Figure 2c). Models agree well, with RMS values mostly < 1.6 kPa/yr (Figure 2g, 2k).
- Aphi (Figure 2d) and SHmax (Figure 2e) are as expected and agree well along the main SAF sections (Figure 2h, 2i, 2l, 2m). Greater disagreement in orientation is expected in low magnitude areas near the edge of model space.

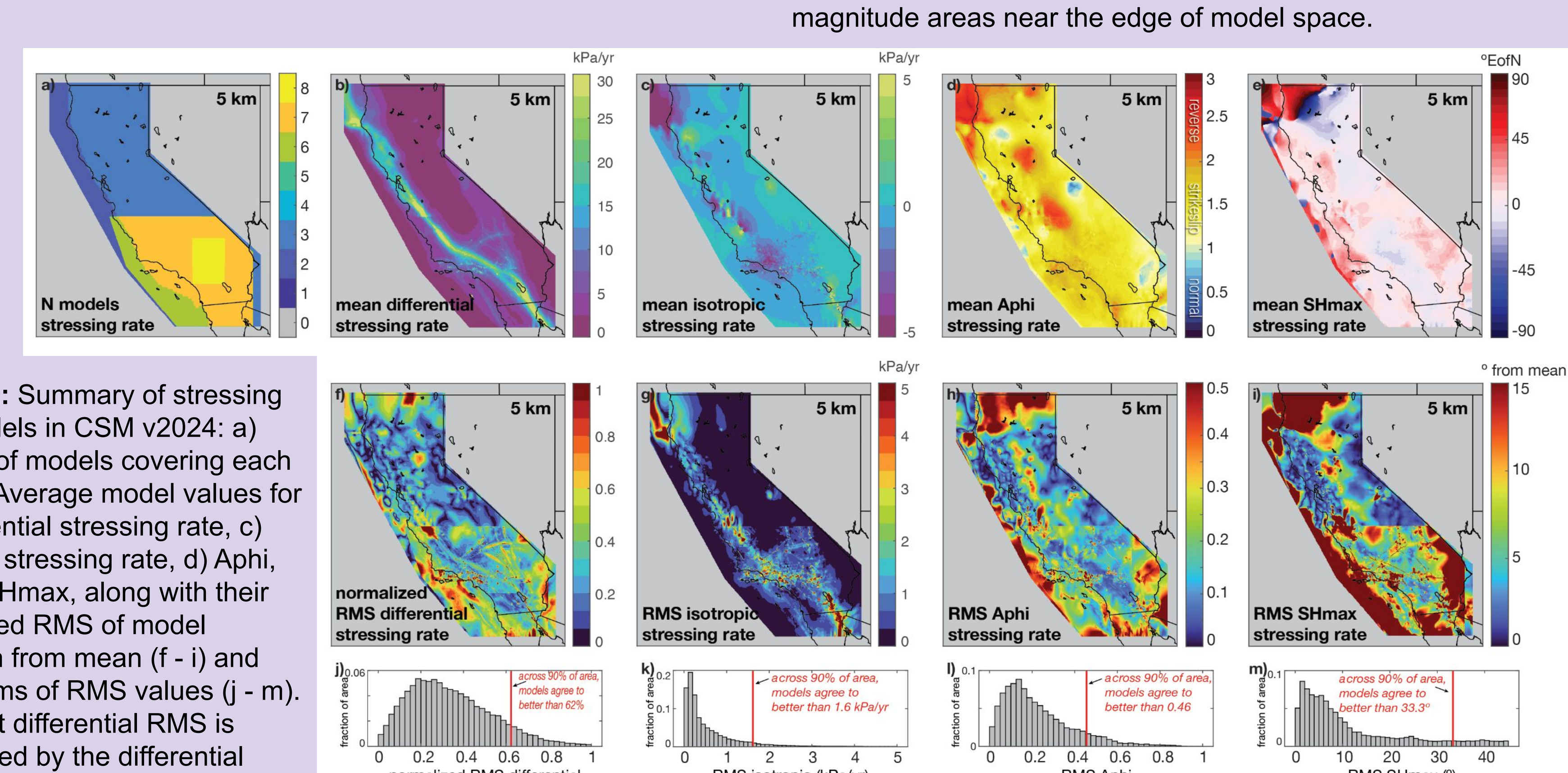

Figure 3: Summary of stressing rate models in CSM v2024: a) number of models covering each region. Average model values for b) differential stressing rate, c) isotropic stressing rate, d) Aphi, and e) SHmax, along with their associated RMS of model deviation from mean (f - i) and histograms of RMS values (j - m). Note that differential RMS is normalized by the differential stressing rate.

Comparing Models of Stress Magnitude

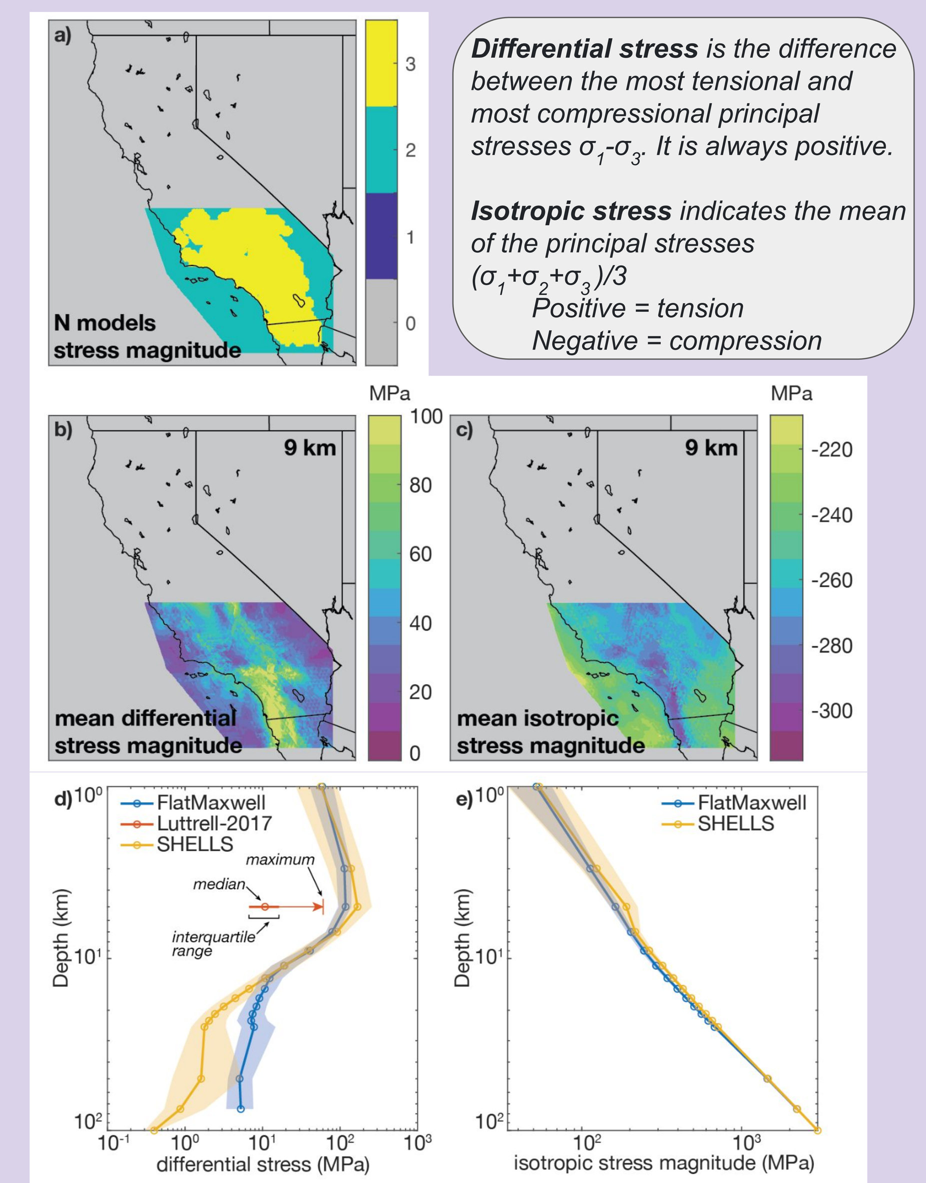

Figure 4: Summary of stress models with magnitude estimates in CSM v2024: a) number of models. Average model values for b) differential stress and c) isotropic stress at 9 km depth. Depth variation in interquartile range (shaded area) and median (line with circles) of d) differential stress and e) isotropic stress.

- Only 3 models include estimates of stress magnitude (Figure 4a). Two (FlatMaxwell and SHELLS) are defined throughout the crust and lithosphere, with values varying with depth. The other (Luttrell-2017) is an estimate of differential stress only, at a single mid-crustal depth.
- Spatial patterns in modeled differential and isotropic stress tend to reflect broader plate boundary features over surface fault expressions (Figure 4b, 4c)
- The two depth-dependent models (FlatMaxwell and SHELLS) generally agree on the range of magnitude values, though the particular features vary (Figure 4d, 4e).
- The third model that estimates only the minimum differential magnitude across the region (Luttrell-2017) gives smaller values than the full geodynamic models (Figure 4d).
- Differences in these models reflect the differences in research question the models were designed to answer (e.g., whether features like faults and topography are assumed a priori or anticipated as emergent features).

Want more info about CSM v2024?

Website

- A new CSM website (https://www.scec.org/science/community-stress-model/) serves as an introduction to the CSM for new and potential users, as well as contextualizing the CSM within the broader CEM project.

Archive

- The entire CSM v2024 is available as an archive with a citable Digital Object Identifier (DOI) at Zenodo (https://zenodo.org/records/15171026).

Explorer

- The new CSM contributions have also been incorporated into the revised web-based Explorer tool (https://central.scec.org/research/csm-explorer/), which allows easy exploration, basic visualization, and selective download of subsets of CSM models.

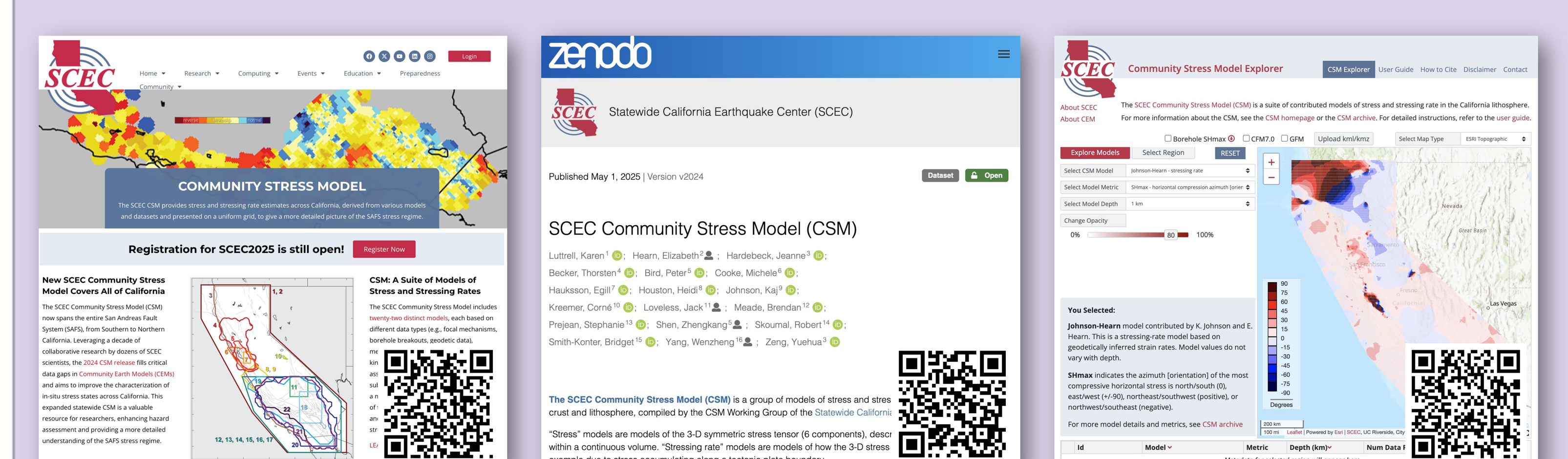

Figure 5: screenshots of the new CSM v2024 website (left), archive (middle), and explorer tool (right), along with QR code links to each.