



**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. 1/2025

**Review of the Northeast Monsoon
2024/2025 in Malaysia**

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Muhammad Firdaus Ammar Abdullah**

MALAYSIAN METEOROLOGICAL DEPARTMENT

**MINISTRY OF NATURAL RESOURCES AND ENVIRONMENTAL
SUSTAINABILITY**

ASSESSMENT REPORT

REVIEW OF THE NORTHEAST MONSOON 2024/2025 IN MALAYSIA

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October 2025

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1.0 OVERVIEW

The 2024/2025 Northeast Monsoon (NEM) season was marked by several notable meteorological features. Based on the Northeast Monsoon Index (NEMI) method (Moten et al. 2014), the monsoon period spanned **13 November 2024** to **25 March 2025**, while the Northeast Monsoon Onset (NEMO) method (Chenoli et al. 2022) indicated an earlier onset on **4 November 2024**, both within the climatological norm. Throughout the season, 15 monsoon surge episodes were identified using the Meridional Easterly Surge Index (MESI) (Fakaruddin et al. 2019), with mixed surges occurring most frequently. Eight of these episodes produced heavy rainfall, particularly during mixed surge events.

The season was also influenced by large-scale climate drivers, notably the negative phase of the North Atlantic Oscillation (NAO), which allowed cold air from the Siberian High to penetrate further south, enhancing the frequency and intensity of cold surges. The Oceanic Niño Index (ONI) remained neutral, while a negative Indian Ocean Dipole (IOD) in November and December enhanced convection and wetter conditions. The Madden–Julian Oscillation (MJO) further influenced the season, as its active phases (4 and 5) in late January and early February enhanced rainfall, especially when concurrent with surge events. However, weaker MJO phases in March led to less convective activity despite ongoing surges, except for 19 March, when a brief active Phase 4 coincided with a mixed surge that caused heavy rain in Sabah and Sarawak. Additionally, the season saw four typhoons and one tropical storm.

2.0 MONSOON ONSET AND WITHDRAWAL

2.1 Onset and Withdrawal of NEM 2024/2025 based on NEMI

Based on NEMI sustained negative values with wind speeds exceeding 2.5 m/s began on **13 November 2024**, indicating the onset of the NEM 2024/2025 as shown in Figure 1. The NEMI also indicated the monsoon withdrawal on **25 March 2025**, marked by the reappearance of westerlies and a return to positive NEMI values.

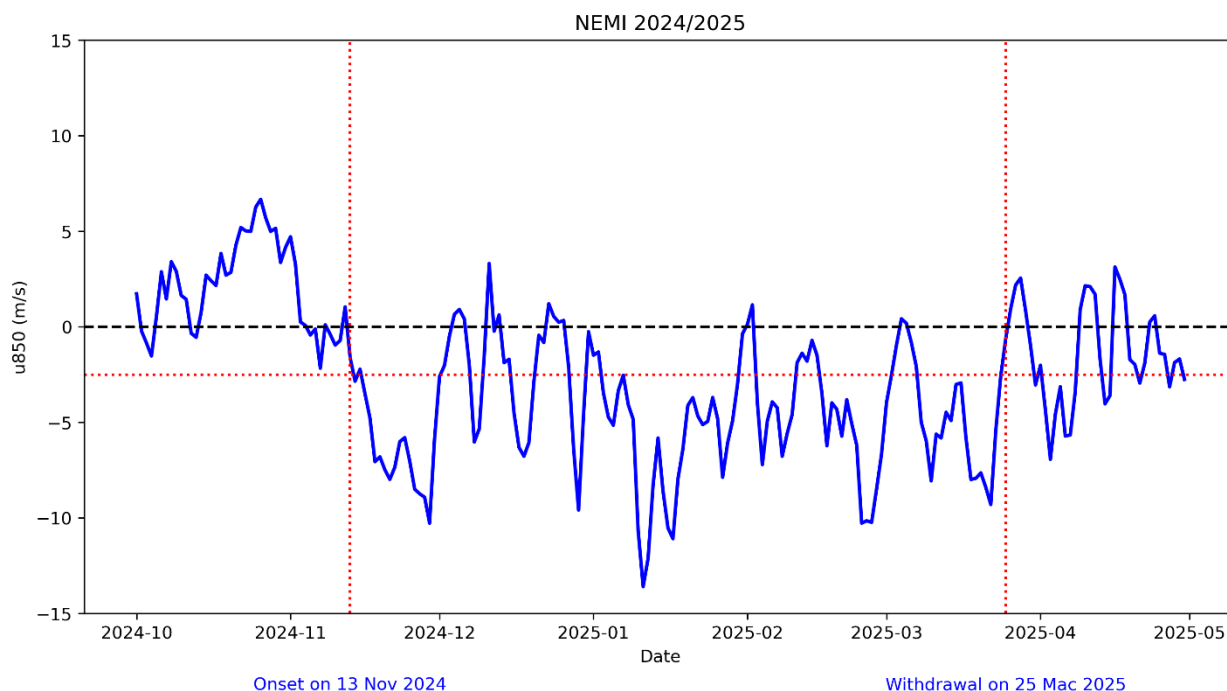


Figure 1. NEMI for the 2024/25 season

2.2 Onset of NEM 2024/2025 based on NEMO

From 1–9 November 2024, the 3-pentad average 925-hPa meridional wind speed was below -1 m/s, fulfilling the first NEMO criterion. Northerly winds stronger than 2.5 m/s (equivalently, less than -2.5 m/s) persisted from 2–9 November, with speeds steady or increasing. The last pentad in this sequence, **4 November 2024**, marks the onset of the 2024/25 NEM, within the climatological onset period (Table 1).

Table 1: NEMO for the 2024/25 season

Pentad Mean (m/s)	3- Pentad Mean (m/s)
-1.23 (30 Oct – 3 Nov 2024)	0.22
-1.64 (31 Oct – 4 Nov 2024)	-0.93
-2.22 (1 – 5 Nov 2024)	-1.70
-2.75 (2 – 6 Nov 2024)	-2.20
-3.39 (3 – 7 Nov 2024)	-2.79
-3.75 (4 – 8 Nov 2024)	-3.29
-3.90 (5 – 9 Nov 2024)	-3.67

2.3 Onset and Withdrawal Climatology 1991 – 2020

Figure 2 shows onset dates for the NEM 2024/2025 season derived from NEMI and NEMO methods lie within the normal climatological range, while the withdrawal date is close to the 1991–2010 mean, indicating the seasonal timing was within expected norms. It is obvious that the onset dates for the NEM 2024/2025 season derived from the NEMI and NEMO methods fall within the normal climatological range, while the withdrawal date is close to the 1991–2010 mean, indicating that the seasonal timing was within expected norms.

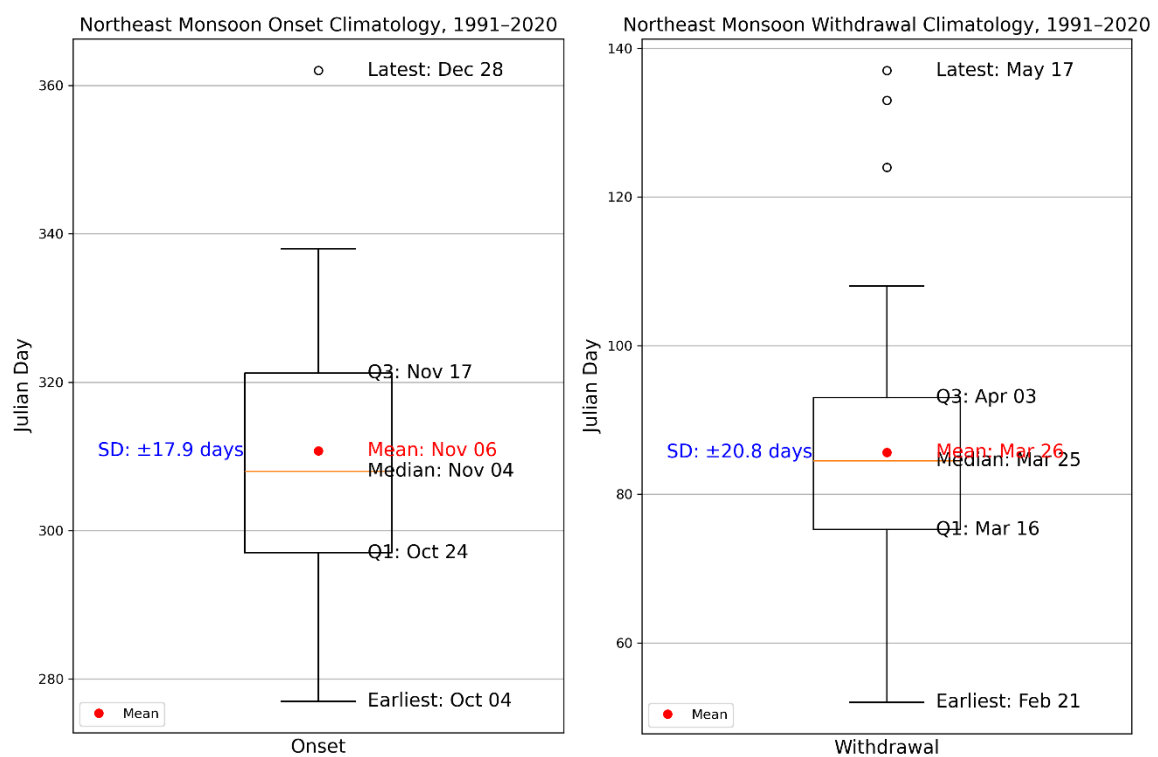


Figure 2. Climatological distribution of NEM onset (left) and withdrawal (right) dates based on box plots

3.0 MONSOON SURGES

3.1 Surge Episodes

During the 2024/2025 NEM season, a total of 15 monsoon surge episodes were identified and classified. Mixed surges were the most frequent, with ten occurrences, followed by easterly surges with four occurrences, and a single meridional surge. The predominance of mixed surges suggests that interactions between northeasterly flows and regional circulation systems played a significant role in driving monsoon variability during this season.

Table 2. Classification of Monsoon Surge Episodes for the 2024/25 NEM Season

Easterly Surge Index	Meridional Surge Index	Mixed Surge Index
22 – 25 Nov 2024	02 – 04 Jan 2025	27 – 29 Nov 2024
10 – 13 Dec 2024		08 – 09 Dec 2024
19 Feb – 02 Mar 2025		14 – 17 Dec 2024
08 – 13 Mar 2025		19 – 22 Dec 2024
		28 – 29 Dec 2024
		09 – 12 Jan 2025
		15 – 17 Jan 2025
		28 – 29 Jan 2025
		07 – 09 Feb 2025
		19 – 20 Mar 2025
Total ESI = 4	Total MSI = 1	Total MES = 10

3.2 Heavy Rainfall During Monsoon Surge

Of the 15 monsoon surge events, eight coincided with heavy rainfall at principal meteorological stations (see Table 3). Notably, six of these were mixed surges, indicating a strong linkage between mixed surge events and heavy rainfall during the season. Figure 3 shows the daily accumulated rainfall recorded at principal meteorological stations in November 2024.

Table 3. Heavy rainfall during the monsoon surges in the 2024/25 season

No.	Surge Period	Surge Types	Date	Station	Amount (mm/day)
1.	22 – 25 Nov 2024	Easterly	22 Nov 2024	Gong Kedak	183.6
				Kota Bharu	165.8
2.	27 – 29 Nov 2024	Mixed	27 Nov 2024	Gong Kedak	330.8
				Kota Bharu	241.4
				Kuala Krai	241.8
				Kapit	156.0
			28 Nov 2024	Gong Kedak	167.6
				Kota Bharu	184.2
			29 Nov 2024	Gong Kedak	256.8
				Kerteh	371.2
				Kota Bharu	151.6
				Kuala Krai	237.2
3.	08 – 09 Dec 2024	Mixed	09 Dec 2024	Kerteh	195.8
				Kuantan	198.0
4.	10 – 13 Dec 2024	Easterly	10 Dec 2024	Kerteh	181.6
5.	28 – 29 Dec 2024	Mixed	29 Dec 2024	Kuala Krai	205.0
				Kuantan	211.4
6.	09 – 12 Jan 2025	Mixed	10 Jan 2025	Mersing	182.4
7.	28 – 29 Jan 2025	Mixed	28 Jan 2025	Bintulu	208.2
				Kuching	192.0
				Miri	177.8
			29 Jan 2025	Bintulu	516.0
				Miri	184.4
8.	19 – 20 Mar 2025	Mixed	19 Mac 2025	Sandakan	298.4
				Mukah	238.4
			20 Mac 2025	Senai	176.2

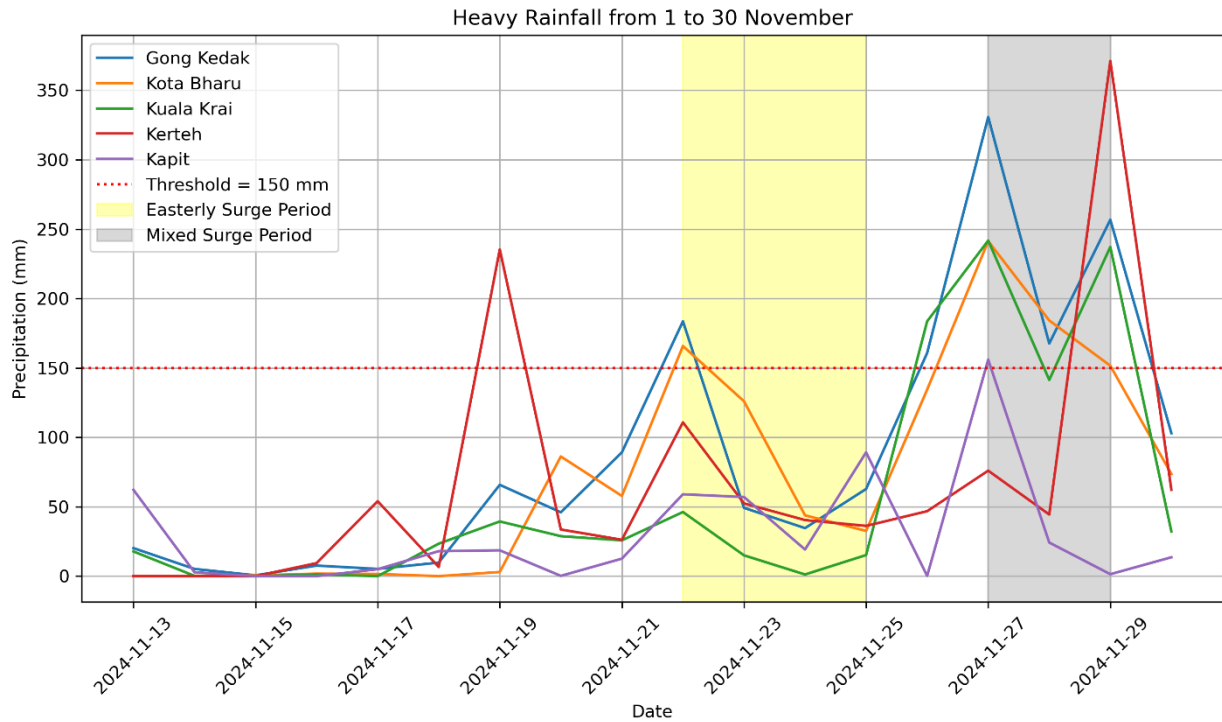


Figure 3. Daily accumulated rainfall exceeding the 150 mm threshold (dashed red line) at principal meteorological stations in November 2024. The shaded regions represent the easterly surge period (yellow) and the mixed surge period (grey), both of which coincided with heavy rainfall events—particularly pronounced during the mixed surge phase.

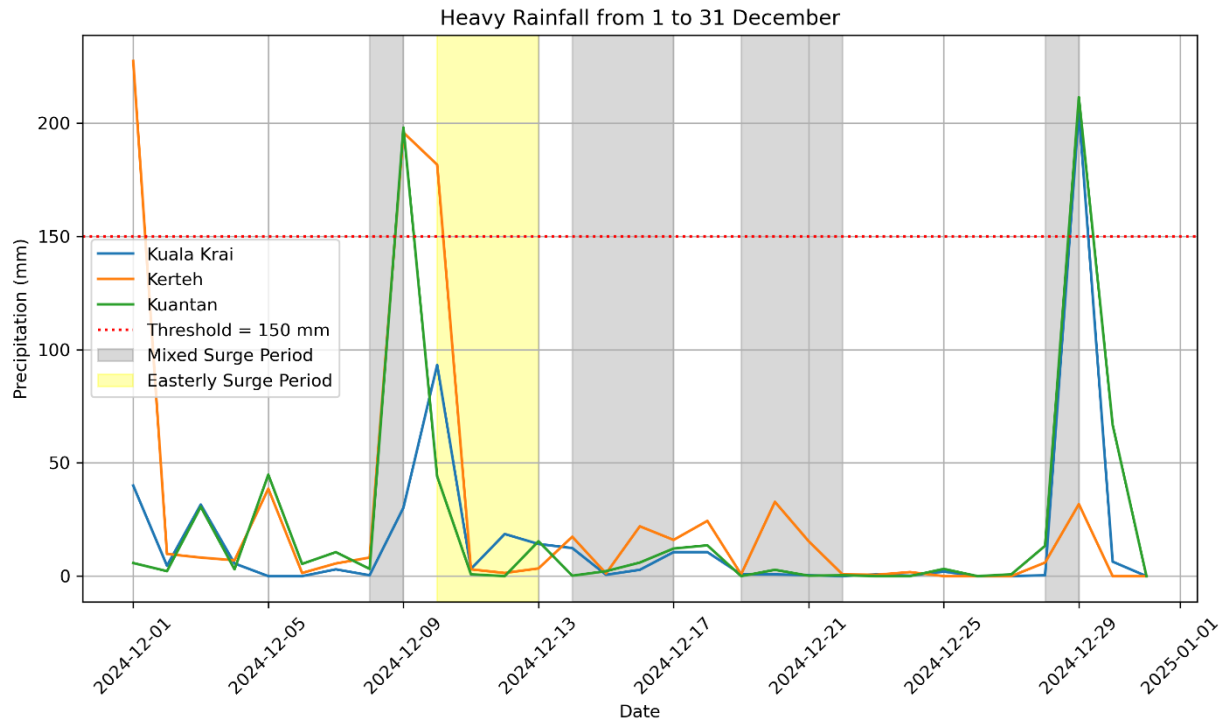


Figure 4. Daily accumulated rainfall exceeding the 150 mm threshold (dashed red line) at principal meteorological stations in December 2024. The shaded regions represent the easterly surge period (yellow) and the mixed surge period (grey), both of which coincided with heavy rainfall events—particularly pronounced during the mixed surge phase.

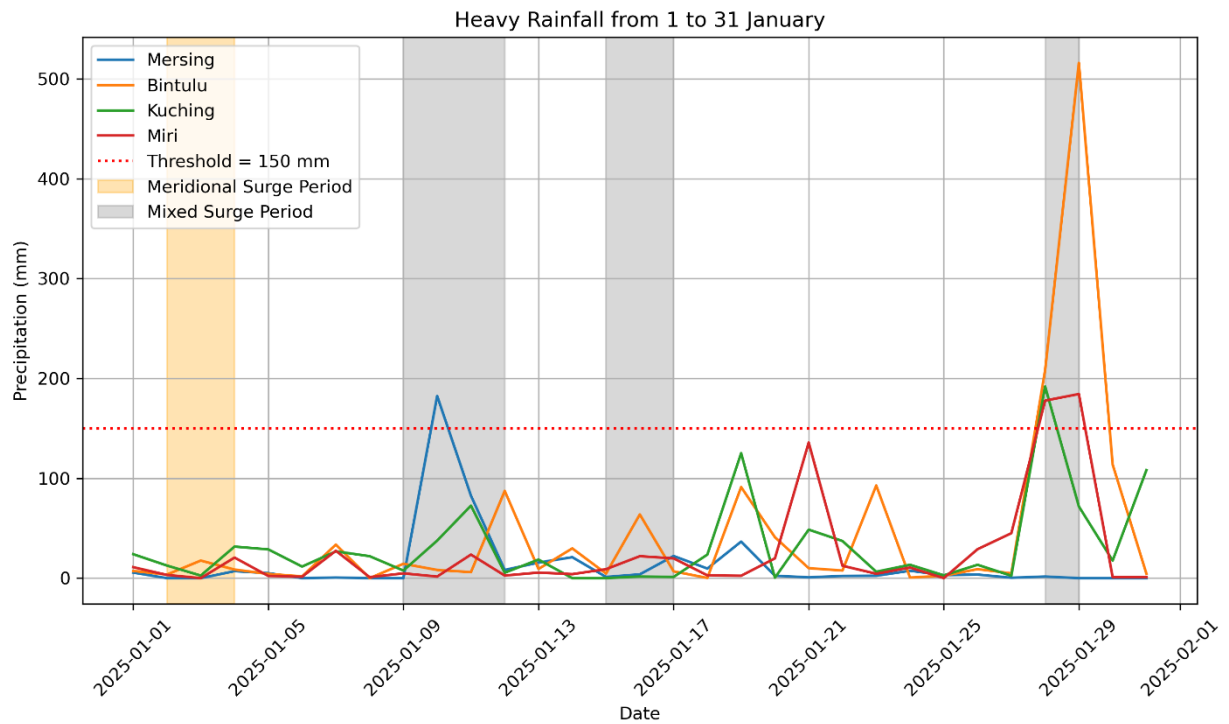


Figure 5. Daily accumulated rainfall exceeding the 150 mm threshold (dashed red line) at principal meteorological stations in January 2025. The shaded regions represent the meridional surge period (orange) and the mixed surge period (grey), both of which coincided with heavy rainfall events—particularly pronounced during the mixed surge phase. .

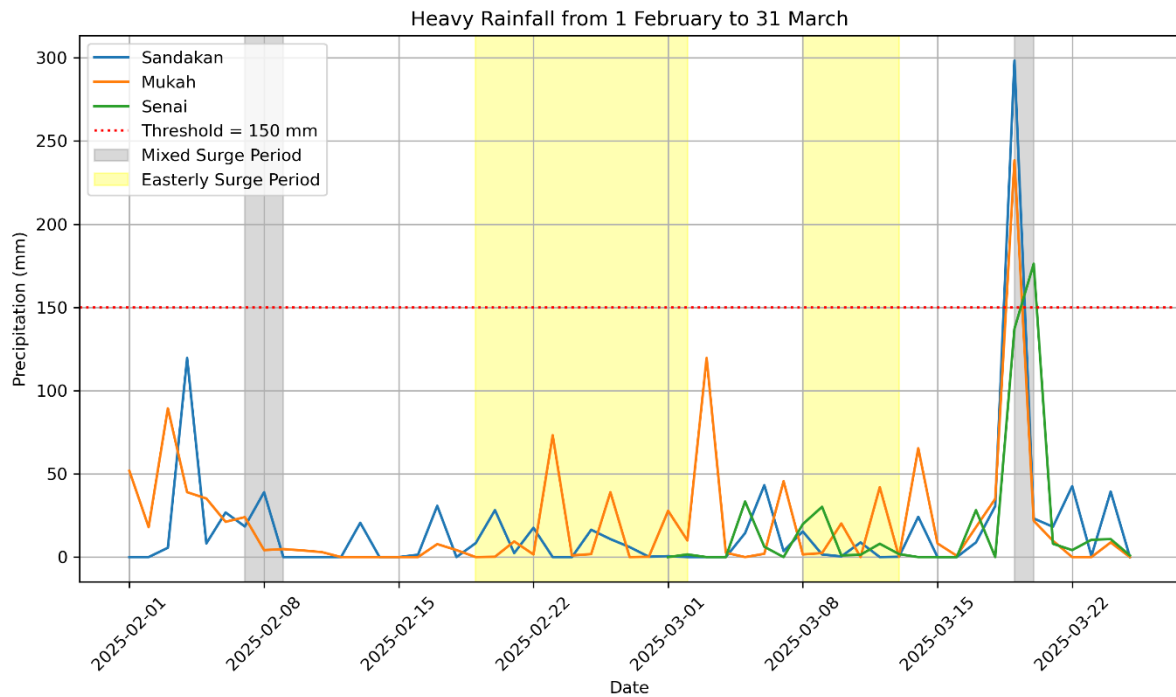


Figure 6. Daily accumulated rainfall exceeding the 150 mm threshold (dashed red line) at principal meteorological stations in February to March 2025. The shaded regions represent the easterly surge period (yellow) and the mixed surge period (grey), both of which coincided with heavy rainfall events—particularly pronounced during the mixed surge phase.

4.0 LARGE-SCALE CLIMATE DRIVER

4.1 North Atlantic Oscillation

Figure 7 shows the daily North Atlantic Oscillation (NAO) index values from September 2024 to March 2025, with positive phases indicated in blue and negative phases in red. Shaded grey bars represent days when heavy rainfall exceeding 150 mm was recorded at principal meteorological stations, suggesting a potential link between negative NAO phases and extreme rainfall events in the region.

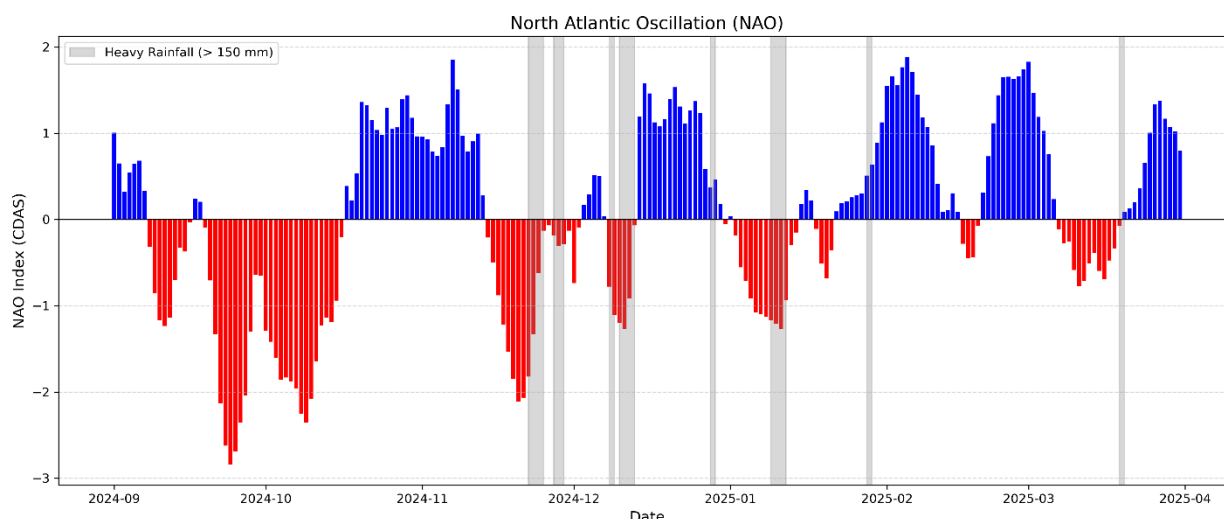


Figure 7. Daily NAO index from September 2024 to March 2025 (Source: NCEP NOAA data, <https://ftp.cpc.ncep.noaa.gov/cwlinks/>)

4.2 Oceanic Niño Index (ONI)

The Oceanic Niño Index (ONI) values for overlapping three-month periods from December 2023–February 2024 (DJF) through November 2025–January 2026 (NDJ) that representing sea surface temperature (SST) anomalies over the Niño 3.4 region in the equatorial Pacific are presented in Table 4. The data was retrieved from <https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/enso.shtml>.

Table 4. The ONI indicates neutral conditions during the 2024/2025 NEM

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2024	1.8	1.5	1.1	0.7	0.4	0.2	0.0	-0.1	-0.2	-0.3	-0.4	-0.5
2025	-0.6	-0.4	-0.2	-0.1	-0.1							

4.3 Indian Ocean Dipole (IOD)

The IOD was negative from November to December 2024. A negative IOD brings warmer seas near Indonesia and cooler seas near Africa, changing wind patterns and causing more moisture and rainfall over the Maritime Continent and southern parts of Australia (Table 5). The data was retrieved from

https://www.cpc.ncep.noaa.gov/products/international/ocean_monitoring/IODMI/DMI_month.html.

Table 5. The IOD was negative from November to December 2024

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2024	0.82	0.3	0.54	0.33	0.16	-0.09	-0.35	0.26	0.11	-0.36	-0.49	-0.5
2025	-0.39	0.0	0.25	0.2	0.21	-0.06	-0.31					

4.4 Madden–Julian Oscillation (MJO)

The active MJO in Phases 4 and 5 from late November to mid-December 2024 likely enhanced convection over the Maritime Continent, supporting heavy rainfall episodes—especially when overlapping with monsoon surges. Similarly, the active MJO in Phases 4 and 5 from late January to early February 2025 likely enhanced convection over the Maritime Continent, contributing to heavy rainfall episodes, particularly during surge events (Figure 8 and 9).

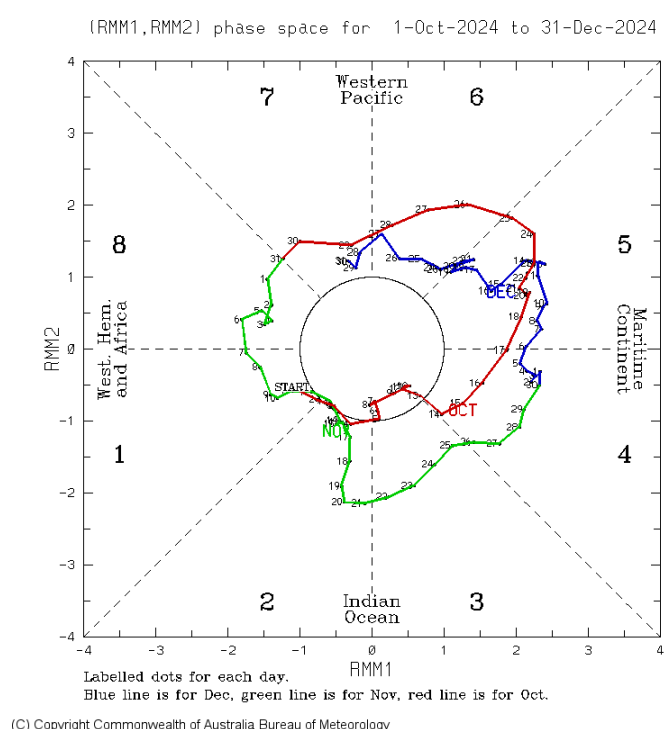


Figure 8. MJO phases from October to December 2024. The red line represents October, the green line represents November, and the blue line represents December.

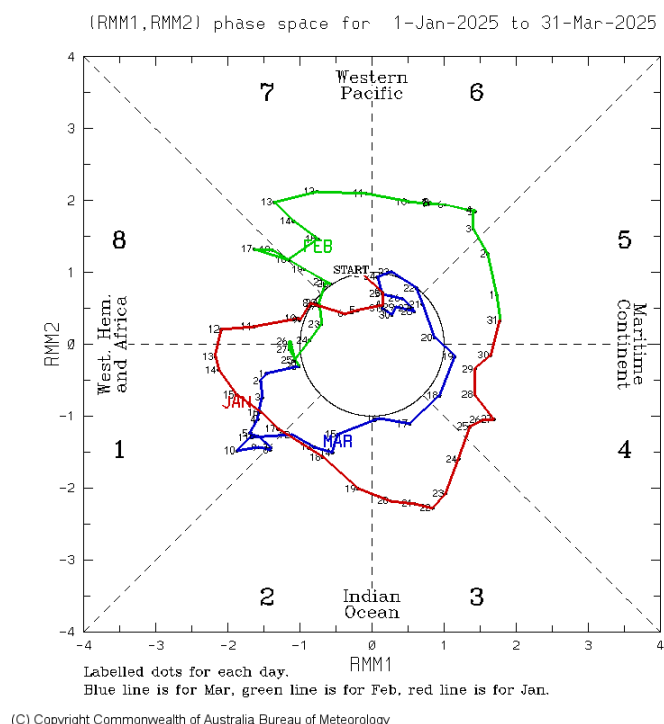


Figure 9. MJO phases from January to March 2025. The red, green and blue lines represent January, February and March 2025, respectively.

4.5 Typhoon (Ty) / Tropical Cyclone (TC) Occurrence

Table 6 lists the typhoons and tropical cyclones that developed during the 2024/2025 Northeast Monsoon (NEM) season. A total of five (5) tropical systems were identified within this period, occurring predominantly in November and December 2024.

Table 6. List of typhoons and tropical cyclones that occurred during the 2024/2025 Northeast Monsoon.

Name of Ty / TC	Date of Ty / TC
Yinxing (Ty)	3 – 12 November 2024
Toraji (Ty)	9 – 14 November 2024
Man-yi (Ty)	8 – 19 November 2024
Usagi (Ty)	11 – 16 November 2024
Pabuk (TS)	22 – 24 December 2024

5.0 SUMMARY

During the 2024/2025 NEM season, a total of 15 surge episodes were identified, of which ten were classified as mixed surges, four as easterly surges, and one as a meridional surge. Analysis indicates that these surges generally coincided with the negative phase of the NAO, which is known to weaken mid-latitude westerlies and allow cold air from the SH to extend further south. Of the 15 surges, eight were associated with heavy rainfall over mainland areas of Peninsular Malaysia and Borneo. The remaining seven episodes also produced rainfall; however, most of the precipitation occurred offshore.

Among the eight surge episodes that led to heavy rainfall, six were mixed surges and two were easterly surges. Further analysis revealed that these events were influenced by a combination of overlapping large-scale climate drivers. Notably, from late November through December, the Madden-Julian Oscillation (MJO) was active in Phases 4 and 5, while the Indian Ocean Dipole (IOD) remained in a negative phase. These overlapping conditions enhanced convective activity, contributing to stronger surge events and more frequent heavy rainfall episodes during this period. Meanwhile, the ONI remained neutral throughout the season, indicating that ENSO did not play a significant role in influencing this monsoon.

An analysis shows that most of the surge events in February and March did not bring significant rainfall. During these two months, the IOD remained neutral, and the MJO was mostly in Phases 1 and 2 from early to mid-March before weakening toward the end of the month. These conditions were unfavorable for convection, resulting in fewer significant rainfall events despite the presence of surges. However, on 19 March, a brief active Phase 4 of the MJO coincided with a mixed surge, leading to heavy rainfall in Sabah and Sarawak. Additionally, disturbances induced by Tropical Storm Pabuk in the upstream region of the SCS disrupted the southward propagation of the mixed surge on 22 December by modifying the prevailing wind supply to the tropical system. Consequently, the associated convection was suppressed, and no heavy rainfall was observed in Peninsular Malaysia and Borneo, even during the mixed surge episode (**Figure A9**).

Table A1. Summary of indices and parameters

Surge Period	Type of Surge	Station	Maximum Rainfall	NAO	MJO	ENSO	IOD
22 – 25 Nov 2024	Easterly	Gong Kedak	183.6 mm	Negative	Phase 3	Neutral	Negative
27 – 29 Nov 2024	Mixed	Kerteh	371.2 mm	Negative	Phase 4	Neutral	Negative
08 – 09 Dec 2024	Mixed	Kuantan	198 mm	Negative	Phase 5	Neutral	Negative
10 – 13 Dec 2024	Easterly	Kerteh	181.6 mm	Negative	Phase 5	Neutral	Negative
14 – 17 Dec 2024	Mixed	No heavy rain		Positive	Phase 5	Neutral	Negative
19 – 22 Dec 2024	Mixed	No heavy rain		Positive	Phase 6	Neutral	Negative
28 – 29 Dec 2024	Mixed	Kuantan	211.4 mm	Negative	Phase 7	Neutral	Negative
02 – 04 Jan 2025	Meridional	No heavy rain		Negative	Centre (Weak)	Neutral	Neutral
09 – 12 Jan 2025	Mixed	Mersing	182.4 mm	Negative	Phase 8	Neutral	Neutral
15 – 17 Jan 2025	Mixed	No heavy rain		Positive	Phase 1	Neutral	Neutral
28 – 29 Jan 2025	Mixed	Bintulu	516 mm	Positive	Phase 4	Neutral	Neutral
07 – 09 Feb 2025	Mixed	No heavy rain		Positive	Phase 6	Neutral	Neutral
19 Feb– 02 Mar 2025	Easterly	No heavy rain		Positive	Phase 8 to Phase 1	Neutral	Neutral
08 – 13 Mar 2025	Easterly	No heavy rain		Negative	Phase 1	Neutral	Neutral
19 – 20 Mar 2025	Mixed	Sandakan	298.4 mm	Negative	Phase 4	Neutral	Neutral

Overview of Wind and Precipitation During Monsoon Surges with Heavy Rainfall

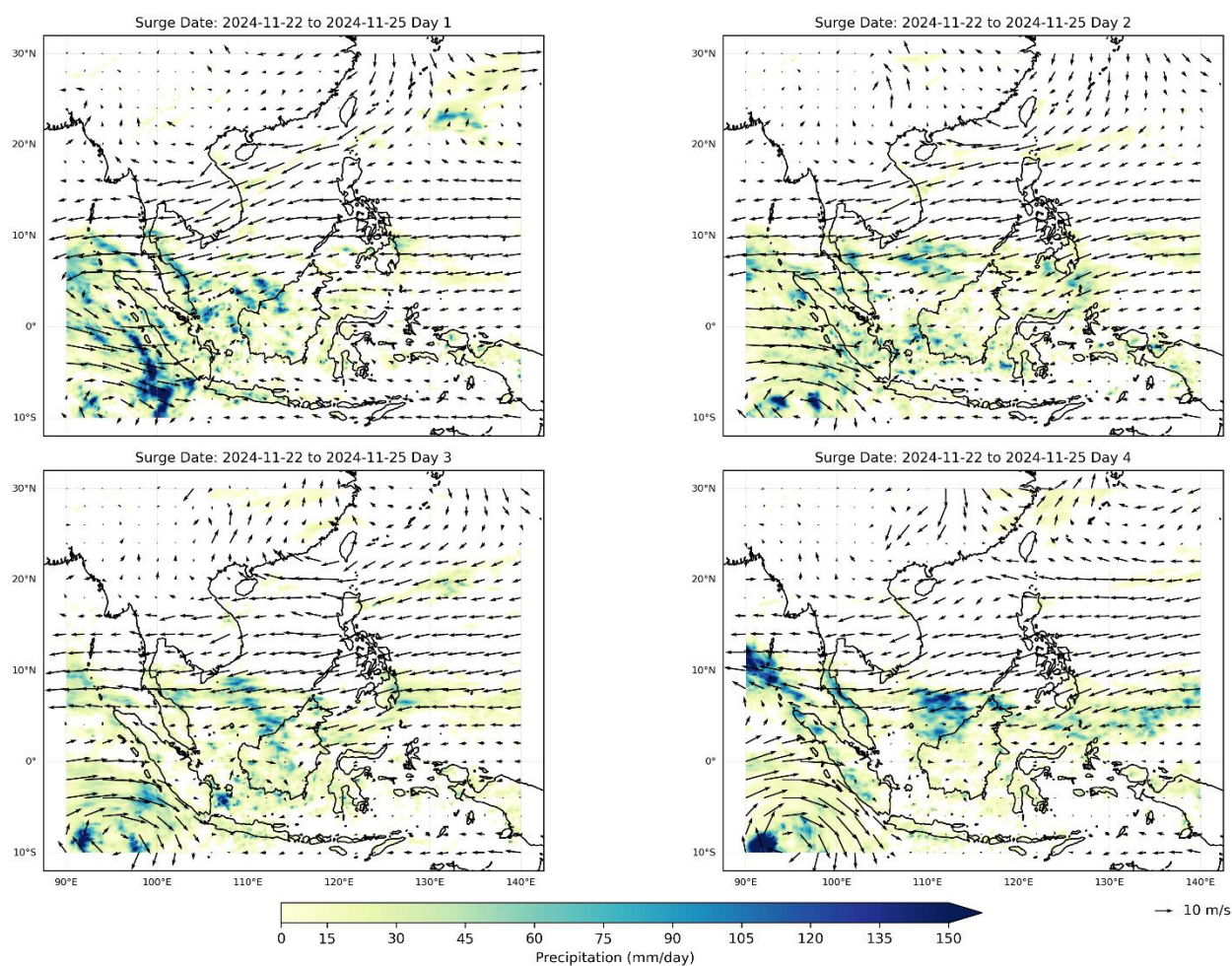


Figure A1. Easterly surge episode associated with heavy rainfall, 22–25 November 2024 (Episode 1).

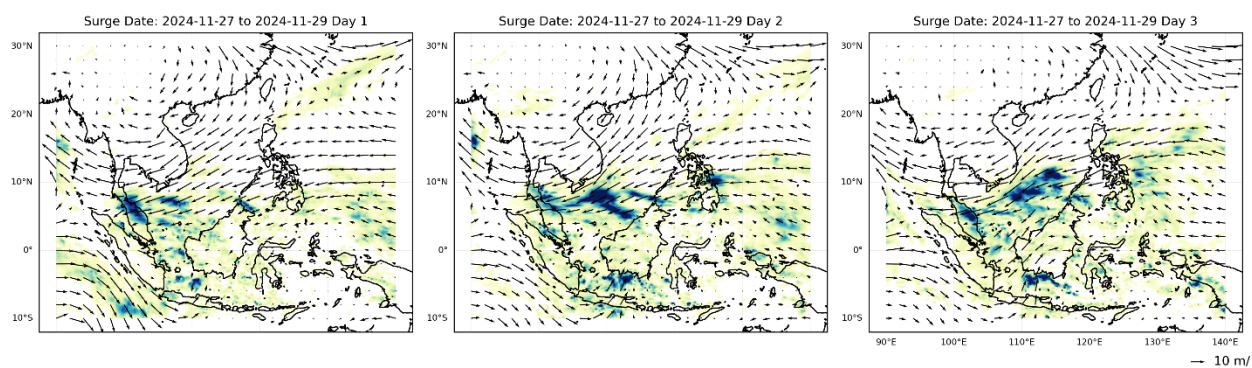


Figure A2. Mixed surge episode associated with heavy rainfall, 27–29 November 2024 (Episode 2).

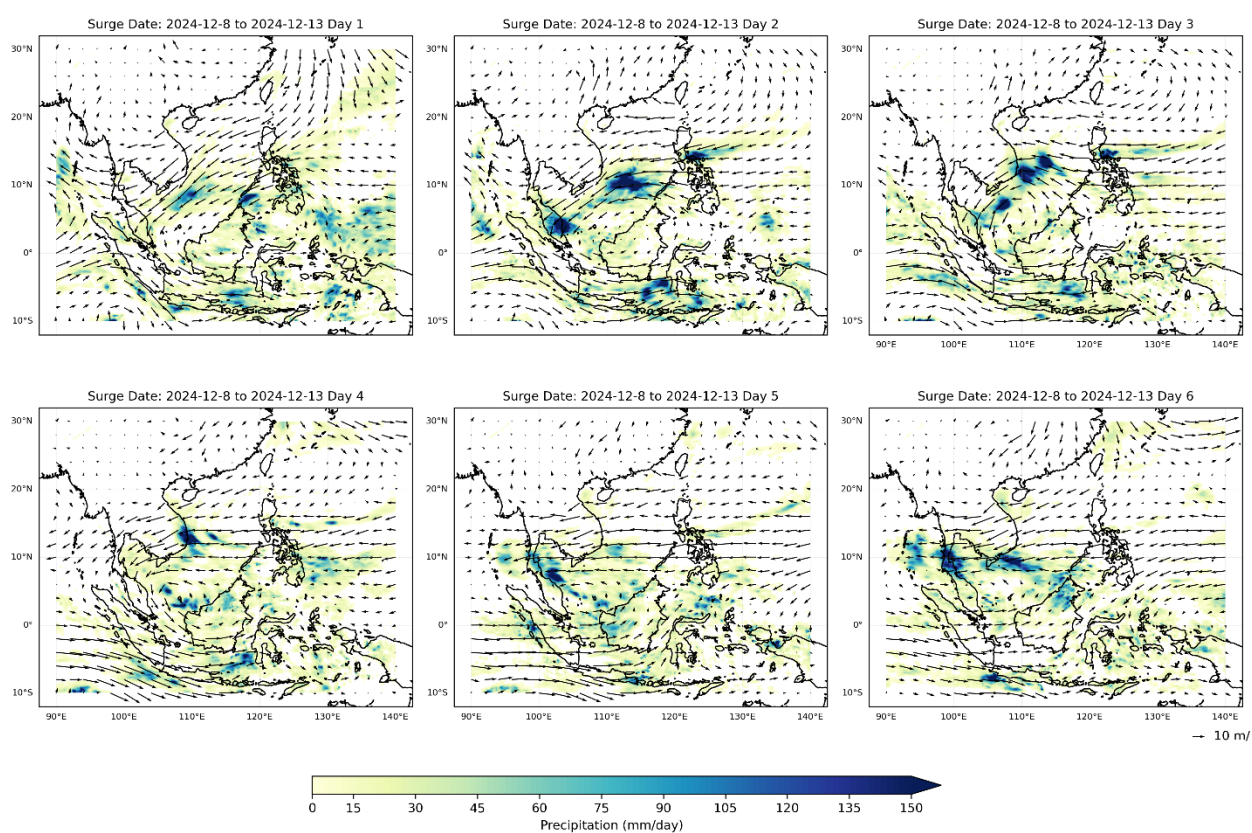


Figure A3. Mixed surge episode (8–9 December 2024), followed by an easterly surge (10–13 December 2024), both associated with heavy rainfall (Episode 3 and Episode 4)

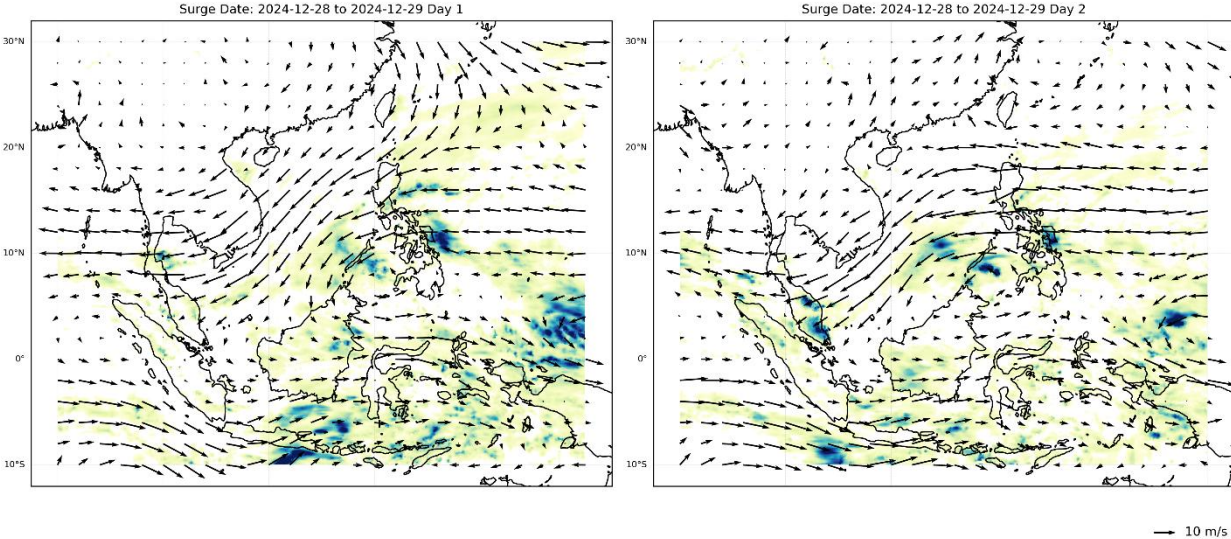


Figure A4. Mixed surge episode and associated heavy rainfall from 28 to 29 December 2024 (Episode 5).

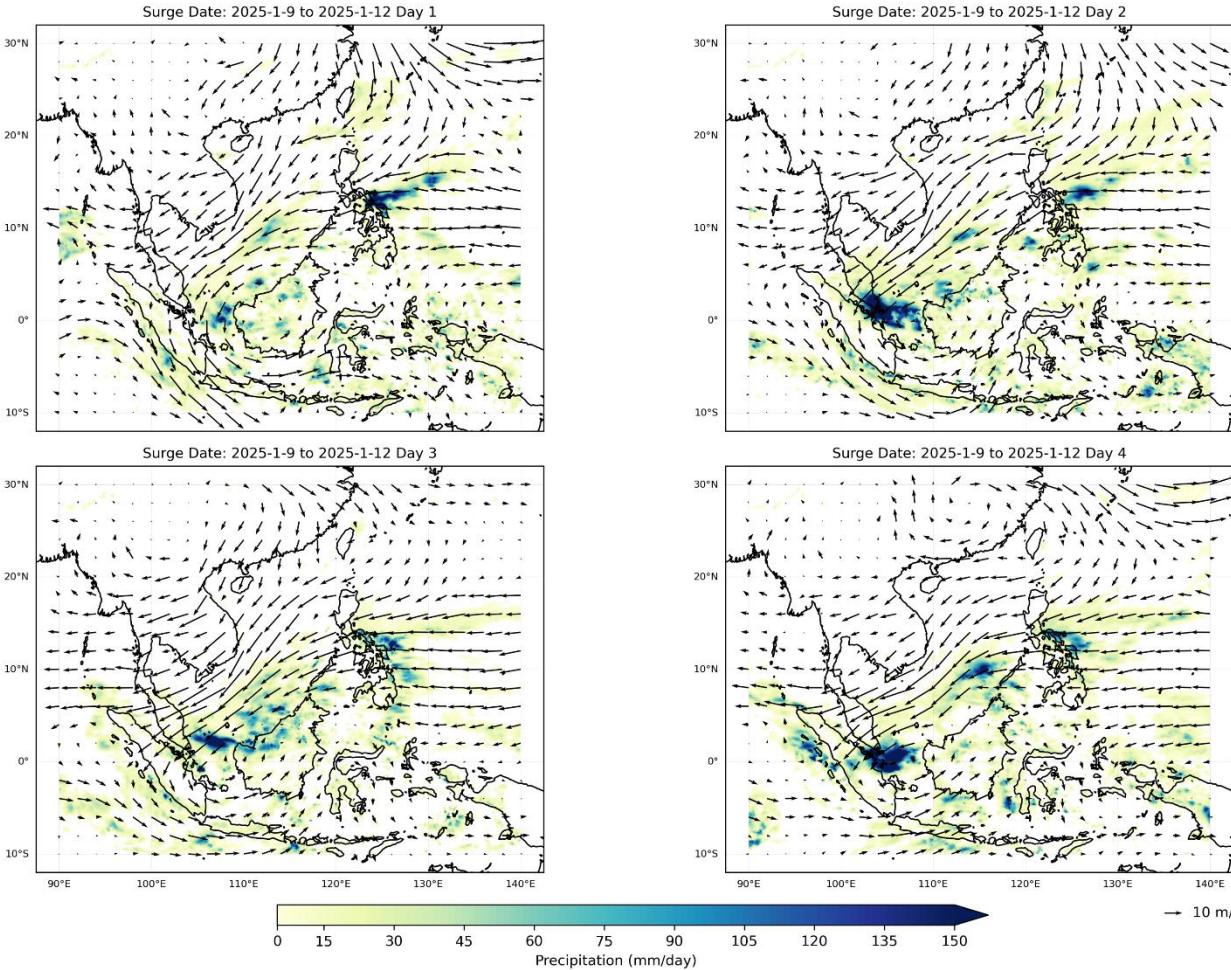


Figure A5. Mixed surge episode and associated heavy rainfall from 9 – 12 January 2025 (Episode 6).

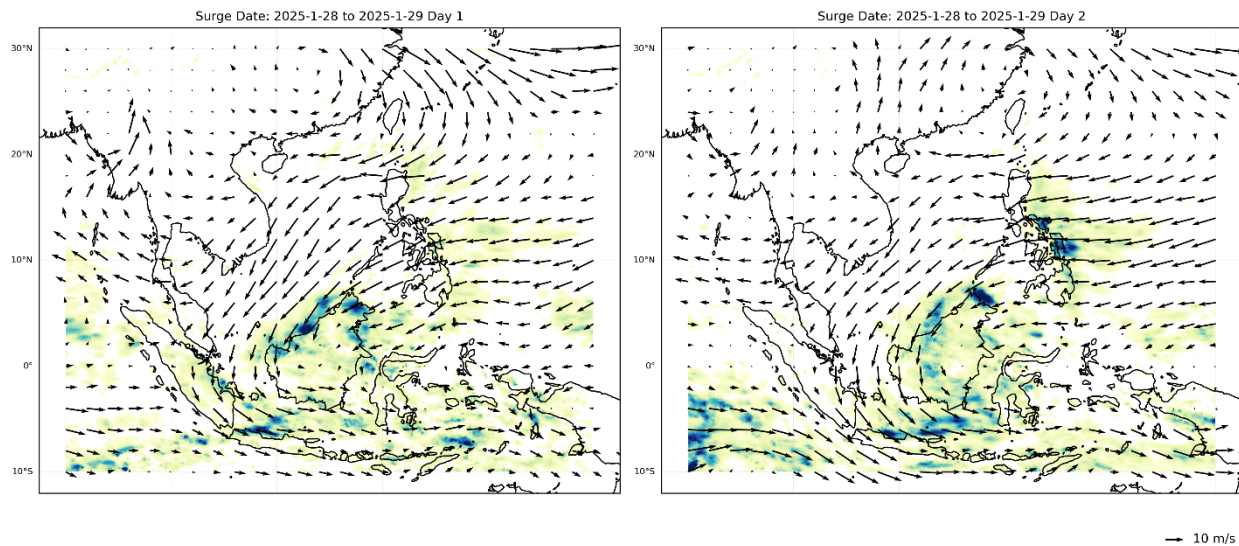


Figure A6. Mixed surge episode and associated heavy rainfall from 28 – 29 January 2025 (Episode 7).

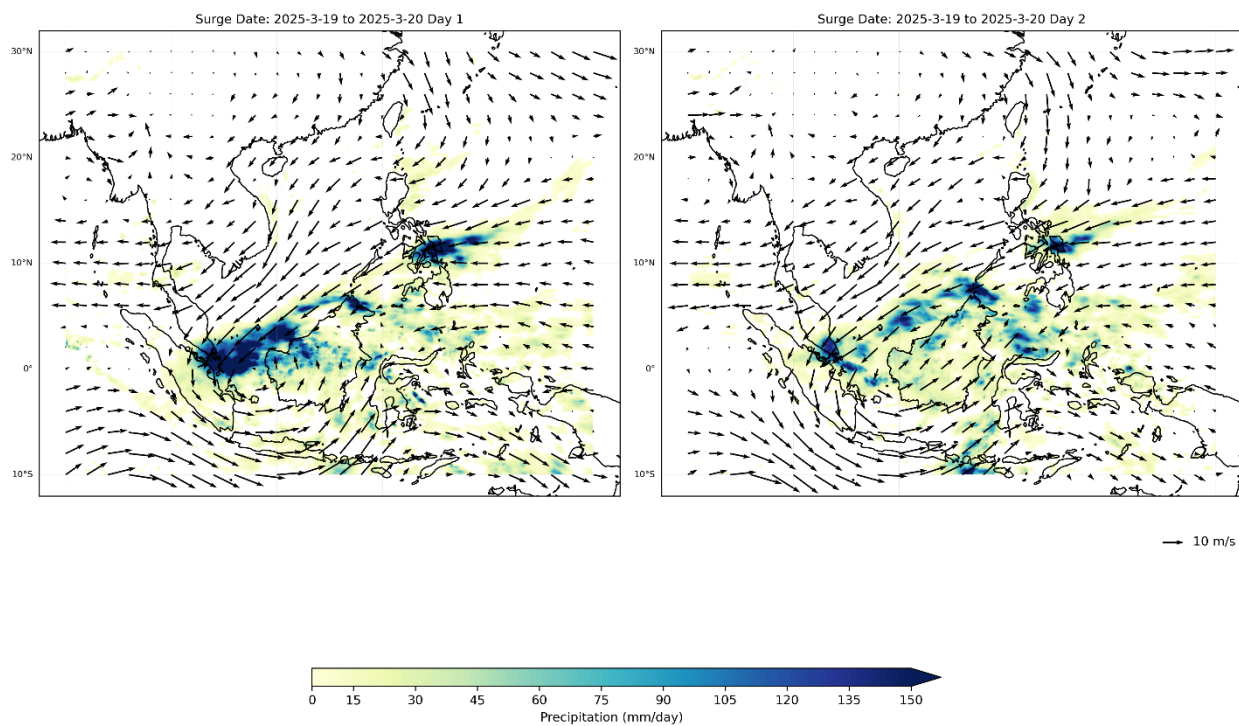


Figure A7. Mixed surge episode and associated heavy rainfall from 19 – 20 March 2025 (Episode 8).

Overview of Wind and Precipitation During Monsoon Surges Without Significant Rainfall

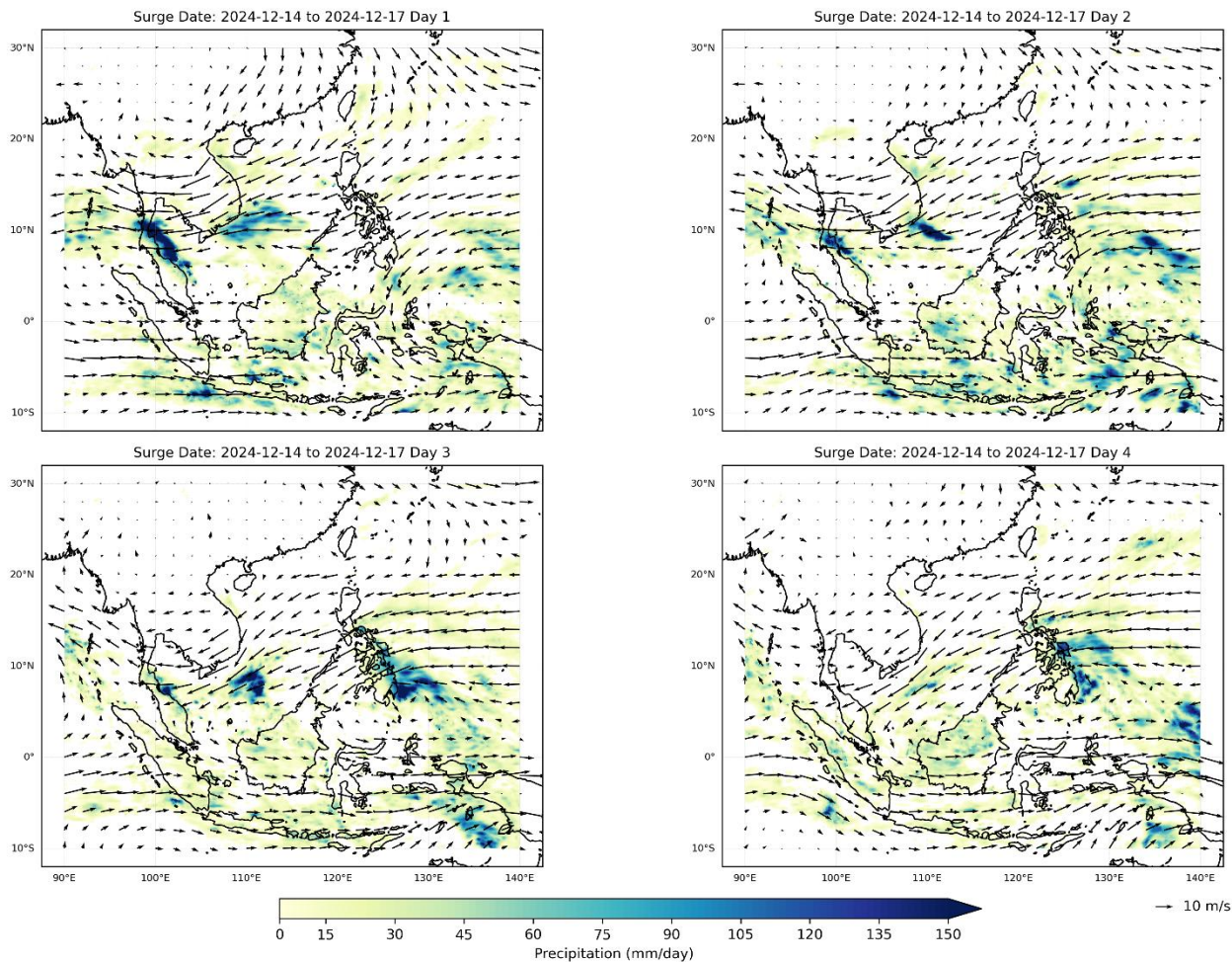


Figure A8. Mixed surge episode from 14 to 17 December 2024 with no heavy rainfall observed at principal meteorological stations.

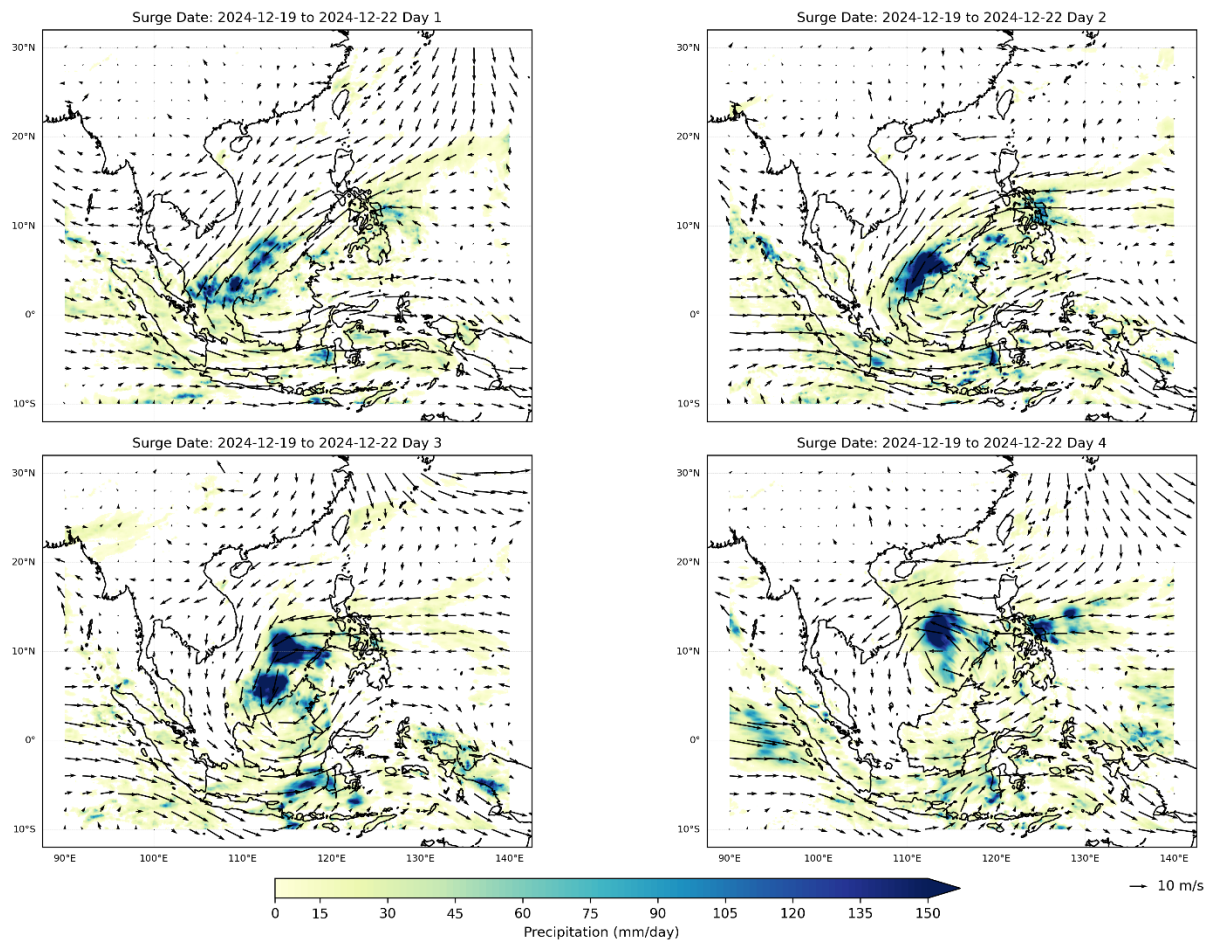


Figure A9. Mixed surge episode from 19 to 22 December 2024 with no heavy rainfall observed at principal meteorological stations.

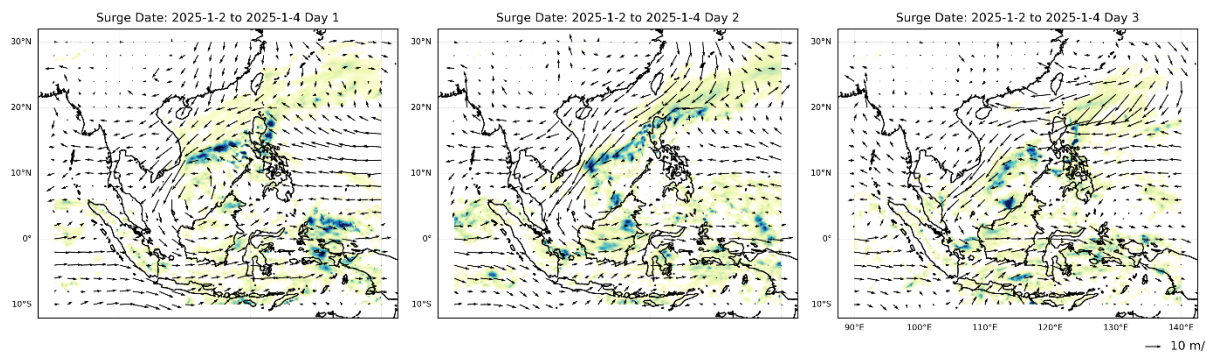


Figure A10. Meridional surge episode from 2 to 4 January 2025 with no heavy rainfall observed at principal meteorological stations.

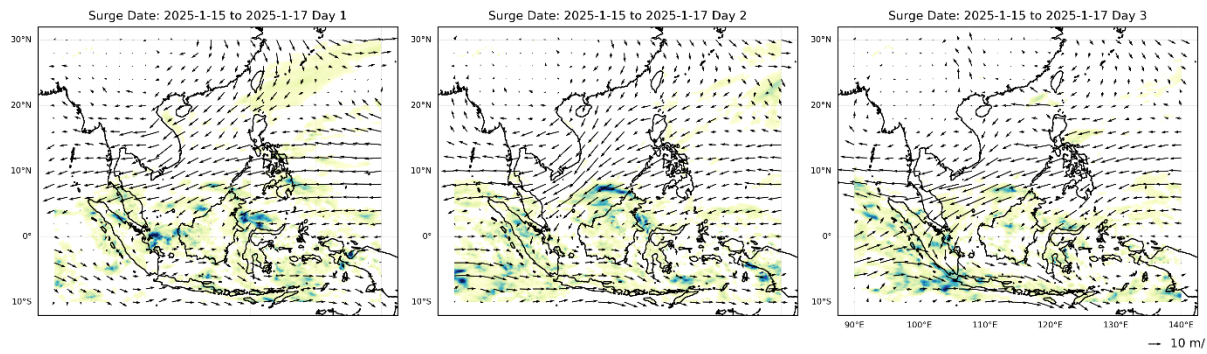


Figure A11. Mixed surge episode from 15 to 17 January 2025 with no heavy rainfall observed at principal meteorological stations.

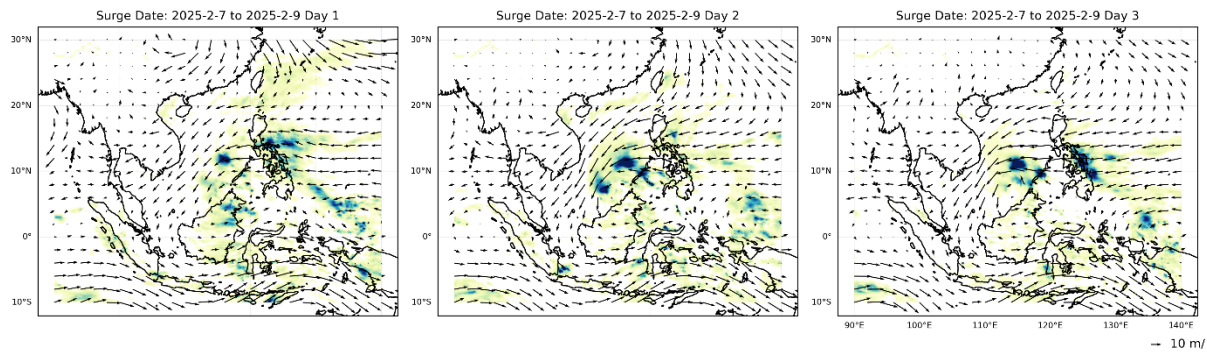


Figure A12. Mixed surge episode from 7 to 9 February 2025 with no heavy rainfall observed at principal meteorological stations.

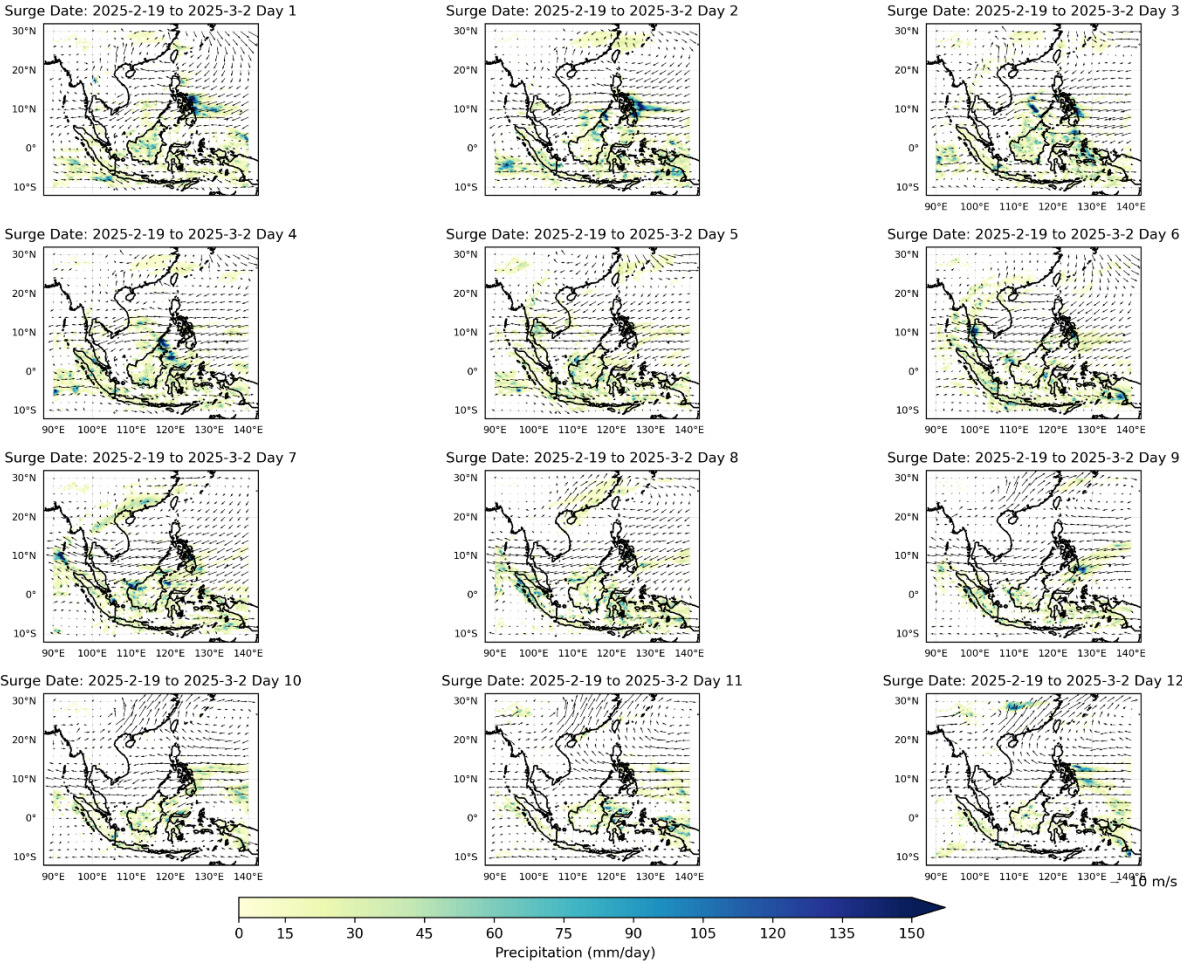


Figure A13. Easterly surge episode from 19 February to 2 March 2025 with no heavy rainfall observed at principal meteorological stations.

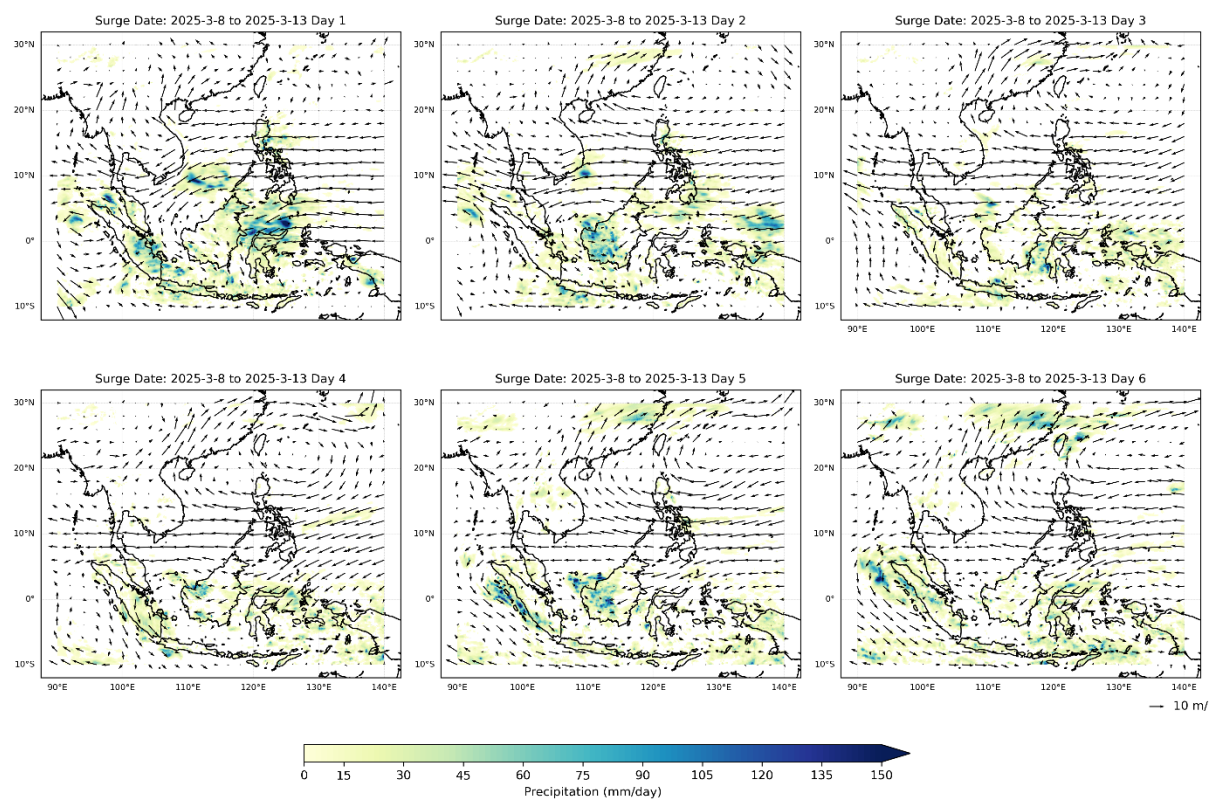


Figure A14. Easterly surge episode from 8 to 13 March 2025 with no heavy rainfall observed at principal meteorological stations.

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