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CHARACTERISTICS OF TECTONIC EARTHQUAKE SUMATERA

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Abstract

This study aims to answer the question: is there a correlation between earthquake events due to Benioff zone activity with earthquake events due to shallow local cesarean activity? Using a spatial statistical local moran, krigging, and kernel density approach to the distribution of 1973 – 2018 earthquake occurrences in the central region of Sumatra, it was found that there was a connection between earthquake events due to Benioff zone activity and earthquake events due to shallow local cesarean activity. The earthquake activity between the Mentawai Islands and the coast of West Sumatera - Bengkulu was more caused by local cesarean activity with superficial hypocenter.

Keywords: spatial statistics; local moran; krigging; kernel; earthquake; sumatera

1. INTRODUCTION

The meeting between two continental plates namely the Australian plate and the Eurasian Plate where one penetrates under the other plate forms an overlapping region between the two plates. The layer between the lower plate and the upper plate is known as the Benioff zone with layers that are deeper and farther away from the subduction zone. Tectonic earthquake events and active volcano sequences are typical phenomena in the region above them. Such characters exist for example in the eastern subduction zone between the Austral-Asian plate and the Eurasian plate off the coast of the Indonesian Ocean which moves 6 cm per year (Shao, 1997).

The hyposentrum of a tectonic earthquake can be in the Benioff zone or in local faults. The question is: Are there links between earthquake events due to Benioff zone activity with earthquake events due to shallow local cesarean activity?

To answer this question, a spatial statistical approach is carried out by taking areas in the central part of Sumatra Island as a case study geomer. In this section there have been several disasters, for example the earthquake that devastated the city of Padang and its surroundings in 2009 and the 2010 earthquake and tsunami in the Mentawai Islands.

Studies and simulations on earthquake and tsunami in this region have been carried out by researchers in various fields of science, especially earth physics, for example studies from Pujiastuti, et al (2008) and Budiman, et al (2009). However, quantitative earthquake studies in geography are lacking. The use of spatial statistics in this paper is expected to provide an illustration of the distribution of tectonic earthquake phenomena in spatial contexts. Spatial statistics are closely related to the first rule of geography (first law of geography) which states that everything is related to everything else, but things are more related than distant things (Tobler, 1970).

2. THE METHODS

The spatial statistical approach was carried out on earthquake location data points from 1 January 1973 to 1 December 2010 from the USGS Earthquake database (USGS / NIEC (PDE) 1973 - 2018 12 01). Kriging interpolation of earthquake hypocentrum depth data was used to estimate the Benioff Zone. The character of this zone is subducting under other plates where the farther away from the subduction zone, the more depth increases. The depth of the earthquake is an indication of the location of the Benioff zone. Thus this zone can be predicted by the depth distribution of the earthquake. In other words both have positive spatial autocorrelation. The Moran Index (Moran I) is an index that determines spatial autocorrelation globally (Griffith, 1987). But the index used in this study is a local Moran index known as the Local Indicator of Spatial Association - LISA (Anselin, 1995). Multivariate LISA between distance from subduction zone and earthquake depth is used to detect outliers in earthquake depth data so that krigging interpolation to determine can be done with corrected data distribution.

LISA (I_i) is formed by the equation:

$$I_i = \frac{x_i - \bar{X}}{S_i^2} \sum_{j=1, j\neq i}^{n} w_{i,j} (x_i - \bar{X})$$

Where x_i is the feature attribute; X is the average of the corresponding attributes; w $_{i,\,j}$ is the spatial weight between feature i and j;

$$S_i^2 = \frac{\sum_{j=1, j\neq i}^{n} w_{ij}}{n-1} - \bar{X}$$

Where n is the total number of features
Where is the total number of features

$$ZI_i = \frac{I_i - \mathrm{E}[I_i]}{\sqrt{\mathrm{V}[I_i]}}$$

$$\mathrm{E}[I_i] = \frac{-w}{(n-1)}$$

$$\mathrm{V}[I_i] = \mathrm{E}[I_i^2] - \mathrm{E}[I_i]^2$$

Outliers are determined at a significant level of 0.05 at a high value of a feature surrounded mainly by low value or low value of a feature surrounded mainly by high value.

Kriging is a geostatistical procedure that can estimate surface shape from the distribution of points that have x, y, and z values by first studying the character of z values to determine the best surface estimation method (Oliver, 1990). Basically the interpolation approach to kriging is no different from the Inverse Distance Weight (IDW) formed from the equation:

$$\hat{Z}(s_0) = \sum_{i=1}^{N} \lambda_i Z(s_i)$$

Where Z (S_i) = value measured at location i
λ_i = unknown weight for value measured at location i
S_0 = predicted location
N = number of measured values

In the IDW approach, the weight of λ_i depends on the distance to be predicted, while in kriging, not only is the distance between points noticed but also with regard to the characteristics of the spatial conditions.

The density of the kernel is used to see the distribution pattern of the location of the earthquake points according to the magnitude of the magnitude. The kernel density approach g (x_j) is an appropriate interpolation approach for the distribution of points individually through equations (Silverman, 1986):

$$g(x_j) = \sum \left\{ (W_i I_i) \left(\frac{3}{\pi h^2}\right) \left(1 - \frac{d_{ij}^2}{h^2}\right)^2 \right\}$$

Where d_{ij} is the distance between points, h is radius, W_i is the weight for each point and I_i is the intensity of the point.

3. RESULT AND DISCUSSION

In the study area there were 5337 points in the earthquake points. After using Local Moran calculations (LISA), 900 points were grouped in the HH and LL categories with a 0.05 confidence level. These points are interpolated using kriging to produce a Benioff zone (figure 1).

The Benioff zone starts at the subduction zone which is a subduction area between the Indo-Australian plate and continues to extend deeper into Sumatra. Cross sections in this region show the deepest average depths ranging from 470 km below the Strait between Malaysia and Sumatera. The Bukit Barisan Mountain Range that extends from the tip of Aceh to Lampung isabove the Benioff zone with a depth of 100-200 km. In this pathway there are active faults and volcanic magma kitchens.

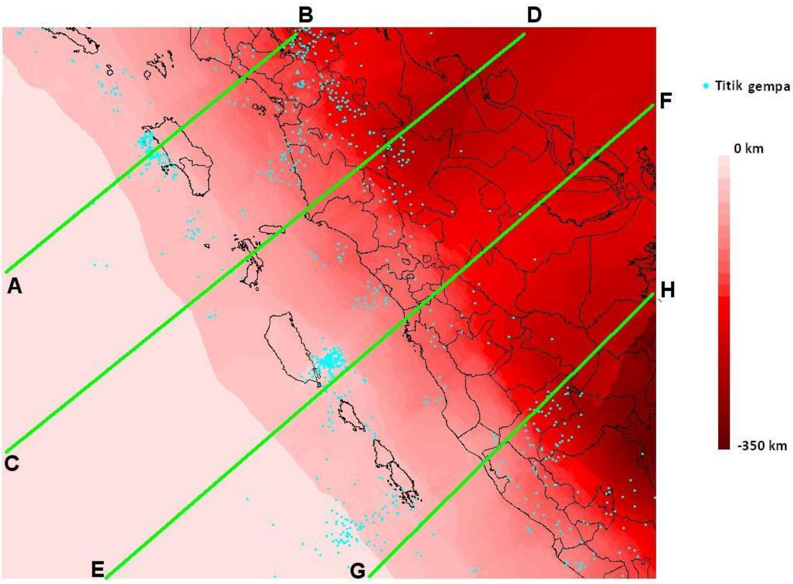

Figure 1. Samples of earthquake points and benioff zones according to depth

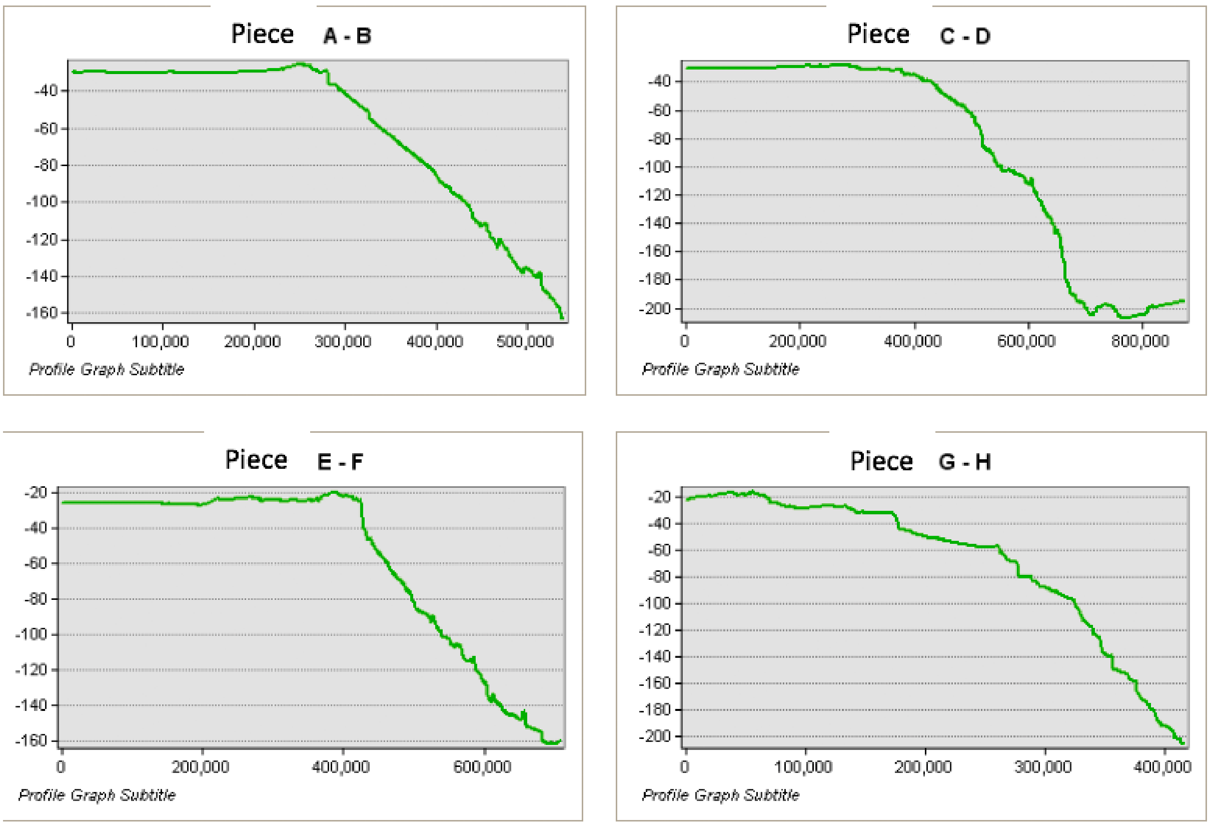

Figure 2. The cross section of the Benioff Zone.

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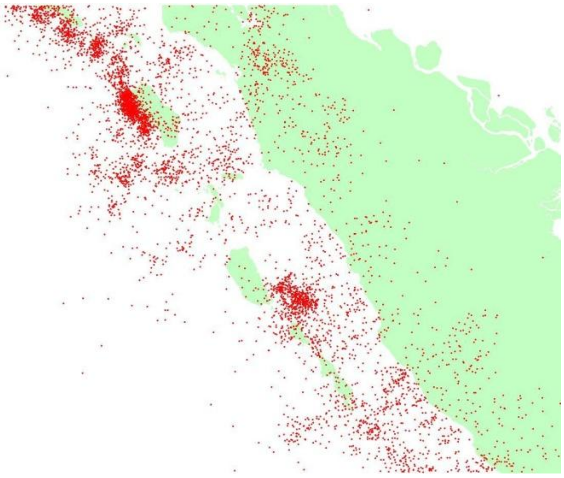
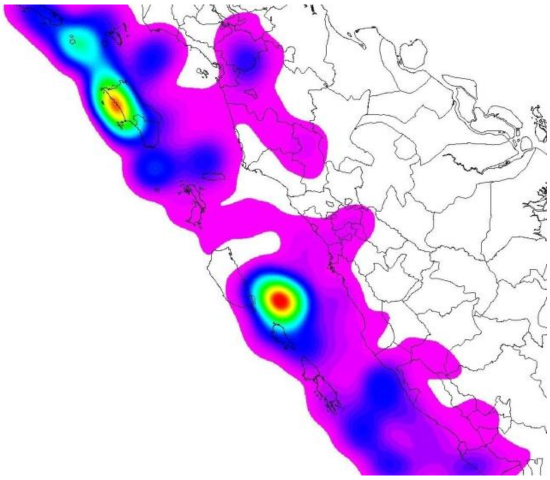
The use of kernel density at each earthquake point with a weighted magnitude value shows the concentration of the earthquake that extends along the eastern part of Sumatra. It appears that the intensity distribution of earthquake magnitude is concentrated in the area between the rows of islands in the Indonesian Ocean Nias, Mentawai, and up to the ranks of the Bukit Barisan Mountains. The highest concentration is shown on the West coast of Nias Island





(SPOT-1) and in the strait between the Mentawai Islands and the coast of West Sumatra - Bengkulu (SPOT-2) (figure 4).

Figure 4. Density of the kernel earthquake magnitudeearthquake points

Figure 3. Distribution of 1973 - 2010 earthquake points

Separation between the location of hypocentrum in the Benioff zone and hypocentric distant from this zone successively produces deep earthquake points and shallow earthquake points. Deep earthquake kernel density (in the Benioff zone) shows the concentration that spreads in West Sumatra with the highest concentration of SPOT-1 (figure 5). The shallow earthquake concentrates along West Sumatra with the highest concentration at SPOT-1 and SPOT-2 (figure 6).

Taking into account the character of deep and shallow earthquakes (figure 4 - 6), it appears that there is a connection between the activity of local active faults that cause earthquakes related to seismic activity due to the activity of the Benioff zone. Anomalies occur in the

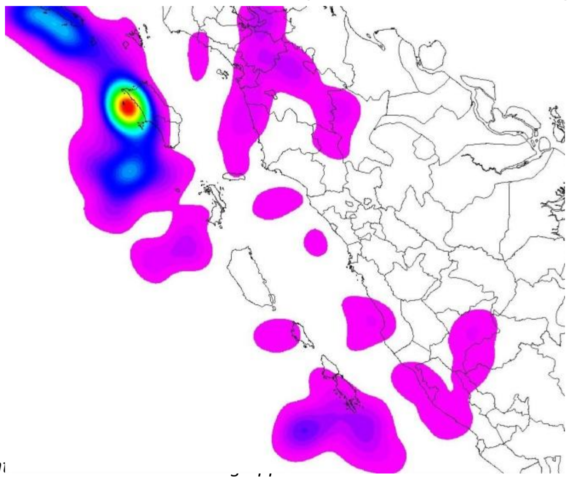


Figure 5. Density of kernel earthquake inside magnitude

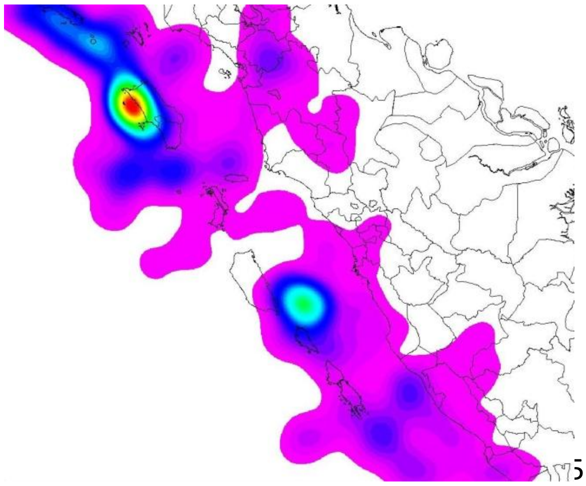


Figure 6. Density of shallow kernel magnitude earthquake

strait between the Mentawai Islands and the coast of West Sumatera - Bengkulu (SPOT-2) where seismic activity in this region is more due to intensive local cesarean activity characterized by superficial hypocenter.

4. Conclusion

The use of the separation approach between deep earthquakes and shallow earthquakes shows a connection between earthquake events due to Benioff zone activity and earthquake events due to shallow local cesarean activity. The earthquake activity between the Mentawai Islands and the coast of West Sumatra - Bengkulu was more caused by local cesarean activity with superficial hypocenter. However, the causal relationship between Benioff zone activities and local cesarean activities needs a more in-depth study.

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