Long and Short Wavelength of Geodetic Strain Rate Tapering Earthquake Potential in Western Java

L S Heliani¹, C Pratama¹*, A Wibowo², D P Sahara³, R Ilahi⁴, D Lestari¹

¹Department of Geodetic Engineering, Universitas Gadjah Mada, Indonesia
²Department of Informatics, Universitas Diponegoro, Indonesia
³Global Geophysics Research Group, Institut Teknologi Bandung, Indonesia
⁴Graduate School of Geomatics Engineering, Universitas Gadjah Mada, Indonesia
*Corresponding Author: cecep.pratama@ugm.ac.id

Abstract. Shallow earthquake produced by intra-island fault in a populated region could be a catastrophic disaster. Java island is the most populated area specifically in Western Java since there include Jakarta, the capital city of Indonesia. Cimandiri, Lembang and Baribis fault as main intra-island fault are considered to be responsible due to some shallow historical earthquake in Western Java. However, convergent plate margin such as Java Island generates a broad spectrum of deformation pattern that potentially distracts the deformation due to Baribis fault. In addition, slow relative motion of Sunda block and postseismic deformation due to the 2006 Java tsunami earthquake involve along those fault. Here, we intend to conduct a wavelength decomposition of strain rate calculated from GNSS (Global Navigation Satellite System) data. We expect to separate long wavelength due to wider-region deformation such as deformation due to the interacting plate and postseismic deformation to obtain Short wavelength due to each fault. We utilized the daily position of recent continuous geodetic data to produce strain rate. Therefore, we could apply a moving average filter to extract a short wavelength component. We obtained long wavelength (-150 to 150 nanostrain/yr) in Western Java shows extension indicating the postseismic effect is still continuous while short wavelength (-75 to 75 nanostrain/yr) varies in space.

Keywords: GNSS, Wavelength, Fault, Strain

1. Introduction

Comprehension of an active fault may lead us to understand the potential future devastating earthquake. The accumulated energy in an active fault could be represented by stress-strain relationship where geodetic observation such as GNSS data is enable to image those stress-strain contribution. However, the most of the GNSS observation was built after several large earthquakes (e.g. [1]). Therefore, the significant postseismic deformation recorded at the GNSS station may affect the GNSS displacement and its analysis to identified an active fault.

Cimandiri, Lembang and Baribis fault located in western Java (Figure 1). Dense GNSS observation was built along those fault and might identified tectonic activities ([2], [3]). Previous studies have been investigate the those fault using GNSS [4]. However, coseismic and postseismic deformation due to the Mw 9.2 2004 Sumatra-Andaman (e.g. [5]), the Mw 7.8 2006 Java tsunami
earthquake (e.g. [3]), the Mw 8.6 2012 Indian Ocean earthquake (e.g. [6]) also interplate locking along Java megathrust [7] may affect those GNSS station. In this study, we intend to decompose the long-wavelength due to wider-region deformation to obtain short-wavelength due to local deformation. We utilized GNSS-derived strain rate in western Java and estimate the long-wavelength using moving average filter. Therefore, we evaluate the short wavelength by subtracting the long wavelength from original observation. Hence, we obtain the short wavelength due to an crustal dynamics particularly of active fault in Western Java.

Figure 1. (a) Red square shows interest area of this study, (b) Magenta hexagonal and blue triangle denotes BIG and BPN Continuously Operating Reference Stations (CORS) as a part of Indonesian CORS (InaCORS), respectively. Solid Red lines indicates active fault while dashed red lines indicates proposed faults in this study.

2. Methods
To obtain the surface displacement around western Java, we utilized 47 near-field continuous GNSS observation, provided by Geospatial Information Agency (BIG) and Land Administration Agency (BPN) between 2015 to 2018 (Figure 1b). We processed those GNSS data using GAMIT/GLOBK 10.7 software package along with 11 IGS (International GNSS Service) station as a realization in the International Terrestrial Reference Frame 2008 (ITRF2008) [8]. Those IGS stations consist of XMIS (Australia), DARW (Australia), IISC (India), MOBS (Australia), HYDE (India), YARR (Australia), PNGM (Papua New Guinea), CUSV (Thailand), COCO (Coco Island, Australia) and ALIC (Australia) sites.

The GAMIT/GLOBK procedure conducted three stage approaches [9]. First, we calculate the station coordinates and covariance matrix from each day. Therefore, we remove the outlier and offset from the time series. Finally, we calculate the final velocity and coordinates tied to the International Terrestrial Reference Frame (ITRF) 2008 [10].
Figure 2. GNSS-derived strain rate map. Principal strain rate shown by arrow. Red arrows indicate extension while blue arrows indicate compression. (a) Shaded color denotes dilatation rate. (b) Shaded color denotes maximum shear strain rate.

The estimated GNSS displacement were transformed to Sunda block reference frame using pole parameter defined by Kuncoro [11] (Table 1). Those transformation needed in order to make the velocity field represent the actual displacement due to local deformation.
Table 1. Euler Pole parameter of Sunda block reported by Kuncoro [11]

| Long (λº) | Lat (φº) | Angular Velocity (ω rad/yr) | Sigma Long (σ₁) | Sigma Lat (σ₂) | Angular Velocity (σₒ rad/yr) |
|-----------|----------|----------------------------|-----------------|----------------|-----------------------------|
| -89.4     | 46.2     | 0.327                      | 0.6             | 2.8            | 0.008                       |

The horizontal strain rate estimation follows Shen et al. [12] method in which the dilatation and maximum shear strain rate are defined as in equation (1) and (2), respectively, as described below

\[
\dot{\varepsilon}_{\text{dilatation}} = \lambda_1 + \lambda_2 \quad (1)
\]

\[
\dot{\varepsilon}_{\text{max shear strain}} = (\lambda_1 + \lambda_2)/2 \quad (2)
\]

where \(\dot{\varepsilon}_{\text{dilatation}}\) is the dilatation rate, \(\dot{\varepsilon}_{\text{max shear strain}}\) is the maximum shear strain rate, \(\lambda_1\) and \(\lambda_2\) are the eigen of the horizontal strain rate tensor. Therefore, we calculate the long-wavelength pattern using moving average filter (e.g. [13]) as follow

\[
\bar{y} = \frac{\sum_i^n y_i}{n} \quad (3)
\]

where \(\bar{y}\) is the moving average, \(n\) is the total of the station in the designated radius, and \(y_i\) is the calculated strain rate. By reducing the long-wavelength from the original GNSS-derived strain rate, we obtained the short-wavelength pattern.

3. Results and Discussion

The calculated principal strain suggest that the extension pattern varied from east-west trend to north-south direction (Figure 2). Those variation might indicate several contribution since the 2006 Java Tsunami earthquake produced north-south displacement [3], [7] while the 2012 Indian Ocean earthquake produced east-west deformation in Java Island [6]. In this study, since we focus on long and short wavelength separation, we only demonstrate moving average filter on estimated dilatation rate.

We tested several number of moving average filter (MAF) radius from 22 km to 55 km. We observed that region with denser GNSS network produce robust short wavelength pattern as demonstrated in Figure 3. For example, Northern part of western Java have denser GNSS network than southern part. Therefore, as shown in Figure 3, short wavelength pattern from two different MAF radius in northern part produce almost similar pattern rather than in the southern part.

Previous study shown Baribis fault zone in the north-eastern part of Western Java [14]. Based on our result (Figure 3b and 3d), first, we observed persistent contraction in the northern part of Western Java which may related with the extension of Baribis fault zone. On the other hand, the short wavelength feature also indicate several local contraction in the southern part of Western Java which consistent with the relocated seismicity distribution between 2009 to 2015 reported by Supendi et al. [14]. Second local contraction is due to volcano activity such as Mt. Salak, Mt. Guntur, Mt. Galunggung and Mt. Papandayad. Short wavelength feature (Figure 3d) shows sharp changes of the existence of local contraction. Third local contraction is related with the Cimandiri fault and Lembang fault. Although the contraction is less clear than volcano region and Baribis fault (Figure 3d), note that Cimandiri and Lembang fault mechanism was suggested has a strike-slip component which may indicated by maximum shear strain rate [15]. Additionally, the local contraction also exhibited near southern part of Western Java which may related with the unmapped right-lateral fault [14], [15]. Our study did not investigate the GNSS data that include pre-earthquake motion. Those motion before large earthquake should be investigated in further research.
(a) Long Wavelength (MAF radius 22 Km)  
(b) Short Wavelength (MAF radius 22 Km)  
(c) Long Wavelength (MAF radius 27 Km)  
(d) Short Wavelength (MAF radius 27 km)  

**Figure 3.** Magenta circles and blue triangles shows GNSS data from BIG and BPN, respectively. (a) and (b) shows Long and Short wavelength separation with moving average filter radius by 22 km. (c) and (d) shows Long and Short wavelength separation with moving average filter radius by 27 km.

4. Conclusions

We have been demonstrated the extraction of short wavelength from original deformation in the form of dilatation rate due to crustal dynamics in Western Java. Despite of limitation of our analysis using dilatation rate without maximum shear strain rate, based on our result we conclude that our result satisfactorily estimates the long-wavelength pattern due to a wider-region deformation to generate the short wavelength pattern. Referring to the short-wavelength pattern, we obtained a strong and persistent localized deformation along Baribis fault. On the other hand, we also observed small dip-slip deformation due to Cimandiri and Lembang fault. Additionally, local contraction due to volcano deformation was clearly shown. Part of the region needs to conduct additional campaign data to obtain robust long wavelength estimation. For further research, we consider to continue our analysis to investigate comprehensively based on longer GPS data period including the displacement rate before 2015.

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