Supporting Information for "Larger spatial footprint of wintertime total precipitation extremes in a warmer climate"

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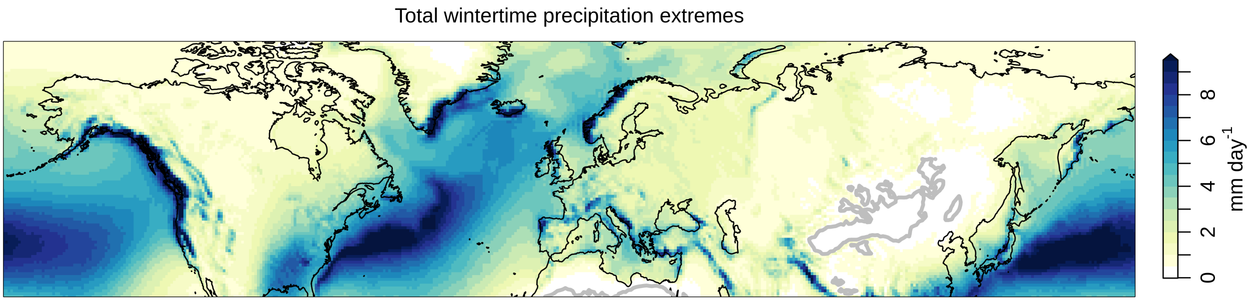

Figure S1. Local 10-year return level of the wintertime total precipitation based on HadAM4 model output for present-day climate. Grey contours over Asia enclose areas where the present-day 10-year return level is below 0.2mm/day (about 18mm/winter).

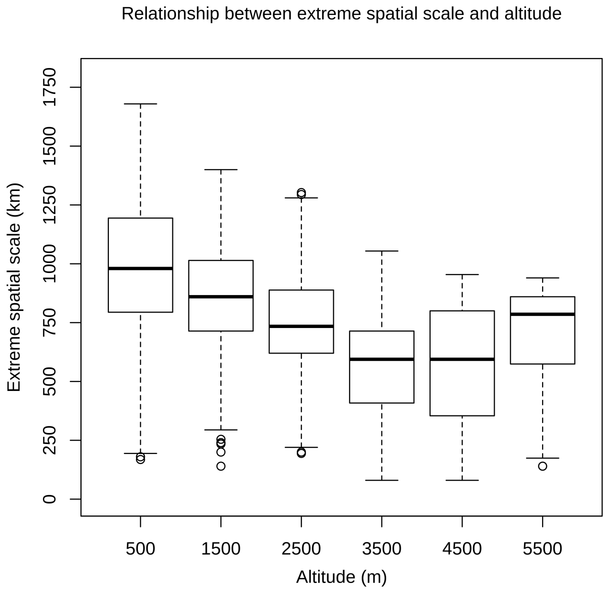

Figure S2. Boxplots showing the relationship between the grid-point local altitude and the present-day 100-year return level of the precipitation extremes' spatial scale (shown is the value of the radius associated with the spatial scale, as in Figure 1). Grid-points were binned based on their altitude by steps of 1000 meters above mean sea level, e.g., the bin labelled by 500m contains grid-points between 0 and 1000m.

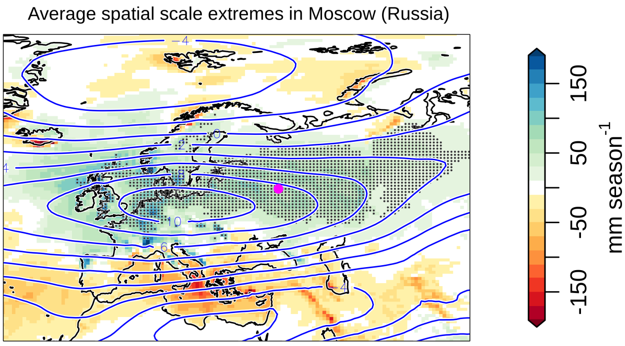

Figure S3. Average of the precipitation field anomaly associated with winters leading to extreme spatial scales (>100-year return level) around Moscow (Russia; shown with a magenta dot) in the present climate. Precipitation is shown with shading. Contours show the anomaly of the zonal wind at 250 hPa during the events (in m/s). Stippling indicates locations where the average precipitation value is higher than the local 10-year return level.

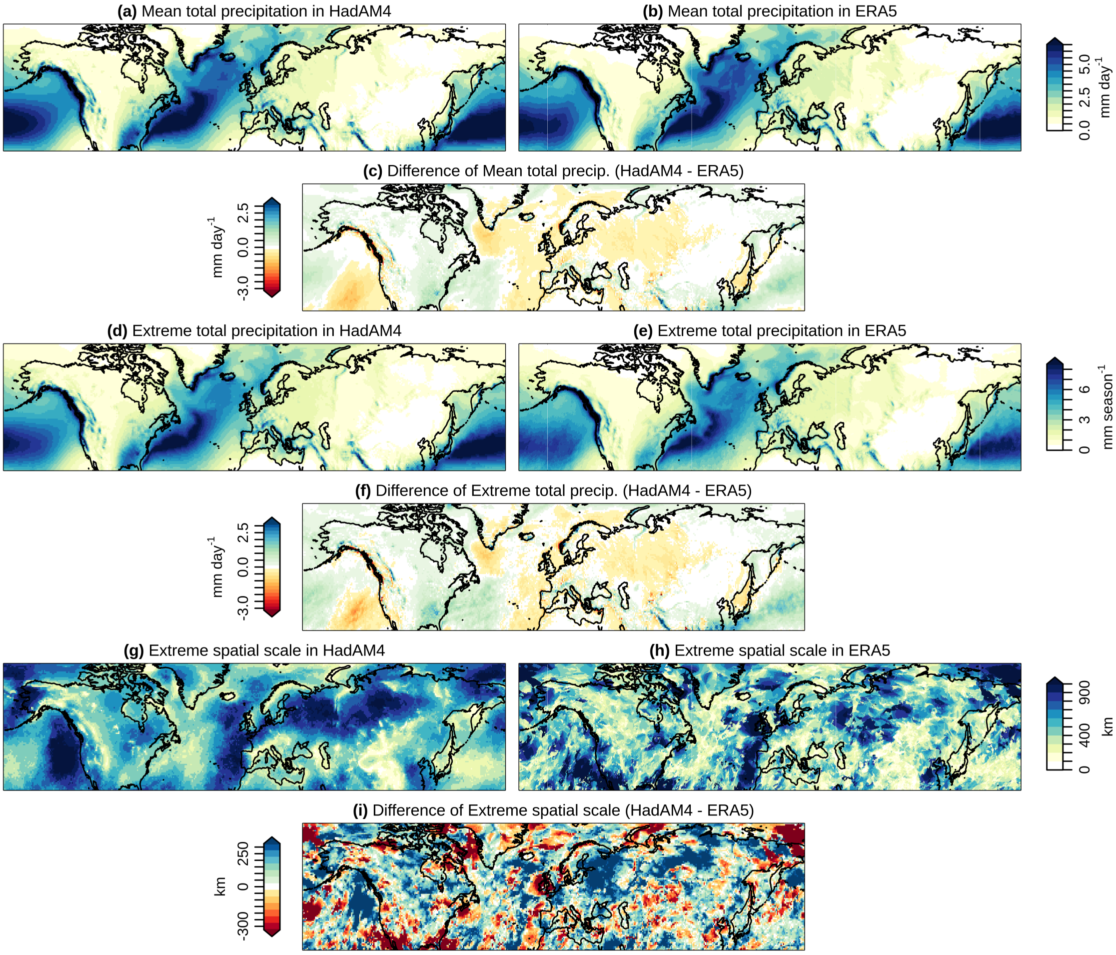

Figure S4. Comparison between precipitation statistics in the HadAM4 model (large ensemble of the period 2006-2015) and ERA5 reanalysis (1980-2020). Mean wintertime total precipitation based on (a) HadAM4 and (b) ERA5; panel (c) shows the difference between HadAM4 and ERA5 values. Extreme wintertime total precipitation (5-year return level) based on (d) HadAM4 and (e) ERA5; panel (f) shows their difference. Radius associated with the extreme spatial scale (computed based on $T_{\mathrm{occur}} = 5$ year and $T_{\mathrm{SS}} = 10$ year; see Methods) of wintertime total precipitation extremes based on (g) HadAM4 and (h) ERA5; panel (i) shows their difference. To compute the differences between HadAM4 and reanalysis, the ERA5 resulting fields are regridded to the native grid of HadAM4.

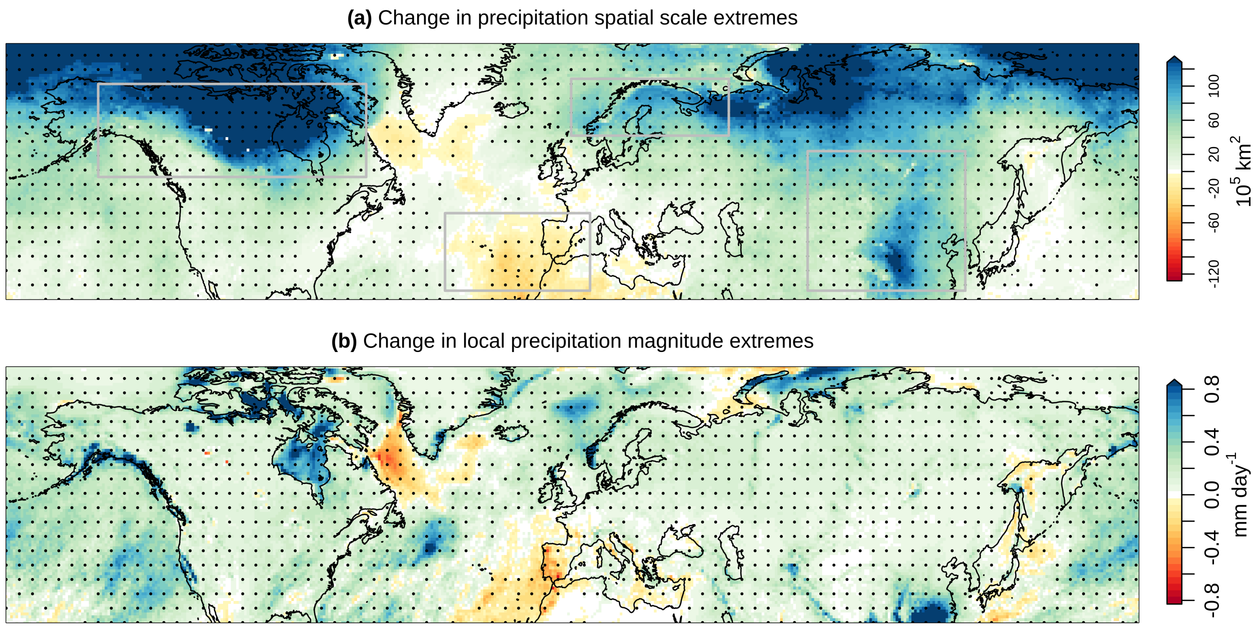

Figure S5. (a) As in Figure 2a, but showing the change in the spatial scale extremes in km^2 rather than the percentage change. Rectangles identify the regions referred to in the main text: (i) Canada, (ii) Northern Africa, Spain and Portugal, (iii) Northern Europe, and (iv) central and eastern Asia. (b) As in Figure 2d, but showing the change in mm.

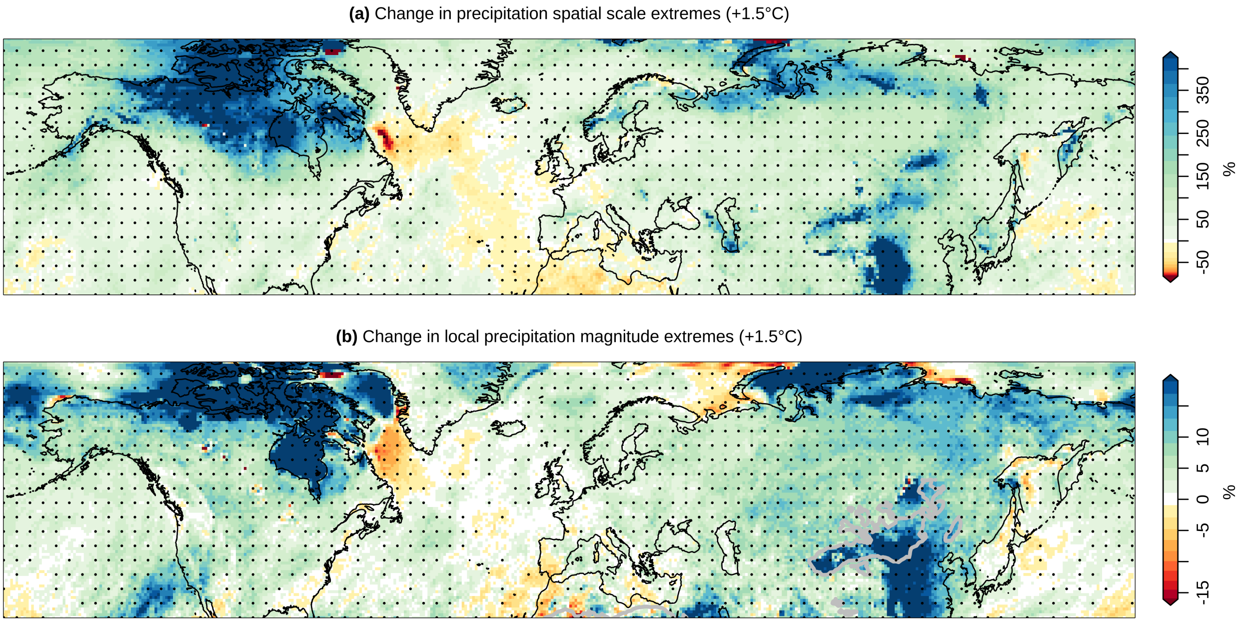

Figure S6. (a) As in Figure 2a, but under a 1.5^{o}C warming scenario. (b) As in Figure 2d, but under a 1.5^{o}C warming scenario.

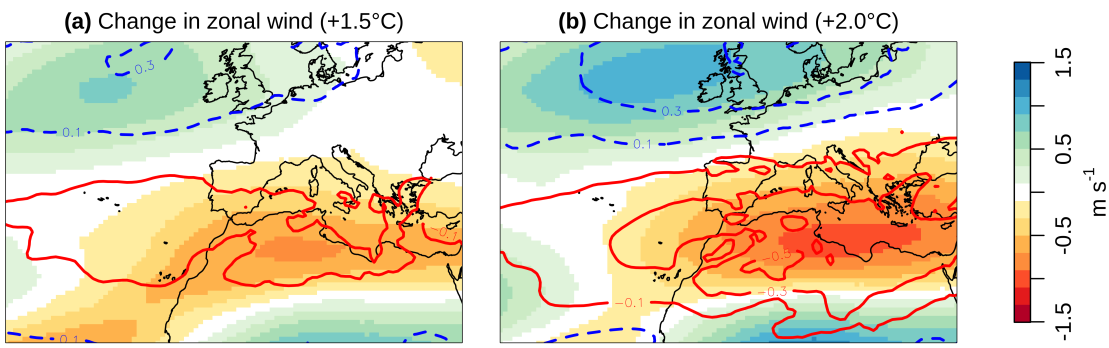

Figure S7. Changes in mean wintertime zonal wind at 250 hPa (shading) and 850 hPa (contours; in m/s) across Northern Africa and southern Europe under (a) 1.5^{o}C and (b) 2.0^{o}C warming scenario. Solid red indicates increase and dashed blue indicates a decrease in the wind at 850 hPa.

Table S1. Sensitivity of the changes, under a +2.0^{o}C warming, in the spatial scale extremes to variations in the return periods used to define extreme events.

		T_{SS} (years)		
		50	100	200
	5	93% (0%, 85%)	82% (0%, 74%)	78% (0%, 71%)
T_{occur} (years)	10	124% (0%, 120%)	97% (0%, 93%)	79% (0%, 78%)
	30	403% (0%, 385%)	201% (0%, 187%)	138% (0%, 126%)

Hemispheric *grid-point area-weighted median* of the changes (%) in spatial scale extremes for different combinations of return periods employed to define extreme events (i.e., T_{SS} and T_{occur}; defined in Methods). The two values (%) in the brackets are median changes driven by changes in the spatial dependencies and precipitation magnitudes, respectively. The table highlights that while the value of the median change depends on the considered return periods, the projected increase is a robust feature across different return periods. Changes driven by the precipitation spatial dependence are small for all considered return periods. Note that the spatial pattern of the changes in the spatial scale extremes is largely insensitive to variations in the return periods (not shown).

Table S2. As in Table S1, but showing the sensitivity of the ratio between the median change in the spatial scale extremes (based on T_{occur} and T_{SS}) and in the magnitude of wintertime total precipitation extremes (based on T_{occur}).

		T_{SS} (years)		
		50	100	200
	5	26	23	22
T_{occur} (years)	10	31	25	20
	30	94	47	32

Table S3. As in Table S1, but showing the sensitivity of the ratio between the median change in the spatial scale in a +2.0^{o}C and +1.5^{o}C warming scenario.

		T_{SS} (years) 50	100	200
	5	1.7	1.7	1.7
T_{occur} (years)	10	1.6	1.6	1.6
	30	2.0	1.8	1.8

Table S4. As in Table S1, but showing the sensitivity of the area fraction (%) exposed to an increase in the spatial scale extremes under a +2.0^{o}C warming scenario (results for +1.5^{o}C warming scenario are shown in brackets).

		T_{SS} (years) 50	100	200
	5	90% (91%)	90% (90%)	90% (89%)
T_{occur} (years)	10	90% (88%)	90% (87%)	89% (86%)
	30	87% (82%)	88% (83%)	87% (82%)

Table S5. As in Table S1, but showing the sensitivity of the present-day median spatial scale extremes and, in brackets, associated changes in a +2.0^{o}C warming scenario.

		T_{SS} (years) 50	100	200
	5	$67 \cdot 10^5 km^2$ ($63 \cdot 10^5 km^2$)	$90 \cdot 10^5 km^2$ ($74 \cdot 10^5 km^2$)	$110 \cdot 10^5 km^2$ ($87 \cdot 10^5 km^2$)
T_{occur} (years)	10	$15 \cdot 10^5 km^2$ ($22 \cdot 10^5 km^2$)	$27 \cdot 10^5 km^2$ ($29 \cdot 10^5 km^2$)	$39 \cdot 10^5 km^2$ ($33 \cdot 10^5 km^2$)
	30	$0.80 \cdot 10^5 km^2$ ($0.96 \cdot 10^5 km^2$)	$3.2 \cdot 10^5 km^2$ ($2.0 \cdot 10^5 km^2$)	$7.2 \cdot 10^5 km^2$ ($3.1 \cdot 10^5 km^2$)