Propagation of convective complex systems triggering potential flooding rainfall of Greater Jakarta using satellite data

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Abstract. A convective cloud system that large, long lived, and exhibits a quasi-circular cloud shield could be called a mesoscale convective complexes (MCC) system. These systems produce a wide variety of severe convective weather such as heavy rainfall. On January 15th, 2013, Jakarta experienced an extraordinary heavy rainfall event. In this study, we examined the propagation of the convective complex system on that date that was triggering heavy rainfall occurred in the Greater Jakarta area, using observations from the Multi-functional Transport Satellite (MTSAT)-IR and the synoptic data. The convective complex system developed from midnight of January 14th, 2013 until the morning of January 15th, 2013 and it was intensified by the influence of low-level westerly winds. The convective complex systems were generated during the nighttime of January 14th, 2013 of over Sumatera, and propagate to the Southeast through Java Sea until the northern coast of the Great Jakarta in the morning of January 15th, 2013. These convective complex systems give heavy rainfall up to 63 mm/h on average over the Greater Jakarta area at 04.00 LT. This heavy rainfall had triggered flash flood in Jakarta January 2013.

1. Introduction
An extraordinary heavy rainfall/flood event had occurred in the Greater Jakarta (GJ) on January 15th, 2013. This event was one of a sequences of rainfall/flood events dated January 15 – 18th, 2013, with at least 20 people lost their lives and thousands of houses were inundated as noted by Wu et al. [1]. This event is one of the worst floods in recorded history over GJ.

The previous studies, an infrequently long duration of heavy rainfall implying the severe flood event that occurred in Jakarta during late January into early February 2007 was reported by Wu et al. [2] using observational data and by Trilaksono et al. [3, 4] using a numerical non-hydrostatic model. They show a constant strong trans-equatorial Asian winter monsoonal flow from Northern Hemisphere plays an important role in the formation of heavy rainfall in Jakarta during late January into early February 2007. While an extraordinary heavy rainfall event over Jakarta in the middle of January 2013, according to Wu et al. [1], was exerted by the eastward propagation of an active phase of the Madden-Julian Oscillation (MJO).
A heavy rainfall as one of a wide variety of severe convective weather could be produced by Mesoscale Convective Complexes (MCC) [5-7]. There were studies on the contribution of MCC substantially to the total rainfall across the various region [8-11]. The MCC is a subclass of mesoscale convective systems (MCSs) defined as a convective cloud system that is large, long lived, and exhibits a quasi-circular cloud shield [5] for the important criteria.

We have identify the convective complex system as a convective cloud system that suited similar criteria with MCC but not showing a quasi-circular cloud shield [12]. In the present study we investigated the propagation of the convective complex system that triggered potential flooding rainfall occurred in the Greater Jakarta area, using observations analysis from the Multi-functional Transport Satellite (MTSAT)-IR and the rainfall data on January 14 – 15th, 2013.

2. Data and Methods
The 3B42 real-time TRMM Multi-Satellite Precipitation Analysis (TMPA-RT) version 6 data of 3 hourly precipitation from January 14-15th, 2013 were used in this study. The 3 hourly dataset is high-frequency intervals temporal resolution with 0.25° x 0.25° spatial resolution where area study focus in the around GJ (figure 1). For detail information about this data can be found at the web page of Goddard Space Flight Center of National Aeronautics and Space Administration (https://pmm.nasa.gov/data-access/downloads/trmm). We examined heavy rainfall over GJ by TRMM dataset confirming the convective complex system. The equivalent temperature black body (TBB) that derived the hourly infrared data of Multi-functional Transport Satellite (MTSAT)-1R imagery from http://database.rish.kyoto-u.ac.jp/arch/ctop/index_e.html [13]. The satellite imagery was used to identify an objective of a convective complex system and their physical characteristics based on the parameters given by Maddox [5] and adopted by Blamey and Reason [14].

To identify convective complex systems we implemented the “Grab ‘em, Tag ‘em, Graph ‘em” (GTG) algorithm [15] as a tools a cloud-tracking and convective systems feature tracking algorithm based on graph theory in gridded infrared dataset. The graph theory implementation requires using graphs as objects along with some graph traversal methods. The criteria to applying GTG algorithm is based on table 1.
Table 1. Physical characteristics based on the parameters given by Maddox [5] and adopted by Blamey and Reason [14] to identify a convective complexes system in this study.

| Physical characteristics | Blamey and Reason [14] Criteria                        |
|--------------------------|--------------------------------------------------------|
| Cloud Top Temperature    | $\leq 221$ K                                          |
| Size                     | $\geq 50000$ km$^2$                                   |
| Shape-eccentricity       | $\geq 0.7$ at maximum extent                          |
| Duration                 | Size and temperature definition must be met for a period $\geq 6$ hours |
| Initiation               | Size and temperature thresholds are first met         |
| Termination              | Size definition are no longer satisfied                |

We plot the trajectories of the convective complex system center hour by hour from the first development until dissipation phase of the system for gain the description of propagation the convective complex system. To assess the relative position and strength of the convective cloud system, we apply time-crosssection plot of TBB and overlying with rainfall in January 14 – 15th, 2013.

3. Results and Discussions

Figure 2 shows the three hourly temporal variation of the rainfall intensity over GJ indicated by red box (figure 1) during flood event (January 15th, 2013) in GJ area (about 7,392.6 km$^2$ of large). The peak of rainfall occurred in the early morning of 15 January 2013. While the others times show less than 40 mm of rainfall.

![Figure 2](image)

**Figure 2.** The accumulation diurnal variation of rainfall distribution (mm/3 hour) during January 14 - 15th, 2013 at around GJ (red box Fig. 1) about 7,392.6 km$^2$ of large. X-label is date and time, for example 1407 = 07.00 LT January 14th.

Figure 3 presents satellite images that depict the evolution of a convective complex cloud cluster near GJ on January 14 - 15th, 2013. The three stages in the life cycle of these convective system are development stage at 1600 LT January 14th, 2013 (figure 3a), mature stage at 0300 LT January 15th, 2013 (figure 3b) and dissipation stage at 0700 LT January 15th, 2013 (figure 3c). These three stages definition is refered to Maddox’s definition [5]. The development stage have cloud cluster with first met criteria of temperature $\leq 221$ K and size $\geq 50,000$ km$^2$. The mature stage have cloud cluster with
maximum size of temperature \( \leq 221 \text{ K} \). The dissipation stage have cloud cluster with last met criteria of temperature \( \leq 221 \text{ K} \) and size \( \geq 50,000 \text{ km}^2 \).

The eccentricity at development stages of convective system was 0.56 (< 0.7 as defined by Maddox [5]). The eccentricity at mature stages of convective system was 0.49 (< 0.7). The shape of these convective system was not match with Maddox’s criteria of MCC. So these cloud cluster was not a MCC, although these convective system bringing heavy rainfall over GJ on January 15th, 2013. For a moment we call it as a convective complex system which defined as a convective cloud system that large, long lived, and very cold cloud shield.

During the development stage in the afternoon (1600 LT) on January 14th, 2013, the group of clouds grew rapidly and propagated southeastward until around early morning (0300 LT) on January 15th, 2013, which marked as the mature stage. During the mature stage, the convective complex system had a cloud shield with an area of around 249,731 km\(^2\) at \( \leq 221 \text{ K} \) of cloud temperature. The center of the convective complex system during this stage was around 5.6\(^o\)S, 106.64\(^o\)E with minimum temperature is 199 K. During the dissipation stage in the morning (0700 LT) on January 15th, 2015, the convective complex system had split into small-scale clouds that propagated southwestward and northeastward toward the Indian Ocean and Java Sea respectively.

![Image](https://example.com/image.png)

**Figure 3.** Horizontal distribution of black body temperature from infrared data obtained by MTSAT-IR over the Greater Jakarta area on January 14 - 15th, 2013, showing (a) development stage (1600 LT January 14th, 2013), (b) mature stage (0300 LT 15 January 2013) and (c) dissipation stage (0700 LT January 15th, 2013).

The life duration of the convective complex system are about 16 hour from 1600 LT January 14th, 2013 until 0700 LT January 15th, 2013. Figure 4 shows the trajectories of the convective complex system center that moved out of the Sumatera Island with southeastward, southwestward and southeastward propagations through northern coast of GJ and finally eastward propagation till Java Sea. The mature stage of the convective complex system activity occur in Java Sea that close to GJ. It is evident that these convective complex system propagation will generally impact heavy rainfall around of GJ during January 15th, 2013.
Figure 4. Trajectory of the convective complex system center on January 14 - 15th, 2013 (dashed line). Cross, filled circle and triangle mark is development, mature and dissipation stages respectively of the convective complex system. Sr, Ck, Cr, TP, Km and Ct denotes Serang, Cengkareng, Curug, Tanjung Priok, Kemayoran and Citeko respectively.

To assess or diagnose the behavior of the convective complex system over a span of A-B line (figure 1) through time, we showed time-cross-section plots of TBB and rainfall of A-B line from 1300 LT January 14th, 2013 until 1000 LT January 15th, 2013 (figure 5). Throughout in January 14 – 15th, 2013 the convective complex system, defined by ≤ 221 K of TBB, develop over the Sumatera Island with an amplitude of ≤ 221 K. The GJ area exists as is indicated by thick vertical dashed lines. Part of the convective complex system propagate over the GJ from 2100 LT January 14th, 2013 until 0800 LT January 15th, 2013. While the heavy rainfall (> 10 mm/hr) over the GJ from 0100 LT January 15th, 2013 until 0700 LT January 15th, 2013. This result has agreement with previous study that maximum rainfall was found at 0000 – 1100 LT over around the GJ [16]. The convective complex system has a southeastward propagation speed equal to 18.7 m/s. According to Wu et al. [1] with the eastward propagation of the active phase of the MJO, moderate westerly winds occurred over Java Island during the heavy rain event.
The convective complexes system developed from midnight on January 14th, 2013 until the morning of January 15th, 2013 and it was intensified by the influence of low-level westerly winds. The convective complex systems were generated during the nighttime of January 14th, 2013 of over Sumatera, and they propagate to the Southeast through Java Sea until northern coast of Great Jakarta the morning of January 15th, 2013. These convective complex systems give heavy rainfall up to 63 mm/h average over the Greater Jakarta area at 04.00 LT. The 63 mm/h of rainfall may triggered flash flood in Jakarta January 2013.

4. Conclusions
On January 15th, 2013, Jakarta experienced an extraordinary heavy rainfall that triggered flood event. The convective complex system developed from midnight on January 14th, 2013 until the morning of January 15th, 2013 and it was intensified by the influence of low-level westerly winds. The combined satellite and synoptic data analysis has successfully identified the convective complex systems that were generated during the nighttime of January 14th, 2013 over Sumatera, and propagated to the Southeast through Java Sea until northern coast of Great Jakarta the morning of January 15th, 2013. These convective complex systems generated heavy rainfall up to 63 mm/h on average over the Greater Jakarta area at 04.00 LT. This heavy rainfall had triggered flash flood in the Greater Jakarta basins.

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