Comparing modeled fire dynamics with charcoal records for the Holocene

Max-Planck-Institut für Meteorologie

Tim Brücher[1], Victor Brovkin[1], Silvia Kloster[1], Jennifer R Marlon[2], Mitchell J Power[3]

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(1)Max Planck Inst. f. Meteorology Hamburg, Germany.

(2)Department of Geography, University of Oregon, Eugene, OR, United States.

(3)Department of Geography, University of Utah, Salt Lake City, UT, United States.

abstract

An Earth System model of intermediate complexity, CLIMBER-2, and a land surface model JSBACH that includes dynamic vegetation, carbon cycle, and fire regime are used for simulation of natural fire dynamics through the last 8,000 years. To compare the fire model results with the charcoal reconstructions, several output variables of the fire model (burned area, carbon emissions) and several approaches of model output processing are tested. The Z-scores out of the charcoal dataset have been calculated for the period 8,000 to 200 BP to exclude a period of strong anthropogenic forcing during the last two centuries.

The model analysis points mainly to an increasing fire activity during the Holocene for most of the investigated areas, which is in good correspondence to reconstructed fire trends out of charcoal data for most of the tested regions, while for few regions such as Europe the simulated trend and the reconstructed trends are different. The difference between the modeled and reconstructed fire activity could be due to absence of the anthropogenic forcing in the model simulations, but also due to limitations of model assumptions for modeling fire dynamics. For the model trends, the usage of averaging or Z-score processing of model output resulted in similar directions of trend. Therefore, the approach of fire model output processing does not effect results of the model-data comparison.

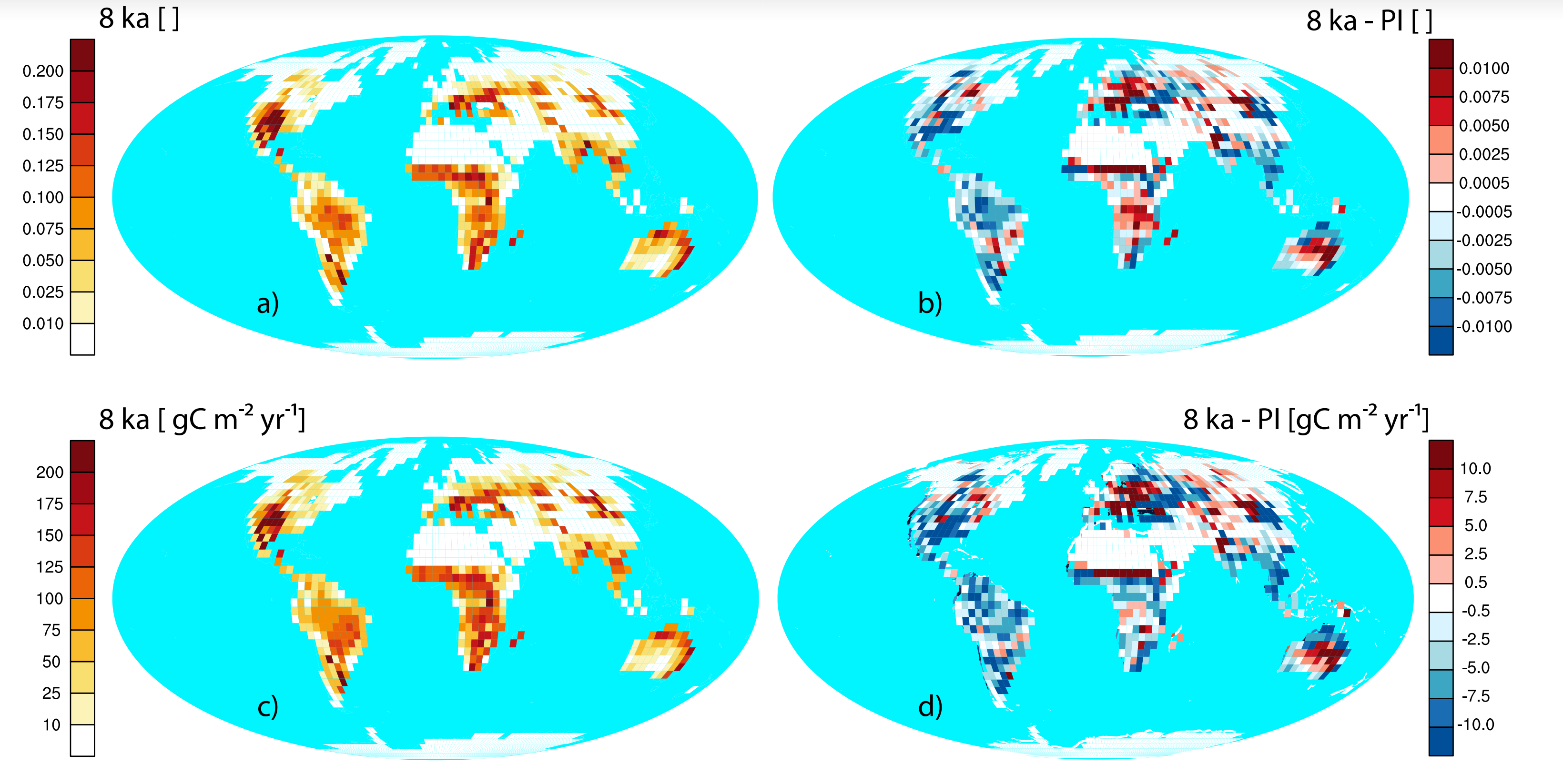
Global fire modeling is still in its infancy; improving our representations of fire through validation exercises such as what we present here is thus essential before testing hypotheses about the effects of extreme climate changes on fire behavior and potential feedbacks that result from those changes.

Brücher, T., Brovkin, V., Kloster, S., Marlon, J. R., and Power, M. J.: Comparing modelled fire dynamics with charcoal records for the Holocene, Clim. Past Discuss., 9, 6429-6458, doi:10.5194/cpd-9-6429-2013, 2013

conclusions

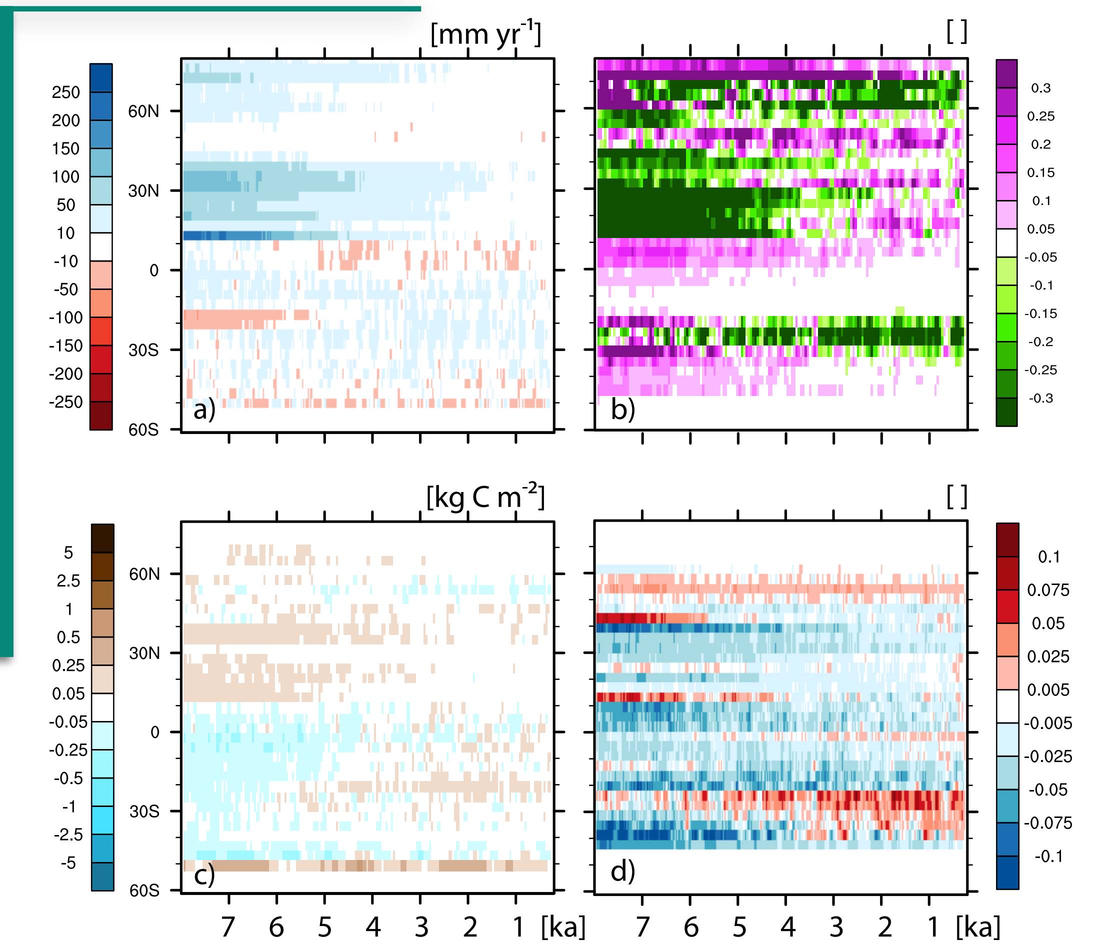
- Close to the overall increase in fire activity out of charcoal reconstructions we simulate a total increase of app. 14 Mha (from 512 to 526 Mha) for burned area.
- For most of the investigated regions the model simulates an increase in burned area and carbon emissions. The trends in the carbon emissions were higher than trends detected in burned area.
- A rank correlation analysis points to the overall agreement between simulated and observed trends in fire activity over the whole study period, while on finer time scales the model does not match the centennial- or millennial-scale variability inferred from the charcoal records.
- It is useful to convert the time series of modelled burned area or carbon emissions to Z-score to provide a method for comparing modelled and observed palaeofire variability.

changes in fire



top: Yearly burned fraction of grid cell area [m^2 m^{-2}] of natural fire activity **(a)** and carbon emissions [g C m^{-2} yr^{-1}] **(c)** for the mid-Holocene (8 ka = 8000 cal yr BP) and their anomalies **(b, d)** to burned fraction with pre-industrial (PI = 200 cal yr BP) climate.

transient climate changes



Northern subtropics, including North Africa, were substantially wetter, presumably due to an intensification of the monsoon circulation. This led to the significant increase of vegetation cover in subtropical drylands and in the Sahel/Sahara region. While the Northern Hemisphere was warmer over the Holocene, the temperature anomalies in southern extra-tropics (30–60 S) were small. The simulated total burned area for the mid Holocene is at 514 Mha yr^{-1} and increases slightly by 14 Mha yr^{-1} (app. 2.5 %) to 528 Mha yr^{-1}.

left: Transient anomalies of latitudinal averaged values (over land) for **(a)** yearly precipitation [mm yr^{-1}], **(b)** desert fraction [m^2 m^{-2}], **(c)** carbon [kg C m^{-2}] stored in green biomass, and **(d)** fraction of burned area [m^2 m^{-2}]. The base period for calculating all anomalies is pre-industrial climate (PI).

method

Transformation to Z-scores in 4 steps:

(1) rescaling values using a mini-max transformation

$$ci_s' = \frac{ci_s - \min(ci_s)}{\max(ci_s) - \min(ci_s)}$$

(2) homogenisation of variance using the Box–Cox transformation

$$ci_s^{*} = \begin{cases} \frac{(ci_s' + \alpha)^{\lambda_s} - 1}{\lambda_s}, & \lambda_s \neq 0 \\ \log(ci_s' + \alpha) & \lambda_s = 0 \end{cases}$$

(3) rescaling values once more to Z-scores:

$$ci_s^{Z} = \frac{ci_s^{*} - \overline{ci_s^{*}}}{S_{ci_s^{*}}}$$

(4) Charcoal influxes are reported as the geometric mean of Z-score time series:

$$Z_{region} = \sum_{sites} \frac{ci_s^{Z}}{N_{sites}}$$

(5) For comparison, the modelled time series of burned area F and carbon emissions C will be aggregated in two ways:

(i) area weighted regional means (F, C):

$$F_{region}(t) = \sum_g f_g(t) \cdot a_g$$

$$C_{region}(t) = \sum_g c_g(t) \cdot a_g$$

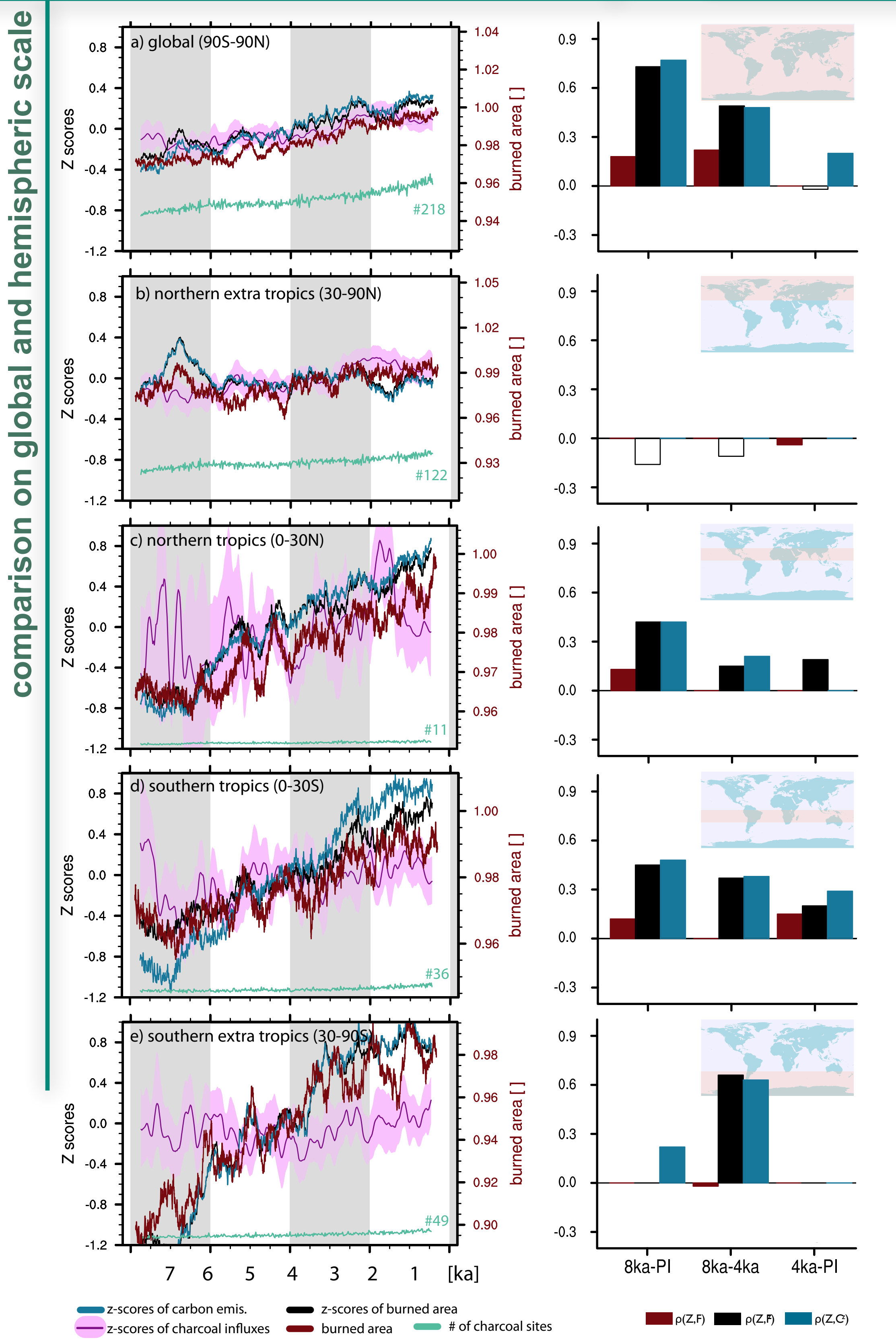
(ii) regional Z-scores (F^Z, C^Z):

$$F^{Z}_{region}(t) = \frac{\sum_g f_g^{z}(t)}{N_g}$$

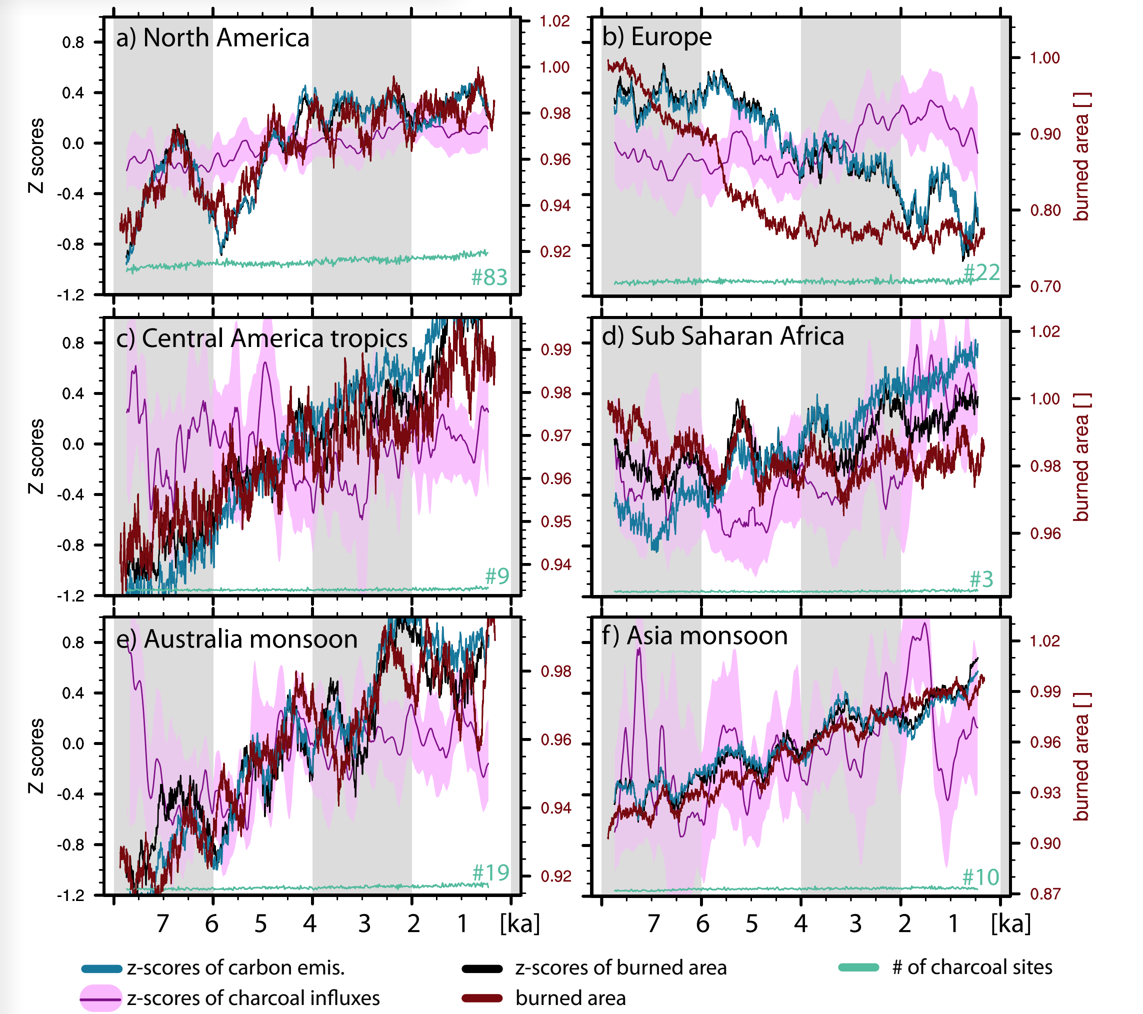
$$C^{Z}_{region}(t) = \frac{\sum_g c_g^{z}(t)}{N_g}$$

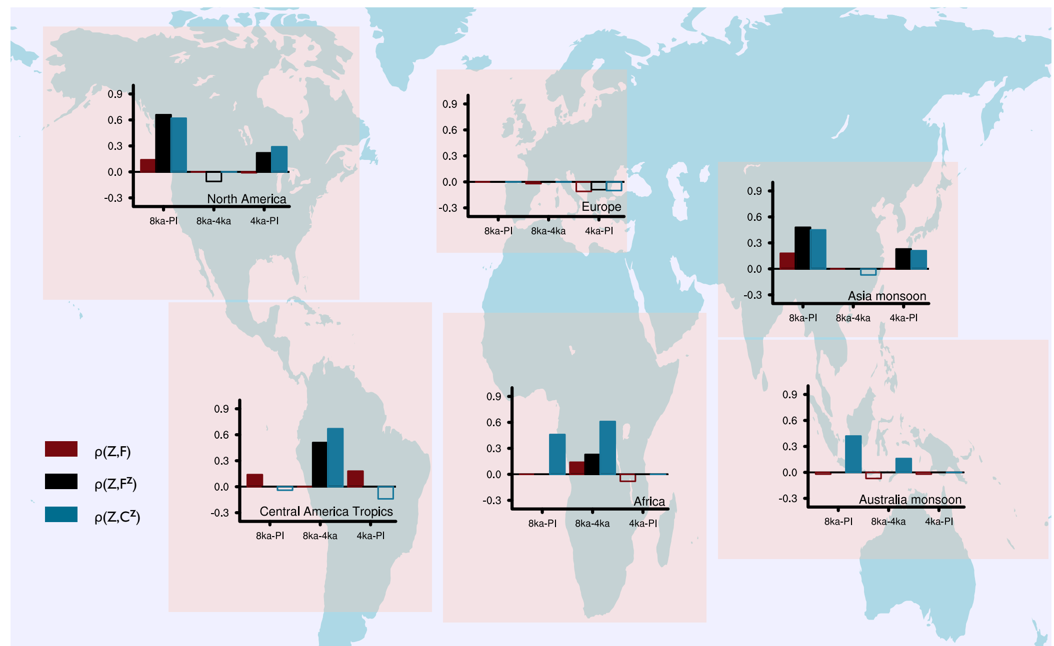
model vs. charcoal

comparison on global and hemispheric scale



comparison on regional scale





Line charts: Averaged values for reconstructed and modelled biomass burning during the present interglacial as global, hemispheric (left) and regional (right) values. Reconstructions are shown by Z-scores of charcoal influxes (Z, pink), and Z-score transformed values of modelled burned area (F^Z, black) and carbon emissions by fire (C^Z, blue). Untransformed model output of burned area (F, red) and the number of sites used in the reconstructions (green) are also given. For all time series a running mean of 250 yr is applied. Please note the varying, relative scale of modelled burned area.

Bar charts: The bars indicate the corresponding rank correlations (after Spearman). Significant, positive values are given by filled bars for three different time windows: 8 ka–PI, 8 ka–4 ka, and 4 ka–PI.