Supplement: Investigating oxygen and carbon isotopic relationships in speleothem records over the last millennium using multiple isotope-enabled climate models

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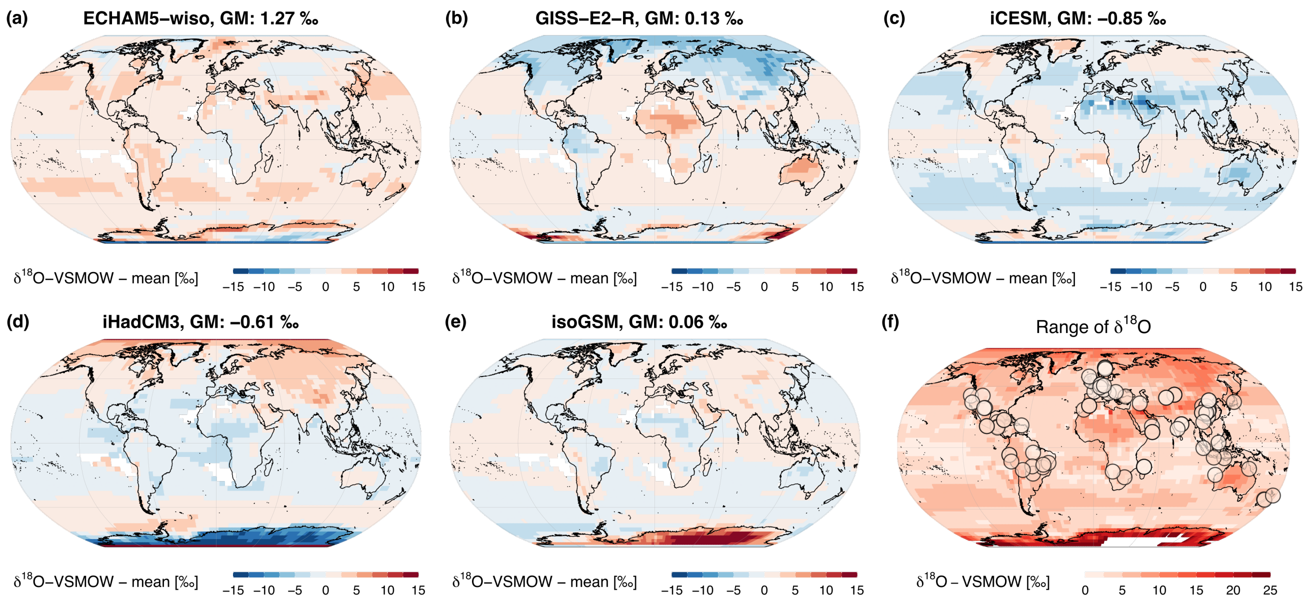

Figure SF1. As Fig. 3 minus the multi-model mean for better visibility, where individual simulations differ from the multi-model mean.

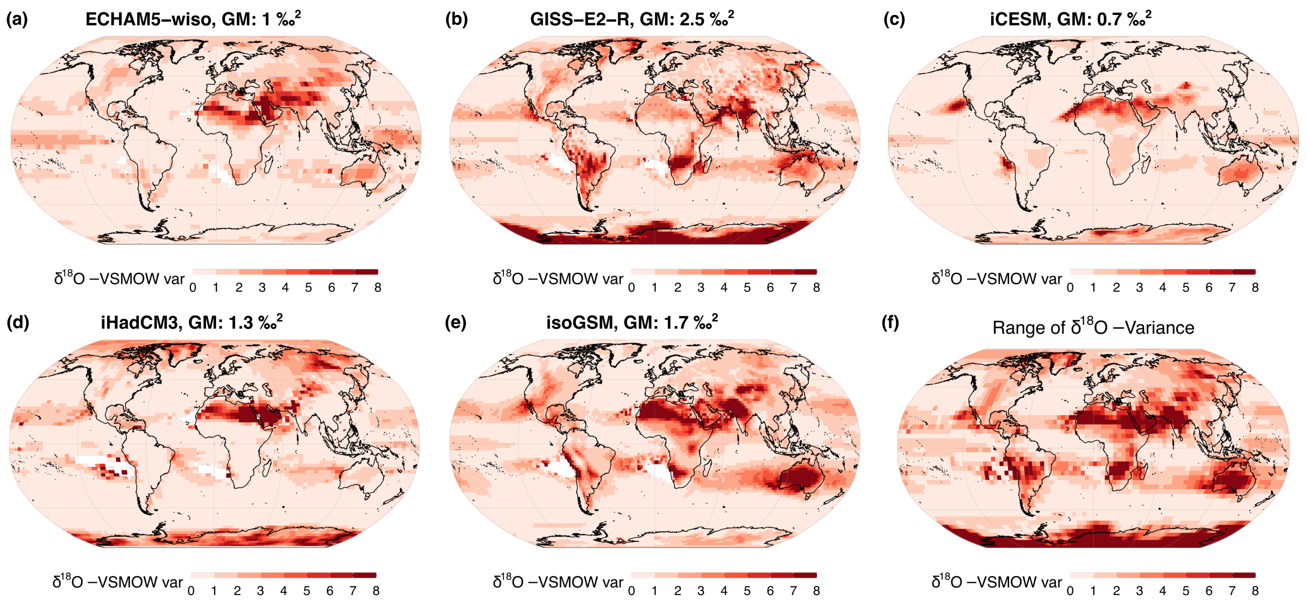

Figure SF2. As Fig. 3 but for the variance over the whole 1000 yr time period per gridbox.

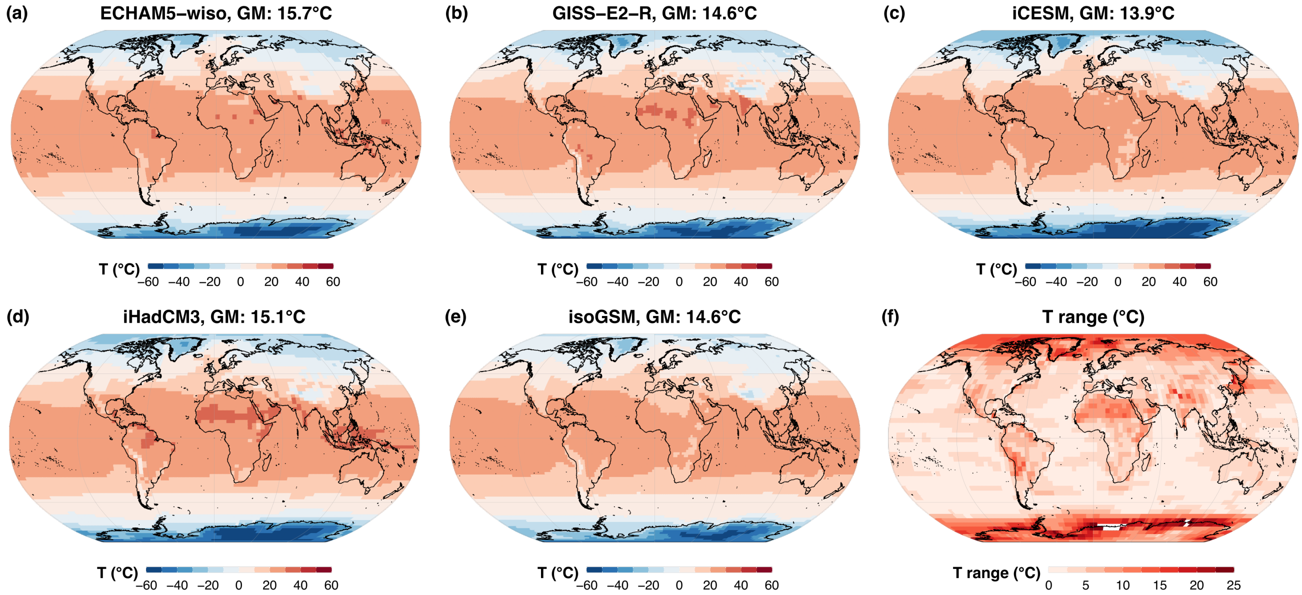

Figure SF3. As Fig. 3 but for surface air temperature.

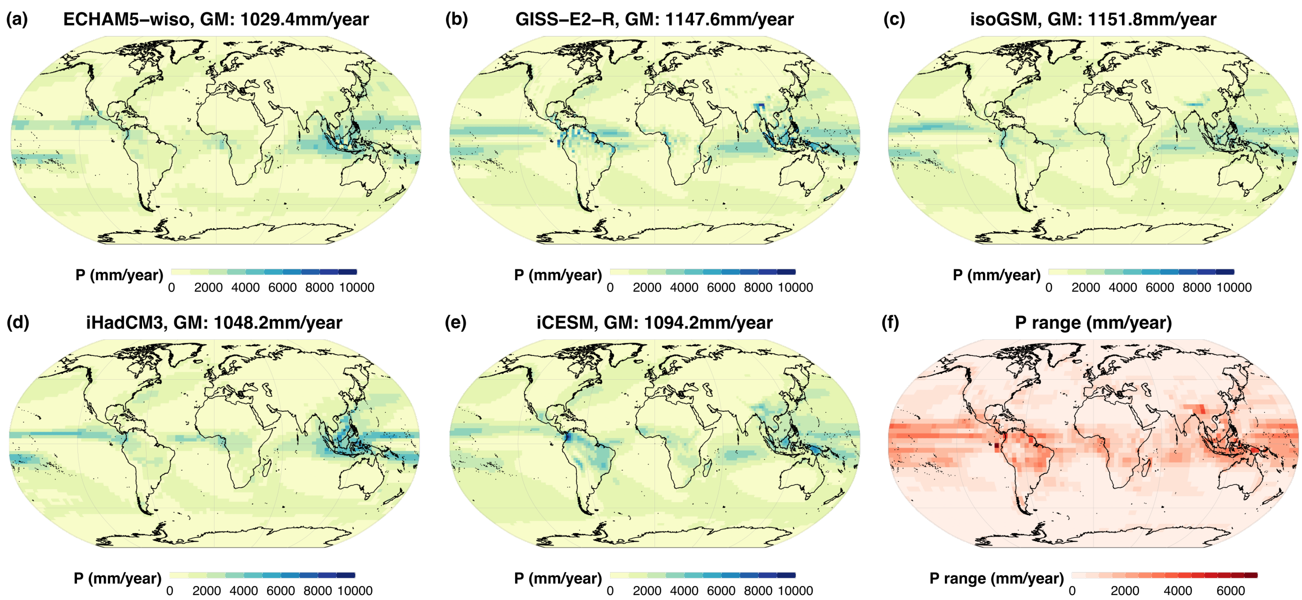

Figure SF4. As Fig. 3 but for precipitation.

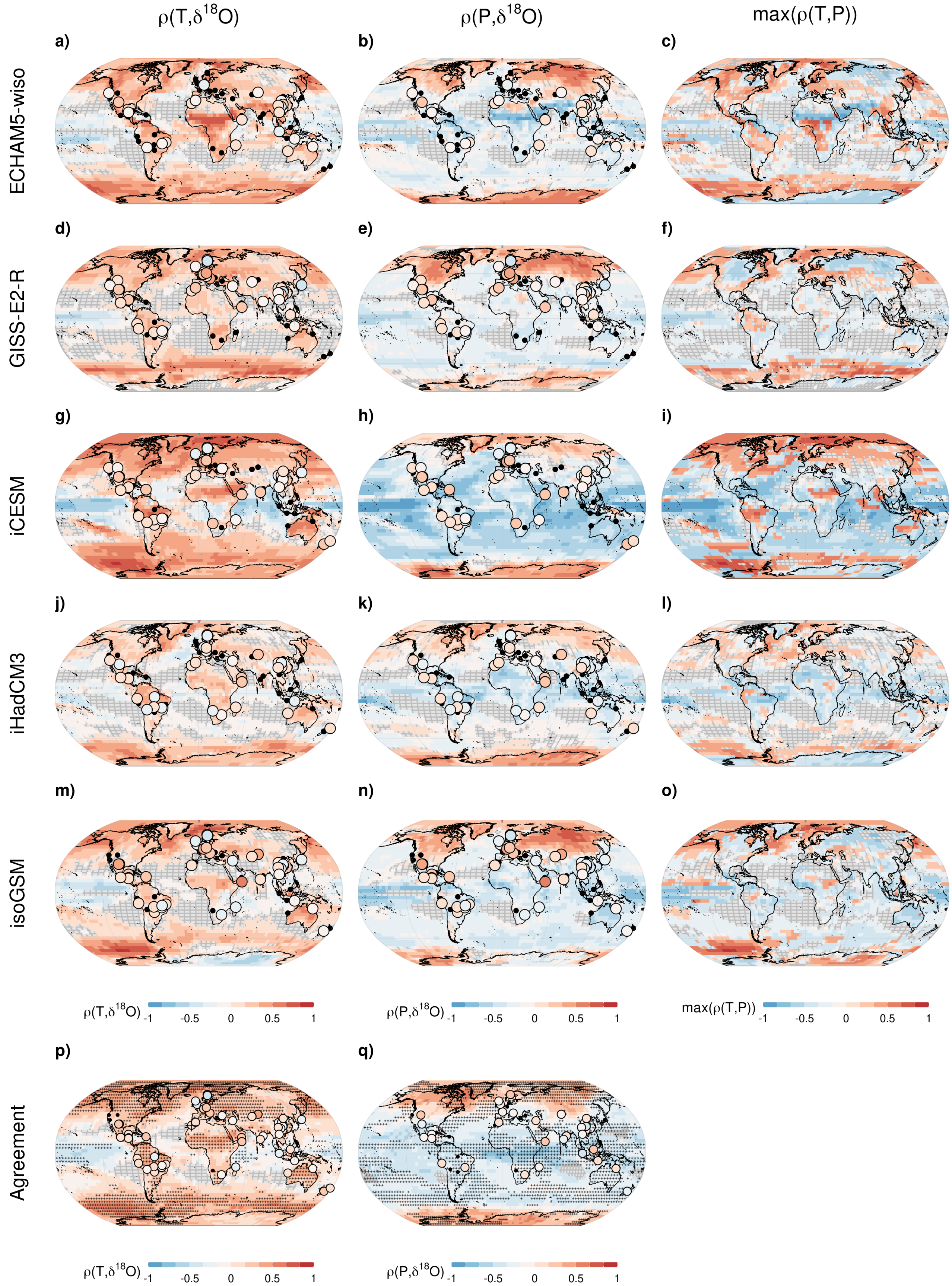

Figure SF5. a-o) shows the correlation between simulated temperature or precipitation to simulated $\delta^{18}O_{iw}$ in the first two columns. The third column shows the areas, where absolute correlation estimated of $\delta^{18}O_{sim}$ are higher to temperature (red colors) or to precipitation (blue colors). Each row shows one simulation (a-c) iCESM, d-f) ECHAM5-wiso, g-i) GISS-E2-R, j-l) iHadCM3, m-o) isoGSM. p-q) show the agreement between the simulations. If a pair of simulations agrees in sign, the score increases by one.

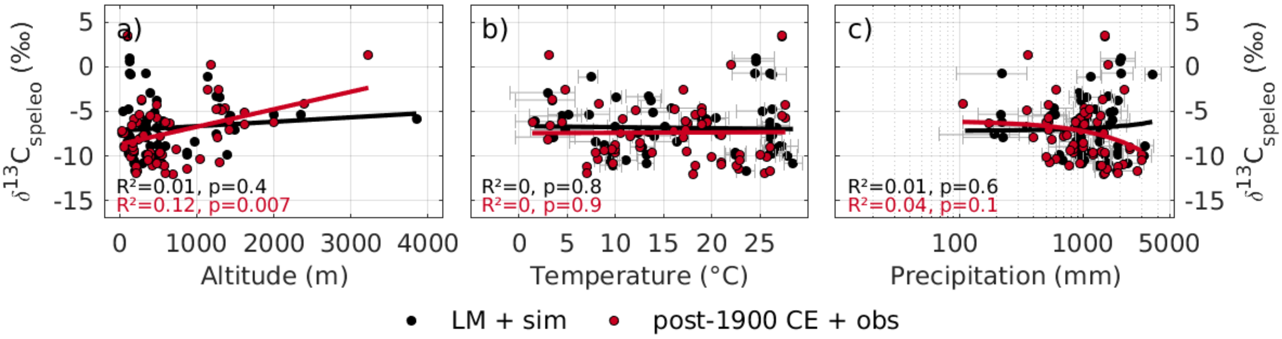

Figure SF6. $\delta^{13}C_{speleo}$, altitude, temperature and precipitation globally with the last century data from Fohlmeister et al. (2020) selection.

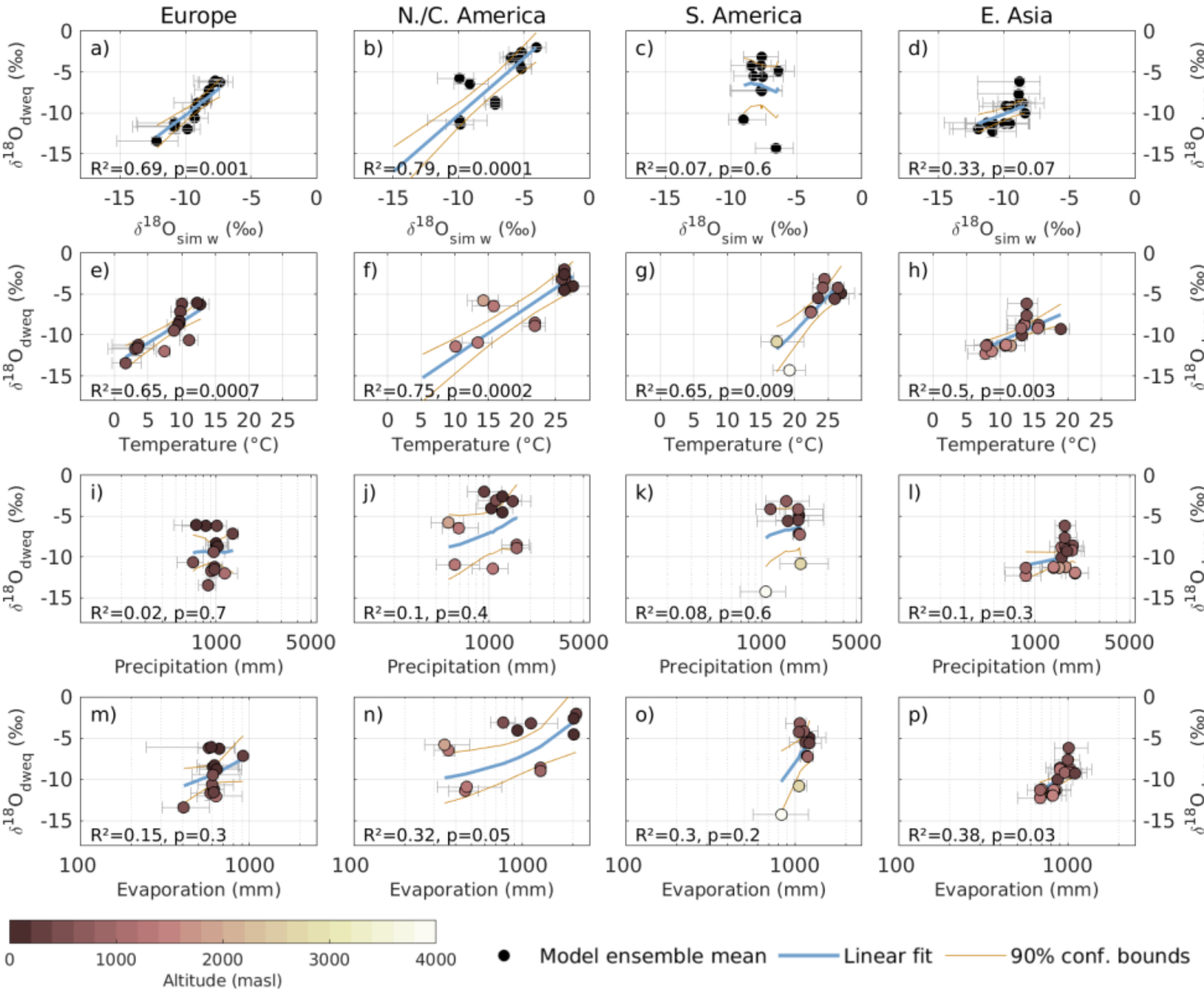

Figure SF7. As Fig. 7 but for different continents. Continents are defined as Europe (36.7-75°N, 30°W-30°E), North and Central America (8.1-60°N, 50-150°W), South America (60°S-8°N, 30-150°W), and East Asia (15-39°N, 100-125°E).

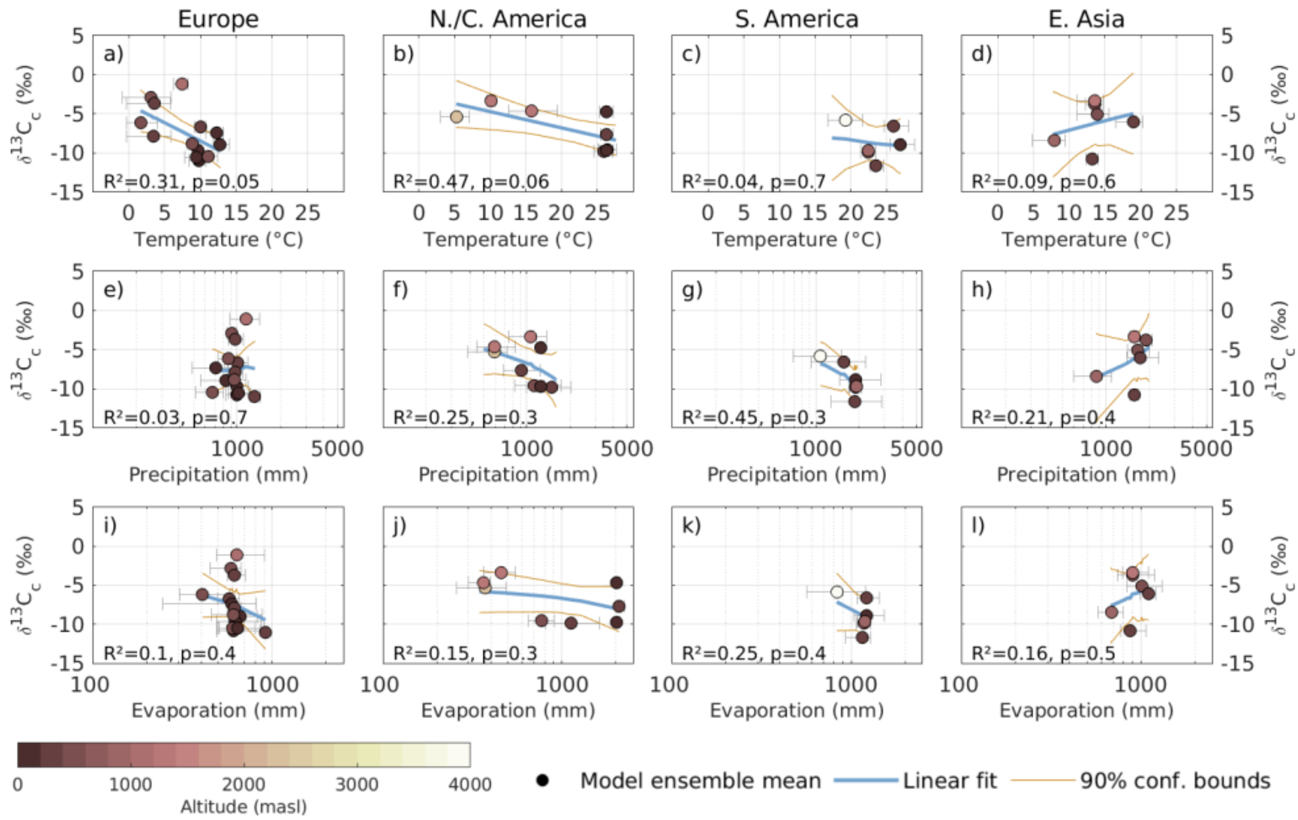

Figure SF8. As Fig. 8 but for different continents.

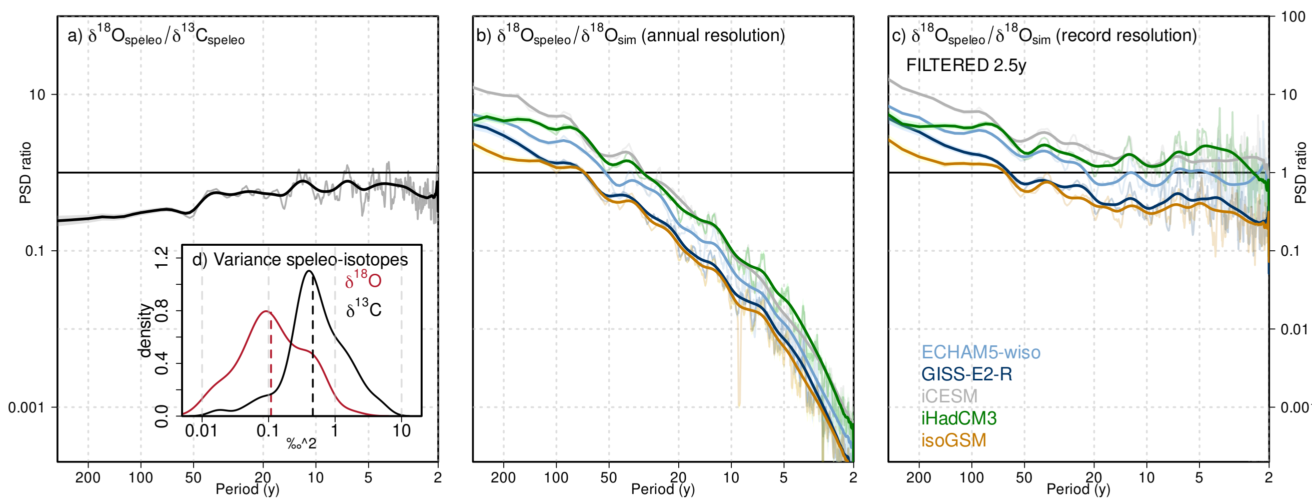

Figure SF9. As Fig. 9 but in b) with a 2.5 yr karst filter applied (as in Bühler et al. (2021) following Dee et al. (2015)) to the annually resolved $\delta^{18}O_{sim}$ which is later down-sampled to the individual records' resolution.

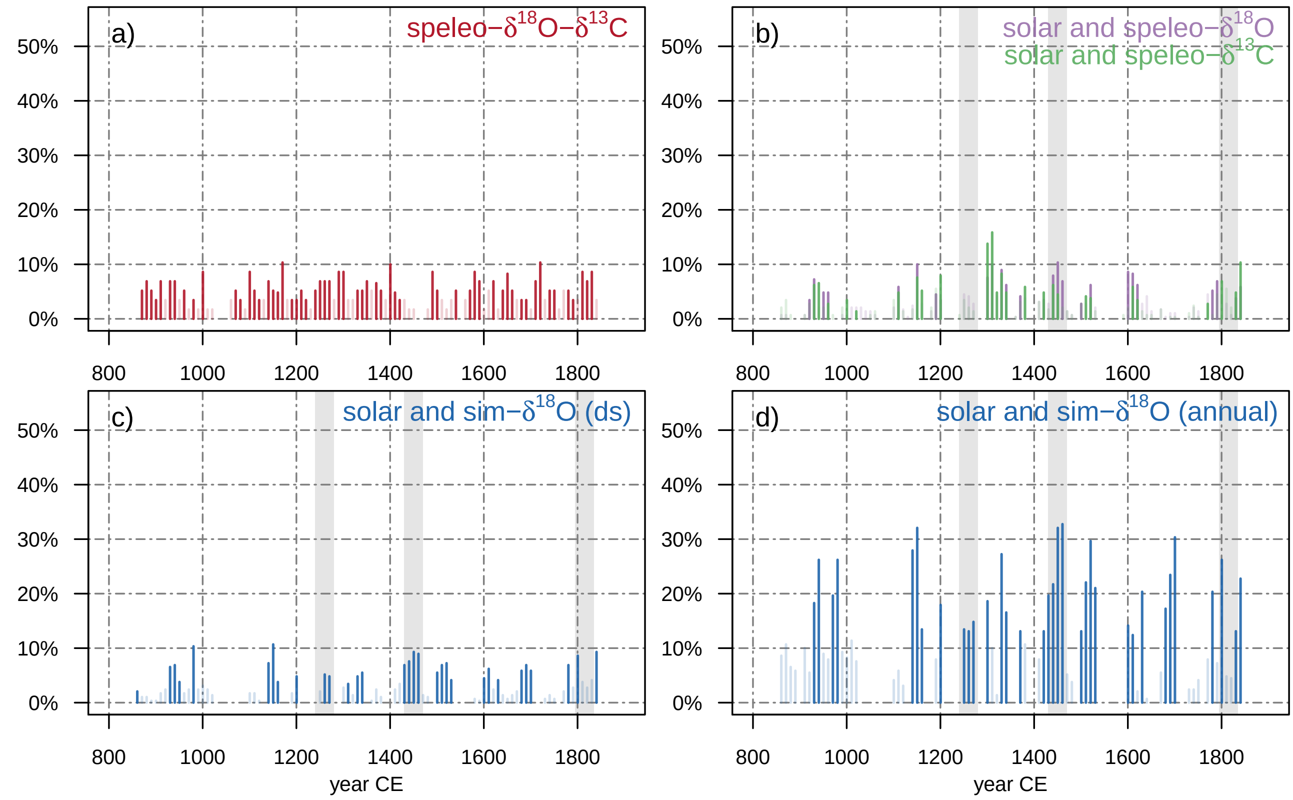

Figure SF10. As Fig. 10 but using the respective solar forcings used in the simulations.

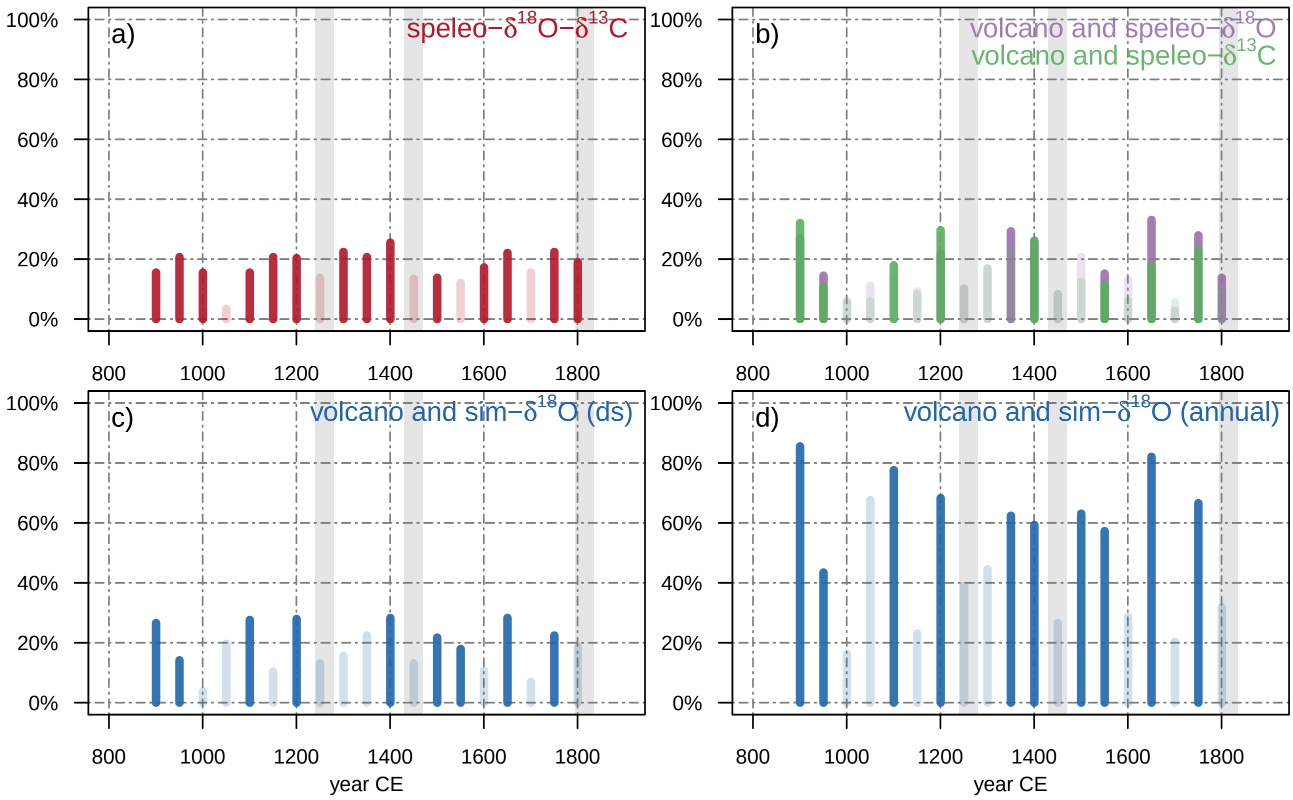

Figure SF11. As Fig. 10 but using bin-sizes of 50 yr which corresponds to the average age-uncertainty in the last millennium sub-sample of the SISALv2 database that we consider here.

Table ST1. Linear regression between isotopes, simulated climate variables and geographical information with 90% intervals of the distribution for p, R^2, slope and intercept.

		p	R^2	*slope*	*intercept*
$\delta^{18}O_{iw}$-$\delta^{18}O_{dweq}$	Tropics	**0.01** (0.00, 0.03)	0.35 (0.13, 0.39)	1.02 (0.51, 1.54)	1.78 (-1.87, 5.43)
	Subtropics	**0.00** (0.00, 0.01)	0.44 (0.27, 0.61)	0.74 (0.41, 1.07)	-2.02 (-5.01, 0.97)
	Extratropics	**0.00** (0.00, 0.00)	0.67 (0.58, 0.76)	1.03 (0.80, 1.25)	0.07 (-2.24, 2.38)
Temperature-$\delta^{18}O_{dweq}$	Tropics	**0.00** (0.00, 0.00)	0.47 (0.38, 0.54)	0.78 (0.54, 1.02)	-24.67 (-30.64, -18.70)
	Subtropics	**0.00** (0.00, 0.00)	0.71 (0.60, 0.81)	0.51 (0.38, 0.64)	-15.82 (-17.71, -13.94)
	Extratropics	**0.00** (0.00, 0.00)	0.49 (0.39, 0.58)	0.54 (0.36, 0.71)	-15.02 (-16.74, -13.30)
Precipitation-$\delta^{18}O_{dweq}$	Tropics	**0.01** (0.00, 0.02)	0.22 (0.15, 0.30)	-0.00 (-0.00, -0.00)	-2.80 (-4.34, -1.26)
	Subtropics	**0.00** (0.00, 0.00)	0.48 (0.39, 0.57)	-0.00 (-0.00, -0.00)	-5.29 (-6.79, -3.79)
	Extratropics	**0.05** (0.01, 0.12)	0.14 (0.08, 0.20)	0.00 (0.00, 0.00)	-12.48 (-14.54, -10.43)
Evaporation-$\delta^{18}O_{dweq}$	Tropics	0.27 (0.06, 0.56)	0.04 (0.01, 0.10)	0.00 (-0.00, 0.00)	-7.19 (-9.92, -4.45)
	Subtropics	0.08 (0.01, 0.21)	0.18 (0.08, 0.30)	-0.00 (-0.01, -0.00)	-5.58 (-8.24, -2.91)
	Extratropics	**0.04** (0.00, 0.10)	0.17 (0.09, 0.26)	0.00 (0.00, 0.01)	-12.46 (-14.31, -10.60)
Temperature-$\delta^{13}C_c$	Tropics	0.61 (0.25, 0.96)	0.02 (0.00, 0.05)	-0.16 (-0.68, 0.36)	-2.88 (-16.09, 10.32)
	Subtropics	0.77 (0.57, 0.97)	0.02 (0.00, 0.07)	-0.10 (-0.77, 0.57)	-4.29 (-15.20, 6.63)
	Extratropics	**0.04** (0.01, 0.08)	0.18 (0.13, 0.24)	-0.27 (-0.47, -0.06)	-4.86 (-6.86, -2.85)
Precipitation-$\delta^{13}C_c$	Tropics	0.65 (0.31, 0.96)	0.01 (0.00, 0.04)	0.00 (-0.00, 0.00)	-7.47 (-10.01, -4.93)
	Subtropics	0.69 (0.57, 0.82)	0.04 (0.01, 0.07)	0.00 (-0.00, 0.00)	-6.75 (-11.55, -1.96)
	Extratropics	0.60 (0.25, 0.95)	0.02 (0.00, 0.06)	-0.00 (-0.00, 0.00)	-6.44 (-9.16, -3.72)
Evaporation-$\delta^{13}C_c$	Tropics	0.65 (0.31, 0.96)	0.01 (0.00, 0.04)	0.00 (-0.00, 0.00)	-7.90 (-11.92, -3.87)
	Subtropics	0.75 (0.50, 0.97)	0.03 (0.00, 0.10)	0.00 (-0.01, 0.01)	-6.45 (-12.95, 0.05)
	Extratropics	0.15 (0.04, 0.32)	0.10 (0.04, 0.17)	-0.00 (-0.01, 0.00)	-5.31 (-7.58, -3.05)
Latitude-$\delta^{18}O_{dweq}$		**0.00**	0.22	-0.06 (-0.09, -0.04)	-6.46 (-7.16, -5.74)
Altitude-$\delta^{18}O_{dweq}$		**0.00**	0.33	-0.00 (-0.00, -0.00)	-5.41 (-6.20, -4.61)
Latitude-$\delta^{13}C_c$		0.77	0.00	-0.00 (-0.03, 0.02)	-6.83 (-7.68, -5.99)
Altitude-$\delta^{13}C_c$		0.43	0.01	0.00 (-0.00, 0.00)	-7.23 (-8.17, -6.28)

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