

# 2024

ANNUAL CLIMATE  
ASSESSMENT



# Singapore's Climate in 2024

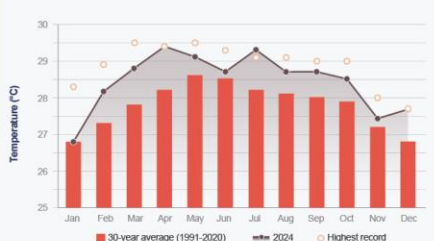


## Annual mean temperature



Annual mean temperature was 28.4°C, 0.6°C above the long-term average and the warmest year on record, tied with 2019 and 2016.

## Monthly mean temperature



Monthly mean temperatures were equal to or above their long-term averages, with July's mean temperature surpassing the previous July record by 0.2°C.

## Monthly total rainfall



2024 was the 12th wettest year since 1980, with an average annual rainfall 8.1% higher than the long-term average.

## NOTABLE WEATHER EVENTS IN 2024



### Unusual dry spell

Singapore experienced a dry spell of 18 days between 13 and 30 July due to drier air in the region. Low rainfall in July also contributed to the higher temperatures.



### Blustery Sumatra squall

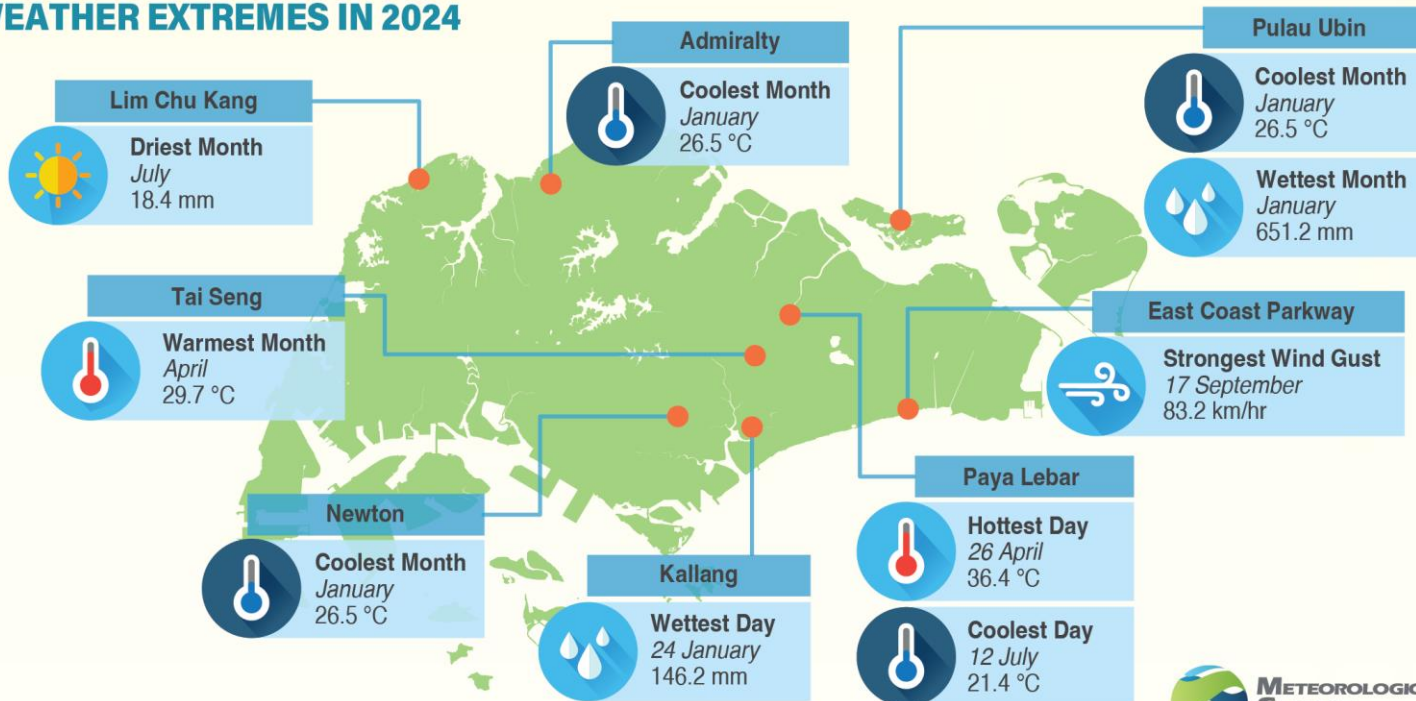
An intense Sumatra squall swept across Singapore in the evening of 17 September, with wind gusts strong enough to fall trees and damage infrastructure.



### Heavy rain

Widespread rain that started around midnight and continued into the afternoon on 14 October led to flooding in many areas.

## WEATHER EXTREMES IN 2024



# Overview of Singapore's Climate in 2024

2024 was the warmest year on record for Singapore, tied with 2019 and 2016. At the Changi climate station, all months were equal to or warmer than the long-term average (1991 – 2020). July 2024 was the warmest July since 1929, during which Singapore also experienced a dry spell from 13 to 30 July 2024. While there were some dry periods in 2024, Singapore also experienced above-average rainfall during some months, including November 2024 which broke the record for the highest November islandwide average rainfall since 1980. Singapore's annual total rainfall for 2024 was 8.1% above the long-term annual average. The 2023/2024 El Niño event contributed to Singapore's warmer temperatures in 2024 and could have contributed to the drier conditions between February and April.

This report reviews Singapore's weather and climate in 2024 and updates Singapore's long-term rainfall and temperature trends.

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## Large-scale Climate Variability in 2024

Climate drivers, such as the El Niño – Southern Oscillation (ENSO), are sources of year-to-year variability for Singapore’s climate as well as the global climate.

In 2024, the key climate driver was ENSO. The 2023/2024 El Niño event, which ended in March 2024, contributed to Singapore’s warmer temperatures in 2024. The Indian Ocean Dipole (IOD) was neutral for most of 2024 and had little impact on Singapore’s climate. Further information on sea surface temperatures, ENSO, IOD, and the Madden-Julian Oscillation (MJO) and how these drivers modulated Singapore’s climate in 2024 is described below.

### Sea Surface Temperature

Sea surface temperature (SST) refers to the temperature of the upper few meters of the ocean. Not only are SSTs used in monitoring climate drivers such as ENSO and IOD (see following sections), SSTs are also used to track stress to marine life such as corals, as well as quantifying climate change.

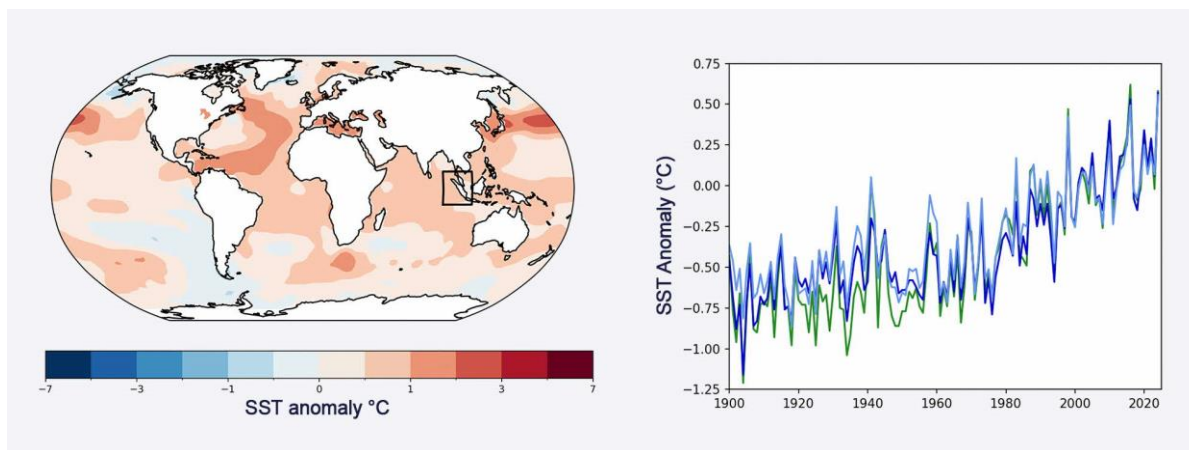


Figure 1: Left: Sea surface temperature (SST) anomaly (°C) for 2024 (ERSSTv5 dataset), relative to the 1991 – 2020 long-term average. Black box indicates the region used for the trend. Right: SST anomaly for region around Singapore using three long-term SST datasets: ERSSTv5 (green), COBE2 (blue), and HadISST (light blue).

In 2024, global SSTs were exceptionally warm<sup>1</sup> with the warmest anomalies over parts of the northern Atlantic and Pacific Oceans (Figure 1, left). For the region around Singapore (black box in Figure 1 left), SSTs were either the warmest or second warmest year on record, depending on the dataset used (Figure 1, right). In 2024, the average anomaly was 0.56°C – 0.58°C above the 1991 – 2020 baseline, similar to 2016 which was the previous warmest year on record. Since 1900, SSTs in this region have been warming at a rate of 0.06°C/decade – 0.08°C/decade, although in the last 50 years, the rate has increased to 0.11°C/decade – 0.15°C/decade. Notable peaks in 1983, 1998, 2016, as well as 2024 (Figure

<sup>1</sup> WMO press release 10 January 2025 <https://wmo.int/news/media-centre/wmo-confirms-2024-warmest-year-record-about-155degc-above-pre-industrial-level>

1, right) correspond to years following the formation of El Niño events, highlighting how climate drivers can amplify SSTs.

## The El Niño – Southern Oscillation (ENSO) Overview

The El Niño event that developed in 2023 continued into 2024, gradually weakening before returning to ENSO neutral conditions in April 2024<sup>2</sup> (Figure 2). El Niño events refer to the ENSO phase where SSTs are warmer than average over in the central and eastern tropical Pacific Ocean, typically resulting in reduced rainfall over the western Pacific. The Nino3.4 index shown in Figure 2 is a common index used to monitor El Niño events, with sustained values above 0.65°C indicating El Niño conditions. Overall, the 2023/2024 El Niño event was considered moderate to strong, but weaker than the previous 2015/2016 El Niño event.

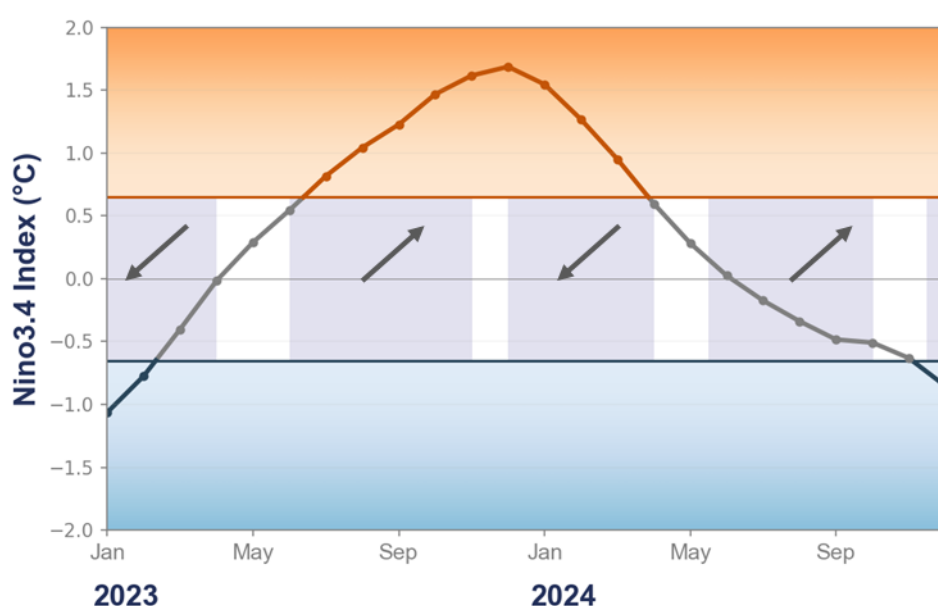


*Figure 2: Nino3.4 index from January 2023 to December 2024. The index measures the average SST anomaly in the central-eastern equatorial Pacific Ocean (termed the ‘Nino3.4 region’), averaged over three months. The anomaly is calculated relative to 1976 – 2014, with the tropical long-term warming trend removed. The approximate timing of the Northeast (downward pointing arrows) and Southwest (upward pointing arrows) monsoon seasons are shaded in grey. The El Niño conditions ended in the first part of 2024, returning to ENSO neutral conditions in April 2024. The index passed the La Niña threshold in December 2024.*

Even though the El Niño event was in the decay phase during the start of 2024, the event impacted Singapore’s climate. Decaying El Niño events typically bring warmer-than-usual air temperatures to Singapore and the surrounding region. Warmer temperatures are also seen in the ocean, with SSTs in the region around Singapore on average 0.50°C – 0.75°C above the long-term average in March – May following an El Niño event (Figure 3). This is in contrast with the cooler-than-usual temperatures following a La Niña event. In 2024, SSTs also followed this pattern, although the above-average temperatures extended further east than

<sup>2</sup> The values of the Nino3.4 index and classification of events can differ between centres, due to the data used, as well as how the index is calculated (such as whether the background warming trend is removed and the climatology period).

usual, possibly associated with the western Pacific Ocean SSTs warming faster than the global average.

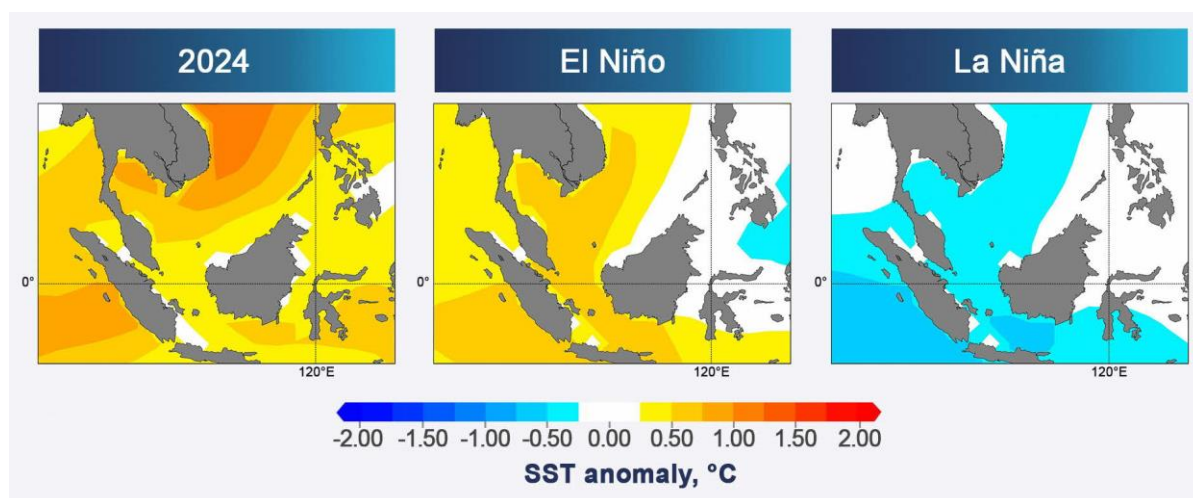


Figure 3: March – May SST anomalies in 2024 (left), past El Niño events since 1961 – 2023 (centre) and past La Niña events since 1961 – 2023 (right), with the long-term warming trend removed. SSTs around Singapore were warmer than average in March – May 2024, similar as to what is seen after an El Niño event. SSTs tend to be cooler after a La Niña event.

El Niño events also bring a higher chance of dry conditions during the dry phase of the Northeast Monsoon and the first inter-monsoon period (February – May). These drier conditions can also contribute to the warmer temperatures due to the lack of cloud cover. In 2024, Singapore experienced below-average rainfall in March and April, with near-average rainfall in February.

For most of the second half of the year, the Nino3.4 index was in the neutral range, only reaching the La Niña threshold in December 2024 (Figure 2). This is considered a late onset, as La Niña events typically develop around the middle of the year. La Niña events refer to the ENSO phase where SSTs are cooler than average in the central and eastern tropical Pacific Ocean, typically resulting in increased rainfall over the western Pacific. In September/October 2024, there were signs of La Niña conditions developing. However, unfavourable trade winds in early November slowed the cooling of the SSTs in the eastern Tropical Pacific. There were also warmer-than-average temperatures in the oceans around the globe in 2024. These factors could have led to the later establishment of La Niña conditions in 2024.

For Singapore, La Niña events typically bring more rainfall, particularly during the Southwest Monsoon season (June to September)<sup>3</sup>, and to a lesser extent at the end of the Northeast Monsoon season (February) and into the first inter-monsoon period (March to May). La Niña events also tend to moderate Singapore’s temperature. However, given the late onset of the La Niña conditions, it is unlikely to have influenced Singapore’s climate in 2024.

## The Indian Ocean Dipole (IOD) Overview

The IOD refers to a broad pattern of temperature differences in the western and eastern Indian Ocean. Sustained warmer anomalies in the western tropical Indian Ocean and cooler anomalies in the eastern tropical Indian Ocean indicate a positive IOD event, while cooler

<sup>3</sup> See the 2020 Annual Climate Assessment Report for more information.

anomalies in the west and warmer anomalies in the east indicate a negative IOD event. This difference in SST is measured by the IOD Index.

The IOD Index was predominately neutral throughout 2024 (Figure 4). The positive IOD event that developed in 2023 persisted into January 2024. Positive IOD events typically end by December. However, when strong El Niño events and positive IOD events coincide, a positive IOD event can extend into January (e.g. January 1998). The IOD Index returned to neutral in February 2024, remaining neutral for the rest of the first half of the year. There was a cooling trend in the IOD Index towards the end of the year, with the monthly IOD Index passing the negative threshold in December. However, based on the average of three SST datasets, the negative values did not persist long enough to declare a negative IOD event.

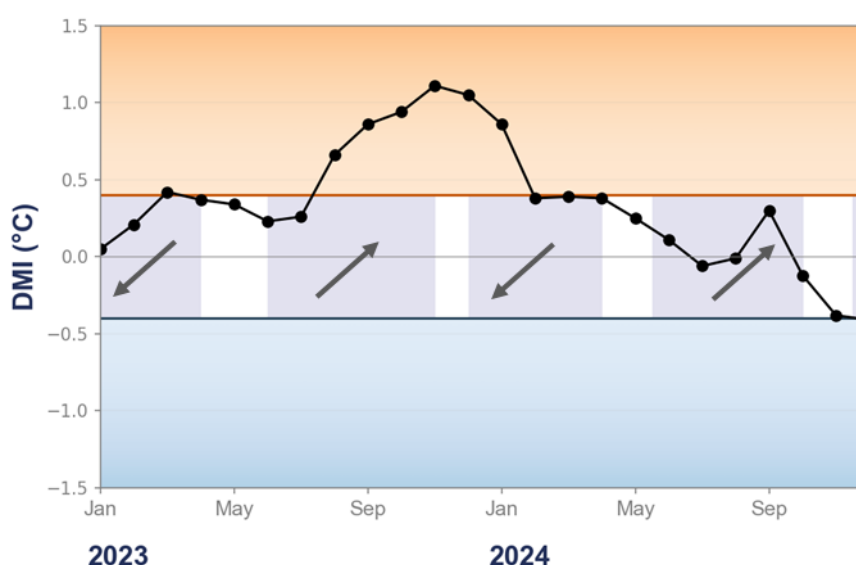


Figure 4: The IOD Index shows values within the neutral range (white/grey) for most of 2024, based on the average of three long-term SST datasets. The approximate timing of the Northeast (downward pointing arrows) and Southwest (upward pointing arrows) monsoon seasons are shaded in grey. After the positive IOD event in 2023, the Index returned to neutral in February 2024. While the Index approached the negative IOD threshold (blue line) towards the end of the year, the negative values were not sustained for long enough for a negative IOD event to be declared.

Overall, the impact of the IOD on Singapore's rainfall in 2024 is likely to have been small, but the IOD may have contributed to Singapore's warmer temperatures. The impact of IOD on Singapore's climate in January specifically is difficult to ascertain, due to few observed cases (the last was in 1998). However, Singapore's temperatures tend to be warmer after strong positive IOD events, and therefore the 2023/2024 positive IOD event may have also contributed to Singapore's warmer temperatures in the first half of the year, along with the 2023/2024 El Niño event.

## The Madden-Julian Oscillation (MJO) Overview

At the subseasonal timescale, the MJO is an important driver for climate variability in Singapore. The MJO is characterised by a pulse of cloud or rain that moves eastward around the equator, with a typical cycle lasting between 30 to 60 days. The MJO's path along the equatorial region is divided into sub-geographical locations, known as phases, which are

marked by the location of enhanced or suppressed convective activity and the associated rainfall. While the MJO is not always present, when it is active, it can modulate Singapore's rainfall and provide predictability for rainfall in the coming weeks. Here, we review two MJO events that likely impacted Singapore's rainfall in January and November 2024 (Figure 5).

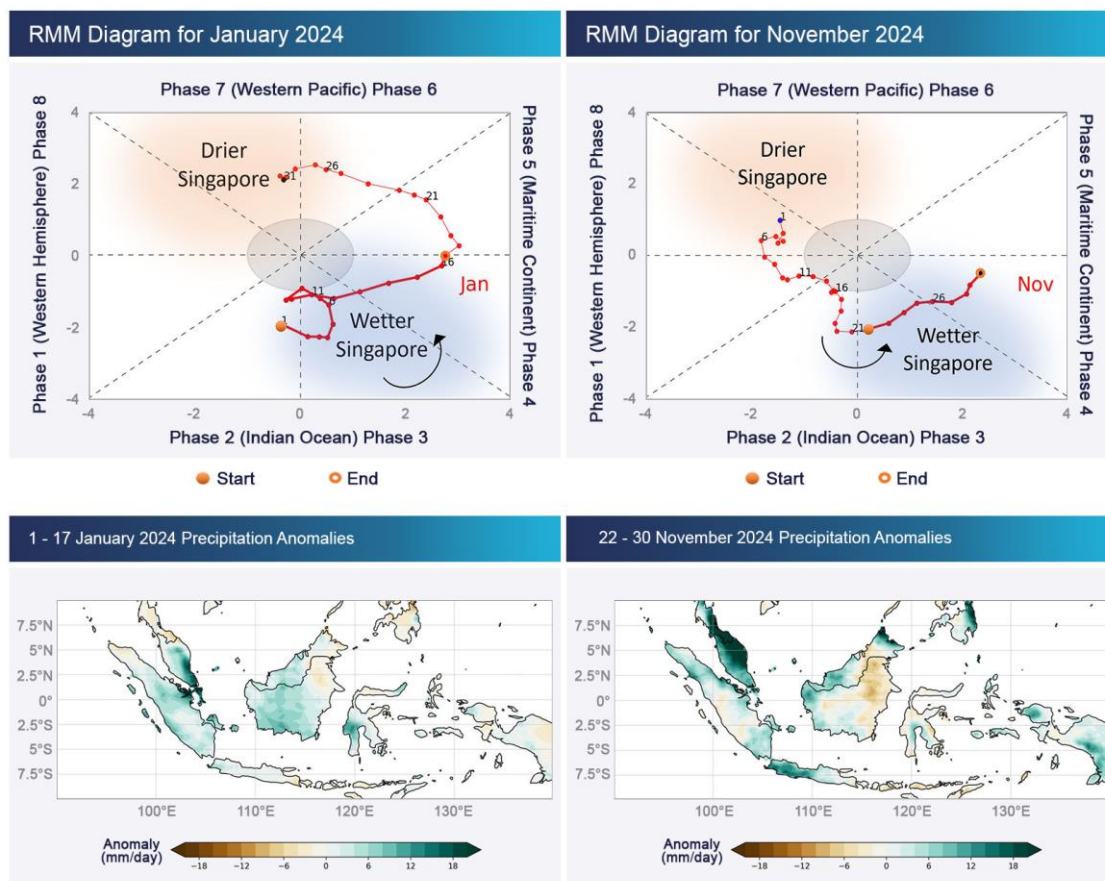


Figure 5: Top: Real-Time Multivariate MJO (RMM) diagrams for January 2024 (left) and November 2024 (right), with blue and black dots denoting the start and the end of the month, respectively. Each data point indicates one day. An MJO signal is present when the data points are outside the grey unit circle. The thick lines in the left and right diagrams indicate the periods 1 – 17 January and 22 – 30 November, respectively, which coincide with the blue shading that indicates phases that typically bring wetter conditions to Singapore. Bottom: Rainfall anomalies for 1 – 17 January 2024 (left) and for 22 – 30 November 2024 (right) show wetter than usual conditions (green colours<sup>4</sup>).

Both January and November 2024 were wetter than average for Singapore, likely with some contribution from the MJO. In the first two weeks of January, an MJO signal was present over the Indian Ocean (Phases 2 and 3) and then propagated eastwards through the Maritime Continent (Phases 4 and 5) during the third week of the month (Figure 5, top left). This is consistent with the positive rainfall anomalies observed across most of the Maritime Continent region during 1 – 17 January (Figure 5, bottom left). The MJO event likely brought higher amounts of rainfall to Singapore, with more than 60% of the total monthly rainfall recorded

<sup>4</sup> Data sources: CHIRPS (rainfall), Bureau of Meteorology, Australia (RMM values)

during the first 17 days of the month, when the MJO was mostly active over the Indian Ocean (Phases 2 and 3) and the western half of the Maritime Continent (Phase 4).

In the last week of November 2024, an MJO signal was present over the eastern Indian Ocean (Phase 3) and the western half of the Maritime Continent (Phase 4, Figure 5, top right). In the absence of any other drivers of variability, this would typically contribute to above-average rainfall across the Maritime Continent, as is seen over many regions in Figure 5 (bottom right). The fact that some regions experienced drier-than-normal conditions during this time is a reminder that the overall conditions are not determined by the MJO alone. It is likely that other synoptic conditions contributed to these dry areas. November 2024 was the wettest November that Singapore has experienced since 1980. The MJO possibly contributed significantly to this record, with 176mm (42% of the total monthly rainfall) recorded during the time the MJO was passing through Phases 3 and 4.

The two examples presented here demonstrate the role the MJO plays in modulating subseasonal rainfall over the Maritime Continent, with a focus on Singapore. Other impactful large-scale climate drivers, such as the 2023/2024 El Niño, likely played a minor role in the region's rainfall patterns during January and November. More information on Singapore's rainfall in 2024 can be found under the Rainfall Section (page 17).

# Temperature

## Global Temperature

The global average temperature for 2024 was the warmest on record likely exceeding 1.5°C above the 1850 – 1990 long-term average for one calendar year for the first time<sup>5</sup>. Many parts of the world experienced temperatures much warmer than average (Figure 6). Furthermore, the years 2015 to 2024 were the ten warmest years on record in all six global datasets monitored<sup>5</sup>.

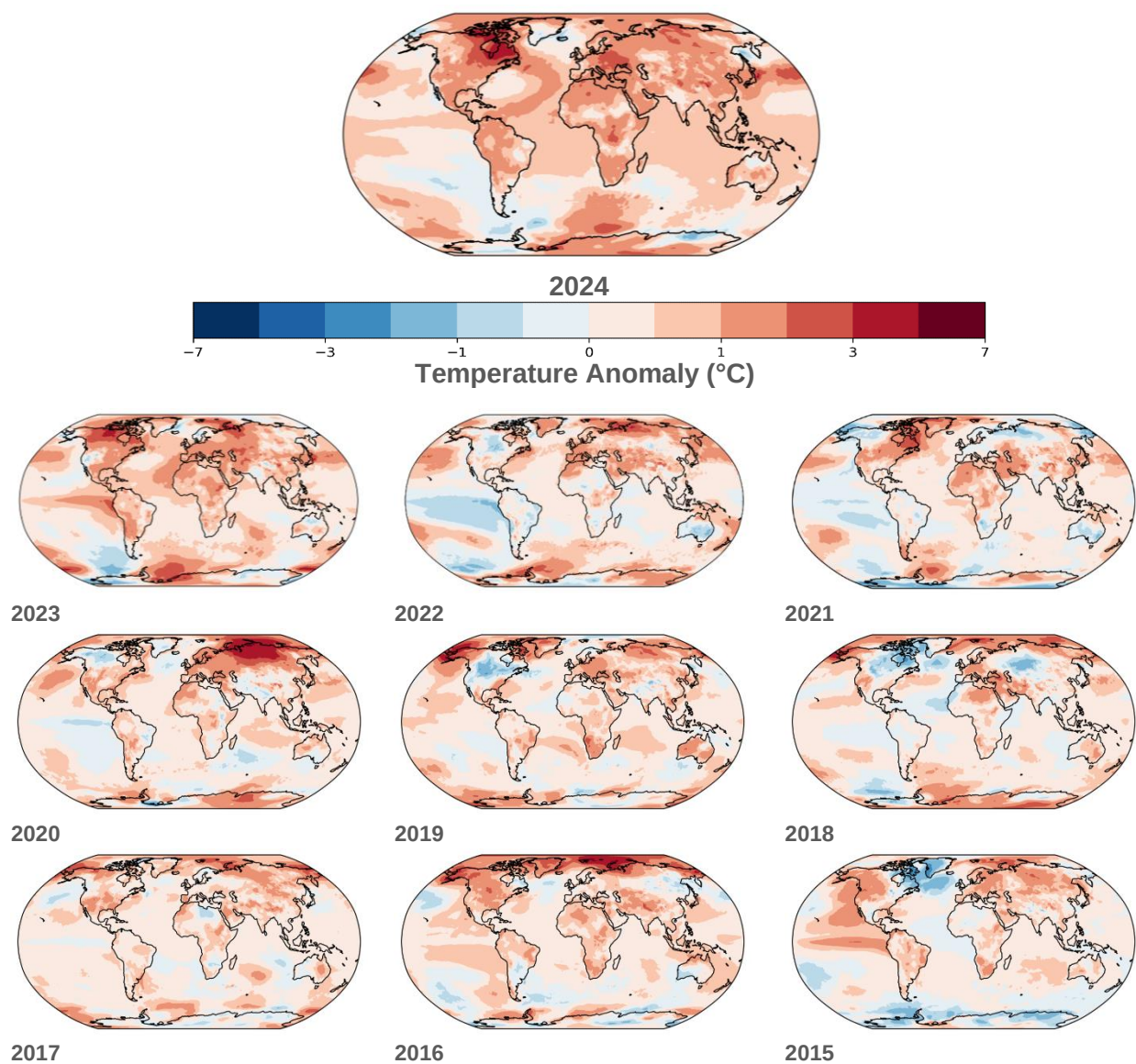


Figure 6: Global annual surface air temperature anomaly for 2024. Subsequent figures show the anomalies for the past 10 years. Anomalies are relative to the 1991 – 2020 climatology<sup>6</sup>.

<sup>5</sup> WMO press release 10 January 2025 <https://wmo.int/news/media-centre/wmo-confirms-2024-warmest-year-record-about-155degc-above-pre-industrial-level>

<sup>6</sup> Data source: ERA5

## Singapore's Temperature in 2024

At the Changi climate station, the annual mean temperature in 2024 was 28.4°C, 0.6°C above the long-term<sup>7</sup> average and the warmest on record, tying with 2019 and 2016 (Figure 7, bottom). 2024's annual mean daily maximum and minimum temperatures of 32.1°C and 25.9°C were ranked third (tied with 1998) and highest on record (tied with 2019), respectively.

The mean temperature for the last decade from 2015 to 2024 reached a new high of 28.11°C, 0.05°C above the previous record for the decade from 2014 to 2023. This is the fourth consecutive year that Singapore's decadal mean temperature record has been broken, with 6 of the top 10 warmest years occurring in the last decade.

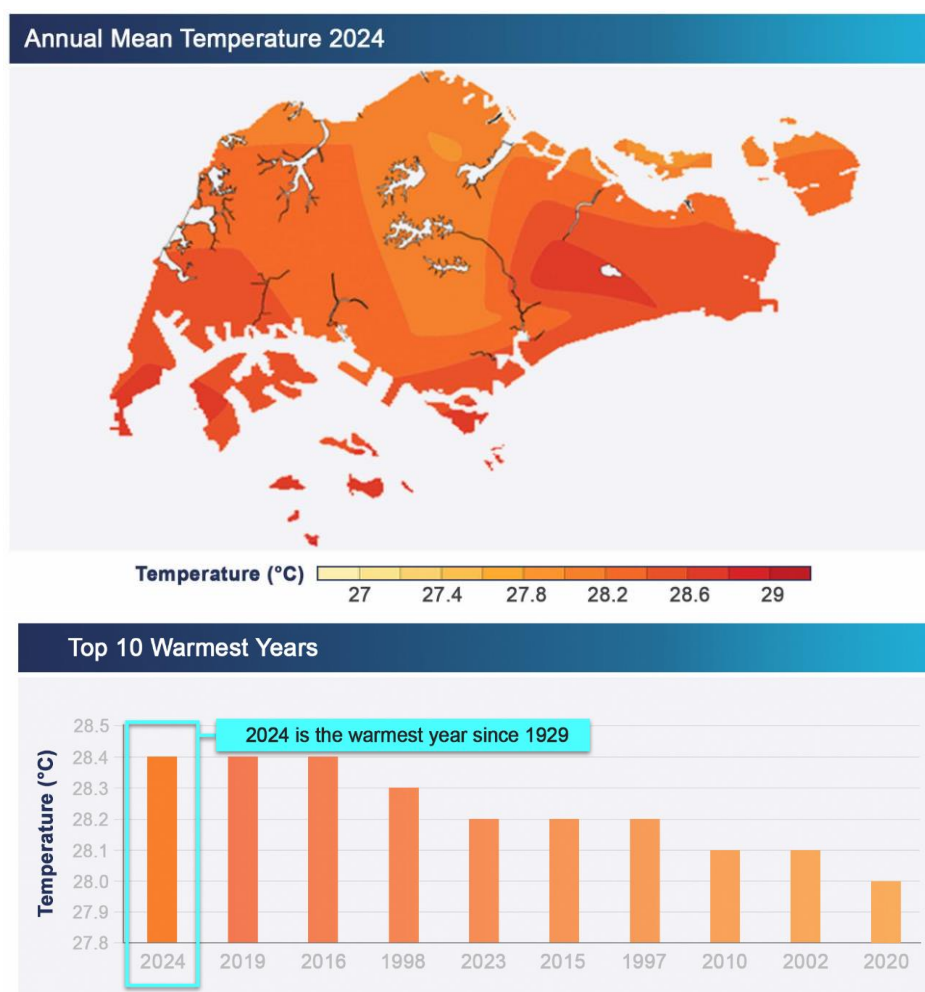


Figure 7: Annual mean temperature across Singapore in 2024 (top) and the top 10 warmest years on record (based on the Changi climate station) (bottom).

Monthly mean temperatures at the Changi climate station were above their respective long-term average except for January, where the monthly mean temperature of 26.8°C was equal to January's long-term average from 1991 – 2020 (Figure 8).

The warmer-than-usual conditions are likely associated with the 2023/2024 El Niño event, as El Niño events tend to exert their strongest effects on Singapore's temperatures around 4 –

<sup>7</sup> This refers to the most recent 30-year reference period from 1991 to 2020.

5 months after the peak of the El Niño events and can continue to have a lingering effect during the months after the events have ended.

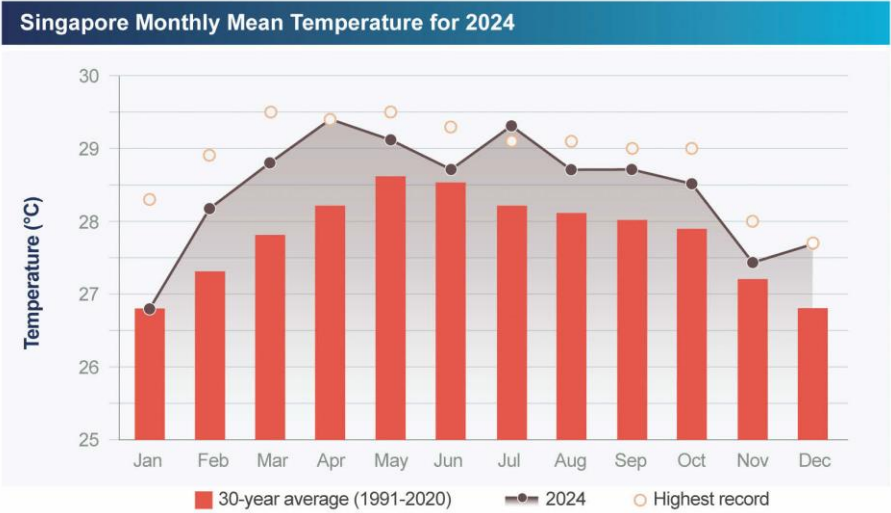


Figure 8: Climate station monthly mean temperature for 2024 (solid line), long-term average (bars, 1991 – 2020) and the corresponding historical extremes (circle).

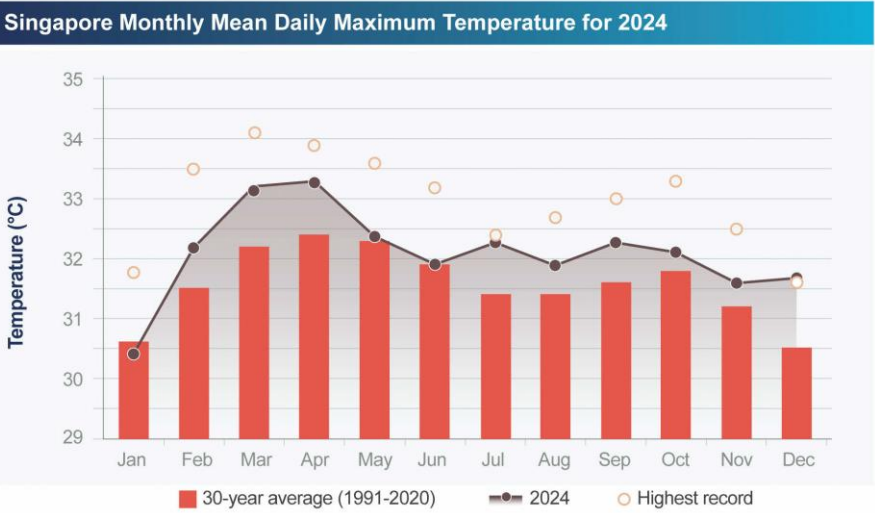


Figure 9: Climate station monthly mean daily maximum temperature for 2024 (solid line), long-term average (bars, 1991 – 2020) and the corresponding historical extremes (circle).

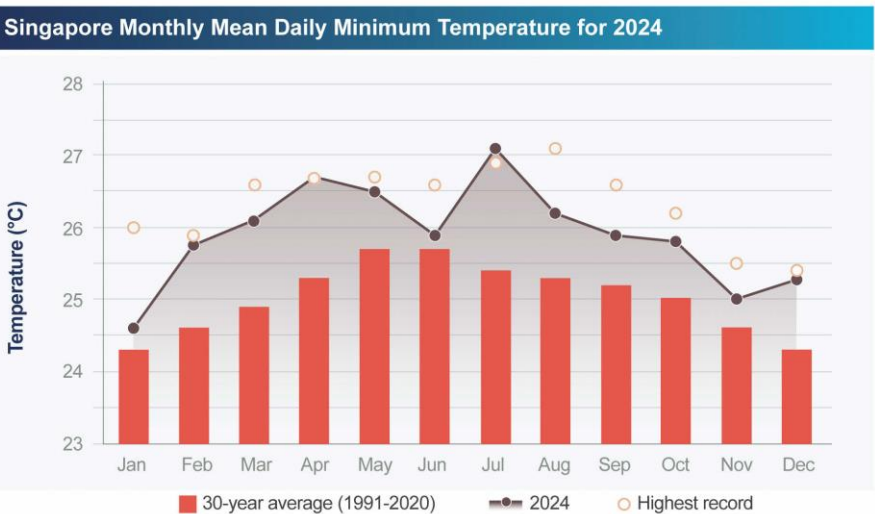


Figure 10: Climate station monthly mean daily minimum temperature for 2024 (solid line), long-term average (bars, 1991 – 2020) and the corresponding historical extremes (circle).

April was the warmest month in Singapore in 2024. The month's mean temperature of 29.4°C was 1.2°C above the long-term average and tied with 2016 as the warmest April on record (Figure 8). April 2024's mean daily minimum temperature of 26.7°C also tied with 2016 for the highest April mean daily minimum temperature (Figure 10). While the temperature for any particular month depends on a variety of factors such as climate drivers and day-to-day variability in the weather, Singapore's warmest monthly temperatures typically occur during the hot season (March – May) after a strong El Niño event (Figure 11). The three warmest hot seasons (1998, 2016, and 2024) all occurred during the decay phase of moderate-to-strong El Niño events (1997/1998, 2015/2016, and 2023/2024). Due to the long-term warming trend, earlier hot seasons tended not to be as warm. For example, the El Niño event in 1982/1983 was stronger than that in 2023/2024, although its March – May temperature (28.17°C) was near the 1991 – 2020 long-term average (28.24°C).

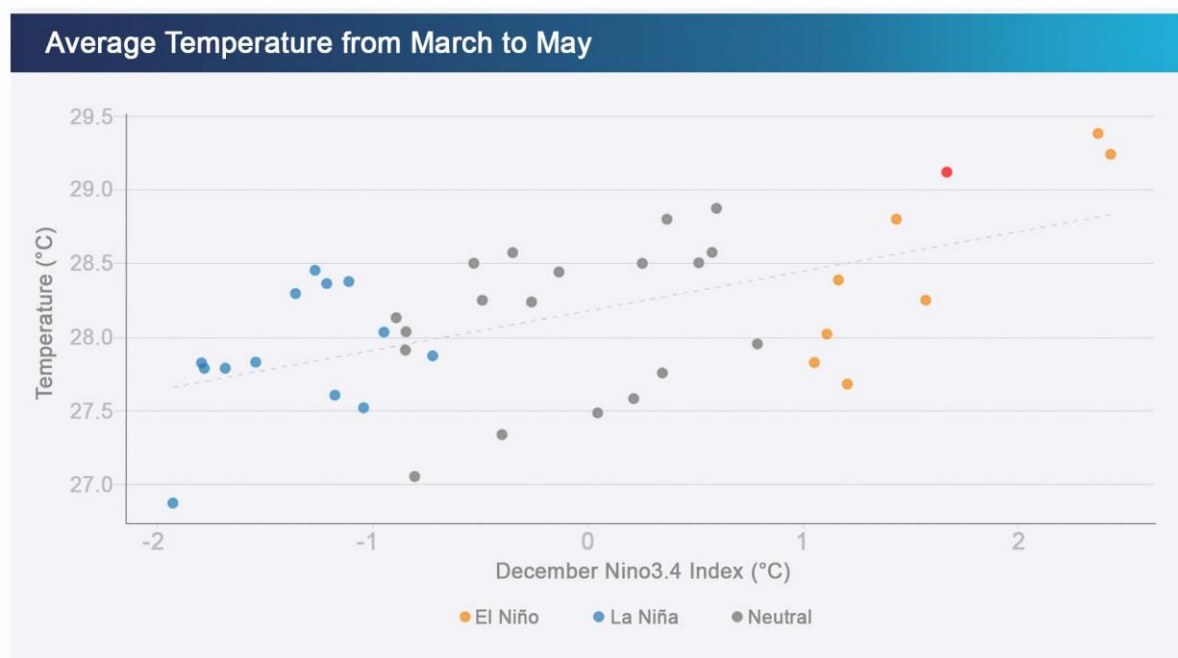


*Figure 11: Scatter plot of Singapore's March – May temperature (based on Changi Climate Station) against December Nino3.4 Index for the period 1984 – 2024, El Niño and La Niña periods are highlighted in light orange and blue dots, respectively; with the red dot corresponding to 2024. Singapore's average temperature during March – May is more closely related to the ENSO state in the previous December rather than the ENSO state in March or April.*

The second warmest month in 2024 was July, which was also the warmest July on record. July 2024's mean temperature of 29.3°C was 1.1°C above the long-term average for the month and surpassed the previous warmest July recorded in 2015 by 0.2°C (Figure 8). The month's mean daily minimum temperature of 27.1°C also broke the previous July record of 26.9°C set in 2019 (Figure 10). Warm temperatures in July 2024 were likely influenced by the long-term warming trend, dry conditions, and lingering effects of the 2023/2024 El Niño event.

While December 2024 was one of the cooler months of the year, the last month of the year saw a number of daily maximum temperature records broken. The mean daily maximum

temperature of 31.7°C in December broke the previous record of 31.6°C recorded in 2016 and 2018 (Figure 9). Notably, Changi climate station's highest daily maximum temperature for the month of December was broken by a wide margin on 7 December 2024, when the station recorded a temperature of 35.6°C. This exceeded the previous record of 33.9°C set on 1 December 2021 by 1.7°C. The highest temperature recorded that day was 36.2°C at Paya Lebar, which also broke the record for December's highest daily maximum temperature across all stations (35.9°C set on 6 December 2016 at Seletar). Dry conditions at the start of the month may have contributed to higher daily maximum temperatures. The high maximum temperatures also contributed to making December 2024 the warmest December on record with monthly mean temperature of 27.7°C, tying with 2015 and 2021 (Figure 8).

Other records for highest daily minimum and maximum temperatures are listed in Table 2 (for the climate station) and Table 3 (for all stations). No lowest temperature records were matched or broken in 2024.

## Singapore's Long-term Temperature Trends: Historical

Including the temperature trends for 2024, annual temperatures at the Changi climate station have risen at rates of 0.11°C and 0.31°C per decade for the maximum and minimum temperatures, respectively, between 1984 and 2024 (Figure 12). On top of this, periods with El Niño (orange shades) tend to amplify the annual temperatures, while periods with La Niña (blue shades) tend to moderate the annual temperatures.

Singapore's temperature observations highlight the influence of the long-term warming trend on top of the year-to-year variability associated with large-scale climate drivers. Often, the warmest annual mean temperatures associated with El Niño events occur in the year after the El Niño forms, as seen in 2016 (after the 2015/2016 El Niño) and 1998 (after the 1997/1998 El Niño). Temperatures in 2024 continue this pattern – exceeding 2023 to tie with 2016 and 2019 as the warmest years on record (a strong positive IOD event occurred in 2019). This pattern is less pronounced in annual minimum temperatures, in part due to the larger long-term warming trend. In Singapore's annual maximum temperatures, the warmest years also correspond to El Niño events – both the year the El Niño forms as well as the following year (e.g. 1997, 1998 and 2015, 2016).

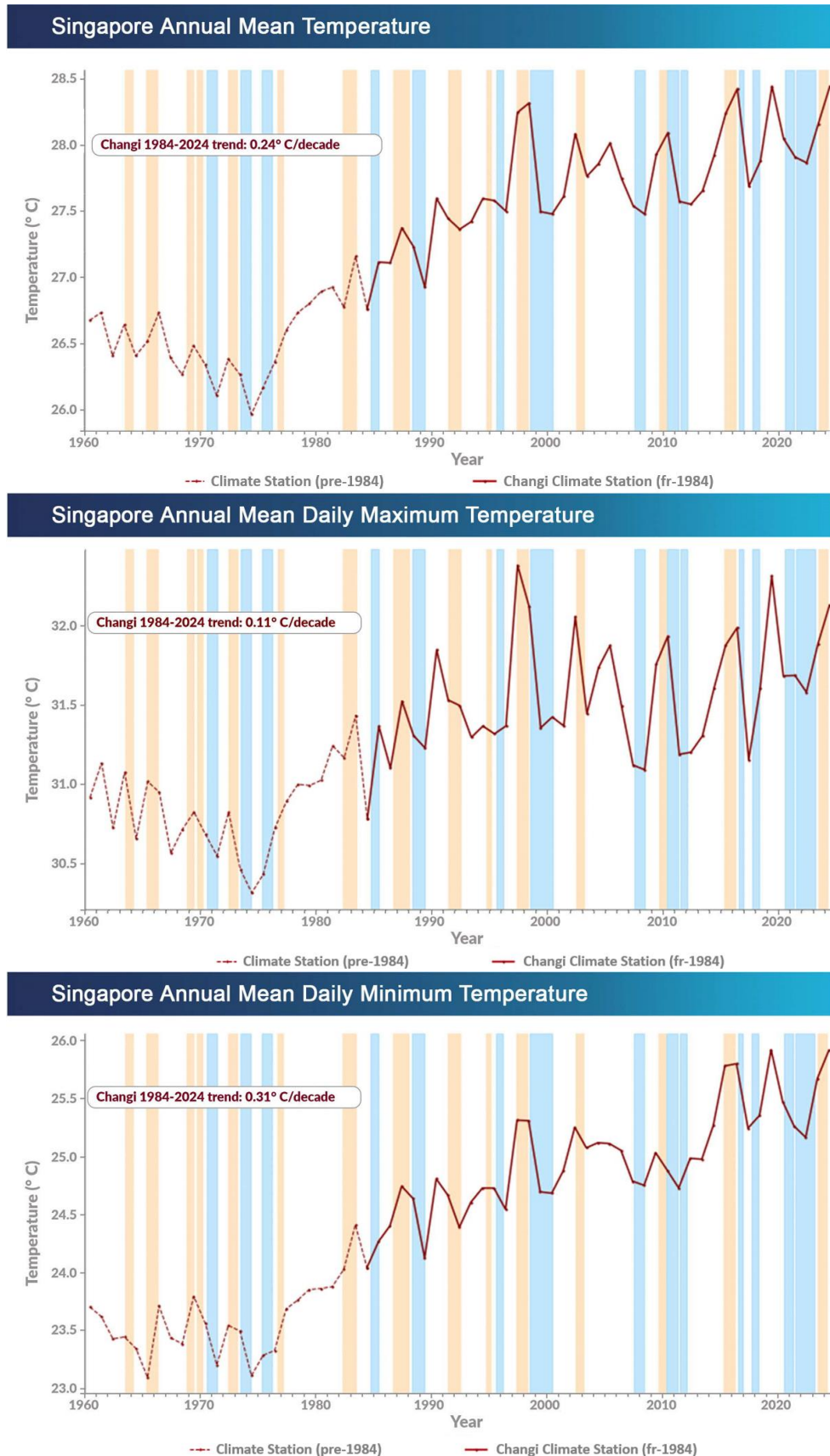


Figure 12: Annual mean temperatures since 1960 (based on the climate station). El Niño and La Niña years from 1961 onwards are highlighted in light orange and blue bars, respectively.

## Heat Stress

Hot ambient conditions can elevate the risk of heat-related illness, mortality and morbidity, whilst reducing physical work capacity with consequences for productivity. The human body responds to heat stress by redistributing blood flow towards the skin to improve heat transfer to the environment, and secreting sweat for evaporative cooling. The restricted evaporation under a warmer and more humid environment may lead to heat accumulation in the body and result in heat stress that can cause heat-related illnesses.

The wet bulb globe temperature (WBGT) is an internationally recognised measurement that reflects the main environmental factors contributing to heat stress. Besides air temperature, WBGT is also affected by humidity, wind speed, and solar radiation. Singapore uses observed WBGT derived from a network of nine sensors as a heat stress indicator. Heat stress is categorised into high (WBGT (°C)  $\geq 33$ ), moderate ( $31 \leq$  WBGT (°C)  $< 33$ ), and low (WBGT (°C)  $< 31$ ) risk levels.

The annual average daily mean WBGT and daily maximum WBGT (°C) in 2024 were higher than in 2023 at 27.0 and 30.5, respectively (Figure 13). Monthly average daily mean WBGTs were higher than their respective 2018 – 2023 average for most months (Figure 14). However, Singapore experienced only 21 days of high heat stress<sup>8</sup> in 2024, fewer than 2023 (where there were 37 days). Most of these days occurred in March, April and May (Figure 15). The highest 15-minute average WBGT (°C) in 2024 was 34.4, recorded at Bishan Stadium on 7 March and at Bedok Stadium on 28 May.

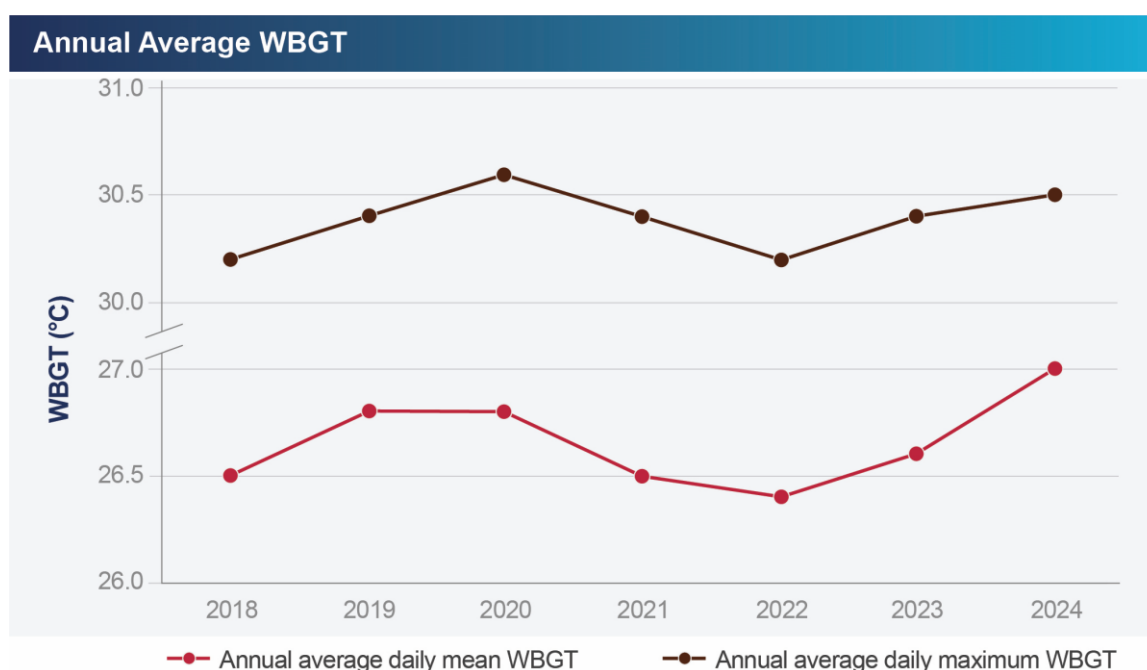


Figure 13: Annual average WBGT based on available data from nine WBGT stations islandwide from 2018 to 2024.

<sup>8</sup> A day of high heat stress is defined when any hourly-average WBGT at a station is equal to or greater than 33°C. Warm temperatures coupled with other factors (humidity, wind speed and solar radiation) contribute to occurrences of high heat stress. More information available at: <https://www.weather.gov.sg/learn-heat-stress/>.

### Monthly Average Daily Mean WBGT

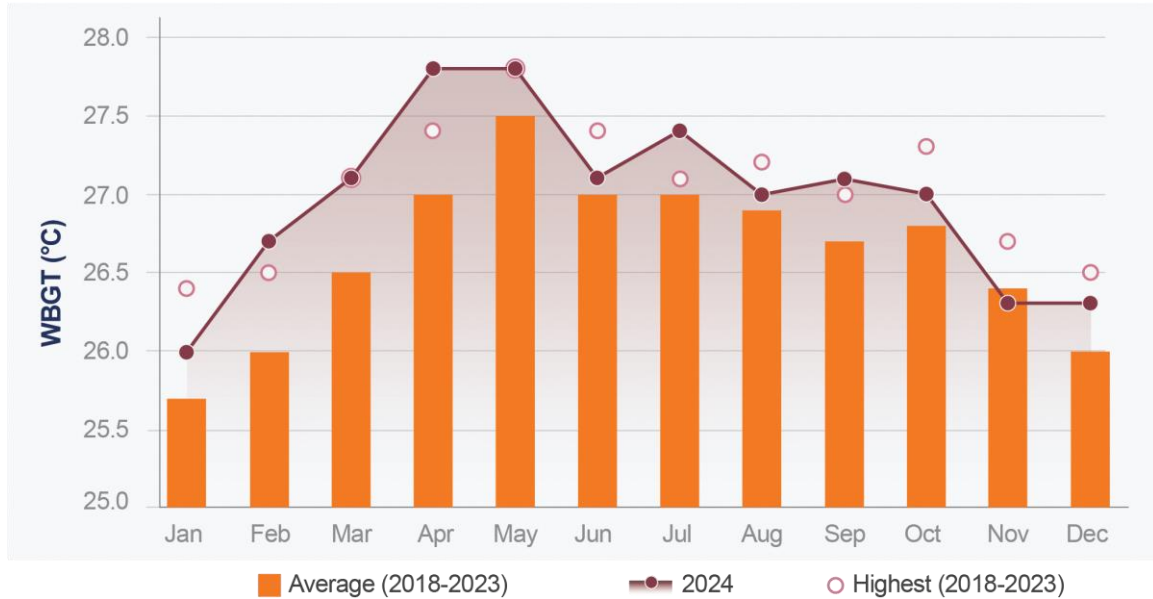


Figure 14: Monthly average daily mean WBGT based on available data from nine WBGT stations islandwide in 2024 (solid line), average from 2018 to 2023 (bars) and highest from 2018 to 2023 (circle).

### Number of Days of High Heat Stress

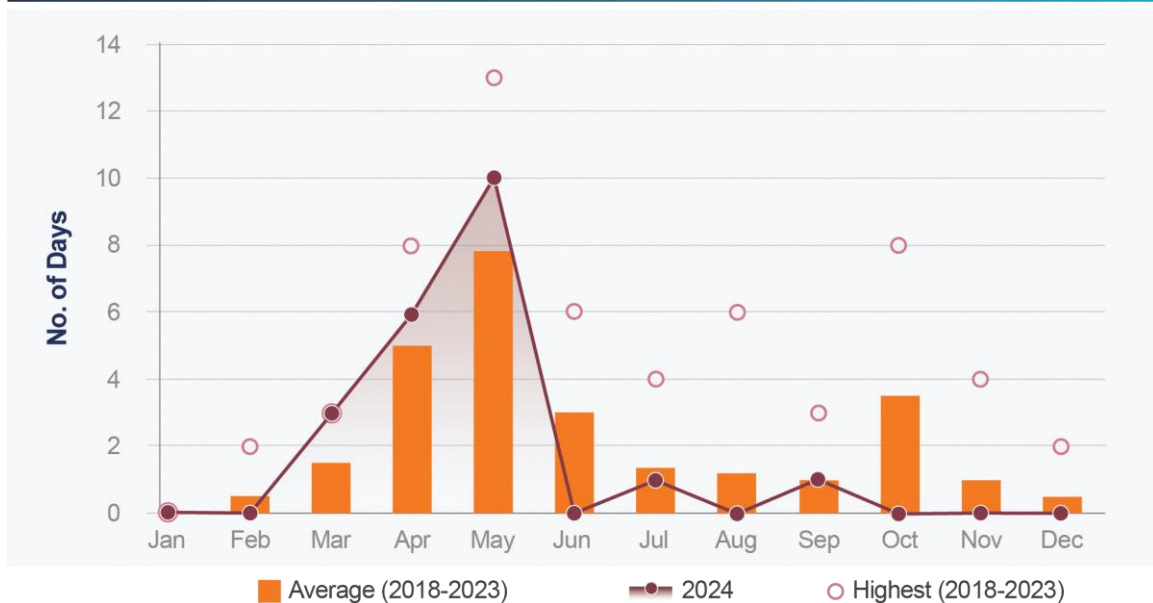


Figure 15: Monthly number of days of high heat stress in 2024 (solid line), monthly average from 2018 to 2023 (bars) and highest monthly number from 2018 to 2023 (circle).

# Rainfall

## Singapore's Rainfall in 2024

Singapore's annual total rainfall averaged across the islandwide stations<sup>9</sup> (2739.8 mm) was 8.1% above the long-term average of 2534.3 mm, making 2024 Singapore's 12<sup>th</sup> wettest year on record (Figure 16). West and central Singapore experienced the highest rainfall totals (Figure 17 left), although most of Singapore experienced more rainfall than usual (Figure 17 right). The Changi climate station recorded 2432.0 mm of rainfall in 2024, 15.1% above its long-term average of 2113.3 mm.

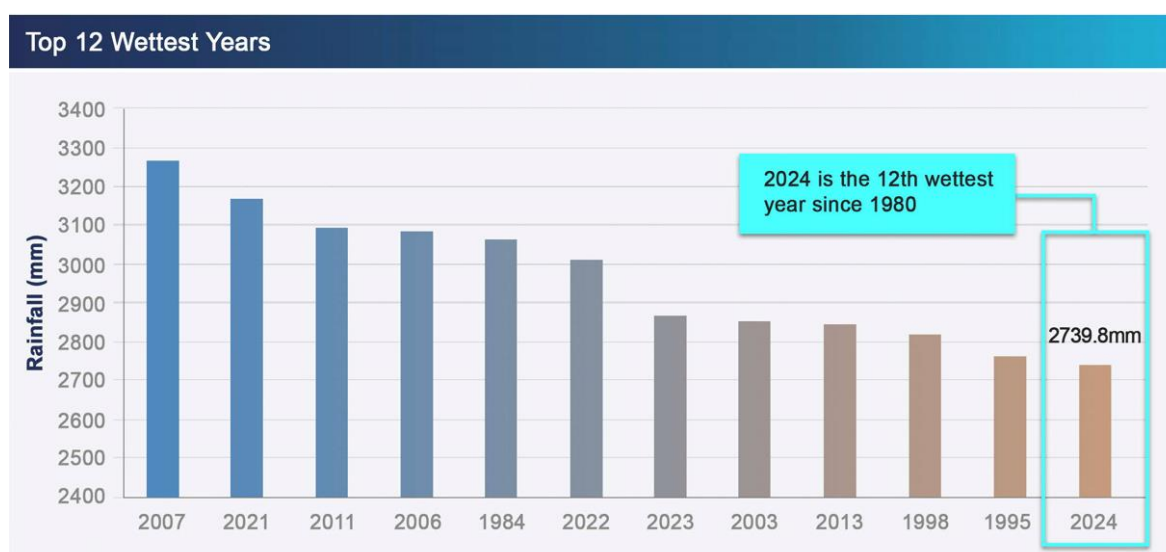


Figure 16: The top 12 wettest years since 1980 based on the Singapore average.

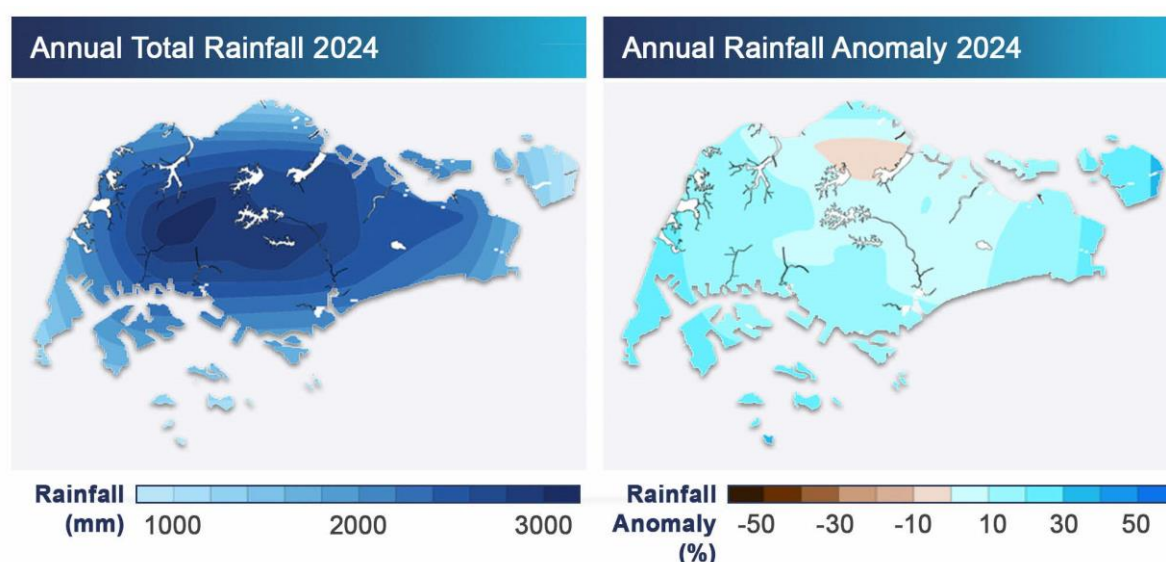


Figure 17 Left: Annual total rainfall distribution across Singapore in 2024. Right: Annual rainfall anomalies (in percentage term) across Singapore in 2024.

<sup>9</sup> The 32 stations with continuous rainfall records starting from 1980.

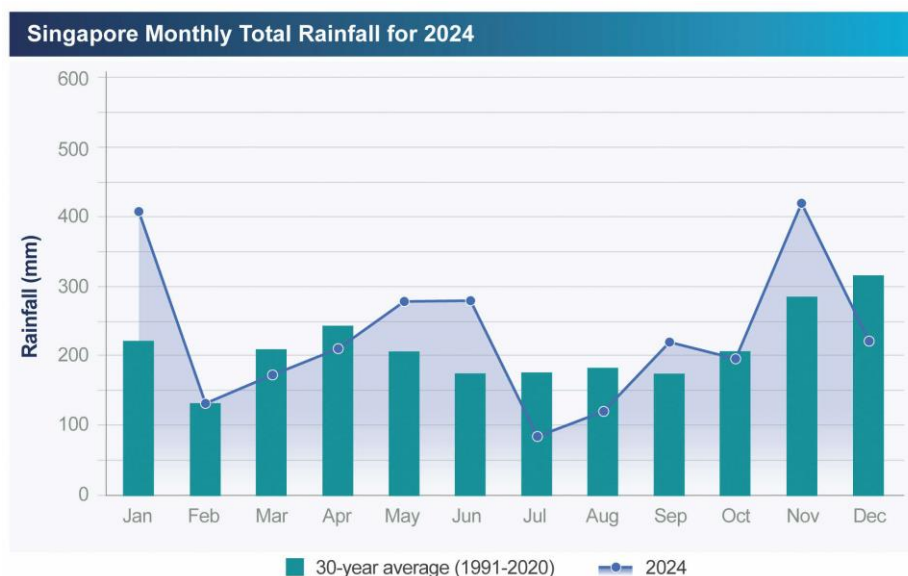


Figure 18: Singapore average monthly total rainfall for 2024 (solid line) and long-term average (bars, 1991 – 2020).

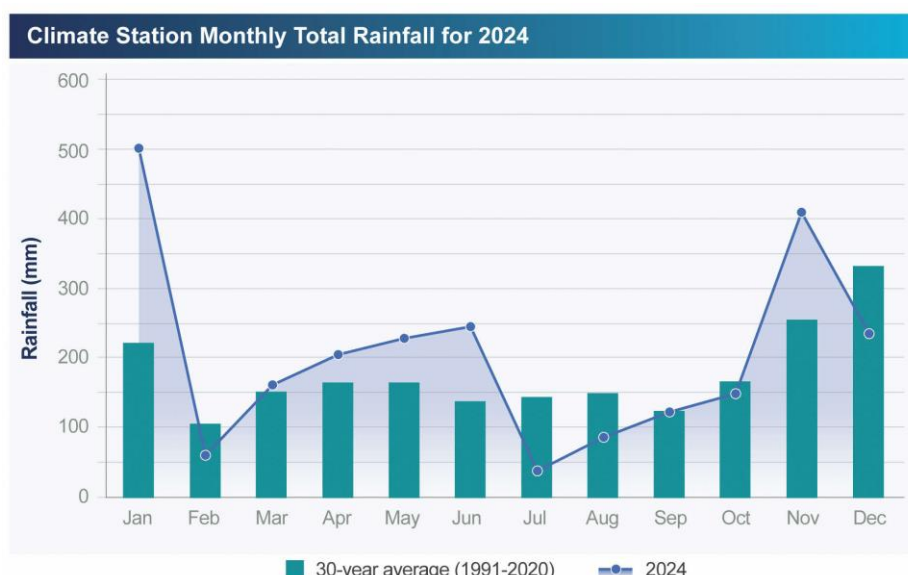


Figure 19: Climate station monthly total rainfall for 2024 (solid line) and long-term average (bars, 1991 – 2020).

Singapore's monthly rainfall for 2024 was highly variable. January's islandwide average rainfall of 407.5 mm was 83.3% above the month's long-term average (Figure 18). The monthly total rainfall at Changi climate station (499.6 mm) was also 125.5% above its long-term average for January (Figure 19). The MJO likely contributed to the high total in the first half of the month (see MJO Overview Section (page 6) for more information).

After a wet start to the year, islandwide average rainfall for February, March and April dropped slightly below their respective long-term averages (Figure 18). More rain fell over Singapore in May and June, with islandwide average rainfall for May and June 35.8% and 58.2% above their respective long-term averages. However, Singapore experienced a dry spell of 18 days between 13 and 30 July 2024. As a result, July's islandwide average rainfall (84.6 mm) was

52.7% below the long-term average. The dry weather continued into August with islandwide average rainfall of 120.8 mm, which was 33.8% below the month's long-term average.

After the drier period, November 2024's islandwide average rainfall (419.0 mm) broke the record for the wettest November since 1980 (Figure 18). It was 47.4% above its long-term average and exceeded the previous highest November rainfall of 390.1 mm recorded in 1992. The monthly total rainfall at Changi climate station (407.4 mm) was also 60.3% above its long-term average for November (Figure 19). Similarly to January, the MJO again likely contributed to Singapore's high rainfall total in November 2024.

The year ended on a drier note, with December 2024's islandwide average rainfall (221.3 mm) 30.0% below its long-term average (Figure 18). From the second week of the month until the end of the month, the MJO was in Phases 5-7, which typically bring drier conditions to Singapore at this time of the year.

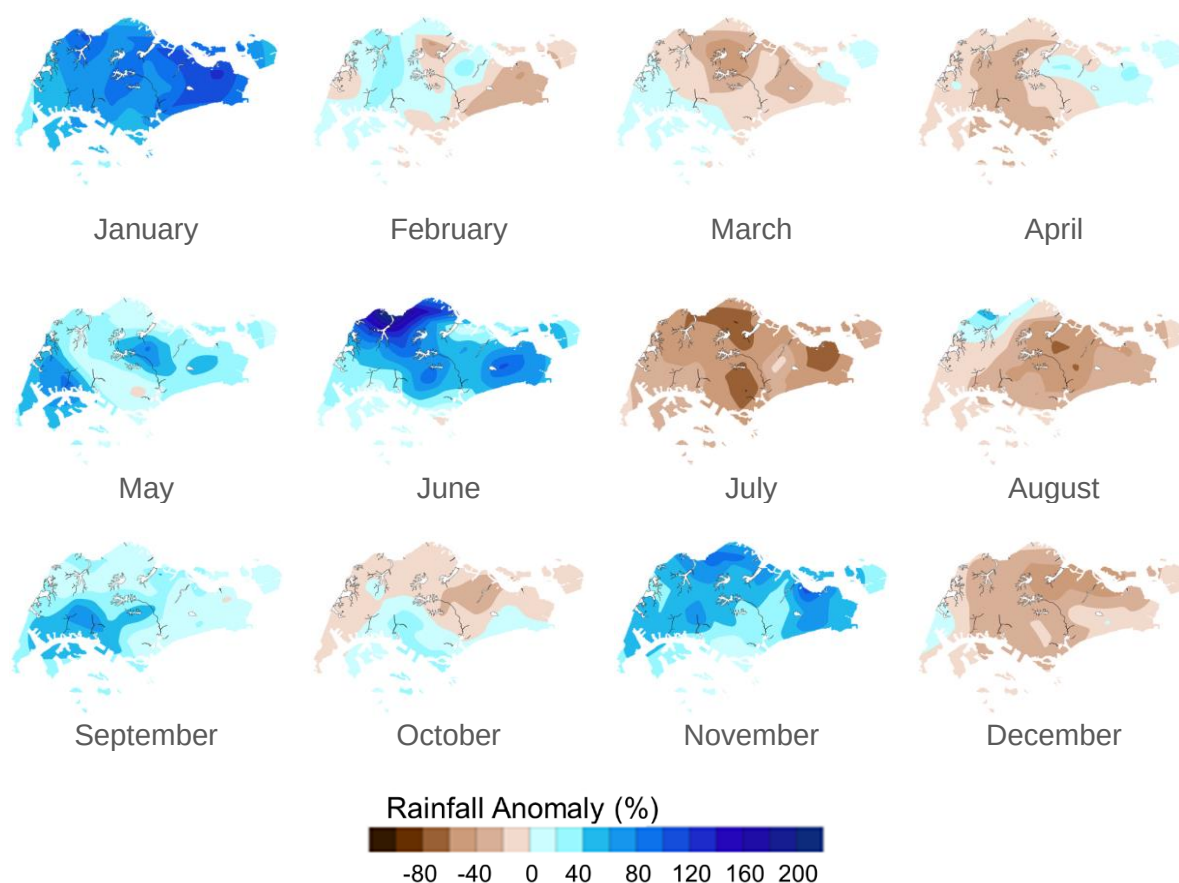


*Figure 20: Monthly rainfall anomalies (in percentage term) across Singapore in 2024 (relative to the climatological period 1991 – 2020 for the particular month).*

As with temperature, climate drivers also influenced Singapore's rainfall, with changes arising from El Niño and La Niña events most noticeable when looking over several months. For a particular month, rainfall will also be affected by the presence of other shorter-lived drivers like the MJO, or day-to-day variations in the weather.

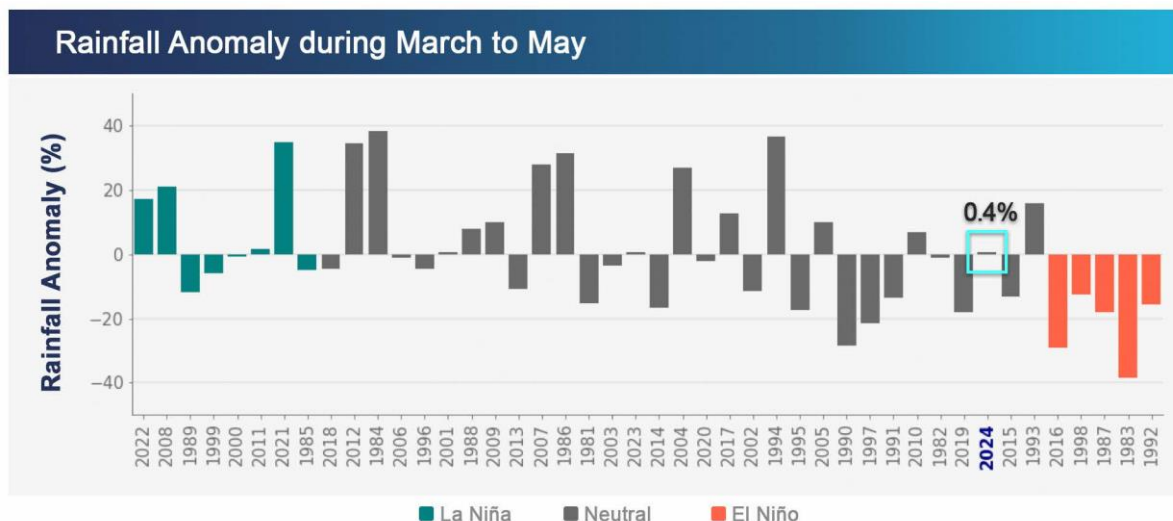


Figure 21: Singapore’s average rainfall during March – May for the period 1981 – 2024 compared to climatology, ordered from strongest La Niña to strongest El Niño during March – May.

During March – May, Singapore tends to experience less rainfall when an El Niño event is present, while near to above average rainfall occurs when a La Niña event is present (Figure 21). Unlike for temperature (see page 12), Singapore’s rainfall is more closely associated with the current ENSO state, rather than the earlier state. With the return to ENSO neutral conditions in April 2024, most of the March – May period was under ENSO neutral conditions, in line with the near-average rainfall recorded over Singapore during this time (although March and April individually experienced below average rainfall). ENSO neutral conditions prevailed for much of the rest of 2024.

### Notable Event: Dry Spell in July

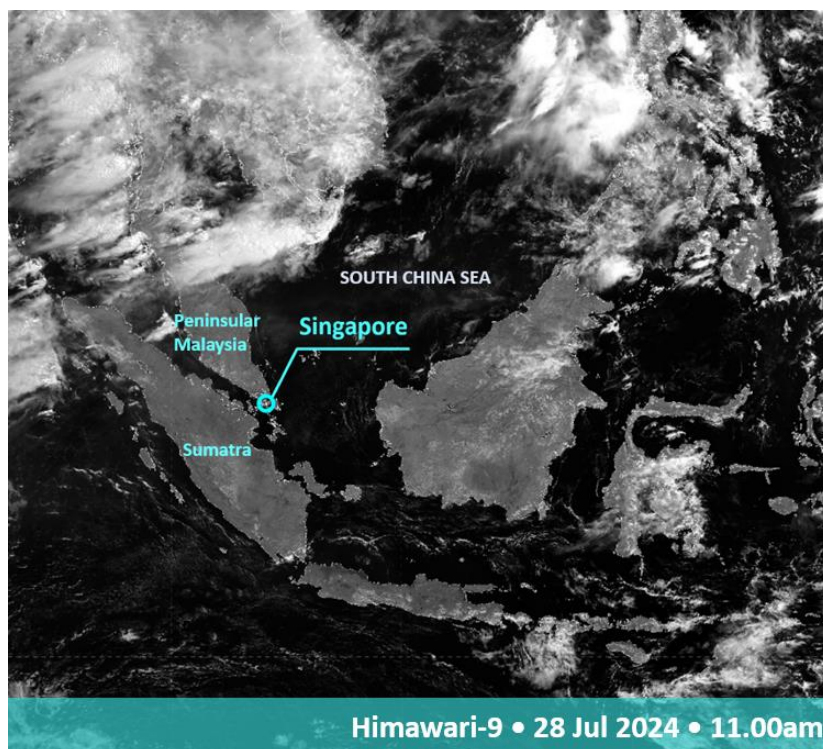


Figure 22: Satellite image on 28 July 2024, with dark areas indicating clear skies in the ocean region around Singapore.

Singapore and the surrounding region experienced dry weather in the second half of July 2024. During the same time, at least three tropical cyclones formed in the northern part of the South China Sea. The resulting stronger winds and the movement of drier air into the region resulted in Singapore experiencing a dry spell<sup>10</sup> of 18 days between 13 July and 30 July. The last recorded dry spell in Singapore lasted 17 days from 31 July to 16 August 2019.

With little rainfall occurring in Singapore from mid-July, the second fortnight of the month also experienced warm weather, with daily maximum temperatures ranging between 32.8°C and 35.2°C. Nights were warm as well, with daily minimum temperatures staying above 28°C in most parts of the island.

As a result of so little rainfall occurring from around mid-July, many areas across the island registered well below average rainfall for the month of July. The dry spell eventually ended at the close of the month, with the occurrence of thundery showers on 31 July.

### Notable Event: Intense Sumatra Squall Line Brought Gusty Winds



*Figure 23: A tree at East Coast Park uprooted by strong winds from the Sumatra squall (photo by Malcolm Tan)*

On the evening of 17 September 2024, an intense Sumatra squall line developed over the Strait of Malacca and swept across the whole of Singapore from 7pm to 8.30pm, bringing widespread thundery showers and gusty winds. Maximum wind gusts recorded at automatic weather stations ranged from about 40km/h to 80km/h, with East Coast Parkway recording the highest wind gust of 83.2km/h at 7.33pm. Pasir Panjang, Changi, Sembawang and Seletar also recorded wind gusts of above 70km/h.

Despite the intense rainfall rate caused by the squall, it was so fast-moving that Singapore's islandwide average rainfall from the event was only about 10.3 mm. The highest rainfall of 26 mm was recorded at Bishan. Temperatures during the evening dropped from about 30°C – 31°C

to 24°C – 25°C as the squall moved over Singapore. The temperature drops were rapid, with most automatic weather stations measuring a decrease of about 5°C within a short span of 5

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<sup>10</sup> A dry spell is defined as a period of at least 15 consecutive days with daily total rainfall of less than 1.0 mm, averaged over islandwide stations with long-term records.

minutes. The steepest temperature drop over a 5-minute period was observed at Ang Mo Kio, where temperature decreased by 7.1°C from 30.9°C at 7.24pm to 23.8°C at 7.29pm. The lowest temperature of 23.7°C was recorded at Jurong Island at 7.25pm.

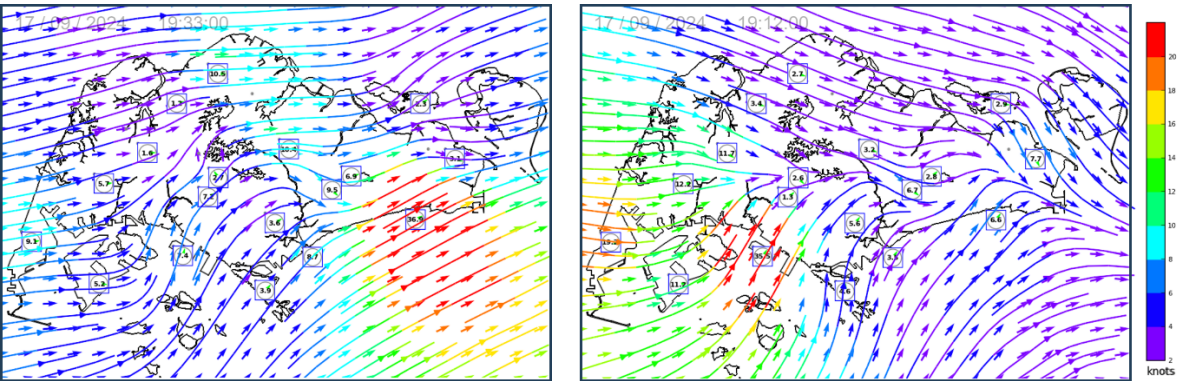


Figure 24: Wind contours from automated weather stations around Singapore showing the presence of strong winds (in red) generated by the Sumatra squall line.

The wind gusts from the squall line were strong enough to generate some damage, mostly in the form of fallen trees and broken branches. NParks reported more than 300 tree-related incidents across the island. Some damage to infrastructure was also reported.

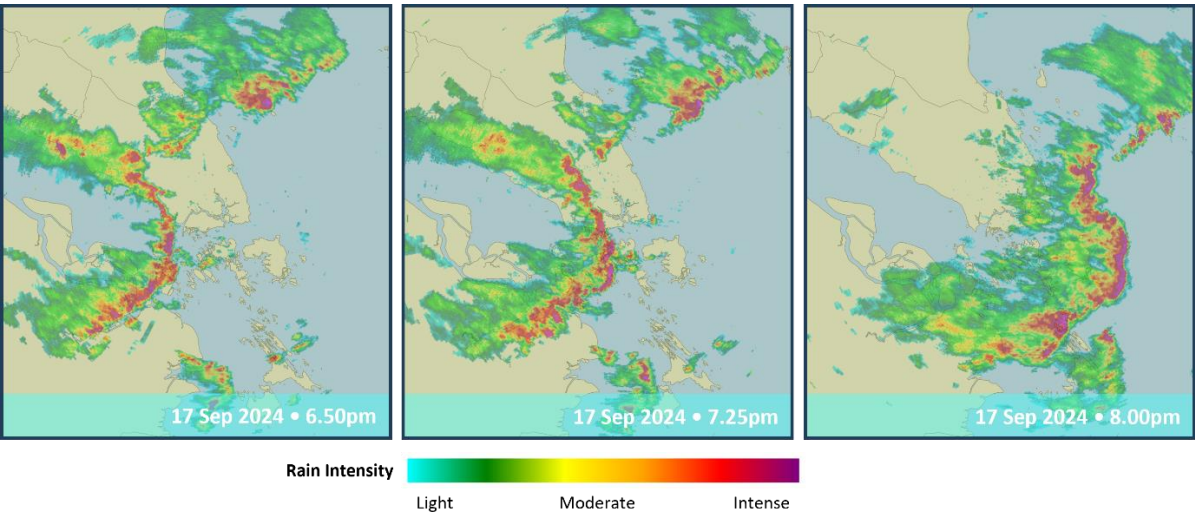


Figure 25: Sequence of weather radar images showing the squall line moving across Singapore, starting from 6.50pm to 8.00pm on 17 September 2024.

## Notable Event: Heavy Rains Brought Flash Floods on 14 October

October falls within the inter-monsoon period, when the presence of the rainband in the vicinity of Singapore, coupled with light and variable winds, encourages the development of intense thunderstorms.

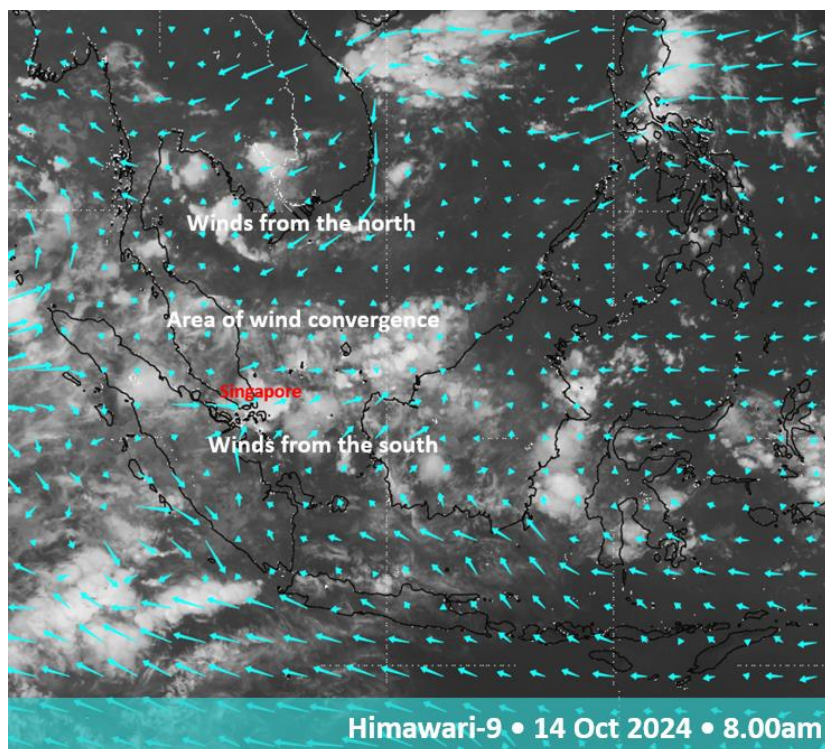
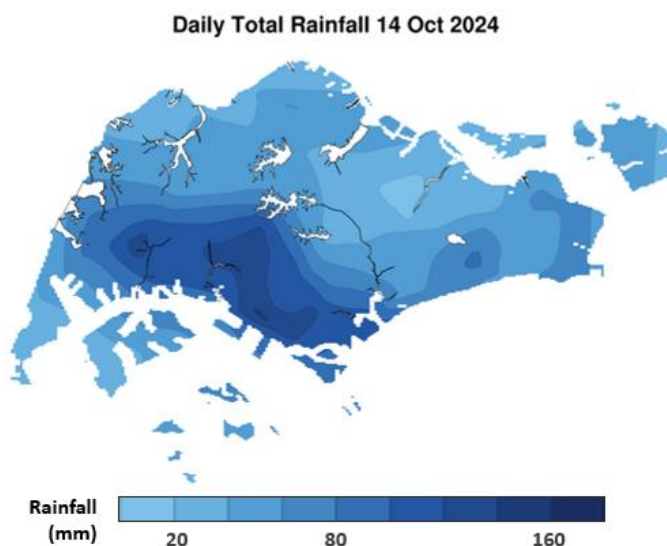


*Figure 26 Left: Satellite image overlaid with near surface (925 hPa) winds on 14 October 2024. Winds from the north and south converge over Singapore and its vicinity. Below: Daily total rainfall across Singapore on 14 October 2024*

On 14 October 2024, regional convergence of winds caused widespread thunderstorms over the island, starting around midnight and continuing into the afternoon. Many rain gauges over southern, western and central parts of Singapore (such as Jurong, Clementi, Queenstown, and Bukit Timah) measured daily rainfall of above 100 mm. The highest daily rainfall recorded that day was 145.8 mm at Kent Ridge.

The heavy rain resulted in flash floods in many areas, such as Tampines and Bukit Timah.



## Singapore's Long-term Rainfall Trend: Historical

Singapore's average annual total rainfall increased on average 86.1 mm per decade from 1980 to 2024. However, it is highly variable, a characteristic of rainfall in the tropics (Figure 27). Notably, years with predominantly La Niña conditions (e.g. 2022, 2021, 2011) tend to be wetter, while years when El Niño conditions developed (e.g. 2016, 1997, 1982) tend to be drier.

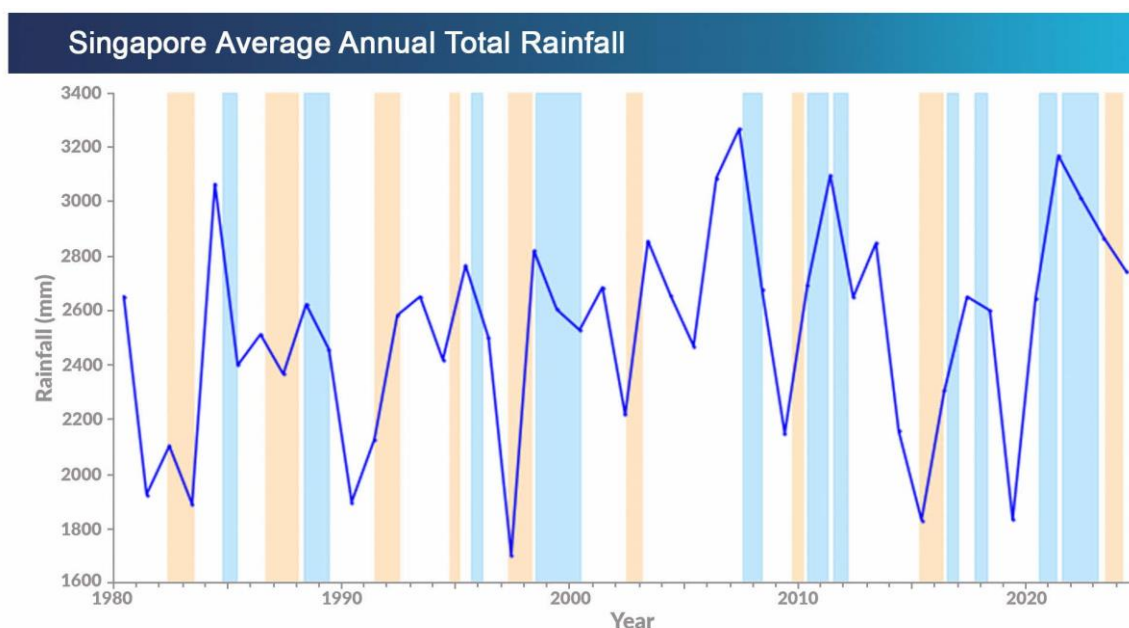


Figure 27: Average annual total rainfall since 1980 (across the islandwide stations). El Niño and La Niña years are highlighted in light orange and blue bars, respectively.

While there has been a gradual increase in Singapore's average annual total rainfall, there is no significant trend in the frequency of heavy rain events and the highest 60-minute rainfall intensity across the islandwide stations from 1980 to 2024. In 2024, the monthly highest 60-minute rainfall intensity fell below the long-term average, except in September, November, and December (Figure 28). Among the months with higher-than-average rainfall intensity, September and December were above the 90<sup>th</sup> percentile of the recent 10 years (2014 – 2023). The highest 60-minute rainfall intensity was 93 mm on 29 December at Coronation Walk. However, the highest 60-minute rainfall intensity for all months in 2024 remained consistently below the 90<sup>th</sup> percentile for the longer 1980 – 2023 period. This indicates that while 2024 saw a few rainfall events with higher rainfall intensity relative to the long-term average and the past decade, they were not exceptionally high when compared to historical records.

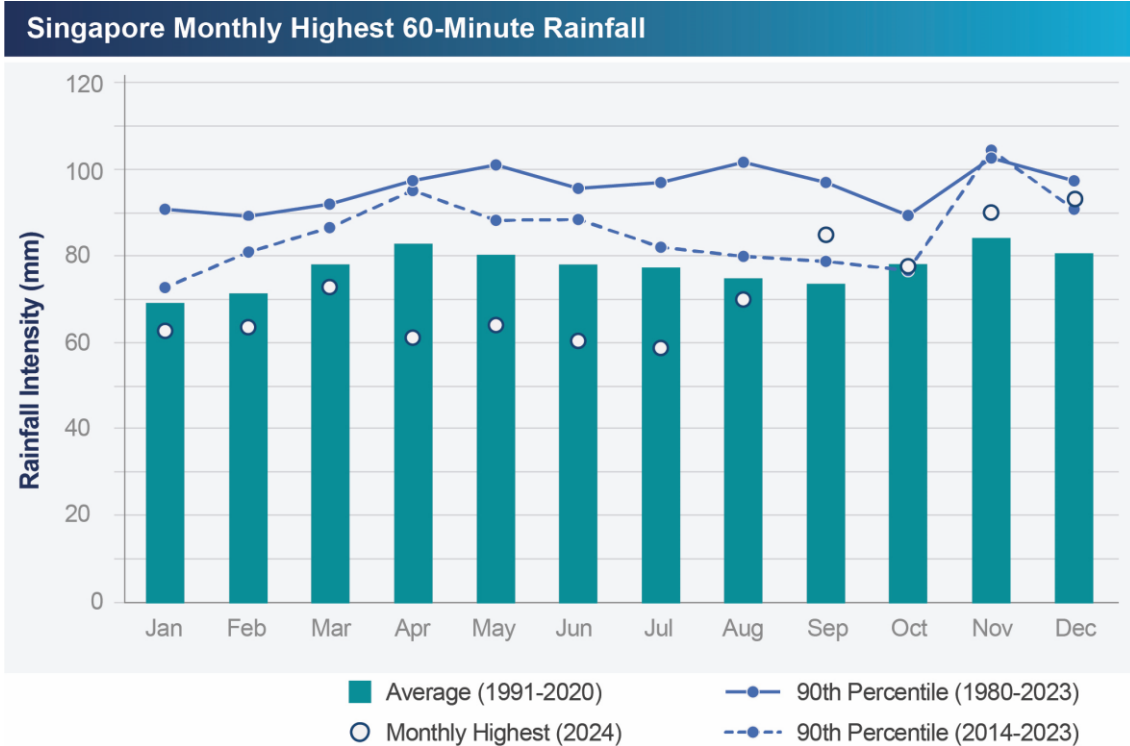


Figure 28: Monthly highest 60-minute rainfall intensities averaged over the 1991 – 2020 long-term period (blue bars) and the highest recorded 60-minute rainfall intensity in 2024 (white dots) across the islandwide stations. The solid blue line is the 90<sup>th</sup> percentile rainfall intensity for the 1980 – 2023 period, while the dotted blue line shows the 90<sup>th</sup> percentile for the most recent decade (2014 – 2023).

## Weather Extremes and Records in 2024

Table 1: Temperature, rainfall and wind extremes recorded at the climate station in 2024 and the corresponding historical extremes.

|                                   | Climate Station Records |                                           |
|-----------------------------------|-------------------------|-------------------------------------------|
|                                   | 2024                    | Historical Extremes*                      |
| <b>Hottest Day (°C)</b>           | 35.8<br>9 Apr           | <b>36.0</b><br>26 Mar 1998                |
| <b>Coollest Day (°C)</b>          | 22.4<br>20 Oct          | <b>19.4</b><br>30 Jan 1934<br>31 Jan 1934 |
| <b>Warmest Month (°C)</b>         | 29.4<br>Apr             | <b>29.5</b><br>Mar 1998<br>May 2023       |
| <b>Coollest Month (°C)</b>        | 26.8<br>Jan             | <b>24.2</b><br>Jan 1934                   |
| <b>Wettest Day (mm)</b>           | 85.4<br>4 May           | <b>512.4</b><br>2 Dec 1978                |
| <b>Wettest Month (mm)</b>         | 499.6<br>Jan            | <b>818.6</b><br>Jan 1893                  |
| <b>Driest Month (mm)</b>          | 36.8<br>Jul             | <b>0.2</b><br>Feb 2014                    |
| <b>Strongest Wind Gust (km/h)</b> | 75.9<br>17 Sep          | <b>90.7</b><br>29 Nov 2010                |

\*Rainfall records since 1869; temperature records since 1929; wind records since 1984

Table 2: Summary of record-matching and record-breaking (in bold) temperatures at the climate station in 2024.

| Record Temperatures for Climate Station                          |        |                         |             |
|------------------------------------------------------------------|--------|-------------------------|-------------|
| Climate Extreme                                                  | 2024   | Previous Record (Year)  | New Record  |
| Highest Daily Minimum Temperature for February (°C)              | 27 Feb | 26.9<br>(1998 and 2016) | <b>27.1</b> |
| Highest Daily Minimum Temperature for March (°C)                 | 30 Mar | 27.5<br>(1998 and 2016) | <b>27.8</b> |
| Highest Daily Maximum Temperature for April (°C)                 | 9 Apr  | 35.8<br>(1983)          | 35.8        |
| Highest Daily Minimum Temperature for April (°C)                 | 25 Apr | 28.4<br>(1983)          | 28.4        |
| Highest Monthly Mean Temperature for April (°C)                  | Apr    | 29.4<br>(2016)          | 29.4        |
| Highest Monthly Mean Daily Minimum Temperature for April (°C)    | Apr    | 26.7<br>(2016)          | 26.7        |
| Highest Monthly Mean Temperature for July (°C)                   | Jul    | 29.1<br>(2015)          | <b>29.3</b> |
| Highest Monthly Mean Daily Minimum Temperature for July (°C)     | Jul    | 26.9<br>(2019)          | <b>27.1</b> |
| Highest Daily Minimum Temperature for September (°C)             | 2 Sep  | 27.9<br>(2015 and 2023) | <b>28.1</b> |
| Highest Daily Minimum Temperature for October (°C)               | 28 Oct | 28.2<br>(2021)          | 28.2        |
| Highest Daily Maximum Temperature for November (°C)              | 1 Nov  | 34.6<br>(2023)          | 34.6        |
| Highest Daily Maximum Temperature for December (°C)              | 7 Dec  | 33.9<br>(2021)          | <b>35.6</b> |
| Highest Monthly Mean Temperature for December (°C)               | Dec    | 27.7<br>(2015 and 2021) | 27.7        |
| Highest Monthly Mean Daily Maximum Temperature for December (°C) | Dec    | 31.6<br>(2016 and 2018) | <b>31.7</b> |

Table 3: Summary of record-breaking (in bold) temperatures at all stations in 2024.

| Record Temperatures for All Stations                |               |        |                                  |             |
|-----------------------------------------------------|---------------|--------|----------------------------------|-------------|
| Climate Extreme                                     | Location      | 2024   | Previous Record (Location, Year) | New Record  |
| Highest Daily Minimum Temperature for March (°C)    | Pasir Panjang | 30 Mar | 28.4<br>(Semakau Island, 2016)   | <b>28.7</b> |
| Highest Daily Minimum Temperature for April (°C)    | Pasir Panjang | 30 Apr | 29.3<br>(Semakau Island, 2009)   | <b>29.5</b> |
| Highest Daily Maximum Temperature for December (°C) | Paya Lebar    | 7 Dec  | 35.9<br>(Seletar, 2016)          | <b>36.2</b> |

## Sea Level

### Singapore's Long-term Sea-level Trends: Historical

Global mean sea level has increased by approximately  $1.5 \pm 0.4$  mm/yr over the 20<sup>th</sup> century and since the 1990s, this rate has been increasing up to  $3.4 \pm 0.4$  mm/yr (Oppenheimer et al., 2019). This acceleration is primarily attributed to the combined effects of thermal expansion due to ocean warming, melting of glaciers, and ice sheet loss in Greenland and Antarctica. Regionally in Southeast Asia, mean sea level has been rising at  $\sim 4.4$  mm/yr (1993 – 2021), which is higher than the global mean (Figure 29). This regional deviation from the global mean is influenced by a combination of factors, including oceanographic processes such as changes in ocean currents, the redistribution of heat and mass, and land subsidence in some areas. Furthermore, there are often differences with tide gauge records (circles, Figure 29), as tide-gauge records are also affected by vertical land movement.

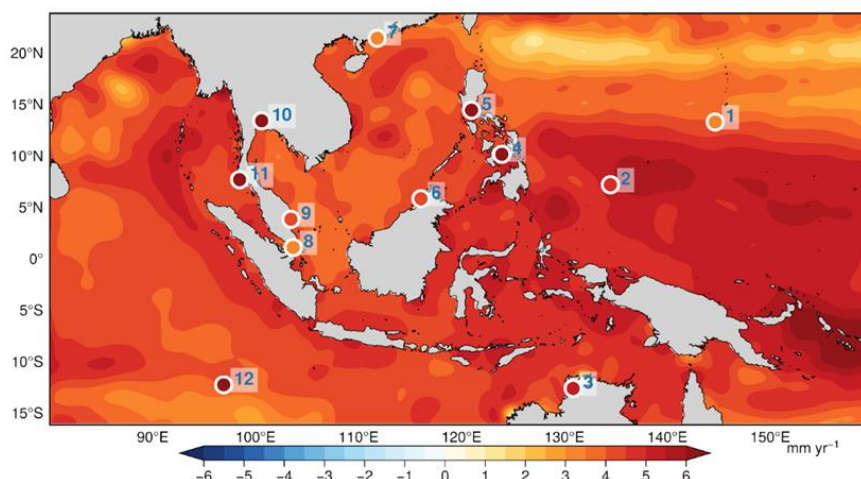


Figure 29: Observed mean sea level (mm/yr) for the period 1993 – 2021 from satellite altimetry. Locations indicated with circles are tide-gauge records included in the analysis in the V3 Science Report, Chapter 12 (Figure 12.8).

In Singapore, the rate of sea-level rise (for the period 1993 – 2021) varies between 3.27 mm/yr (Sultan Shoal) to 3.77 mm/yr (Tanjong Pagar). The latter station's rates, while lower than the regional average, exceed the global mean. Figure 30 shows the six longest tide gauges in Singapore, each beginning at a different year, with the rate of sea-level rise given for the entire record. The rates of rise vary from  $1.82 \pm 0.21$  mm/yr to  $3.64 \pm 0.43$  mm/yr due to the varied lengths in the available data, with typically larger increases seen for gauges with the shortest records. For Sembawang and Raffles, two of the longest tide-gauge records, the rate of increase is higher after the 1990s, similar to the global sea-level trend that also has risen faster over recent years. This shift is less noticeable in the other long tide-gauge record from Sultan Shoal.

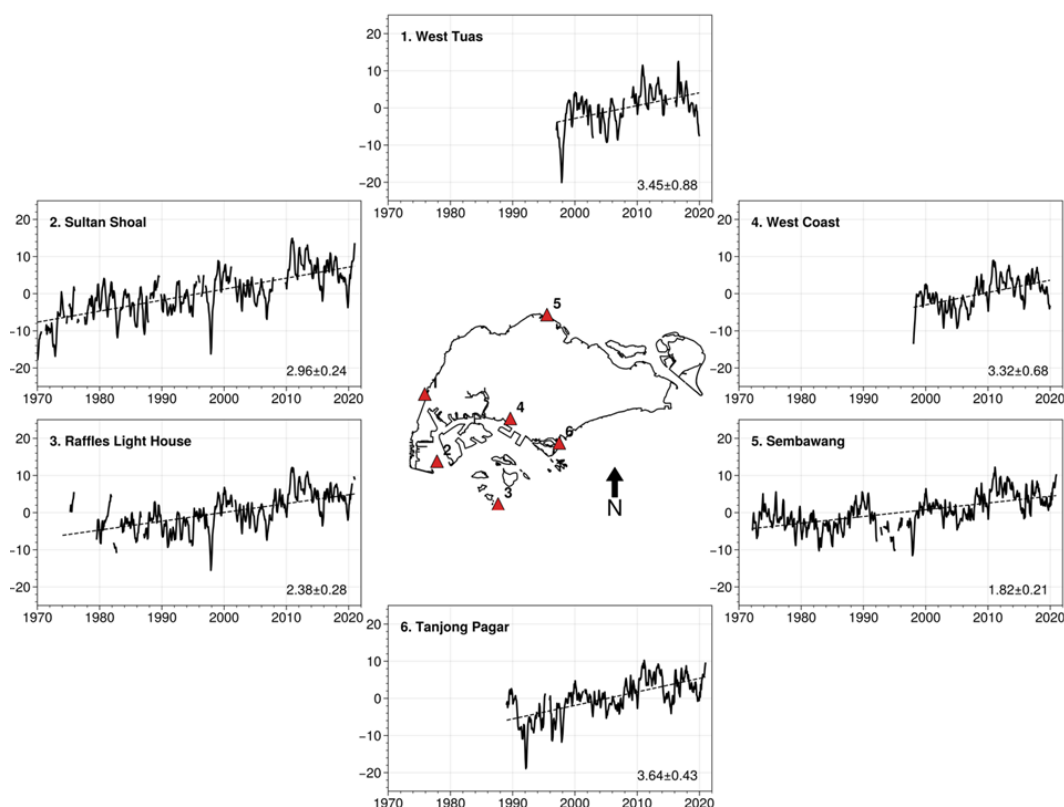


Figure 30: Monthly tide-gauge records at the six longest tide gauges in Singapore.

## Singapore's Long-term Sea-level Trends: Future

According to the Third National Climate Change Study (V3), relative sea level in Singapore across the six tide gauges is projected to rise under both the low (SSP1-2.6) and high (SSP5-8.5) emission scenario throughout this century. The rate of sea-level rise over the next 30 years is also projected to increase as compared to the observed rate from 1998 to 2022 (Table 4). For example, Sultan Shoal experiences a rate of  $3.39 \pm 0.04$  mm/yr between 1998 and 2022 and is projected to experience sea-level rise of 5.05 to 7.21 mm/yr (Table 4).

Table 4: Rates of relative sea-level rise at Singapore's six tide gauges over an observed period (1998 – 2002) and a future period (2020 – 2050) under the low (SSP1-2.6) and high (SSP5-8.5) emissions scenario (taken from V3 projections).

|   | Tide gauge          | Observed rate (1998 – 2022; mm/yr) | Future projected rate under SSP1-2.6 (2020 – 2050; mm/yr) | Future rate projected under SSP5-8.5 (2020 – 2050; mm/yr) |
|---|---------------------|------------------------------------|-----------------------------------------------------------|-----------------------------------------------------------|
| 1 | West Tuas           | $3.2 \pm 0.04$                     | $4.63 \pm 0.29$                                           | $6.13 \pm 0.39$                                           |
| 2 | Sultan Shoal        | $3.39 \pm 0.04$                    | $5.33 \pm 0.28$                                           | $6.83 \pm 0.38$                                           |
| 3 | Raffles Light House | $3.14 \pm 0.04$                    | $4.33 \pm 0.28$                                           | $5.81 \pm 0.39$                                           |
| 4 | West Coast          | $4.04 \pm 0.04$                    | $4.71 \pm 0.27$                                           | $6.24 \pm 0.39$                                           |
| 5 | Sembawang           | $3.11 \pm 0.03$                    | $4.27 \pm 0.27$                                           | $5.79 \pm 0.38$                                           |
| 6 | Tanjong Pagar       | $3.02 \pm 0.03$                    | $4.56 \pm 0.28$                                           | $6.09 \pm 0.39$                                           |

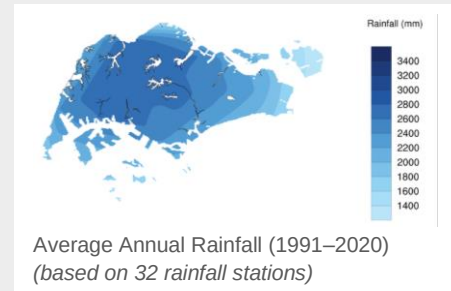
## General Climate of Singapore

Singapore has a tropical climate which is warm and humid, with abundant total annual rainfall of approximately 2200 mm. Generally, the eastern parts of Singapore receive less rainfall compared to other parts of the island. The winds are generally light but with a diurnal variation due to land and sea breezes.

The temperature variation throughout the year is relatively small compared to mid-latitude regions. The daily temperature range has a minimum usually not falling below 23–25°C during the night, and a maximum usually not rising above 31–33°C during the day.

Singapore's climate is traditionally classified into four periods according to the average prevailing wind direction:

- a) Northeast Monsoon (December to early March).
- b) Inter-monsoon (Late March to May).
- c) Southwest Monsoon (June to September).
- d) Inter-monsoon (October to November). The transitions between the monsoon seasons occur gradually, generally over a period of two months (the inter-monsoon periods). The winds during the inter-monsoon periods are usually light and variable in direction.



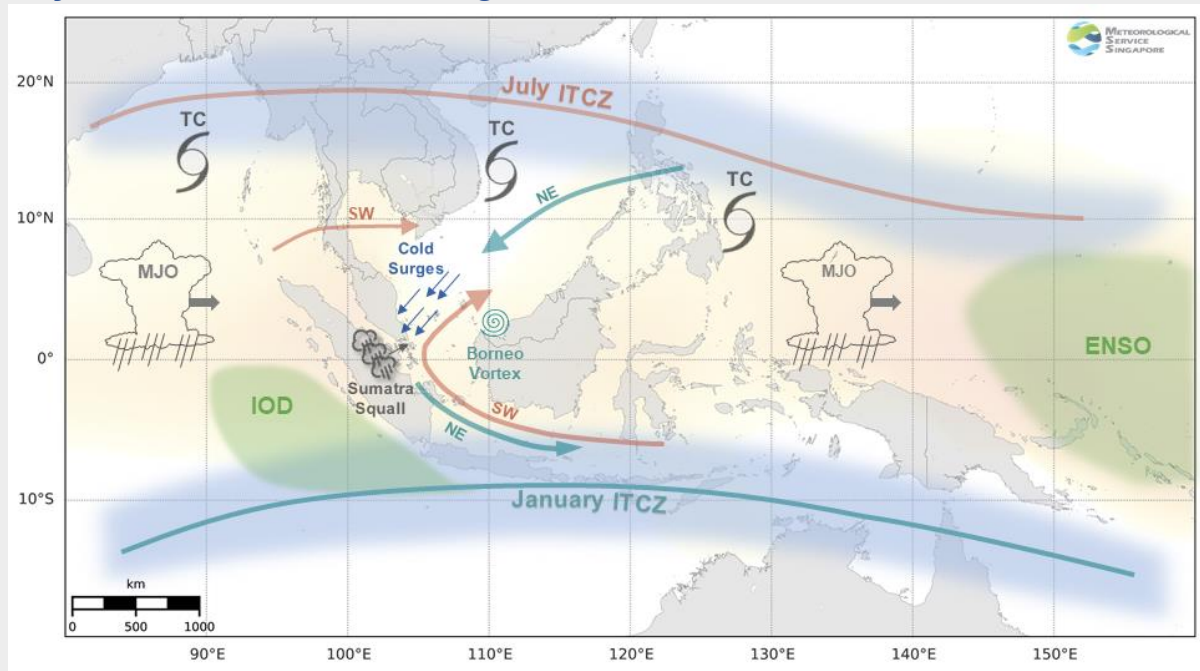
The three main rain-bearing weather systems that affect Singapore are the localised convective showers/thunderstorms, Sumatra squalls and Northeast Monsoon surges. The convective showers/thunderstorms occur throughout the year while Sumatra squalls commonly occur between April and November. The monsoon surges occur during the Northeast Monsoon season.

**Sea Breeze Induced Thunderstorms:** Sea breezes are winds formed as a result of temperature differences between the land and the adjoining sea. The sea breeze, carrying a large amount of moisture from the sea, blows inland during the day where the moist air mixes with the rising warm land air and, under unstable conditions, form rain clouds in the afternoon. During the Inter-monsoon periods, when winds are light, sea breezes are more common.

**Sumatra Squalls:** A Sumatra squall is an organised line of thunderstorm that develops over Sumatra or the Strait of Malacca, often overnight, and moves eastward to affect Peninsular Malaysia and Singapore. In a typical event, the squall line can bring about one to two hours of thundery showers. Often this happens in the predawn or morning hours. Some Sumatra squalls are also accompanied by strong wind gusts with speeds up to 80 km/h (22 m/s) which can uproot trees.

**Northeast Monsoon Surges:** A Northeast Monsoon surge is a surge of cold air from Central Asia. During the period December through early March, the continental northern Asia including Siberia experiences very low, cold temperatures. From time to time, this cold air surges southward from Central Asia to the South China Sea. This results in a sudden increase in northeasterly winds over the South China Sea blowing toward the warm tropics. The sea warms and moistens the overlaying air and the winds converge to bring widespread rain in the tropics. December and January are usually the wettest months of the year in Singapore. The few widespread moderate to heavy rain spells caused by surges of Northeast Monsoon winds contribute significantly to the rainfall in these months. A typical rain spell generally lasts for a few days.

## Key Climate Drivers Affecting Weather and Climate



The **El Niño – Southern Oscillation (ENSO)** is the major influence on climate variability in the western tropical Pacific and Maritime Continent. It affects the year-to-year chance of droughts, extreme rainfall and floods, tropical cyclones, extreme sea levels, and coral bleaching.

The **Intertropical Convergence Zone (ITCZ)** is a persistent east-west band of converging low-level winds, cloudiness, and rainfall stretching across the Maritime Continent into the Pacific Ocean bringing monsoonal rains. It migrates every year southward across the equator and back again, affecting most countries across the Maritime Continent.

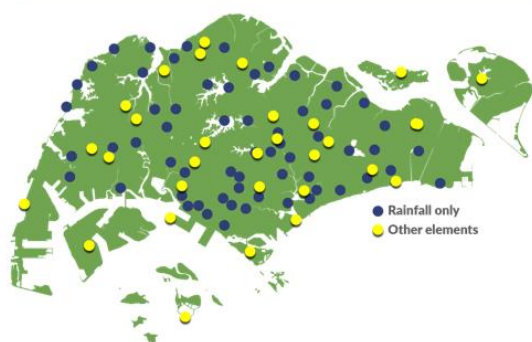
Indian Ocean sea surface temperatures impact rainfall and temperature patterns across the Maritime Continent. Warmer than average sea surface temperatures can provide more moisture for weather systems crossing the region. Sustained changes in the difference between sea surface temperatures of the tropical western and eastern Indian Ocean are known as the **Indian Ocean Dipole (IOD)**. The IOD has three phases: neutral, positive and negative.

The **Madden-Julian Oscillation (MJO)** can be characterized as an eastward moving "pulse" of cloud and rainfall near the equator that typically takes around 30 to 60 days to circle the globe when present. Besides influencing the region's wind and bringing more rain, it can also bring periods of drier conditions associated with its dry or 'suppressed' phase.

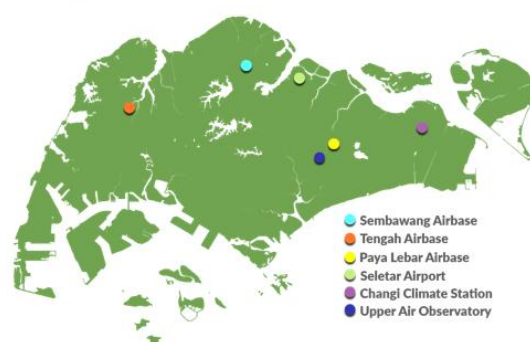
A **Borneo Vortex** typically appears off the northwestern coast of northern Borneo. If a monsoon cold surge event coincides with a vortex, Singapore can experience enhanced rainfall as the convection strengthens over northwest Borneo and weakens north of Java. The lifetime of the vortex is typically a few days.

**Tropical cyclones (TCs)** typically form over large bodies of relatively warm water away from the equator. Because of the large-scale spatial extent of some TCs, they can have a remote impact on Singapore's weather.

### Network of Automated Weather Stations



### Manned Weather Stations



## About the Meteorological Service Singapore (MSS)

The MSS is Singapore's national authority on weather and climate. It is a pillar under the National Environment Agency (NEA).

MSS currently operates a network of five manned observation stations, one upper air observatory and around 100 automatic weather stations. Almost all the automatic weather stations measure rainfall and more than one-fifth of them measure other meteorological elements such as temperature, relative humidity, pressure, and wind. This observation network serves as the main source of climate data for this report.



The Changi Climate Station

The manned observation station at Changi is MSS's designated climate station. The climate station, first located at Outram in 1869, has moved several times over the years due to changes in local land use, before moving to its current site at Changi. The climate station serves as the reference station where its records are used for tracking the national long-term climate trends. The oldest climate station records are for monthly rainfall (starting from 1869) and temperature (starting from 1929, with a break from 1942 to 1947).

The installation of the automatic weather station network from 2009 greatly expanded the coverage of weather observations across Singapore. Prior to this, there were around 40 manual rainfall stations and just a few temperature stations in Singapore. For the purpose of analysing long-term climate trends and establishing climatological averages, only stations with continuous long-term (at least 30 years) records can be used.

Singapore is located deep within the tropics where wind and atmospheric conditions evolve rapidly. The twice daily soundings provide the main source of complete upper air information to support operations. In addition to operational purposes, the observation records from the station would also be useful for monitoring of long-term upper air conditions in the equatorial tropics, as the records extend back many decades to the 1950s.



Upper Air Observatory

### Further Information

Meteorological Service Singapore: [www.weather.gov.sg](http://www.weather.gov.sg)

Centre for Climate Research Singapore: [ccrs.weather.gov.sg](http://ccrs.weather.gov.sg)

Email enquiries: [NEA MSS Engage@nea.gov.sg](mailto:NEA_MSS_Engage@nea.gov.sg)