Kourou

Climate-driven changes in infrastructure design assumptions

Report generated using ClimateVision V 1.1.0

November 2025

Table of content

For more information see legal and IP notices in Appendix C.

Introduction and goals

Companies engaged in the design and construction of both on- and off-shore infrastructures rely on meteorological and oceanographic assumptions. Variables such as temperature, wind, precipitation, wave height, and sea level play pivotal roles in project feasibility, design, and operation. However, these assumptions, typically grounded in a study of past weather records, may become inadequate over a project's lifetime, especially under the influence of climate change.

This report is designed to help address this challenge. It provides a summary of future local climate projections crucial for designing resilient infrastructures.

It was generated automatically based state-of-the-art climate projections using ClimateVision, Callendar’s tool designed to automatically generate precise and actionable local climate insights.

This report is delivered with:

- A user guide detailing the data and methodology used,
- Spreadsheets containing the raw and intermediate data for the project site.

Executive summary

The objective of this report is to provide an overview of the available scientific knowledge on current and future climate for the following geographic point:

Latitude : 5.175835095729317
Longitude : -52.646340677738955
Projection : WGS84

This report is based on meteorological reanalyses from the European Centre for Medium-Range Weather Forecasts (ECMWF) and climate projections produced for the Intergovernmental Panel on Climate Change (IPCC) 6th assessment report. The sources and methods used are introduced in each chapter and detailed in the attached methodological note.

These data show the following local trends, all changes are relative to the 1981-2023 reference period:

- The temperature is currently increasing by about 0.2°C per decade and will most likely continue to increase at a similar pace over the next few decades. In a low emissions scenario, the warming stabilizes in the second half of the century around +1.1°C compared to the historical baseline. It should continue to rise in the other scenarios and could exceed +3.5°C at the end of the 21st century in a high emissions scenario.

- In an intermediate or high emissions scenario, extreme heat waves are likely to become more severe during the second half of the 21st century. The maximum temperature of the 50-year return period heat wave could increase by 2.6°C in a high emission scenario by 2050, and 4.9°C by 2080. The historical 50-year return period maximum temperature is 31.1°C.

- In an intermediate or high emissions scenario, extreme cold spells are very likely to become less severe in the second half of the 21st century. The minimum temperature of the 50-year return period cold spell could increase by 1.3°C in a high emission scenario by

2050, and 2.7°C by 2080. The historical 50-year return period minimum temperature is 22.5°C.

- The average precipitation shows no significant trend (a negligible +97 mm per decade) and will most likely to continue at a similar rate over the next few decades. In a low emissions scenario, annual average precipitation could reach 2584 mm a year by the end of the century. Under a high emissions scenario, average annual precipitation are not expected to vary significantly during the 21st century, with projected values of about 2200 mm per year. Historical average is around 2577 mm per year.

- In an intermediate or high emissions scenario, no consensus is found on the severity of extreme precipitation trends during the 21st century. The historical 50-year return period rainfall amount is 248 mm within 24 hours. By 2100 in a high emissions scenario, this extreme value is projected to change by ±6 mm. This result should be interpreted with caution, as there is little agreement among projections.

- In intermediate- and high-emissions scenarios, no trends are found on the extreme wind speeds during the 21st century. The 50-year return period hourly wind speed could change by -0.0 m/s under a high emissions scenario by 2050, and +0.2 m/s by 2080. The historical 50-year return period hourly wind speed is 9.7 m/s.

- By mid-century, sea level is likely to rise by about 23 centimetres compared to the average 1985-2014 level. By 2080, sea level could rise by about 38 to 54 centimetres, depending on the level of emissions and the underlying assumptions, with a low probability of exceeding 149 centimetres in a pessimistic scenario.

Average surface temperature

1. Overview of the data and methods used

The past climate is based on the closest data point of the ERA5 reanalysis on sea and the closest data point of the ERA5-Land reanalysis on land. The spatial resolution of these data are respectively 0.25 x 0.25° and 0.1 x 0.1°. Future climate projections are based on 12 models from the CMIP6 project[1]. Projections are downscaled and bias corrected using the past climate as a reference.

Please note that values for the reference period are based on reanalysis data, a widely used method for reconstructing past atmospheric conditions by combining observations and high-resolution weather models. Depending on specific local features, results may differ from in-situ observations or reanalysis corrected with in-situ observations.

2. Average surface temperature

Over the reference period (1981-2023), the median annual temperature was 26.2°C with a 90% confidence interval extending from 25.7 to 26.7°C.
A warming trend is visible in the historical data. Over the period 1991-2020, the temperature has increased on average by about 0.2°C per decade.

[1] The models used are listed in Appendix A.

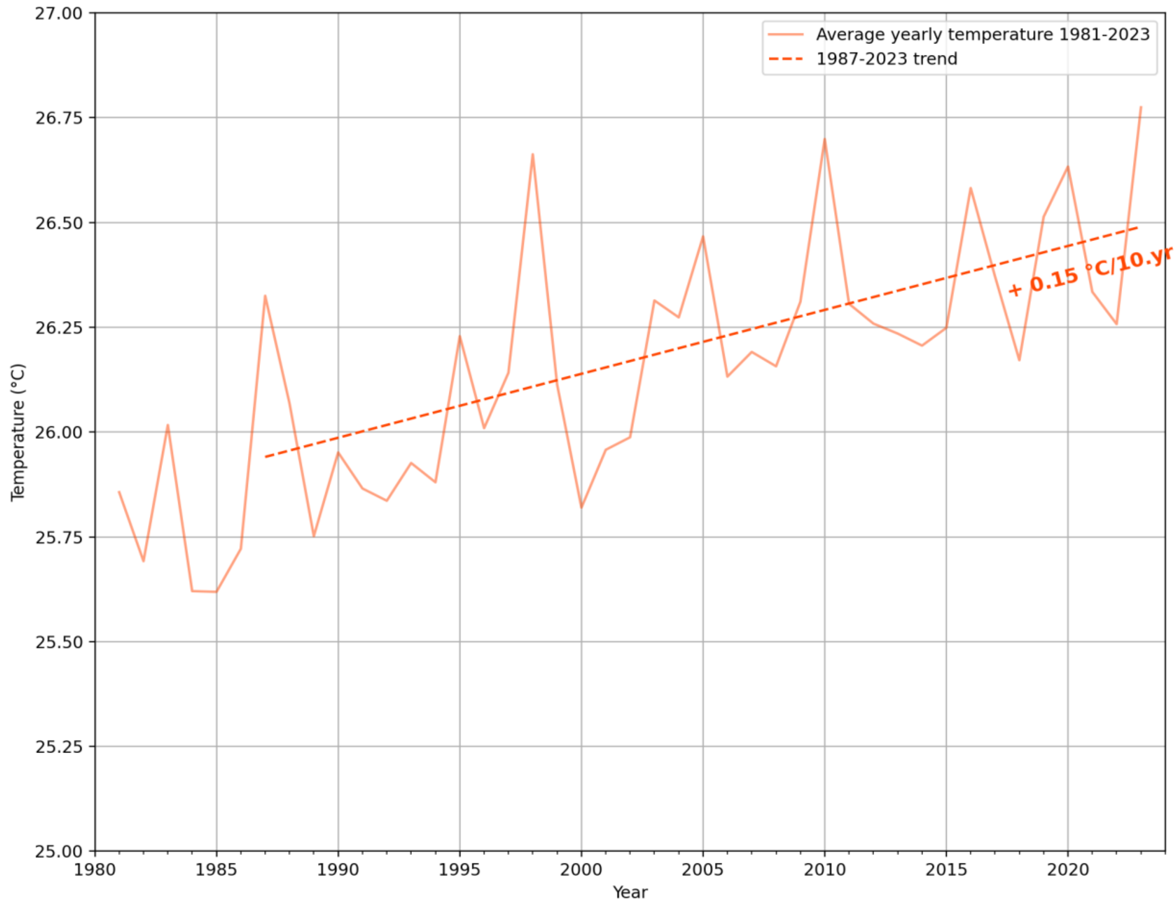


Figure 1: Average annual temperature and trend

3. Future projections

Temperature is very likely to increase significantly during the 21st century.

Over the next three decades, the best estimate of annual average temperature is approximately 26.9°C with little influence from the emissions scenario.

This is consistent with the trend observed over the last 3 decades. The median projection for average annual temperature is higher than the natural variability (90 CI). This strongly suggests that historical temperatures do not provide good guidance even for short-term project design.

The influence of future emissions scenario on temperatures becomes significant around the middle of the century. By 2040, the average yearly temperature is projected to be 0.4°C higher in the worst-case emissions scenario (SSP5-8.5) compared to the best-case scenario (SSP1-2.6). At the end of the century, this difference approaches 2.1°C.

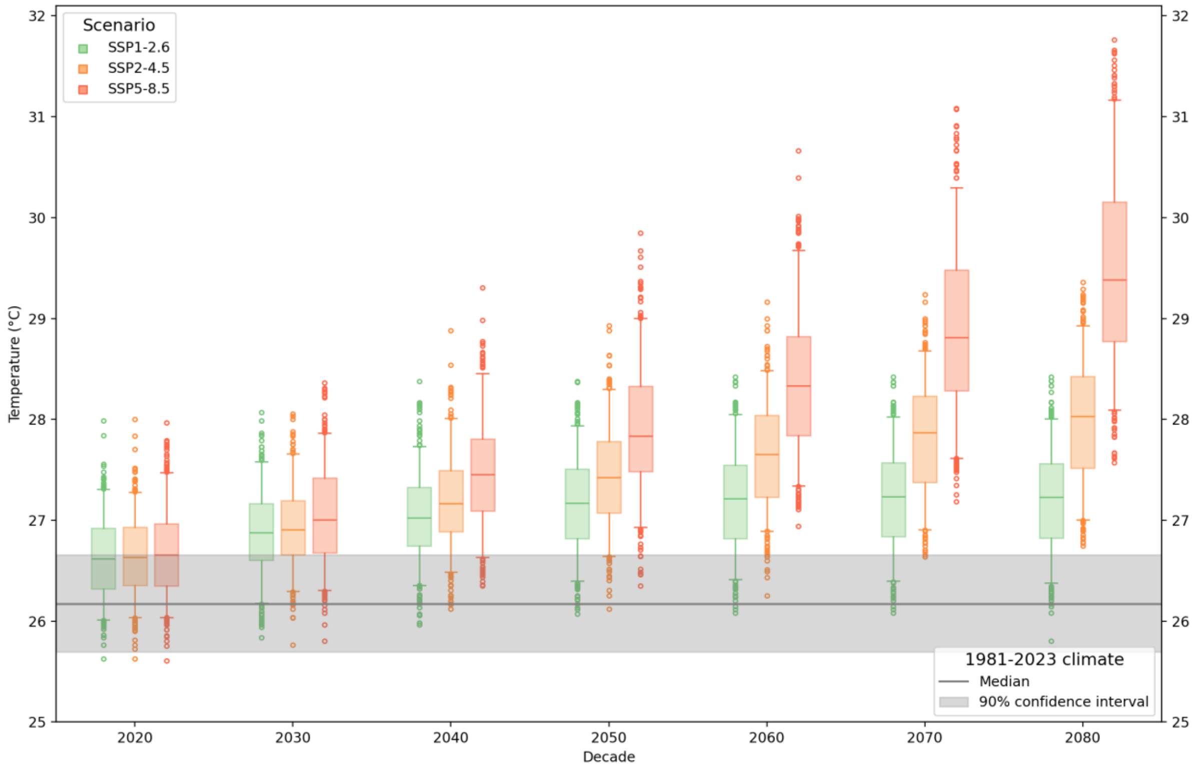
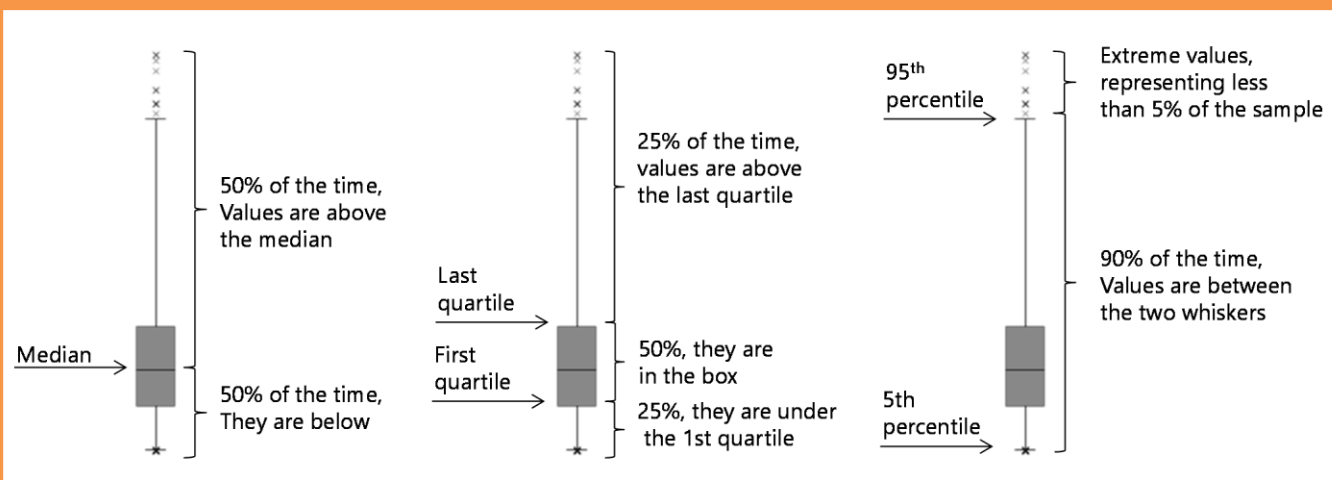


Figure 2 : Annual temperature, multimodel boxplot

Box 1: how to read a boxplot

A boxplot is a graphical method to simply convey the distribution of data. It allows to visually estimate the most important data percentiles (minimum, maximum, median, first and last quartiles) and various key characteristics of a sample (spread, skewness, outliers, etc.).

Several variations of this visual data display exist. In this document, boxplots can be read as follows:



The difference is more pronounced for the upper bound of the confidence interval: the gap between the 95th percentile of temperature of the worst-case and best-case scenario is 0.73°C by mid-century and 3.16°C for the 2080 decade. The high emission scenario thus leads to a disproportionate increase in the severity of the warmest years.

	Scenario			Uncertainties
	SSP1-2.6 (Low GHG emissions scenario)	SSP2-4.5 (Intermediate GHG emissions scenario)	SSP5-8.5 (Very high GHG emissions scenario)	
Reference (1985-2014)	26.2°C			
Short term (2020-2049)	26.9 [26.2, 27.6]	26.9 [26.3, 27.7]	27.0 [26.3, 27.9]	Low
Mid-century (2035-2064)	27.2 [26.4, 27.9]	27.4 [26.6, 28.3]	27.8 [26.9, 29.0]	Medium
End of century (2070-2099)	27.2 [26.4, 28.0]	28.0 [27.0, 28.9]	29.4 [28.1, 31.2]	High

Figure 3: Average temperature projections (median and 90% confidence interval)

In the low emissions scenario, the warming stabilizes in the second half of the century at around 1.1°C. Temperature continues to rise in the other scenarios. At the end of the century, the temperature increase is about 2.1°C compared to 2000 in the SSP2-4.5 and 3.5°C for the SSP5-8.5.

4. Individual model projections

Most models indicate that the annual temperature will rise beyond the natural climate variability (90% confidence interval) in all scenarios. But there is a significant dispersion among models for long-term warming, especially in the high emission scenario. As a result, uncertainties remain high for the end of the century.

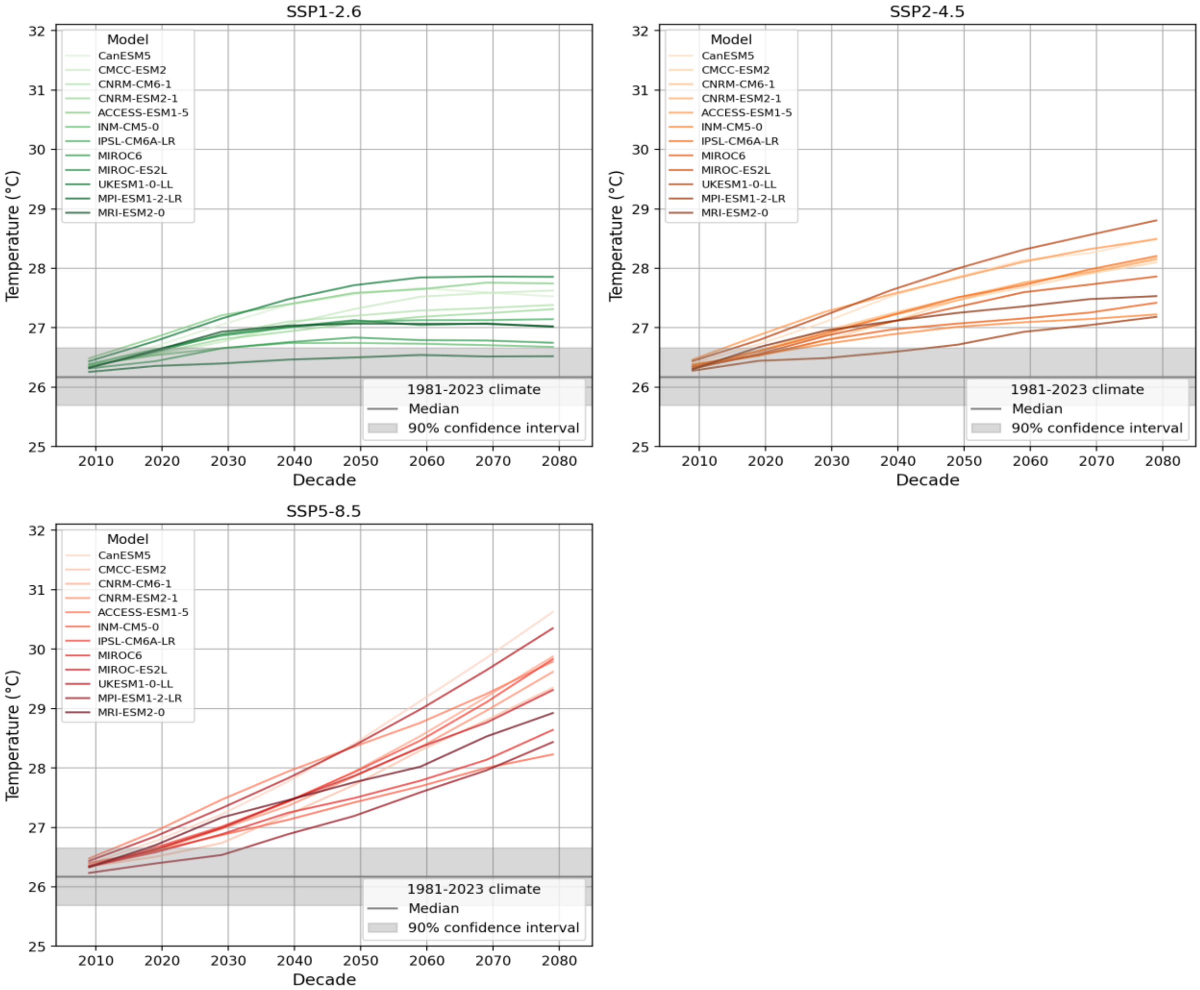


Figure 4: Average temperature by decade (30 year rolling average)

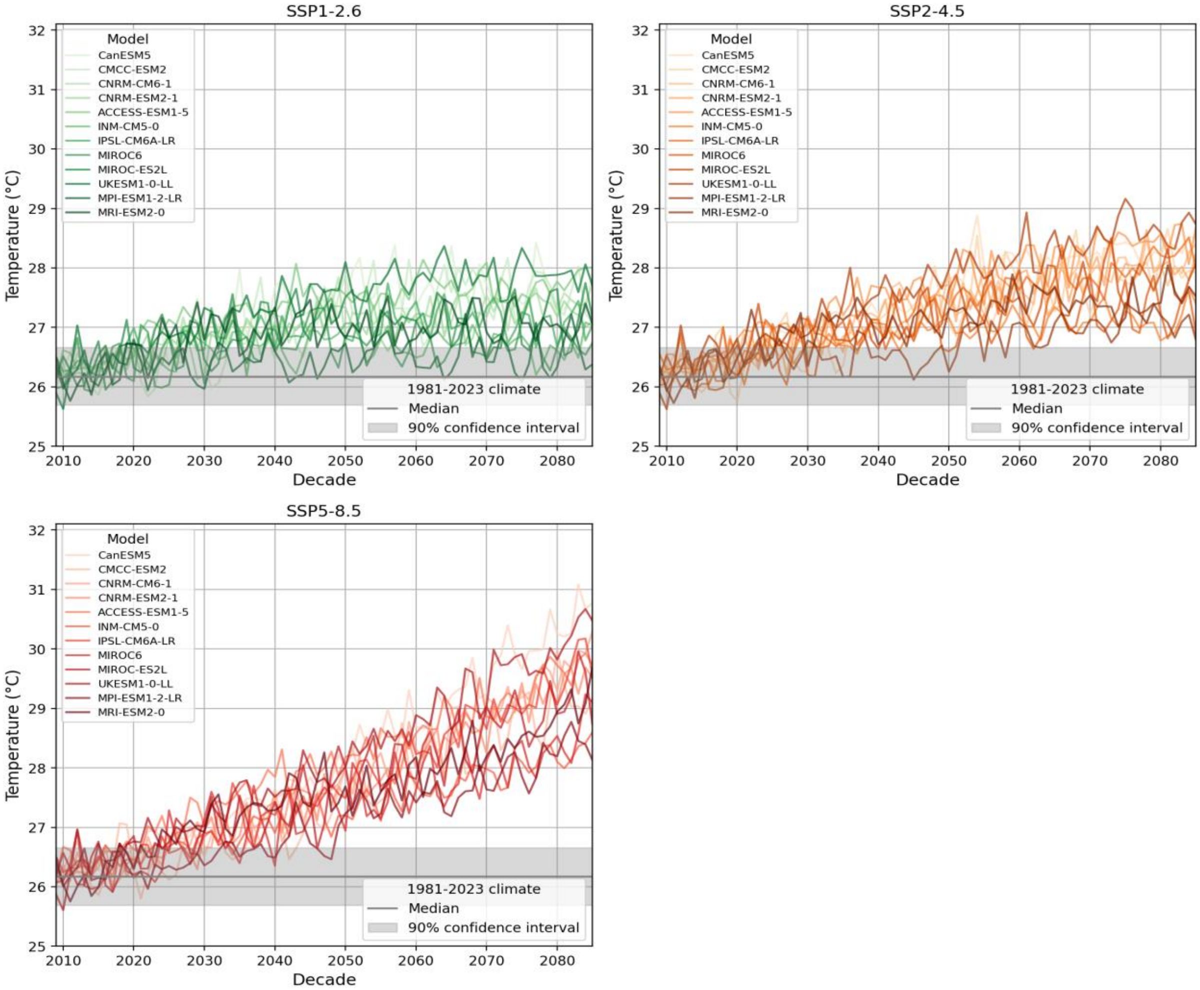


Figure 5: annual temperature simulation

Maximum temperature

1. Overview of the data and methods used

The past climate is based on the closest data point of the ERA5 reanalysis on sea and the closest data point of the ERA5-Land reanalysis on land. The spatial resolution of these data are respectively 0.25 x 0.25° and 0.1 x 0.1°. Future climate projections are based on 12 models from the CMIP6 project[2]. Projections are downscaled and bias corrected using the past climate as a reference.

Temperature extremes for a given return time are evaluated from the known maxima and a Generalized extreme value distribution.

Please note that values for the reference period are based on reanalysis data, a widely used method for reconstructing past atmospheric conditions by combining observations and high-resolution weather models. Depending on specific local features, results may differ from in-situ observations or reanalysis corrected with in-situ observations.

All statistical fits presented in this chapter are obtained through an automated fitting process using the Generalized Extreme Value distribution with Maximum Likelihood Estimation. No manual fine-tuning or adjustment has been applied to individual cases. As a result, some fits may appear unusual or less than ideal. However, these fits remain valuable for a broad, qualitative understanding of trends across different models and scenarios.

2. Reference climate

Over the reference period (1981-2023), the maximum hourly temperature observed was 31.2°C in August 2003 and the maximum daily temperature was 28.7°C in September 2023. Over these 30 years, the maximum hourly temperature was 30.4°C on annual average and the maximum daily temperature 27.9°C.

[2] The models used are listed in Appendix A.

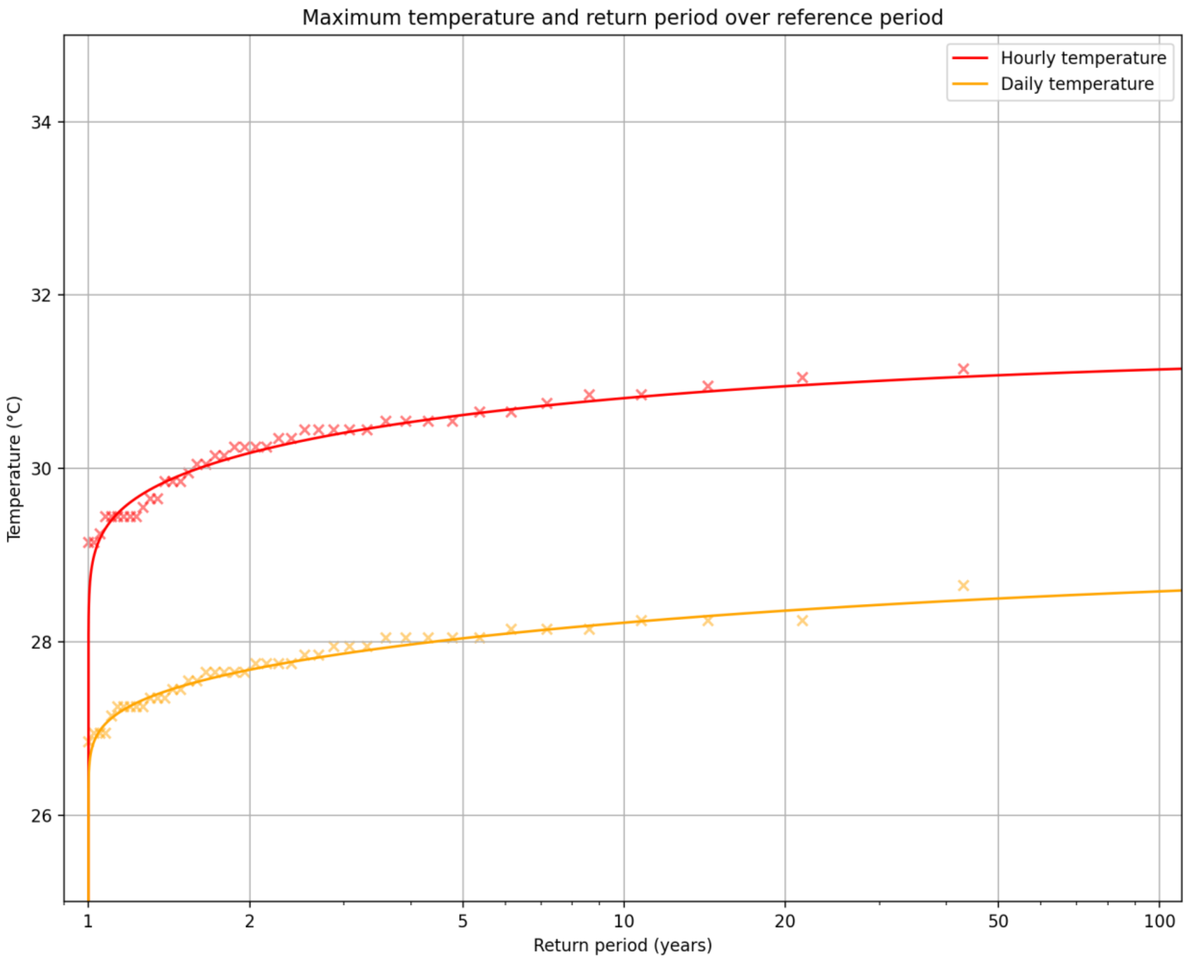


Figure 6: Return periods for maximum temperature on the reference period

RETURN PERIOD (years)	MAXIMUM TEMPERATURE (°C)	
	Hourly average	Daily average
5	30.6	28.0
10	30.8	28.2
20	31.0	28.4
50	31.1	28.5
100	31.1	28.6

Figure 7: Hourly and daily maximum temperatures for selected return periods

3. Future projections

Extreme heat waves are very likely to become more severe in the second half of the 21st century.

There is a broad consensus among the models on the evolution of heat extremes. For the high emission scenario (SSP5-8.5), all indicate an increase in maximum daily temperature in the coming years. For the intermediate scenario (SSP2-4.5), the trend should become significant in the near future.

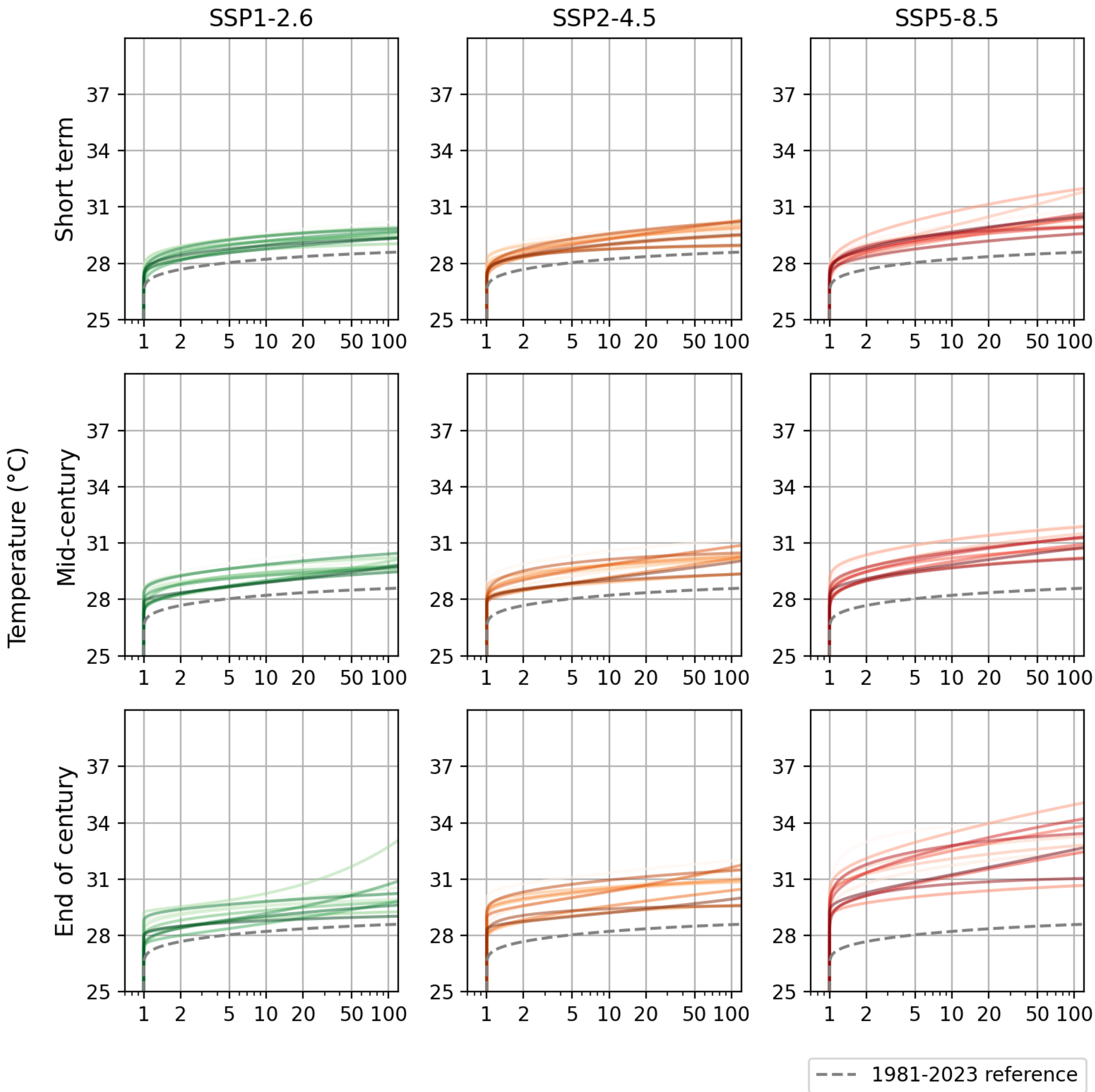


Figure 8: Daily maximum temperature, multimodel return level plots for selected time horizons

The evolution is similar for hourly temperatures. Most models suggest that maximum hourly temperature should evolve like the daily ones.

Based on the multimodel median, over the century, the maximum hourly temperature for a 100-year heat wave could increase by 0.4°C in a low emission scenario, 1.6°C in a medium emissions scenario and 4.0°C in a high emission scenario compared to 2000. The increase should be of the same order of magnitude for shorter return periods.

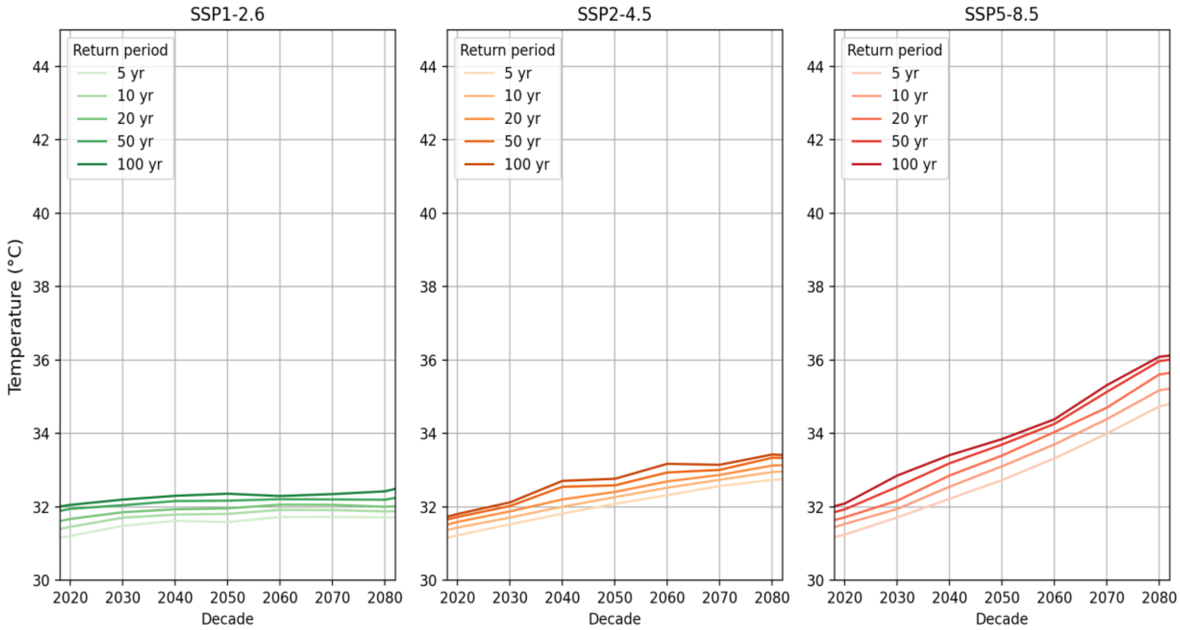


Figure 9: Evolution of hourly temperature for extreme heatwave based on multimodel median

For daily averaged temperatures, the 100-year heat wave could increase by 0.6°C in a low emission scenario, 1.8°C in a medium emissions scenario and 3.6°C in a high emission scenario. The increase should be of the same order of magnitude for shorter return periods:

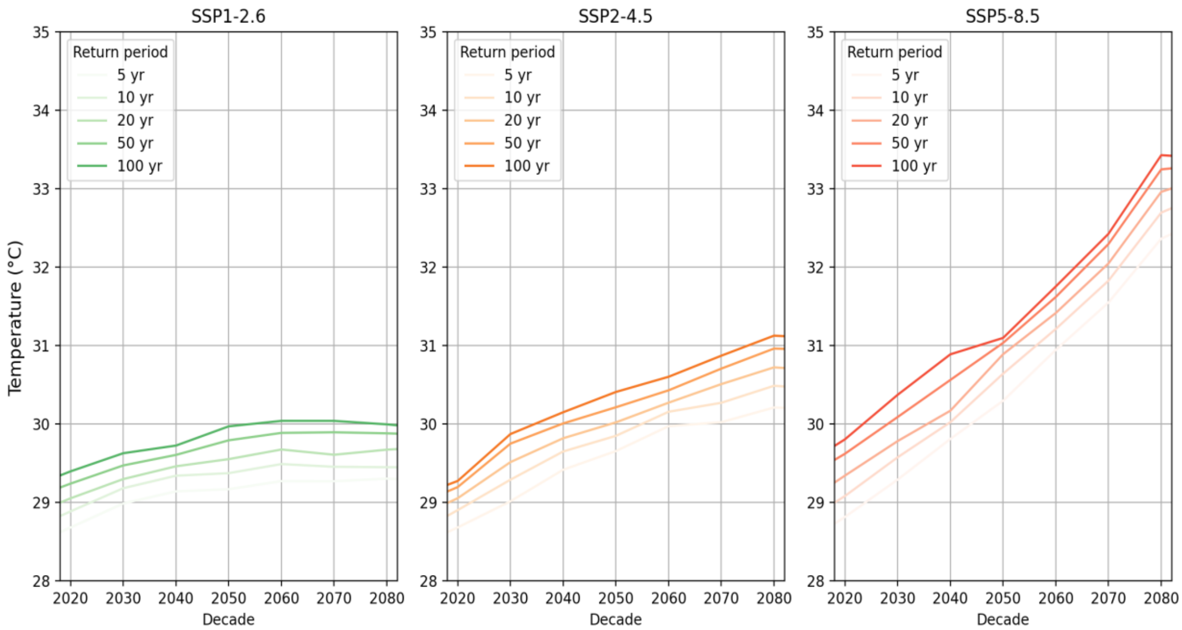


Figure 10: Evolution of daily temperature for extreme heatwave based on multimodel median

Minimum temperature

1. Overview of the data and methods used

The past climate is based on the closest data point of the ERA5 reanalysis on sea and the closest data point of the ERA5-Land reanalysis on land. The spatial resolution of these data are respectively 0.25 x 0.25° and 0.1 x 0.1°. Future climate projections are based on 12 models from the CMIP6 project[3]. Projections are downscaled and bias corrected using the past climate as a reference.
Temperature extremes for a given return time are evaluated from the known maxima and a Generalized extreme value distribution.

Please note that values for the reference period are based on reanalysis data, a widely used method for reconstructing past atmospheric conditions by combining observations and high-resolution weather models. Depending on specific local features, results may differ from in-situ observations or reanalysis corrected with in-situ observations.

All statistical fits presented in this chapter are obtained through an automated fitting process using the Generalized Extreme Value distribution with Maximum Likelihood Estimation. No manual fine-tuning or adjustment has been applied to individual cases. As a result, some fits may appear unusual or less than ideal. However, these fits remain valuable for a broad, qualitative understanding of trends across different models and scenarios.

2. Reference climate

Over the reference period (1981-2023), the minimum hourly temperature observed was 22.4°C in February 2001 and the minimum daily temperature was 23.9°C in February 2001. Over these 30 years, the minimum hourly temperature was 23.3°C on annual average and the minimum daily temperature 24.5°C.

[3] The models used are listed in Appendix A.

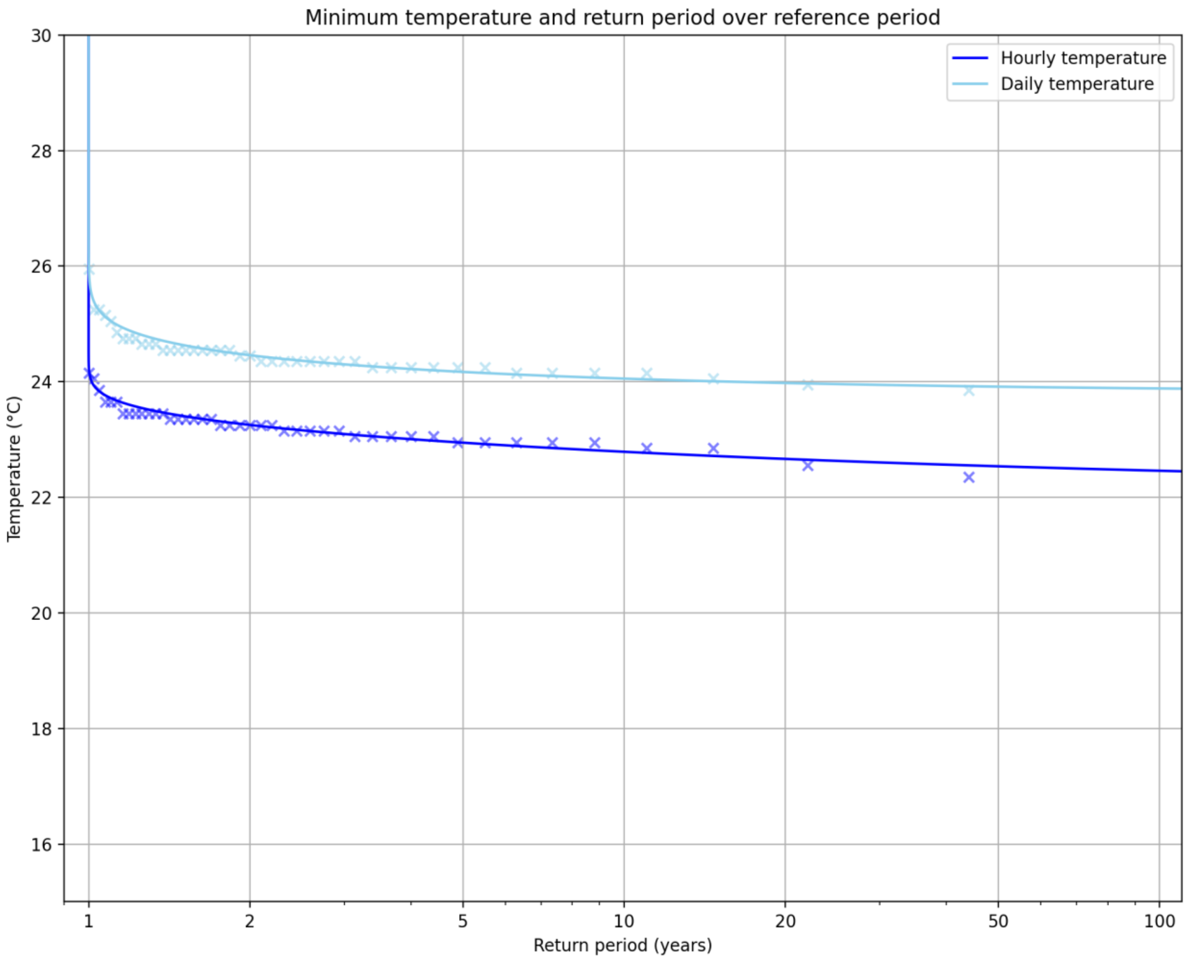


Figure 11: Return periods for minimum temperature on the reference period

RETURN PERIOD (years)	MINIMUM TEMPERATURE (°C)	
	Hourly average	Daily average
5	22.9	24.2
10	22.8	24.0
20	22.7	24.0
50	22.5	23.9
100	22.5	23.9

Figure 12: Hourly and daily minimum temperatures for selected return periods

3. Future projections

Extreme cold spells are very likely to become less severe in the second half of the 21st century.

There is a broad consensus among the models on the evolution of minimum daily temperature. Most models indicate an increase overall in minimum daily temperature for all scenarios. For scenario SSP1-2.6, no trend is seen around 2030 and 2070, while increasing trends are observed around 2050. For scenario SSP2-4.5, no trend is seen around 2030 and 2070, while increasing trends are observed around 2050. For scenario SSP5-8.5, no trend is seen around 2030 and 2070, while increasing trends are observed around 2050.

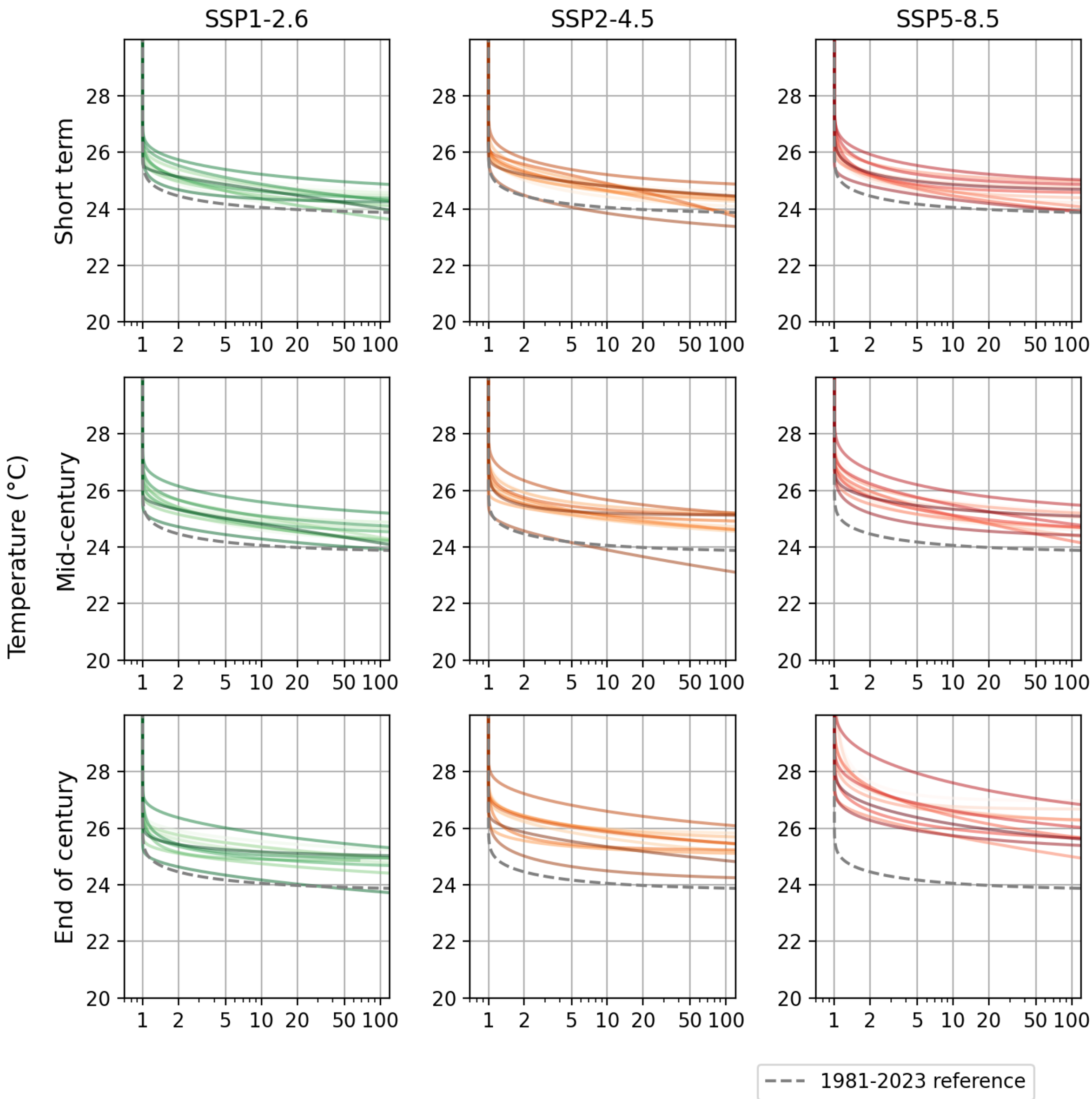


Figure 13: Daily minimum temperature, multimodel return level plots for selected time horizons

Based on the best estimate, over the century, the minimum hourly temperature for a 100-year cold spell could increase by 1.0°C in a low emission scenario, 2.0°C in a medium emissions scenario and 2.6°C in a high emission scenario.

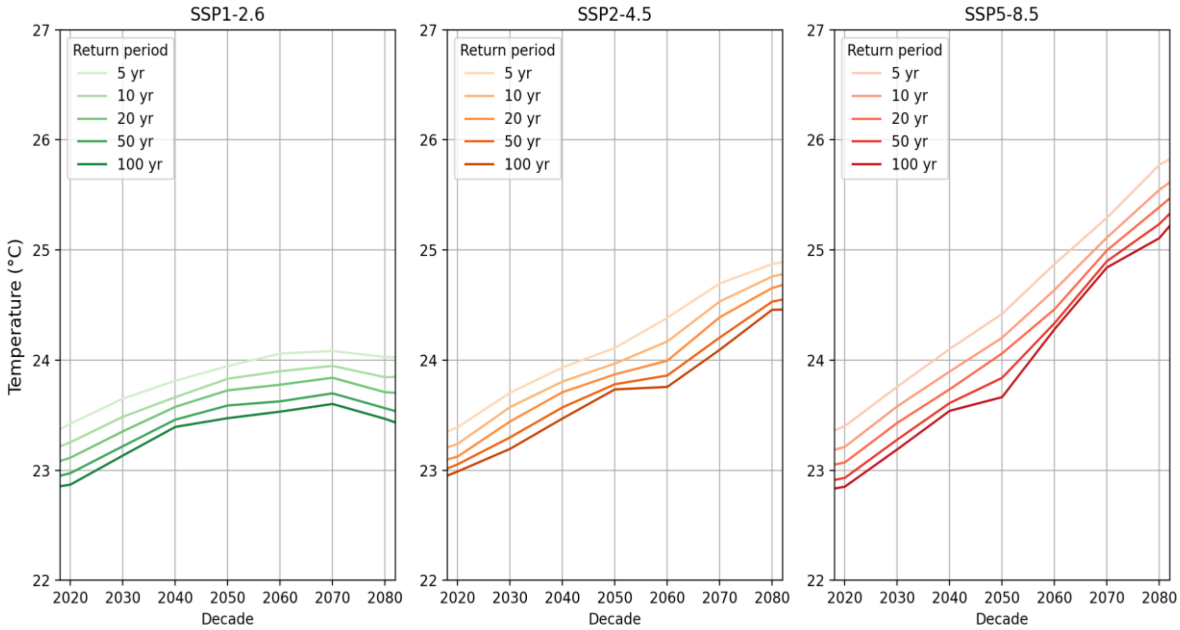


Figure 14: Evolution of hourly temperature for cold spells based on multimodel median

For daily averaged temperatures, the 100-year cold spell could increase by 1.0°C in a low emission scenario, 1.7°C in a medium emissions scenario and 2.5°C in a high emission scenario. The increase should be of a similar order of magnitude, though some deviation is possible:

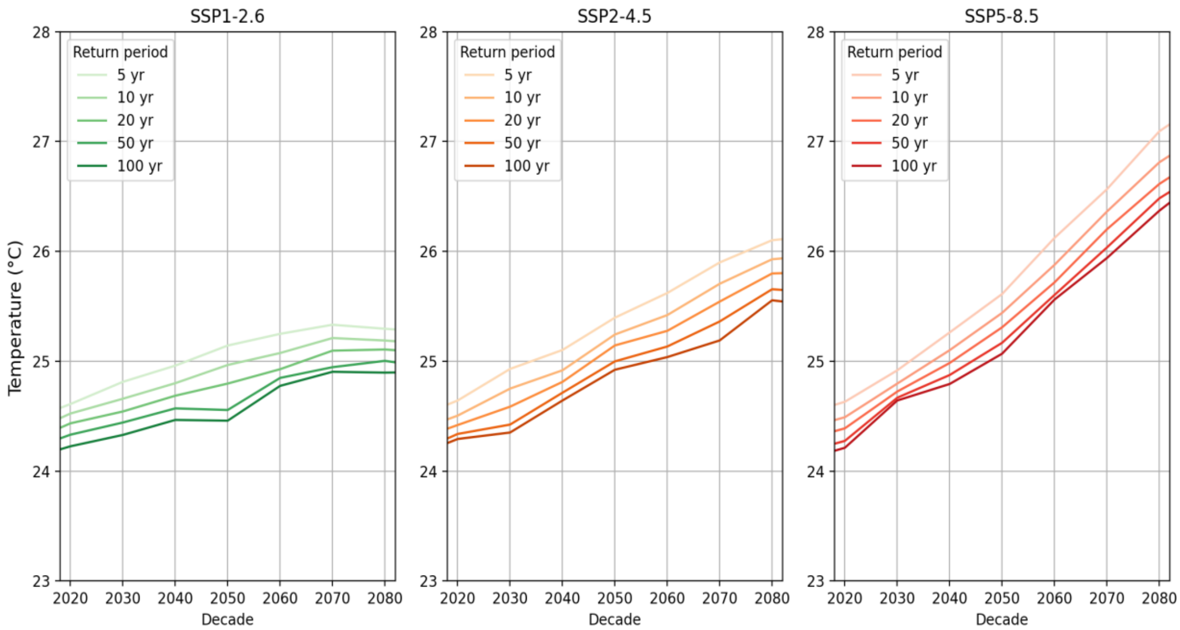


Figure 15: Evolution of daily temperature for cold spells based on multimodel median

Average precipitations

1. Overview of the data and methods used

The past climate is based on the closest data point of the ERA5 reanalysis on sea and the closest data point of the ERA5-Land reanalysis on land. The spatial resolution of these data are respectively 0.25 x 0.25° and 0.1 x 0.1°. Future climate projections are based on 12 models from the CMIP6 project[4]. Projections are downscaled and bias corrected using the past climate as a reference.

Please note that values for the reference period are based on reanalysis data, a widely used method for reconstructing past atmospheric conditions by combining observations and high-resolution weather models. Depending on specific local features, results may differ from in-situ observations or reanalysis corrected with in-situ observations.

2. Reference climate and observed trend

Over the reference period (1981-2023), the median annual precipitations were 2545 mm with a 90% confidence interval extending from 1937 to 3449 mm/year. On average 18 % of the days were without precipitations (daily total ≤ 1 mm/day).

No significative trend is present over the reference period.

[4] The models used are listed in Appendix A.

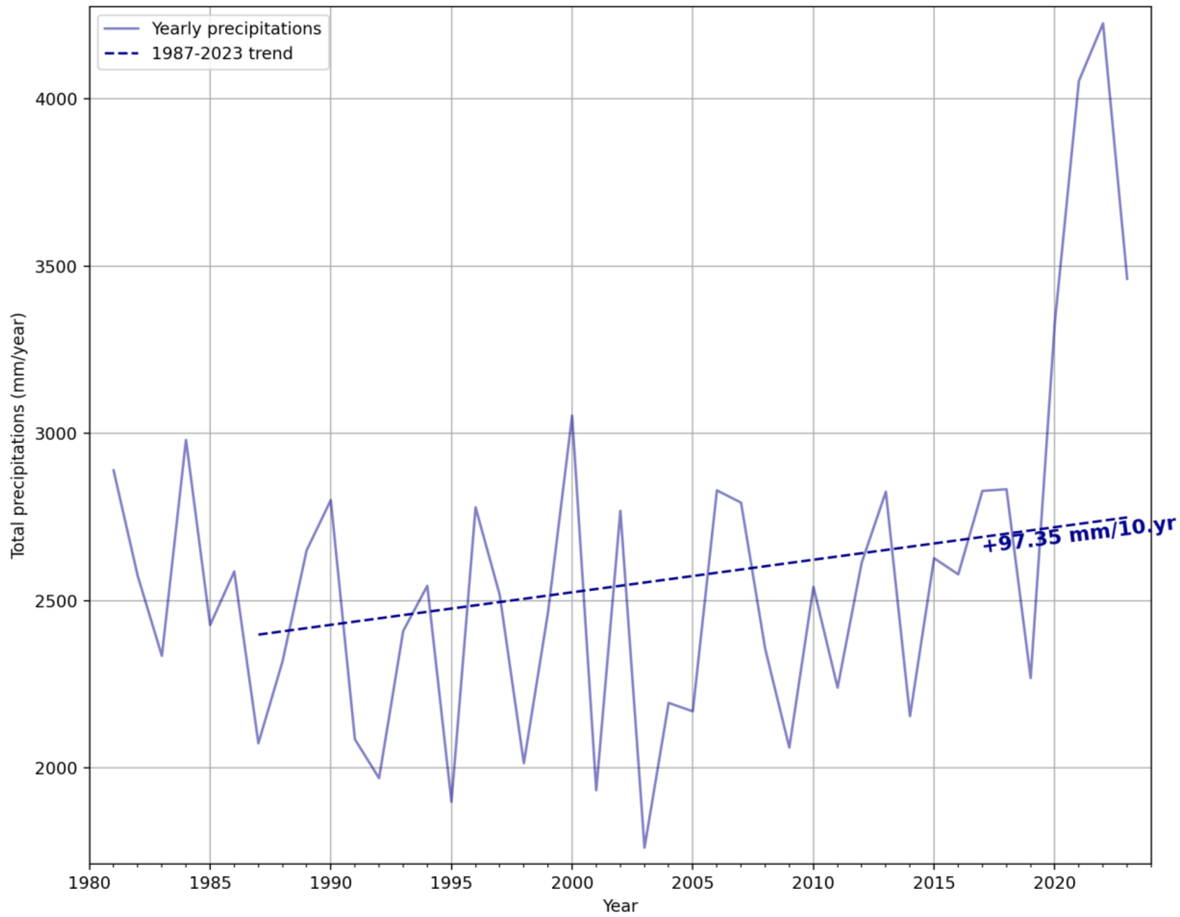


Figure 16: Total annual precipitations and trend

3. Future projections

Average annual precipitations are not expected to vary significantly during the 21st century.

	Scenario			Uncertainties
	SSP1-2.6 (Low GHG emissions scenario)	SSP2-4.5 (Intermediate GHG emissions scenario)	SSP5-8.5 (Very high GHG emissions scenario)	
Reference (1985-2014)	2545 mm/year			
Short term (2020-2049)	2470 mm/year [1803, 3312]	2445 mm/year [1760, 3384]	2389 mm/year [1767, 3159]	Medium
Mid-century (2035-2064)	2465 mm/year [1826, 3384]	2404 mm/year [1753, 3233]	2337 mm/year [1687, 3068]	Low
End of century (2070-2099)	2532 mm/year [1839, 3557]	2446 mm/year [1775, 3365]	2166 mm/year [1544, 3011]	High

Figure 17: Total annual precipitations projections (median and 90% confidence interval)

Over the next three decades, the best estimate of annual total precipitations is approximately 2490 mm/year with little influence from the emissions scenario. This is consistent with the trend observed over the last 3 decades.

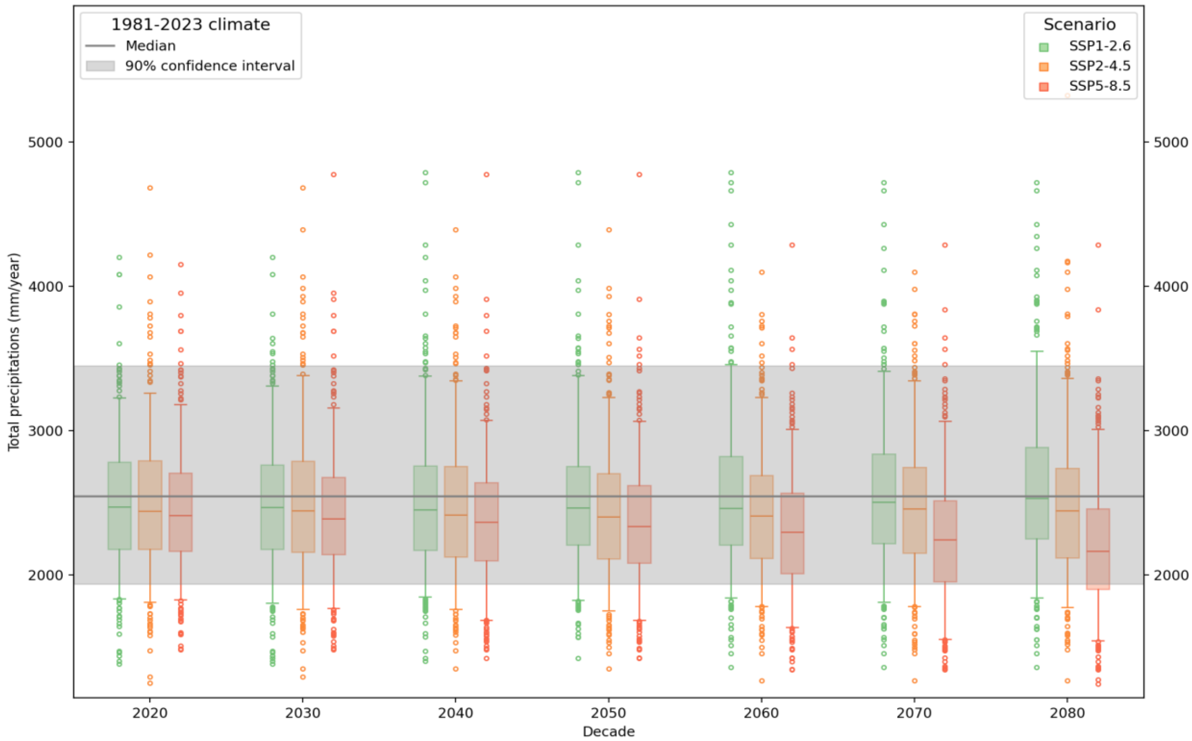


Figure 18 : Total annual precipitations, multimodel boxplot

In the second half of the century, the total annual rainfall pattern is expected to differ between the emissions scenarios.

4. Individual model projections

All models indicate that the total annual rainfall will remain close to the current climate median and in most cases within its the 90% confidence interval.

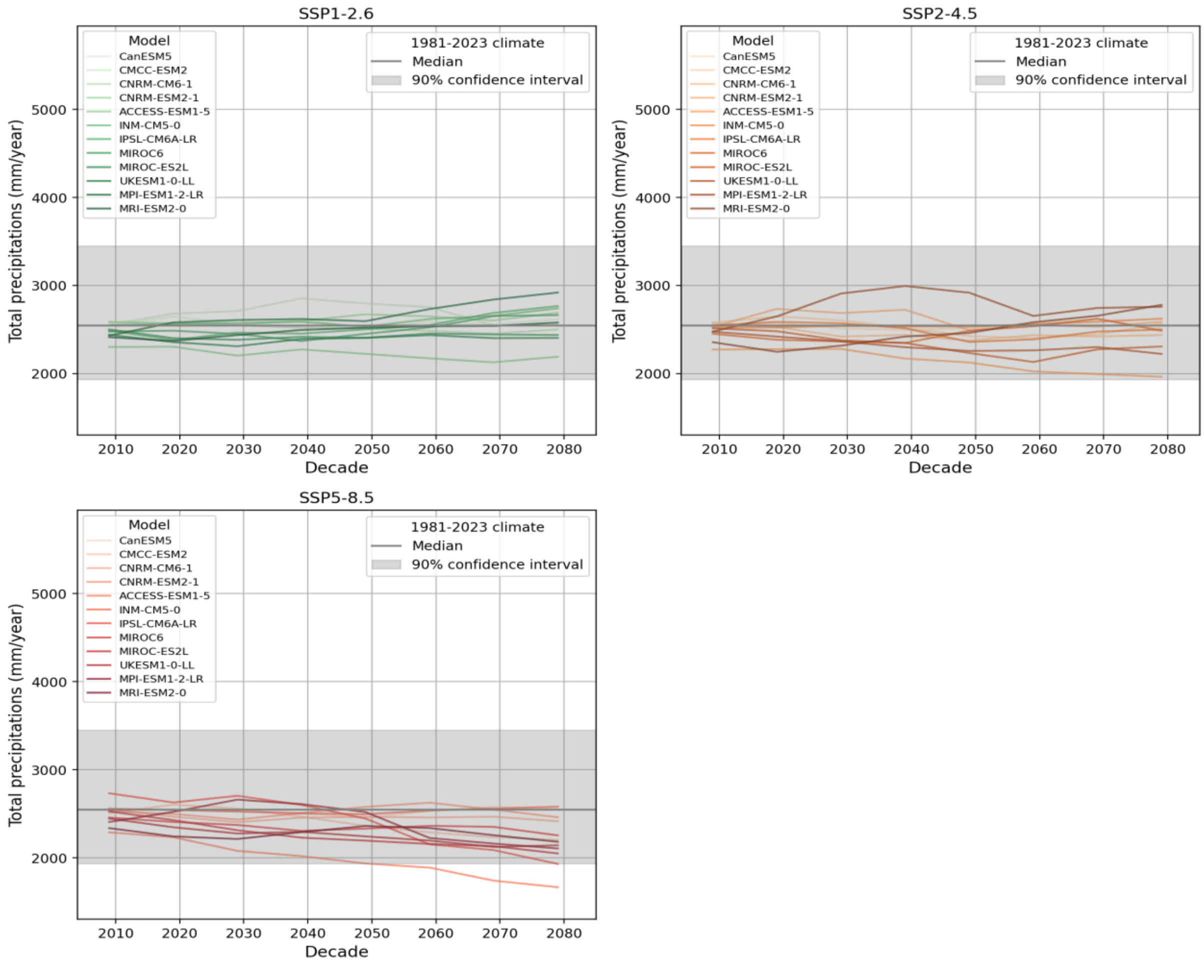


Figure 19: Total annual precipitations by decade (30 year rolling average)

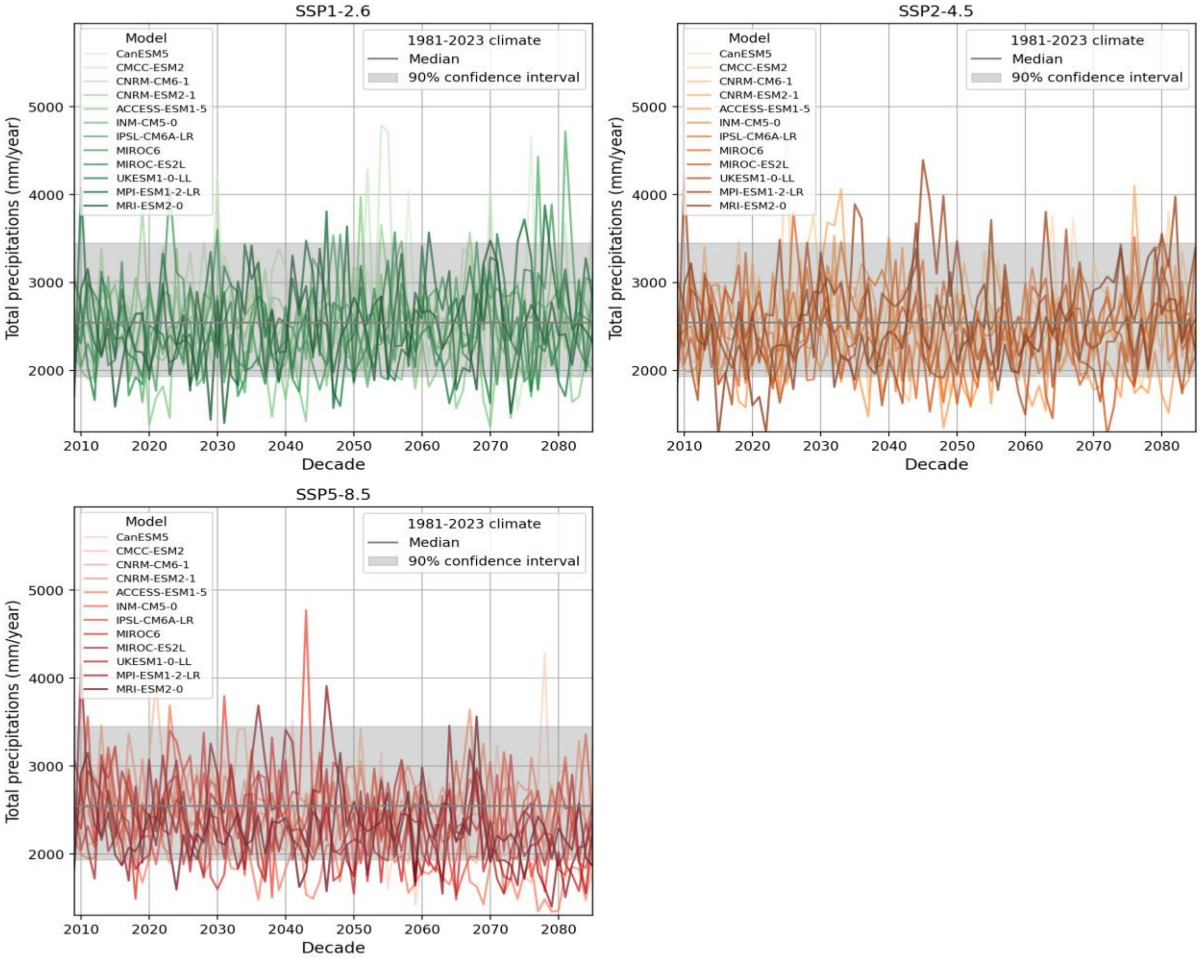


Figure 20: Total annual precipitations simulations

Maximum daily precipitations

1. Overview of the data and methods used

The past climate is based on the closest data point of the ERA5 reanalysis on sea and the closest data point of the ERA5-Land reanalysis on land. The spatial resolution of these data are respectively 0.25 x 0.25° and 0.1 x 0.1°. Future climate projections are based on 12 models from the CMIP6 project[5]. Projections are downscaled and bias corrected using the past climate as a reference.

Precipitations extremes for a given return time are evaluated from the known maxima and a Generalized extreme value distribution.

Please note that values for the reference period are based on reanalysis data, a widely used method for reconstructing past atmospheric conditions by combining observations and high-resolution weather models. Depending on specific local features, results may differ from in-situ observations or reanalysis corrected with in-situ observations.

All statistical fits presented in this study are obtained through an automated fitting process using the Generalized Extreme Value distribution with Maximum Likelihood Estimation. No manual fine-tuning or adjustment has been applied to individual cases. As a result, some fits may appear unusual or less than ideal. However, these fits remain valuable for a broad, qualitative understanding of trends across different models and scenarios.

2. Reference climate

Over the reference period (1981-2023), the maximum amount of rainfall during a single day was 206 mm/day in May 2021. Over the last 30 years, the wettest day received 98 mm/day on average.

[5] The models used are listed in Appendix A.

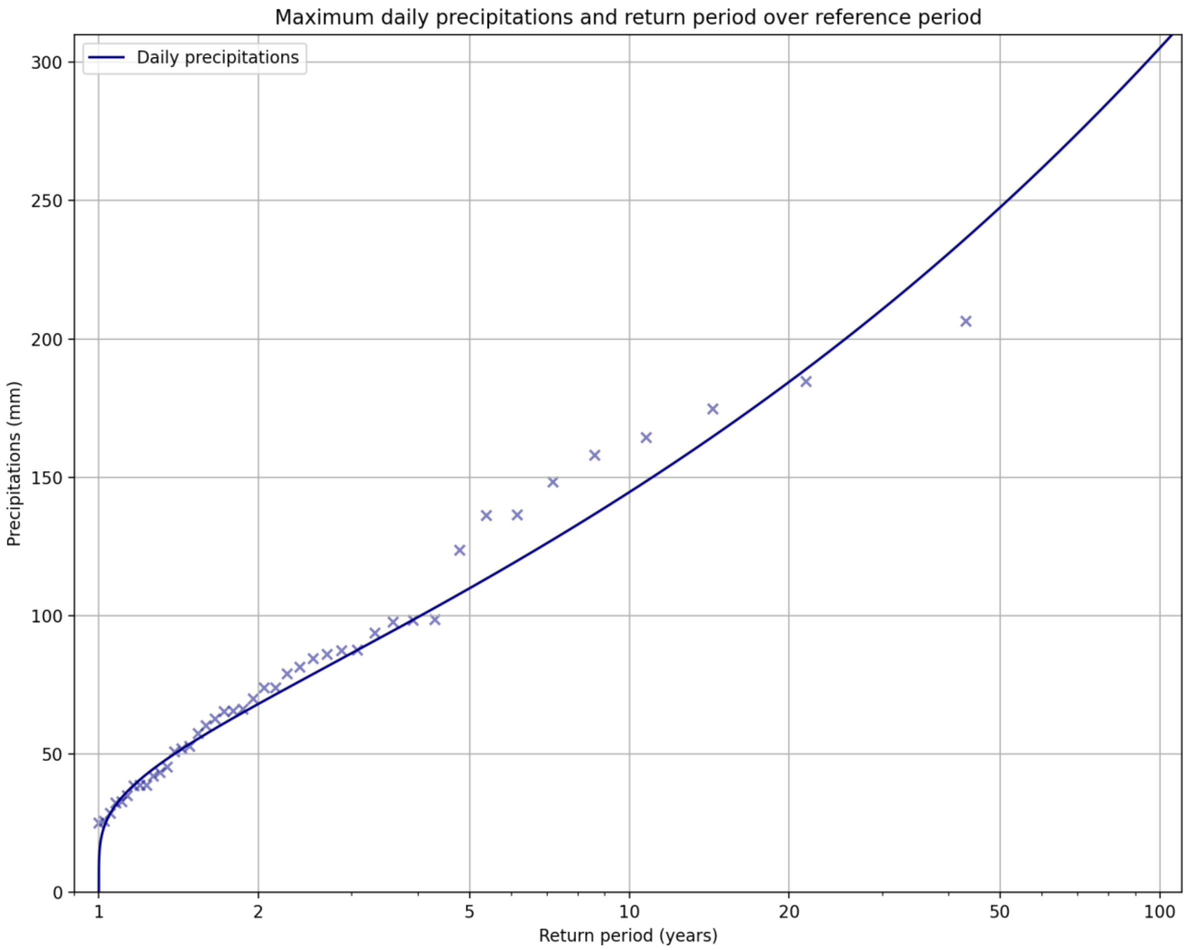


Figure 21: Return periods for maximum daily precipitations over the reference period

Return period	Maximum daily precipitations
5	110 mm/day
10	145 mm/day
20	184 mm/day
50	248 mm/day
100	305 mm/day

Figure 22: Maximum daily precipitations for selected return periods

3. Future projections

The severity of extreme precipitations events over the 21st century is uncertain.

There is a non consensus among the models on the evolution of precipitations extremes. Extreme precipitations levels for short return periods (≤ 10 years) are diverging over the next decades. Furthermore, projections are diverging for longer return periods and for longer time horizons.

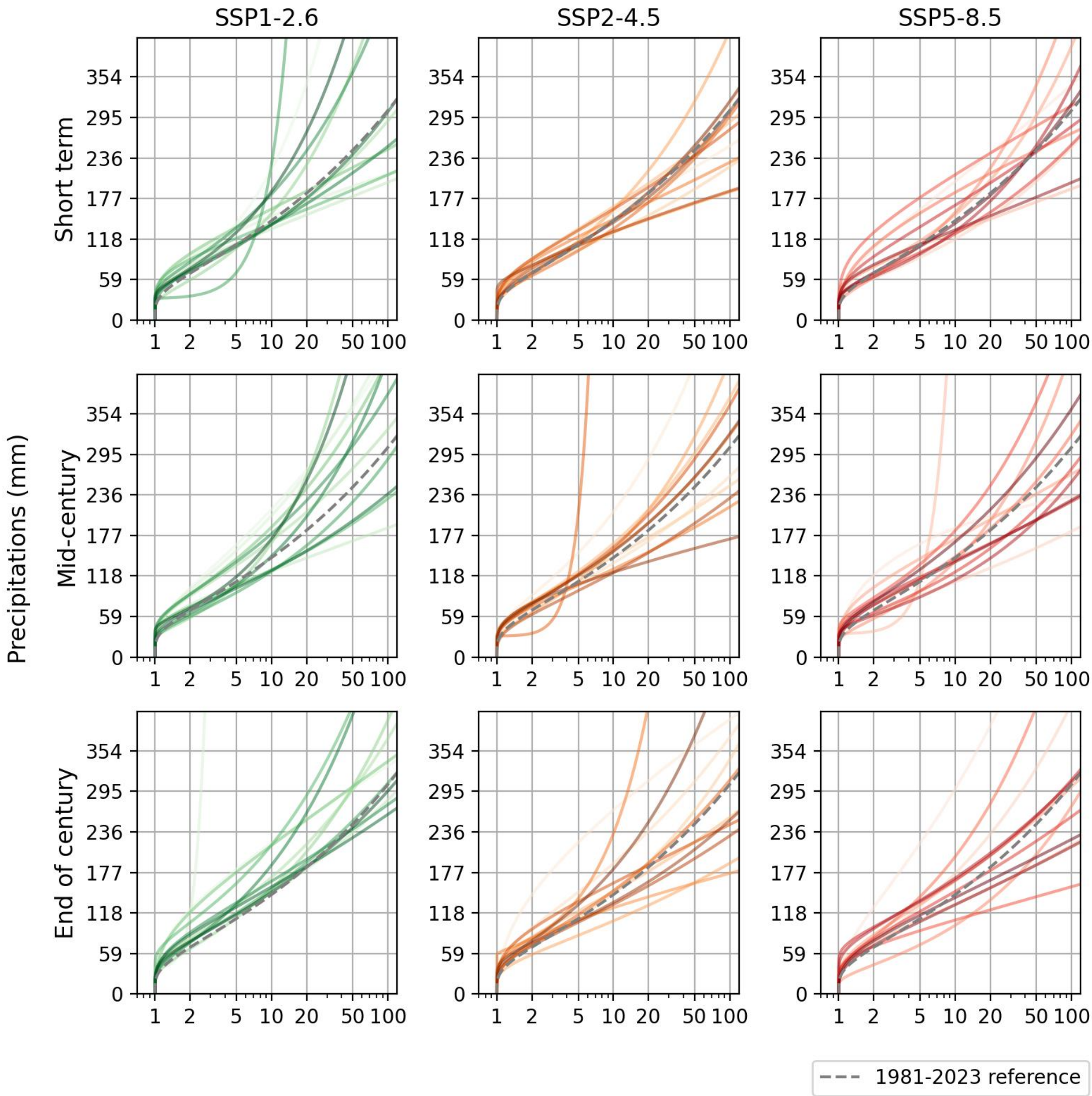


Figure 23: Daily precipitations, multimodel return level plots for selected time horizons

Multimodel medians tend to remain stable but values are to be considered with care as there is little consensus among projections.

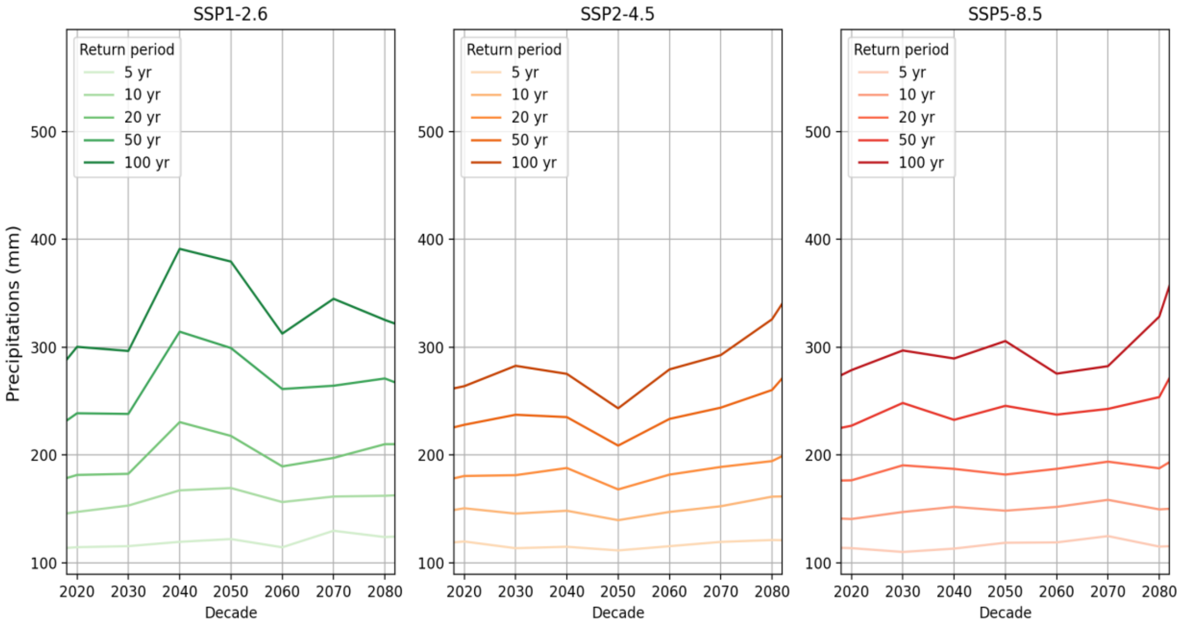


Figure 24: Evolution of daily precipitations for extreme rainfall events based on multimodel median

Wind speed

1. Brief overview of the data and methods used

The past climate is based on the closest data point of the ERA5 reanalysis on sea and the closest data point of the ERA5-Land reanalysis on land. The spatial resolution of these data are respectively 0.25 x 0.25° and 0.1 x 0.1°. Future climate projections are based on 12 models from the CMIP6 project[6]. Projections are downscaled and bias corrected using the past climate as a reference.

Wind speeds over 10 minutes, 1 minute and 3 seconds are extrapolated using an empirical model from the ISO 19901-1:2015.
The wind speed extremes for a given return time are evaluated from the known maxima and a generalized extreme value distribution. The 95th centile is used as an estimate of the wind speed corresponding to a 1-yr return period.

Please note that values for the reference period are based on reanalysis data, a widely used method for reconstructing past atmospheric conditions by combining observations and high-resolution weather models. Depending on specific local features, results may differ from in-situ observations or reanalysis corrected with in-situ observations.

All statistical fits presented in this study are obtained through an automated fitting process using the Generalized Extreme Value distribution with Maximum Likelihood Estimation. No manual fine-tuning or adjustment has been applied to individual cases. As a result, some fits may appear unusual or less than ideal. However, these fits remain valuable for a broad, qualitative understanding of trends across different models and scenarios.

2. Reference climate

Over the reference period (1981-2023), the maximum wind speed observed over a 1-hour period at 10 metres was 9.7 $m.s^{-1}$ in March 2022.
This is equivalent to a maximum wind speed of 10.3 $m.s^{-1}$ over a 10-minute period, 11.1 $m.s^{-1}$ over 1 minute and 12.1 $m.s^{-1}$ over 3 seconds.

[6] The models used are listed in Appendix A.

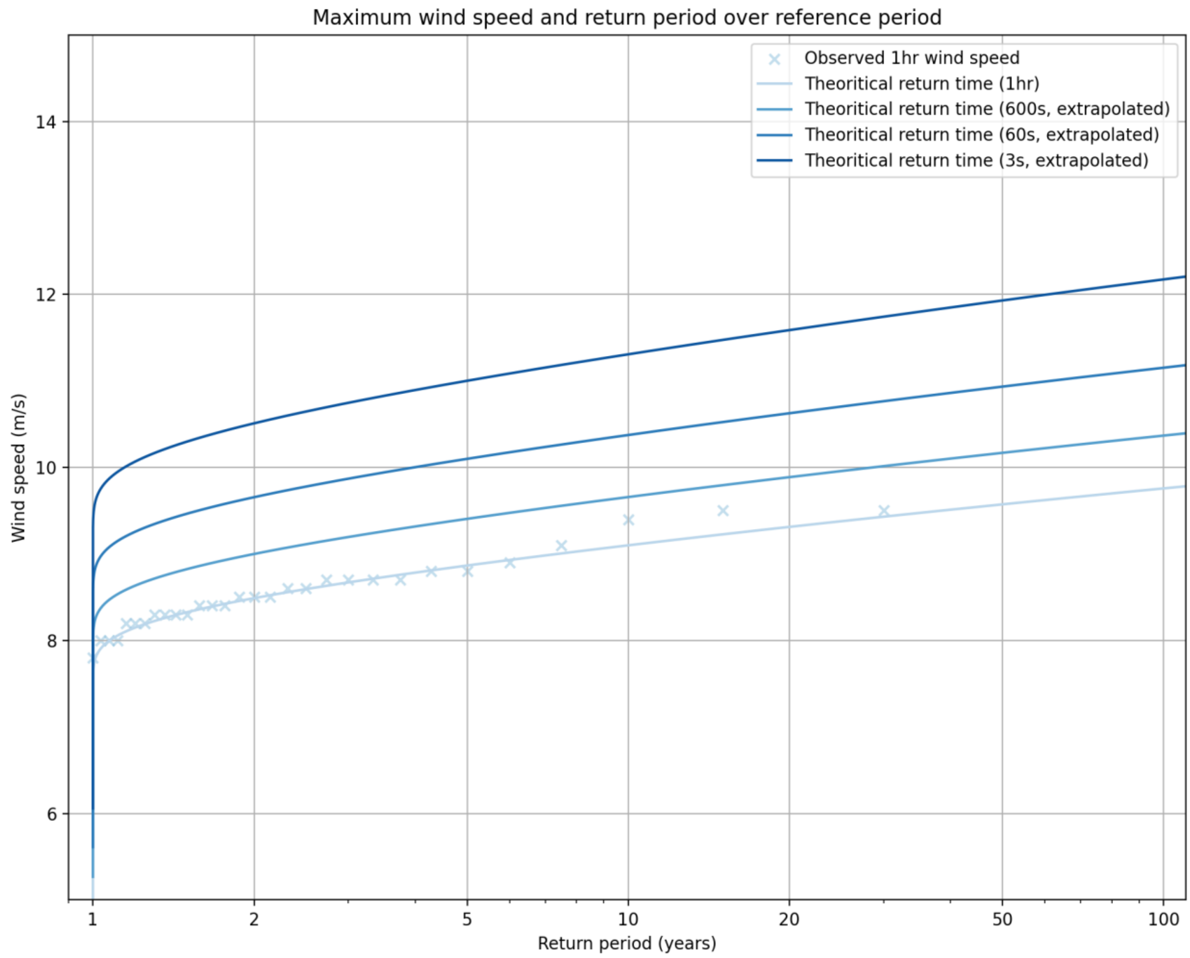


Figure 25: Return periods for maximum wind speeds on the reference period

Based on observations during the reference period, the maximum wind speed for a 100-year return period can be estimated at approximately 10.4 $m.s^{-1}$ over a 10-minute period, 11.2 $m.s^{-1}$ over 1 minute and 12.3 $m.s^{-1}$ over 3 seconds.

RETURN PERIOD	THEORETICAL MAXIMUM WIND SPEED ($m.s^{-1}$)			
	1 hour	10 minutes	1 minute	3 seconds
1 (95th centile)	7.5	7.9	8.5	9.2
5	9.0	9.5	10.2	11.1
10	9.2	9.8	10.5	11.4
20	9.4	10.0	10.7	11.7
50	9.7	10.3	11.0	12.0
100	9.8	10.4	11.2	12.3

Figure 26: Maximum wind speeds for selected return periods

3. Future projections

The evolution of extreme wind speeds over the 21st century shows no significant trend. There is a non consensus among the models on the evolution of extreme wind speed. Extreme wind speed levels should remain stable over the next decades for short return periods (≤ 10 years). Futhermore, projections should remain stable with little deviation for longer return periods and for farther time horizons.

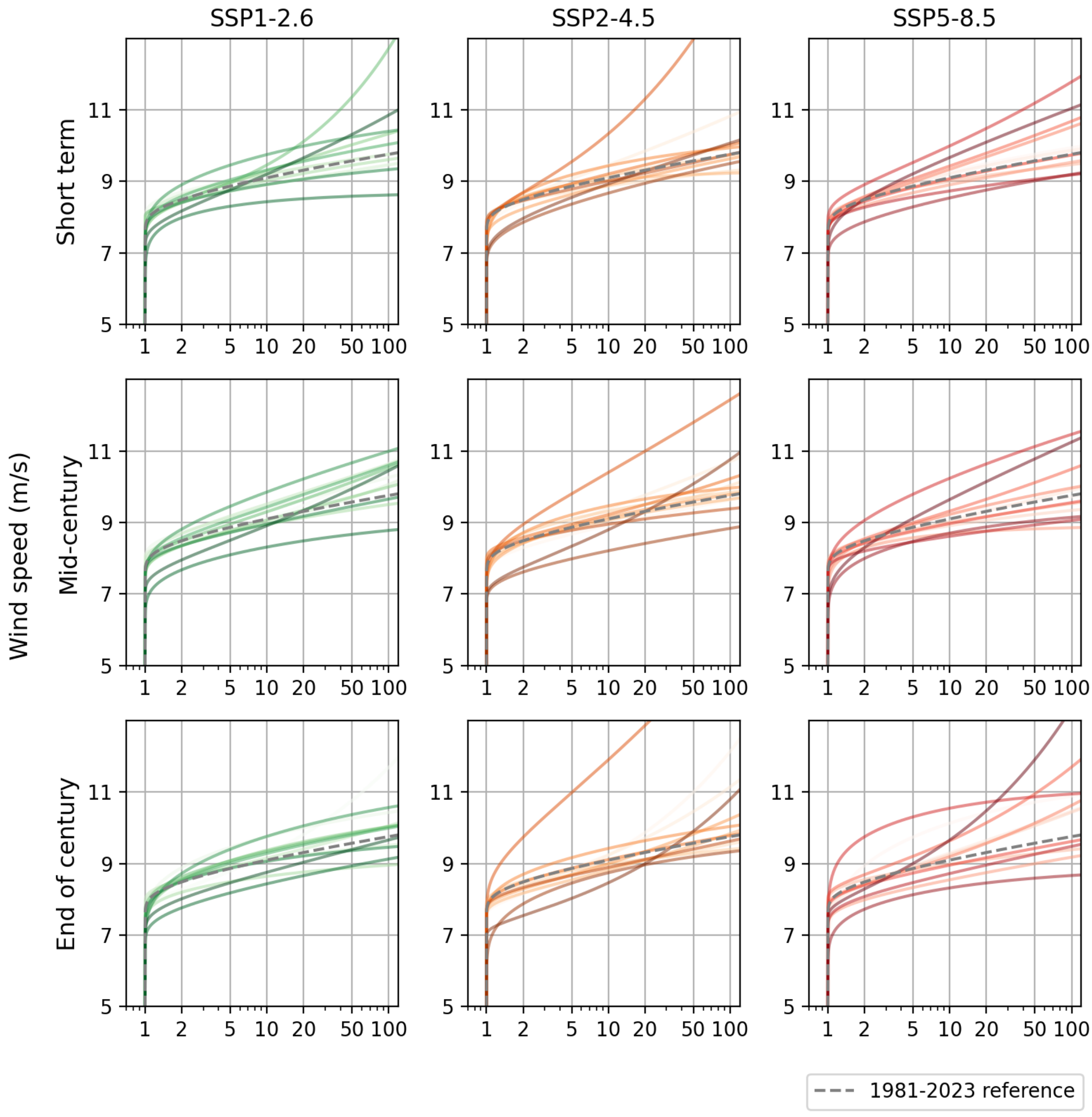


Figure 27: 1-hour maximum wind speed, multimodel return level plots for selected time horizons

Based on the multimodel median, over the century, the 1-hour maximum wind speed for a 100-year event could be modified by approximately 0.1 $m.s^{-1}$ in a high emission scenario and 0.3 $m.s^{-1}$ in a low emissions scenario.

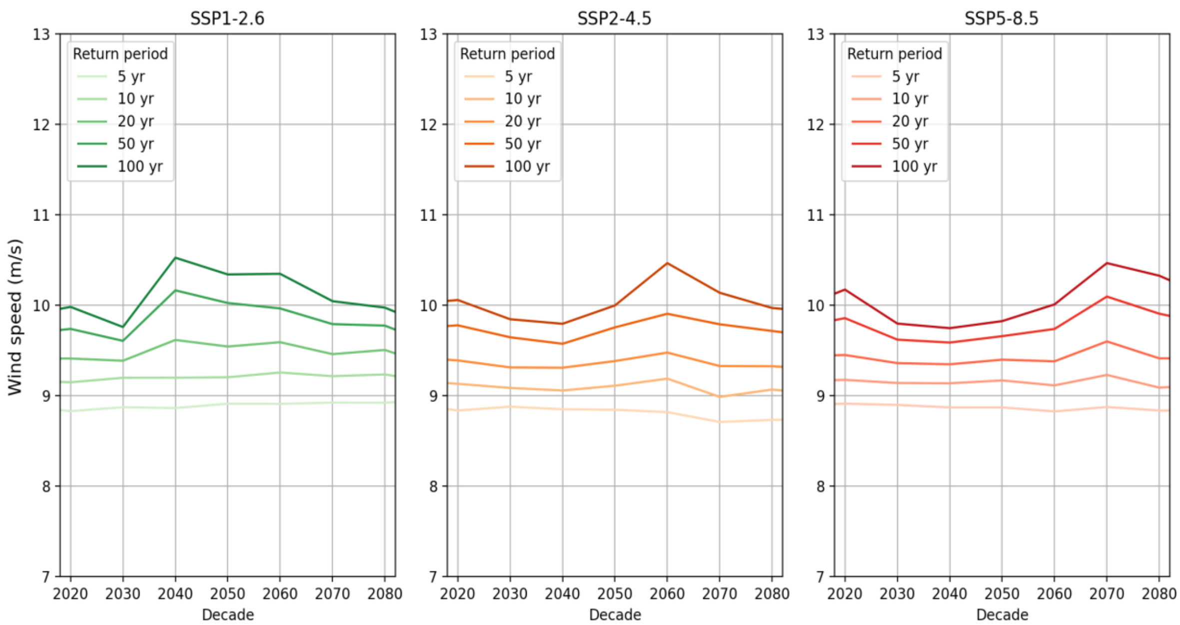


Figure 28: Evolution of extreme 1-hr wind speed based on multimodel median

EMISSIONS SCENARIO	MID-CENTURY 100-YR MAXIMUM WIND SPEED (m.s^{-1})			
	1 hour	10 minutes	1 minute	3 seconds
SSP1-2.6	10.3	11.0	11.8	12.9
SSP2-4.5	10.0	10.6	11.4	12.5
SSP5-8.5	9.8	10.4	11.2	12.3

Figure 29: 100-year return period extreme wind at the mid-21st century based on multi-model median

EMISSIONS SCENARIO	END OF CENTURY 100-YR MAXIMUM WIND SPEED (m.s^{-1})			
	1 hour	10 minutes	1 minute	3 seconds
SSP1-2.6	10.0	10.6	11.4	12.5
SSP2-4.5	10.0	10.6	11.4	12.5
SSP5-8.5	10.3	11.0	11.8	12.9

Figure 30: 100-year return period extreme wind at the end of the 21st century based on multi-model median

Sea level

1. Overview of the data and methods used

Future sea level is based on the closest data point of the IPCC's 6th assessment report's projections. The spatial resolution of these data is 1°.

Box 2: Assumptions for sea level projections

While there is a high level of confidence that sea levels will continue to rise in the coming decades and centuries due to the warming of the Earth's atmosphere and oceans caused by human activities, the exact level at some point in the future is still uncertain.

To reflect those uncertainties, the IPCC's Sixth Assessment Report provide two sets of projections:

- "Medium confidence" projections include only processes that can be projected skillfully with at least medium confidence,
- "Low confidence" projections consider processes whose quantification is highly uncertain regarding the timing of their possible onset and/or their effect on sea level rise.

Low confidence projections are on average higher and the gap between the two projections increases with time and greenhouse gases concentrations.

The projection to be used depends on the lifespan of the project, on its ability to adapt to a faster-than-expected sea level rise, and on the level of risk that is deemed acceptable.
According to the IPCC, stakeholders that are risk tolerant (e.g., those planning for investments that can be easily adapted to unforeseen conditions) may prefer to use projections in the medium confidence range while those with a low risk tolerance (e.g., those planning for long-term investment in critical infrastructure) may wish to consider sea level rise that falls within the high-end scenario.

2. Best estimate

Based on median projections, by mid-century, sea level is likely to have risen by about 23 centimeters compared to the average level over the period 1985-2014. This result is not very sensitive to the emission scenario or assumptions used.

By 2080, the sea level could have risen by about 0.4 to 0.6 meter depending on the level of emissions and the assumptions made.

3. Medium confidence projections

Taking into account only processes that can be modeled with medium or high confidence, the median projection for sea level by 2050 compared to the average from 1985-2014 is expected to be approximately 23 centimeters with the upper bound of the 90% confidence interval around 40 centimeters.

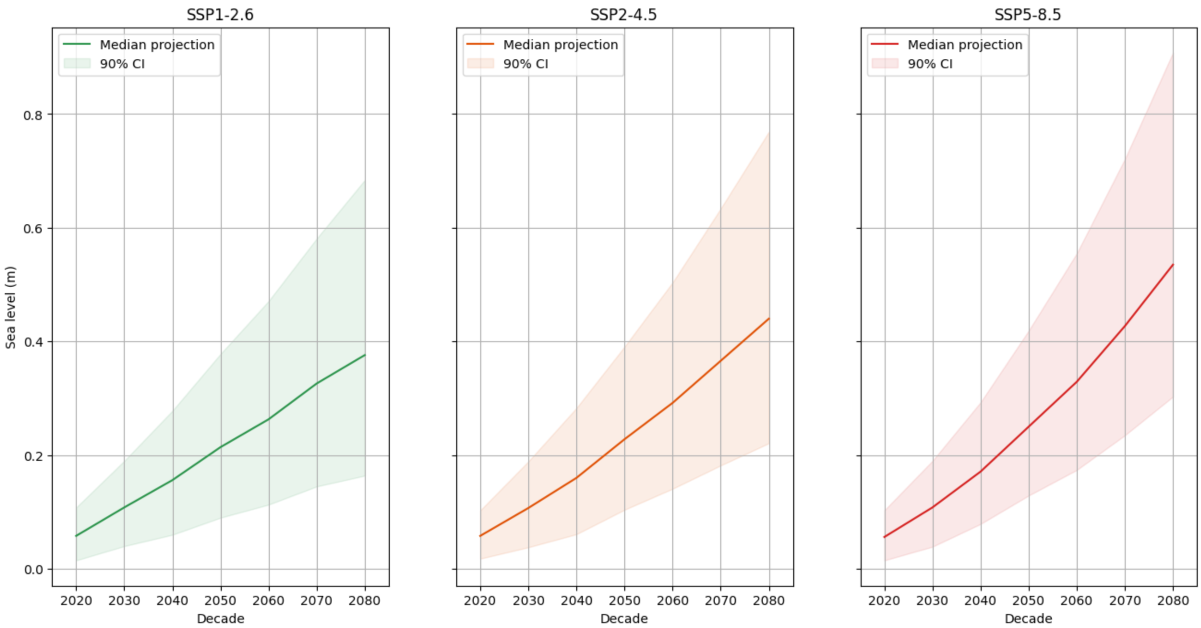


Figure 31: Sea level compared to 1985-2014 average, medium confidence projections

The influence of emission levels remains limited in the second half of the century. In 2080, the median projection varies from 38 to 54 centimeters, depending on the scenario, with the upper bound of the confidence interval between 68 and 91 centimeters.

	Scenario		
	SSP1-2.6 (Low GHG emissions scenario)	SSP2-4.5 (Intermediate GHG emissions scenario)	SSP5-8.5 (Very high GHG emissions scenario)
Mid-century (2050)	21 cm [9, 38]	23 cm [10, 39]	25 cm [13, 42]
End of century (2080)	38 cm [16, 68]	44 cm [22, 77]	54cm [30, 91]

Figure 32: Sea level medium confidence projection compared to 1985-2014 average (median and 90% confidence interval)

4. Low confidence projections

Taking into account all the processes, even when their modeling is still uncertain, does not change significantly the median projection for 2050 but the 90% confidence interval is wider, with its upper between 46 and 58 centimeters depending on the emissions scenario.

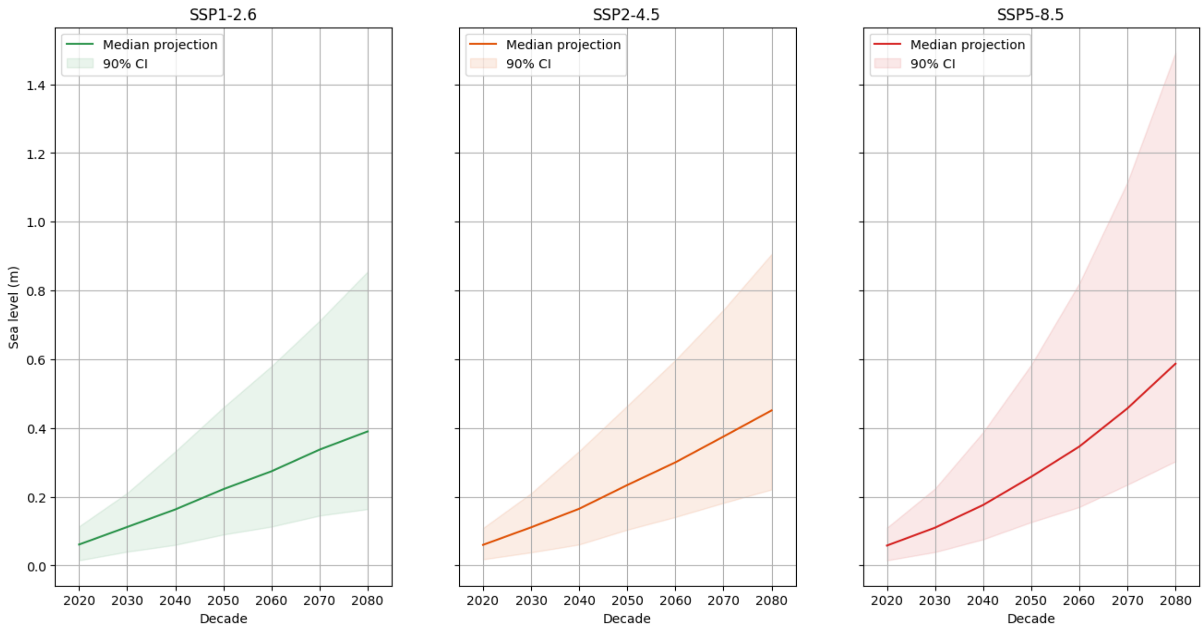


Figure 33: Sea level compared to 1985-2014 average, low confidence projections

With these assumptions, sea level is projected to rise at approximately the same rate in the second half of the century: the median projection for 2080 ranges from 39 to 59 centimeters depending on the emissions scenario. The uncertainties are however larger, especially in high emissions scenarios: in the high-end scenario, the upper bound of the 90% confidence interval reaches 149 centimeters.

	Scenario		
	SSP1-2.6 (Low GHG emissions scenario)	SSP2-4.5 (Intermediate GHG emissions scenario)	SSP5-8.5 (Very high GHG emissions scenario)
Mid-century (2050)	22 cm [9, 46]	23 cm [10, 46]	26 cm [13, 58]
End of century (2080)	39 cm [16, 86]	45 cm [22, 91]	59 cm [30, 149]

Figure 34: Sea level low confidence projection compared to 1985-2014 average (median and 90% confidence interval)

Significant wave height

1. Brief overview of the data and methods used

The past climate is based on the closest data point of the ERA5 reanalysis on sea. The spatial resolution of these data is 0.25 x 0.25°. Future climate projections are based on 8 models from the CSIRO *CMIP6 global wind-wave 21st century climate projections* project[7]. Projections are downscaled and bias corrected using the past climate as a reference.

The significant wave height extremes for a given return time are evaluated from the known maxima and a generalized extreme value distribution. The 95th centile is used as an estimate of the significant wave height corresponding to a 1-yr return period.

Please note that values for the reference period are based on reanalysis data, a widely used method for reconstructing past atmospheric conditions by combining observations and high-resolution weather models. Depending on specific local features, results may differ from in-situ observations or reanalysis corrected with in-situ observations.

All statistical fits presented in this study are obtained through an automated fitting process using the Generalized Extreme Value distribution with Maximum Likelihood Estimation. No manual fine-tuning or adjustment has been applied to individual cases. As a result, some fits may appear unusual or less than ideal. However, these fits remain valuable for a broad, qualitative understanding of trends across different models and scenarios.

Given the limited availability of projections of significant wave heights, a specific subset - in this case, that of the CSIRO - was used. This implies that the models and scenarios employed in this section may differ from those specified by ClimateVision users.

2. Reference climate

Over the reference period (1985-2014), the maximum significant wave height observed over a was 2.5 m in February 1996.

[7] hdl.handle.net/102.100.100/601698?index=1.

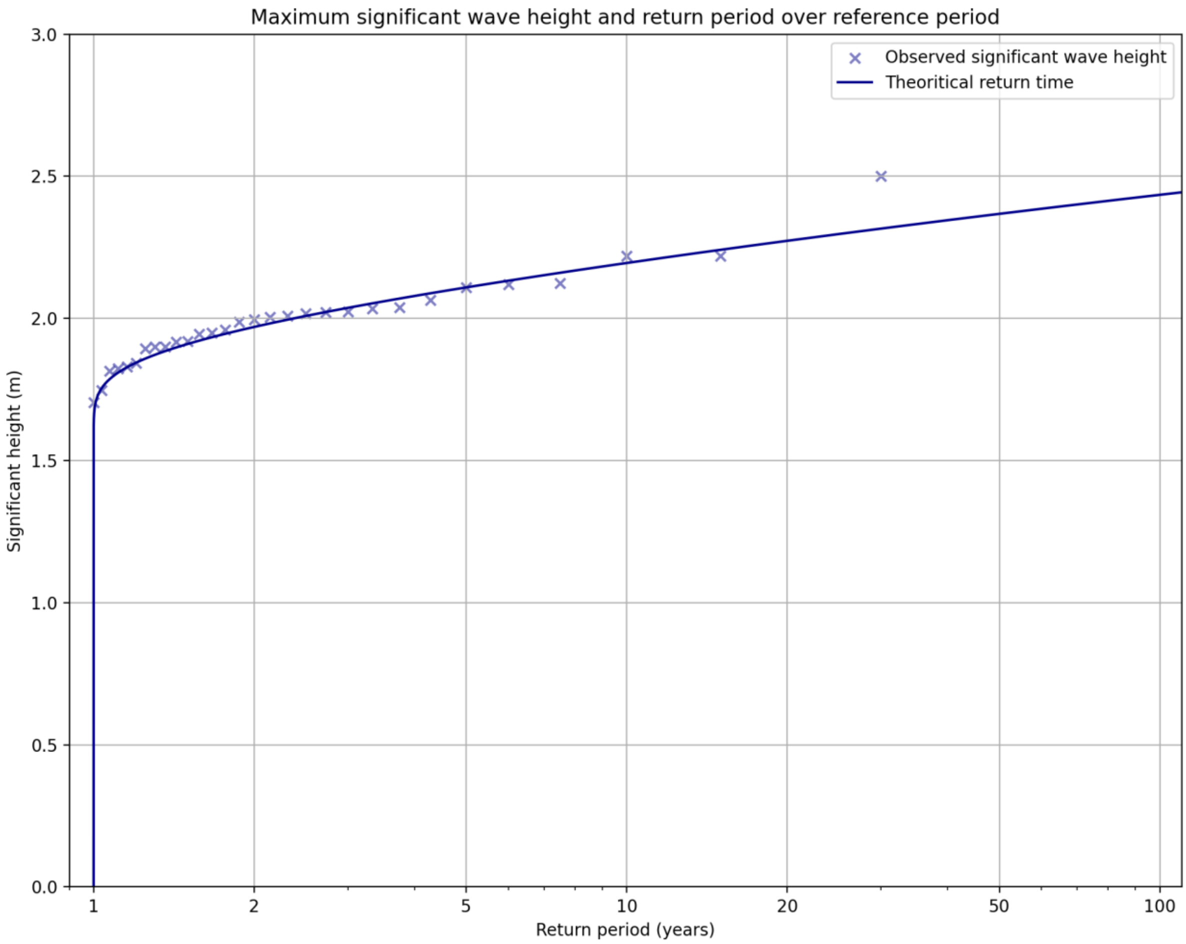


Figure 35: Return periods for maximum significant wave height on the reference period

Based on observations during the reference period, the maximum significant wave height for a 100-year return period can be estimated at approximately 2.4 meters.

RETURN PERIOD (yr)	SIGNIFICANT WAVE HEIGHT (m)	PEAK WAVE PERIOD (s)
1 (95th centile)	1.7	13.3
5	2.1	13.8
10	2.2	13.9
20	2.3	14.0
50	2.4	14.1
100	2.4	14.1

Figure 36: Maximum significant wave height for selected return periods

3. Future projections

The evolution of extreme significant wave height at the end of the 21st century remains uncertain.

There is no consensus among the models on the evolution of extreme wave height. Under the most pessimistic emissions scenario, the return levels projected by the various models are found to be less dispersed than those calculated using the same models over the historical period (a -16.0% increase of the 5-95% range).

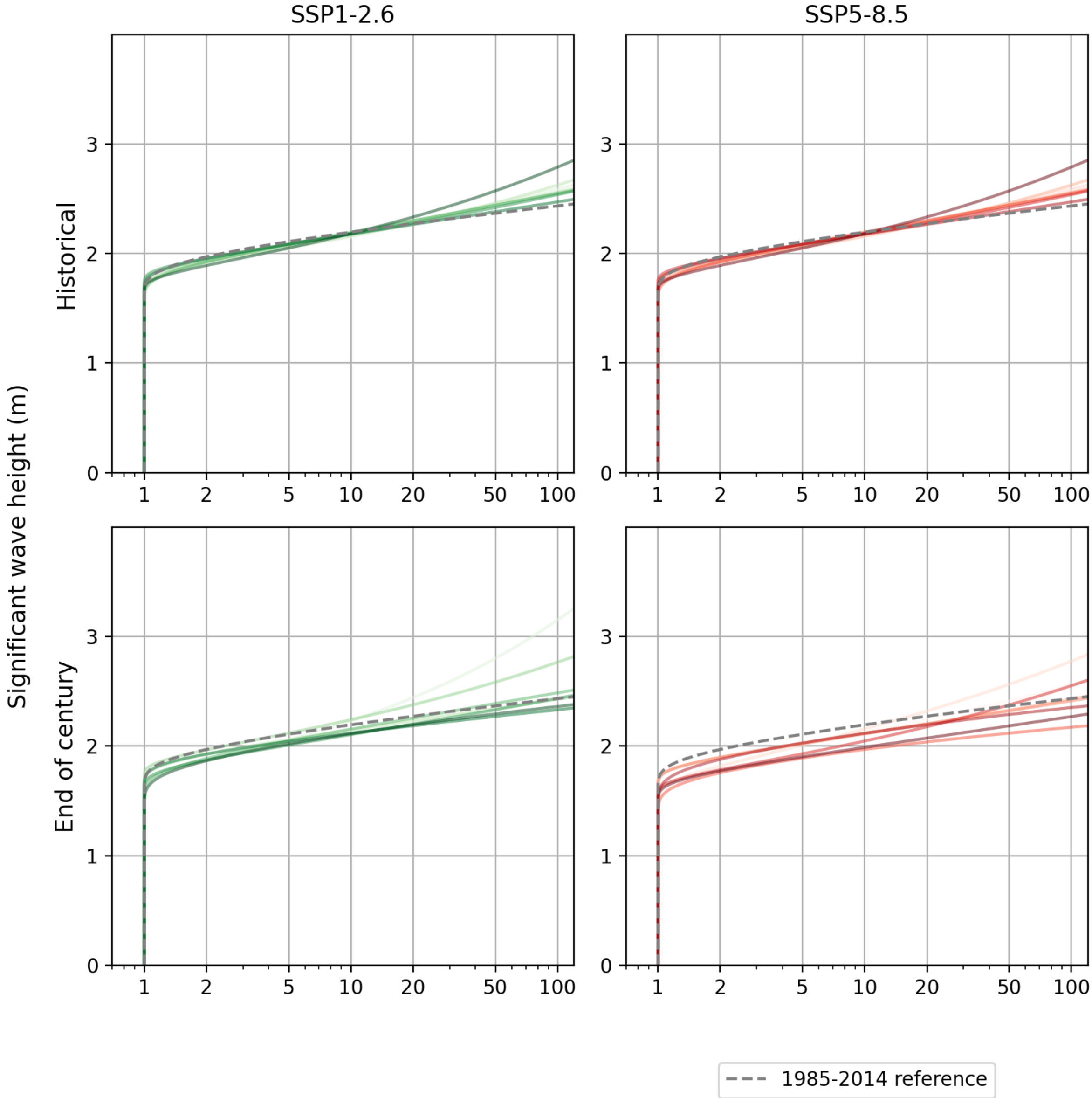


Figure 37: maximum significant wave height, multimodel return level plots for selected time horizons

Based on the multimodel median, over the century, the maximum significant wave height for a 100-year event could be modified by approximately 0.0 meters in a high emission scenario and -0.1 meters in a low emissions scenario.

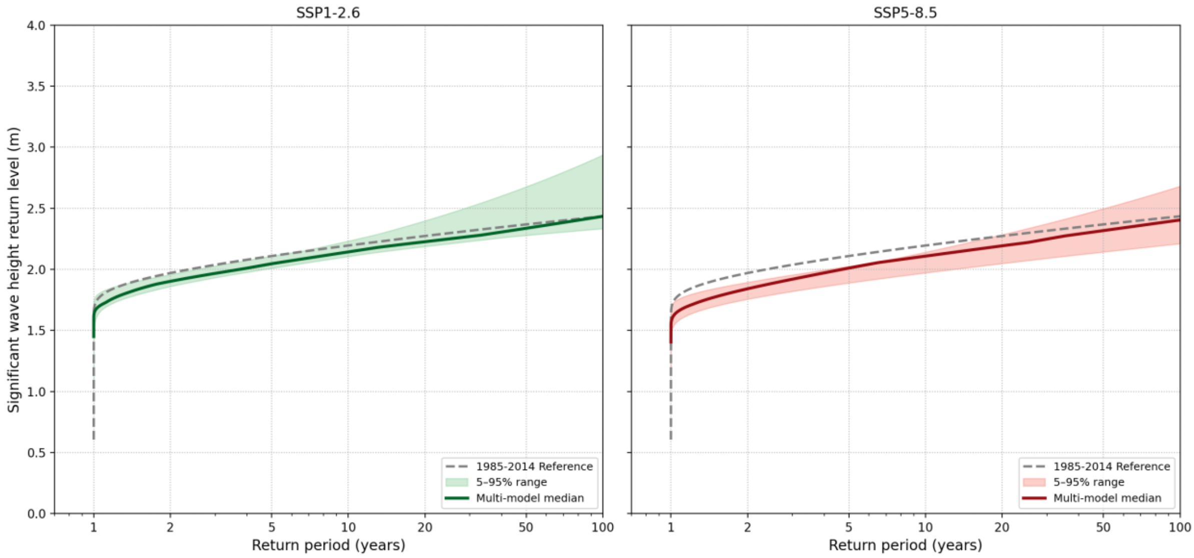


Figure 38: Multi-model median (interpolated) of return levels of significant wave height at the end of the century (2071-2100)

EMISSIONS SCENARIO	END OF CENTURY MAXIMUM SIGNIFICANT WAVE HEIGHT (m)			
	50-year	Peak wave period (s)	100-year	Peak wave period (s)
SSP1-2.6	2.3 [2.3, 2.8]	14.0	2.4 [2.4, 3.1]	14.1
SSP5-8.5	2.3 [2.1, 2.4]	14.0	2.4 [2.2, 2.6]	14.1

Figure 39 : return level of extreme significant wave height at the end of the 21st century based on multi-model median

EMISSIONS SCENARIO	PROJECTED CHANGES BY THE END OF THE CENTURY (m)	
	50-year	100-year
SSP1-2.6	-0.0 [-0.3, 0.3]	-0.2 [-0.4, 0.4]
SSP5-8.5	-0.2 [-0.5, 0.1]	-0.3 [-0.5, 0.1]

Figure 40: projected change of extreme significant wave height at the end of the 21st century based on multi-model median

EMISSIONS SCENARIO	PROJECTED CHANGES BY THE END OF THE CENTURY (%)	
	50-year	100-year
SSP1-2.6	-2.0 [-12.4, 12.0]	-5.6 [-15.1, 16.1]
SSP5-8.5	-8.0 [-17.6, 3.0]	-11.2 [-18.8, 2.8]

Figure 41 : projected evolution of extreme significant wave height based on multi-model median

Finally, it is possible to estimate the maximum wave height using the significant wave height.

EMISSIONS SCENARIO	END OF CENTURY MAXIMUM WAVE HEIGHT (m)	
	50-year	100-year
SSP1-2.6	4.3 [4.3, 5.2]	4.5 [4.5, 5.8]
SSP5-8.5	4.3 [4.0, 4.4]	4.5 [4.2, 4.8]

Figure 42 : projected evolution of extreme wave height based on multi-model median

Appendix A: Models used

The projections used in this report come from the following global circulation models for all chapters except wind and waves:

Model	Producer	Country
FGOALS-g3	Institute of Atmospheric Physics (IAP), Chinese Academy of Sciences	China
CanESM5	Canadian Centre for Climate Modelling and Analysis (CCCma)	Canada
CMCC-ESM2	Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC)	Italy
CNRM-CM6-1	Centre National de Recherches Météorologiques (CNRM) & CERFACS	France
CNRM-ESM2-1	CNRM & CERFACS	France
ACCESS-ESM1-5	CSIRO	Australia
EC-Earth3	EC-Earth Consortium	-
INM-CM5-0	Institute of Numerical Mathematics (INM)	Russia
IPSL-CM6A-LR	Institut Pierre-Simon Laplace (IPSL)	France
MIROC6	JAMSTEC, AORI, NIES	Japan
MIROC-ES2L	National Institute for Environmental Studies (NIES)	Japan
UKESM1-0-LL	UK Met Office Hadley Centre & UKESM project partners	United-Kingdom
MPI-ESM1-2-LR	Max Planck Institute for Meteorology (MPI-M)	Germany
MRI-ESM2-0	Meteorological Research Institute (MRI)	Japan

Due to the limited availability of wave projections, only 3 models were used:

Model	Producer	Country
ACCESS-CM2	CSIRO	Australia
EC-EARTH3	European consortium	Europe
FIO-ESM v2.0	FIO	China

Waves projections for the scenario SSP2-4.5 were available only from the FIO's model.

Appendix B: Definitions and abbreviations

Best estimate: In this document “best estimate” always refers to the multimodel median projection, i.e.: the middle value in the range of possible outcome yield by the set of models being used.

Bias: The difference between the observed data and modeled results that occurs due model imperfections.

Coupled Model Intercomparison Project (CMIP): A project of the World Climate Research Program to coordinate global climate modeling efforts. The projections produced within the framework of the CMIP project serve as a reference for the IPCC reports: the 5th wave of the CMIP project (CMIP5) corresponds to the 5th IPCC assessment report published in 2014, the 6th wave (CMIP6) is being finalized and corresponds to the 6th IPCC assessment report, published in 2021.

Correction: Bias correction or adjustment of modeled values to reflect the observed distribution and statistics.

Downscaling: Derivation of local to regional-scale (10-100 kilometers) information from larger scale modeled or observed data. There are two main approaches: dynamical downscaling and statistical downscaling.

European Centre for Medium-Range Weather Forecasts (ECMWF): European Centre for Medium-Range Weather Forecasts

Emissions Scenario: Estimates of future greenhouse gas emissions released into the atmosphere. Such estimates are based on possible projections of economic and population growth and technological development, as well as physical processes within the climate system.

ERA5: ERA5 is the fifth generation ECMWF atmospheric reanalysis of the global climate. It provides hourly estimates of a large number of atmospheric, land and oceanic climate variables 1940 to present on a regular 0.25°x0.25° grid.

General Circulation Model (GCM): A global computer model of the climate system that can be used to simulate past, present and future climate. GCMs represent the effects of such factors as reflective and absorptive properties of atmospheric water vapor, greenhouse gas concentrations, clouds, annual and daily solar heating, ocean temperatures, and ice boundaries.

Shared Socioeconomic Pathways (SSP): SSPs are a set of scenarios developed by the scientific community to explore different possible futures of socioeconomic development and their implications for greenhouse gas emissions and climate change. In this document, 3 SSPs are uses: SPP1-2.6 (low emissions scenario), SPP2-4.5 (intermediate emissions scenario) and SPP5-8.5 (very high emissions scenario).

Spatial downscaling: Refers to the methods used to derive climate information at finer spatial resolution from coarser spatial resolution GCM output.

Reanalysis: Reconstruction of historical weather and climate conditions using a combination of observational data, including surface weather stations, satellites, buoys, and other instruments, and numerical models.

Reference period: In accordance with the recommendations of the World Meteorological Organization, this document uses a reference period of 30 years. The reference period for all variables is 1985-2014. This period was chosen to be consistent with the standards of the CMIP6 project.

Return period: Refers to the average time interval between occurrences of an extreme event of a certain magnitude. As extrems events with long return periods are very rare, return period is typically calculated statistical methods such as the generalized extreme value (GEV) distribution.

Appendix C: legal notices

4. ERA5

Contains modified Copernicus Climate Change Service information 2022.

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5. CMIP6

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Model	Producer	License
FGOALS-g3	Institute of Atmospheric Physics (IAP), Chinese Academy of Sciences	CC BY-SA 4.0
CanESM5	Canadian Centre for Climate Modelling and Analysis (CCCma)	CC BY-SA 4.0
CMCC-ESM2	Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC)	CC BY-SA 4.0
CNRM-CM6-1	Centre National de Recherches Météorologiques (CNRM) & CERFACS	CC BY-NC-SA 4.0
CNRM-ESM2-1	CNRM & CERFACS	CC BY-NC-SA 4.0
ACCESS-ESM1-5	CSIRO	CC BY-SA 4.0
EC-Earth3	EC-Earth Consortium	CC BY-SA 4.0
INM-CM5-0	Institute of Numerical Mathematics (INM)	CC BY-SA 4.0
IPSL-CM6A-LR	Institut Pierre-Simon Laplace (IPSL)	CC BY-NC-SA 4.0
MIROC6	JAMSTEC, AORI, NIES	CC BY-SA 4.0
MIROC-ES2L	National Institute for Environmental Studies (NIES)	CC BY-SA 4.0

UKESM1-0-LL	UK Met Office Hadley Centre & UKESM project partners	CC BY-SA 4.0
MPI-ESM1-2-LR	Max Planck Institute for Meteorology (MPI-M)	CC BY-SA 4.0
MRI-ESM2-0	Meteorological Research Institute (MRI)	CC BY-SA 4.0

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6. CSIRO

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Consult https://data.csiro.au/collection/csiro:53176

7. FIO

CSIRO waves data is licensed under a Creative Commons International License CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/).

Consult https://figshare.com/collections/Simulated_long-term_3-hourly_ocean_surface_waves_parameters_from_FIO-ESM_v2_0_CMIP6_experiments_for_past_present_and_future_climate_research/4839729/1

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