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Application of Graph-Theory Based Algorithm for Identifying Convective Complex Systems over Greater Jakarta basins

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Application of Graph-Theory Based Algorithm for Identifying Convective Complex Systems over Greater Jakarta basins

D E Nuryanto[1,2*], E Aldrian[3], H Pawitan[1] and R Hidayat[1]

[1]Department of Geophysics and Meteorology, FMIPA Bogor Agricultural University, Kampus IPB Darmaga, Bogor 16680, West Java, Indonesia
[2]Research and Development Center, The Indonesian Agency for Meteorology Climatology and Geophysics, Jl Angkasa I No 2 Kemayoran Jakarta Pusat 10720, Indonesia
[3]Agency for The Assessment and Application of Technology, Jl MH Thamrin No 8 Jakarta 10340, Indonesia

Email : danang.eko@bmkg.go.id

Abstract. Heavy rainfalls over the Greater Jakarta (GJ) basins during January 14 - 15th, 2013 were suspected to be derived from convective complex systems (CCSs) as subsets of mesoscale convective systems (MCSs). This study, implementing a graph-theory based algorithm on black body temperature (TBB) dataset, identified CCS over GJ during heavy rainfall event on January 14 - 15th, 2013. We found that convective cloud cluster for ≤ 221 K of TBB more than 6 hours (about 16 hours of duration) with average of eccentricity was 0.47. The maximum area of this system was about 249,731.9 km^2 at 0300 Local Time (LT) January 15th, 2013. Ones of these convective system features is not match with MCC definition. We defined this convective system as convective cloud system that large, long lived, and very cold of cloud shield. This system is in agreement with heavy rainfall (more than 40 mm/3h) at 0200 – 0400 LT January 15th, 2013 over GJ basins.

1. Introduction

Mesoscale convective systems (MCSs) are features of complex organized thunderstorms that vary in size and continues for hours. Mesoscale convective complexes (MCCs) are a subset of large and well-organized mesoscale convective systems (MCSs) defined as convective cloud system that is large, long lived, and exhibits a quasi-circular cloud shield [1].

Identification of convective systems utilizes a particular spatial-temporal criterion that requires high-resolution (< 3 hourly) geostationary weather satellite data [1]. Past studies identifying the characteristics of the convective systems were fully manual and required both infrared (IR) images that supplied the cloud-top brightness temperature, and visible (VIS) images that provided information on cloud characteristics [2]. Recently, a fully automated method namely the Tracking of Organized Convection (TOOCAN) algorithm has been introduced for identifying and tracking convective systems in meteorological applications [3]. The existing methods for identification of convective systems in infrared datasets still need human intervention.

Graph theory is still rarely used in the atmospheric sciences for predicting details of the changing atmosphere for a period between 0 to 6 h over a small area (e.g. a city) and forecasting MCSs, specifically thunderstorms with radar and satellite data [4,5]. According to Chaudhuri and Middey

[4,5], the implementation of graph theory is suitable to express relationship among the atmospheric variables at a particular time.

This study was attempted to implement a graph-theory based algorithm on black body temperature (TBB) dataset, that were derived from the hourly infrared data of Multi-functional Transport Satellite (MTSAT)-IR imagery, for identifying convectice complex system (CCS) over the Greater Jakarta (GJ) during heavy rainfall event on January 14 - 15th, 2013. This method is called the "Grab 'em, Tag 'em, Graph 'em" (GTG) algorithm and it is a fully automated graph-theory based algorithm [6]. For the preliminary study, we used MCC criteria from Blamey and Reason [7] for identifying CCS.

2. Data and Methods

The equivalent black body temperature that was derived from hourly infrared data of Multi-functional Transport Satellite (MTSAT)-IR imagery was obtained from http://database.rish.kyoto-u.ac.jp/arch/ctop/index_e.html [8]. 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 [1] and adopted by Blamey and Reason [7]. The studied area was located in the GJ basins as part of Indonesian Maritime Continent (IMC), see figure 1. The synoptic data from several weather stations of BMKG around GJ, i.e., at Serang (6.117°S, 106.133°E), Cengkareng (6.117°S, 106.650°E), Curug (6.233°S, 106.650°E), Tanjung Priok (6.100°S, 106.867°E), Kemayoran (6.183°S, 106.583°E), and Citeko (6.700°S, 106.933°E) were compared with a convective complex cloud cluster.

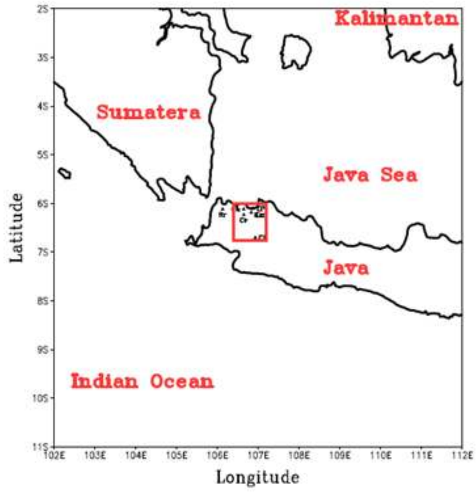

Figure 1. The study area (106.40°E – 107.20°E, 6.01°S – 6.76°S) around of the Great Jakarta (red box).

The methods for identifying the convective systems are usually based on forward or backward algorithm that executes in two stages, that is a cloud detection stage, and a tracking stage [3,9,10]. The cloud detection stage involves identifying the cloud areas of interest from a TBB data via a particular criterion of temperature and area at time increments. These criterion varies according to the particular convective systems and the location study.

Previous studies identified the temperature ranges of TBB associated with convective clouds in large convective systems to range from a 255 K temperature threshold to identify large-scale areas, to a 195 K temperature threshold to identify the convectively most active areas of the system [1,3,7,11,12,13,14]. There are some advantages in using the colder temperature threshold since it tracks the center of the system better and there was also a better representation of two systems that were in close proximity of each other [7].

In this study we implemented the "Grab 'em, Tag 'em, Graph 'em" (GTG) algorithm and is a fully automated graph-theory based algorithm [6]. The GTG algorithm works by using cloud elements

(CEs) with a particular size and temperature of TBB as the graph's vertices, defining the graph's edges as areas of overlap between CEs, and defining CEs that are correlated throughout time as cloud clusters (CCs). The advantages of graph theory implementation is to anticipate a problem relating to spontaneous splitting or merging of cloud areas though they belonged to the same system as identifying by Mathon and Laurent [15].

Figure 2 provides a schematic of the algorithm that works by first identifying areas of interest in the gridded TBB dataset to create a graph nodes and edges, then searching the graph for the type of convective systems. For a preliminary study, we used MCC criteria from Blamey and Reason [7] for identifying CEs and CCs, see given in Tabel 1. The properties of a CE in the region of interest are defined by cloud shield of 221 K, representing by graph nodes. The graph edges represented CEs in consecutive times that are correlated via the percentage of area overlap. The minimum weight of an edge occurs while the percentage overlap between two nodes is at least 66 %, and the maximum weight occurs for a 50 % overlap or in excess of 10,000 km^2 [16,17] as implemented by Whitehall et al. [6]. Within the graph construct, a cloud cluster (CC) is defined as the collection of CEs and edges. A CC can have a minimum duration of six times (6 hours), and maximum of *m* times, where *m* is number of times being considered.

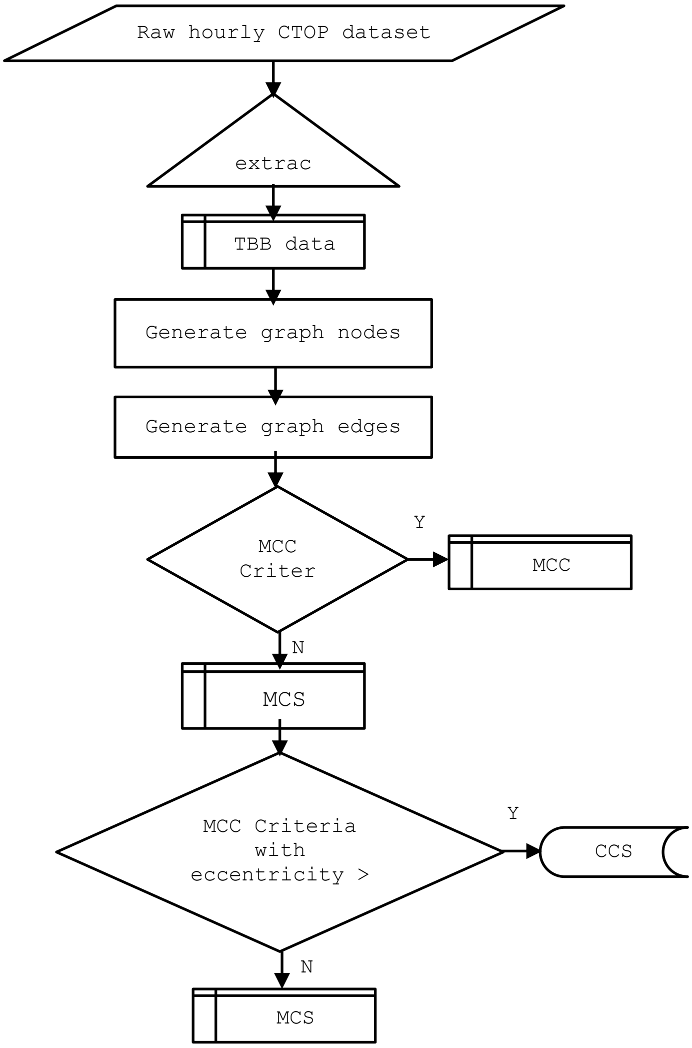

Figure 2. A schematic of the graph theory based algorithm for detection and tracking of CCS.

Table 1. Physical characteristics based on the parameters given by Maddox [1] and adopted by Blamey and Reason [7] to identify a convective complexes system in this study.

Physical characteristics	**Blamey and Reason [7] Criteria**
Cloud Top Temperature	≤ 221 K
Size	ε 50000 km^2
Shape-eccentricity	ε 0.7 at maximum extent
Duration	Size and temperature definition must be met for a period ε 6 hours
Initiation	Size and temperature thresholds are first met
Termination	Size definition are no longer satisfied

3. Results and Discussions

The area over GJ basins was examined for the 48 hour periods between January 14th, 2013 0000 UTC (0700 Local Time (LT) on January 14th to January 15th, 2013 2300 UTC (0600 LT on January 16th) using the infrared TBB data from the MTSAT-IR dataset. Table 2 shows the results of implementing a graph-theory based algorithm on MTSAT-IR dataset. We found some matches of MCC criteria for cloud size and duration for ≤ 221 K of TBB. But we did not find any match of the essential criteria of MCC (eccentricity < 0.7). The average of eccentricity was 0.47 for 16 hours of duration. The highest eccentricity from this study was about 0.69. The averages of TBB was about 208 – 214 K. The maximum area of this system was about 249,731.9 km2 at 0300 LT January 15th, 2013.

Figure 3 shows the spatial distribution of black body temperature from infrared data obtained by MTSAT-IR over GJ basins at 1600 LT, 2200 LT January 14th, 2013 through 0300 LT and 0700 LT January 15th, 2013. We described the phase of the convective systems as development stage (1600 – 2200 LT January 14th, 2013), mature stage (0300 LT January 15th, 2013) and dissipation stage (0700 LT January 15th, 2013). From this results, we defined this system as CCS defining as convective cloud system that large, long lived, and very cold of cloud shield.

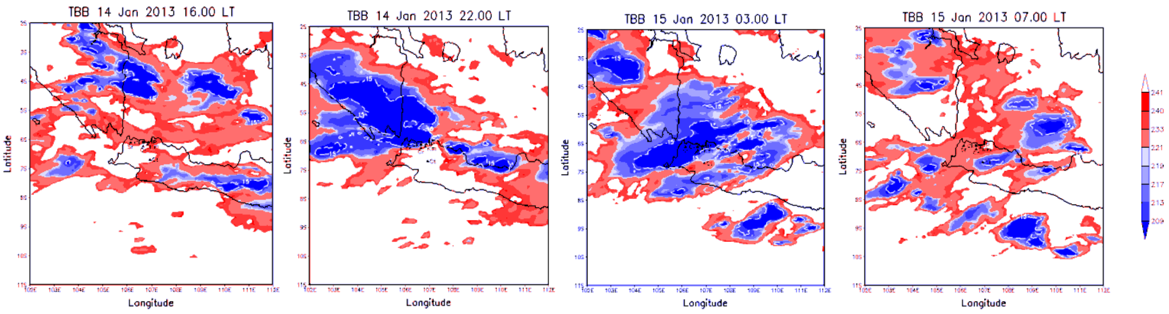

Figure 3. Horizontal distribution of black body temperature from infrared data obtained by MTSAT-IR over GJ basins respectively at 1600 LT, 2200 LT January 14th, 2013 through 0300 LT and 0700 LT January 15th, 2013.

Table 2. The results of implementing graph-theory based algorithm.

Time (LT)	Center of lat	Center of lon	Area Size (km^2)	Averages of brightness temperature (K)	Min of brightness temperature (K)	Max of brightness temperature (K)	Eccentricity
14/01/2013 16:00	-3.56	105.36	64187.5	210.8980	197	221	0.56
14/01/2013 17:00	-3.88	106.24	133185.1	211.6234	200	221	0.36
14/01/2013 18:00	-4.12	105.92	163859.4	212.0409	198	221	0.28
14/01/2013 19:00	-4.20	105.28	161730.4	210.7845	196	221	0.36
14/01/2013 20:00	-4.36	104.96	161651.5	209.1844	194	221	0.50
14/01/2013 21:00	-4.68	104.32	158655.1	208.1417	196	221	0.69
14/01/2013 22:00	-4.92	104.56	195164.6	210.2626	196	221	0.59
14/01/2013 23:00	-5.40	105.52	237351.7	211.5355	195	221	0.51
15/01/2013 00:00	-5.48	106.00	225365.9	210.2239	194	221	0.41
15/01/2013 01:00	-5.80	106.64	222921.4	208.2395	193	221	0.43
15/01/2013 02:00	-5.72	106.64	247129.7	210.2856	195	221	0.45
15/01/2013 03:00	-5.80	106.64	249731.9	212.9719	199	221	0.49
15/01/2013 04:00	-5.80	106.48	211960.6	213.8616	199	221	0.52
15/01/2013 05:00	-6.12	107.20	130030.9	213.5318	198	221	0.49
15/01/2013 06:00	-6.04	107.60	104560.9	213.4962	201	221	0.34
15/01/2013 07:00	-5.88	109.20	54803.8	214.2705	204	221	0.46

Figure 4 shows the TBB and rainfall distribution at specific sites around GJ, i.e: Cengkareng (202 K/41 mm), Citeko (224 K/1 mm), Kemayoran (200 K/19 mm), Tanjung Priok (211 K/44 mm), Curug (201 K/26 mm) and Serang (206 K/59 mm) during 0200 – 0400 LT January 15th, 2013. During this time the convective systems reach the mature stage at 0300 LT January 15th, 2013. This system in mature stage have good agreement with heavy rainfall at 0200 – 0400 LT January 15th, 2013 over GJ basins. Previous study showed that maximum rainfall was found at 0000 – 1100 LT over around the GJ [18]. Except at Kemayoran, the low temperature of clouds (TBB < 212 K) provides a significant rainfall at Cengkareng, Tanjung Priok and Serang with measured more than 40 mm/3h at such time. The higher portion of convective rainfall corresponded well to the thicker clouds colder than 210 K [19]. The TBB about 210 K also had been convinced to detect the precipitating core around the tropical deep convective activity [20].

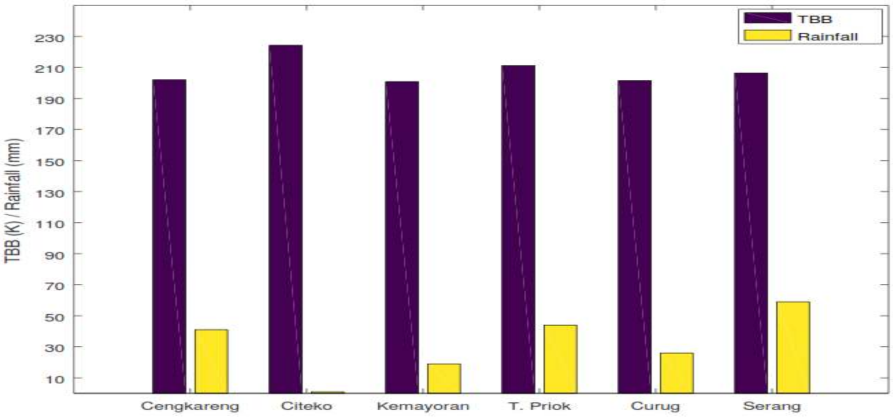

Figure 4. TBB (K) at 0400 LT January 15th, 2013 and rainfall distribution (mm/3 hour) during 0200 – 0400 LT January 15th, 2013 at specific sites around GJ, i.e: Cengkareng, Citeko, Kemayoran, Tanjung Priok, Curug and Serang.

4. Conclusions

The implementation of a graph-theory based algorithm was successfully performed on black body temperature (TBB) dataset, that identified CCS over GJ basins during heavy rainfall event on January 14 - 15th, 2013. We found convective cloud cluster for ≤ 221 K of TBB more than 6 hours (over 16 hours of duration) with average of eccentricity was 0.47. The maximum area of this system was about 249,731.9 km^2 at 0300 LT January 15th, 2013. The eccentricity of these convective system was not match with MCC definition. Then, we defined this convective system as convective cloud system that large, long lived, and very cold of cloud shield. This system was in good agreement with heavy rainfall (more than 40 mm/3h) at 0200 – 0400 LT January 15th, 2013 over GJ basins.

Acknowledgments

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