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Supporting Information for

Regional amplification of projected changes in extreme temperatures strongly controlled by soil moisture-temperature feedbacks

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Introduction

This Supporting Information include a supplementary text, figures and a table which are referred to in the main article.

Text S1. Discussion on ACCESS experimental set-up

The GLACE-CMIP5 experiment was originally performed with five global climate models (Seneviratne et al. 2013). In a more recent study, Lorenz et al. (2016) added the ACCESS model (Bi et al. 2013; Kowalczyk et al. 2013; Lorenz et al. 2014) to the GLACE-CMIP5 ensemble. The ACCESS simulations include a few deviations of the described experimental set-up compared to the other five models. In the ACCESS CTL experiment, sea surface temperatures were prescribed from observations and not from model output over the historical period (Lorenz et al. 2016). Furthermore, in the SM20c simulation of ACCESS, the seasonal cycle of prescribed soil moisture was slightly shifted in the middle of the 20th century for technical reasons and corrected again at the end of the 21st century.

Because of these deviations in experimental set up, we decided to base our main analyses on the results of the other five models without including the ACCESS model. Nonetheless, as shown in supplementary figures S2, S4 and S7, the results are qualitatively similar when including the ACCESS model, except for the Central North America (CNA) region. For CNA, the ACCESS model simulation shows considerably less TX_X increase for both the CTL and SM20c experiments (causing a large range in Figure S2), likely due to an increase of soil moisture at the end of the 21st century (Lorenz et al. 2016) and potentially due to some inconsistency of prescribing soil moisture in SM20c. This also influences the assigned contribution in Figure S7. In addition, we find a large spread for TX_X for SMnoVar in CNA caused by the cooler temperatures in the ACCESS model (not shown).

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Lorenz, R. et al., 2014. Representation of climate extreme indices in the ACCESS1.3b coupled atmosphere – land surface model. *Geoscientific Model Development*, 7, pp.545–567.

Seneviratne, S.I. et al., 2013. Impact of soil moisture-climate feedbacks on CMIP5 projections: First results from the GLACE-CMIP5 experiment. *Geophysical Research Letters*, 40, pp.5212–5217.

Figures S1 to S8

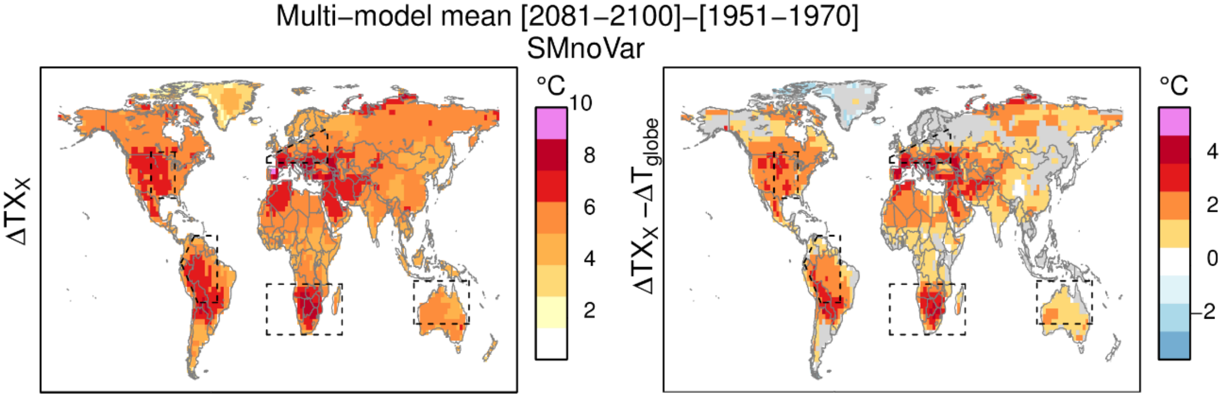

Figure S1. Projected changes in TX$_X$ between 2081-2100 and 1951-1970 for SMnoVar (left) and additional increase of TX$_X$ versus T$_{globe}$ between 2081-2100 and 1951-1970 for SMnoVar (right). White color denotes insufficient model agreement; i.e. fewer than four of the five models show the same sign of the change.

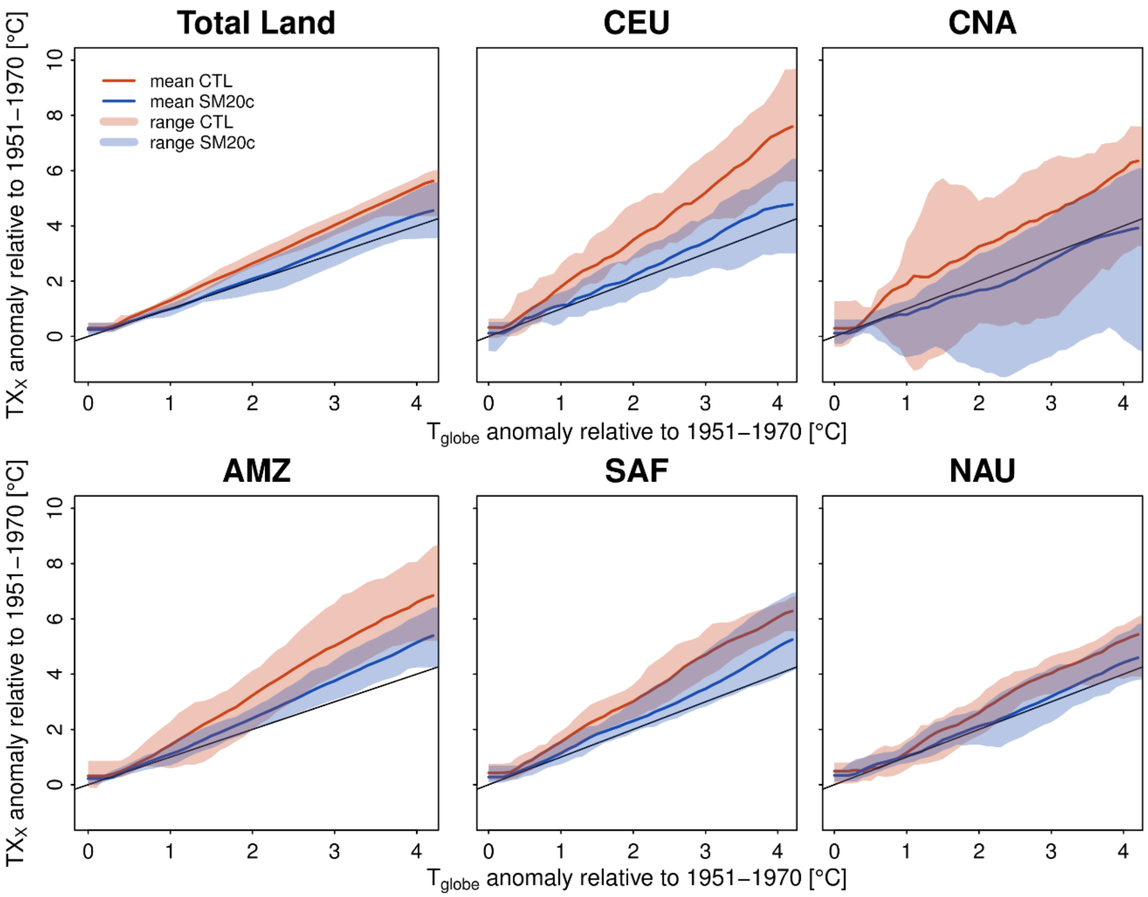

Figure S2. Land TX_X/regional TX_X anomalies versus global mean temperature anomalies as in Figure 2 but including the ACCESS model from Lorenz et al. (2016). The solid lines are the multi-model mean of CTL (red) and SM20c (blue). The range presents the minimum and maximum values of the five individual models in CTL (red shading) and SM20c (blue shading). The identity line indicates identical TX_X anomaly and T_{globe} anomaly increase (black). Anomalies are calculated as 20-year running means from 1971 to 2100 relative to the base period of 1951-1970. Note that the global warming already reached by 1951-1970 needs to be accounted when comparing the values of the x-axis to the so-called 1.5°C or 2°C "global warming targets".

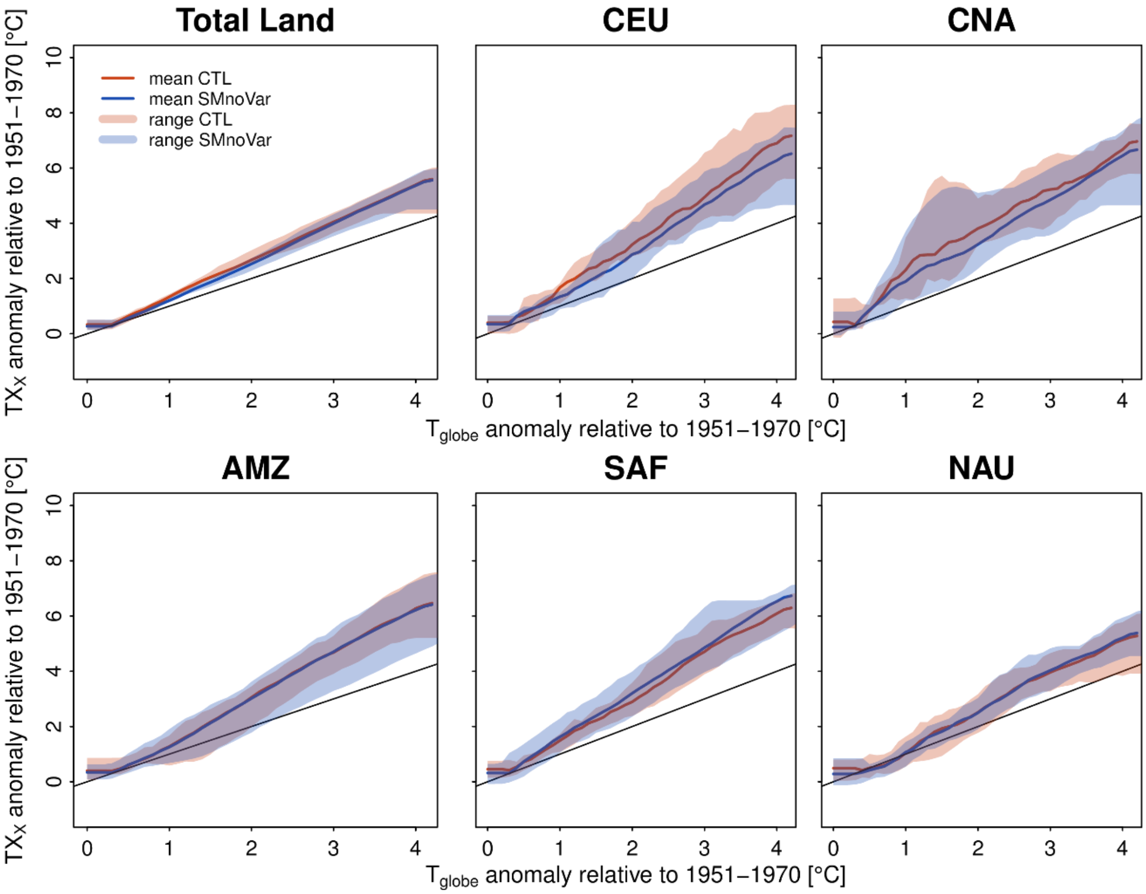

Figure S3. Land TX_X/regional TX_X anomalies versus global mean temperature anomalies as in Figure 2 for SMnoVar experiment instead of SM20c. The solid lines are the multi-model mean of CTL (red) and SMnoVar (blue). The range presents the minimum and maximum values of the individual models in CTL (red shading) and SMnoVar (blue shading). The identity line indicates identical TX_X anomaly and T_{globe} anomaly increase (black). Note that anomalies are calculated as 20-year running means from 1971 to 2100 relative to the base period of 1951-1970. Note that the global warming already reached by 1951-1970 needs to be accounted when comparing the values of the x-axis to the so-called 1.5°C or 2°C "global warming targets".

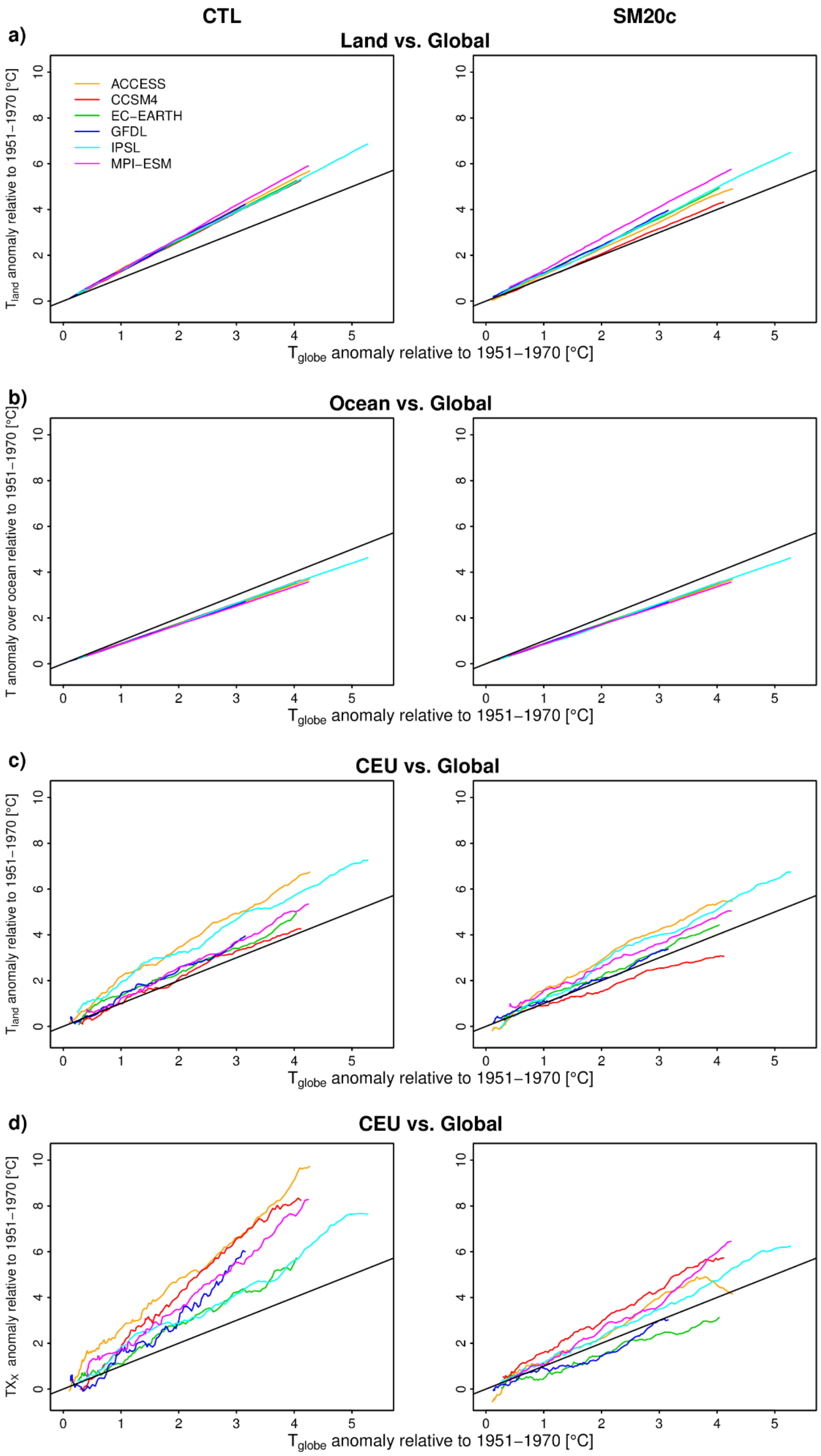

Figure S4. Scaling of a) mean Land temperature anomalies b) mean Temperature anomalies over ocean c) mean land temperature anomalies over CEU and d) TX_X anomaly over CEU versus global mean temperature anomaly from 1971-2100 with base period 1951-1970.

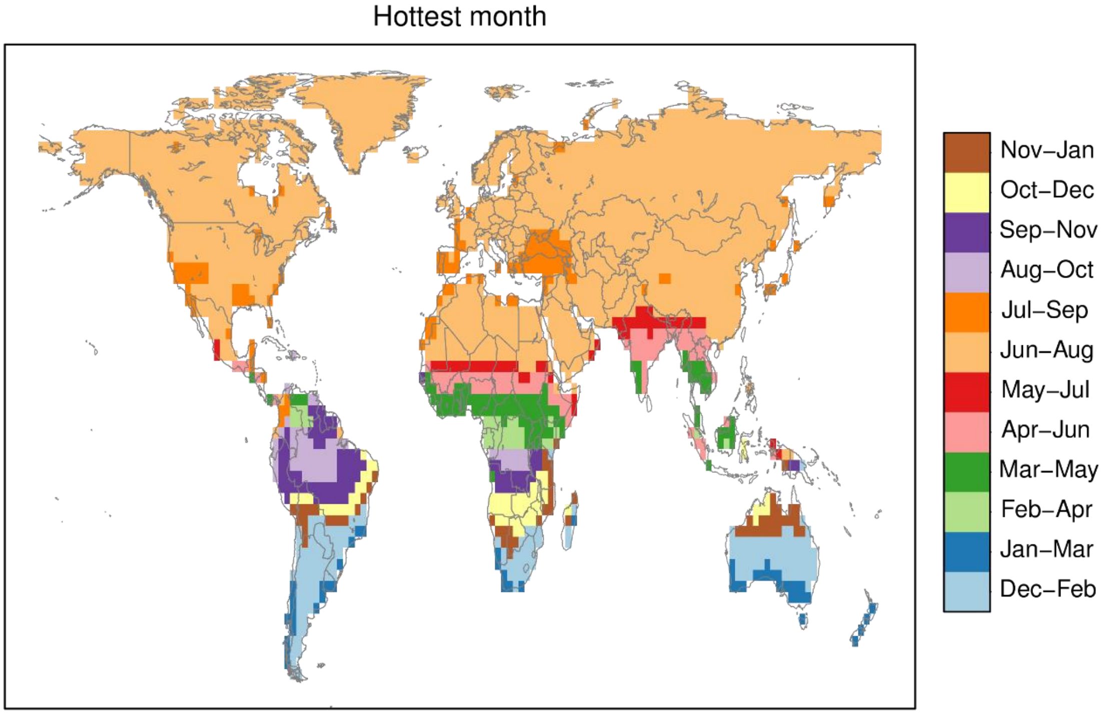

Figure S5. Multi-model mean of three hottest consecutive months in GLACE-CMIP5 experiments from monthly mean temperatures of the time period 1951-1970.

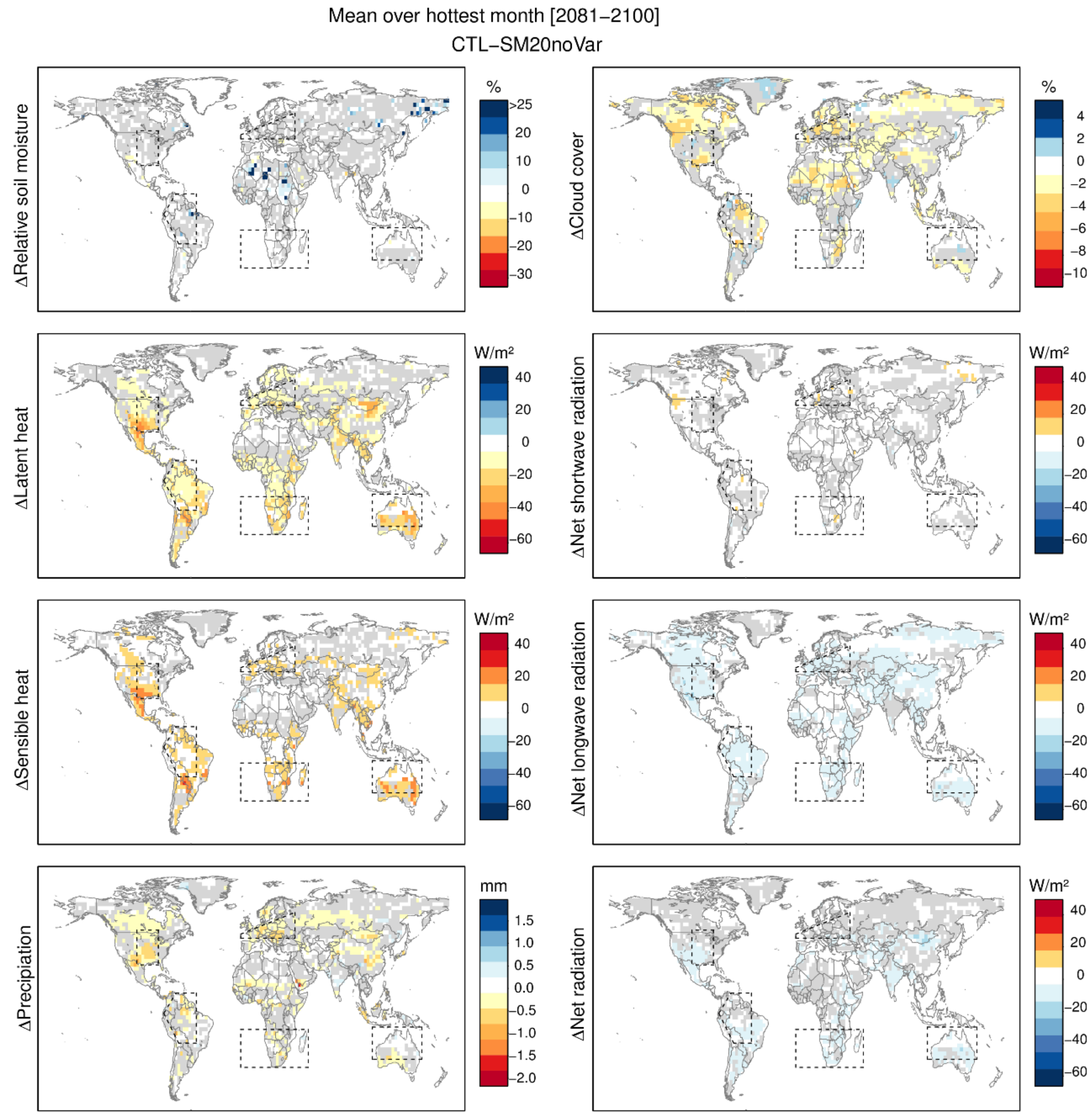

Figure S6. Differences between CTL and SMnoVar (see Figure 3 for SM20c) for future changes (2081–2100) of soil moisture, latent heat, sensible heat, precipitation, cloud cover, shortwave, longwave, and net radiation in the three hottest consecutive months (see Figure S5). Relative soil moisture is computed as change between CTL and SMnoVar divided by SMnoVar. Grey color denotes insufficient model agreement; i.e., fewer than four of the five models show the same sign of the change.

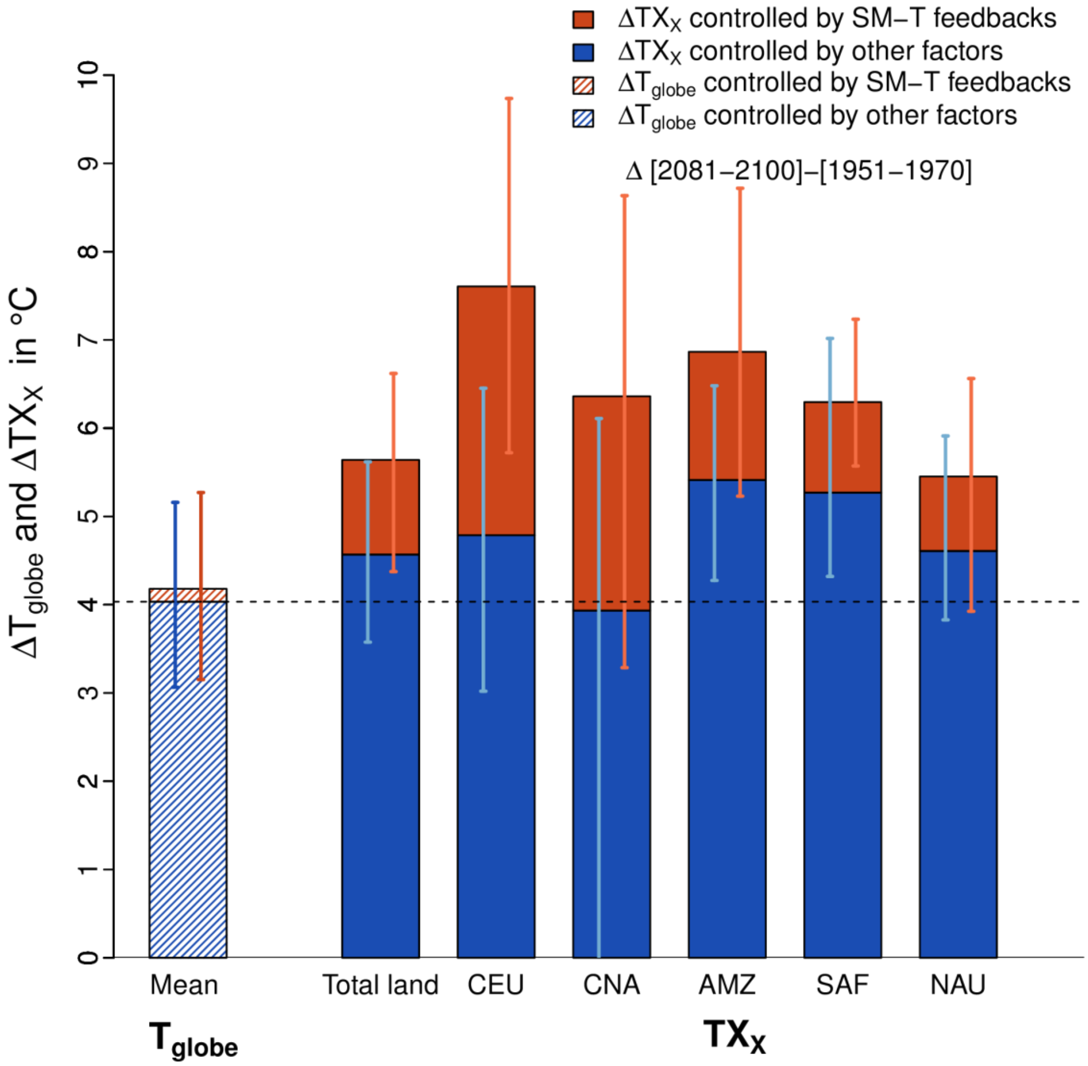

Figure S7. Projected change in global mean temperature (left), and in total land and regional TX_X (right) model between 2081-2100 and 1951-1970 due to soil moisture-temperature feedback (red) and other factors (blue) as in Figure 4 but also including the ACCESS model. The range is determined as minimum and maximum values from the model ensemble.

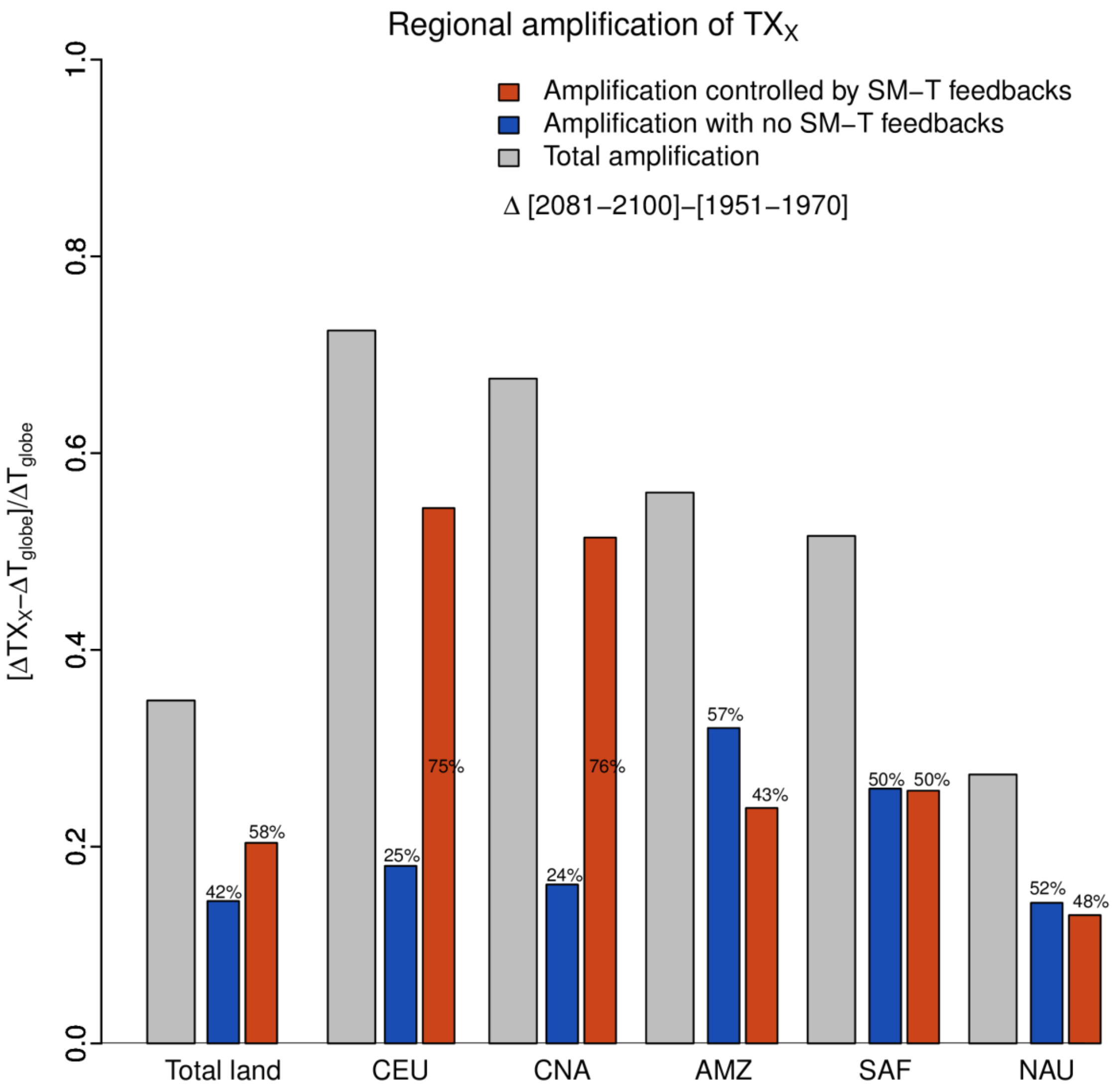

Figure S8. Contribution of soil moisture temperature coupling (red) vs other factors (blue) for total land TX$_X$ and regional amplification of TX$_X$ (grey) in CEU, CNA, AMZ, SAF, NAU.

ESM Acronym	**Atmospheric Model**	**Land Surface model**	**Reference**
CCSM4	National Center for Atmospheric Research Community	Community Land Model (CLM4)	Neale et al. 2013; Lawrence et al. 2011
EC-EARTH	Integrated Forecasting System European Centre for Medium-Range Weather Forecasts	Hydrology-Tiled ECMWF Scheme for Surface Exchange over Land (H-TESSEL)	Hazeleger et al. 2012; Balsamo et al. 2009
GFDL	Geophysical Fluid Dynamics Laboratory (GFDL) Earth System Model 2 (ESM2)	Land Model 3.0 (LM3.0)	Dunne et al. 2012; Shevliakova et al. 2009
IPSL	Laboratoire de Météorologie Dynamique atmospheric model (LMDZ5A)	Organizing Carbon and Hydrology in Dynamic Ecosystems (ORCHIDEE; with two-layer soil hydrology scheme)	Cheruy et al. 2013; Dufresne et al. 2013; Hourdin et al. 2013
MPI-ESM	European Centre/Hamburg forecast system	Jena Scheme for Biosphere-Atmosphere Coupling in Hamburg (JSBACH)	Hagemann et al. 2013; Stevens et al. 2013; Brovkin et al. 2009; Raddatz et al. 2007
ACCESS (Note that the ACCESS model is not used in the main analysis, see Discussion Text S1)	*Australian Community Climate and Earth System Simulator*	*Community Atmosphere Biosphere Land Exchange*	*Lorenz et al. 2014, Bi et al. 2013; Kowalczyk et al. 2013*

Table S1. Models contribution to GLACE-CMIP5 experiments. Adapted from Seneviratne et al. 2013, Table 1.

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