Comparison of SHmax orientations from stress inversions of focal mechanisms with 17 different strain models determined from GPS data in southern California: Contribution to the SCEC stress model

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What?/Why?

Using 170,000 earthquake focal mechanisms (1981–2010), Yang and Hauksson (2013) inverted for the state of stress in the southern California crust. They also determined the regional variations in the maximum horizontal compressive stress (SHmax) from the stress field. The SHmax is best resolved where seismicity rates are high and sufficient data are available to constrain the stress field.

We compare the regional variations in SHmax trends across southern California with 17 different published strain models determined from GPS data. In general there is a -5 degree average rotation between the strain models and SHmax. A typical standard deviation is 15 degrees.

The detailed regional variations in the SHmax trends are very similar to the pattern of the GPS-measured maximum shortening axes of the surface strain rate tensor field although the strain field tends to be smoother, and possibly appears to capture some of the upper-mantle deformation field.

We also compare the second invariant of rate with the rate of seismicity across southern California with the strain rate in these 17 different models. Preliminary results suggest that most seismicity occurs in regions of average strain rate. We will also explore these data sets in the context of the nascent SCEC community stress model.

Comparison of SHmax and GPS Strain

Below; comparison of SHmax (blue) orientations and maximum compressive strain (green) for the 6 "best" or most "rough" GPS strain models. Mean difference and standard deviation for each GPS model and the SHmax orientations are also shown.

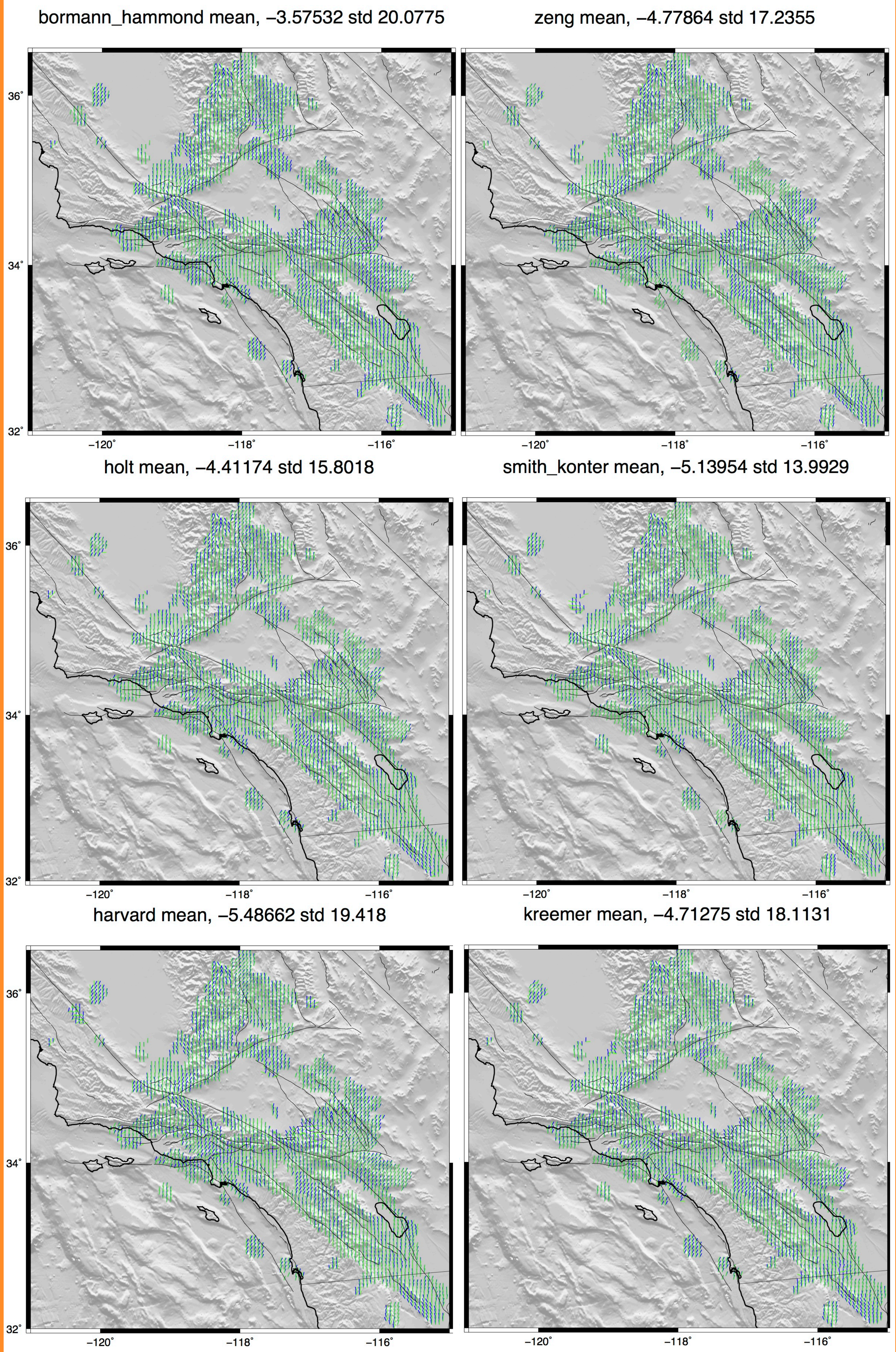

Table: Comparison of Models

In the table below, we show the cross-correlation coefficient for 6 GPS models versus UCERF2, and the UCERF background seismicity probability (SEISM). The Holt GPS model has the highest coefficient. The standard deviation between the maximum compressive strain direction and SHmax orientations is also shown, again the Holt model is in best agreement. The relative rank of the models is also shown, with the Holt model having a rank of 1.

GPS Model	UCERF2	SEISM	SHmax	Rank
	Cross-correlation	Cross-correlation	Standard Deviation	
borman	.65	.71	20.1	5
harvard	.61	.59	19.4	6
holt	.76	.80	15.8	1
kreemer	.66	.79	18.1	4
smith_konter	.71	.75	14.0	2
zeng	.76	.75	17.2	3

Conclusions

The six GPS models compare well with the SHmax model from Yang and Hauksson (2013). The Holt model has the smallest variance, and thus provides the best fit. Some of the discrepancies are caused by short wavelength groundwater anomalies or long wavelength upper Mantle effects in the GPS data.

Acknowledgements

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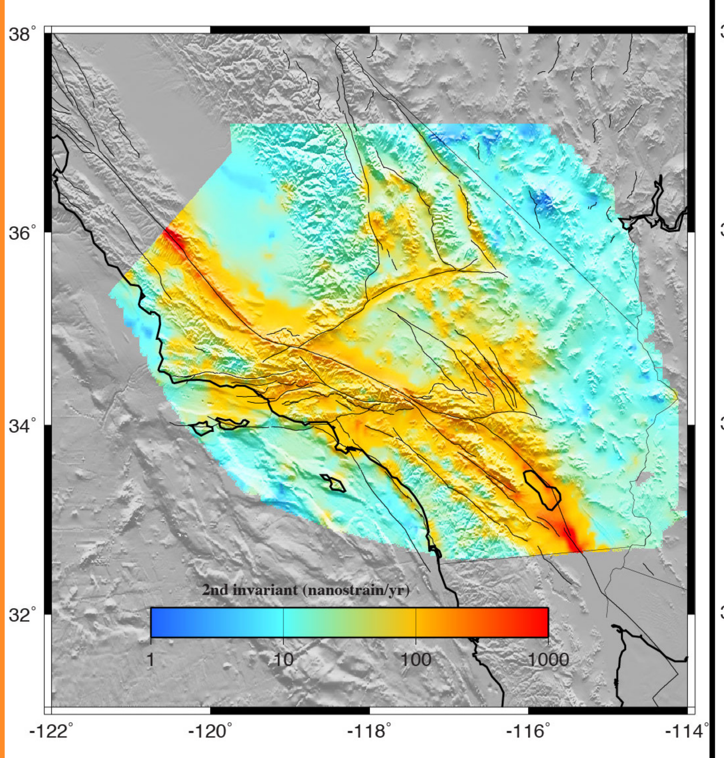
Comparing modern seismicity with GPS strain rate, UCERF background seismicity, UCERF prediction for M≥6.7 for the next 30 years, & the last 162 years of M≥4 quakes?

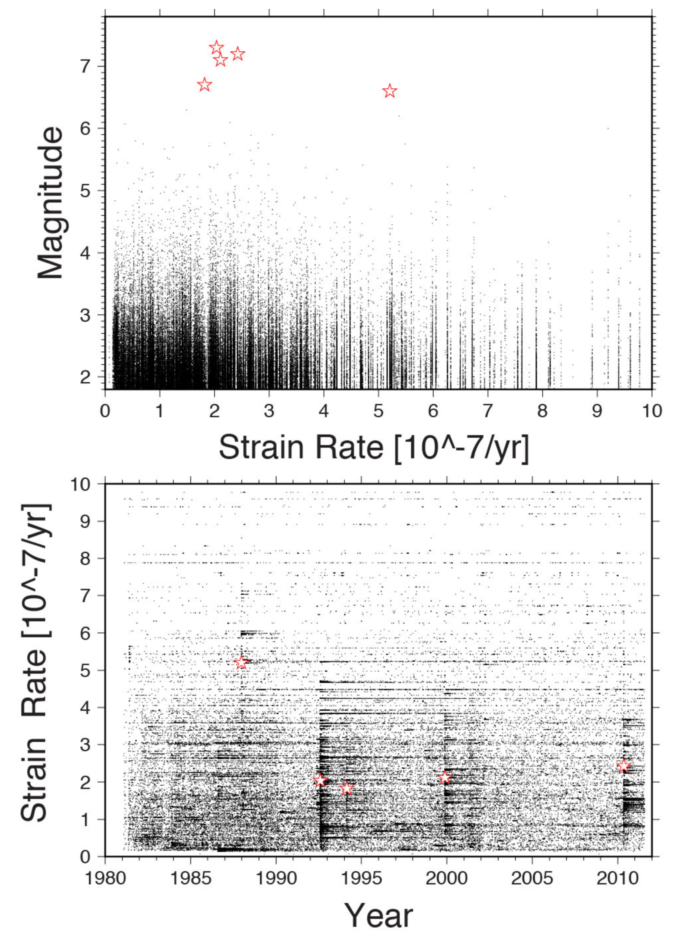
Conclusions: The seismicity occurs preferentially where these parameters have small values. Only the M≥6 (1850-2012) occur at higher probabilities. These observations suggest that low-slip rate faults or low strain rate areas are stressed to a critical level causing small magnitude background seismicity. In contrast, high strain rate faults appear to be locked while they accumulate strain energy in response to rapid tectonic loading. A time period of 160 years is not long enough to illuminate the seismicity behavior of the high strain rate areas.

GPS-Holt Model

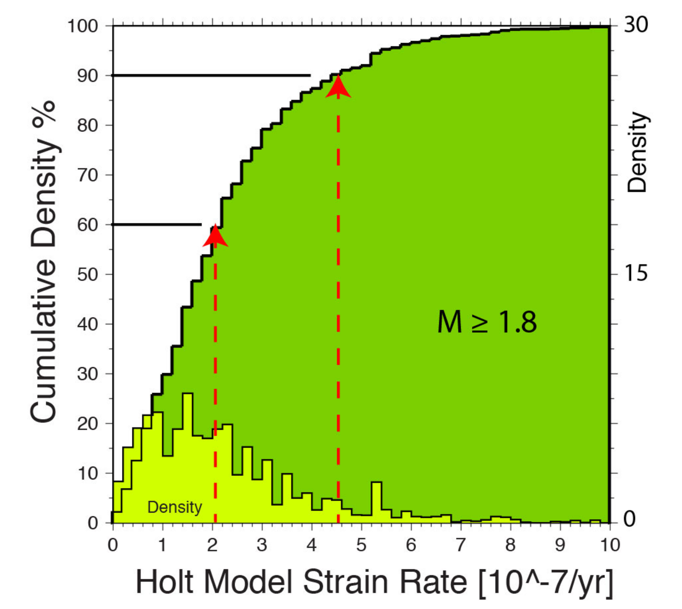
The Holt GPS strain model was selected as typical model for southern California. The GPS velocities control the calculated strain rates and styles of strain rates. Constraints on expected shear directions and magnitudes are part of the model.



(Below) Strain rate at each epicenter in the SCSN catalog versus magnitude and date of the earthquake. Most small and big quakes occur at low strain rates.

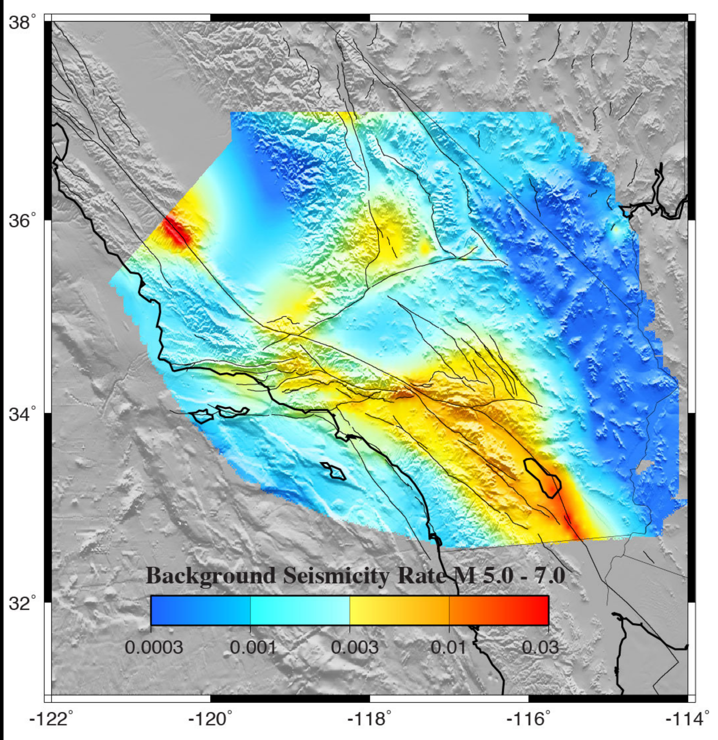


(Below) Cumulative and density histograms showing that most of the seismicity occurs at low GPS strain rates.

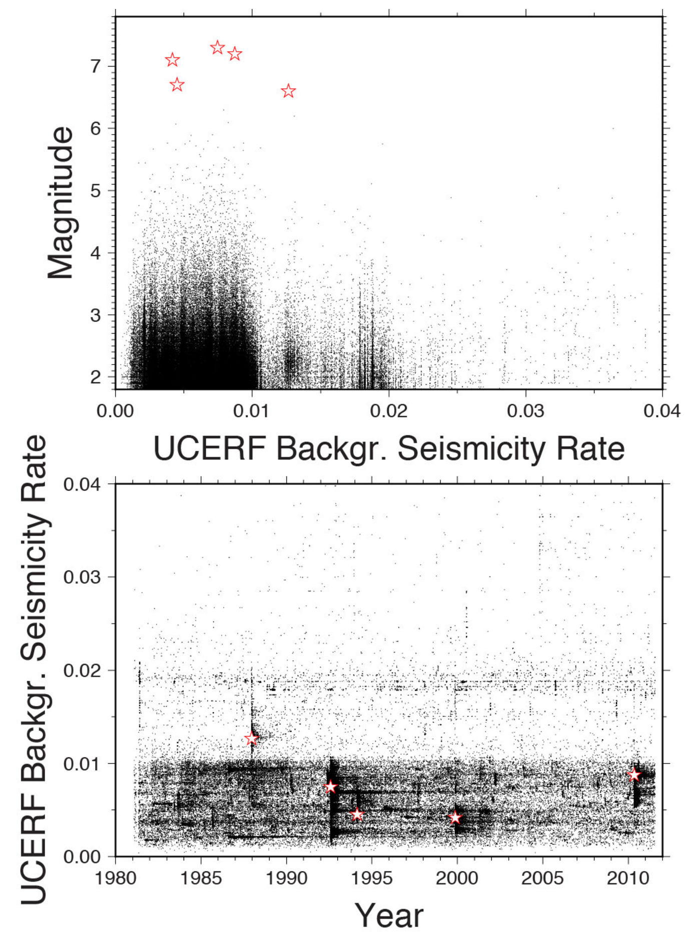


Background Seismicity

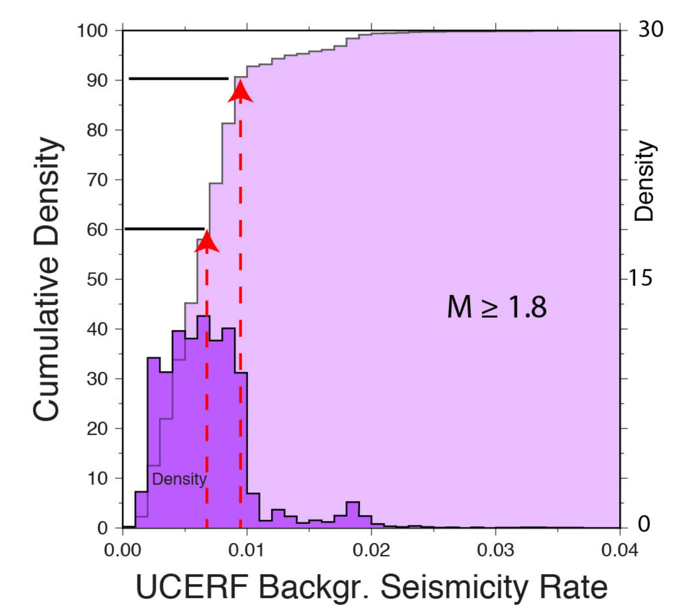
The UCERF background seismicity model is used to account for M 5.0 - 6.5 earthquakes on faults and for random M 5.0 – 7.0 earthquakes that do not occur on faults included in the model (as in models of Frankel et al., 1996, 2002 and Petersen et al., 1996).



(Below) "Modeled background seismicity rate" at each epicenter in the SCSN catalog versus magnitude and date of the earthquake. Most quakes occur at low background rates.

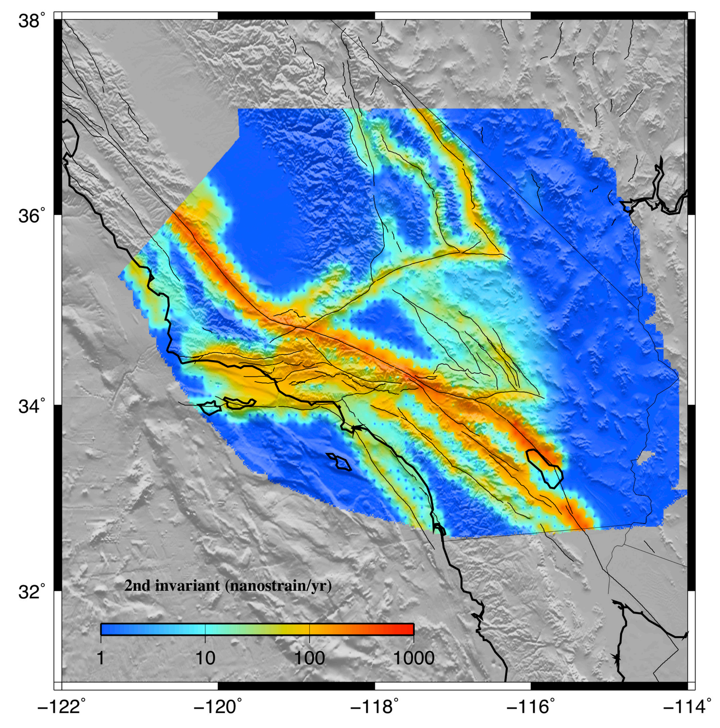


(Below) Cumulative and density histograms showing that most of the seismicity occurs at low UCERF background seismicity rates.

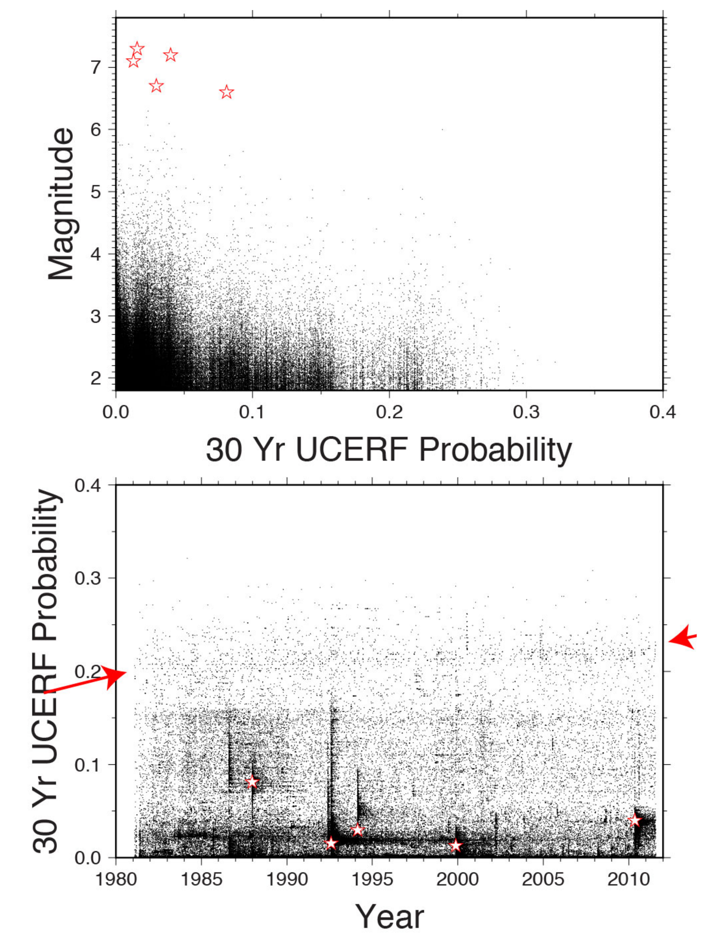


UCERF

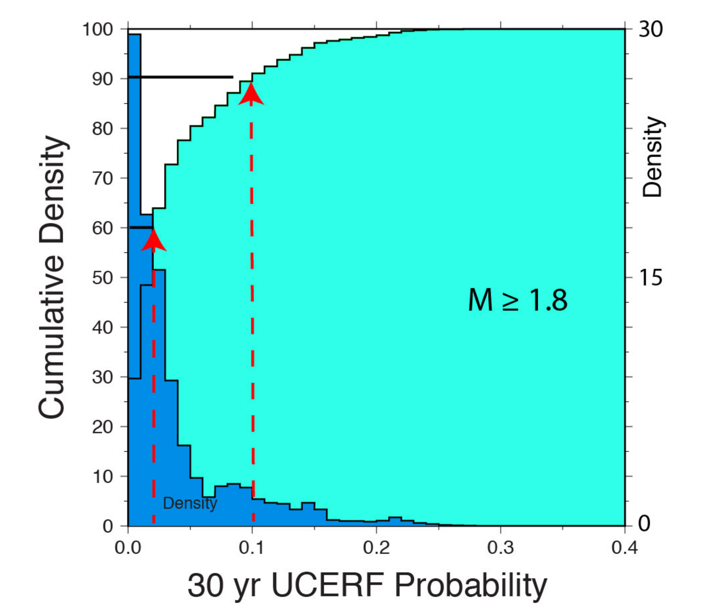
The colors on this southern California map represent the UCERF probabilities of having a nearby earthquake rupture (within 3 or 4 miles) of magnitude 6.7 or larger in the next 30 years. As shown in the table, the chance of having such an event somewhere in California exceeds 99%.



(Below) "30 yr UCERF Probability" at each epicenter in the SCSN catalog versus magnitude and date of the earthquake. Most small and big quakes occur at low UCERF probabilities.

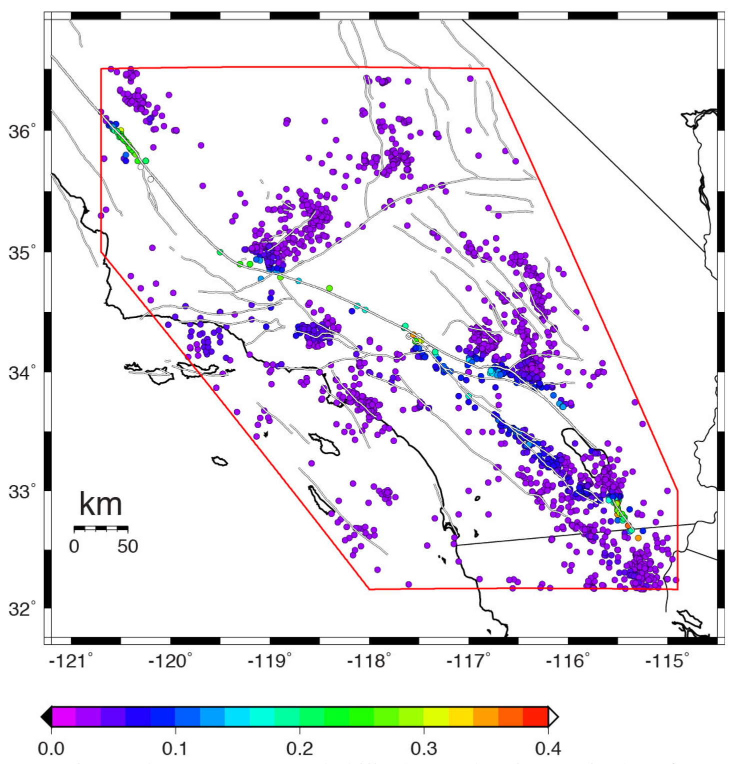


(Below) Cumulative and density histograms showing that most of the seismicity occurs in regions with low 30 yr UCERF probabilities for M≥6.7 earthquakes.

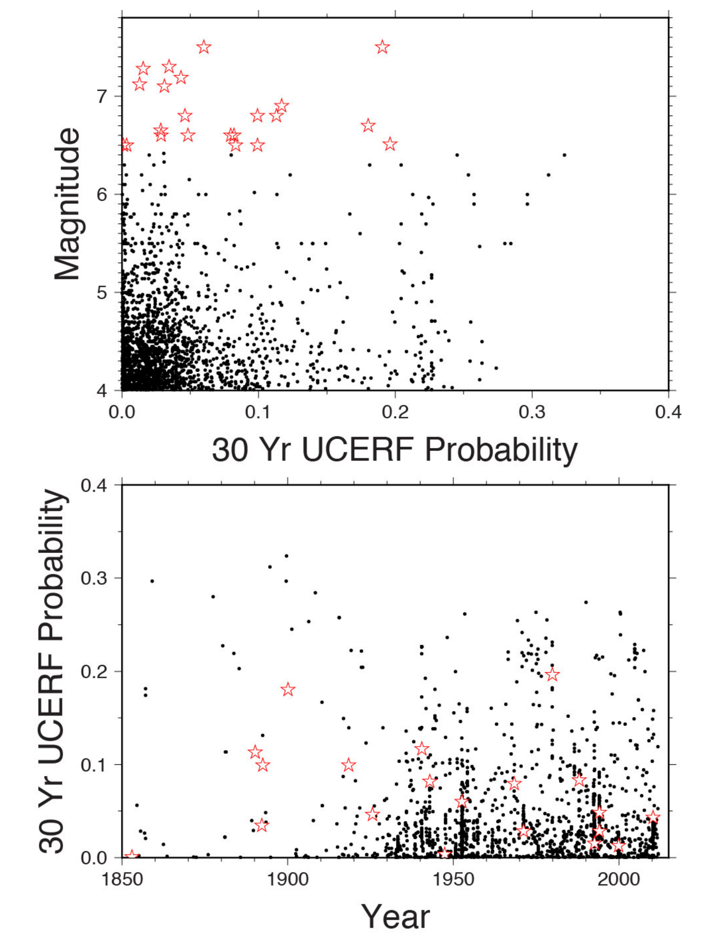


Seismicity: 1850 - 2012

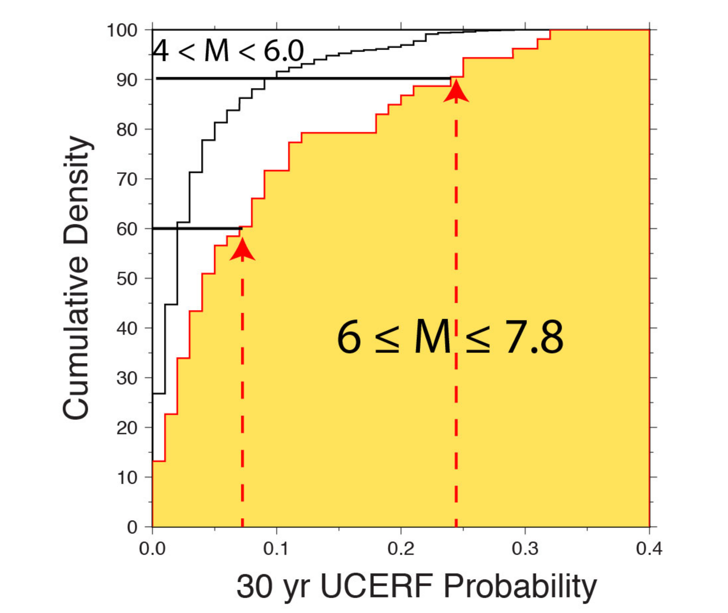
The UCERF3 earthquake catalog is an update of the catalog compiled for UCERF2 which is documented in Felzer and Cao (2008). The present document summarizes the updates and changes from the previous catalog (see also, UCERF-3; Appendix K.)



(Below) "30 yr UCERF Probability" at each epicenter in the 160 yr UCERF catalog versus magnitude and date of the earthquake. Most small and big quakes occur at low UCERF probabilities.

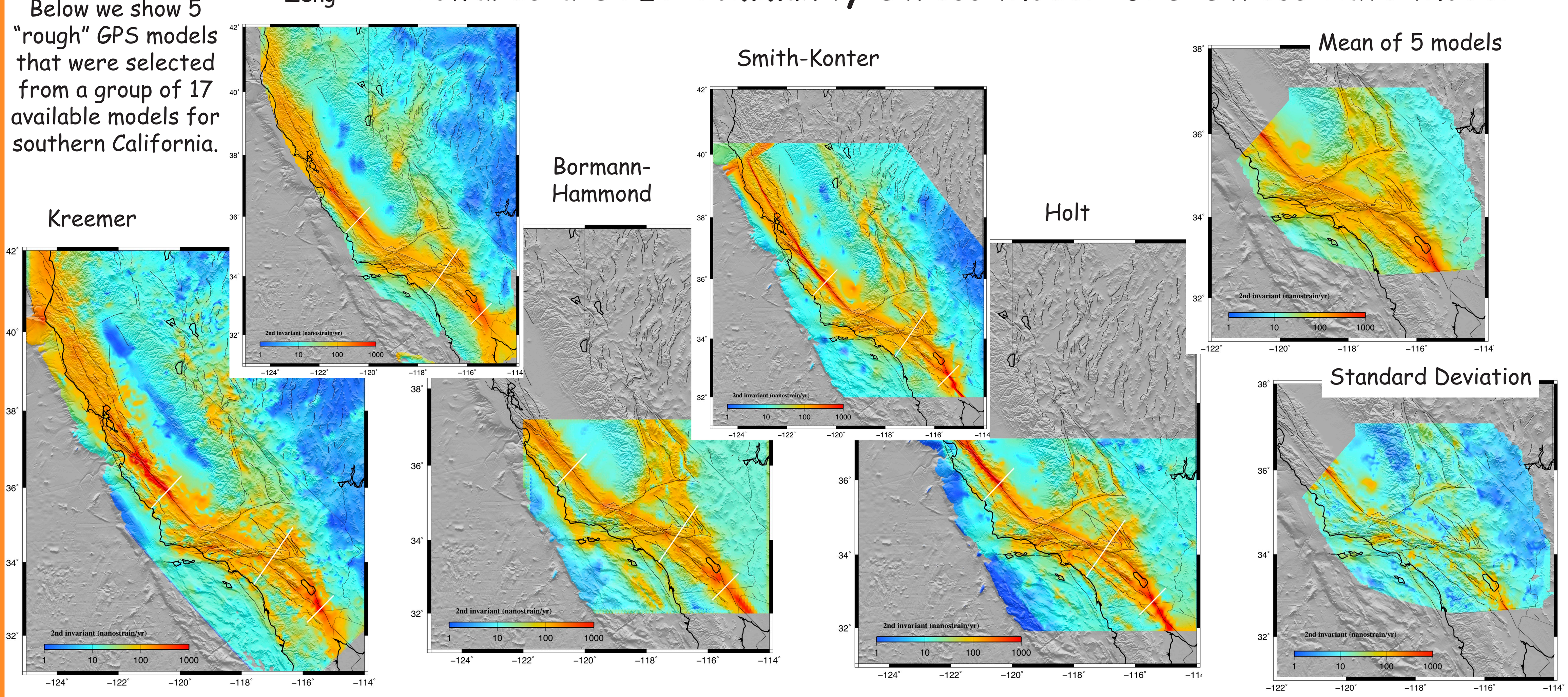


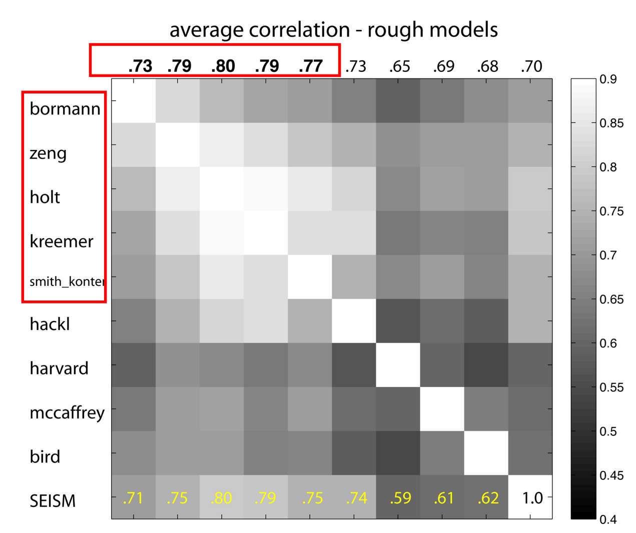
(Below) Cumulative and density histograms showing that earthquakes in the magnitude range of 6 -7.8 occur in higher UCERF probability regions than event with smaller mags or 4.0 - 6.0.



Towards a SCEC Community Stress Model: GPS Stress Rate Model

GPS Models
Below we show 5 "rough" GPS models that were selected from a group of 17 available models for southern California.





Conclusions

To generate the first version of the SCEC/CSM stress rate model, one could multiply the mean of the 5 rough models by shear modulus. Such a model would be a good representation of the regional crustal deformation signal measured by the GPS strain field.