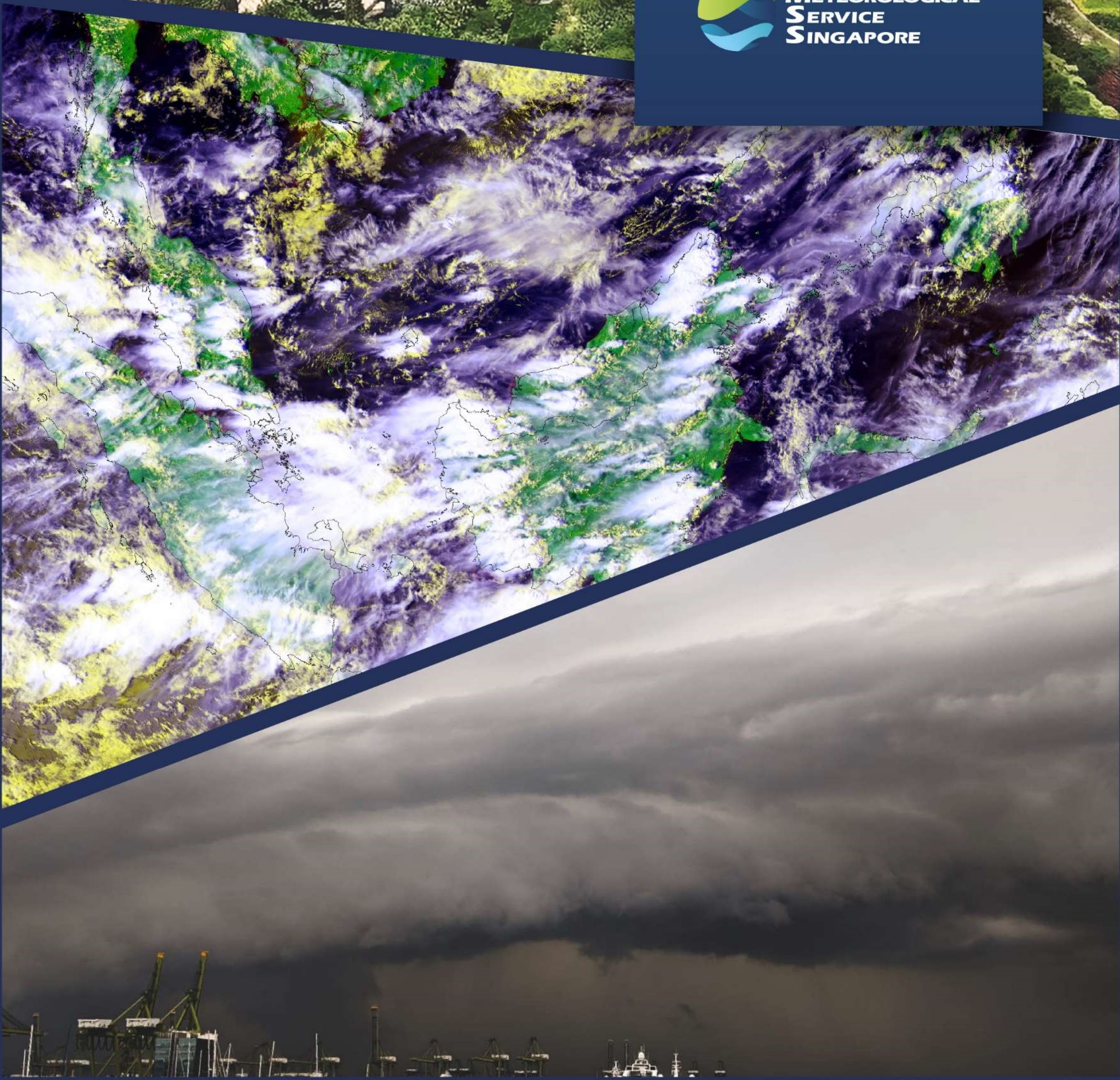



2020

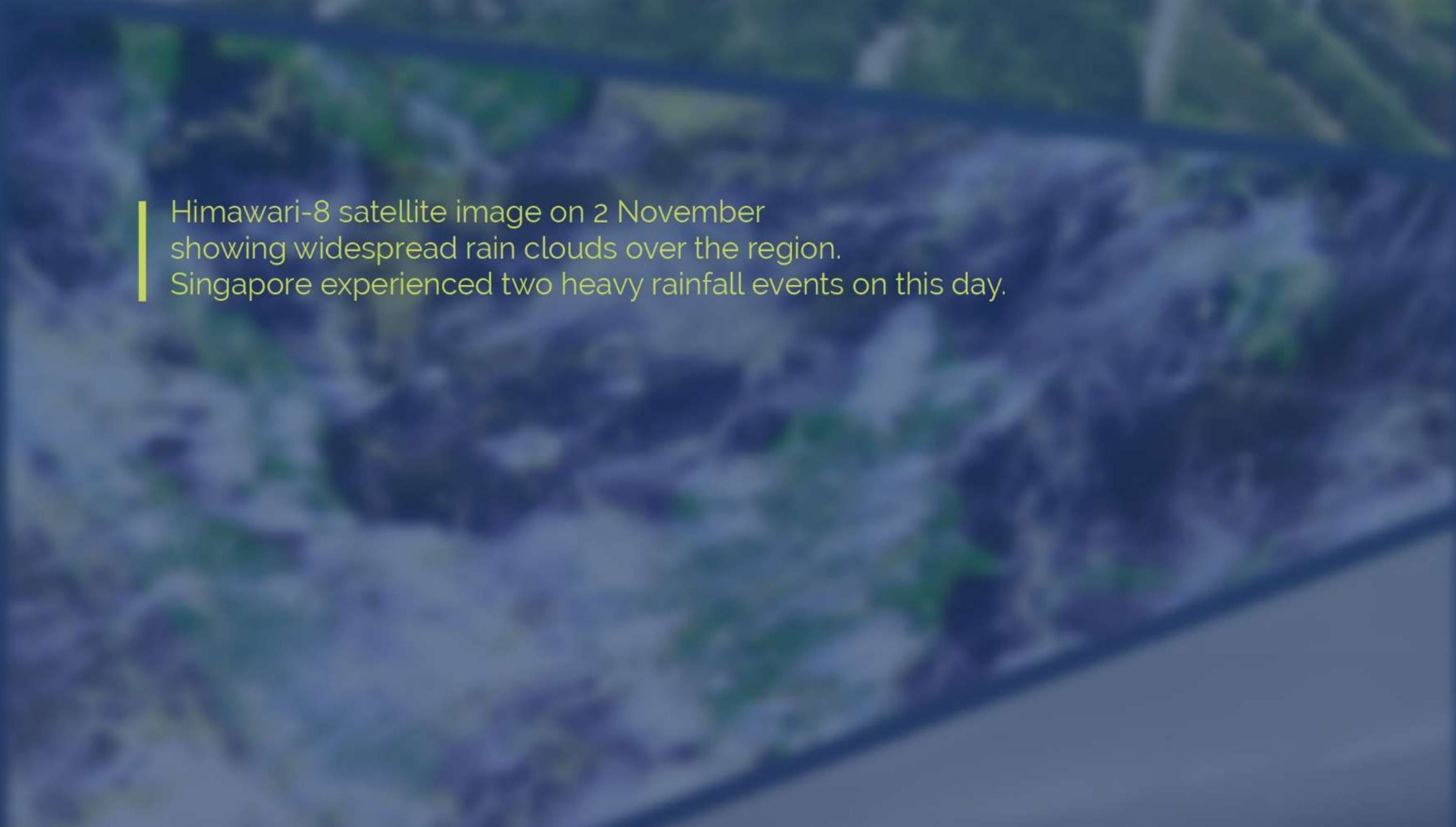
ANNUAL CLIMATE ASSESSMENT

SINGAPORE

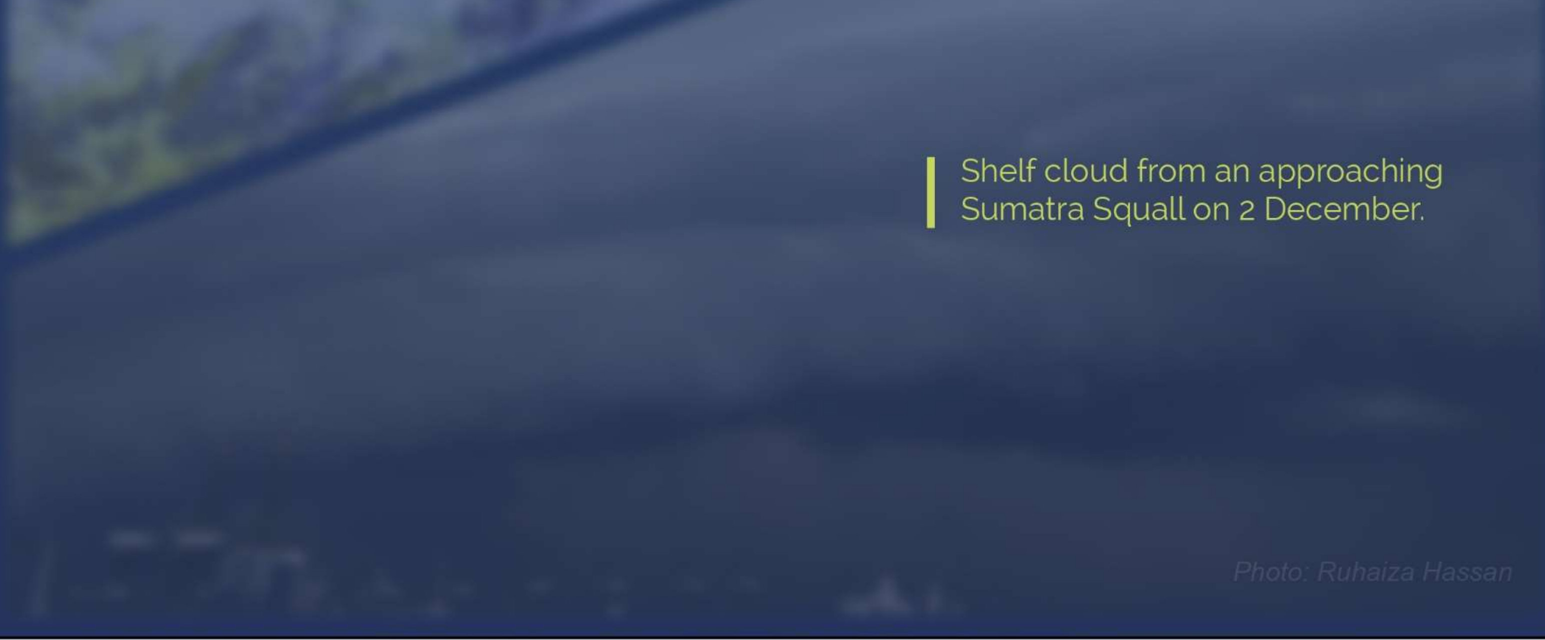
METEOROLOGICAL SERVICE SINGAPORE



Singapore experienced a warm and dry start to the year in 2020.



Himawari-8 satellite image on 2 November showing widespread rain clouds over the region. Singapore experienced two heavy rainfall events on this day.



Shelf cloud from an approaching Sumatra Squall on 2 December.

Photo: Ruhaiza Hassan

Singapore's Climate in 2020

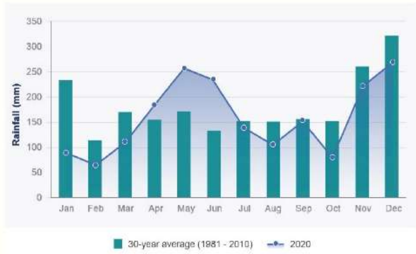
Annual mean temperature

Annual mean temperature was 28.0°C, 0.5°C higher than the 1981-2010 long-term average and ranks as the eighth warmest year on record.

Monthly mean temperature

The record 28 consecutive months of warmer-than-average mean temperatures, starting in February 2018, ended with cooler-than-average temperatures in June 2020.

Monthly total rainfall



The Changi climate station recorded an annual rainfall of 1886.6mm, the eighth driest year in the last 30 years.

NOTABLE WEATHER EVENTS IN 2020

Remarkable June

The Changi climate station recorded 21 rain days, the highest in June in the last 30 years. It was also the second coolest June in the last 20 years.

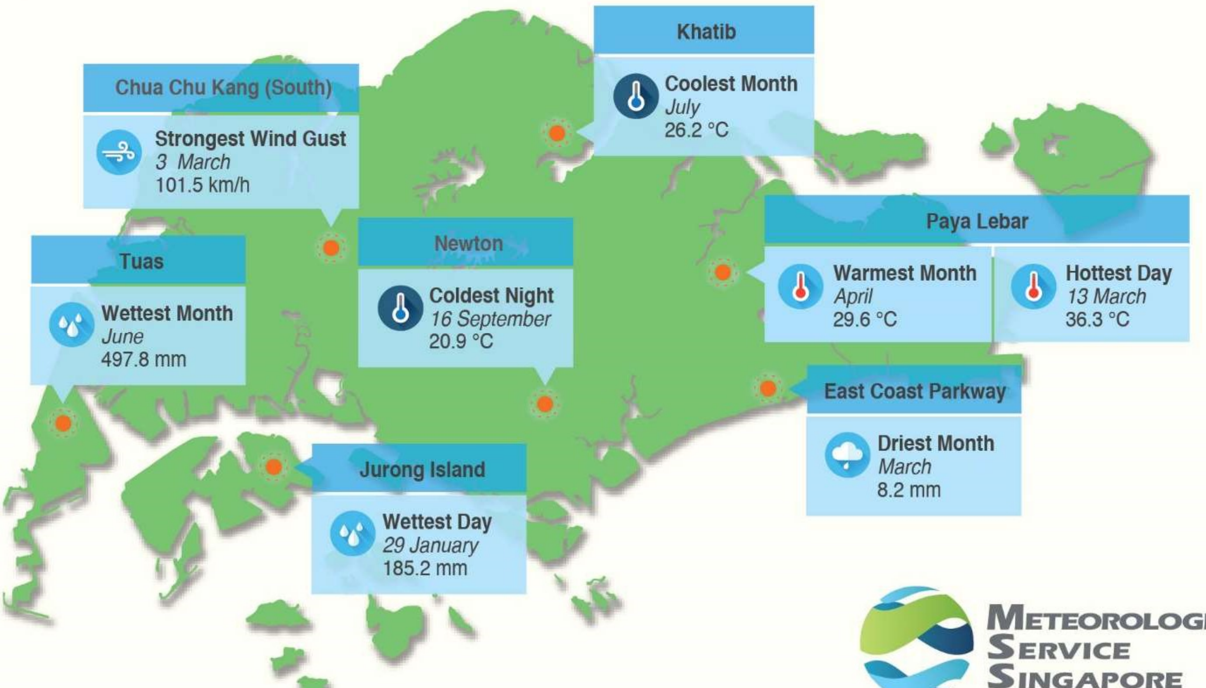
Coolest day

Intense thundery showers brought the temperature to a cool 20.9°C on 16 September, the coolest day of the year. Overall, September was one of only two months in 2020 with below average temperature.

October Sumatra squalls

14 Sumatra squalls passed through Singapore in October, bringing widespread rain and gusty winds. Tropical cyclones in the South China Sea contributed to the high frequency.

WEATHER EXTREMES IN 2020



Meteorological Service Singapore

Singapore Climate in 2020

The year 2020 saw the end of the record number of consecutive months of warmer-than-average mean temperatures in Singapore. This record began in February 2018 and continued into the first five months of 2020, resulting in a record 28 warmer-than-average months in a row. In June 2020 the trend ended with unseasonably wet conditions contributing to cooler-than-average temperatures over the island. Despite these cooler temperatures, the annual mean temperature in 2020 was 28.0°C, 0.5°C above the long-term average of 27.5°C.

Four of the past six years are amongst the top 10 warmest years on record with respect to the annual mean temperature, since Singapore temperature records began in 1929. This includes 2020 which ranks as eighth warmest. The other three warm years include 2019 and 2016 (joint warmest years on record at 28.4°C) and 2015 (joint fourth warmest with 1997 at 28.2°C[1]).

The mean temperature for the last 10 years from 2011 to 2020 was 27.94°C, and ranks as the second warmest decade, marginally less than the previous warmest decade from 2010 to 2019 (27.95°C[1]).

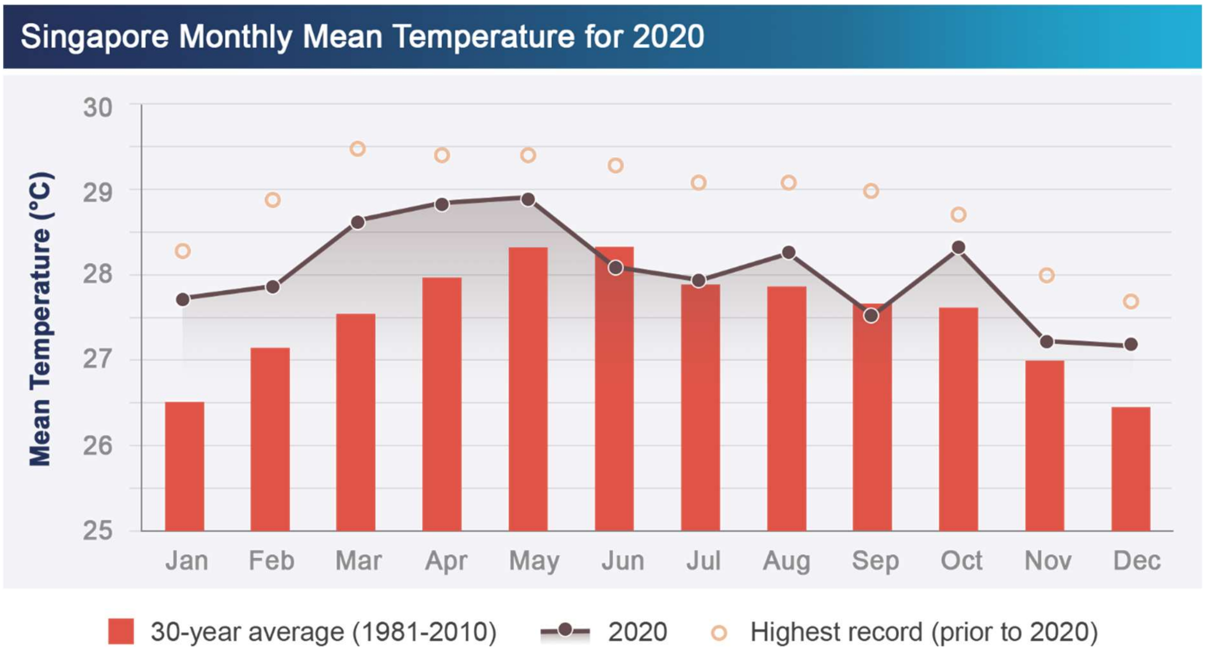


Figure 1: Singapore monthly mean temperature for 30-year average from Changi climate station (bars, 1981 – 2010) compared to 2020 (solid line). Also shown are the highest recorded monthly values for the historical period prior to 2020 as 'dots'. No long-term monthly temperature records were broken in 2020.

Considering the individual months (Figure 1), the monthly mean temperatures remained above their respective monthly average for the first five months, peaking in May 2020 at 28.9°C. In June 2020, the monthly mean average temperature was 28.1°C, 0.2°C below the long-term average and the second coolest June in the past 20 years. Similar slightly cooler-than-average mean temperature conditions occurred again in September 2020, with a monthly average temperature of 27.5°C, joint with September 2013 as the coolest

[1] Small deviation from TYR 2019 due to improved method for calculating annual average temperature.

Septembers in the last 10 years (0.1° below the long-term average). October marked a return to warmer-than-average temperature, recording 28.3°C, 0.7°C above the long-term average. No long-term monthly temperature records were broken in 2020.

For rainfall, the 2020 annual total rainfall was near average over most of the islandwide rainfall stations. However, at the Changi climate station (Figure 2), the annual total rainfall recorded was 1886.6 mm, which was 12.9% below the long-term annual average of 2165.9 mm. This year's annual rainfall ranks eighth lowest over the past 30 years.

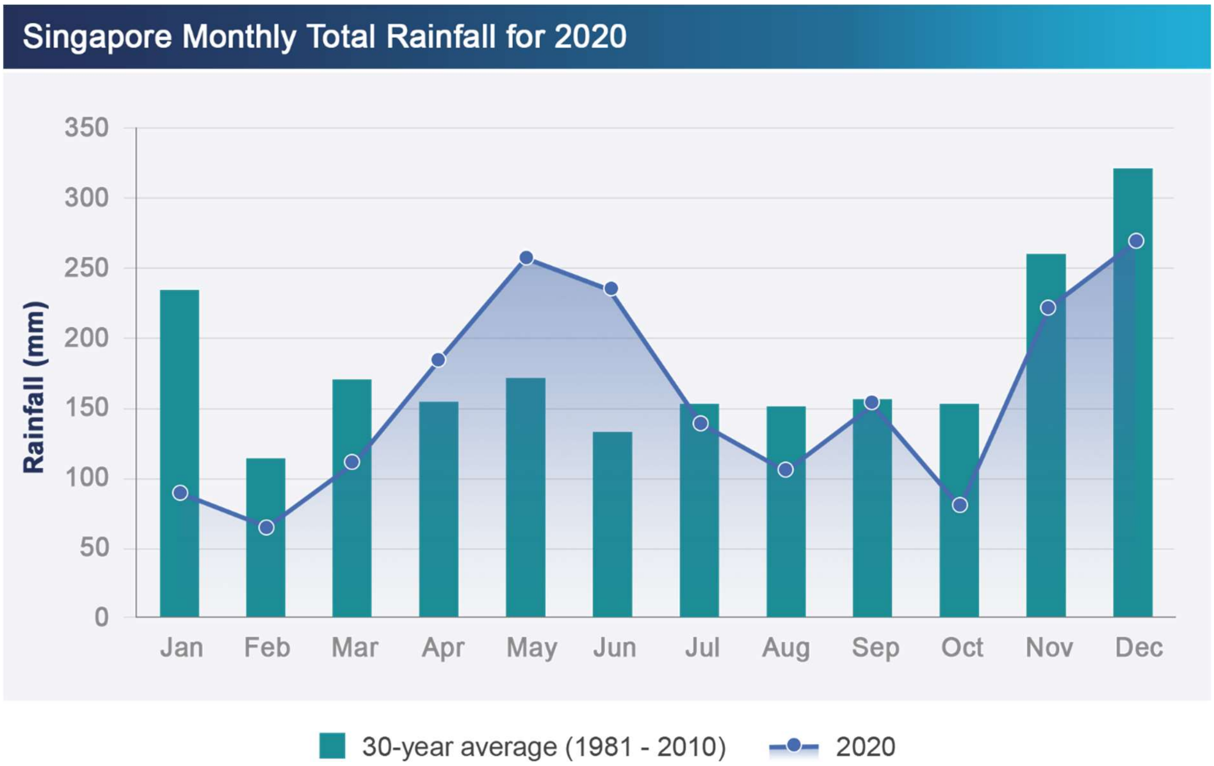


Figure 2: Singapore monthly total rainfall for 30-year average from Changi climate station (bars, 1981 – 2010) compared to 2020 (solid line). The annual total rainfall of 1886.6 mm for 2020 was 12.9% below the long-term annual average of 2165.9 mm.

The driest period relative to climatology in 2020 was between January to March (Figure 3). Islandwide, the January to March monthly rainfall was more than 30% below average in each of these three months.

In contrast, the 2020 Southwest Monsoon season (June – September) was wetter-than-average. The Southwest Monsoon season is typically the drier period of the year, however the two highest islandwide average monthly rainfall totals of 310.1 mm and 302.4 mm occurred in June and September 2020. These values were 99% and 63% above their respective long-term monthly averages. For the whole Southwest Monsoon season, islandwide total rainfall was 30% above the long-term average for June – September 2020. This was the third wettest June – September since 1981.

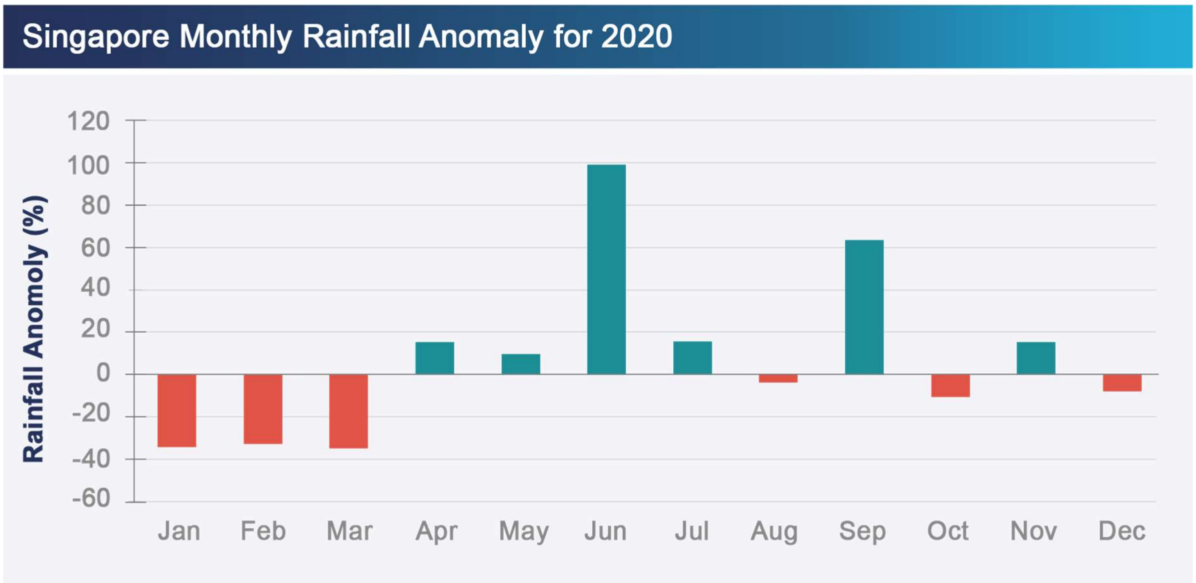


Figure 3: Singapore monthly rainfall anomaly for 2020 averaged over 28 stations islandwide. Rainfall was significantly below-average in first few months of the year during the Northeast Monsoon and above-average for the Southwest Monsoon season (June – September 2020).

There were more frequent intense heavy rainfall events over the island in 2020. Based on the rainfall stations with long-term records, there were six days of very heavy rainfall in 2020 where the *hourly* rainfall total exceeded 70 mm. This hourly rainfall value represents the top one per cent of all heavy rainfall events recorded in Singapore (in the climatological reference period 1981-2010). These rainfall events led to flash floods at various locations across Singapore. The hourly rainfall total of 106.0 mm recorded in August 2020 at Bedok South was the highest in 2020. As a reference, the highest ever hourly rainfall total of 130.7 mm was recorded at Ulu Pandan in July 2007.

The number of days with very heavy hourly rainfall (>70mm) in 2020 is the highest recorded since 2013, as shown in the table below.

Year	2013	2014	2015	2016	2017	2018	2019	2020
No. of days	9	3	2	5	2	3	1	6

Table 1: Annual number of days with very high rainfall events (hourly rainfall total >= 70 mm) since 2013 recorded at rainfall stations with long-term records.

La Niña conditions developed in the third quarter of 2020 and continued to strengthen during the rest of the year. Based on historical observations, La Niña events tend to have a stronger effect on Singapore's rainfall during the Southwest Monsoon season, where they bring wetter-than-average conditions.

The strong positive Indian Ocean Dipole (IOD) present in the second half of 2019, quickly returned to neutral at the start of 2020. No further significant IOD events developed in 2020.

Notable Weather Events in 2020

Remarkable June

June 2020 was a remarkable month, weather-wise. At the Changi climate station, the total rainfall in June 2020 was 233.8 mm which ranks June 2020 as the wettest June in the last 10 years, surpassing June 2011 by 20.8 mm.

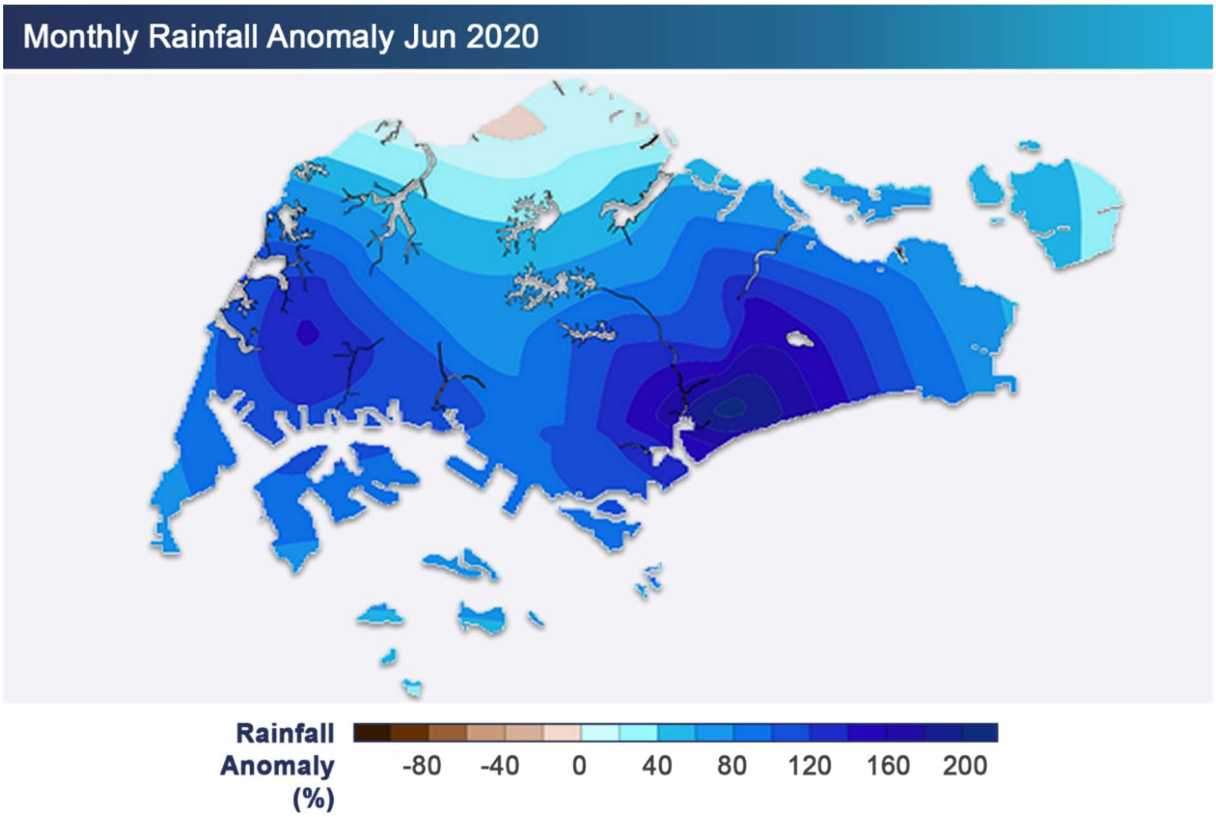


Figure 4: Rainfall anomaly map for June 2020

There were 21 rain days at the Changi climate station in June 2020, the highest in the last 30 years and surpassing the previous high of 19 rain days in June 2010.

The wet weather in June 2020 was mostly due to strong solar heating of land areas, at times coupled with large-scale convergence of winds in the surrounding region, and to the passage of Sumatra squalls on some days. The heavy thundery showers on several days particularly on 23 June 2020 brought intense rainfall and contributed to flash floods at various locations in the island.

In the morning of 23 June 2020, a Sumatra squall from the Strait of Malacca moved over Singapore bringing two spells of widespread, heavy thundery showers in the morning (Figure 5). The highest hourly total rainfall in the first spell was 67.2 mm recorded at Nicoll Highway. The second spell of intense thundery showers fell mainly over the western part of the island, and the highest hourly total rainfall of 65.8 mm (10am-11am) was recorded at Tuas. Flash floods were reported that morning in Jurong, Bedok and Changi.

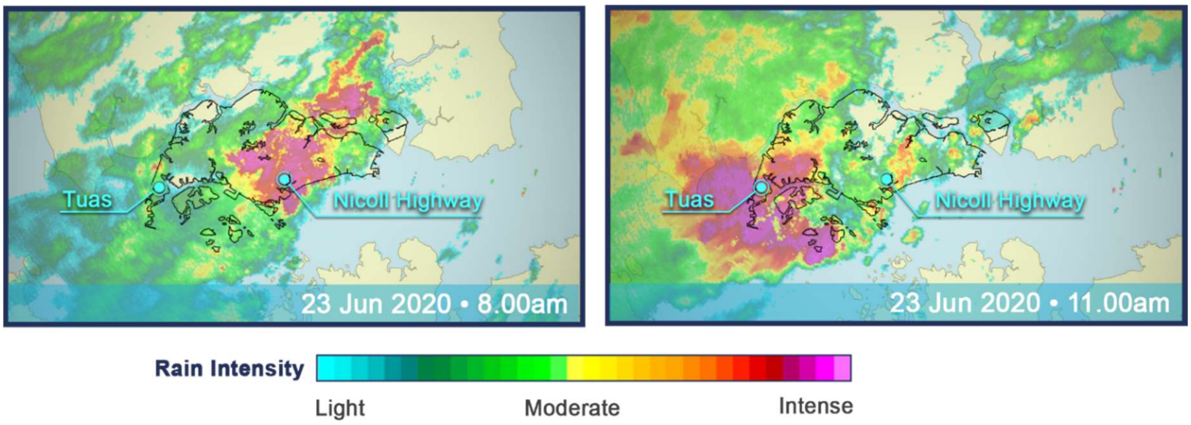


Figure 5: Weather radar images of the squall that moved over the island in the early morning (left) and again in the late morning (right) on 23 June 2020.

Although there were some warm days in June 2020, the high number of rain days during the month brought cooler conditions across the island. At the Changi climate station, for instance, the temperature remained below 30°C for five consecutive days between 20 and 24 June 2020.

Coolest Day

A generally wet Southwest Monsoon season in 2020 brought cooler temperatures over Singapore on some days, particularly in September 2020. The lowest daily minimum temperature in 2020 was 20.9°C, recorded on 16 September 2020 at Newton, the coolest day in the year. Overall, September was one of only two months in 2020 with below average temperature.

The cool weather on 16 September 2020 was due to a Sumatra squall that developed under the indirect influence of Tropical Storm ‘Noul’ over the South China Sea (Figure 6). The squall brought widespread and intense thundery showers over Singapore for a few hours from midnight followed by light to moderate rain (Figure 7). This further cooled the air with the temperature falling to slightly below 21°C between 3.30am and 4am that morning.

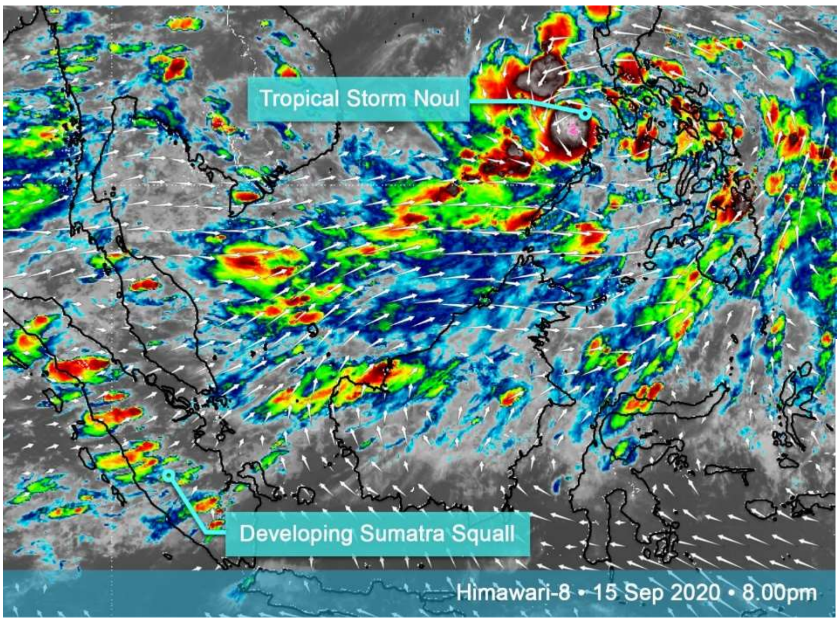


Figure 6: Himawari-8 satellite image at 8pm on 15 September 2020, shows a developing Sumatra squall over central Sumatra under the influence of Tropical Storm ‘Noul’ brewing over the South China Sea.

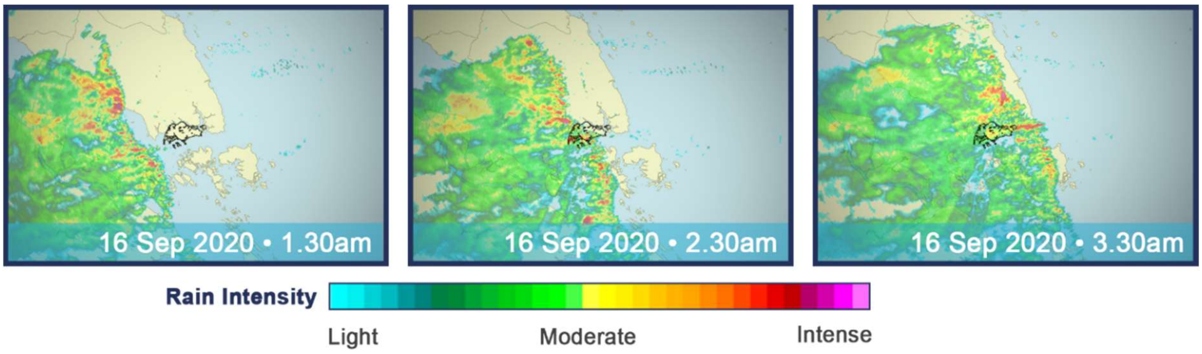


Figure 7: Series of weather radar images of a well-organized Sumatra squall on 16 September 2020. Widespread and intense thundery showers fell over Singapore between midnight and 3am followed by light rain that cleared within the next hour.

High occurrence of Sumatra squalls in October

14 Sumatra squalls passed over Singapore in October 2020, the highest number for October since 2010. Sumatra squalls are organised line of thunderstorms that bring strong gusty winds and heavy rain. On average, Singapore experiences 45 squalls per year, with most occurring between April and November. In 2020, about 50 Sumatra squalls crossed over Singapore.

The high frequency of Sumatra squalls in October 2020 can be partly attributed to the presence of several tropical cyclones over the South China Sea and western Pacific Ocean. These cyclones altered the wind flow over equatorial Southeast Asia, bringing favourable conditions for the development and eastward passage of the Sumatra squalls (Figure 8).

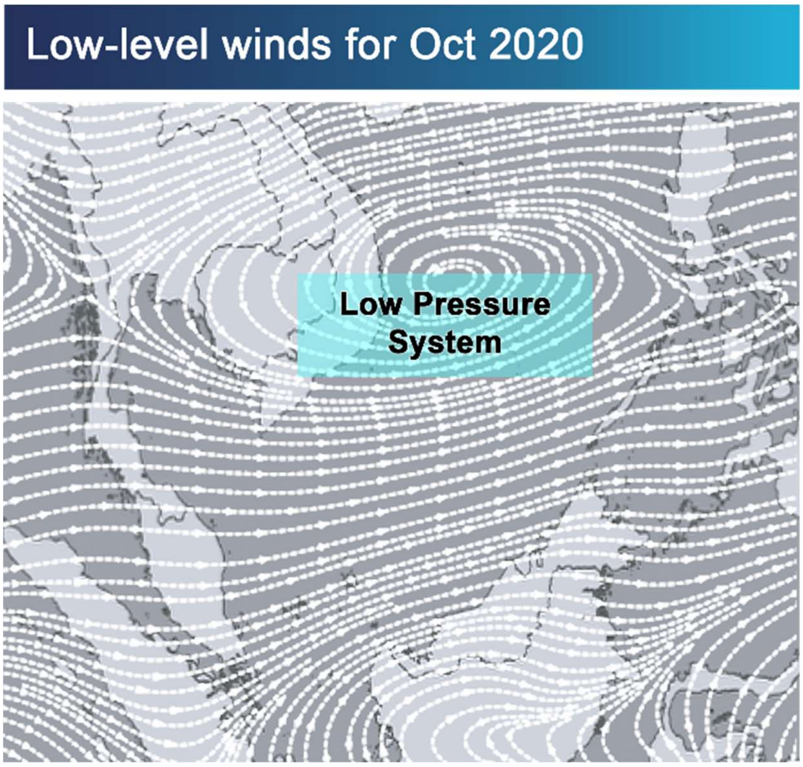


Figure 8: Average low-level wind field (October 2020) blowing from the southwest or west over Singapore and the surrounding region, and low- pressure system over the northern part of the South China Sea. (Source: JMA TCC ITACS platform).

Large-scale Climate Variability in 2020

Southeast Asia’s climate is influenced by climate drivers operating on different temporal and spatial scales, such as the Indian Ocean Dipole (IOD), El Niño-Southern Oscillation (ENSO), Madden Julian Oscillation (MJO), and the seasonal monsoons. These drivers are realisations of various atmospheric and oceanic processes. Sometimes several of these climate drivers are active at the same time, such as ENSO and the Southwest Monsoon activity this year.

Surrounded by two large ocean basins (Pacific and Indian Oceans), these basins can influence the climate in our region and indeed played key roles in determining Singapore’s climate in 2020. Overall, the two ocean basins had opposite effects on Singapore’s rainfall in 2020 – although impacting different seasons – thereby making 2020 a fairly average year in terms of rainfall.

The El Niño Southern Oscillation (ENSO) Overview

The key driver from the tropical Pacific Ocean in 2020 was ENSO, with the development of La Niña conditions in the second half of the year. 2020 started with ENSO neutral conditions, which prevailed for the first half of the year, as indicated by the Nino3.4 index in Figure 9. However, by the end of June, there were signs of La Niña conditions developing, with MSS entering the La Niña Watch phase in July.

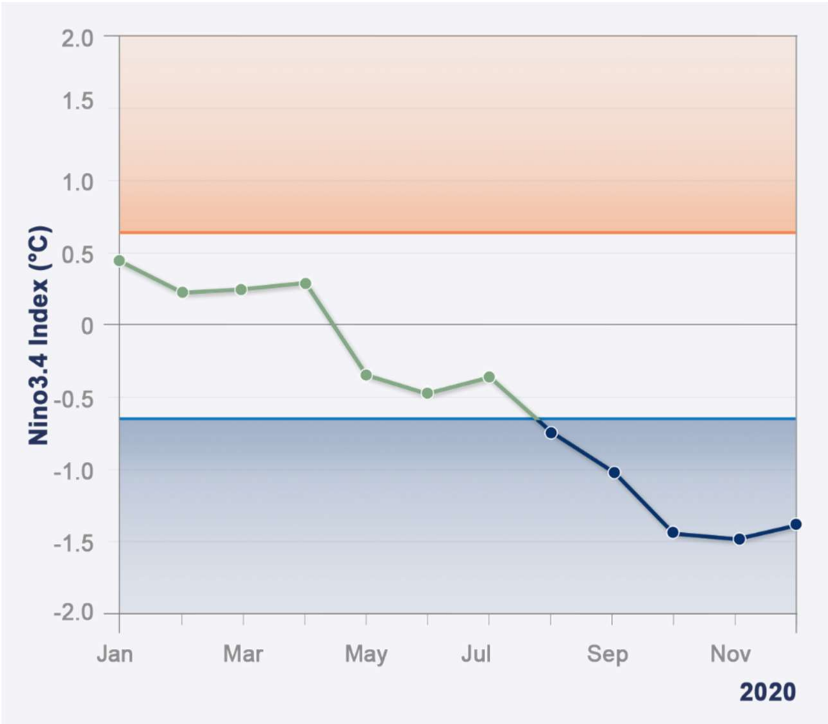


Figure 9: Nino3.4 index from January to December 2020. The index indicates La Niña conditions from August onwards.

La Niña conditions developed in the third quarter of 2020, with the Nino3.4 index passing the La Niña threshold in August. The La Niña conditions continued to strengthen and reached moderate strength by the end of the year. The 2020/2021 La Niña event has been stronger than the two previous events (in 2016 and 2017/2018), although this event looks unlikely to be as strong as the 2010/2011 event.

Southwest Monsoon and the El Niño-Southern Oscillation

Every year the Inter Tropical Convergence Zone moves northward, bringing about the start of the Southwest Monsoon season between May and June (Figure 10). This is the traditional rainy season of northern Southeast Asia, bringing thunderstorms, floods, and landslides to the region. In contrast, southern Southeast Asia begins its traditional dry season, with risk of hazards such as drought and transboundary haze.

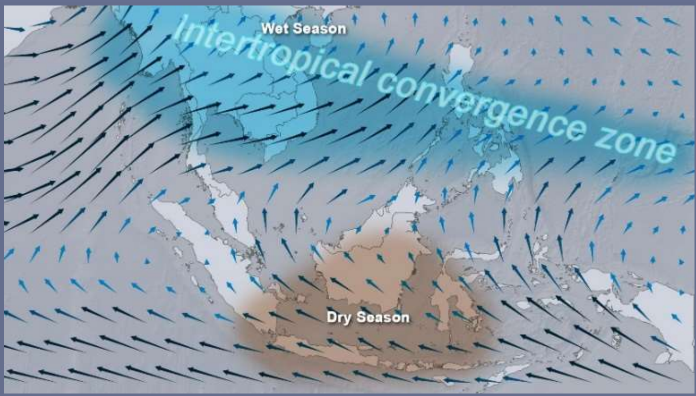


Figure 10: Average conditions during the Southwest Monsoon season (June – September).

Singapore lies between these two zones. Typically, temperatures are warm during the Southwest Monsoon season, and short duration showers/thunderstorms in the afternoon are common, and occasional Sumatra squalls bring gusty winds and heavy rain. The prevailing winds generally blow from the southeast or southwest.

The characteristics of the Southwest Monsoon season are influenced by both the Indian and Pacific Oceans. Most El Niño and La Niña events develop between May and October, and the occurrence of these events tend to influence the Southwest Monsoon conditions.

ENSO Teleconnections

During La Niña events, the sea surface temperatures in the western Pacific Ocean are warmer than normal and the easterly trade winds are stronger than normal. This pattern reverses during El Niño events. The weakening (El Niño) and strengthening (La Niña) of the easterly trade winds are visible over the ocean to the east of the Philippines in Figure 11. These changes in the ocean and atmosphere bring significant anomalies to the areas directly affected by the shift in the cycle. Outside of these areas 'teleconnections' (a significant response in areas remote to the phenomena) in both the ocean and atmosphere lead to changes around the globe, including the region around Singapore.

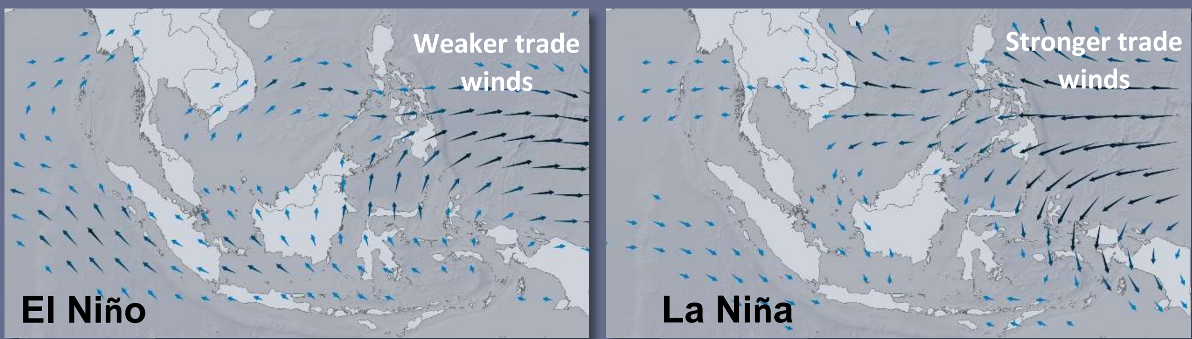


Figure 11: Wind anomalies[2] during the Southwest Monsoon season based on ENSO conditions. The average difference in the wind during El Niño years (left) and La Niña years (right) compared to climatology (see Figure 10) with weaker trade winds during El Niño and stronger trade winds during La Niña events. Darker colour indicating stronger anomalies.

One way to look at the teleconnections is to look at the correlation between the Nino3.4 index (which MSS uses to monitor ENSO events) and precipitation. In Figure 12, areas that are brown show more rainfall when there is a La Niña event (and less during El Niño events), while those in green have less rainfall during La Niña events (and more during El Niño events). The darker the colour, the stronger the teleconnection. It shows that Singapore and the surrounding region experience more rainfall than usual over the Southwest Monsoon season during La Niña events.

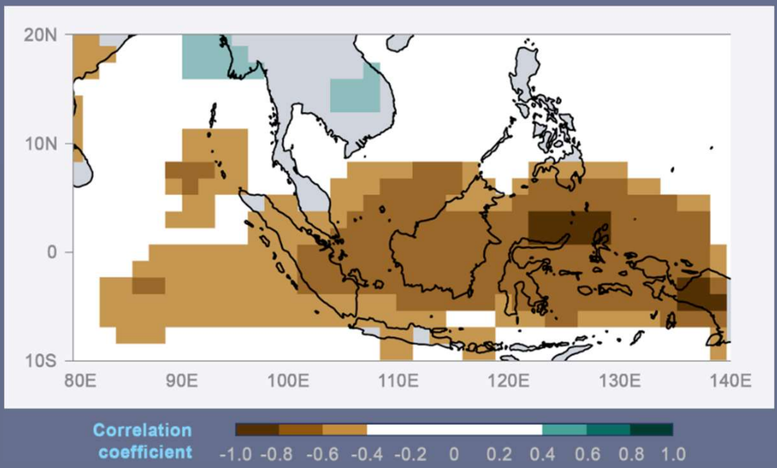


Figure 12: Rainfall teleconnection for ENSO phases during the Southwest Monsoon season[3]: Brown indicates less (more) rainfall during El Niño (La Niña) events, while green indicates more (less) rainfall during El Niño (La Niña) events. Only significant correlations are shown.

During the Southwest Monsoon, there is a different response over land compared to over the sea areas around Singapore (Figure 13). During La Niña events, the temperature over Singapore and the surrounding land areas tend to be cooler than average (shown in red), while there is no noticeable change on average over the oceans.

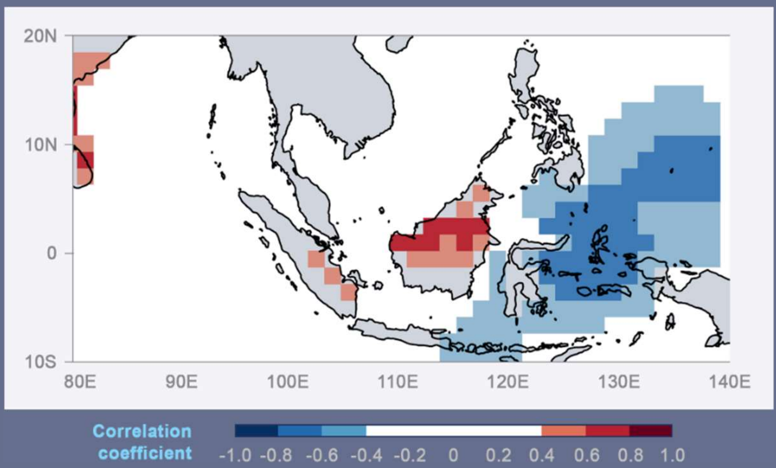


Figure 13: Temperature teleconnection for ENSO phases during the Southwest Monsoon season[3]. Red indicates warmer (cooler) temperatures during El Niño (La Niña) events, while blue indicates cooler (warmer) during El Niño (La Niña) events. Only significant correlations are shown.

ENSO teleconnections affect not only Southeast Asia but reach out around the globe. Large-scale circulations in the atmosphere and the oceans interact to spread the influence of ENSO events. These connections are also not instantaneous, with faster connections occurring in the atmosphere than in the ocean. Slower connections trigger a lagged or delayed response, sometimes for months afterwards. And as impacts of ENSO events reach out around the global, they can even feedback to the tropical Pacific Ocean itself, such as contributing to the fast transitions we see between El Niño and La Niña events in some years.

We live in a complex system, and just like no two La Niña events are alike, no two Southwest Monsoon seasons are alike. The interplay between these two large scale drivers is a part of Singapore's natural variability. Understanding these teleconnections not only helps us better understand why Singapore sometimes receives wetter or drier Southwest Monsoon seasons but can also help us to better predict what the next Southwest Monsoon season might bring.

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[2] Data source: National Centers for Environmental Prediction (NCEP) reanalysis.

[3] The Pearson's correlation coefficient was calculated over 1980–2014 using the Hadley Centre Global Sea Ice and Sea Surface Temperature v1.1 (Rayner et al. 2003, Journal of Geophysical Research: Atmospheres, 108), with the version 2 of the Global Precipitation Climatology Project data (GPCP; Adler et al. 2003, Journal of Hydrometeorology, 4) for Figure 12 and with Berkeley Earth Land/Ocean Temperature Record (BEST; Rohde and Hausfather, 2020, Earth System Science Data, 12) for Figure 13.

La Niña conditions and the Southwest Monsoon in 2020

Between June and September 2020, the rainfall pattern showed wetter conditions for much of the region around Singapore (Figure 14, left), as expected during a La Niña event (Figure 12). In particular, the Malay Peninsula, southern Borneo, and Sulawesi received more rainfall than normal. During this same time, the temperature was near to above average for Southeast Asia (Figure 14, right). The land areas around Singapore were the closest to average, corresponding to the areas that tend to experience cooler temperatures during La Niña events (Figure 13).

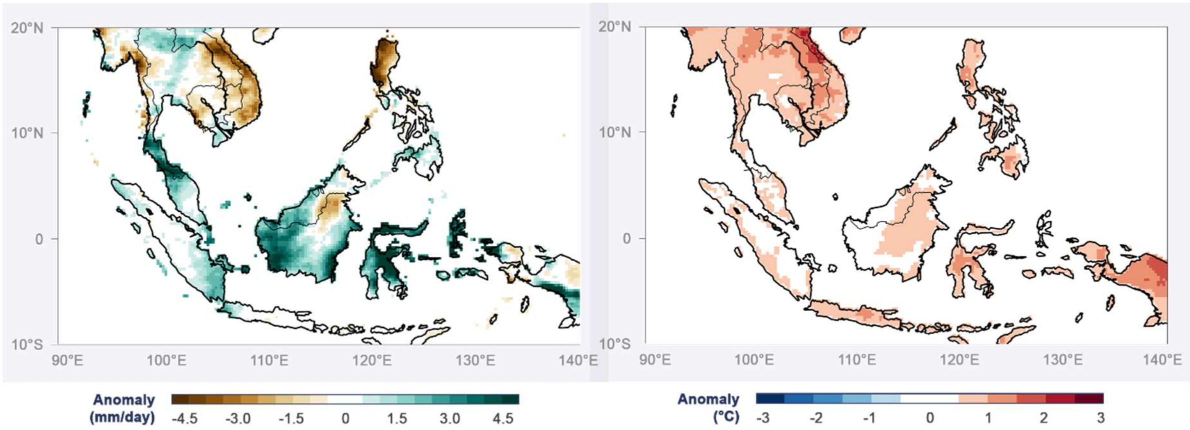

Figure 14: June – September 2020 anomalies for (left) rainfall [4], with areas in green (brown) recording more (less) rainfall than average during the Southwest Monsoon season and (right) for temperature[5], with red areas indicating warmer than average temperature for the Southwest Monsoon season.

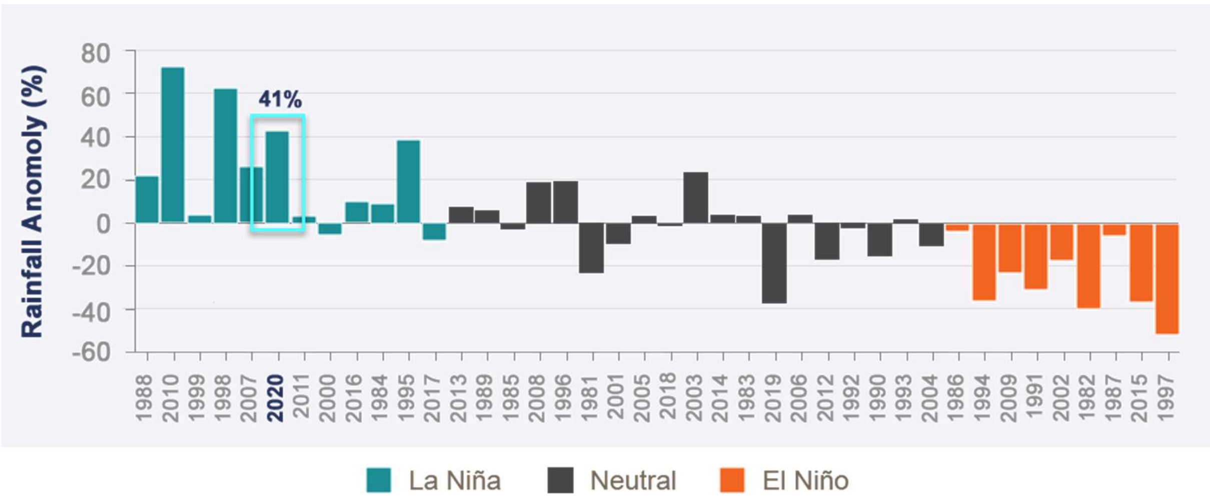

Figure 15: Singapore's rainfall during June – September for the period 1981 – 2020 compared to climatology, ordered from strongest La Niña to strongest El Niño, averaged over 28 stations islandwide. The rainfall anomaly in 2020 is highlighted in aqua.

During the Southwest Monsoon, La Niña events typically bring wetter than average rainfall to Singapore. Based on the strength of the Nino3.4 index[6], the Southwest Monsoon seasonal

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[4] Data source: Climate Hazards Group InfraRed Precipitation with Stations (CHIRPS); Funk et al. 2015, Scientific Data 2.
[5] Data source: ERA5 dataset produced by the European Centre for Medium-range Weather Forecasts, UK (ECMWF)
[6] The strength of the Nino3.4 index is calculated based on the strength during the Southwest Monsoon season, not the peak strength of the event.

rainfall between 1981 and 2020 showed that all Southwest Monsoon seasons that overlapped with a La Niña event recorded near or above average rainfall (Figure 15). Among these La Niña events, those with near average rainfall tended either to be when the end of the La Niña event overlapped with the Southwest Monsoon (e.g. in 2000), or when the La Niña event formed after the season (e.g. 2017 and 1984). The rainfall in the 2020 Southwest Monsoon season followed this trend and was above average (aqua box, Figure 15). Similarly, El Niño events tend to have below average rainfall. There is still variability on top of the ENSO strength, with some ENSO-free Southwest Monsoon seasons recording more rainfall than some Southwest Monsoon seasons with La Niña conditions. Overall, about half of the Southwest Monsoon seasons were influenced by either an El Niño or La Niña event.

For temperature, the impact of La Niña events on the Southwest Monsoon season is superimposed on top of the long-term warming trend from climate change and local urbanisation. The dominant feature of Figure 16, showing the recent June – September temperature anomaly trend for the Singapore climate station, is the increase of the temperature during the Southwest Monsoon season from the 1970s onwards. The Southwest Monsoon seasons between 1961 and 1980 were cooler than those between 2001 and 2020. At sub-decadal timescales, there are noticeable differences based on the climate drivers (such as ENSO and IOD); the Southwest Monsoon season co-occurring with El Niño events (orange dots) tend to be warmer than those seasons without El Niño events, while the reverse is true for La Niña events (blue dots). In 2020, the average temperature during the Southwest Monsoon season was only slightly above the 1981–2010 average, indicative of a La Niña event plus the long-term warming trend.

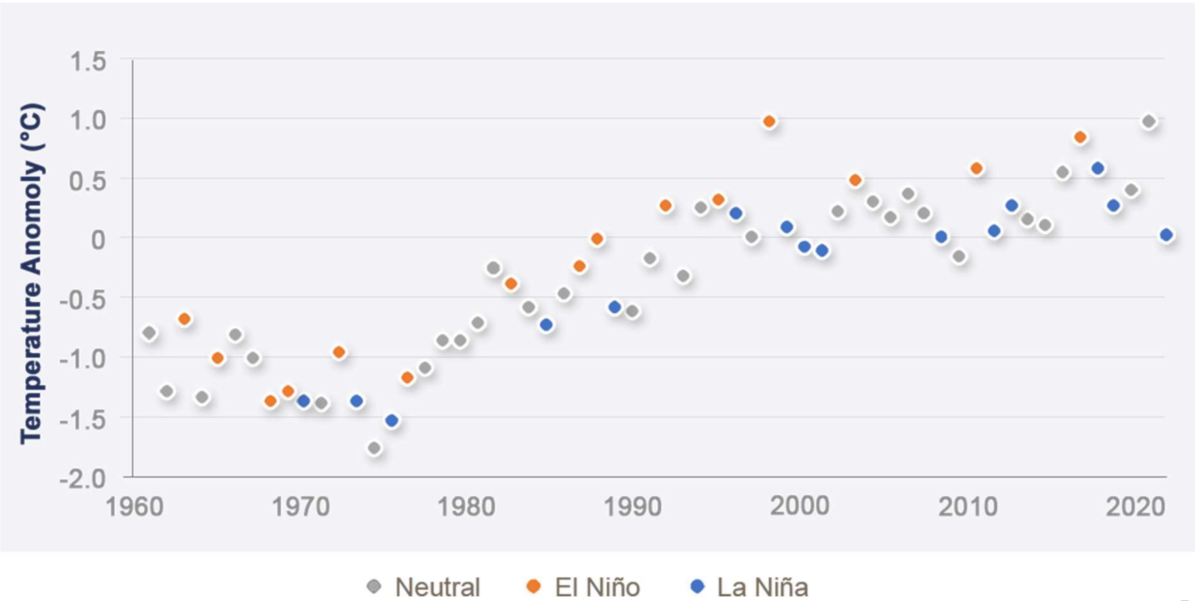


Figure 16: Temperature anomaly during June – September based on the Singapore climate station[7], with the colour based on whether an ENSO event. The anomalies are relative to the 1981 – 2010 average. In 2020, the average temperature over the Southwest Monsoon season was near average.

Figure 16 shows clearly that recent La Niña years were already warmer compared to El Niño years several decades ago for the Southwest Monsoon season.

[7] Since 1984 Singapore's climate station has been located at Changi International Airport, see page 23 for more information.

Indian Ocean Dipole (IOD) Overview

The IOD refers to a broad pattern of temperature differences in the western and eastern Indian Ocean. The IOD Index (also known as the Dipole Mode Index) measures the difference between the sea surface temperature anomalies in the western and eastern tropical Indian Ocean. Sustained positive (negative) values indicate a positive (negative) IOD event.

After the strong positive Indian Ocean Dipole (IOD) event in the second half of 2019 (maximum IOD Index above 2°C) and drier conditions in Singapore and the region, the IOD quickly returned to neutral in January 2020 (Figure 17). IOD events typically decay to neutral with the start of the rainy monsoon season in the Southern Hemisphere around December. The return of the IOD to neutral at the start of 2020 was later than usual, while the remote impact on Singapore continued for several months. Figure 17 also shows that since mid-January, the IOD index has been neutral.

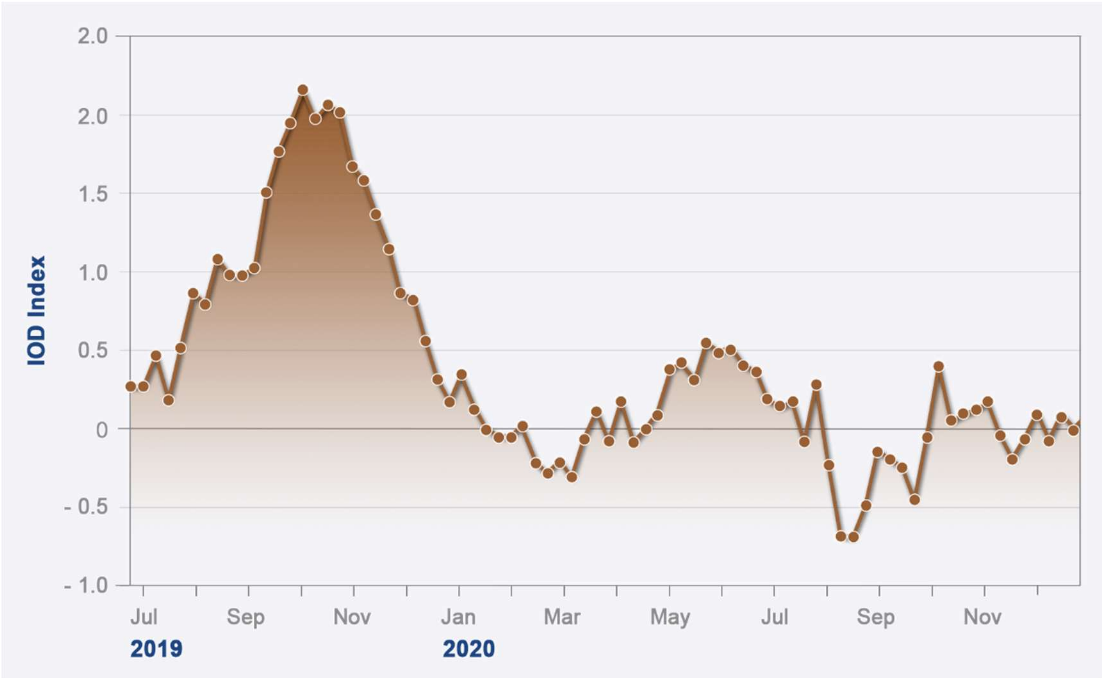


Figure 17: The Indian Ocean Dipole (IOD) index[8] shows that the strong IOD in the second half of 2019 quickly returned to neutral in January 2020. However, the remote impact from the Indian Ocean continues for several months.

Positive IOD events and January – March rainfall and temperature

While positive IOD events decay with the start of the rainy monsoon season in the Southern Hemisphere, they can still have a lasting effect on Singapore's rainfall and temperature. In the past four positive IOD events, Singapore and the surrounding region had on average been drier than usual in the following January – March period. The same happened in 2020 (Figure 18 left), with drier conditions for much of Sumatra, the Malay Peninsula and northern Borneo.

The temperatures during this time were also much warmer than normal over equatorial Southeast Asia, with warmer anomalies in the January to March period (Figure 18 right) compared to that in the Southwest Monsoon months (Figure 14 right).

[8] Data source: Bureau of Meteorology, Australia.

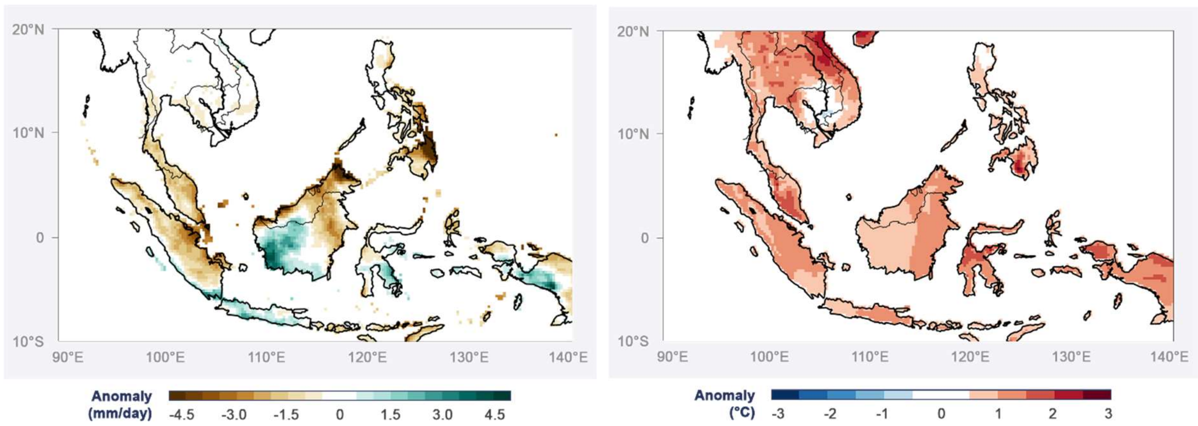


Figure 18: January – March 2020 rainfall anomalies[9] (left) and temperature anomalies[10] (right) against the 1981 – 2010 climatology. Average surface temperature anomalies for January – March show warmer conditions (red shades) over land for most parts of Southeast Asia.

The Madden-Julian Oscillation

At the subseasonal timescale, the Madden-Julian Oscillation (MJO) is an important driver for climate variability in Singapore. The MJO is characterised by a pulse of cloud/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, or phases, marked by the location of increased/suppressed rainfall or convective activity. While the MJO is not always present, when it does occur, it can provide predictability for rainfall in the coming weeks.

The MJO was active on several occasions in 2020, which influenced the regional rainfall patterns (Figure 19). At the end of March 2020, a pulse of the MJO signal developed in the eastern Indian Ocean (Phase 3) before moving quickly into the western Maritime Continent (Phase 4) at the start of April. By 5 April the active phase had moved to the eastern Maritime Continent (Phase 5), which tends to bring drier conditions for Singapore (Figure 19, middle left). The convective portion of the MJO continued moving eastward through the Western Pacific (Phases 6 and 7) entering Phase 1 on 13 April. Figure 19 (top left) shows the average rainfall anomaly during this time – while some areas around Singapore were drier than normal (as would be expected based on the MJO), the signal was not very coherent, possibly due to the fast speed of the MJO during this time (three phases during 1 week). For the rest of April 2020, the MJO continued moving eastward, reaching the Indian Ocean on 21 April, and continued moving eastward for the rest of the month. The average rainfall anomaly during the end of April (21 – 30) is in Figure 19 (top right) showing wetter than average conditions for the western Maritime Continent, as would be expected during MJO phases 2 and 3. This MJO signal took approximate 1 month to circumnavigate the globe – making April 2020 an example of a faster MJO.

In the fourth quarter of 2020, a slower moving MJO occurred, taking approximately two months to move from the Maritime Continent (Phase 5) to the Indian Ocean (Phase 3; Figure 19 middle right). At the beginning of October 2020, an MJO signal appeared over the eastern Maritime Continent (Phase 5) before slowly moving eastward. This slower movement may be related to the La Niña conditions present in the Pacific at the time. For the rest of October

[9] Data source: CHIRPS
[10] Data source: ERA5

2020, the MJO remained in phases 5 to 7, which generally brought drier conditions to Singapore and the surrounding region. This was also seen in October 2020, with the dry anomalies recorded in the area surrounding Singapore (Figure 19 lower left). In contrast, during November, the MJO signal propagated eastward through phases 8 to 3, two of which brought wetter conditions for Singapore (Figure 19 lower right).

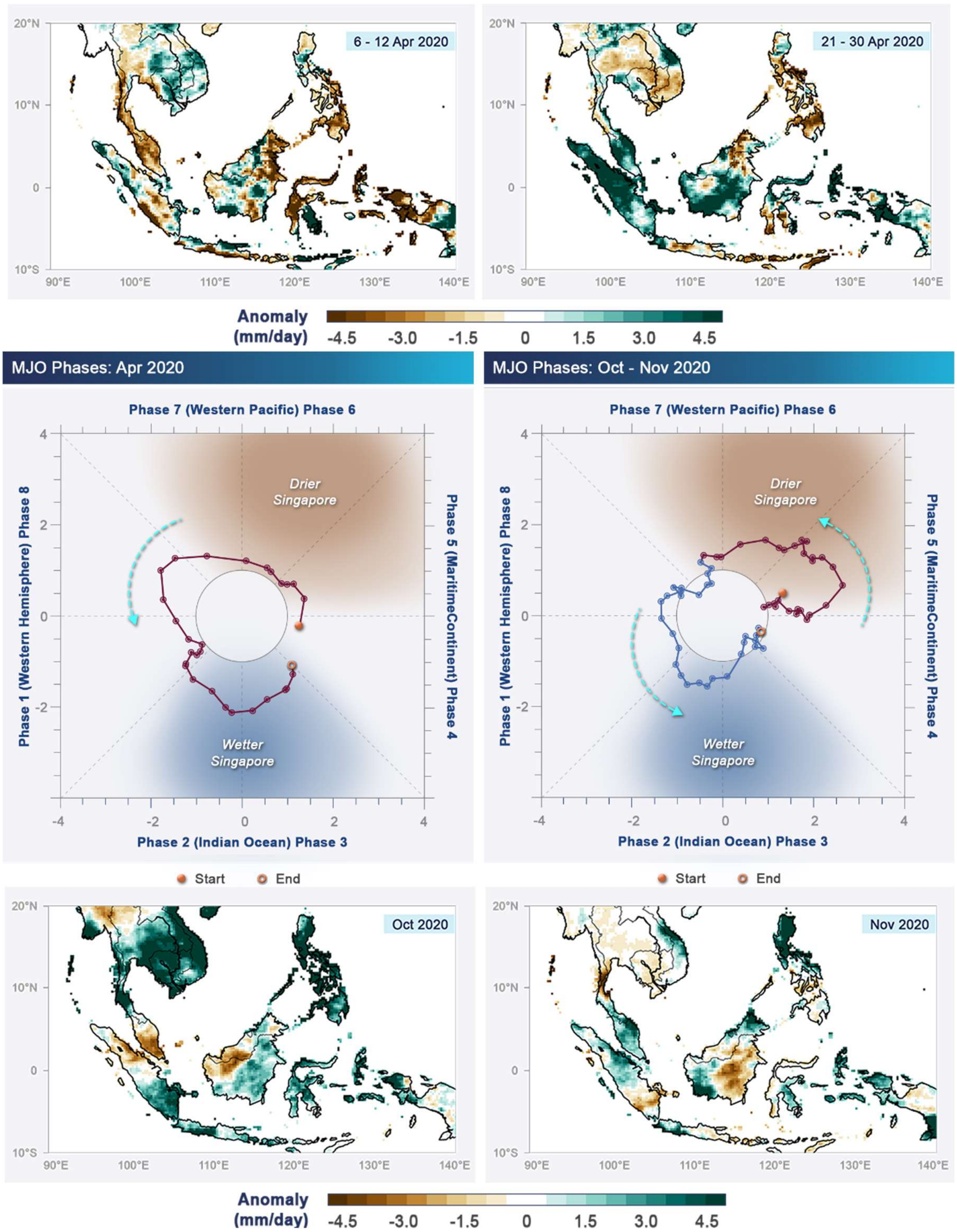
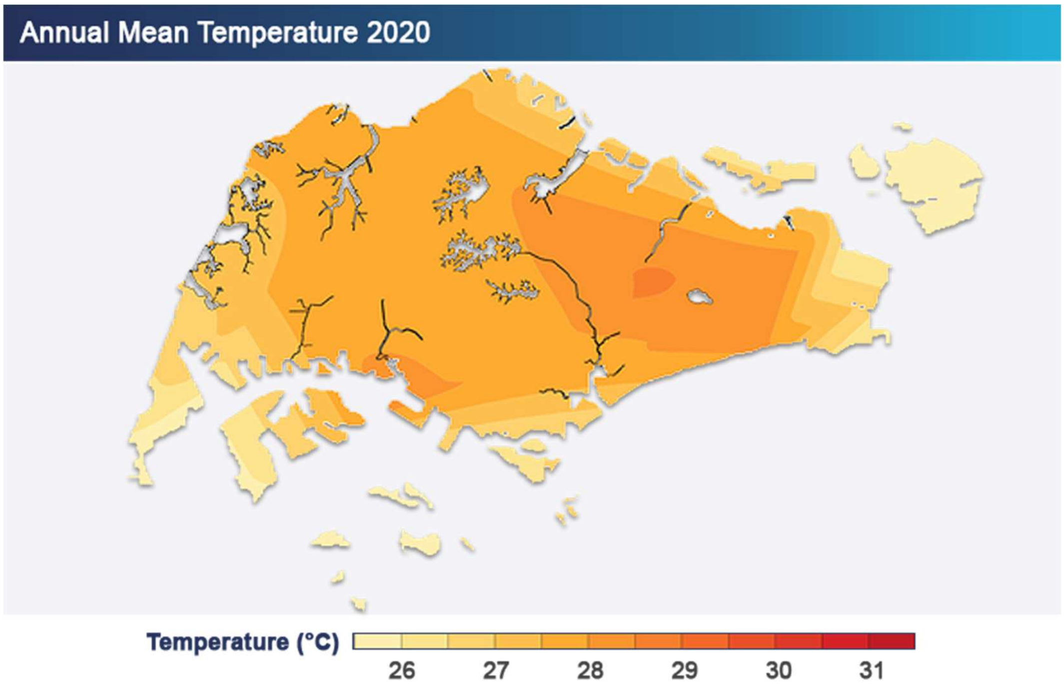


Figure 19 Top: Rainfall anomalies for two different periods in April, for 6–12 April (left) and 21–30 April (right) under different phases of the MJO. Middle: MJO phases for April (black left), and October (red right), November (blue right). Lower: Monthly rainfall anomaly for October (left) and November (right)[11].

[11] Data source: CHIRPS (rainfall), Bureau of Meteorology, Australia (RMM values)

Temperature in 2020

2020 was the 8th warmest year in Singapore based on temperature records since 1929. This is on par with 2005, with an annual mean temperature of 28°C, 0.5°C higher than the 1981–2010 long-term average. Four out of the last six years are amongst the top 10 warmest years in Singapore based on temperature records in Singapore since 1929. Following closely behind the 2019 and 2016 joint warmest years are 1998, 2015 and 1997 as the third (28.3°C) and joint fourth warmest years (28.2°C). The mean temperature for the last 10 years (2011–2020 at 27.94°C) was the second warmest on record and the last five years (2016–2020 at 28.1°C) was equal warmest on record.



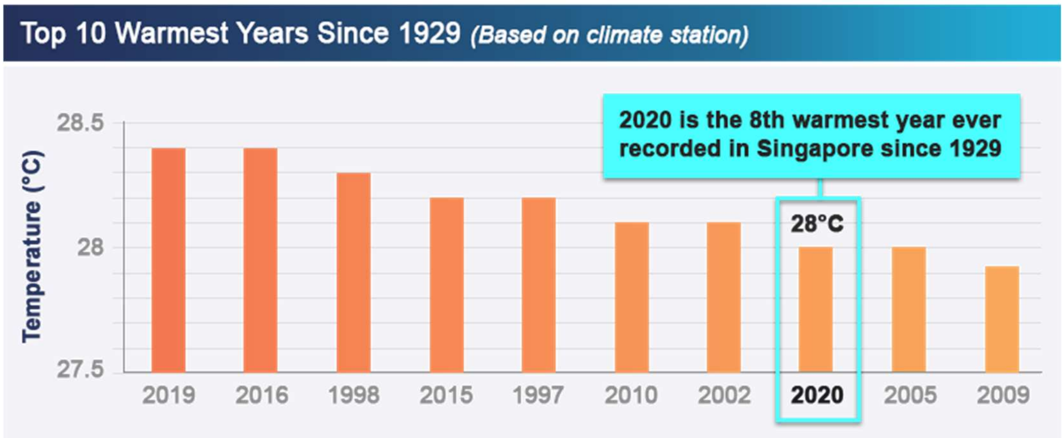


Figure 20: Annual mean temperature across Singapore in 2020 (top) and the top 10 warmest years on record (based on the Changi climate station).

Globally, significant parts of the world recorded above average temperatures (Figure 21) and the global average temperature for 2020 was about 0.5°C above the 1981–2010 long-term average and 1.2°C[12] above the pre-industrial baseline (1850–1900). This was one of the top

[12] Based on five independently maintained global temperature datasets: HadCRUT.4.6 produced by the UK Met Office in collaboration with the Climatic Research Unit at the University of East Anglia, UK; NOAA Global Temp

three warmest years on record globally together with 2016 and 2019; and the past 5 years (2016–2020) and past ten years (2011–2020) were the warmest periods on record. Since 1980s, each decade has been warmer than the previous one, highlighting the persistent long-term climate change trend.

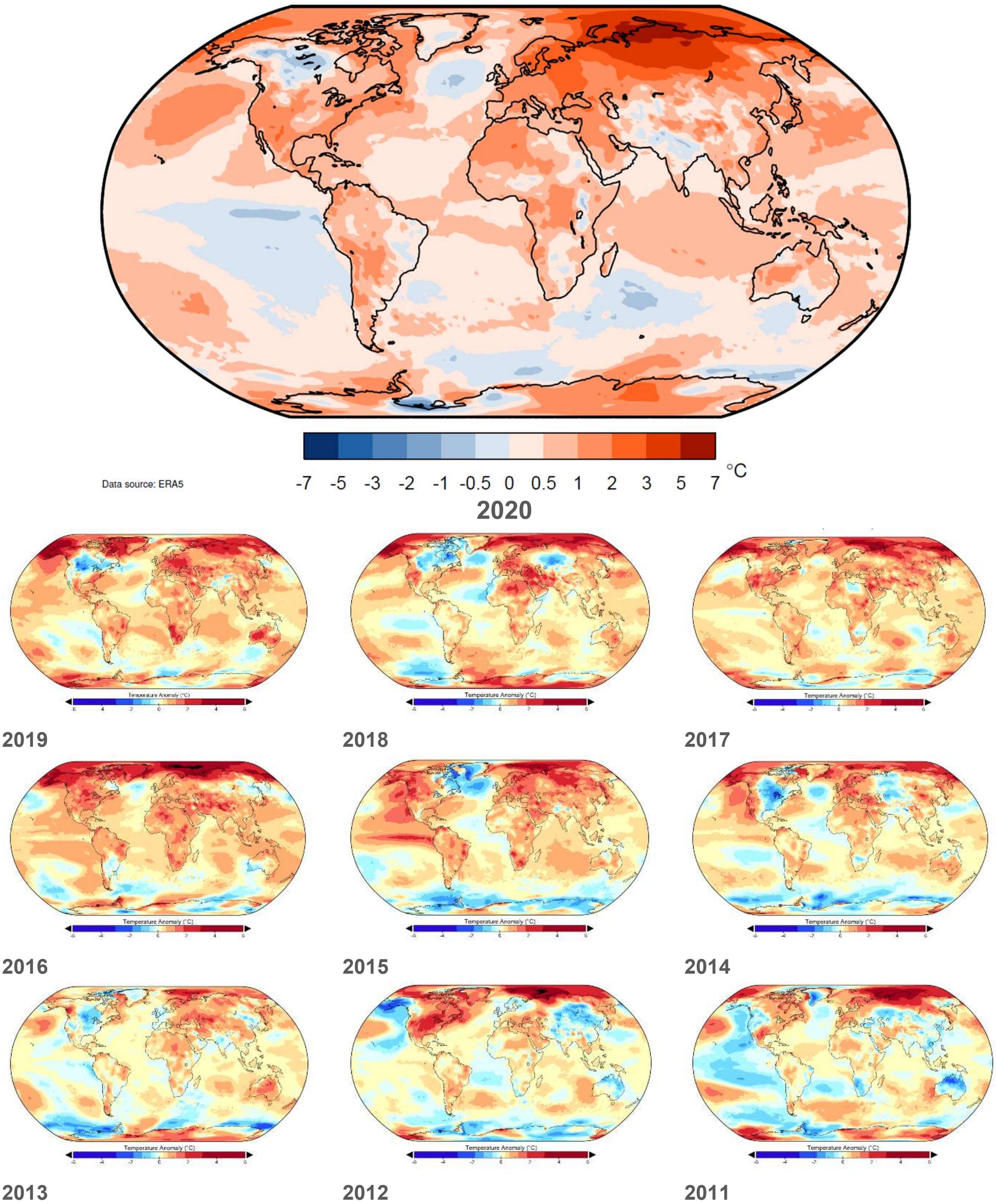


Figure 21: Global annual surface air temperature anomaly (relative to the average from 1981–2010) for the past 10 years. Globally, the last decade (2011–2020) was the warmest decade on record. Since the 1980s, each decade has been warmer than the previous one.[13]

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produced by National Oceanic and Atmospheric Administration, National Centers for Environmental Information, USA; GISTEMP produced by the National Aeronautics and Space Administration Goddard Institute for Space Studies, USA; JRA-55 produced by the Japan Meteorological Agency, Japan; and ERA-Interim produced by ECMWF.

[13] Data source: ERA5. Credit: ECMWF, Copernicus Climate Change Service

Rainfall in 2020

2020 was a year with contrasting dry and wet periods. The annual total rainfall was slightly above average over most of the rainfall stations islandwide. At the Changi climate station, the annual total rainfall recorded was 1886.6 mm, which was 12.9% below the long-term annual average of 2165.9 mm and ranks 2020 as the eighth lowest over the past 30 years.

Rainfall islandwide was below average rainfall from January to March and again in October (see Figure 23). There were also extended drier areas across Singapore during August and December. Two months of well above average rainfall (June and September) combined with four months of slightly above rainfall (April, May, July and November) balanced the overall annual total rainfall islandwide towards slightly above average rainfall for 2020.

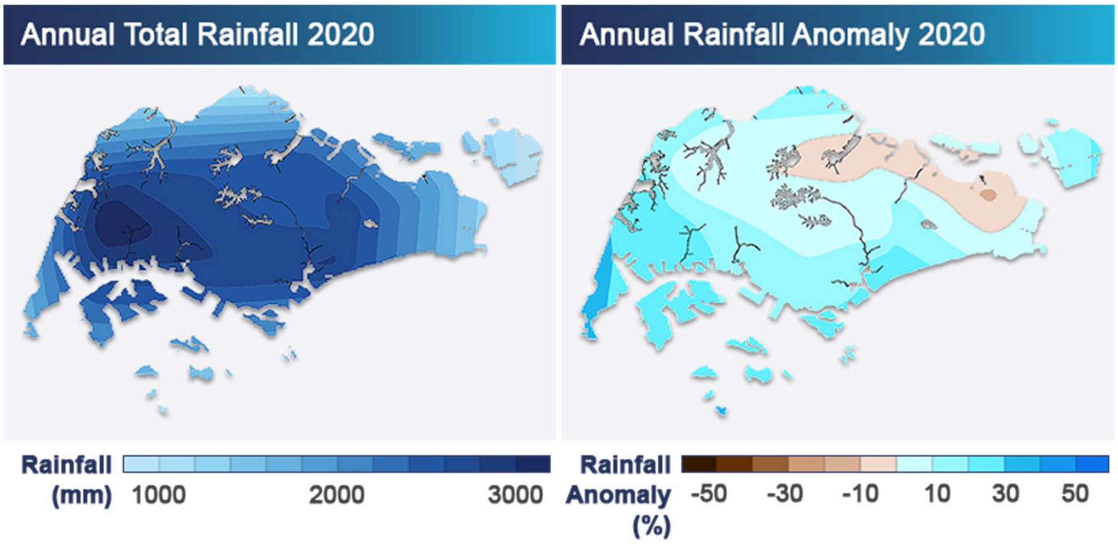
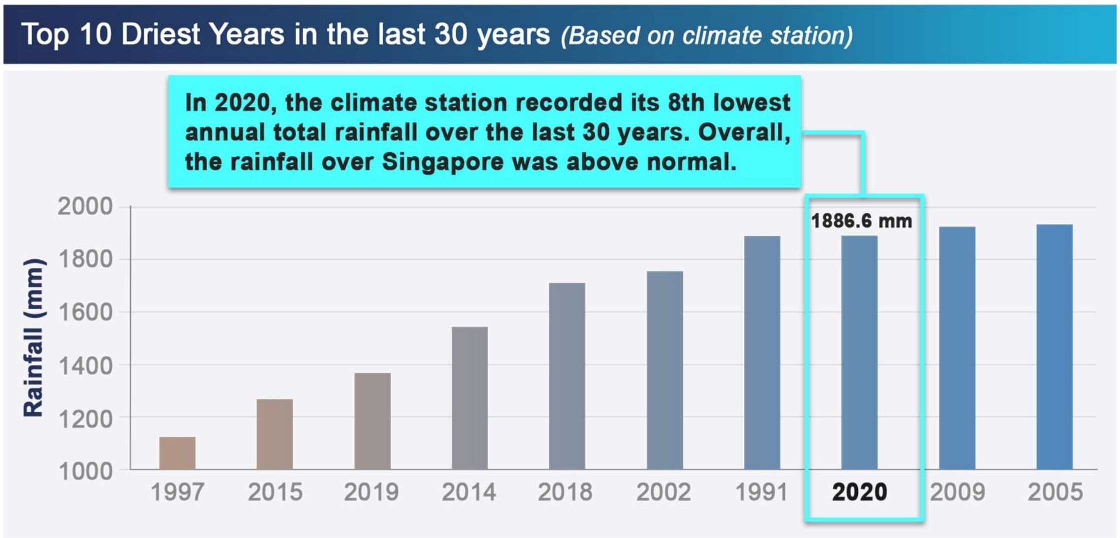


Figure 22: Annual total rainfall distribution across Singapore in 2020 (left), and annual rainfall anomalies (in percentage term) across Singapore (relative to the 1981–2010 average) in 2020 (right).



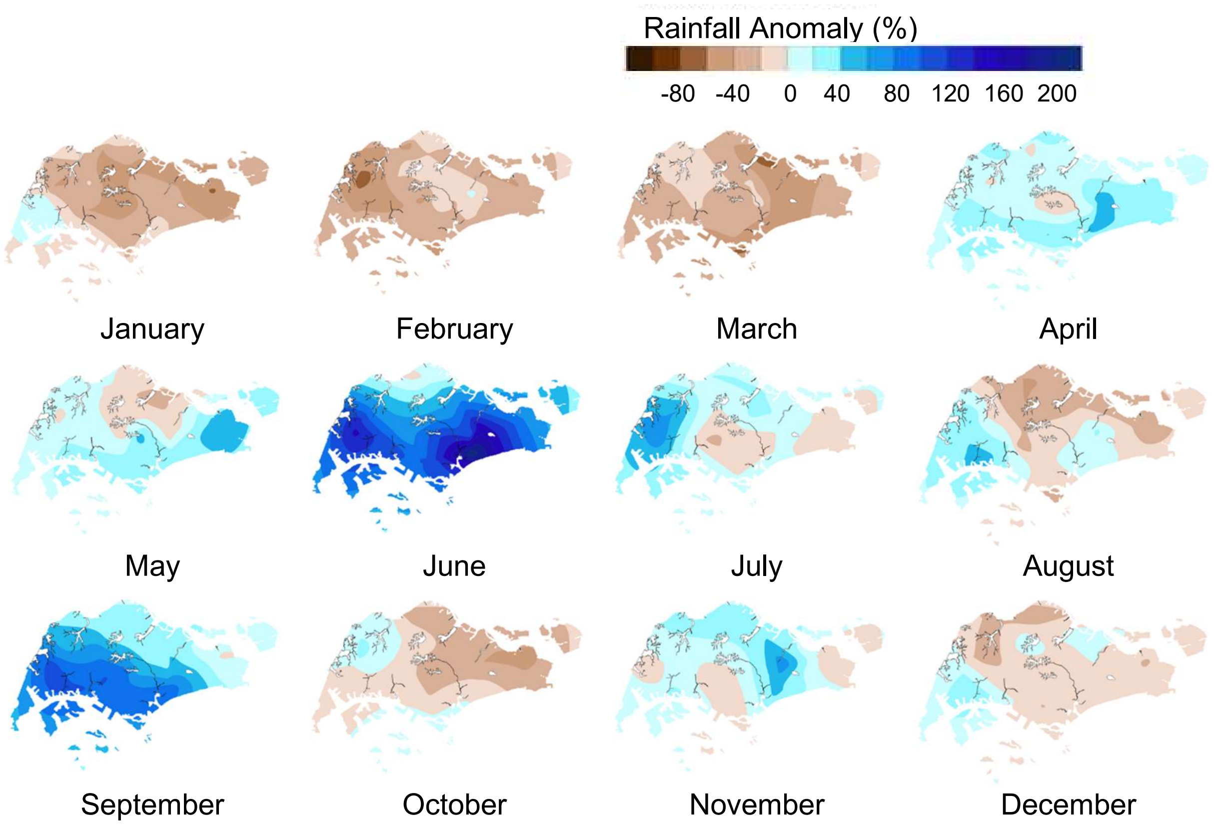


Figure 23: Monthly rainfall anomalies (in percentage term) across Singapore in 2020 (relative to the 1981–2010 average for the particular month).

General Climate of Singapore

Singapore has a tropical climate which is warm and humid, with abundant total annual rainfall of approximately 2,200 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 the 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.

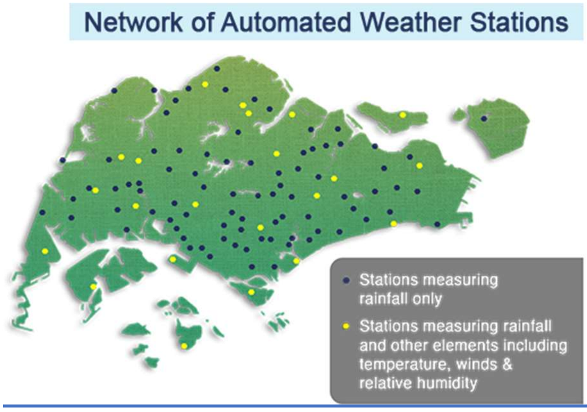
Average Annual Rainfall (1981–2010)
(based on 28 rainfall stations)

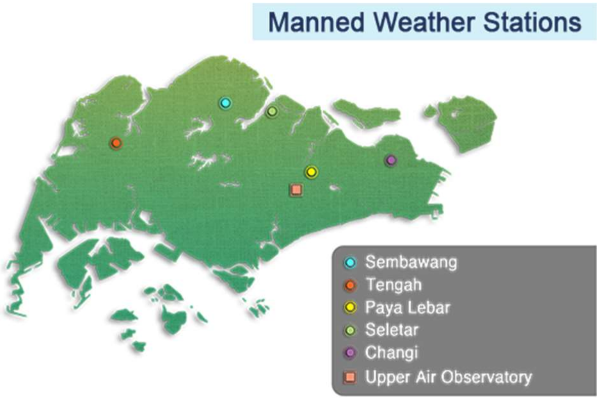
The three main rain-bearing weather systems that affect Singapore are the Northeast Monsoon surges, "Sumatra" squalls and localised convective showers/thunderstorms. The convective showers/thunderstorms occur throughout the year while "Sumatra" squalls commonly occur between April and November. The monsoon 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 Straits 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 heartland of 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 tropical regions. December and January are usually the wettest months of the year in Singapore. The occurrence of a 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.





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. All the automatic weather stations measure rainfall and more than one-fifth of them measure other meteorological elements including temperature, relative humidity, pressure, and wind. This observation network serves as the main source of climate data for this report.

The manned observation station at Changi is our 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. This limits the number of stations available for such purpose to 28 stations for rainfall and three stations for temperature.

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.

Further Information
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Centre for Climate Research Singapore : ccrs.weather.gov.sg
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