The SCEC Community Stress Model (CSM) Project

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Community Stress Model (CSM):

• New project starting in SCEC4.

• Long-term goal: a model or set of models of stress and stressing rate in the southern California lithosphere.

• The CSM will probably not be a single model, but a (hopefully small) set of models.

• Any branches in the CSM will be based on clearly-defined differences in data or assumptions.

Who are the users of the CSM and what do they need?

External users: Rupture dynamics, geodynamics, seismic hazard, stress triggering, others?
Needs: You tell us! (Invite representatives of external user communities to all workshops.)
Provide: One or more reference stress and stressing rate models, accessible through an interface developed jointly with the user communities.

Internal users: Researchers working on problems directly related to stress.
Needs: Access to existing data and models, easier ways to integrate and compare models and observations.
Provide: A modeling environment with tools that will enable researchers to develop and test candidate models against suites of data and/or quantitatively compare their models with other models.

Progress:

- First workshop, September 2011, at SCEC Annual Meeting. Large wide-ranging group discussion.

- Second workshop, October 2012: compiled and compared existing stress and stressing rate models from the SCEC community.
  - All models in common format on pre-defined 3D grid.
  - Most models were submitted as full 6-component stress or stressing rate tensors.

- Third workshop planned for May 29-30 2013: focus on reconciling stressing rate models, and validating models with data.

Contributed Models:

Stress:

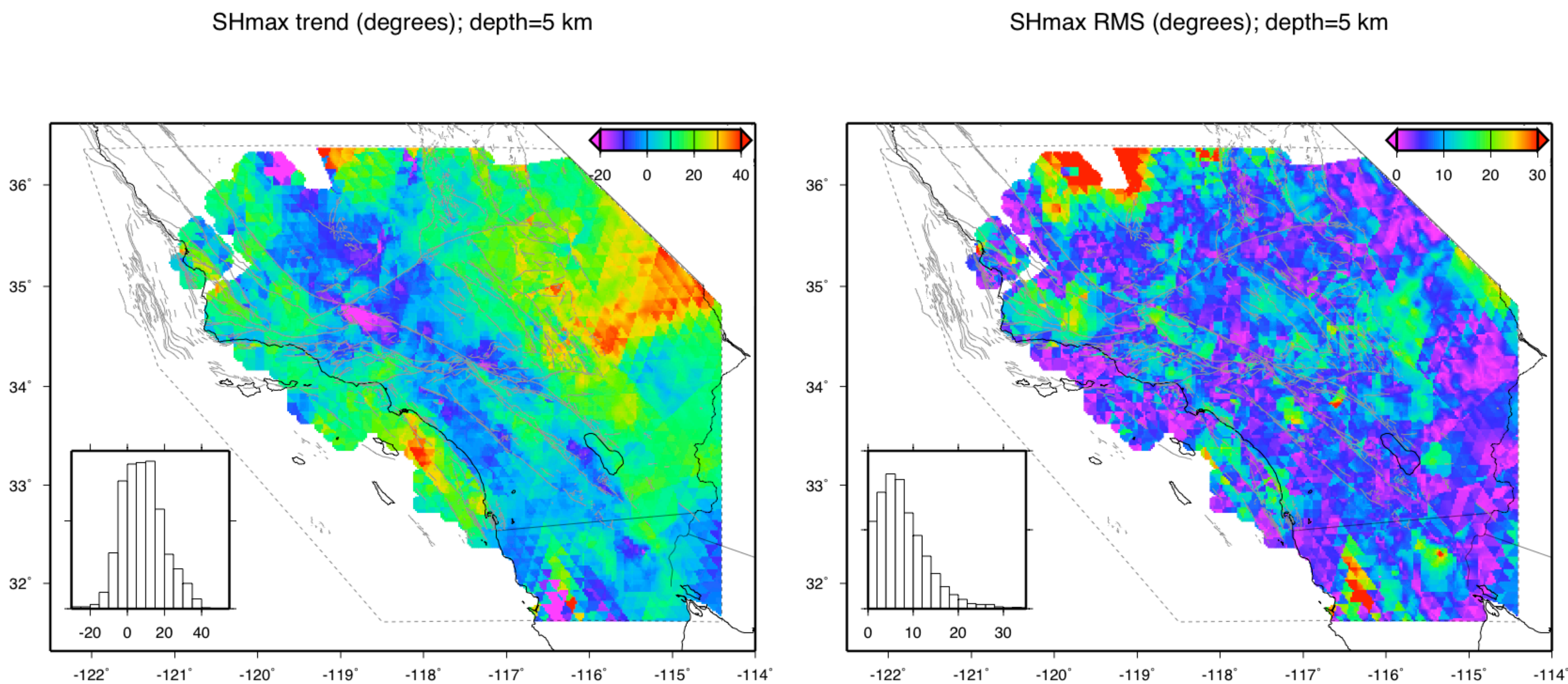
1) Inversion of focal mechanisms for stress orientation. – *Wenzheng Yang and Egill Hauksson (Caltech).*

2) Finite element model including topography, depth-dependent rheology, frictional faults, and long-term deformation model. – *Peter Bird (UCLA).*

3) Inversion for stress field that fits topography, fault loading from dislocation model, tectonic loading, and focal mechanisms. – *Karen Luttrell (USGS), Bridget Smith-Konter (Texas), and David Sandwell (UC San Diego).*

4) Global model from density-driven mantle flow, plus lithosphere gravitational potential energy, fit to geoid and global plate motions. – *Attreyee Ghosh and Thorsten Becker (USC).*

Average Stress Model: average normalized deviatoric stress tensor.



* Average of Bird; Luttrell, Smith-Konter & Sandwell; and Yang & Hauksson models, everywhere at least two of these models are defined.

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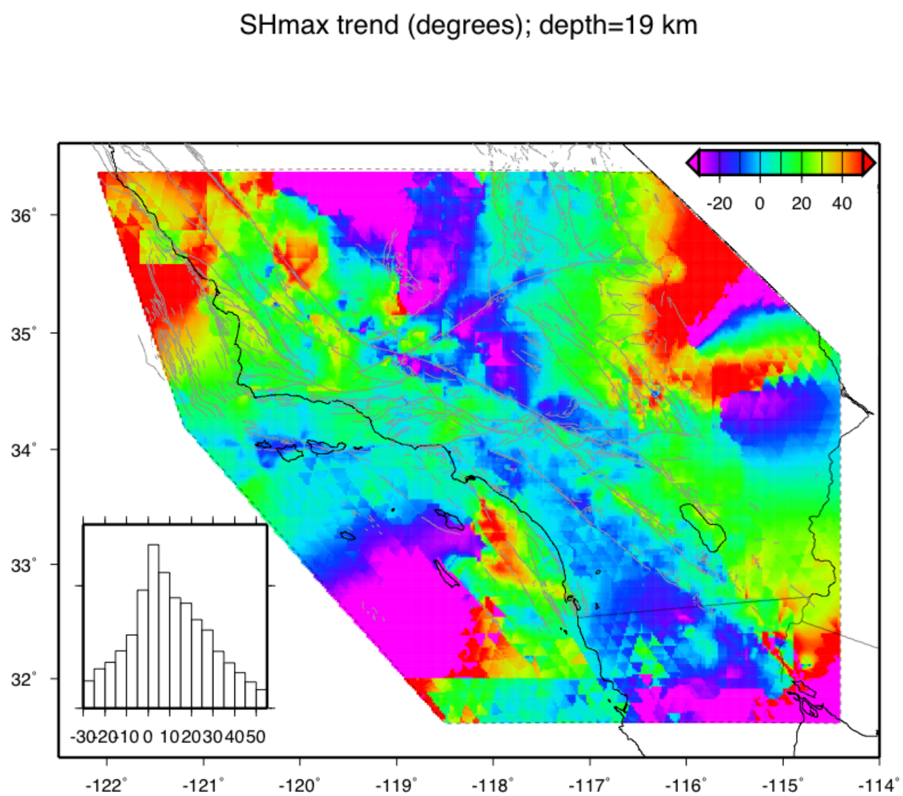

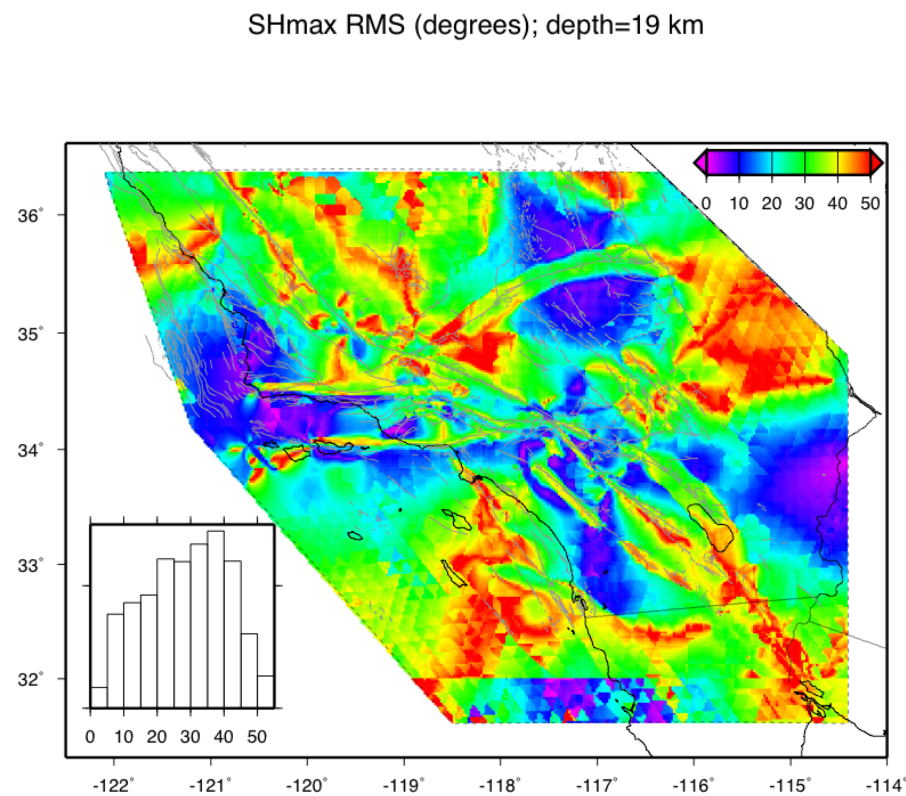

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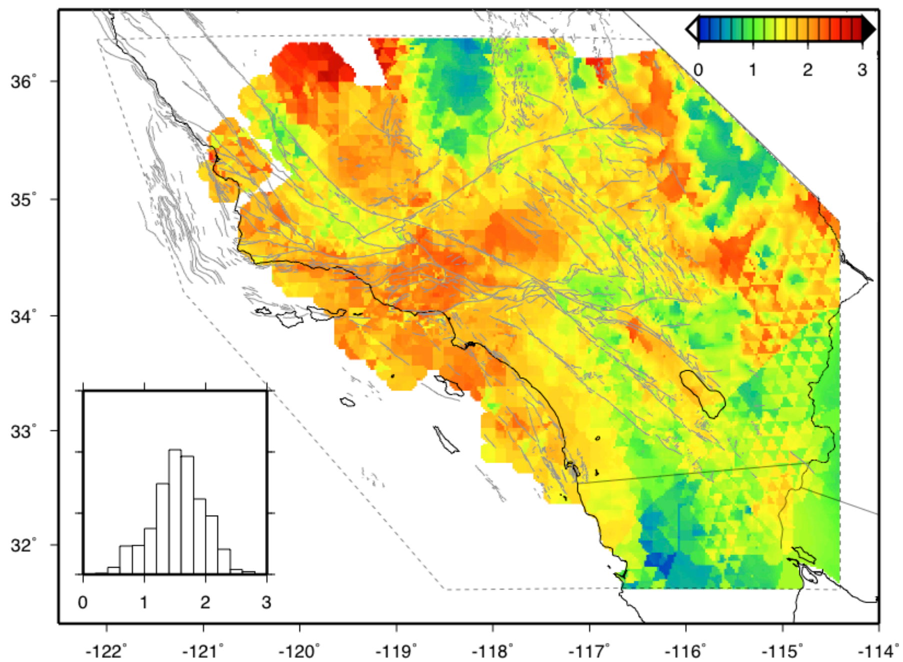
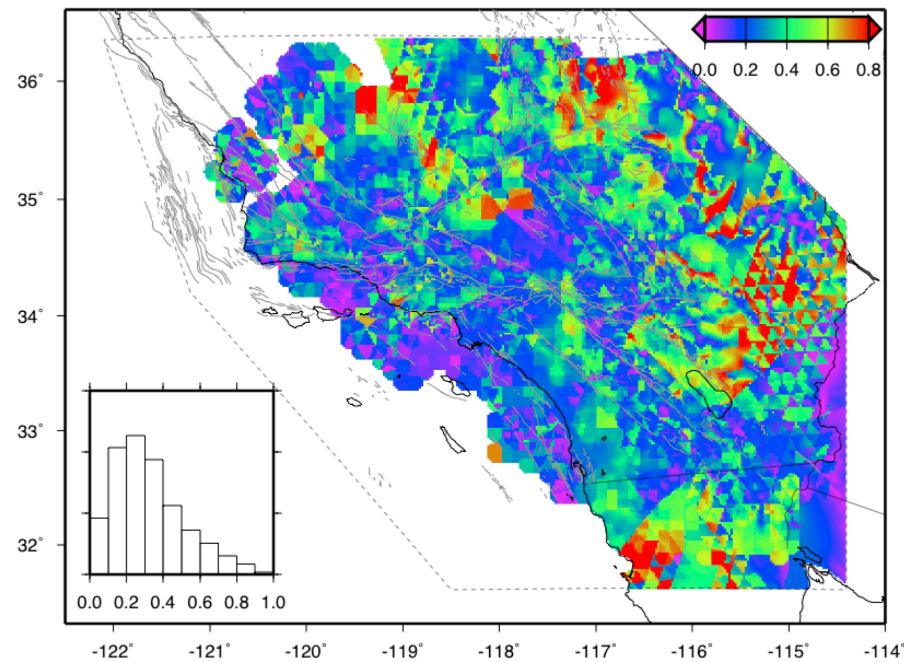
Average Stress Model: average normalized deviatoric stress tensor.

A_phi; depth=5 km



A_phi RMS; depth=5 km



phi=(σ2-σ3)/(σ1-σ3)

Aphi=phi 0-1 : normal faulting (σ1 most vertical)

Aphi=2-phi 1-2 : strike-slip faulting (σ2 most vertical)

Aphi=2+phi 2-3 : reverse faulting (σ3 most vertical)

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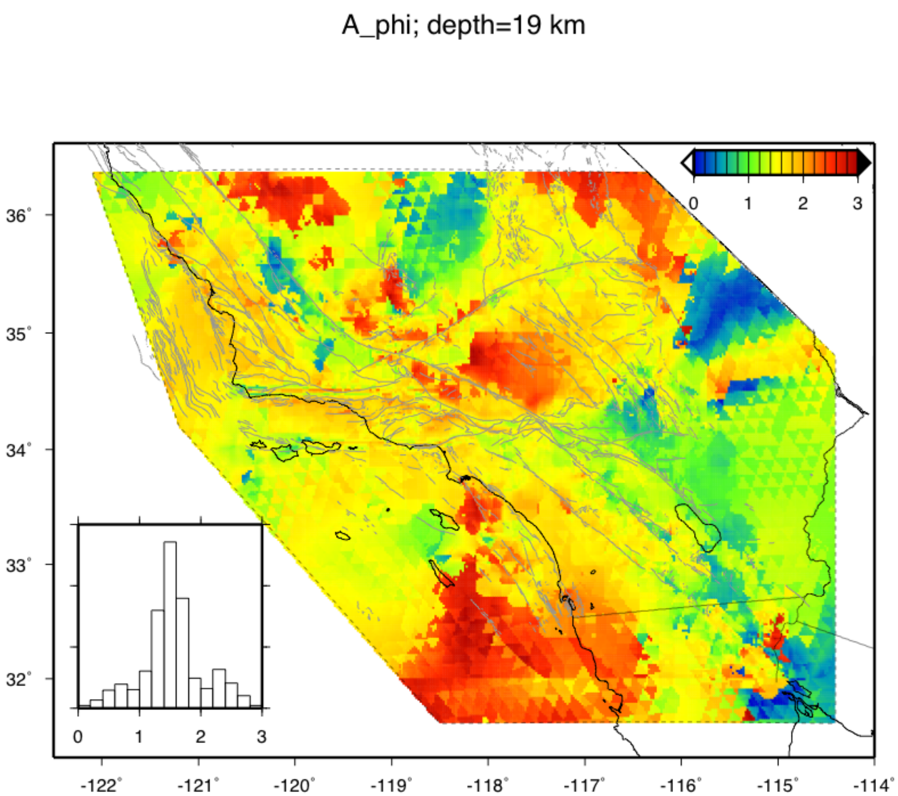

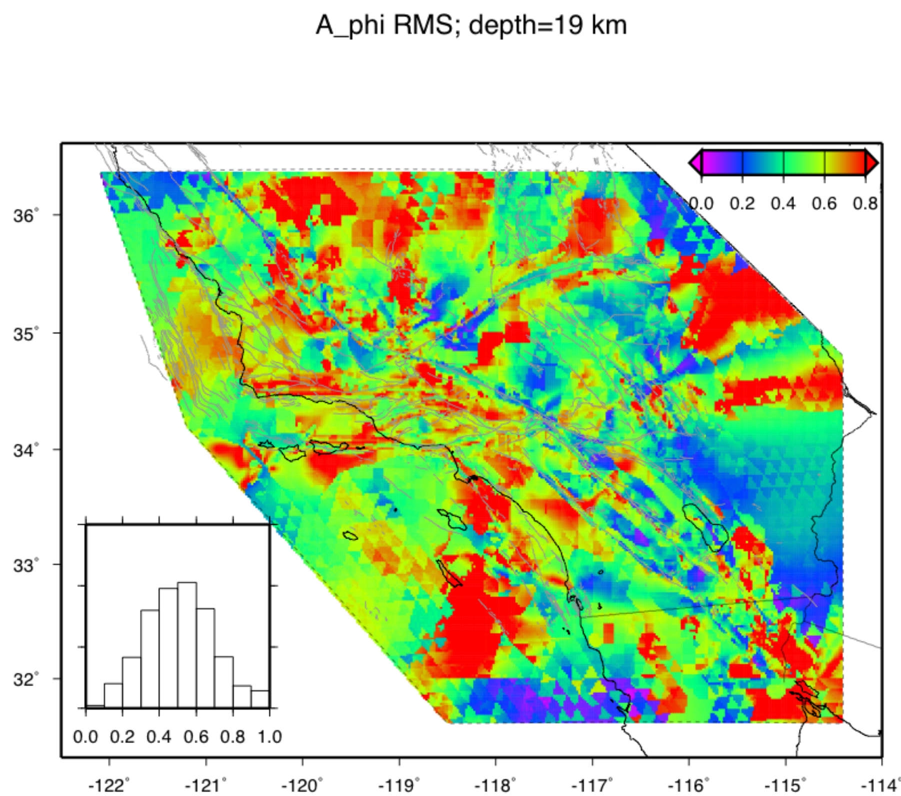

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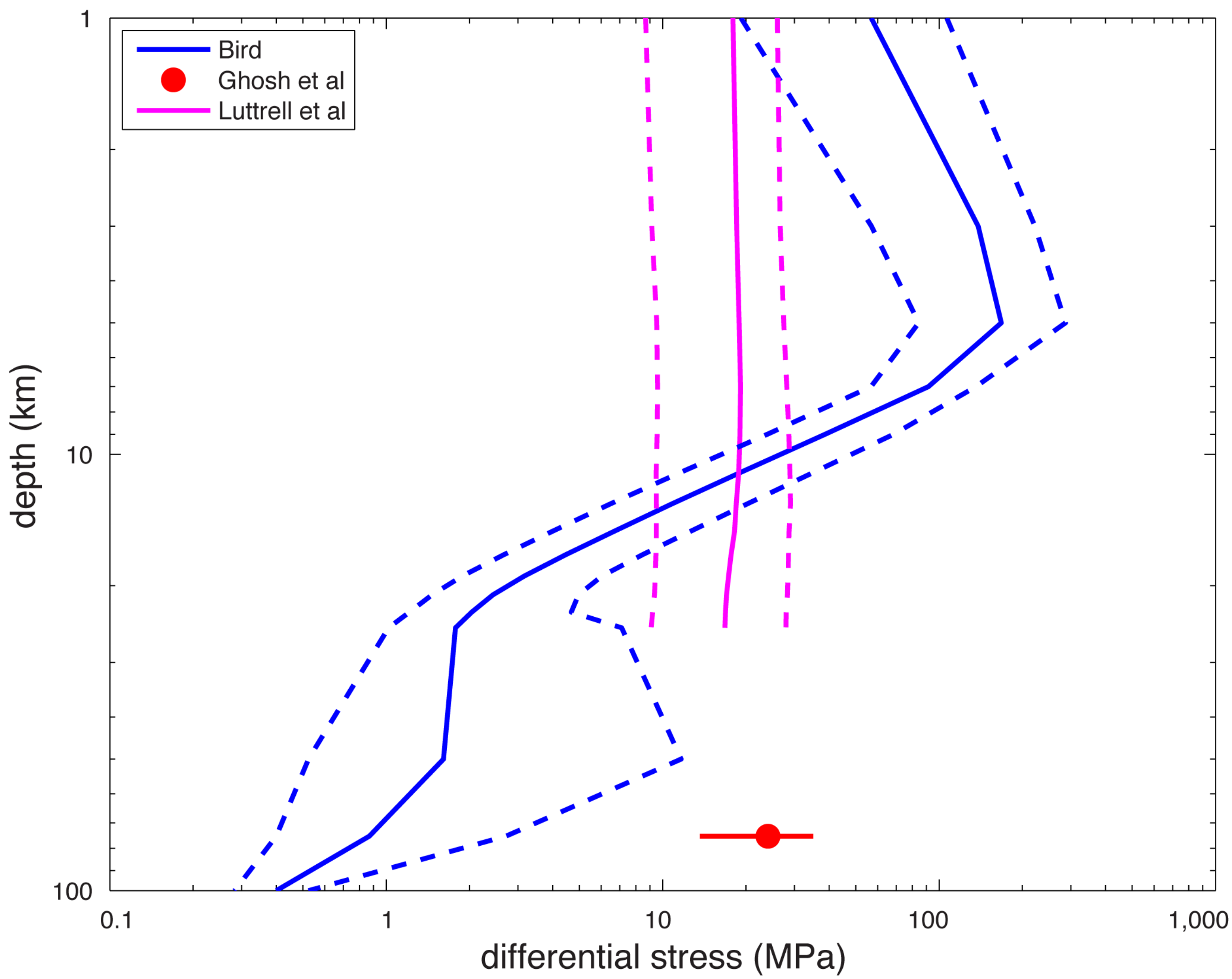
Stress Models: differential stress ($\sigma1$-$\sigma3$) versus depth.



Solid line/symbol: median. Dashed line: middle 68%.

Contributed Models:

Stressing Rate:

1) Block model fit to geodetic data. – *Jack Loveless (Smith) and Brendan Meade (Harvard).*

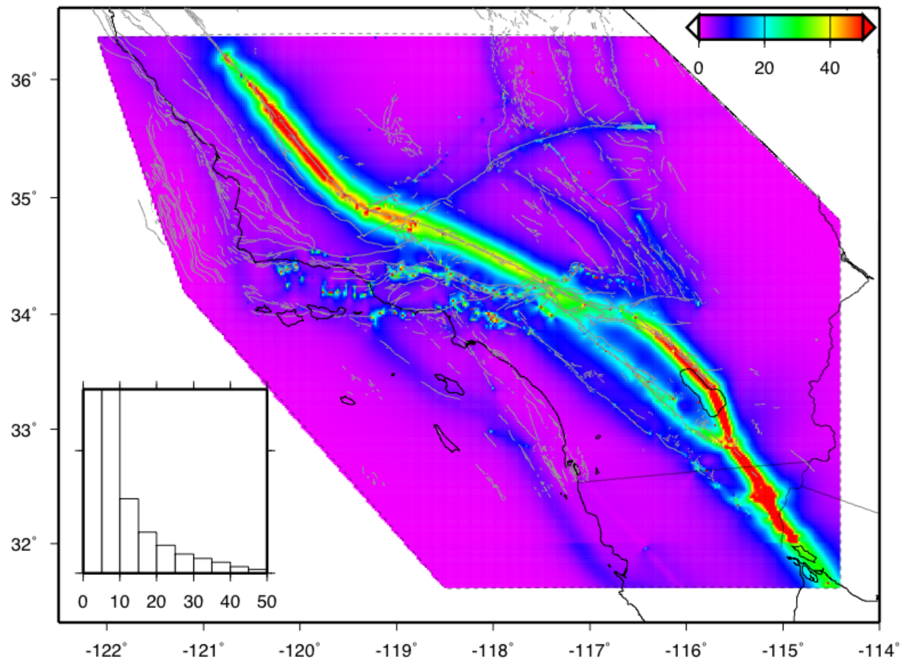
2) Fault loading from dislocation model using geologic and geodetic slip rates. – *Bridget Smith-Konter (Texas), and David Sandwell (UC San Diego).*

3) Fault loading from dislocation model plus static stress changes from earthquakes. – *Anne Strader and David Jackson (UCLA).*

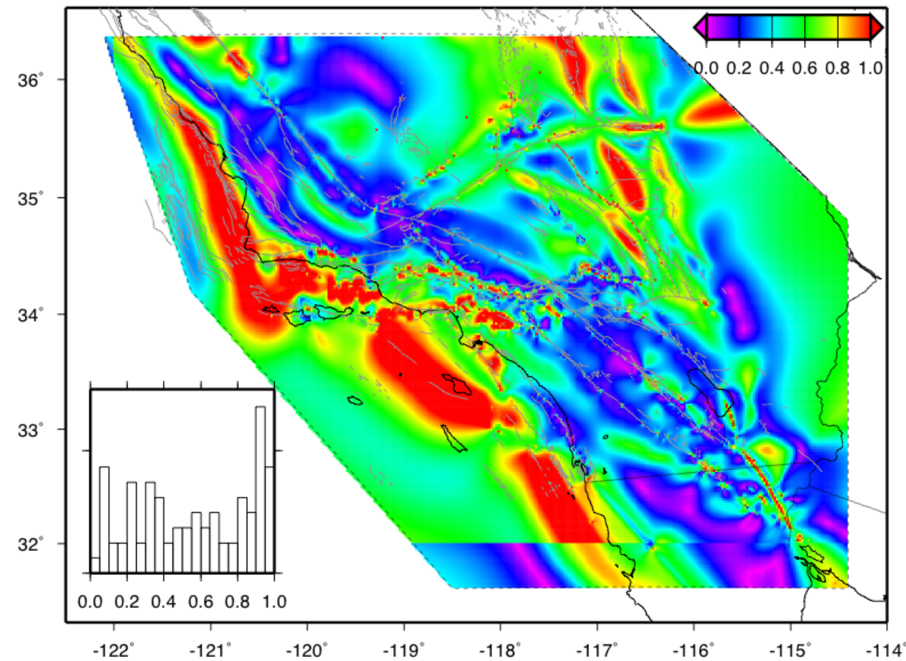
4) Local boundary element model fit to slip rates. – *Michele Cooke (UMass) and Scott Marshall (Appalachain State).*

Average Stress Rate Model: average differential stressing rate: $\delta(\sigma 1-\sigma 3)/\delta t$.

diff stressing rate (kPa/yr); depth=5 km

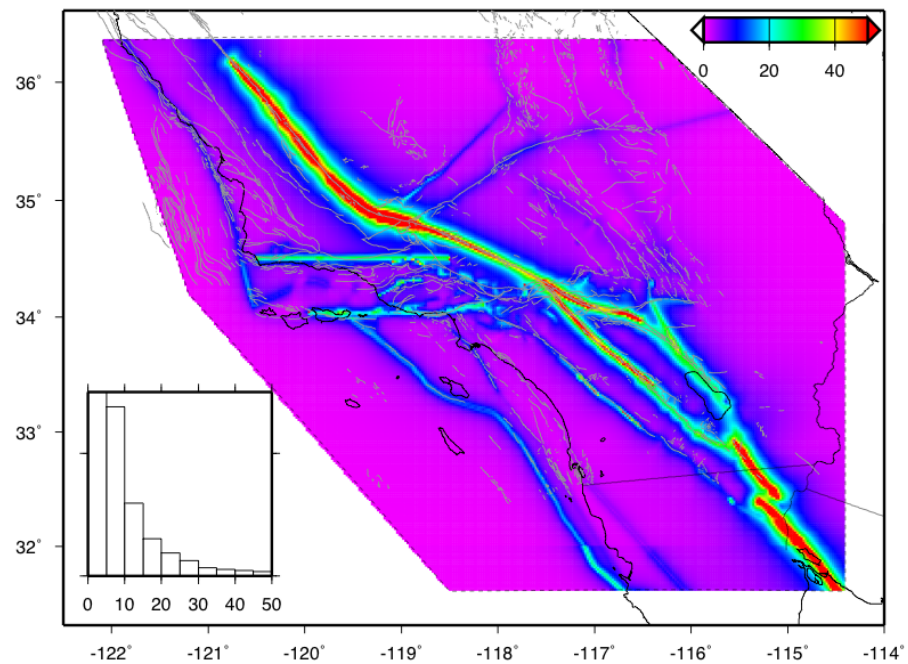


diff stressing rate RMS (fraction); depth=5 km



Average Stress Rate Model: average differential stressing rate: $\delta(\sigma 1-\sigma 3)/\delta t$.

diff stressing rate (kPa/yr); depth=17 km



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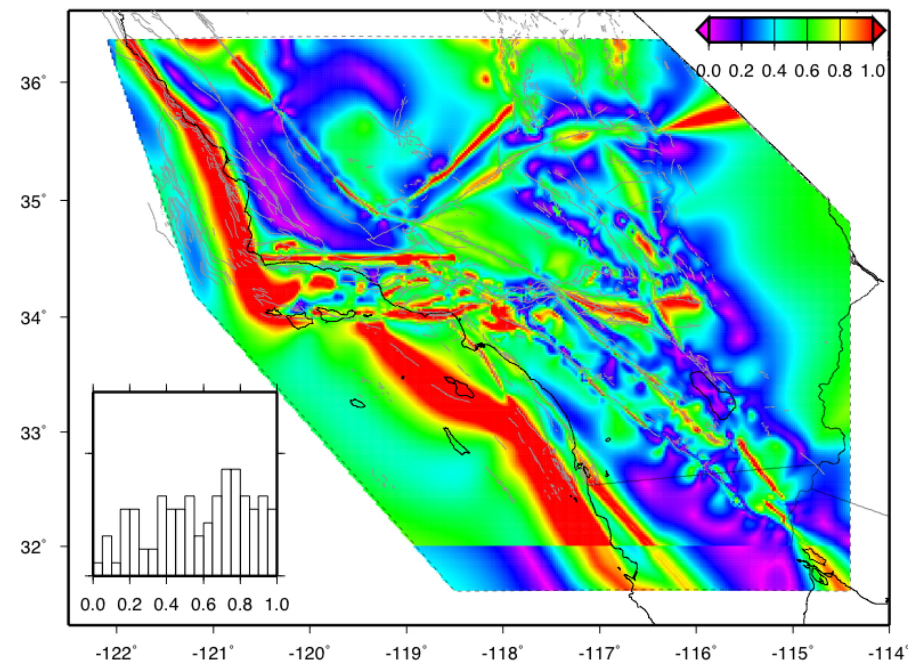
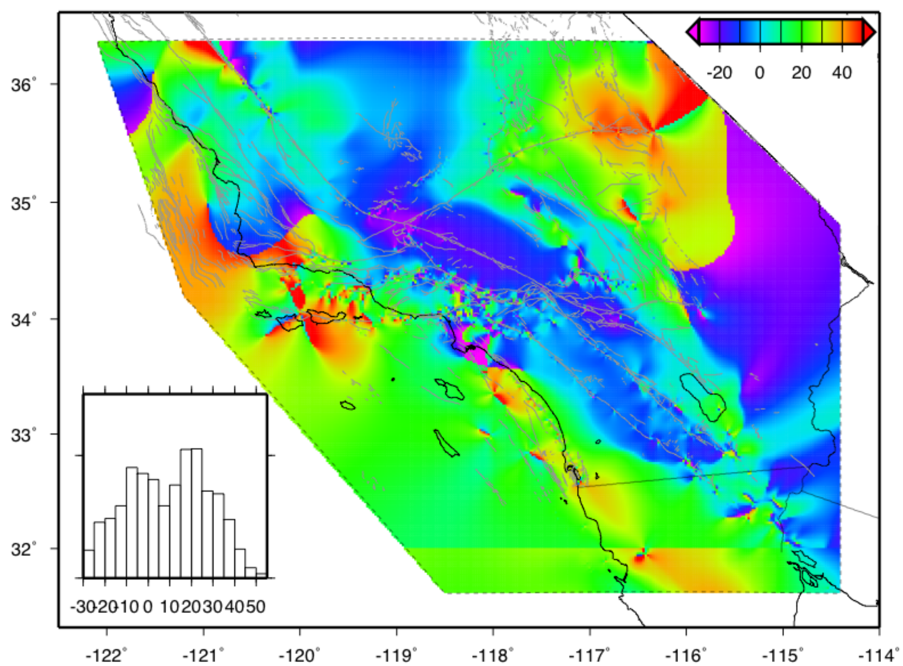


Average Stress Rate Model: average normalized deviatoric stress tensor – orientation only.

SHmax trend (degrees); depth=5 km



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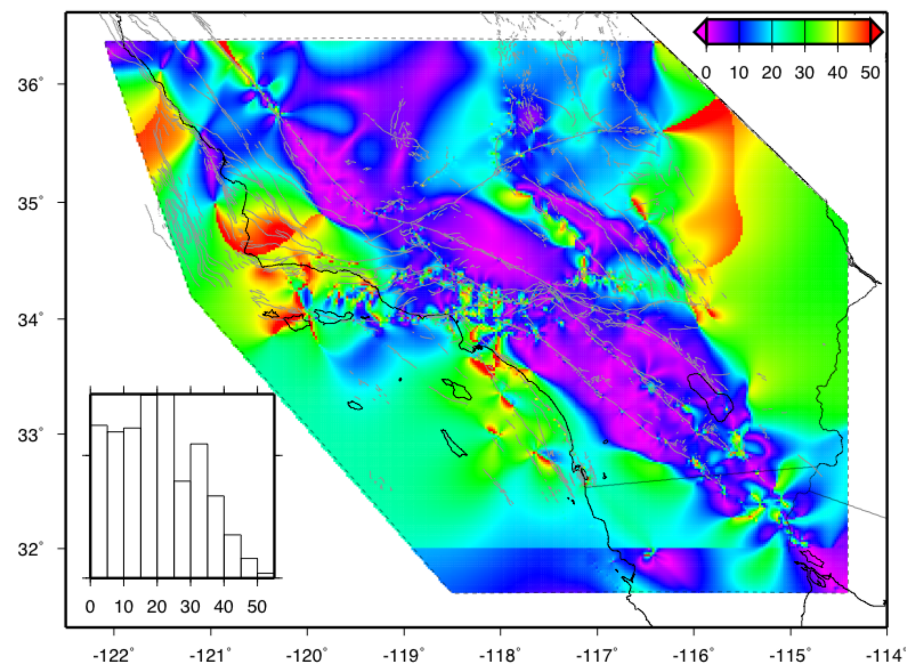
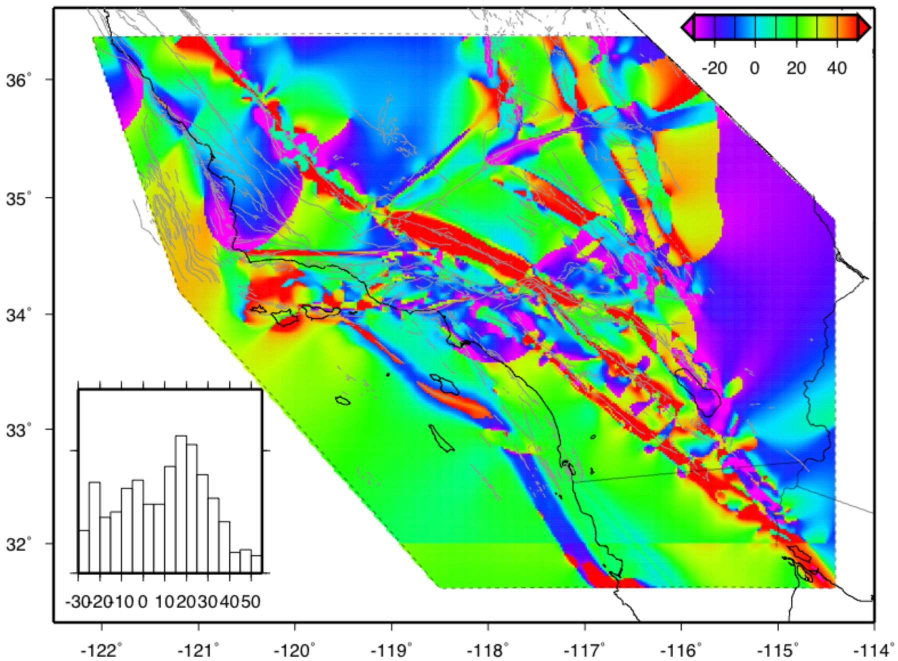


Average Stress Rate Model: average normalized deviatoric stress tensor – orientation only.

SHmax trend (degrees); depth=19 km



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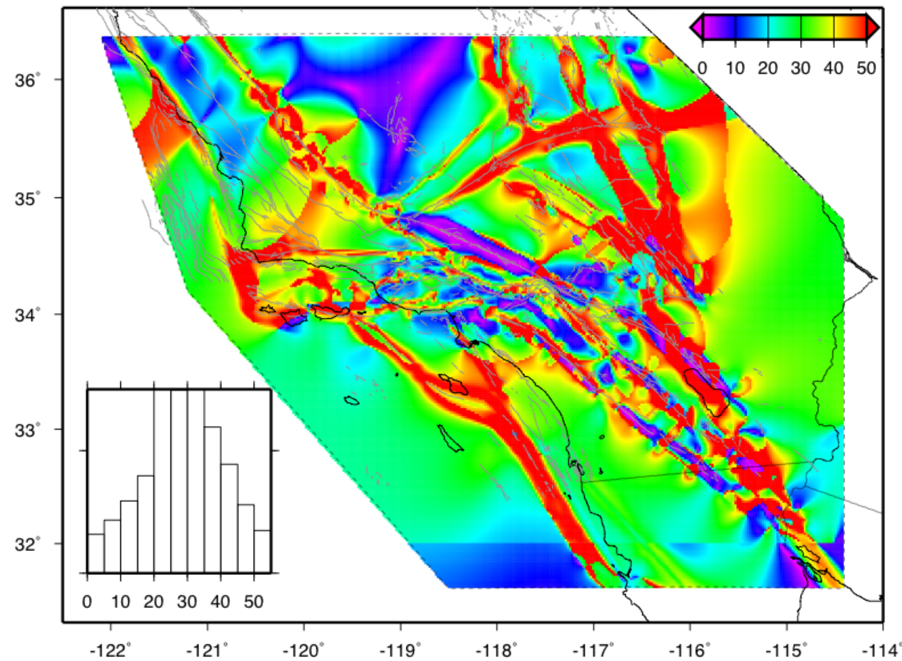

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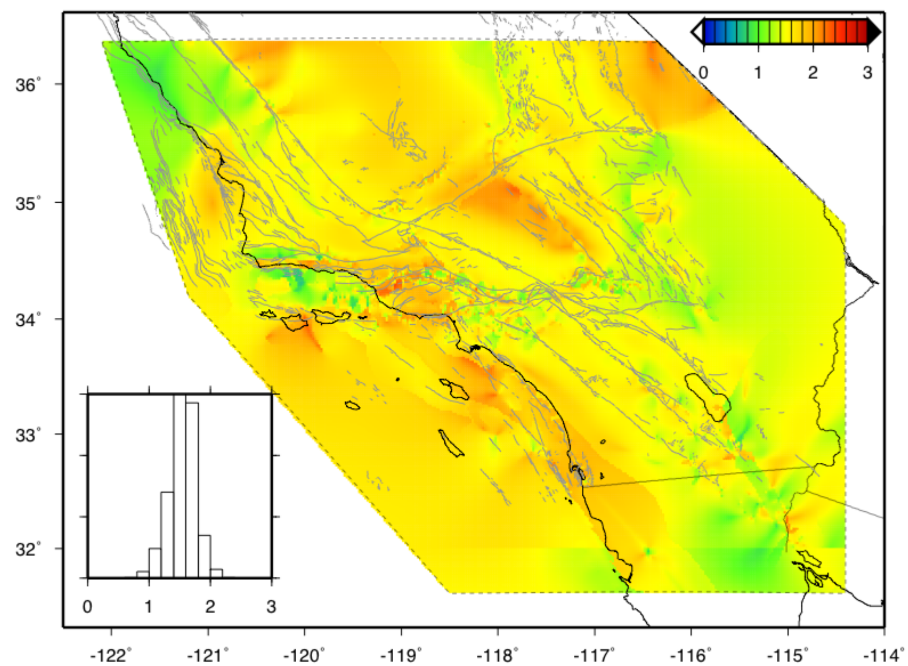

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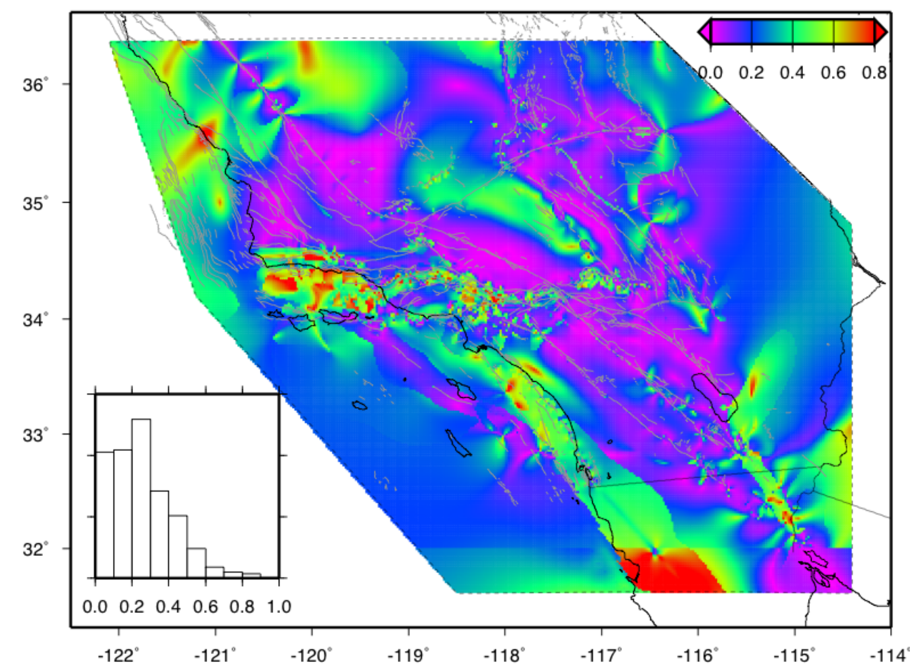

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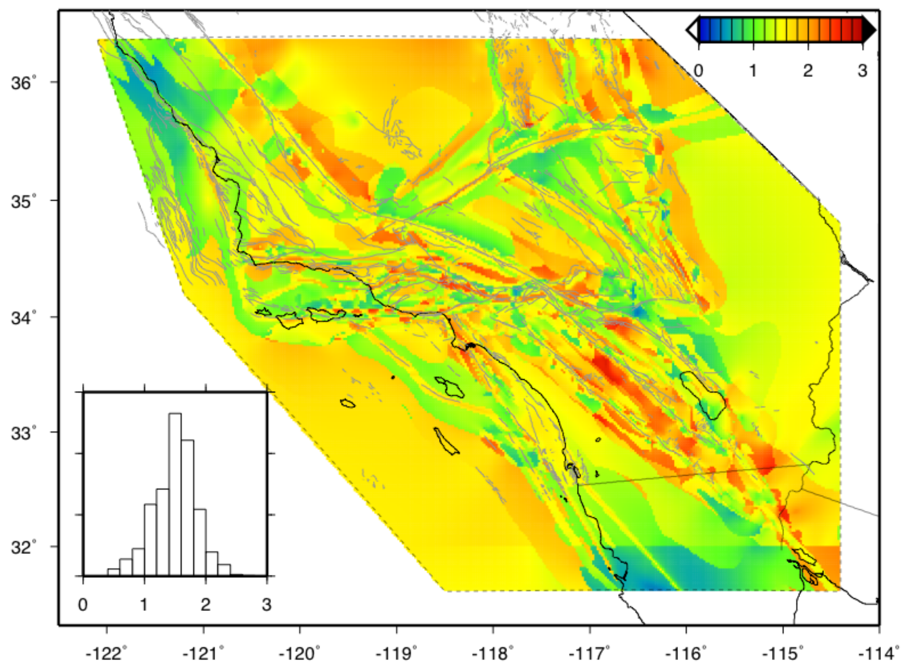

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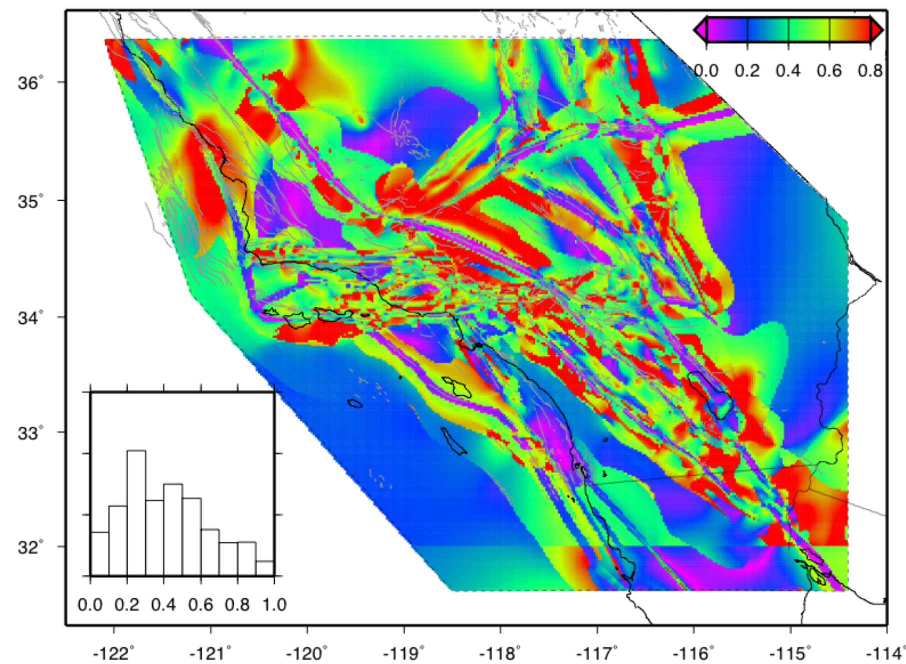

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How can the CSM benefit from a better understanding of ductile rheology?

- Physics-based stress and stressing rate models rely on assumptions about rheology.

- Stress and stressing rate models are generally in good agreement in the upper crust where elastic and brittle deformation dominate.

- Models become more different near the base of the seismogenic zone. Much of this disagreement is due to differences in assumed fault locking depth – better understanding of the brittle-ductile transition could reduce this source of uncertainty.

- Very poor agreement of models below seismogenic depths. Therefore, the depths where we are in most need better constraints are the depths where ductile rheology is important.

- If you have a physics-based model of stress and/or stressing rate in the lithosphere, please consider contributing it to the CSM project.