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Review of the May-October 2017 Southwest Monsoon in Malaysia

By
Diong Jeong Yik, Yip Weng Sang,
Nursalleh K Chang, Azlai Ta'at

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Abstract

The 2017 Southwest monsoon in Malaysia began on 16 May 2017 and ended on 23 October 2017. Both the synoptic features of the onset and withdrawal generally agreed with the large scale climatology features of the southwest monsoon. During this southwest monsoon, westerlies were generally weak over the South China Sea region. At the lower troposphere, the monsoon trough migrated northwards as the season progressed and by September the monsoon trough began to move equatorward signaling the slow withdrawal of the monsoon. In the upper troposphere, the Tropical Upper Tropospheric Trough (TUTT) was very well established by July but weakened after that. The large scale climatic drivers such as the El Nino-Southern Oscillation **(**ENSO) and the Indian Ocean Dipole (IOD) remained neutral during this season. Consistent with the weaker monsoon, except for July and October, the whole country received above-normal rainfall. During the peak of the monsoon, four major maximum rainfalls were observed with each maximum rainfall occurring 35 days apart. Spectral analysis on the season's rainfall revealed that besides the 30-60 days mode, a broad spectrum between 10-20 days and 4-6 days was also very prominent. The Pacific typhoon season which usually peaks during the southwest monsoon was relatively inactive in 2017. Most of the typhoon during this season occurs in July.

Introduction

The southwest monsoon in Malaysia is part of the Asian Summer monsoon regime. Due to the prevailing south westerly wind during this time of the year, it is known as the southwest monsoon by the locals. It usually begins in mid-May and ends in mid-October during which the monsoon trough was located in the north of the Malaysian region. Hence, one would expect less rain to occur due to the absence of any large-scale weather systems during this time of the year. Nevertheless, rain can be expected during the break phase or lull period of the monsoon. As a whole, the 2017 Asian summer monsoon which lasted from May to October was slightly weaker than normal.

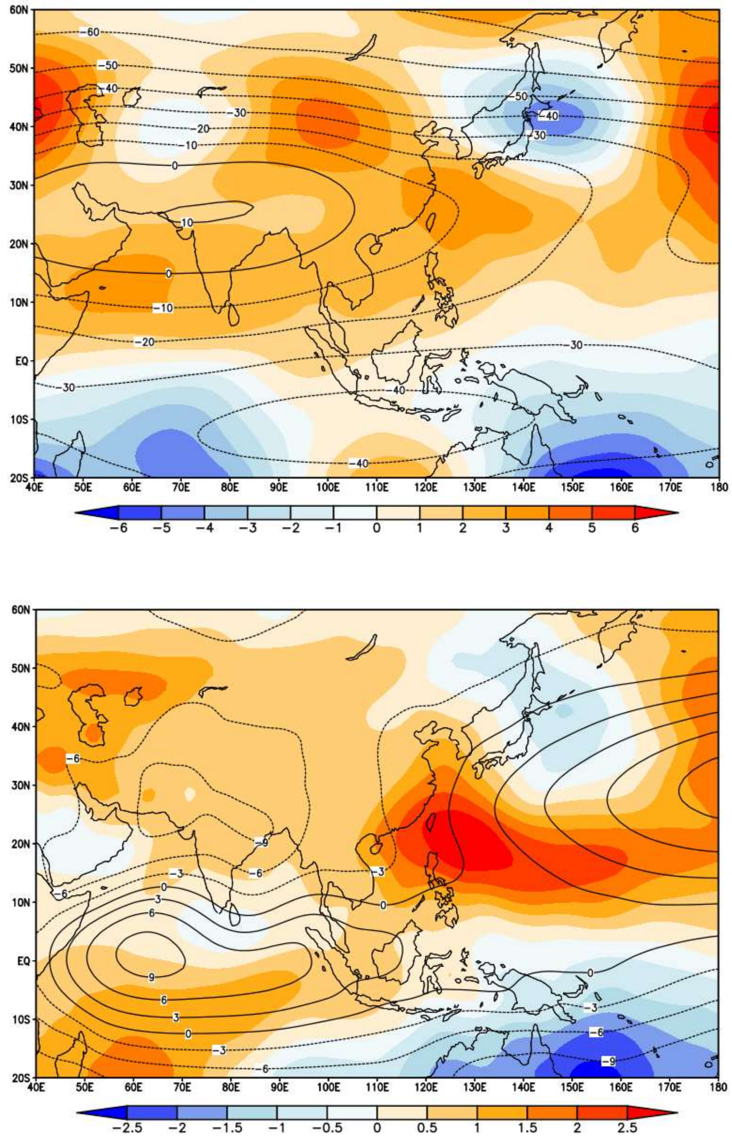
1. Data

To depict the atmospheric circulation, the Japanese 55-year Reanalysis (JRA-55, Kobayashi et al., 2015) data were used in this report. The sea-surface temperature conditions and Nino Indices were provided by the Climate Prediction Center (CPC), National Ocean and Atmospheric Administration (NOAA). The Dipole Mode Index which measures the temperature gradient between the western equatorial Indian Ocean and the southeastern Indian Ocean was obtained from the Japan Agency for Marine-Earth Science and Technology (JAMSTEC). The outgoing longwave radiation (OLR) data were used as a proxy for tropical convective activity. These data were taken from NOAA and the base period for the normal was taken from 1981 to 2010. Stations rainfall data from the Malaysian Meteorological Department were utilised in this report while gridded rainfall data were obtained from the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS). The anomalies used in this report refer to the deviation from the normal. Pentad refers to the 5-day mean.

2. Overview of Asian Summer Monsoon circulation and convection

The 2017 Asian summer monsoon which lasted from May to October was slightly weaker than normal. Although in the upper troposphere, the Tibetan High was stronger than normal (**Figure 1a**), the weak summer monsoon circulation was evident in the lower troposphere. The low-level Somali jet was located between the equator and 10ºN, and the monsoon circulation was weaker than normal (**Figure 1b**).

Anomalous low-level cyclonic circulation was observed over the southern Indian subcontinent and in the southern Indian Ocean. In the northwestern Pacific region, the subtropical ridge at 850-hPa was remarkably strong and penetrated the southeastern coast of China. The monsoon trough in the Southeast Asia region was slightly weaker than normal. This showed that the monsoon in Southeast Asia and the Indian subcontinent were slightly weak.



(a)

(b)

Figure 1: Four-month (June-September 2017) mean stream function and its anomaly. (a) Mean stream function and its anomaly at 200-hPa. Contours indicated mean stream function at intervals of 1×10^{6} m^2/s while colour shadings indicated departure form climatological mean. (b) Similar to (a) except at 850-hPa. The climatological mean was calculated using data from 1981-2010. Positive (negative) anomalies indicated clockwise (anti-clockwise) circulation.

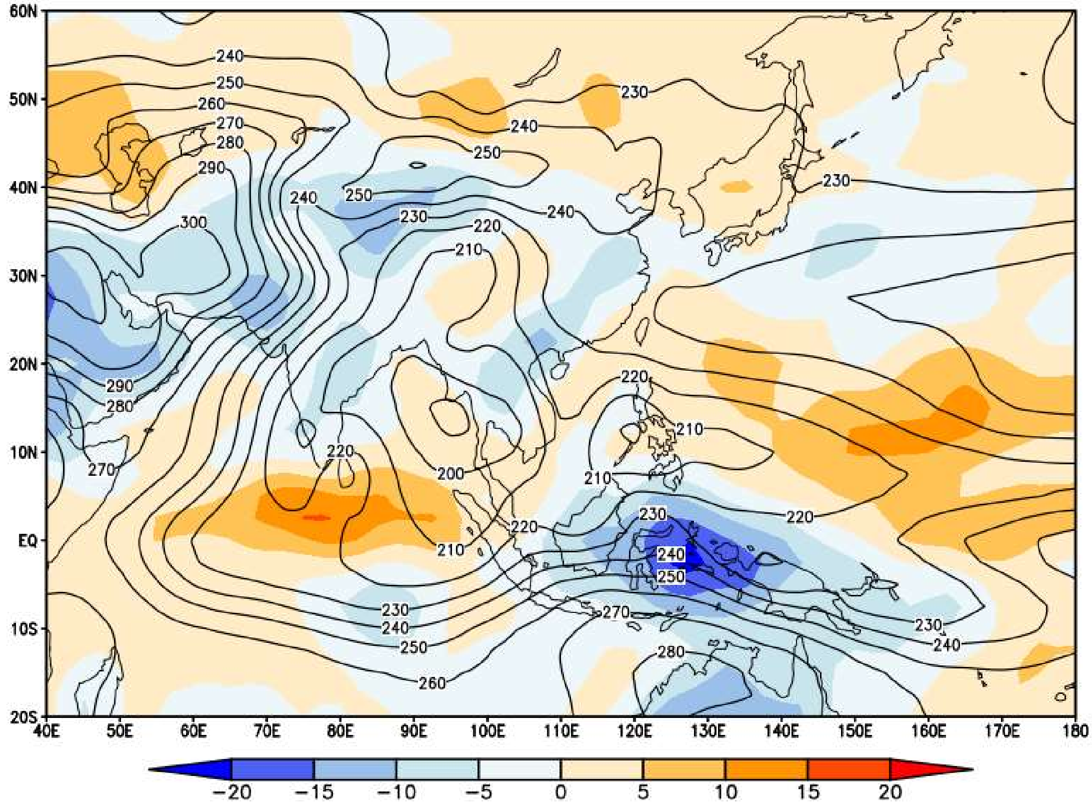


Figure 2: Four-month (June-September 2017) mean outgoing longwave radiation (OLR) and its anomaly. The colour shadings indicated the anomalies OLR (W/m^2) from normal (1981-2010). The contours depicted the mean four-month OLR. Positive anomalies denote suppressed convection while negative anomalies denote active convection. For mean value OLR, in the monsoon region, active convection values were below the 240 W/m^2 threshold.

The convective activity in the region was suppressed in the Bay of Bengal region, in the Indian Ocean, western Maritime Continent, and the western Pacific Ocean (**Figure 2**). The anomalous convection band was mainly confined in the eastern Maritime Continent, in the West Asia region, and along the east coast of mainland China. This was in contrast to the normal monsoon season where the main convection band was located north of 5°N, extending from the Bay of Bengal towards the equatorial western Pacific.

3. Onset and Withdrawal of the monsoon in Malaysia

Climatologically, Malaysia experienced relatively dry weather during the southwest monsoon. The arrival of the relatively dry weather in 2017 roughly coincided with the onset of the southwest monsoon (**Figure 3,** top), defined by using the SWMI (Diong et al., 2015). The onset and withdrawal of the monsoon were defined on the first day of the 5-day consecutively when the index turns negative and positive, respectively. In Malaysia, the onset of the 2017 monsoon which was indicated by the negative meridional shear fell on 16 May 2017 while the withdrawal of the monsoon fell on 23 October 2017.

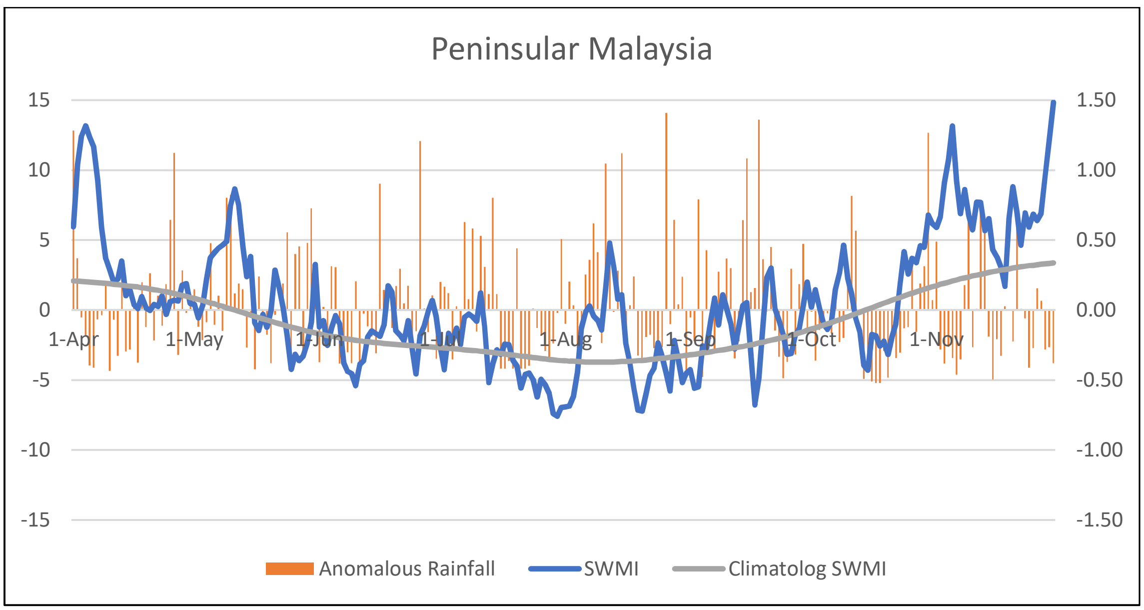


Figure 3: SWMI (blue line), climatology (grey line), and standardised daily rainfall in Peninsular Malaysia (red bar).

3.1 Synoptic features of monsoon onset

Figure 4 shows the evolution of the low and upper-level tropospheric circulation, one pentad before the onset and one pentad during the onset. At the 850-hPa, one pentad before the onset, a pair of cyclonic vortex straddling the equatorial region in the eastern Indian Ocean was observed (**Figure 4a**). At the same time, the subtropical ridge was still seen around the Indochina Peninsular. With the monsoon trough located around 5°N, south westerlies were observed in the Peninsular Malaysian region for the first time since early May. In the upper troposphere, the 200-hPa northern subtropical ridge was located around 10°N-12°N. Two anticyclonic vortices were embedded in this ridge (**Figure 4c**). The upper-level wind in the Malaysian region and the South China Sea (SCS) region remained zonal easterlies. These pentad circulations for the two tropospheric levels before the onset were consistent with the climatology circulation before the onset.

The southwesterlies from the previous pentad persisted and were also observed in the onset of pentad (**Figure 4b**). This indicated the arrival of the monsoon in Peninsular Malaysia. In Borneo, the wind was generally southwesterlies to north easterlies. At this point, a notable change in the northern hemisphere circulation was noted when the cyclonic vortex in the Bay of Bengal shifted northeastward. Corresponding to this shift, the monsoon trough shifted north to around 15°N, in the vicinity of the Indochina region. This monsoon trough replaced the subtropical ridge which retreated eastward together with the subtropical high. In the upper troposphere, the anticyclonic vortex in the SCS moved northwestward to its new location in the Indochina region (**Figure 4d**). This strengthened the northeasterlies flow in the Malaysian and SCS regions. The southwesterlies in the lower level and the northwesterlies in the upper level completed the monsoon circulation in these regions. These circulation features corresponded well with the climatological onset circulation features.

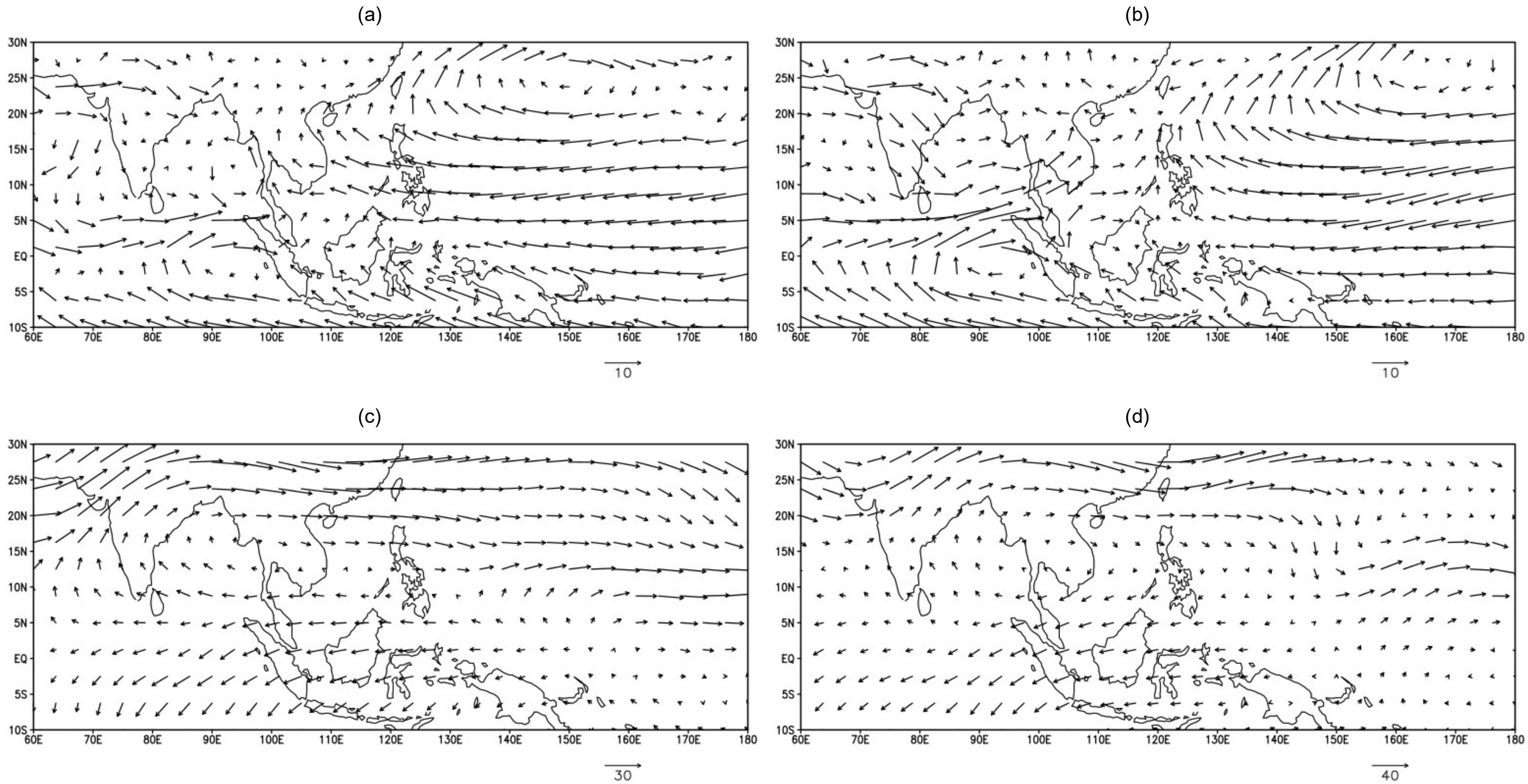


Figure 4: 850-hPa circulation at (a) one pentad before the onset, (b) during the onset pentad. 200-hPa circulation at (c) one pentad before the onset and (d) during the onset pentad. The onset pentad was calculated five days from the beginning of the onset date.

3.2 Synoptic features of monsoon withdrawal

The evolution of the lower and upper levels of tropospheric circulation for the withdrawal pentad and one pentad after withdrawal are shown in **Figure 5**. During the withdrawal pentad, the Indochina region was dominated by 850-hPa easterlies (**Figure 5a**) with the presence of the monsoon trough to the south of this region. This showed that the summer monsoon had withdrawn from the Indochina-Bay of Bengal region. To the north at 15°N in the SCS, with the southward movement of the monsoon trough, the subtropical ridge started to penetrate the region. In the Malaysian region, as the monsoon trough still located north of Peninsular Malaysia, the region was dominated by weak westerlies. In the upper troposphere, the circulation over the SCS region was dominated by the northeasterlies (**Figure 5c**). At this level, the subtropical ridge was located at around 25°N. An anticyclonic vortex was embedded within this ridge.

One pentad after the withdrawal, the 850-hPa monsoon trough in the SCS retreated westward (**Figure 5b**). By this time, the low-level winds over the southern SCS region and the Malaysian region weakened considerably and the direction became variable. In the north, easterlies penetrated further into the Indochina region. A pair of the cyclonic vortex was seen straddling the equatorial region to the west of 100°E. In the upper troposphere circulation, the subtropical ridge at 200-hPa (**Figure 5d**) near the Asiatic landmass weakened while the anticyclonic vortex over the Asiatic land shifted eastward and retreated from the continent. These synoptic features in the low and upper-level of the troposphere showed that the monsoon withdrew completely from the Malaysian region during this time.

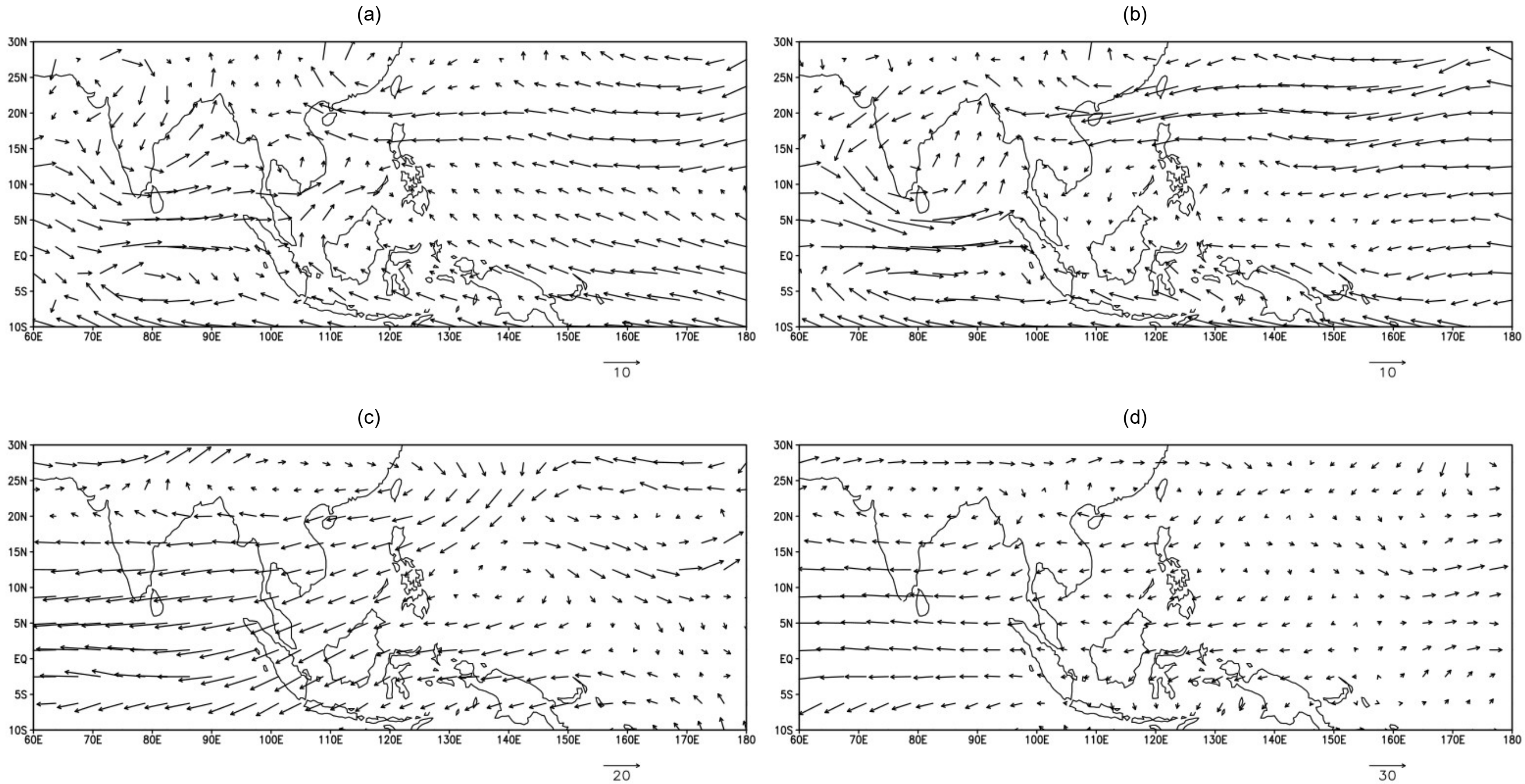


Figure 5: 850-hPa circulation at (a) during the withdrawal pentad, (b) one pentad after the withdrawal pentad. 200-hPa circulation at (c) during the withdrawal pentad and (d) one pentad after the withdrawal pentad. The withdrawal pentad was calculated five days from the beginning of the withdrawal date.

4. Mean zonal wind and monthly circulation

Figure 6 depicts the time-longitude mean 850-hPa zonal wind averaged between 10ºN and 30ºN from 1 June to 15 October 2017. The westerly flows were represented by warm colour shadings while the easterly flows were represented by cold colour shadings. It could be seen that the westerlies in the southern China region (110ºE - 120ºE) were particularly weak. In the western North Pacific, the ridge was strong and rarely retreated eastward except during late July and early August. By the first week of September, the monsoonal westerly winds retreated westwards and South China was dominated by easterly winds originated from the western Pacific Ocean. This indicated the gradual withdrawal of the Asian Summer monsoon.

In May 2017, the low level (**Figure 7a**) subtropical ridge was observed in the western Pacific Ocean between 10°N and 25°N. This subtropical ridge had retreated from the South China region. In addition to this, the double trough feature near the equator vanished and the monsoon trough was located stretching across northern India, passing through the Bay of Bengal, and connecting to Myanmar between 10°N and 20°N. In the upper troposphere (**Figure 7b)**, the northern subtropical ridge was observed stretching across the Bay of Bengal to the western Pacific Ocean between 10°N to 15°N. An anticyclone was embedded in this ridge at around the center of the Indochina Peninsular. This ridge shifted towards the northeast direction relative to its position in April 2017 (figure not shown) and it laid close to its climatological mean position. In the lower level, south westerly to westerly winds of 5 knots were observed in Malaysia while in the upper level, the north easterly wind prevailed at the speeds of between 20 knots to 25 knots. The strengthening of the north easterlies from 15 knots to 20 knots in April to 20-25 knots in May together with other features signalled the arrival of the summer monsoon in this region.

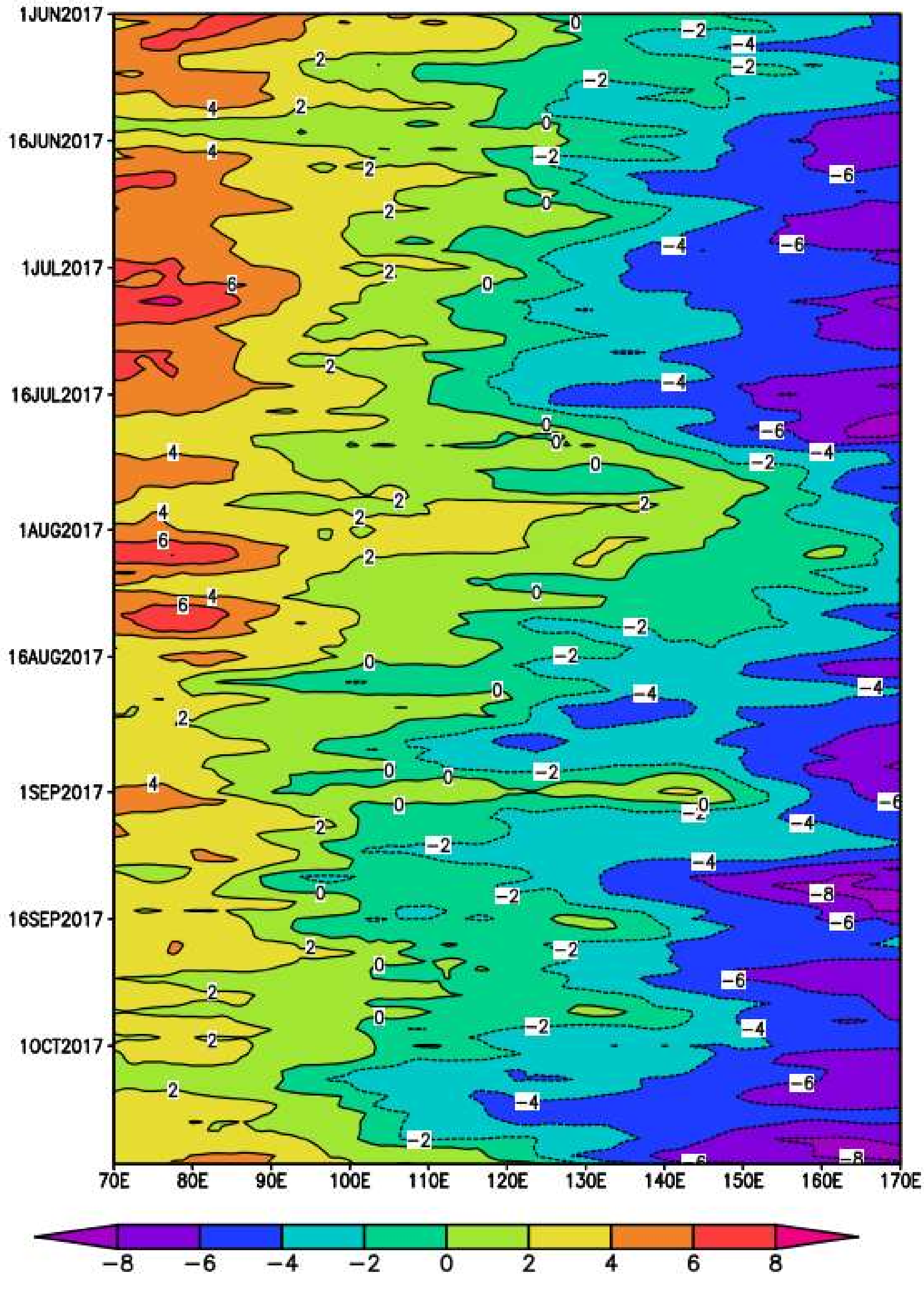
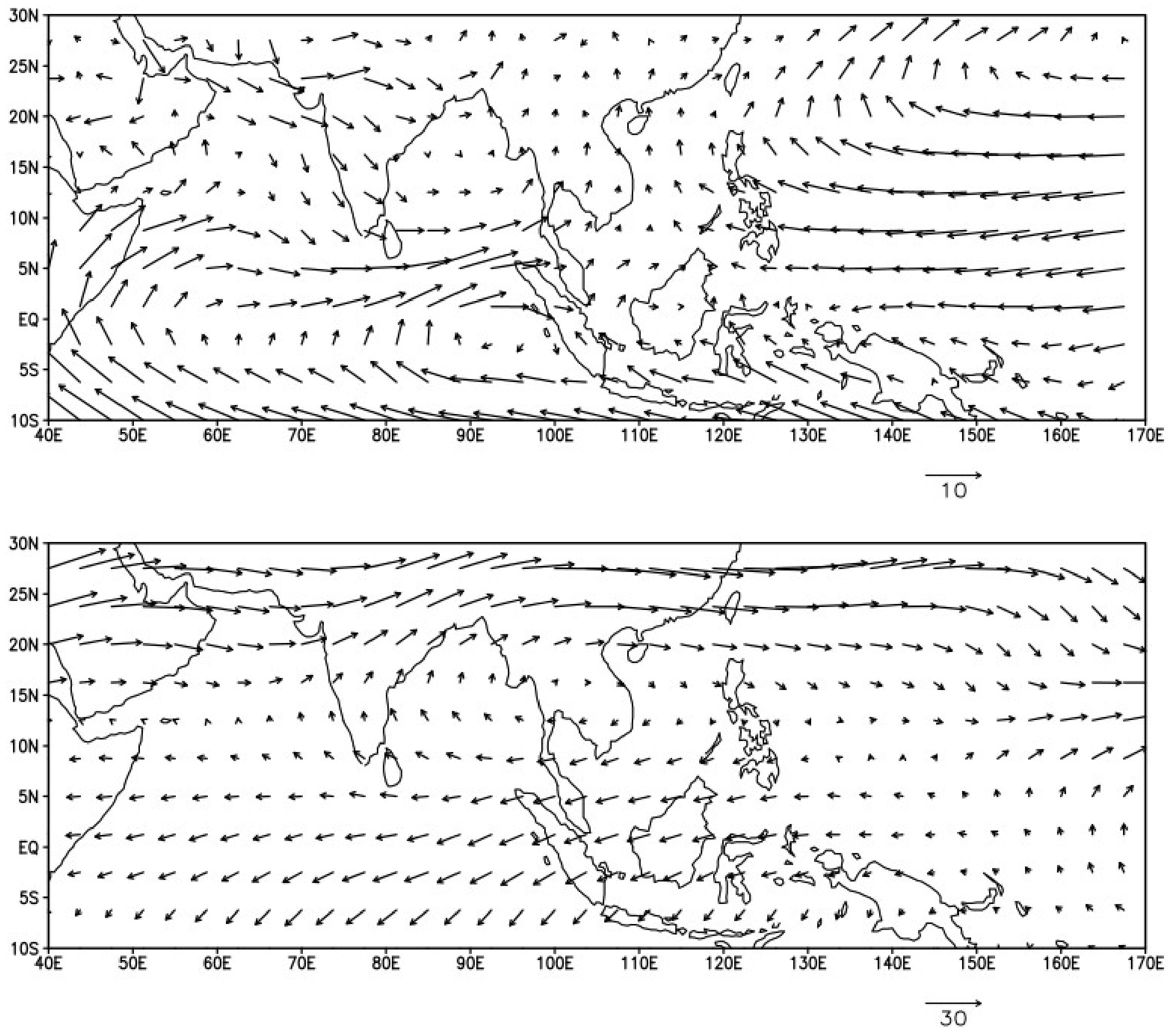


Figure 6: Time-Longitude mean of 850-hPa zonal wind averaged between 10ºN and 30ºN from 1 July to 31 October 2017.



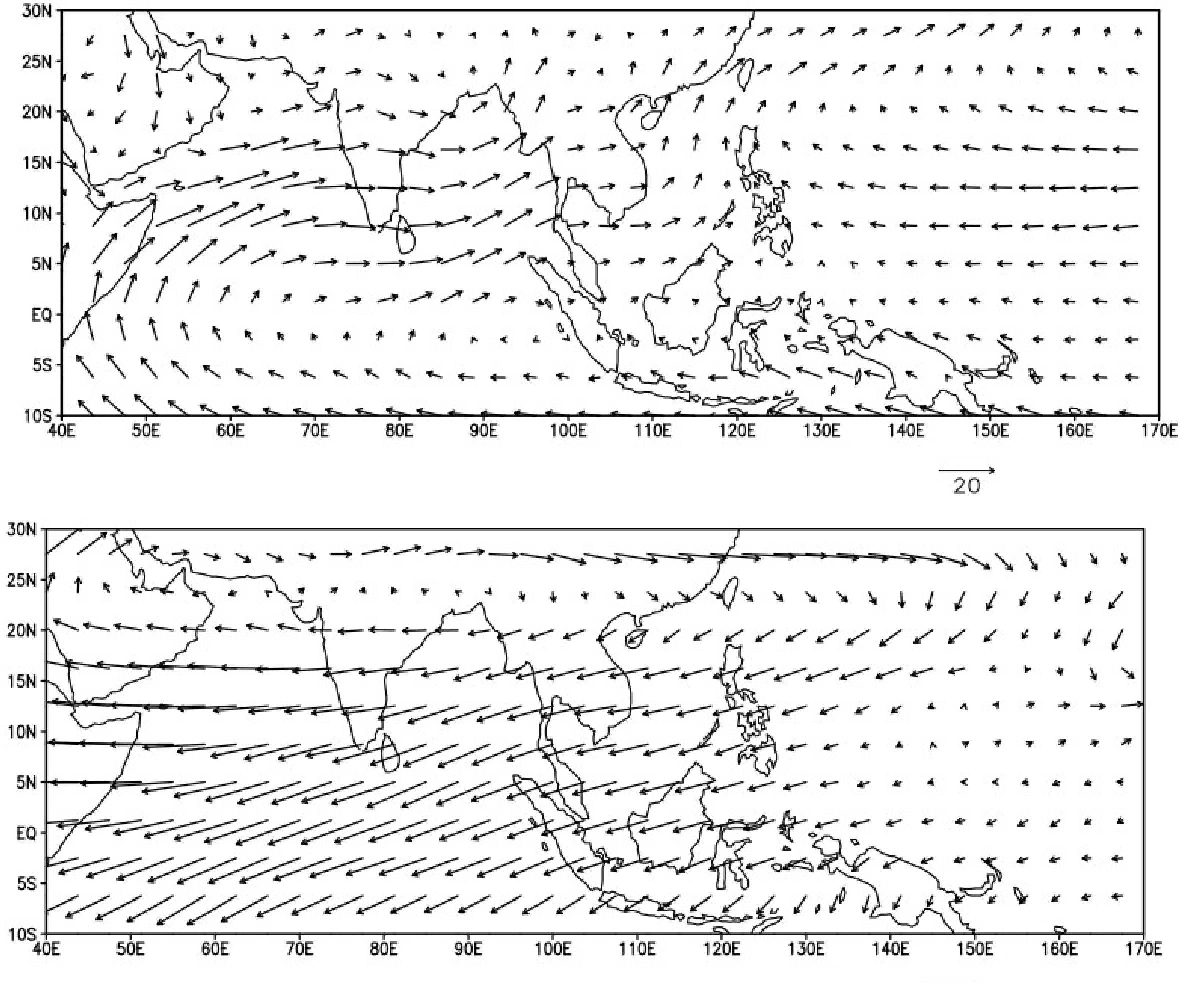
(a)

(b)

Figure 7: May circulation. (a) shows 850-hPa wind circulation while (b) shows 200-hPa wind circulation

The 850-hPa circulation for June is depicted in **Figure 8a**. The subtropical ridge during this time was located near its climatological mean position extending from the northwestern Pacific towards the Pacific basin. The monsoon trough had shifted by about 10° latitude north from its position in May and was observed to extend from the north of the Indian sub-continent between 20°N-30°N to the southern east coast of China. In the Indochina-South China Sea region, the monsoon trough was weaker than normal. Meanwhile, in the upper-level circulation, an elongated east-west subtropical ridge was observed in the 20°N-25°N latitude belt with an anticyclonic vortex located in the Bay of Bengal region embedded in it (**Figure 8b**). This subtropical ridge axis had shifted north relative to its position in May while the anticyclonic vortex had shifted northwestward. The Tropical Upper Tropospheric Trough (TUTT) which is known to provide a favourable condition for the genesis of tropical storms in the Pacific basin was located between 160°E-170°E. Furthermore, in the SCS region, westerly to southwesterly winds between 5 knots to 10 knots prevailed at 850-hPa level while stronger winds of 20 knots were observed over the Bay of Bengal region. In the upper-level, strong northeasterlies of 30 knots persisted over the whole SCS region. Both the upper and low-level circulation had intensified since May.

The low-level circulation for July is shown in **Figure 9a**. The monsoon trough at 850-hPa continued its northward migration since June and was located at around 25°N in the northern Indian sub-continent. This trough spanned across the northern Indochina and slanted southeastward to around 5°N in the western Pacific. At the same time, an east-west orientation of 200-hPa subtropical was located between 25°N-30°N (**Figure 9b**). In the previous month, TUTT strengthened and became pronounced during this time. The upper-level northeasterly winds dominated the Malaysian region at a speed of 35 knots to 40 knots, which were stronger than the winds in June. In the lower-level, weak southwesterly winds at around 5 knots were observed over the southern part of Peninsular Malaysia, Sabah, and Sarawak while the northern part of Peninsular Malaysia experienced stronger south westerlies during this time.



(b)

Figure 8: Same as Figure 7 but for June circulation

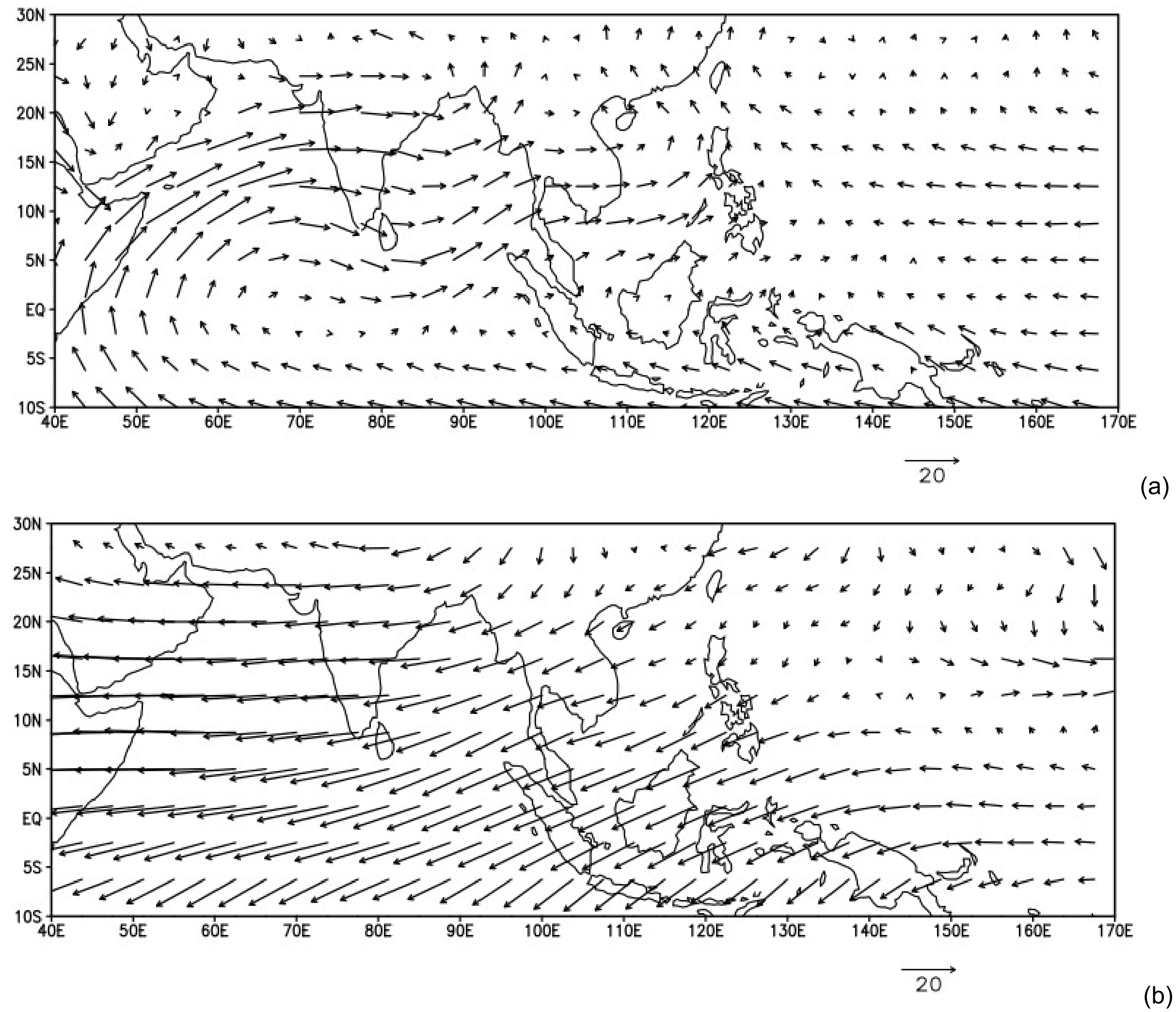
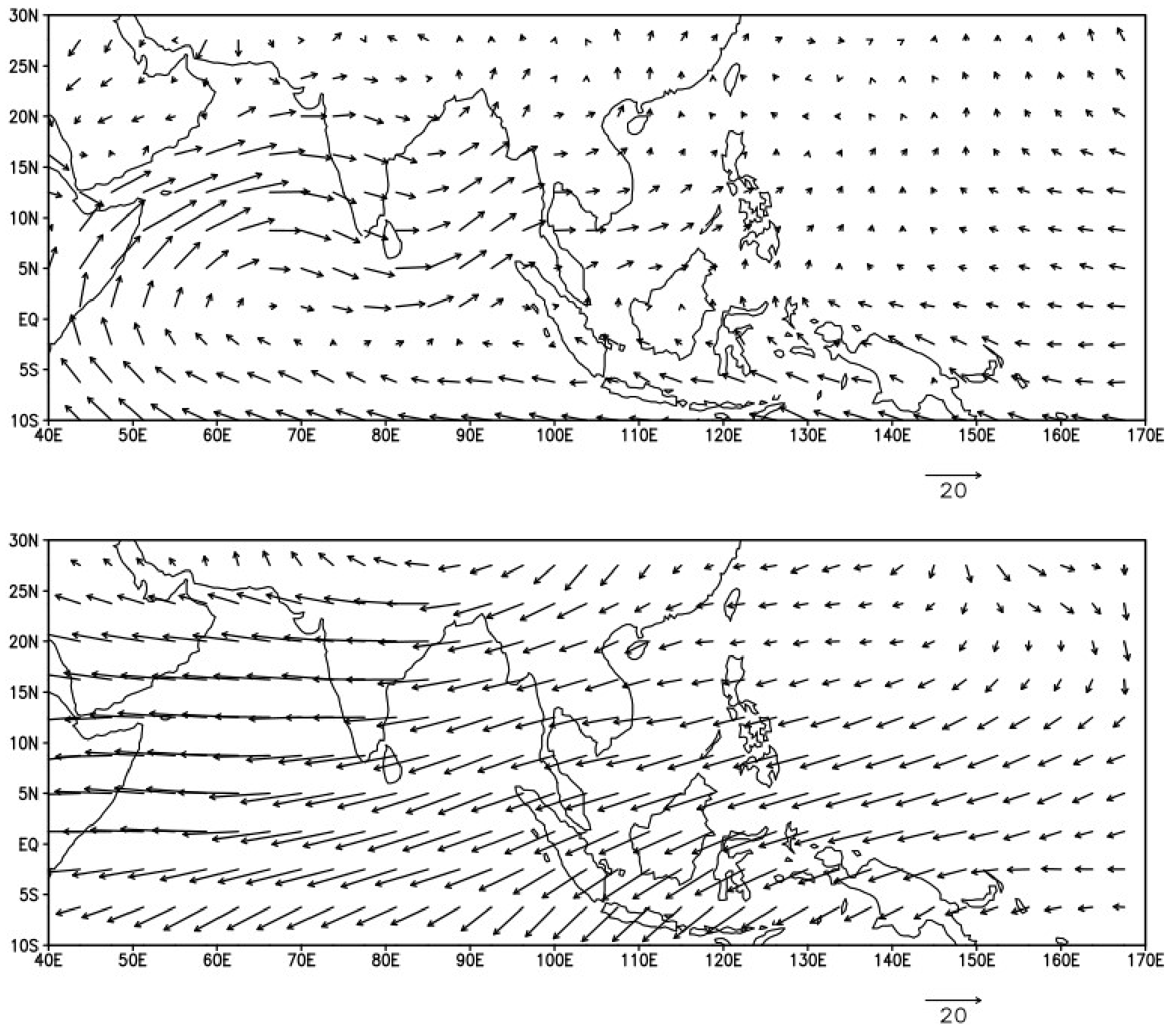


Figure 9: Same as Figure 7 but for July circulation.

In August, the axis of the monsoon trough at 850-hPa was quasi-stationary since July, except in the western Pacific, where the monsoon trough had migrated north from 5°N to around 15°N (**Figure 10a**). In tandem with the movement of the trough in the western Pacific, the axis of the subtropical ridge in the western Pacific also migrated poleward. However, the monsoon trough as a whole was still located slightly southwards from its climatological mean position. At 200-hPa, the subtropical ridge was also quasi-stationary with an east-west elongated ridge axis and located near its mean climatological position (**Figure 10b)**. The low-level westerly winds dominated the Malaysian region. In the upper-level troposphere, the Malaysian region was dominated by the northeasterly winds with a speed of around 35-40 knots.

Figure 11a shows the 850-hPa subtropical in September was located between 20°N-30°N while the monsoon trough started to migrate southward to around 10°N-15°N in the SCS region. The monsoon trough extended southeastward from around 30°N in northern India towards the western Pacific at around 10°N. In the upper troposphere, the northern subtropical ridge also started to migrate equatorward (**Figure 11b**). With the movement of the subtropical ridge, the anticyclonic vortex was located around the eastern edge of the Tibetan Plateau. The upper-level northeasterlies in the Malaysian region became more zonally with a slight decrease in the wind speed, from around 35-40 knots in the previous months to around 30 knots. In the lower troposphere, the region was dominated by weak south westerlies.

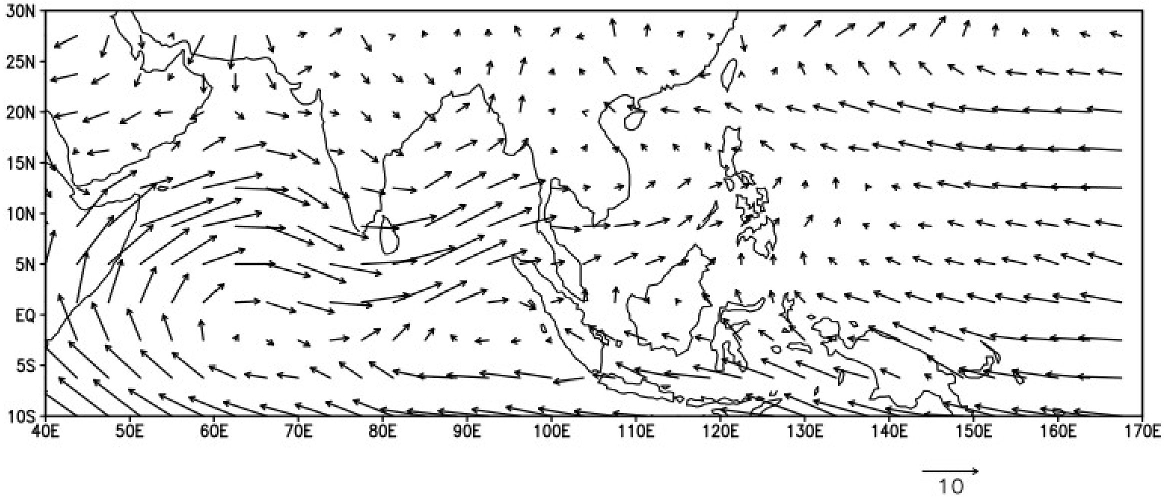
In October, the monsoon trough at 850-hPa remained at around 10°N (**Figure 12a**). This east-west trough was located near its mean climatological position. With the migration of the trough, the subtropical ridge intruded westward. In the upper troposphere, the subtropical ridge migrated equatorward. It laid across the Indian subcontinent extending towards the western Pacific at the latitude between 15°N-20°N (**Figure 12b**). The anticyclonic vortex had moved southeastward indicating the withdrawal of the summer monsoon in the region. Over the Malaysian region, the upper level was dominated by zonal easterlies with a speed between 15-30 knots while in the lower troposphere, prevailing westerlies between 5-10 knots were observed.



(a)

(b)

Figure 10: Same as Figure 7 but for August circulation



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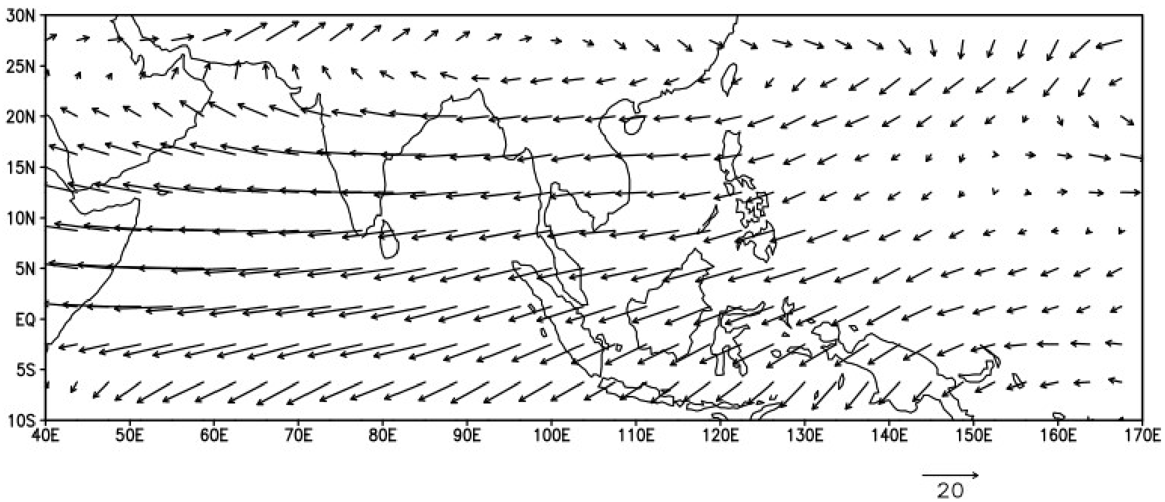
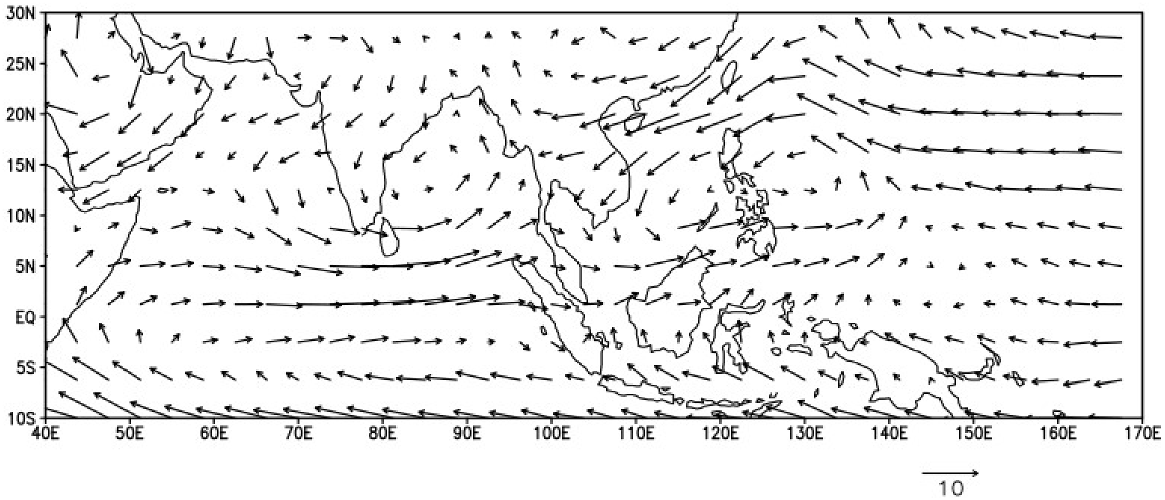


(b)

Figure 11: Same as Figure 7 but for September circulation



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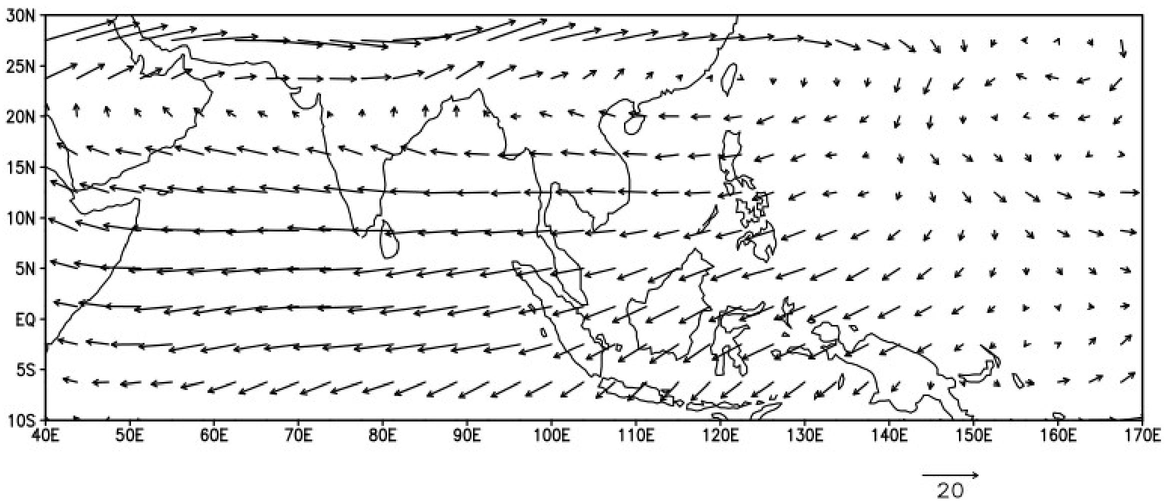

(b)

Figure 12: Same as Figure 7 but for October circulation

5. Sea surface temperature

5.1 El Nino-Southern Oscillation (ENSO) condition in the Pacific Basin

In July 2017, across the central and eastern Pacific Ocean, most of the average sea surface temperatures (SSTs) showed near to above mean condition. These near to above mean SSTs receded east of the dateline in August. With these SSTs distributions in the basin in August, the convection was evidently suppressed near the dateline, while it enhanced in the equatorial eastern Maritime Continent. Across the central and eastern Pacific, the SSTs were observed to have been near to below mean condition since September. During this time, the enhanced convection center shifted north and located near the Philippines while the convection in the dateline remained suppressed. Across most of the tropical Pacific Ocean, the low-level trade winds were near average while the upper-level winds were anomalously westerly. The ocean and atmospheric conditions during the summer monsoon remained consistent with the El Nino-Southern Oscillation (ENSO) neutral conditions.

5.2 Indian Ocean Dipole (IOD)

In the Indian Ocean, the Dipole Mode Index (DMI) which is an indicator to show the Indian Ocean Dipole (IOD) indicated a neutral IOD throughout the period although the index values had generally been above zero since January 2017. During the neutral IOD phase, the ascending branch of the Walker circulation could be found around the eastern Maritime Continent while the descending branch was located in the western Indian Ocean basin during the whole boreal summer monsoon. Due to waters from the Pacific flowed through the marginal seas surrounding the eastern Maritime Continent and towards the Indian Ocean, the sea surface temperatures in the tropical Indian Ocean remained close to normal.

6. Precipitation

Figure 13 depicts the average monthly mean rainfall in Peninsular Malaysia and Borneo from May to October 2017. From the figure, it was noted that the average monthly mean rainfall in July and October was slightly below normal while the rest of the months recorded above mean rainfall in Peninsular Malaysia. In Borneo, July was the only month that recorded below-average monthly rainfall. However, unlike in Peninsular Malaysia, the October rainfall in Borneo remained normal. Slightly higher rainfall were recorded in other months throughout the country during this time.

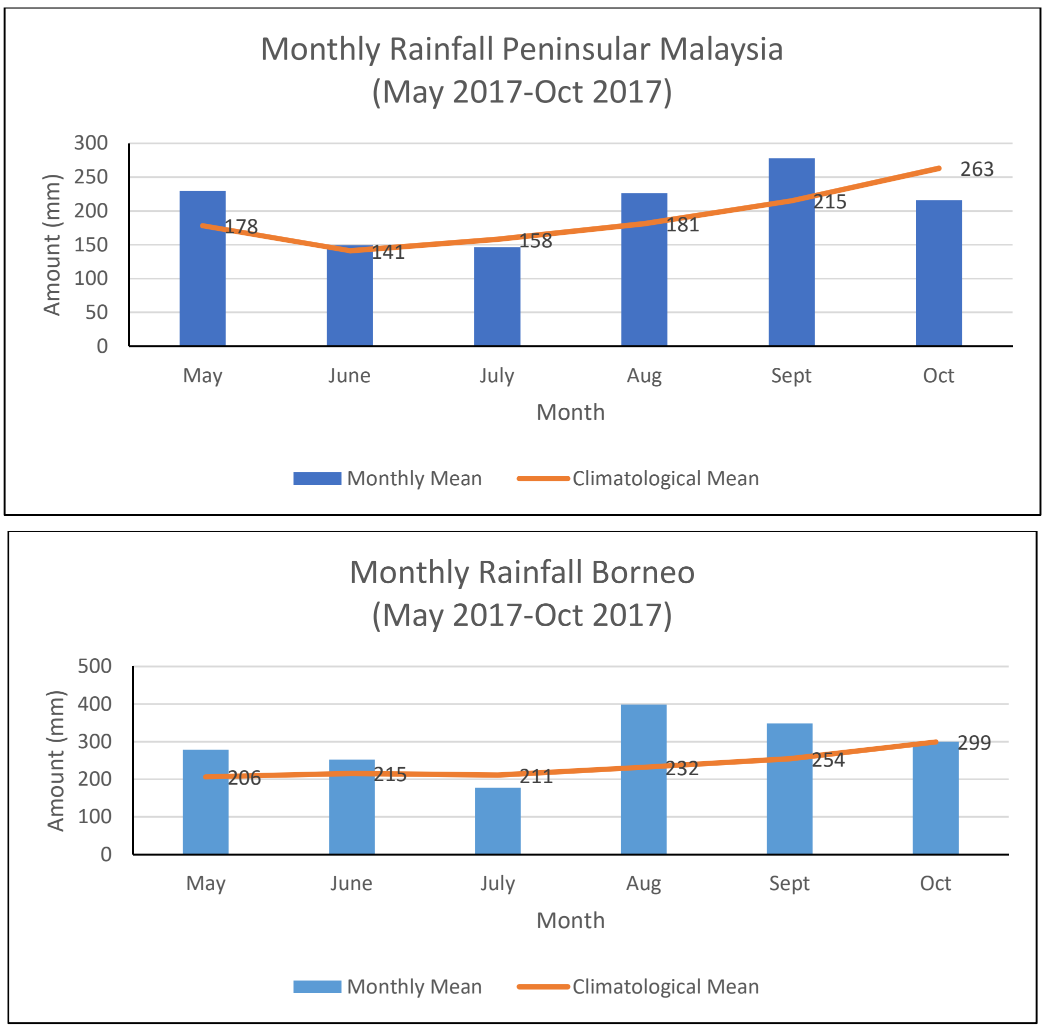

Figure 13: Average Monthly Mean Rainfall in Peninsular Malaysia (top) and Borneo (bottom)

To elucidate the spatial-temporal rainfall distribution during the peak of the 2017 summer monsoon, the anomalous rainfall starting from June to September 2017 were calculated (**Figure 14**). There was a clear northwest-southeast contrast in the rainfall distribution in Peninsular Malaysia with the northwestern region receiving above normal rainfall and the southeastern region receiving below normal rainfall. In Borneo, the whole state of Sarawak received below normal rainfall. The rainfall distribution during this season in Sabah was delineated into the east coast and west coast and the interior region. It should be noted that the rainfall distribution in Sabah during this time of the year was known to be influenced by the presence of tropical disturbances and typhoons in the western Pacific region.

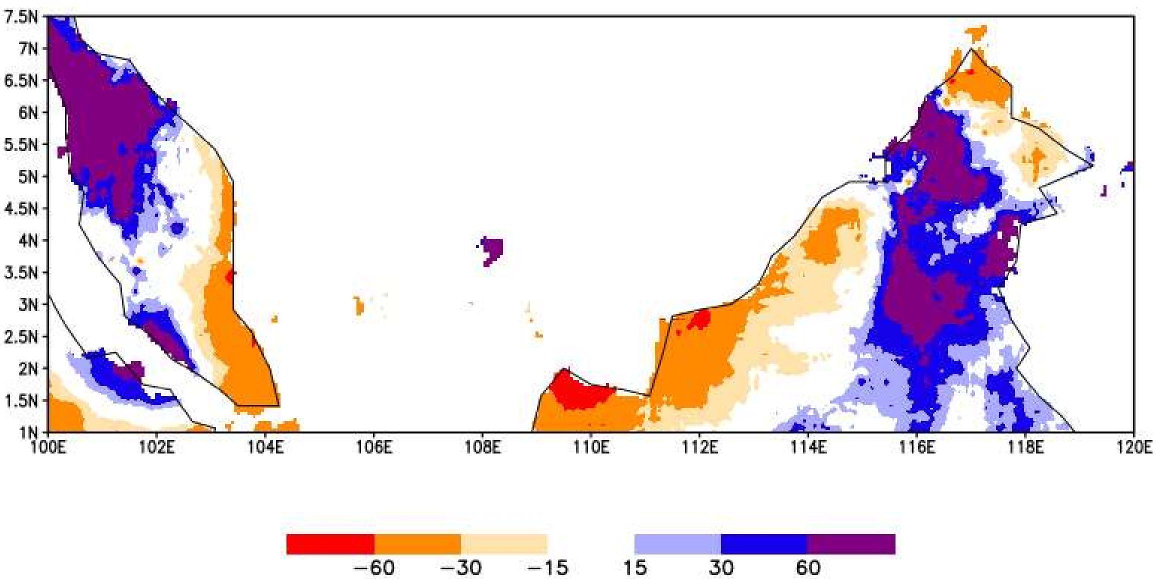

Figure 14: Anomalous Monthly Mean Rainfall in Malaysia during the period of JJAS 2017.

Figure 15 and **Figure 16** depict the spatial distribution of monthly rainfall. It generally followed the seasonal rainfall pattern as shown in **Figure 14** but with some monthly variations. Throughout this monsoon season, conditions were rather wet in the northwestern region of Peninsular Malaysia while on the east coast of Malaysia, particularly in the southeast region of the peninsular, it consistently received below normal rainfall throughout the monsoon period. The regions on the east coast and southeast coast of Malaysia also received below normal rainfall. In June and July, the dry season peaked with smaller spatial coverage of above-normal rainfall in the northwest of Peninsular Malaysia and larger spatial coverage of below-normal rainfall (**Figure 15**). A similar case was also observed in Sarawak during June and July. During June, July and September 2018 (**Figure 16**), the whole of Sarawak region received below normal rainfall while for the rest of the month in the season, the Fourth and Fifth Division received normal to higher than normal rainfall. In Sabah, the West Coast and Interior Region received normal to higher than normal rainfall throughout the season while the rest of the regions received below normal rainfall.

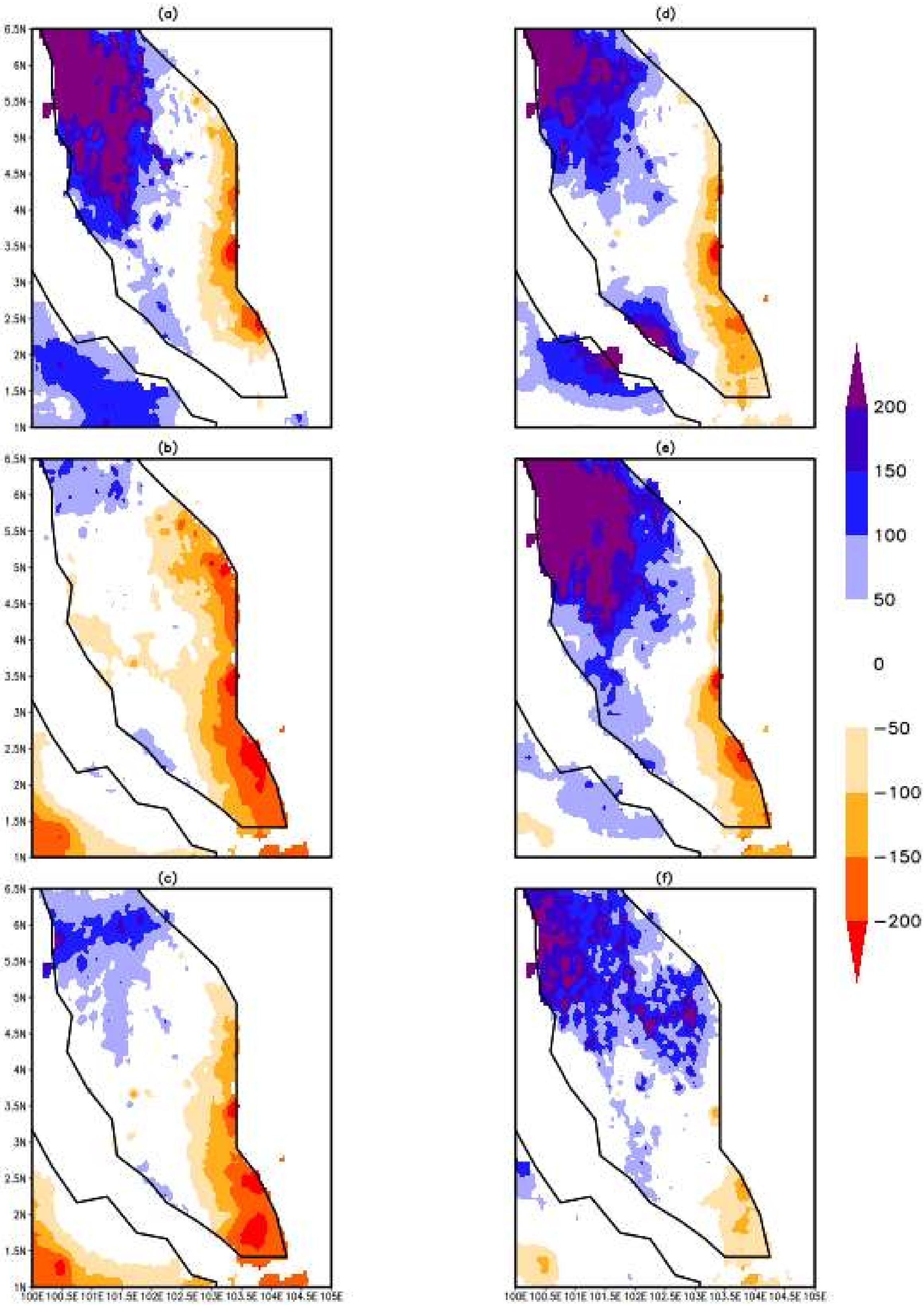

Figure 15: Anomalous Monthly Mean Rainfall in P. Malaysia for (a) May, (b) June, (c) July, (d) August, (e) September and (f) October 2017

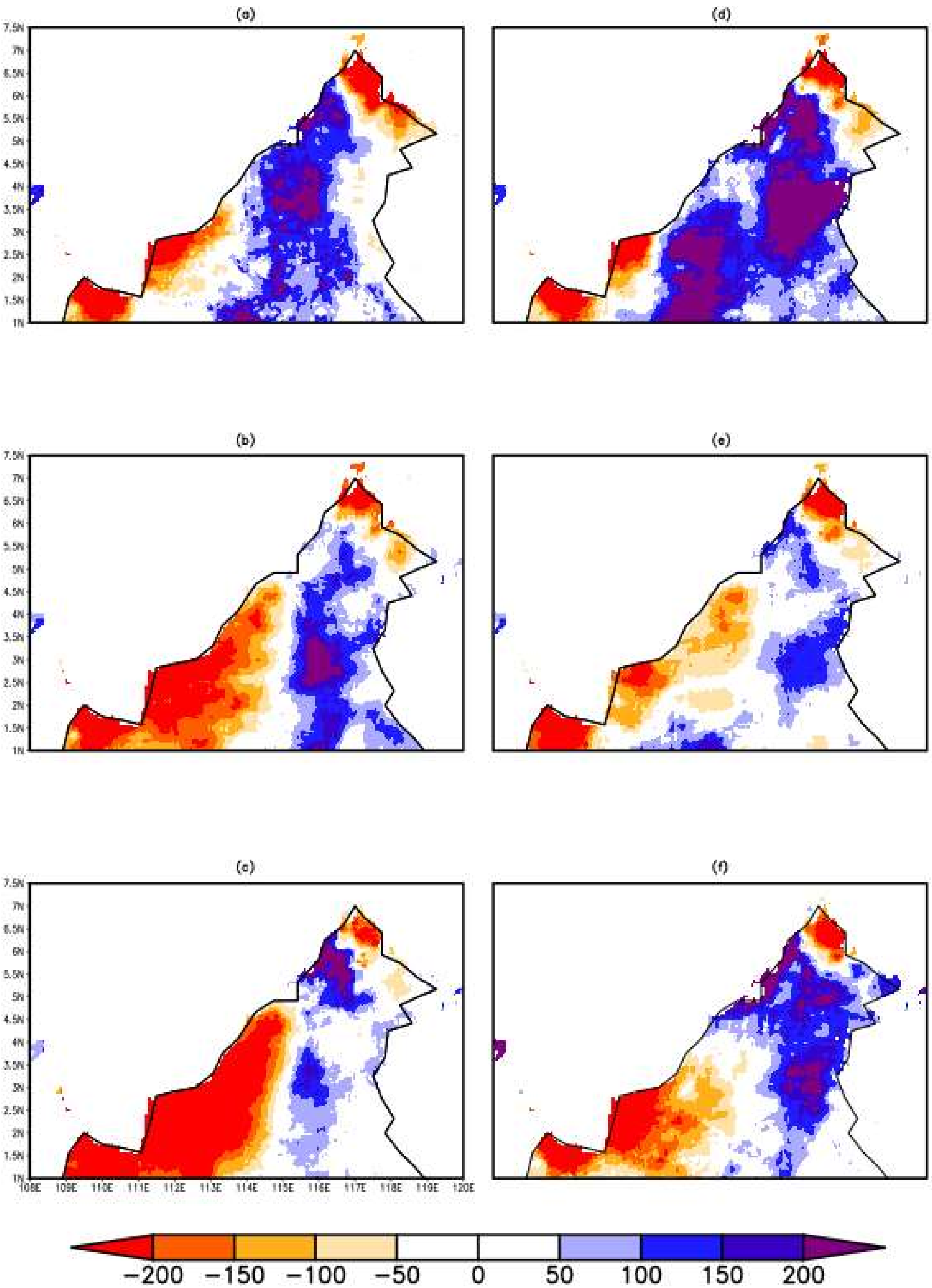

Figure 16: Anomalous Monthly Mean Rainfall in Sarawak and Sabah for (a) May, (b) June, (c) July, (d) August, (e) September and (f) October 2017

Since the average duration of a break in the summer monsoon was about five to seven days, the pentad rainfall data from 21 May to 8 Oct are shown in **Figure 17**. The line represented the pentad running mean of the data. To avoid the uncertainty in the rainfall relationship between onset and withdrawal, we only consider the data from 1 June to 31 September 2017. During this period, four major maximum rainfalls were observed. The amount of these maximum rainfall occurrences increased from early monsoon to late monsoon. Each of these episodes was separated roughly at a duration of 35 days apart. This is also shown in the spectral analysis of the June to August (JJA) 2017 rainfall (**Figure 18**). This period appeared to be a component of the active/break cycle associated with 30-60 days mode in the Indian summer monsoon as shown in previous studies. The broad spectrum between 10 to 20 days and 4 to 6 days were also prominent in the spectral analysis. The former was often associated with the biweekly oscillation in the tropics while the later was associated with the ITCZ oscillation.

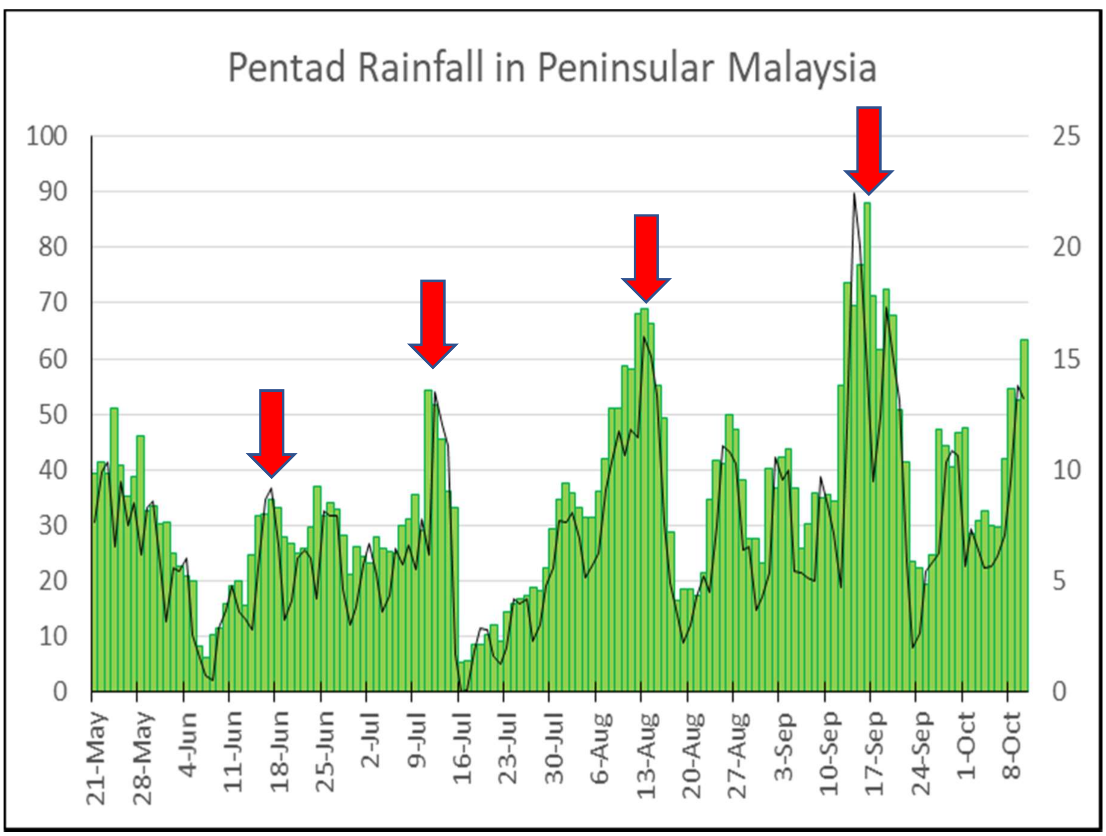

Figure 17: Pentad Rainfall in Peninsular Malaysia.

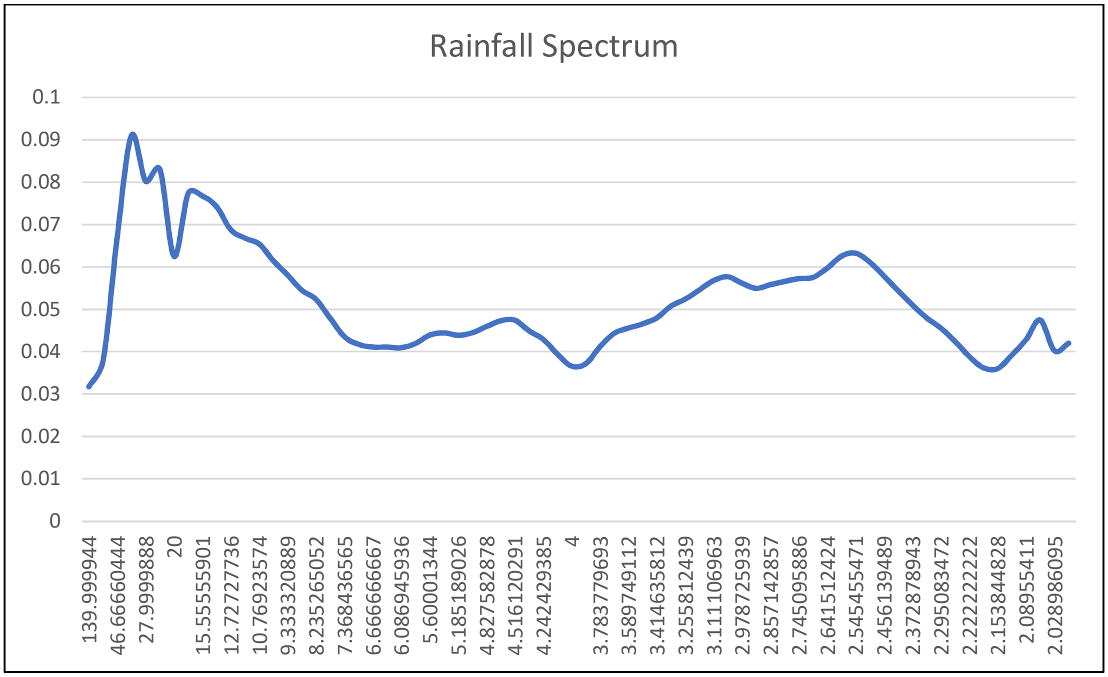

Figure 18: Rainfall Spectrum

7. Tropical cyclones

Tropical cyclones typically appear in early May, although in the northwestern Pacific they could appear any time of the year. From May onwards, the number of tropical cyclones increased and usually peaked in August. During the northern hemisphere summer months, the monsoon trough was often located in the vicinity of Indochina Peninsular-Philippines and spanned across the northwestern Pacific. Coupled with the warm SSTs, this trough was the breeding ground for tropical cyclones. Once formed, it usually tracks northwestward along the monsoon trough, and along the way, they might develop into a tropical depression, tropical storm, or into a typhoon.

Generally, Malaysia is virtually not in the typical path of the tropical cyclones but there were few cases of tropical cyclones tracked into the region. Nevertheless, the weather in Malaysia especially during the summer monsoon was known to have a distant effect cast by tropical cyclones. Depending on the path, intensity, and location of the tropical cyclones, it might cause the weather to be drier or wetter as they could influence the circulation over the region. Based on the data retrieved from RSMC Tokyo, a total of 23 tropical cyclones that reached at least tropical storm stage had formed over the western North Pacific from May to October 2017. The named storm from May to October 2017 are shown in Table 1.

Month	Name	Category
June	Merbok	TS
July	Nanmadol	STS
	Talas	STS
	Noru	STS
	Kulap	TY
	Roke	TS
	Sonca	TS
	Nesat	TY
	Haitang	TS
August	Nalgae	TS
	Banyan	TY
	Hato	TY
	Pakhar	STS
	Sanvu	TY
	Mawar	STS
September	Guchol	TS
	Talim	TY
	Doksuri	TY
October	Khanun	TY
	Lan	TY
	Saola	STS
	Damrey	TY

Table 1: Number of named storms from May to October 2017.
Data source: RSMC Tokyo.

The 2017 Pacific typhoon season did not produce any number of Category 5-equivalent typhoon on the Saffir-Simpson scale and the number of typhoons and super typhoons was below average. Unlike the climatology, the number of tropical cyclones for 2017 peaked in July. In September only three systems were detected. Most of the tropical cyclones during the southwest monsoon tracked poleward.

8. Conclusion

The 2017 southwest monsoon season which started on 19 May 2017 and ended on 29 September 2017 for the whole Malaysian region was generally weaker than normal. Westerlies/south westerlies were generally weak in the SCS region throughout the season. In the Pacific and Indian Ocean basin, SSTA remained mainly neutral throughout the season. Rainfall in the Malaysian region was generally slightly above normal with four major peaks in the pentad rainfall. The rainfall spectrum revealed strong oscillation at 60 days period followed by another peak at 10-20 days and 4-6 days.

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