*What will the climate of Sint Maarten look like in 2050 and 2100?*

Royal Netherlands Meteorological Institute
*Ministry of Infrastructure and Water Management*

# Climate scenarios for Sint Maarten

PHOTO SHERENN LEBLANC

The **Meteorological Department St. Maarten (MDS)**, commonly known as the Met Office, operates 24/7 to enhance safety and quality of life on St. Maarten and in the region. It provides reliable early warnings for severe weather, seismic activity, and climate events to help communities and decision-makers prepare and minimize socio-economic impact. Since St. Maarten's constitutional change on October 10, 2010, MDS has been fully responsible for its meteorological services, becoming fully independent on January 1, 2013.

The **International Panel on Deltas and Coastal Areas (IPDC)** helps deltas, coasts, and islands adapt to climate change. It supports them in protecting ecosystems, livelihoods, and economies. Initiated by the Government of the Netherlands, and supported by Deltares and Stichting Climate Adaptation Services, the IPDC provides technical expertise for climate scenarios, risk assessments, and adaptation planning. On Sint Maarten, the IPDC works to strengthen the island's resilience to climate impacts and support national adaptation strategies. These climate scenarios are an important part of that work.

The **Royal Netherlands Meteorological Institute (KNMI)** is the national institute for weather and climate in the Netherlands.It conducts scientific research on climate change, represents the Netherlands in the IPCC, and advises the government on climate and weather risks.
KNMI develops high-quality climate scenarios that translate global climate research into regional insights. The climate scenarios for Sint Maarten are based on KNMI's 2023 scenarios for the Netherlands, improved and adapted to the context of Sint Maarten.

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# The climate is changing; what does this mean for Sint Maarten?

## It's getting warmer

*By 2050, Sint Maarten's average temperature is expected to be about 0.8 to 1.3°C higher than today, and by 2100 it could be up to 3.3°C warmer. As temperatures rise all year round, Sint Maarten will face higher temperatures than ever before, and the heat season will last longer.*
*The heat can cause health problems, especially for vulnerable people.*

## It's getting drier

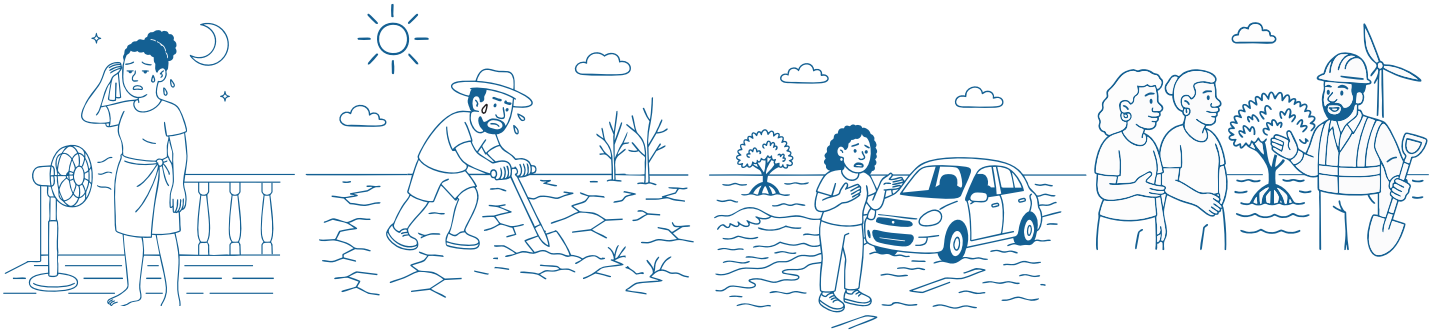
*Sint Maarten is expected to receive less rain in the future. In the best case, the change will be small, but in the worst case, rainfall could drop by almost half by 2100. Just like today, rainfall will vary a lot from year to year, with some years much drier than others. The dry season may also last longer. This will put extra pressure on nature, farming, and water resources.*

## The sea-level is rising

*As a result, the sea around Sint Maarten could be about 22 cm higher by 2050 than today, and by 2100 up to 46 to 78 cm.*
*Over the next few hundred years, the sea will keep rising, and a rise of more than 1 meter is only a matter of time.*
*This means smaller beaches and a greater risk of flooding and storm damage along the coast.*

## What now?

*Climate change brings challenges for Sint Maarten.*
*The effects are already being felt through higher temperatures, longer dry periods and rising sea levels — signs that adaptation is needed now.*
*Sint Maarten can strengthen its resilience by protecting water resources, improving infrastructure, and helping communities to cope with heat.*



# Introduction

**The climate scenarios for Sint Maarten show what the island's future climate could look like in 2050 and 2100.**

These scenarios are based on strong scientific knowledge. They provide the knowledge necessary to reduce safety risks and help policymakers and other professionals prepare the island for the future. These scenarios are based on those for the Netherlands, which were created by the Royal Netherlands Meteorological Institute (KNMI) and published in 2023 [1]. You can find in-depth information at the end of this report. For the scientific methods, results and background, there is a technical report available.


## The climate is changing

It is certain that human activities are warming the planet by releasing greenhouse gases. The IPCC concluded in its Sixt Assessment report of 2021 [2] that the Earth's temperature has never risen as quickly as it has now. In 2024, the average temperature across the globe was 1.5 °C higher than it was in the pre-industrial period (1850–1900). With further warming, the frequency and intensity of heatwaves, extreme rainfall, and droughts will continue to increase worldwide. Some changes, like the warming of the oceans, the melting of ice sheets, and the rise in sea level, will continue for hundreds or thousands of years. In addition, hurricanes are becoming stronger, and they can become major hurricanes more quickly. The IPCC concludes that small islands like Sint Maarten already face increasing risks [3].

## Observed climate change on Sint Maarten

Sint Maarten's climate is already changing. Since 1985, the beginning of our observations, the temperature is rising with around 0.1 °C each decade. The amount of rain that falls varies a lot from year to year, with some years much wetter or drier than others. Tropical storms

and hurricanes can bring a lot of rain. For example, during Hurricane Lenny (1999), more than 500 milimeters of rain fell in two days time, bringing the annual rainfall sum above 1800 milimeters. There are also dry years. For example, in 2015, Sint Maarten received less than 500 milimeters of rain, which is about half of its normal amount. That year, there was a Caribbean-wide drought, caused by El Niño.

### Climate change impacts

Rising temperatures and sea levels are already affecting Sint Maarten. As one of the most densely populated areas in the Caribbean, much of its infrastructure and housing is located near the coast, increasing exposure to coastal hazards. More extremely hot days impact island life, health, and increase electricity use for air conditioning. Warmer ocean temperatures cause coral to bleach, harming coral reefs that protect the shoreline. Higher sea levels cause beaches to disappear and make flooding from waves and storm surges more likely, especially when heavy rain occurs at the same time, for instance, during a passing storm system. These risks are greater because Sint Maarten lies within the hurricane belt, making it vulnerable to intense tropical storms and hurricanes.

# Current climate

**Sint Maarten has a tropical savanna climate (Aw), characterized by a dry season ranging from December to May with less rainfall (on average 68mm/month) and a wet season ranging from June to November (on average 115mm/month).**

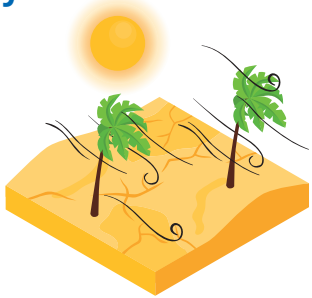
Annual rainfall averages about 1112mm. The wet and dry seasons align with the hurricane season. Rainfall shows large interannual variability, ranging from around 500mm in very dry years to over 1700 mm in particularly wet years. This strong variability can mask the drying trend.

The prevailing easterly winds, which typically blow at a speed of 4.5 m/s, contribute to the island's pleasant climate by moderating temperatures throughout the year.
Wind speeds also fluctuate from year to year, and there is a relationship between wind speed and rainfall: years with stronger winds often coincide with dry conditions, while years with lower wind speeds tend to be wetter.

## wet years

**Wet years can often be linked to years with hurricanes that passed through the Caribbean resulting in rainfall, high waves and storm damage on Sint Maarten.**

## dry years



**Dry years often align with periods of higher wind speeds. This can be caused by drivers such as El Niño.**

# What are anomalies?

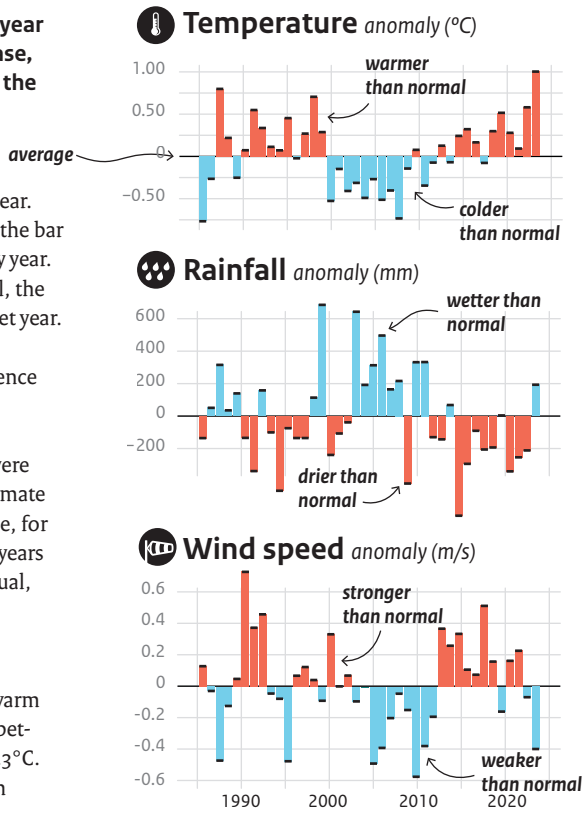
**Anomalies show how different a year is from what's normal. In this case, normal is defined as the average of the years 1991-2020.**

Imagine you know the average amount of rain Sint Maarten gets each year.

- If one year it rains less than normal, the bar goes down — that means it was a dry year.
- If one year it rains more than normal, the bar goes up — that means it was a wet year.

The bigger the bar, the bigger the difference from normal!

So, anomalies help us see which years were abnormal. This way, we can see if the climate of Sint Maarten is changing. For example, for temperature, you can see that in recent years the temperature is often higher than usual, meaning that the climate is warming.




### Temperatures

Temperatures on Sint Maarten remain warm throughout the year, generally ranging between 24°C and 30°C, and on average 27.3°C. The highest mean temperatures occur in August and September, while the coolest period is observed around January and February. In recent decades, a rise in temperature can be observed, resulting in an increasing number of years that are warmer than average, especially 2024 was particularly hot. Because Sint Maarten lies in the tropics, where both seasonal and year-to-year temperature variations are small, this warming is quickly noticeable and already has visible impacts on the island's environment and society.

### Rainfall

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### Wind

Wind speeds also fluctuate from year to year, and there is a relationship between wind speed and rainfall: years with stronger winds often coincide with drier than usual conditions, while years with lower wind speeds tend to be wetter.

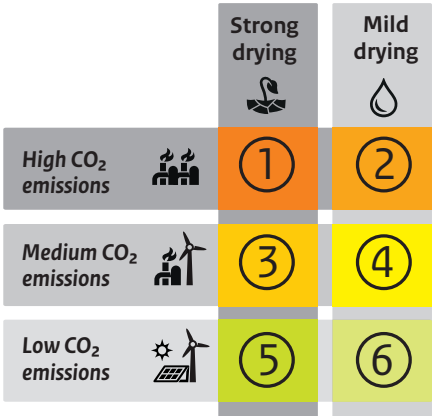
# Climate scenarios for Sint Maarten

**We use the latest climate models to explore what the future climate of Sint Maarten might look like.**

To cover the range of possible futures, we created four different scenarios that show how the climate could change in 2050 and 2100. The differences between the scenarios are due to uncertainties about the future, mainly because we don't know exactly how much greenhouse gas the world will emit or how the climate will react to those emissions. We first divide the possible futures by emission levels (low and high), and then by how dry Sint Maarten could become (mild or strong drying). Together, these four scenarios give a realistic picture of the range of future climates that Sint Maarten may face. We also include a moderate emissions scenario to meet the needs of policymaking.

## Scenarios with high, moderate and low emissions

The first difference between the scenarios comes from the amount of pollution released into the air. Greenhouse gases, such as carbon dioxide ($CO_2$), trap heat as if the Earth is covered by a blanket, making the planet warmer.




How much these gases are released depends on global action and climate policy.

In the low emissions scenario, countries take strong action to meet the Paris Agreement goals, keeping global warming to about 0.8°C (0.4°C–1.5°C) by 2100.

In the high-emission scenario, emissions keep increasing, and the planet warms by about 4°C (2.8°C–5.6°C) by 2100.

The moderate scenario shows what would happen if only modest climate actions are implemented, resulting in around 1.9°C (1.3°C–2.9°C) of warming by 2100. Each scenario helps to show what different global choices today could mean for Sint Maarten climate in the future. We don't know which of the scenarios is more likely.

## Scenarios with strong and mild drying

Each emission scenario includes two versions—one with **strong drying** and one with **mild drying**. This distinction reflects the uncertainty in how rainfall over Sint Maarten may change in a warming world. Some projections indicate that Sint Maarten could become much drier, while others suggest only a modest decrease in rainfall. By providing both versions, we capture this range of possible future conditions. Combining the strong and mild drying scenarios with the three emission levels gives a total of six scenarios.

# Natural variability and trends

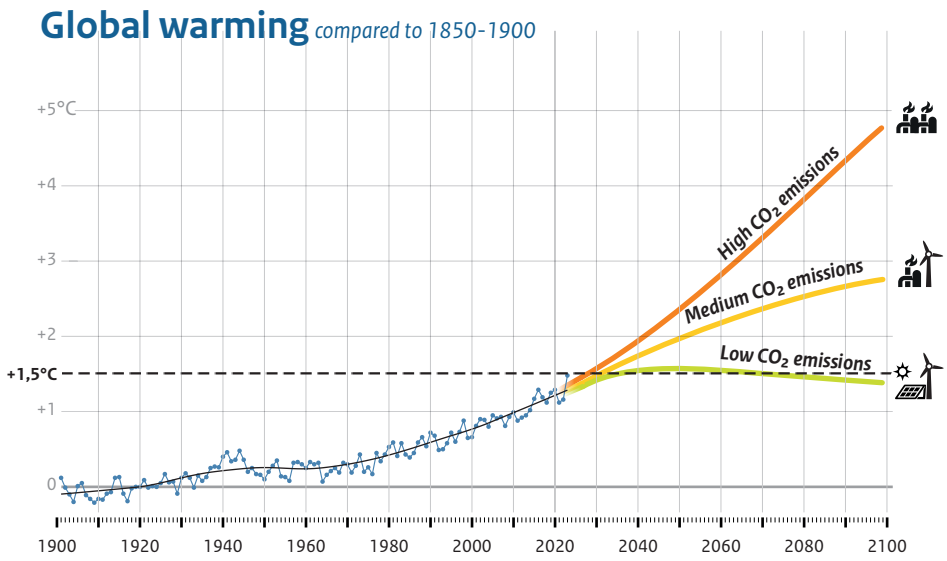
## Regional climate scenarios

Climate models generally operate on a large scale, representing large scale global circulations and how they change. To translate these large-scale models towards small-scale regions, such as Sint Maarten, we use historical observations. These past records "correct" the model so that it represents how the local climate responds to broader climate patterns, allowing us to project future conditions more accurately. The resulting climate scenarios are therefore optimized for the location of the island's measuring station, situated at the airport. However, since weather conditions can vary across the island, locally the climate may differ from the modeled scenarios.

## Natural variability and trends

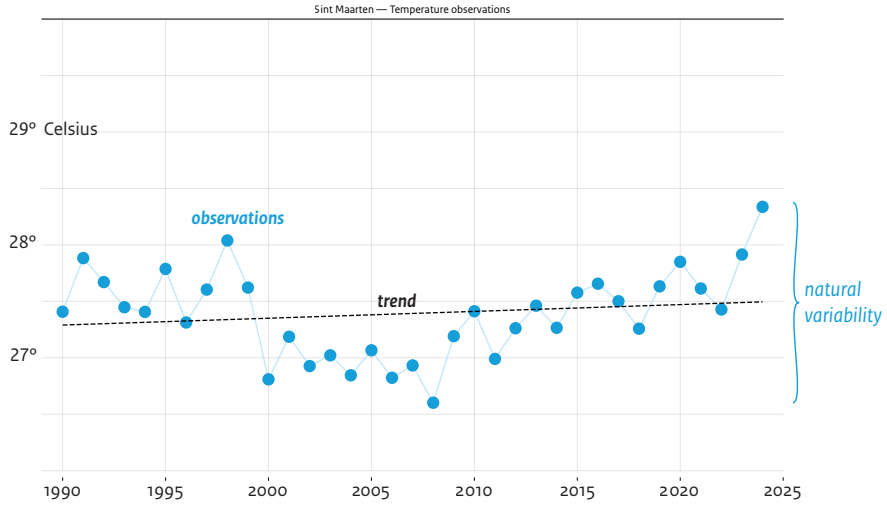
The climate naturally varies because of interactions between the atmosphere, oceans, land, and ice caps. Events like El Niño and La Niña are good examples of this natural variability. They influence temperature, wind, and rainfall on a regional scale.

We can't predict this kind of variability from year to year. So, we can't say whether 2046, for example, will be warm or cold, wet or dry. What we can do is look at the long-term trend.




If the scenarios show that the climate will get warmer, then the chance that 2046 will also be warm, increases.

It's important to remember that even in the highest emission scenario, not every single year will be hotter than today. The key change is in the average over several decades, which



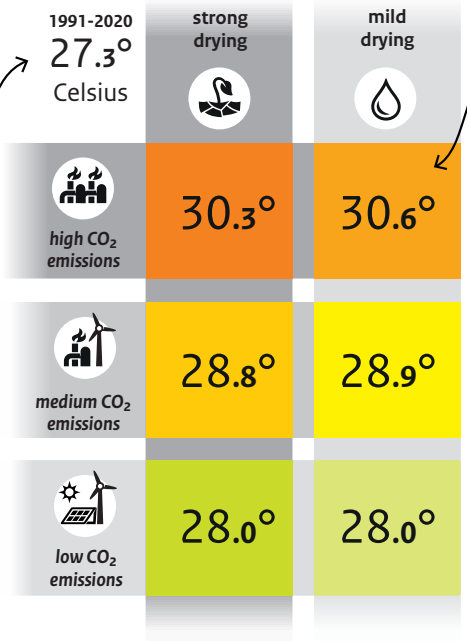

will become warmer. For instance, if projections suggest that average temperatures will rise by the end of the century, some years around that period may be warmer, while others could still be cooler. Those ups and downs are part of the natural variability of the climate.

# Temperature

## It's getting warmer

### PRESENT

In the current climate on Sint Maarten, the annual average temperature is 27.3 °C. Sint Maarten has a tropical climate, temperature variations are mild, with the warmest months from July to September with an average temperature of 28.7°C and the coolest months are January and February with an average temperature of 25.6°C. This seasonal variation is smaller than the typical day–night temperature difference.




### FUTURE

The temperatures on Sint Maarten will keep rising in the future. How much they'll continue to rise depends on the scenario. Under the low-emission scenario, temperatures are expected to increase until around 2050, after which they will stabilize. In the high-emission scenario, temperatures keep increasing, reaching several degrees higher by 2100. The strongest warming is expected during the wet season, which is already the warmest time of the year. By the end of the century, the average annual temperature could be higher than today's warmest month, which is around 29°C in August.

Differences are largest between the emission scenarios but also appear between the strong and mild drying pathways. Natural variations such as El Niño and La Niña will continue to affect temperatures from year to year.

## Did you know that...

*... temperature alone doesn't tell the whole story of how hot it feels? The perceived heat depends on a combination of factors like temperature, wind, humidity and sunlight. Less wind, high humidity and a lot of sunlight can drastically increase the perceived temperature.*

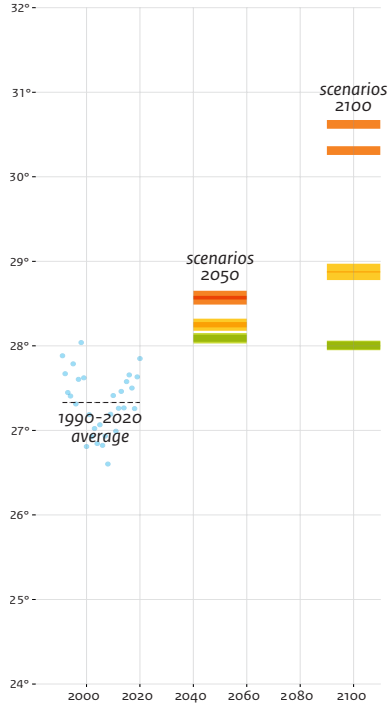
### Heat in the sea

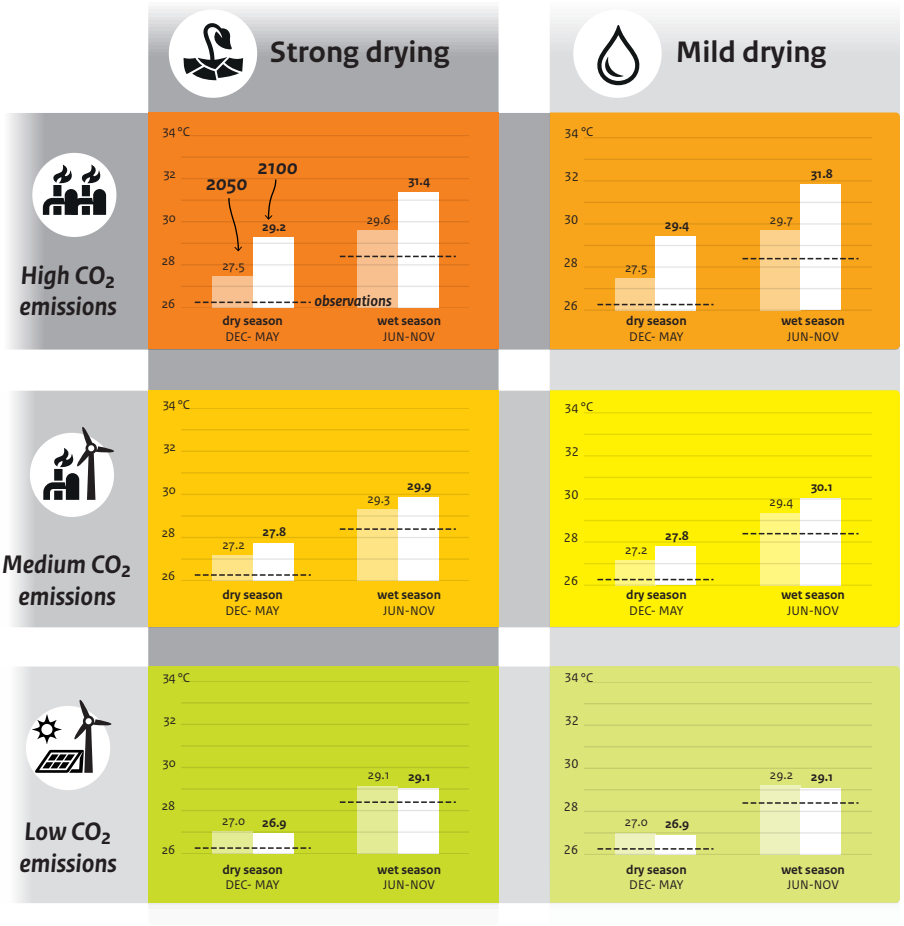
The sea around Sint Maarten is also warming up. Since 1970, it has warmed by approximately 0.16°C every decade. Marine heat waves happen when the sea is much hotter than normal for several days. These hot events are happening more often, and with higher temperatures.

As the oceans keep warming, marine heat waves will become more common. As with hot days on land, what is now considered hot may become normal in the future. How warm the sea gets will depend on how much the world continues to emit greenhouse gases.

# Temperature

## Warming over time



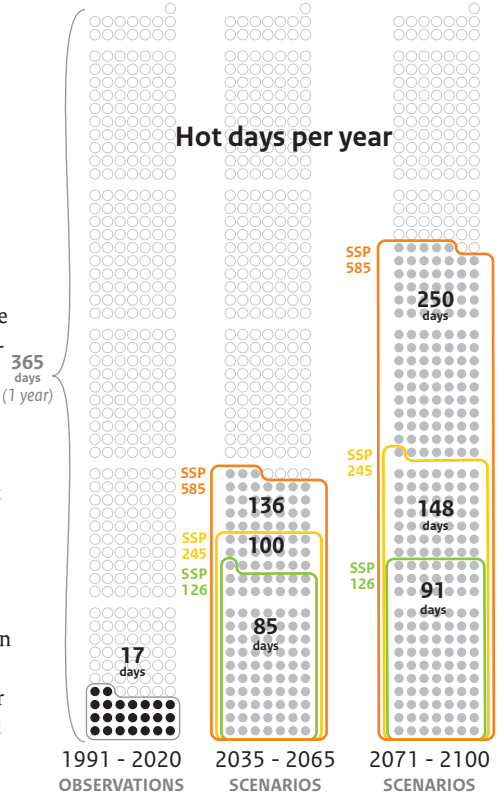



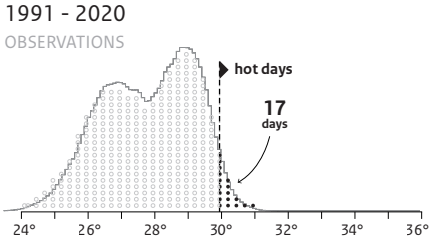
## Temperature

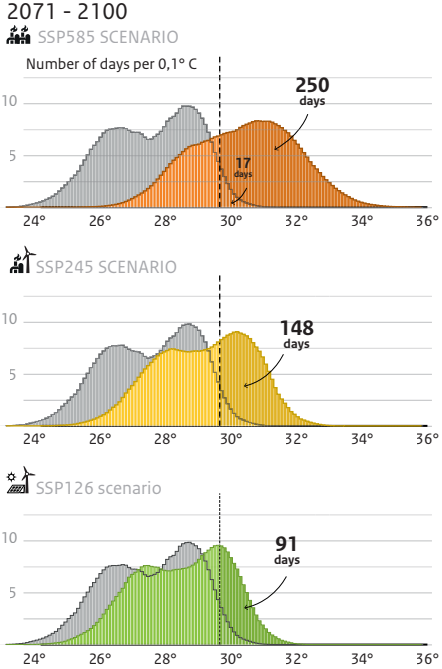
# More hot days

**The average temperature on Sint Maarten will increase. As a consequence, the number of hot days will increase, and the warmest days will become even warmer.**

This means that Sint Maarten will often experience temperatures that were not experienced before.
Hot days are here defined as days when the average temperature exceeds 29.5°C. This average includes both daytime and nighttime temperatures. As a result, the maximum daytime temperature on such days will be higher than 29.5°C, because the cooler nighttime temperatures are also included in the calculation.
In the current climate, an average year has 17 hot days. Around 2050, in the low-emission scenario an average year has 85 extremely hot days and in the high-emission scenario 136 hot days. By the end of the century, in the low-emission scenario an average year will have 91 extremely hot days. In the high-emission scenario there will be 249 hot days. This means more than 8 months of the year experience heat, making what is now considered extreme effectively the new normal.



# Rainfall

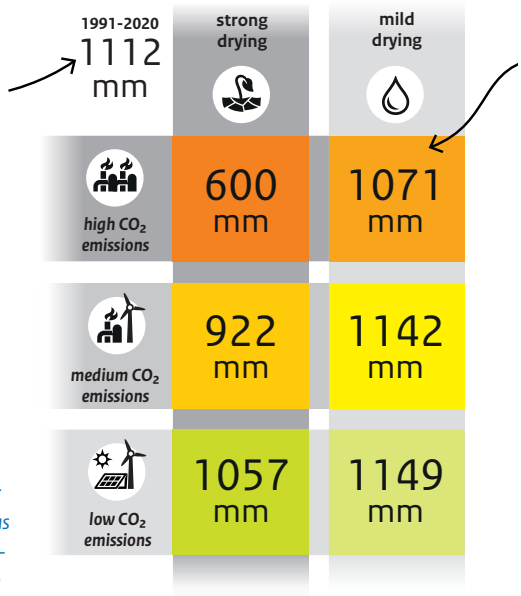
## It's getting drier

### PRESENT

Rainfall is very important for Sint Maarten, this is clear from the fact that the seasons are called the dry and the wet season. In the current climate, the annual average rainfall is 1112mm/yr. However, the amount of rainfall is very variable over the years and tightly connected to regional factors and large scale drivers such as El Niño and La Niña. There are dry years with around 500mm rainfall per year, like in 2015. And wet years with more than 1700mm rainfall, like. Due to the high year-to-year variability, no clear trend is visible in the observations

### Did you know that...

*... Sint Maarten's rainfall varies strongly from year to year? This is caused by large scale drivers such as El Niño/La Niña and regional drivers like fluctuations in sea surface temperatures, sea level pressure and trade winds. How these drivers will behave in the future is still a topic that is debated among researchers.*



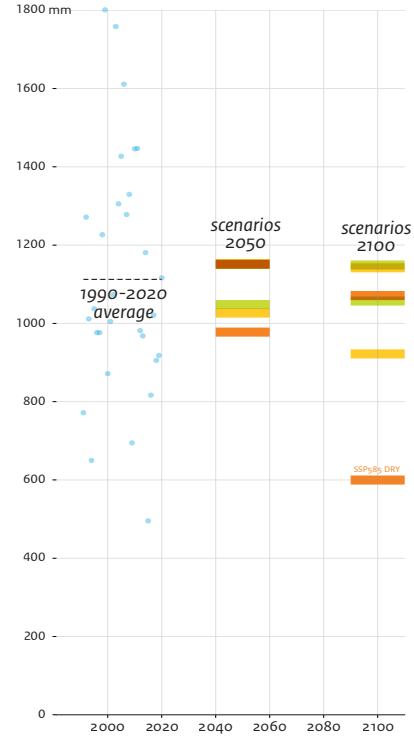

### FUTURE

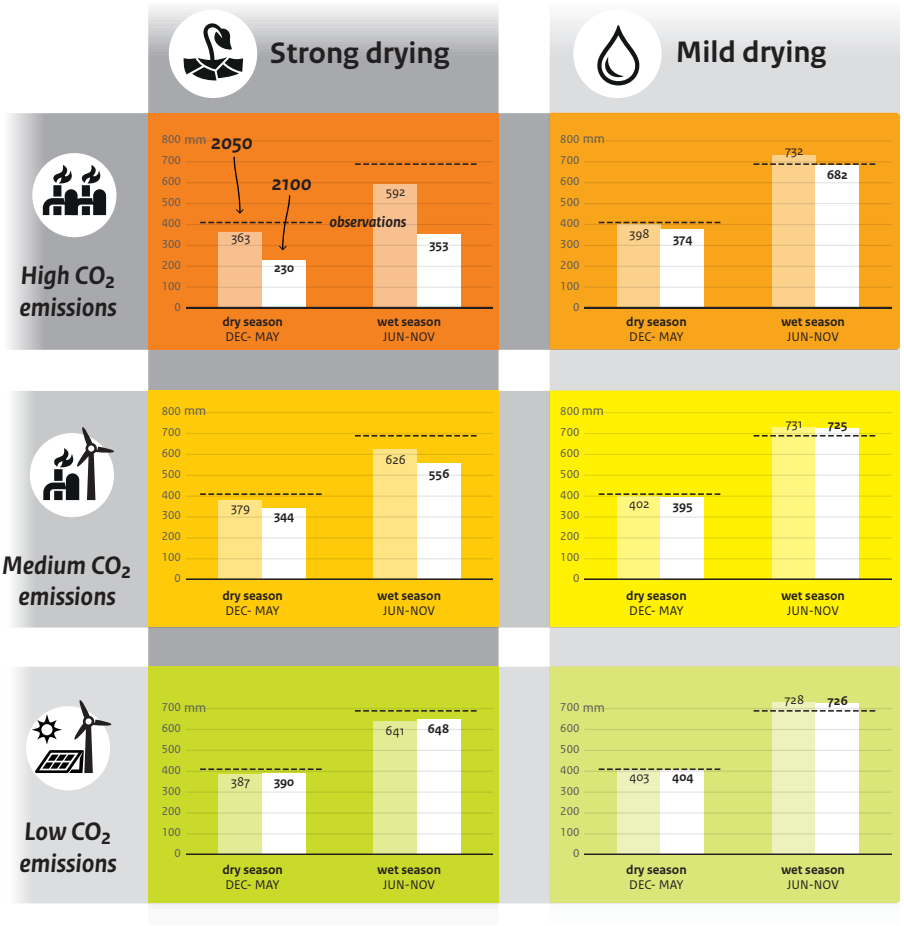
Most future scenarios for rainfall on Sint Maarten point to a drier climate in the coming decades. The drying signal is strongest in the high-emission and strong-drying scenarios, where annual rainfall could be reduced by up to half compared to today. In the low- and middle-emission or mild-drying scenarios, changes are smaller. On top of this trend, the year-to-year variation takes place.

In the strong drying scenario, both seasons are projected to become drier, with the dry season lasting longer and the wet season recovering less. In these drier future climates, extremely dry years could become even more severe, partly influenced by natural climate patterns such as El Niño and La Niña. In the mild drying scenario, most drying takes place in the dry season. In this scenario, the wet season can become slightly wetter, depending on the emission scenario.

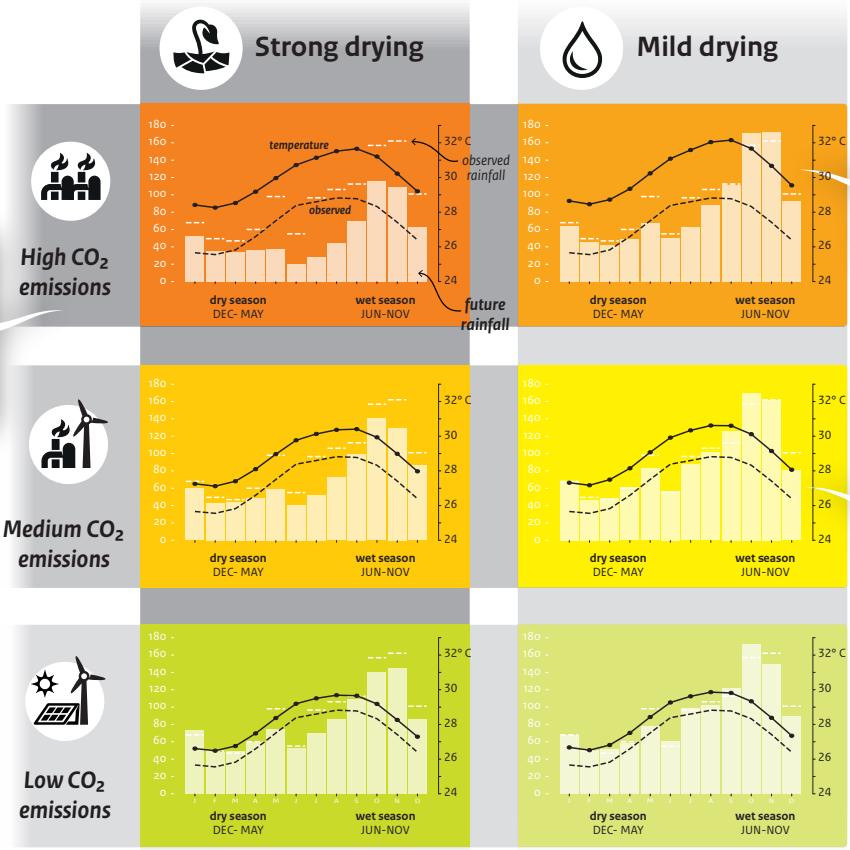
# Rainfall

## Drying over time



# Monthly change




In the high emission scenario, the dry season is prolonged for the normally wet season months June and July. In the dry models they are the driest months of the year.

The months August, September and October will warm the most.

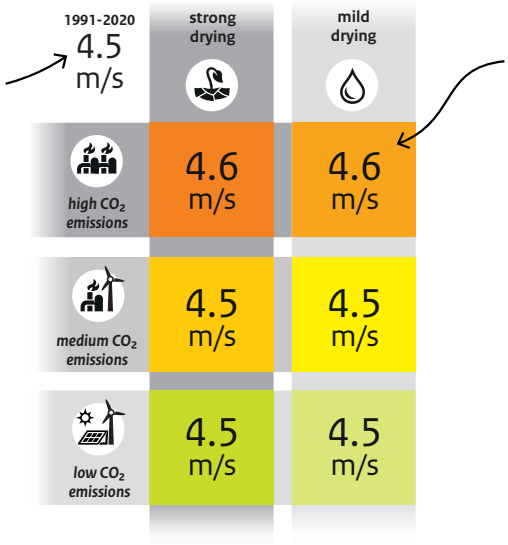
In the moderate and high scenario, the average temperature rises each month by +1.5°C or more, taking the climate to a 'new normal'.

## Wind

# Wind speed increases

### PRESENT

Sint Maarten experiences average wind speeds of around 4.5 m/s throughout the year, largely driven by the persistent easterly trade winds that blow steadily across the island. Winds tend to be stronger during the dry season and lighter during the wet season. There is also some year-to-year variability, with annual averages typically ranging from about 4.0 m/s to 5.0 m/s.




### FUTURE

Climate scenarios suggest that wind speeds on Sint Maarten will remain relatively stable in the future, with only a slight increase or decrease expected, depending on the scenarios. The increase is slightly stronger for the higher emissions scenario and in the dry season. The decrease is projected in the wet season of the strong drying scenario.

### Did you know that...

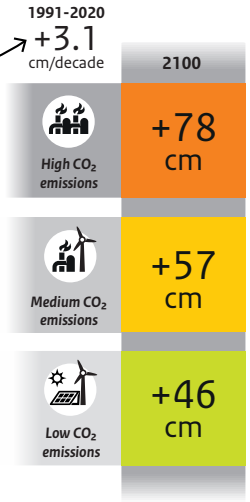
*... although wind speeds appear to change very little, even a small change in the average wind speed can have a relatively large impact. Wind influences, among other things, the perceived temperature, ocean temperatures, waves, and rainfall patterns.*

## Sea level

# The sea level rises

### PRESENT

The sea level is rising. In the period 1993-2023, the sea level near Sint Maarten has risen with approximately 3.1 centimeters per decade. Rising sea levels pose a threat to the low-lying areas of like the well-known beaches. We see that the sea level is rising faster along the coast of South America than elsewhere in the Caribbean. The speed of the sea level rise in the Caribbean is comparable with the worldwide mean




### FUTURE

The sea level around Sint Maarten will keep rising in the future. How much exactly is dependent on the emission scenario. The higher the emissions, the more warming takes place and the more the sea will rise.

Up to 2050, the sea level rise is very comparable for each scenario. Later in the century, the emission scenario will have a larger impact on the resulting sea level rise. By around 2100, sea level could rise by up to about 3.4 m if processes that are not well understood , mainly the potential instability of the Antarctic ice sheet, make a large contribution. These are the so-called low likelihood-high impact scenarios indicated by the dotted lines in the figure below.
During storms, high waves and storm surge occur on Sint Maarten. The risen sea level will increase the impact of these high waves

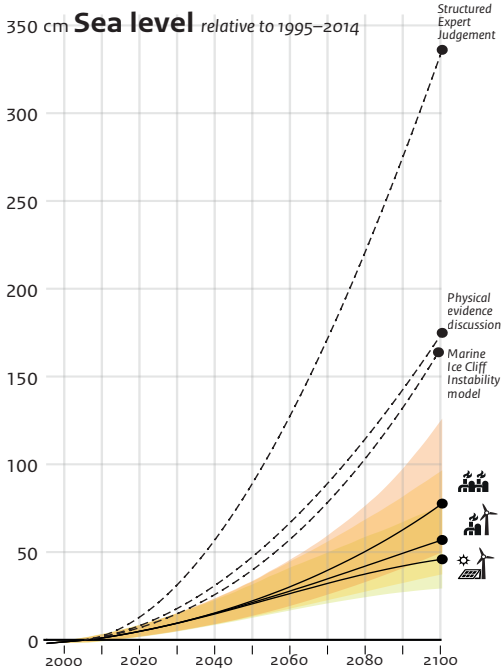
Even in the lower emission scenario, sea level rise will continue not only during this century but for many years to come. This is because the ice sheets will continue to melt even when warming stops. As a result, it is no question whether the sea level will increase by more than a meter but when this will happen.

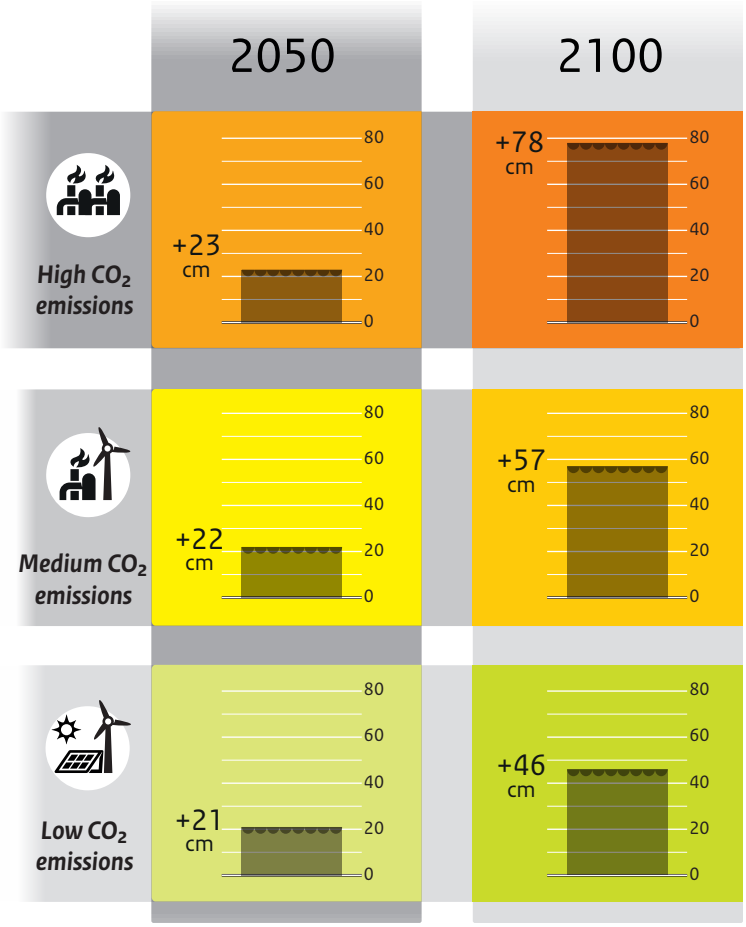
### Did you know that...

*... melting ice isn't the main cause of sea level rise? Although melting ice caps and glaciers do contribute, the biggest factor is actually the warming of the ocean itself. As seawater warms, it expands and takes up more space, leading to a rise in sea level. This process is known as thermal expansion.*

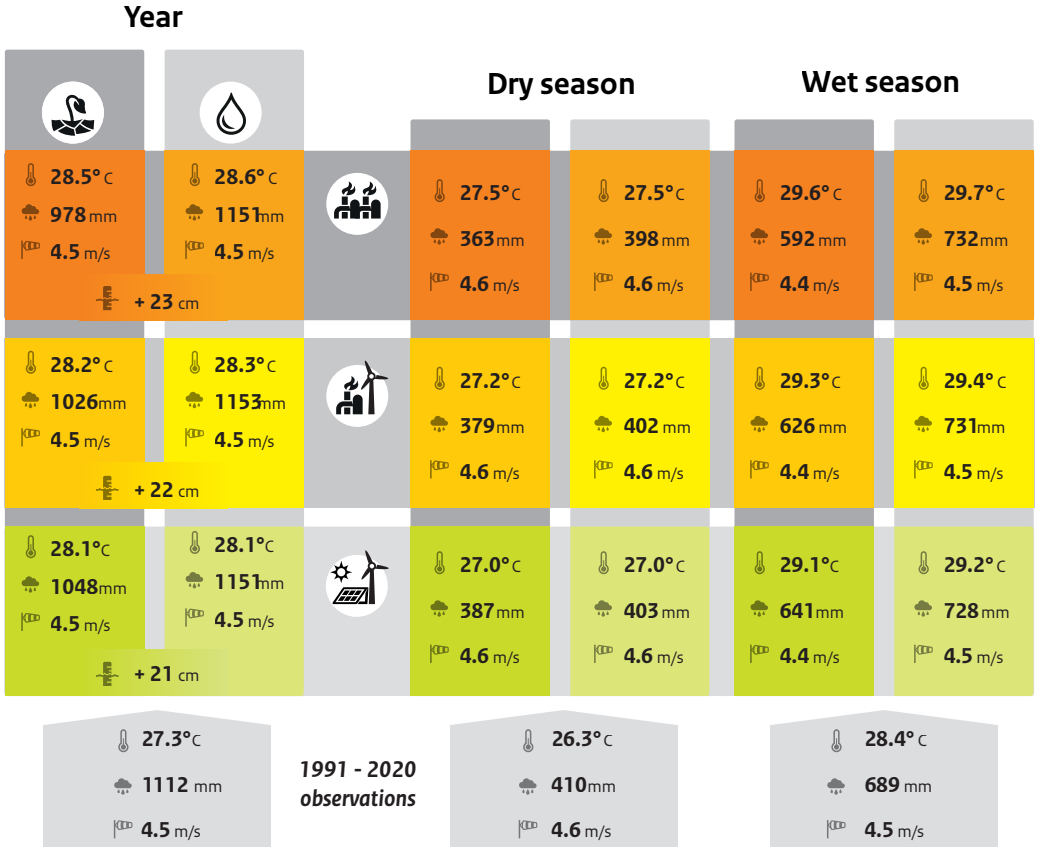
## Sea level

# Sea level rise over time

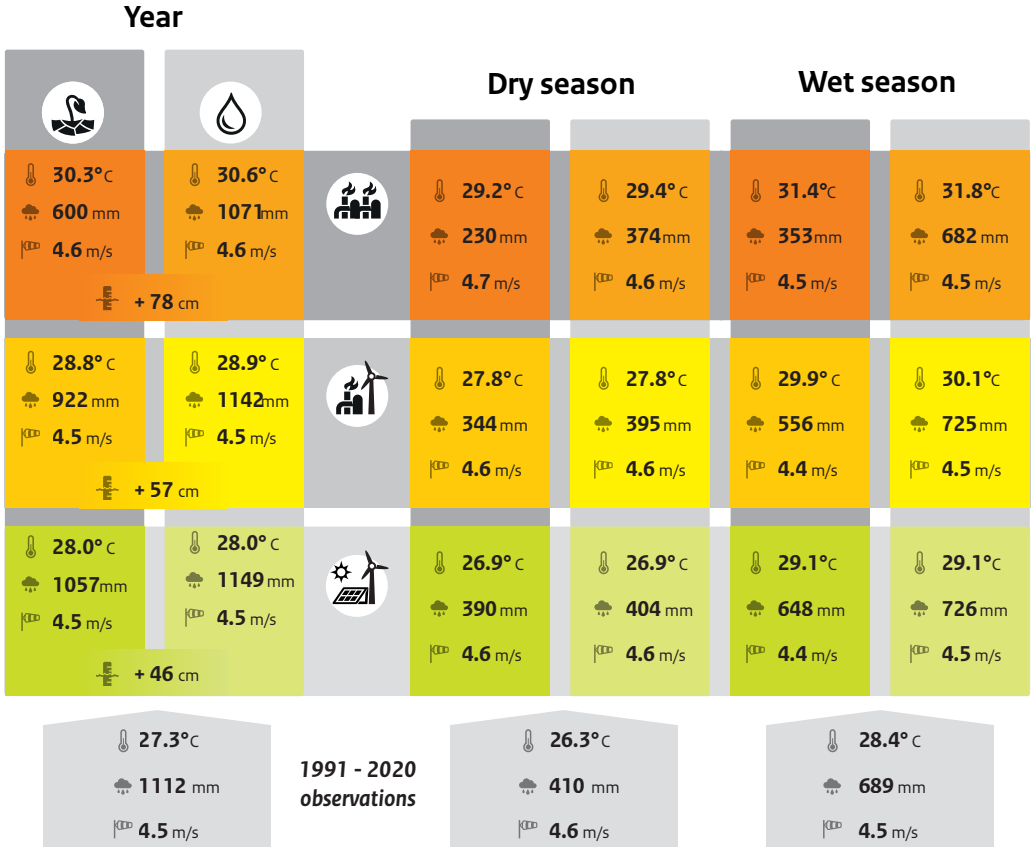


# Climate scenarios for 2050



# Climate scenarios for 2100



# Background information

## What is a climate scenario?

A climate scenario is a realistic and coherent picture of what the future climate could look like, it is made to study the possible consequences of climate change [2]. The current rapid changing climate is caused by humans emitting greenhouse-gases that warm the planet. It is not possible to predict future human activities. Therefore, the scenarios are not predictions and it is impossible to say which scenario is most likely.

## Shared Socioeconomic Pathways (SSPs)

To compare the results of different climate models, researchers use socio-economic scenarios, known as Shared Socioeconomic Pathways (SSPs). These SSPs describe possible future developments in demographics, society, the economy, and technology. They differ in their levels of greenhouse gas and aerosol emissions, as well as in land use.
In the first part of its Sixth Assessment Report on the physical science basis of climate change, the IPCC presents results based on five SSPs. These scenarios cover a wide range — from one with ambitious climate policies aligned with the Paris Agreement (limiting warming to around 1.5°C, SSP1-1.9) to one where emissions continue to rise sharply (SSP5-8.5). In this report, we also include three scenarios: a low-emission scenario (SSP1-2.6) and a high emission scenario (SSP5-8.5) to provide the range in which climate change will take place. Additionally, a moderate scenario is included. This is the 'business-as-usual' scenario (SSP2-4.5) and is important for several policy makers to use this scenario for their short-term adaptation plans in the Caribbean. Because the amount of greenhouse gases in the atmosphere largely determines global temperature change, a low-emission scenario leads to less warming than a high-emission scenario. Which path the world follows and how much the planet warms, ultimately depend on global climate policy. The differences between these socio-economic scenarios become especially significant in the long term, after 2050.

## Scientific uncertainty

In addition to uncertainty about global climate policy, there is also scientific uncertainty regarding the extent to which the climate system responds to changes in the concentration of greenhouse gases in the atmosphere. The climate sensitivity — the increase in the global average temperature associated with a doubling of the amount of $CO_2$ in the air — is currently estimated at +2.5 to +4.0°C and is now known more precisely than in the previous IPCC report from 2013.

On a more regional scale, uncertainties in climate processes play a large role. Climate processes related to temperature, precipitation, winds and sea-surface temperature are complex. These processes strongly influence each other. The strength of the trade winds can influence the sea-surface temperatures, which influence temperature and rainfall on the islands. Well-known climate processes influencing the Caribbean climate are El Niño and its counterpart La Niña. Uncertainties about the climate response of such regional processes are important to take into account.
In principle, uncertainty about the future climate can be reduced by conducting more research into the functioning of the climate system and by developing better climate models. However, the climate also exhibits unpredictable behaviour. These natural varia-

tions , which result from interactions between the atmosphere, oceans, land, and ice sheets, occur on all time scales and ensure that even over a 30-year period there can be significant differences.
We can estimate the influence of these natural variations by performing multiple model simulations, differing only by a small disturbance in the initial conditions. After about ten years, these simulations produce different outcomes. Temperature changes due to climate change (the trend) will soon become larger than natural temperature variations (the noise) in the near future. This does not generally apply to changes in precipitation and wind. For instance, the natural variation in average wind speed over a 30-year period can be about 10%. This means that one 30-year period may turn out to have 10% higher or lower wind speeds.

## Statistical downscaling

For the climate scenarios for Sint Maarten, the same global climate models and methods are used as for the KNMI'23 scenarios for the Netherlands. However, there is one key difference. For the Netherlands, a regional climate model is used to translate information from the global models, whereas for Sint Maarten, this translation is done statistically.
From the results of the 29 available models for the Caribbean, the 10 wettest and 10 driest models were selected — representing the largest projected increases and decreases in rainfall up to 2100, respectively. The group with the 10 wettest models is called the mild-drying scenario, for even in the wettest groups there are signs of future drying. The 10 driest models are grouped in the strong drying scenario.
The relatively coarse modelled time series of temperature, rainfall, and wind were then adjusted using observational data to create regionally modelled future time series for each emission scenario and for both the mild drying and strong drying groups, this process is called statistical downscaling.
For the observational data, we used the data from the Princess Juliana Airport station, provided by the Meteorological Department St. Maarten. Since this includes only one station, we compared it with data from the NOAA Global Surface Summary of the Day dataset and with ERA5 data. As a result, the models are effectively downscaled for a single station, meaning the scenarios for temperature, rainfall, and wind are optimized for Princess Juliana Airport.
Although climate normals for temperature, rainfall and wind might vary over the island, we expect the climate scenario values to be representative for the whole island. This implies that a location that has a current climate of 27.7 °C (while the airport has a climate of 27,3 °C) and the scenarios indicate a change of +1.6 ° in 2100, the new climates in 2100 for this location will be 29.3 °C.

## Three estimates of the maximum sea-level rise

There is currently no scientific consensus on the rate at which sea level could rise to its maximum in the future under a high-emission scenario. Three methods have been used to estimate that rate:
Physical evidence discussion. This method consists of organizing an open discussion among climate scientists and sea level experts about the largest sea level rise that is still physically plausible [4].
Marine Ice Cliff Instability model. In this method, we used the result of a numerical model that simulates the physical mechanisms of Marine Ice Cliff Instability in Antarctica [5].
Structured Expert Judgement. This method uses a survey of the world's leading glaciologists. When completing the survey, they did not have to discuss their views or justify their estimates of Antarctic and Greenland contributions to sea level rise using physical mechanisms [6], which makes this method less conservative than the "Physical evidence discussion."
Each method resulted in an estimate of the highest possible sea level rise. The probabi-

lity that such an estimate would be exceeded cannot be calculated but based on the characteristics of these methods and a comparison with baseline scenarios, we suspect that this probability, under the high-emission scenario, is between 0 and 5%. Under a lower emission scenario, the probability is smaller.

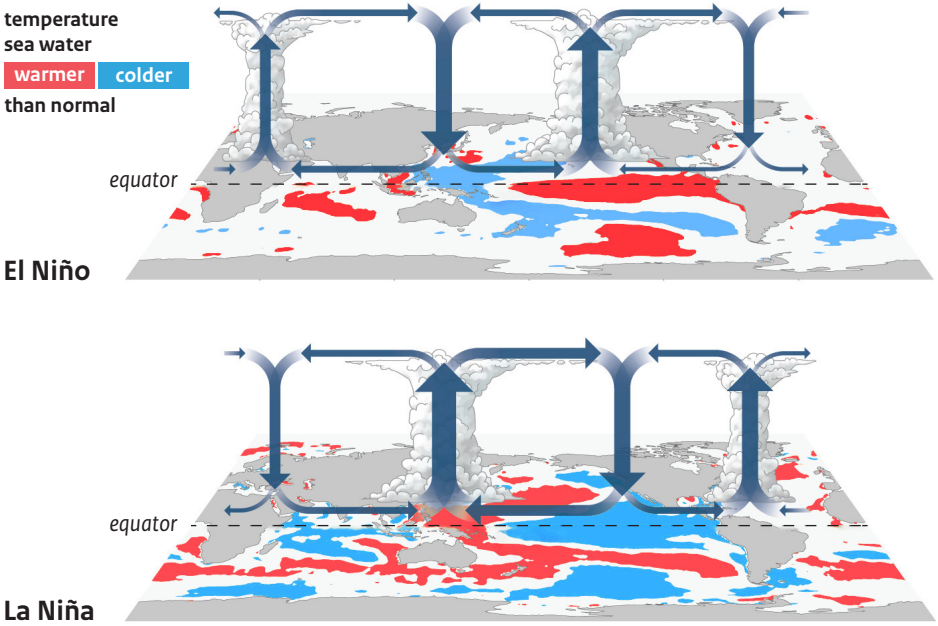
### Seasonal definitions

The seasons for Sint Maarten are determined by using the hurricane season. Hurricanes and tropical storms bring a lot of rain to Sint Maarten. Therefore, the hurricane season is labelled as the wet season (June – November), and the other half of the year the dry season (December – May).

### Walker circulation and the El Niño bias

El Niño and La Niña are climate patterns occurring around the equator in the Pacific Ocean. They influence global air circulation, which is driven by fluctuations in sea surface temperature in the tropical Pacific Ocean.

During La Niña, sea surface temperatures in the eastern Pacific are lower than normal. Air rises over the western Pacific and the Caribbean region, while it descends over the central Pacific. Between these areas, there are easterly and westerly winds in the lower and upper atmospheric layers. This so-called Walker circulation shifts westward during La Niña. Where air rises — such as over the Caribbean — there is heavy rainfall; where air descends, there is little precipitation.
During El Niño, the eastern Pacific warms up, causing the Walker circulation to shift eastward. Air then rises over the central Pacific and descends over the Caribbean region. As a result, the Caribbean receives less rainfall during El Niño than during La Niña. There is currently scientific uncertainty about the future El Niño and La Niña cycle. The CMIP6 models point towards an El Niño dominated future, where the observations show a trend towards La Niña.
If the models are incorrect about El Nino, the extreme dry models are less likely. However, we do not yet know how the El Niño and La Niña cycle will behave in the future.



## Climate change impact on extreme weather and hurricanes

The climate scenarios do not show every possible effects of climate change on Sint Maarten. Some important topics, like extreme rainfall and hurricanes, are not discussed because they require different scientific methods and climate models that were not part of this study. Still, we can describe what science currently says about these risks in general while studies for Sint Maarten lack.

Even though total yearly rainfall may decrease, extreme rain events could become heavier, because a warmer atmosphere can hold more moisture and release more rain in short, intense downpours [7].

Hurricanes are expected to become stronger as the climate warms. They draw their energy from warm ocean waters, and as sea surface temperatures rise, storms can intensify more rapidly and reach higher peak wind speeds. The Caribbean has already experienced this in recent decades with several devastating hurricanes. Stronger storms also produce higher waves and more dangerous storm surges. In addition, hurricanes are projected to become wetter, delivering heavier rainfall as a warmer atmosphere can hold more moisture. While the number of the most intense hurricanes is expected to increase, it remains uncertain whether the total number of tropical storms in the region will change [1, 7].

KNMI'23 examined Hurricane Irma (2017) in a warmer climate and found that the most severe hurricanes are likely to produce even stronger winds and significantly more rainfall. This means that the strongest hurricanes of the future could have even greater impacts than those observed today [8, p. 40].

# Glossary

**Anomalies** are values that deviate from what is standard, normal or expected.

The **climate** is the average weather for about thirty years.

**Climate change** is the long-term change in regional or global climate patterns.

A **climate scenario** is a realistic picture of the future climate that makes scientific sense. They are made using historical data and assumptions on how much greenhouse gas the world emits and how the climate will respond to these emissions. Climate scenarios are important for planning and adaptation.

The **dry Season** is the period of the year with the least rain on average, from December to May.

**El Niño** is a natural climate pattern where the surface of the Pacific Ocean becomes warmer than usual, changing temperature, wind and rain patterns around the world. In the Caribbean, El Niño causes drier conditions and suppresses hurricane activity. El Niño is the opposite from La Niña.

**Emissions** are gases or particles released into the air, often from burning fuels like coal, oil, or gas. Some emissions, such as carbon dioxide ($CO_2$), trap heat in the atmosphere and contribute to climate change.

**Extremely hot days** are days with a temperature at least as high as the top 5% warmest days in 1991-2020.

**IPCC** stands for *Intergovernmental Panel on Climate Change*. It's a science collaboration from around the world that studies climate change and provides reports to help governments understand its causes, impacts, and possible solutions.

**IPDC** stands for *The International Panel on Deltas and Coastal Areas* and helps deltas, coasts, and islands adapt to climate change. It supports them in protecting their ecosystems, communities, and economies while dealing with other social challenges.

**La Niña** is a natural climate pattern where the surface of the Pacific Ocean becomes cooler than usual, changing wind and rain patterns around the world. In the Caribbean, La Niña causes wetter conditions and enhances hurricane activity. La Niña is the opposite from El Niño.

**Marine Heat Waves** are defined by IPCC as a period of 5 days or more where the ocean temperature exceeds the 90th percentile in SST from 1982 to 2016.

**Observations** are a measurement of a weather variable, such as temperature, amount of rain and wind speed.

**SSP** stands for *Shared Socioeconomic Pathways* (SSPs), have a number followed by a value that (approximately) represents the radiative forcing in $W/m^2$ by the year 2100. The numbering ranges from 1, the sustainable pathway, to 5, the pathway with high greenhouse gas emissions. In this report, SSP1-2.6 is referred to as the low scenario, SSP2-4.5 as the moderate scenario, and SSP5-8.5 as the high scenario.

The **wet season** is the period of the year with the most rain on average, from June to November. This is also the hurricane season.

# References


[1] van Dorland, R., Beersma, J., Bessembinder, J., et al. (2024). KNMI National Climate Scenarios 2023 for the Netherlands. Scientific report WR-23-02, De Bilt.

[2] IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

[3] Oppenheimer, M., Glavovic, B., Hinkel, J., van der Wal, R., Magnan, A. K., Abd-Elgawad, A., Cai, R., Cifuentes-Jara, M., Deconto, M., Ghosh, T., Hay, J., Isla, F., Marzeion, B., Meyssignac, B., \& Sebesvari, Z. (2019). Sea level rise and implications for low lying islands, coasts and communities. Intergovernmental Panel on Climate Change (IPCC).

[4] Wal, R.S.W., Nicholls, R., Behar, D., McInnes, K., Stammer, D., Lowe, J., Church, J., DeConto, R., Fettweis, X., Goelzer, H., Haasnoot, M., Haigh, I., Hinkel, J., Horton, B., James, T., Jenkins, A., LeCozannet, G., Levermann, A., Lipscomb, W., White, K., 2022: A High-End Estimate of Sea Level Rise for Practitioners. Earth's Future 10.

[5] DeConto, R.M., Pollard, D., Alley, R.B. et al., 2021: The Paris Climate Agreement and future sealevel rise from Antarctica. Nature 593, 83–89.

[6] Bamber, J. L., et al., 2019: Ice sheet contributions to future sea-level rise from structured expert judgment, Proceedings of the National Academy of Sciences 116(23), pp. 11195-11200.

[7] Seneviratne, S.I., X. Zhang, M. Adnan, W. Badi, C. Dereczynski, A. Di Luca, S. Ghosh, I. Iskandar, J. Kossin, S. Lewis, F. Otto, I. Pinto, M. Satoh, S.M. Vicente-Serrano, M. Wehner, and B. Zhou, 2021: Weather and Climate Extreme Events in a Changing Climate. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change[Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1513–1766, doi: 10.1017/9781009157896.013.

[8] KNMI, 2023: KNMI'23-klimaatscenario's voor Nederland, KNMI, De Bilt, KNMI-Publicatie 23-03.

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