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Supplement of

Detection and explanation of spatiotemporal patterns in Late Cenozoic palaeoclimate change relevant to Earth surface processes

Sebastian G. Mutz and Todd A. Ehlers

Correspondence to: Sebastian G. Mutz (sebastian.mutz@uni-tuebingen.de)

South Alaska

Large scale patterns and modes of climate change

The geographical subdivisions of South Alaska in the LGM and PLIO (Fig. S10 b,c) results are more stable than clusters calculated for the MH. LGM-C_1 and LGM-C_2 experience a strong decrease in 2m air temperature, air temperature amplitude and freeze-thaw days, as well as increases in consecutive freezing days and meridional wind speeds (Fig. S10 e). LGM-C_4 is the only cluster not covered with ice during the LGM, and characterised by increases in consecutive dry days and 2m air temperature amplitude, and decreases in consecutive wet days, maximum precipitation and zonal wind speeds (Fig. S10 e). The geographically dominant modes of changes in the PLIO are PLIO-C_3 and PLIO-C_4. The former is has a more continental setting and is characterised by increases in consecutive wet days, maximum precipitation, 2m air temperature, while the latter is a mode of change observed in greater coastal proximity and characterised by moderate increases in 2m air temperature and zonal wind speeds only (Fig. S10 f).

Discriminability

Clusters in the LGM and PLIO are associated with higher discrimination scores than the MH. LGM-C_2 and LGM-C_3 have the highest discriminability cause primarily by changes in meridional winds (30%-40%) and maximum precipitation (40%-50%) and consecutive freezing days (10%-20%) respectively (Fig. S10 e). PLIO-C_1 and PLIO-C_2 show highest discriminability in the PLIO, which is contributed to most by 2m air temperature amplitude (Fig. S10 f).

Figures

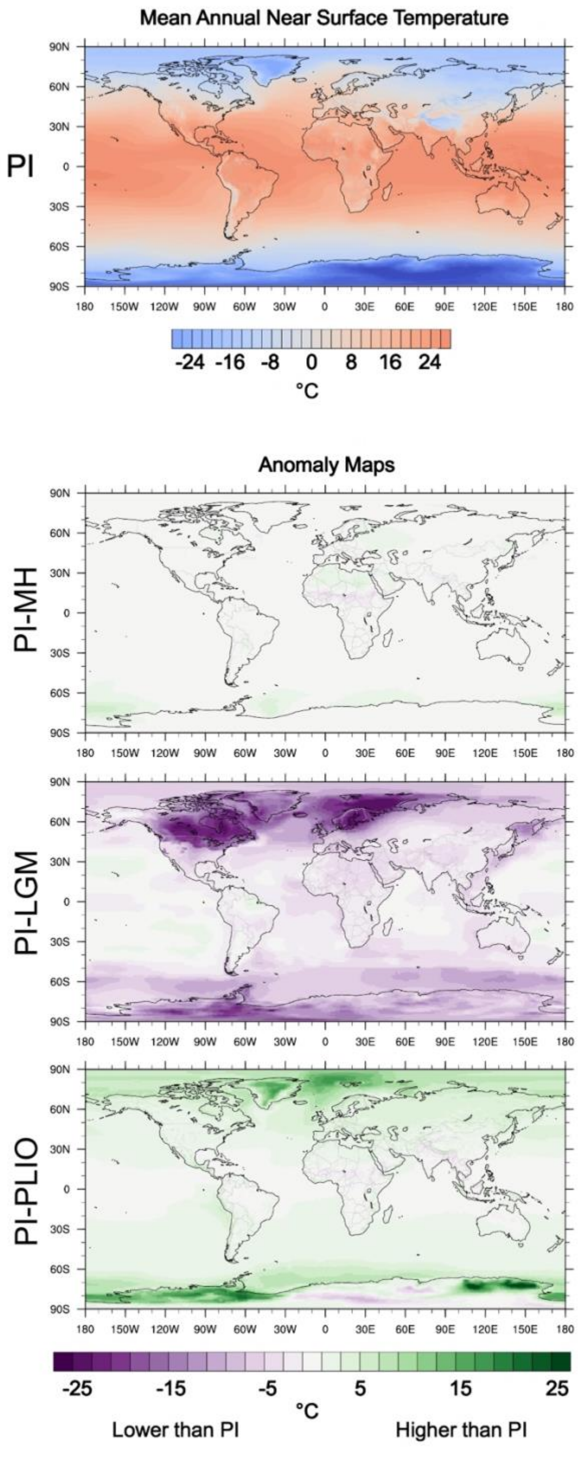


Fig. S01

S01: Pre-industrial (PI) mean annual near surface temperature, and differences in mean annual near surface temperature values between PI and Mid-Holocene (PI-MH), PI and Last Glacial Maximum (PI-LGM), and PI and Late Pliocene (PI-PLIO) climates.

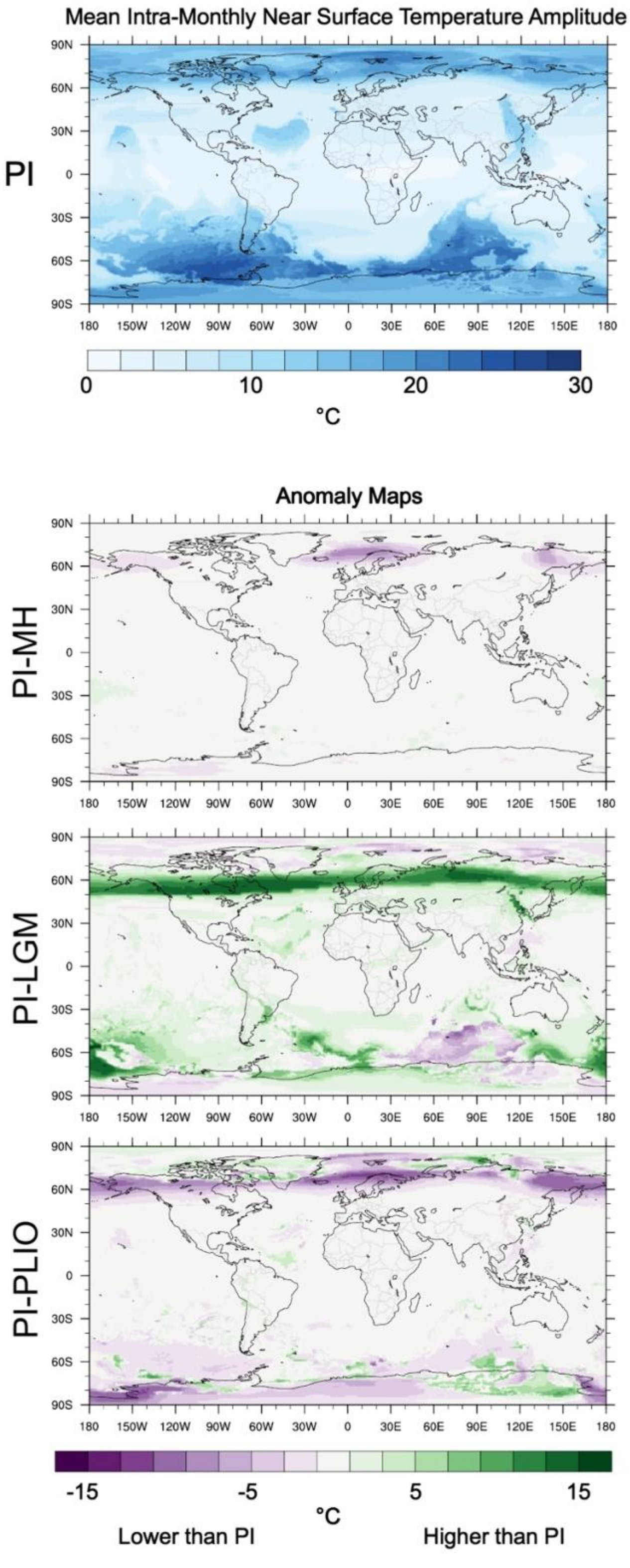


Fig. S02

S02: Pre-industrial (PI) mean intra-monthly near surface temperature amplitude, and differences in mean intra-monthly near surface temperature amplitude values between PI and Mid-Holocene (PI-MH), PI and Last Glacial Maximum (PI-LGM), and PI and Late Pliocene (PI-PLIO) climates.

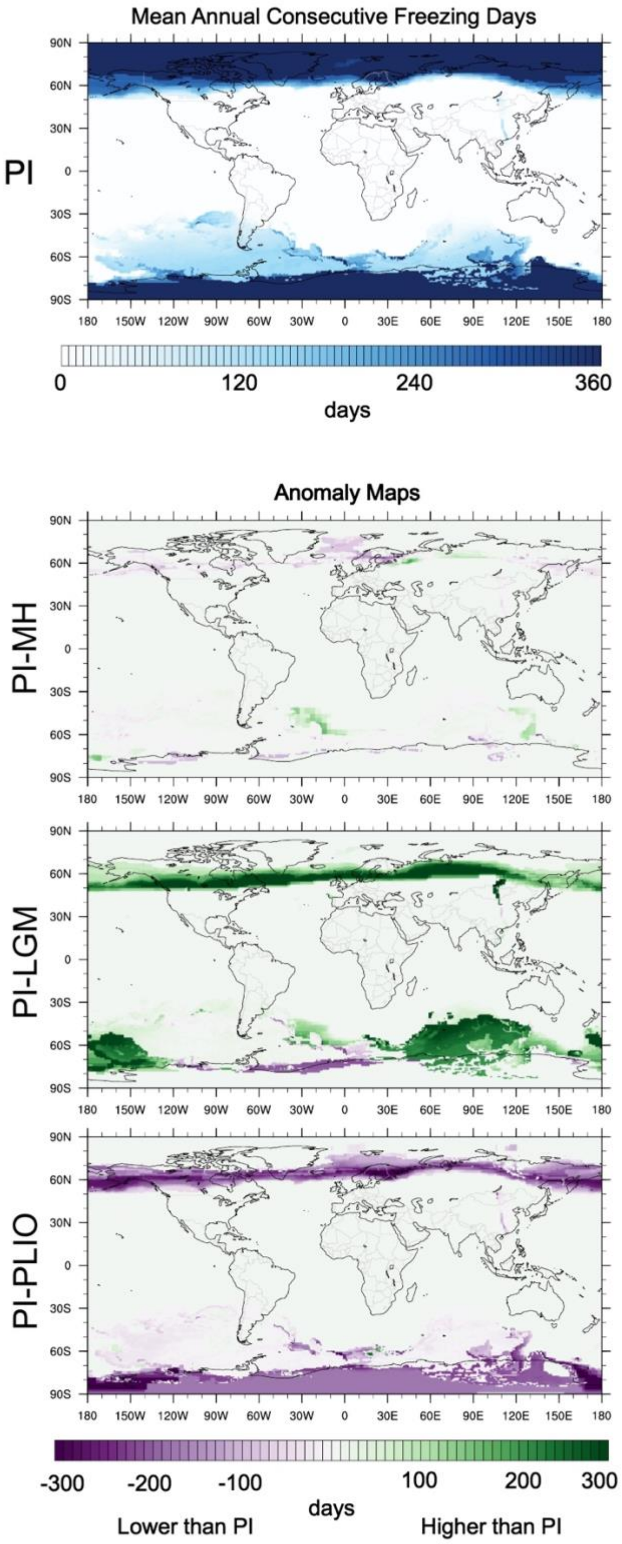


Fig. S03

S03: Pre-industrial (PI) mean annual consecutive freezing days, and differences in mean annual consecutive freezing days between PI and Mid-Holocene (PI-MH), PI and Last Glacial Maximum (PI-LGM), and PI and Late Pliocene (PI-PLIO) climates.

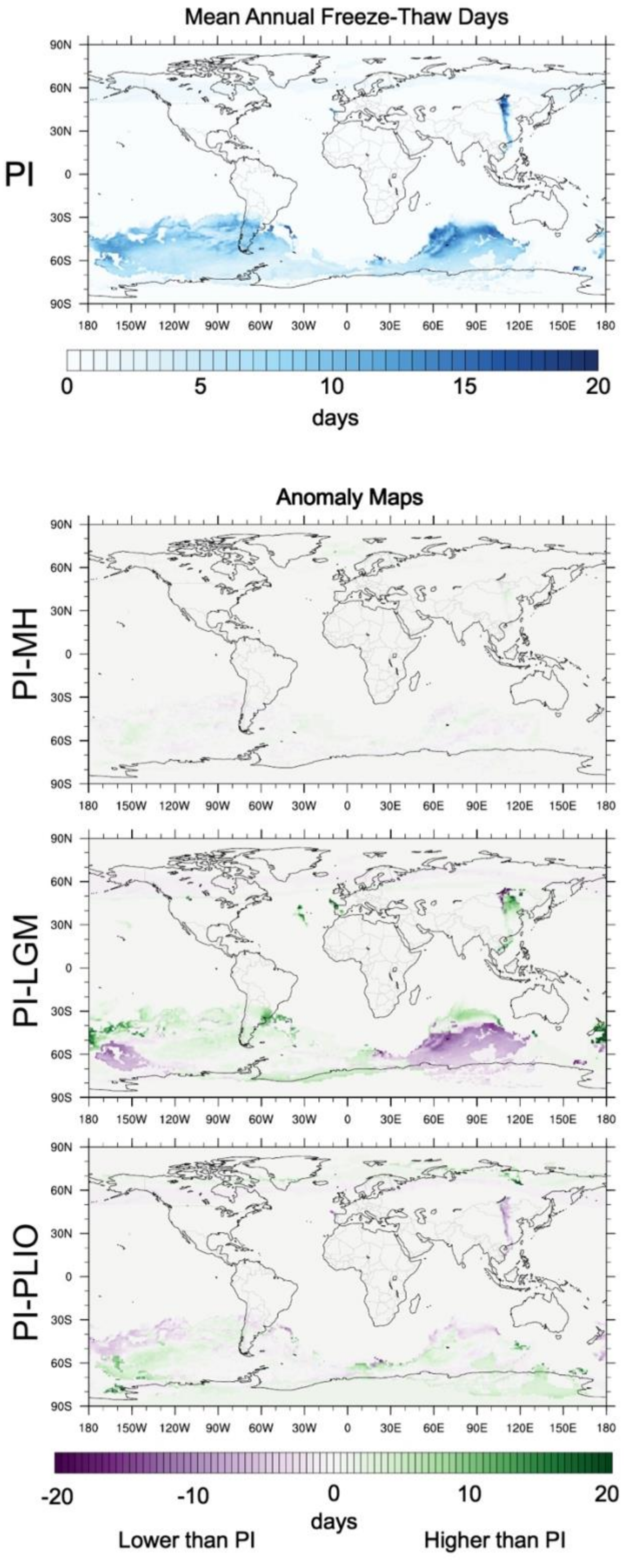


Fig. S04

S04: Pre-industrial (PI) mean annual freeze-thaw days, and differences in mean annual freeze-thaw days between PI and Mid-Holocene (PI-MH), PI and Last Glacial Maximum (PI-LGM), and PI and Late Pliocene (PI-PLIO) climates.

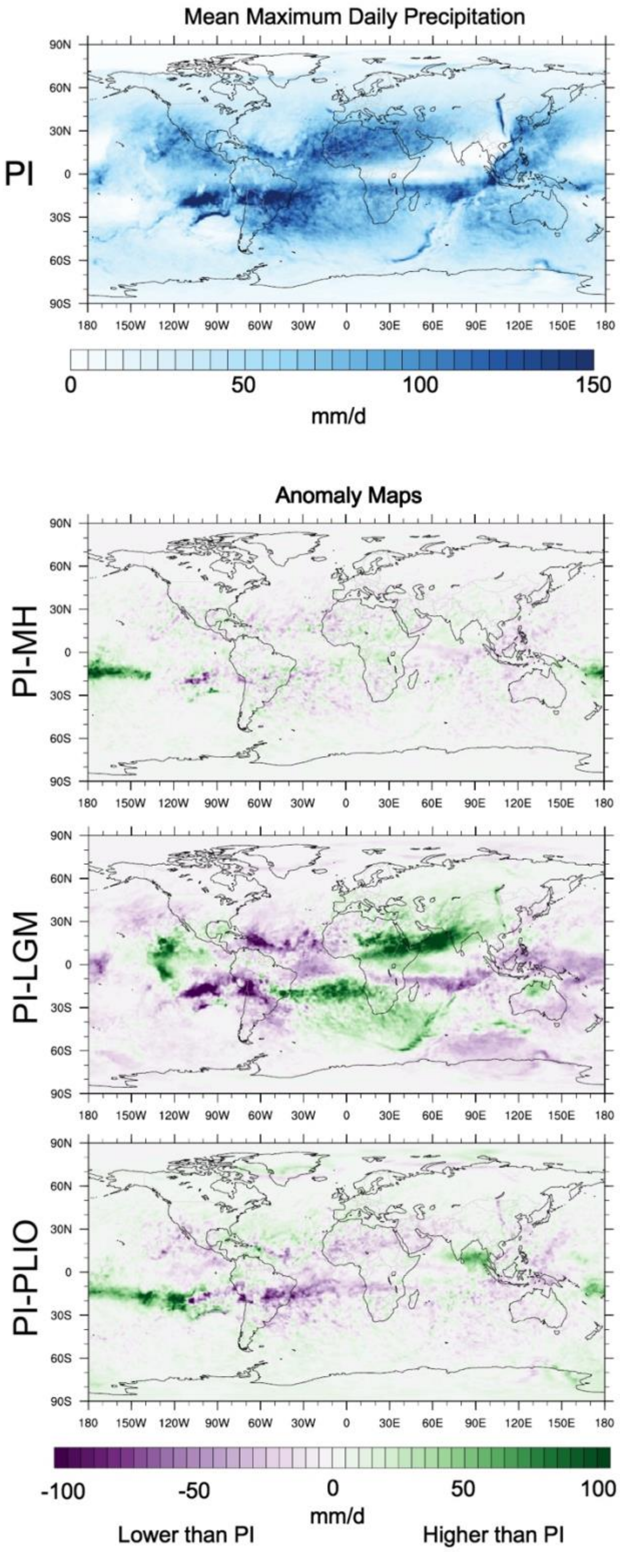


Fig. S05

S05: Pre-industrial (PI) annual mean of maximum daily precipitation, and differences in annual mean of maximum daily precipitation values between PI and Mid-Holocene (PI-MH), PI and Last Glacial Maximum (PI-LGM), and PI and Late Pliocene (PI-PLIO) climates.

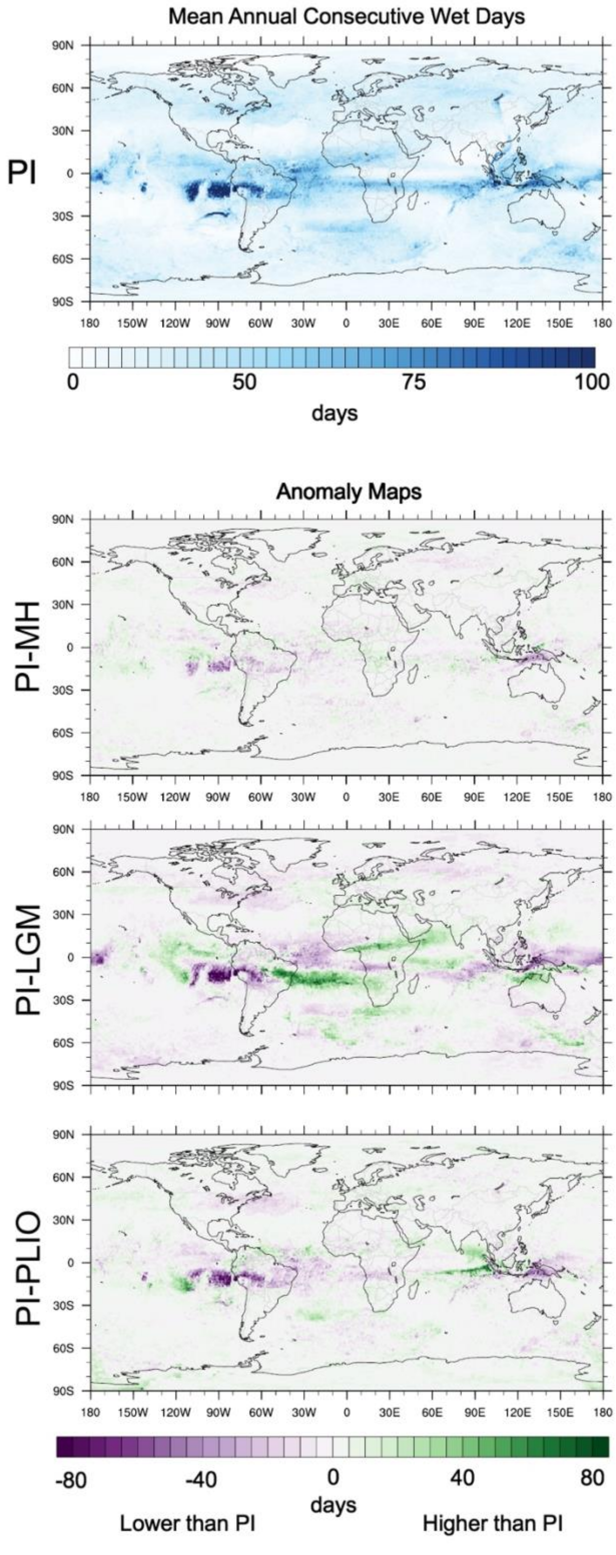


Fig. S06

S06: Pre-industrial (PI) mean annual consecutive wet days, and differences in mean annual consecutive wet days between PI and Mid-Holocene (PI-MH), PI and Last Glacial Maximum (PI-LGM), and PI and Late Pliocene (PI-PLIO) climates.

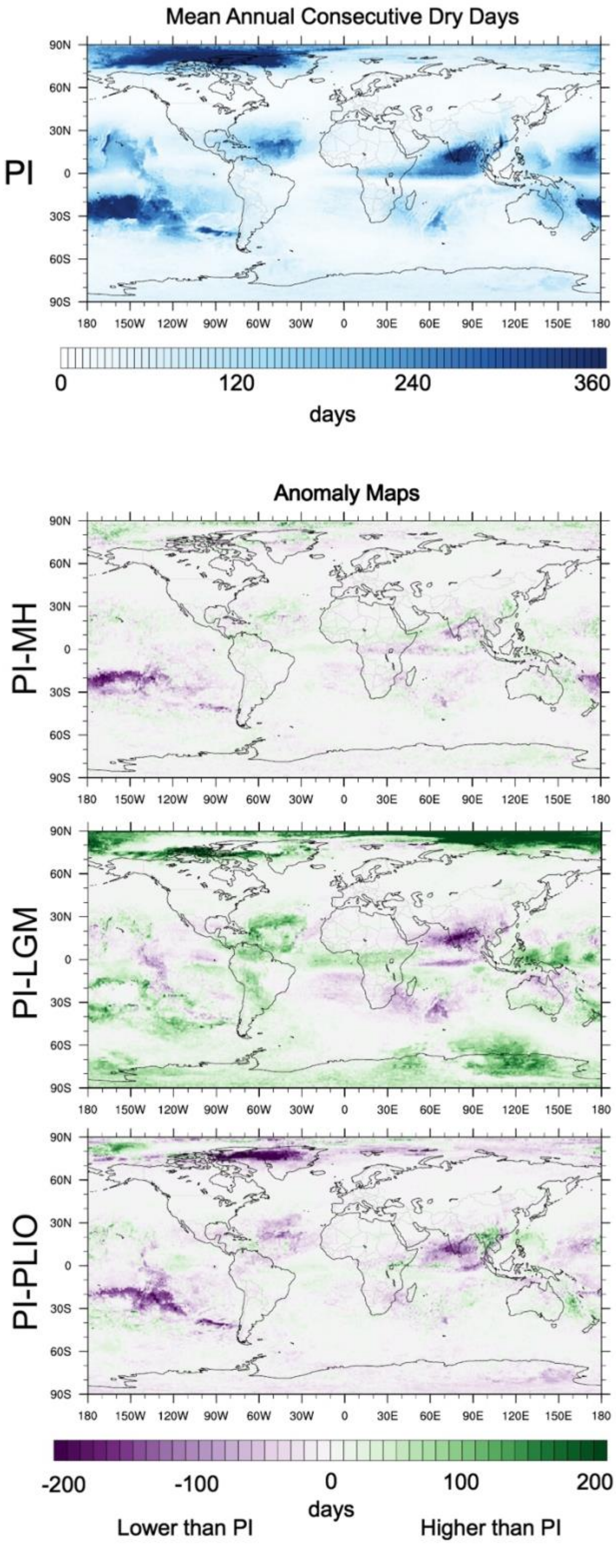


Fig. S07

S07: Pre-industrial (PI) mean annual consecutive dry days, and differences in mean annual consecutive dry days between PI and Mid-Holocene (PI-MH), PI and Last Glacial Maximum (PI-LGM), and PI and Late Pliocene (PI-PLIO) climates.

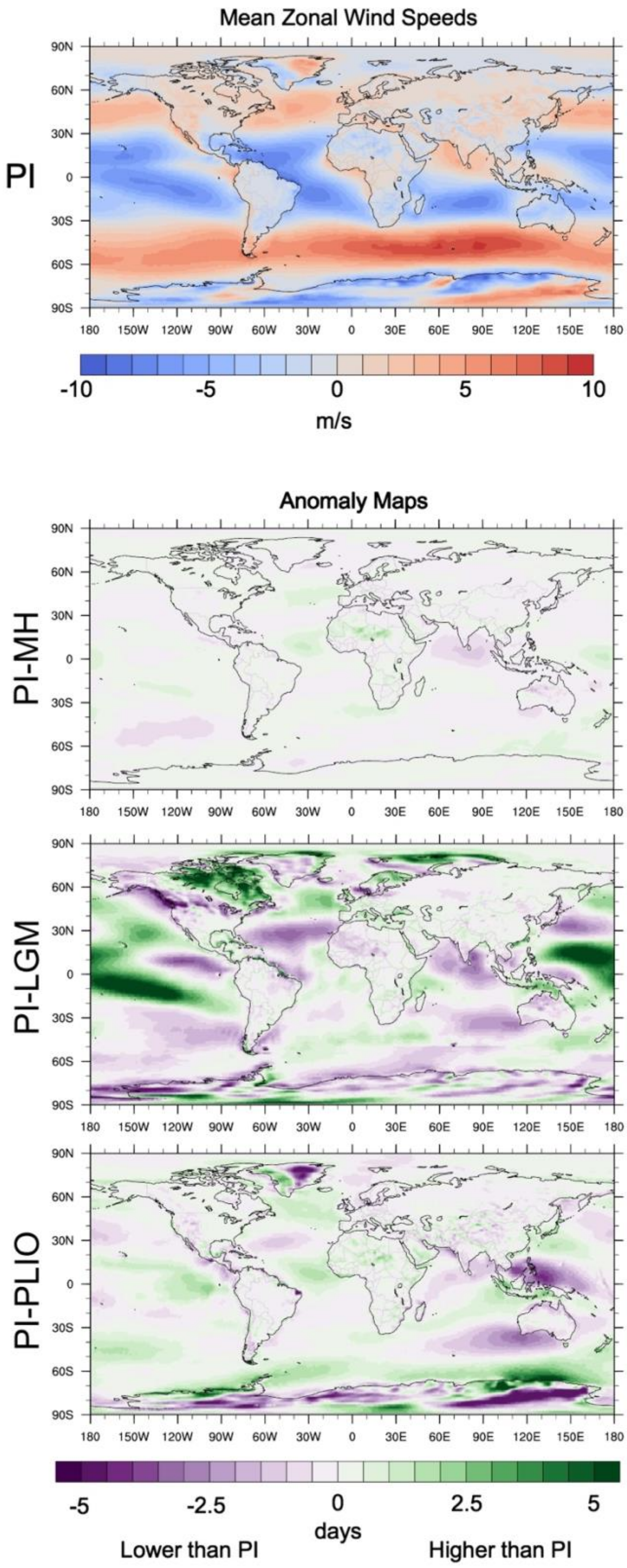


Fig. S08

S08: Pre-industrial (PI) mean zonal wind speeds, and differences in mean zonal wind speeds between PI and Mid-Holocene (PI-MH), PI and Last Glacial Maximum (PI-LGM), and PI and Late Pliocene (PI-PLIO) climates.

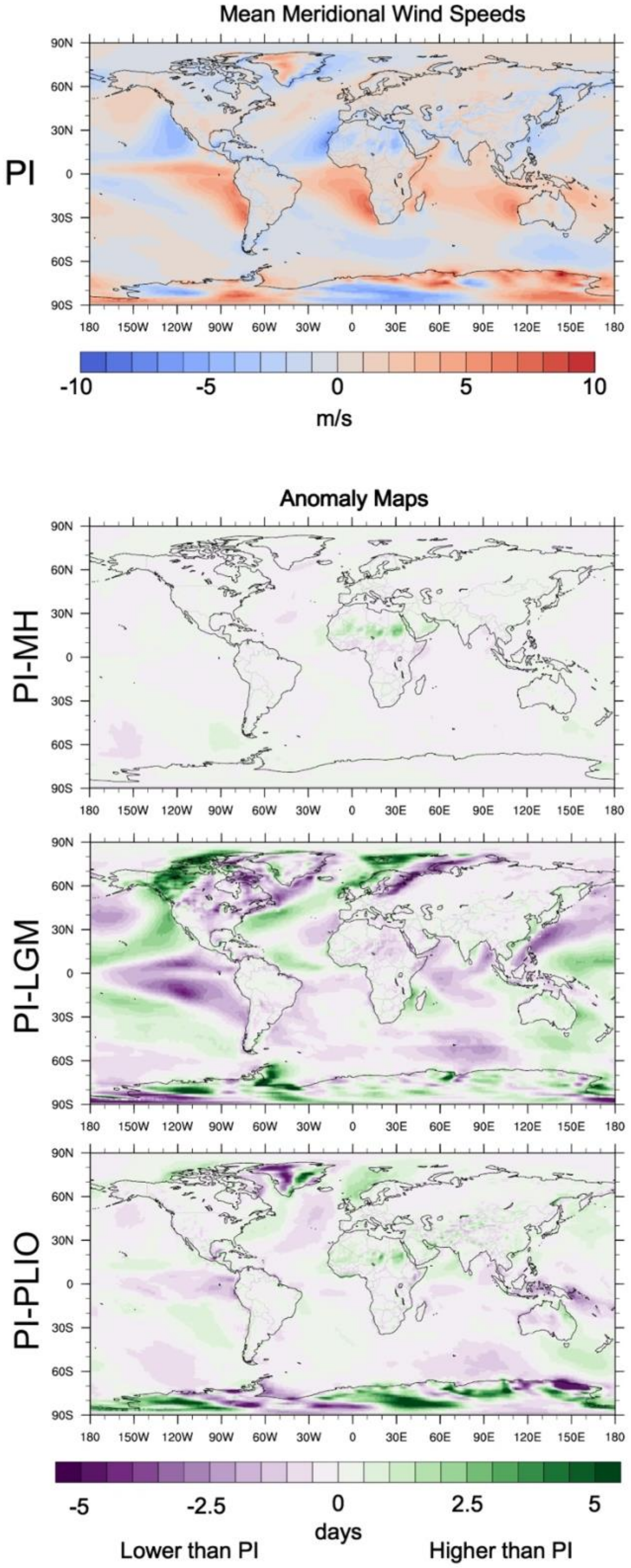
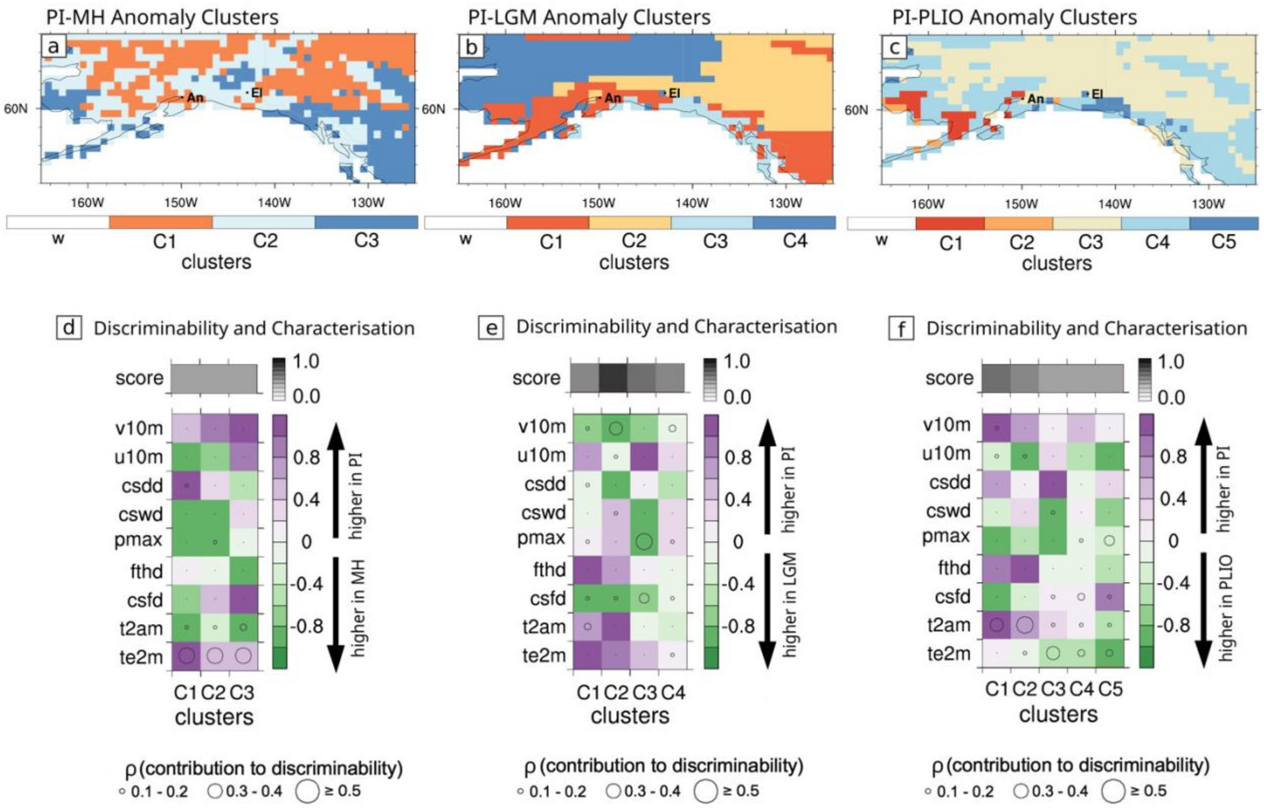


Fig. S09

S09: Pre-industrial (PI) mean meridional wind speeds, and differences in mean meridional wind speeds between PI and Mid-Holocene (PI-MH), PI and Last Glacial Maximum (PI-LGM), and PI and Late Pliocene (PI-PLIO) climates.



S10: The multivariate anomaly maps for time slice comparisons PI-MH(a), PI-LGM(b) and PI-PLIO(c) show the geographical coverage of clusters C_1-C_i in Southwest Alaska, which describe the spatial extend of regions characterised by similar modes of change. The corresponding modes of change (d,e and f) for each cluster are expressed as relative changes in each of the 9 investigated variables: 2m air temperature (te2m), 2m air temperature amplitude (t2am), consecutive freezing days (csfd), freeze-thaw days (fthd), maximum precipitation (pmax), consecutive wet days (cswd), consecutive dry days (csdd), zonal near surface wind speeds (u10) and meridional near surface wind speeds (v10). The score (d,e and f) expresses the goodness of discriminability between the palaeoclimate pairs PI-MH(d), PI-LGM(e) and PI-PLIO(f) in each of the anomaly clusters. The size of the circles corresponds to the relative contribution of each of the 9 climatic attribute variables to the measured discriminability in each anomaly cluster for all three time slice comparisons.

South Alaska

	PI-MH Anomaly Clusters			PI-LGM Anomaly Clusters				PI-PLIO Anomaly Clusters				
cluster	C1	C2	C3	C1	C2	C3	C4	C1	C2	C3	C4	C5
v10 (m/s)	0.07	0.13	0.14	-2.22	-3.35	-2.39	-0.37	0.35	0.26	0	0.16	0.06
u10 (m/s)	-0.08	-0.06	0.07	1.94	-0.17	3.09	0.92	-0.07	-0.25	0.08	-0.1	-0.24
csdd (d)	1.44	0.41	-0.82	-0.52	-7.04	1	-3.67	2.1	0.55	2.77	-0.16	1.06
cswd (d)	-0.47	-0.44	0.14	-0.11	2.2	-4.1	1.57	-0.76	0.74	-2.25	0.31	-1.54
pmax (mm/d)	-0.88	-0.75	-0.17	1.39	4.37	-10.2	2.82	-1.99	-1.31	-2.34	-0.19	-0.72
fthd (d)	0	-0.01	-0.07	0.63	0.48	0.12	-0.04	0.92	0.98	-0.05	-0.19	-0.56
csfd (d)	-0.28	0.22	0.4	-13.36	-10.96	-8.07	-2.05	-13	-3.75	0.67	1.92	11.08
t2am (K)	-0.69	-0.17	-0.7	2.77	3.91	-0.04	-1.39	8.44	5.77	1.78	1.52	-4.05
te2m (K)	1.46	0.73	0.72	7.94	7.92	4.02	1.31	0.97	-0.73	-2.87	-3.05	-6.51

Western South America

	PI-MH Anomaly Clusters						PI-LGM Anomaly Clusters						PI-PLIO Anomaly Clusters					
cluster	C1	C2	C3	C4	C5	C6	C1	C2	C3	C4	C5	C6	C1	C2	C3	C4	C5	C6
v10 (m/s)	-1.01	0.05	0	0	0.02	-0.01	1.07	-0.25	1.08	0.33	-0.01	-0.08	0.12	0.03	-0.2	-0.34	-0.16	0.13
u10 (m/s)	-0.65	0.27	-0.14	-0.12	-0.05	0.03	1.26	-1.96	-1.53	0.11	0.15	0	0.43	-0.16	-0.04	-3.09	0.42	-0.37
csdd (d)	0.15	-1.27	0.94	0.56	-0.7	-2.81	-0.29	-3.94	0.28	0.96	-1.73	-1.45	3.95	-0.12	-2.21	-0.92	1.11	-0.36
cswd (d)	1.24	0.92	-0.78	-0.25	0.57	0.68	0.67	4.43	-0.36	-1.12	0.32	2.28	-2.11	-0.06	2.3	3.15	-0.08	5.41
pmax (mm/d)	1.1	0.33	-0.52	-0.13	2.67	4.45	-9.01	3.47	6.47	-1.81	-0.36	8.86	-4.07	1.43	10.14	0.99	0.3	8.57
fthd (d)	-0.01	-0.24	0.18	-0.07	0	0	0.12	1.25	1.19	-0.12	-0.62	-0.02	0.17	0.02	0.04	0.59	0.62	-0.99
csfd (d)	-0.08	-2.81	-1.7	0.1	0.03	0	-29.93	-24.23	-24.82	-0.9	-2.55	-0.12	1.26	0.12	0.27	3.31	5.97	26.73
t2am (K)	1.52	0.55	-0.47	0.08	0.09	-0.43	-2.98	-3.4	-1.01	-0.49	-4.64	0.07	0.97	0.75	0.32	-0.29	1.13	-4.66
te2m (K)	1.01	0.94	-0.05	-0.17	-0.46	-1.29	8.72	8.45	7.38	1.48	1.3	1.27	-0.97	-1.09	-2.05	-3.94	-4.62	-6.64

Europe

	PI-MH Anomaly Clusters						PI-LGM Anomaly Clusters						PI-PLIO Anomaly Clusters							
cluster	C1	C2	C3	C4	C5	C6	C1	C2	C3	C4	C5	C6	C1	C2	C3	C4	C5	C6	C7	C8
v10 (m/s)	-0.12	-0.05	0.01	-0.53	0.13	-0.07	-1.31	3.17	0.43	-1.87	0.15	0.01	-0.64	-0.37	-0.48	-0.09	-0.02	0.15	0.06	0.05
u10 (m/s)	-0.03	0.08	-0.05	-0.2	0.21	-0.43	-0.98	0.11	1.15	-0.74	0.01	-0.2	0.22	0.56	-0.64	0.19	0.14	0.03	0	0.17
csdd (d)	-0.32	0.52	-0.32	1.36	0.26	-2.31	-5.75	-4.97	-0.86	2.76	-4.33	-0.57	1.87	-2.38	0	-0.16	0.79	2.05	-1.66	-0.56
cswd (d)	0.11	-0.32	-0.23	-0.64	-0.54	-1.93	3.44	1.76	0.02	-5.71	1.73	0.35	-1.47	2.79	-0.28	-0.19	-0.95	-1.09	0.55	1.8
pmax (mm/d)	0.25	-1.34	-0.41	-1.8	-1.71	-0.52	9.79	1.55	2.48	1.76	4.77	2.28	-5.41	0.36	-0.33	-0.25	-0.43	-1.09	2.15	1.97
fthd (d)	0.01	0.01	-0.12	0.01	0	0.06	0.6	0.55	0.7	0.49	-0.26	-0.18	0.05	-0.33	0.05	0.06	0.2	-0.23	0.28	-0.33
csfd (d)	-0.27	0.22	0.77	0.19	0.03	9.88	-14.74	-15.04	-22.66	-28.19	-3.39	-2.69	0.27	-2.29	0.48	0.49	2.76	2.74	2.65	8.47
t2am (K)	-0.18	-0.06	0.43	-0.29	-1.18	0.02	-2.31	0.08	-4.89	-4.34	-4.63	-2.56	0.12	-2.31	-0.13	0.16	1.38	2.32	0.89	3.03
te2m (K)	-0.16	-0.41	-0.62	-0.71	-1.34	-1.44	19.84	18.32	18.05	13.84	6.32	4.32	-1.16	-1.66	-1.68	-2.11	-3.29	-3.85	-3.86	-6.42

Himalaya-Tibet

	PI-MH Anomaly Clusters					PI-LGM Anomaly Clusters						PI-PLIO Anomaly Clusters				
cluster	C1	C2	C3	C4	C5	C1	C2	C3	C4	C5	C6	C1	C2	C3	C4	C5
v10 (m/s)	0	0.34	-0.03	-0.1	-0.09	0.15	0.03	0.1	-0.11	-0.01	-0.74	-0.05	-0.2	-0.05	0.05	0.23
u10 (m/s)	-0.05	0.32	0.07	-0.01	0.08	0.07	-0.06	-0.17	0.61	0.09	0.57	-0.21	0.1	0.03	0	0.39
csdd (d)	2.16	0.13	0.8	0.45	-1	-3.37	-1.51	-0.17	-3.64	-4.15	-1.12	4.51	2.26	-0.08	1.27	-3.25
cswd (d)	-1.44	0.29	-0.44	-0.06	0.06	1.59	0.42	0.09	4.6	1.54	0.83	-3.05	-0.94	0.23	-0.74	1.85
pmax (mm/d)	-4.78	3.39	-0.69	-0.53	-0.09	3.5	2.32	1.58	24.37	7.05	10.76	-9.72	-2.42	1.35	-1.32	2.73
fthd (d)	0	0.01	-0.01	0.04	-0.04	-0.05	-0.23	-0.02	0	-0.13	-0.61	-0.03	-0.02	0.12	-0.13	0.02
csfd (d)	-0.04	-0.04	0.12	-0.55	-0.25	-2.55	-2.65	-0.37	0	-0.83	13.71	-0.22	0.22	1.41	1.92	4.2
t2am (K)	0.08	0	0.13	-0.32	-0.16	-3.98	-1.49	-0.91	-1.11	-1.27	-5.49	-0.24	-0.06	0.2	1.88	1.95
te2m (K)	1.31	0.6	0.52	0.32	-0.2	5.37	3.36	2.69	2.66	2	-1.44	0.84	-0.95	-2.26	-3.51	-5.03

Supplemental table S1: Attribute variable values for each anomaly cluster, time slice comparison and region. Green values denote an increase in values relative to the reference simulation, whereas purple values denote a decrease in values relative to the reference simulation.