KEMENTERIAN SUMBER ASLI DAN
KELESTARIAN ALAM
Ministry of Natural Resources and Environmental
Sustainability

MALAYSIAN METEOROLOGICAL DEPARTMENT
MINISTRY OF NATURAL RESOURCES AND
ENVIRONMENTAL SUSTAINABILITY

Research Publication No. 1/2026

Review of the Northeast Monsoon 2022/2023 in Malaysia

Nur Zu Ira Bohari, Fatimah Zaharah Saleh,
Nursalleh K Chang and
Muhammad Firdaus Ammar Abdullah

RESEARCH PUBLICATION NO. 1/2026

Review Of The Northeast Monsoon 2022/2023 In Malaysia

By
Nur Zu Ira Bohari, Fatimah Zaharah Saleh, Nursalleh K Chang and Muhammad Firdaus Ammar Abdullah

Contents

REVIEW OF THE NORTHEAST MONSOON 2022/2023 IN MALAYSIA

Nur Zu Ira Bohari, Diong Jeong Yik, Fatimah Zaharah Saleh,
Nursalleh K Chang and Muhammad Firdaus Ammar Abdullah

Abstract

KEYWORDS: Northeast Monsoon, Cold Surge, Heavy Rainfall

This study investigates the characteristics of rainfall episodes associated with cold surge events during the Northeast Monsoon season from October 2022 to March 2023 across Malaysia. A total of five cold surge events were identified and classified into three types: Meridional Surge (MS), Easterly Surge (ES), and Mixed Surge (MES). Significant rainfall occurred mainly during the third, fourth, and fifth surge episodes, with several stations recording more than 200 mm in each individual surge event. The first and second surges were classified as dry surges due to limited precipitation, despite the presence of enhanced northeasterly wind flow. Four tropical cyclones (TCs) were identified over the Western Pacific, South China Sea (SCS), and the Philippines region during the study period. The heavy rainfall and associated flood events observed, particularly in December 2022, were primarily driven by the Northeast Monsoon circulation rather than tropical cyclone influence. The five cold surge events were associated with MJO activity spanning Phases 3–7, with several surges coinciding with more than one MJO phase. Enhanced rainfall over Malaysia was generally linked to MJO Phases 4–5. The Oceanic Niño Index (ONI) indicated the presence of La Niña conditions from late 2022 to early 2023, with SST anomalies below -0.5°C observed from September 2022 to February 2023. A transition toward neutral ENSO conditions began in early 2023, aligning with the seasonal weakening of La Niña.

1.0 INTRODUCTION

This report examines the onset, withdrawal, and period of cold surges of the Northeast Monsoon (NEM) during the 2022/2023 season. The daily analysis included rainfall and monsoon surges by regions in Malaysia. The monsoon system over Malaysia is characterized by wind patterns rather than the rainfall distribution as delineated by Ramage (1971).

2.0 DATA AND METHODOLOGY

This section explains and provides details of all the data and methods used in this report. The data includes the daily rainfall recorded by the observation stations by the Malaysian Meteorological Department's (MET Malaysia). The data also included wind 925-hPa, 850-hPa levels and mean sea level pressure (MSLP) that were obtained from the ECMWF ERA5 reanalysis (Hersbach et al., 2020) and quantitative daily precipitation from satellite observations obtained from NASA's Global Precipitation Measurement (GPM) IMERG data for IMERG V07B (Huffman et al., 2019). In addition, the data of the Tropical Cyclone best track data (1951 - 2023) was obtained from the Regional Specialized Meteorological Center (RSMC) - Tokyo that documents the formation, movement, and development of tropical cyclones (TC) of the Western North Pacific within the framework of the World Weather Watch (WWW) Program of the World Meteorological Organization (WMO). The atmospheric circulations and the anomalies plots were plotted using the GrADS (Grid Analysis and Display System) program.

2.1 Definition Onset and Withdrawal of the NEM 2022/2023

The daily average wind data from the global reanalysis wind dataset were used in this report to objectively define the onset and withdrawal dates as well as the monsoon surges. The onset and withdrawal of the NEM 2022/2023 were calculated using the criteria proposed by Moten et al. (2014).

Northeast Monsoon Index (NEMI) was obtained by using the average zonal wind component at 925-hPa and 850-hPa over a red box as shown in **Figure 1**. The onset of the NE monsoon occurs if the easterly wind component is sustained for at least seven days, and at least with one day where the speed is greater than 5 knots (2.5m/s). Meanwhile, the withdrawal of the NEM is said to have taken place when the easterly wind component has weakened to less than 2.5m/s for seven consecutive days and the westerly wind component (positive value) starts to penetrate the Malaysian region.

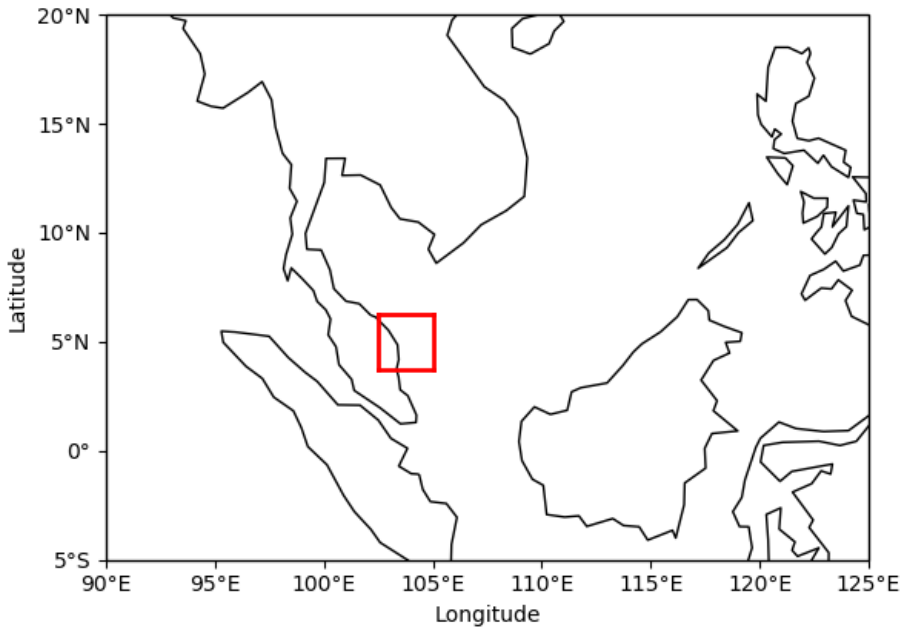

Figure 1: Red box area at 3.75° N to 6.25° N and 102.50° E to 105.00°E used for computing the onset and withdrawal of NEM (Moten et al. 2014)

2.2 Definition Monsoon Surges of the NEM 2022/2023

The definitions of the meridional surge (MS) and easterly surge (ES) were adopted from Chang et al. (2005) and Hai et al. (2017). The cold surge index from Chang et al. (2005) was calculated to detect all the surge events based on outbreaks of cold air outburst from the Siberian High moving towards the equatorial South China Sea (SCS). By adapting the index definition from Hai et al. (2017), the ES was defined due to the strengthening or equatorward movement of the subtropical ridge in the northwestern Pacific as a result of a Siberian High outbreak Raman et al. (1978).

The Meridional Surge Index (MSI) was calculated as the average of 925 hPa meridional winds along 15°N between 110°E to 117.5°E, while ESI was calculated as the average of 925 hPa zonal winds along 120°E between 7.5°N and 15°N. A MS or ES event was identified when the respective index exceeded 8 m s^{-1} for at least three consecutive days. For the MES, it was considered when MS and ES occurred concurrently. A Mixed Surge (MES) was defined when MS and ES occurred simultaneously. The spatial domains used for the surge index calculations are illustrated in **Figure 2**.

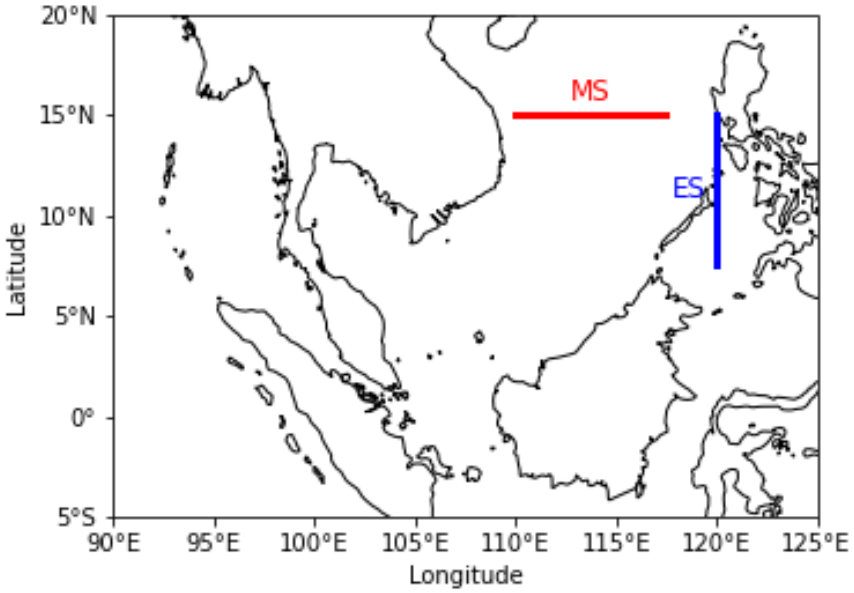

Figure 2: Monsoon surges areas in the Malaysian region.

3.0 RESULTS AND DISCUSSION

3.1 Synoptic Plots

The synoptic plots in every figure starts from episode of surge 1 to 8 that were plotted using GrADS program as illustrated in **Figure 10** to **Figure 19**. The types of the data used for synoptic plots included GPM satellite data in NetCDF format, MSLP and wind in GrADS CTL file.

3.2 Onset and Withdrawal NEM 2022/2023

The onset and withdrawal date for NEM 2022/2023 season was on 6 November 2022 and 23 March 2023, respectively as shown in **Figure 3**. The onset and withdrawal dates fall within the normal range of the climatological onset, which was consistent with Moten et al. (2014) as shown in **Figure 4**. Based on the study, the onset date before 24 October is considered as early onset, while the date after 25 November is considered as late onset.

Similarly, the withdrawal date before 7 March is considered as early withdrawal, while the withdrawal date after 6 April is considered as late withdrawal. A synoptic analysis of low-level winds was performed alongside the NEMI to examine the circulation characteristics of the 2022/2023 Northeast Monsoon. The synoptic patterns were consistent with the NEMI-derived onset and withdrawal dates as shown in **Figure 5** and **6**.

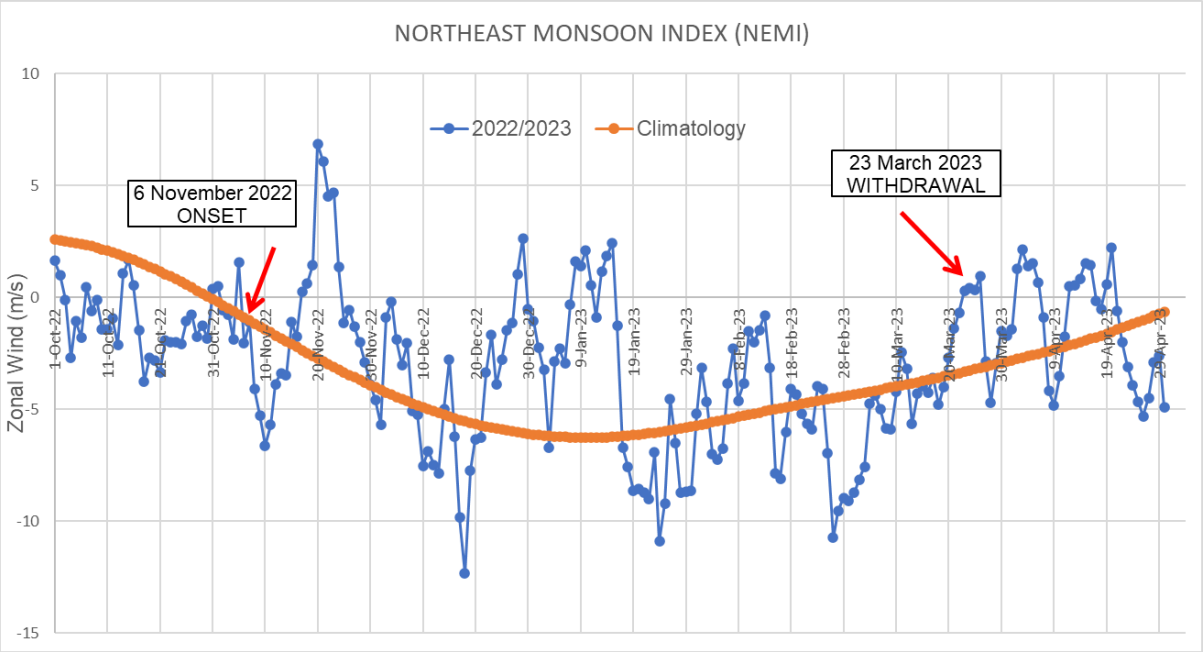

Figure 3: Onset and withdrawal dates calculated based on Northeast Monsoon Index (NEMI) analysis

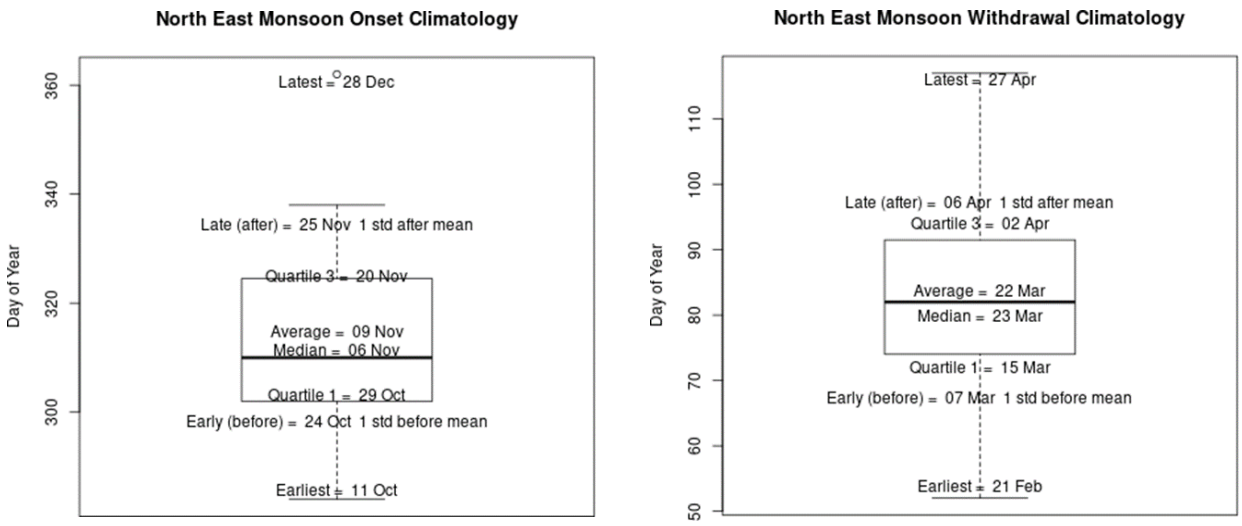

Figure 4: Climatology onset and withdrawal dates of Northeast Monsoon based on Moten et al. (2014).

Based on the synoptic low-level wind analysis, the onset of the Northeast Monsoon (NEM) 2022/2023 was characterised by the establishment of persistent northeasterly flow over Malaysia from 5 November 2022 onward. The low-level wind analysis at 925-hPa showed that on the pentad before onset, the strong north-to-northeast winds flow from China extending southward across Vietnam, the Philippines, and the SCS. As the strong northeasterly flow reaches the SCS, it curves slightly southwestward before crossing over the east coast of Peninsular Malaysia. The monsoon flow intensified during 6–10 November 2022, consistent with the onset identified using the NEMI. Conversely, the weakening of easterly winds during 21–25 March 2023, followed by the establishment of persistent westerlies thereafter, marked the retreat of the NEM.

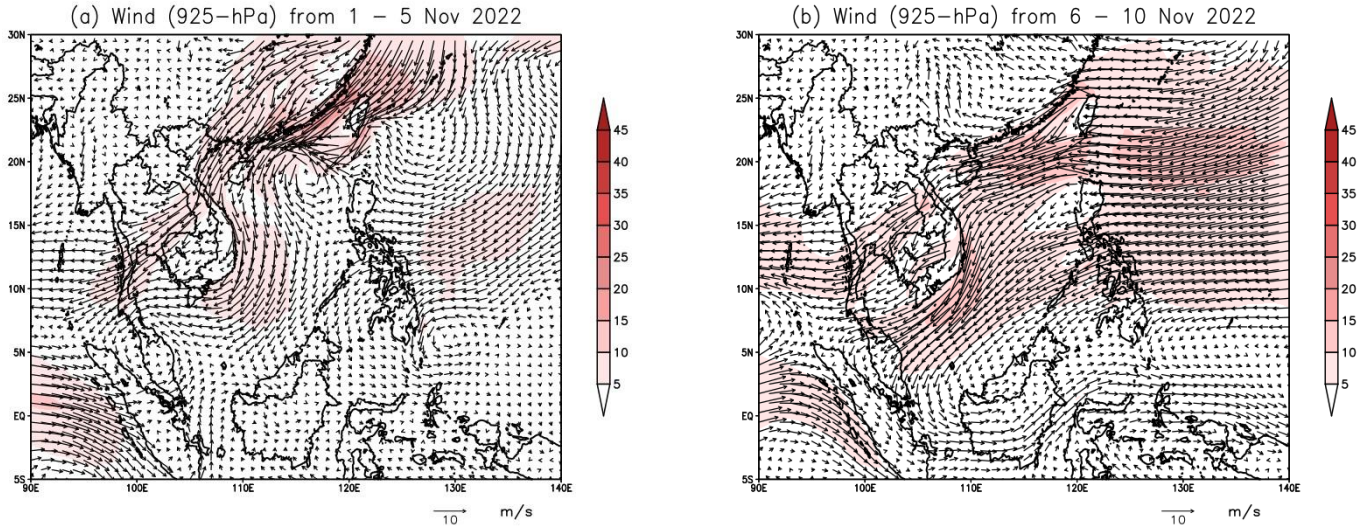

Figure 5: The low-level winds analysis at 925-hPa during the pentad (a) before and (b) during onset.

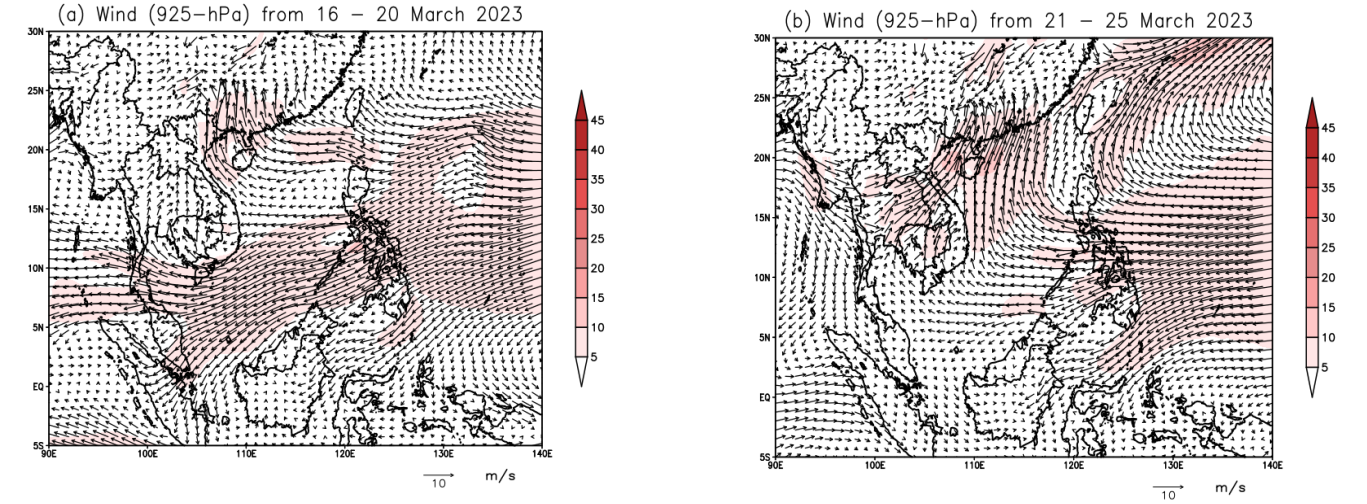

Figure 6: The low-level winds analysis at 925-hPa during the pentad (a) before and (b) during withdrawal

3.3 Monsoon Surges of the NEM 2022/2023

The date and period of monsoon surges were calculated using MESI and a total of ten surges were observed during NEM 2022/2023. A total of ten individual monsoon surge events were identified using the MESI. The minimum duration of a surge was four days for mixed surge (MES) and easterly surge (ES). This NEM 2022/2023 experienced 3 MS, 3 ES and 4 MES, as shown in the MESI time series plotted in **Figure 7.** The total of surges during NEM season and NEM 2022/2023 is illustrated in **Table 1**. **Table 2** shows the total number of monsoon surges and surge days during NEM 2022/2023 in comparison with climatology. For subsequent analysis, these events were grouped into five surge episodes when consecutive surges occurred in close temporal proximity and exhibited continuous synoptic influence. **Table 3** summarizes the statistics of the monsoon surge characteristics during the season.

Table 1: Number and types of monsoon surges observed during NEM 2022/2023

Monsoon Surges		
MS	**ES**	**MES**
27 Oct 2022- 31 Oct 2022 (5 days)	29 Nov 2022 - 2 Dec 2022 (4 days)	3 Jan 2023 - 8 Jan 2023 (6 days)
8 Dec 2022 - 2 Jan 2023 (26 days)	21 Jan 2023 - 26 Jan 2023 (6 days)	16 Jan 2023 - 20 Jan 2023 (5 days)
19 Feb 2023 - 24 Feb 2023 (6 days)	31 Jan 2023 - 17 Feb 2023 (18 days)	27 Jan 2023 - 30 Jan 2023 (4 days)
		25 Feb 2023 - 28 Feb 2023 (4 days)

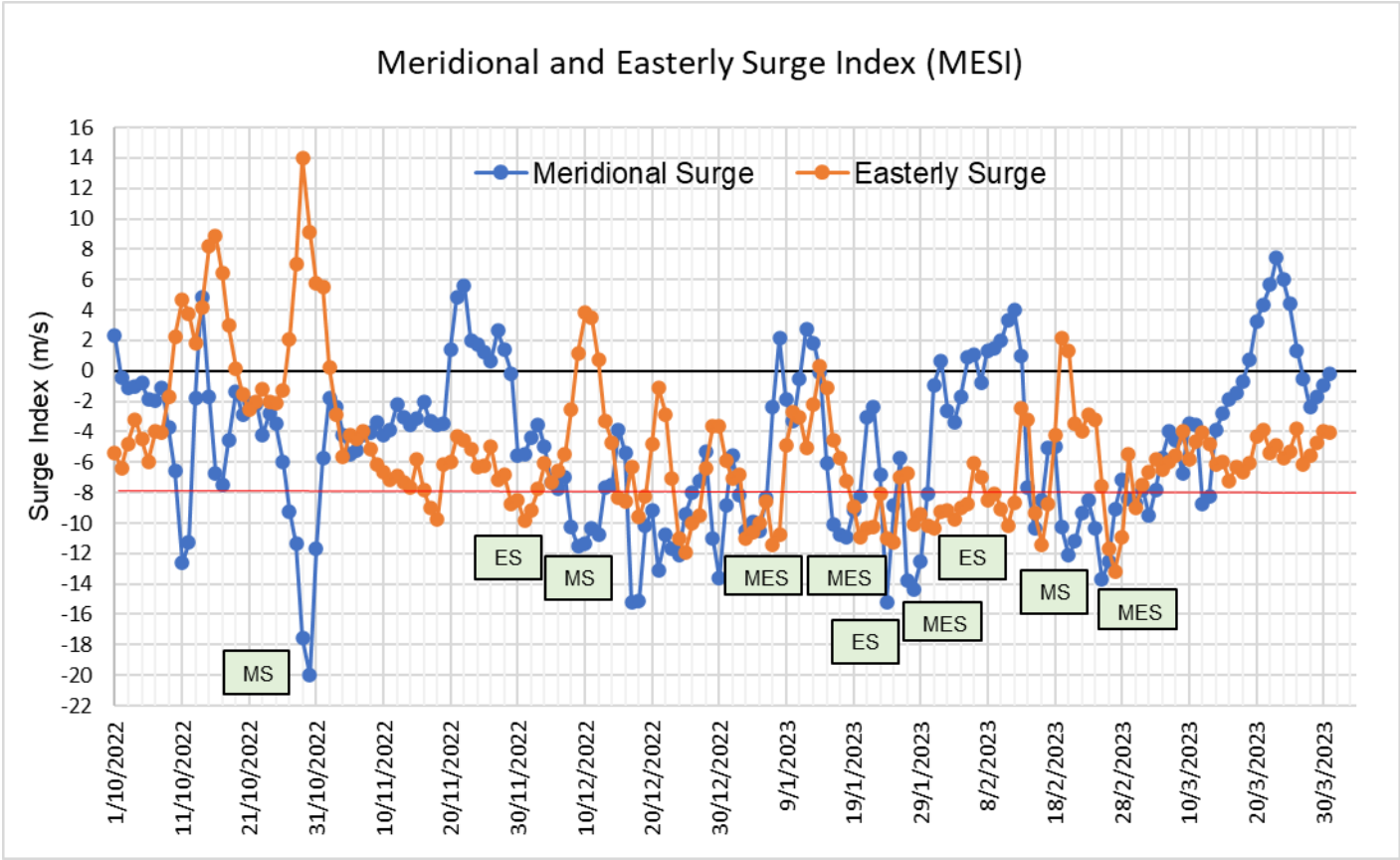

Figure 7: The monsoon surges of NEM 2022/2023 calculated using the Meridional and Easterly Surge Index (MESI) analysis

Table 2: The total number of surges and days per season during NEM 2022/2023 compared to the climatology

	Climatology	NEM 2022/2023
Number of surges	29	10
Days per season	76	84

Table 3: Statistics of the monsoon surges during NEM 2022/2023

MS	Climatology	NEM 2022/2023
First Surge	22 October	27 October
Last Surge	25 February	24 February
No. of Surge	11	3
Days per Season	28 days	37 days
Average Days per Episode	3 days	12 days
ES	**Climatology**	**NEM 2022/2023**
First Surge	17 November	29 November
Last Surge	20 March	17 February
No. of Surge	13	3
Days per Season	38 days	28 days
Average Days per Episode	3 days	9 days
MES	**Climatology**	**NEM 2022/2023**
First Surge	7 December	3 January
Last Surge	10 February	28 February
No. of Surge	5	4
Days per Season	10 days	19 days
Average Days per Episode	2 days	4 days

3.4 Tropical Cyclone (TC) Occurrence during NEM 2022/2023

A list of tropical cyclones that were present within the Western Pacific Ocean, the SCS, and the Philippines region during the period of study as shown in **Table 4**. The period includes late October 2022 through March 2023 to align with the broader Northeast Monsoon season. MET Malaysia also monitors weather conditions in sea areas and issuing maritime warnings within 24 nautical miles (~45km) from the Malaysian coastline and shipping areas especially when the tropical cyclones are in the vicinity of the region as shown in **Figure 8.** The tracks of TC Nalgae, Banyan, Yamaneko and Pakhar are shown in **Figure 9**. TC Nalgae was observed east of the Philippines and made landfall in the Philippines. TC Banyan was a relatively weak and short-lived system in the Western Pacific. TC Yamaneko formed and dissipated over the Western Pacific Ocean and while TC Pakhar developed east of the Philippines and move east-northeastward eventually weakening without making significant landfall. During December 2022, Malaysia experienced heavy rainfall leading to flood and landslides, particularly in Peninsula Malaysia. However, these events were primarily attributed to the Northeast Monsoon’s effects rather than the influence of TC Nalgae, Banyan, Yamaneko and Pakhar. As a result, these storms did not have any significant impact on Malaysia's weather.

Table 4: The Tropical Cyclone (TC) that have developed in the western north Pacific (WNP) and Philippines region during the NEM 2022/2023 season.

No.	Tropical Cyclone (TC)	Classification	Date		Strong Wind / Rough Seas Warnings due to TCs (area affected)	Max Wind (kts)
			Genesis	Dissipation		
1.	Nalgae	Severe Tropical Storm	27/10/22	3/11/22	7 (Condore, Reef North, Layang-layang, Palawan, Bunguran, Reef South, Labuan)	60
2.	Banyan	Tropical Storm	31/10/22	1/11/22	7 (Condore, Reef North, Layang-layang, Palawan, Bunguran, Reef South, Labuan)	35
3.	Yamaneko	Tropical Storm	12/11/22	14/11/22	-	35
4.	Pakhar	Tropical Storm	11/12/22	12/12/22	8 (Condore, Reef North, Layang-Layang, Palawan, Labuan, Tioman, southern part of Samui, Reef South)	40

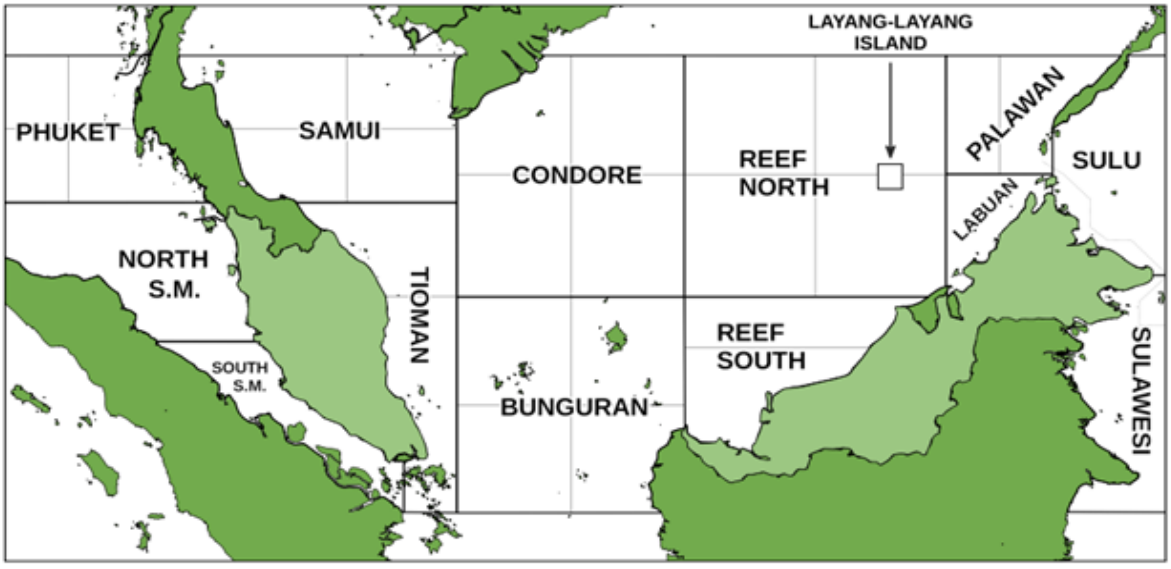

Figure 8: National Waters and Shipping Monitoring Area

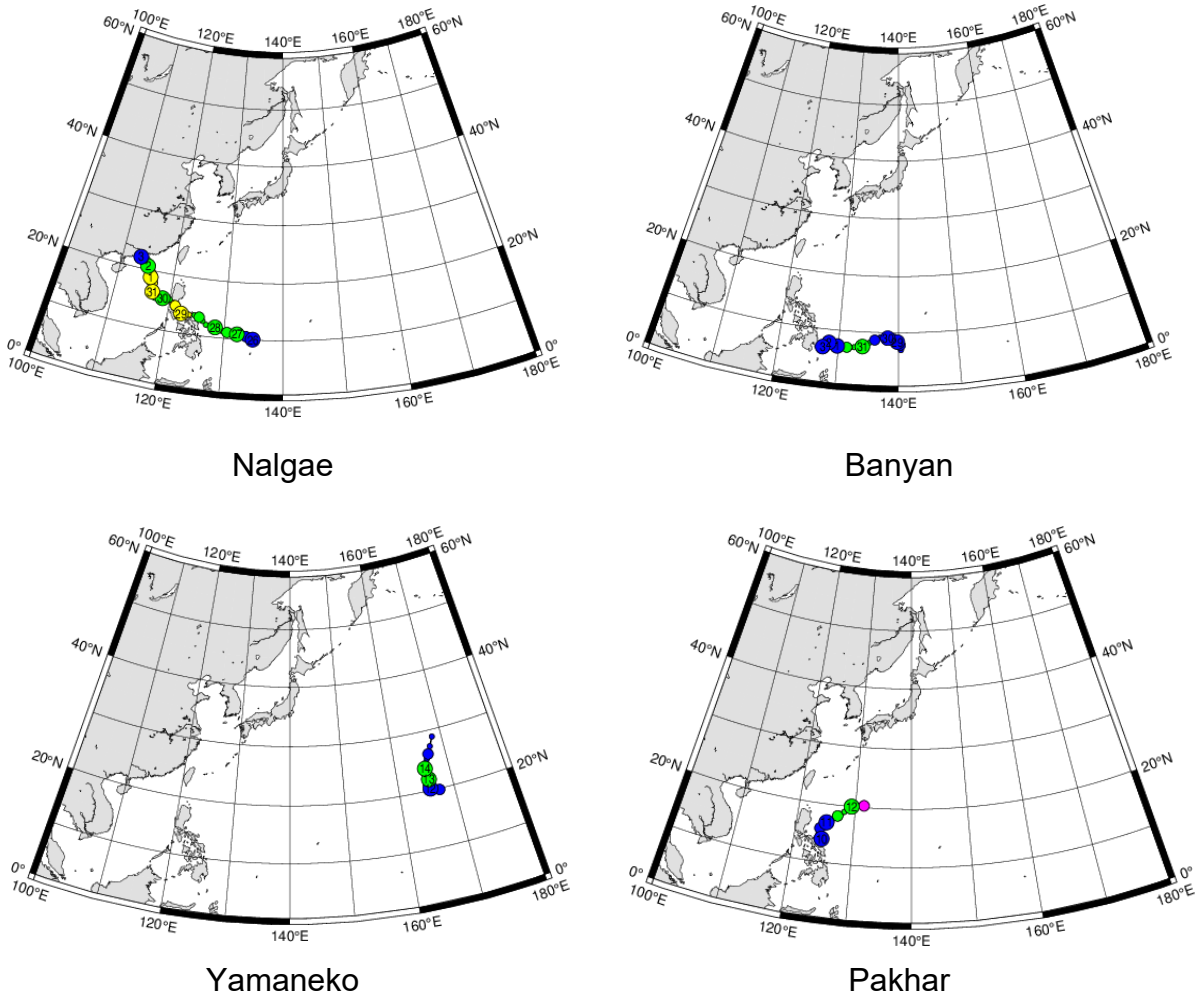

Figure 9: Tracks of TC from October 2022 until March 2023. The circled numbers represent the date of occurrence of the TYs and TSs (Source: National Institute of Informatics (NII), Research Organization of Information and Systems (ROIS), Japan http://agora.ex.nii.ac.jp/digital-typhoon/latest/track).

3.5 Episode of Surges during NEM 2022/2023

3.5.1 Episode 1: 27 October - 31 October 2022 (MS)

The first episode of surge of the season was identified as a meridional surge. The duration of surge was 5 days. **Figure 10** shows the surge event before, during and after from 26 October 2022(-1) until 31 October 2022. On the day before the surge, clear characteristics of the northeast monsoon were present. A monsoon trough extending from the SCS towards the western Pacific, and was connected to a

cyclonic circulation near 130°E. The tight cyclonic circulation east of the Philippines indicating the presence of TC Nalgae. Over the Indochina Peninsula and southern China, the wind pattern shows weaker divergence. Over Malaysia, winds are mostly northeasterly and intensify over the SCS on during the surge day on 27 October 2022. During this period, two cyclonic systems associated with TCs Banyan and Nalgae were present east of the Philippines, with TC Nalgae later crossing the Philippines. Both of these TC did not significantly affect Malaysia's weather as it remained far from the region. The east coast of Peninsular Malaysia and parts of northern Borneo show light to moderate convective activity. In the part of after surge day (+1), the winds are fairly consistent and moderate in strength over the east coast of Malaysia. Stronger wind speeds are shown in areas closer to the Vietnamese coast and north of Borneo. Meanwhile, there's a convergence zone to the north (near Taiwan and southern China), where wind patterns shift and intensify. Overall, the rainfall was observed less than 100 mm over the east coast of Peninsular Malaysia due to a strong onshore northeasterly flow during the surge day and after surge day.

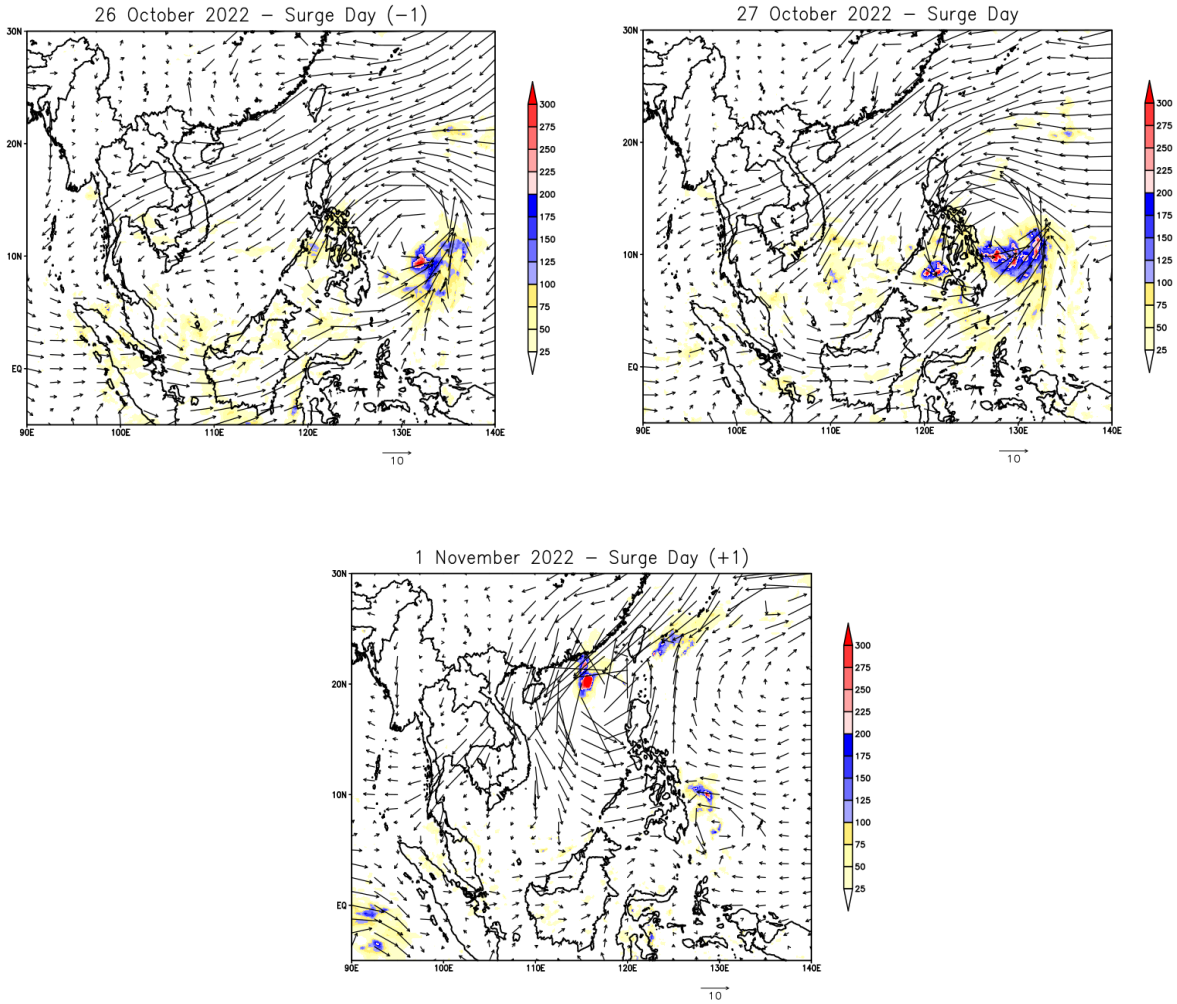

Figure 10: The daily wind at 925-hPa level and rainfall (shaded) during the first episode of surge (27 October – 31 October 2022).

3.5.2 Episode 2: 29 November - 2 December 2022 (ES)

The second episode of surge of the season was identified as an easterly surge. The duration of surge was 4 days. **Figure 11** shows the surge event before, during and after from 29 November 2022 until 2 December 2022. On the day before the surge, strong northeasterly winds are observed over the East and South China Seas. During the surge day on 29 November 2022, northeasterly flow extending from East Asia through the South China Sea and reaching toward the equatorial regions. Compared to the previous day (28 November 2022), the winds on November 29 intensified considerably. Cyclonic curvature in the low-level winds was evident over

northern Borneo. The convergence associated with this system enhance convective activity and result in localized heavy rainfall over Sabah and northern Kalimantan. During the surge day, no significant rainfall was observed along the east coast of Peninsular Malaysia, whereas in the Borneo region, rainfall was recorded but did not exceed 100 mm per day. By 3 December 2022, the surge signal remains visible but begins to weaken slightly. The northeasterly flow is still present but is less intense compared to 29 November. By 3 December, the lingering strong northeasterlies maintain a moist inflow pattern over the southern SCS and Peninsular Malaysia. Significant rainfall exceeding 150 mm/day is observed along Eastern Peninsular Malaysia, Western Borneo, Northern Thailand and Central South China Sea.

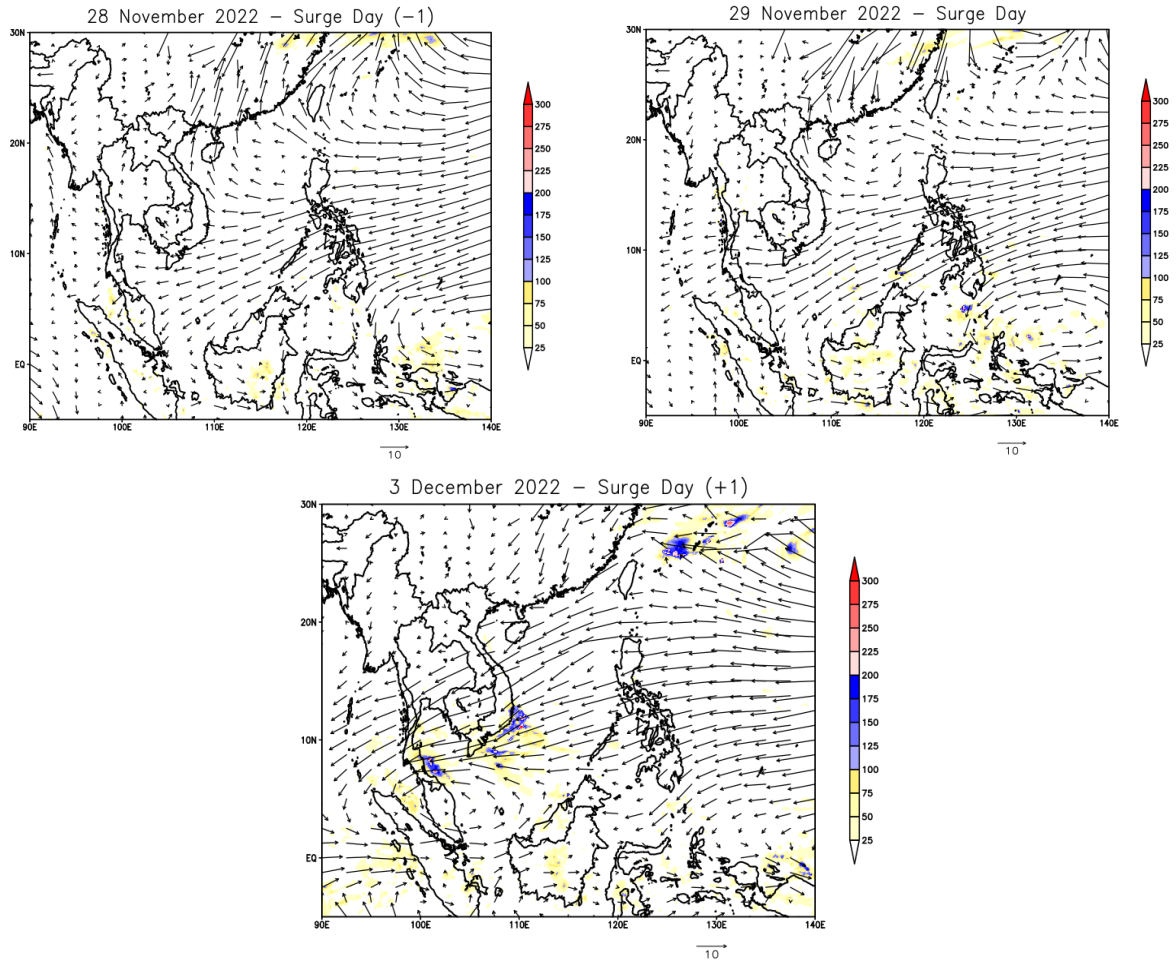

Figure 11: The daily wind at 925-hPa level and rainfall (shaded) during the second episode of surge (29 November – 2 December 2022).

3.5.3 Episode 3: 8 December 2022 - 8 January 2023 (MS and MES)

The third episode of surge was identified as a meridional surge and mixed surge. The duration of surge was 32 days. **Figure 12** shows the surge event before, during and after from 8 December 2022 until 8 January 2023.

The day before the surge, strong northeasterly monsoonal flow dominated the South China Sea (SCS), extending toward Borneo. Rainfall was generally weak, with isolated precipitation over southwest Borneo, northern Sumatra, and southern Vietnam. A vortex over the Sarawak region contributed to moderate rainfall ranging from 25 to 100 mm/day. Another cyclonic circulation was located over the western Pacific Ocean, east of the Philippines, stretching from the SCS into the western Pacific.

During the onset of the surge on 8 December 2022, heavy rainfall was observed along the east coast of Malaysia, with daily rainfall amounts ranging from as low as 25 mm/day to over 150 mm/day. The northeasterly winds are observed to extend from the East China Sea into SCS moving towards the equatorial region. Moderate rainfall was observed over parts of the central Philippines and east of the Philippines. Rainfall intensities over most regions remained below 100 mm/day, with scattered areas receiving 25–75 mm/day. Also, on 3 January 2023 (surge day), a strong northeasterly flow was observed extending from mainland China and the northern SCS down across the Philippines. Heavy rainfall, with accumulations exceeding 100 mm, was observed east of the Philippines and over parts of the central South China Sea.

On 9 January 2023 (Surge Day +1), heavy rainfall is concentrated over the central and eastern parts of the Philippines, with localized rainfall amounts exceeding 150 mm/day. During this surge episode, several stations along the east coast of Peninsular Malaysia recorded significant rainfall. Notably, Kerteh received 449.6 mm, Kuala Terengganu 366.0 mm, Gong Kedak 341.0 mm, Kuala Krai 180.4 mm, and Kota Bharu 165.2 mm. These values clearly indicate the occurrence of widespread heavy rainfall across Terengganu and Kelantan during this event.

Significant rainfall persisted on 9 January 2023 (Surge Day +1), even though the main surge event officially ended on 8 January. Intense rainfall continued over the eastern Philippines.

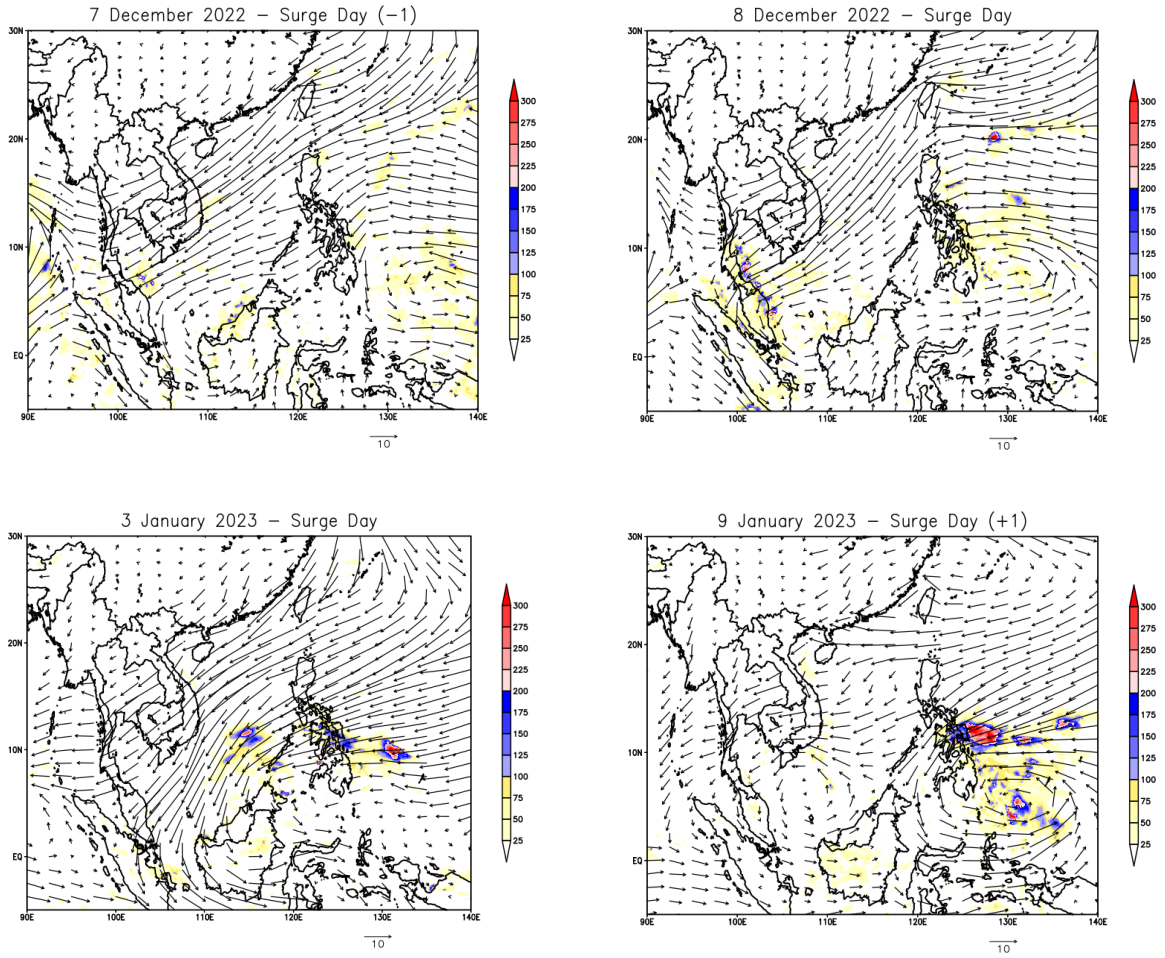

Figure 12: The daily wind at 925-hPa level and rainfall (shaded) during the third episode of surge (8 December 2022 – 8 January 2023).

3.5.4 Episode 4: 16 January – 17 February 2023 (MES and ES)

The fourth episode of surge was identified as a mixed surge and easterly surge. The duration of surge was 33 days. **Figure 13** shows the surge event before, during and after from 16 January 2023 until 17 February 2023. On Surge Day (-1), a cyclonic vortex was detected over the southern Philippines. Rainfall activity remained limited, with light precipitation observed over the western Philippines. The northeasterly wind flow was observed originating from the east of China Sea and

extending toward the SCS. During the onset of the surge on 16 January 2023, no heavy rainfall was observed along the east coast of Peninsular Malaysia, due to the diffluent flow of the northeasterly winds.

Persistent northeasterly flow extended across the SCS by 21 January 2023 (surge day). A weak cyclonic circulation developed over northern and central Borneo, particularly near northern Kalimantan and the coastal regions of Sabah and Sarawak. Rainfall amounts in central and southeastern Borneo remained below 150 mm, whereas heavy rainfall exceeding 200 mm was recorded in Kluang and Mersing (Johor) and in Kudat (Sabah).

During 27 January 2023 (surge day), moderate to heavy rainfall affected the east coast of Peninsular Malaysia, Johor, Sabah, and the central SCS, with amounts exceeding 150 mm. A broad cyclonic circulation persisted over the central SCS. The combination of surge winds and a low-level vortex embedded within this circulation contributed to precipitation ranging from 75 to 200 mm along the east coast of Peninsular Malaysia and parts of central Borneo.

Northeasterly winds continued to dominate the region by 31 January 2023 (surge day). A cyclonic circulation remained near the southern SCS and western Borneo, while wind convergence over Borneo was associated with rainfall amounts below 150 mm. A ridge pattern was noticeable east of China, extending across the northern region.

On the 18 February 2023 (surge day +1), northeasterly winds continued to flow into Peninsular Malaysia. A cyclonic circulation was observed over the vicinity of the Philippines, with accumulated rainfall amounts below 200 mm recorded over the eastern part of the Philippines.

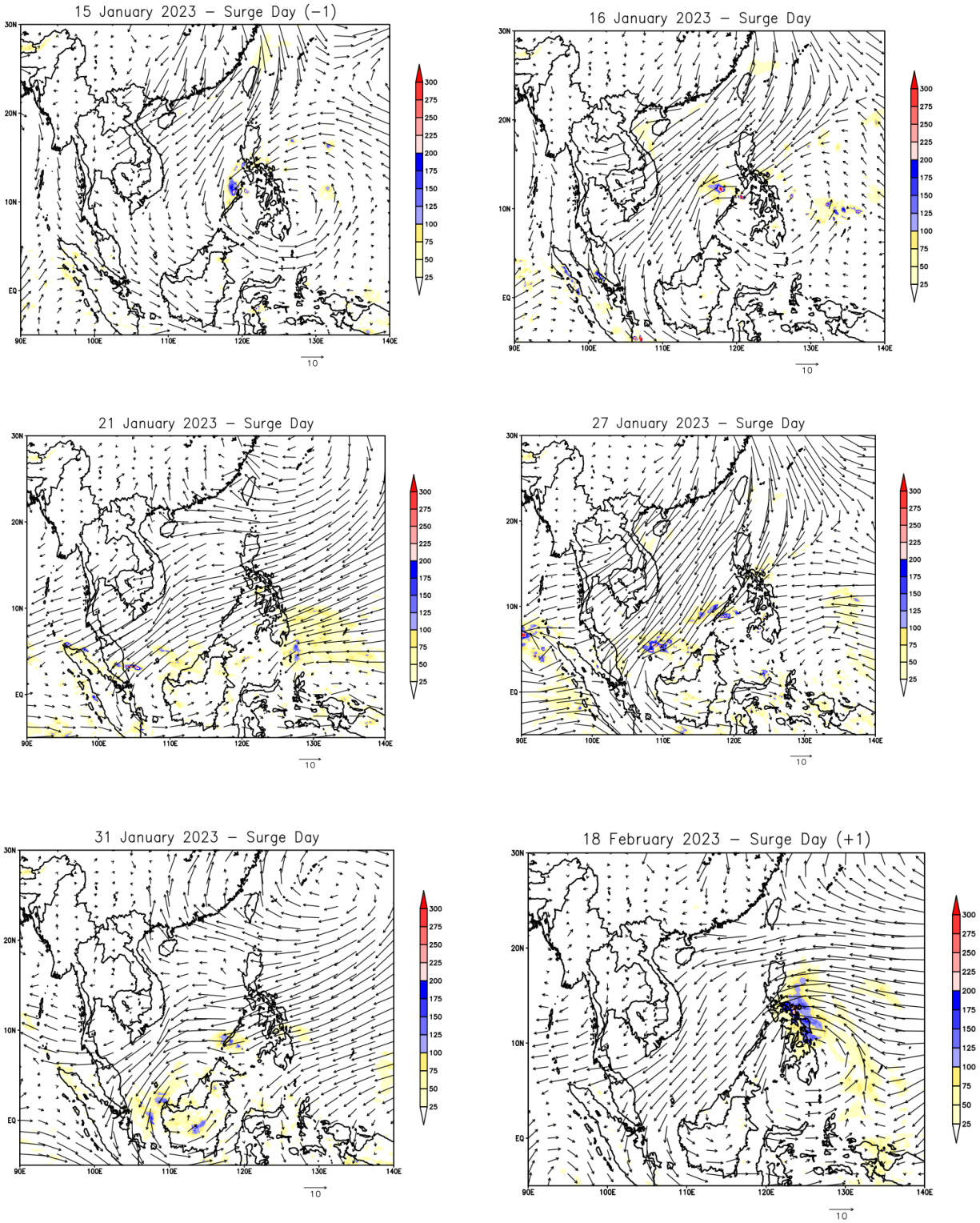

Figure 13: The daily wind at 925-hPa level and rainfall (shaded) during the fourth episode of surge (16 January – 17 February 2023).

3.5.5 Episode 5: 19 February - 28 February 2023 (MS and MES)

The fifth cold surge episode was identified as a meridional surge and mixed surge, with a duration of 10 days, from 19 to 28 February 2023. **Figure 14** illustrates the atmospheric conditions before, during, and after the surge event.

On 18 February 2023 (Surge Day -1), northeasterly winds persisted across the region, continuing to flow into Peninsular Malaysia. A cyclonic circulation was observed over the vicinity of the Philippines. Accumulated rainfall amounts below 200 mm were recorded over the eastern part of the Philippines. On 19 February 2023 (surge day), no rainfall across was observed across Peninsular Malaysia, Sabah, and Sarawak. But a cyclonic vortex was observed over the Philippines region, with moderate rainfall (below 200 mm) primarily confined to that region.

By 25 February 2023 (surge day), the northeasterly wind flow intensified further, covering a wide area from the Indochina Peninsula to Borneo. A broad cyclonic circulation is observed over the southern South China Sea. A trough-like pattern appears to extend from the central SCS into southern Peninsular Malaysia and Sarawak, indicating a region favourable for rainfall development. Southern Sarawak recorded rainfall amounts below 150 mm, indicating localized convective activity rather than widespread heavy precipitation.

However, the large-scale circulation over the South China Sea exhibited a broad region of cyclonic-like flow extending toward the equatorial region. This circulation was associated with enhanced low-level winds directed toward the southern parts of Peninsular Malaysia after the fifth episode had ceased. Consequently, heavy rainfall was recorded over the southern region, particularly in Johor state. Kluang registered a rainfall total of 199.6 mm, while Senai recorded 150.22 mm, both exceeding the threshold for heavy rainfall. Although the main surge episode had concluded by 1 March 2023, some weaker northeasterly winds were still present in the region. As a result, moderate rainfall was recorded over southern Johor, with amounts below 150 mm.

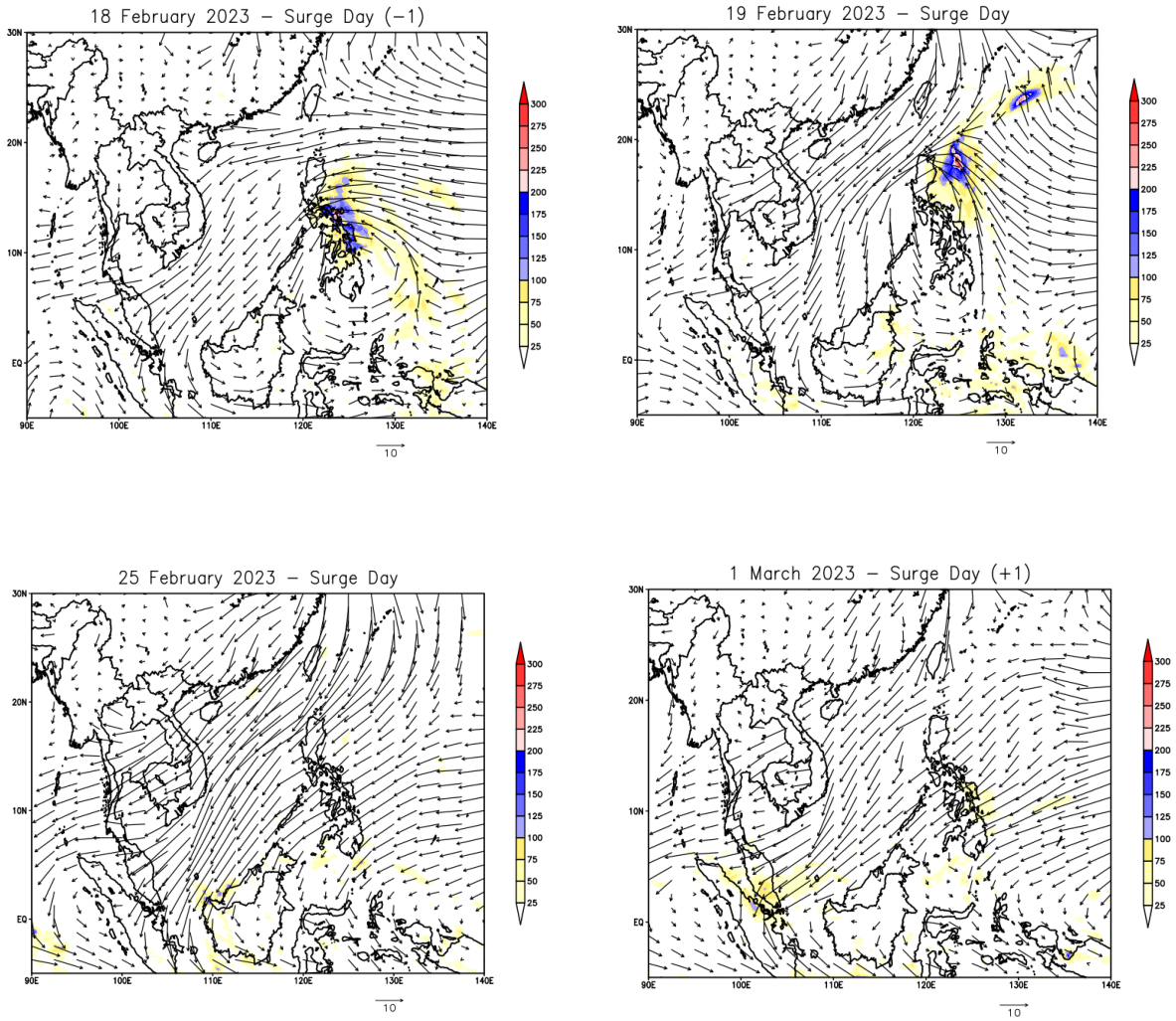

Figure 14: The daily wind at 925-hPa level and rainfall (shaded) during the fifth episode of surge (19 February – 28 February 2023).

3.6 Heavy Rainfall Episode during NEM 2022/2023

Five rainfall episodes were identified between October 2022 and February 2023. **Table 5** summarizes the rainfall accumulations exceeding 150 mm. The third surge, which lasted from 8 December 2022 to 8 January 2023, recorded the highest rainfall totals, particularly in Kota Bharu, Kelantan (449.6 mm) and Kuala Terengganu (366.0 mm), indicating a significant monsoonal impact over the east coast of Peninsular Malaysia. The fourth episode, occurring in late January 2023, brought substantial rainfall to southern Peninsular Malaysia and Sabah, with Kudat recording over 270.6 mm and 252.0 mm of rainfall. In contrast, some surge episodes, such as the first and second did not result in notable rainfall, highlighting their classification as dry surges.

Table 5: The heavy rainfall episodes throughout the NEM 2022/2023 season

Rainfall Episode	Surge Date	Associated Surge	Area	Rainfall Amount (mm)
First	27 - 31 Oct 2022	MS	-	-
Second	29 Nov - 2 Dec 2022	ES	-	-
Third	8 Dec 2022 - 8 Jan 2023	MS and MES	Kerteh, Terengganu	165.2
			Kota Bharu, Kelantan	449.6
			Kuala Krai, Kelantan	180.4
			Gong Kedak, Terengganu	341.0
			Kuala Terengganu	366.0
			Kuala Terengganu	227.8
			Gong Kedak, Terengganu	145.0
Fourth	16 Jan – 17 Feb 2023	MES and ES	Kluang, Johor	247.4
			Mersing, Johor	211.0
			Kudat, Sabah	270.6
			Kudat, Sabah	252.0
Fifth	19 - 28 Feb 2023	MS and MES	Senai, Johor	150.22
			Kluang, Johor	199.6

3.7 ENSO, MJO and IOD Variability

3.7.1 El-Nino Southern Oscillation (ENSO)

According to the National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center, the Oceanic Niño Index (ONI), the standard measure of El Niño–Southern Oscillation (ENSO) conditions, indicated La Niña from late 2022 into early 2023. The ONI is calculated as a three-month running mean of sea surface temperature (SST) anomalies in the Niño 3.4 region (5°N–5°S, 120°–170°W). From SON 2022 to DJF 2022–23, ONI values remained below –0.5°C, ranging from –1.0 to –0.7, indicating persistent La Niña conditions. The strongest anomalies occurred in SON 2022 (–1.0 °C), reflecting a moderate to strong La Niña phase during the boreal autumn. By JFM 2023, the ONI had increased to –0.4, moving toward neutral conditions, signalling the weakening of the La Niña phase. This transition is consistent with seasonal climatological patterns, where La Niña events often decay by late boreal winter or early spring. The data of ENSO for 2022 and 2023 are tabulated in **Table 6**.

Table 4: The ONI information during the NEM 2022/2023 season

Year	**2022**			**2023**	
Month	**SON**	**OND**	**NDJ**	**DJF**	**JFM**
ONI	-1.0	-0.9	-0.8	-0.7	-0.4

3.7.2 Madden Julian Oscillation (MJO)

The Madden-Julian Oscillation (MJO) is a dominant mode of intraseasonal variability in the tropics, known to influence large-scale convection, atmospheric circulation, and rainfall patterns. It often modulates regional weather phenomena, including monsoons and cold surge events over Southeast Asia. This report presents the characteristics of MJO activity during periods in which northeast monsoon surge events occurred between October 2022 and March 2023. When the MJO index falls within the unit circle, the MJO is considered weak or indiscernible. When the index is outside the circle, the MJO is considered active or strong as shown in **Figure 15** and **Figure 16**.

During the five cold surge episodes, the associated MJO activity was distributed across Phases 3–7 as follows: Phase 3 (2 events), Phase 4 (3 events), Phase 5 (2 events), Phase 6 (3 events), and Phase 7 (4 events). The total number of MJO events (14) exceeds the number of cold surge episodes (5) because some surge events coincided with multiple MJO events or spanned more than one MJO phase. Generally, MJO Phases 4 and 5 are associated with enhanced rainfall over the Maritime Continent, including Malaysia (Wheeler et al., 2004). The following table (**Table 7**) summarizes active MJO days and phases that coincided with surge periods. The dates shaded in the table below indicate periods where MJO activity overlapped with surge events.

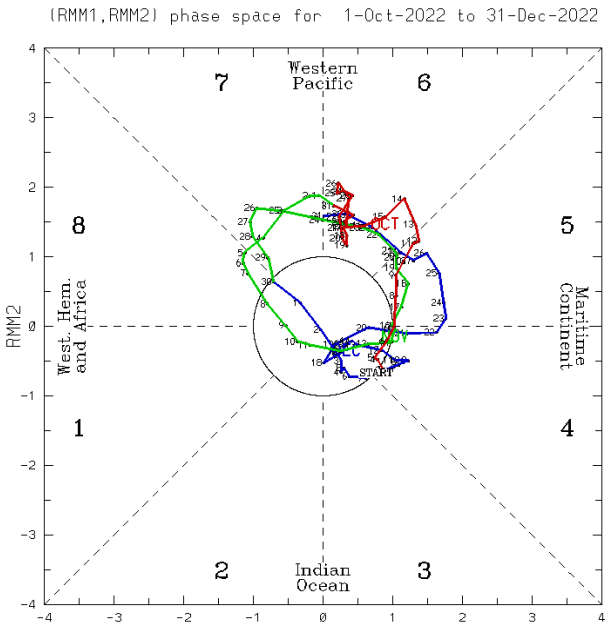

Figure 15: The MJO phase diagram for October (red) - November (green) – December (blue) (*Source: Bureau of Meteorology*)

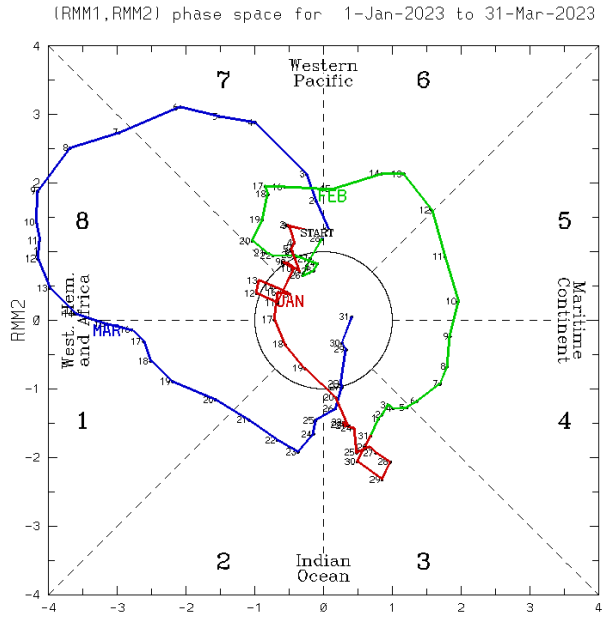

Figure 16: The MJO phase diagram for January (red) - February (green) – March (blue) (*Source: Bureau of Meteorology*)

Table 7: Major MJO Events during NEM Monsoon 2022/2023

Month	Date	Num of MJO Days	Phase
October	7	1	4
	8 - 12	5	5
	13 - 31	***19***	***6***
November	1 - 4	4	7
	5	1	8
	15	1	4
	17 - 20	4	5
	21 - 23	3	6
	24 - 29	***6***	***7***
December	***8 - 11***	***4***	***4***
	21 - 22	***2***	***4***
	23 - 28	***6***	***5***
	29 - 31	***3***	***6***
January	***1 - 6***	***6***	***7***
	20 - 31	***12***	***3***
February	***1 - 5***	***5***	***3***
	6 - 9	***4***	***4***
	10 - 11	***2***	***5***
	12 - 15	***4***	***6***
	16 - 22	***7***	***7***
	28	***1***	***7***
March	1	1	6
	2 - 6	5	7
	7 - 14	8	8
	15 - 20	6	1
	21 - 25	5	2
	26	1	3
Total Num. of MJO Days		126 days	

(Bold dates indicates Cold Surge Events)

3.7.3 Indian Oscillation Dipole (IOD)

The Indian Ocean Dipole (IOD) is an important driver of interannual climate variability in the tropical Indian Ocean, influencing atmospheric circulation, rainfall patterns, and monsoon intensity. It is defined by the difference in sea surface temperature (SST) anomalies between the western and eastern equatorial Indian Ocean. The weekly SSTA for the IOD region from October 2002 to March 2023 is shown in **Figure 17**. A negative IOD (values < –0.4 °C) is typically associated with enhanced convection and rainfall over the eastern Indian Ocean and parts of Southeast Asia, while a positive IOD (values > +0.4 °C) can suppress rainfall in those regions. A negative IOD phase in early October to early November 2022 enhanced early-season convection and contributed to the initial moistening of the atmosphere ahead of the monsoon onset. However, from December to February, the IOD remained in a neutral phase with minimal direct influence on regional weather. In late February to March 2023, the return to a positive IOD phase coincided with the final surge event (fifth surge) and the subsequent weakening of the monsoonal flow. Despite these variations, cold surges remained the dominant drivers of rainfall across Peninsular Malaysia, Sabah, and Sarawak during the NEM.

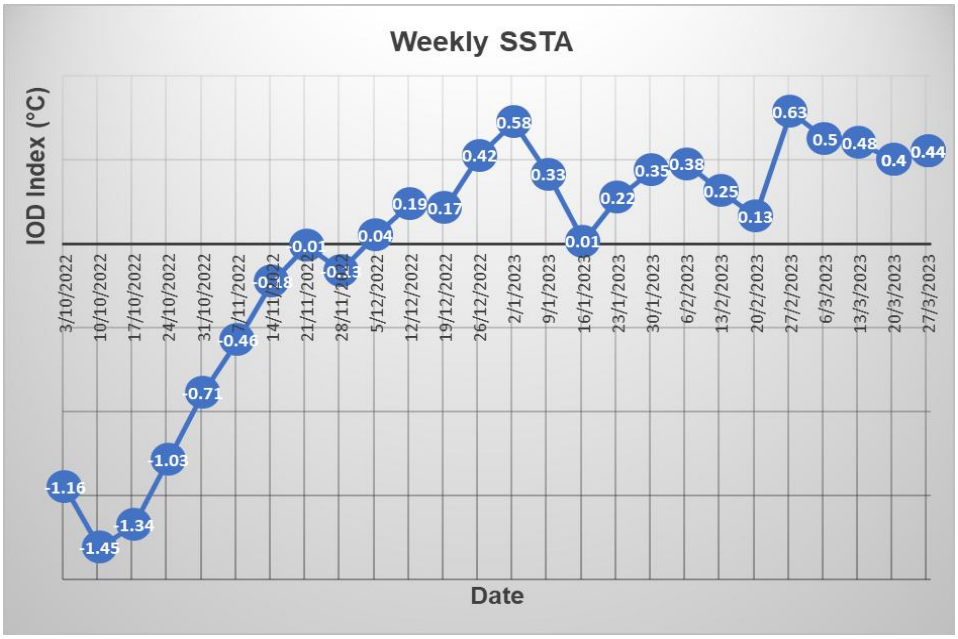

Figure 17: Weekly SSTA for IOD region from October 2022 to March 2023

4.0 CONCLUSION

The analysis of fifth cold surge episodes during the Northeast Monsoon 2022/2023 reveals varying impacts on rainfall distribution across Malaysia. Surge-induced heavy rainfall was prominent during the third, fourth and fifth events. The spatial distribution of rainfall showed a tendency for heavier precipitation over the east coast during early surges and a shift toward southern Peninsular Malaysia and Sabah in later episodes. The final surge in February (19 – 28 February 2023) brought notable rainfall to southern Johor, highlighting the continued influence of surge events on local precipitation. While four tropical cyclones occurred during the 2022/2023 Northeast Monsoon season, none had a direct influence on Malaysia. TC Nalgae made landfall in the Philippines, while the others remained relatively weak or short-lived over the Western Pacific. The heavy rainfall and flood events experienced, especially in Peninsular Malaysia, were attributed to cold surge episodes and monsoonal dynamics rather than tropical cyclone activity. The ONI analysis confirmed a moderate to strong La Niña event from SON 2022 through DJF 2022–23, with the strongest cooling in SON 2022 (–1.0°C). During this period, monsoon surges and dry northeasterly winds were observed. By JFM 2023, the ONI values approached neutral, suggesting a weakening La Niña phase consistent with typical seasonal patterns. IOD conditions fluctuated during the 2022–2023 Northeast Monsoon. The negative IOD phase in early October likely enhanced pre-monsoonal convection. From December to February, the IOD transitioned into a neutral phase, exerting minimal influence on rainfall. A positive IOD emerged in late February and persisted into March 2023, coinciding with the final (fifth) surge episode and a gradual reduction in monsoon activity.

4.1 REFERENCES

Chang, C. P., P. A. Harr, and H. J. Chen, 2005: Synoptic disturbances over the equatorial South China Sea and western maritime continent during boreal winter. *Mon. Weather Rev.*, **133**, 489–503, https://doi.org/10.1175/MWR-2868.1.

Hai, O. S., A. A. Samah, S. N. Chenoli, K. Subramaniam, and M. Y. A. Mazuki, 2017: Extreme rainstorms that caused devastating flooding across the east coast of Peninsular Malaysia during November and December 2014. *Weather Forecast.*, **32**, 849–872, https://doi.org/10.1175/WAF-D-16-0160.1.

Hersbach, H., and Coauthors, 2020: The ERA5 global reanalysis. *Q. J. R. Meteorol. Soc.*, **146**, 1999–2049, https://doi.org/10.1002/qj.3803.

Moten, S., and Coauthors, 2014: *Statistics of Northeast Monsoon Onset, Withdrawal and Cold Surges in Malaysia*.

Wheeler M. C. and Hendon H. H. (2004). An All-Season Real-Time Multivariate MJO Index: Development of an Index for Monitoring and Prediction. *American Meteorological Society.* 132, 1917-1932.

MALAYSIAN METEOROLOGICAL DEPARTMENT
JALAN SULTAN
46667 PETALING JAYA
SELANGOR DARUL EHSAN
Tel : 603-79678000
Fax : 603-79550964
www.met.gov.my