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The Effect of Moving Rainstorm in Increasing River Discharge in Ciliwung Basin, Case Study: 15-16 January 2013 Flood Events

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Abstract. The objective of this study is to investigate the effect of moving rainstorm in increasing peak discharge in the 2013 flood event in Ciliwung Rivers Basin (CRB). The effect is analyzed based on 13 scenarios of synthetic rain, i.e.: (1) three scenarios for stationer rainfall that: uniformly distributed along the basin, concentrated in upstream area, and concentrated in downstream areas; (2) ten scenarios of the moving rainfall for 0.5, 1, 2, 4, or 8 m/s velocity and to-downstream or to-upstream direction of movement. The scenarios are done based on equivalent volume. The hydrological simulation conducted by distributed hydrological model, Gridded Surface Subsurface Hydrologic Analysis (GSSHA). The result shows that moving rainstorm has significant effects in increasing the peak discharge and decreasing the time to peak of the discharge in the CRB.
Keywords: Moving rainstorm; Flood; Jakarta; Ciliwung

INTRODUCTION

Jakarta is the capital city of Indonesia with a high potency of hydrometeorological disasters, especially flood. The flood that occurred in 2013 was one of the worst flood after the 2007 flood. It caused various losses, including public facilities damages, for up to 20 trillion rupiahs.

Wu et al. [1] stated that the convective system causes heavy rainfall on 2007 in Jakarta is over the mountains in the afternoon and over the plains in the night and morning [1]. Trilaksono et al. [2] stated that there is a semidiurnal variation with the peak in early morning that move southward of Jakarta [2]. Meanwhile, the convective system triggered a massive flood in 2013 which moved at a speed of 8 m/s to the southeast [3] and when rainfall moves simultaneously with a sea-land breeze circulation, the total amount of diurnal rainfall is increased [4].

The study above shows that there was a movement of rainstorm that triggered massive flood in 2007 and 2013 from the mountains and the sea. The previous study showed how moving rainstorm has had an important role in increasing river discharge [5]. The objective of this study is to prove the effect of moving rainstorm against river discharge in Ciliwung Basin Basin (CRB).

METHODOLOGY

The distributed hydrological model was used to investigate the effects of moving rainstorms in increasing peak discharge in the CRB. This model was run to simulate 13 scenarios of synthetic rain, i.e.: (1) three scenarios for stationer rainfall that: uniformly distributed along the basin, concentrated in upstream area, and concentrated in downstream areas; (2) ten scenarios of the moving rainfall for 0.5, 1, 2, 4, or 8 m/s velocity and to-downstream or to-upstream direction of movement.

The numerical model used in this study is Gridded Surface Subsurface Hydrological Analysis [6]. The domain of the model is Ciliwung Watershed from the upstream area at Gede-Pangrango Mountain Area to the outlet at M.T.

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Haryono hydrological station, DKI Jakarta Province. Figure 1 showed the domain of the hydrological model. The data of topography, rivers, and land cover are vector dataset with scale 1:25,000 which can be downloaded from the website of Badan Informasi Geospasial (BIG) at http://portal.ina-sdi.or.id/. The contour topography was converted to DEM and used as the surface elevation of the model. The river dataset is used to correct the DEM data, especially in the gently slope area. The land cover dataset is used as a proxy for roughness parameterization. There are four classifications for roughness parameterization that is: forest, cultivated area, water body, and urban area. The roughness value for each land cover classification was taken into account in the process of calibration.

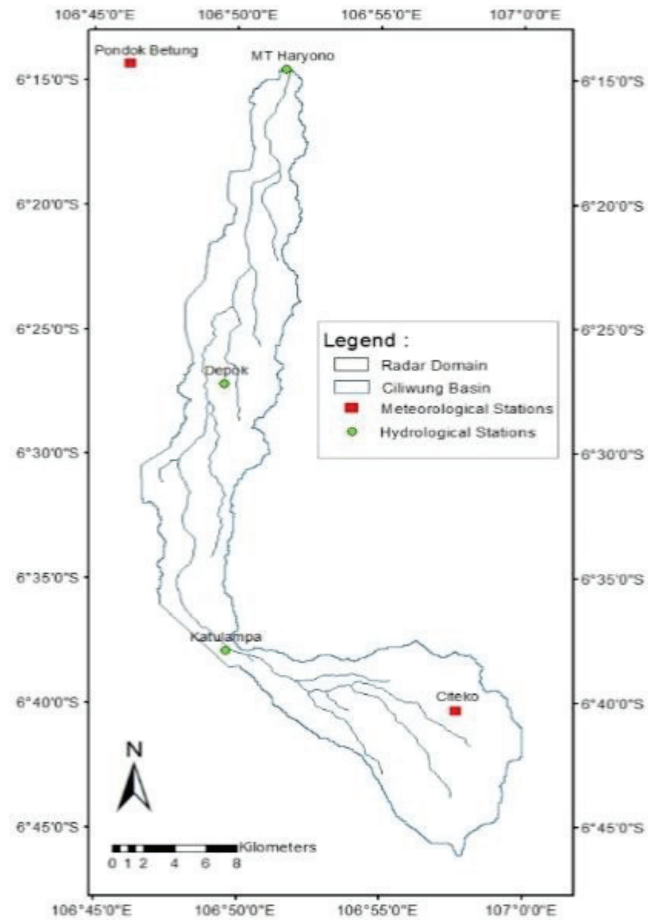

FIGURE 1. Ciliwung basin.

The discharge data is provided by Balai Besar Wilayah Sungai (BBWS) Ciliwung-Cisadane and it was used to calibrate the model. The calibration was conducted on the date when one of the extreme events is occur over The Ciliwung Rivers, namely January 15-16, 2013. The rain rate datasets are estimated by radar reflectivity in dBZ unit (decibels of reflectivity) from Doppler c-band Radar[7]. The result of simulated model shows a good agreement with the observation data of the volume of discharge without any significant bias (Figure 2. b), but failed to replicate the time series hydrograph (Figure 2. a). Thus, the parameterization in the model is good enough to explain the role of rainfall volume and its characteristics to the overland flow. The calibration process produces the roughness parameterization of the model and ratio of effective rainfall. That value is 0.184, 0.01, 0.01, and 0.001 for forest, cultivated area, urban area, and water body, respectively. Effective rainfall was used in this study is 0.7.

$Z = 10{,}22R^{0{,}67}$……………………………………………………………………(Equation 1)

Z = Radar reflectivity ($mm^{-6}m^{-3}$)

R = Radar rain rate ($mm.h^{-1}$)

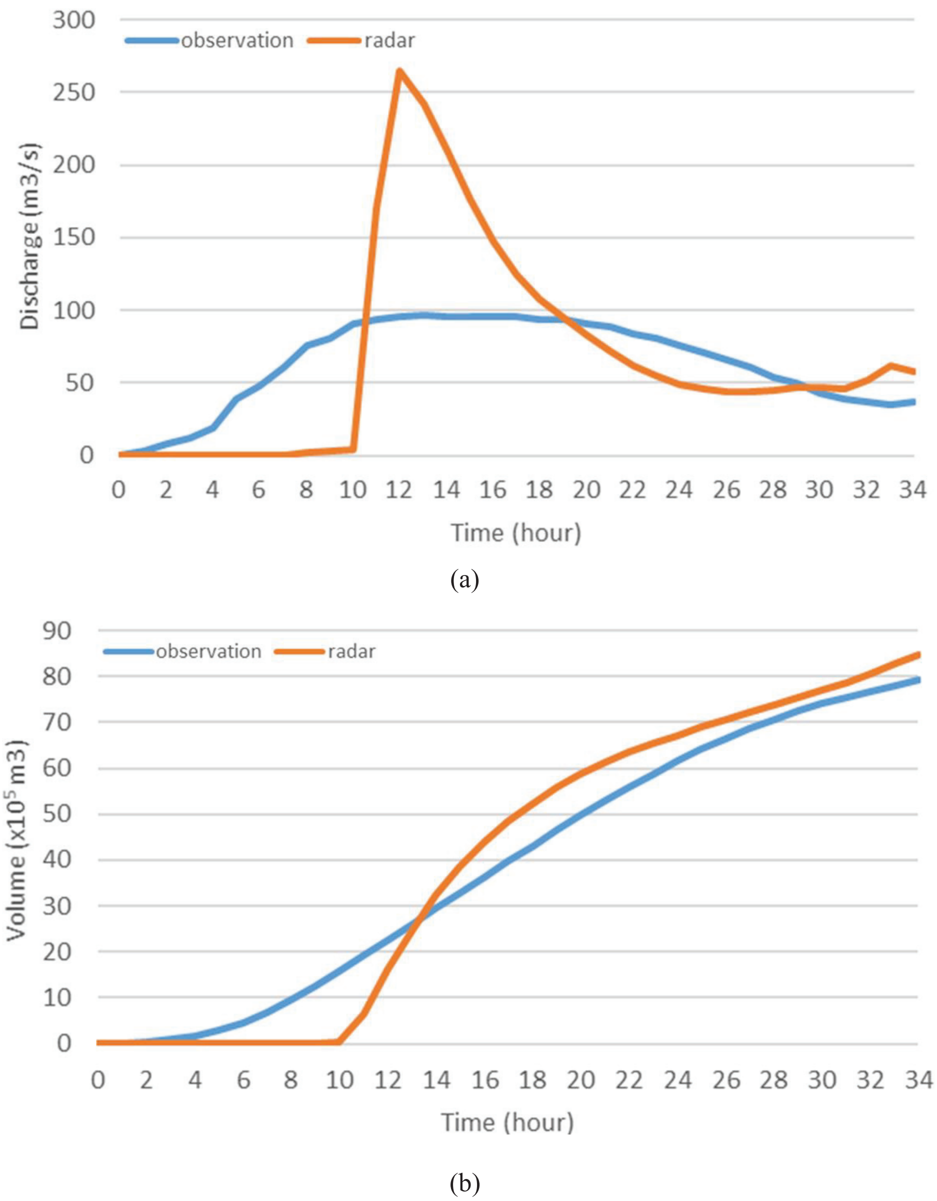

FIGURE 2. Calibration result showed by: (a) hydrograph and (b) mass curve.

The effects of moving rainstorms is assessed by comparing thirteen scenarios of synthetic rainfall and a real scenario. All scenarios using equivalent rainfall that is rainfall with equivalent volume. it shows in Table 1.

TABLE 1. Rainstorm scenarios.

Rainstormn Scenarios	Location	Velocity
Real		
Stationer	Upper river Lower river Uniform along the basin	
Moving rainstorm	Moving downstream Moving upstream	8 m/s 4 m/s 2 m/s 1 m/s 0.5 m/s

RESULTS

Comparison between Rainstorm Scenarios

In hydrologic simulation, rainfall usually assumed to occur uniformly along the basin. However, Figure 3 shows that the moving rainstorm scenario produces the highest river discharge compared to stationary rainfall.

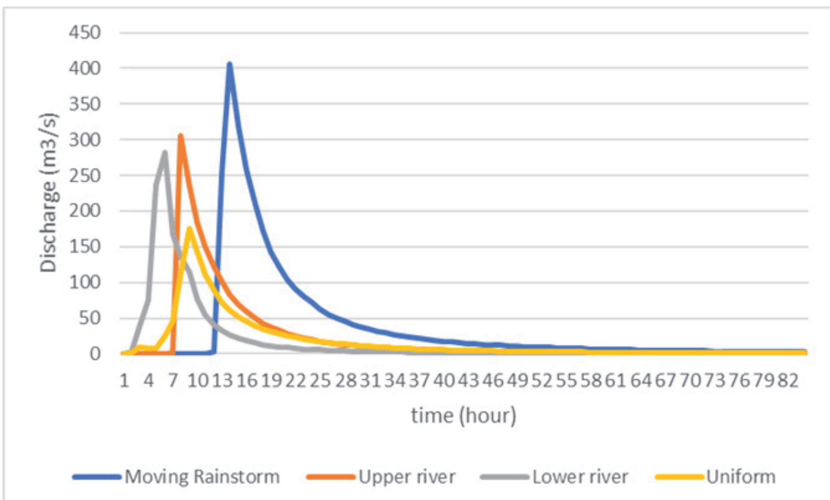

FIGURE 3. River discharge comparison of each rainstorm moving patterns.

When comparing the stationer rainfall, the rainfall that concentrated in upper river has the highest peak of hydrograph but has later rising limb, it is because the rainfall that concentrated in upper river takes time to get to the outlet. Meanwhile the rainfall that concentrated in lower river has a fast rising limb because the concentrated rain located near the outlet, so that the runoff is directly measured at the outlet. And the rainfall that uniformly occur along the river has the longest base time, it is because rainfall occurs along the river at the same time.

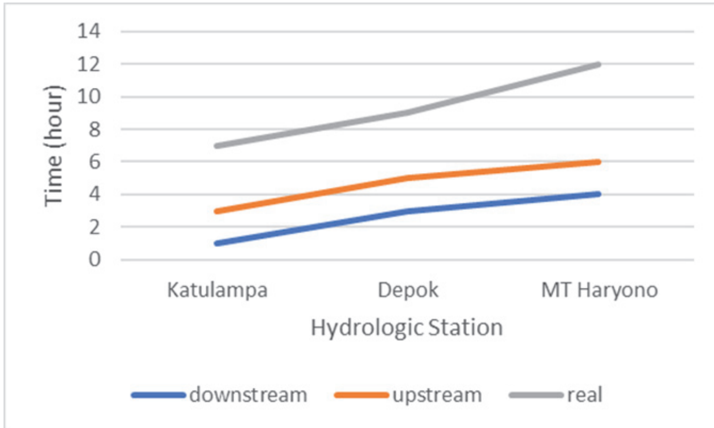

FIGURE 4. Water-level time to peak.

Figure 4 shows that moving rainstorm, either move to downstream or to upstream, has faster time to peak of water level compared with real rainstorm scenario.

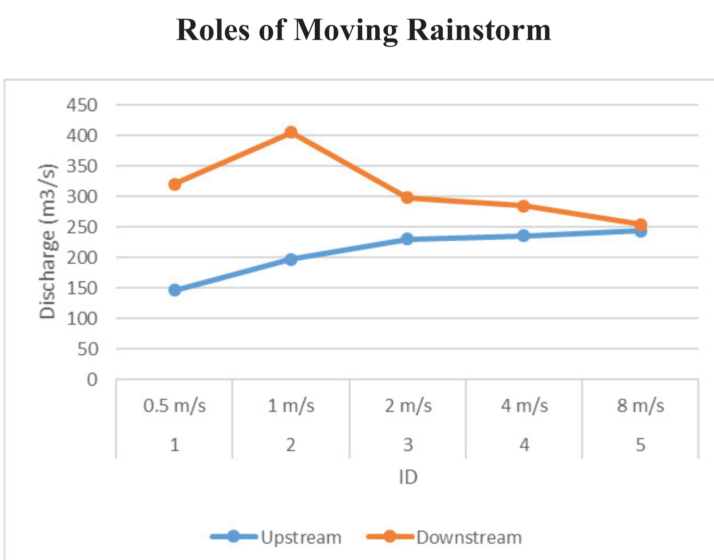

FIGURE 5. Peak of river discharge for each velocity

Figure 5 shows the role of rainfall patterns and rainfall velocity in resulting hydrograph. Rainfall moves to downstream produce greater discharge than rainfall moves to upstream at the same velocity. de Lima and Singh [7] stated that the faster speed of rainfall will produce the lower hydrograph, in contrast the slower speed of rainfall will produce higher hydrograph [7]. But in this study there is significant difference, because in the case of rainfall moves to upstream, the faster speed of rainfall, the higher the peak hydrograph. Meanwhile, in the case of rainfall moves to downstream, the highest peak hydrograph is not produced by the fastest or the slowest speed.

In case of rainfall moves to upstream, the faster the speed of rain, the higher it produce peak discharge. This is probably caused by the shape of Ciliwung basin which tend to be narrower in the upper river. So when the speed of rainfall become faster, the rainfall will get faster to upper river, in accordance with the previous discussion that the upper river flow will be potentially generate higher hydrograph. Whereas in the case of rainfall moves to downstream, the highest hydrograph is produced by a speed of 1 m/s. Singh [5] stated that the rainfall moves to downstream which has the equal velocity with river flow capable of producing the highest discharge [5]. The possibility of Ciliwung river flow velocity is around 1 m/s so that at that speed and the downstream movement produce the highest peak hydrograph.

CONCLUSIONS

Jakarta flood happened in 2013 is caused by heavy rainfall that moves to the southeast, relatively moving upstream of the CRB. But in recent time, study about rainfall characteristic that causes flood is still limited, so the comprehension of flooding is still inadequate, while another study stated one of the rainfall characteristics that have an important role in increasing water discharge is moving rainstorms.

Based on the result of this study, the moving rainstorm has significant role towards increasing river discharge and accelerating time to peak of river discharge. So, in the next study, it is important to consider moving rainstorm in flood simulation.

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