AGU PUBLICATIONS

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Supporting Information for

On the remote impacts of mid-Holocene Saharan vegetation on South American hydroclimate: a modelling intercomparison

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Text S1.

Model evaluations

A comparison of the model pre-Industrial simulations with observational and reanalysis datasets indicates that overall, the models faithfully capture the large-scale patterns of precipitation, though there are some model-specific regional biases (Fig. S2). For example, there is an overestimation of precipitation in northwestern Amazon region in UofT-CCSM4 and an under-estimation of precipitation in northern South America in iCESM 1.2. To different extents, some shortcomings are common to all models. These include: (i) a double-ITCZ and (ii) an under-estimation of precipitation over the southwestern South Atlantic Ocean. However, all models show reasonable magnitudes and distributions of annual precipitation, especially over the domain of the West African Monsoon, the Inter Tropical Convergence Zone and the South Atlantic Convergence Zone.

Text S2.

Representation of the mid-Holocene Green Sahara (MH_{GS}) in the models

The mid-Holocene (MH) was characterized by large-scale vegetation changes from desert to shrub and savanna over northern Africa. The PMIP4 recommendations for vegetation sensitivity experiments include changing vegetation over the Sahara to evergreen shrub up to 25 °N and savanna/steppe vegetation poleward of 25 °N (Otto-Bliesner et al., 2017). The vegetation changes also led to decreases in dust mobilization and soil albedo, and changes in surface hydrology.

Different models in this study treat the presence of the Green Sahara differently. In the EC-Earth 3.1 MH_{GS} simulation, vegetation over the Sahara was set to shrub, and dust was reduced by up to 80% relative to the PI. In the iCESM 1.2 MH_{GS} simulation, present day Sahelian land surface and vegetation characteristics at 11 °N were imposed over the Sahara. The use of an interactive dust scheme led to a decrease in dust mobilization. In the UofT-CCSM4 MH_{GS} simulation, tropical rainforests were extended northwards, the Sahara was completely replaced by evergreen shrubs up to 25 °N and almost completely (90%) replaced by a mix of steppe and savanna beyond 25 °N. Further, soil albedo was reduced to reflect greater moisture and organic matter, and the presence of five megalakes was incorporated through land surface changes. In the GISS-E2.1-G MH_{GS} simulation, bare soil and grass over the Sahara were replaced by arid shrub below 25 °N and by grassland above 25 °N.

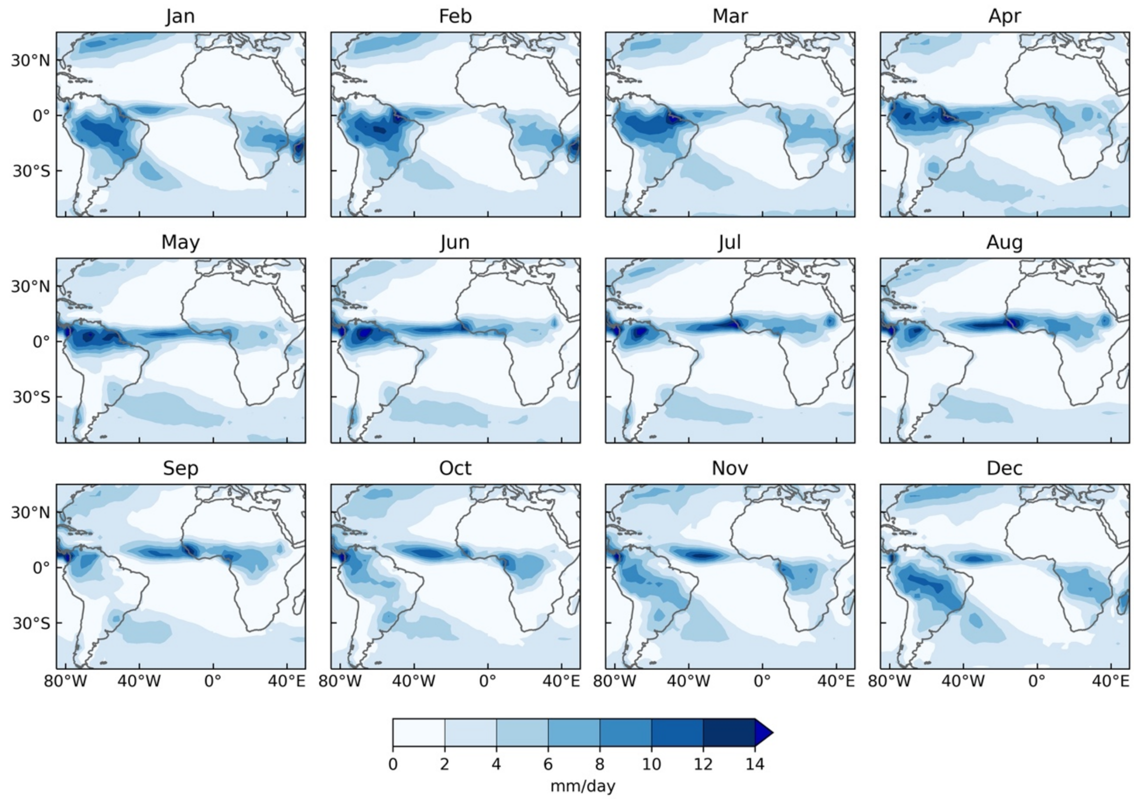

Figure S1. Present-day monthly precipitation patterns from the Global Precipitation Climatology Project (GPCP) version 2.2 from 1979-2009 (Huffman et al., 2015).

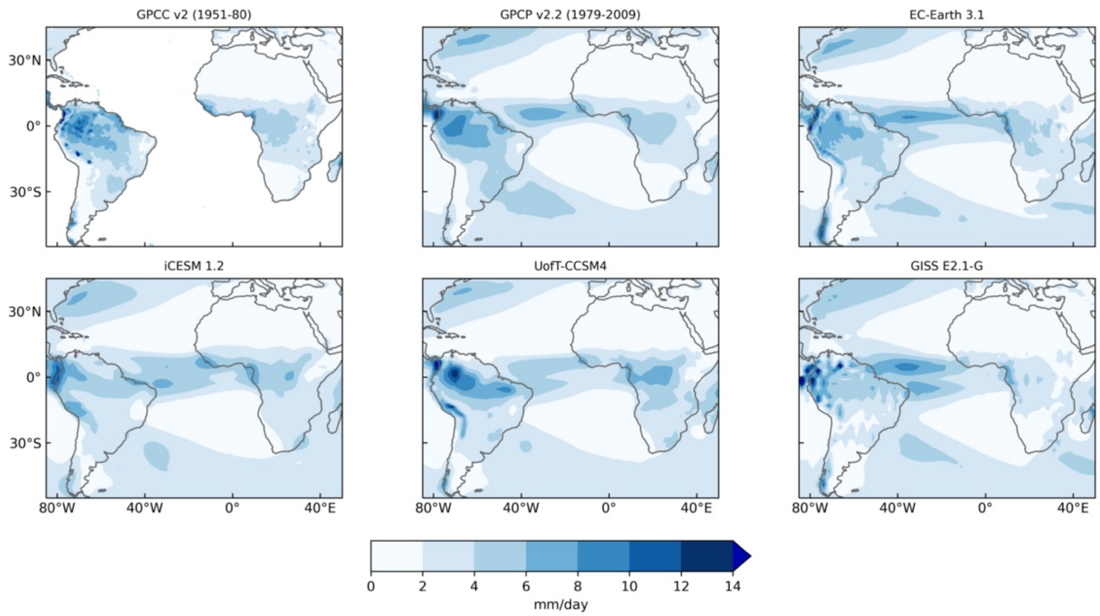

Figure S2. Comparison of annual precipitation patterns over South America between the Global Precipitation Climatology Centre (GPCC) Reanalysis Dataset, Global Precipitation

Climatology Project (GPCP) Dataset and the PI simulations from EC-Earth 3.1, iCESM 1.2, UofT-CCSM4 and GISS-E2.1-G.

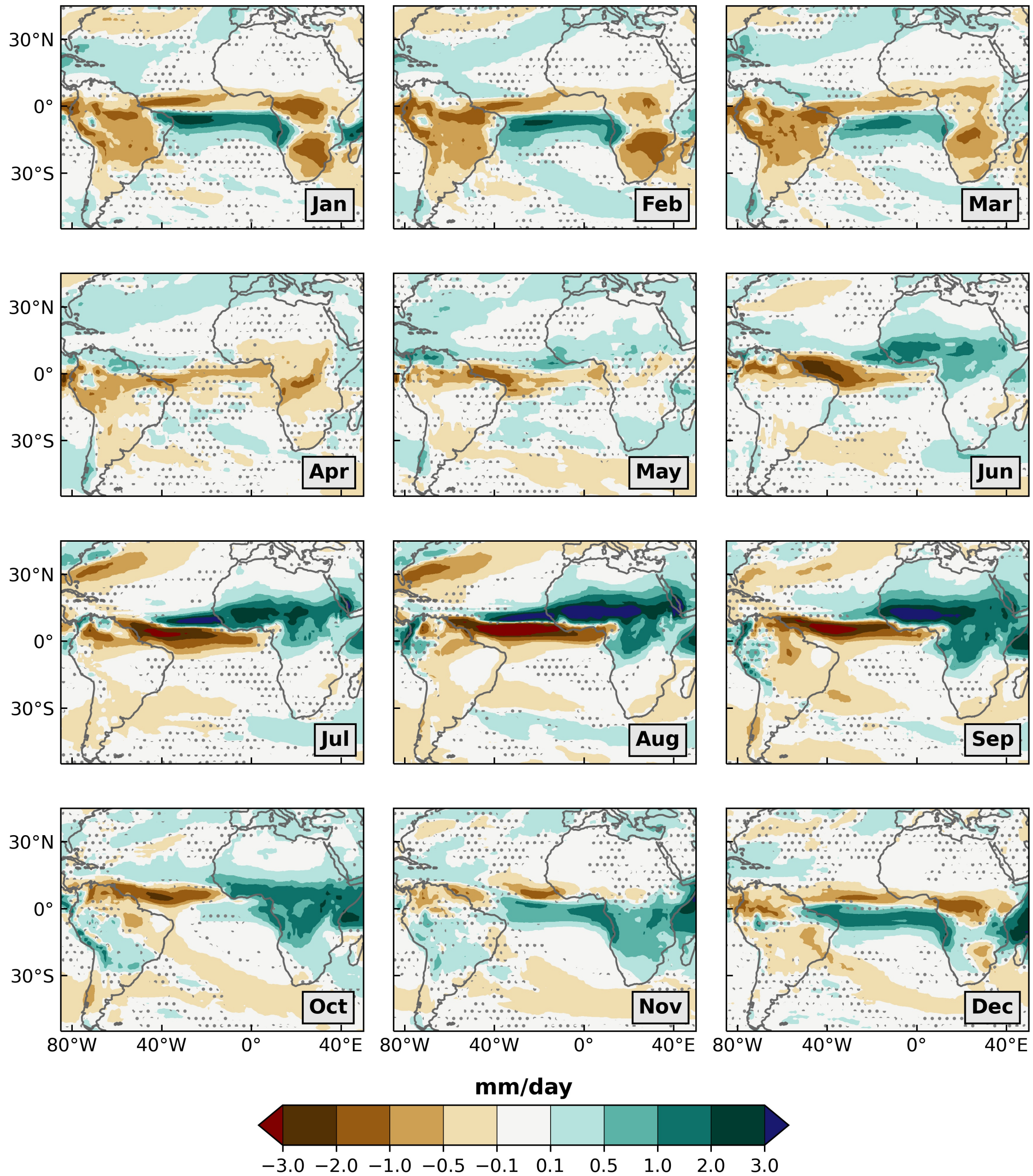

Figure S3. Precipitation changes between MH_{PMIP} and PI experiments, shown as multi-model averages for each month. Areas in which less than three models agree on the sign change are hatched.

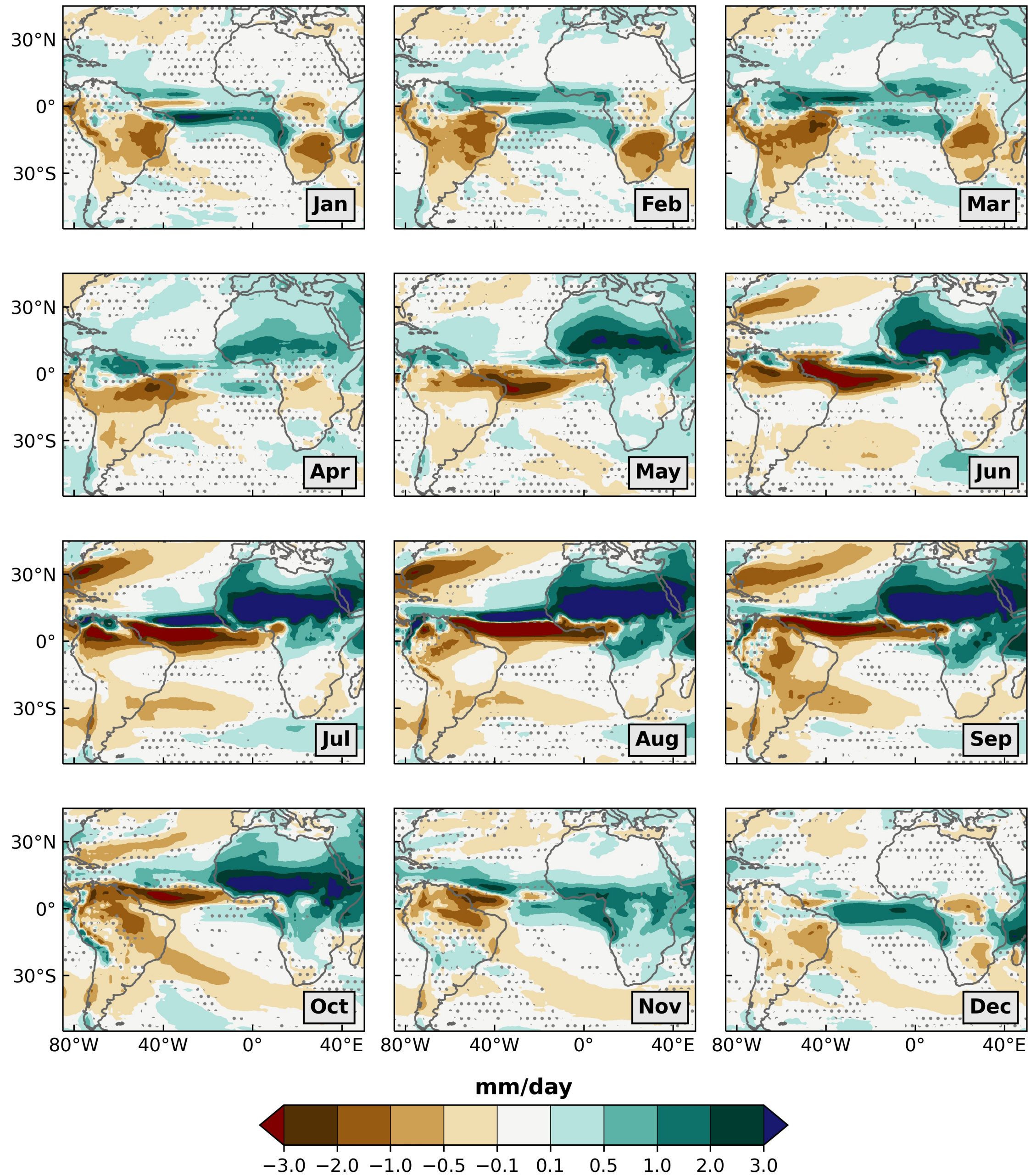

Figure S4. Precipitation changes between MH_{GS} and PI scenarios, shown as multi-model averages for each month. Areas in which less than three models agree on the sign change are hatched.

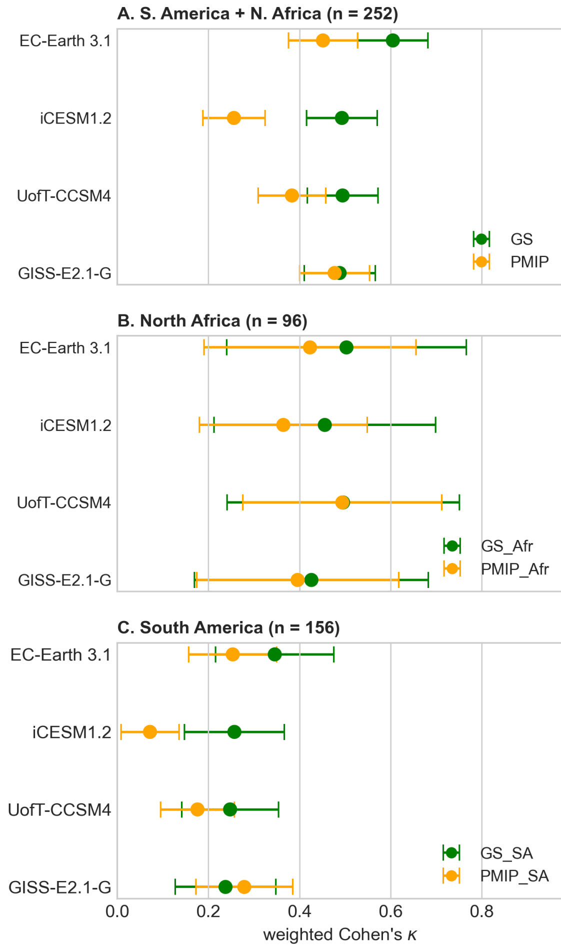

Figure S5. Weighted Cohen's k score between MH_{GS} (blue dots) and MH_{PMIP} (orange dots) scenarios over (a) South America and northern Africa, (b) northern Africa (0° to 38°N and 20°W to 45°E) and (c) South America (50°S to 15°N and 80°W to 30°W) regions. All datapoints are statistically significant ($p < 0.05$). Error bars indicate 95% confidence intervals.

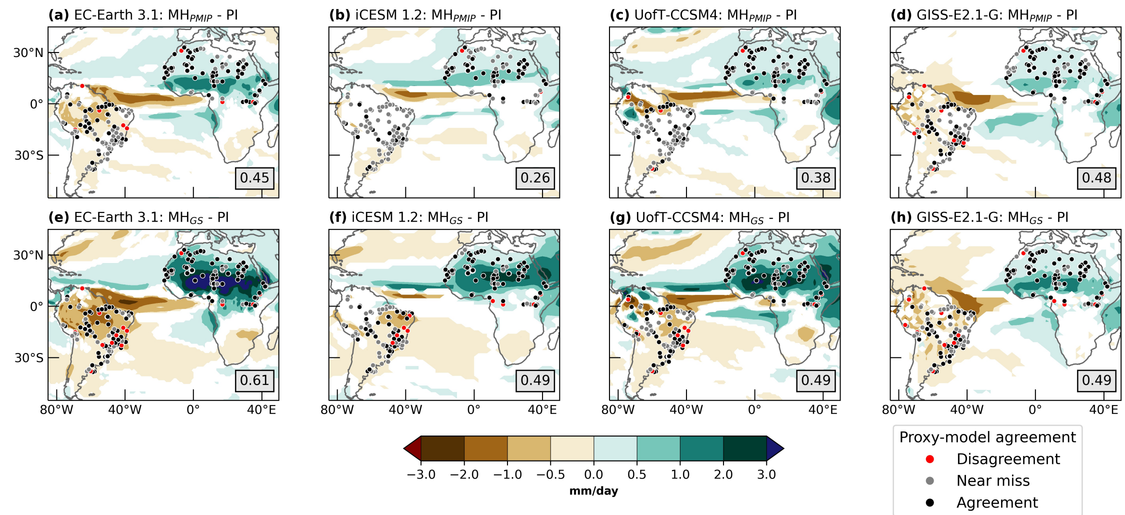

Figure S6. Proxy-model agreement over the region of study. Colors show MH-PI annual precipitation changes in mm/day. Only changes significant at the 95% confidence level are shown. Proxy sites are shown by circles, with the color indicating disagreement ("total miss"; red), near-miss (grey) and agreement (black).

	EC-Earth 3.1	**iCESM 1.2**	**UofT-CCSM4**	**GISS-E2.1-G**
Model name	EC-Earth	Community Earth System Model	Community Climate System Model	Goddard Institute for Space Studies Model
Atmospheric component	Integrated Forecast System	Community Atmosphere Model v5.3 (iCAM5)	Community Atmosphere Model v4 (CAM4)	Goddard Institute for Space Studies Model E2.1
Atmospheric grid	1.125 x 1.125 (62)	1.9 x 2.5 (30)	1 x 1 (26)	2 x 2.5 (40)
Oceanic component	Nucleus for European Modelling of the Ocean v2 (NEMO2)	Parallel Ocean Program v2.0 (POP2)	Parallel Ocean Program v2.0 (POP2)	GISS Ocean Model v1
Oceanic grid	1 x 1 (46)	1 x 1 (60)	1 x 1 (60)	1 x 1.25 (40)
Simulation protocols	CMIP5 / PMIP3	CMIP6 / PMIP4	CMIP6 / PMIP4	CMIP6 / PMIP4
Feedbacks incorporated in the MH_{GS} simulation	Vegetation, dust	Vegetation, dust, soil	Vegetation, soil, lakes	Vegetation
PI-to-MH albedo change over northern Africa	0.3 to 0.15	0.3 to 0.15	0.3 to 0.16	0.3 to 0.19
Reference for simulations	Pausata et al. (2016)	Tabor et al. (2020)	Chandan and Peltier (2020)	This paper

Table S1. Model details. Numbers in parentheses indicate number of vertical levels in the atmospheric or oceanic grid.