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Main Diurnal Cycle Pattern of Rainfall in East Java

Achmad Fahruddin Rais[1,2,a)] and Rezky Yunita[2]

[1]*Faculty of Earth Sciences and Technology, Institut Teknologi Bandung, Indonesia*
[2]*Indonesian Climatological, Meteorological, and Geophysical Agency, Indonesia*
[a)]Corresponding author: achmad.rais@bmkg.go.id

Abstract. The diurnal cycle pattern of rainfall was indicated as an intense feature in East Java. The research of diurnal cycle generally was only based on satellite estimation which had limitations in accuracy and temporal resolution. The hourly rainfall data of Climate Prediction Center Morphing Technique (CMORPH) and gauge were blended using the best correction method between transformation distribution (DT) and quantile mapping (QM) to increase the accuracy. We used spatiotemporal composite to analyse the concentration patterns of maximum rainfall and principal component analysis (PCA) to identify the spatial and temporal dominant patterns of diurnal rainfall. QM was corrected CMORPH data since it was best method. The eastern region of East Java had a rainfall peak at 14 local time (LT) and the western region had a rainfall peak at 16 LT.

INTRODUCTION

The analysis of rainfall showed strong diurnal cycle pattern in East Java[1,2]. The diurnal cycle was indicated by the concentration of morning maximum rainfall in the sea and night maximum rainfall in the land. The maximum rainfall of East Java occured in high intensity and caused the flood[3].

Generally, the research of rainfall diurnal cycle was based on satellite estimation data in East Java[1,2,4,5]. The satellite-based rainfall estimation data was the only main source, while the hourly gauge rainfall data was not analysed in the research. Moreover, the temporal resolution of the satellite data was 3 hours, so that the rainfall diurnal cycle peak was not presice.

The rainfall of western region and eastern region of East Java was different[1]. The positive rainfall anomaly occured in the eastern area firstly and then in the western area. The time difference of positive rainfall anomaly is possible to indicate the different diurnal cycle of rainfall. The purpose of this study is to provide precise main pattern of rainfall diurnal cycle in East Java.

METHODOLOGY

The data used in this study are :

- Hellman gauge rainfall data (mm/h) of Meteorological Climatological and Geophysical Agency (BMKG) in 4 locations, namely Perak II at the altitude of 3 m, Tretes at the altitude of 832 m, Karangploso at the altitude of 600 m and Karang Kates at the altitude of 325 m over the period of 2010 to 2014 (Figure 1).
- CMORPH (mm/h) in the latitude 6.06˚S to 8.92˚S and the longitude 110.72˚E to 114.63˚E at 8 km spatial resolution over the period of 2010 to 2014.
- Global Land One-kilometer Base Elevation (GLOBE) digital elevation model data in the latitude 6.06˚S to 8.92˚S and the longitude 110.72˚E to 114.63˚E at 1 km spatial resolution.

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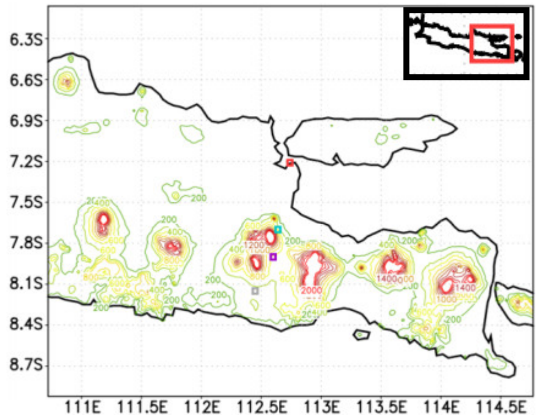

FIGURE 1.The Hellman gauge location of Perak II (red box), Tretes (blue box), Karang Ploso (violet box) and Karang Kates (grey box).

The instrument correction of Hellman gauge was calculated by comparing rainfall data of Hellman gauge to OBS gauge[6] and removing rainfall data of Hellman gauge that was much smaller than rainfall data of OBS gauge. CMORPH was corrected by the best method between distribution transformation (DT)[7] and quantile mapping (QM)[8]. The best method was determined by calculating the percent correct of multicategoric[9]. The multicategoric was determined with no rain, slight rain (0.1 mm/h to 4.9 mm/h), moderate rain (5 mm/h to 9.9 mm/h), heavy rain (10 mm/h to 20 mm/h) and very heavy rain (more than 20 mm/h). The correction factor obtained in Perak II would be used as a reference of CMORPH data at the altitude of 0 m to 200 m, Karang Kates as a reference of CMORPH data at the altitude of 201 m to 400 m, Karang Ploso as a reference of CMORPH data at the altitude of 401 m to 600 m and Tretes as a reference of CMORPH data at altitude greater than 600 m. While at 4 locations of Hellman gauge, gauge data blank was filled with corrected CMORPH. The altitude of mentioned locations was based on GLOBE data.

The diurnal cycle of rainfall was identified by calculating the spatiotemporal composite of blended rainfall to analyse the concentration pattern of maximum rainfall. Principal component analysis (PCA) was used to analyse the dominant spatial and temporal patterns of rainfall[10]. The empirical orthogonal function (EOF) referred to spatial coefficient of PCA and the principal component (PC) referred to temporal score. EOF was examined by calculating the spatial regression between rainfall in each grids and composite rainfall in the box that represents pole of EOF (further explained as coef 1 and coef 2) to find its compatibility to real condition[11].

RESULTS

After the instrument correction is performed, the completeness of Hellman gauge data during the period of 2010 to 2014 in Perak II is 97.65%, Tretes is 71.52%, Karang Ploso is 67.82% and Karang Kates is 23.31%. In Perak II, Karang Ploso and Karang Kates, the best percent correct is 90.94%, 92.87% and 86.51% shown by QM. While in Tretes, the largest percent correct is 85.50%, shown by CMORPH without correction (figure 2). Therefore, the QM method is used to correct CMORPH at the altitude of 0 m to 600 m.

Data	Perak II	Tretes	K. Ploso	K. Kates
CMORPH	90.67%	**85.50%**	89.47%	85.51%
CMORPH DT	90.58%	85.48%	89.47%	85.50%
CMORPH QM	**90.94%**	85.17%	**92.87%**	**86.51%**

FIGURE 2. The percent correct of CMORPH without correction (CMORPH), corrected by DT (CMORPH DT) and corrected by QM (CMORPH QM).

In general, composite CMORPH-gauge blended shows diurnal cycles as well as composite CMORPH does but has lower value than CMORPH. The largest difference between CMORPH-gauge blended and CMORPH value occurs in the peak of rainfall at 16 LT and the smallest difference occurs at 07 LT.

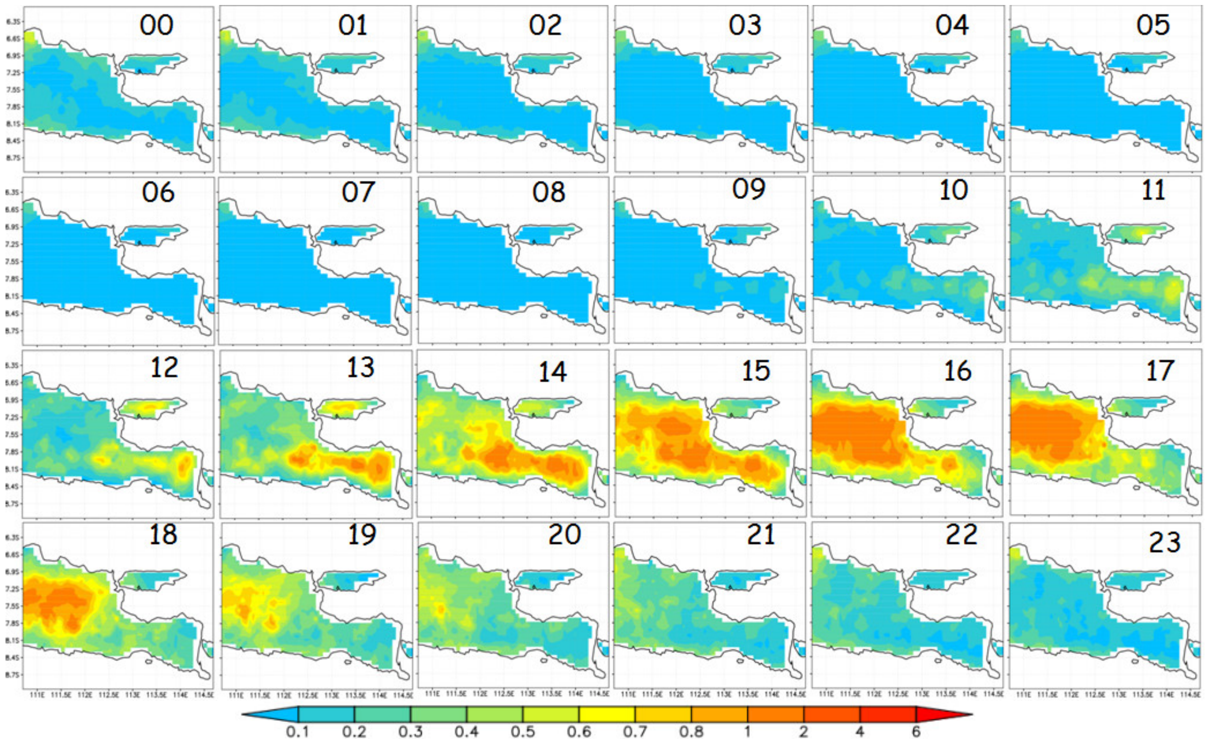

FIGURE 3. The spatiotemporal distribution of composite rainfall every hours (mm/h) in the local time.

Compatible to general diurnal cycle pattern of rainfall in Java[2], maximum rainfall concentrated on shore begins at 22 LT to 04 LT. Then maximum rainfall concentration moves to the centre part of East Java at 10 LT to 20 LT. In the eastern region where the mountains is located, the maximum rainfall peak occurs at 14 LT. The peak of maximum rainfall occurs at 16 LT in the western and central region which is dominated by lowland (figure 3).

20 principal components (PCs) show that the temporal distribution of rainfall peak is between 12 LT to 19 LT. The explained variance cumulation of 20 PCs reaches 55.4%. The negative and positive spatial distributions of 20 EOFs show diverse patterns. Since the mode 1 and 2 of PCA have higher explained variance (13.3% and 6.1%), only EOF 1 and 2 are selected.

EOF 1 is positive in all of East Java regions and the concentration of maximum values is located in the western and centre region. Otherwise, EOF 2 has negatif and positif values. The maximum values are concentrated in the southern and eastern regions, while the minimum value are in the western and northern regions. The peak value of PC is greater than PC 2. PC1 peak occurs at 16 LT and PC 2 at 14 LT (figure 5).

The examination result shows that the EOF 1 is compatible to real condition since the spatial distribution of EOF 1 and the spatial distribution of coef 1 have similar pattern. While in the examination of EOF 2, the negative distribution of EOF 2 does not correspond to the spatial distribution of coef 2 (Figure 6). It indicates that the negative distribution of EOF 2 is not compatible to real condition, so we only use the positive distribution.

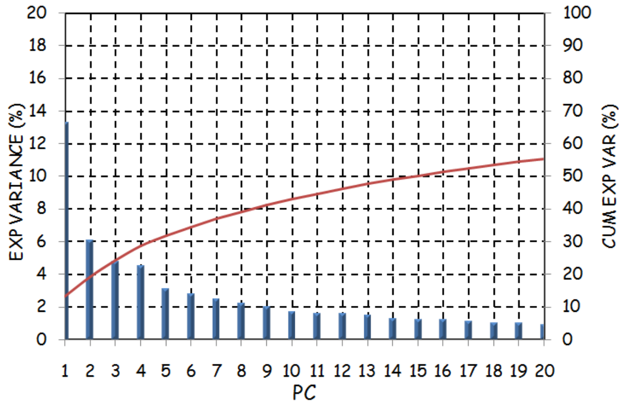

FIGURE 4. The explained variance (blue) and the explained variance cumulation (red) of 20 PCs .

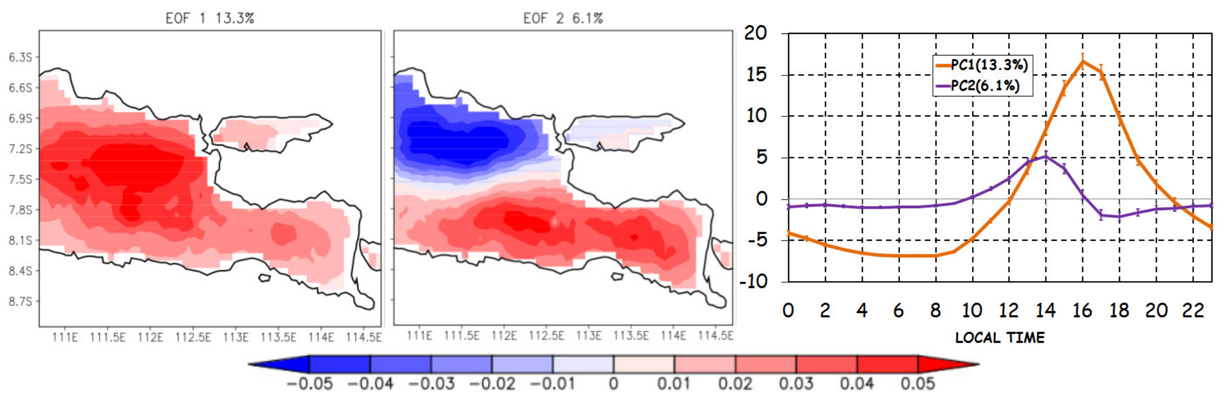

FIGURE 5. The spatial distribution map of EOF 1 and 2 (left and middle) and the temporal distribution graphic of PC 1 and 2 (right).

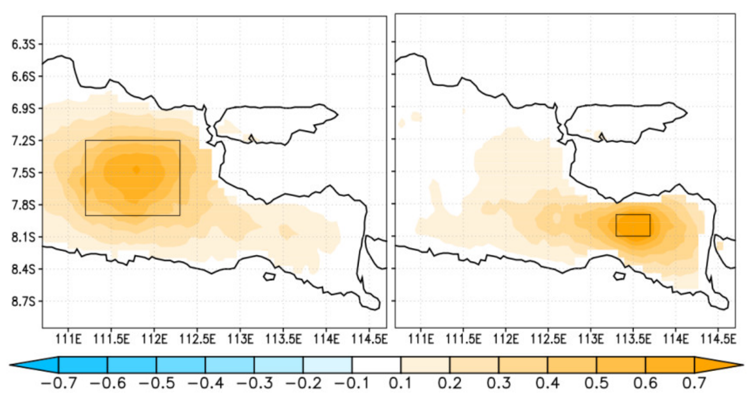

FIGURE 6. The distribution of regression coefficient or coef 1 (left) and coef 2 (right).

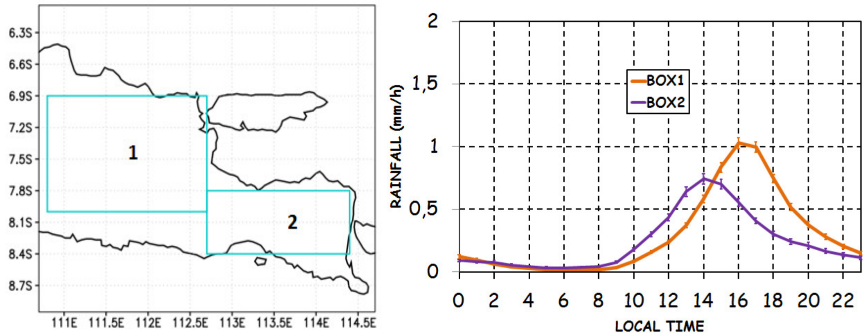

FIGURE 7. The map location of box 1 and 2 (left) and the temporal distribution graphic of composite rainfall in box 1 and 2 (right).

The spatiotemporal analysis of composite rainfall shows the similar result to the spatial distribution pattern of EOF 1 and EOF 2. The area of rainfall distribution is divided into box 1 and box 2 representing the western region which is dominated by lowland and the eastern region where the mointains are located. The different characteristics of topography in the western region and the eastern region are able to influence the variation of rainfall. The satellite-gauge blended rainfall data is capable of describing the characteristics of topography since the blending process has involved GLOBE data.

As well as the previous study[2], we also find that formerly the composite rainfall is increasing in the western region followed by the eastern region. The rainfall begins increasing at 09 LT in the western region while in the eastern region at 10 LT. Meanwhile, the peak of diurnal rainfall in both regions occurs differently. At 16 LT, the peak occurs in the western region. While in the eastern region, the peak occurs at 14 LT. The peak of rainfall diurnal cycle in western region corresponds to the peak of PC 1. As well as the western region, the peak in eastern region also corresponds to PC 2. The western region has more rainfall intensity than the eastern region.

SUMMARY

The accuracy of CMORPH data has been increased by blending CMORPH and gauge data based on QM. QM is used to correct CMORPH data at the altitude of 0 m to 600 m. QM is the best method since it is able to increase the accuracy more than DT and original CMORPH.

It is clear that there are 2 main diurnal cycle patterns of rainfall in East Java. The first pattern is the western region with a peak at 16 LT. The second pattern is the eastern region with a peak at 14 LT. The composite rainfall in the western region also has greater intensity than the eastern region in each hours.

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