Supplementary tables for

Palaeoclimate constraints on a world with post-industrial warming of 2 degrees and beyond

by Fischer et al., Nature Geoscience

Supplementary Table S1 – Average CO_2 concentrations for the time intervals discussed in the manuscript

Time period	Date	Concentration	SD	Reference
	1750-1800	279 ppm	3 ppm	(*1*) and references therein
Baseline period	1850-1900	290 ppm	4 ppm	(*1*) and references therein
RCP2.6	2100	421 ppm		(*2*)
RCP8.5	2100	936 ppm		(*2*)
HTM	10-5 ka BP	262 ppm	3 ppm	(*1*) and references therein
LIG	129-116 ka BP	276 pm	4 ppm	(*1*) and references therein
LIG warm period	124.5-125.5 ka BP	278 ppm	3 ppm	(*1*) and references therein
MPWP	3.3-3 Ma BP	366 ppm	42 ppm	(*3, 4*)
EECO	53-51 Ma BP	1400 ppm	470 ppm	(*5*)

References for Table S1

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Supplementary Table S2 - Global mean temperature anomalies relative to preindustrial (1850-1900) for the time intervals discussed in the manuscript. Note that for the LIG estimate we used the global SST estimate by ref.[3] and used a scaling factor of 1.6 to translate global SST to global surface air temperatures[4].

Time period	Date	Temperature (^{o}C)	SD	Reference
Baseline period	1850-1900	0		By definition
RCP2.6	2080-2100	0.9-2.4 (5-95% confidence interval)		(*1*)
RCP8.5	2080-2100	3.2-5.5 (5-95% confidence interval)		(*1*)
HTM	10-5 ka BP	0.7	0.4	(*2*)
LIG warm period	125 ka BP	0.8	0.5	(*3,4*)
MPWP	3.3-3 Ma BP	3.8	0.8	(*5,6*)
EECO	53-51 Ma BP	13	3	(*7*)

References for Table S2

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Supplementary Table S3 - Greenland or Arctic temperature anomalies relative to preindustrial (1850-1900) for the time intervals discussed in the manuscript.

Time period	Date	Temperature	SD	Reference
Baseline period	1850-1900	0		By definition
RCP2.6	2100	2.8	1.7	(*1*)
RCP8.5	2100	8.9	1.9	(*1*)
HTM	10-5 ka BP	2.5	0.6	Greenland: (*2*)
LIG warm period	125 ka BP	8.5	2.5	Greenland: (*3*)
MPWP	3.3-3 Ma BP	~8		North Atlantic high latitude SST: (*4*)

References for Table S3

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Supplementary Table S4 - Antarctic temperature anomalies relative to preindustrial (1850-1900) for the time intervals discussed in the manuscript

Time period	Date	Temperature	SD	Reference
Baseline period	1850-1900	0		By definition
RCP2.6	2080-2100	0.8	0.6	(*1*)
RCP8.5	2080-2100	3.1	1.2	(*1*)
HTM	10-5 ka BP	-0.6	0.9	(*2, 3*)
LIG warm period	124.5-125.5 ka BP	2-6		(*2, 4*)
MPWP	3.3-3 Ma BP	~2		Southern Ocean sites: (*5*)

References for Table S4

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Supplementary Table S5 - Evidence for changes in Last Interglacial monsoons

	proxies	Direction of change, intensity	uncertainties
Indian monsoon	Speleothem $\delta^{18}O$[1]	+ precipitation (? no actual season)	Temperature, source and circulation regime effect.
	Speleothem $\delta^{18}O$[2]	+ precipitation	Temperature, source and circulation regime effect.
	Speleothem $\delta^{18}O$[3]	+ precipitation	Temperature, source and circulation regime effect. + Threshold level
	Marine sediment core: Arabian sea monsoon stack[4,5]	+ precipitation (no change in (*5*))	Proxies related to winds effect.
East Asian monsoon	Speleothem $\delta^{18}O$[6,7]	+ precipitation (annual?)	Temperature, source and circulation regime (Indian monsoon) effect, seasonality (annual mean rather than summer).
	Leaf waxes δD in loess[8]	+ precipitation (annual)	Temperature, source and circulation regime (Indian monsoon) effect, seasonality (annual mean rather than summer). +aridity

	Speleothem growth frequency[9]	+ precipitation ?	reinforcement of surficial vegetation productivity and soil depth under clearly favourable climatic conditions, Threshold effect.
	Pollen[10]	+ precipitation	Age model
	Loess MS[11,12]	+ precipitation (no change for (12))	kinetics of chemical weathering and biotic activities (temperature, pCO2, winter monsoon effect)
	Loess Fed/Fet[13]	+ precipitation	kinetics of chemical weathering and biotic activities (temperature, pCO2, winter monsoon effect)
	Loess Microcodium Sr/Ca ratio in Loess[14]	+ precipitation (quantification of precipitation)	calibration of the proxy, temperature
	Loess grainsize and brGDGTs (pH)[15]	No changes	Source of brGDGTs
North Africa monsoon	Marine sediment core: XRF[16] and model[17] with XRF[18] data.	+ precipitation (runoff)	Vegetation role on sediment load.
	Speleothem[19-21]	+ precipitation (annual?)	Temperature, source and circulation regime effect.

	Marine sediment core: Sapropel[16,22]	+ precipitation	Sea level and export production and deep-water ventilation control on sapropel formation
	Marine sediment core: $\delta^{18}O$ residual+sapropel[23]	+ precipitation	Sea level and export production and deep-water ventilation control on sapropel formation
West Africa monsoon	Marine sediment core: Ba/Ca and $\delta^{18}O_{sw}$[24]	No change for $\delta^{18}O_{sw}$ (but probably biased for the late Holocene[25] + precipitation for Ba/Ca	source and circulation regime effect, advection. Change of source in the catchment for Ba/Ca.
	Marine sediment core: XRF and δD leaf waxes[26] (Cape Verde plateau)	+ precipitation	Age model
	Marine sediment core: Al/K as congo river discharge[27] (Central Africa)	+ precipitation	Control on element chemistry
	Marine sediment core: Si/Al with XRF[28] (Northwest Africa)	No change	Control on element chemistry

South Africa monsoon	Marine sediment core : δD leaf waxes[29]	- precipitation	plant physiological versus climatic parameters, seasonal timing of leaf wax formation, relative humidity, Temperature, source and circulation regime effect.
	Marine sediment core: Grain size aridity index[30]	- precipitation	
	Pretoria saltpan lake : Soil texture[31]	- no change	Age model
	Marine sediment core : Fe/K XRF[32]	- precipitation	runoff variability and associated soil erosion without any prior changes in bedrock weathering
	$\delta^{13}C$ leaf waxes[33] (Lake Malawi, 11°S)	no change	plant physiological versus climatic parameters, seasonal timing of leaf wax formation, Effect of vegetation
Australia-Indonesia monsoon	Speleothem $\delta^{18}O$ Borneo[34] (Hadley circulation)	No change or slightly less precipitation.	Temperature, source and circulation regime effect.

	Marine sediment core: Pollen[35] (5°S)	- precipitation	
	Speleothem growth frequency[36]	-precipitation	Temperature and other cave effects.
	Marine sediment core: Nd/Ca in foraminifera[37] (9°S).	no change	Source of Nd?
South America monsoon	Speleothem $\delta^{18}O$[38,39]	-precipitation	Temperature, source and circulation regime effect.
	Growth intervals of speleothem and young travertine[40]	-precipitation	Threshold level, cave effects
	Speleothem $\delta^{18}O$[41] (western Amazonia)	-precipitation	Temperature, source and circulation regime effect.
North America monsoon	Marine sediment cores: XRF[42] (5,9 and 12°N)	Slightly + precipitation	Source of elements

References for Table S5

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Supplementary Table S6 - LIG Vegetation evidence
Excel file: www_TableS6.xlsx

Supplementary Table S7 - LIG Fire evidence
Excel file: www_TableS7.xlsx

Supplementary Table S8: Model projections of CO_2 (ppm), Global Average Surface Air Temperature Rise ($\Delta SAT\ ^oC$), and Eustatic Sea Level Rise (ESL, m), relative to pre-industrial (PI) baseline (here the model average and uncertainty for the century 1800-1900AD). Data are averages and $\pm 1\sigma$ uncertainties calculated multi-model ensemble over the years 10,000-12,000AD in transient model runs from four models that consider eight extended CO_2 emissions scenarios (Clark et al., 2016). Time interval reflects an approach to ESL equilibrium but postdate peak CO_2 and temperatures. For the 160, 320, 640, and 960 GtC scenarios, uncertainties estimated from fractional anomalies in multi-model ensembles proportional to CO_2

Emission Scenarios		PI - 0 GtC	160 GtC	320 GtC	640 GtC	960 GtC	1280 GtC	2560 GtC	3840 GtC	5120 GtC
CO_2 (ppm)	Average	289.1	335.4	348.6	371.8	399.2	420.2	642.4	910.6	1243.2
	Uncertainty	2.0	0.2	0.3	0.2	1.9	80.8	80.6	114.5	142.2
$\Delta SAT\ (^oC)$	Average	0.00	0.90	1.10	1.41	1.77	2.14	3.77	5.33	7.05
	Uncertainty	0.10	0.03	0.03	0.03	0.04	0.85	0.56	0.35	0.57
ESL Rise (m)	Average	0.00	1.72	3.50	12.17	16.89	24.80	37.46	45.69	51.94
	Uncertainty	0.14	0.10	0.15	0.32	0.21	3.42	2.46	2.08	2.42
Notes		*UVic+Bern*	*UVic*	*UVic*	*UVic*	*UVic*	*UVic+Bern*	*UVic+Bern*	*UVic+Bern*	*UVic+Bern*

Supplementary Table S9: Projected peak future eustatic sea-level rise rates in response to warming (cm/yr) includes ice melting and steric effects, and associated coeval global average surface temperature anomalies ΔSAT °C (after Clark et al., 2016). Uncertainties are $\pm 1\sigma$ among multi-model ensembles. For the 160, 320, 640, and 960 GtC scenarios where a single model was run, uncertainties are estimated from fractional anomalies in multi-model ensembles.

Emission Scenarios		PI - 0 GtC	160 GtC	320 GtC	640 GtC	960 GtC	1280 GtC	2560 GtC	3840 GtC	5120 GtC
Peak ESL Rise Rate (cm/yr)	Century	19th	23rd	23rd	23rd	23rd	23rd	26th	25th	25th
	Rate	0.00	0.14	0.25	0.37	0.51	0.70	1.57	2.50	3.28
	Uncertainty	0.00	0.02	0.04	0.06	0.08	0.11	0.17	0.48	0.79
Coeval Temperature (°C)	DSAT	0.00	1.09	1.35	1.94	2.51	2.51	4.90	6.55	8.05
	Uncertainty	0.10	0.44	0.54	0.77	1.00	1.09	1.12	0.87	0.29
Notes		*UVic+Bern*	*UVic*	*UVic*	*UVic*	*UVic*	*UVic+Bern*	*UVic+Bern*	*UVic+Bern*	*UVic+Bern*

Supplementary Table S10: Estimated CO_2, global average surface air temperature rise (ΔSAT), and eustatic sea Level (ESL) rise, for past warm events based on paleoclimatic data for the Holocene Thermal Maximum (HTM), Last Interglacial (LI), Mid-Pliocene Warm Period (MPWP,) and Early-Eocene Climatic Optimum (EECO). Ages are before present (BP). Uncertainties are ±1σ estimates, asymmetrical for sea level. No sea level is given for HTM, because this is a transient event far from equilibrium.

Event	:	HTM	LIG	MPWP	EECO
Age		6-9 ka	116-129 ka	3.3-3.0 ma	48-54 ma
CO_2 (ppm)	Value	262	276	366	1400
	Uncertainty	3	4	42	470
ΔSAT (^{o}C)	Value	0.7	0.8	3.8	13
	Uncertainty	0.4	0.5	0.8	3
ESL Rise[1] (m)	Value	n/a	7.5	6	70
	Uncertainty -	n/a	1.5	0	7
	Uncertainty +	n/a	1.5	>30	4

Notes [(1)] Eustatic sea levels for LIG, MPWP follow Dutton et al., (2015). Effective sea level for EECO assumes complete melting of preindustrial ice inventory (63 +3 -6m) plus steric effects for warming of 10 ± 2 ^{o}C (full ocean depth, 7 ± 1 m) but excludes changes in ocean basin geometry as irrelevant to future projection. For the steric height calculation, the mean change in density is 0.133 kg m^{-3}°C^{-1} over the temperature range 3-21 degrees, and here we assumed a temperature change of 10 ± 2 °C relative to modern, applied over the full ocean depth. This yields a steric sea level change of 7 ± 1 m

Supplementary Table S11. Model EECO Global Average Surface Air Temperatures (SAT, ^oC) for varying CO_2-equivalent (ppm). Anomalies (DT, ^oC) relative to preIndustrial (PI) and EECO boundary conditions (BC)[1]. Ensembles are averages and standard deviations of runs within CO_2 classes.

Model	CO_2 (ppm)	EECO SAT (^oC)	EECO BC[1] (^oC)	PI BC[2] (^oC)	EECO BC Effect[3] (^oC)	DT EECO - EECO BC (^oC)	DT EECO - PI BC (^oC)	Ensemble DT EECO - EECO BC (^oC)	Ensemble DT EECO - PI control (^oC)	Reference
1X CO_2 baseline										
UVic	280	15.19	15.19	13.24	1.95	0.00	1.95	0.00 $\pm$ 0.00	.43 $\pm$ 1.22	Meissner et al., 2014
HadCM3L	280	14.60	14.60	12.80	1.80	0.00	1.80			Lunt et al., 2010
CCSM-W	280	14.90	14.90	13.10	1.80	0.00	1.80			Lunt et al., 2012
CCSM-H	280	17.10	17.10	13.00	4.10	0.00	4.10			Lunt et al., 2012
ECHAM	280	18.50	18.50	14.70	3.80	0.00	3.80			Lunt et al., 2012
GISS	280	14.90	14.90	13.80	1.10	0.00	1.10			Roberts et al., 2011
2X CO_2										
HadCM3L	560	18.54	14.60	12.80	1.80	3.94	5.74	4.50 $\pm$ 0.90	7.73 $\pm$ 1.83	Lunt et al., 2010
CCSM-H	560	21.12	17.10	13.00	4.10	4.02	8.12			Lunt et al., 2012
ECHAM	560	24.03	18.50	14.70	3.80	5.53	9.33			Lunt et al., 2012
4X CO_2										
HadCM3L	1120	21.95	14.60	12.80	1.80	7.35	9.15	6.42 $\pm$ 0.81	9.06 $\pm$ 1.16	Lunt et al., 2010
CCSM-W	1120	20.95	14.90	13.10	1.80	6.05	7.85			Lunt et al., 2012
CCSM-H	1120	23.17	17.30	13.00	4.30	5.87	10.17			Lunt et al., 2010; 2012
6X CO_2										
HadCM3L	1680	24.56	14.60	12.80	1.80	9.96	11.76	9.23 $\pm$ 1.03	11.11 $\pm$ 0.93	Lunt et al., 2010
UVic	1680	23.69	15.19	13.24	1.95	8.50	10.45			Meissner et al., 2014
8X CO_2										
CCSM-W	2240	23.59	14.90	13.10	1.80	8.69	10.49	8.59 $\pm$ 0.14	11.64 $\pm$ 1.63	Lunt et al., 2012
CCSM-H	2240	25.79	17.30	13.00	4.30	8.49	12.79			Lunt et al., 2012
16X CO_2										
CCSM-W	4480	26.46	14.90	13.10	1.80	11.56	13.36	11.87 $\pm$ 0.43	14.92 $\pm$ 2.20	Lunt et al., 2012
CCSM-H	4480	29.47	17.30	13.00	4.30	12.17	16.47			Lunt et al., 2012
Unique Runs, not included in ensembles due to differing CO_2										
UVic	840	20.42	15.19	13.24	1.95	5.23	7.18			Meissner et al., 2014
GISS	1204	24.90	14.90	13.80	1.10	10.00	11.10			Roberts et al. 2011; Lunt et al., 2012 (4)
UVic	2520	25.60	15.19	13.24	1.95	10.41	12.36			Meissner et al. 2014

Notes. 1) EECO BC is PI + EECO Land Surface Albedo Effect. (2) Models Run with Pre-Industrial boundary conditions, CO_2 = 280-290 ppm. (3) Land surface component of temperature change due to EECO boundary conditions, including continental configuration, elevation, and removal of ice cover (Lunt et al., 2012). 4) SAT = skin temperature + 1.5^oC