Spatial Mapping of b-value of earthquakes at Salton Trough and Imperial Valley, Southern California

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1 Introduction

The Imperial Valley, situated to the south of the Salton Sea in southern California (Figure 1), is a region characterized by transtensional tectonics. This involves a complex interplay between the Cerro Prieto fault in the south, which is part of the main plate boundary, and the San Jacinto fault in the west. Additionally, there is a significant right step between the Cerro Prieto fault and the southern San Andreas fault Fuis et al. (1990). The Salton trough is the host of two of the largest fluid-dominated geothermal energy fields in the world: the Salton Sea geothermal production field in southern California and the Cerro Prieto field in Mexico. Geothermal production in these fields has inadvertently led to an increase in seismic activity in the region White et al. (2022).

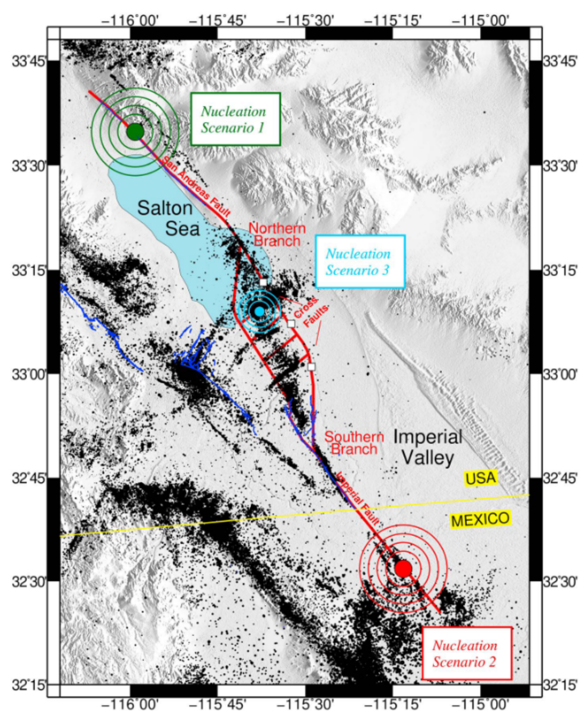

Figure 1: Fault traces (blue curves, USGS, 2006) and microseismicity lineaments (black dots) from relocated seismicity of Hauksson et al. (2012) of Salton Trough and Imperial Valley area in Southern California (adopted from Kyriakopoulos et al. (2019))

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Detailed analysis of seismic data has greatly contributed to advancements in seismology and earthquake forecasting. The recent series of earthquakes in the geothermal field of Mexico, which consisted of three events with a magnitude above 4.0, highlights the immediate requirement for improved evaluation of seismic risks in the Salton Trough/Imperial Valley area. This region is especially worrisome because it is located close to the San Andreas Fault, where a significant earthquake could result in catastrophic outcomes.

The b-value in Gutenberg-Richter relation is a crucial parameter in earthquake seismology that is obtained from the Gutenberg-Richter frequency-magnitude distribution. The b-value is the defined by the slope of magnitude frequency distribution of earthquakes and is independent of whether global, regional or local seismicity in analyzed Fiedler et al. (2018). The b-value offers valuable information about the stress conditions of the Earth's crust and can serve as an indicator of areas with an elevated risk of experiencing significant earthquakes. Schorlemmer et al. (2004) showed that by mapping b-values in both space and time, it is possible to identify patterns that are associated with earthquake events and the distribution of stress. The objective of this project is to create a Python Jupyter Notebook that will use the techniques described by Schorlemmer et al. (2004) to generate a space-time b-value map for the Salton Trough/Imperial Valley.

2 Method and Data

2.1 b-value Estimation

The earthquake size distribution can be described by a power-law with an exponent b, which shows the Gutenberg-Richter relationship Gutenberg and Richter (1944):

$$\log(N) = a - bM \tag{1}$$

Where b is the slope of the number of events (N) with greater than magnitude M provides the seismic activity and a provides productivity. b-value will be computed using the maximum-likelihood estimator Aki (1965); Bender (1983); Utsu et al. (1995):

$$b = \frac{1}{\bar{M} - M_c} \log_{10}(e) \tag{2}$$

Where $\bar{M}$ is the mean magnitude, $e = \exp(1)$, and M_c is the magnitude of completeness adjusted for bin size to account for potential bin size biases Guo and Ogata (1997); Utsu et al. (1995). We will estimate the magnitude of completeness using the maximum curvature method. The statistical uncertainty for maximum likelihood b-value estimates can be determined from Shi and Bolt (1982).

$$\sigma_b = \frac{b^2}{\log(e)} \sqrt{\frac{\sum_{i=1}^{n} (M_i - \bar{M})}{n(n-1)}} \tag{3}$$

Where n is the number of events above M_c, M_i is the magnitude of individual AE events and $\bar{M}$ is the mean magnitude for events greater or equal than M_c.

2.2 Data and Spatial Mapping of b-value.

We will use the Southern California Earthquake Data Center (SCEDC) relocated high-quality catalog spanning the period 1981 - 2022 by Hauksson et al. (2012). We will use catalog from 2022 to recent from SCEDC (2013). From the catalog, we will separate the events of the Salton Trough and Imperial Valley region. We will cut the catalog at a depth of 20 Km. The processing steps for spatial mapping of b-vlaue will be adopted from Schorlemmer et al. (2004). Which include broadly following steps:

1. Determine the optimal dimensions of the sampling volume by mapping b values with a wide range of radii and selecting the largest radius that gives the most detailed resolution of the b value heterogeneity. Along the selected fault segment, the high data density permits the definition of the dominant dimensions of the seismotectonic fabric, which is about 8–10 km.

2. Map the difference in b value between two periods, selecting numerous possible catalog divisions to observe if there is heterogeneity in spatial b-value distribution.

3. Identify significant changes of b values by the Utsu test Utsu et al. (1995)

In order to obtain data for this project, the following constraints will be taken into consideration:

1. Spatial and Temporal constraints: Latitude Range: 31^o - 35^o; Longitude Range: -117^o - -112^o; Time: 1977-01-01 to Recent
2. Magnitude and depth range of earthquakes: Depth Range: 0 - 20 Km

3 Expected Outcomes

This work will present spatial b-value mapping for Salton Trough and Imperial Valley area. Following is the one of a example of spatial b-value mapping carried out by Schorlemmer et al. (2004). Authors utilized NCSN catalog from 1981 to 2003 using different radius r and $N_{min} = 50$ (number of minimum earthquakes to estimate b-value).

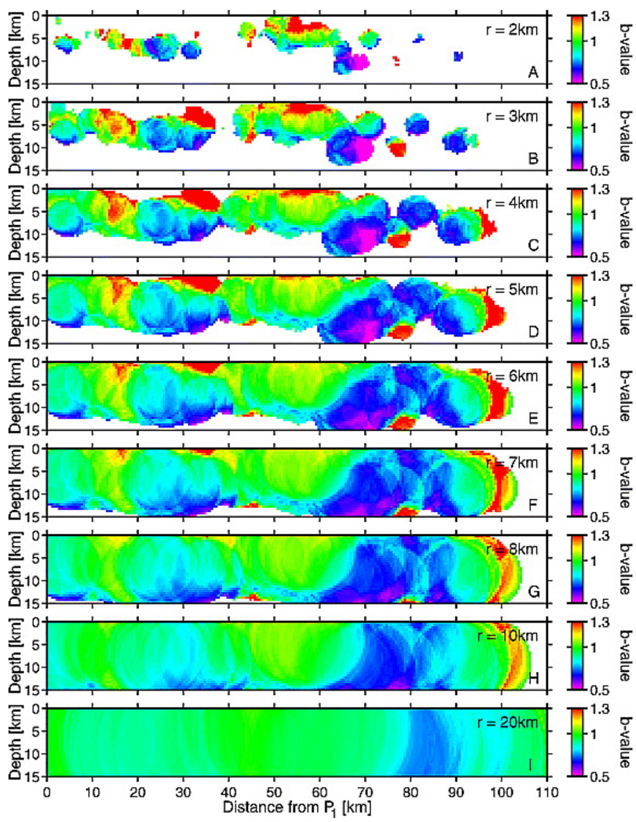

Figure 2: Distribution of b values in the Parkfield segment of the San Andreas fault computed with the NCSN catalog from 1981 to 2003 using different radii r and $N_{\min} = 50$. (a) $r = 2$ km. (b) $r = 3$ km. (c) $r = 4$ km. (d) $r = 5$ km. (e) $r = 6$ km. (f) $r = 7$ km. (g) $r = 8$ km. (h) $r = 10$ km. (i) $r = 20$ km. Schorlemmer et al. (2004)

4 Preliminary Results

The seismicity distribution of the Salton Trough and Imperial Valley obtained from SCEDC of 1977 to 06-11-2024 time period is shown in Figure 3. In the imperial valley area largest earthquake of 1979-10-15 23:16:54 with magntidue 6.5 M_w. Close to Salton Sea we can observed shallow depth ($\leq$ 5km) seismicity cluster which is the area associated with geothermal production since 1982.

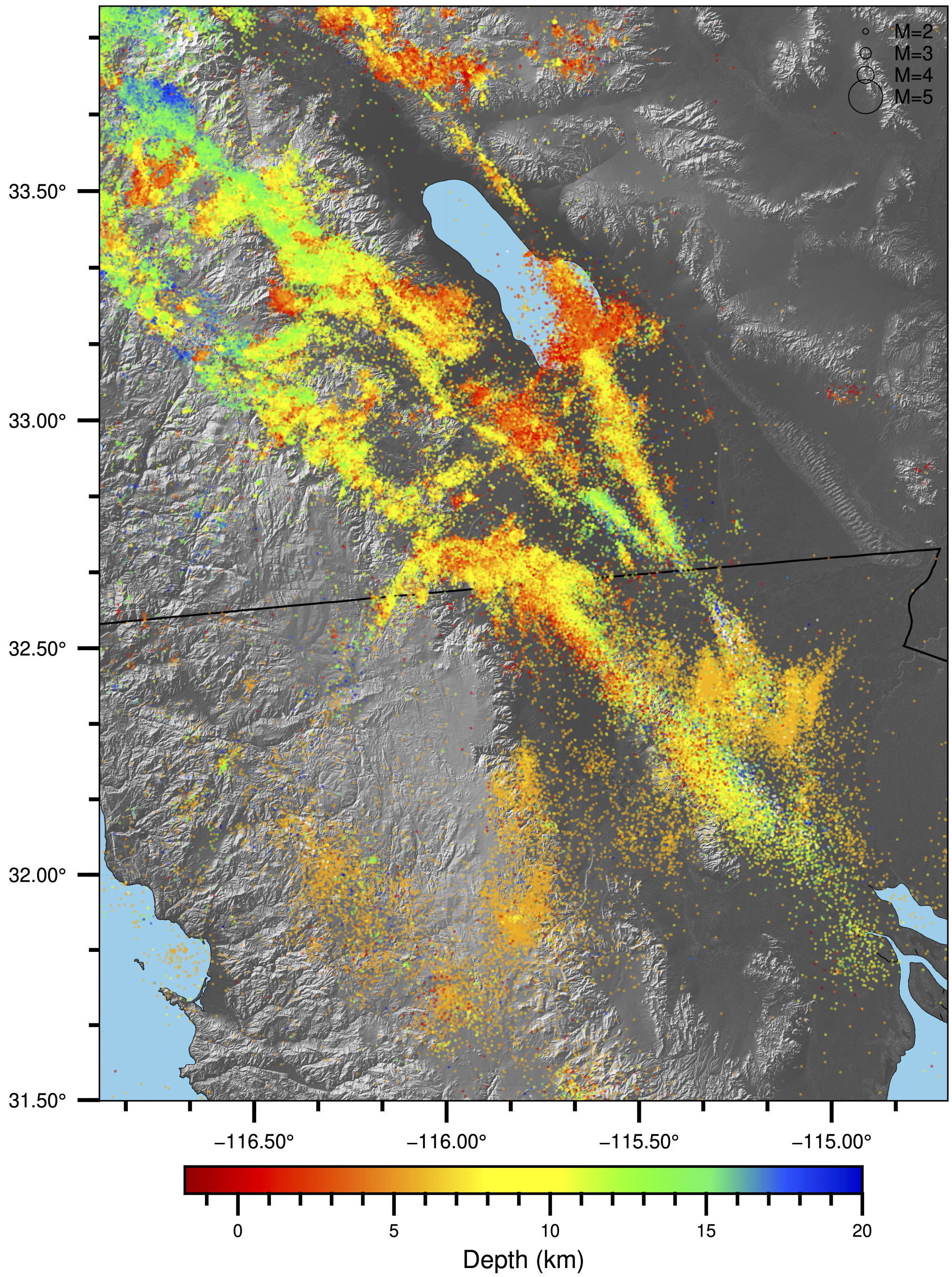

Figure 3: The seismicity distribution of the Salton Trough and Imperial Valley obtained from SCEDC of 1977 to 06-11-2024 time period obtained on SCEDC (2013)

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