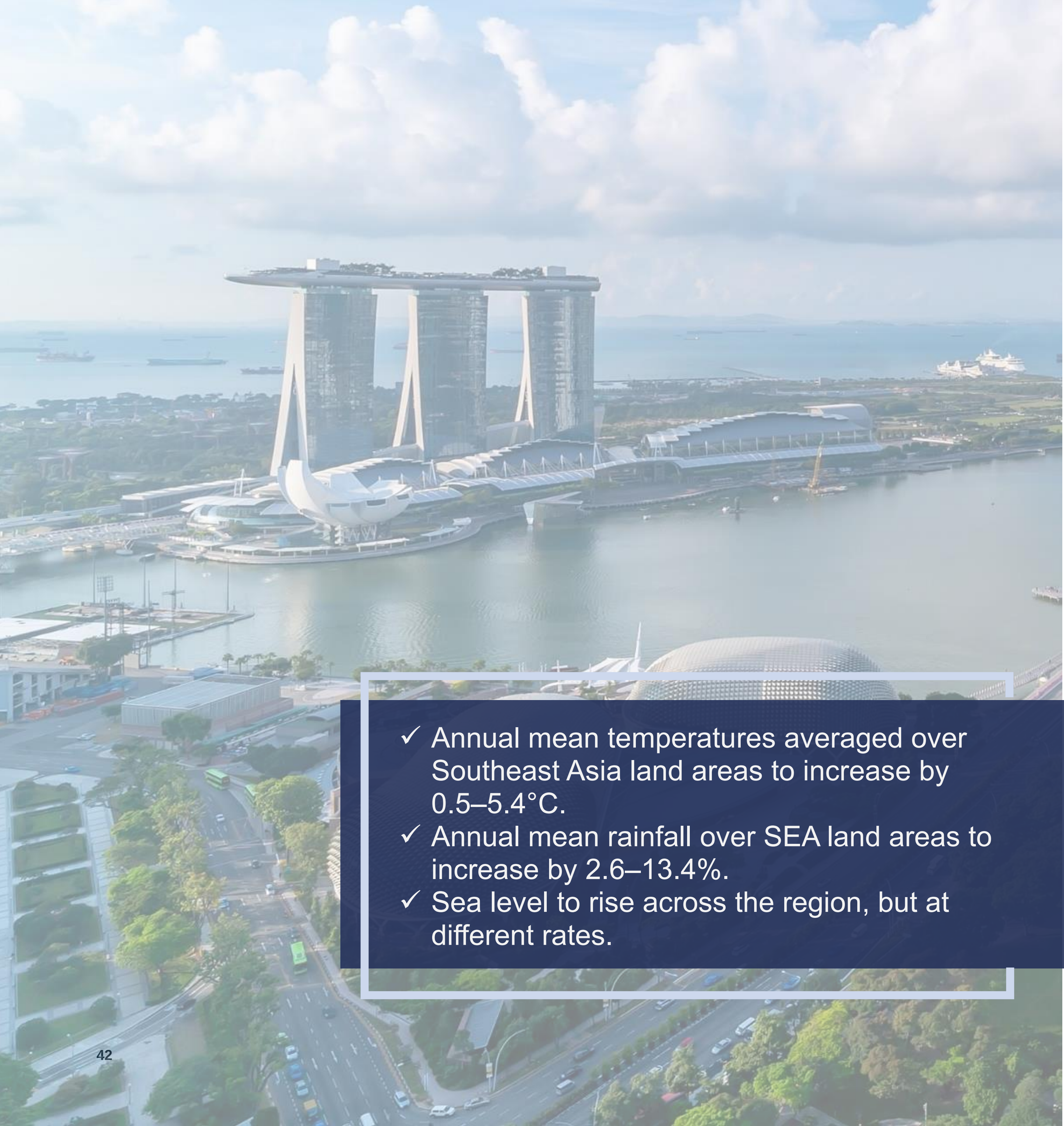
4 REGIONAL CLIMATE CHANGE PROJECTIONS



- ✓ Annual mean temperatures averaged over Southeast Asia land areas to increase by 0.5–5.4°C.
- ✓ Annual mean rainfall over SEA land areas to increase by 2.6–13.4%.
- ✓ Sea level to rise across the region, but at different rates.

While the focus of V3 and this report is on climate change projections over Singapore, V3 also covers regional projections for the SEA region. This is because Singapore's climate is affected by what happens in the region, and Singapore's interest in sharing high-resolution regional projections with ASEAN countries for their use in national climate change assessments and impact studies.

In this chapter regional climate change projections for some of the key climate variables that include temperature, rainfall, winds, and relative humidity are shown.

4.1 How will temperature change over the region?

Projected changes in daily mean and maximum temperatures in the Southeast Asian region are shown in the following sub-sections.

4.1.1 Daily mean temperature

Figure 4.1 shows the projected changes in the seasonal mean near-surface air temperatures over the SEA domain during the end-century under the high emissions scenario. Daily mean temperature over the SEA region is expected to increase in the end-century, with higher increases over land compared to the surrounding seas.

During the December-January-February (DJF) season, annual average daily mean temperature increase is expected to be in the range of 2.0–5.5°C, in the end-century, with higher values over Myanmar, Thailand, Laos and Cambodia. For the MAM season, the corresponding increase is in the range of 2.5–6.0°C, with higher increases over Myanmar, Thailand, and Laos. For the JJA season, it is in the range of 2.0–6.0°C with higher increases over Laos, Vietnam, and Indonesia. For the SON season, it is in the range of 2.0–6.0°C.

4.1.2 Daily maximum temperature

Figure 4.2 shows the projected changes in the average seasonal maximum of daily maximum temperatures (alternatively, the hottest day of the season), over the SEA domain in the end-century under the high emissions scenario. On average, the hottest day of the season is expected to become hotter over the SEA region in the end-century across seasons with higher increase over land compared to seas.

During the DJF season, the expected increase is in the range of 2.0–6.0°C. For the MAM season, it is in the range of 1.5–6.5°C, with higher increases over Laos, Vietnam, Indonesia, and New Guinea. For the JJA season, it is in the range of 2.0–6.5°C, with higher increases over Thailand, Cambodia, Laos, Vietnam, and Indonesia. For the SON season, it is in the range of 2.5–6.5°C with higher increases over Cambodia, Laos, Vietnam, and Indonesia.

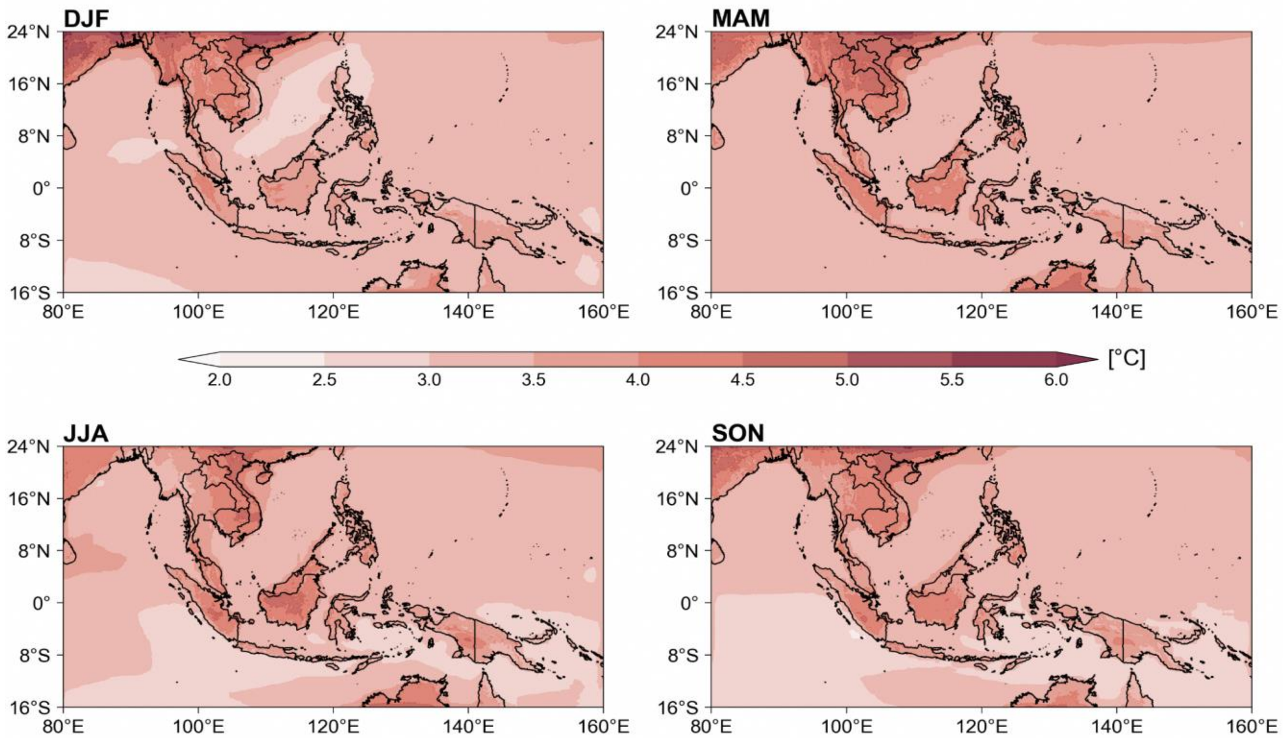


Figure 4.1: Projected changes in seasonal mean near-surface air temperature during end-century (2080–99) relative to the historical period (1995–2014) under the high emissions scenario.

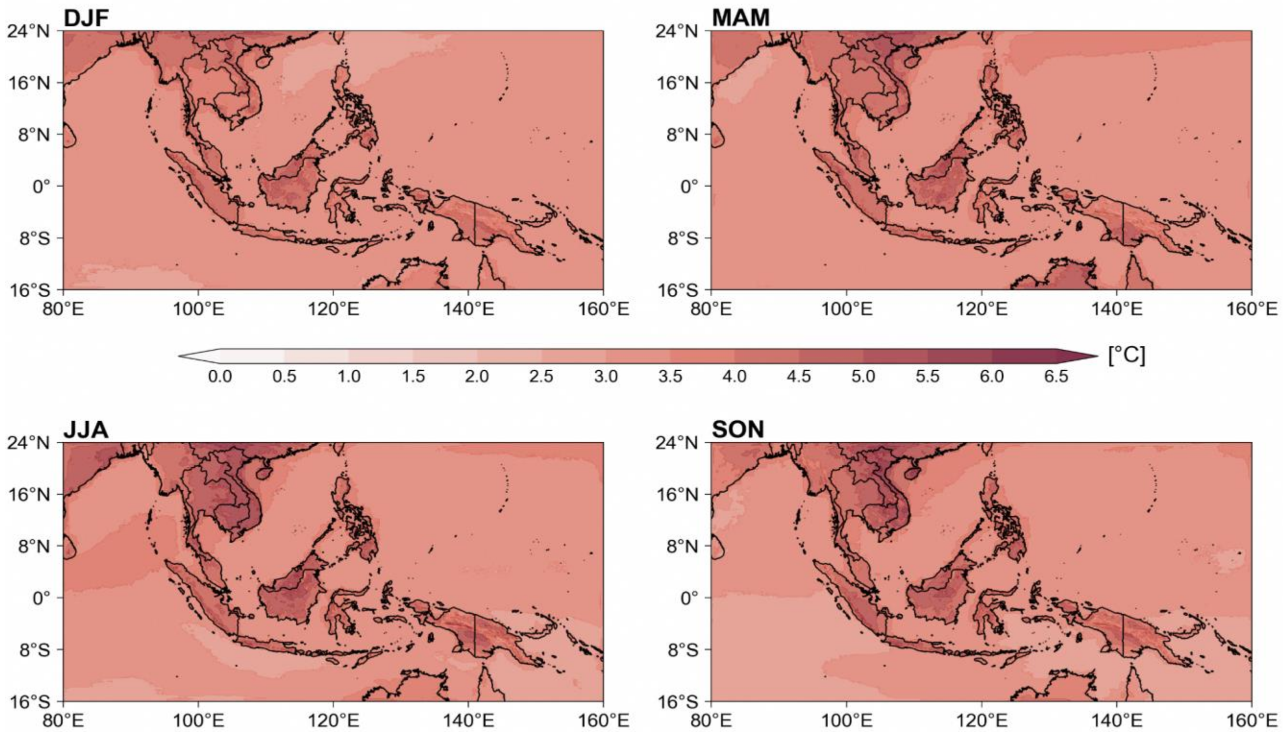


Figure 4.2: Ensemble-mean (six downscaled GCMs 8 km) changes in seasonal maximum of daily maximum temperature (TXx) over end-century (2080-99) relative to the historical period (1995–2014) over the SEA domain under the SSP5-8.5 scenario.

4.2 How will rainfall change over the region?

Projected changes in annual and seasonal mean rainfall along with rainfall extremes in the Southeast Asian region are shown in the following sub-sections.

4.2.1 Seasonal mean rainfall

Figure 4.3 shows the percentage changes in the seasonal mean rainfall over the V3 SEA domain in the end-century under the high emissions scenario. Seasonal mean rainfall changes vary with seasons over land and ocean regions. Increase in rainfall is expected over parts of Indochina across the four seasons.

For the DJF season, there is large increase (>90%) over the climatologically dry regions of Thailand. For the MAM season, the seasonal mean rainfall is projected to increase (10–70%) over many SEA land areas.

For the JJA season, the mean rainfall projections show increases (10–90%) over Myanmar, Thailand, Malaysia, and around Java. Note that Java climatologically experiences little rainfall in JJA. There is a decrease (10–30%) in the mean rainfall over parts of Cambodia, Vietnam, Borneo, and New Guinea. For the SON season, there are increases of at least 10% over parts of SEA with higher increases over Myanmar and around Nusa Tenggara.

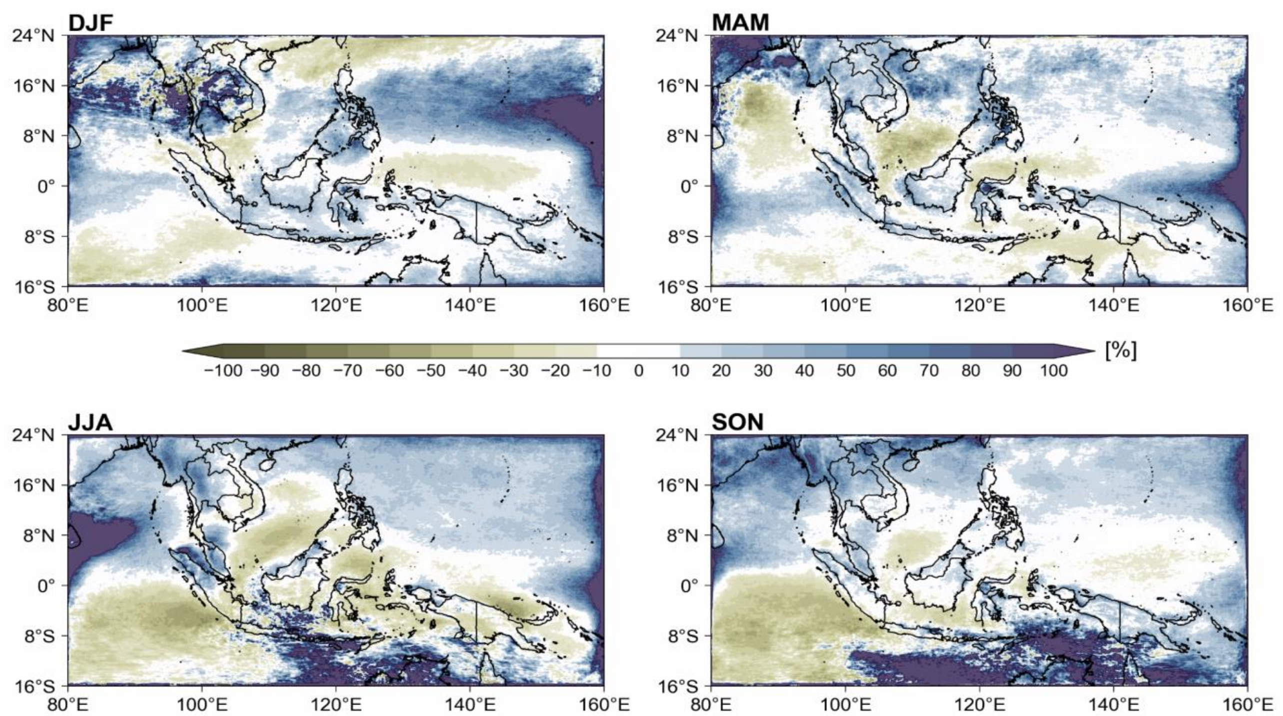


Figure 4.3: Percentage change of ensemble-mean downscaled (8km) changes in seasonal mean rainfall over end-century (2080-99) relative to the historical period (1995–2014) over the SEA domain under the SSP5-8.5 scenario.

Table 4.1 shows the projected changes in annual and seasonal mean rainfall over the V3 SEA domain land points during end-century for the three SSPs. Overall, rainfall on annual and seasonal timescales is projected to increase under all emissions scenarios. Largest projected increases are mostly associated with the high emissions scenario. The average annual total rainfall is projected to increase by up to 13.4% under the high emissions scenario. For DJF season, the projected increase is up to 14.5%, for MAM it is up to 16.8%, for JJA it is up to 14.6% (under the medium emissions scenario), and for SON it is up to 19%.

Table 4.1: Projected percentage changes in annual and seasonal mean rainfall during end-century over SEA domain land points for the three SSPs. The number outside the brackets shows the mean from the six models, and the ones in the brackets show the range from minimum to maximum.

Months	End-Century rainfall changes (%)		
	SSP1-2.6	SSP2-4.5	SSP5-8.5
Annual	3.9 (2.6–5.5)	5.8 (3.8–7.9)	8.7 (4.2–13.4)
DJF	2.4 (−0.3–10.6)	5.0 (0.0–10.5)	8.0 (2.5–14.5)
MAM	2.8 (0.2–5.8)	5.3 (0.4–10.6)	7.5 (0.2–16.8)
JJA	5.0 (0.8–10.7)	5.1 (−3.7–14.6)	7.4 (−1.7–13.4)
SON	4.9 (1.7–8.0)	8.0 (3.3–13.8)	12.7 (5.1–19.0)

4.2.2 Rainfall extremes

Figure 4.4 shows the percentage changes in the maximum 1-day rainfall (RX1day) over the V3 SEA domain across different seasons in the end-century under the high emissions scenario. End-century RX1day is expected to increase in most of the SEA land areas across the four seasons.

During the DJF season, the projected percentage increases in RX1day are largest over Thailand, Laos, and Cambodia. For the MAM season, the RX1day projections show increases (30–70%) over the SEA land regions. During the JJA season, the projected RX1day increases (at least 10%) over most of the SEA land regions with decreases (−5–40%) around the Java Sea. For the SON season, the RX1day projections increase (at least 30%) across the SEA land regions. Some of the largest percentage increases occur over climatologically dry regions (e.g., Indochina in DJF, and around the Java Sea in JJA).

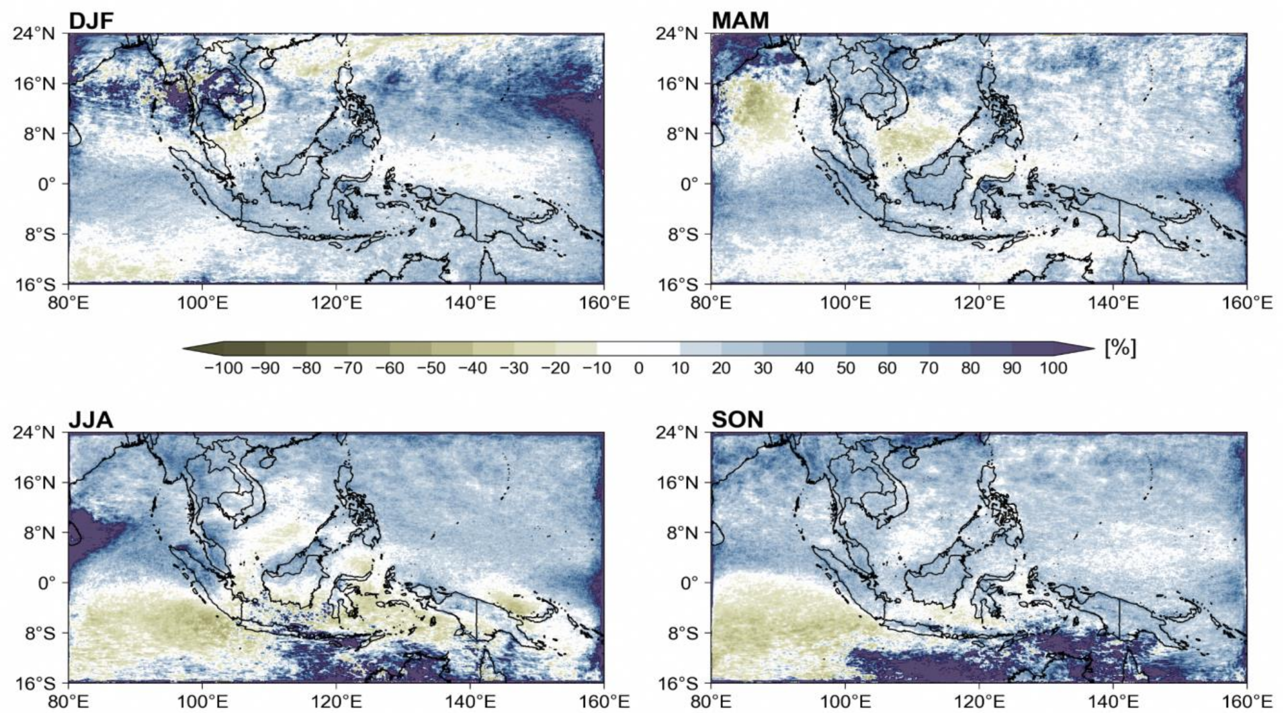


Figure 4.4: Percentage change of ensemble-mean downscaled (8km) changes in seasonal RX1day over end-century (2080–99) relative to the historical period (1995–2014) over the SEA domain under the SSP5-8.5 scenario.

4.3 How will winds change over the region?

End-century projections of 10m wind speed over the region for the four seasons under the high emissions scenario are shown in Figure 4.5. One of the prominent features is increased wind speeds, especially during the months of JJA over the northern ASEAN region, Sumatra, and Borneo, by up to and potentially exceeding 30%.

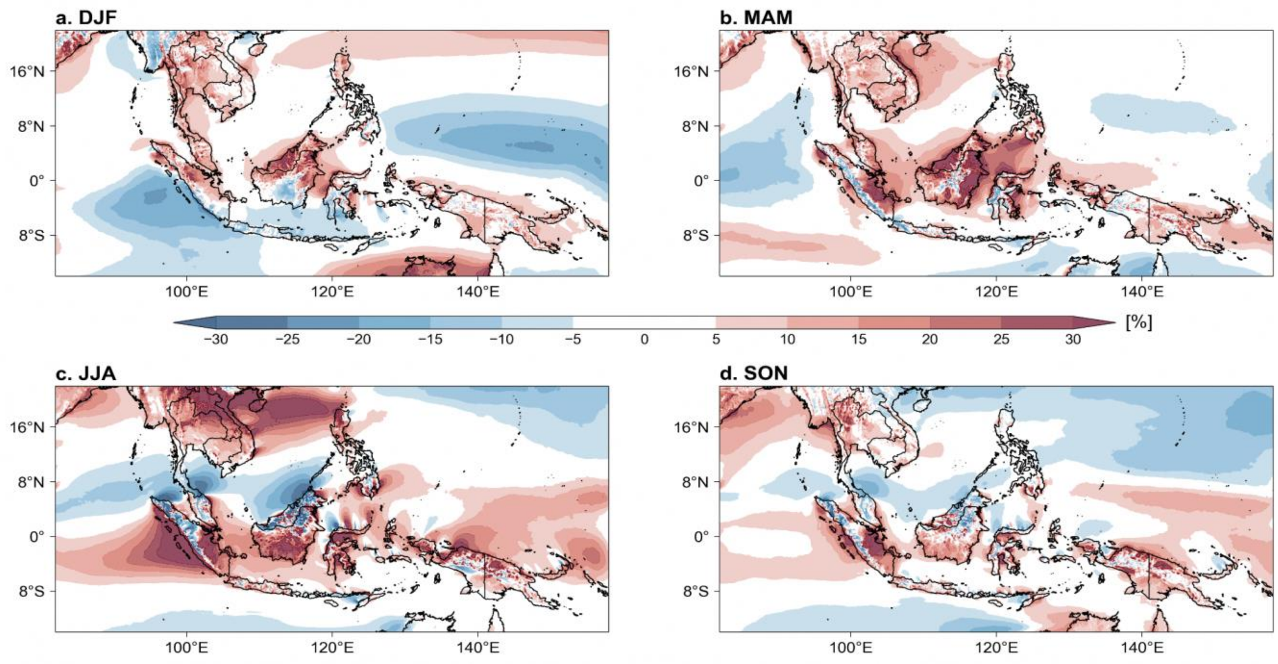


Figure 4.5: Projected change in seasonal 10-m wind speed during the end-century (2080–99) relative to the historical period (1995–2014) over the SEA domain under the high emissions scenario.

4.4 How will relative humidity change over the region?

Table 4.2 shows the end-century projected changes in average seasonal mean near-surface relative humidity for the three SSP scenarios. The largest projected changes are under the high emissions scenario. During the DJF season, the projected change is up to −1.8%, for MAM season it is up to -2.7%, for JJA it is up to −3.7%, and for SON season it is up to −3.0%. Overall, JJA shows the largest decrease, followed by SON.

Table 4.2: Projected changes (%) in seasonal mean near-surface relative humidity for the three SSP scenarios. The number outside the brackets shows the mean from the 6 models, and the ones in the brackets show the range from minimum to maximum.

Seasons	End-Century relative humidity changes (%)		
	SSP1-2.6	SSP2-4.5	SSP5-8.5
DJF	0.0 (−0.4 to 0.4)	−0.3 (−0.5 to 0.1)	−0.9 (−1.8 to −0.3)
MAM	−0.6 (−1.3 to 0.3)	−0.8 (-1.6 to 0.2)	−1.3 (−2.7 to −0.4)
JJA	−0.2 (−0.6 to 0.2)	−0.8 (−1.9 to −0.1)	−1.9 (−3.7 to −0.7)
SON	0.0 (−0.6 to 0.4)	−0.4 (−1.3 to 0.2)	−1.3 (−3.0 to 0.1)

4.5 How will relative sea-level change over the region?

The mechanisms driving Global Mean Sea Level (GMSL) rise primarily encompass two main contributors: thermal expansion of ocean waters and mass loss from ice sheets. However, additional physical processes such as ocean circulation patterns, density changes, and vertical land movement introduce spatial variability in sea-level change across the globe. This results in non-uniform relative sea-level change around the world.

V3 provides sea-level projections for 13 locations within the Southeast Asian region, excluding the six tide gauges in Singapore, for up to 2100 and 2150. Here, a subset of these locations is shown, and it includes Cebu City, Manila, Phuket, Bangkok, Johor Bahru, Kota Kinabalu, Penang, Danang and Yangon (Figure 4.6). Refer to Chapter 12 of the Science Report for projections of the full list of locations. Note that the IPCC AR6 did not provide projections for any locations within Indonesia.

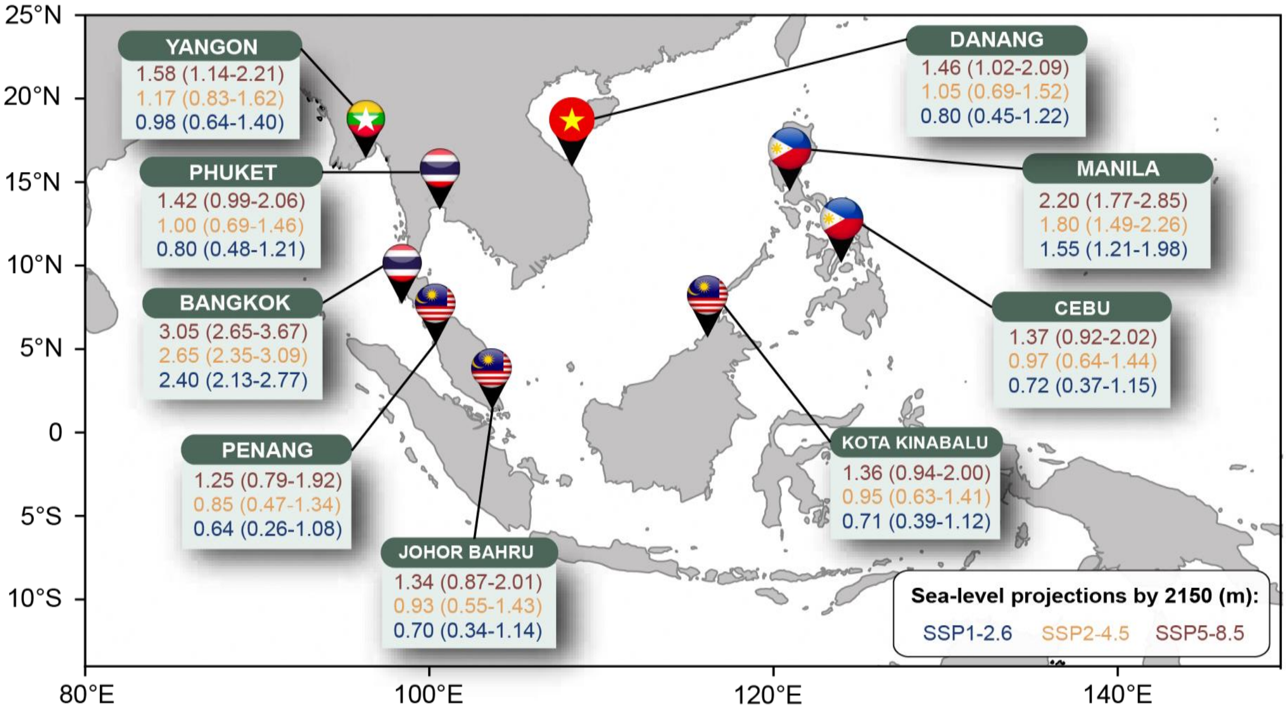


Figure 4.6: Projected relative sea-level rise at some of the most densely populated Southeast Asian cities by 2150 under all emission scenarios considered in V3. Projections are relative to the baseline period 1995–2014. More locations are included in Chapter 12 of the V3 Science Report.

In the coming century and next, relative sea level will rise significantly across these various locations, with Bangkok emerging as the city that has twice the projected sea-level rise than most of the other cities by 2150 under the high emissions scenario, as shown in Figure 4.6.

Under the low emissions scenario the "locked-in" relative sea level rise could likely reach up to 1 m in most of these cities and up to 2 to 3 m in Manila and Bangkok by 2150. Under the high emissions scenario relative sea-level rise could likely reach up to 2 m in most cities and exceed 3m in Bangkok by 2150.

The main driver behind the rapid relative sea-level rise at Manila and Bangkok is the excessive depletion of groundwater, which has caused land subsidence and consequent rise in relative sea-level since the 1970s. See Chapter 12 of the Science Report for more detailed references.