

## 2019 Climate and Weather: The Year in Review

The year 2019 continued the warm trend seen in Singapore over the past decades. Since February 2018, Singapore's monthly mean temperatures were above the respective monthly average for 23 consecutive months. The annual mean temperature in 2019 was 28.4°C. This was 0.9°C higher than the 1981-2010 long-term average, and equalled the previous warmest year record of 28.4°C set in 2016.

Four of the past 5 years are among the top 10 warmest years on record with respect to annual mean temperature, since temperature records began in 1929. Following closely behind the 2019 and 2016 joint warmest years are 2015, 1998 and 1997 as the joint third warmest years (28.3°C).

The mean temperature for the last 10 years from 2010 to 2019 was 27.94°C, surpassing the previous warmest decade (27.89°C from 2009 to 2018).

Above-average temperatures were recorded in all months of 2019, with August (29.1°C) and September (29.0°C) breaking the record for the warmest August and September respectively (Figure 1). The previous records were 28.9°C (August 2016) and 28.8°C (September 1997). November 2019 (28.0°C) also tied the record for warmest November.

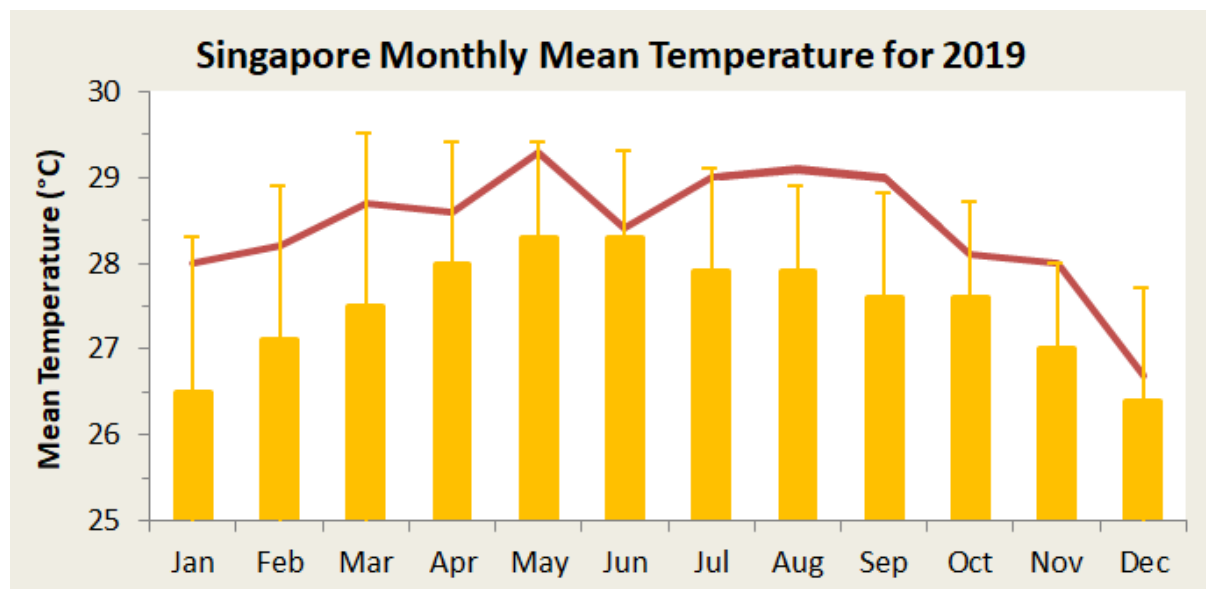


Figure 1: Singapore monthly mean temperature for 30 year average from Changi climate station (yellow bars, 1981 – 2010) compared to 2019 (solid red line). Also shown are the monthly record values for the historical period prior to 2019 as dashed 'whiskers'. Monthly records were equalled in 2019 for November and broken for August and September.

Other than the high temperatures, 2019 was also particularly dry. The 2019 annual total rainfall was below average over most of the islandwide rainfall stations. At the Changi climate station (Figure 2), the rainfall recorded was 1368 mm, which was 37% below the 1981-2010 long-

term average. This is the third driest year behind 1997 (1119 mm) and 2015 (1267 mm) since rainfall records began in 1869.

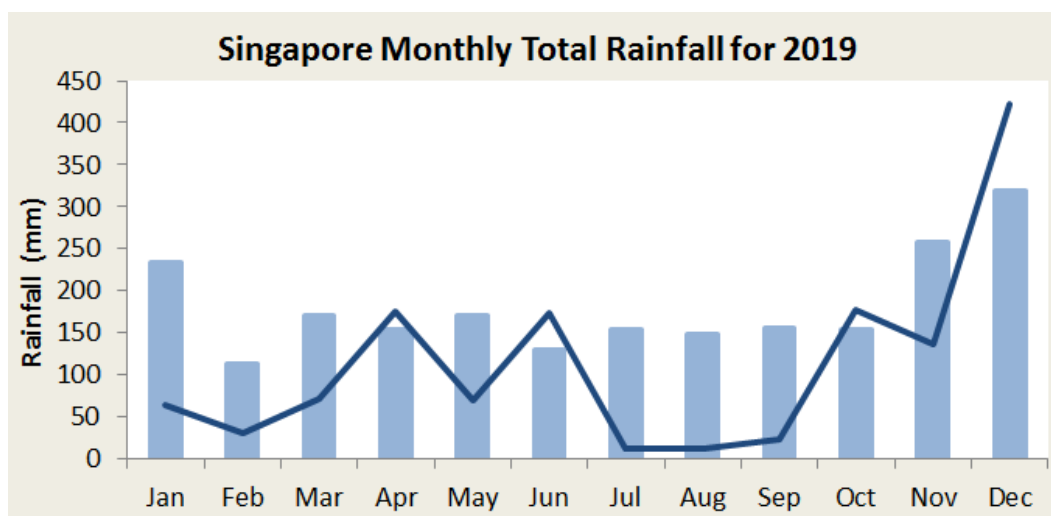


Figure 2: Singapore monthly total rainfall for 30-year average from Changi climate station (blue bars, 1981 – 2010) compared to 2019 (solid blue line). The annual total rainfall of 1368 mm for 2019 was 37% below the long-term annual average.

During the year, the driest periods were from January to March and July to September where rainfall was significantly below normal. For the period from July to September, Singapore entered a rainfall deficit situation<sup>1</sup> where monthly rainfall of more than 40% below normal was recorded in each of these three months (Figure 3).

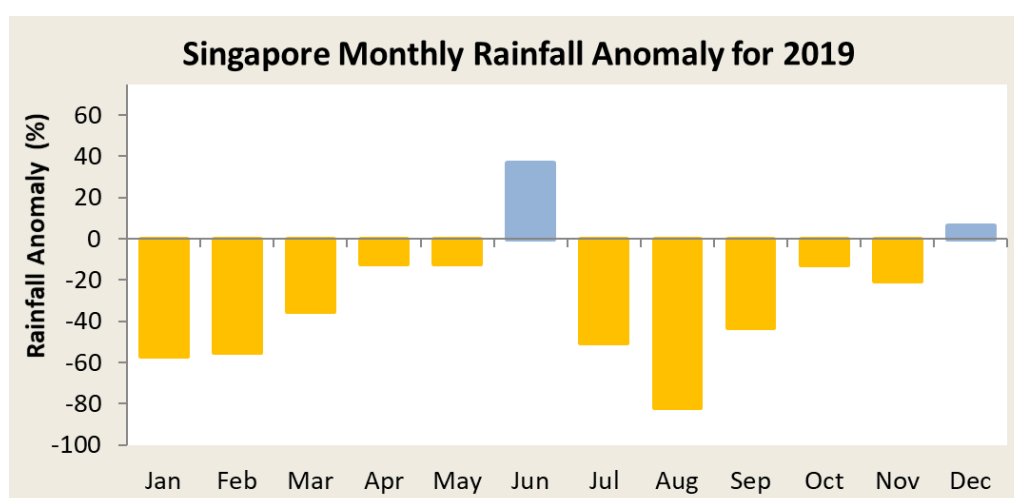


Figure 3: Singapore monthly rainfall anomaly for 2019 averaged over 28 stations islandwide. There were significant below-normal periods early in the year and for the July – September period.

During this period, Singapore experienced a dry spell<sup>2</sup> from 31 July to 16 August 2019.

Overall, 2019 was a neutral year for the El Niño Southern Oscillation (ENSO). At the start of the year, El Niño conditions were weak and the effect on global temperature from the end of 2018 to the start of 2019 was not warm or extensive enough in time and space to be attributed to a full-fledged El Niño event.

<sup>1</sup> A rainfall deficit situation refers to a period of at least three consecutive months with monthly rainfall more than 40% below the climatological rainfall, averaged over rainfall stations with long term records across the island

<sup>2</sup> A dry spell is defined as a period of at least 15 consecutive days with daily total rainfall of less than 1mm, averaged over rainfall stations with long-term records across the island.

The year however saw the development of one of the strongest, positive Indian Ocean Dipole (IOD) events since the 1960s. A positive IOD typically contributes to drier, and consequently warmer, conditions over Singapore and the nearby region during the Southwest Monsoon season (June – September). Thus, the development of this IOD event since the middle of 2019 contributed significantly to the below-average rainfall and higher temperatures observed, especially during the third quarter.

## Weather Extremes in 2019

	2019		Since 1869 (rainfall), 1929 (temperature), 1984 (wind)
	All Available Stations	Changi Climate Station	Climate Station Records
Hottest Day (°C)	<b>36.4</b> 17 Apr <i>Paya Lebar</i>	<b>34.8</b> 12 Mar	<b>36.0</b> 26 Mar 1998
Coldest Night (°C)	<b>21.1</b> 11 Mar <i>Sembawang</i>  3 Jul <i>Pasir Panjang</i>  29, 30 Sep <i>Khatib</i>	<b>21.9</b> 18 Feb	<b>19.4</b> 30, 31 Jan 1934
Wettest Day (mm)	<b>119.8</b> 16 May <i>Jurong Pier</i>	<b>92.2</b> 27 Oct	<b>512.4</b> 2 Dec 1978
Warmest Month (°C)	<b>30.0</b> May <i>Paya Lebar</i>	<b>29.3</b> May	<b>29.5</b> Mar 1998
Coolest Month (°C)	<b>26.1</b> Dec <i>Jurong West</i>	<b>26.7</b> Dec	<b>24.2</b> Jan 1934
Wettest Month (mm)	<b>449.0</b> Dec <i>Pasir Ris</i>	<b>421.5</b> Dec	<b>818.6</b> Jan 1893
Driest Month (mm)	<b>2.0</b> Aug <i>East Coast Parkway</i>	<b>11.8</b> Aug	<b>0.2</b> Feb 2014
Strongest Wind Gust (km/h)	<b>105.4</b> 20 Feb <i>Pulau Ubin</i>	<b>57.6</b> 22 Jun	<b>90.7</b> 29 Nov 2010

Table 1: Temperature, rainfall and wind extremes recorded at Changi climate station in 2019 compared to the historical record; additional information from all available stations provides further context.

## Notable Weather Events in 2019

### *Transboundary haze occurrence in September*

On several days in September 2019, Singapore was affected by transboundary haze from land and forest fires in Sumatra and Kalimantan. The haze caused the 24-hr Pollutant Standard Index (PSI) to deteriorate to within the high end of the Moderate and Unhealthy ranges.



*Figure 4: Haze shrouding Singapore's skyline on the morning of 22 September 2019 (Source: MSS)*

The escalation of fires in the surrounding region can be attributed to significantly drier-than-normal conditions over southern Southeast Asia during the Southwest Monsoon season (June–September). The persistent dry conditions were due to a prevailing Indian Ocean Dipole event that contributed to suppressed rain cloud formation, and to the intrusion of a dry air mass from high-pressure systems over the Australian continent. Smoke haze from persistent land and forest fires in Sumatra and Kalimantan was blown by the prevailing winds and affected many parts of the region including Singapore.

On 14 September, the 24-hr PSI entered the *Unhealthy* range for the first time in 2019 when prevailing southerly winds brought dense haze from southern Sumatra to Singapore (Figure 5 (top)). The 24-hr PSI remained in the Unhealthy range on most days until 23 September. Between 21 and 23 September, a shift in the direction of the prevailing winds brought haze from fires in western Kalimantan to Singapore (Figure 5 (bottom)). At the peak of the haze episode, the 24-hr PSI reached a high of 154 in southern Singapore on 19 September.



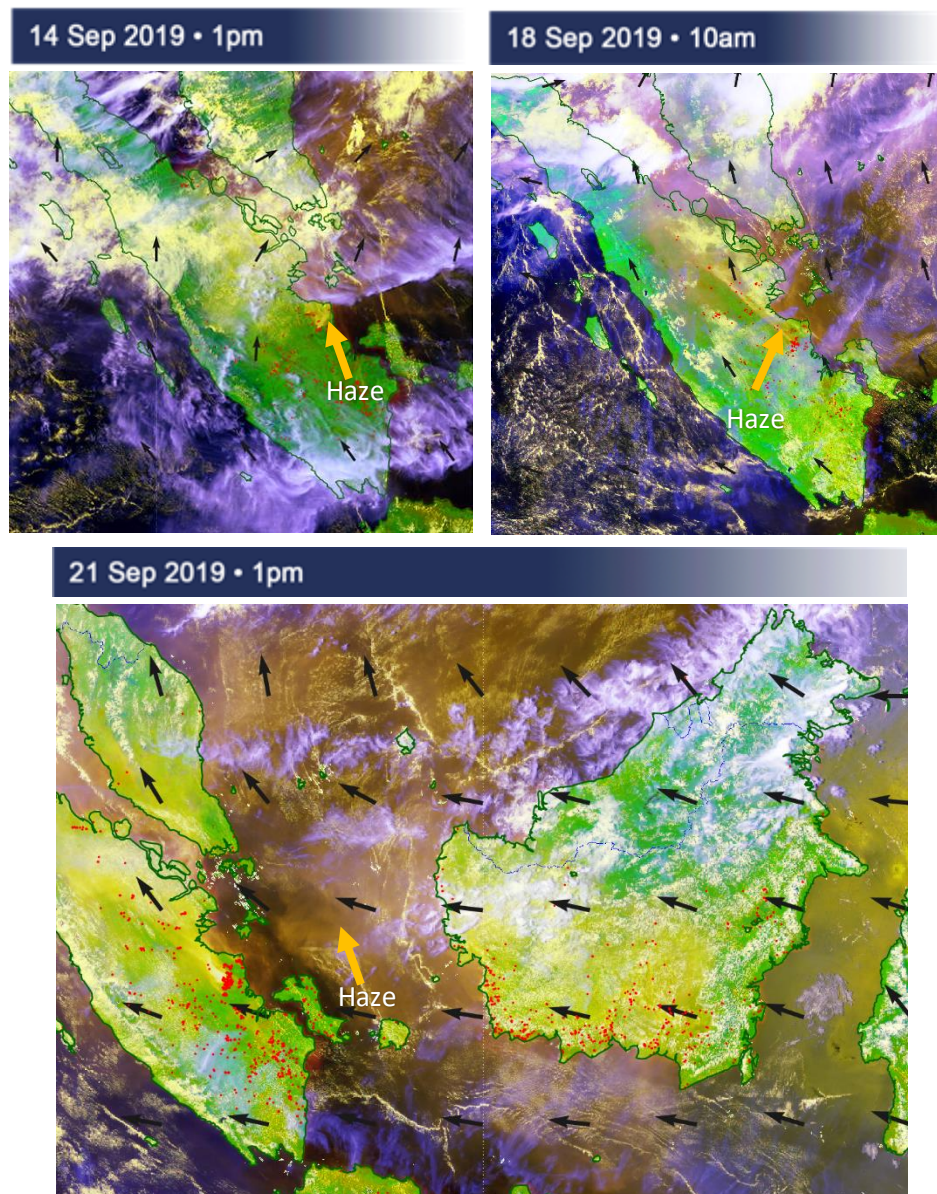


Figure 5: Himawari-8 satellite images showing smoke haze emanating from fire hotspots (red dots) in Sumatra (top) and Kalimantan (bottom) blowing toward Singapore by the prevailing winds (depicted by arrows).

### **First recorded landspout in Singapore**

On 27 September 2019, a landspout was sighted for several minutes at Gul Way in southwestern Singapore. A landspout is a rotating column of air over land that stretches vertically to a developing towering cumulus or cumulonimbus cloud over it.

On that morning, the presence of moist air from the surrounding sea areas and localised convergence of winds over the southern and western coasts of Singapore were conducive for the development of intense thunderstorm clouds over the southwestern part of Singapore (Figures 6 and 7). The intense thunderstorm cloud that developed over Tuas in the morning generated a rotating column of winds over Gul Way. The strong winds ripped off parts of the roof of a factory building (Figure 8).

This was the first recorded occurrence of a landspout in Singapore.

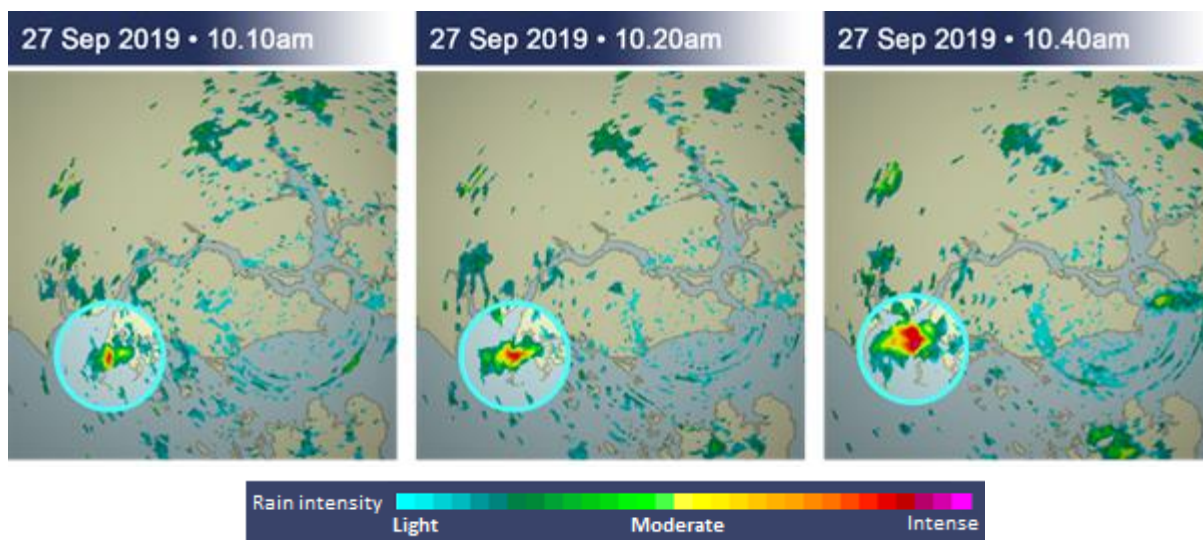


Figure 6: Time series of weather radar images showing the development of an intense thunderstorm over the Tuas area on 27 September 2019.

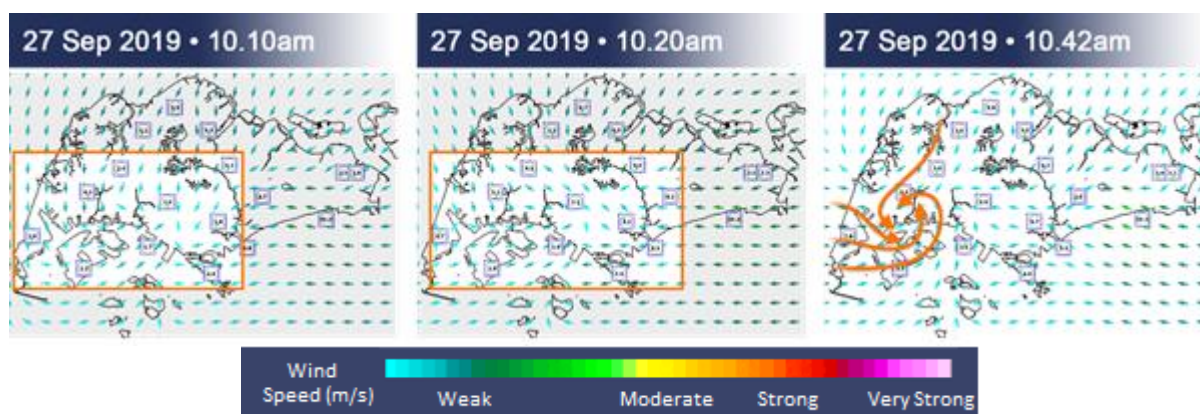


Figure 7: Time series of surface winds (depicted by arrows) on the morning of 27 September 2019. The red box (left and middle) shows the area with localised wind convergence. Streamlines of surface winds (right) shows the rotating wind flow over the area feeding into the intense thunderstorm.

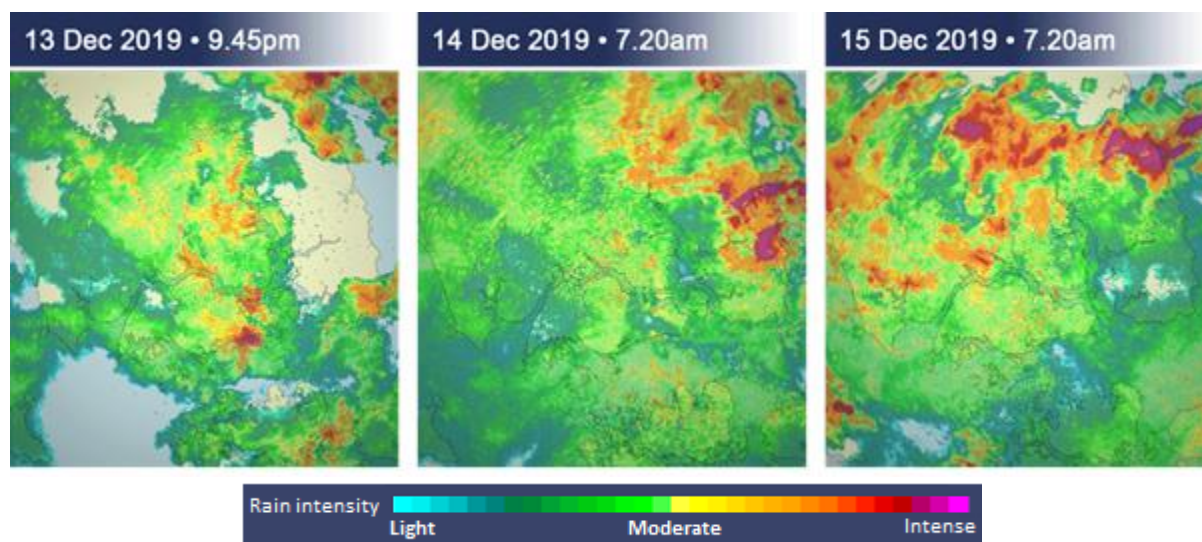


Figure 8: A landspout ripped off parts of a factory building's roof at Gul Way in the Tuas area (Source: STOMP)



### ***Longest Northeast Monsoon surge in past 10 years***

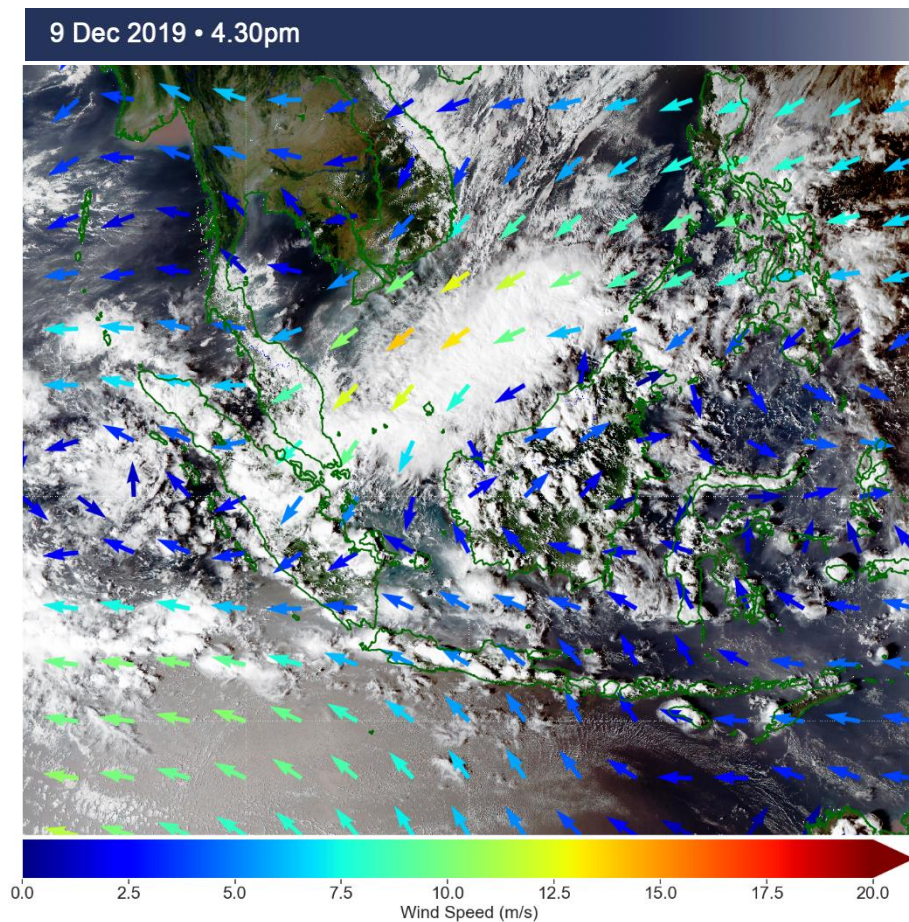
In the first two weeks of December 2019, Singapore experienced an extended period of cool, cloudy and windy conditions. Between 9 and 15 December, periods of rain and showers fell over many parts of the island and were heavy on some occasions. In particular, widespread rain fell continuously over the 13 December weekend before dissipating on the evening of 15 December (Figure 9).



*Figure 9: Time series of weather radar images shows widespread continuous rain over Singapore on 13-15 December 2019 due to a Northeast Monsoon surge.*

The windy and rainy weather was due to a Northeast Monsoon surge<sup>3</sup> that prevailed over the equatorial South China Sea region (Figure 10). Lasting about seven days, it was the longest Northeast Monsoon surge episode affecting Singapore in the past 10 years. Cool conditions prevailed with the daily maximum temperature ranging between 26.5°C and 29.9°C on almost all days, and the lowest daily minimum temperature during the period was 22.0°C on 11 December. The highest daily total rainfall recorded was 100.4 mm on 9 December 2019 at Pulau Ubin.

<sup>3</sup> A monsoon surge refers to the strengthening of northeasterly winds blowing from a strong high-pressure system over the northern Asian continent toward the South China Sea, bringing periods of prolonged widespread rain and windy conditions to the surrounding region including Singapore and Peninsular Malaysia.



*Figure 10: Himawari-8 satellite image showing cloudiness over the southern South China Sea region on 9 December 2019. Prevailing strong winds due to the monsoon surge are depicted by arrows.*

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