Supplementary material

1 Text S1: LPJ-GUESS setup

The LPJ-GUESS simulations were initialized with data from the CRU TS3.0 observed climate database (Mitchell and Jones, 2005) covering the period 1901-2000. For the historical period we used monthly data of temperature, precipitation, number of rain days (precipitation > 1mm) and cloudiness, at 0.5° × 0.5° resolution. From 2001, the forcing time series was extended for each GCM × CO_2 emission scenario combination, with anomalies constructed from the relevant GCM scenario simulation, using a delta-change approach. The anomaly for a given variable, e.g. temperature, and month was constructed by subtracting from the simulated monthly average value for that month in the GCM scenario simulation the average value for the corresponding calendar month for 1961-1990 from a 20th Century control run with the same GCM. In the case of precipitation, anomalies were applied geometrically, i.e. by subtraction of logs. Anomalies were bilinearly interpolated to 0.5° × 0.5° resolution and added to the CRU 1961-1990 averages for the same variable and calendar month.

This method downscales the GCM climate output to the CRU grid, correcting for systematic biases but preserving inter-annual variability. It has been shown that GCMs tend to exhibit a positive bias in the frequency of precipitation events, while heavy rain events are underrepresented (Sun et al., 2006). We therefore held the number of rain days per month constant at the 1961-1990 CRU averages after 2001. Shortwave radiation replaced cloudiness from the CRU dataset from 2001, the 1961-1990 CRU cloudiness was recalculated to shortwave radiation as reference for the GCM anomalies. Historical [CO_2] from McGuire et al (2001) were used for the period 1901-1998 and TRENDS (http://cdiac.esd.ornl.gov/trends/co2/contents.htm) for the years 1999 and 2000. After 2001 concentrations vary according to the Bern-CC reference concentrations (Prentice et al., 2001) for each scenario until 2100 after which they were held constant at the 2100 value.

Although all future climate data is represented as change fields superimposed on the CRU 1961-1990 climatology there can still be an abrupt change in simulated vegetation and carbon balance at the time of the merge of the data series (2001). This abrupt change is caused in part by differences in inter-annual variability of the climate variables which sometimes causes diebacks of the vegetation and fire outbreaks in LPJ-GUESS. A second reason for the abrupt change at 2001 is the CRU-GCM discrepancy in the climate variables between 1961-1990 to 2001. To minimize these effects the trend and the variation of the first 20 years (2001-2020) of the scenario period were adjusted to give a smooth transition from historical CRU to future scenario GCM data. For each gridcell and month a new linear trend was applied between the 10 year monthly averages centred at 2000 and 2020 respectively. Secondly, for each month, gridcell and climate variable, we applied a linearly decreasing adjustment of the future variability by matching the histograms of the de-trended future period of 2001-2020 to the histograms of the de-trended historical period 1985-2005. We use the global PFT parameters described in (Ahlström et al., 2012).

2 Supplementary Table

Table S1. Parameters from the replacement model.

GPP	*β1*	*β2*	*β3*	*β4*	*β5*	*β6*	*β7*
Value	*-523.5478*	*-1.0339*	*0.0504*	*0.2945*	*-0.0001973*	*0.4677*	*-0.000095087*
Er+Fire	*β8*	*β9*	*β10*	*β11*	*β12*		
Value	*-54.2665*	*5.4203*	*-0.1078*	*0.6707*	*0.0171*		
Initial Cpool values (Pg C)	*1901*	*2001*					
	2118.4	*2197.4*					

3 Text S2: Validation of statistical emulator

Due to data limitation we included all available data for calibration of the statistical emulator. We performed a validation of the emulator by re-calibrating the emulator after exclusion of one third of the available datasets. In Figure S1 below (see Figure 3 for comparison) the CM4 A2, HadCM3 A1B, CCSM3 B1 and ECHAM5 A2 have been excluded when calibrating the emulator (highlighted in red). The average of the other two α values from each GCM were used for the excluded simulations. Excluding about one third of the data do not change the relationship between α and SST variability significantly (Figure S2), and it does not affect the conclusions drawn in the paper.

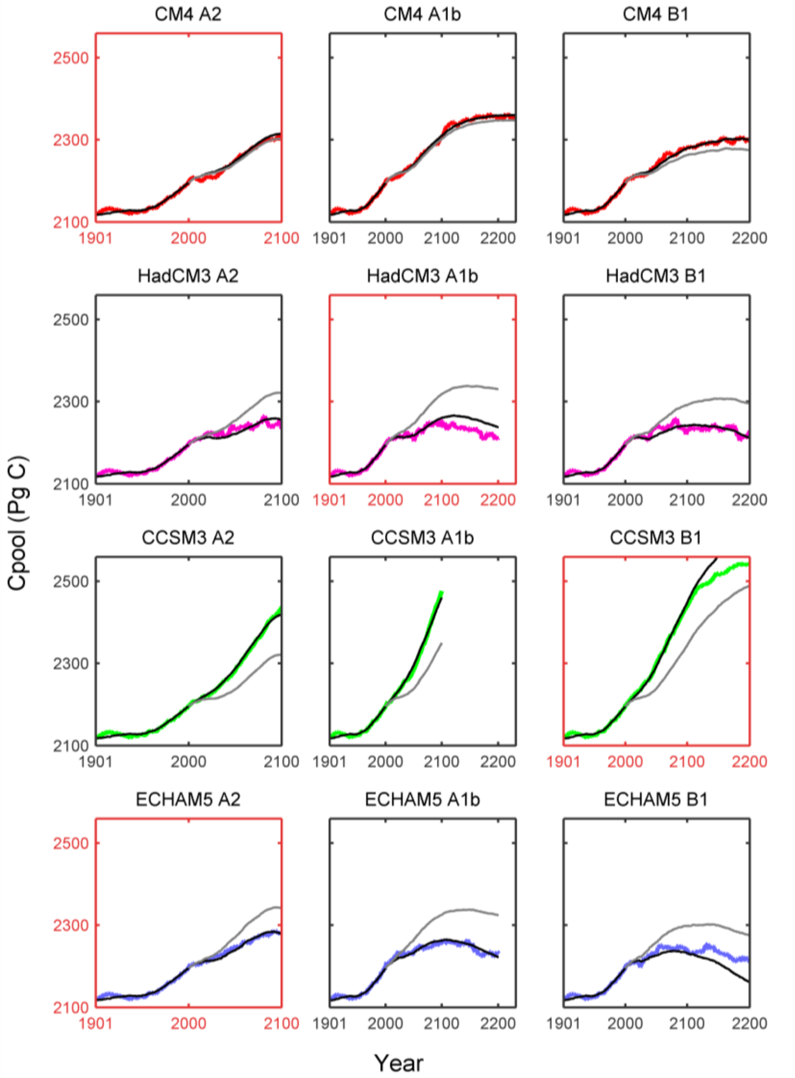
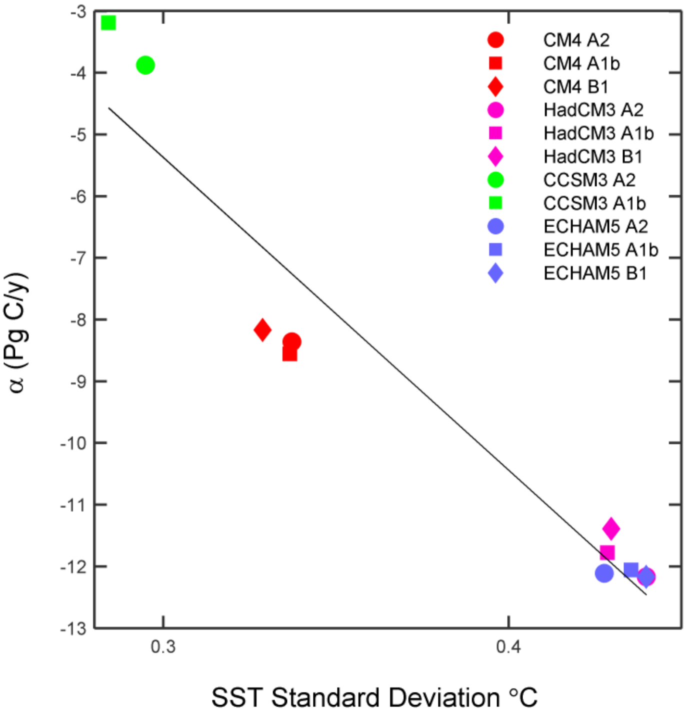


Figure S1. Results of the validation. Red borders indicate datasets excluded in the validation of the statistical carbon balance emulator. See Figure 3 in main paper for reference.



1 Figure S2. Results of the validation. The α values of CM4 A2, HadCM3 A1B, CCSM3 B1
2 and ECHAM5 A2 are here the average of the other two simulations per GCM. See Figure 4 in
3 main paper for reference.

4 Supplementary Figures

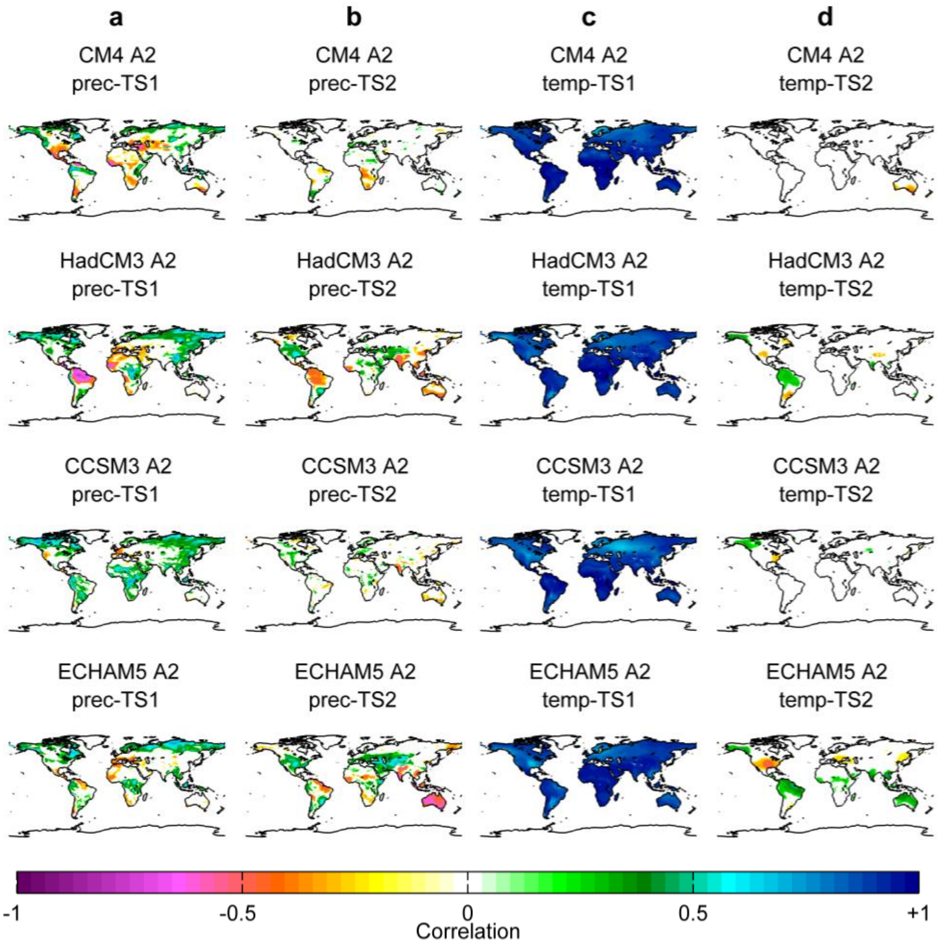


Figure S3. Spatial patterns of correlation (Pearson *r*) between the first two EOF modes of GCM-simulated SST (a and b in Figure 2 and S4) under the A2 scenario and precipitation and temperature. (a) correlations between precipitation and the time series of the first EOF mode (TS1). (b) correlations between precipitation and the time series of the second EOF mode (TS2). (c) correlations between temperature and the time series of the first EOF mode (TS1). (d) correlations between temperature and the time series of the second EOF mode (TS2). The correlations presented in colours are all statistically significant at 5% level.

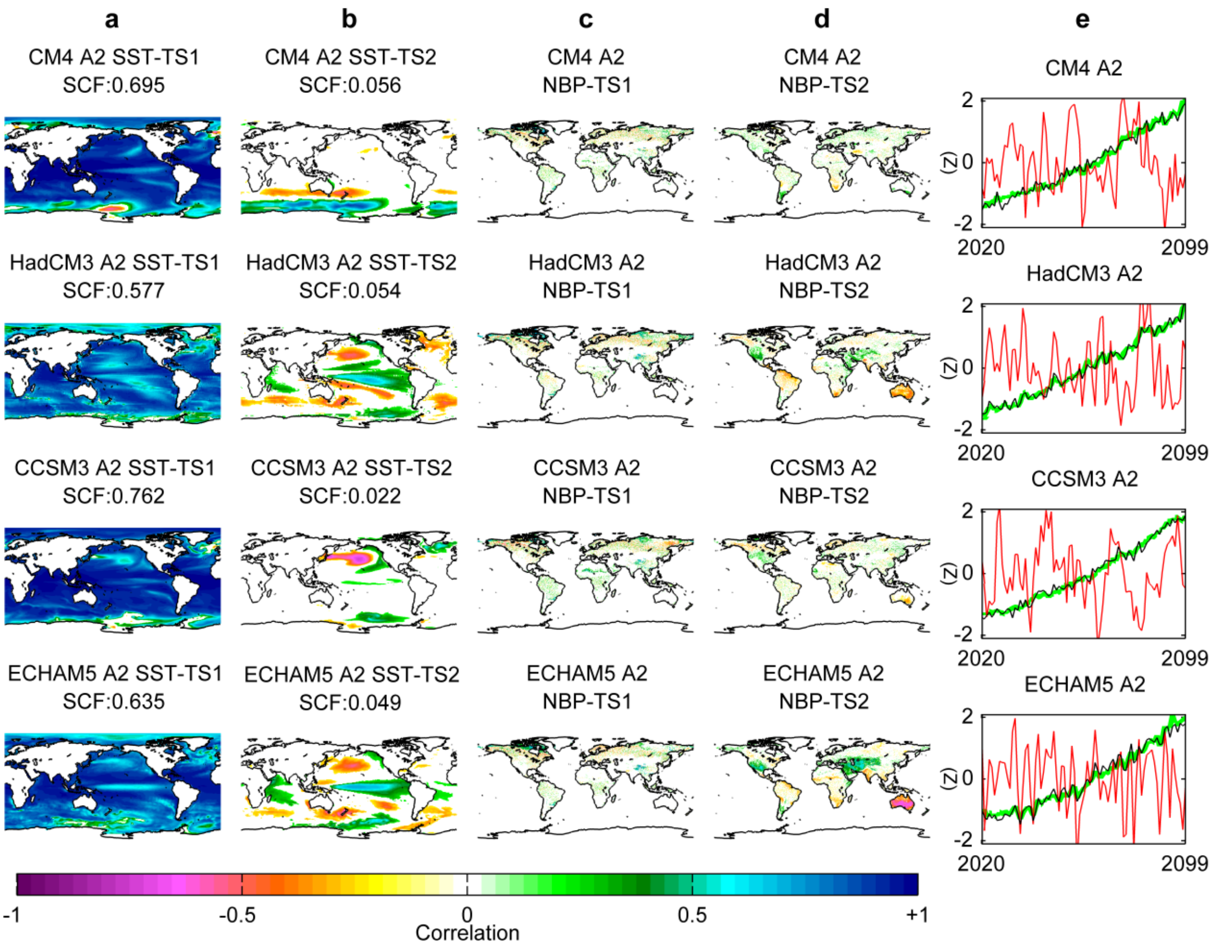


Figure S4. Spatial patterns of correlation (Pearson *r*) between the first two EOF modes of GCM-simulated SST under the A2 scenario and the original simulated SST and simulated NBP. (a) correlations between original SST and the time series of the first EOF mode (TS1; green line in (e)). (b) correlations between original SST and the time series of the second EOF mode (TS2; red line in (e)). (c) correlations between simulated NBP and the time series of the first EOF mode. (d) correlations between simulated NBP and the time series of the second EOF mode. (e) standardized time series (Z-scores) with mean zero and standard deviation one of the first EOF mode, TS1, (green), second EOF mode, TS2, (red) and global land temperature (black) . The correlations presented in colours are all statistically significant at 5% level.

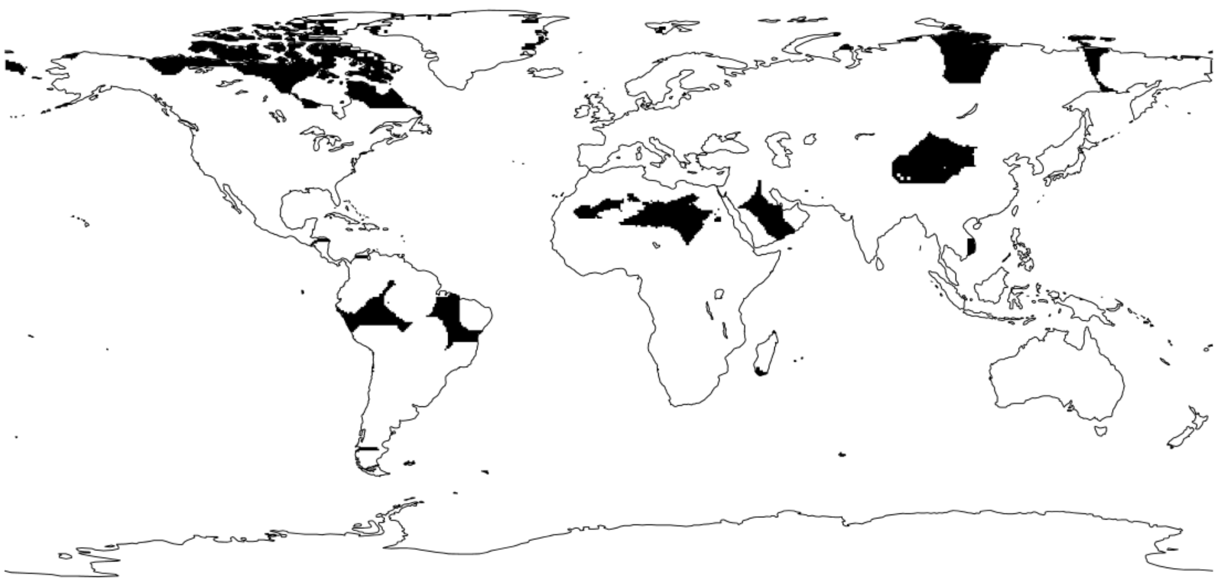


Figure S5. Location and extent of CRU precipitation gridcells with at least one 10-year period with no interannual variability (black). About 13% of the all the gridcells used in this study had at least one 10-year period with no interannual variability.

References

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