Variations of stress parameters in the Southern California plate boundary around the South Central Transverse Ranges

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SCEC Cajon Pass Earthquake Gate Area, September 4th, 2020
Introduction:
Inverting focal mechanisms for the principal stress orientations

Objectives:
- Obtaining a reliable, high-resolution information about stress parameters South Central Transverse Ranges (SCTR)
- Coming up with ingredients affecting the stress in the crust
Methodology:

A linear damped stress inversion on the earthquake focal mechanisms (MSATSI software)

Determines the orientation of the principal stresses and the stress ratio:

\[ R = \frac{\sigma_1 - \sigma_2}{\sigma_1 - \sigma_3} \]

- Using declustered seismicity.
- Selecting the fault plane with the largest fault instability
- Discretizing the focal mechanisms using the optimum number of events per grid cell

Hardebeck and Michael, 2006; Michael, 1984; 1987; Martínez-Garzón et al., 2014; Vavrycuk, 2014
Seismicity Distribution in the SCTR:

South Central Transverse Ranges (CP, SGP):
Years: 1981 to 2017
SCTR: ~3,200 focal mechanisms
Aftershocks: ~9,600 focal mechanisms
declustered catalog

CP: Cajon Pass
SGP: San Gorgonio Pass
SGM: San Gabriel Mountains
SBM: San Bernardino Mountains
SJM: San Jacinto Mountains

- Seismicity catalog by Hauksson et al., (2012)
- Earthquake focal mechanisms catalog by Yang et al., (2012).
- Declustered following Zaliapin and Ben-Zion, (2013).
Key point:

**In Strike-slip regime:** \( R = \frac{\sigma_1 - \sigma_2}{\sigma_1 - \sigma_3} \)

R increases \((R \to 1)\), stress regime towards transpressional.
R decreases \((R \to 0)\), stress regime towards transtensional.
Depth Dependent Stress Ratio (R) in SCTR:

Key point:
Transpressional stress regime adjacent to the highest topography.

Sharp changes in stress ratio near Cajon Pass.

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Maximum Horizontal Compressional Stress ($S_{Hmax}$) in SCTR:

Key point:
Rotation of the $S_{Hmax}$ near the Crafton Hills area.

No other significant rotation in the $S_{Hmax}$ direction in SCTR.

Changes in the stress plunge angles below 15 km depth.

$S_{Hmax}$ is estimated following Lund and Townend (2007)
Stress Distribution in SCTR:

Data separated in six sub-regions based on geological structures and seismicity distribution:
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Amplified compressional stress components near CP and the sharp stress ratio changes between the NW and SE of the junction of the SAF and SJFZ.
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Variations of the stress ratio results versus elevation. The relationship between the two variables are significant with a p-value of <0.0001, where 25% of the stress ratio variability may be explained by the topography.

Stress Distribution in SCTR:

Abolfathian et al., 2020
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Stress Distribution in SCTR:

Abolfathian et al., 2020
The total stress field ($\tau_T$) can be written:

$$\tau_T = \tau_R + \tau_L + \Delta\tau_{ST}$$

($\tau_R + \tau_L$) : the background stress field associated with the loading components

$\tau_R$ : regional far-field loading
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Abolfathian et al., 2020
Provides information on the dominant loading mechanisms of the mainshocks that drive the aftershocks.
Discussion

• Stress field deviations from the regional strike-slip faulting are consistent with larger damage zone areas.

Ben-Zion and Zaliapin, 2019
Discussion

- Stress field deviations from the regional strike-slip faulting are consistent with larger damage zone areas.

- Temporal changes in the SCTR during the ~37 years

Ben-Zion and Zaliapin, 2019
Summary

• Local stress deviations from the regional stress field provide information on dominant local loadings.

• **Significant variations of stress parameters with depth:**
  Transpressional stress components in regions with high topography, similar observed in Cajon Pass, San Gorgonio Pass and near Hot Springs area.

• **Higher topography produces compressional stress components at the bottom of the seismogenic zone.**

• **Sharp variation in stress ratio near Cajon Pass!!**

• Comparing stress field inversions using declustered seismicity and aftershocks help to identify the main loading in an area.

• The spatio-temporal variations of background stress field are also examined and found to be in general in agreement with the discussed spatial background stress field variations

Selected References:

