23

Europe
Supplementary Material

Coordinating Lead Authors:
R. Sari Kovats (UK), Riccardo Valentini (Italy)

Lead Authors:
Laurens M. Bouwer (Netherlands), Elena Georgopoulou (Greece), Daniela Jacob (Germany), Eric Martin (France), Mark Rounsevell (UK), Jean-Francois Soussana (France)

Contributing Authors:
Martin Beniston (Switzerland), Maria Vincenza Chiriacò (Italy), Philippe Cury (France), Michael Davies (UK), Paula Harrison (UK), Olaf Jonkeren (Netherlands), Mark Koetse (Netherlands), Markus Lindner (Finland), Andreas Matzarakis (Greece/Germany), Reinhard Mechler (Germany), Annette Menzel (Germany), Marc Metzger (UK), Luca Montanarella (Italy), Antonio Navarra (Italy), Juliane Petersen (Germany), Martin Price (UK), Boris Revich (Russian Federation), Piet Rietveld (Netherlands), Cristina Sabbioni (Italy), Yannis Sarafidis (Greece), Vegard Skirbekk (Austria), Donatella Spano (Italy), Jan E. Vermaat (Netherlands), Paul Watkiss (UK), Meriwether Wilson (UK), Thomasz Zylicz (Poland)

Review Editors:
Lucka Kajfez Bogataj (Slovenia), Roman Corobov (Moldova), Ramón Vallejo (Spain)

This chapter on-line supplementary material should be cited as:

Kovats, R.S., R. Valentini, L.M. Bouwer, E. Georgopoulou, D. Jacob, E. Martin, M. Rounsevell, and J.-F. Soussana, 2014: Europe – supplementary material. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Available from www.ipcc-wg2.gov/AR5 and www.ipcc.ch.

Table SM23-1 | Lists of countries in European regional groupings.

European Union EU15	European Union EU27[a]	European Environment Agency (EEA) (33)
Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom	Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, United Kingdom	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom

[a] At the time of publication, the EU comprised 28 member states, as Croatia acceded in 2013.

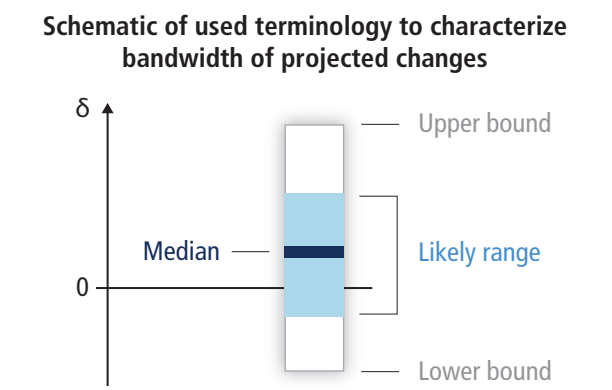

Figure SM23-1 | Explanation of terminology for Tables SM23-2, SM23-3, and SM23-4 (tables updated from Jacob et al., 2013). The figure depicts the range of projected climate change signals for several parameters/indices averaged over different sub regions towards the end of the 21st century shown in Tables 23-2to 23-4. The range of projected changes is estimated on the basis of climate change projections of the A1B scenario (* for parameter based on 9 simulations, ** for parameter based on 20 simulations), RCP4.5 (8 simulations) and RCP8.5 (9 simulations). The different numbers of simulations used is due to the limited data availability. In a first step the climate change signals for each parameter/index were calculated for each individual model on its native model grid. In order to overlay the climate change information of the individual models with the five major sub regions (applied from Metzger et al., 2005), the estimated climate change signals on the native model grids had to be remapped onto a unifying grid which allowed to spatially aggregate the estimated climate change signals for each of the sub regions and each of the models. For each parameter/index and sub region the resulting bandwidth of the ensemble of spatially-averaged climate change signals is categorized in the tables by providing the upper and lower boundary of the bandwidth of projected changes as well as the median. Moreover the central 66 percent of the projected changes are indicated as "likely range".

Table SM23-2 | Projected changes of selected climate parameters and indices for 2071–2100 with respect to 1971–2000 spatially averaged for European sub-regions for the A1B scenario (updated from Jacob et al., 2013). Numbers are based on 9 (indicated with *) and 20 (indicated with **) regional model simulations. The different numbers of simulations used is due to the limited data availability. The "*likely* range" defines the range of 66% of all projected changes around the ensemble median. The definition of indices is described below.

A1B	Climate parameter	Measure	Southern	Atlantic	Continental	Alpine	Northern
2071–2100 minus 1971–2000	Mean annual temperature in K**	Median	3.6	2.5	3.3	3.4	3.8
		Lower bound	2.3	1.9	2.1	2.8	3.2
		Likely in the range	3.3 to 4.1	2.1 to 3.5	2.8 to 4.5	3.1 to 4.5	3.5 to 5.0
		Upper bound	5.5	4.7	5.7	5.4	5.8
	Frost days per year*	Median	–24	–24	–44	–50	–54
		Lower bound	–34	–39	–56	–72	–71
		Likely in the range	–31 to –12	–34 to –15	–53 to –27	–57 to –38	–55 to –40
		Upper bound	–12	–13	–26	–37	–38
	Summer days per year*	Median	48	21	32	14	7
		Lower bound	33	9	21	4	3
		Likely in the range	33 to 51	16 to 32	22 to 41	11 to 20	5 to 14
		Upper bound	51	34	43	21	27
	Tropical nights per year*	Median	47	8	21	3	4
		Lower bound	18	2	14	1	1
		Likely in the range	35 to 52	6 to 17	16 to 35	2 to 9	1 to 7
		Upper bound	60	32	43	11	10
	Growing season length in days per growing season**	Median	36	41	52	47	41
		Lower bound	14	23	20	27	25
		Likely in the range	27 to 41	33 to 51	33 to 62	34 to 56	27 to 46
		Upper bound	51	55	81	75	61
	Warm spell duration index in days per year*	Median	91	44	42	57	67
		Lower bound	67	29	26	46	37
		Likely in the range	85 to 112	35 to 72	37 to 69	51 to 84	47 to 96
		Upper bound	144	125	94	126	119
	Cold spell duration index in days per year*	Median	–5	–5	–6	–5	–6
		Lower bound	–8	–9	–9	–8	–9
		Likely in the range	–5 to –4	–6 to –4	–6 to –5	–5 to –4	–8 to –5
		Upper bound	–3	–4	–4	–4	–5
	Annual total precipitation in %**	Median	–15	2	3	6	16
		Lower bound	–24	–11	–9	0	4
		Likely in the range	–17 to –11	–3 to 4	–1 to 5	4 to 9	12 to 20
		Upper bound	–7	7	10	10	28
	Annual total precipitation where RR > 99p of 1971/2000 in %**	Median	15	40	30	33	42
		Lower bound	5	16	9	21	19
		Likely in the range	11 to 20	26 to 60	23 to 44	24 to 38	28 to 52
		Upper bound	30	72	54	70	74

Table SM23-3 | Projected changes of selected climate parameters and indices for 2071–2100 with respect to 1971–2000 spatially averaged for European sub-regions based on the RCP4.5 and RCP8.5 scenarios (updated from Jacob et al., 2013). Numbers are based on 9 (RCP8.5) and 8 (RCP4.5) regional model simulations. The "*likely* range" defines the range of 66% of all projected changes around the ensemble median. The definition of indices is described below.

	Climate parameter	Measure	Southern		Atlantic		Continental		Alpine		Northern	
			RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
2071–2100 minus 1971–2000	Mean annual temperature in K	Median	2.0	4.2	1.7	3.2	2.1	4.1	2.4	4.6	2.9	5.2
		Lower bound	1.9	3.8	1.3	2.5	1.6	3.6	1.8	3.8	2.0	4.1
		Likely in the range	1.9 to 2.7	3.9 to 5.4	1.4 to 2.1	2.7 to 3.6	1.6 to 3.2	3.7 to 5.2	1.9 to 3.4	3.9 to 6.0	2.0 to 4.2	4.1 to 6.2
		Upper bound	3.2	5.7	2.9	4.2	3.2	5.3	3.6	6.3	4.3	6.5
	Frost days per year	Median	–22	–43	–28	–40	–34	–62	–40	–70	–40	–68
		Lower bound	–31	–51	–33	–60	–41	–73	–47	–93	–52	–93
		Likely in the range	–29 to –11	–51 to –23	–30 to –15	–50 to –26	–40 to –18	–65 to –50	–41 to –26	–85 to –57	–43 to –26	–83 to –60
		Upper bound	–10	–22	–12	–21	–16	–46	–25	–55	–24	–58
	Summer days per year	Median	27	54	11	24	20	37	8	19	4	13
		Lower bound	21	43	6	17	11	27	3	10	2	5
		Likely in the range	25 to 33	46 to 60	6 to 14	22 to 28	13 to 24	30 to 46	4 to 14	12 to 24	2 to 16	6 to 22
		Upper bound	37	67	33	38	28	49	18	25	23	28
	Tropical nights per year	Median	20	45	3	7	9	22	1	4	1	1
		Lower bound	7	23	0	3	2	11	0	1	0	0
		Likely in the range	11 to 24	25 to 57	1 to 5	3 to 12	9 to 27	17 to 31	1 to 3	2 to 5	0 to 5	1 to 3
		Upper bound	41	58	18	17	30	37	8	6	7	13
	Growing season length in days per growing season	Median	27	49	39	58	26	58	31	61	23	55
		Lower bound	16	34	24	41	17	52	23	52	17	37
		Likely in the range	17 to 33	38 to 53	27 to 43	47 to 68	20 to 38	53 to 71	23 to 39	52 to 83	19 to 33	41 to 60
		Upper bound	38	58	45	75	41	75	45	95	42	78
	Warm spell duration index in days per year	Median	37	123	21	67	24	76	36	100	37	85
		Lower bound	30	95	18	46	18	54	27	74	22	68
		Likely in the range	34 to 73	100 to 183	19 to 34	47 to 92	18 to 45	55 to 97	28 to 58	75 to 140	23 to 44	70 to 116
		Upper bound	84	191	56	106	53	107	70	165	65	132
	Cold spell duration index in days per year	Median	–4	–5	–4	–5	–5	–6	–5	–5	–6	–6
		Lower bound	–6	–5	–6	–6	–7	–8	–7	–6	–7	–7
		Likely in the range	–4 to –3	–5 to –4	–5 to –4	–6 to –4	–6 to –4	–7 to –6	–6 to –4	–6 to –4	–7 to –6	–7 to –5
		Upper bound	–3	–4	–2	–3	–4	–5	–3	–4	–5	–5
	Annual total precipitation in %	Median	–3	–11	1	4	9	10	4	11	10	22
		Lower bound	–10	–23	–2	–2	0	0	3	4	7	17
		Likely in the range	–9 to 1	–19 to –3	–1 to 6	1 to 7	1 to 12	4 to 18	3 to 7	6 to 13	8 to 17	18 to 32
		Upper bound	2	–1	8	9	13	24	9	15	21	33
	Annual total precipitation where RR > 99p of 1971/2000 in %	Median	14	17	21	43	24	39	24	49	22	51
		Lower bound	7	9	10	29	10	23	11	23	16	45
		Likely in the range	8 to 24	11 to 26	13 to 44	32 to 68	15 to 29	27 to 47	11 to 39	23 to 57	17 to 40	45 to 76
		Upper bound	38	27	46	81	44	63	39	68	47	77

References

Karl, T.R., N. Nicholls, and A. Ghazi, 1999: CLIVAR/GCOS/WMO workshop on indices and indicators for climate extremes: workshop summary. *Climatic Change*, **42**, 3-7.

Peterson, T.C., C. Folland, G. Gruza, W. Hogg, A. Mokssit, and N. Plummer, 2001: *Report on the Activities of the Working Group on Climate Change Detection and Related Rapporteurs, 1998-2001*. CLIVAR, World Climate Research Program, International Council for Science, Intergovernmental Oceanographic Commission, World Meteorological Organization. WMO Report WCDMP-47, WMO-TD 1071, Geneva, Switzerland, 143 pp., etccdi.pacificclimate.org/docs/wgccd.2001.pdf

ETCCDI/CRD Climate Change Indices *etccdi.pacificclimate.org/list_27_indices.shtml*

Definition of Indices

Number of frost days: Annual count of days when TN (daily minimum temperature) < 0°C. Let TN_{ij} be daily minimum temperature on day *i* in year *j*. Count the number of days where: $TN_{ij} < 0°C$.

Number of summer days: Annual count of days when TX (daily maximum temperature) > 25°C. Let TX_{ij} be daily maximum temperature on day *i* in year *j*. Count the number of days where: $TX_{ij} > 25°C$.

Number of tropical nights: Annual count of days when TN (daily minimum temperature) > 20°C. Let TN_{ij} be daily minimum temperature on day *i* in year *j*. Count the number of days where: $TN_{ij} > 20°C$.

Growing season length: Annual (1 Jan to 31 Dec in Northern Hemisphere (NH)) count between first span of at least 6 days with daily mean temperature TG > 5°C and first span after 1 July of 6 days with TG < 5°C. Let TG_{ij} be daily mean temperature on day *i* in year *j*. Count the number of days between the first occurrence of at least 6 consecutive days with: $TG_{ij} > 5°C$, and the first occurrence after 1 July of at least 6 consecutive days with: $TG_{ij} < 5°C$.

Warm spell duration index: Annual count of days with at least 6 consecutive days when TX > 90th percentile. Let TX_{ij} be the daily maximum temperature on day *i* in period *j* and let $TX_{in}90$ be the calendar day 90th percentile centered on a 5-day window for the base period 1971-2000. Then the number of days per period is summed where, in intervals of at least 6 consecutive days: $TX_{ij} > TX_{in}90$.

Cold spell duration index: Annual count of days with at least 6 consecutive days when TN < 10th percentile. Let TN_{ij} be the daily maximum temperature on day *i* in period *j* and let $TN_{in}10$ be the calendar day 10th percentile centered on a 5-day window for the base period 1971-2000. Then the number of days per period is summed where, in intervals of at least 6 consecutive days: $TN_{ij} < TN_{in}10$.

Annual total precipitation in wet days: Let RR_{ij} be the daily precipitation amount on day *i* in period *j*. If *I* represents the number of days in *j*, then:

$$PRCPTOT_j = \sum_{i=1}^{I} RR_{ij}$$

Annual total precipitation when RR > 99p: Let RR_{wj} be the daily precipitation amount on a wet day *w (RR ≥ 1.0mm)* in period *i* and let $RR_{wn}99$ be the 99th percentile of precipitation on wet days in the 1971-2000 period. If *W* represents the number of wet days in the period, then:

$$R99p_j = \sum_{w=1}^{W} RR_{wj} \text{ where } RR_{wj} > RR_{wn}99$$

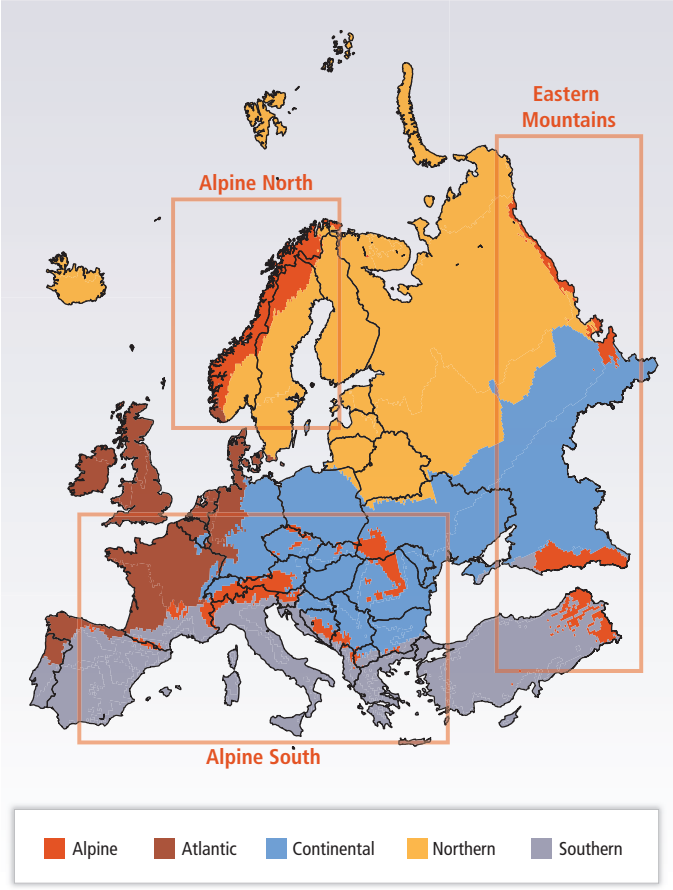

Figure SM23-2 | Sub-regional classification of IPCC Europe region with three Alpine areas (orange patches within squares). Based on Metzger et al., 2005.

Table SM23-4 | Projected changes of selected climate parameters and indices for 2071–2100 with respect to 1971–2000 spatially averaged for three alpine sub-regions based on the RCP4.5 and RCP8.5 scenarios (regions applied from Metzger et al., 2005; data and methods based on and updated from Jacob et al., 2013). Numbers are based on 9 (RCP8.5) and 8 (RCP4.5) regional model simulations. For Alpine North only 8 (RCP8.5) and 7 (RCP4.5) simulations are available. The "*likely* range" defines the range of 66% of all projected changes around the ensemble median. The definition of indices is described above.

	Climate parameter	Measure	Alpine North		Alpine South		Eastern mountains	
			RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
2071–2100 minus 1971–2000	Mean annual temperature in K	Median	3.0	4.8	1.9	4.4	2.4	5.0
		Lower bound	1.9	3.4	1.6	3.6	2.0	4.2
		Likely in the range	1.9 to 3.9	3.6 to 5.8	1.7 to 2.5	3.7 to 5.8	2.1 to 3.6	4.5 to 6.9
		Upper bound	4.0	6.4	3.2	6.1	3.8	7.3
	Frost days per year	Median	–42	–75	–35	–67	–33	–67
		Lower bound	–55	–105	–43	–90	–44	–89
		Likely in the range	–45 to –30	–96 to –57	–39 to –23	–87 to –58	–40 to –22	–84 to –56
		Upper bound	–28	–56	–21	–55	–18	–46
	Summer days per year	Median	0	0	9	23	16	37
		Lower bound	0	0	3	13	8	22
		Likely in the range	0 to 1	0 to 1	6 to 17	16 to 37	8 to 21	24 to 45
		Upper bound	3	1	25	41	29	47
	Tropical nights per year	Median	0	0	1	3	4	10
		Lower bound	0	0	0	0	1	6
		Likely in the range	0	0	0 to 4	1 to 5	2 to 7	7 to 17
		Upper bound	0	0	11	7	15	18
	Growing season length in days per growing season	Median	35	64	28	62	27	58
		Lower bound	20	40	23	49	23	53
		Likely in the range	22 to 38	46 to 84	26 to 35	54 to 90	23 to 39	55 to 81
		Upper bound	53	104	40	93	48	88
	Warm spell duration index in days per year	Median	47	95	31	103	31	103
		Lower bound	26	60	24	65	29	87
		Likely in the range	29 to 50	75 to 136	25 to 53	68 to 141	30 to 82	92 to 173
		Upper bound	66	161	63	164	91	176
	Cold spell duration index in days per year	Median	–6	–4	–5	–5	–5	–5
		Lower bound	–7	–6	–7	–5	–7	–6
		Likely in the range	–7 to –5	–6 to –4	–5 to –3	–5 to –4	–6 to –3	–6 to –5
		Upper bound	–4	–3	–3	–4	–3	–4
	Annual total precipitation in %	Median	9	21	3	5	1	7
		Lower bound	3	6	–2	–2	–1	–4
		Likely in the range	5 to 12	8 to 25	–1 to 9	1 to 9	0 to 8	–2 to 14
		Upper bound	13	28	10	12	11	14
	Annual total precipitation where RR > 99p of 1971/2000 in %	Median	36	72	19	37	17	36
		Lower bound	13	24	6	14	8	26
		Likely in the range	14 to 39	28 to 91	9 to 29	18 to 47	9 to 26	26 to 40
		Upper bound	60	101	44	51	61	53