Climate Fact Sheet

Open-Air Laboratory Ireland

At a glance

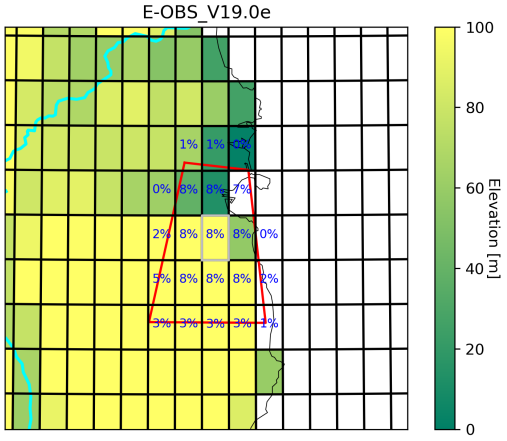
The Climate Fact Sheet provides brief and concise information on possible future climate developments for the Open-Air Laboratory Ireland in the 21st century. They are based on the results of 51 regional climate model simulations, which are based on the Representative Concentration Pathways (RCPs). RCP8.5 represents a worst case scenario, RCP4.5 a medium mitigation scenario, and RCP2.6 a stringent mitigation scenario. 18 different indices for climate change are presented, which are relevant for various societal sectors. They are supplemented by an expert judgement of the reliability of the shown changes. The relationship to the climate of the near past is illustrated by some of the key figures calculated from observation data for the Open-Air Laboratory Ireland. At the end of the 21st century, the annual mean near-surface temperature is projected to increase between 0.0 °C and 1.4 °C in RCP2.6, between 1.1 °C and 2.5 °C in RCP4.5, and between 1.7 °C and 3.8 °C in RCP8.5; these increases are robust for all scenarios. For the annual precipitation at the end of the 21st century the projections show changes between -7.4 % and 12.5 % for RCP2.6, between -3.0 % and 8.2 % for RCP4.5, and between -16.3 % and 17.4 % for RCP8.5. For annual precipitation, none of the projected changes for the end of the 21st century are robust.

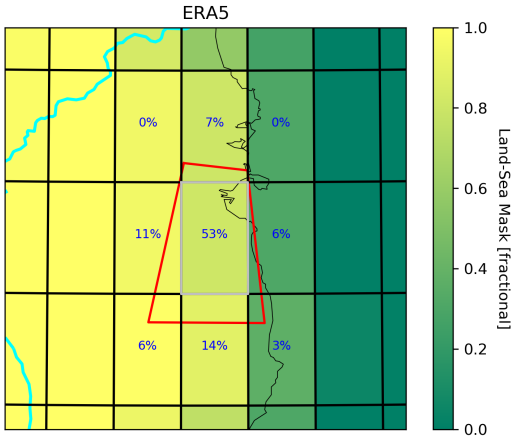
	Projected Climate Changes for the end of the 21st century			
Parameter	Worst case scenario	Medium mitigation scenario	Stringent mitigation scenario	Details
temperature	increase	increase	increase	pp. 5, 14
summer days	increase	increase	increase	pp. 5, 14
hot days	increase	tendency towards increase	tendency towards increase	pp. 6, 14
tropical nights	increase	tendency towards increase	tendency towards increase	pp. 6, 14
duration of heat waves	increase	tendency towards increase	tendency towards increase	pp. 7, 14
days > 5 °C	increase	increase	increase	pp. 7, 14
heating degree days	decrease	decrease	decrease	pp. 8, 14
frost days	decrease	decrease	decrease	pp. 8, 14
spring frost days	decrease	decrease	decrease	pp. 9, 14
precipitation	no changes	no changes	tendency towards increase	pp. 9, 14
precipitation > 20 mm	increase	tendency towards increase	tendency towards increase	pp. 10, 15
dry days	increase	tendency towards increase	no changes	pp. 10, 15
wet days	decrease	tendency towards decrease	no changes	pp. 11, 15
p95th	increase	increase	tendency towards increase	pp. 11, 15
p99th	increase	tendency towards increase	tendency towards increase	pp. 12, 15
wind speed	decrease	decrease	tendency towards decrease	pp. 12, 16
water balance	no changes	no changes	no changes	pp. 13, 16
sultriness	increase	increase	increase	pp. 13, 16

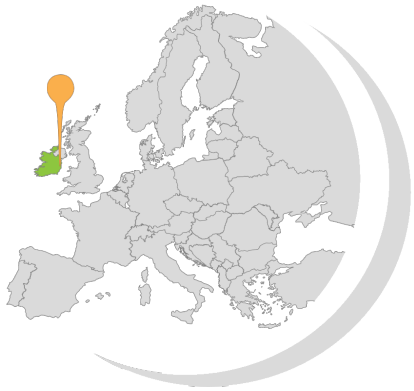
Today's climate and observed changes

Climate indices for today's climate for the region Open-Air Laboratory Ireland

The Open-Air Laboratory Ireland is chosen to be the Ringsend area in Dublin, located at the lower part of the Dodder river basin. Dublin has a maritime climate, characterized by mild winters, cool summers, and few extreme temperatures. For the region of the Open-Air Laboratory Ireland, data has been extracted from the longterm daily gridded observational data E-OBS (V19.0e). Together with the ERA5 reanalysis data, these are used as present day climate reference. The figures below show the representation of the Open-Air Laboratory Ireland (red line) for the E-OBS V19.0e grid on the left and the ERA5 grid on the right. The numbers in blue give the share of the gridboxes contributing to the regional mean values. For the region indicated in the two figures, climate indices for the period of 1971 to 2000 (E-OBS) and 1989 to 2018 (ERA5) are derived from the respective dataset.







	E-OBS (1971-2000)	ERA5 (1989-2018)
summer days [days/year]	1	0
hot days [days/year]	0	0
tropical nights [days/year]	0	0
days > 5 °C [days/year]	291	309
frost days [days/year]	41	15
spring frost days [days/year]	4	1
precipitation [mm/day]	2.9	2.6
precipitation > 20 mm [days/year]	7	3
dry days [days/year]	199	193
wet days [days/year]	167	170

Observed changes in the past and recent climate for Open-Air Laboratory Ireland

For the period of 1950 to 2010, an increase of the annual mean temperature of about 0.02 °C/year can be derived from E-OBS (V19.0e). For the more recent period of 1980 to 2010, the increase is about 0.03 °C/year. The lowest annual mean temperature recorded since 1950 in the series of measurements for E-OBS (V19.0e) was in the year 1963 with 7.8 °C, the highest value in the year 2006 with 10.0 °C.

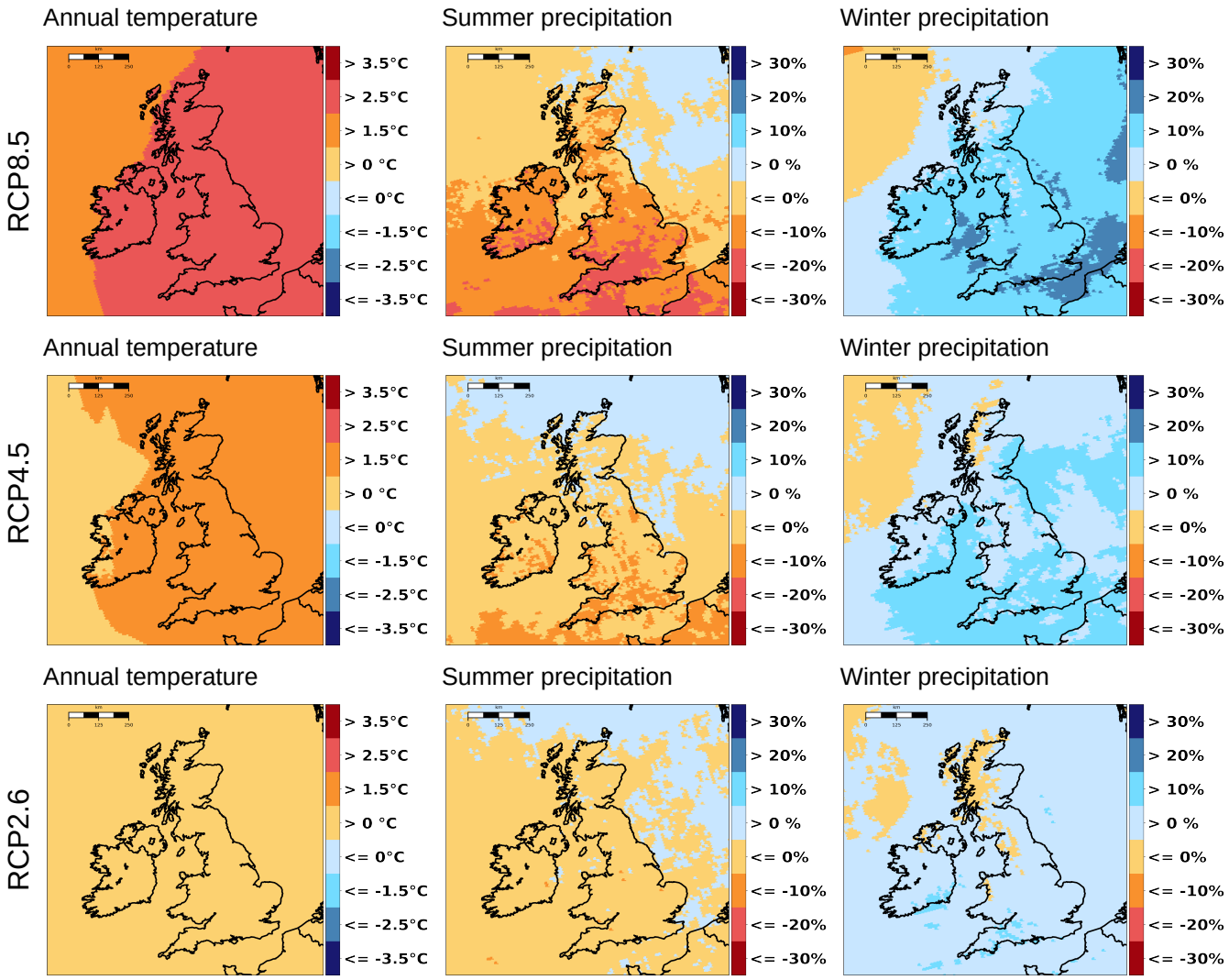
For the annual mean precipitation, the measurements do not show any clear trends during the course of the 21st century. The lowest annual precipitation values since 1950 in E-OBS (V19.0e) were recorded in the year 2005 with 663 mm, the highest values in 1960 with 1452 mm.

Data source for the information on observed climate: E-OBS gridded observational dataset (V19.0e, temporal/spatial resolution: daily/0.1°, http://surfobs.climate.copernicus.eu/dataaccess/access_eobs.php), as well as C3S, Copernicus Climate Change Service (2017): ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service Climate Data Store (CDS). Access: https://cds.climate.copernicus.eu/. Daily values of mean, minimum and maximum temperature as well as daily mean precipitation were selected.

Projected climate changes

The projected changes shown in this Climate Fact Sheet are based on an ensemble of climate projections which were created in the context of the EURO-CORDEX initiative as well as on regional climate projections provided by the ReKliEs-DE project, funded by the German Ministry of Research and Education (see page 19 for more information). Climate projections give possible future pathways of climate for the coming decades, based on scenarios for the development of global population, the economy, and technological development, resulting in different concentrations of greenhouse gases in the atmosphere. Here, projections are based on three different Representative Concentration Pathways (RCPs). RCP8.5 represents a worst case scenario, RCP4.5 a medium mitigation scenario, and RCP2.6 a stringent mitigation scenario. The global climate projections are regionally refined by regional climate models. All EURO-CORDEX and ReKliEs-DE simulations are stored on a common grid with a horizontal grid resolution of about 12 x 12 km. The projected changes for the Open-Air Laboratory Ireland are calculated as a weighted average of all grid cells that fall within the OAL, in the same way as was done for the observed data. Projected changes are calculated from a baseline period of 1971 to 2000 for two future time periods 2036 to 2065, and 2070 to 2099.

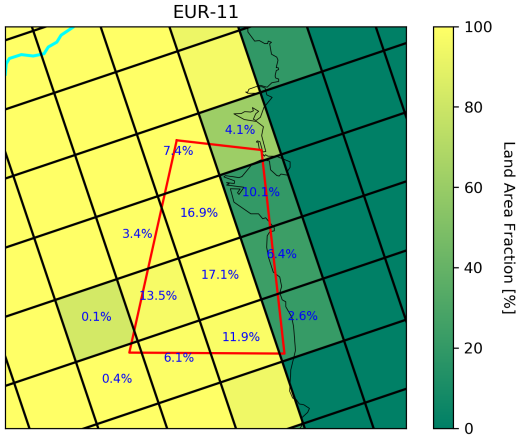
Mean changes for the period 2070 - 2099 relative to 1971 - 2000



Projected climate changes

Representation of the Open-Air Laboratory Ireland on the rotated grid of the climate projections

All model simulations used in this Climate Fact Sheet were realized on a common grid defined by the EURO-CORDEX initiative. To keep the grid box sizes as equal as possible, the position of the poles has been rotated in the simulations, so that the equator crosses the EURO-CORDEX domain. Consequently, the grid shown in the figure on the right is rotated compared to the ERA5 and E-OBS-v19.0 grids. Moreover, the coordinates of the grid were homogenized among the different RCMs, but the fixed surface fields such as land-sea distribution and model orography were not necessarily homogenized. The figure to the right shows the region for which the data from the regional climate projections were extracted for the Open-Air Laboratory Ireland. The respective weight of the grid boxes within the region are given accordingly. The background shows the fractional land-sea distribution as it is used for the simulations done with REMO2009 and REMO2015.



Symbols of the expert judgement on the robustness of the projections

Increase: The majority of the simulations project significant increases

Tendency towards an increase: The majority of the simulations project non-significant increases

Decrease : The majority of the simulations project significant decreases

Tendency towards a decrease: The majority of the simulations project non-significant decreases

Unclear: The majority of the simulations project significant changes, but do not agree on the direction of change

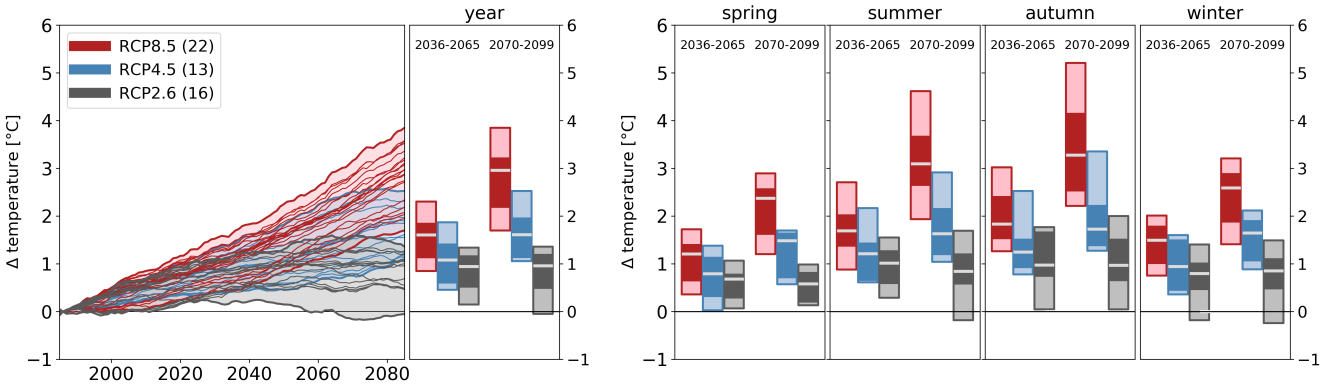
No changes: The majority of the simulations project non-significant changes, with no preferred direction of change

Please consider:

Each climate index presented on the following pages is complemented by an expert judgement on the robustness of the projected changes, which is described in more detail on page 16. The definition of each climate index is given on page 18. Their graphical representation is explained on page 17. These information are necessary for the understanding of the figures. All climate indices are displayed with the identical method. Together with the figures, the projected annual changes for each index for the middle and the end of the 21st century are provided as short narratives.

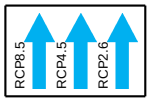
Projected changes in temperature-based indices

Annual and seasonal temperature

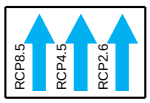


For all three RCPs an increase in the annual temperature is projected for the end of the 21st century.

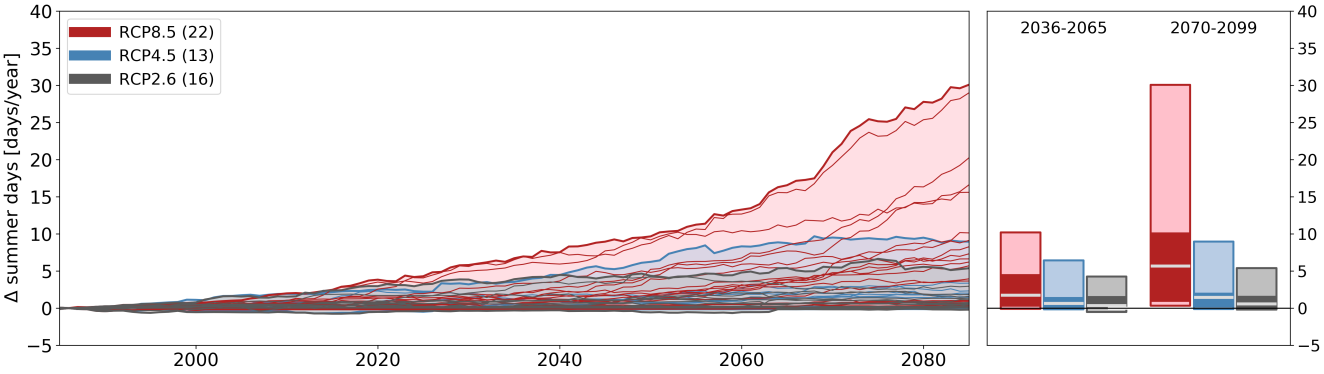
The bandwidth of projected annual changes for the **middle of the 21st century** spans from 0.8 to 2.3 °C for RCP8.5, from 0.5 to 1.9 °C for RCP4.5, and from 0.1 to 1.3 °C for RCP2.6.



For the **end of the 21st century,** the projected annual increases for RCP8.5 is between 1.7 and 3.8 °C, for RCP4.5 between 1.1 and 2.5 °C, and for RCP2.6 between 0.0 and 1.4 °C.

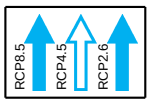


Summer days

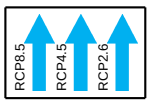


For all three RCPs an increase in the annual number of summer days is projected for the end of the 21st century.

The bandwidth of projected annual changes for the **middle of the 21st century** spans from 0 to 10 days/year for RCP8.5, from 0 to 6 days/year for RCP4.5, and from -1 to 4 days/year for RCP2.6.

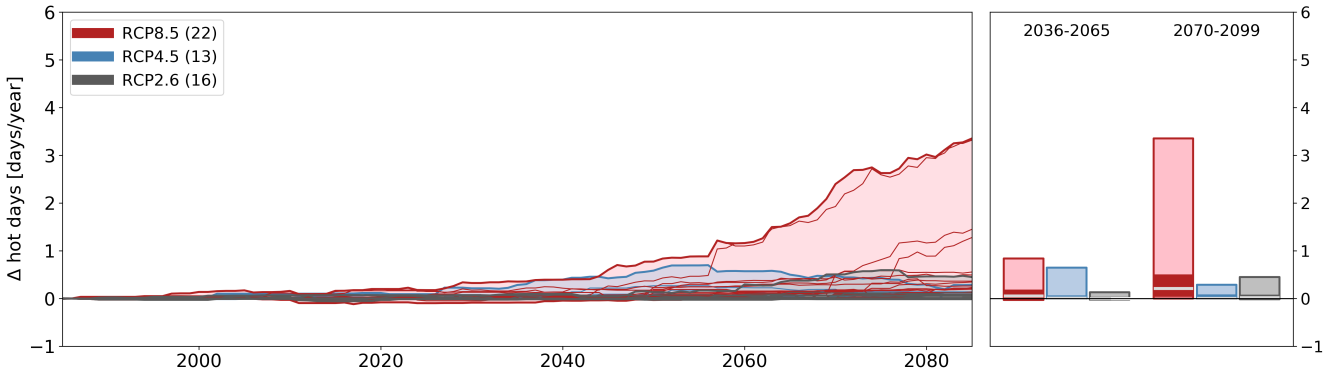


For the **end of the 21st century,** the projected annual increases for RCP8.5 is between 0 and 30 days/year, for RCP4.5 between 0 and 9 days/year, and for RCP2.6 between 0 and 5 days/year.



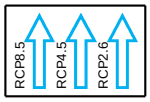
Projected changes in temperature-based indices

Hot days

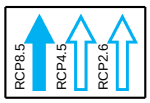


For all three RCPs an increase in the annual number of hot days is projected for the end of the 21st century.

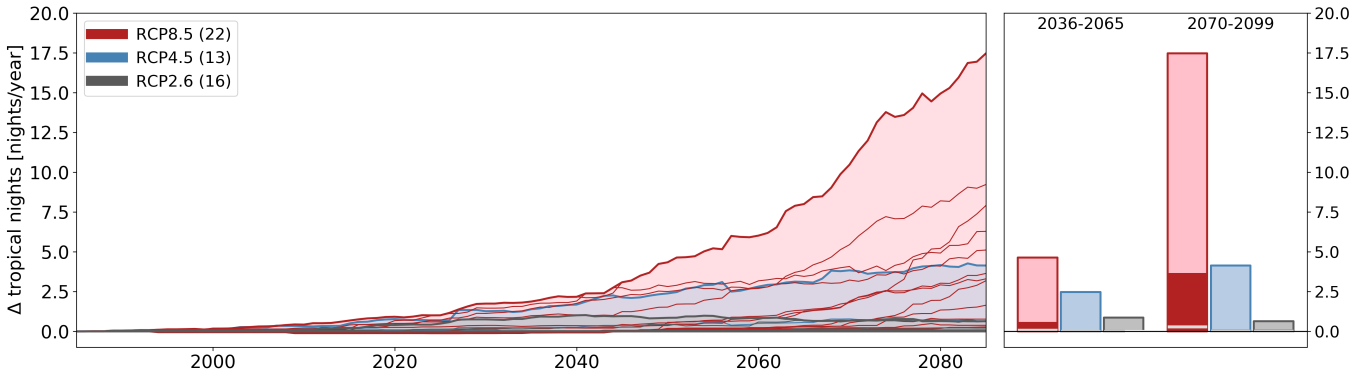
The bandwidth of projected annual changes for the **middle of the 21st century** spans from 0.0 to 0.8 days/year for RCP8.5, from 0.0 to 0.6 days/year for RCP4.5, and from 0.0 to 0.1 days/year for RCP2.6.



For the **end of the 21st century,** the projected annual increases for RCP8.5 is between 0.0 and 3.4 days/year, for RCP4.5 between 0.0 and 0.3 days/year, and for RCP2.6 between 0.0 and 0.4 days/year.

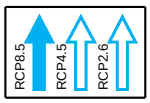


Tropical nights

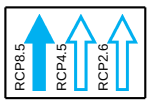


For all three RCPs an increase in the annual number of tropical nights is projected for the end of the 21st century.

The bandwidth of projected annual changes for the **middle of the 21st century** spans from 0.0 to 4.64 nights/year for RCP8.5, from 0.0 to 2.47 nights/year for RCP4.5, and from 0.0 to 0.86 nights/year for RCP2.6.

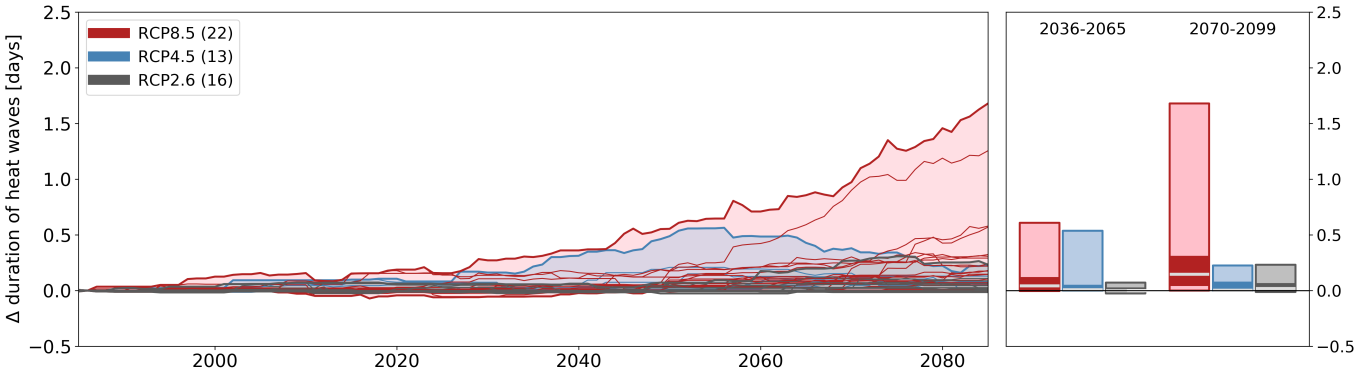


For the **end of the 21st century,** the projected annual increases for RCP8.5 is between 0.0 and 17.46 nights/year, for RCP4.5 between 0.0 and 4.14 nights/year, and for RCP2.6 between 0.0 and 0.64 nights/year.



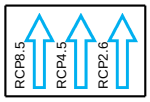
Projected changes in temperature-based indices

Duration of heat waves

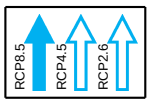


For all three RCPs an increase in the annual maximum duration of heat waves is projected for the end of the 21st century.

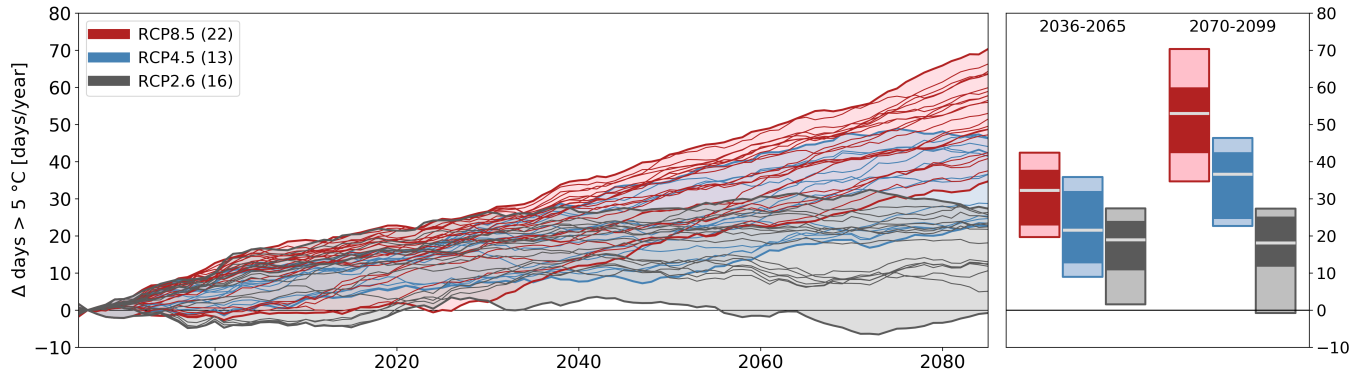
The bandwidth of projected annual changes for the **middle of the 21st century** spans from 0.0 to 0.61 days for RCP8.5, from 0.0 to 0.54 days for RCP4.5, and from -0.03 to 0.07 days for RCP2.6.



For the **end of the 21st century,** the projected annual increases for RCP8.5 is between 0.0 and 1.68 days, for RCP4.5 between 0.0 and 0.23 days, and for RCP2.6 between -0.01 and 0.23 days.

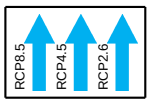


Days warmer than 5 °C

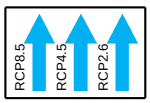


For all three RCPs an increase in the annual number of days > 5 °C is projected for the end of the 21st century.

The bandwidth of projected annual changes for the **middle of the 21st century** spans from 20 to 42 days/year for RCP8.5, from 9 to 36 days/year for RCP4.5, and from 2 to 27 days/year for RCP2.6.

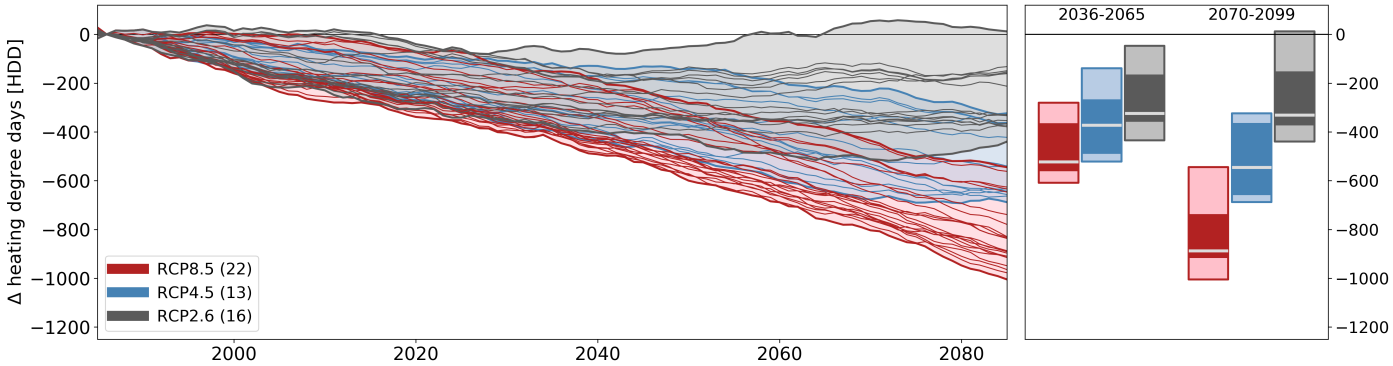


For the **end of the 21st century,** the projected annual increases for RCP8.5 is between 35 and 70 days/year, for RCP4.5 between 23 and 46 days/year, and for RCP2.6 between -1 and 27 days/year.



Projected changes in temperature-based indices

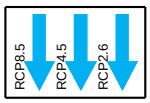
Heating degree days



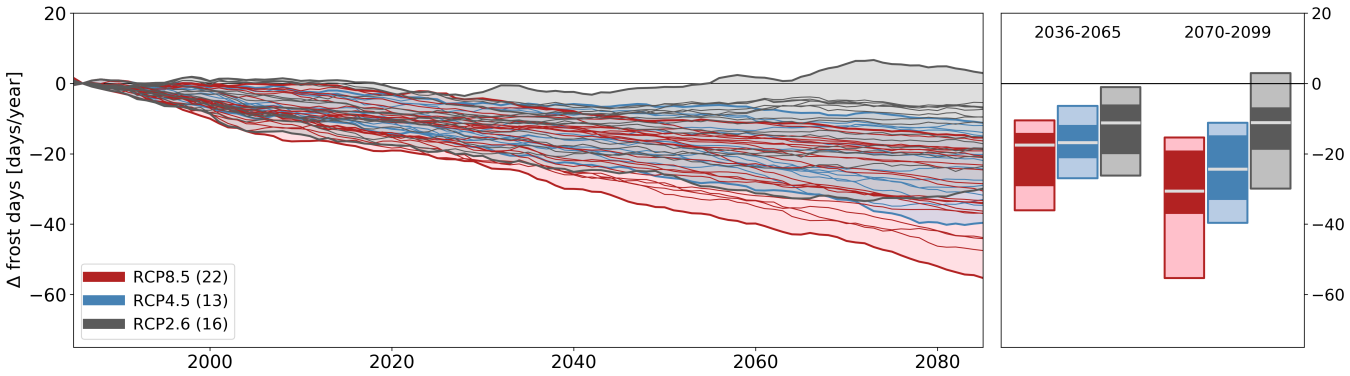
For all three RCPs a decrease in the annual number of heating degree days is projected for the end of the 21st century.

The bandwidth of projected annual changes for the **middle of the 21st century** spans from -609 to -280 HDD for RCP8.5, from -521 to -139 HDD for RCP4.5, and from -434 to -47 HDD for RCP2.6.

For the **end of the 21st century,** the projected annual changes for RCP8.5 is between -1005 and -545 HDD, for RCP4.5 between -688 and -324 HDD, and for RCP2.6 between -440 and 12 HDD.

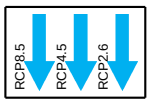


Frost days

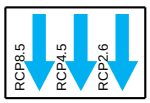


For all three RCPs a decrease in the annual number of frost days is projected for the end of the 21st century.

The bandwidth of projected annual changes for the **middle of the 21st century** spans from -36 to -10 days/year for RCP8.5, from -27 to -6 days/year for RCP4.5, and from -26 to -1 days/year for RCP2.6.

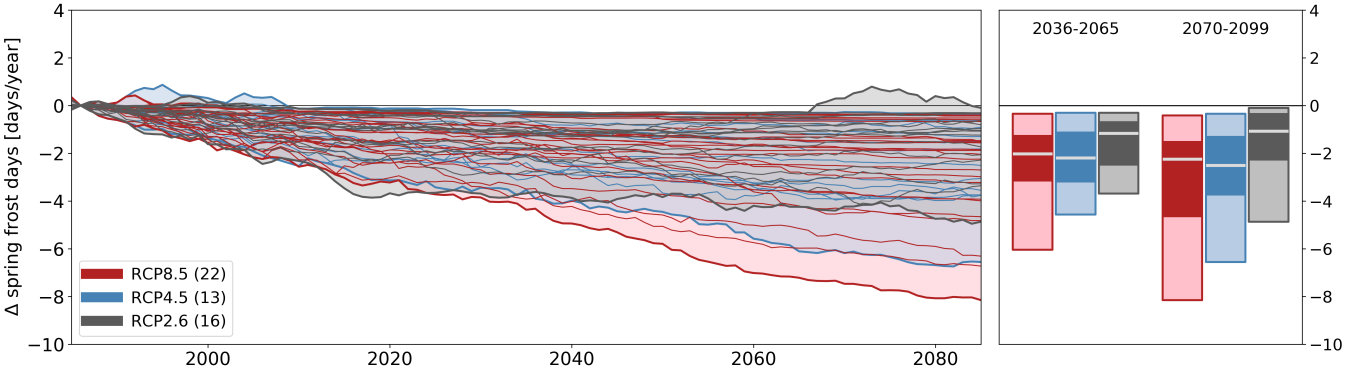


For the **end of the 21st century,** the projected annual changes for RCP8.5 is between -55 and -15 days/year, for RCP4.5 between -40 and -11 days/year, and for RCP2.6 between -30 and 3 days/year.



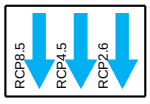
Projected changes in temperature-based indices

Spring frost days

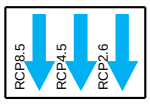


For all three RCPs a decrease in the annual number of spring frost days is projected for the end of the 21st century.

The bandwidth of projected annual changes for the **middle of the 21st century** spans from -6 to 0 days/year for RCP8.5, from -5 to 0 days/year for RCP4.5, and from -4 to 0 days/year for RCP2.6.

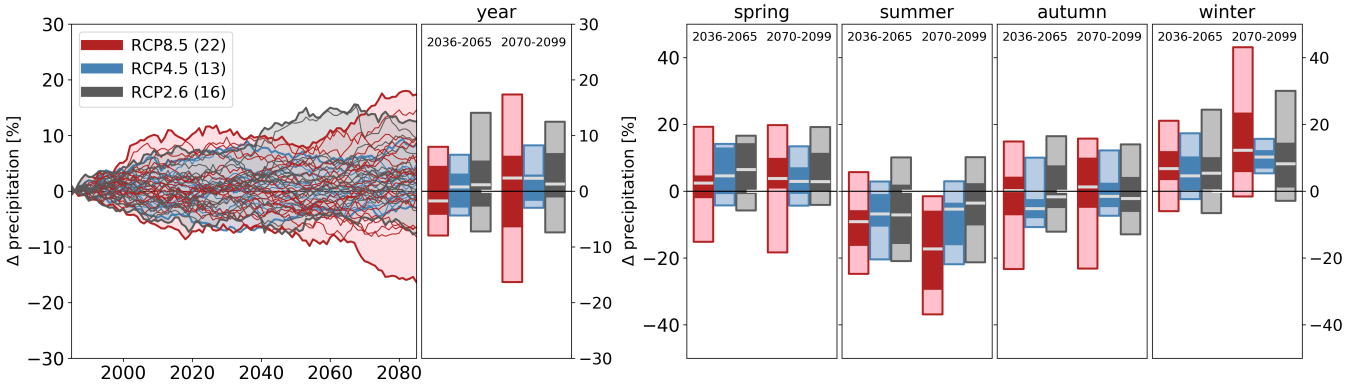


For the **end of the 21st century,** the projected annual changes for RCP8.5 is between -8 and 0 days/year, for RCP4.5 between -7 and 0 days/year, and for RCP2.6 between -5 and 0 days/year.



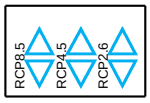
Projected changes in precipitation-based indices

Annual and seasonal precipitation

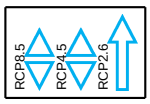


For the three different RCPs no clear change in the annual precipitation is projected for the end of the 21st century.

The bandwidth of projected annual changes for the **middle of the 21st century** spans from -8.0 to 8.0 % for RCP8.5, from -4.4 to 6.5 % for RCP4.5, and from -7.2 to 14.1 % for RCP2.6.

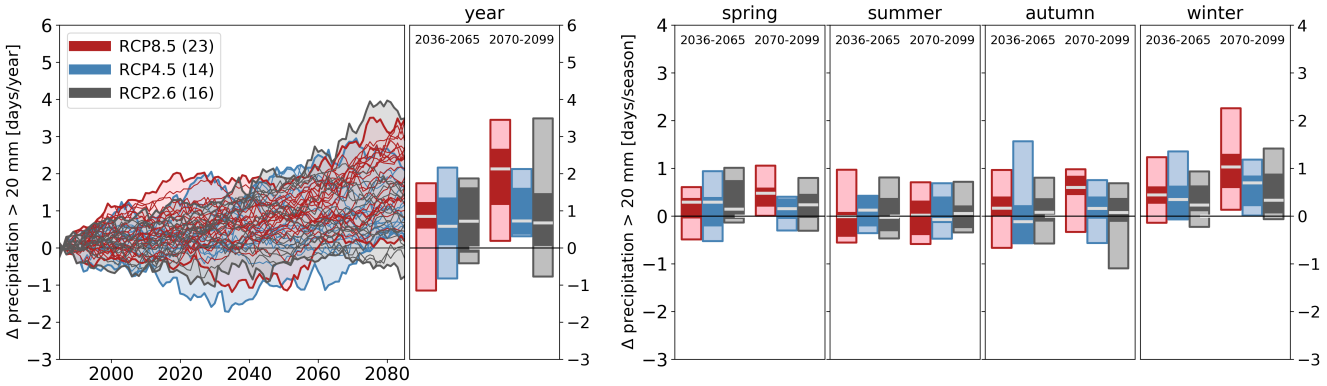


For the **end of the 21st century,** the projected annual changes for RCP8.5 is between -16.3 and 17.4 %, for RCP4.5 between -3.0 and 8.2 %, and for RCP2.6 between -7.4 and 12.5 %.



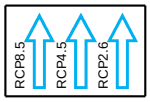
Projected changes in precipitation-based indices

Days with precipitation > 20 mm/day

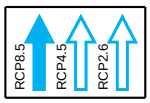


For all three RCPs an increase in the annual number of days with precipitation exceeding 20 mm is projected for the end of the 21st century.

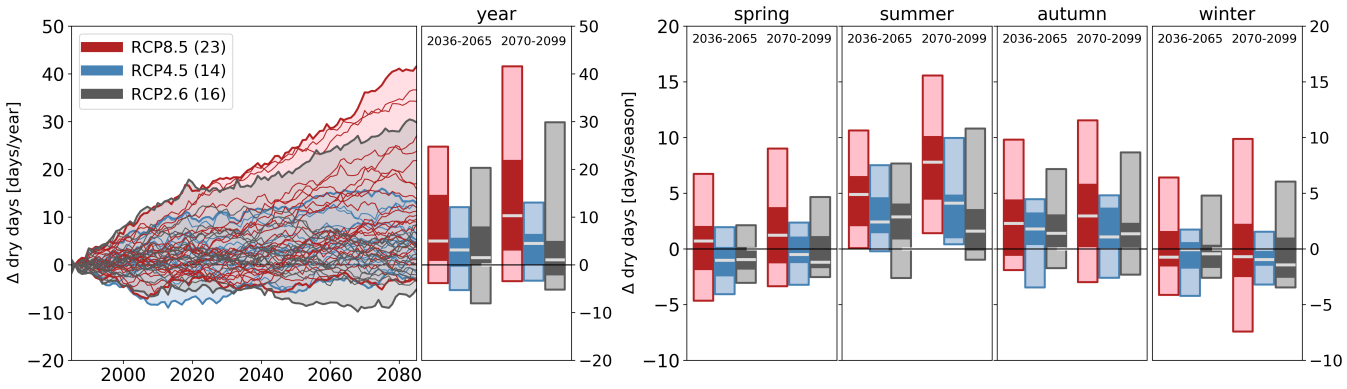
The bandwidth of projected annual changes for the **middle of the 21st century** spans from -1.1 to 1.7 days/year for RCP8.5, from -0.8 to 2.2 days/year for RCP4.5, and from -0.4 to 1.9 days/year for RCP2.6.



For the **end of the 21st century,** the projected annual increases for RCP8.5 is between 0.2 and 3.5 days/year, for RCP4.5 between 0.3 and 2.1 days/year, and for RCP2.6 between -0.8 and 3.5 days/year.

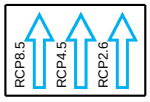


Dry days (precipitation < 1 mm/day)

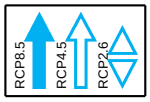


For most of the simulations, an increase in the annual number of dry days is projected for the end of the 21st century.

The bandwidth of projected annual changes for the **middle of the 21st century** spans from -4 to 25 days/year for RCP8.5, from -5 to 12 days/year for RCP4.5, and from -8 to 20 days/year for RCP2.6.

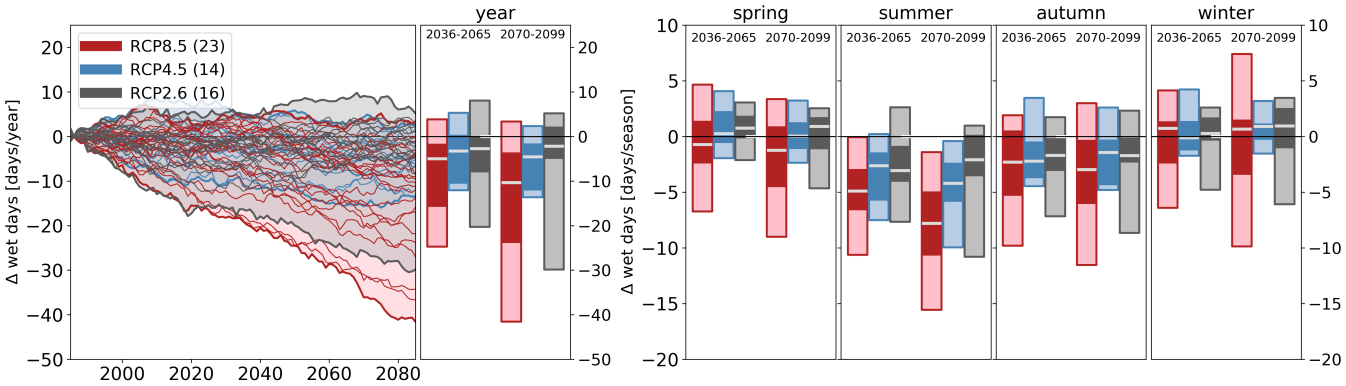


For the **end of the 21st century,** the projected annual changes for RCP8.5 is between -3 and 42 days/year, for RCP4.5 between -3 and 13 days/year, and for RCP2.6 between -5 and 30 days/year.



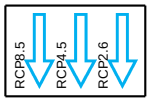
Projected changes in precipitation-based indices

Wet days (precipitation ≥ 1 mm/day)

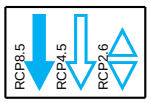


For most of the simulations, a decrease in the annual number of wet days is projected for the end of the 21st century.

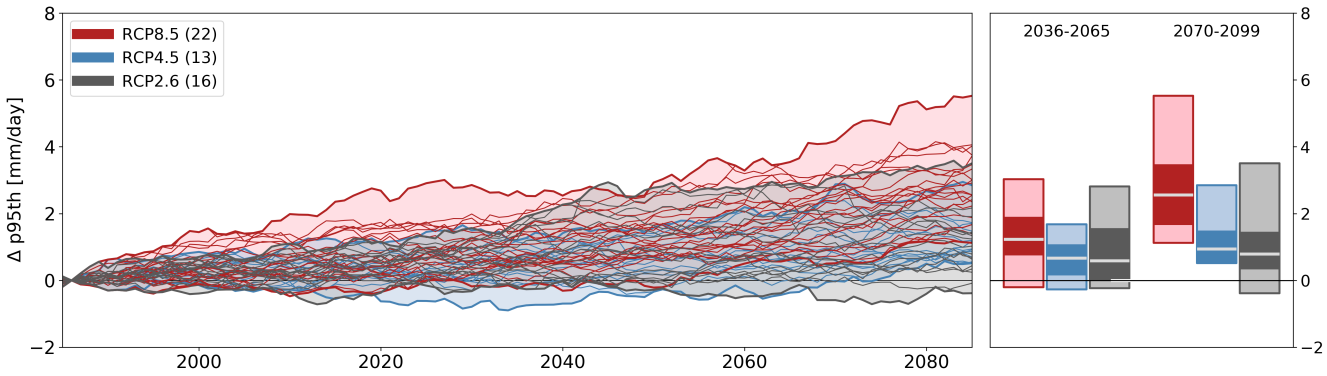
The bandwidth of projected annual changes for the **middle of the 21st century** spans from -25 to 4 days/year for RCP8.5, from -12 to 5 days/year for RCP4.5, and from -20 to 8 days/year for RCP2.6.



For the **end of the 21st century,** the projected annual changes for RCP8.5 is between -42 and 3 days/year, for RCP4.5 between -14 and 2 days/year, and for RCP2.6 between -30 and 5 days/year.

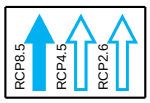


95th percentile of precipitation on wet days

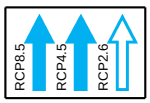


For all three RCPs an increase in the annual 95th percentile of precipitation on wet days is projected for the end of the 21st century.

The bandwidth of projected annual changes for the **middle of the 21st century** spans from -0.2 to 3.0 mm/day for RCP8.5, from -0.3 to 1.7 mm/day for RCP4.5, and from -0.2 to 2.8 mm/day for RCP2.6.

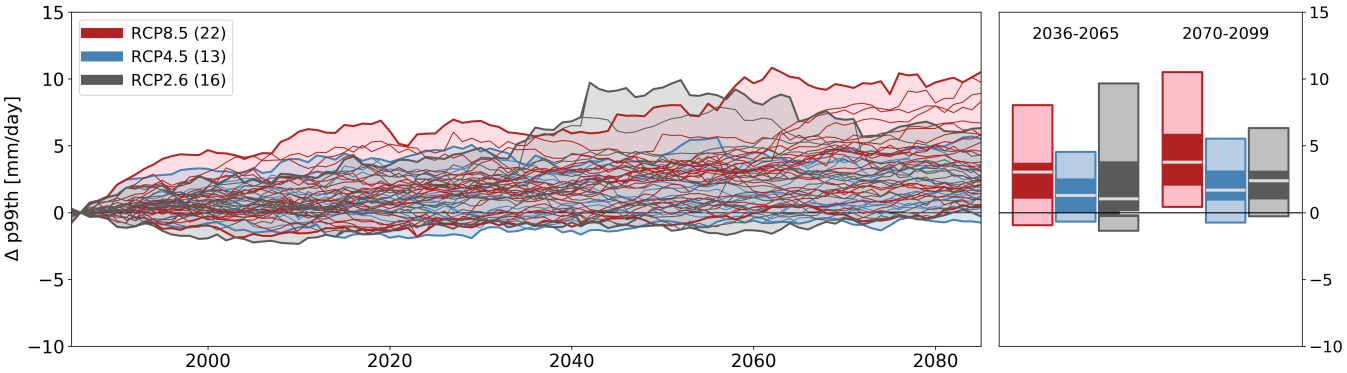


For the **end of the 21st century,** the projected annual increases for RCP8.5 is between 1.1 and 5.5 mm/day, for RCP4.5 between 0.5 and 2.8 mm/day, and for RCP2.6 between -0.4 and 3.5 mm/day.



Projected changes in precipitation-based indices

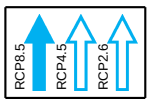
99th percentile of precipitation on wet days



For all three RCPs an increase in the annual 99th percentile of precipitation on wet days is projected for the end of the 21st century.

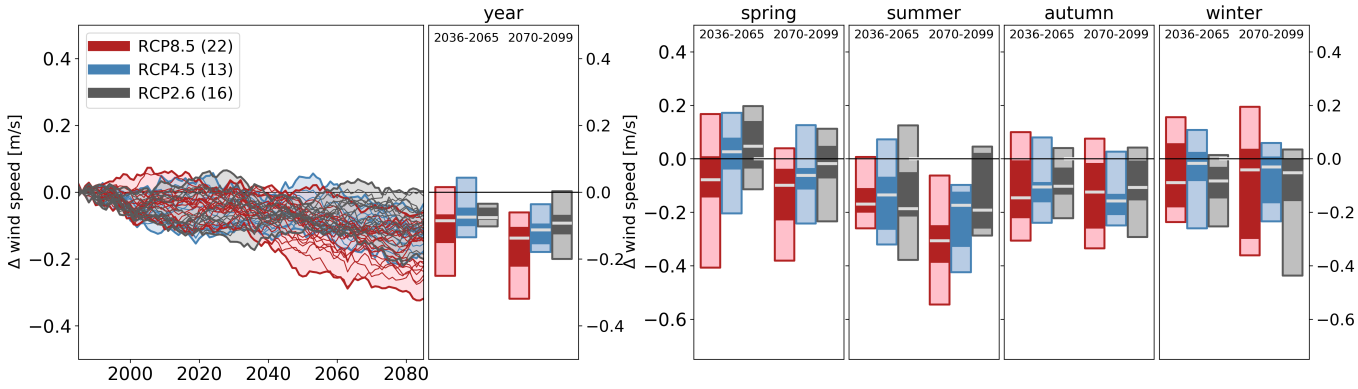
The bandwidth of projected annual changes for the **middle of the 21st century** spans from -0.9 to 8.0 mm/day for RCP8.5, from -0.7 to 4.5 mm/day for RCP4.5, and from -1.4 to 9.7 mm/day for RCP2.6.

For the **end of the 21st century,** the projected annual increases for RCP8.5 is between 0.4 and 10.5 mm/day, for RCP4.5 between -0.7 and 5.5 mm/day, and for RCP2.6 between -0.3 and 6.3 mm/day.



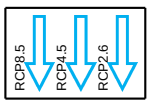
Projected changes in other indices

Wind speed

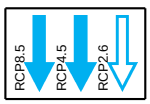


For all three RCPs a decrease in the annual wind speed is projected for the end of the 21st century.

The bandwidth of projected annual changes for the **middle of the 21st century** spans from -0.25 to 0.02 m/s for RCP8.5, from -0.14 to 0.04 m/s for RCP4.5, and from -0.1 to -0.03 m/s for RCP2.6.

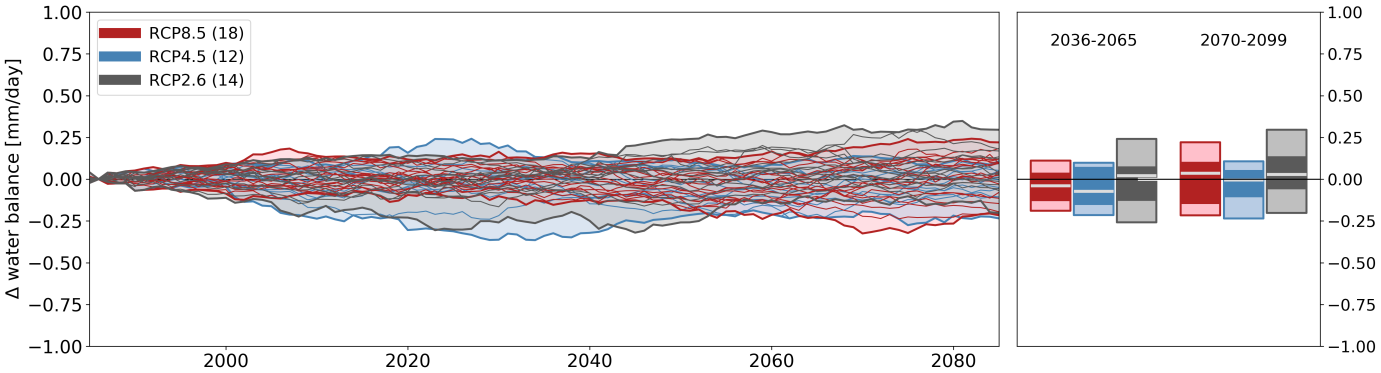


For the **end of the 21st century,** the projected annual changes for RCP8.5 is between -0.32 and -0.06 m/s, for RCP4.5 between -0.18 and -0.04 m/s, and for RCP2.6 between -0.2 and 0.0 m/s.



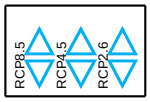
Projected changes in other indices

Climatic water balance (precipitation minus evaporation)

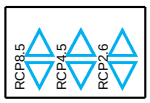


For the three different RCPs no clear change in the annual climatic water balance is projected for the end of the 21st century.

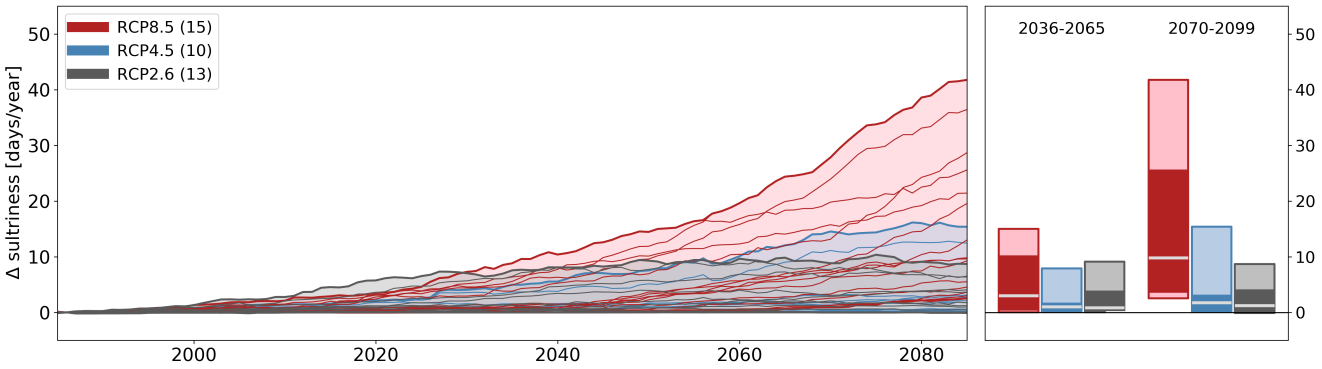
The bandwidth of projected annual changes for the **middle of the 21st century** spans from -0.19 to 0.11 mm/day for RCP8.5, from -0.21 to 0.1 mm/day for RCP4.5, and from -0.26 to 0.24 mm/day for RCP2.6.



For the **end of the 21st century,** the projected annual changes for RCP8.5 is between -0.22 and 0.22 mm/day, for RCP4.5 between -0.23 and 0.11 mm/day, and for RCP2.6 between -0.2 and 0.3 mm/day.

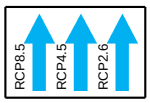


Sultriness

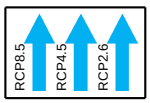


For all three RCPs an increase in the annual number of sultriness days is projected for the end of the 21st century.

The bandwidth of projected annual changes for the **middle of the 21st century** spans from 0.01 to 14.98 sultriness days for RCP8.5, from 0.04 to 7.9 sultriness days for RCP4.5, and from 0.01 to 9.13 sultriness days for RCP2.6.



For the **end of the 21st century,** the projected annual increases for RCP8.5 is between 2.52 and 41.75 sultriness days, for RCP4.5 between 0.11 and 15.38 sultriness days, and for RCP2.6 between -0.1 and 8.7 sultriness days.



Overview
temperature-based indices

	projected climate changes	minimum to maximum 2036-2065	minimum to maximum 2071-2100
RCP8.5	temperature [°C]	0.85 to 2.30	1.70 to 3.85
	number of summer days [days/year]	-0.09 to 10.21	0.34 to 30.08
	number of hot days [days/year]	-0.03 to 0.84	0.00 to 3.35
	number of tropical nights [nights/year]	0.00 to 4.64	0.00 to 17.46
	maximum duration of heat waves [days]	-0.00 to 0.61	0.00 to 1.68
	number of days > 5 °C [days/year]	19.66 to 42.40	34.67 to 70.30
	number of heating degree days [HDD]	-608.59 to -280.04	-1004.71 to -544.71
	number of frost days [days/year]	-36.08 to -10.47	-55.30 to -15.38
	number of spring frost days [days/year]	-6.04 to -0.35	-8.15 to -0.42
RCP4.5	temperature [°C]	0.46 to 1.87	1.06 to 2.53
	number of summer days [days/year]	-0.15 to 6.43	-0.14 to 8.95
	number of hot days [days/year]	0.00 to 0.65	0.00 to 0.29
	number of tropical nights [nights/year]	0.00 to 2.47	0.00 to 4.14
	maximum duration of heat waves [days]	0.00 to 0.54	0.00 to 0.23
	number of days > 5 °C [days/year]	8.97 to 35.86	22.69 to 46.37
	number of heating degree days [HDD]	-521.31 to -139.34	-688.06 to -323.59
	number of frost days [days/year]	-26.97 to -6.39	-39.62 to -11.20
	number of spring frost days [days/year]	-4.56 to -0.31	-6.55 to -0.34
RCP2.6	temperature [°C]	0.15 to 1.34	-0.05 to 1.36
	number of summer days [days/year]	-0.53 to 4.24	-0.21 to 5.37
	number of hot days [days/year]	-0.03 to 0.13	-0.01 to 0.45
	number of tropical nights [nights/year]	0.00 to 0.86	0.00 to 0.64
	maximum duration of heat waves [days]	-0.03 to 0.07	-0.01 to 0.23
	number of days > 5 °C [days/year]	1.55 to 27.43	-0.78 to 27.34
	number of heating degree days [HDD]	-434.29 to -47.36	-439.67 to 12.16
	number of frost days [days/year]	-26.21 to -1.02	-29.93 to 2.95
	number of spring frost days [days/year]	-3.69 to -0.30	-4.87 to -0.10

Overview
precipitation-based indices

	projected climate changes	minimum to maximum 2036-2065	minimum to maximum 2071-2100
RCP8.5	precipitation [%]	-7.95 to 7.96	-16.34 to 17.37
	number of days with precipitation > 20 mm [days/year]	-1.15 to 1.74	0.19 to 3.45
	number of dry days [days/year]	-3.83 to 24.76	-3.41 to 41.55
	number of wet days [days/year]	-24.76 to 3.83	-41.59 to 3.38
	p95th [mm/day]	-0.20 to 3.03	1.12 to 5.52
	p99th [mm/day]	-0.94 to 8.04	0.43 to 10.51
RCP4.5	precipitation [%]	-4.36 to 6.53	-3.00 to 8.24
	number of days with precipitation > 20 mm [days/year]	-0.82 to 2.16	0.31 to 2.12
	number of dry days [days/year]	-5.30 to 12.08	-3.34 to 13.03
	number of wet days [days/year]	-12.08 to 5.30	-13.63 to 2.34
	p95th [mm/day]	-0.27 to 1.68	0.52 to 2.85
	p99th [mm/day]	-0.67 to 4.54	-0.75 to 5.52
RCP2.6	precipitation [%]	-7.21 to 14.07	-7.42 to 12.49
	number of days with precipitation > 20 mm [days/year]	-0.42 to 1.87	-0.77 to 3.49
	number of dry days [days/year]	-8.08 to 20.32	-5.18 to 29.83
	number of wet days [days/year]	-20.32 to 8.08	-29.86 to 5.18
	p95th [mm/day]	-0.24 to 2.81	-0.38 to 3.50
	p99th [mm/day]	-1.37 to 9.66	-0.29 to 6.33

Overview
other indices

	projected climate changes	minimum to maximum 2036-2065	minimum to maximum 2071-2100
RCP8.5	wind speed [m/s]	-0.25 to 0.02	-0.32 to -0.06
	climatic water balance [mm/day]	-0.19 to 0.11	-0.22 to 0.22
	number of sultriness days [days/year]	0.01 to 14.98	2.52 to 41.75
RCP4.5	wind speed [m/s]	-0.14 to 0.04	-0.18 to -0.04
	climatic water balance [mm/day]	-0.21 to 0.10	-0.23 to 0.11
	number of sultriness days [days/year]	0.04 to 7.90	0.11 to 15.38
RCP2.6	wind speed [m/s]	-0.10 to -0.03	-0.20 to 0.00
	climatic water balance [mm/day]	-0.26 to 0.24	-0.20 to 0.30
	number of sultriness days [days/year]	0.01 to 9.13	-0.10 to 8.70

Expert judgement on the robustness of the projections

To judge on the robustness of the projected changes, the agreement of the projections on the sign of the projected changes for the end of the 21st century, as well as the statistical significance of the changes projected by each single simulation is taken into account. Statistical significance is calculated using the Mann-Whitney test (respectively U-test), which is applied for each model simulation individually. The Null-Hypothesis is formulated to test the distribution of the annual values of the respective index in future climate against their distribution in today's (reference) climate, assuming a confidence level of 0.9.

Increase is assigned in case that the majority of the simulations (>66%) project future increases of the climate index, with a majority projecting significant increases.

Decrease is assigned in case that the majority of the simulations (>66%) project future decreases of the climate index, with a majority projecting significant decreases.

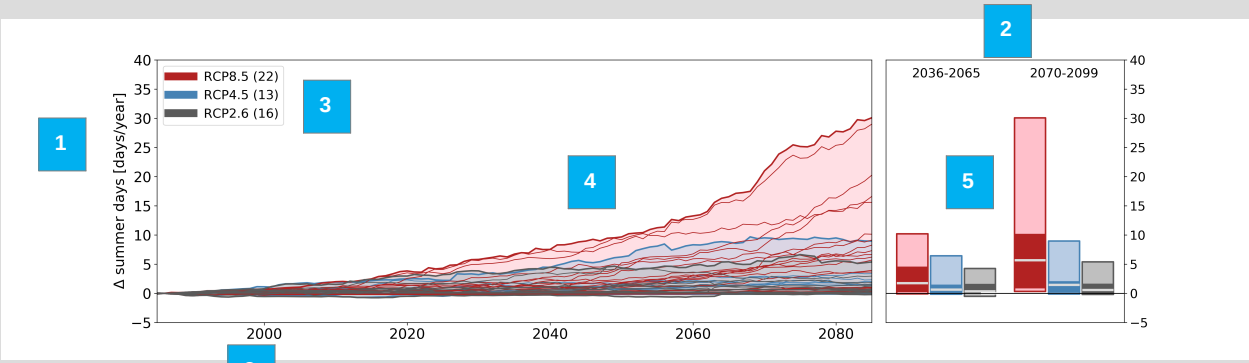
Tendency towards an increase is assigned in case that the majority of the simulations (>66%) project future increases of the climate index, with no majority projecting significant increases.

Tendency towards a decrease is assigned in case that the majority of the simulations (>66%) project future decreases of the climate index, with no majority projecting significant decreases.

Unclear: The majority of the simulations project significant changes (increases or decreases), but there is no agreement on a specific direction of the change.

No Changes: The majority of the simulations project only non-significant changes and there is no majority (>66%) agreeing on a specific direction of the change.

Reading the climate change figures



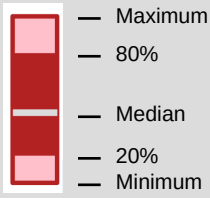
1 **Scale and units** of the projected changes for the respective index.

2 **Time scale:** years for the time series diagram and 30-year periods for the boxplot diagrams.

3 **Legend** for the time series and boxplot diagrams. Colors are indicating the underlying emission scenarios, where RCP denotes Representative Concentration Pathways.
RCP8.5: Pathway for a "worst case" scenario with high greenhouse gas emissions. RCP4.5: "medium mitigation" scenario, with medium amount of greenhouse gas emissions. RCP2.6: "stringent mitigation" scenario, with smaller or even negative greenhouse gas emissions. The numbers in brackets indicate the number of simulations entering the analysis for the respective index and scenario. As some variables are not provided for all model simulations, the numbers slightly differ for some of the indices from the total number of simulations available.

4 The **time series diagram** shows the projected 30-year running mean changes in the respective index with respect to the climate reference period of 1971 to 2000. The values are centered around the 15th year of each 30-year period, i.e. each value represents the mean value of the 30 years around this year. Each line belongs to a specific model simulation. The color-coding corresponds to the three different emission scenarios (as indicated in the legend). In addition, the shaded color background for each RCP encloses the minimum and maximum projected changes.

5 In the **boxplot diagram** the range of the projected changes is shown for two specific time periods relative to the climate reference period of 1971 to 2000: The middle of the 21st century is represented by the years 2036 to 2065, the end of the 21st century by the period from 2070 to 2099. The bars show some characteristics of the ensemble of projections.



The total range of projections is found between the minimum and maximum value indicated in the bars. The median denotes the simulation of which the value of projected change is located in the center of the entire bandwith of the ensemble. In addition, those values are marked where 20% of the ensemble project changes below or above this value.

Red color stands for the worst case scenario (RCP8.5), RCP4.5 is given in blue and RCP2.6 in gray colors.

Definition of the climate indices

Parameter	Definition
Temperature	Defined as the temperature in 2 m height above surface. The seasonal temperatures are based on the meteorological calendar, i.e. spring covers March, April and May, summer is calculated as mean of the months June, July, August, autumn temperature is calculated from September, October, and November values, and winter from December, January, and February.
Summer days	Number of days per year with daily maximum temperatures of at least 25 °C
Hot days	Number of days per year with daily maximum temperatures of at least 30 °C
Tropical nights	Number of days per year with daily minimum temperatures of at least 20 °C
Duration of heat waves	Maximum annual duration [in days] of consecutive days with daily maximum temperatures of at least 30 °C
Days > 5 °C	Number of days per year with a daily average temperature above 5 °C
Heating degree days	The total amount of heating degree days per year can be used as measure for the need of heating per year. Heating degree days are defined using a temperature threshold (here 15 °C), below which heating is needed. It is calculated by summing up the daily differences of temperature and the threshold when temperatures are below the threshold. It is given in units of HDD.
Frost days	Number of days per year with daily minimum temperatures below 0 °C
Spring frost days	Number of days between 1st of April and 31st of May with a daily minimum temperature below 0 °C
Annual and seasonal precipitation	The sum of annual and seasonal precipitation is calculated from daily precipitation sums. It contains liquid as well as solid precipitation (rain and snow). The seasonal precipitation sums are based on the meteorological calendar, i.e. spring precipitation covers March, April and May, summer precipitation sums up months June, July, August, autumn precipitation is calculated from September, October, and November values, and winter precipitation sums up the months December, January, and February.
Precipitation > 20 mm/day	Number of days per year with daily precipitation (rain and snow) higher than 20 mm
Dry days	Number of days per year with daily precipitation (rain and snow) lower than 1 mm
Wet days	Number of days per year with daily precipitation (rain and snow) of at least 1 mm
95th percentile of precipitation	Value of total daily precipitation that is exceeded on five percent of all wet days per year
99th percentile of precipitation	Value of total daily precipitation that is exceeded on one percent of all wet days per year
Wind speed	Mean annual wind speed in m/s
Climatic water balance	Difference between annual precipitation and annual evaporation in mm/day
Sultriness days	Number of days per year with daily values of vapor pressure greater than 18.8 hPa. The vapor pressure is calculated based on daily values of the near-surface air temperature and the relative humidity using the Magnus Formula.

Background information

Data sources for the information on observed climate

E-OBS gridded observational dataset (V19.0e, temporal/spatial resolution: daily/0.1°, http://surfobs.climate.copernicus.eu/dataaccess/access_eobs.php), as well as C3S, Copernicus Climate Change Service (2017): ERA5: Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service Climate Data Store (CDS). Access: https://cds.climate.copernicus.eu/.

Data sources for the climate projections

The projected climate changes presented in this Climate Fact Sheet are based on regional climate projections, which are presented in the framework of the EURO-COREX initiative (http://www.euro-cordex.net) as well as on regional climate projections provided by the ReKliEs-DE project, funded by the German Ministry of Research and Education (http://reklies.hlnug.de). The climate projections in this Fact Sheet are based on the Representative Concentration Pathways (RCPs), of which the RCP8.5 represents a worst case scenario, RCP4.5 a medium mitigation scenario, and RCP2.6 a stringent mitigation scenario. 51 climate projections were obtained in August 2018 from the ESGF data portal via the data node at the German Climate Computing Centre (https://esgf-data.dkrz.de). Of these, 16 simulations for the stringent mitigation scenario (RCP2.6), 13 simulations for the medium mitigation scenario (RCP4.5) and 22 simulations for the worst case emission scenario (RCP8.5) are available. The table below provides an overview of the regional climate models and their respective global forcing data. The EURO-CORDEX simulations are available on a grid with a spatial horizontal resolution of 12 km x 12 km. The climate change signals for the different variables presented in this Climate Fact Sheet are calculated as the weighted mean value for all grid cells located in this region.

worst case scenario (RCP8.5)	
driving GCM and realization	RCM, version number
CanESM2, r1i1p1	CCLM4-8-17, v1
CanESM2, r1i1p1	REMO2015, v1
EC-EARTH, r12i1p1	CCLM4-8-17, v1
EC-EARTH, r12i1p1	REMO2015, v1
EC-EARTH, r12i1p1	RACMO22E, v1
EC-EARTH, r12i1p1	RCA4, v1
EC-EARTH, r1i1p1	RACMO22E, v1
EC-EARTH, r1i1p1	WRF361H, v1
EC-EARTH, r3i1p1	HIRHAM5, v2
HadGEM2, r1i1p1	CCLM4-8-17, v1
HadGEM2, r1i1p1	RACMO22E, v2
HadGEM2, r1i1p1	RCA4, v1
HadGEM2, r1i1p1	REMO2015, v1
HadGEM2, r1i1p1	WRF361H, v1
IPSL-CM5A-MR, r1i1p1	RCA4, v1
MPI-ESM-LR, r1i1p1	CCLM4-8-17, v1
MPI-ESM-LR, r1i1p1	REMO2009, v1
MPI-ESM-LR, r1i1p1	RCA4, v1a
MPI-ESM-LR, r1i1p1	WRF361H, v1
MPI-ESM-LR, r2i1p1	REMO2009, v1
MIROC5, r1i1p1	CCLM4-8-17, v1
MIROC5, r1i1p1	REMO2015, v1

medium mitigation scenario (RCP4.5)	
driving GCM and realization	RCM, version number
EC-EARTH, r12i1p1	CCLM4-8-17, v1
EC-EARTH, r12i1p1	RCA4, v1
EC-EARTH, r12i1p1	RACMO22E, v1
EC-EARTH, r1i1p1	RACMO22E, v1
EC-EARTH, r3i1p1	HIRHAM5, v2
HadGEM2, r1i1p1	CCLM4-8-17, v1
HadGEM2, r1i1p1	RACMO22E, v2
HadGEM2, r1i1p1	RCA4, v1
IPSL-CM5A-MR, r1i1p1	RCA4, v1
MPI-ESM-LR, r1i1p1	CCLM4-8-17, v1
MPI-ESM-LR, r1i1p1	REMO2009, v1
MPI-ESM-LR, r1i1p1	RCA4, v1a
MPI-ESM-LR, r2i1p1	REMO2009, v1

stringent mitigation scenario (RCP2.6)	
driving GCM and realization	RCM, version number
EC-EARTH, r12i1p1	CCLM4-8-17, v1
EC-EARTH, r12i1p1	RCA4, v1
EC-EARTH, r12i1p1	REMO2015, v1
EC-EARTH, r12i1p1	RACMO22E, v1
EC-EARTH, r3i1p1	HIRHAM5, v2
GFDL-ESM2G, r1i1p1	REMO2015, v1
HadGEM2, r1i1p1	RACMO22E, v2
HadGEM2, r1i1p1	REMO2015, v1
HadGEM2, r1i1p1	RCA4, v1
IPSL-CM5A-LR, r1i1p1	REMO2015, v1
MIROC5, r1i1p1	REMO2015, v1
MPI-ESM-LR, r1i1p1	REMO2009, v1
MPI-ESM-LR, r1i1p1	CCLM4-8-17, v1
MPI-ESM-LR, r1i1p1	RCA4, v1a
MPI-ESM-LR, r1i1p1	WRF361H, v1
MPI-ESM-LR, r2i1p1	REMO2009, v1

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