

## **Supplementary A: Detailed information about the analysed data sets**

The ECHAM5/MPI-OM1 model of the MAX-Planck-Institute in Hamburg (Germany) couples an atmospheric model and an ocean model (MPI-OM1). The ocean model interacts with a dynamically sea ice model (Marsland et al.; 2003) and has 23 vertical levels. The atmospheric model has 31 vertical levels. The horizontal resolution is  $1.875^\circ \times 1.875^\circ$  (T63). This model is performed well on a number of criteria, which were considered in the Fourth Assessment Report of the IPCC. In total we studied 47 different simulations from MPI. The References or DOIs for all experiments as well as the forcing are included in Table A1.

Table A1: Information of the used datasets. The indicated years correspond to the model forcing in terms of historical and/or projected greenhouse gas forcing.

<b>Dataset (run)</b>	<b>Correspondent years (forcing)</b>	<b>Number of winters</b>	<b>Reference or DOI</b>
PRE	well-mixed greenhouse gases CO <sub>2</sub> , CH <sub>4</sub> and N <sub>2</sub> O constant for 1860	505	Roeckner, et al., 2006: IPCC-AR4 MPI-ECHAM5_T63L31 MPI-OM_GR1.5L40 Plcntrl (pre-industrial control experiment): atmosphere 6 HOUR values MPImet/MaD Germany. WDDC. DOI:10.1594/WDDC/EH5-T63L31_OM-GR1.5L40_CTL_6H.
ESSENCE (1-20)	1950-2000 (observed greenhouse gas concentrations)	1000	Sterl et al. (2008)
ESSENCE (21-37)	1950-2030 (until 2000: observed greenhouse gas concentrations 2001-2030: SRES A1B)	1360	Sterl et al. (2008)
ECHAM5/MPI-OM1 20C (1-3)	1860-2000: PRE initialised in year 2190 2001-2100: commitment experiment for 21 <sup>th</sup> century; constant 2000	720	Roeckner et al., 2006 IPCC-AR4 MPI-ECHAM5_T63L31 MPI-OM_GR1.5L40 20C3M runs no.1-3. WDDC. DOI:10.1594/WDDC/EH5-T63L31_OM-GR1.5L40_20C_1_6H. DOI:10.1594/WDDC/EH5-T63L31_OM-GR1.5L40_20C_2_6H. DOI:10.1594/WDDC/EH5-T63L31_OM-GR1.5L40_20C_3_6H.
C20SA (1-3)	2001-2030: ECHAM5/MPI-OM1 20C; anthropogenic aerosols = 0	87	Roeckner, 2004: EH5-T63L31_OM-GR1.5L40_C20SA_1, 6h values. WDDC. CERA-DB "EH5-T63L31_OM_C20SA_1_6H" "EH5-T63L31_OM_C20SA_2_6H" "EH5-T63L31_OM_C20SA_3_6H" <a href="http://cera-www.dkrz.de/WDDC/ui/Compact.jsp?acronym=EH5-T63L31_OM_C20SA_1_6H">http://cera-www.dkrz.de/WDDC/ui/Compact.jsp?acronym=EH5-T63L31_OM_C20SA_1_6H</a> <a href="http://cera-">http://cera-</a>

			<a href="http://www.dkrz.de/WDCC/ui/Compact.jsp?acronym=EH5-T63L31_OM_C20SA_2_6H">www.dkrz.de/WDCC/ui/Compact.jsp?acronym=EH5-T63L31_OM_C20SA_2_6H</a> <a href="http://cera-www.dkrz.de/WDCC/ui/Compact.jsp?acronym=EH5-T63L31_OM_C20SA_3_6H">http://cera-www.dkrz.de/WDCC/ui/Compact.jsp?acronym=EH5-T63L31_OM_C20SA_3_6H</a>
20C3M (1-3)	1860-2000: PRE plus solar constant and effects of volcanic aerosols	420	<p>Roeckner, 2005: IPCC MPI-ECHAM5_T63L31 MPI-OM_GR1.5L40 20C3M_all runs no.1-3: atmosphere 6 HOUR values MPImet/MaD Germany. WDCC. CERA-DB</p> <p>"EH5-T63L31_OM_20C3M_1_6H"  "EH5-T63L31_OM_20C3M_2_6H"  "EH5-T63L31_OM_20C3M_3_6H"</p> <p><a href="http://cera-www.dkrz.de/WDCC/ui/Compact.jsp?acronym=EH5-T63L31_OM_20C3M_1_6H">http://cera-www.dkrz.de/WDCC/ui/Compact.jsp?acronym=EH5-T63L31_OM_20C3M_1_6H</a>  <a href="http://cera-www.dkrz.de/WDCC/ui/Compact.jsp?acronym=EH5-T63L31_OM_20C3M_2_6H">http://cera-www.dkrz.de/WDCC/ui/Compact.jsp?acronym=EH5-T63L31_OM_20C3M_2_6H</a>  <a href="http://cera-www.dkrz.de/WDCC/ui/Compact.jsp?acronym=EH5-T63L31_OM_20C3M_3_6H">http://cera-www.dkrz.de/WDCC/ui/Compact.jsp?acronym=EH5-T63L31_OM_20C3M_3_6H</a></p>

15 **Supplementary B:**

Table B1: As Table 2 but indicating the raw number of events per dataset. The different GCM datasets indexed by corr are results corrected by the CWT.

1-year Return Level		DWD	ERA1	NCEP	GCM	GCM <sub>corr</sub>	ESS <sub>corr</sub>	20C <sub>corr</sub>	PRE <sub>corr</sub>
		30yrs	30yrs	30yrs	4092yrs	4092yrs	2360yrs	720yrs	505yr
Events per year	0	12	12	12	1705	1734	940	301	195
	1	10	10	9	1278	1258	790	242	180
	2	5	6	7	699	666	413	101	83
	3	2	0	1	289	286	153	42	33
	4	1	2	1	75	108	43	24	10
	5	0	0	0	33	30	14	7	4
	6	0	0	0	8	8	6	2	0
	7	0	0	0	4	2	1	1	0
	8	0	0	0	1	0	0	0	0
2-year Return Level									
Events per year	0	20	18	19	2591	2593	1473	454	311
	1	6	10	8	1068	1065	651	195	145
	2	3	1	2	342	341	190	53	40
	3	1	1	1	72	78	39	13	7
	4	0	0	0	17	10	4	5	2
	5	0	0	0	2	5	3	0	0
5-year Return Level									
Events per year	0	24	25	26	3388	3378	1943	595	414
	1	6	4	3	607	621	370	113	81
	2	0	1	0	82	84	40	13	10
	3	0	0	1	14	8	6	3	0
	4	0	0	0	0	0	1	0	0
	5	0	0	0	1	1	0	0	0

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Table B2: As Table 2 but indicating the empirical return period based on the raw number of events per dataset. The different GCM datasets indexed by corr are results corrected by the CWT.

1-year Return Level		DWD 30yrs	ERA1 30yrs	NCEP 30yrs	GCM 4092yrs	GCM <sub>corr</sub> 4092yrs	ESS <sub>corr</sub> 2360yrs	20C <sub>corr</sub> 720yrs	PRE <sub>corr</sub> 505yrs
Events per year	0	2.50	2.50	2.50	2.4	2.36	2.51	2.39	2.59
	1	3.00	3.00	3.33	3.20	3.25	2.99	2.98	2.81
	2	6.00	5.00	4.29	5.85	6.14	5.71	7.13	6.08
	3	15	-	30	14	14	15	17	15
	4	30	15	30	55	38	55	30	51
	5	-	-	-	124	136	169	103	126
	6	-	-	-	512	512	393	360	-
	7	-	-	-	1023	2046	2360	720	-
	8	-	-	-	4092	-	-	-	-
2-year Return Level		Empirical return period							
Events per year	0	1.50	1.67	1.58	1.58	1.59	1.60	1.59	1.62
	1	5.00	3.00	3.75	3.83	3.84	3.63	3.69	3.48
	2	10	30	15	12	12	12	14	13
	3	30	30	30	57	52	61	55	72
	4	-	-	-	241	409	590	144	253
	5	-	-	-	2046	818	1364	-	-
5-year Return Level		Empirical return period							
Events per year	0	1.25	1.20	1.15	1.21	1.21	1.21	1.21	1.22
	1	5.00	7.50	10.00	6.74	6.60	6.38	6.61	6.23
	2	-	30	-	50	49	59	55	501
	3	-	-	30	292	511	393	240	-
	4	-	-	-	-	-	2360	-	-
	5	-	-	-	4092	4092	-	-	-

### Supplementary C:

Accumulated return period estimated with negative Binomial distribution for x and  
 35 more events. For example 3 or more events.

1-year Return Level	Pois	ERA1	NCEP	GCM	GCM <sub>corr</sub>	ESS <sub>corr</sub>	20C <sub>corr</sub>	PRE <sub>corr</sub>
		30yrs	30yrs	4092yrs	4092yrs	2360yrs	720yrs	505yr
1	1.58	1.65	1.67	1.72	1.75	1.66	1.71	1.63
2	3.78	3.79	3.80	3.82	3.83	3.80	3.81	3.79
3	12.45	10.75	10.46	9.80	9.53	10.60	9.87	11.25
4	53	35	33	28	26	34	28	40
5	273	128	113	83	73	120	86	161
2-year Return Level								
1	2.54	2.61	2.73	2.74	2.74	2.67	2.70	2.61
2	11.09	10.50	9.83	9.78	9.76	10.15	9.97	10.51
3	70	54	40	40	39	47	43	55
4	571	332	181	172	170	242	204	335
5-year Return Level								
1	5.52	6.12	7.36	5.80	5.73	5.64	5.74	5.58
2	57	34	24	42	44	49	44	53
3	871	180	70	324	386	520	380	660

## Supplementary D:

$\Psi$ -values and confidence interval for the different datasets.

Return Level	ERA1	NCEP	GCM	GCM <sub>corr</sub>	ESS <sub>corr</sub>	20C <sub>corr</sub>	CTRL <sub>corr</sub>
1	0.1595±0.1127	0.1972±0.1123	0.3062±0.0188	0.6383±0.0055	0.1777±0.0071	0.2919±0.0294	0.1020±0.0115
2	0.0727±0.0650	0.1962±0.0271	0.2081±0.0090	0.3168±0.0039	0.1297±0.0040	0.1661±0.0049	0.0713±0.0031
5	0.2464±0.0290	0.8186±0.1881	0.1161±0.0023	0.1095±0.0025	0.0491±0.0027	0.0908±0.0043	0.0240±0.0037