Annual Report: Collaborative Research – Analysis and Integration of the Earthquake Stress Cycle Evolution and Pattern Informatics Techniques

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Over the past year we have made significant progress in several areas of significance, as follows.

Forecasting (Southern California Data):

(a) We have continued to refine the PI method for identifying the upcoming rupture dimension as well as location and, by extension, the total moment release, of an upcoming event in southern California of earthquake magnitude [1]. In addition, we have applied the PI technique to short-term forecasting and earthquake stress shadows, as shown in Figure 2, and discussed at this year's annual meeting [2, 3, 4]. Figure 1 shows the results for short-term forecasting in regions surrounding the epicenter of large earthquakes, in this case the 1987 Superstition Hills event. In this case, blue regions are quiescent, while red regions show increased activation.

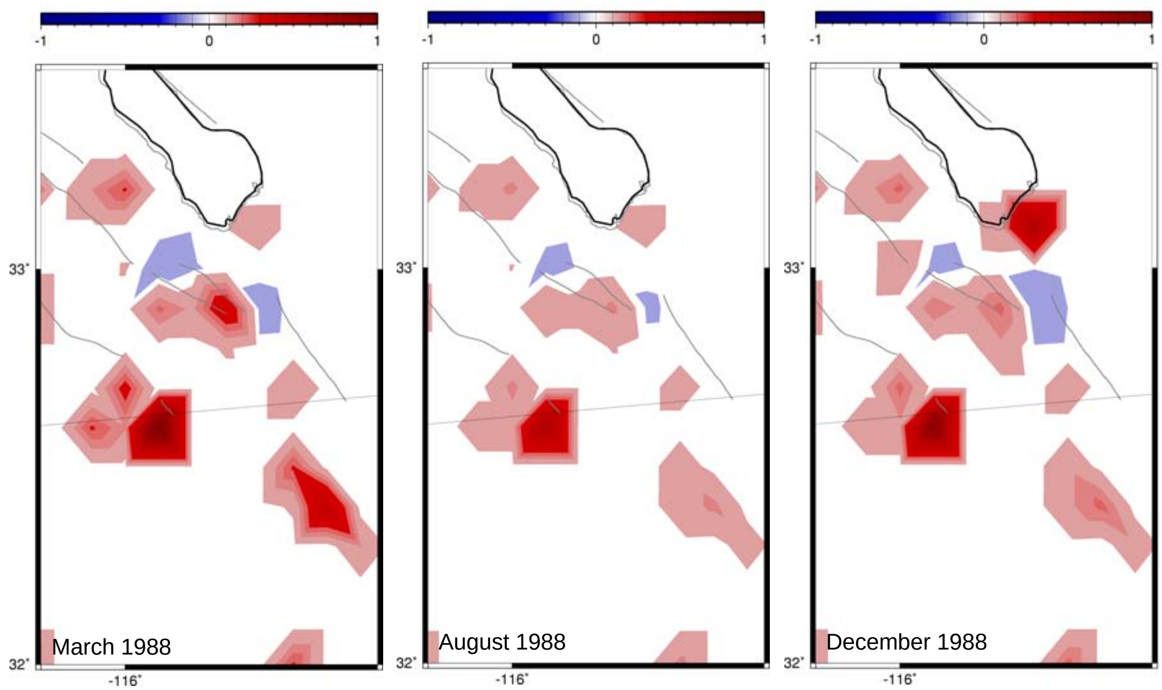

Figure 1: PI index for the region around the 1987 Superstition Hill earthquake, from March through December of 1988, for two month periods. Color scale is normalized to the maximum. The blue regions represent areas of reduced activity, while red regions are areas of increased activity.

(b) At UWO, we have focused on investigating the small-scale patterns in the regional seismicity in order to identify changes in the local seismicity over time that are analogous to those seem in AMR calculations [3]. In addition, we have begun a comparison between anomalies identified using the PI index and scenarios from the SAM technique. Figure 2 (right) shows anomalies at two locations in California. On the top is shown an anomaly at approximately 37.5°, -121.5°. At the bottom of Figure 1 are shown several anomalies along the San Jacinto and southern San Andreas. Scenarios for the Calaveras fault (Figure 3) produce cumulative Benioff strain curves with a correlation that suggests that the region is nearing failure. In the south (Figure 4), several scenarios are possible, but the PI index can help to distinguish between the more likely candidates. The success of this comparison has been documented in a paper for *SRL* [5].

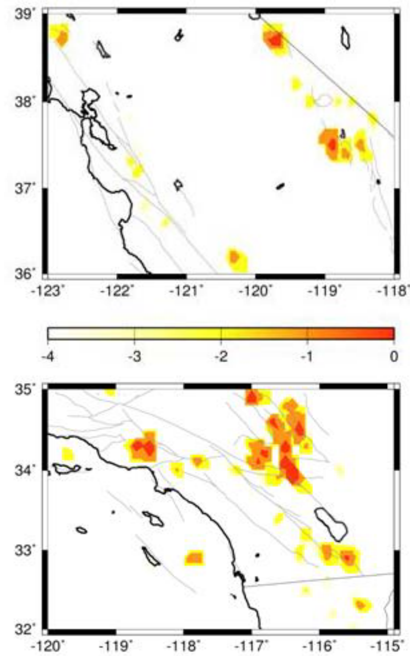

Figure 2: PI index for two subregions of the 1999-1989 calculation (Tiampo et al., *EPL*, 2002). The color scale is logarithmic, where the value is the exponent to the base 10.

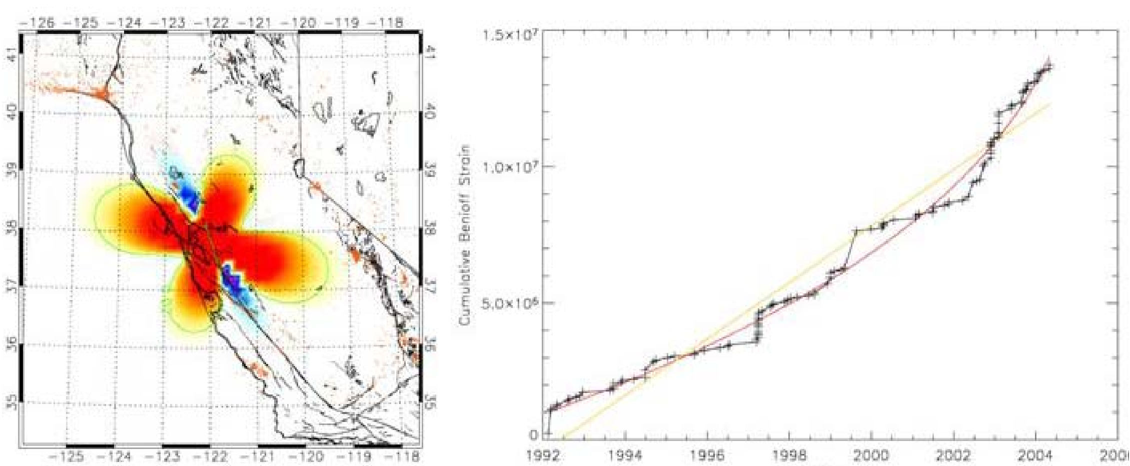

Figure 3: Cumulative Benioff strain calculation for the Calaveras fault, north of San Francisco, corresponding to the small anomaly seen in Figure 1, top. Note the good fit to the AMR curve, implying a failure time in the near future.

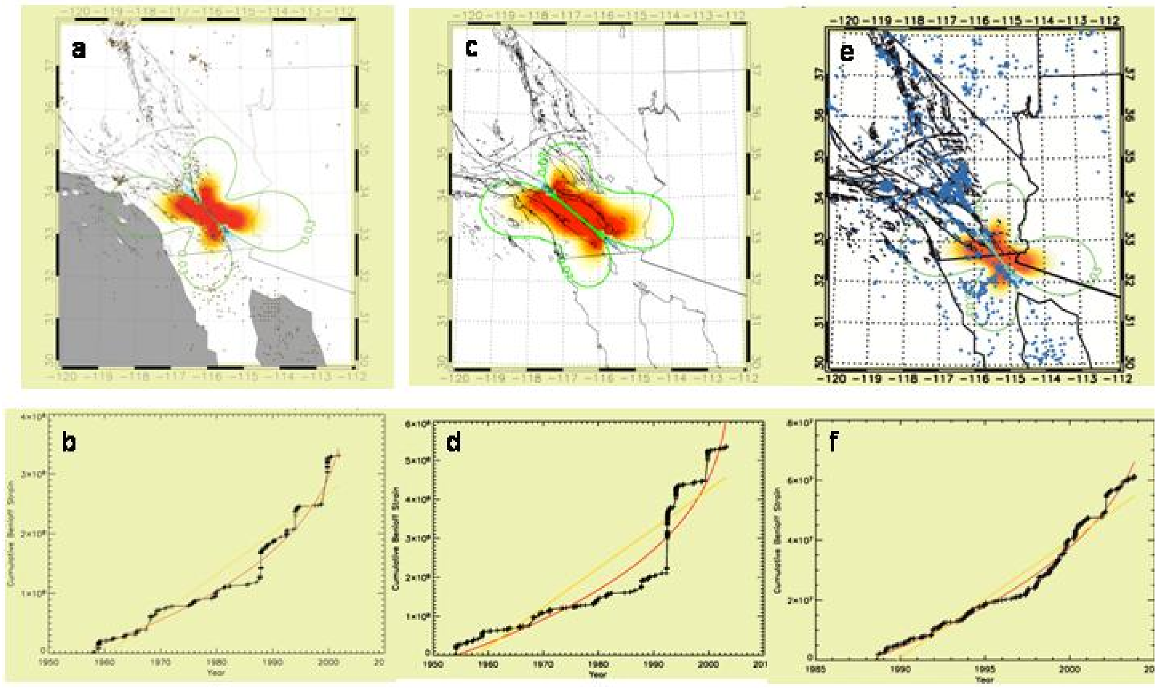

Figure 4: Cumulative Benioff strain calculation for three scenarios along the southern San Andreas and San Jacinto faults, at varying magnitudes, corresponding to the small anomaly seen in Figure 1, bottom. Note that all of these provide a relatively good fit to the AMR curve.

Earthquake Fault Systems Physics:

(a) At UWO we have focused on investigating the analytical relationship between the PI index and SAM, and have focused on elucidating this relationship using the catalog data. In Figure 5 is shown the cumulative PI index from 1960 to 1991 for both the Landers and Joshua epicenters. Note the close similarity to an AMR curve (Figure 3, for example) that is near failure. It should also be pointed out that there is a significant difference between this and the AMR curve. As the PI index nears failure, it tapers off to a constant, and does not continue to infinity. This suggests that it may be possible to construct a time-to-failure relationship that is more accurate than existing methods.

(b) We have extended the pattern informatics and eigenvector expansion techniques previously tested on seismicity to the deformation in models [6, 7] Finally, we have included this work in an application to the Parkfield/Coalinga interaction prior to both 1983 and 2004 [8].

(c) We have made significant progress in understanding one of the basic statistical parameters of mean field systems, ergodicity, and applied it to the southern California fault system seismicity. This work was published in both PRL and PAGEOPH [9, 10]. We have shown that the property of ergodicity is related to the stationarity of the system, and can be used to identify multiple spatial correlation lengths. Finally, this supports our hypothesis that earthquake fault systems have characteristics of mean-field systems.

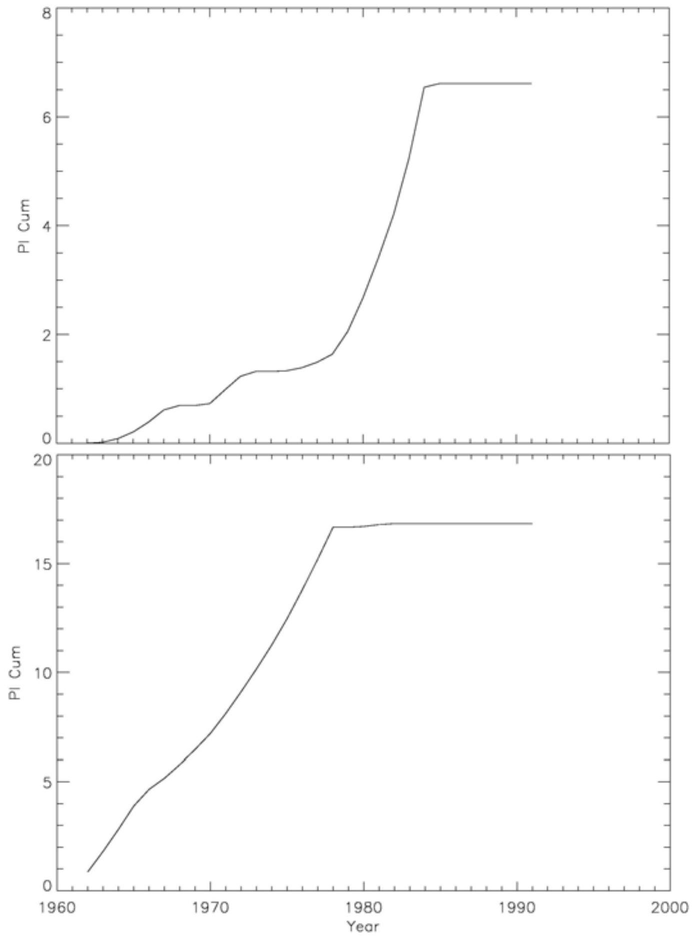

Figure 5: Cumulative PI index for the Landers earthquake epicenter (top) and the Joshua Tree epicenter (bottom), prior to their occurrence.

Publications under this grant:

[1] Tiampo, K.F., Rundle, J.B., and Klein, W. Rupture Source Identification Prior to the Occurrence of Large Events. AGU Fall Meeting, 2003.

[2] Tiampo, K.F., Rundle, J.B., Klein, W., and Samsonov, S. Seismicity rate and stress change using the Pattern Informatics technique. Presentation, Fourth ACES Meeting, Beijing, July 2004.

[3] Tiampo, K.F., Bowman, D.D., Rundle, J.B., and Klein, W. Linking Seismicity and Stress Change. Poster Presentation, SCEC Annual Meeting, September, 2004.

[4] Tiampo, K.F., Rundle, J.B, Klein, W. Stress shadows determined from a phase dynamical measure of historic seismicity, submitted to *Pure and Applied Geophysics*, November 2004.

[5] Tiampo, K., D. Bowman, J. Clark, and J. Rundle, SAM and the PI index: Complementary approaches to earthquake forecasting, submitted to *SRL*, November 2004.

The following work was funded under prior SCEC grants:

[6] Tiampo, K.F., Rundle, J.B., Klein, W., Ben-Zion, Y., and McGinnis, S. Using eigenpattern analysis to constrain seasonal signals in southern California, *Pure and Applied Geophysics*, 161, no. 10, 2004.

[7] Tiampo, K.F., Rundle, J.B., Sá Martins, J., Klein, W., and McGinnis, S. Methods for evaluation of geodetic data and seismicity developed with numerical simulations: Review and applications, *Pure and Applied Geophysics*, 161, no. 7, 2004.

[8] Tiampo, K.F., Rundle, J.B, Klein, W. Temporal evolution of stress interactions at Parkfield and Coalinga, CA, submitted to *Tectonophysics*, November 2004.

[9] Tiampo, K.F., Rundle, J.B., Klein, W., Sá Martins, J.S., and Ferguson, C.D. Ergodic dynamics in a natural threshold system, *Physical Review Letters*, 91, 238501, 2003.

[10] Tiampo, K.F., Rundle, J.B., Klein, W., and Sá Martins, J.S. Ergodicity in natural fault systems, *Pure and Applied Geophysics*, 161, no. 10, 2004.