Journal of Atmospheric and Solar-Terrestrial Physics 179 (2018) 81–93

Contents lists available at ScienceDirect

Journal of Atmospheric and Solar-Terrestrial Physics

journal homepage: www.elsevier.com/locate/jastp

Southwest monsoon onset dates over Malaysia and associated climatological characteristics

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ABSTRACT

In Malaysia precipitation prevails throughout the year. However, the southwest monsoon (late May to September) is characterised with low precipitation, less cloud, high outgoing long-wave radiation (OLR) and often featured by dry epochs. Therefore, onset of the monsoon here is best determined by considering multiple onset parameters such as wind, OLR, rainfall and relative humidity. We used modified Malaysian Meteorological Department wind shear index based on major convection centres during the monsoon onset. The 850 hPa winds were chosen to investigate the onsets of the monsoon in view of the marked orographic and mesoscale processes. The next criterion was the presence of sustained westerlies averaged between 850 hPa and 600 hPa from all the available radiosonde stations data over Malaysia for at least 5 days. As the strongest convective activity in the tropics is represented by OLR of less than 220 W m^{-2}, the third criterion was to check whether the value of OLR was greater than 220 W m^{-2} over the region. The mean date of the summer monsoon onset over Malaysia is found to be 19 May, with a standard deviation of 8 days. Further, climatological composites show that there is a gradual change from easterlies to westerlies from the surface up to 500 hPa in Malaysian stations both in Peninsular Malaysia and East Malaysia during May. OLR and rainfall analysis reveal that, the southwest monsoon daily rainfall over Malaysia is less than 10 mm and OLR is greater than 220 W m^{-2}. Additionally, monsoon onset tends to be late during the El Niño years and earlier during the La Niña years.

1. Introduction

Malaysia, being surrounded by the Andaman Sea to the west, the South China Sea (Fig. 1), the Sulu Sea and Celebes Sea to the east, is subjected to the seasonal rhythm of the Asian winter and summer monsoons in consonance with the temporal influence and variation of large-scale differential land-sea heating in the Asia continent. However, Malaysia, being in the Maritime Continent, experiences a wet monsoon during boreal winter and a relatively dry season during boreal summer (Chang et al., 2005). Even though the onset of the southwest monsoon over the South China Sea and Malaysia is not as spectacular as that over the Indian subcontinent and in the East Asian region, its uniqueness lies in its simultaneous onset commencement across a large latitudinal belt from 3° N to 20° N (Wang et al., 2004). Therefore, Ta Tao and Chen (1987) and Lau and Yang (1997) suggest that onset of the southwest monsoon in this region can be considered as the pre-cursor to the southwest monsoon onset in the East Asian region.

Determination of the southwest monsoon onset dates and a generally accepted definition of the onset criteria are necessary to assess the extent, impact and the interannual variabilities of the monsoon due to its substantial socioeconomic consequences in the country. For example, during a significant warm phase of the El Niño-Southern Oscillation, forest fires in the neighbouring country are known to cause severe transboundary haze towards Malaysia (Lim and Ooi, 1998, Nichol, 1997, 1998), threatening health and water supply as well as disrupting transport activities. Also, onset criteria based on indices would help to facilitate studies on the monsoon variability and to assess the capability of mesoscale and climate models in simulating and predicting the monsoon variability (Wang and Fan, 1999). Cook and Buckley (2009) and Lin and Luo (2017) employed an easy, objective and applicable approach to determine the timing of the summer monsoon onset and withdrawal in the South China Sea. However, to date,

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https://doi.org/10.1016/j.jastp.2018.06.017
Received 27 September 2017; Received in revised form 29 June 2018; Accepted 29 June 2018

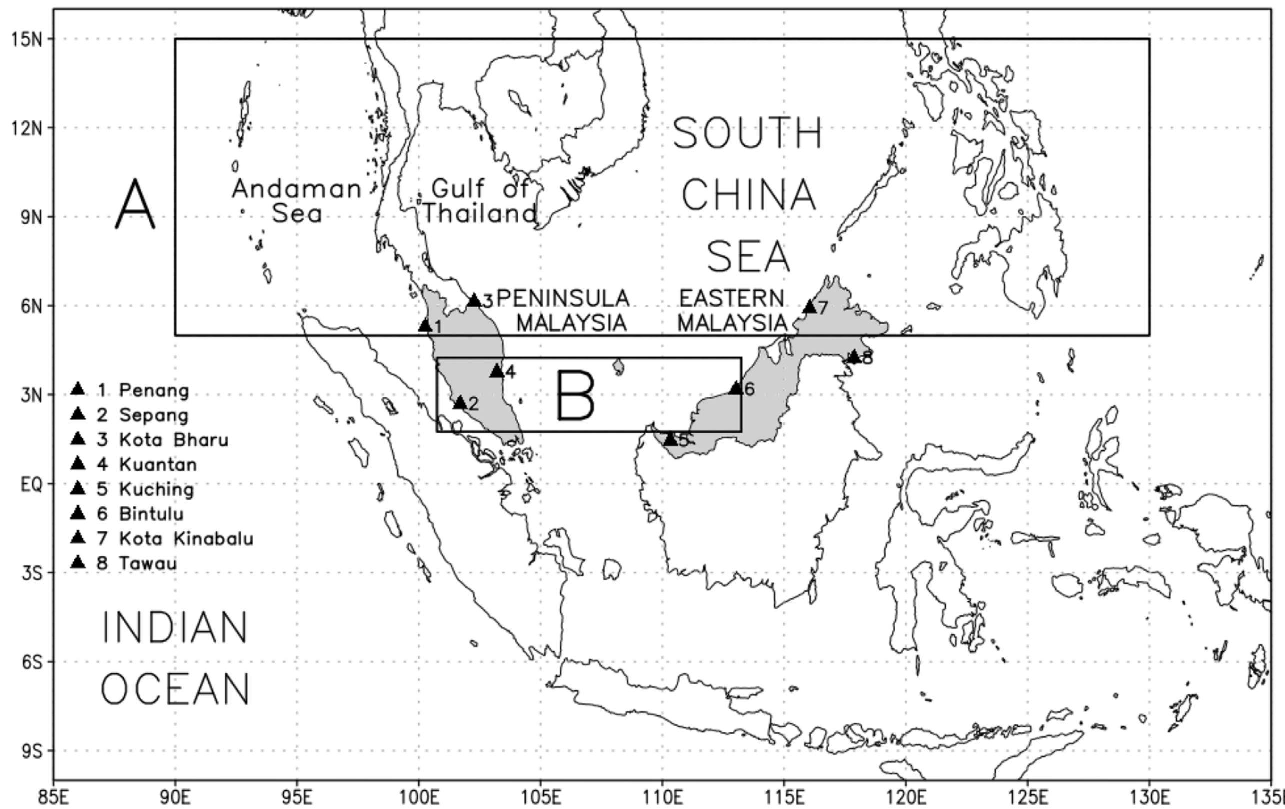

Fig. 1. Topography map of the study region. The box A covers from 90°E to 130°E and 5°N to 15°N and box B from 100.75°E to 113.25°E and 1.75°N to 4.25°N. Peninsular Malaysia and east Malaysia are shaded in grey.

there is no comprehensive work done to define the onset of summer/southwest monsoon in Malaysia.

In a study on Indochina, Orgill (1967) defined the onset of the southwest monsoon as the date when equatorial westerlies at the 700 hPa level extend northwards of 15° N over Indochina. His study indicates that the onset can occur as early as 1 May and as late as 3 June. The mean date falls on 17 May. Owing to the abrupt northward displacement of the near-equatorial trough, Lim and Azizan (2004) are of the opinion that this date could well apply to the Malaysian region. Nevertheless, Matsumoto (1997) noted that the wind system in northern part of the Indochina Peninsula is already southwesterly in April both at 850 and 700 hPa and could basically be mid-latitude westerlies. This thus poses the doubt in the applicability of Orgill's definition of southwest monsoon onset to Malaysia. There are many studies (Chen et al., 1996; Hsu et al., 1999; Qian and Yang, 2000; Jin and Tao, 2003; Wang et al., 2004) conducted to define monsoon onset indices based on low-level or surface winds, precipitation or outgoing longwave radiation (OLR), cloud top black body temperature (TBB) or a combination of some of these and other measured/derived parameters. These led to many different definitions and attempts were made to standardize monsoon onset indices to facilitate intercomparison of research or forecast results. Zeng and Lu (2004) proposed a globally unified monsoon onset and retreat indices based on percipitable water. The summer monsoon onset over India and East Asia is noted to be sudden and dramatic and is accompanied by the commencement of abundant rainfall. The above-mentioned indices are therefore likely to be applicable to these monsoon regions having distinct wet summer and dry winter due to synoptic-scale forcing. Therefore, this study seeks to define better the dates of the summer monsoon onset over Malaysia using reanalysis and observational upper air data and to obtain the characteristic features of the monsoon onset.

We introduce the data and methods used to define the onset dates and to investigate the synoptic conditions associated with the onset dates in Section 2 of this paper. Section 3 examines the criteria used to define the southwest monsoon onset over Malaysia. In Section 4 we determine the onset dates based on the criterion developed in Section 3. Features of the onset in a selected year are analysed and discussed in Section 5. Onset characteristics derived from the composite of various meteorological parameters are then presented in Section 6. Influence of El Niño Southern Oscillation (ENSO) on the onset dates are discussed in Section 7. We summarize and conclude in Section 8.

2. Data and methods

In this study, we used 35-years (1981–2015) of the latest global atmospheric ERA-Interim reanalysis datasets produced by the European Centre for Medium-Range Weather Forecasts (ECMWF). The data used in the analysis are the interpolated dataset to 0.125° from the native T255 horizontal using Meteorological Archival and Retrieval System (MARS) obtained from the European Centre for Medium-Range Weather Forecasts (ECMWF), ERA-Interim (Dee et al., 2011). The data include upper winds, mean sea level pressure (MSLP), sea surface temperature (SST) and outgoing longwave radiation (OLR). It is difficult to describe the characteristics of the large-scale complex monsoon using a single index. Therefore, to facilitate the determination of the monsoon onset dates, we adapted the modified indices by Diong et al. (2015) which was based on the study by Wang and Fan (1999). We used a combination of several observational parameters that were associated with the dynamics and mechanisms of the monsoon variability.

The Tropical Rainfall Measuring Mission (TRMM) rainfall data (available from http://www.esrl.noaa.gov/psd/data/gridded/) was utilized to study the spatial and temporal distribution of rainfall over the Malaysian region during the monsoon onset. The temporal and spatial resolutions of TRMM data are 3 h and 0.25° × 0.25° latitude-longitude grid respectively (Kummerow et al., 1998). Three hourly rainfall data were extracted for the period 1999–2011 and the monthly