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Analysis of Aftershock Decay West Pasaman Earthquake 25 February 2022 using Geostat Software Version 2.0 for Seismic Risk Reduction

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SARI
Telah terjadi gempa bumi di wilayah Pasaman Barat dengan Magnitudo M6.1 pada tanggal 25 Februari 2022 pada koordinat 0,15° Lintang Utara dan 99,98° Bujur Timur dengan kedalaman 10 Km. Peristiwa ini mengakibatkan serangkaian gempa susulan. Penelitian ini bertujuan untuk menganalisis waktu peluruhan gempa susulan yang terjadi di wilayah tersebut sebagai langkah mitigasi dan mengurangi risiko gempa bumi. Metode yang digunakan dalam penelitian ini adalah metode Mogi I, Mogi II, Omori dan Utsu pada *software* Geostat V2.0. Penelitian ini menggunakan data repositori gempa BMKG untuk jangka waktu 7 hari sejak *Mainshock* terjadi. Hasil perhitungan menunjukkan gempa susulan diprediksi akan meluruh pada hari ke-36 untuk metode Mogi I (r = -0.88135), hari ke-11 untuk Mogi II (r = -0.93627), hari ke-36 untuk Utsu (r = -0.88184) dan hari ke 39 untuk Omori (r = 0,95683). Metode yang cocok untuk memprediksi waktu peluruhan gempa susulan adalah metode Omori (r = 0,95683). Perkiraan waktu peluruhan gempa susulan dapat digunakan sebagai upaya mitigasi dan pengurangan risiko gempa bumi.

Kata kunci : Omori, Mogi I, Mogi II, Utsu, peluruhan gempa susulan, pengurangan risiko gempa

ABSTRACT
There has been an earthquake in the West Pasaman Region with a magnitude of M6.1 on February 25, 2022 at coordinates 0.15° North Latitude and 99.98° East Longitude with a depth of 10 km. This event resulted in a series of aftershocks. This study aims to analyze the decay time of aftershocks that occurred in the area as a mitigation measure and reduce the risk of earthquakes. The method used in this research is the method of Mogi I, Mogi II, Omori and Utsu in GEOSTAT V2.0 software. This study uses the earthquake repository data BMKG for a period of 7 days since the Mainshock occurred. The calculation results show that aftershocks are predicted to decay on the 36th day for the Mogi I method (r = -0.88135), the 11th day for Mogi II (r = -0.93627), the 36th day for Utsu (r = -0.88184) and day 39 for Omori (r = 0.95683). A suitable method for predicting the decay time of aftershocks is the Omori method (r = 0.95683). Estimated time of aftershock decay can be used as an effort to mitigate and reduce the risk of earthquakes.

Keywords: Omori, Mogi I, Mogi II, Utsu, aftershock decay, seismic risk reduction

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INTRODUCTION

Earthquake activity (Seismicity) in Indonesia is classified as very active. This can be seen from the frequency of earthquakes which were recorded as approximately 40,000 earthquakes from 2009 to 2016 (PuSGeN, 2017). The high frequency of earthquakes in Indonesia is a consequence of the confluence of three tectonic plates in Indonesia, namely the Eurasian Plate, the Indo-Australian Plate and the Pacific Plate (Sunarjo et al., 2012) (Fig. 1). The tectonic of Sumatra Island is a manifestation of the large Eurasian and Indo-Australian plates (Fig. 2).

These two main plates collide along the subduction zone line with the position of the Indo-Australian Plate obliquely and subducting under the island of Sumatra. This event gave rise to a horizontal fault along the island of Sumatra. Earthquake activity in this subduction zone can be observed at a depth of more than 100 km with a subduction slab slope of about 30-40 degrees. This type of subduction shows an indication of a high level of earthquake activity. The Sumatran fault is a fault with a right lateral orientation or a dextral fault with a length of up to 1900 km. This large fault extends from Aceh to the Sunda Strait between Java Island and Sumatra Island. This large fault is divided into 19 large segments with lengths ranging from 60 to 200 kilometers. Based on modeling, the sliprate value of the Great Sumatran Fault ranges from 4 - 15 mm/year (PuSGeN, 2017).

An earthquake is a phenomenon where the earth's surface vibrates as a consequence of an instantaneous release of energy within the earth, marked by the breaking of rocks in the weak points of the earth's crust (Lay and Wallace, 1995; Shearer, 2009; Stein and Wysession, 2003). Aftershock is a series of earthquakes that occurred after the mainshock. In general, this series of earthquakes is smaller than the Mainshock and can last for a period of weeks or even months (Fig. 3) (Riga and Balocchi, 2017).

On 25 February 2022 there was an earthquake with magnitude M6.1 which triggered a series of aftershocks. The monitoring results of the Meteorology, Climatology, Geophysics Agency (BMKG) noted that there had been 208 aftershocks since one week after the main earthquake. Apart from that the main earthquake (mainshock) also caused damage to buildings in several places such as hospitals, schools, residents' houses and others. The series of aftershocks that occurred one week after the main earthquake caused panic in the community when the aftershocks ended. Therefore this study aims to determine the end time of aftershocks as initial information to the public for the right steps to mitigate earthquake disasters.

RESEARCH METHODS

This research uses a statistical method approach such as the Mogi II, Utsu, Omori and Mogi I, methods to determine the decay time of aftershocks. The degree of frequency or activity ofaftershocks expressed in terms of time and frequency is shown in the formula (Mogi, 1962).

$$n(t) = \frac{a}{t+b} \quad (1)$$

The intensity of earthquakes that occur more than within 100 days is formulated in the following equation (Omori, 1894).

$$n(t) = a.t^{-b} \quad (2)$$

A formula to explain the relationship between the time and frequency of aftershocks that occur during a period of less than 100 days (Mogi, 1962).

$$n(t) = a.e^{-bt} \quad (3)$$

Calculation of aftershocks that decrease the frequency or activity of occurrence over a period of less than 100 days can be through the following equation (Utsu, 1957).

$$n(t) = \frac{a}{(t+c)^b} \quad (4)$$

$n(t)$ is the accumulation or total of aftershocks n expressed in time interval t. Aftershocks are declared over when the earthquake is worth 1 ($n(t)=1$) while a and b are constants. The empirical formula applied to determine the end time of aftershocks shows a correlation between frequency and time. This variable is the dependent variable (y) and the independent variable (x) (Supranto, 2008).

$$\bar{Y} = a + b\bar{X_i} \quad (5)$$

To find out constants a and b, it can be solved by formula (Supranto, 2008).

$$a = \bar{Y} - b\bar{X_i} \quad (6)$$

and

$$b = \frac{n\Sigma X_i Y_i - \Sigma X_i \Sigma Y_i}{n\,\Sigma X_i{}^2 - (\Sigma X_i{}^2)} \quad (7)$$

To find out the correlation between constants a and b, it can be known by using the formula (Supranto, 2008).

$$r = \frac{n\Sigma X_i Y_i - \Sigma X_i \Sigma Y_i}{\sqrt{n\,\Sigma X_i{}^2 - (\Sigma X_i{}^2)}\,\sqrt{n\Sigma Y_i{}^2 - (\Sigma Y_i)^2}} \quad (8)$$

If the value of r is positive, it means that the correlation is positive, the relationship is equivalent. The higher the value of the variable (x), the higher the variable (y). If the value of r is negative, it means that the correlation is negative, the relationship is ambivalent. The higher the variable (x), the lower the variable(y) (Sugiyono, 2007) (Table 1).

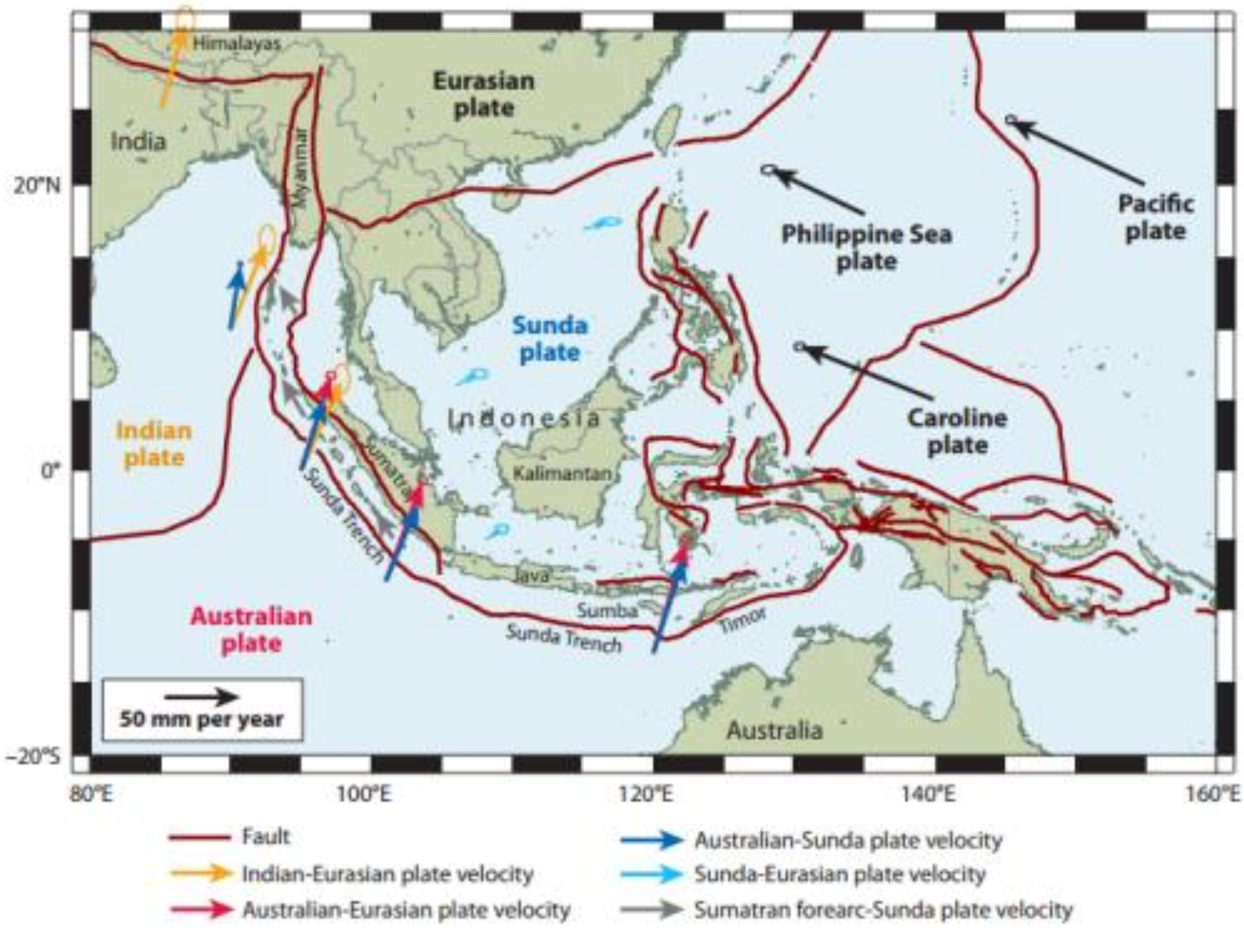

Figure 1. Indonesia's tectonic (McCaffrey, 2009)

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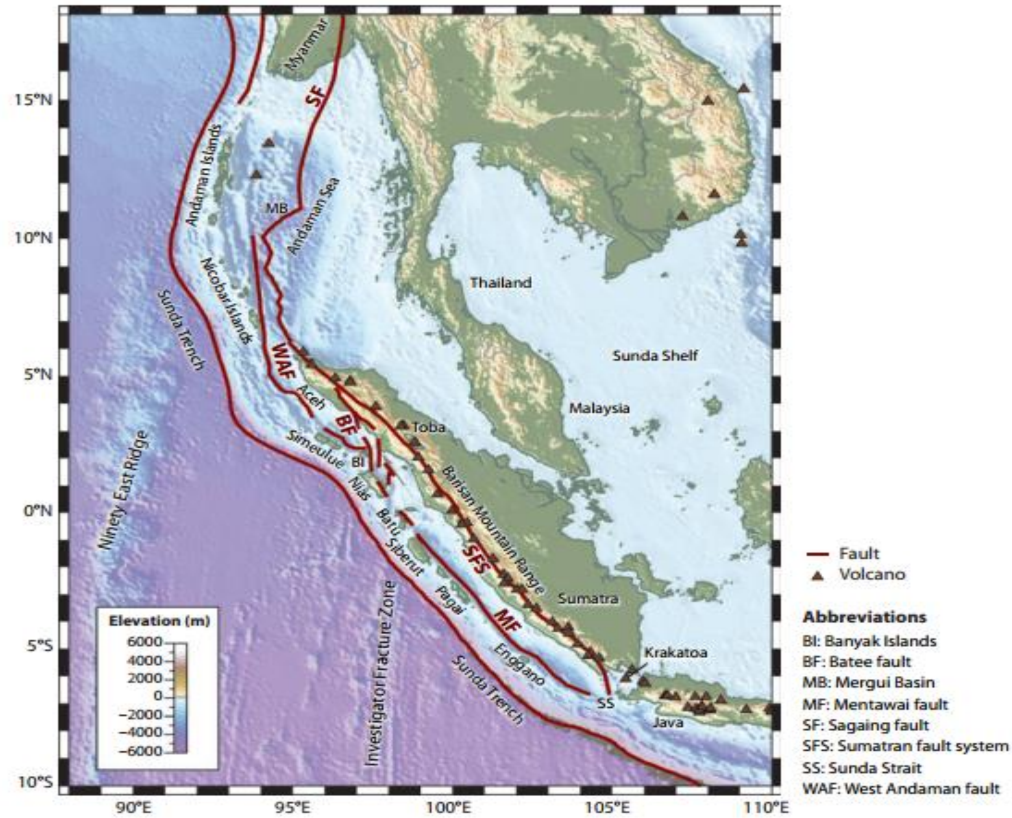

Figure 2. The great sumatran fault (McCaffrey, 2009)

Table 1. Correlation value of the dependent variable and independent (Sugiyono, 2007).

Score	Definition	Score	Definition
0,00-0,19	Very Low	0,00 - (-0,19)	Very Low
0,20-0,39	Low	(-0,20) - (-0,39)	Low
0,40-0,59	Medium	(-0,40) - (-0,59)	Medium
0,60-0,79	Strong	(-0,60) - (-0,79)	Strong
0,80-1,00	Very Strong	(-0,80) - (-1,00)	Very Strong

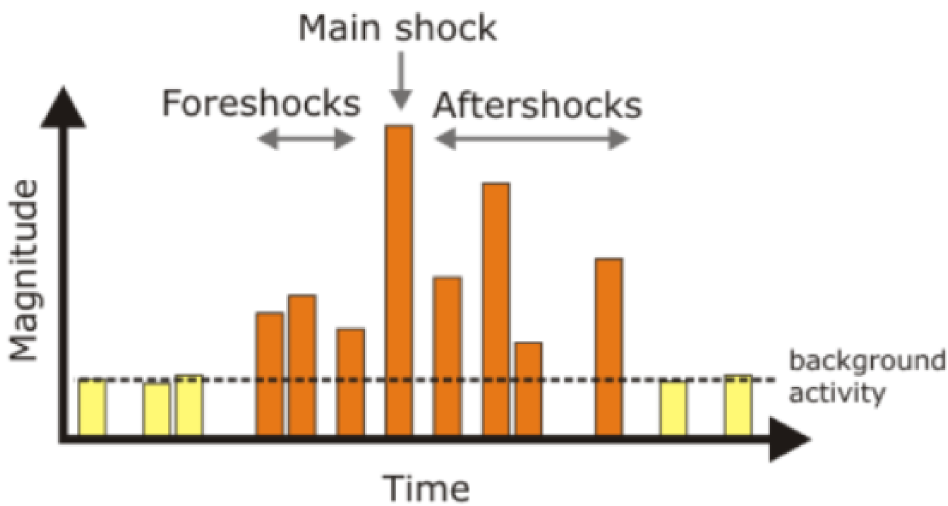

Figure 3. Earthquake sequences (Abdelnaby, 2012)

RESULTS AND DISCUSSION

The results of data processing and research analysis that have been inputted into the Geostat V2.0 Software with one-day time intervals produce the respective calculations as follows (Fig. 4). In Mogi II's calculations (Fig. 5), the decay time of the aftershocks was obtained on the 11th day of March 7, 2022 at 23:23:16 UTC after the main earthquake (r = *-0.93627*). In Utsu's calculations (Fig. 6), the decay time of the aftershocks was obtained on the 36th day of April 1, 2022 at 13:11:19 UTC after the main earthquake (r = *-0.88184*). In Omori's calculation (Fig. 7), the aftershock decay time was obtained on the 39th day of April 5, 2022 at 05:19:44 UTC after the main earthquake (*r = 0.95683*). In the Mogi I calculations (Fig. 8), the decay time of the aftershocks was obtained on the 36th day of April 1, 2022 at 19:58:09 UTC after the main earthquake (*r = -0.88135*).

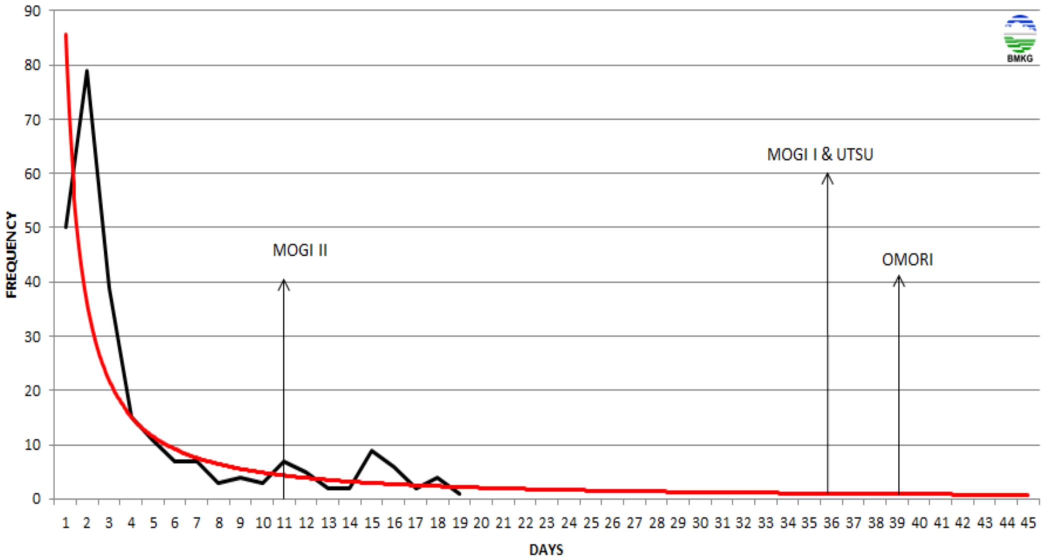

Figure 4. Aftershock earthquake decay trendline

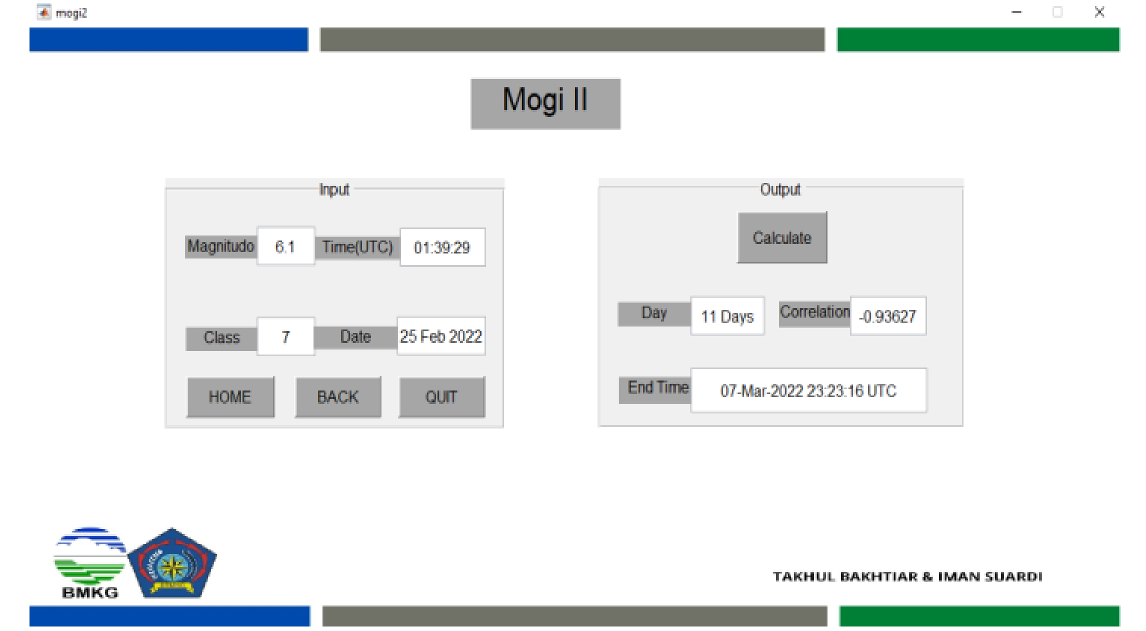

Figure 5. Display of Mogi II calculations

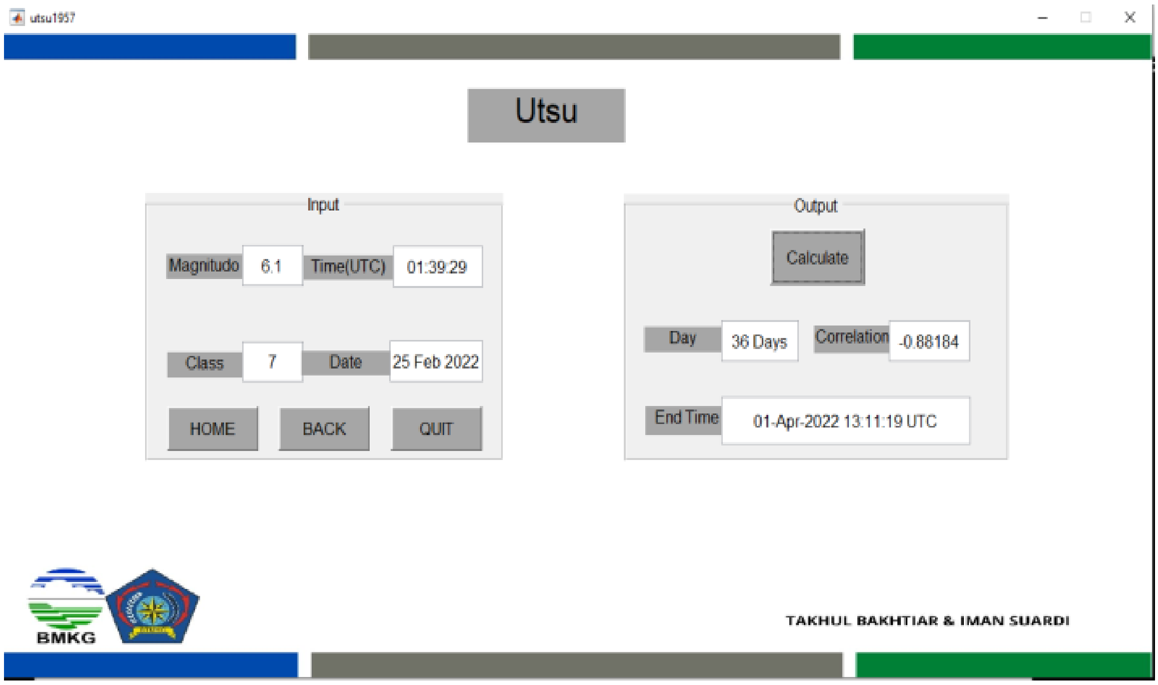

Figure 6. Utsu calculation display

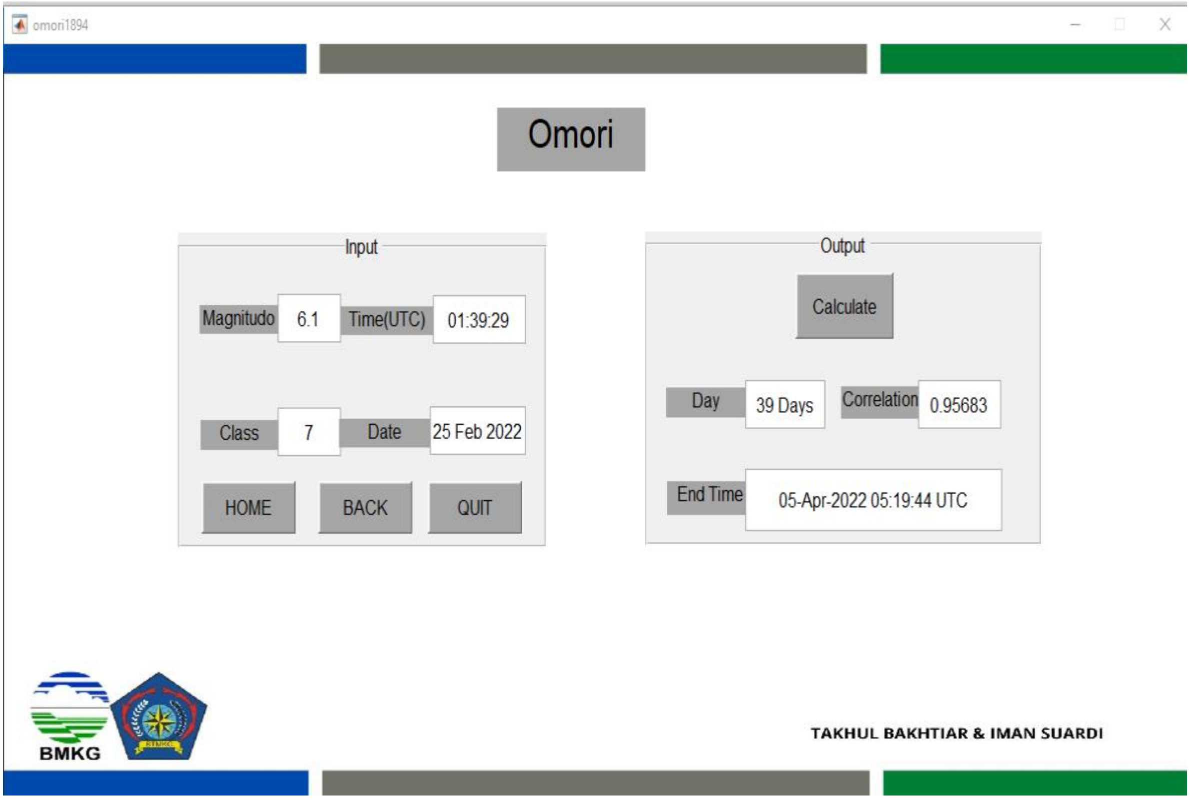

Figure 7. Display of omori calculations

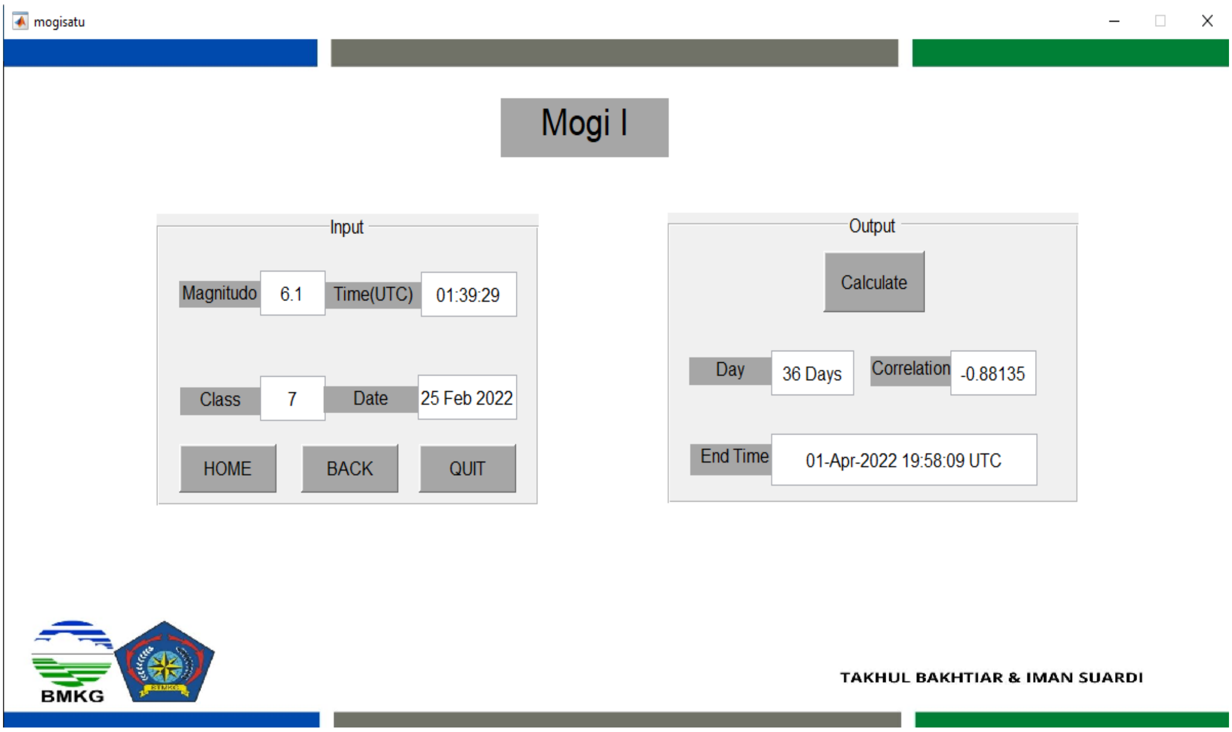

Figure 8. Display of Mogi I calculations

The Agency for Meteorology Climatology and Geophysics (BMKG)
Indonesia Tsunami Eary Warning System (InaTEWS)

Format origin results for:
Latitude : -1 until 1
Longitude: 99 until 101
Depth : 1 until 1000
Magnitude: 1 until 9.5
Time : 2022/02/25 until 2022/03/10

Date	Time	Lat	Lon	Dep	M	MT	Region
2022/03/09	15:24:02.958	0.21 N	99.93 E	10	2.3	-	Northern Sumatra, Indonesia
2022/03/09	14:22:55.488	0.23 N	100.00 E	10	2.5	-	Northern Sumatra, Indonesia
2022/03/08	21:44:00.861	0.08 N	100.02 E	10	3.0	-	Northern Sumatra, Indonesia
2022/03/08	07:07:13.102	0.21 N	100.04 E	10	2.6	-	Northern Sumatra, Indonesia
2022/03/08	03:56:33.519	0.27 N	99.97 E	10	3.0	-	Northern Sumatra, Indonesia
2022/03/07	20:59:19.494	0.59 N	99.71 E	10	3.2	-	Northern Sumatra, Indonesia
2022/03/07	16:29:56.657	0.28 N	100.01 E	10	3.2	-	Northern Sumatra, Indonesia
2022/03/07	12:40:38.618	0.23 N	99.95 E	10	3.0	-	Northern Sumatra, Indonesia
2022/03/05	10:06:34.175	0.47 N	99.86 E	10	3.2	-	Northern Sumatra, Indonesia
2022/03/05	05:01:05.314	0.48 N	99.89 E	10	3.2	-	Northern Sumatra, Indonesia
2022/03/04	17:00:41.235	0.18 N	100.02 E	10	3.0	-	Northern Sumatra, Indonesia
2022/03/03	09:16:12.882	0.10 N	100.01 E	10	3.3	-	Northern Sumatra, Indonesia
2022/03/03	09:14:23.610	0.20 N	100.03 E	10	3.0	-	Northern Sumatra, Indonesia
2022/03/03	06:37:04.630	0.10 N	100.00 E	10	4.8	Yes	Northern Sumatra, Indonesia
2022/03/02	21:57:39.664	0.15 N	100.07 E	10	3.0	-	Northern Sumatra, Indonesia
2022/03/02	19:46:24.393	0.35 N	100.23 E	17	3.0	-	Northern Sumatra, Indonesia
2022/03/02	19:33:11.293	0.22 N	99.93 E	10	2.8	-	Northern Sumatra, Indonesia
2022/03/02	17:37:43.078	0.20 N	100.02 E	10	3.1	-	Northern Sumatra, Indonesia
2022/03/02	17:32:58.542	0.22 N	100.09 E	10	2.7	-	Northern Sumatra, Indonesia
2022/03/02	04:41:15.701	0.21 N	99.98 E	10	3.7	-	Northern Sumatra, Indonesia
2022/03/01	23:32:08.803	0.23 N	99.98 E	10	3.2	-	Northern Sumatra, Indonesia
2022/03/01	22:01:28.640	0.16 N	100.09 E	10	3.0	-	Northern Sumatra, Indonesia
2022/03/01	15:37:03.977	0.15 N	99.97 E	10	4.5	-	Northern Sumatra, Indonesia
2022/03/01	06:03:11.163	0.13 N	100.11 E	10	3.0	-	Northern Sumatra, Indonesia
2022/03/01	02:56:42.868	0.19 N	100.09 E	10	3.5	-	Northern Sumatra, Indonesia
2022/02/28	17:58:02.929	0.05 N	100.10 E	12	2.4	-	Northern Sumatra, Indonesia
2022/02/28	13:17:44.016	0.20 N	99.96 E	10	2.8	-	Northern Sumatra, Indonesia
2022/02/28	10:31:34.775	0.10 N	100.00 E	10	4.3	-	Northern Sumatra, Indonesia
2022/02/28	08:55:01.833	0.19 N	99.96 E	10	3.6	-	Northern Sumatra, Indonesia
2022/02/28	04:32:28.197	0.26 N	99.87 E	10	3.0	-	Northern Sumatra, Indonesia

Figure 9. BMKG observation data from February, 25 2022 to March, 10 2022 around West Pasaman (BMKG)

CONCLUSIONS

Based on the results of calculations using the Geostat V2.0 Software, a calculation method that is close to BMKG real time observations is the Omori method with a decay time on the 39th day of April 5 2022 at 05:19:44 UTC after the main earthquake (*r = 0.95683*) (Fig. 9). Estimated time of aftershock decay can be used as an effort to mitigate and reduce the risk of earthquakes.

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