Trends of rainfall regime in Peninsular Malaysia during northeast and southwest monsoons

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Abstract. The trends of rainfall regime in Peninsular Malaysia is mainly affected by the seasonal monsoon. The aim of this study is to investigate the impact of northeast and southwest monsoons on the monthly rainfall patterns over Badenoch Estate, Kedah. In addition, the synoptic maps of wind vector also being developed to identify the wind pattern over Peninsular Malaysia from 2007 – 2016. On the other hand, the archived daily rainfall data is acquired from Malaysian Meteorological Department. The temporal and trends of the monthly and annual rainfall over the study area have been analysed from 2007 to 2016. Overall, the average annual precipitation over the study area from 2007 to 2016 recorded by rain gauge is 2562.35 mm per year.

Keywords: Rainfall; wind; Malaysia

1. Introduction
The Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report showed that some extreme events such as heavy precipitation events and hot extreme heat wave have changes in frequency and intensity [1]. Besides, the total global land precipitation has increased about 2% since the starting of the 20th century also reported by [2]. The rainfall from 1890 to 1980 over 55 Japanese stations have had reported increase in recent decades [3]. During the 20th century in the United States (USA), [4] found that the number of rainy days has increased by 6%. Inversely, Southeast Asia region experienced the reduction in terms of the number of rainy days [5].

Peninsular Malaysia experiences rainfall seasonally with the approximately 2440 mm of rain annually [6]. However, some region of the country receives different amount of annual precipitation. This is due to seasonal variation in Malaysia is mainly influenced by the northeast monsoon and southwest monsoon. During the northeast monsoon, the eastern region in Peninsular Malaysia affected by the massive floods due to the heavy rainfall. Floods are extreme events in Malaysia which may adversely affect economic, social, political and disruption to normal services. Hence, lot of studies have been carried out on extreme events, such as characterizing the events into wet and dry categories [7, 8].

2. Study Area
Peninsular Malaysia is in Southeast Asia within the latitudes of 1° to 7° N and the longitudes of 99° to 105° E (south of Thailand, north of Singapore, and east of Sumatra). Peninsular Malaysia has an area of approximately 130,598 km² (Figure 1) and an estimated population of 23 million. The coordinate of the study area is 05° 33' 05" N, 100° 45' 26" E, which is located at the northern region of Peninsular
Malaysia. Since Peninsular Malaysia is located at the equator and it enjoys a humid tropical climate throughout the year; the weather is warm and humid, and the average temperature approximately 20 °C to 32 °C [9]. The study area experience two pronounced seasons, which are southwest monsoon and northeast monsoon seasons and largely affected by the temperature humidity and heavy rainfall.

Figure 1. Location of study area at Basdenoch Estate, Kedah (05° 33’ 05” N, 100° 45’ 26” E) [10].

3. Methodology
Daily rainfall data from the rain gauge station at Badenoch Estate, Kedah was collected from the Malaysian Meteorological Department ((MMD) from 2007 to 2016. This station was selected with the missing data < 10% as missing data more than 20% could influence rainfall trends estimation [11]. All the rainfall data were recorded based on the automatic tipping rain gauge method and the sensitivity is about 0.5 mm/tip [12]. The 24-h daily rainfall data were collected at 00:00 Universal Time Coordinated (UTC) or 8.00 a.m. local time. On the other hand, 20th Century Reanalysis V2 data provided by the NOAA/OAR/ESRL PSD was utilized to identify the wind vector in the study region throughout the period.

4. Results and Discussion
The monthly and annual temporal variabilities of rain gauge from 2007 to 2016 over Badenoch Estate, Kedah are shown in Figures 2 and 3. The temporal trend of monthly precipitation clearly showed that the seasonal monsoon affects the amount of precipitation over the study area. Overall, the average annual precipitation over the study area from 2007 to 2017 recorded by rain gauge is 2562.35 mm per year. Since the precipitation in Malaysia is seasonal, thus the rainfall amount and the probability of occurrence of rain keep on changing throughout the year [6]. In 2007, the highest amount of total rainfall was recorded over the study area, approximately 3017.9 mm. Inversely, in 2009, the lowest amount of total rainfall was recorded over the study area, which was about 1944.8 mm.
Malaysia is located at Southeast Asia region or the western part of the Maritime Continent. Thus, the precipitation in Malaysia is greatly under the influence of monsoons. Basically, there are two monsoon regimes namely northeast monsoon and southwest monsoon [13]. Meanwhile, the mean synoptic charts of the wind vector (Figures 4 and 5) were also developed for the Malaysia region. The results showed that the monthly wind patterns in Malaysia was determined by the seasonal monsoons. During southwest monsoon (May to August), Malaysia is largely affected by low level southwesterly winds [14]. On the other hand, Malaysian experiences the northeast monsoon in November and ends in February the following year. During this period, most of the southern region of the South China Sea (include Malaysia) affected by the cold surge from northern Asia (Chang et al., 2005). In addition, the region also influenced by the Inter-tropical Convergence Zone (ITCZ) and is usually wetter as compared to southwest monsoon.

Figures 4 and 5 shows the wind vector plots from the analysis data, which is clearly define the ITCZ area. As shown in Figure 4 and 5, there is a clear demarcation between the southwesterly and northeasterly trade wind systems. These two opposing wind components produce an area of strong
convergence at the interface that is associated with the northeast and southwest monsoons caused by ITCZ [15].

Figure 4. The mean wind vector at 1000 mb over the Malaysia region for January – June 2007 to 2016.
Figure 5. The mean wind vector at 1000 mb over the Malaysia region for July – December 2007 to 2016.

5. Conclusion
This study analyzes the trends of rainfall regime in Badenoch Estate, Kedah, Malaysia from 2007 to 2016. The study revealed that the rainfall trends affected by the seasonal monsoon and clearly identify by the synoptic maps of wind vector developed 20th Century Reanalysis V2 data provided by the NOAA/OAR/ESRL PSD. Future study will focus on the evaluation of rain gauge with the satellite product during dry and wet spells. In addition, study about the characterization of rainfall such as the precipitation amount and the extreme precipitation events also can be investigated.
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