Rain Detection using Himawari-8 Imagery; Case Study Singkawang West Kalimantan

C S Dharma*, N J Trilaksono

1 Indonesian Navy Center for Hydrography and Oceanography Office, North Jakarta, Indonesia
2 Atmospheric Sciences Research Group, Faculty of Earth Sciences and Technology, Institut Technology Bandung, West Java, Indonesia

Email: meteorobo@gmail.com

Abstract. The occurrence of convective activity often appears in a localized area and short duration. The formation of a low cloud might give an insight into the formation of bigger cumulus that can be seen as a Convective Initiation (CI) and if constantly developing it may lead to a bigger cloud with extreme rainfall. Detection of convective activity that leads to extreme rainfall is important to people who live near shore and areas that prone to flood. Himawari-8 imagery and data from an automatic weather station in Singkawang, West Kalimantan, was applied to detect short time, low-intensity rainfall that had been observed in the equator, near shore, during midnight and early morning. The appearance of CI was analyzed using rapid cloud-top cooling based on Himawari-8 imagery. It was found that the observed rainfall was in agreement with the cloud formations. Those data were validated by three days of a rain event with maximum cumulative rain of 30 mm observed in a single day. There was also appeared a small low cloud that grows into a bigger cloud above the observed area.

1. Introduction
Climate change has many different implications for people’s life, from the changes of an ecosystem and biological diversity through the variations of dissolved minerals in Lake Oubeira in Algeria [1] to the Livinghood of the fisherman in Bengkulu Province in Indonesia [2]. Nowadays climate change increases the possibility of extreme weather occurring in a shorter time [3] as observed in Jakarta and its surrounding areas, and the same pattern of heavy rainfall with shorter periods was also investigated in Korea [4]. The corresponding disaster mitigation by analyzing the rain intensity and duration with sewer size on that area was conducted accordingly.

The local scale convective phenomenon that causes rainfall with extreme intensity is one of the weather anomalies that can cause disasters. Along with the trend of climate change, extreme rainfall events have the potential to become more frequent [5,6,7]. Convective events have other potential hazards that might come together with such as lightning, strong winds [8], also if convective activities come with intensive rains it could lead to floods [9] This incident has the potential to cause unwanted economic losses. Although this phenomenon is difficult to predict, mitigation efforts such as forecasting rain conditions and attempts to make short-term predictions available by using satellite imagery [10]. Satellite imagery with the best temporal resolution for the Indonesian territory is produced by the Himawari-8 satellite that was launched by the Japan Meteorological Agency (JMA) in 2014.
Offshore and inshore propagation of convective activity has been observed on the West Coast of Indonesia region expanding from West Coast of Sumatera and Kalimantan, this mainly driven by the combination of the strength of local wind circulation and the concave shape of the coastline that generate convergence zone and affect local atmospheric stability which can further initiate convective activity [9,11,12,13]. Singkawang was located in West Kalimantan and has a concave coastline, depending on the convective activity, the region might experience an abundance of rain events that might lead to a flood.

This research aims to detect short time high-intensity rain on November 8th, 2017, that was observed by a weather station, located in Singkawang, West Kalimantan validated by convective cloud distribution captured by the Himawari-8 satellite. Those processes would be the proposed mitigation towards the existence of rain that might lead to floods.

2. Data and Method

2.1 Description of the study sites
This study was conducted at Singkawang (Figure 1), West Kalimantan, Indonesia, about 58.9 nautical miles North West of Pontianak, the Capital City of West Kalimantan. Singkawang City has divided administratively into four subdistricts, North, East, West, and South district. Singkawang is located to the East of the North Natuna Sea, The city can be easily accessed by car from Pontianak.

![Figure 1. The location of Automatic Weather Station at South Singkawang, West Kalimantan, Indonesia.](image)

2.2 Material
The data used in this study were Automatic Weather Station (AWS) data from the Indonesian Navy Center for Hydrography and Oceanography (Pushidrosal), located on the green dot on the map in figure 1. Indonesia has a three-time zone, the local time will be mentioned as Waktu Indonesia Barat (WIB = UTC +7) or Western Indonesia Local time. The convention of Internationally renowned for Borneo will be mentioned as Kalimantan in this paper. Also, rainfall data were used from the Tropical Rainfall Measuring Mission 3B42 [14] (TRMM) satellite which observed each 3-hour interval with 0.25 x 0.25 degree resolution. Other supporting data used is the Himawari-8 geostationary satellite imagery, Himawari Standard Data (HSD) which observes every 10 minutes above Indonesian territory. Each data
is then analyzed for rainfall on November 8th, 2017 from 13.50 UTC to 15.00 UTC, when the rain event happens.

Pushidrosal conducted weather observations in Singkawang, West Kalimantan using AWS, the duration of the observations is from the end of October 2017 until December 2018, the AWS data used were the data in November 2017. Based on Climatological data, the West Kalimantan region experienced two peaks of rain events throughout the year, including Singkawang, and in the month of the observation period, namely, November 2017 is the second peak of rainfall (shown in Figure 2) of the rainy season in Singkawang. This generally happens in areas with climate zone B in Indonesia [15].

Figure 2. Rainfall pattern in Singkawang, West Kalimantan 1998-2019. Singkawang has a type B climate region, with two peak rainfall in April and October. The observation period in November is one of the peak rainfall seasons, which is in the second peak of rainfall in Singkawang.

2.3 Methods
This study seeks to determine how the process of short-duration rain was observed on November 8th, 2017, based on AWS, and TRMM observational data also from Himawari-8 satellite imagery. HSD data from the Himawari-8 satellite is processed with two different software, the first is by using Satpy, a python-based satellite data processing module. This module has different composites that can display the spatial spreads of the convective cloud based on the temperature range of the data processing acquired from each of the Himawari-8 band.

Other tools explored in this research is from the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) Nowcasting and Very Short-range Forecasting (NWC) Satellite Application Facilities (SAF) hereinafter abbreviated as NWCSAF, which is in the form of satellite image processing called SAFNWC/GEO version 2018, hereinafter abbreviated as NWC/GEO. NWC/GEO has two methods to predict the thunderstorm, using Convective Initiation (CI) from NWC/GEO CI, this calculates the information of pixels that can evolve into a thunderstorm, and the development of thunderstorm from NWC/GEO Rapid Development Thunderstorm Convection Warning (NWC/GEO RDT-CW).

The CI calculation [16] is processed in several stages; such as the determination of the research area which is Singkawang; processing the pixels in the image that has the potential to become CI’s; then guessing the CI from the 2D movement of each pixel; calculation of cloud cell detection; and tracking its movement, fixing, updating and completing 2D motion calculations for each pixel; calculating static and dynamic characteristics of the satellites by each of the observed pixel; discover the initial CI formation [17] with the boundary parameters of the CI formation requirements, and; in the final stage evaluate the convective activity by assessing the probability of occurrence of the CI and localizing the CI region that is obtained. Those processes can be generally seen in the scheme in Figure 3.

Validation of CI methods [18] will be compared based on the RDT-CW, Cloud Phase product from NWC/GEO calculation. This product was intended to identify, monitor, and tracks the appearance of convective system clouds; detect rapidly developing convective cells from Infrared (IR) Bands, and
updating the position of the convective cells through forecasting information. Generally, RDT-CW products were calculated by the following steps [19], detecting and tracks the cloud systems, determines the convective cloud objects, and finally, forecasting the position of the convective cloud objects. There are four cloud phases for the final product of RDT-CW such as Triggering, Triggering from Split, Growing, Mature, and Decaying.

Rain events that can cause flooding will require four main components [20], namely, rain intensity, rain duration, soil wetness level, and the response of the sewer to the ongoing rain. However, in this study, the discussion will be focused only on the components of rain intensity and rain duration recorded by AWS and Himawari-8. The lowest limit for knowing that the level of extreme rainfall that occurs in a short time has been studied [20], and extreme rainfall stands for 60 minutes or less is 56.8mm, an extraordinary event with rainfall of 37.6mm and the usual rainfall is 24.5mm, while for this study using a reference from the BMKG which uses a rain forecast categorizations such as heavy rain per hour was 10.0 - 20.0mm per hour [21].

Figure 3. The general process of CI determination from NWC/GEO, The first step is choosing the Project Area, The second step is processing NWC/GEO High-Resolution Wind (HRW) data for 2D Movement Field analysis, The third step is Detection and Tracking of Warm Cloud using NWC/GEO CT data. The fourth step is Pixel Image Analysis using NWC/GEO Cloud Mask data, the fifth step is filtering of Day/Night Time Microphysics from NWC/GEO CMIC data, The sixth step is Analyzing Brightness Temperature (BT) and Brightness Temperature Difference (BTD) using specified Himawari-8 bands, and finally CI Diagnosis.

3. Results and Discussion
3.1. Results
In November 2017 there were 21 (twenty-one) rainy days with the largest recorded cumulative rainfall was on November 15th, 2017, the cumulative rain is 36mm but lasting for a total of 8hour observations, and the second one is, on November 8th, 2017, shorter duration with cumulative rain of 30mm from 20.50-22.20 WIB, (Figure 4). This indicates that at that time there was daily rain with moderate intensity, but categorized as heavy rain intensity for one hour of observation. This event will be the main focus of the research. TRMM data was explored for the same periods, and the comparison, there was observed 2,4 and 0.94mm rain, on November 6th and 7th 2017, while slightly higher rain intensity was recorded on November 8th and 9th 2017, each amounting to 4.4 and 3.7mm, as for November 10th and 11th 2017 there was rain with the intensity of 9.8 and 15.1mm, while on November 15th, 2017 TRMM recorded daily accumulated rain of 31.7mm. Both of these data were used as a reference for further analysis with Himawari-8 imagery data.

Some of the favorable atmospheric conditions that could trigger the formation of convective clouds are a sufficient amount of water vapor in the lower troposphere, at the same time, a fairly immense
change in the rate of humidity in the cloud-forming region is also required, followed by vertical movement of humid air masses in the lowest atmosphere to the height of the level of free convection [22]. Daily weather conditions on November 8th, 2017, in Singkawang based on AWS data, the average daily temperature, humidity, and pressure are 27.6°C, 86%, and 1008.1mb. This value decreases in temperature conditions and increases in humidity and pressure conditions. On the same day, at 20.00, 21.00, and 22.00 WIB the condition decreased by 0.4 - 2.9°C for temperature and increased by 8.4% for humidity and 0.8 - 1.3mb for pressure.

Figure 4. Singkawang Daily Cumulative Rainfall Pattern, November 6 to 11, 2017; each of the AWS observations, on November 6th, 2017, amounting to 0.6mm, from 16.10 to 17.00 WIB, with a duration of 60 minutes; November 7th, 2017, 23.4mm, from 12.30 to 14.00 WIB, with a duration of 1 hour 20 minutes; November 8th, 2017, 30.4mm, from 20.50 - 22.20 WIB, with a duration of 1 hour 20 minutes; November 9th, 2017, 4.4mm, from 00.10 to 01.20 WIB early morning, with a duration of 1 hour 10 minutes, and November 9th, 2017 from 08.40 to 11.00 WIB, 16.4mm, with a duration of 2 hours 20 minutes.

Figure 5. Distribution of clouds from IR Cloud Day composite, in Singkawang (Red Triangle) West Kalimantan on November 8, 2017, (from a to c) at 20.50, 21.20, and 22.00 WIB. The image was oriented as North is the upper side, and the South is the bottom side. On the center of the image (on the Left/West side of the red triangle) is the location of Singkawang City, it appears that there is some convective activity developing from the grey shadow cloud region into bright narrow white and becoming a large convective cloud on the right side of the image, at this time the cloud was mostly moving from East of Kalimantan to the West.

In addition to the Infrared (IR) composite for Himawari HSD data processing, Satpy has other composite processing such as colorized IR Clouds (Figure 6), Mid-Vapor (Figure 7), and water vapor
An image of cloud distribution with IR composite on the incident date is shown in Figure 5. Rainfall events observed in this study, mostly occurred at night, while Himawari-8 satellite imagery which is available quickly on the Himawari-8 nict website page did not display cloud distribution at night, so it requires further processing to determine the formation of convective clouds at night. Therefore, the results of Himawari-8 satellite image processing using IR composites are required (Figure 5), so it is possible to detect the formation of convective clouds before, during, and after a rain event. A further distinction of cloud growth from convective activity can be achieved, by applying a Colorized IR Cloud composite, so that it can be distinguished from the growing convective cloud (orange color) from other clouds. The temperature range used in this figure for gray is from 253.13 - 303.15K and for the spectral color the temperature range is 193.15 - 253.15K.

The condition of the distribution of water vapor even though only 1-2% reaching supersaturation to create cloud which is hard for current measurements techniques to observe in the lower to the middle layer 700-300mb is needed in the formation of convective clouds [24], with the support of vertical air movement, the water vapor will condense until it reaches the level of free convection, the distribution of water vapor at a medium height of the atmosphere can be seen by utilizing the mid vapor composite tools in Satpy in Figure 7.

![Figure 6](image)

**Figure 6.** Distribution of convective clouds from Colorized IR Cloud composite, in Singkawang (Red Triangle) West Kalimantan on November 8, 2017, (from a to c) at 20.50, 21.20, and 22.00 WIB. These are the colorized convective clouds from Figure 5, the cloud convective activity can be spotted on the left side of the red triangle, which is Singkawang is located. Convective cloud was yellow-colored from the beginning of its growth, become rapidly grown with the intense dark orange color, and the final development by the widening spread of orange color on the west side of Singkawang.

Although there were many technical considerations regarding the topographic conditions, satellite bias, and observations interval from different satellites [25,26]. The distribution of water vapor during
The formation of a convective cloud generally from Himawari-8 can be seen in Figure 8. The water vapor content inside the cloud is depicted by the bright white color. The water vapor content in the convective cloud was generated by Satpy, with a temperature range of -3.0 - 278.15K.

**Figure 8.** The distribution of water vapor on a convective cloud from Water Vapor2 composite, in Singkawang (Red Triangle) West Kalimantan on November 8, 2017, (from a to c) at 20.50, 21.20 dan 22.00 WIB. Convective cloud usually has a greater amount of water vapor inside, that condensed from vapor to create cloud water and finally rain.

Furthermore, to find out whether the convective activity might as well create a heavy thunderstorm, the detection of how rapid is the cloud generation distributes in the research area, was conducted by using the CI method (Figure 9). The application of the recent development of satellite data processing, from the NWC/GEO software. CI is often used to detect the potential appearance of clouds in the form of pixels in the image that has the potential to grow into storm clouds within a specified time frame, accompanied by atmospheric conditions that support the occurrence of storm clouds in the calculation process [19].

**Figure 9.** The spread of Convective Initiation probability for the next 30 minutes (from a to c) on November 8, 2017, (from left to right) at 20.50, 21.20 dan 22.00 WIB. Based on NWC/GEO Himawari-8 HSD, CI processing, on Singkawang (located on the upper left white box with annotation). CI events mostly formed in the North Natuna Sea and the Java Sea, South of East Kalimantan, but consistently not found in Singkawang. Therefore, heavier weather with thunderstorms might occur for the next 30 minutes in the North Natuna Seas and some parts of the Java Sea.

### 3.2. Discussion

The observed rain events from November 6 to 11, 2017, based on AWS data was insufficient to be categorized as extreme weather that may lead to a flood. The duration of each rain incident was
momentary and the intensity was limited to 30.4mm per hour which appears only on November 8th, 2017. The difference is shown by the value observed between TRMM and AWS also suggests that there is little possibility that the flood will occur during the observed periods.

The application of the CI method for the same periods that have been implemented in this research to detect the convective activity was missed to identify the rapid growth of cumulus clouds on a narrow spatial scale, but when compared to Satpy, both Himawari-8 imagery shows a localized convective activity on the West of Singkawang. One of the reasons that NWC/GEO missed detecting CI near Singkawang, despite the atmospheric conditions, might be the subjective determination of the night microphysics filtering and threshold that had been applied to the calculation [19]. Visual validation of CI with RDT-CW can be seen in figure 10. CI was not observed in Singkawang because the development of the convective cloud shown in the RDT-CW product was not consistent as they alternate the growth rate of the cloud as a decay-mature-decay from 10 minutes observations time interval from 20.00-20.50 WIB.

The changes in the cloud phase might give the visual detection of the cloud to the rain observed by AWS on the ground at 20.50 WIB. The consecutive growth of the convective condition becomes slightly consistent from 21.00-22.50 WIB as the cloud becomes mature. Overall the atmospheric conditions of CI for the convective activity above Singkawang are not significant, compared with the convective activity within the North Natuna Sea, with consistent convective activity combinations of growing-mature-mature from time to time.

4. Conclusions
The application of Satpy software is very useful for detecting convective cloud formation activities. Even though CIs occurrence is well captured with NWC/GEO outside Singkawang, they can be used as a mitigation effort to predict and detect the potential growth of convective cloud that might lead to flood disasters. Validation of rainfall from station data by RDT-CW supported the changes of cloud phase from decaying to mature cloud that produces rain. It also confirms the dismissal of CI above Singkawang because of the inconsistent cloud growth. Further investigation for the determinations of night microphysics filtering, refining the definitions of CI areas, and temperature threshold for CI might be useful for future CI detection in Singkawang.
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