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Nowcasting Earthquakes by Visualizing the Earthquake Cycle with Machine Learning:A Comparison of Two Methods

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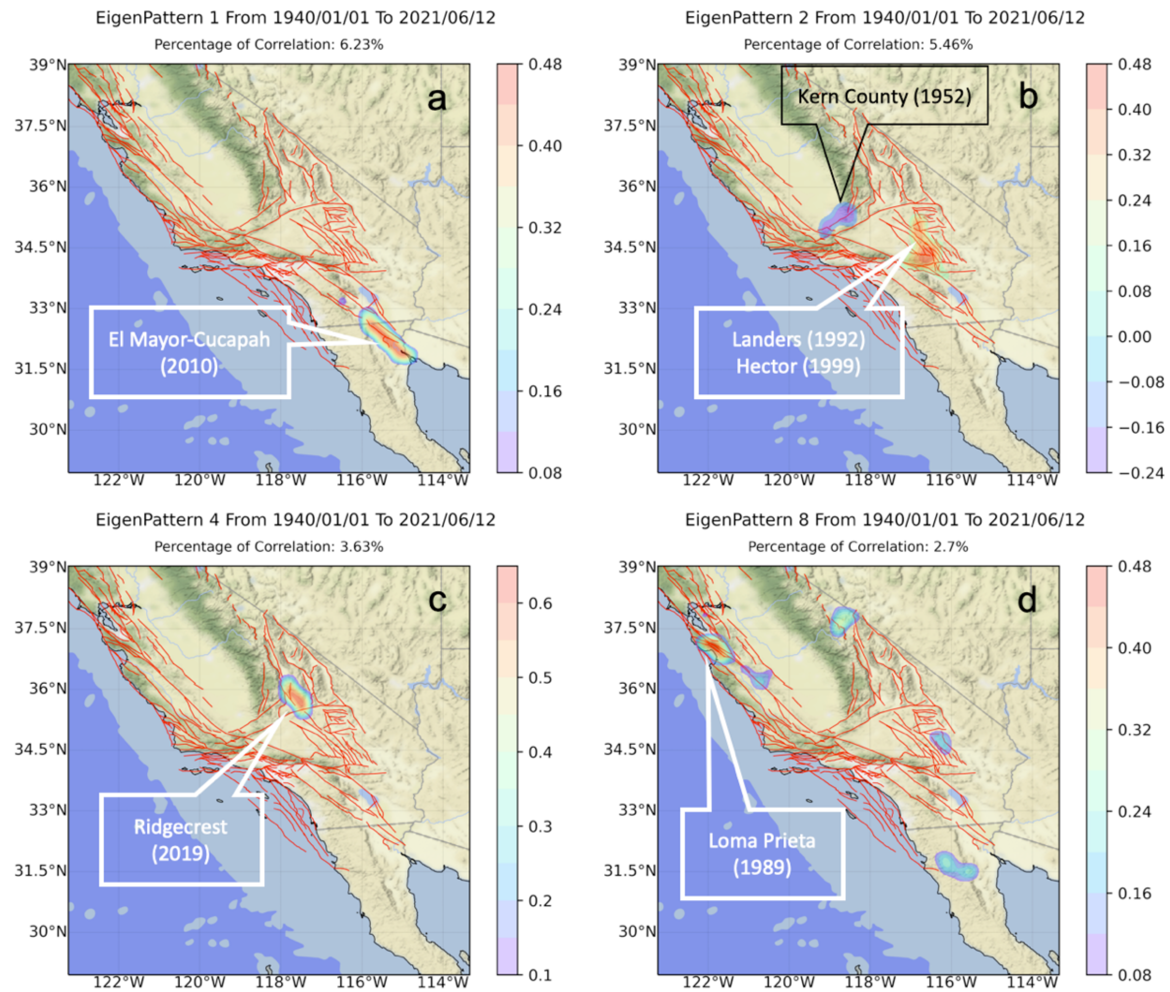
Abstract Text:

The earthquake cycle of stress accumulation and release is associated with the elastic rebound hypothesis proposed by H.F. Reid following the M7.9 San Francisco earthquake of 1906. However, observing details of the actual values of time- and space-dependent tectonic stress is not possible at the present time. In previous research, we have proposed two methods to image the earthquake cycle in California by means of proxy variables. These variables are based on correlations in patterns of small earthquakes that occur nearly continuously in time. One of these is based on the construction of a time series by the unsupervised detection of small earthquake clusters. The other is based on expanding earthquake seismicity in PCA-derived patterns, to construct a weighted correlation time series. The purpose of the present research is to compare these two methods by evaluating their information content using decision thresholds and Receiver Operating Characteristic methods together with Shannon information entropy. Using seismic data from 1940 to present in California, we find that both methods provide nearly equivalent information on the rise and fall of earthquake correlations associated with major earthquakes in the region. We conclude that the resulting time series can be viewed as proxies for the cycle of stress accumulation and release associated with major tectonic activity. The figure shows the PCA patterns of small earthquakes associated with 5 major M>7 earthquakes in California since 1950.



Plain-Language Summary:

The earthquake cycle of stress accumulation and release is associated with the elastic rebound hypothesis proposed by H.F. Reid following the M7.9 San Francisco earthquake of 1906. However, observing details of the actual values of time- and space-dependent tectonic stress is not possible at the present time. We propose methods to image the earthquake cycle in California by means of proxy variables. One of these methods identifies bursts of small earthquakes by an unsupervised cluster detection method. The other method identifies patterns of small earthquakes using Principal Component Analysis. Both methods are used to build time series that resemble the hypothesized stress accumulation and release cycle of major earthquakes. We apply the method to California earthquakes and show there is information content in these time series that can be detected using methods that originate from the invention or radar in the 1940's (Receiver Operating Characteristics), combined with Shannon Information entropy metrics. These methods might be used for seismic "nowcasting", the evaluation of the current level of risk.

Session Selection:

IN012. Applications of unsupervised machine learning to discover patterns in geological and geophysical data

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Abstract Title:
Nowcasting Earthquakes by Visualizing the Earthquake Cycle with Machine Learning:A Comparison of Two Methods

Requested Presentation Type:
Assigned by Program Committee (oral, eLightning or poster discussion session)

Previously Published?:
No

AGU On-Demand:
Yes

Abstract Payment:
Paid (agu-fm21-793591-0696-5897-0274-0277)

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