Klimaatlas Report

Denmark

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National Center for Climate Research (NCKF) at DMI

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Colophon

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Content

Background

The impacts of climate change are experienced differently from one area to another. This report summarises the key results describing how the climate is expected to change towards the year 2100 in Denmark. The focus is on a small selection of commonly used indicators, in particular temperature, precipitation, and sea levels. The data are sourced from DMI's Klimaatlas (version v2025a, which, in addition to the content presented in this report, contains a wide range of other data on the future Danish climate at a municipal level.

About Klimaatlas

Klimaatlas provides a comprehensive database for the future Danish climate. Klimaatlas is based on DMI's own data, international collaborations and knowledge from reports by the UN Intergovernmental Panel on Climate Change (IPCC). Funding comes from the 2018 and 2022 Finance Acts. Climate indicators are calculated in a high-resolution grid (1x1 km) and aggregated for the whole of Denmark, municipalities, watersheds and coastal stretches.

Klimaatlas does not in itself provide any information about the effects of climate change, as data on, for example, groundwater levels, sewerage, mitigation measures and other local conditions are not included in Klimaatlas. However, Klimaatlas can help to quantify changes in temperature and precipitation, for example, and identify where the problems will be greatest. Impact analyses should be carried out subsequently on the basis of data from Klimaatlas and local conditions, among other things. Read more about Klimaatlas here: https://www.dmi.dk/klima-atlas/om-klimaatlas/

Emission scenarios

Climate change depends primarily on changes in the concentration of greenhouse gases (such as carbon dioxide) in the atmosphere. Therefore, the concentration of greenhouse gases is included in the climate models used in Klimaatlas. This is done using so-called emission scenarios, which are realistic estimates of the future development of global greenhouse gas concentrations in the atmosphere.

The UN Intergovernmental Panel on Climate Change (IPCC) bases its work on a set of emission scenarios for the development of global climate models. The IPCC's fifth main report and special reports from 2018 and 2019 used the so-called RCP scenarios ('Representative Concentration Pathways'). The latest and sixth main report from the IPCC (2021-22) uses a new set of scenarios called SSP ('Shared Socioeconomic Pathways'). Klimaatlas uses a combination of these two sets of scenarios, where the atmospheric indicators (e.g. temperature, precipitation, wind) are based on the RCP scenarios and the sea level indicators are based on the SSP scenarios. Read more about why both sets of emission scenarios are included in the Klimaatlas here: https://www.dmi.dk/klima-atlas/oftestilledespoergsmaal

Klimaatlas allows you to see how the climate in Denmark is expected to change under selected scenarios from the IPCC's work. Guidance on which scenario is relevant for different projects can

be found in 'Guidance on the use of emission scenarios for climate adaptation' - prepared by DMI in collaboration with the Danish Environmental Protection Agency, January 2025. See more at: https://www.dmi.dk/fileadmin/klimaatlas/rapporter/Vejledningsrapporter/Vejledning_i_anvendelse_af_udledningsscenarier_til_klimatilpasning.pdf

Time periods and uncertainties

Data in Klimaatlas is usually presented as averages over 30-year periods. In Klimaatlas Denmark's current climate is defined by the average for the "reference period" 1981-2010. This period is the starting point for projections and for data showing relative changes. Klimaatlas presents data for four time periods: 1981-2010, 2011-2040, 2041-2070 and 2071-2100.

Data for the future climate in Denmark in Klimaatlas is based on up to 72 different climate models. The models that calculate the climate can be compared, as they cover the same geographical area and contain the same amount of greenhouse gases in the atmosphere.

The calculations of the future climate are associated with uncertainties. These uncertainties can be seen in the spread of results between the models. In Klimaatlas, the intervals for uncertainty are indicated for the individual indicators as a column in the figures and in the data tables.

Uncertainty is given in Klimaatlas as 10th and 90th percentiles around the median value (50th percentile). For the average temperature indicator, this means, for example, that the upper uncertainty limit is the level at which only 10% of the models are warmer. Similarly, the lower uncertainty limit is the level at which only 10% of the models are cooler.

Guide to the graphs

This section explains how to read the figures in *Klimaatlas*. The graphs compile information for each indicator and show uncertainty ranges for all emissions scenarios and all time periods. The most likely change is around the median, while the upper and lower estimates illustrate the magnitude of the uncertainty. Values for all periods and scenarios can be found in Klimaatlas (http://www.dmi.dk/klimaatlas).

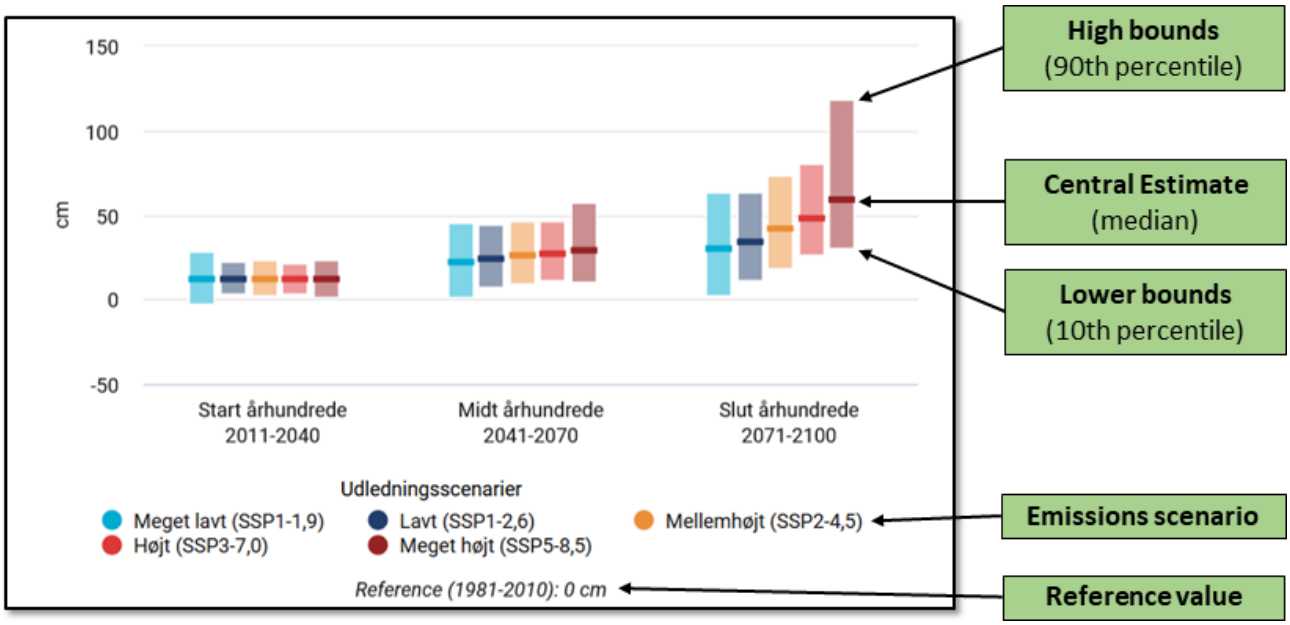

Figure 1. Sketch of the graphs in Klimaatlas. Example of change in mean sea level across Denmark.

In this hypothetical example (Figure 1), which shows changes in mean sea level across Denmark, the best estimate (the solid line) at the end of the century under a very high emissions scenario (SSP5-8.5) is a mean sea level rise of 59 cm. The lower estimate of 30 cm (the 10th percentile) and the upper estimate of 118 cm (the 90th percentile) form the lower and upper bounds of the column and can also be read from the figure. The expected change in mean sea level is therefore 59 cm, with an uncertainty range from 30 cm to 118 cm.

The figure also includes a reference value. This value represents the level during the reference period (1981–2010) and can be used to provide context for the changes. In this case, the reference value is 0 cm, as the figure shows change relative to the reference period.

All values underlying the graphs can also be retrieved from *Klimaatlas*. A selection of these values is also presented at the end of this report (see summary table).

Temperature

Since the 1870s, the average temperature in Denmark has increased by approximately 1.5 °C. During the 30-year period from 1981 to 2010, the annual mean temperature for Denmark as a whole was 8.3 °C. In general, temperatures are lowest in central Jutland and highest along the coasts.

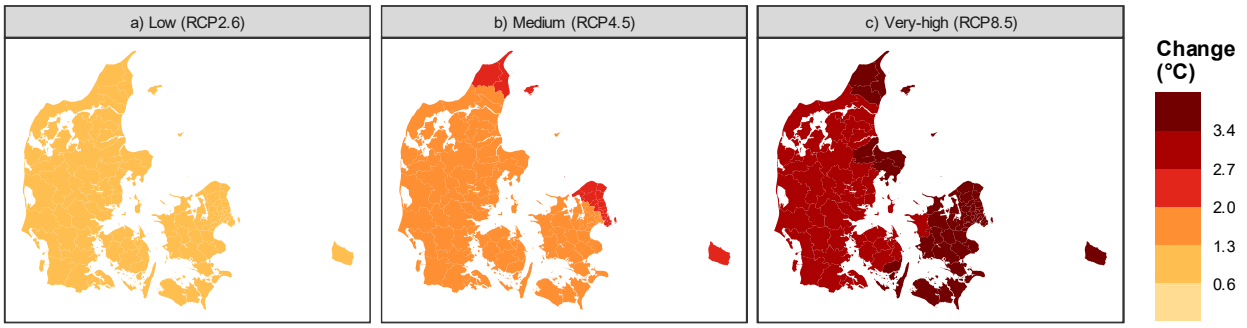

Figure 2. Change in the annual average temperature (°C) between 1981-2010 and 2071-2100 in a) low, b) medium and c) very high emissions scenario.

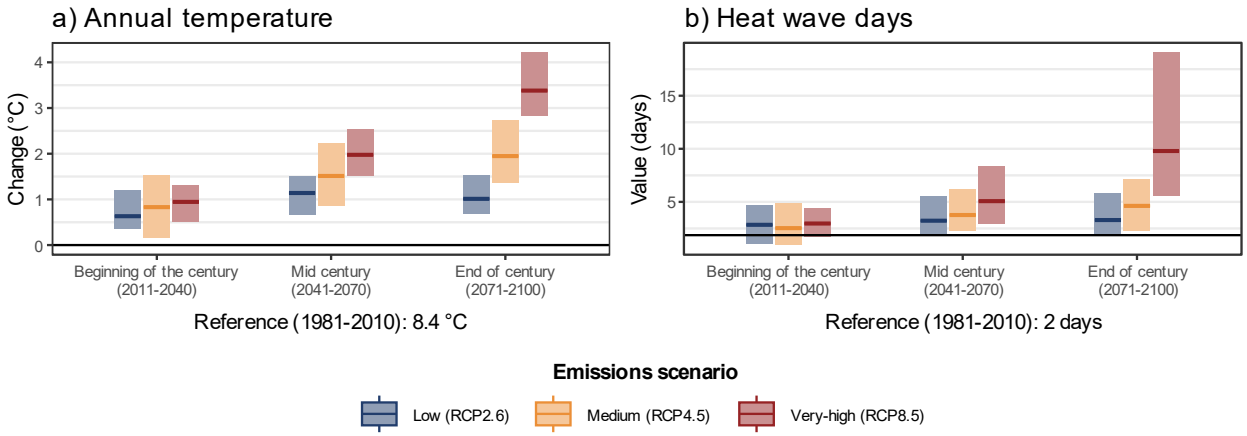

Figure 3. Future a) change in annual average temperature compared to 1981-2010 and b) average number of heatwave days over the year under different emissions scenarios in Denmark. The black line shows the value for the reference period (1981-2010).

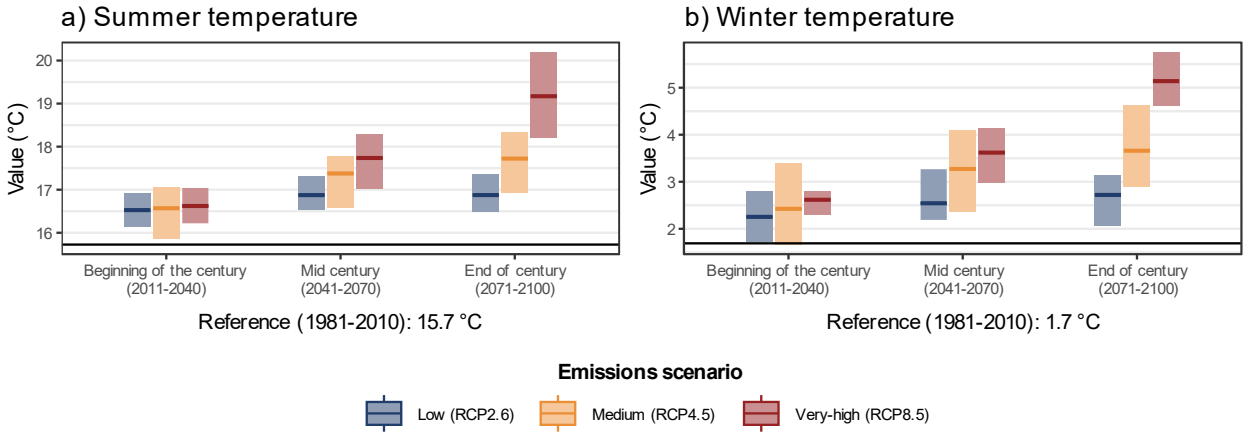

Figure 4. Future average temperature for a) summer (Jun-Aug) and b) winter (Dec-Feb) under different emissions scenarios in Denmark. The black line shows the value for the reference period (1981-2010).

Precipitation

The average annual precipitation in Denmark has changed since the 1870s, increasing by approximately 100 mm. During the 30-year period from 1981 to 2010, the annual total for the country as a whole was 746 mm. On average, the most rain falls in central Jutland and the least in the Kattegat region.

We can expect more intense rainfall events in summer, even though summers are likely to become drier across large parts of the European continent. The most extreme rainfall events are also expected to become even heavier. In a so-called 10-year event, it rains so much that, statistically, it occurs only once in 10 years. *Klimaatlas* shows the rainfall amounts corresponding to 2-, 5-, 10-, 20-, 50- and 100-year events for both hourly and daily precipitation, both now and in the future.

A cloudburst is defined in Denmark as more than 15 mm of rain within 30 minutes. In *Klimaatlas*, a 3-year event in hourly precipitation is used as an approximation, as the underlying climate models do not provide data at a higher temporal resolution than one hour. Cloudbursts are calculated in the same way as other extreme events.

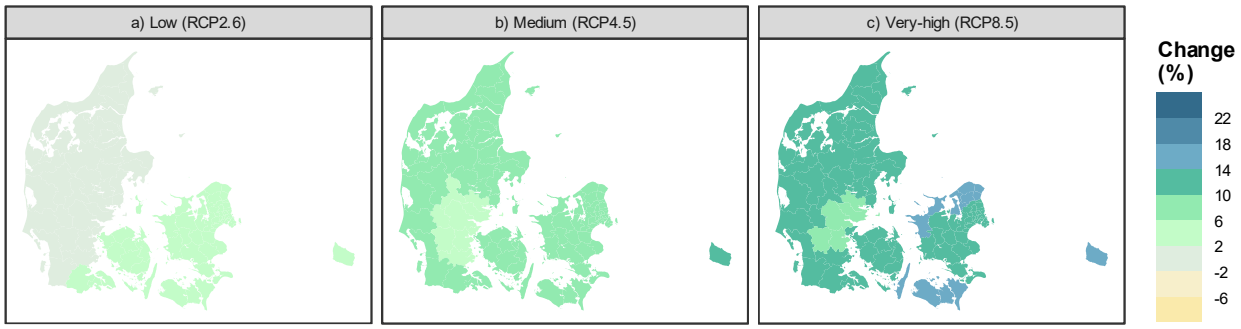

Figure 5. Percentage changein the annual average annual precipitation between 1981-2010 and 2071-2100 in a) low, b) medium and c) very high emissions scenario.

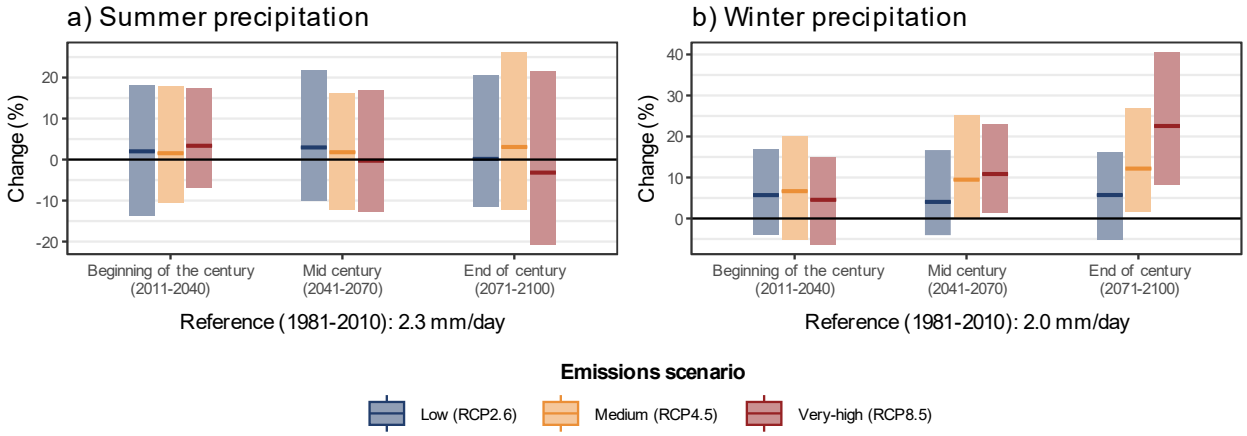

Figure 6. Percentage change in average precipitation a) in summer (Jun-Aug) and b) in winter (Dec-Feb) relative to the reference period 1981-2010 under different emissions scenarios in Denmark.

Note that the expected changes in summer precipitation stand out from the other indicators because the most likely change is very small compared with the uncertainty range from the 10th to the 90th percentile. As a result, it is highly uncertain whether summer precipitation will increase, decrease, or remain unchanged.

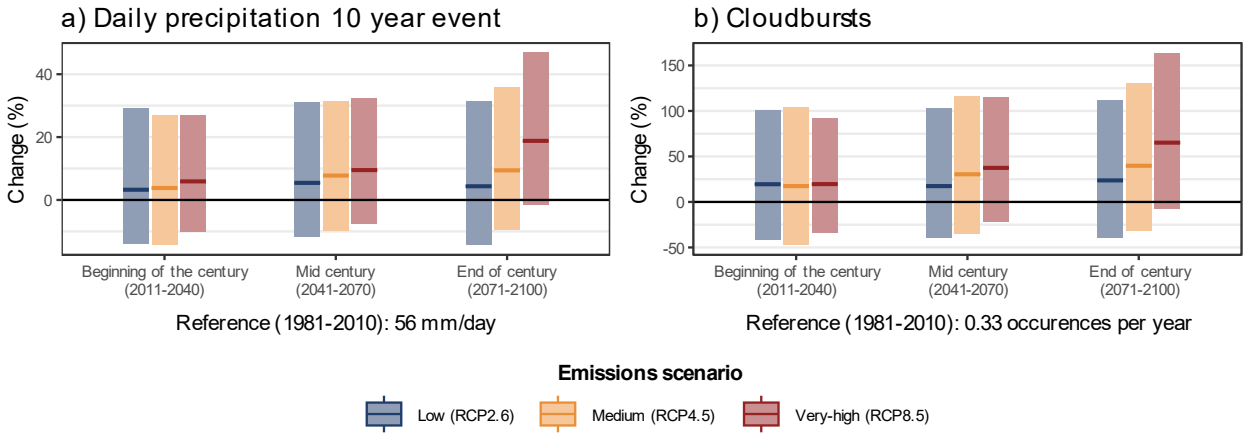

Figure 7. Percentage change in a) 10 year event for daily precipitation and b) annual frequency of cloudburds relative to ift. 1981-2010 under different emissions scenarios in Denmark.

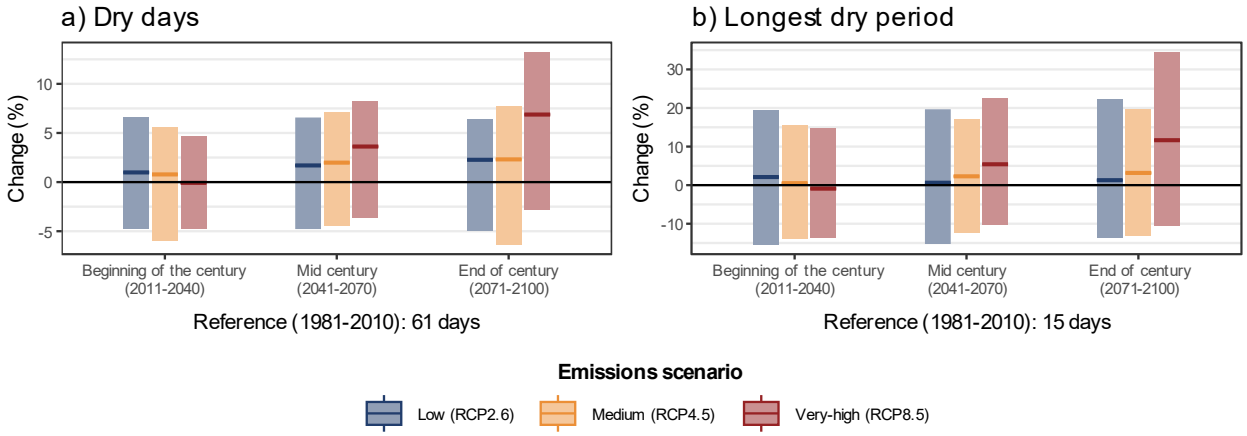

Figure 8. Percentage change in a) number of dry days (with less than 1 mm precipitation) and b) length of the longest continuous dry period in summer(Jun-Aug) relative to 1981-2010 under different emissions scenarios Denmark.

Sea level

The average sea level around Denmark increased by approximately 2 mm per year over the 20th century. Sea level rise is expected to continue both globally and around Denmark in the future.

In *Klimaatlas*, projections of future sea level around Denmark are based on global sea level figures combined with knowledge of land uplift in Denmark. Statistical analysis of water level observations from the Danish Coastal Authority, together with data from climate models and knowledge of general sea level changes in Denmark, provides estimates of sea level for different storm surge heights. These are presented as 20-, 50- and 100- year events for elevated water levels. A 20-year storm surge corresponds to an elevated water level that statistically occurs only once in 20 years.

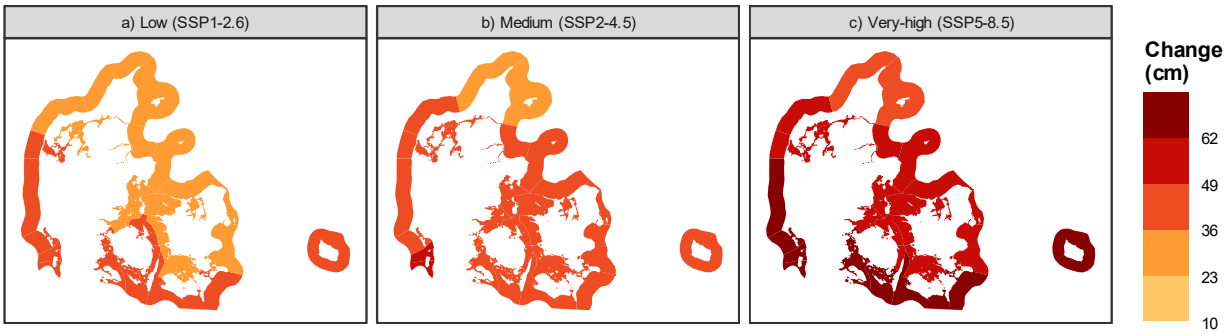

Figure 9. Change between 1981-2010 and the future period 2071-2100 in average sea level (cm) for Denmark in a a) low, b) medium and c) very-high emissions scenario.

Denmark borders Femern Bælt, Vadehavskyst nordlig and Nordsjællands kyst coastal stretches.

Femern Bælt

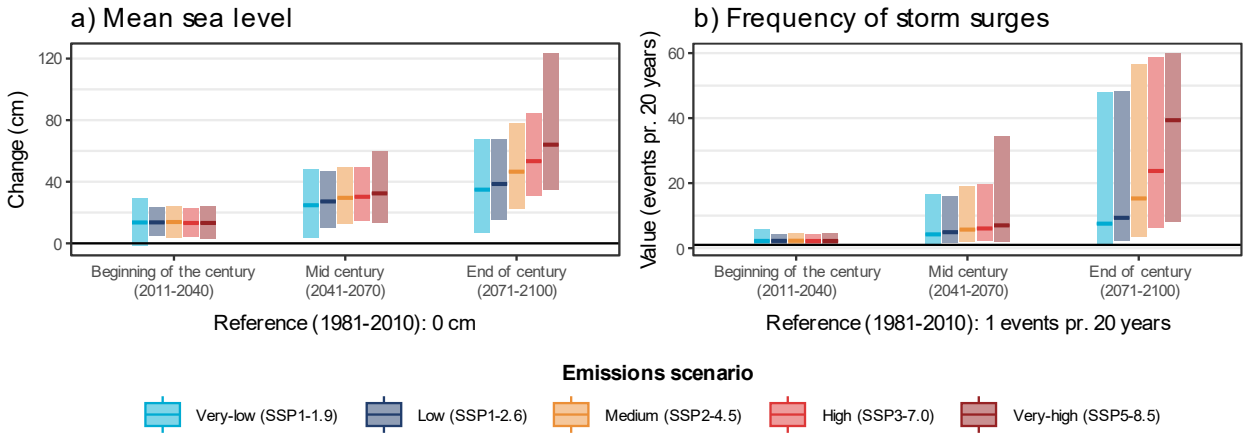

Figure 10. Future a) change in mean sea level relative to the reference period 1981-2010 and b) frequency of a 20-year storm surge, as defined in the reference period, for 'Femern Bælt' coastal stretch under different emissions scenarios. The black line shows the value for the reference period

(1981-2010). Note also that this indicator is capped to show a maximum of 60 storm surges per 20 years, even if the calculated value is higher.

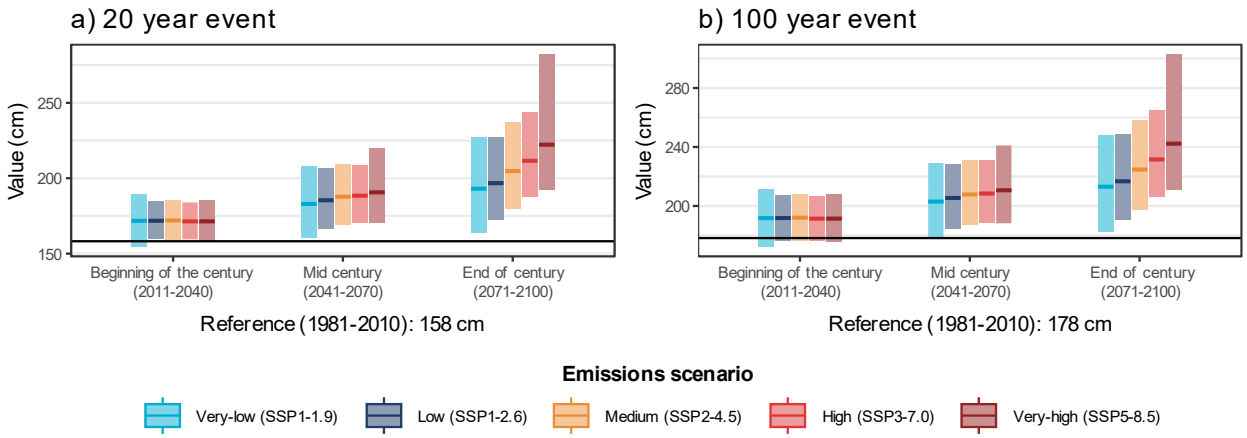

Figure 11. Future height of a) 20- and b) 100-year storm surge for 'Femern Bælt' coast stretch under different emissions scenarios. The black line shows the value for the reference period (1981-2010).

Vadehavskyst nordlig

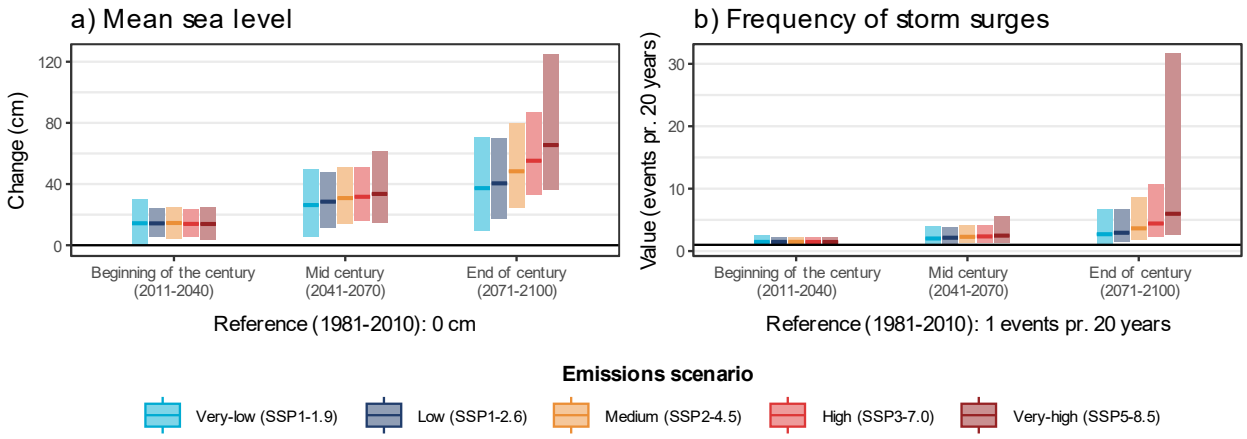

Figure 12. Future a) change in mean sea level relative to the reference period 1981-2010 and b) frequency of a 20-year storm surge, as defined in the reference period, for 'Vadehavskyst nordlig' coastal stretch under different emissions scenarios. The black line shows the value for the reference period (1981-2010). Note also that this indicator is capped to show a maximum of 60 storm surges per 20 years, even if the calculated value is higher.

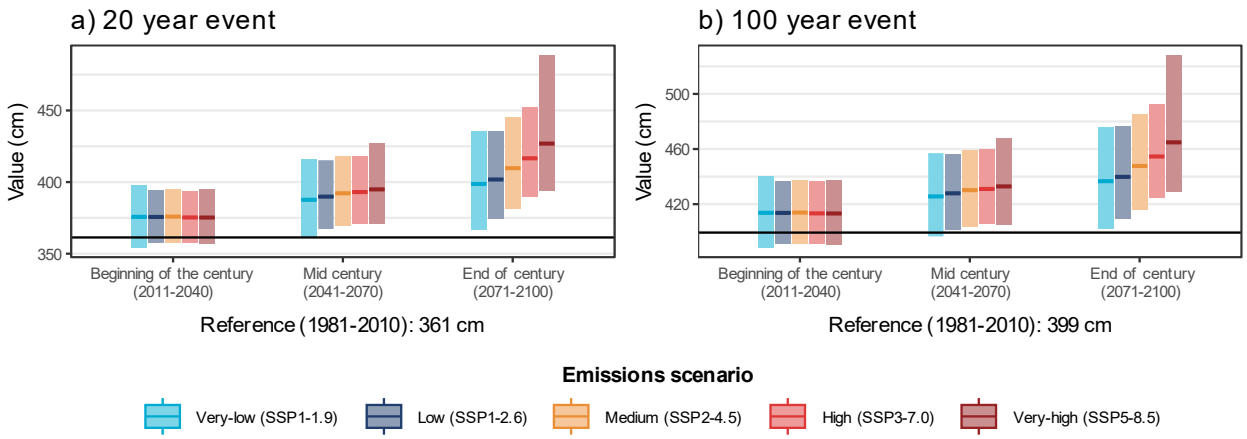

Figure 13. Future height of a) 20- and b) 100-year storm surge for 'Vadehavskyst nordlig' coast stretch under different emissions scenarios. The black line shows the value for the reference period (1981-2010).

Nordsjællands kyst

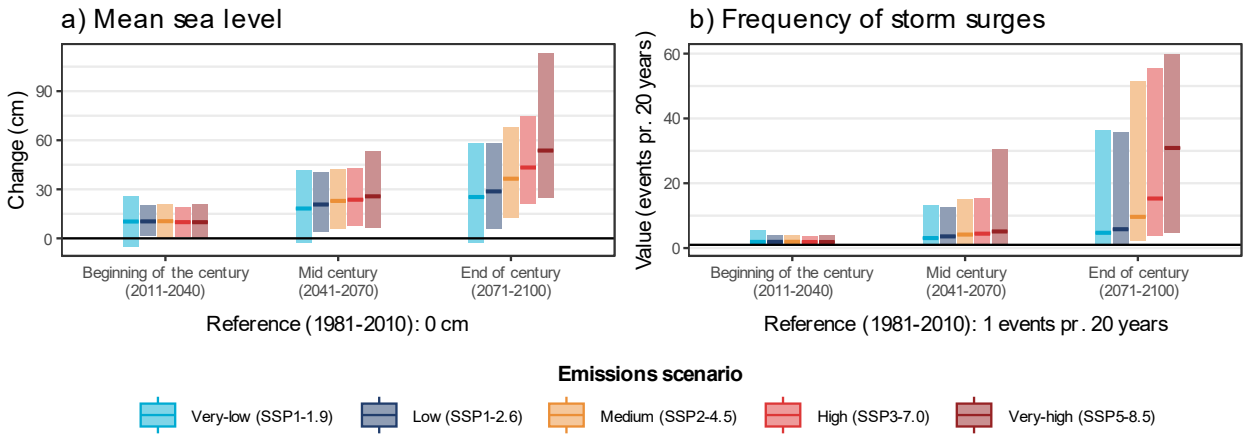

Figure 14. Future a) change in mean sea level relative to the reference period 1981-2010 and b) frequency of a 20-year storm surge, as defined in the reference period, for 'Nordsjællands kyst' coastal stretch under different emissions scenarios. The black line shows the value for the reference period (1981-2010). Note also that this indicator is capped to show a maximum of 60 storm surges per 20 years, even if the calculated value is higher.

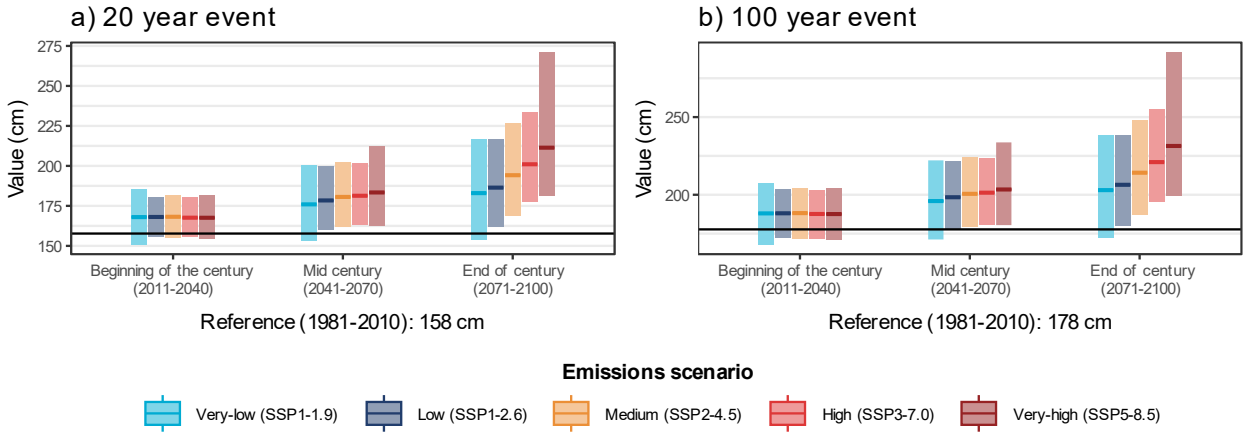

Figure 15. Future height of a) 20- and b) 100-year storm surge for 'Nordsjællands kyst' coast stretch under different emissions scenarios. The black line shows the value for the reference period (1981-2010).

Summary table

Table 1. The future climate in Denmark. Data are shown for a low (RCP2.6 / SSP1-2.6), medium (RCP4.5 / SSP2-4.5), and very high emissions scenario (RCP8.5 / SSP5-8.5) at the end of the century (2071–2100) and for the reference period (1981–2010). Uncertainty (10th–90th percentile) is shown in square brackets. Values are presented as averages for 'Whole year', 'Winter' (Dec, Jan, Feb), or 'Summer' (Jun, Jul, Aug). Additional data can be found in Klimaatlas.

	Indicator	Season	Reference (1981-2010)	Emissions scenario (2071-2100)			Units
				Low	Medium	Very-high	
Denmark	Annual temperature (change)	Whole year	0	1.0 [0.7-1.5]	1.9 [1.4-2.7]	3.4 [2.8-4.2]	°C
	Heat wave days	Whole year	2 [1-3]	3 [2-6]	5 [2-7]	10 [6-19]	days
	Summer temperature	Summer	15.7 [15.4-15.9]	16.9 [16.5-17.3]	17.7 [16.9-18.3]	19.2 [18.2-20.2]	°C
	Winter temperature	Winter	1.7 [1.4-2.0]	2.7 [2.1-3.1]	3.7 [2.9-4.6]	5.1 [4.6-5.8]	°C
	Summer precipitation (change)	Summer	0	0.2 [-11.5-20.7]	3.1 [-12.3-26.2]	-3.2 [-20.7-21.5]	%
	Winter precipitation (change)	Winter	0	5.7 [-5.1-16.1]	12.2 [1.7-27.0]	22.6 [8.3-40.6]	%
	Daily precipitation 10 year event (change)	Whole year	0	4 [-14-31]	9 [-9-36]	19 [-2-47]	%
	Cloudbursts (change)	Whole year	0	24 [-40-111]	40 [-31-131]	65 [-7-164]	%
	Dry days (change)	Summer	0	2 [-5-6]	2 [-6-8]	7 [-3-13]	%
	Longest dry period (change)	Summer	0	1 [-14-22]	3 [-13-20]	12 [-11-35]	%
Femern Bælt	Mean sea level (change)	Whole year	0	39 [15-68]	47 [23-78]	64 [35-124]	cm
	Frequency of storm surges	Whole year	1 [0-1]	9 [2-48]	15 [4-57]	39 [8-60]	events pr. 20 years
	20 year event	Whole year	158 [150-166]	197 [172-227]	205 [179-237]	222 [192-282]	cm
	100 year event	Whole year	178 [166-190]	217 [191-249]	225 [198-258]	242 [211-303]	cm
Va de	Mean sea level (change)	Whole year	0	40 [17-70]	48 [24-80]	66 [36-125]	cm

	Indicator	Season	Reference (1981-2010)	Emissions scenario (2071-2100)			Units
				Low	Medium	Very-high	
	Frequency of storm surges	Whole year	1 [1-1]	3 [1-7]	4 [2-9]	6 [3-32]	events pr. 20 years
	20 year event	Whole year	361 [346-377]	402 [374-435]	410 [381-445]	427 [394-489]	cm
	100 year event	Whole year	399 [379-420]	440 [409-476]	448 [416-486]	465 [429-528]	cm
Nordsjællands kyst	Mean sea level (change)	Whole year	0	29 [6-58]	36 [12-68]	54 [25-113]	cm
	Frequency of storm surges	Whole year	1 [0-2]	6 [1-36]	10 [2-51]	31 [5-60]	events pr. 20 years
	20 year event	Whole year	158 [150-166]	186 [162-217]	194 [169-226]	211 [181-271]	cm
	100 year event	Whole year	178 [165-190]	206 [180-238]	214 [187-248]	231 [200-292]	cm