

1 **Allowable CO<sub>2</sub> emissions based on regional and impact-related climate targets**

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12 **Global temperature targets, such as the widely accepted 2°C limit, may fail to**  
13 **communicate the urgency of reducing CO<sub>2</sub> emissions. Translation of CO<sub>2</sub> emissions**  
14 **into regional- and impact-related climate targets could be more powerful because**  
15 **they resonate better with national interests. We illustrate this approach using**  
16 **regional changes in extreme temperatures and precipitation. These scale robustly**  
17 **with global temperature across scenarios, and thus with cumulative CO<sub>2</sub> emissions.**  
18 **This is particularly relevant for changes in regional extreme temperatures on land,**  
19 **which are much greater than changes in the associated global mean.**

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21 The IPCC 5<sup>th</sup> Assessment Report included a figure in the Summary for Policymakers  
22 (SPM) of the Working Group 1 (WG1) that linked global mean temperature changes  
23 ( $\Delta T_{\text{glob}}$ ) to total CO<sub>2</sub> emissions from 1870 onwards<sup>1</sup> (Fig. 1). This figure is compelling

24 because it shows a clear linear relationship between cumulative CO<sub>2</sub> emissions and a  
25 measure of the global climate response. The obvious consequences are that every ton of  
26 CO<sub>2</sub> contributes about the same amount of global-scale warming, no matter when it is  
27 emitted, that any target for the stabilization of  $\Delta T_{\text{glob}}$  implies a finite CO<sub>2</sub> budget or quota  
28 that can be emitted, and that global net emissions at some point need to be zero<sup>2,3,4,5,6</sup>.

29

30 This simple relationship between CO<sub>2</sub> emissions and changes in  $\Delta T_{\text{glob}}$  (Fig. 1) has helped  
31 overcome one communication barrier for the public in relating greenhouse gas emissions  
32 with the climate system response. Yet, another obstacle remains the actual appreciation of  
33 associated climate impacts, namely the translation of changes in global mean temperature  
34 to regional-scale consequences for society and the environment. In this Perspective, we  
35 demonstrate the feasibility of – as well as make the case for – quantitatively relating  
36 global-scale cumulative CO<sub>2</sub> emissions to regional climate targets. We illustrate this  
37 approach by scaling changes in hot and cold extreme temperatures and heavy  
38 precipitation events with changes in the global mean temperature.

39

#### 40 **Global vs regional climate targets**

41 Our experience shows that the implications of projected global mean temperature  
42 changes tend to be underestimated at regional (and country) level, because these are  
43 much smaller than the expected changes in regional temperature mean and extremes over  
44 most land areas<sup>7,8,9,10</sup>. The limitations of focusing on global mean temperature as a  
45 measure of climate change has, for instance, been evidenced by the public debate about

46 the recent “hiatus”. This has fixated attention on changes in  $\Delta T_{\text{glob}}$  instead of the  
47 discernible worldwide impacts of the continued increases in radiative forcing<sup>1,11,12,13,14</sup>.  
48  
49 As illustrated in Fig. 2, a 2°C target for  $\Delta T_{\text{glob}}$  implies increases in both warm and cold  
50 temperature extremes greater than 2°C over most land regions. This is due to the land-sea  
51 contrast<sup>15,16</sup> in response to radiative forcing, as well as to feedbacks (e.g. from decreases  
52 in soil moisture, snow, or ice<sup>7,8,17,18,19,20</sup>), which further amplify changes in extreme  
53 temperatures in some key regions. As an example, the 2°C global mean temperature  
54 target implies 3°C warming in hot temperature extremes in the Mediterranean region (Fig.  
55 2a) and ca. 5.5° warming in cold temperature extremes over land in the Arctic region (Fig.  
56 2b). Hence, these changes in regional extremes are greater than those in global mean  
57 temperature by a factor of ca. 1.5 and 2.5 to 3 (Supplementary Figure S1), respectively.  
58 As highlighted above, this stronger warming of extremes on land compared to that of  
59 global mean temperature is related both to the larger warming of mean temperature on  
60 land (Fig. 2c), as well as to an additional specific warming of extremes in several regions  
61 (Figs. 2a,b). Subjectively, such regional changes in extremes may better convey the  
62 consequences of crossing the respective cumulative CO<sub>2</sub> emissions threshold, compared  
63 to the associated change in  $\Delta T_{\text{glob}}$  (2°C), which appears relatively mild in comparison.  
64  
65 We make the case here for more easily interpretable analyses that relate global  
66 cumulative CO<sub>2</sub> emissions targets to changes in regional extremes or other impact-  
67 relevant quantities in addition to changes in global mean temperature. While the IPCC  
68 Synthesis Report<sup>21</sup> has shown cumulative CO<sub>2</sub> emissions alongside the famous “reasons

69 for concerns”, the employed bars of various degrees of red only provide a qualitative  
70 assessment. We highlight hereafter how quantitative analyses relating cumulative  
71 emissions to climate change at the national or regional scale could provide more targeted  
72 and actionable information for the decision process.

73

#### 74 **Relating extremes to global CO<sub>2</sub> emissions**

75 We thus assess the extent to which the implications of Fig. SPM.10 (Fig. 1) from the  
76 IPCC AR5 WG1 SPM<sup>1</sup> can be expanded to relate cumulative global emissions in CO<sub>2</sub>  
77 with *regional changes* in temperature extremes (annual maximum and minimum  
78 temperatures, see Box 1). The result is displayed in Fig. 3 for four example regions with  
79 relatively strong scaling (Mediterranean basin, contiguous U.S., and Brazil for annual  
80 maximum daytime temperatures; the Arctic for annual minimum nighttime temperatures;  
81 for other regions, see Supplementary Figures S4 and S5). The analyses display the  
82 scaling of the considered regional changes with the changes in global mean temperature  
83 for a range of climate projections, and provide the associated expected allowable  
84 cumulative global CO<sub>2</sub> emissions (but without considering the uncertainty in translating  
85  $\Delta T_{\text{glob}}$  to cumulative emissions).

86

87 The results show that changes in regional extreme temperatures display a rather linear  
88 scaling with  $\Delta T_{\text{glob}}$ , which is also mostly independent of the emission scenario considered  
89 (Fig. 3). Hence, regional changes in temperature extremes can be usefully related to given  
90 cumulative CO<sub>2</sub> targets, without any consideration of the emission pathway. However,  
91 scaling for regional extremes on land is generally steeper than for  $\Delta T_{\text{glob}}$  (see also

92 analyses for other land regions in Supplementary Figures S4 and S5). Hence, as expected  
93 from Fig. 2, the relationship between the increase in regional temperature extremes and  
94 the increase in global mean temperature typically implies a larger change of the former at  
95 more local scales.

96

97 For instance, a 2°C warming in hot extremes (annual warmest daytime temperature, TXx)  
98 takes place in the Mediterranean for a change of 1.4°C in  $\Delta T_{\text{glob}}$  (Fig. 3a). The  
99 corresponding allowable cumulative CO<sub>2</sub> emissions are therefore 600 GtC for a 2°C  
100 warming of hot extremes in the Mediterranean region compared to ca. 750-800 for a 2°C  
101 warming in global mean. Given current political tensions around the Mediterranean basin,  
102 implications of locally more rapid climate change could extend to regional impacts<sup>22</sup>,  
103 adding to wider political instability (see for example the purported impacts of drought in  
104 Syria<sup>23,24</sup>).

105

106 Scaling extreme hot temperatures in the contiguous U.S. and Brazil (Figs. 3b,c) by  $\Delta T_{\text{glob}}$   
107 provides qualitatively similar results, but highlights greater uncertainty of projections in  
108 these regions. In the contiguous U.S., although the expected value of scaling with  $\Delta T_{\text{glob}}$   
109 is greater than 1, the uncertainty range bounds the 1:1 line. Conversely, the regional  
110 response in Brazil is significantly different from the 1:1 line despite the larger uncertainty  
111 range compared to the Mediterranean region. The response of the regional changes in  
112 annual coldest daily temperatures (TNn) in the Arctic (Fig. 3d) conveys a very stark  
113 message. In this case, as seen in Fig. 2, the regional response is ca. 2.5-3 times greater for  
114 the coldest extremes than for the global mean temperature change, with an increase of

115 about 5.5°C for the 2°C global warming target. In addition, it is evident that a regional  
116 2°C threshold was passed in the simulations around year 2000 for TNn in the Arctic,  
117 while it is projected to be reached by ca. 2030 for TXx in the Mediterranean, Brazil and  
118 the contiguous U.S., and only by the mid-2040s for the global mean temperature, under  
119 the business-as-usual (RCP8.5) emissions scenario.

120

121 While we illustrated the concept of regional and impact-related climate targets with  
122 regional changes in temperature extremes, similar reasoning can be applied to a range of  
123 other responses to global climate forcing<sup>7,25</sup> (e.g. changes in heavy precipitation events,  
124 see hereafter). These are also highly relevant in comprehending the regional implications  
125 of global CO<sub>2</sub> emissions. As a further illustration, we display in Fig. 4 the scaling of  
126 heavy precipitation events with global mean temperature, and the respective relationship  
127 between cumulative CO<sub>2</sub> emissions and resulting changes in heavy precipitation in  
128 Southern Asia. As for regional temperature extremes, multi-model average changes in  
129 heavy precipitation display an almost linear scaling with the global mean temperature<sup>26</sup>  
130 (roughly consistent with the Clausius-Clapeyron relationship in that region), and thus  
131 could be used to inform regional decision-makers on suitable allowable targets for global  
132 emissions. Moreover, it should be noted that, while the ensemble mean response is robust  
133 across models and emissions scenarios, individual model projections can diverge strongly  
134 from this mean response (in the investigated region as well as in other locations, see  
135 Supplementary Figures S6 and S7). This point is denoted by the red-shaded uncertainty  
136 range, which, in most regions, is substantially larger than for temperature extremes. This  
137 behaviour is due to the increasing relevance of internal climate variability at regional-to-

138 local scale<sup>27</sup>, higher model uncertainty, and the spatially more heterogeneous nature of  
139 precipitation extremes compared to temperature extremes.

140

141 Despite the associated uncertainty, analyses such as the ones in Figs. 3 and 4b provide  
142 more information to regional stakeholders than a global mean temperature target, since  
143 they quantitatively and directly highlight the expected regional response (in extremes and  
144 other variables than temperature), with attendant lower and upper bounds. Such estimates  
145 are thus more useful when assessing associated impacts, and engaging with policymakers.

146

#### 147 **Limitations of approach**

148 Some caveats are attached to the above findings, most importantly:

149 1. Scaling relationships are only meaningful as long as associated uncertainties in  
150 projections are kept within reasonable bounds. This is the case for some climate  
151 features, such as temperature extremes or heavy precipitation events<sup>1,7</sup>, but for  
152 others, such as droughts, tropical cyclones, or storms, uncertainties are generally  
153 larger than the climate change signals<sup>1,7,28</sup>. In such situations, no emissions target  
154 (or implied global temperature target) may currently be set based on avoiding  
155 changes in these extremes.

156 2. Some changes in the climate system may be abrupt (i.e. non-linearly related to  
157 emissions) due to tipping points<sup>29</sup>. Again, uncertainties in the associated  
158 projections are very large, especially under high-end emissions. Due to the non-  
159 linearity of the respective features, relationships could be difficult to derive  
160 (although some features have been assessed, such as the dependency of mean sea

161 level rise on global mean temperature increase at equilibrium<sup>30</sup> and the probability  
162 of abrupt changes for given global temperature thresholds<sup>31</sup>).

163 3. Although we find a relatively robust scaling of regional-scale temperature and  
164 precipitation extremes with  $\Delta T_{\text{glob}}$ , we can expect that the reliability of scaling  
165 will diminish at increasingly smaller scales due to internal climate variability<sup>27,32</sup>  
166 and a larger contribution of local processes to the response (including by local  
167 land surface and human forcing, see point 5.).

168 4. It is likely that climate models share common biases for some regional climate  
169 phenomena<sup>33,34,35,36</sup>. In this case, scaling features could be derived, but would be  
170 erroneous; an issue that would need to be examined with careful model  
171 evaluation<sup>37,38</sup> contingent on the availability of appropriate observations.

172 5. The relationship between changes in regional climate and  $\Delta T_{\text{glob}}$  would be  
173 expected to alter in the presence of time-varying local forcing by, for example,  
174 aerosols<sup>39</sup>, land use and land cover change<sup>40,41,42</sup>, urban development<sup>43</sup>, or human  
175 water use<sup>44,45</sup>. These effects are likely to play an important role on local scale, but  
176 less for the larger regions considered here (Figs. 3 and 4 and regions from the  
177 IPCC Special Report on Extremes (SREX<sup>7</sup>) in Supplementary Information).

178 6. The ranges in Fig. 3 and Fig. 4b reflect the uncertainty in the scaling of the  
179 regional quantities with  $\Delta T_{\text{glob}}$ , but do not include uncertainties associated with  
180 the scaling of  $\Delta T_{\text{glob}}$  with the cumulative CO<sub>2</sub> emissions (Fig. 1). This additional  
181 uncertainty source is also relevant for the decision process when assessing  
182 regional climate targets (as is the case for climate targets based on the global  
183 mean temperature). For a given impact threshold, the uncertainty in the



184 cumulative carbon would be wider, and as a consequence the cumulative carbon  
185 budget would be smaller if the desire were to avoid the impact with high  
186 probability<sup>5</sup>. More in-depth analyses of the CMIP5 archive would help determine  
187 the total uncertainty range when directly relating imposed greenhouse gas forcing  
188 to simulated regional extremes.

189

### 190 **Using regional targets in decision making**

191 We focus here on regional changes because local stakeholders and decision-makers are  
192 more likely to be able to relate to them than to global mean temperature changes.

193 However, we stress that this does not imply that countries should only be concerned  
194 about climate changes affecting them directly in a geographical sense. Indeed, because of  
195 globalization, major climate disruptions in some countries can strongly affect others, for  
196 instance due to political unrest, migration, impacts on global food production, supply  
197 chains and trade<sup>23,46,47</sup>. Even when not directly affected by given changes, individual  
198 countries are more likely to understand the implications of respective climate targets for  
199 other parties if they can more readily quantify their implications for different regions.

200 This could also help pave the way to solutions that integrate both climate mitigation and  
201 adaptation within climate negotiations, by incorporating the avoided costs of impacts in  
202 negotiations when discussing the costs of mitigation. In this context, it is possible that  
203 different (and possibly lower global targets<sup>48,49,50</sup>) than 2°C may well be desirable.

204

205 Linking cumulative CO<sub>2</sub> emission targets to regional consequences, such as changing  
206 climate extremes, would be of particular benefit for political decision making, both in the

207 context of climate negotiations and adaptation. We stress that the quantification of  
208 regional targets will not necessarily imply that involved parties will agree on the suitable  
209 (and common) cumulative global CO<sub>2</sub> emission target. However, this information can  
210 help in the development of solutions and in the communication with the public. Similarly  
211 robust regional scaling might be expected for other features of the climate system beside  
212 those considered here<sup>51,52</sup>, and could be explored for impact-based simulations<sup>53,54,55</sup>.  
213 Indeed, such relationships can be determined for any regional and/or impact-relevant  
214 climatic feature that scales robustly with changes in global mean temperature (or is at  
215 least monotonically related to it), and which is not associated with larger uncertainty  
216 ranges or biases in current climate models.

217

218 In view of the inherent model uncertainty and in order to avoid possible risks associated  
219 with the indiscriminate use of such information, we recommend that IPCC calibrated  
220 language be applied when assessing the *confidence* of any such derived relationships,  
221 with only situations of *high confidence* justifying derivation of quantitative estimates<sup>7</sup>. In  
222 addition to the requirement of *high confidence* levels, high signal to (model) noise ratio  
223 (traditionally referred to in *likelihood* terms in the IPCC language<sup>7</sup>) is a prerequisite for  
224 deriving meaningful allowable CO<sub>2</sub> emissions ranges. Furthermore, any assessment of  
225 projected changes in climate risks and impacts also needs to consider the contributions of  
226 changes in vulnerability and exposure of human and natural systems to those climate  
227 hazards<sup>25</sup>. Bearing in mind these requirements, quantitative tools for decision making that  
228 relate regional (or even country-scale) impacts to global CO<sub>2</sub> emissions targets could be  
229 one way of advancing climate negotiations by more locally exposing what is at stake.

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- 236 **The Summary for Policymakers of the IPCC AR5 working group 1 report**  
237 **(approved line by line by the IPCC plenary) includes for the first time a figure**  
238 **relating cumulative CO<sub>2</sub> emissions with projected changes in global mean**  
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413 **This article provides time series of climate extreme indices in CMIP5 projections,**  
414 **which have been used as basis for the present analyses.**

415

416

417 **Supplementary Information** is available in the online version of the paper.

418

419 **Acknowledgements**

420 S.I.S. acknowledges the ERC DROUGHT-HEAT project funded by the European  
421 Community's Seventh Framework Programme (grant agreement FP7-IDEAS-ERC-  
422 617518). A.J.P. and M.G.D. were supported by the Australian Research Council (ARC)  
423 Centre of Excellence for Climate System Science grant CE110001028. M.G.D. was also  
424 supported by ARC Grant DE150100456. This work contributes to the World Climate  
425 Research Programme (WCRP) Grand Challenge on Extremes. We acknowledge the  
426 WCRP Working Group on Coupled Modelling, which is responsible for CMIP, and we  
427 thank the climate modelling groups for producing and making available their model  
428 output. For CMIP the US Department of Energy's Program for Climate Model Diagnosis  
429 and Intercomparison provides coordinating support and led development of software  
430 infrastructure in partnership with the Global Organization for Earth System Science  
431 Portals. We are grateful to Nicola Maher for help with processing CMIP5 data. The  
432 climate extremes indices calculated for the different CMIP5 runs were obtained from the  
433 Environment Canada CLIMDEX website <http://cccma.ec.gc.ca/data/climdex/>.

434

435 **Author contributions**

436 S.I.S., M.G.D. and A.J.P. designed the study, following an initial discussion between  
437 S.I.S, A.J.P. and R.K. S.I.S. coordinated the conception and writing of the article. M.G.D.

438 performed the analyses. R.L.W. contributed to the interpretation of regional impacts. All  
439 authors commented on the manuscript and analyses.

440

441 **Author information**

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443 The authors declare no competing financial interests. Correspondence and requests for  
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447

448 **Figure legends**

449

450 **Figure 1. Global mean surface temperature increase as a function of cumulative**

451 **total global CO<sub>2</sub> emissions.** This figure from the IPCC WG1 SPM<sup>1</sup> (Fig. SPM.10) was  
452 derived from various lines of evidence. Model results over the historical period (1860 to  
453 2010) are indicated in black. The coloured plume illustrates the multi-model spread over  
454 the four RCP scenarios. The multi-model mean and range simulated by CMIP5 models,  
455 forced by a CO<sub>2</sub> increase of 1% per year is given by the thin black line and grey area. For  
456 a specific amount of cumulative CO<sub>2</sub> emissions, the 1% per year CO<sub>2</sub> simulations exhibit  
457 less warming than those driven by RCPs, which include additional non-CO<sub>2</sub> forcings.  
458 Temperature anomalies are given relative to the 1861–1880 base period, emissions  
459 relative to 1870.

460

461 **Figure 2. Extreme (and mean) temperature changes associated with 2°C target.** The

462 figure displays the local changes in (a) hottest daytime temperature (TX<sub>x</sub>), (b) annual  
463 coldest nighttime temperature (TN<sub>n</sub>), (c) and mean temperature (T<sub>mean</sub>) associated with  
464 a global warming of 2°C. The analysis is based on RCP8.5 scenario simulations  
465 (ensemble average year: 2044). The respective scaling expressed as ratio of global mean  
466 temperature increase is provided in Supplementary Figure S1. Note that very similar  
467 results are obtained with the RCP4.5 scenario simulations (Fig. 3 and Supplementary  
468 Figures S2 and S3). Figs 2a and 2b also display the outlines of the regions analysed in Fig.  
469 3.

470

471 **Figure 3. Scaling between regional changes in annual temperature extremes and**  
472 **changes in global mean temperature, with associated global cumulative CO<sub>2</sub>**  
473 **emissions targets.** See Box 1 for details on the underlying analysis. Results are shown  
474 for annual maximum daytime temperature (TXx) in (a) the Mediterranean region (30:45N,  
475 10W:45E), (b) the contiguous U.S. (25:50N, 125W:67W), and (c) Brazil (30S:0N,  
476 65W:50W), and for the annual minimum nighttime temperature (TNn) in (d) the Arctic  
477 (65:90N, 180W:180E). The four analysed regions are indicated in Figs. 2a and 2b. The  
478 solid black line denotes the ensemble average in the historical runs until 2010 (combined  
479 with RCP8.5 for 2006-2010) and the solid red (blue) line denotes the ensemble average  
480 of the future projections following the RCP8.5 (RCP4.5) scenario simulations. The red  
481 shaded area indicates the total range (minimum to maximum value) between all  
482 considered simulations and experiments. The dashed black line shows the 1:1-line. Grey  
483 dashed lines show the temperatures / CO<sub>2</sub> emissions associated with 2°C increases in  
484 global mean and regional extreme temperatures, respectively. Note the different vertical  
485 axis for TXx and TNn. Only land grid cells were used for calculating the regional TXx  
486 and TNn averages.

487

488 **Figure 4. Scaling of 5-day heavy precipitation events with global mean temperature**  
489 **changes, with associated global cumulative CO<sub>2</sub> emissions targets.** See Box 1 for  
490 details on the underlying analysis. (a) Map of ratio of percentage changes in heavy  
491 precipitation events (annual maximum consecutive 5-day precipitation, Rx5day) with  
492 changes in global mean temperature for the RCP8.5 scenario simulations (ensemble

493 average ratio  $\Delta Rx5day/\Delta T_{glob}$ ).  $\Delta T_{glob}$  and  $\Delta Rx5day$  were calculated from each model run  
494 as the difference between the average of the first (1861-1880) and last (2080-2099) 20-  
495 year time slices. (b) Scaling of percentage changes in Rx5day in Southern Asia (10:30N,  
496 60:110E; see outlined box on Fig. 4a) with global mean temperature changes and  
497 cumulative global CO<sub>2</sub> emissions. The solid black line denotes the ensemble average in  
498 the historical runs until 2010 (combined with RCP8.5 for 2006-2010) and the solid red  
499 (blue) line denotes the ensemble average of the future projections following the RCP8.5  
500 (RCP4.5) scenario simulations. The red shaded area indicates the total range (minimum  
501 to maximum value) between all considered simulations and experiments. Grey dashed  
502 lines show the percentage change in Rx5day / CO<sub>2</sub> emissions associated with a 2°C  
503 increase in global mean temperature. Only land grid cells were used for calculating the  
504 regional Rx5day average.



505

506 **Box 1: Calculating the relationships among regional extremes, global means, and**  
507 **cumulative emissions.**

508

509 We use output from the climate model simulations contributing to the Coupled Model  
510 Intercomparison Project Phase 5 (CMIP5)<sup>56</sup>. Here we present results for climate extreme  
511 indices representative of the hottest day (TXx) and coldest night (TNn) of the year, as  
512 well as the annual maximum consecutive 5-day precipitation total (Rx5day). Climate  
513 extremes indices<sup>57</sup> were calculated for the historical simulations<sup>58</sup> and future projections<sup>59</sup>  
514 from the CMIP5 ensemble. We use one run (r1i1p1) from models that provide historical  
515 simulations during 1861-2005, as well as RCP8.5 and RCP4.5 scenario simulations for  
516 the 21<sup>st</sup> century (see Supplementary Table 1). For the analysis of transient changes we  
517 concatenated historical (1861-2005) and RCP (2006-2099) simulations. We restricted our  
518 analyses to 1861-2099, which was common to all model runs. Global mean temperatures  
519 were calculated as the area-weighted global averages of annual mean temperatures.  
520 Extreme indices fields were remapped to a common 2.5°x2.5° analysis grid to allow  
521 calculation of local ensemble averages and ensure that the same regions from each model  
522 contribute to the regional analyses.

523

524 Scatter plots showing the scaling relationship between changes in global mean  
525 temperature ( $\Delta T_{\text{glob}}$ ) and regional extremes indices changes (e.g. Figures 3, 4b) are based  
526 on decadal averages of the respective variables. These averages of local anomalies  
527 relative to the 1861-1880 average were calculated for moving 10-year windows, and

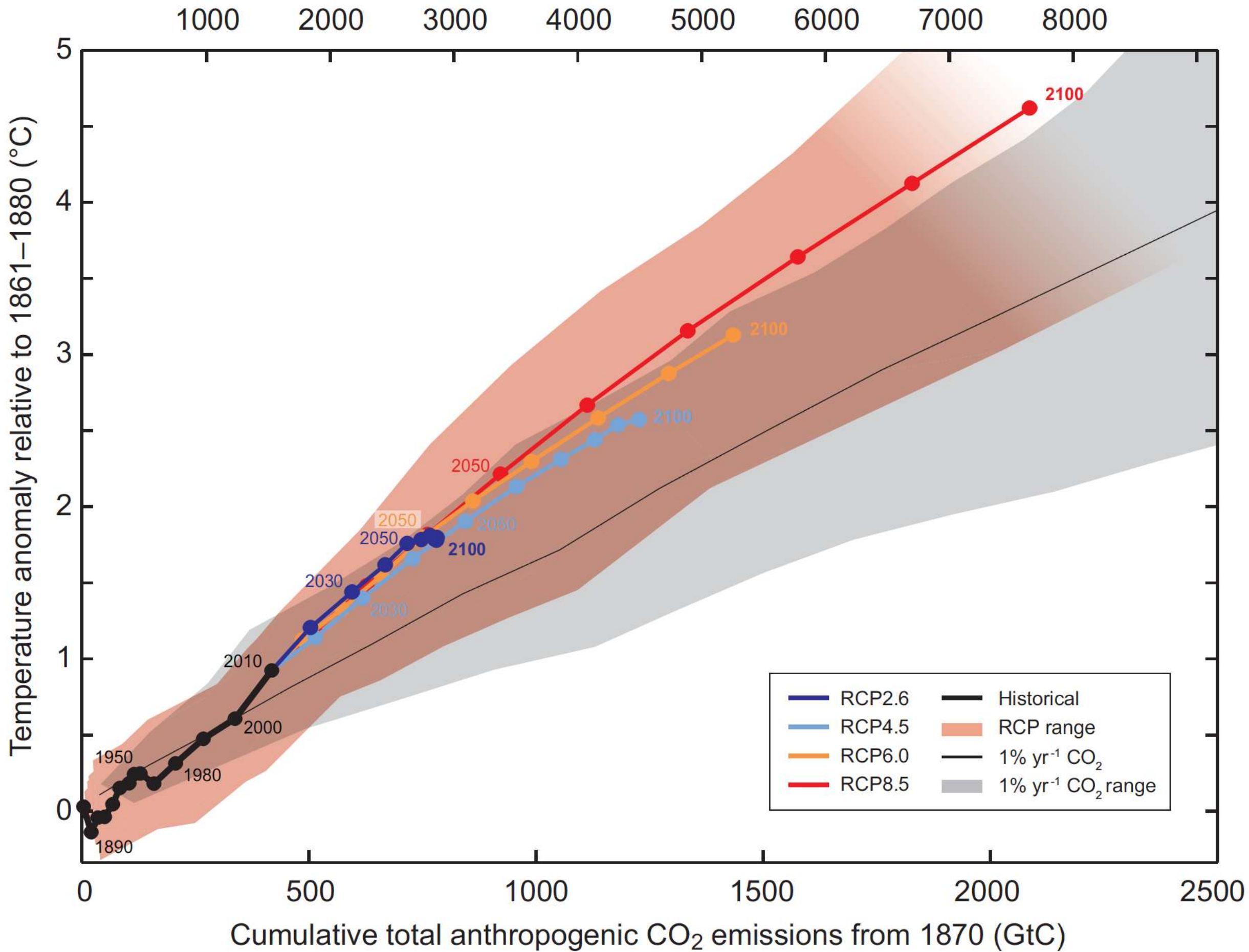
528 moving average values were assigned to the last year of each window period (i.e., the  
529 value for year 2010 represents the average during 2001-2010; note that in the case of Fig.  
530 1 the decadal global temperature averages are assigned to the year directly following that  
531 decade). These moving 10-year averages were also used to produce maps of local  
532 changes for a global mean temperature increase of 2°C (e.g. Figure 2). The indicated  
533 cumulative CO<sub>2</sub> emissions corresponding to different global mean temperature increases  
534 (red tics on horizontal axis in Figures 3 and 4b) were approximated from the RCP8.5  
535 ensemble average in Figure 1 (single values were assigned to each of the chosen tic  
536 marks). This means, 500 GtC at approximately 1.2°C, 1000 GtC at 2.35°C, 1500 GtC at  
537 3.5°C, and 2000 GtC at 4.45°C. Respective analyses regarding the scaling of extreme  
538 temperatures and precipitation in all 26 regions of the IPCC Special Report on Extremes  
539 (SREX)<sup>7</sup> and the global land are provided in the Supplementary Information.

540

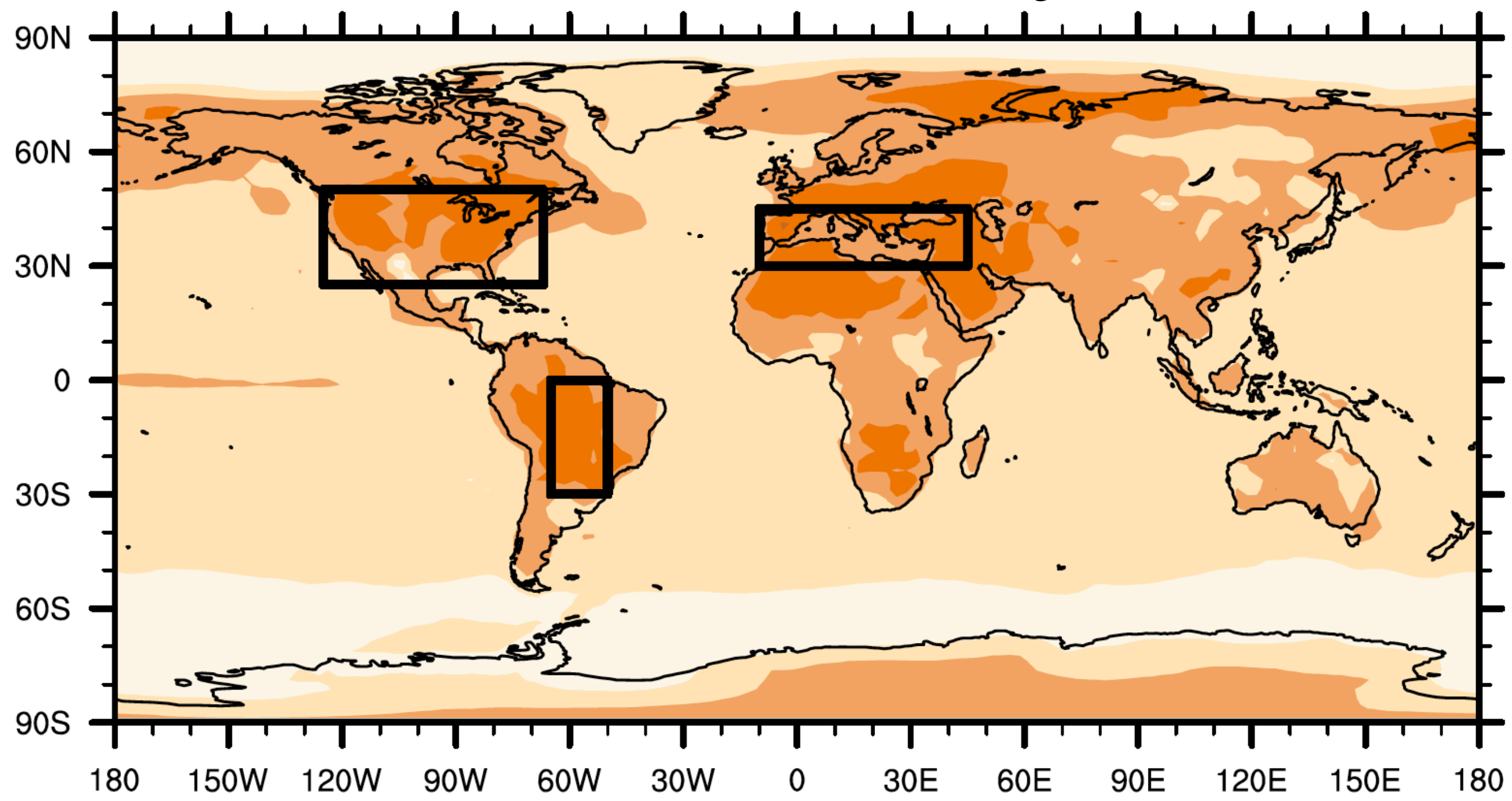
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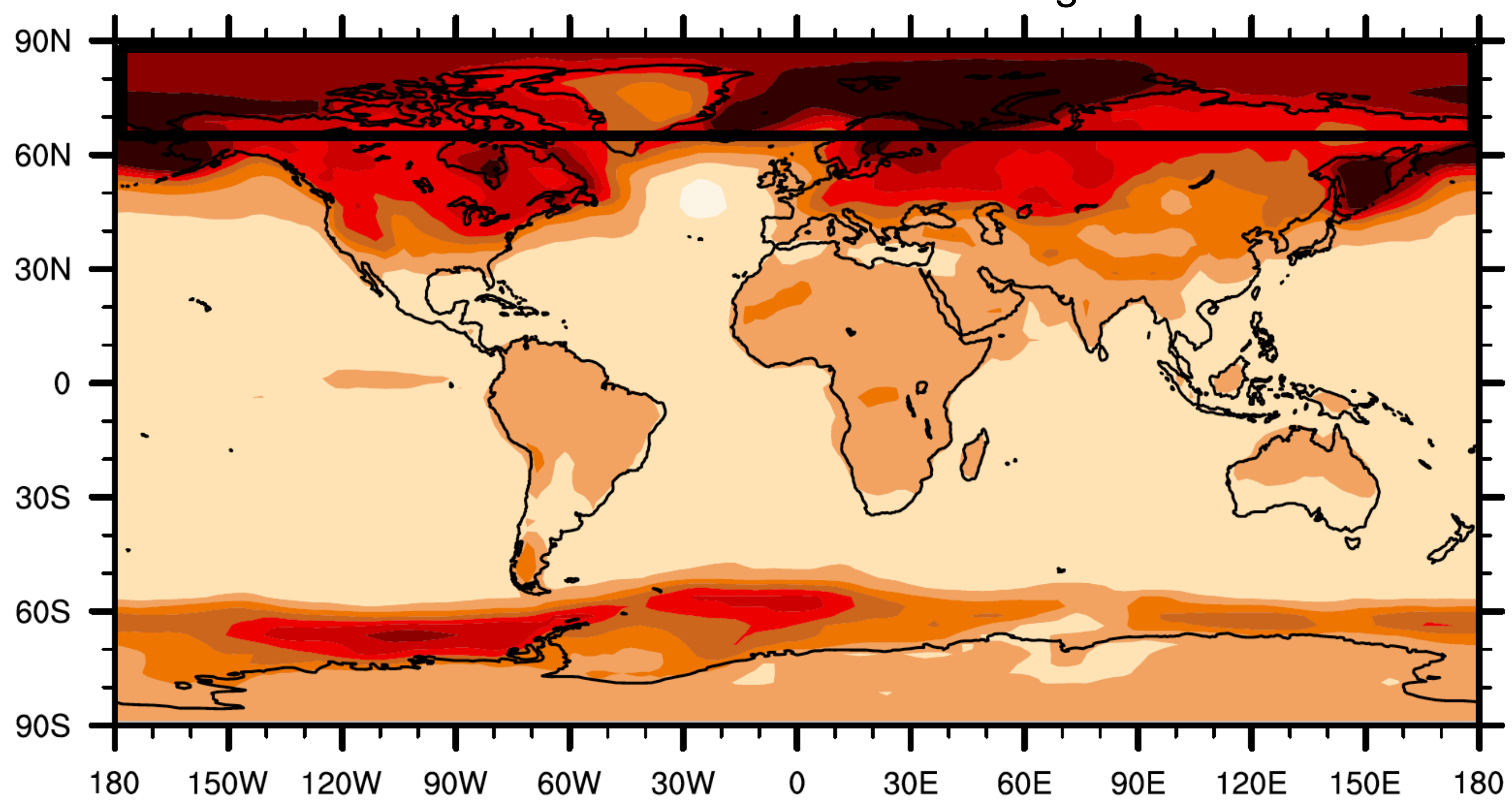
Cumulative total anthropogenic CO<sub>2</sub> emissions from 1870 (GtCO<sub>2</sub>)



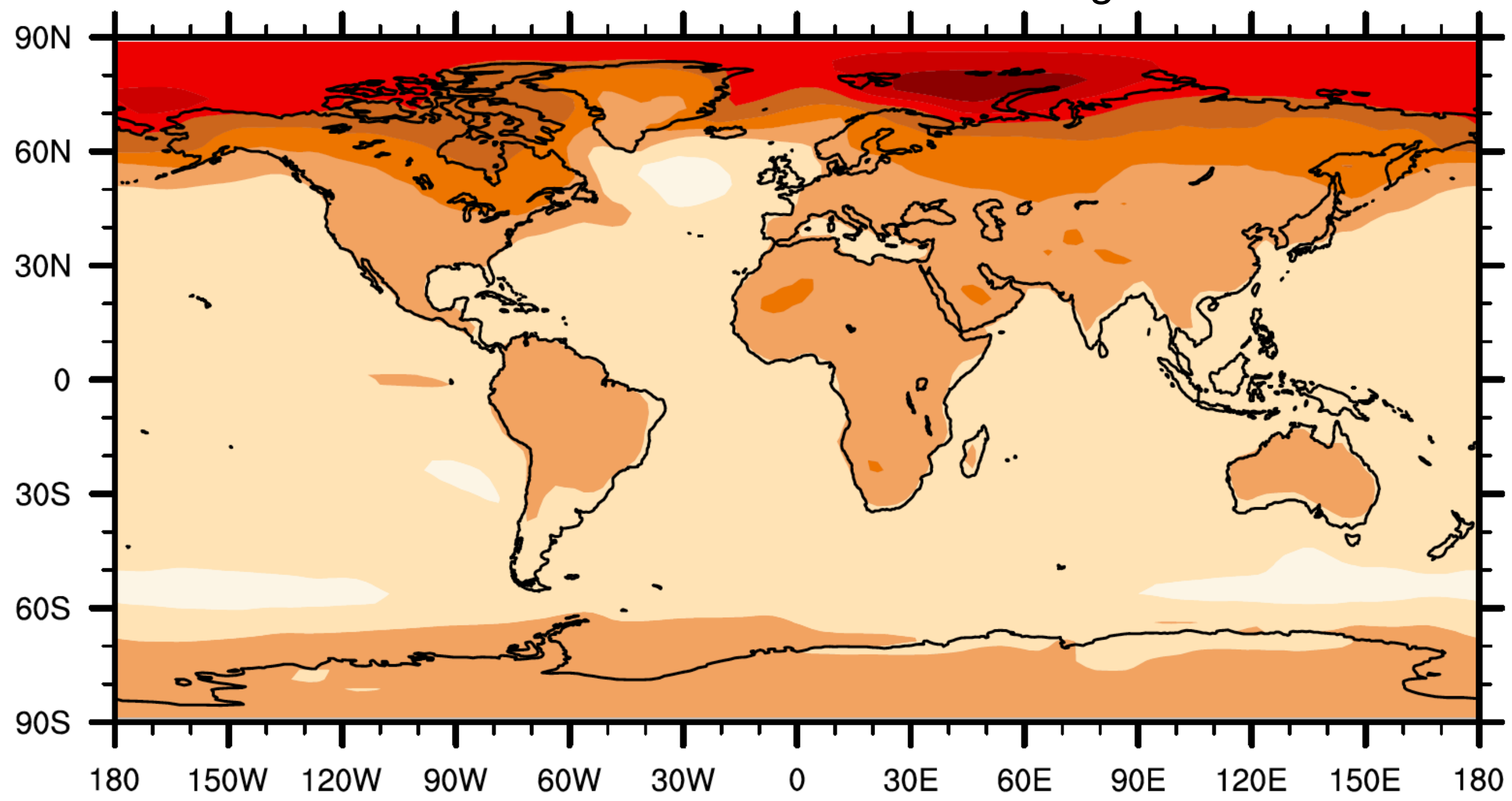
**a** TXx local change when  $\Delta T_{\text{glob}} = 2^{\circ}\text{C}$



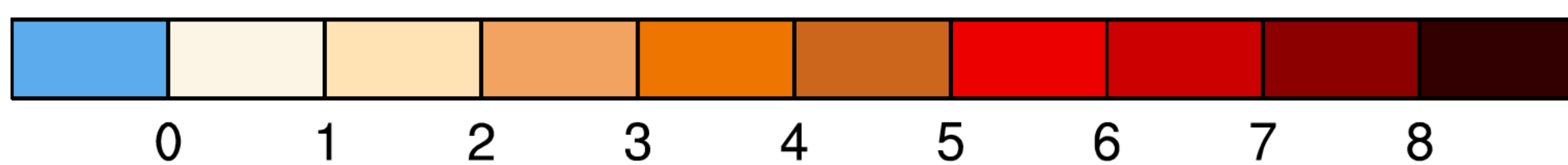
**b** TNn local change when  $\Delta T_{\text{glob}} = 2^{\circ}\text{C}$



**c** Tmean local change when  $\Delta T_{\text{glob}} = 2^{\circ}\text{C}$

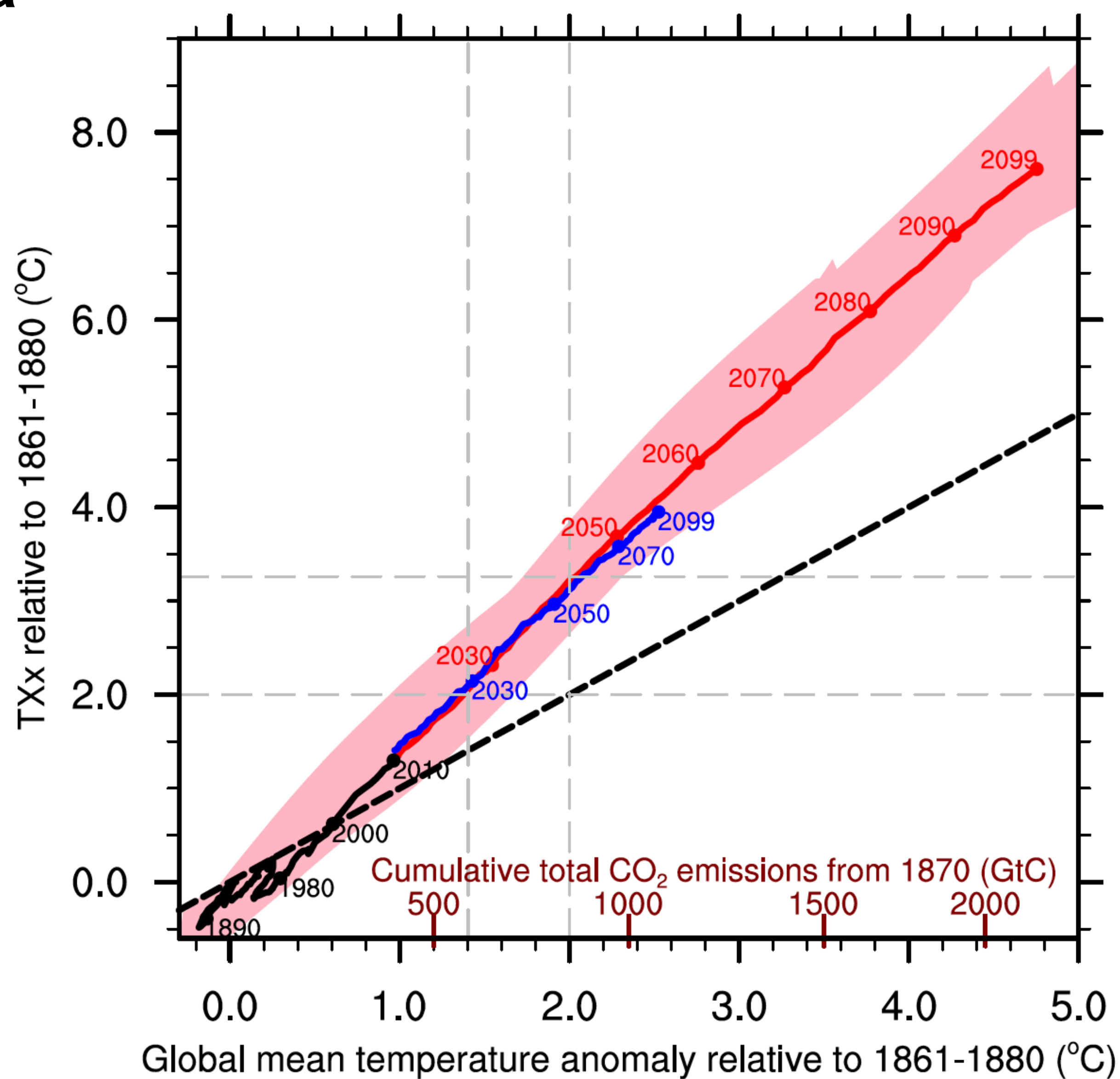


[°C]

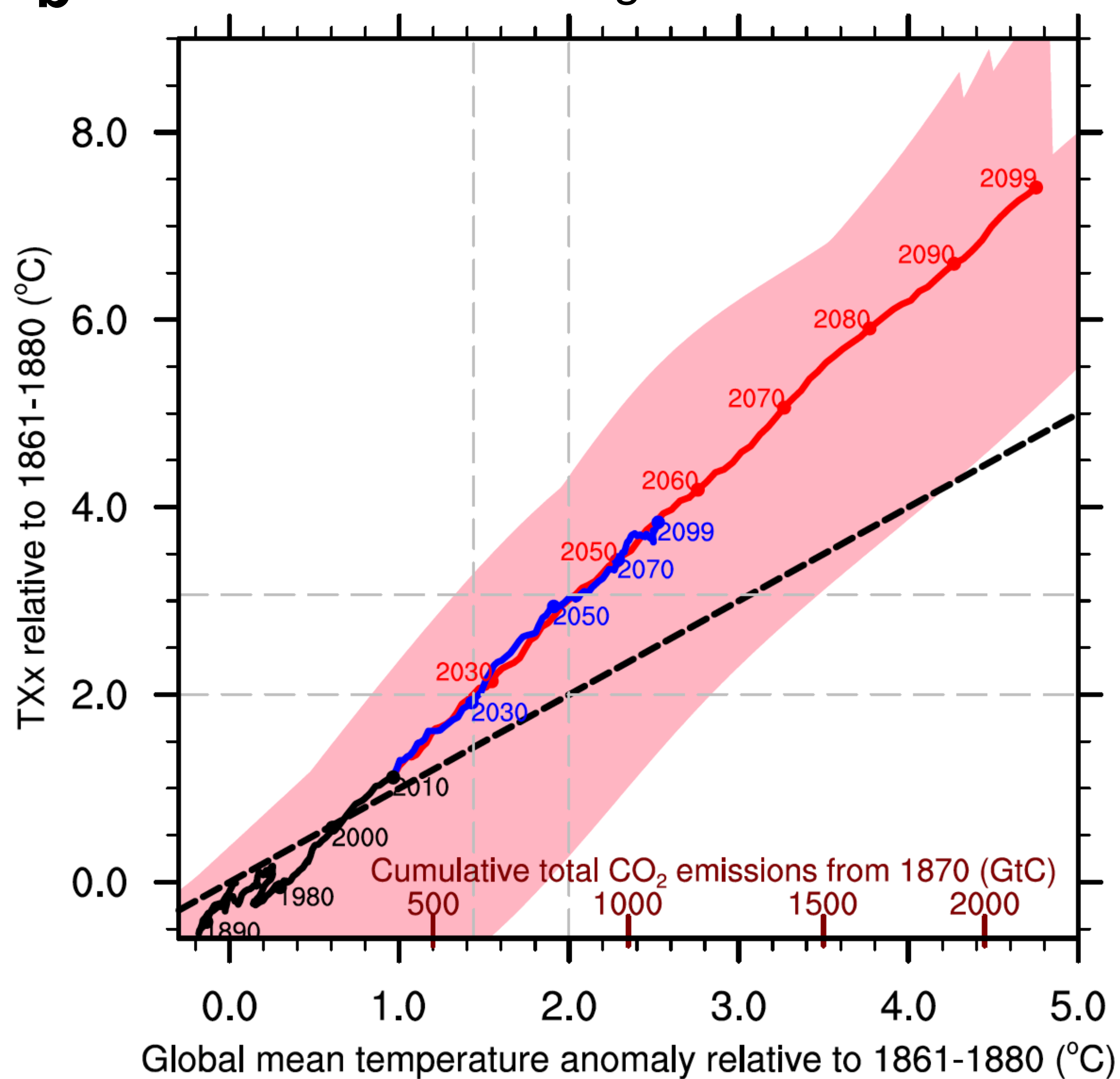


**a**

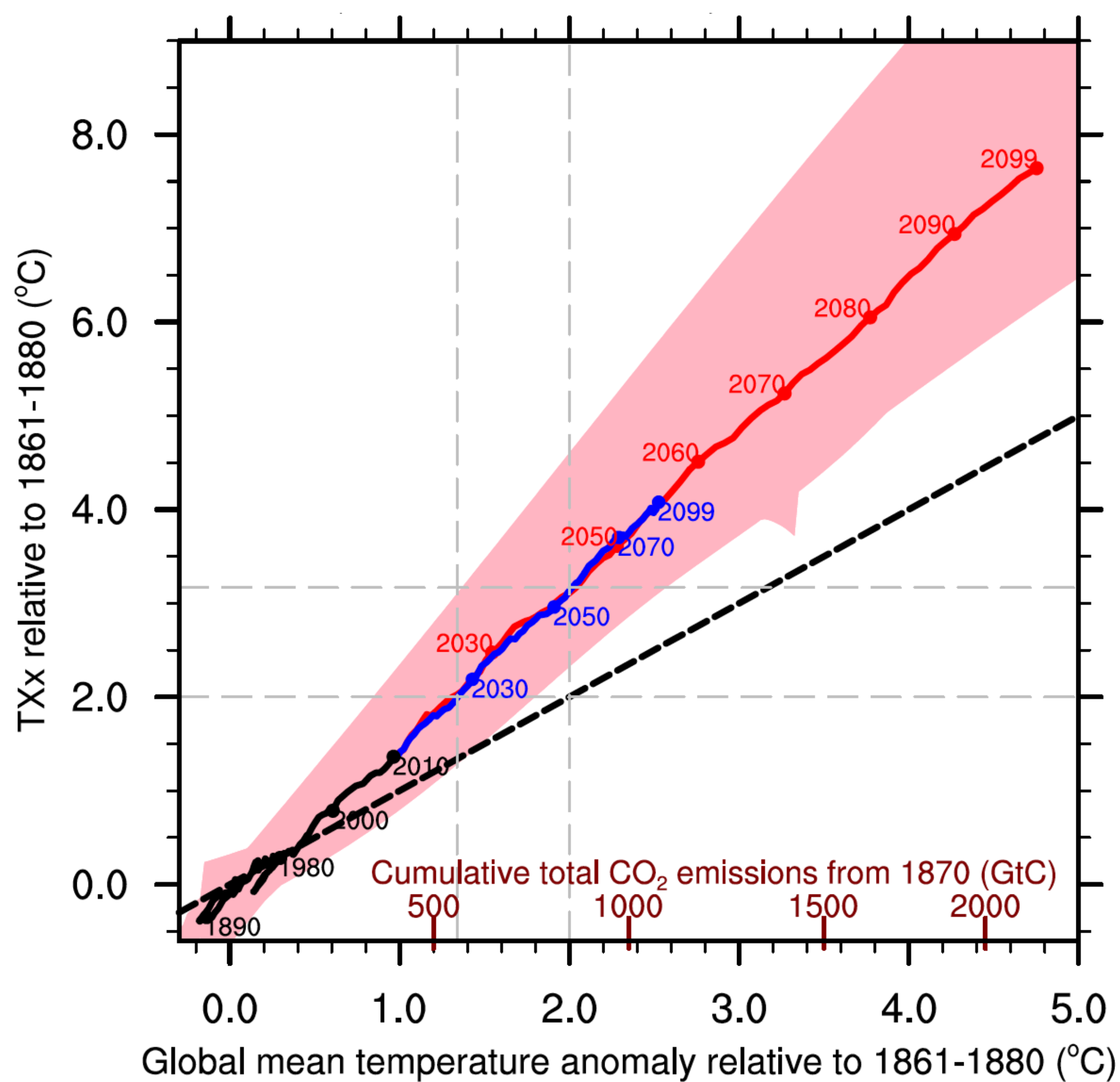
TXx Mediterranean

**b**

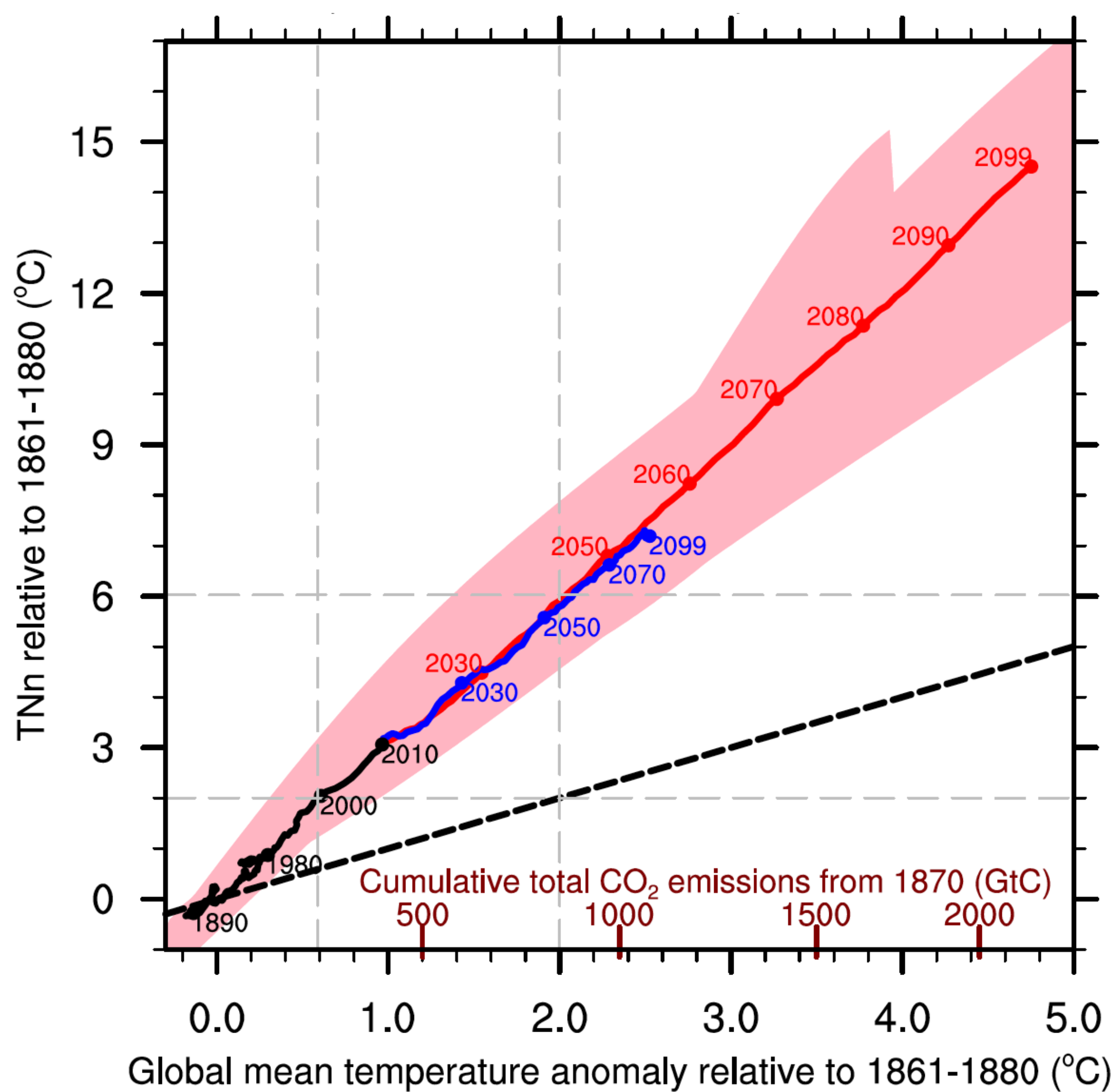
TXx Contiguous U.S.

**c**

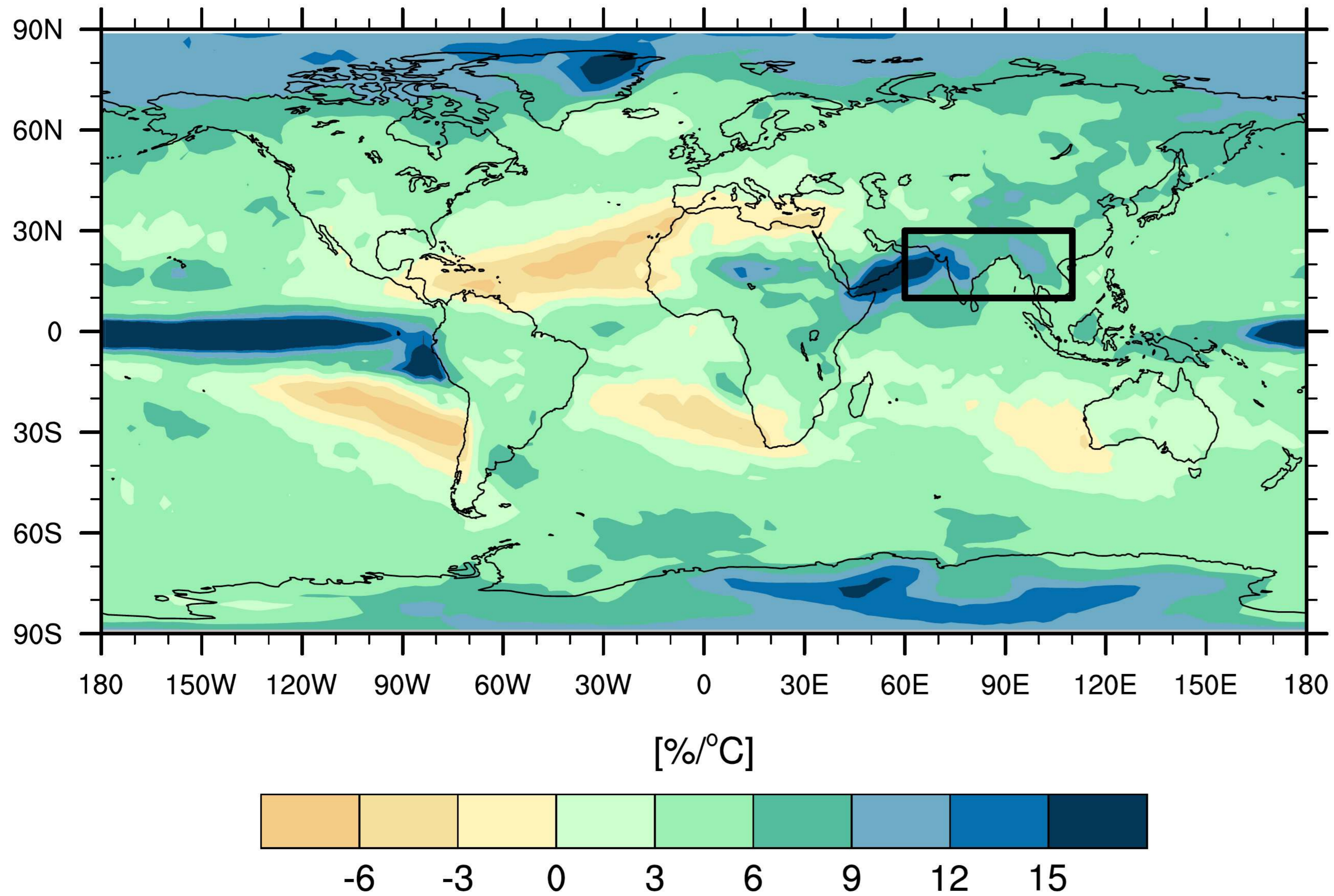
TXx Brazil

**d**

TNn Arctic



**a** Rx5day local scaling with  $\Delta T_{\text{glob}}$



**b** Rx5day Southern Asia

