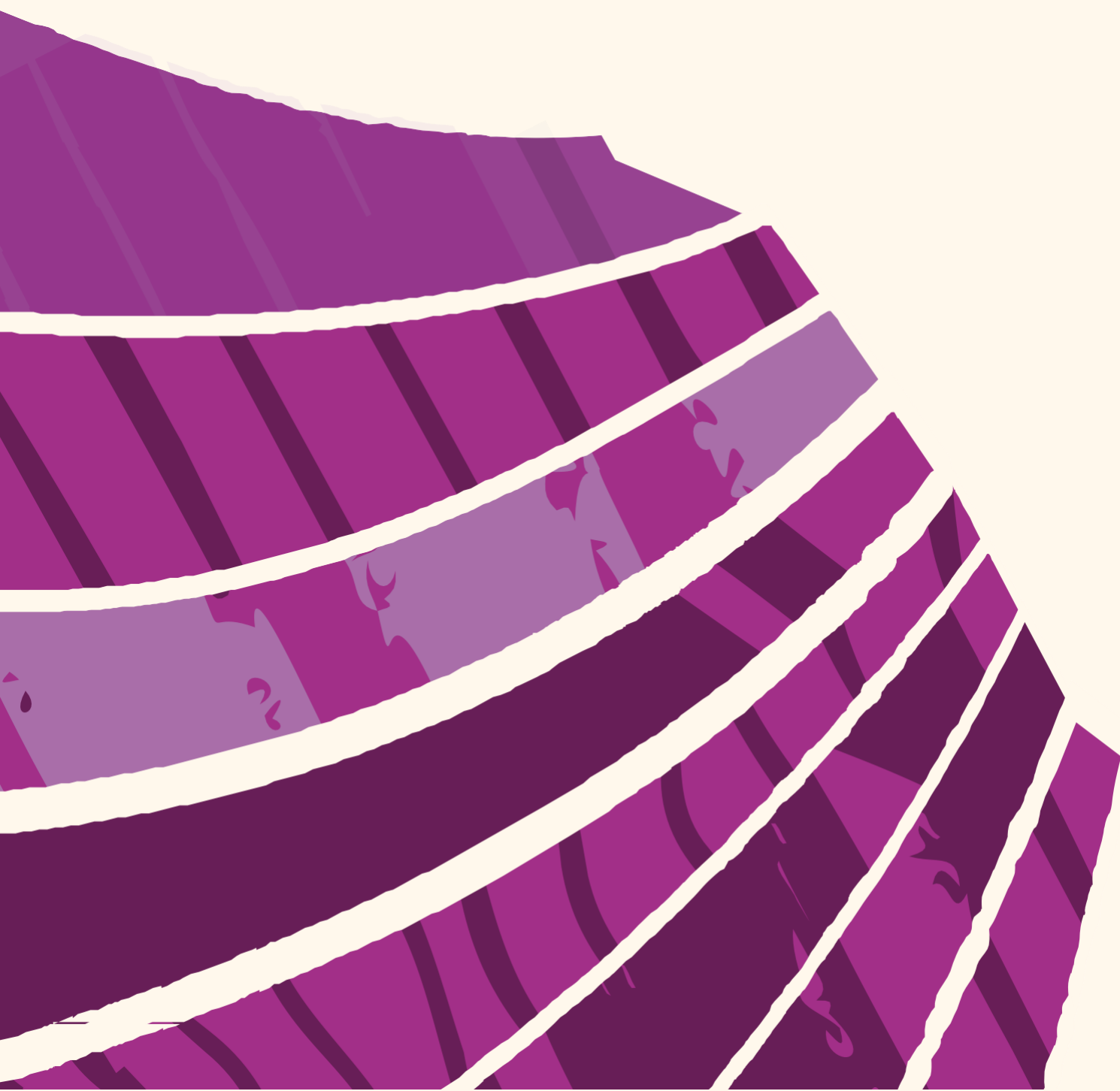


Appendix to Chapter 1

Physical and ecological manifestation of climate change in Austria



Second Austrian Assessment Report on Climate Change | AAR2

Appendix to Chapter 1

Physical and ecological manifestation of climate change in Austria

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1.A.1 Supplementary figures

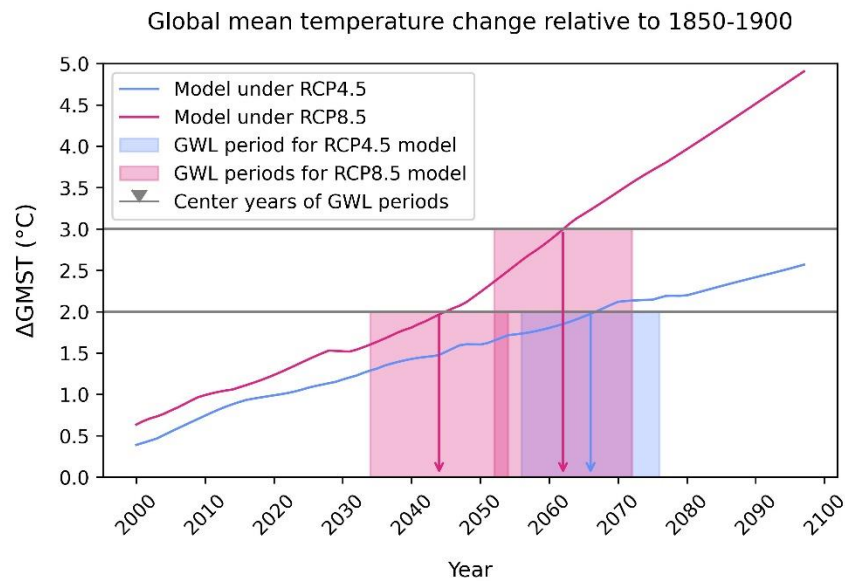


Figure 1.A. 1 Concept of defining global warming levels (GWLs) in AAR2. The curves represent outputs of global climate models, namely annual mean changes in global mean surface temperature (GMST) from the pre-industrial reference period 1850-1900. The different point in time when 2.0°C and 3.0°C of temperature is reached by the respective models is marked with arrows. Shaded areas centered around that point signify the 20-year periods used to represent these GWLs in AAR2. Figure adapted from James et al. (2017).

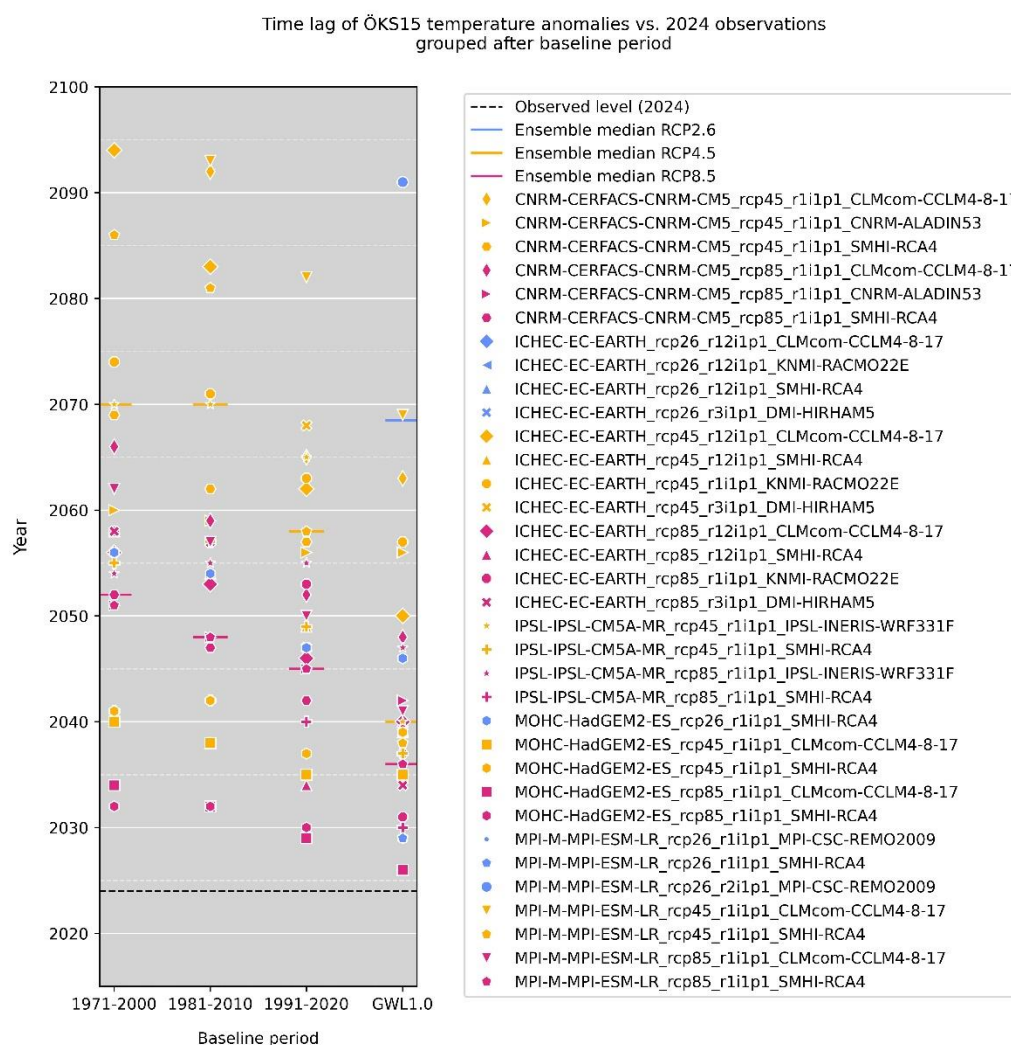


Figure 1.A. 2 Year when modeled temperature increase based on ÖKS15 simulations reaches the observed level (reference year: 2024). Observations are derived from SPARTACUS data. Each model of the ÖKS15 ensemble is represented by a unique symbol, in a way that the same combination of global and regional background model is represented by the same symbol. Colors of the symbols signify the related RCP. The symbols are grouped after different baseline periods for the temperature anomalies. The year is calculated from data filtered with a 41-year LOESS function (see also [Chapter Box 1.1 Figure 2](#)). The corresponding data can be found in Table 1.A. 3. Data sources: ÖKS15 and SPARTACUS (Truhetz and Leuprecht, 2018; GeoSphere Austria, 2020).

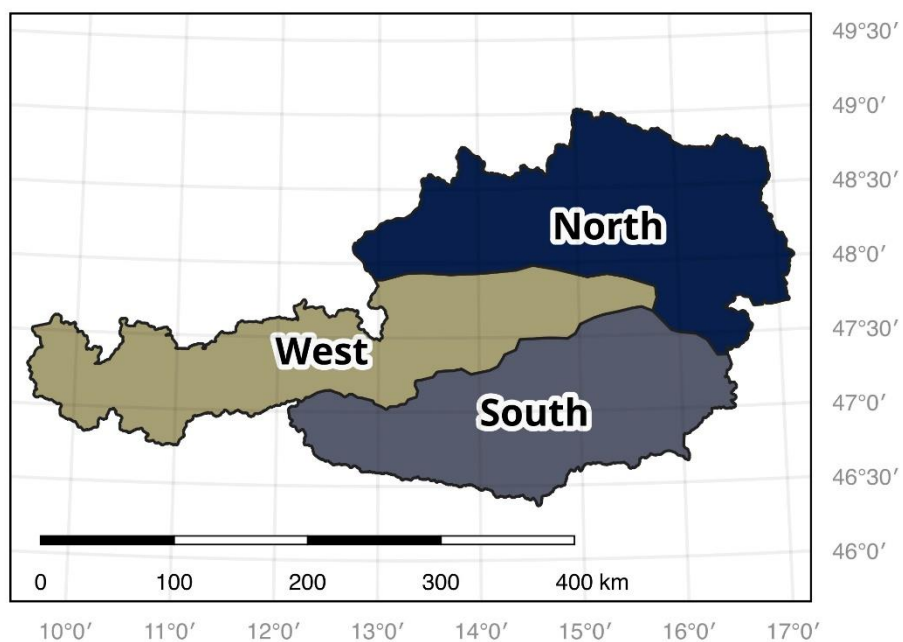


Figure 1.A. 3 Regions in Austria used in the evaluations of climatic indicators.

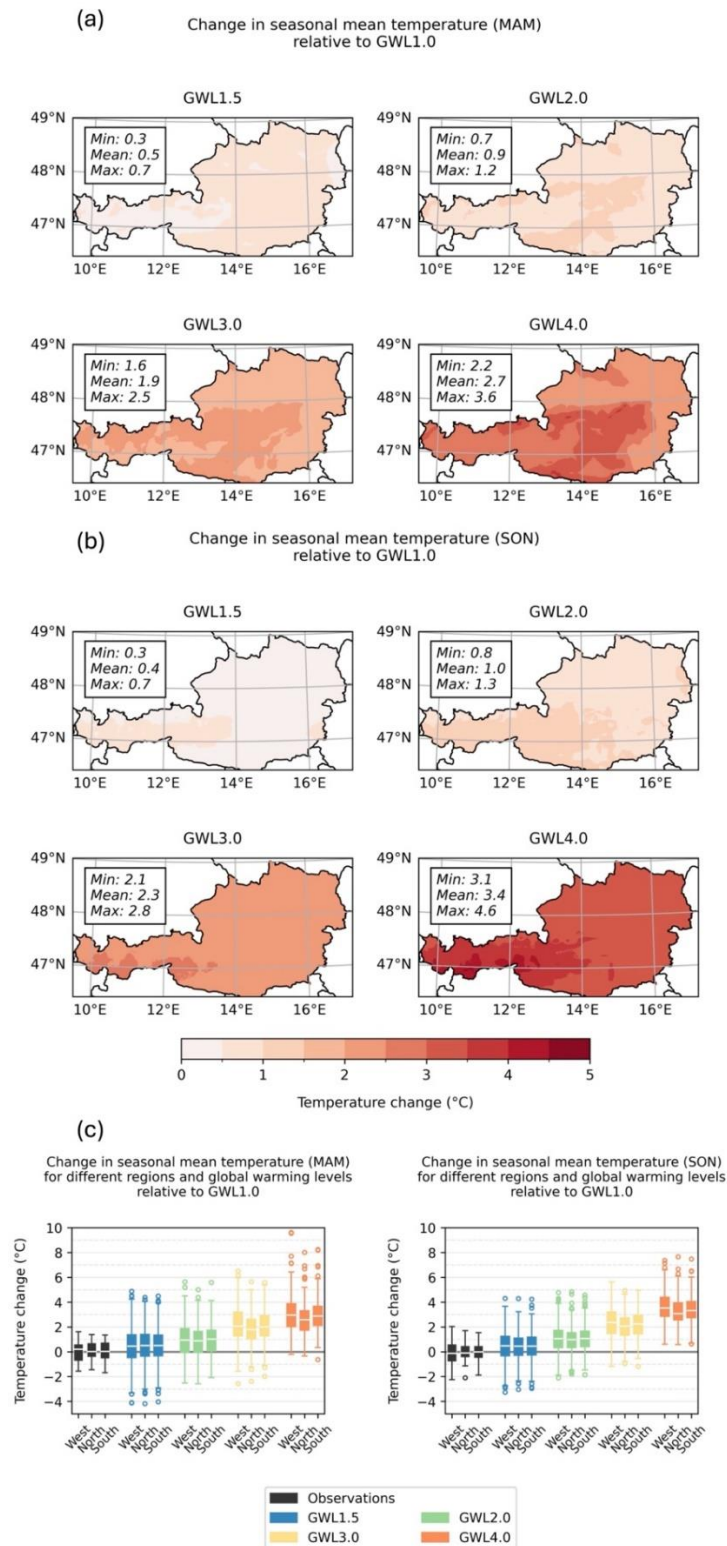


Figure 1.A. 4 Projected changes in seasonal mean temperature for spring (March-May, a) and autumn (September-November, b) for different warming levels, based on ÖKS15 simulations. Observations are derived from SPARTACUS data. Maps depict ensemble mean changes, boxplots (c) show both inter-annual and ensemble range of changes for three regions in Austria. The regions associated with the labels 'West', 'North' and 'South' can be seen in Figure 1.A. 3. The changes are calculated as averages (a, b) or annual values (c) of the periods at GWL 1.5°C, GWL 2.0°C, GWL 3.0°C and GWL 4.0°C. They relate to averages at GWL 1.0°C, which corresponds to the period 2001-2020 for the observations and different periods for each ÖKS15 model. The black bar in the boxplots (c) shows annual anomalies from the average of the period 2001-2020. Observations for the indicators shown in this figure are presented in Figure 1.A. 7. Data sources: ÖKS15 and SPARTACUS (Truhetz and Leuprecht, 2018; GeoSphere Austria, 2020).

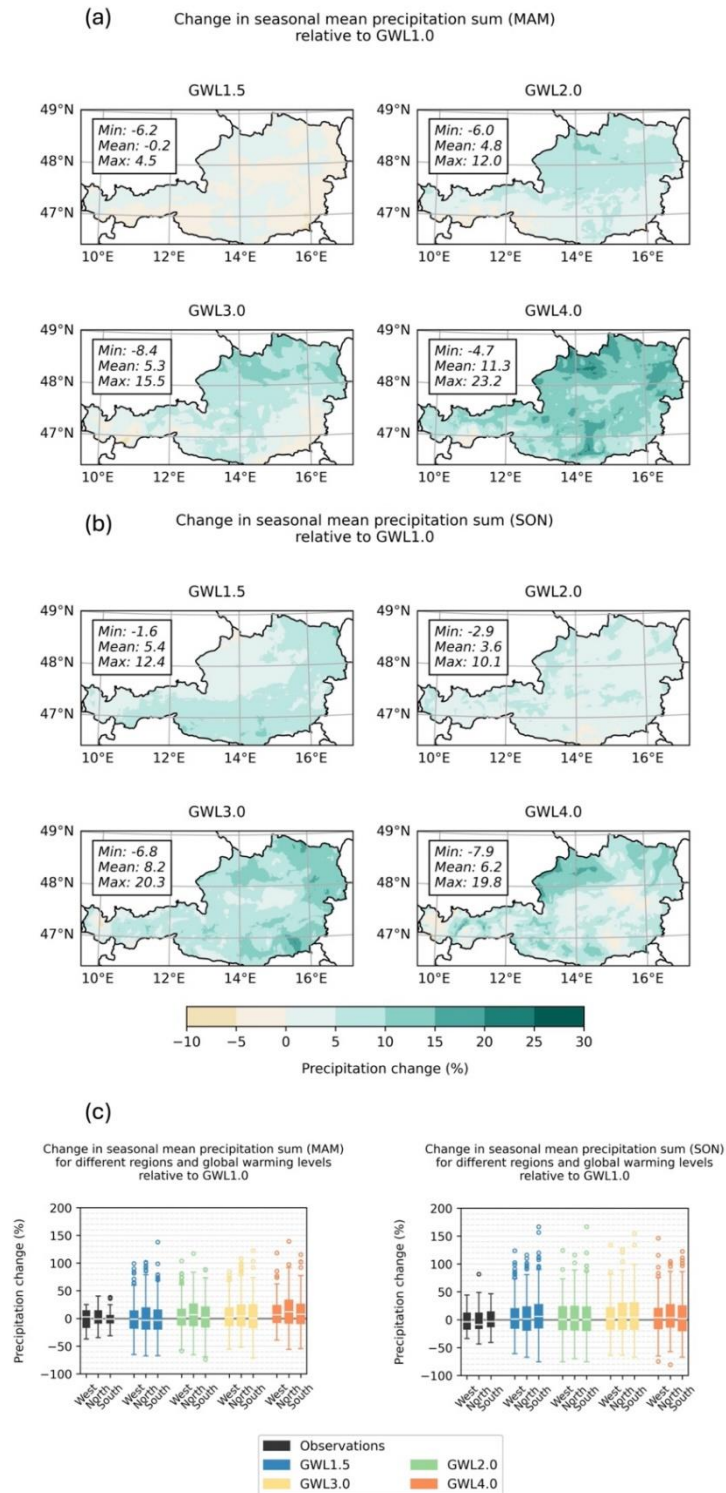


Figure 1.A. 5 Projected changes in seasonal mean precipitation sum for spring (March-May, a) and autumn (September-November, b) for different warming levels, based on ÖKS15 simulations. Observations are derived from SPARTACUS data. Maps depict ensemble mean changes, boxplots (c) show both inter-annual and ensemble range of changes for three regions in Austria. The regions associated with the labels 'West', 'North' and 'South' can be seen in Figure 1.A. 3. The changes are calculated as averages (a, b) or annual values (c) of the periods at GWL 1.5°C, GWL 2.0°C, GWL 3.0°C and GWL 4.0°C. They relate to averages at GWL1.0, which corresponds to the period 2001-2020 for the observations and different periods for each ÖKS15 model. The black bar in the boxplots (c) shows annual anomalies from the average of the period 2001-2020. Observations for the indicators shown in this figure are presented in Figure 1.A. 9. Data sources: ÖKS15 and SPARTACUS (Truhetz and Leuprecht, 2018; GeoSphere Austria, 2020).

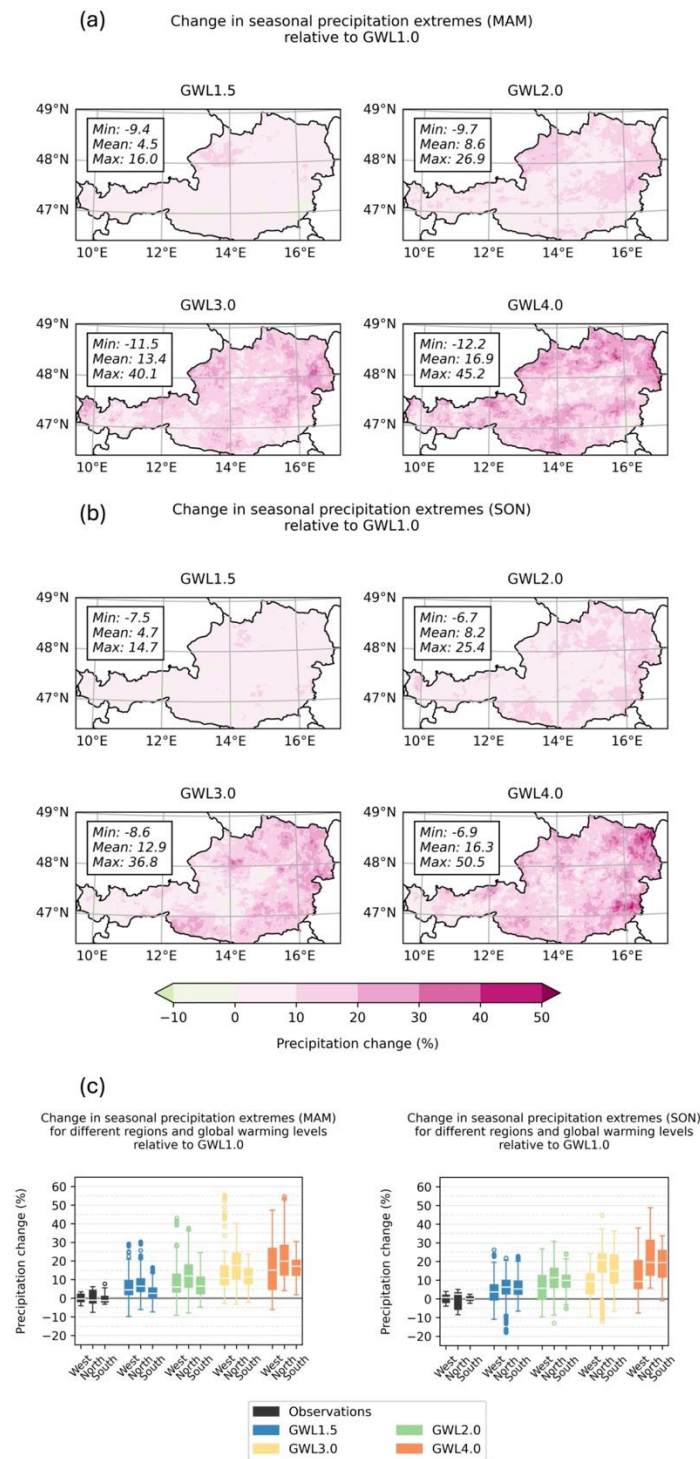


Figure 1.A. 6 Projected changes in seasonal extremes (99.9 percentile) of daily precipitation sums for spring (March-May, a) and autumn (September-November, b) for different warming levels, based on ÖKS15 simulations. Observations are derived from SPARTACUS data. Maps depict ensemble mean changes, boxplots (c) show both inter-annual and ensemble range of changes for three regions in Austria. The regions associated with the labels 'West', 'North' and 'South' can be seen in Figure 1.A. 3. The changes are calculated as averages (a, b) or annual values (c) of the periods at GWL 1.5°C, GWL 2.0°C, GWL 3.0°C and GWL 4.0°C. They relate to averages at GWL 1.0°C, which corresponds to the period 2001-2020 for the observations and different periods for each ÖKS15 model. The black bar in the boxplots (c) shows annual anomalies from the average of the period 2001-2020. Observations for the indicators shown in this figure are presented in Figure 1.A. 10. Data sources: ÖKS15 and SPARTACUS (Truhetz and Leuprecht, 2018; GeoSphere Austria, 2020).

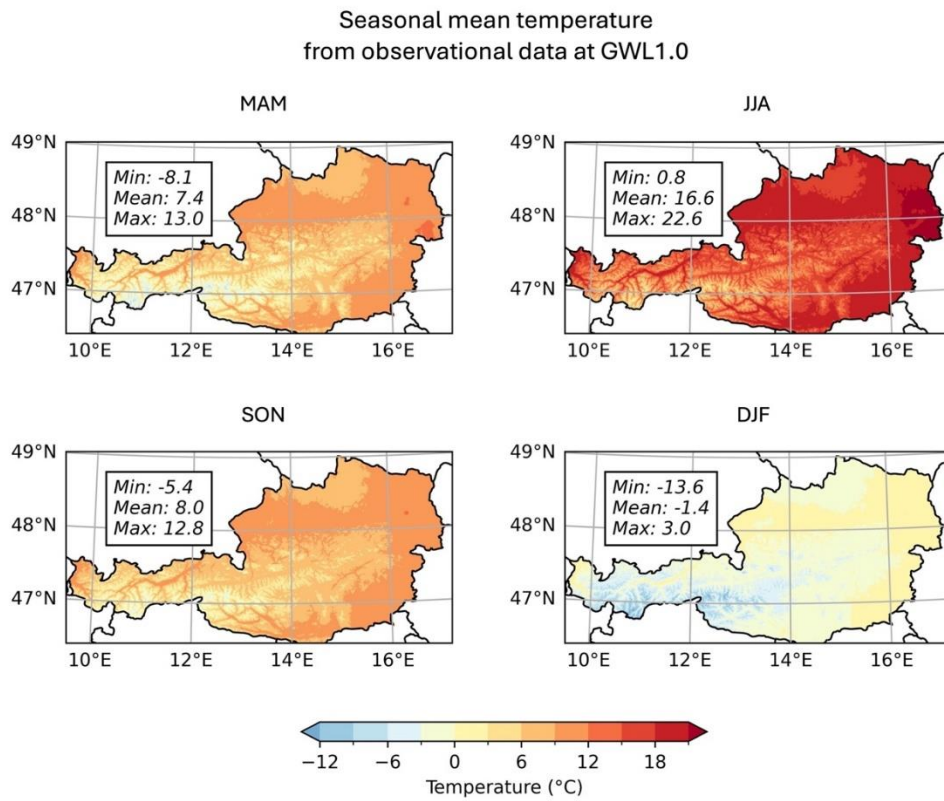
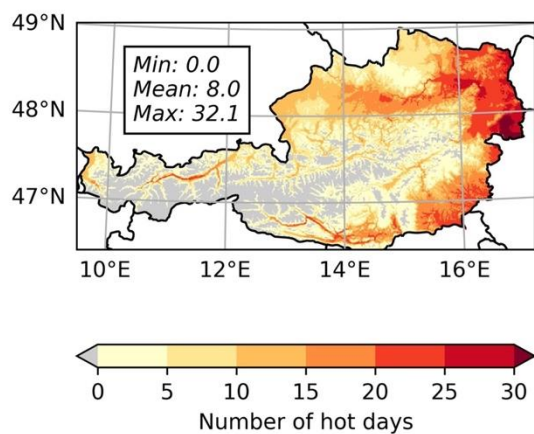


Figure 1.A. 7 Observed seasonal mean temperature derived from SPARTACUS data. Maps depict averages at GWL 1.0°C, which corresponds to the period 2001-2020. Data source: SPARTACUS (GeoSphere Austria, 2020).

(a)

Annual mean number of hot days ($\geq 30^\circ\text{C}$)
from observational data at GWL1.0



(b)

Annual mean number of tropical nights
from observational data at GWL1.0

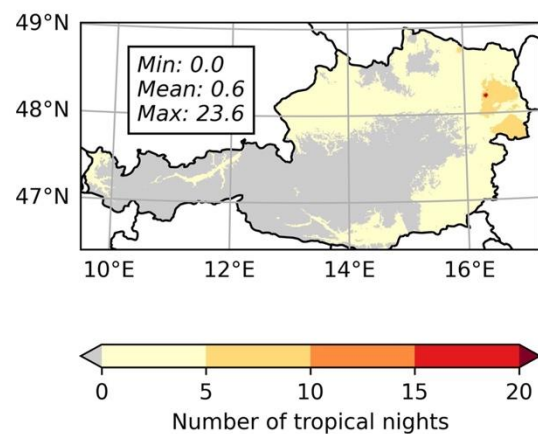


Figure 1.A. 8 Observed annual mean number of hot days (a) and tropical nights (b) derived from SPARTACUS data. Maps depict averages at GWL 1.0°C, which corresponds to the period 2001-2020. Data source: SPARTACUS (GeoSphere Austria, 2020).

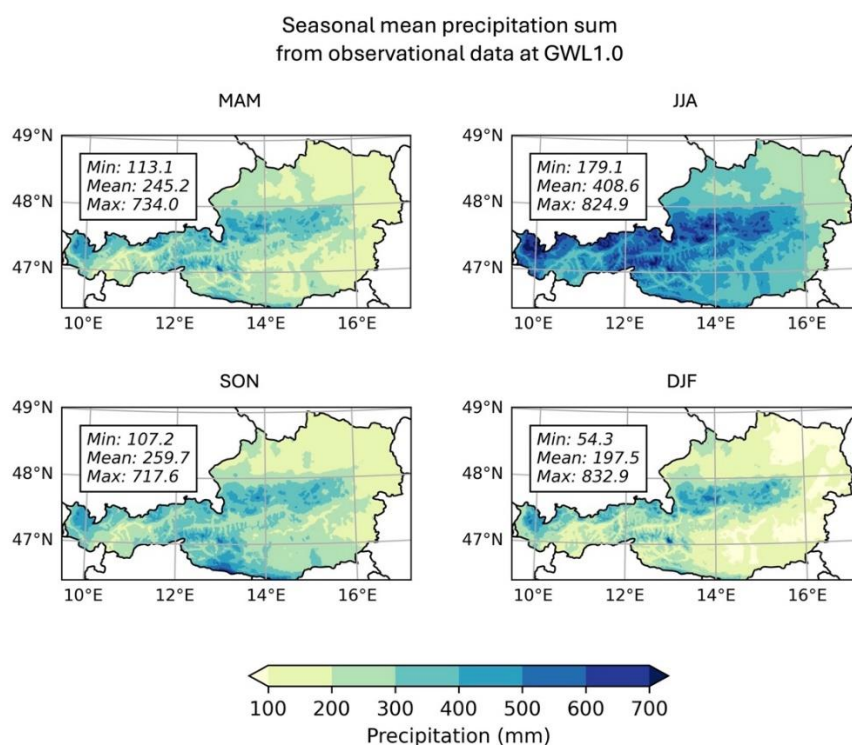


Figure 1.A. 9 Observed seasonal mean precipitation sum derived from SPARTACUS data. Maps depict averages at GWL 1.0°C, which corresponds to the period 2001-2020. Data source: SPARTACUS (GeoSphere Austria, 2020).

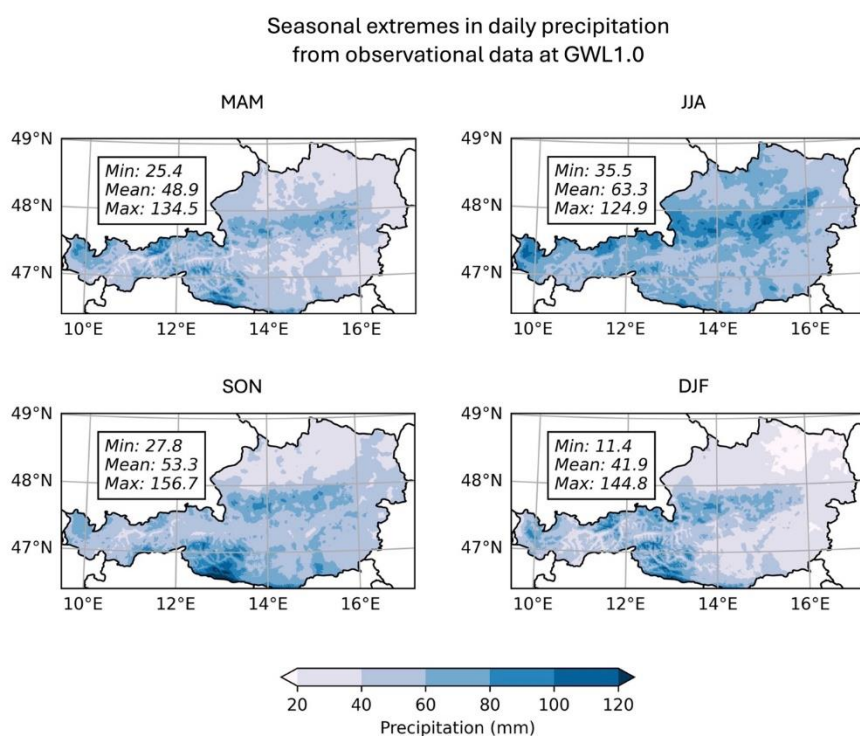


Figure 1.A. 10 Observed seasonal extremes (99.9 percentile) of daily precipitation sums derived from SPARTACUS data. Maps depict averages at GWL 1.0°C, which corresponds to the period 2001-2020. Data source: SPARTACUS (GeoSphere Austria, 2020).

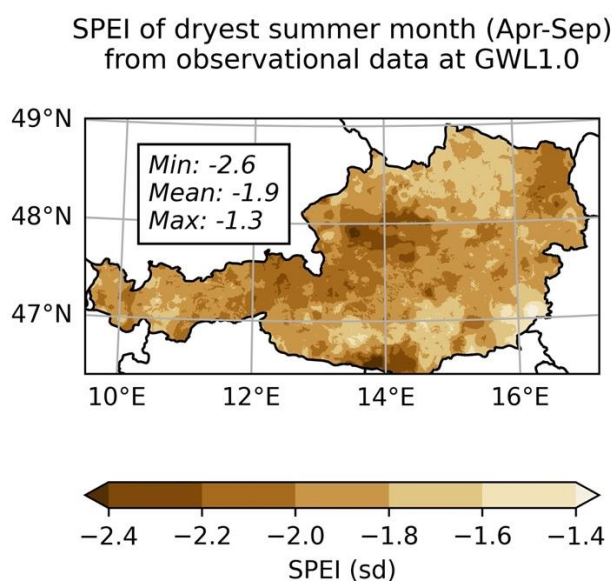


Figure 1.A. 11 Observed water balance surplus or deficit, represented by the standardized precipitation-evapotranspiration index (SPEI) of the driest month in the summer half-year (Apr-Sep), derived from SPARTACUS data. Maps depict 10th percentiles of SPEI at GWL 1.0°C, which corresponds to the period 2001-2020. Data source: SPARTACUS (GeoSphere Austria, 2020), FORSITE II.

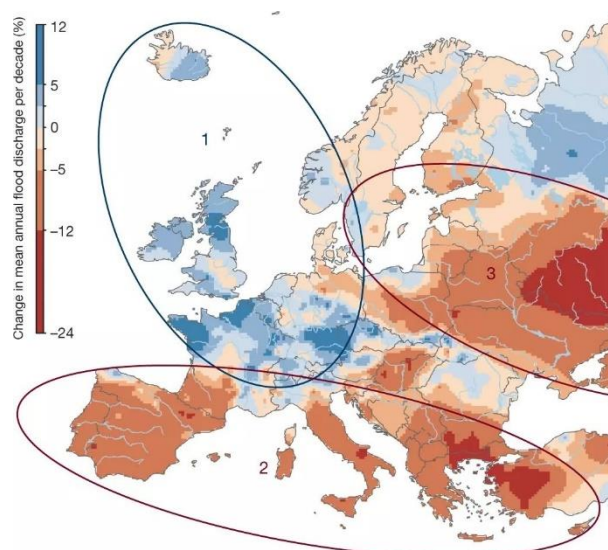


Figure 1.A. 12 Generalized changes in HQ100 from scenario analyses (delta change) for individual mechanisms. 2021-2050 compared to 1976-2006. From Blöschl et al. (2019).

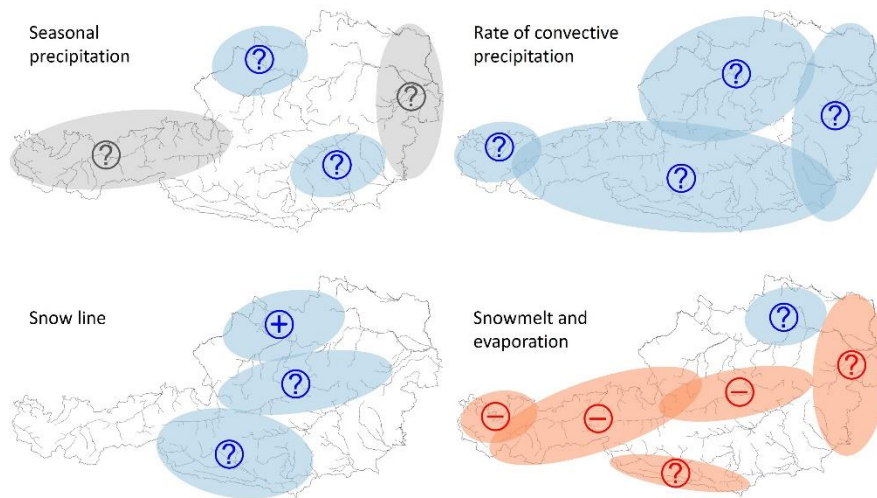


Figure 1.A. 13 Generalized changes in HQ100 scenario analyses (delta change) for all mechanisms together (top); trends in annual maxima for the series 1955-2014 (middle), and 1976-2014 (bottom). Figure adapted from Blöschl et al. (2011, 2018).

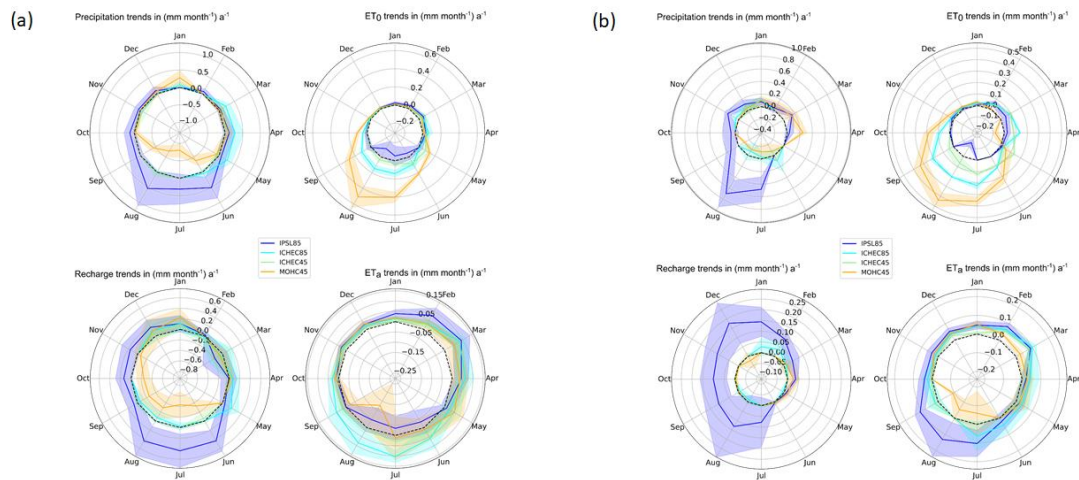


Figure 1.A. 14 Averaged monthly trends in precipitation, reference evapotranspiration (ET₀), modeled recharge, and actual evapotranspiration rates (ET_a) for (a) western sites in Austria (Lauterach, Leutasch, Achenkirch, Gschlössboden, Sillianberger Alm, Zetttersfeld, Gumpenstein, Elsbethen, Aichfeld, and Pettenbach), and for (b) eastern sites in Austria (Kalsdorf, Schalladorf, Lobau, and Frauenkirchen); the radial axis of the circular plots shows the trends in mm month⁻¹ a⁻¹, and the months are given on the polar axis. The zero line (black and dashed) refers to values of the past which were normalized to zero; inside the zero-line, negative monthly trends are shown, outside are positive trends. Solid lines show the mean and the shaded areas the standard deviation for each climate scenario for the sites; more details see Schöbl (2023).

1.A.2 Supplementary Tables

Table 1.A. 1 Definitions and units of climate indicators used in Chapter 1.

Relevant variable	Indicator Name	Indicator definition	Unit
Temperature	Mean temperature	Average temperature of the year or the seasons (DJF, MAM, JJA, SON)	°C
	Hot days (su30)	Number of days with Tmax ≥ 30°C	days
	Summer days (su25)	Number of days with Tmax ≥ 25°C	days
	Tropical nights (tr20)	Number of days with Tmin ≥ 20°C	days
	Heat episodes (Kysely days) (kys)	A Kysely episode is determined when the maximum temperature exceeds 30.0°C for at least three days in a row and lasts as long as the maximum temperature averaged over the entire episode remains above 30.0°C and never falls below a maximum temperature of 25.0°C on any day (according to Kysely 2004). The indicator shows the sum of all days per year that fall into a Kysely episode	days
	Cooling degree days (cool)	Sum of daily differences between inside (20°C) and outside temperatures (Tmean) for all days with Tmean > 20°C	°C
	Heating degree days (hdd)	Sum of daily differences between inside (20°C) and outside temperatures (Tmean) for all days with Tmean < 12°C	°C
	Vegetation period (gsl)	Number of days between beginning and end of growing season. The start/end of the annual growing season is considered to be the first/last calendar day of a succession of several days with an average daily air temperature of at least (≥) 5 °C if this period extends over at least six days and is longer than the subsequent period on days with an average daily air temperature below 5 °C	days
	Freezing days (fd0)	Number of days with Tmin < 0°C	days
	Ice days (id0)	Number of days with Tmax < 0°C	days
Precipitation	Extreme ice days (id7)	Number of days with Tmax < 0°C & Tmin < -7°C	days
	Precipitation sum	Precipitation summed up over the year or the seasons (DJF, MAM, JJA, SON)	mm
	Wet days (1 mm) (rr1)	Number of days with precipitation sums ≥ 1 mm	days
	Precipitation intensity (sdii)	Annual or seasonal precipitation sum divided by the corresponding number of wet days of that period	mm
	Heavy precipitation days (20 mm) (rr20)	Number of days with precipitation sums ≥ 20 mm	days

Max. 5-day precipitation (rx5day)	Maximum precipitation sum of 5 consecutive days per year	mm
Extremes in daily precipitation	99.9 percentile of seasonal (DJF, MAM, JJA, SON) daily precipitation sums, evaluated over 30-year periods	mm
Longest dry period (cdd)	Longest consecutive period with daily precipitation sums ≤ 1 mm of the year	days
Days in dry periods	Number of days in ≥ 5 -day periods with daily precipitation sums ≤ 1 mm during the summer half year (April-September)	days
Dry hiking days (hd1525)	Number of days with Tmax between 15°C and 25°C and precipitation sums ≤ 1 mm	days
Cloudy days (cloudy)	Number of days with average cloudiness > 80 %	days
Clear days (clear)	Number of days with average cloudiness < 20 %	days
Climatic water balance (normalized) (SPEI)	Precipitation - potential evapotranspiration (normalized)	1
Climatic water balance (abs) (CWB)	Precipitation - potential evapotranspiration (absolute)	mm

Table 1.A. 2 Global warming levels (GWLs) for models across different generations used in AAR2. The table contains periods for fixed GWLs and GWLs for fixed periods.

Model name	Period for GWLs					GWLs for period		
	GWL1.0	GWL 1.5	GWL 2.0	GWL 3.0	GWL 4.0	2021-2050	2041-2060	2081-2100
CMIP3								
CCCma_CGCM3_B1_r1	1977-1996	1995-2014	2013-2032	2062-2081		2.3	2.6	3.2
HadCM3_B1_r1	2011-2030	2039-2058	2056-2075			1.3	1.6	2.4
IPSL_CM4_B1_r1	1991-2010	2013-2032	2037-2056			1.8	2.1	2.8
MPI-M_ECHAM5_B1_r1	2021-2040	2040-2059	2057-2076			1.0	1.5	2.5
CCCma_CGCM3_A1B_r1	1977-1996	1994-2013	2011-2030	2043-2062	2077-2096	2.4	2.9	4.0
CNRM-CM3_A1B_r1	1977-1996	2004-2023	2021-2040	2053-2072		2.2	2.7	3.6
HadCM3_A1B_r1	2007-2026	2024-2043	2038-2057	2070-2089		1.5	2.1	3.2
IPSL_CM4_A1B_r1	1990-2009	2010-2029	2026-2045	2056-2075		2.0	2.5	3.8
MPI-M_ECHAM5_A1B_r1	2016-2035	2030-2049	2043-2062	2065-2084		1.3	1.9	3.5
HadCM3_A2_r1	2011-2030	2028-2047	2041-2060	2064-2083		1.4	2.0	3.7
MPI-M_ECHAM5_A2_r1	2014-2033	2036-2055	2047-2066	2066-2085		1.2	1.7	3.7
NCAR-PCM_A2_r1	2001-2020	2031-2050	2051-2070			1.4	1.7	2.8
CMIP5								
BNU-ESM_rcp26_r1i1p1_200601-210012	1984-2003	1998-2017	2015-2034			2.188	2.242	2.184
CNRM-CM5_rcp26_r1i1p1_200601-210012	2003-2022	2034-2053				1.379	1.598	1.675
CanESM2_rcp26_r1i1p1_200601-210012	1992-2011	2004-2023	2024-2043			2.046	2.287	2.296
EC-EARTH_rcp26_r12i1p1_200601-210012	1994-2013	2014-2033				1.646	1.808	1.779

GFDL-ESM2M_rcp26_r1i1p1_200601-210012	2002-2021				1.264	1.293	1.303
HadGEM2-ES_rcp26_r1i1p1_200512-209911	2001-2020	2014-2033			1.717	1.935	1.868
IPSL-CM5A-LR_rcp26_r1i1p1_200601-230012	1985-2004	2001-2020	2022-2041		2.039	2.202	2.314
IPSL-CM5A-MR_rcp26_r1i1p1_200601-210012	1992-2011	2006-2025	2037-2056		1.802	2.016	1.946
MIROC5_rcp26_r1i1p1_200601-210012	2008-2027	2037-2056			1.294	1.509	1.511
MPI-ESM-LR_rcp26_r1i1p1_200601-210012	1994-2013	2013-2032			1.724	1.752	1.655
MPI-ESM-LR_rcp26_r2i1p1_200601-210012	1989-2008	2007-2026			1.768	1.850	1.695
NorESM1-ME_rcp26_r1i1p1_200601-210112	2008-2027	2075-2094			1.340	1.470	1.495
NorESM1-M_rcp26_r1i1p1_200601-210012	2008-2027				1.312	1.406	1.428
bcc-csm1-1-m_rcp26_r1i1p1_200601-210012	1986-2005	2002-2021	2034-2053		1.965	2.030	1.813
bcc-csm1-1_rcp26_r1i1p1_200601-209912	1988-2007	2013-2032			1.734	1.751	1.765
BNU-ESM_rcp45_r1i1p1_200601-210012	1984-2003	1998-2017	2014-2033	2054-2073	2.293	2.657	3.250
CNRM-CM5_rcp45_r1i1p1_200601-210012	2002-2021	2028-2047	2049-2068		1.456	1.815	2.517
CanESM2_rcp45_r1i1p1_200601-210012	1993-2012	2008-2027	2022-2041	2066-2085	2.115	2.502	3.095
EC-EARTH_rcp45_r12i1p1_200601-210012	1994-2013	2013-2032	2035-2054		1.754	2.147	2.688
EC-EARTH_rcp45_r1i1p1_200601-209912	1993-2012	2013-2032	2035-2054		1.801	2.122	2.648

HadGEM2- ES_rcp45_r1i1p1_200512- 209911	2002- 2021	2019- 2038	2034- 2053	2069- 2088		1.709	2.221	3.018
IPSL-CM5A- LR_rcp45_r1i1p1_200601- 230012	1985- 2004	2004- 2023	2021- 2040	2060- 2079		2.150	2.602	3.167
IPSL-CM5A- MR_rcp45_r1i1p1_200601- 210012	1992- 2011	2007- 2026	2024- 2043	2068- 2087		2.043	2.357	3.104
MPI-ESM- LR_rcp45_r1i1p1_200601- 210012	1993- 2012	2013- 2032	2035- 2054			1.822	2.071	2.501
NorESM1- ME_rcp45_r1i1p1_200601- 210212	2008- 2027	2032- 2051	2058- 2077			1.355	1.725	2.204
NorESM1- M_rcp45_r1i1p1_200601- 210012	2009- 2028	2030- 2049	2064- 2083			1.400	1.671	2.155
bcc-csm1-1- m_rcp45_r1i1p1_200601- 210012	1986- 2005	2002- 2021	2025- 2044			2.000	2.142	2.479
bcc-csm1- 1_rcp45_r1i1p1_200601- 209912	1988- 2007	2012- 2031	2034- 2053			1.862	2.119	2.534
GFDL- ESM2M_rcp60_r1i1p1_200601- 210012	2005- 2024	2047- 2066	2065- 2084			1.274	1.389	2.279
HadGEM2- ES_rcp60_r1i1p1_200512- 209911	2001- 2020	2020- 2039	2038- 2057	2063- 2082		1.676	2.083	3.489
IPSL-CM5A- LR_rcp60_r1i1p1_200601- 210012	1985- 2004	2003- 2022	2023- 2042	2062- 2081		2.067	2.506	3.521
MIROC5_rcp60_r1i1p1_200601- 210012	2015- 2034	2043- 2062	2062- 2081			1.170	1.428	2.451
BNU- ESM_rcp85_r1i1p1_200601- 210012	1984- 2003	1999- 2018	2013- 2032	2036- 2055	2055- 2074	2.534	3.237	5.266
CNRM- CM5_rcp85_r1i1p1_200601- 210012	2002- 2021	2021- 2040	2036- 2055	2058- 2077	2078- 2097	1.641	2.204	4.019
CanESM2_rcp85_r1i1p1_200601- 210012	1991- 2010	2004- 2023	2017- 2036	2040- 2059	2059- 2078	2.329	3.024	5.163
EC- EARTH_rcp85_r12i1p1_200601- 210012	1994- 2013	2009- 2028	2025- 2044	2051- 2070		2.020	2.574	-80.259

EC-EARTH_rcp85_r1i1p1_200601-210012	1992-2011	2010-2029	2026-2045	2052-2071	2073-2092	1.970	2.488	4.264
GFDL-CM3_rcp85_r1i1p1_200601-210012	2001-2020	2013-2032	2025-2044	2045-2064	2061-2080	2.014	2.719	4.936
GFDL-ESM2M_rcp85_r1i1p1_200601-220012	2005-2024	2027-2046	2042-2061	2073-2092	2100-2119	1.458	1.937	3.233
HadGEM2-ES_rcp85_r1i1p1_200512-209912	2000-2019	2014-2033	2026-2045	2045-2064	2062-2081	1.980	2.724	5.007
IPSL-CM5A-LR_rcp85_r1i1p1_200601-230012	1985-2004	2001-2020	2017-2036	2038-2057	2056-2075	2.372	3.153	5.360
IPSL-CM5A-MR_rcp85_r1i1p1_200601-210012	1992-2011	2006-2025	2021-2040	2041-2060	2057-2076	2.168	2.963	5.106
MIROC5_rcp85_r1i1p1_200601-210012	2007-2026	2024-2043	2039-2058	2063-2082		1.544	2.044	3.677
MPI-ESM-LR_rcp85_r1i1p1_200601-210012	1993-2012	2008-2027	2028-2047	2052-2071	2072-2091	1.961	2.530	4.340
NorESM1-ME_rcp85_r1i1p1_200601-210012	2003-2022	2024-2043	2038-2057	2060-2079		1.544	2.110	3.792
NorESM1-M_rcp85_r1i1p1_200601-210012	2007-2026	2023-2042	2040-2059	2064-2083		1.568	2.031	3.629
bcc-csm1-1-m_rcp85_r1i1p1_200601-210012	1986-2005	2001-2020	2019-2038	2050-2069	2076-2095	2.189	2.584	4.139
bcc-csm1-1_rcp85_r1i1p1_200601-209912	1988-2007	2010-2029	2027-2046	2050-2069	2074-2093	1.950	2.511	4.202
ÖKS15								
SDM_ICHEC-EC-EARTH_rcp26_r12i1p1_CLMcom-CCLM4-8-17_all	1994-2013	2014-2033				1.59	1.82	1.78
SDM_ICHEC-EC-EARTH_rcp26_r12i1p1_KNMI-RACMO22E_all	1994-2013	2014-2033				1.59	1.82	1.78
SDM_ICHEC-EC-EARTH_rcp26_r12i1p1_SMHI-RCA4_all	1994-2013	2014-2033				1.59	1.82	1.78

SDM_MOHC-HadGEM2-ES_rcp26_r1i1p1_SMHI-RCA4_all	2001-2020	2014-2033			1.69	1.95	1.87
SDM_MPI-M-MPI-ESM-LR_rcp26_r1i1p1_MPI-CSC-REMO2009_all	1994-2013	2013-2032			1.64	1.76	1.65
SDM_MPI-M-MPI-ESM-LR_rcp26_r1i1p1_SMHI-RCA4_all	1994-2013	2013-2032			1.64	1.76	1.65
SDM_MPI-M-MPI-ESM-LR_rcp26_r2i1p1_MPI-CSC-REMO2009_all	1989-2008	2007-2026			1.73	1.85	1.70
SDM_CNRM-CERFACS-CNRM-CM5_rcp45_r1i1p1_CLMcom-CCLM4-8-17	2002-2021	2028-2047	2049-2068		1.35	1.84	2.52
SDM_CNRM-CERFACS-CNRM-CM5_rcp45_r1i1p1_CNRM-ALADIN53	2002-2021	2028-2047	2049-2068		1.35	1.84	2.52
SDM_CNRM-CERFACS-CNRM-CM5_rcp45_r1i1p1_SMHI-RCA4	2002-2021	2028-2047	2049-2068		1.35	1.84	2.52
SDM_ICHEC-EC-EARTH_rcp45_r12i1p1_CLMcom-CCLM4-8-17	1994-2013	2013-2032	2035-2054		1.68	2.17	2.69
SDM_ICHEC-EC-EARTH_rcp45_r12i1p1_SMHI-RCA4	1994-2013	2013-2032	2035-2054		1.68	2.17	2.69
SDM_ICHEC-EC-EARTH_rcp45_r1i1p1_KNMI-RACMO22E	1993-2012	2013-2032	2035-2054		1.70	2.13	2.65
SDM_MOHC-HadGEM2-ES_rcp45_r1i1p1_CLMcom-CCLM4-8-17	2002-2021	2019-2038	2034-2053	2069-2088	1.57	2.26	3.02
SDM_MOHC-HadGEM2-ES_rcp45_r1i1p1_SMHI-RCA4	2002-2021	2019-2038	2034-2053	2069-2088	1.57	2.26	3.02
SDM_IPSL-IPSL-CM5A-MR_rcp45_r1i1p1_IPSL-INNERIS-WRF331F	1992-2011	2007-2026	2024-2043	2068-2087	1.93	2.40	3.10
SDM_IPSL-IPSL-CM5A-MR_rcp45_r1i1p1_SMHI-RCA4	1992-2011	2007-2026	2024-2043	2068-2087	1.93	2.40	3.10
SDM_MPI-M-MPI-ESM-LR_rcp45_r1i1p1_CLMcom-CCLM4-8-17	1993-2012	2013-2032	2035-2054		1.70	2.08	2.50
SDM_MPI-M-MPI-ESM-LR_rcp45_r1i1p1_SMHI-RCA4	1993-2012	2013-2032	2035-2054		1.70	2.08	2.50

SDM_CNRM-CERFACS-CNRM-CM5_rcp85_r1i1p1_CLMcom-CCLM4-8-17	2002-2021	2021-2040	2036-2055	2058-2077	2078-2097	1.51	2.24	4.02
SDM_CNRM-CERFACS-CNRM-CM5_rcp85_r1i1p1_CNRM-ALADIN53	2002-2021	2021-2040	2036-2055	2058-2077	2078-2097	1.51	2.24	4.02
SDM_CNRM-CERFACS-CNRM-CM5_rcp85_r1i1p1_SMHI-RCA4	2002-2021	2021-2040	2036-2055	2058-2077	2078-2097	1.51	2.24	4.02
SDM_ICHEC-EC-EARTH_rcp85_r12i1p1_CLMcom-CCLM4-8-17	1994-2013	2009-2028	2025-2044	2051-2070		1.88	2.62	
SDM_ICHEC-EC-EARTH_rcp85_r12i1p1_SMHI-RCA4	1994-2013	2009-2028	2025-2044	2051-2070		1.88	2.62	
SDM_ICHEC-EC-EARTH_rcp85_r1i1p1_KNMI-RACMO22E	1992-2011	2010-2029	2026-2045	2052-2071	2073-2092	1.82	2.53	4.26
SDM_MOHC-HadGEM2-ES_rcp85_r1i1p1_CLMcom-CCLM4-8-17	2000-2019	2014-2033	2026-2045	2045-2064	2062-2081	1.83	2.79	5.01
SDM_MOHC-HadGEM2-ES_rcp85_r1i1p1_SMHI-RCA4	2000-2019	2014-2033	2026-2045	2045-2064	2062-2081	1.83	2.79	5.01
SDM_IPSL-IPSL-CM5A-MR_rcp85_r1i1p1_IPSL-INERIS-WRF331F	1992-2011	2006-2025	2021-2040	2041-2060	2057-2076	2.00	3.03	5.11
SDM_IPSL-IPSL-CM5A-MR_rcp85_r1i1p1_SMHI-RCA4	1992-2011	2006-2025	2021-2040	2041-2060	2057-2076	2.00	3.03	5.11
SDM_MPI-M-MPI-ESM-LR_rcp85_r1i1p1_CLMcom-CCLM4-8-17	1993-2012	2008-2027	2028-2047	2052-2071	2072-2091	1.82	2.56	4.34
SDM_MPI-M-MPI-ESM-LR_rcp85_r1i1p1_SMHI-RCA4	1993-2012	2008-2027	2028-2047	2052-2071	2072-2091	1.82	2.56	4.34
SDM_ICHEC-EC-EARTH_rcp26_r3i1p1_DMI-HIRHAM5	1994-2013	2014-2033				1.59	1.82	1.78
SDM_ICHEC-EC-EARTH_rcp45_r3i1p1_DMI-HIRHAM5	1993-2012	2013-2032	2035-2054			1.70	2.13	2.65
SDM_ICHEC-EC-EARTH_rcp85_r3i1p1_DMI-HIRHAM5	1992-2011	2010-2029	2026-2045	2052-2071	2073-2092	1.82	2.53	4.26

CMIP6				
CAMS-CSM1-0_ssp119_r2i1p1f1_gn_201501-209912	2032-2051			
CNRM-ESM2-1_ssp119_r1i1p1f2_gr_201501-210012	2007-2026	2058-2077		
CanESM5_ssp119_r1i1p1f1_gn_201501-210012	1990-2009	2003-2022	2015-2034	
EC-Earth3-Veg-LR_ssp119_r1i1p1f1_gr_201501-210012	1997-2016	2020-2039		
EC-Earth3-Veg_ssp119_r1i1p1f1_gr_201501-210012	1984-2003	2002-2021	2020-2039	
FGOALS-g3_ssp119_r1i1p1f1_gn_201501-210012	1997-2016			
GFDL-ESM4_ssp119_r1i1p1f1_gr1_201501-210012	2011-2030			
IPSL-CM6A-LR_ssp119_r1i1p1f1_gr_201501-210012	1993-2012	2009-2028	2028-2047	
MIROC-ES2L_ssp119_r1i1p1f2_gn_201501-210012	2012-2031			
MIROC6_ssp119_r1i1p1f1_gn_201501-210012	2016-2035			
MPI-ESM1-2-LR_ssp119_r1i1p1f1_gn_201501-210012	2003-2022			
MRI-ESM2-0_ssp119_r1i1p1f1_gn_201501-210012	2005-2024	2021-2040		
UKESM1-0-LL_ssp119_r1i1p1f2_gn_201501-210012	2004-2023	2015-2034	2030-2049	
ACCESS-CM2_ssp126_r1i1p1f1_gn_201501-210012	2006-2025	2018-2037	2033-2052	
ACCESS-ESM1-5_ssp126_r1i1p1f1_gn_201501-210012	2004-2023	2021-2040	2064-2083	

AWI-CM-1-1- MR_ssp126_r1i1p1f1_gn_201 501-210012	1993- 2012	2013- 2032	2041- 2060
BCC-CSM2- MR_ssp126_r1i1p1f1_gn_201 501-210012	2009- 2028	2032- 2051	
CAMS-CSM1- O_ssp126_r2i1p1f1_gn_20150 1-209912	2023- 2042		
CAS-ESM2- O_ssp126_r1i1p1f1_gn_20150 1-210012	2012- 2031	2028- 2047	2050- 2069
CESM2- WACCM_ssp126_r1i1p1f1_gn_ _201501-210012	1997- 2016	2012- 2031	2029- 2048
CESM2_ssp126_r4i1p1f1_gn_ 201501-210012	2000- 2019	2017- 2036	2033- 2052
CMCC-CM2- SR5_ssp126_r1i1p1f1_gn_201 501-210012	1993- 2012	2014- 2033	2029- 2048
CMCC- ESM2_ssp126_r1i1p1f1_gn_2 01501-210012	1994- 2013	2022- 2041	2033- 2052
CNRM-CM6-1- HR_ssp126_r1i1p1f2_gr_2015 01-210012	1994- 2013	2008- 2027	2021- 2040
CNRM-CM6- 1_ssp126_r1i1p1f2_gr_20150 1-210012	2003- 2022	2018- 2037	2050- 2069
CNRM-ESM2- 1_ssp126_r1i1p1f2_gr_20150 1-210012	2006- 2025	2038- 2057	
CanESM5- CanOE_ssp126_r1i1p2f1_gn_ 201501-210012	1986- 2005	2000- 2019	2011- 2030
CanESM5_ssp126_r1i1p1f1_g n_201501-210012	1990- 2009	2004- 2023	2017- 2036
EC-Earth3-Veg- LR_ssp126_r1i1p1f1_gr_2015 01-210012	1998- 2017	2021- 2040	
EC-Earth3- Veg_ssp126_r1i1p1f1_gr_201 501-210012	1984- 2003	2003- 2022	2020- 2039
EC- Earth3_ssp126_r1i1p1f1_gr_2 01501-210012	1999- 2018	2013- 2032	2034- 2053

FGOALS-f3- L_ssp126_r1i1p1f1_gr_20150 1-210012	1992- 2011	2011- 2030	2047- 2066		
FGOALS- g3_ssp126_r1i1p1f1_gn_2015 01-210012	1996- 2015				
FIO-ESM-2- O_ssp126_r1i1p1f1_gn_20150 1-210012	1987- 2006	2007- 2026	2025- 2044		
GFDL- ESM4_ssp126_r1i1p1f1_gr1_ 201501-210012	2011- 2030				
GISS-E2-1- G_ssp126_r1i1p1f2_gn_2015 01-210012	2008- 2027	2022- 2041			
GISS-E2-1- H_ssp126_r1i1p1f2_gn_2015 01-210012	2004- 2023	2016- 2035	2034- 2053		
HadGEM3-GC31- LL_ssp126_r1i1p1f3_gn_2015 01-210012	2000- 2019	2012- 2031	2028- 2047		
HadGEM3-GC31- MM_ssp126_r1i1p1f3_gn_20 1501-210012	2006- 2025	2019- 2038	2031- 2050		
IITM- ESM_ssp126_r1i1p1f1_gn_20 1501-209912	1999- 2018	2036- 2055			
INM-CM4- 8_ssp126_r1i1p1f1_gr1_2015 01-210012	2005- 2024	2041- 2060			
INM-CM5- O_ssp126_r1i1p1f1_gr1_2015 01-210012	2007- 2026	2027- 2046			
IPSL-CM5A2- INCA_ssp126_r1i1p1f1_gr_20 1501-210012	1987- 2006	2002- 2021	2020- 2039	2047- 2066	2069- 2088
IPSL-CM6A- LR_ssp126_r1i1p1f1_gr_2015 01-210012	1993- 2012	2010- 2029	2029- 2048		
KACE-1-0- G_ssp126_r1i1p1f1_gr_20150 1-210012	1991- 2010	2005- 2024	2015- 2034		
KIOST- ESM_ssp126_r1i1p1f1_gr1_2 01501-210012	1993- 2012	2011- 2030			

MCM-UA-1- O_ssp126_r1i1p1f2_gn_201501-210012	1994- 2013	2014- 2033	2053- 2072	
MIROC- ES2L_ssp126_r1i1p1f2_gn_201501-210012	2010- 2029	2032- 2051		
MIROC6_ssp126_r1i1p1f1_gn_201501-210012	2016- 2035	2054- 2073		
MPI-ESM1-2- HR_ssp126_r1i1p1f1_gn_201501-210012	2002- 2021	2032- 2051		
MPI-ESM1-2- LR_ssp126_r1i1p1f1_gn_201501-210012	2002- 2021	2033- 2052		
MRI-ESM2- O_ssp126_r1i1p1f1_gn_201501-210012	2005- 2024	2020- 2039		
NESM3_ssp126_r1i1p1f1_gn_201501-210012	2000- 2019	2012- 2031	2040- 2059	
NorESM2- LM_ssp126_r1i1p1f1_gn_201501-210012	2018- 2037			
NorESM2- MM_ssp126_r1i1p1f1_gn_201501-210012	2013- 2032			
TaiESM1_ssp126_r1i1p1f1_gn_201501-210012	2008- 2027	2018- 2037	2031- 2050	
UKESM1-0- LL_ssp126_r1i1p1f2_gn_201501-210012	2003- 2022	2014- 2033	2027- 2046	
ACCESS- CM2_ssp245_r1i1p1f1_gn_201501-210012	2006- 2025	2019- 2038	2031- 2050	2062- 2081
ACCESS-ESM1- 5_ssp245_r1i1p1f1_gn_201501-210012	2005- 2024	2020- 2039	2036- 2055	
AWI-CM-1-1- MR_ssp245_r1i1p1f1_gn_201501-210012	1993- 2012	2011- 2030	2030- 2049	
BCC-CSM2- MR_ssp245_r1i1p1f1_gn_201501-210012	2009- 2028	2026- 2045	2048- 2067	
CAMS-CSM1- O_ssp245_r2i1p1f1_gn_201501-209912	2015- 2034	2046- 2065	2080- 2099	

CAS-ESM2- 0_ssp245_r1i1p1f1_gn_201501-210012	2012- 2031	2030- 2049	2043- 2062	2073- 2092	
CESM2- WACCM_ssp245_r1i1p1f1_gn_201501-210012	1997- 2016	2015- 2034	2030- 2049	2066- 2085	
CESM2_ssp245_r4i1p1f1_gn_201501-210012	2000- 2019	2019- 2038	2033- 2052	2069- 2088	
CMCC-CM2- SR5_ssp245_r1i1p1f1_gn_201501-210012	1993- 2012	2016- 2035	2029- 2048	2057- 2076	
CMCC- ESM2_ssp245_r1i1p1f1_gn_201501-210012	1994- 2013	2021- 2040	2031- 2050	2056- 2075	
CNRM-CM6-1- HR_ssp245_r1i1p1f2_gr_201501-210012	1994- 2013	2010- 2029	2024- 2043	2053- 2072	
CNRM-CM6- 1_ssp245_r1i1p1f2_gr_201501-210012	2004- 2023	2021- 2040	2039- 2058	2075- 2094	
CNRM-ESM2- 1_ssp245_r1i1p1f2_gr_201501-210012	2007- 2026	2028- 2047	2046- 2065	2079- 2098	
CanESM5- CanOE_ssp245_r1i1p2f1_gn_201501-210012	1986- 2005	2000- 2019	2011- 2030	2035- 2054	2071- 2090
CanESM5_ssp245_r1i1p1f1_gn_201501-210012	1990- 2009	2004- 2023	2015- 2034	2040- 2059	2074- 2093
EC-Earth3- CC_ssp245_r1i1p1f1_gr_201501-210012	1984- 2003	1998- 2017	2026- 2045	2064- 2083	
EC-Earth3-Veg- LR_ssp245_r1i1p1f1_gr_201501-210012	1997- 2016	2017- 2036	2040- 2059	2081- 2100	
EC-Earth3- Veg_ssp245_r1i1p1f1_gr_201501-210012	1984- 2003	2001- 2020	2024- 2043	2058- 2077	
EC- Earth3_ssp245_r1i1p1f1_gr_201501-210012	1999- 2018	2013- 2032	2035- 2054	2076- 2095	
FGOALS-f3- L_ssp245_r1i1p1f1_gr_201501-210012	1992- 2011	2012- 2031	2031- 2050		
FGOALS- g3_ssp245_r1i1p1f1_gn_201501-210012	1997- 2016	2022- 2041	2056- 2075		

FIO-ESM-2- O_ssp245_r1i1p1f1_gn_201501-210012	1987- 2006	2008- 2027	2023- 2042	2066- 2085
GFDL- CM4_ssp245_r1i1p1f1_gr1_201501-210012	2006- 2025	2022- 2041	2040- 2059	
GFDL- CM4_ssp245_r1i1p1f1_gr2_201501-210012	2006- 2025	2022- 2041	2040- 2059	
GFDL- ESM4_ssp245_r1i1p1f1_gr1_201501-210012	2009- 2028	2037- 2056	2064- 2083	
GISS-E2-1- G_ssp245_r1i1p1f2_gn_201501-210012	2008- 2027	2023- 2042	2045- 2064	
GISS-E2-1- H_ssp245_r1i1p1f2_gn_201501-210012	2004- 2023	2018- 2037	2032- 2051	2073- 2092
HadGEM3-GC31- LL_ssp245_r1i1p1f3_gn_201501-210012	2000- 2019	2010- 2029	2024- 2043	2052- 2071
IITM- ESM_ssp245_r1i1p1f1_gn_201501-209912	2000- 2019	2027- 2046	2052- 2071	
INM-CM4- 8_ssp245_r1i1p1f1_gr1_201501-210012	2005- 2024	2026- 2045	2054- 2073	
INM-CM5- O_ssp245_r1i1p1f1_gr1_201501-210012	2008- 2027	2028- 2047	2063- 2082	
IPSL-CM6A- LR_ssp245_r1i1p1f1_gr_201501-210012	1993- 2012	2009- 2028	2024- 2043	2056- 2075
KACE-1-0- G_ssp245_r1i1p1f1_gr_201501-210012	1991- 2010	2004- 2023	2014- 2033	2041- 2060
KIOST- ESM_ssp245_r1i1p1f1_gr1_201501-210012	1993- 2012	2012- 2031	2031- 2050	
MCM-UA-1- O_ssp245_r1i1p1f2_gn_201501-210012	1994- 2013	2014- 2033	2037- 2056	
MIROC- ES2L_ssp245_r1i1p1f2_gn_201501-210012	2010- 2029	2032- 2051	2054- 2073	
MIROC6_ssp245_r1i1p1f1_gn_201501-210012	2016- 2035	2037- 2056	2064- 2083	

MPI-ESM1-2- HR_ssp245_r1i1p1f1_gn_201 501-210012	2002- 2021	2028- 2047	2054- 2073		
MPI-ESM1-2- LR_ssp245_r1i1p1f1_gn_2015 01-210012	2003- 2022	2027- 2046	2048- 2067		
MRI-ESM2- O_ssp245_r1i1p1f1_gn_20150 1-210012	2005- 2024	2021- 2040	2040- 2059		
NESM3_ssp245_r1i1p1f1_gn_ 201501-210012	2000- 2019	2015- 2034	2033- 2052		
NorESM2- LM_ssp245_r1i1p1f1_gn_201 501-210012	2020- 2039	2046- 2065	2076- 2095		
NorESM2- MM_ssp245_r1i1p1f1_gn_20 1501-210012	2019- 2038	2037- 2056	2069- 2088		
TaiESM1_ssp245_r1i1p1f1_gn _201501-210012	2010- 2029	2022- 2041	2034- 2053	2059- 2078	
UKESM1-0- LL_ssp245_r1i1p1f2_gn_2015 01-210012	2004- 2023	2014- 2033	2025- 2044	2050- 2069	2081- 2100
ACCESS- CM2_ssp370_r1i1p1f1_gn_20 1501-210012	2006- 2025	2018- 2037	2030- 2049	2053- 2072	2073- 2092
ACCESS-ESM1- 5_ssp370_r1i1p1f1_gn_20150 1-210012	2004- 2023	2024- 2043	2039- 2058	2060- 2079	
AWI-CM-1-1- MR_ssp370_r1i1p1f1_gn_201 501-210012	1993- 2012	2013- 2032	2028- 2047	2055- 2074	
BCC-CSM2- MR_ssp370_r1i1p1f1_gn_201 501-210012	2008- 2027	2023- 2042	2037- 2056	2065- 2084	
BCC- ESM1_ssp370_r1i1p1f1_gn_2 01501-205512	2013- 2032	2032- 2051			
CAMS-CSM1- O_ssp370_r2i1p1f1_gn_20150 1-209912	2022- 2041	2037- 2056	2057- 2076		
CAS-ESM2- O_ssp370_r1i1p1f1_gn_20150 1-210012	2014- 2033	2031- 2050	2043- 2062	2065- 2084	
CESM2- WACCM_ssp370_r1i1p1f1_gn _201501-210012	1997- 2016	2019- 2038	2032- 2051	2054- 2073	2076- 2095

CESM2_ssp370_r4i1p1f1_gn_201501-210012	1999-2018	2021-2040	2034-2053	2059-2078	2078-2097
CMCC-CM2-SR5_ssp370_r1i1p1f1_gn_201501-210012	1993-2012	2016-2035	2030-2049	2054-2073	2078-2097
CMCC-ESM2_ssp370_r1i1p1f1_gn_201501-210012	1994-2013	2022-2041	2032-2051	2054-2073	2078-2097
CNRM-CM6-1-HR_ssp370_r1i1p1f2_gr_201501-210012	1994-2013	2010-2029	2023-2042	2048-2067	2067-2086
CNRM-CM6-1_ssp370_r1i1p1f2_gr_201501-210012	2004-2023	2023-2042	2036-2055	2057-2076	2074-2093
CNRM-ESM2-1_ssp370_r1i1p1f2_gr_201501-210012	2009-2028	2027-2046	2043-2062	2063-2082	2080-2099
CanESM5-CanOE_ssp370_r1i1p2f1_gn_201501-210012	1986-2005	1999-2018	2010-2029	2030-2049	2047-2066
CanESM5_ssp370_r1i1p1f1_gn_201501-210012	1990-2009	2004-2023	2014-2033	2034-2053	2050-2069
EC-Earth3-AerChem_ssp370_r1i1p1f1_gr_201501-210012	2009-2028	2023-2042	2038-2057	2057-2076	2074-2093
EC-Earth3-Veg-LR_ssp370_r1i1p1f1_gr_201501-210012	1998-2017	2019-2038	2036-2055	2057-2076	2078-2097
EC-Earth3-Veg_ssp370_r1i1p1f1_gr_201501-210012	1984-2003	2002-2021	2023-2042	2048-2067	2067-2086
EC-Earth3_ssp370_r1i1p1f1_gr_201501-210012	1999-2018	2013-2032	2029-2048	2054-2073	2075-2094
FGOALS-f3-L_ssp370_r1i1p1f1_gr_201501-210012	1992-2011	2012-2031	2027-2046	2055-2074	
FGOALS-g3_ssp370_r1i1p1f1_gn_201501-210012	1997-2016	2018-2037	2037-2056	2075-2094	
GFDL-ESM4_ssp370_r1i1p1f1_gr1_201501-210012	2012-2031	2032-2051	2048-2067	2074-2093	
GISS-E2-1-G_ssp370_r1i1p1f2_gn_201501-210012	2008-2027	2024-2043	2039-2058	2071-2090	

GISS-E2-1- H_ssp370_r1i1p1f2_gn_2015 01-210012	2005- 2024	2018- 2037	2031- 2050	2060- 2079	
IITM- ESM_ssp370_r1i1p1f1_gn_20 1501-209812	2001- 2020	2023- 2042	2042- 2061	2079- 2098	
INM-CM4- 8_ssp370_r1i1p1f1_gr1_2015 01-210012	2007- 2026	2026- 2045	2043- 2062	2074- 2093	
INM-CM5- O_ssp370_r1i1p1f1_gr1_2015 01-210012	2006- 2025	2023- 2042	2041- 2060	2075- 2094	
IPSL-CM5A2- INCA_ssp370_r1i1p1f1_gr_20 1501-210012	1987- 2006	2002- 2021	2021- 2040	2049- 2068	2070- 2089
IPSL-CM6A- LR_ssp370_r1i1p1f1_gr_2015 01-210012	1993- 2012	2010- 2029	2025- 2044	2046- 2065	2067- 2086
KACE-1-0- G_ssp370_r1i1p1f1_gr_20150 1-210012	1991- 2010	2005- 2024	2015- 2034	2037- 2056	2063- 2082
MCM-UA-1- O_ssp370_r1i1p1f2_gn_20150 1-210012	1994- 2013	2015- 2034	2032- 2051	2061- 2080	
MIROC- ES2L_ssp370_r1i1p1f2_gn_20 1501-210012	2010- 2029	2030- 2049	2046- 2065	2075- 2094	
MIROC6_ssp370_r1i1p1f1_gn _201501-210012	2017- 2036	2034- 2053	2050- 2069		
MPI-ESM-1-2- HAM_ssp370_r1i1p1f1_gn_20 1501-205512	2015- 2034	2033- 2052			
MPI-ESM1-2- HR_ssp370_r1i1p1f1_gn_201 501-210012	2001- 2020	2025- 2044	2041- 2060	2072- 2091	
MPI-ESM1-2- LR_ssp370_r1i1p1f1_gn_2015 01-210012	2004- 2023	2026- 2045	2043- 2062	2069- 2088	
MRI-ESM2- O_ssp370_r1i1p1f1_gn_20150 1-210012	2005- 2024	2022- 2041	2036- 2055	2064- 2083	
NorESM2- LM_ssp370_r1i1p1f1_gn_201 501-210012	2023- 2042	2042- 2061	2060- 2079		
NorESM2- MM_ssp370_r1i1p1f1_gn_20 1501-210012	2022- 2041	2037- 2056	2053- 2072	2081- 2100	

TaiESM1_ssp370_r1i1p1f1_gn_201501-210012	2010-2029	2024-2043	2034-2053	2052-2071	2072-2091
UKESM1-0-LL_ssp370_r1i1p1f2_gn_201501-210012	2004-2023	2013-2032	2022-2041	2041-2060	2060-2079
ACCESS-CM2_ssp585_r1i1p1f1_gn_201501-210012	2005-2024	2016-2035	2029-2048	2046-2065	2062-2081
ACCESS-ESM1-5_ssp585_r1i1p1f1_gn_201501-210012	2004-2023	2018-2037	2030-2049	2051-2070	2069-2088
AWI-CM-1-1-MR_ssp585_r1i1p1f1_gn_201501-210012	1993-2012	2010-2029	2027-2046	2050-2069	2070-2089
BCC-CSM2-MR_ssp585_r1i1p1f1_gn_201501-210012	2008-2027	2021-2040	2034-2053	2056-2075	
CAMS-CSM1-0_ssp585_r2i1p1f1_gn_201501-209912	2023-2042	2038-2057	2055-2074	2079-2098	
CAS-ESM2-0_ssp585_r1i1p1f1_gn_201501-210012	2011-2030	2024-2043	2036-2055	2053-2072	2068-2087
CESM2-WACCM_ssp585_r1i1p1f1_gn_201501-210012	1997-2016	2011-2030	2024-2043	2044-2063	2059-2078
CESM2_ssp585_r4i1p1f1_gn_201501-210012	2000-2019	2014-2033	2025-2044	2045-2064	2062-2081
CMCC-CM2-SR5_ssp585_r1i1p1f1_gn_201501-210012	1993-2012	2012-2031	2024-2043	2043-2062	2060-2079
CMCC-ESM2_ssp585_r1i1p1f1_gn_201501-210012	1994-2013	2020-2039	2030-2049	2046-2065	2061-2080
CNRM-CM6-1-HR_ssp585_r1i1p1f2_gr_201501-210012	1994-2013	2009-2028	2020-2039	2042-2061	2057-2076
CNRM-CM6-1_ssp585_r1i1p1f2_gr_201501-210012	2004-2023	2019-2038	2031-2050	2049-2068	2063-2082
CNRM-ESM2-1_ssp585_r1i1p1f2_gr_201501-210012	2007-2026	2023-2042	2036-2055	2055-2074	2070-2089
CanESM5-CanOE_ssp585_r1i1p2f1_gn_201501-210012	1986-2005	1999-2018	2010-2029	2028-2047	2044-2063

CanESM5_ssp585_r1i1p1f1_gn_201501-210012	1990-2009	2003-2022	2013-2032	2031-2050	2045-2064
EC-Earth3-CC_ssp585_r1i1p1f1_gr_20101-210012	1984-2003	1998-2017	2027-2046	2047-2066	2062-2081
EC-Earth3-Veg-LR_ssp585_r1i1p1f1_gr_20101-210012	1997-2016	2019-2038	2032-2051	2052-2071	2066-2085
EC-Earth3-Veg_ssp585_r1i1p1f1_gr_201501-210012	1984-2003	2002-2021	2018-2037	2041-2060	2058-2077
EC-Earth3_ssp585_r1i1p1f1_gr_201501-210012	1999-2018	2015-2034	2026-2045	2048-2067	2064-2083
FGOALS-f3-L_ssp585_r1i1p1f1_gr_201501-210012	1992-2011	2012-2031	2027-2046	2050-2069	2069-2088
FGOALS-g3_ssp585_r1i1p1f1_gn_20101-210012	1997-2016	2020-2039	2038-2057	2065-2084	
FIO-ESM-2-0_ssp585_r1i1p1f1_gn_201501-210012	1987-2006	2007-2026	2021-2040	2044-2063	2061-2080
GFDL-CM4_ssp585_r1i1p1f1_gr1_201501-210012	2005-2024	2020-2039	2032-2051	2050-2069	2070-2089
GFDL-CM4_ssp585_r1i1p1f1_gr2_201501-210012	2005-2024	2020-2039	2032-2051	2050-2069	2070-2089
GFDL-ESM4_ssp585_r1i1p1f1_gr1_201501-210012	2012-2031	2030-2049	2043-2062	2066-2085	
GISS-E2-1-G_ssp585_r1i1p1f2_gn_20101-210012	2007-2026	2021-2040	2034-2053	2056-2075	2081-2100
HadGEM3-GC31-LL_ssp585_r1i1p1f3_gn_20101-210012	2000-2019	2011-2030	2021-2040	2038-2057	2054-2073
HadGEM3-GC31-MM_ssp585_r1i1p1f3_gn_201501-210012	2004-2023	2016-2035	2025-2044	2040-2059	2055-2074
IITM-ESM_ssp585_r1i1p1f1_gn_201501-209912	2001-2020	2026-2045	2039-2058	2067-2086	
INM-CM4-8_ssp585_r1i1p1f1_gr1_201501-210012	2004-2023	2021-2040	2037-2056	2060-2079	

INM-CM5- O_ssp585_r1i1p1f1_gr1_2015 01-210012	2006- 2025	2021- 2040	2037- 2056	2065- 2084	
IPSL-CM6A- LR_ssp585_r1i1p1f1_gr_2015 01-210012	1993- 2012	2009- 2028	2025- 2044	2041- 2060	2057- 2076
KACE-1-0- G_ssp585_r1i1p1f1_gr_20150 1-210012	1991- 2010	2005- 2024	2014- 2033	2034- 2053	2053- 2072
KIOST- ESM_ssp585_r1i1p1f1_gr1_2 01501-210012	1993- 2012	2008- 2027	2029- 2048	2055- 2074	
MCM-UA-1- O_ssp585_r1i1p1f2_gn_20150 1-210012	1994- 2013	2012- 2031	2027- 2046	2049- 2068	2067- 2086
MIROC- ES2L_ssp585_r1i1p1f2_gn_20 1501-210012	2010- 2029	2025- 2044	2038- 2057	2061- 2080	
MIROC6_ssp585_r1i1p1f1_gn _201501-210012	2013- 2032	2031- 2050	2044- 2063	2067- 2086	
MPI-ESM1-2- HR_ssp585_r1i1p1f1_gn_201 501-210012	2002- 2021	2024- 2043	2040- 2059	2064- 2083	
MPI-ESM1-2- LR_ssp585_r1i1p1f1_gn_2015 01-210012	2003- 2022	2025- 2044	2039- 2058	2062- 2081	
MRI-ESM2- O_ssp585_r1i1p1f1_gn_20150 1-210012	2004- 2023	2017- 2036	2029- 2048	2055- 2074	2074- 2093
NESM3_ssp585_r1i1p1f1_gn_ 201501-210012	1999- 2018	2011- 2030	2024- 2043	2045- 2064	2063- 2082
NorESM2- LM_ssp585_r1i1p1f1_gn_201 501-210012	2014- 2033	2033- 2052	2047- 2066	2068- 2087	
NorESM2- MM_ssp585_r1i1p1f1_gn_20 1501-210012	2016- 2035	2030- 2049	2045- 2064	2067- 2086	
TaiESM1_ssp585_r1i1p1f1_gn _201501-210012	2008- 2027	2019- 2038	2027- 2046	2043- 2062	2058- 2077
UKESM1-0- LL_ssp585_r1i1p1f2_gn_2015 01-210012	2004- 2023	2014- 2033	2022- 2041	2037- 2056	2051- 2070

Table 1.A. 3 Year when models of the ÖKS15 ensemble match the observed temperature increase of the year 2024 for different baseline periods and GWL 1.0°C. Observations are derived from SPARTACUS data. The year is calculated from data filtered with a 41-year LOESS function. The data is visualized in Figure 1.A. 2. Data sources: ÖKS15 and SPARTACUS (Truhetz and Leuprecht, 2018; GeoSphere Austria, 2020).

ÖKS15 ensemble member	Baseline period			
	1971-2000	1981-2010	1991-2020	GWL1.0
CNRM-CERFACS-CNRM-CM5_rcp45_r1i1p1_CLMcom-CCLM4-8-17	n/a	2092	2065	2063
CNRM-CERFACS-CNRM-CM5_rcp45_r1i1p1_CNRM-ALADIN53	2060	2059	2056	2056
CNRM-CERFACS-CNRM-CM5_rcp45_r1i1p1_SMHI-RCA4	2069	2062	2057	2057
CNRM-CERFACS-CNRM-CM5_rcp85_r1i1p1_CLMcom-CCLM4-8-17	2066	2059	2052	2048
CNRM-CERFACS-CNRM-CM5_rcp85_r1i1p1_CNRM-ALADIN53	2051	2048	2045	2042
CNRM-CERFACS-CNRM-CM5_rcp85_r1i1p1_SMHI-RCA4	2052	2047	2042	2037
ICHEC-EC-EARTH_rcp26_r12i1p1_CLMcom-CCLM4-8-17	n/a	n/a	n/a	n/a
ICHEC-EC-EARTH_rcp26_r12i1p1_KNMI-RACMO22E	n/a	n/a	n/a	n/a
ICHEC-EC-EARTH_rcp26_r12i1p1_SMHI-RCA4	n/a	n/a	n/a	2040
ICHEC-EC-EARTH_rcp26_r3i1p1_DMI-HIRHAM5	n/a	n/a	n/a	n/a
ICHEC-EC-EARTH_rcp45_r12i1p1_CLMcom-CCLM4-8-17	2094	2083	2062	2050
ICHEC-EC-EARTH_rcp45_r12i1p1_SMHI-RCA4	2058	2054	2049	2039
ICHEC-EC-EARTH_rcp45_r1i1p1_KNMI-RACMO22E	2074	2071	2063	2057
ICHEC-EC-EARTH_rcp45_r3i1p1_DMI-HIRHAM5	n/a	n/a	2068	2039
ICHEC-EC-EARTH_rcp85_r12i1p1_CLMcom-CCLM4-8-17	2056	2053	2046	2040
ICHEC-EC-EARTH_rcp85_r12i1p1_SMHI-RCA4	2040	2038	2034	2026
ICHEC-EC-EARTH_rcp85_r1i1p1_KNMI-RACMO22E	2058	2057	2053	2031
ICHEC-EC-EARTH_rcp85_r3i1p1_DMI-HIRHAM5	2058	2057	2047	2034
IPSL-IPSL-CM5A-MR_rcp45_r1i1p1_IPSL-INERIS-WRF331F	2070	2070	2065	2040
IPSL-IPSL-CM5A-MR_rcp45_r1i1p1_SMHI-RCA4	2055	2057	2049	2037
IPSL-IPSL-CM5A-MR_rcp85_r1i1p1_IPSL-INERIS-WRF331F	2054	2055	2055	2047
IPSL-IPSL-CM5A-MR_rcp85_r1i1p1_SMHI-RCA4	2041	2042	2040	2030
MOHC-HadGEM2-ES_rcp26_r1i1p1_SMHI-RCA4	2056	2054	2047	2046

MOHC-HadGEM2-ES_rcp45_r1i1p1_CLMcom-CCLM4-8-17	2040	2038	2035	2035
MOHC-HadGEM2-ES_rcp45_r1i1p1_SMHI-RCA4	2041	2042	2037	2039
MOHC-HadGEM2-ES_rcp85_r1i1p1_CLMcom-CCLM4-8-17	2034	2032	2029	2026
MOHC-HadGEM2-ES_rcp85_r1i1p1_SMHI-RCA4	2032	2032	2030	2029
MPI-M-MPI-ESM-LR_rcp26_r1i1p1_MPI-CSC-REMO2009	n/a	n/a	n/a	2038
MPI-M-MPI-ESM-LR_rcp26_r1i1p1_SMHI-RCA4	n/a	n/a	n/a	2029
MPI-M-MPI-ESM-LR_rcp26_r2i1p1_MPI-CSC-REMO2009	n/a	n/a	n/a	2091
MPI-M-MPI-ESM-LR_rcp45_r1i1p1_CLMcom-CCLM4-8-17	n/a	2093	2082	2069
MPI-M-MPI-ESM-LR_rcp45_r1i1p1_SMHI-RCA4	2086	2081	2058	2038
MPI-M-MPI-ESM-LR_rcp85_r1i1p1_CLMcom-CCLM4-8-17	2062	2057	2050	2041
MPI-M-MPI-ESM-LR_rcp85_r1i1p1_SMHI-RCA4	2051	2048	2045	2036

A Table on different types of natural hazards in Austria with expected trends and related confidences is available at the following link:

https://files.ece.iiasa.ac.at/aar2/appendix/AAR2_Chapter_01_Appendix_natural_hazard_types.xlsx

1.A.3 Guidance on the identification of key risks for AAR2

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This document serves as background information concerning guidance for a consistent assessment of **risks** in the AAR2, not including transition risks (i.e., financial risks from climate policy). Such *transition risks* are also covered in the AAR2 but are based on published studies.

This document aims to

- (1) give a clear definition of risk so that terms and related concepts will be used in an aligned and unambiguous way throughout the AAR2,
- (2) provide guidance on how to address risk in the different chapters, and
- (3) develop a methodology on how to identify key risks for Austria, building on the IPCC AR6 approach.

Terms and concepts

The main purpose of this document is to define the most relevant terms related to risk to have a common understanding in the AAR2 context. This terminology builds on the ‘risk’ definition as provided in the IPCC AR6 WGII report (IPCC, 2022b). For a more in-depth discussion on risk, please refer to IPCC AR6 WGII Chapter 1, Section 1.3. (Ara Begum et al., 2022), the Glossary of IPCC AR6 WGII (IPCC, 2022a) and the Guidance for IPCC authors on risk (Reisinger et al., 2020). In the following, we present the core aspects and definitions valid for the assessment of risks in the AAR2:

Risk

“The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change. Relevant adverse consequences include those on lives, livelihoods, health and well-being, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species.

Impacts are the consequences of realized risks on natural and human systems. Impacts generally refer to effects on lives; livelihoods; health and well-being; ecosystems and species; economic, social and cultural assets; services (including ecosystem services); and infrastructure. Impacts may be referred to as consequences or outcomes, and can be adverse or beneficial. [In IPCC use, risk refers only to negative (“adverse”) consequences; the potential for positive outcomes should be described in the AAR2 using other terminology (such as ‘opportunity’ or ‘potential benefit/co-benefit’)].

In the context of climate change impacts, risks [i.e., the potential for adverse consequences from these impacts] result from dynamic interactions between climate-related hazards [and] the exposure and vulnerability of the affected human or ecological system [...]. Hazard, exposure and vulnerability may each be subject to uncertainty in terms of magnitude and likelihood of [occurrence/frequency], and each may change over time and space due to socio-economic changes and human decision-making [see [Figure 1.A. 15](#)].

In the context of climate change responses, risks [also] result from the potential for such responses not achieving the intended objective(s), or from potential trade-offs with, or negative side-effects on, other societal objectives, such as the Sustainable Development Goals (SDGs). Risks can arise for example from uncertainty in the implementation, effectiveness or outcomes of climate policy, climate-related investments, and technology development or adoption, and system transitions.” (IPCC, 2022a). Such transition risks are not subject of this background paper.

Annotation for AAR2: In different communities as well as in colloquial language, ‘risk’ (*‘Risiko’*) is sometimes imprecisely understood as what we refer to here as hazard, i.e., the potential occurrence of an adverse event (cf. paragraph “Hazard” below). For instance, flood risk (*‘Hochwasserrisiko’*) represented by, e.g., HQ₁₀₀ only, neglecting any information on exposure and vulnerability, would be the related hazard information, not ‘risk’, as defined here. The IPCC guidance document also states that the concept of risk should not be used to describe outcomes within physical systems only. For example, the term ‘flood risk’ should not be used if it only describes changes in the frequency and intensity of flood events; it would need to be linked explicitly to the consequences of such events for human or ecological systems.

Compound risks “arise from the interaction of different hazards [e.g., flood and landslides], which may be characterized by single extreme events or multiple coincident or sequential events that interact with exposed systems or sectors.” (IPCC, 2022a).

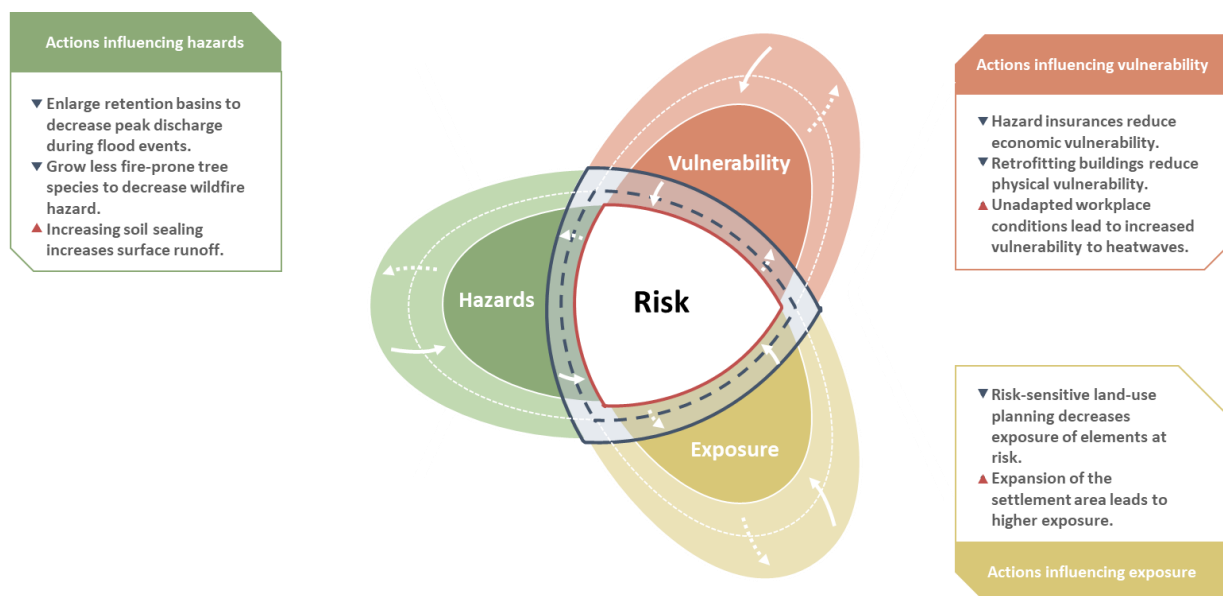


Figure 1.A. 15 This figure illustrates the core components of risk, and related terms. It is based on the initial IPCC risk figure but has been slightly adapted for the AAR2. The white arrows illustrate actions influencing hazard, exposure and vulnerability, which shape risks over time (increase, decrease). In the center the red line illustrates hard limits to adaptation, the outer blue-solid line the status quo of risk. The dashed-blue line illustrates the soft line to adaptation. The area in between (white, transparent) is therefore the solution space. The remaining residual risk is the inner core of the risk. The figure builds on the conceptual framework of risk–adaptation relationships used in SROCC (Garschagen et al., 2019). Illustrative examples are provided in the boxes.

Hazard

“The potential occurrence of a natural or human-induced physical event [e.g., floods, landslides, heat waves etc.] or trend that may cause loss of life, injury or other health impacts, as well as damage and

loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.” (IPCC, 2022a)

Vulnerability

“The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.” (IPCC, 2022a)

Annotation for AAR2: Vulnerability is multi-dimensional and can be characterized by, e.g., physical, social, economic, environmental, institutional and cultural dimensions (see Birkmann et al., 2013; Papathoma-Köhle et al., 2021). As such, the vulnerability dimension could have a distinct (disciplinary) background, such as, e.g., the social dimension of vulnerability, the physical dimension or a combination if an interdisciplinary viewpoint should be emphasized. Moreover, different vulnerability dimensions interact and/or influence each other.

Exposure

“The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected.” (IPCC, 2022a)

Key risks (KR)

“Key risks have potentially severe [emphasis added] adverse consequences for humans and social-ecological systems resulting from the interaction of climate related hazards with vulnerabilities of societies and systems exposed.” (IPCC, 2022a)

Annotation for AAR2: In addition to the 'severity' which characterizes key risks, we describe key risks also by the urgency to act, to identify potential management needs.

Terms relevant in the wider context of risk

In addition to these core concepts and terms defined above, the following terms are relevant in the wider context of risk, as defined in the Glossary of the AAR2, based on the IPCC AR6 WGII Glossary (IPCC, 2022a):

- **Risk assessment:** The qualitative and/or quantitative scientific estimation of risks.
- **Risk management:** Plans, actions, strategies or policies to reduce the likelihood and/or magnitude of adverse potential consequences, based on assessed or perceived risks.
- **Resilience:** The capacity of a system, community or society to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management (modified after UNDRR (n.d.))
- **Governance:** The structures, processes and actions through which private and public actors interact to address societal goals. This includes formal and informal institutions and the associated norms, rules, laws and procedures for deciding, managing, implementing and monitoring policies and measures at any geographic or political scale, from global to local.

Annotation for AAR2: The IPCC also defines adaptive, climate, multi-level and polycentric governance. For details, please refer to the IPCC glossary.

- **Adaptation:** In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects.

Annotation for AAR2: The IPCC also defines specific forms of adaptation. For details, please refer to IPCC (2022a). Be aware that the terms mitigation and adaptation have different meanings in the Disaster Risk Reduction community (see for instance Füssel and Klein (2006), Birkmann et al. (2013).

- **Adaptation limits:** The point at which an actor's objectives (or system needs) cannot be secured from intolerable risks through adaptive actions.
 - Hard adaptation limit – No adaptive actions are possible to avoid intolerable risks.
 - Soft adaptation limit – Options may exist but are currently not available to avoid intolerable risks through adaptive action.
- **Mitigation (of climate change):** A human intervention to reduce emissions or enhance the sinks of greenhouse gases.

Annotation for AAR2: In the hazard research community, mitigation has a different meaning. UNDRR defines mitigation as “the lessening or minimizing of the adverse impacts of a hazardous event. [...] Mitigation measures include engineering techniques and hazard-resistant construction as well as improved environmental and social policies and public awareness.” (UNDRR, n.d.). In the AAR2, to avoid confusion, we use mitigation as understood in the IPCC context. If mitigation is used in a different meaning than defined above, please clearly state the difference and your understanding, such as “technical mitigation for flood management as an option for climate change adaptation”.

Guidance for chapters to identify key risks for Austria

The approach and the workflow developed for the AAR2, visualized in [Figure 1.A. 16](#), aims

- (1) to provide guidance for the AAR2 authorship teams on how to identify key risks in a process ‘standardized’ across chapters, and
- (2) to describe how their results can be ‘integrated’ towards the identification of ‘key risks’ for Austria.

Conceptual Basis

The workflow for the climate-related risk assessment for Austria is built on the related IPCC framing and workflow, its theoretical basis and terms, as described in section Terms and concepts. As such, beyond the chapter-wise identification of risks and their respective risk domains (hazard(s), vulnerability, exposure), we aim to identify key risks, following, in principle, the guidance of the IPCC AR6 WG2. This guidance has been modified in a few details for better integration in the context of the AAR2.

Main adaptations and modifications are:

- For the AAR2, due to its specific structure, we differentiate where chapters come into the workflow and how they contribute (cf. [Figure 1.A. 16](#)). Chapters 1 – 4 and 7 provide the basis, i.e., basic descriptions of relevant risks for Austria; findings on key risks will then also be integrated into chapters 5, 6 and 8.

- In step 1, we filter identified risks based on ‘severity’ criteria, creating a list of key risks, and further add an ‘urgency’ tag where applicable, allowing the descriptions in step 2 to be focused on the most urgent key risks.

At the core of the conceptual basis sits the concept of key risks, described by O’Neill et al. (2022) as follows:

“A key risk (KR) is [...] a potentially ‘severe’ [and urgent] risk and therefore especially relevant to the interpretation of dangerous anthropogenic interference (DAI) with the climate system [...]. The severity [and urgency] of a risk is a context-specific judgement based on a number of criteria discussed [in Step 2]. KRs are ‘potentially’ severe because, while some could already reflect dangerous interference now, more typically they may become severe over time due to changes in the nature of hazards (or, more broadly, climatic impact drivers; IPCC, 2021) and/or of the exposure/vulnerability of societies or ecosystems [...]. They also may become severe due to the adverse consequences of adaptation or mitigation responses to the risk” (e.g., maladaptation or lacking mitigation efforts which increase hazard severity/probability). Dangerous interferences in this guidance are considered over the course of the 21st century.

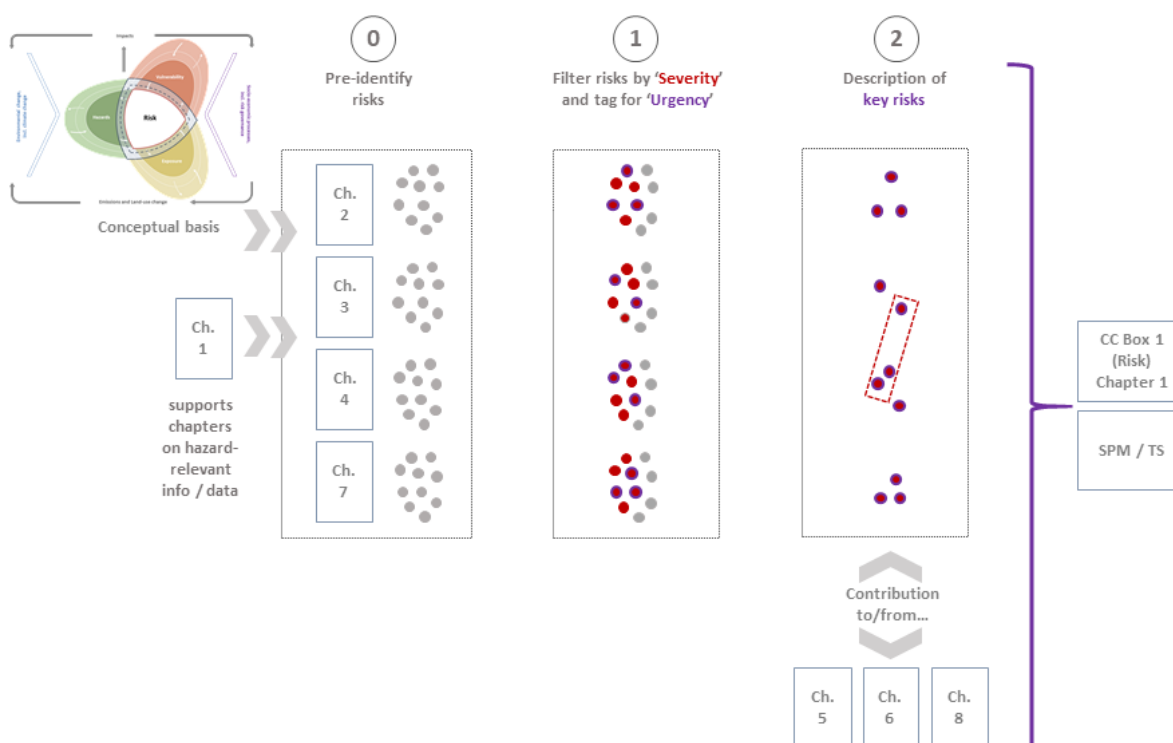


Figure 1.A. 16 Overall Workflow for identification of key risks for Austria.

Step 0 – Description and collection of sectoral risks

Done in FOD by chapters 2, 3, 4, 7 and 1 (cross-cutting)

The sector chapters 2, 3, 4 and 7, with hazard and climate-related input from chapter 1, identified risks throughout their respective First Order Drafts (FOD) and further developed for the Second Order Draft (SOD). These descriptions covered at least the following aspects with reference to the relative chapter sections where relevant literature was indicated as well as a confidence statement

(based on strength of evidence and agreement) addressing the current and the projected risk situation indicating used Global Warming Levels (GWL) and Shared Socio-Economic Pathways (SSPs):

- Name of the risk
- Geographic region
- Potential impact (i.e., potential consequences, losses/damage)
- Potential compound/cascading effects
- Description of the risk components, with indication of future time horizon/scenario:
 - hazard(s),
 - vulnerability,
 - exposure.

Step 1 – Identification of key risks based on severity and urgency criteria

Done in SOD by chapters 2, 3, 4, 7 and 1 (cross-cutting), exchange with chapters 5, 6, and 8

KRs are defined as risks of potential ‘*severity*’ and ‘*urgency*’. This is because “KRs are determined not just by the nature of hazards, exposure, vulnerability and response options, but also by values, which determine the importance of a risk. Importance is understood here as the degree of relevance to interpreting DAI at a given system’s level or scale [...]” (O’Neill et al., 2022). Because such values can vary across individuals, communities or cultures, as well as over time, what constitutes a KR can vary widely from the perspective of each of these groups, or across individuals.

Therefore, AAR2 chapter authors did not make their own judgements about the importance of any particular risks. Instead, we highlighted importance as an overarching factor but identified and evaluated KRs based on four (severity) plus two (urgency) criteria (see below), distinguishing them from the ‘general’ risks identified before. We provided a checklist table with a simple traffic light color scheme to describe the risks. Table 1.A. 4 provides an example how the relevance of the different criteria was assessed.

Severity

Regarding severity, a filter was applied to all collected risks, where key risks are exceptionally severe in one of the following severity criteria or due to a combination of them, adapted from O’Neill et al. (2022), albeit grouped differently:

- Magnitude and likelihood of adverse consequences;
- Potential for irreversibility of consequences and cascading effects;
- Temporal and spatial characteristics (society, environment) of risk;
- Ability to anticipate, cope and recover from risks/impacts.

As in the AR6, “the relative influence of these different criteria is case-specific and is left to author judgement in the identification of KRs (groups of authors in [...] chapters)”.

Magnitude and likelihood of adverse consequences

“Magnitude measures the degree to which particular dimensions of a system are affected, should the risk materialise. Magnitude can include the size or extent of the system, the pervasiveness of the consequences across the system (geographically or in terms of affected population), as well as the degree of consequences. Consequences can be measured by a wide range of characteristics. For example, risks to food security can be measured as uncertain consequences for food consumption, access or prices. The magnitude of these consequences would be the degree of change in these measures induced by climate change and accounting for the interaction with exposure and vulnerability. In addition to pervasiveness

and degree of change, several other aspects can contribute to a judgement of magnitude, although they refer to concepts that are difficult to capture and highly context-specific.”(O’Neill et al., 2022)

The following information may be used to assess the magnitude [see below on Irreversibility and cascading effects and also Watkiss and Betts (2021)]:

Potential for impact thresholds or tipping points. *Higher risks are posed by the potential for exceeding a threshold beyond which the magnitude or rate of an impact substantially increases.*

Regarding likelihood, “[a] higher probability of high-magnitude consequences poses a larger risk a priori, whatever the scale considered. This probability may not be quantifiable, and it may be conditional on assumptions about the hazard, exposure or vulnerability associated with the risk.”

Table 1.A. 4 Example for classification for assessing the relevance of different criteria

Classes for assessing the relevance of criteria	
Select this colour	
very high losses	Likely to very likely significant damages and losses, disturbance of system functionality, major damages and losses within important systems, long-term effects, large extent and high pervasiveness, potential for impact thresholds or tipping points, cascading effects beyond system boundaries and systemic risk, cascading effects beyond system boundaries, potential for systemic risks,
low ability	Moderate to low ability to respond or adapt.
moderate losses	Likely moderate losses and damages, moderate disturbance of system functionality, effects are temporary or unfolding slowly with a moderate extend / pervasiveness.
moderate ability	Moderate to high ability to respond or adapt.
no to low losses	none to low losses and damages. No or rare disturbance of functionality,
high ability	high ability to respond or adapt
no assessment possible	

Potential for irreversibility of consequences and cascading effects

“Consequences that are irreversible, at least over long time scales, would be considered a higher risk than those that are temporary. For example, changes to the prevailing ecosystem in a given location may not be reversible on the decade to century scale.”

“Higher risks are posed by those with the potential to generate downstream cascading effects to other ecosystems, sectors or population groups within the affected system and/or to another system, whether neighbouring or distant.”

Temporal and spatial characteristics (society, environment) of risk

“Risks that occur sooner, [...] increase more rapidly over time, [or change their spatial expansion,] present greater challenges to natural and societal adaptation. A persistent risk (due to the persistence of the hazard, exposure and vulnerability) may also pose a higher threat than a temporary risk due, for example, to a short-term increase in the vulnerability of a population (e.g., due to conflict or an economic downturn).”

Ability to respond and therefore anticipate, cope with and/or recover from risks/impacts

“Risks are more severe if the affected ecosystems or societies have limited ability to reduce hazards (e.g., for human systems, through mitigation, ecosystem management and possibly solar radiation management); to reduce exposure or vulnerability through various human or ecological adaptation options; or to cope with or respond to the consequences, should they occur.”

In addition, in AAR2, we added also the capacity to anticipate risks (e.g., through available scientific evidence, or the availability of early warning systems), to cope with as well as to recover from impacts (see also Birkmann et al., 2013 from a conceptual viewpoint, or Fuchs, 2009, for the specific example of mountain hazards in Austria).

Urgency

In addition to the severity criteria, in AAR2, we introduced ‘urgency’ tags to identify potential management needs and reflect the varying values and levels of importance:

(Societal) risk preference/tolerance

While the previous severity criteria are assessed from a risk expert’s perspective and are mainly based on quantitative data, this urgency criterion addresses the fact that public risk perception varies substantially on temporal as well as spatial scales. Risk perception is strongly determined by economic capacities, social norms, culture, and worldviews, as well as individual characteristics and often requires joint subjective and expert judgment (Klinke and Renn, 2002). Hence, if qualitative data is available, affected communities’ risk tolerance (e.g., on the spectrum from acceptable, tolerable, to intolerable risk) against specific key risks that may lead to severe impacts and adverse consequences should be considered to determine the urgency to act.

Annotation for AAR2: We are aware that the terms (risk preference or tolerance) may be challenging to assess, specifically as these judgements does also have scale effects: for an individual community a local flood risk may be severe while for the economy of Austria it may be not.

Acceptable climate-related risks are those where the group of stakeholders does not ask for additional Climate Risk Mitigation (CRM) measures and the community in the study region is thus satisfied with the status quo. Next comes the transitions zone of tolerable risks, where stakeholders do see a need for additional action but not at any price – here costs and other constraints shall be weighed against potential benefits of additional CRM measures. Finally, intolerable risks are those which “exceed a socially negotiated norm (e.g., the availability of clean drinking water) or value (e.g., continuity of a way of life) despite [current] adaptive action” (Dow et al., 2013, p. 385).

Soft/hard adaptation limits to be crossed

The second ingredient to inform decision makers where action on key risks is urgent concerns barriers and potential soft and hard limits to adaptation. This step is intricately linked to the previous risk tolerance evaluation, building in particular on the key risks identified in the intolerable risk space, and diving deeper into the “ability to respond to the risk” severity criteria.

Constraints make adaptation processes more difficult and are unevenly distributed across regions and groups. Constraints to Climate Change Adaptation may lead to adaptation limits, defined as “conditions or factors that render adaptation ineffective as a response to climate change and are largely insurmountable” (Adger et al., 2007, p. 733) or “the point at which an actor’s objectives (or system needs) cannot be secured from intolerable risks through adaptive actions” (Dow et al., 2013; IPCC, 2019). Adaptation limits can be qualified as “soft” when they can be shifted, for example once adaptive measures become available, and as “hard” when no adaptive action is possible (Klein et al., 2014). Soft adaptation limits are also referred to as barriers, which can be overcome in principle (Dow et al. 2013) or with concerted effort, changes in thinking or shifts in resources (Moser and Ekstrom, 2010; Barnett et al., 2015).

We suggest employing the categorization of constraints that may lead to soft and hard adaptation limits by Thomas et al. (2021) to identify for each previously identified severe key risk key constraints according to the following eight categories, as well as potential interactions between constraints, that may lead to soft and hard limits to adaptation:

- (1) economic: existing livelihoods, economic structures, and economic mobility;
- (2) social/ cultural: social norms, identity, place attachment, beliefs, worldviews, values, awareness, education, social justice, and social support;
- (3) human capacity: individual, organizational, and societal capabilities to set and achieve adaptation objectives over time including training, education, and skill development;
- (4) governance, institutions and policy: existing laws, regulations, procedural requirements, governance scope, effectiveness, institutional arrangements, adaptive capacity, and absorption capacity;
- (5) financial: lack of financial resources;
- (6) information/awareness/technology: lack of awareness or access to information or technology;
- (7) physical: presence of physical barriers; and
- (8) biologic/climatic: temperature, precipitation, salinity, acidity, and intensity and frequency of extreme events including storms, drought, and wind.

Authors of the chapters 1–4 and 7 were asked to rely on the definitions and criteria above to identify risks that could potentially become severe and urgent according to changes in the associated hazards, the study systems’ exposure and/or vulnerability, and important adaptation strategies that could reduce these risks. Wherever possible, identification was based on literature that includes projected future conditions for all three components of risk and adaptation.

Where literature is insufficient, potential severity was based on current vulnerability and exposure and the expectation that hazards will increase in frequency and/or intensity in the future. This approach is more limited in that it does not consider future changes in exposure and vulnerability nor in adaptation but has the benefit of being grounded in observed experience.

Step 2 – Detailed description of Key Risks

Done in SOD by chapters 2, 3, 4, 7 and 1 (cross-cutting), exchange with chapters 5, 6, and 8

Based on the identified key risks in step 1, chapters 1–4 and 7 were asked to describe the key risks with the following criteria to be described:

- Chapter and section
- Name of the key risk
- Geographic region
- Potential impact that would be considered severe, and to whom
- Hazard conditions that would contribute to this risk being severe
- Exposure conditions that would contribute to this risk being severe
- Vulnerability conditions that would contribute to this risk being severe
- Adaptation options with highest potential for reducing risk
- Potential to reach soft/ hard adaption limits reached
- Risk considered as acceptable, tolerable or intolerable
- Severity filters
- Urgency tags
- Confidence in key risk identification

This led to a summary table of key risks identified in the ‘Cross-Cut Risk’. Based on identified and described key risks, Chapter 5, 6 and Chapter 8 contributed to assess the societal responses to climate change risk e.g., with an assessment of adaptation solutions based on the attribute’s justice, feasibility and effectiveness (see IPCC, 2022b).

The overall results of the ‘Cross-Cut Risk’ should provide the essential information to the nature of the key risk, a description of the consequences of the risk that would constitute a severe outcome, and the hazard, exposure and vulnerability conditions that would contribute to the risk being severe. In addition, it provides the adaptation options identified by authors as having the highest potential for reducing the risk. The results were used to formulate the key messages of the ‘Cross-Cut Risk’ (see [Cross-Chapter Box 1](#)), and the information for the SPM and TS (see [Table TS.1](#)).

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