1 Supplementary material for Klimiuk et al., 2024

This document includes one table and 11 figures

Table S1: List of DWD stations used for validation of present-day storylines with their coordinates and names, sorted by latitude.

ST_ID	ST_LON	ST_LAT	ST_NAME
01550	11.0621	47.4830	Garmisch-Partenkirchen
01346	8.0038	47.8748	Feldberg/Schwarzwald
01262	11.8134	48.3477	München-Flughafen
15444	9.9216	48.4418	Ulm-Mähringen
04177	8.3301	48.9726	Rheinstetten
03667	11.2539	49.4258	Nürnberg-Netzstall
03904	6.3789	49.5354	Perl-Nennig
07341	8.7862	50.0900	Offenbach-Wetterpark
00867	10.9679	50.3066	Lautertal-Oberlauter
02667	7.1575	50.8645	Köln-Bonn
01050	13.8470	51.0221	Dresden-Hosterwitz
04763	9.9266	51.0607	Sontra
02932	12.2396	51.4347	Leipzig/Halle
00617	6.8863	51.8730	Borken in Westfalen
03987	13.0622	52.3812	Potsdam
02014	9.6779	52.4644	Hannover
00691	8.7981	53.0451	Bremen
03196	11.9321	53.3222	Marnitz
01981	9.8957	53.4776	Hamburg-Neuwiedenthal
05097	12.7655	54.0654	Tribsees

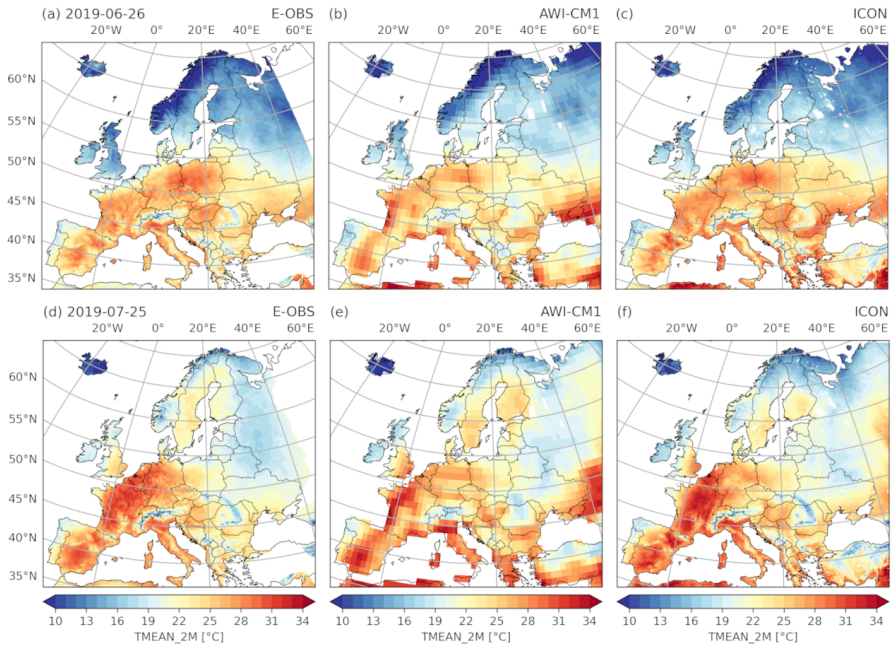

Figure S1: Mean 2m temperature on 26.06.2019 (first peak of the June heatwave) and 25.07.2019 (peak of the July heatwave) for E-OBS (left), AWI-CM1 (middle), and ICON EUR-12 (right).

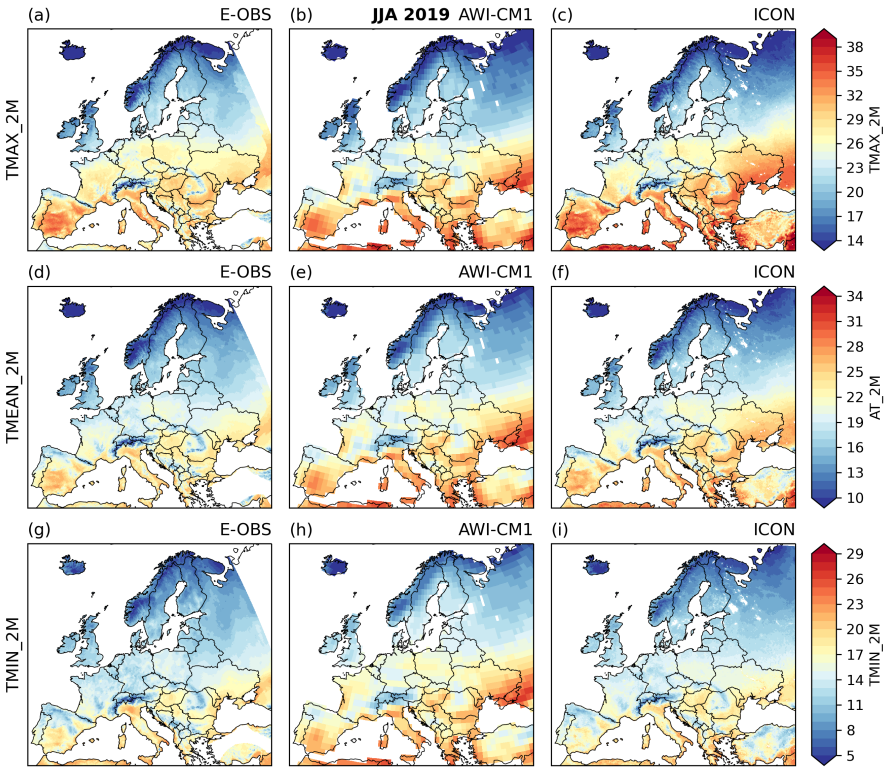

Figure S2: Seasonally averaged maximum, mean, and minimum 2m temperature in June - August 2019 as of (left) E-OBS, (middle) AWI-CM1, (right) ICON EUR-12.

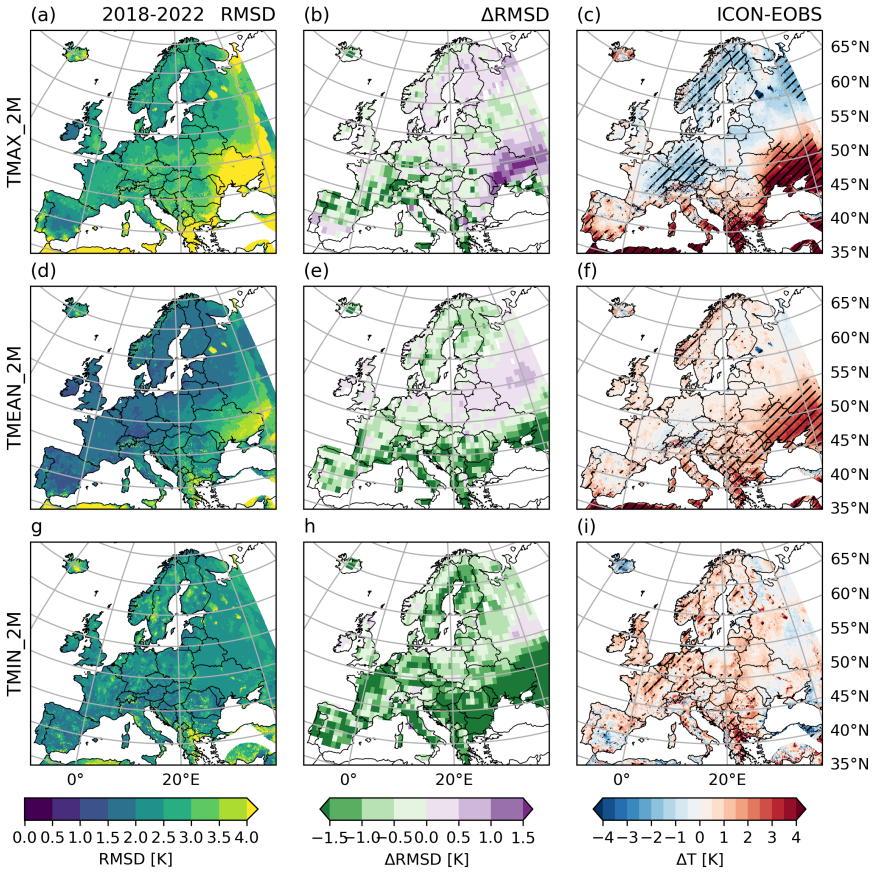

Figure S3: Added value assessment of the ICON EUR-12 simulation for all summers of the simulation period 2018 - 2022 for daily (a-c) maximum, (d-f) mean, and (g-i) minimum 2m temperature. Left column: root mean square difference (RMSD) of the simulated daily 2m temperatures by ICON EUR-12 to E-OBS. Middle column: Change in RMSD achieved by dynamical downscaling; the green colours correspond to the reduced squared error of daily temperatures. Right column: seasonal mean bias with respect to E-OBS; in hatched areas, the difference of ICON EUR011 to E-OBS exceeds the E-OBS ensemble spread.

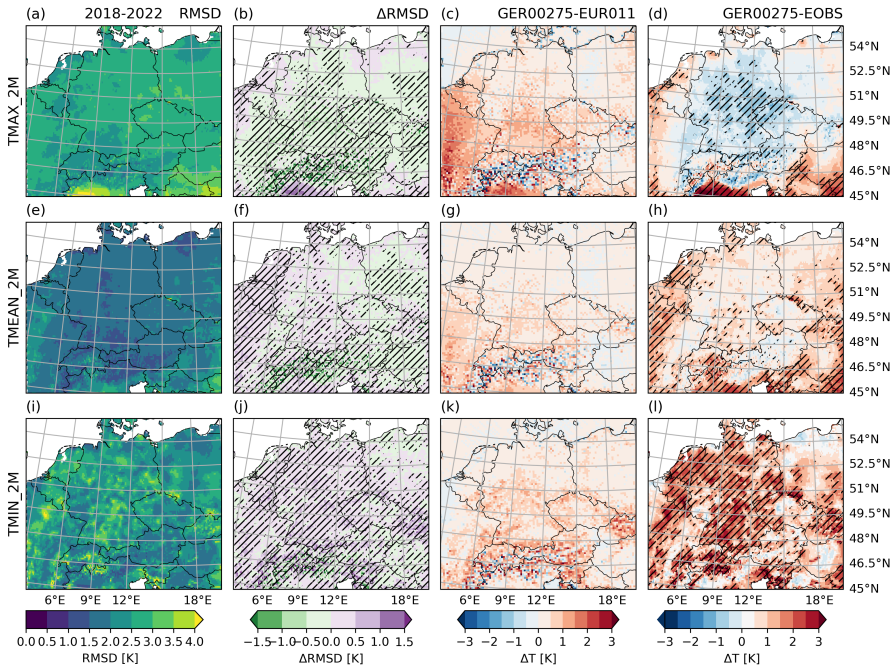

Figure S4: Added value assessment of the nested convective-permitting GER-3 simulation for all summers of 2018 - 2022 for daily (a-d) maximum, (e-h) mean, and (i-l) minimum 2m temperature. First column: root mean square difference (RMSD) of daily 2m temperature to E-OBS of the GER-3 simulation. Second column: Change of RMSD compared to the EUR-12 simulation (significant difference hatched, $p<0.05$). Third column: seasonal mean bias of the GER-3 simulation w.r.t. EUR-12. Fourth column: seasonal mean bias of the GER-3 simulation w.r.t E-OBS (hatching signifies the exceedance of the E-OBS ensemble spread)

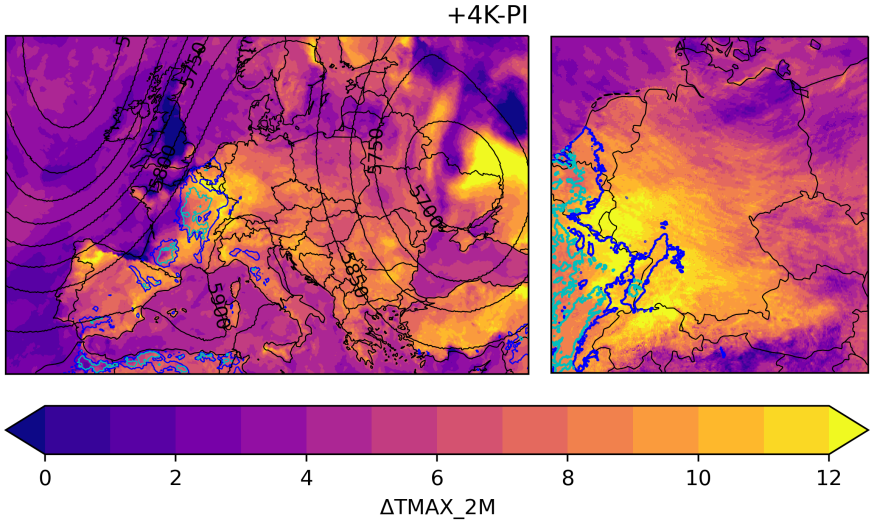

Figure S5: Difference of the maximum 2m temperature on 25.07.2019 between the +4 K warmer world and the pre-industrial climate. Contour lines represent the maximum 2m temperature in the present-day ICON (left) EUR-12 and (right) GER-3 simulations; blue contour: 40°C, Cyan contour: 42°C

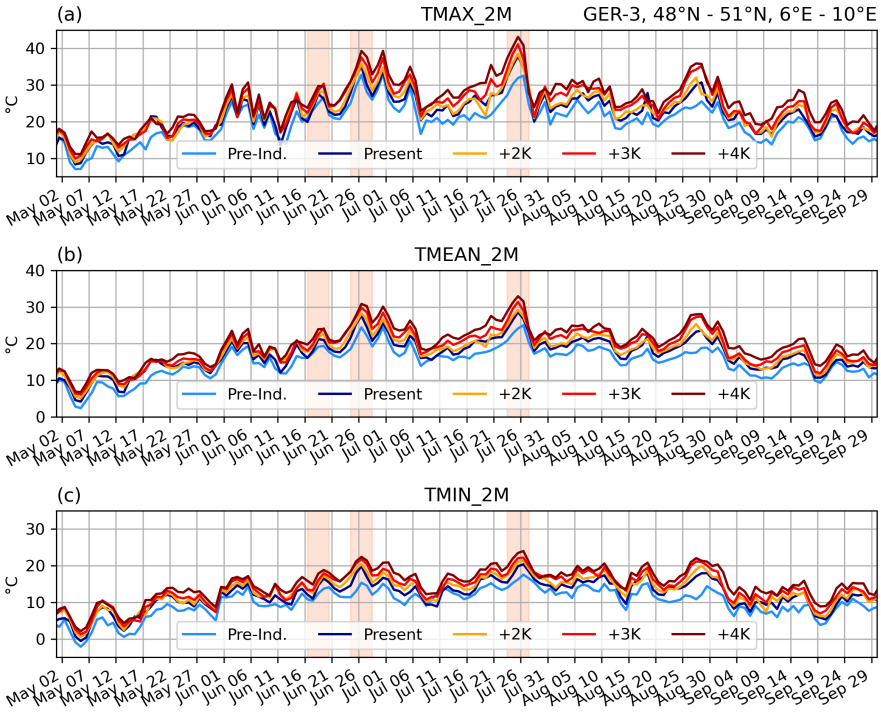

Figure S6: Daily (a) maximum, (b) mean, and (c) minimum temperatures averaged over the longitude/latitude box with boundaries 48° N - 51° N and 6° E - 10° E (see Fig. 1b) over the MJJAS period of the year 2019 based on the GER-3 storyline simulations. The three highlighted periods (orange) are discussed in detail in section 3.3.

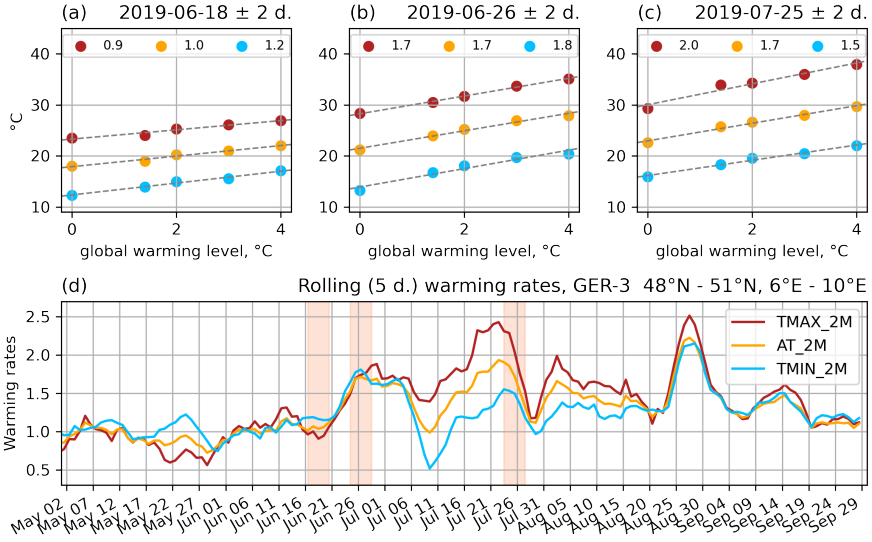

Figure S7: (a-c) Daily maximum (red), mean (orange), and minimum (blue) 2m temperature over the longitude/latitude box 48° N - 51° N, 6° E - 10° E averaged over three 5-day periods plotted against the global warming level. The numbers in the legend represent the slopes of the respective lines; (d) warming rates for the rolling average (5-day window) of daily maximum, mean, and minimum temperatures over the same box. The three highlighted periods are discussed in detail in section 3.3. Based on the GER-3 simulation.

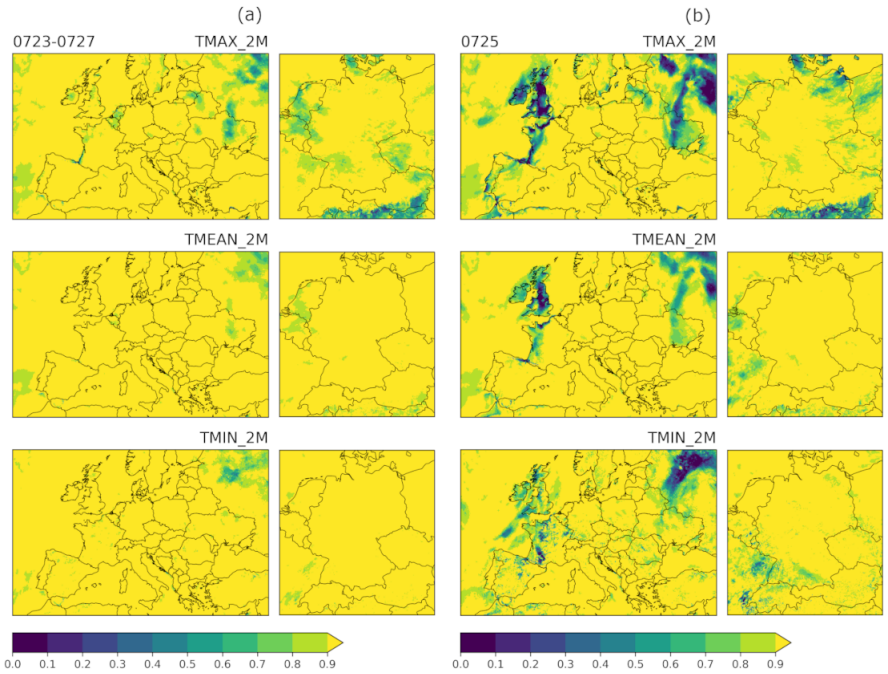

Figure S8: Goodness of linear fit (R-squared) for warming rates of maximum, mean, and minimum 2m temperatures (a) over the period from 23.07.2019 to 27.07.2019, (b) on 25.07.2019.

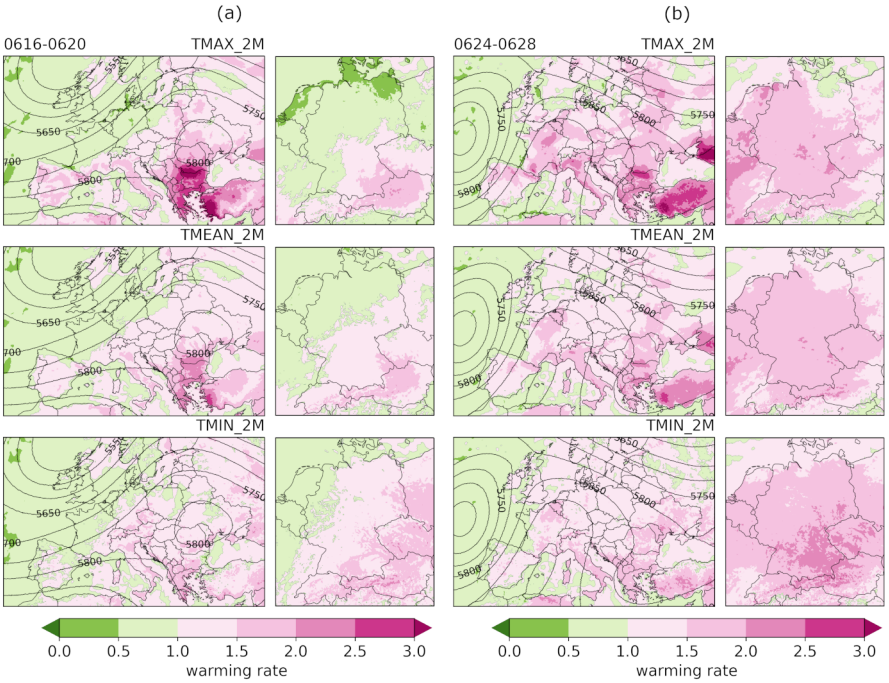

Figure S9: (a) Warming rates for the period from 16.06.2019 to 20.06.2019. (b) Warming rates for the period from 24.06.2019 to 28.06.2019. Contours: geopotential height as of the EUR-12 simulation.

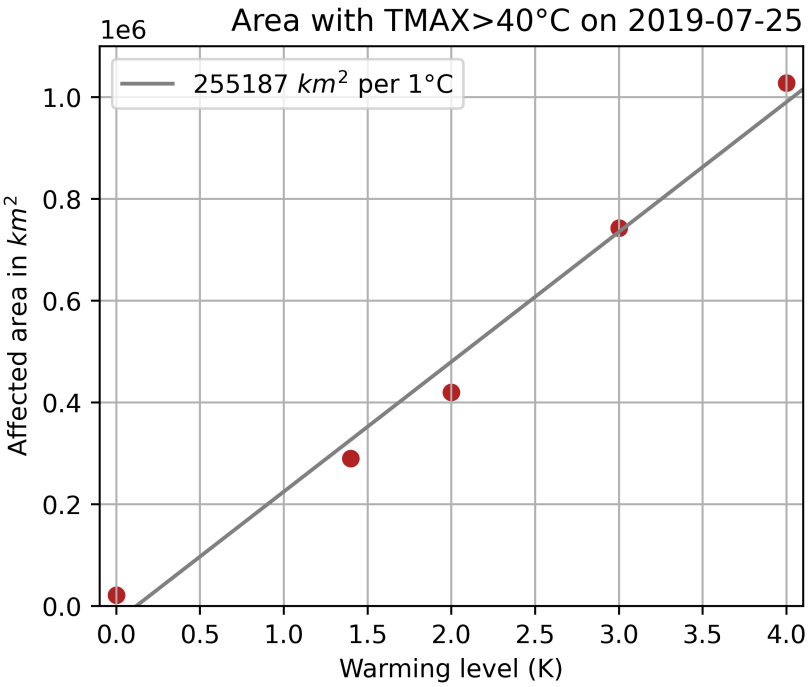

Figure S10: The area affected by the temperatures over 40 °C on 25.07.2019 against the warming level

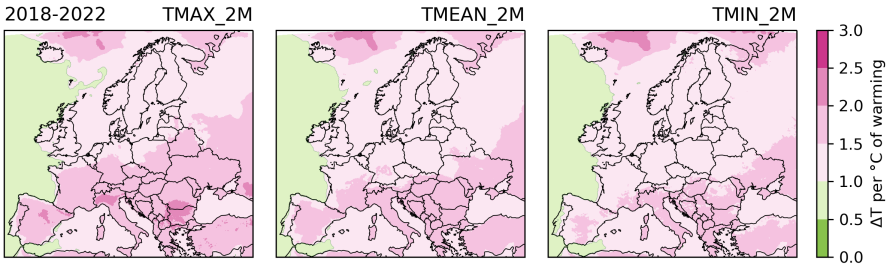

Figure S11: Warming rates for the mean summer 2m temperature averaged over all summers of the simulated period 2018-2022 based on the EUR-12 storylines.