Deep-time geographic dynamics of climate shape global vascular plant diversity

Jiaze Li[1], Iain Colin Prentice[1,2]

[1]*Georgina Mace Centre for the Living Planet, Department of Life Sciences, Imperial College London, Silwood Park Campus, Buckhurst Road, Ascot, SL5 7PY, UK*

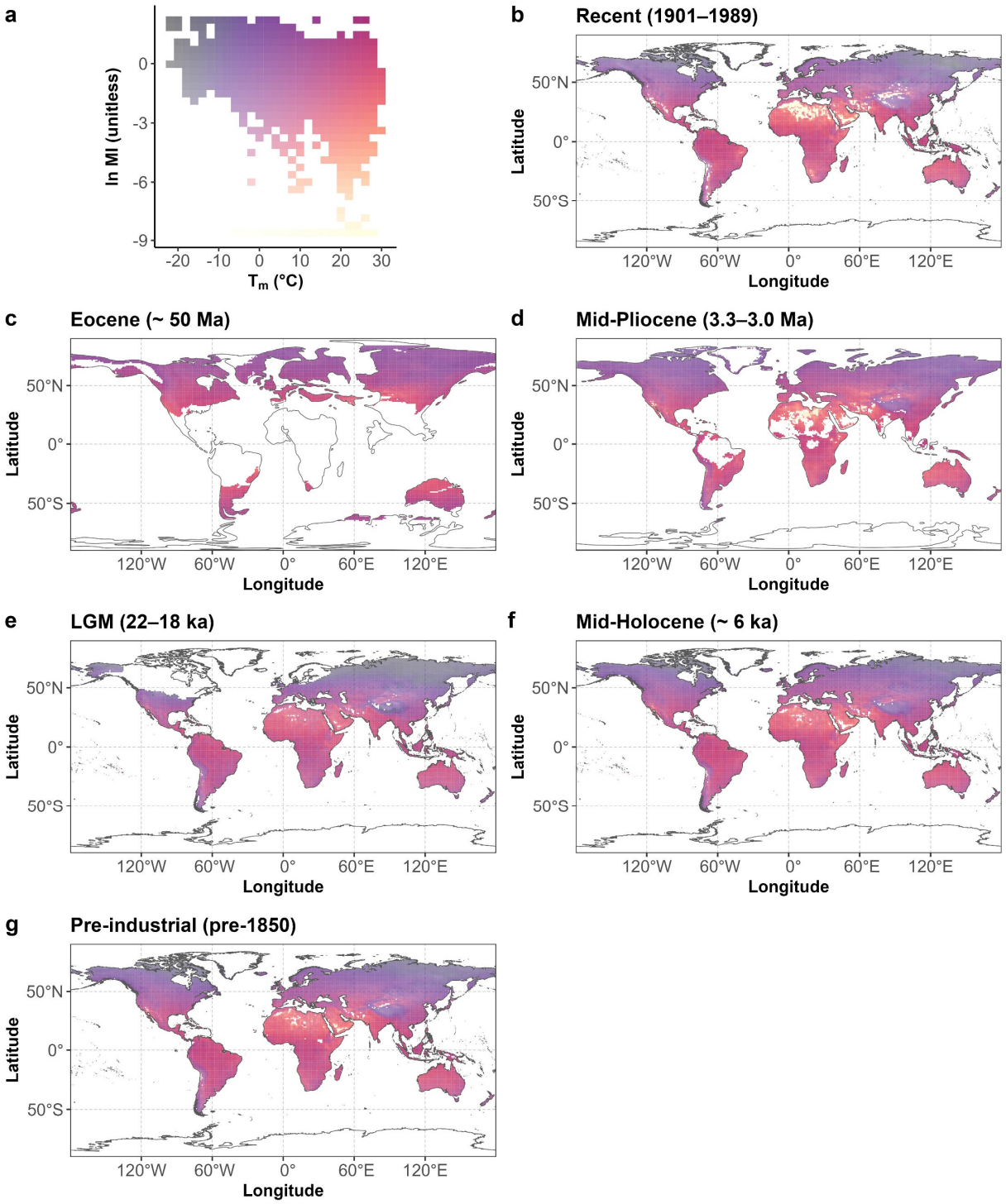
[2]*Department of Earth System Science, Ministry of Education Key Laboratory for Earth System Modeling, Institute for Global Change Studies, Tsinghua University, Beijing 100084, China*

Corresponding author: Jiaze Li (email: jiaze.li19@imperial.ac.uk)

Supplementary Information

SI 1 Supplementary Figures

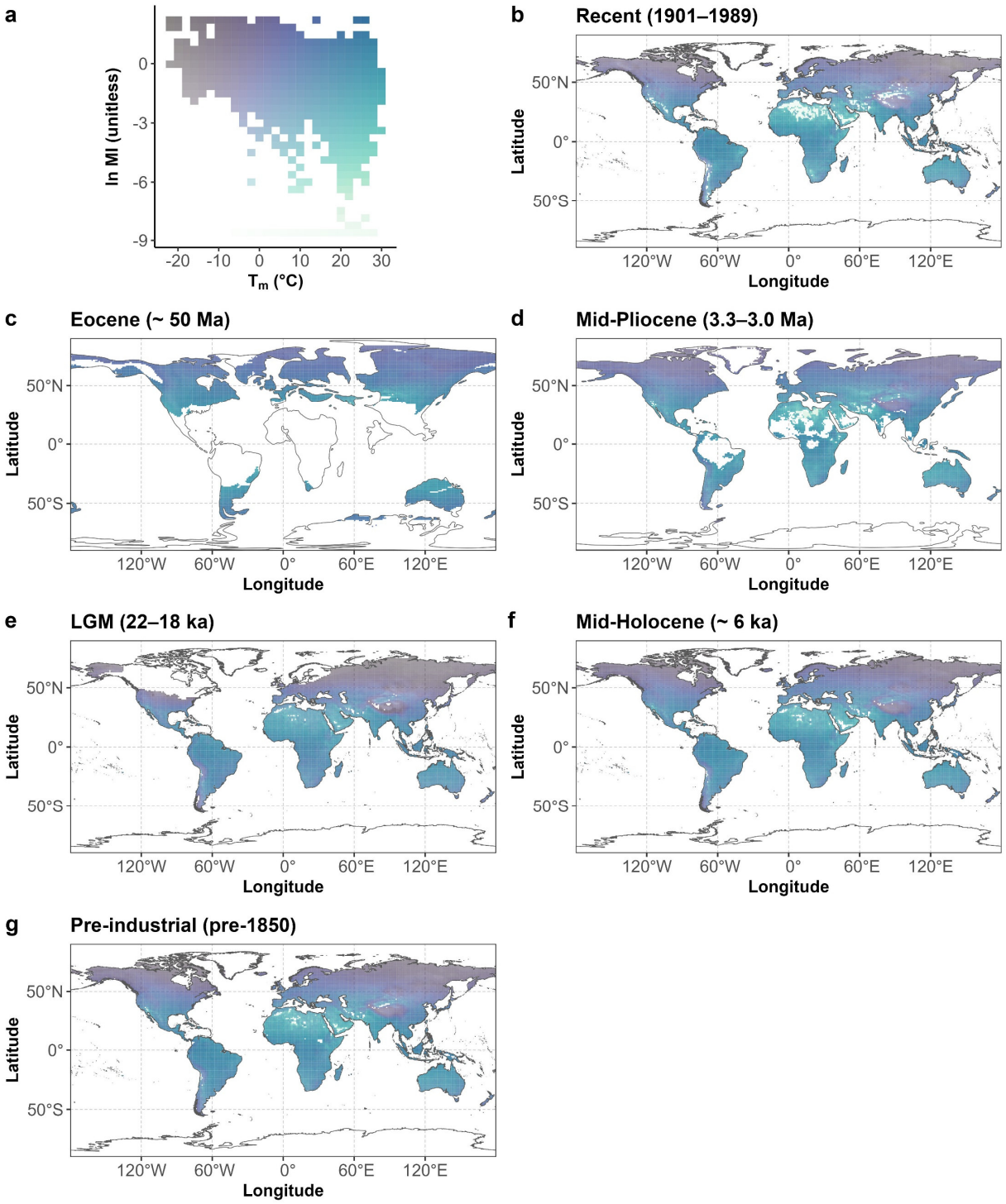
Fig. S1: Alternative colour gradient scheme illustrating the historical geography of recent climates.



a, The two-dimensional climatic space defined by the recent (1901–1989) climatic conditions (T_m and ln MI), partitioned into 30 equal intervals along each axis. Each coloured grid cell ('climatic bin') represents a unique climatic condition (405 cells in total). **b**–**g**, Geographic locations where those

recent climatic conditions existed during the recent period (1901–1989, **b**), Eocene (*ca.* 50 Ma, **c**), Mid-Pliocene (3.3–3.0 Ma, **d**), Last Glacial Maximum (LGM, 22–18 ka, **e**), Mid-Holocene (*ca.* 6 ka, **f**) and pre-industrial period (pre-1850, **g**). Uncoloured areas denote climatic conditions absent during this period. Colours correspond to those in **a**, with identical colours indicating the same climatic conditions. All maps are shown at a 1° spatial resolution.

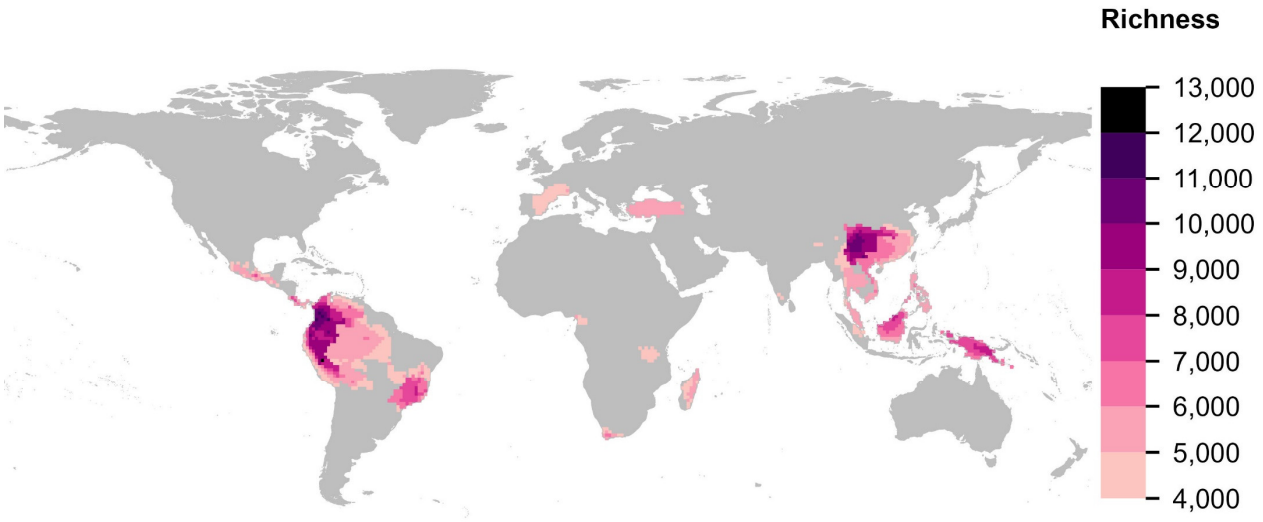
Fig. S2: Another alternative colour gradient scheme illustrating the historical geography of recent climates.



a, The two-dimensional climatic space defined by the recent (1901–1989) climatic conditions (T_m and ln MI), partitioned into 30 equal intervals along each axis. Each coloured grid cell ('climatic bin') represents a unique climatic condition (405 cells in total). **b**–**g**, Geographic locations where those

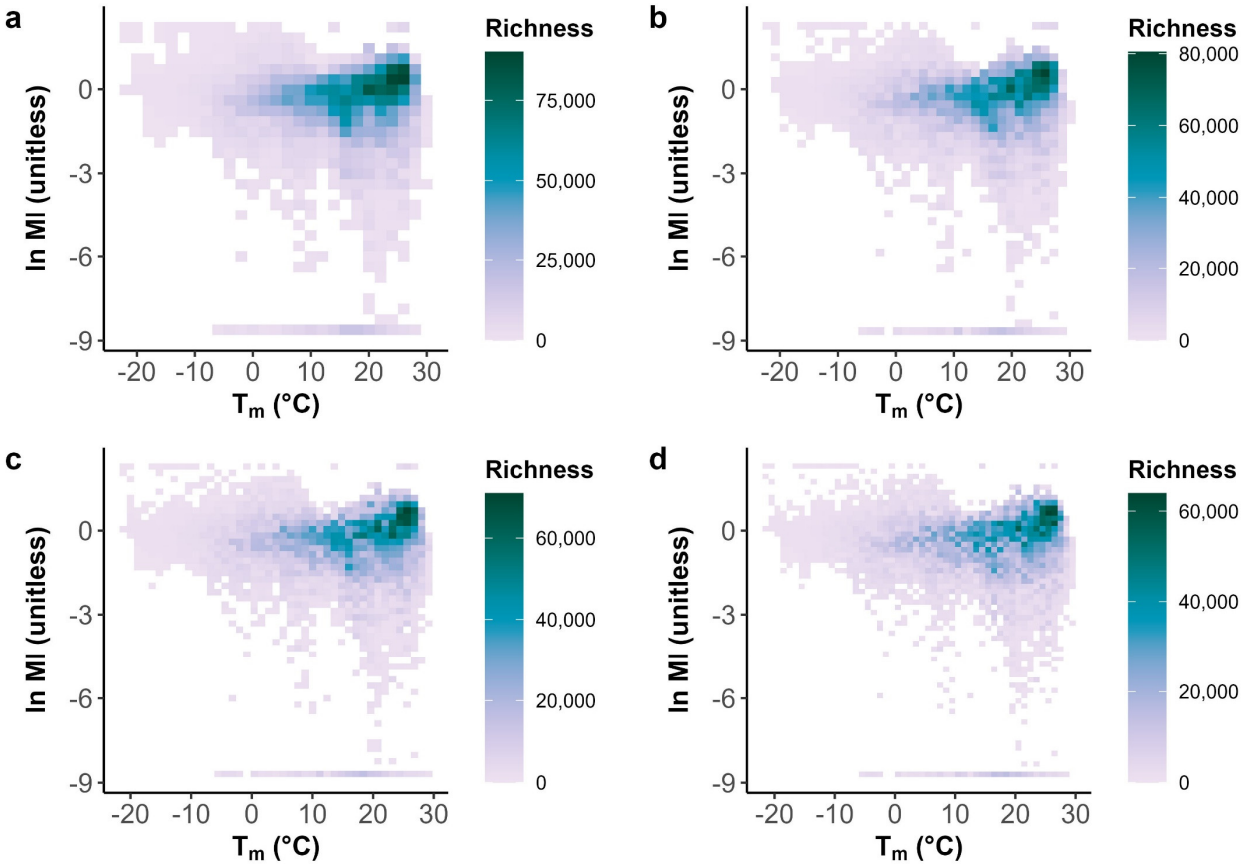
recent climatic conditions existed during the recent period (1901–1989, **b**), Eocene (*ca.* 50 Ma, **c**), Mid-Pliocene (3.3–3.0 Ma, **d**), Last Glacial Maximum (LGM, 22–18 ka, **e**), Mid-Holocene (*ca.* 6 ka, **f**) and pre-industrial period (pre-1850, **g**). Uncoloured areas denote climatic conditions absent during this period. Colours correspond to those in **a**, with identical colours indicating the same climatic conditions. All maps are shown at a 1° spatial resolution.

Fig. S3: Global hotspots of vascular plant species richness.



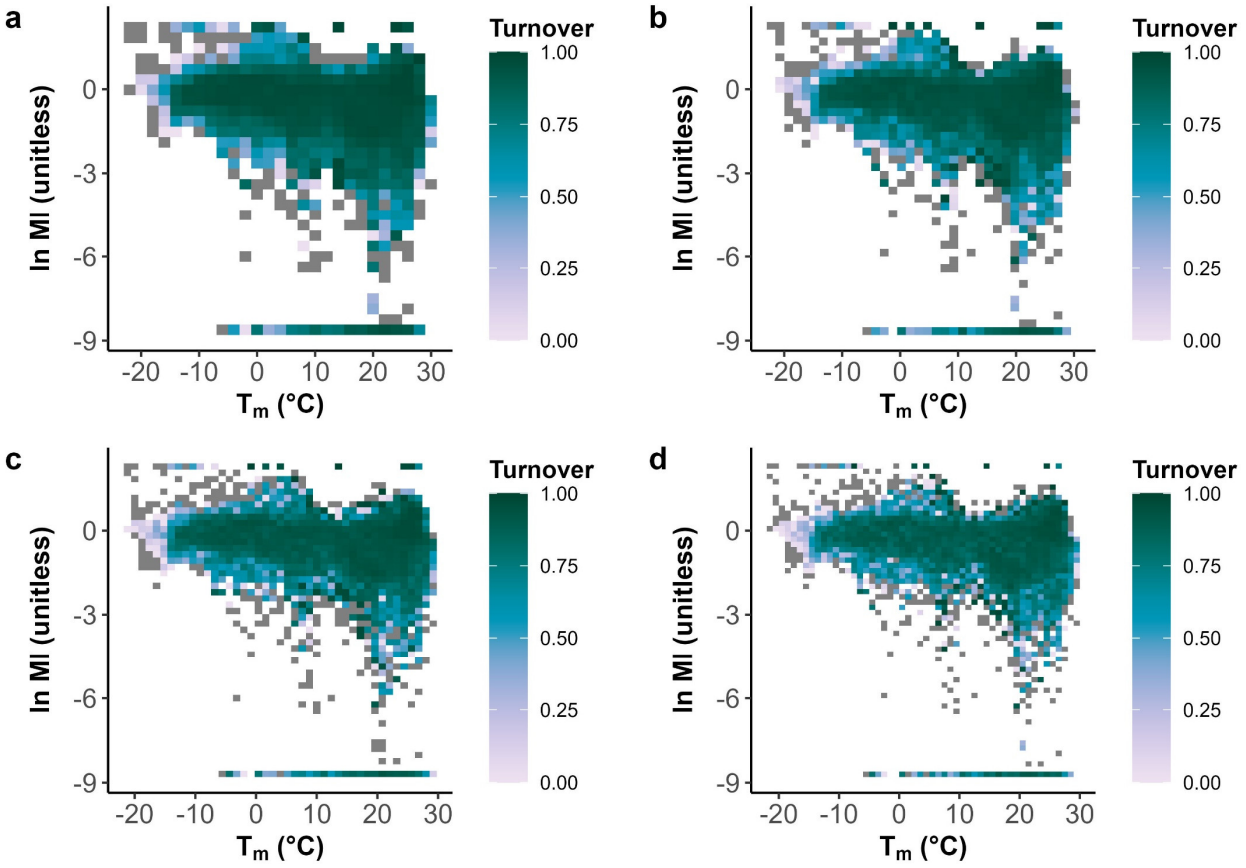
Global hotspots of vascular plant diversity, defined as regions where species richness exceeds the 90th global quantile[1].

Fig. S4: Vascular plant species richness in climatic space at different resolutions.



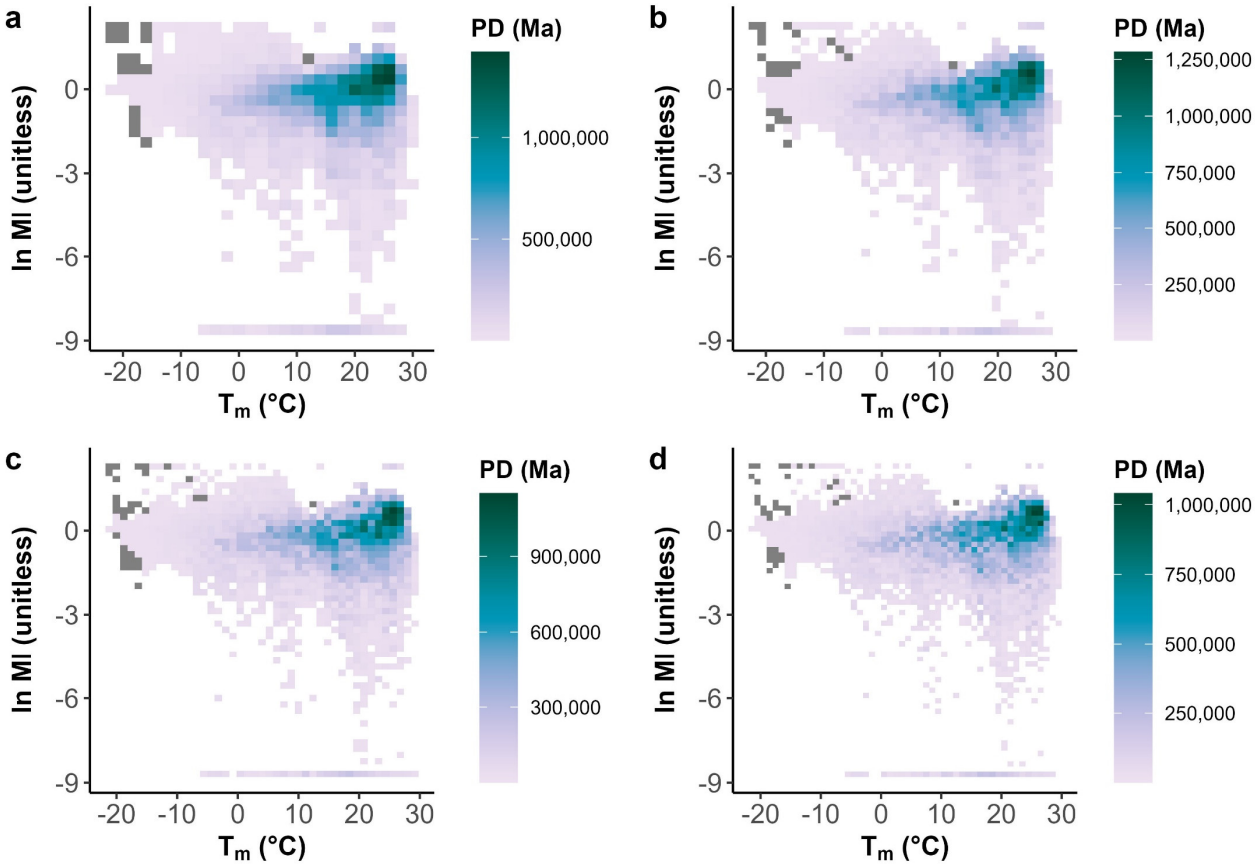
Species richness is shown per grid cell in climatic space defined by recent climatic conditions (T_m and ln MI), at four resolutions: 30 (**a**, 405 cells), 40 (**b**, 628 cells), 50 (**c**, 896 cells) and 60 (**d**, 1182 cells) equal intervals along each axis. Each grid cell ('climatic bin') represents a distinct climatic condition; colours indicate species richness. T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index.

Fig. S5: Vascular plant species turnover in climatic space at different resolutions.



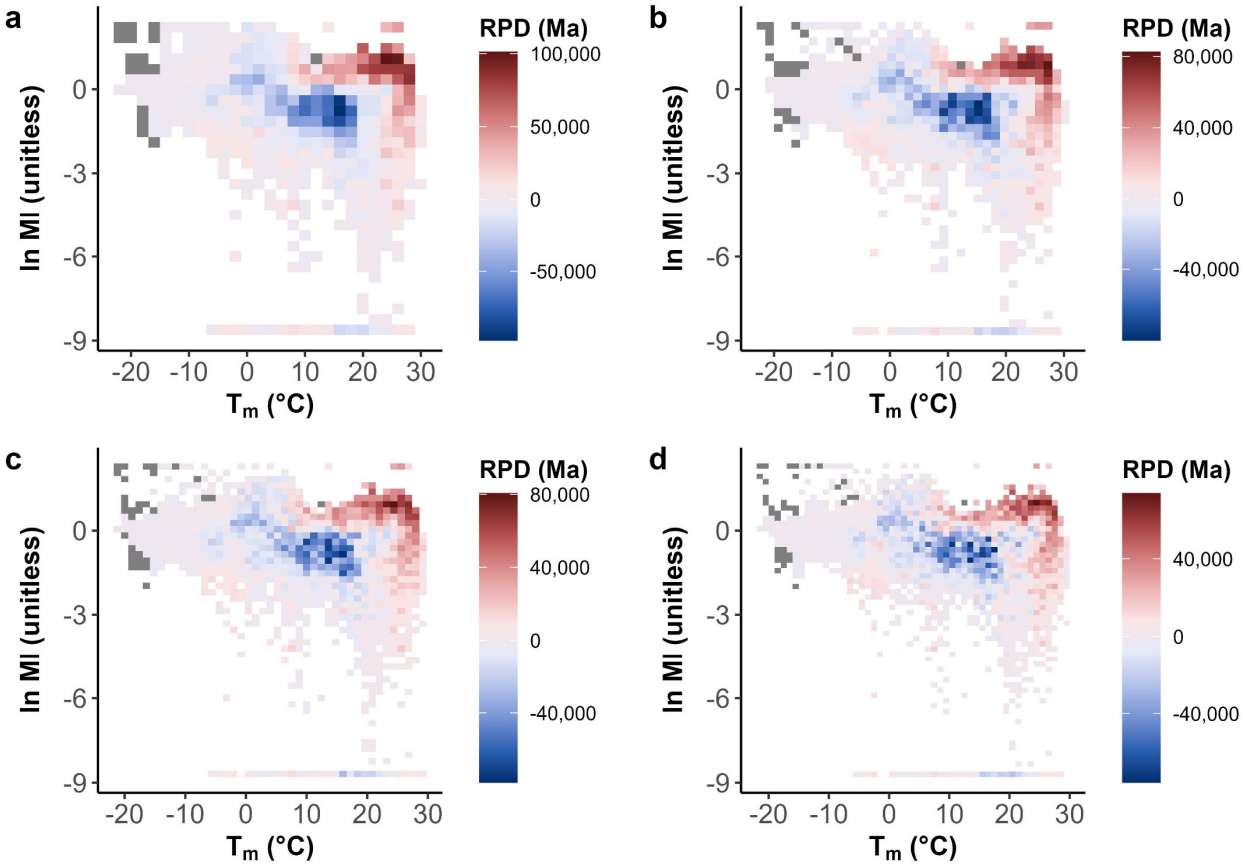
Species turnover (the turnover component of beta-diversity) is shown per grid cell in climatic space defined by recent climatic conditions (T_m and ln MI), at four resolutions: 30 (**a**, 405 cells), 40 (**b**, 628 cells), 50 (**c**, 896 cells) and 60 (**d**, 1182 cells) equal intervals along each axis. Each grid cell ('climatic bin') represents a distinct climatic condition; colours indicate species richness. T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index.

Fig. S6: Phylogenetic diversity of vascular plants in climatic space at different resolutions.



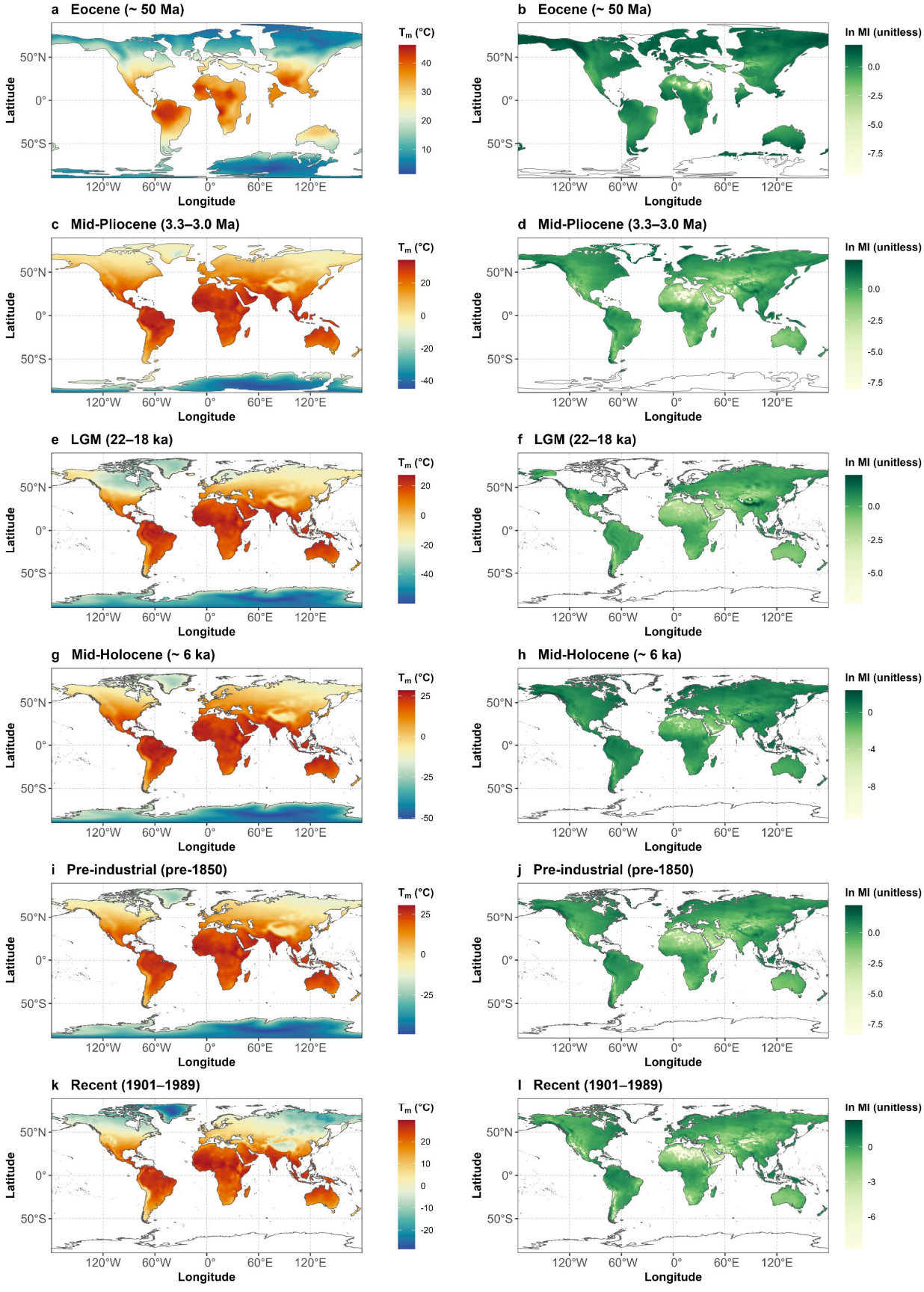
Phylogenetic diversity (Faith's phylogenetic diversity[2], PD, Ma) is shown per grid cell in climatic space defined by recent climatic conditions (T_m and ln MI), at four resolutions: 30 (**a**, 405 cells), 40 (**b**, 628 cells), 50 (**c**, 896 cells) and 60 (**d**, 1182 cells) equal intervals along each axis. Each grid cell ('climatic bin') represents a distinct climatic condition; colours indicate species richness. T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index.

Fig. S7: Relative phylogenetic diversity of vascular plants in climatic space at different resolutions.



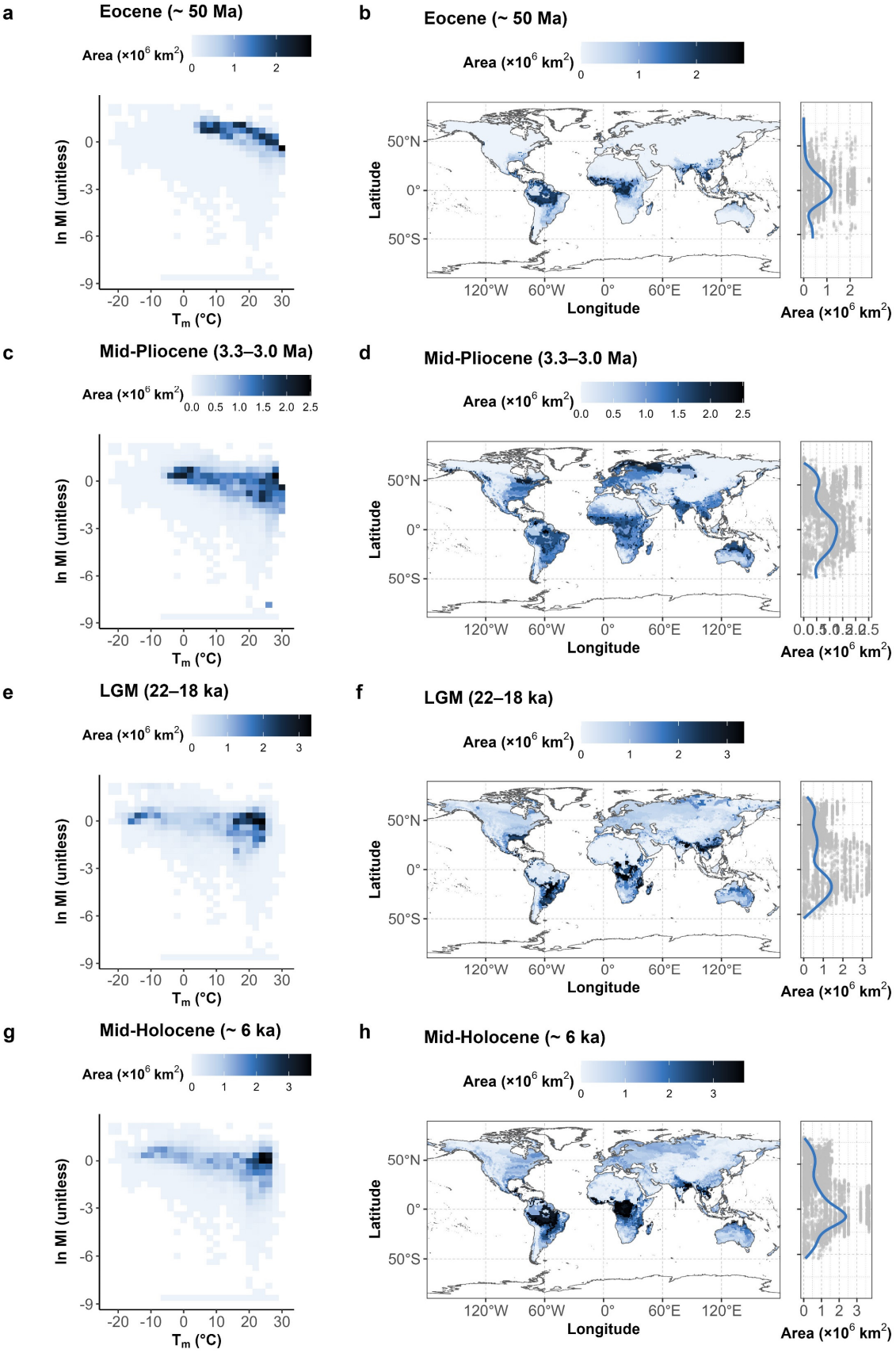
Relative phylogenetic diversity (calculated as the residuals from regressing phylogenetic diversity against species richness, Ma) is shown per grid cell in climatic space defined by recent climatic conditions (T_m and ln MI), at four resolutions: 30 (**a**, 405 cells), 40 (**b**, 628 cells), 50 (**c**, 896 cells) and 60 (**d**, 1182 cells) equal intervals along each axis. Each grid cell ('climatic bin') represents a distinct climatic condition; colours indicate species richness. T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index.

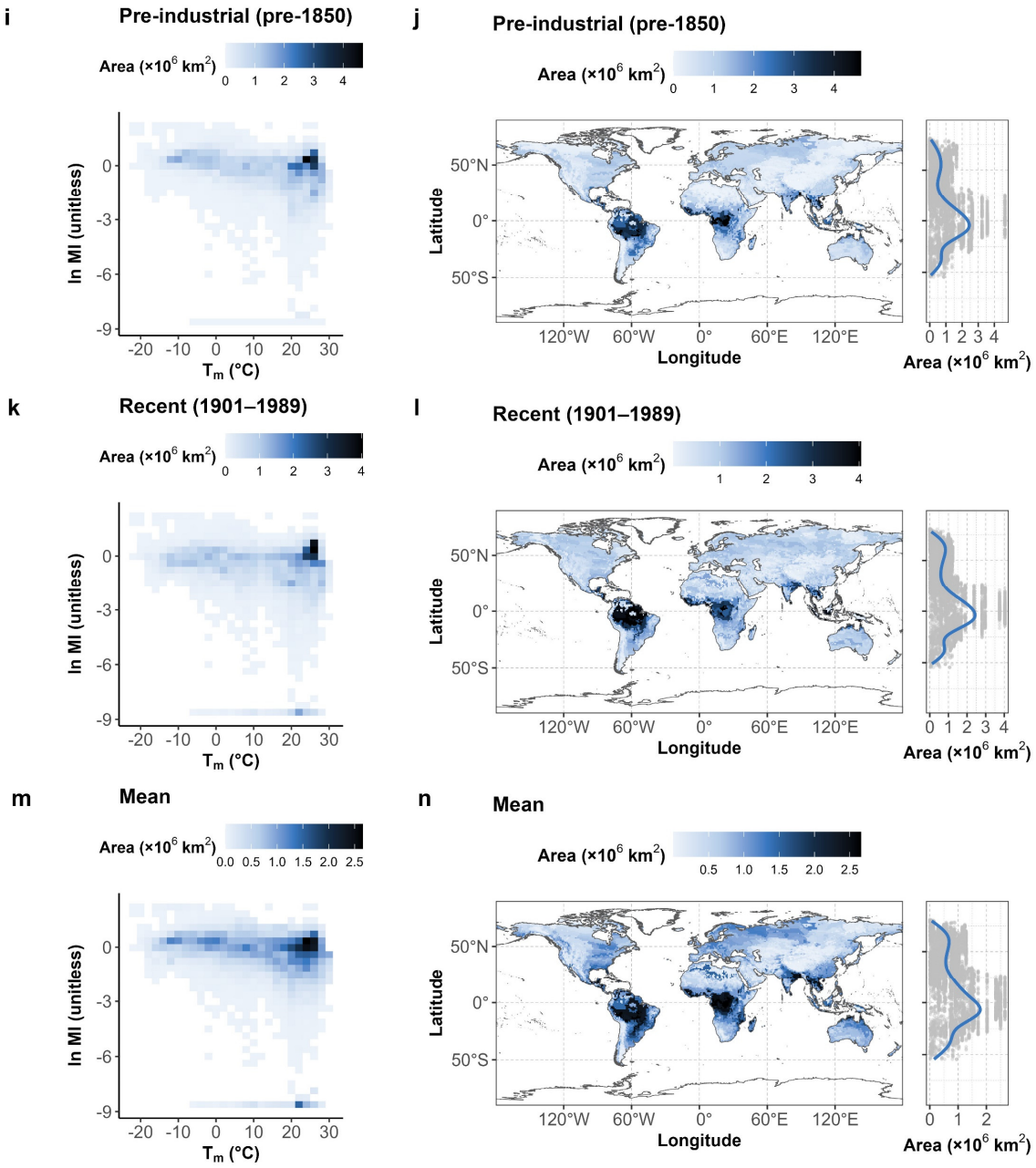
Fig. S8: Global distribution of bioclimatic variables in the selected geological periods at a 1° spatial resolution.



Gridded global distribution of: **a**, temperature index (T_m, °C) and **b**, natural-log-transformed moisture index (ln MI, unitless) of the Eocene (*ca.* 50 Ma); **c**, T_m and **d**, ln MI of the Mid-Pliocene (3.3–3.0 Ma); **e**, T_m and **f**, ln MI of the Last Glacial Maximum (LGM, 22–18 ka); **g**, T_m and **h**, ln MI of the Mid-Holocene (*ca.* 6 ka); **i**, T_m and **j**, ln MI of the pre-industrial period (pre-1850); **k**, T_m and **l**, ln MI of the recent period (1901–1989).

Fig. S9: Geographic extent of climate across geological periods.

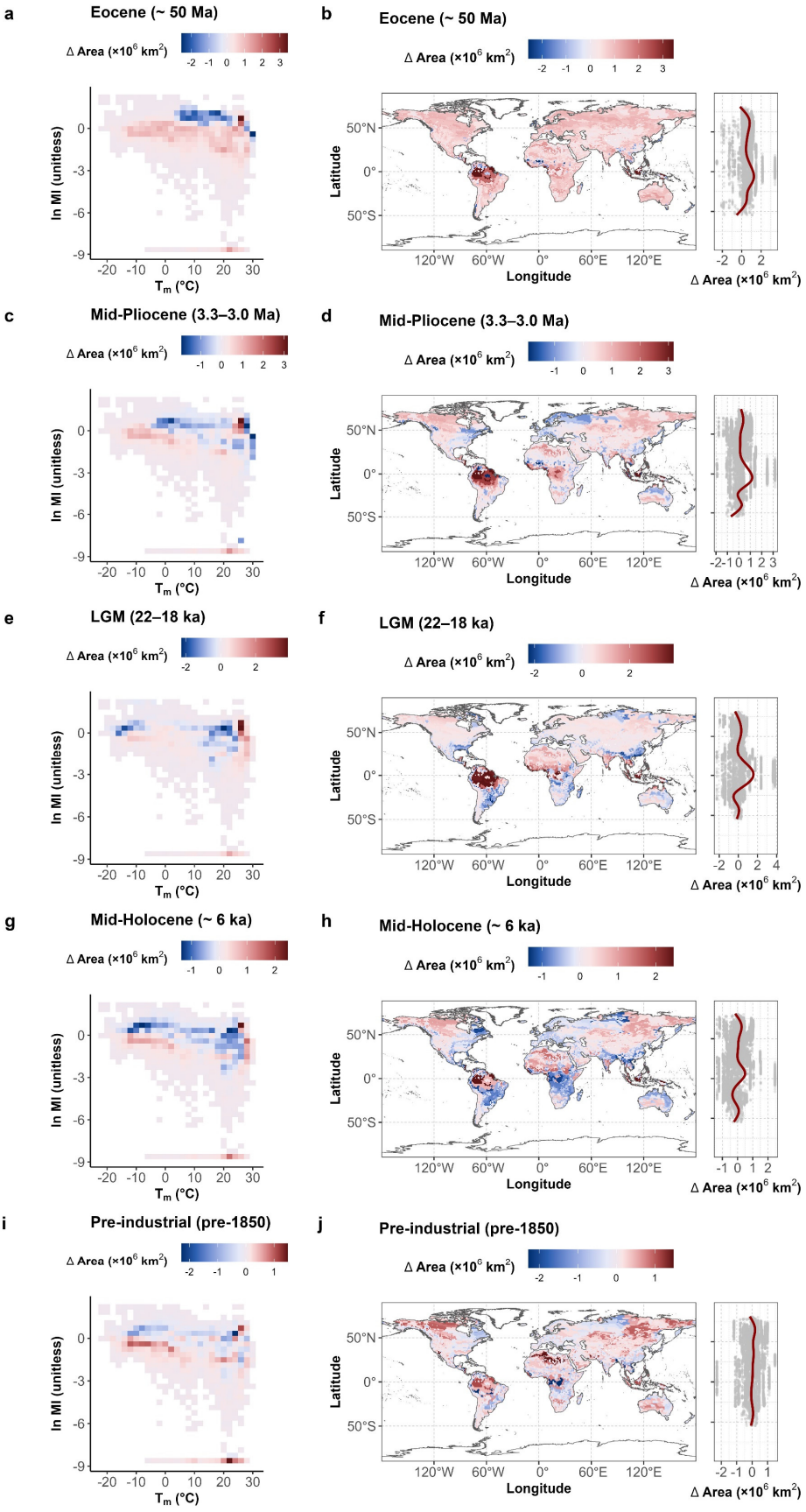




a, **c**, **e**, **g**, **i**, **k** and **m**, Patterns of the geographic extent of climate in climatic space across different geological periods. The geographic extent of climate is calculated as the total land surface area occupied by each climatic condition during the corresponding climatic period, referred to as 'Area' (km^2). Climatic space is defined by the recent (1901–1989) climatic conditions (T_m and ln MI), partitioned into 30 equal intervals along each axis. **b**, **d**, **f**, **h**, **j**, **l** and **n**, Global patterns and latitudinal distributions of Area in recent geographic space at a 1° spatial resolution. **a** and **b**, Eocene (*ca.* 50 Ma); **c** and **d**, Mid-Pliocene (3.3–3.0 Ma); **e** and **f**, Last Glacial Maximum (LGM, 22–18 ka); **g** and **h**, Mid-Holocene (*ca.* 6 ka); **i** and **j**, pre-industrial period (pre-1850); **k** and **l**, recent

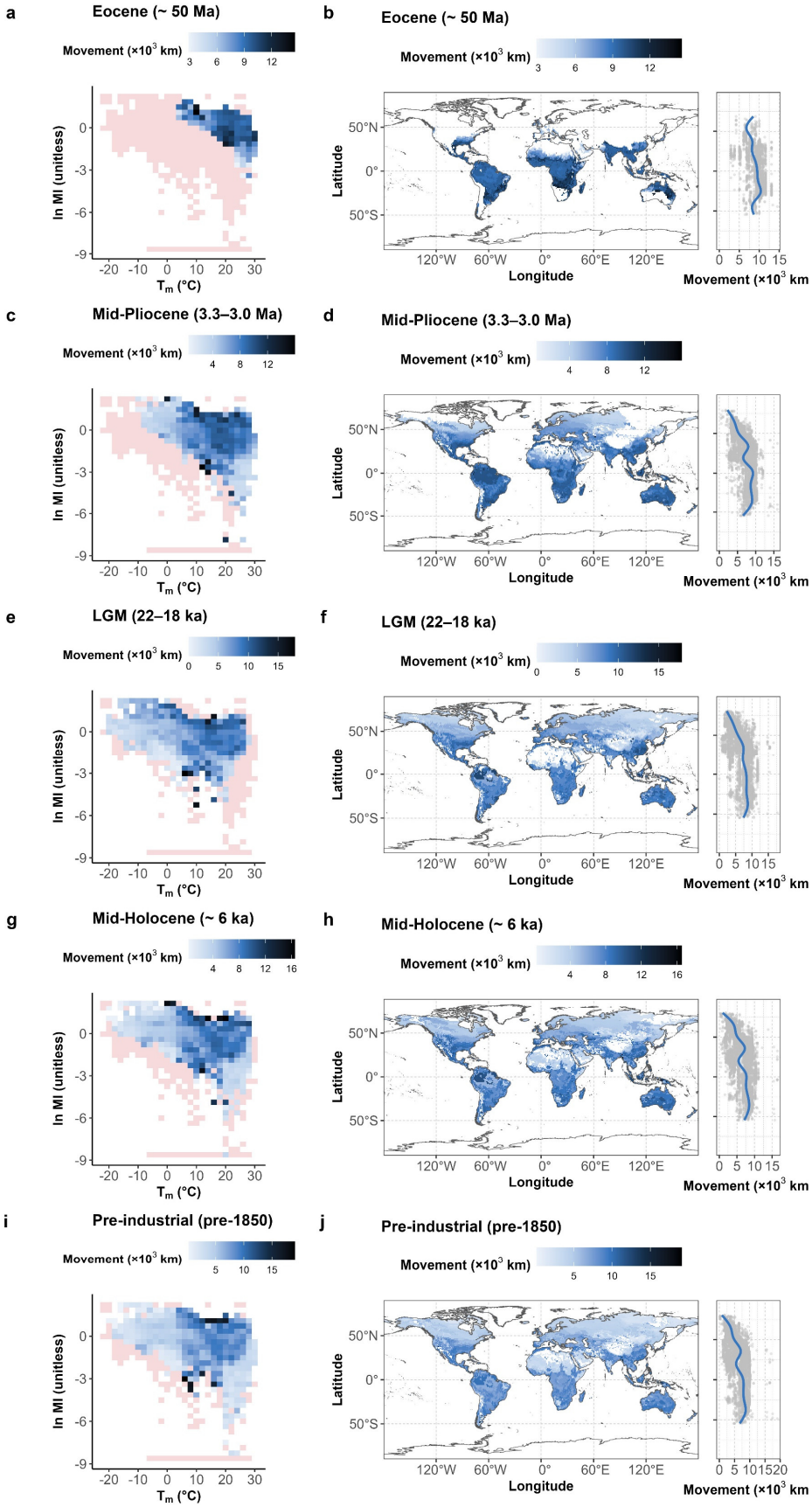
period (1901–1989); **m** and **n**, mean Area since the first appearance of each climatic condition across all selected climatic periods. T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index.

Fig. S10: Changes in the geographic extent of recent climatic conditions from geohistorical periods to the recent period.



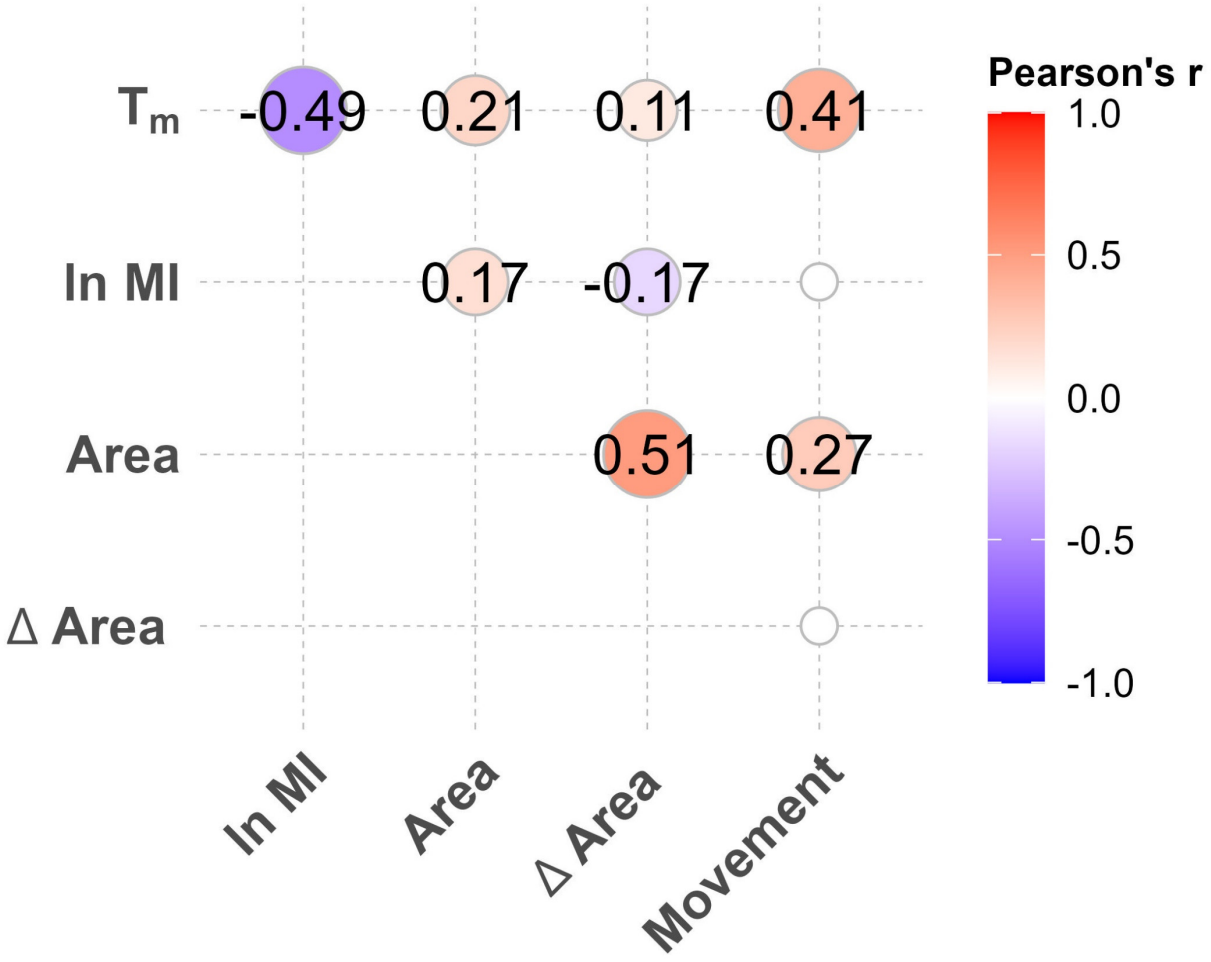
a, **c**, **e**, **g** and **i**, Change in total land area occupied by each climatic condition from its earliest occurrence to the recent period (referred to as ΔArea, km^2) in climatic space. Climatic space is defined by the recent (1901–1989) climatic conditions (T_m and ln MI), partitioned into 30 equal intervals along each axis. **b**, **d**, **f**, **h** and **j**, Global patterns and latitudinal distributions of ΔArea in recent geographic space at a 1° spatial resolution. **a** and **b**, Eocene (*ca.* 50 Ma); **c** and **d**, Mid-Pliocene (3.3–3.0 Ma); **e** and **f**, Last Glacial Maximum (LGM, 22–18 ka); **g** and **h**, Mid-Holocene (*ca.* 6 ka); **i** and **j**, pre-industrial period (pre-1850). T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index.

Fig. S11: Geographic shift of recent climatic conditions from geohistorical periods to the recent period.



a, **c**, **e**, **g** and **i**, Geographic shift of a climatic condition since its earliest occurrence to the recent period (Movement, km) in climatic space. Climatic space is defined by the recent (1901–1989) climatic conditions (T_m and ln MI), partitioned into 30 equal intervals along each axis. The blue colour gradient indicates climatic conditions shared by a geohistorical period and the recent period, while the pink background highlights climatic conditions present in the recent period but absent in the geohistorical period. **b**, **d**, **f**, **h** and **j**, Global patterns and latitudinal distribution of Movement in recent geographic space at a 1° spatial resolution. **a** and **b**, Eocene (*ca.* 50 Ma); **c** and **d**, Mid-Pliocene (3.3–3.0 Ma); **e** and **f**, Last Glacial Maximum (LGM, 22–18 ka); **g** and **h**, Mid-Holocene (*ca.* 6 ka); **i** and **j**, pre-industrial period (pre-1850). T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index.

Fig. S12: Pairwise correlation among explanatory variables.



Pairwise Pearson's correlation coefficients among all explanatory variables. The absolute values of all coefficients are below or around 0.5, indicating a low risk of concurvity or collinearity. T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence to the recent period.

SI 2 Supplementary Tables

Table S1 | Comparison with previous global plant diversity products. Summary of data sources [a], methods for generating global plant diversity maps [b], the number of species included [c], and the spatial resolution of each map [d].

Data source [a]	Type [b]	Number of species [c]	Spatial Resolution [d]
Our research	Data-based	350,864	Any resolution (using 1° as an example)
Barthlott *et al.* (2005)[3]	Data-based	> 3,300 from different regions	10,000 km^2
Kier *et al.* (2005)[4]	Data-based	Not available – estimated for each selected geographical unit	867 Terrestrial ecoregions of the world
Kreft & Jetz (2007)[5]	Model-based	> 3,300 from 1,032 geographic units	110 × 110 km (*ca.* 1°)
Brummitt *et al.* (2021)[6]	Data-based and Model-based	Not available – estimated for each selected geographical unit (data-based); 1,250 (model-based)	Level 3 geo-political regions of the world and 867 ecoregions of WWF (data-based), 10 km^2 (model-based)
Sabatini *et al.* (2022)[7]	Model-based	53,271	400 m^2, 1,000 m^2 and 1 ha for forests, and 10 m^2, 100 m^2 and 1,000 m^2 for non-forests
Cai *et al.* (2023)[1]	Model-based	298,087	7,774 km^2, 23,322 km^2, 69,967 km^2, and 209,903 km^2

World Checklist of Vascular Plants (WCVP)[8]	Database	357,347 accepted species (Feb–June 2024) Notice: > 340,000 species with distribution information available	Level 3 of the Biodiversity Information Standards (TDWG) geographical codes
Global Inventory of Floras and Traits (GIFT)[9]	Database	303,713 vascular plants (v.3.1) Notice: distribution data for some species are not available	3,627 geographic regions

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Table S2 | Climate data used for this study. Databases and model simulations used to extract each climatic variable in different geological periods.

Project	Version	Experiment	Geological period	Model	Simulation	Ensemble	Variable	Resolution	Reference
Deep-Time Model Intercomparison Project (DeepMIP)[10]	version 1.0	Eocene	Eocene (ca. 50 Ma)	CESM1.2-CAM5	× 6 CO_2	r1i1p1f1	elevation/surface altitude, precipitation, surface downwelling shortwave radiation, air temperature	2.5° × 1.9°	Ref [11]
				COSMOS-landveg-r2413	× 4 CO_2		elevation/surface altitude, precipitation, surface downwelling shortwave radiation, air temperature	3.75° × 3.71°	Ref [12]
				GFDL-CM2.1	× 4 CO_2, × 6 CO_2		elevation/surface altitude, precipitation, surface downwelling shortwave radiation, air temperature	3.75° × 3.02°	Ref [13]
				INM-CM4-8	× 6 CO_2		elevation/surface altitude, precipitation, surface downwelling shortwave radiation, air temperature	2.0° × 1.5°	Ref [12]
				NorESM1-F	× 4 CO_2		elevation/surface altitude, precipitation, surface downwelling shortwave radiation, air temperature	2.5° × 1.9°	Ref [14]

Paleoclimat Modeling Intercomparison Project (PMIP)[15]	Phase 4 (PMIP4)	midPliocene-eoi400	Mid-Pliocene (3.3–3.0 Ma)	CESM2	--	r1i1p1f1	elevation/surface altitude, precipitation, surface downwelling shortwave radiation, air temperature	100 km × 100 km	Ref [16]
				GISS-E2-1-G			precipitation, surface downwelling shortwave radiation, air temperature	250 km × 250 km	Refs [17,18]
				HadGEM3-GC31-LL			precipitation, air temperature	250 km × 250 km	Ref [19]
				NorESM1-F			elevation/surface altitude, precipitation, surface downwelling shortwave radiation, air temperature	250 km × 250 km	Ref [14]
		lgm	Last Glacial Maximum (LGM, 22–18 ka)	AWI-ESM-1-1-LR			elevation/surface altitude, precipitation, surface downwelling shortwave radiation, air temperature	250 km × 250 km	Ref [20]
				MPI-ESM1-2-LR			elevation/surface altitude, precipitation, surface downwelling shortwave radiation, air temperature	250 km × 250 km	Ref [21]
		midHolocene	Mid-Holocene (ca. 6 ka)	AWI-ESM-1-1-LR			elevation/surface altitude, precipitation, surface downwelling	250 km × 250 km	Ref [20]

						shortwave radiation, air temperature		
				CESM2		elevation/surface altitude, precipitation, surface downwelling shortwave radiation, air temperature	100 km × 100 km	Ref [16]
				MPI-ESM1-2-LR		elevation/surface altitude, precipitation, surface downwelling shortwave radiation, air temperature	250 km × 250 km	Ref [21]
				MRI-ESM2-0		elevation/surface altitude, precipitation, surface downwelling shortwave radiation, air temperature	100 km × 100 km	Ref [22]
				NESM3		precipitation, surface downwelling shortwave radiation, air temperature	250 km × 250 km	Ref [23]
				NorESM1-F		surface downwelling shortwave radiation	250 km × 250 km	Ref [14]
				NorESM2-LM		elevation/surface altitude, precipitation, air temperature	250 km × 250 km	Ref [24]
Coupled Model Intercomparison	Phase 6 (CMIP6)	piControl	Pre-industrial era	ACCESS-CM2	--	r1i1p1f1	elevation/surface altitude, precipitation, surface downwelling	250 km × 250 km	Ref [26]

Project (CMIP)[25]	(before 1850)			shortwave radiation, air temperature		
		CESM2		elevation/surface altitude, precipitation, surface downwelling shortwave radiation, air temperature	100 km × 100 km	Ref [16]
		MIROC6		elevation/surface altitude, precipitation, surface downwelling shortwave radiation, air temperature	250 km × 250 km	Ref [27]
		MPI-ESM1-2-LR		elevation/surface altitude, precipitation, surface downwelling shortwave radiation, air temperature	250 km × 250 km	Ref [21]
		MRI-ESM2-0		elevation/surface altitude, precipitation, surface downwelling shortwave radiation, air temperature	100 km × 100 km	Ref [22]
		NESM3		precipitation, surface downwelling shortwave radiation, air temperature	250 km × 250 km	Ref [23]
		NorESM2-LM		elevation/surface altitude, precipitation, surface downwelling shortwave radiation, air temperature	250 km × 250 km	Ref [24]

		historical	Recent period (1901–1989)	ACCESS-CM2			surface downwelling shortwave radiation	250 km × 250 km	Ref [26]
				CESM2			surface downwelling shortwave radiation	100 km × 100 km	Ref [16]
				MIROC6			surface downwelling shortwave radiation	250 km × 250 km	Ref [27]
				MPI-ESM1-2-LR			surface downwelling shortwave radiation	250 km × 250 km	Ref [21]
				MRI-ESM2-0			surface downwelling shortwave radiation	100 km × 100 km	Ref [22]
				NESM3			surface downwelling shortwave radiation	250 km × 250 km	Ref [23]
				NorESM2-LM			surface downwelling shortwave radiation	250 km × 250 km	Ref [24]
Climatic Research Unit (CRU) Time-Series	version 4.09	--	Recent period (1901–1989)	Observation-based gridded dataset	--	--	precipitation, air temperature	0.5° × 0.5°	Ref [28]

(TS)[28]				
WorldClim[29]	version 2.1	elevation/surface altitude	30 arc-second grid	Ref [29]

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Table S3 | Summary of Generalised Additive Models (GAMs) incorporating bioclimatic variables and the geographic extent of climate during the Eocene (*ca.* 50 Ma) across multiple climatic space resolutions. Summary statistics of GAMs fitted with species richness as the response variable. Explanatory variables include recent (1901–1989) temperature index (T_m, °C) and natural-log-transformed moisture index (ln MI, unitless), and total land area occupied by each climatic condition (Area, km^2) during the Eocene. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.43	1826164.57	< 0.001				
ln MI	0.29	2621414.09	< 0.001	0.92	0.91	0.90	405
Area	0.28	110054.76	< 0.001				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.42	2528553.22	< 0.001				
ln MI	0.26	3152404.27	< 0.001	0.89	0.88	0.87	628
Area	0.26	153392.87	< 0.001				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.40	2905884.78	< 0.001				
ln MI	0.24	3663735.85	< 0.001	0.87	0.84	0.84	896
Area	0.23	194660.03	< 0.001				
60 equal interval resolution							

Predictor	Concurvity	χ^2	*p*-value	Deviance	R_{pred}^2	R_{adj}^2	N
T_m	0.42	3391694.10	< 0.001				
ln MI	0.23	3897622.26	< 0.001	0.84	0.80	0.79	1182
Area	0.21	159522.60	< 0.001				

Table S4 | Summary of Generalised Additive Models (GAMs) incorporating bioclimatic variables and the geographic extent of climate during the Mid-Pliocene (3.3–3.0 Ma) across multiple climatic space resolutions. Summary statistics of GAMs fitted with species richness as the response variable. Explanatory variables include recent (1901–1989) temperature index (T_m, °C) and natural-log-transformed moisture index (ln MI, unitless), and total land area occupied by each climatic condition (Area, km^2) during the Mid-Pliocene. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.61	1326565.81	< 0.001				
ln MI	0.41	1110697.66	< 0.001	0.91	0.89	0.89	405
Area	0.42	70793.87	< 0.001				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.60	1742019.22	< 0.001				
ln MI	0.37	1494216.90	< 0.001	0.89	0.85	0.85	628
Area	0.39	73973.80	< 0.001				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**

T_m	0.56	2276038.16	< 0.001				
ln MI	0.35	2033348.82	< 0.001	0.86	0.82	0.81	896
Area	0.31	89872.99	< 0.001				
60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.59	2722005.60	< 0.001				
ln MI	0.33	2466028.68	< 0.001	0.83	0.78	0.78	1182
Area	0.32	92430.90	< 0.001				

Table S5 | Summary of Generalised Additive Models (GAMs) incorporating bioclimatic variables and the geographic extent of climate during the Last Glacial Maximum (LGM, 22–18 ka) across multiple climatic space resolutions. Summary statistics of GAMs fitted with species richness as the response variable. Explanatory variables include recent (1901–1989) temperature index (T_m, °C) and natural-log-transformed moisture index (ln MI, unitless), and total land area occupied by each climatic condition (Area, km^2) during the LGM. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.25	1464573.86	< 0.001				
ln MI	0.32	701089.22	< 0.001	0.91	0.89	0.88	405
Area	0.29	43087.69	< 0.001				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.25	2092171.65	< 0.001	0.88	0.85	0.84	628

ln MI	0.28	1260857.35	< 0.001				
Area	0.29	26796.12	< 0.001				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.26	2525533.82	< 0.001				
ln MI	0.25	1610612.17	< 0.001	0.85	0.81	0.80	896
Area	0.26	20900.22	< 0.001				
60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.25	3001882.59	< 0.001				
ln MI	0.24	1830820.53	< 0.001	0.83	0.78	0.77	1182
Area	0.23	23292.10	< 0.001				

Table S6 | Summary of Generalised Additive Models (GAMs) incorporating bioclimatic variables and the geographic extent of climate during the Mid-Holocene (*ca*. 6 ka) across multiple climatic space resolutions. Summary statistics of GAMs fitted with species richness as the response variable. Explanatory variables include recent (1901–1989) temperature index (T_m, °C) and natural-log-transformed moisture index (ln MI, unitless), and total land area occupied by each climatic condition (Area, km^2) during the Mid-Holocene. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.40	1149298.76	< 0.001	0.91	0.91	0.90	405
ln MI	0.38	720379.97	< 0.001				

Area	0.28	91266.85	< 0.001				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.39	1542196.05	< 0.001				
ln MI	0.35	996440.98	< 0.001	0.88	0.85	0.84	628
Area	0.30	34971.45	< 0.001				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.39	1855885.52	< 0.001				
ln MI	0.33	1321145.55	< 0.001	0.86	0.82	0.81	896
Area	0.25	75771.48	< 0.001				
60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.41	2161235.79	< 0.001				
ln MI	0.30	1553946.16	< 0.001	0.83	0.78	0.78	1182
Area	0.23	46616.82	< 0.001				

Table S7 | Summary of Generalised Additive Models (GAMs) incorporating bioclimatic variables and the geographic extent of climate during the pre-industrial period (pre-1850) across multiple climatic space resolutions. Summary statistics of GAMs fitted with species richness as the response variable. Explanatory variables include recent (1901–1989) temperature index (T_m, °C) and natural-log-transformed moisture index (ln MI, unitless), and total land area occupied by each climatic condition (Area, km^2) during the pre-industrial period. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.48	1240918.46	< 0.001				
ln MI	0.34	671161.66	< 0.001	0.91	0.90	0.89	405
Area	0.27	88409.00	< 0.001				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.48	1652612.87	< 0.001				
ln MI	0.33	971836.13	< 0.001	0.89	0.87	0.87	628
Area	0.23	153045.85	< 0.001				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.46	2047651.57	< 0.001				
ln MI	0.30	1270973.81	< 0.001	0.87	0.83	0.83	896
Area	0.21	154572.78	< 0.001				
60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.49	2470587.64	< 0.001				
ln MI	0.29	1595683.32	< 0.001	0.84	0.79	0.78	1182
Area	0.22	124551.12	< 0.001				

Table S8 | Summary of Generalised Additive Models (GAMs) incorporating bioclimatic variables and the geographic extent of climate during the recent period (1901–1989) across multiple climatic space resolutions. Summary statistics of GAMs fitted with species richness as the response variable. Explanatory variables include recent (1901–1989) temperature index (T_m, °C) and natural-log-transformed moisture index (ln MI, unitless), and total land area occupied by each climatic condition (Area, km^2) during the recent period. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model

include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.48	1252944.99	< 0.001				
ln MI	0.21	625065.58	< 0.001	0.93	0.94	0.94	405
Area	0.24	250319.58	< 0.001				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.43	1745430.59	< 0.001				
ln MI	0.18	877454.57	< 0.001	0.92	0.91	0.91	628
Area	0.27	352504.99	< 0.001				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.44	2073100.64	< 0.001				
ln MI	0.16	1046454.26	< 0.001	0.90	0.90	0.90	896
Area	0.24	562136.56	< 0.001				
60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.44	2360696.24	< 0.001				
ln MI	0.15	1236657.04	< 0.001	0.89	0.88	0.88	1182
Area	0.22	752415.89	< 0.001				

Table S9 | Summary of Generalised Additive Models (GAMs) incorporating bioclimatic variables and the average geographic extent of climate across all selected geological periods at multiple climatic space resolutions. Summary statistics of GAMs fitted with species richness as the response variable. Explanatory variables include recent (1901–1989) temperature

index (T_m, °C) and natural-log-transformed moisture index (ln MI, unitless), and the mean total land area occupied by each climatic condition since its first appearance across all selected climatic periods (Area, km^2). Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.56	1095137.37	< 0.001				
ln MI	0.26	540113.96	< 0.001	0.90	0.88	0.87	405
Area	0.38	21689.69	< 0.001				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.54	1441724.54	< 0.001				
ln MI	0.23	665310.71	< 0.001	0.88	0.85	0.84	628
Area	0.38	29428.30	< 0.001				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.51	1593777.78	< 0.001				
ln MI	0.21	821338.15	< 0.001	0.86	0.82	0.81	896
Area	0.38	86385.99	< 0.001				
60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.54	1830603.38	< 0.001				
ln MI	0.20	903978.79	< 0.001	0.84	0.79	0.78	1182
Area	0.35	115607.59	< 0.001				

Table S10 | Relative importance of explanatory variables in Generalised Additive Models (GAMs) incorporating bioclimatic variables and the geographic extent of climate. Summary of the relative importance of each explanatory variable in GAMs fitted across different geological periods and multiple climatic space resolutions. Climatic space is defined by the recent (1901–1989) climatic conditions (T_m and ln MI), partitioned into 30, 40, 50 or 60 equal intervals along each axis. Species richness is the response variable. Explanatory variables include recent (1901–1989) temperature index (T_m, °C) and natural-log-transformed moisture index (ln MI, unitless), and total land area occupied by each climatic condition (Area, km^2) during different geological periods. The method for calculating the relative importance of each explanatory variable is described in the Methods section of the main text.

30 equal interval resolution				
Geological period	**T_m**	**ln MI**	**Area**	**Unexplained**
Eocene (*ca.* 50 Ma)	33.48%	42.52%	15.69%	8.31%
Mid-Pliocene (3.3–3.0 Ma)	27.97%	30.72%	32.43%	8.88%
Last Glacial Maximum (LGM, 22–18 ka)	32.73%	28.20%	29.85%	9.22%
Mid-Holocene (*ca.* 6 ka)	27.94%	28.03%	35.39%	8.64%
Pre-industrial (pre-1850)	28.41%	27.77%	35.16%	8.67%
Recent period (1901–1989)	28.60%	27.34%	37.46%	6.60%
Mean	27.15%	27.03%	36.31%	9.51%
40 equal interval resolution				
Geological period	**T_m**	**ln MI**	**Area**	**Unexplained**
Eocene	34.76%	39.48%	15.18%	10.58%

(*ca.* 50 Ma)				
Mid-Pliocene (3.3–3.0 Ma)	28.15%	28.90%	31.59%	11.37%
Last Glacial Maximum (LGM, 22–18 ka)	34.46%	28.02%	25.66%	11.87%
Mid-Holocene (*ca.* 6 ka)	28.77%	26.54%	32.91%	11.79%
Pre-industrial (pre-1850)	29.04%	26.40%	33.84%	10.72%
Recent period (1901–1989)	30.01%	25.84%	35.67%	8.48%
Mean	27.96%	25.14%	35.04%	11.85%
50 equal interval resolution				
Geological period	**T_m**	**ln MI**	**Area**	**Unexplained**
Eocene (*ca.* 50 Ma)	33.23%	38.20%	15.55%	13.02%
Mid-Pliocene (3.3–3.0 Ma)	28.23%	28.95%	28.93%	13.89%
Last Glacial Maximum (LGM, 22–18 ka)	34.00%	27.65%	23.84%	14.51%
Mid-Holocene (*ca.* 6 ka)	28.32%	26.29%	31.33%	14.06%
Pre-industrial (pre-1850)	28.95%	26.10%	31.50%	13.45%
Recent period (1901–1989)	29.42%	25.11%	35.60%	9.88%
Mean	26.88%	24.45%	34.71%	13.96%
60 equal interval resolution				

Geological period	T_m	ln MI	Area	Unexplained
Eocene (*ca.* 50 Ma)	33.67%	35.90%	14.40%	16.02%
Mid-Pliocene (3.3–3.0 Ma)	28.77%	28.33%	26.38%	16.53%
Last Glacial Maximum (LGM, 22–18 ka)	34.59%	26.37%	21.98%	17.06%
Mid-Holocene (*ca.* 6 ka)	28.45%	25.14%	29.52%	16.89%
Pre-industrial (pre-1850)	29.64%	25.23%	28.79%	16.34%
Recent period (1901–1989)	29.51%	23.96%	35.19%	11.34%
Mean	27.12%	22.95%	33.56%	16.37%

Table S11 | Summary of Generalised Linear Models (GLMs) incorporating bioclimatic variables and the geographic extent of climate. Summary of both linear GLMs and quadratic GLMs incorporating second-order polynomial terms to account for non-linear relationships, developed for each geological period. All models were constructed based on a climatic space defined by the recent (1901–1989) climatic conditions (T_m and ln MI), partitioned into 30 equal intervals along each axis. Species richness is the response variable. Explanatory variables include recent (1901–1989) temperature index (T_m, °C) and natural-log-transformed moisture index (ln MI, unitless), and total land area occupied by each climatic condition (Area, km^2) during different geological periods. The table reports key model statistics, including deviance, McFadden's R^2, Akaike information criterion (AIC) and sample size (N) for each model.

Geological period	Model	Deviance	McFadden's R^2	AIC	N
Eocene (ca. 50 Ma)	Linear	4557951.76	0.42	4562008.83	405
	Quadratic	3350951.63	0.57	3355014.69	

Mid-Pliocene (3.3–3.0 Ma)	Linear	3794049.22	0.52	3798106.28	405
	Quadratic	2330398.35	0.70	2334461.41	
Last Glacial Maximum (LGM, 22–18 ka)	Linear	3044519.46	0.61	3048576.53	405
	Quadratic	1948587.22	0.75	1952650.29	
Mid-Holocene (ca. 6 ka)	Linear	3165583.22	0.60	3169640.28	405
	Quadratic	1781927.91	0.77	1785990.98	
Pre-industrial (pre-1850)	Linear	3455835.36	0.56	3459892.42	405
	Quadratic	1751546.27	0.78	1755609.34	
Recent period (1901–1989)	Linear	3466057.64	0.56	3470114.70	405
	Quadratic	1414545.75	0.82	1418608.81	
Mean	Linear	2836269.57	0.64	2840326.64	405
	Quadratic	1427989.61	0.82	1432052.68	

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Table S12 | Coefficients of explanatory variables in Generalised Linear Models (GLMs) incorporating bioclimatic variables and the geographic extent of climate. Summary of the coefficients (Estimate and *p*-value) of explanatory variables in both linear GLMs and quadratic GLMs incorporating second-order polynomial terms to account for non-linear relationships, developed for each geological period. All models were constructed based on a climatic space defined by the recent (1901–1989) climatic conditions (T_m and ln MI), partitioned into 30 equal intervals along each axis. Species richness is the response variable. Explanatory variables include recent (1901–1989) temperature index (T_m, °C) and natural-log-transformed moisture index (ln MI, unitless), and total land area occupied by each climatic condition (Area, km^2) during different geological periods.

Geological period	Model	Coefficient	T_m	T_m^2	ln MI	ln MI^2	Area	Area^2
Eocene (ca. 50 Ma)	Linear	Estimate	5.54×10^{-2}	– –	2.28×10^{-1}	– –	1.55×10^{-7}	– –
		p-value	< 0.001	– –	< 0.001	– –	< 0.001	– –
	Quadratic	Estimate	1.26×10^{-1}	-3.26×10^{-3}	7.20×10^{-2}	-4.57×10^{-2}	8.98×10^{-7}	-4.04×10^{-13}
		p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Mid-Pliocene (3.3–3.0 Ma)	Linear	Estimate	4.07×10^{-2}	– –	1.72×10^{-1}	– –	6.82×10^{-7}	– –
		p-value	< 0.001	– –	< 0.001	– –	< 0.001	– –
	Quadratic	Estimate	1.10×10^{-1}	-3.27×10^{-3}	9.18×10^{-2}	-1.12×10^{-2}	2.11×10^{-6}	-7.46×10^{-13}
		p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Last Glacial Maximum	Linear	Estimate	4.92×10^{-2}	– –	1.83×10^{-1}	– –	6.22×10^{-7}	– –

(LGM, 22–18 ka)		*p*-value	< 0.001	– –	< 0.001	– –	< 0.001	– –
	Quadratic	Estimate	9.80×10^{-2}	-2.17×10^{-3}	1.61×10^{-1}	-4.08×10^{-3}	1.63×10^{-6}	-3.91×10^{-13}
		p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Mid-Holocene (ca. 6 ka)	Linear	Estimate	4.28×10^{-2}	– –	1.68×10^{-1}	– –	5.73×10^{-7}	– –
		p-value	< 0.001	– –	< 0.001	– –	< 0.001	– –
	Quadratic	Estimate	1.11×10^{-1}	-3.22×10^{-3}	1.26×10^{-1}	-5.27×10^{-3}	1.46×10^{-6}	-2.66×10^{-13}
		p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Pre-industrial (pre-1850)	Linear	Estimate	4.33×10^{-2}	– –	1.75×10^{-1}	– –	5.07×10^{-7}	– –
		p-value	< 0.001	– –	< 0.001	– –	< 0.001	– –
	Quadratic	Estimate	1.26×10^{-1}	-4.04×10^{-3}	1.10×10^{-1}	-6.66×10^{-3}	1.50×10^{-6}	-2.43×10^{-13}
		p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Recent period (1901–1989)	Linear	Estimate	4.34×10^{-2}	– –	1.88×10^{-1}	– –	5.37×10^{-7}	– –
		p-value	< 0.001	– –	< 0.001	– –	< 0.001	– –
	Quadratic	Estimate	1.32×10^{-1}	-4.21×10^{-3}	1.88×10^{-1}	4.04×10^{-4}	1.88×10^{-6}	-3.59×10^{-13}
		p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Mean	Linear	Estimate	3.72×10^{-2}	– –	1.39×10^{-1}	– –	9.43×10^{-7}	– –
		p-value	< 0.001	– –	< 0.001	– –	< 0.001	– –
	Quadratic	Estimate	1.06×10^{-1}	-3.28×10^{-3}	3.49×10^{-2}	-1.43×10^{-2}	2.26×10^{-6}	-5.26×10^{-13}
		p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Table S13 | Summary of the Generalised Additive Models (GAMs) with species richness as the response variable and climate and its deep-time geographic dynamics as explanatory variables for all recent climatic conditions across multiple climatic space resolutions. Summary statistics of GAMs fitted with species richness as the response variable. Explanatory variables include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence to the recent period. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.68	485359.95	< 0.001				
ln MI	0.57	243133.72	< 0.001				
Recent Area	0.84	106864.19	< 0.001	0.95	0.95	0.95	342
ΔArea	0.62	35550.61	< 0.001				
Movement	0.42	41212.21	< 0.001				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.63	656361.87	< 0.001				
ln MI	0.53	341180.83	< 0.001				
Recent Area	0.76	213932.33	< 0.001	0.93	0.93	0.92	529
ΔArea	0.55	37366.92	< 0.001				

Movement	0.43	28029.86	< 0.001				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.68	824598.86	< 0.001				
ln MI	0.50	465665.46	< 0.001				
Recent Area	0.76	325886.77	< 0.001	0.91	0.91	0.91	751
ΔArea	0.55	20190.12	< 0.001				
Movement	0.40	55998.89	< 0.001				
60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.61	885554.69	< 0.001				
ln MI	0.48	591684.02	< 0.001				
Recent Area	0.77	381718.80	< 0.001	0.90	0.90	0.89	986
ΔArea	0.55	40336.41	< 0.001				
Movement	0.39	90781.19	< 0.001				

Table S14 | Summary of the Generalised Additive Models (GAMs) with species richness as the response variable and climate and its deep-time geographic dynamics as explanatory variables for recent climatic conditions that first appeared in the Eocene (*ca.* 50 Ma), across multiple climatic space resolutions. Summary statistics of GAMs fitted with species richness as the response variable. Explanatory variables include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence (i.e. Eocene) to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence (i.e. Eocene) to the recent period. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each

explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.69	208593.97	< 0.001				
ln MI	0.82	161160.60	< 0.001				
Recent Area	0.77	29935.28	< 0.001	0.92	0.92	0.90	88
ΔArea	0.79	15949.11	< 0.001				
Movement	0.47	37054.35	< 0.001				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.75	156233.82	< 0.001				
ln MI	0.82	146852.11	< 0.001				
Recent Area	0.87	85445.79	< 0.001	0.95	0.96	0.94	137
ΔArea	0.72	13256.22	< 0.001				
Movement	0.66	16157.92	< 0.001				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.70	228305.67	< 0.001				
ln MI	0.80	144820.57	< 0.001				
Recent Area	0.83	111722.55	< 0.001	0.94	0.95	0.93	195
ΔArea	0.70	19006.82	< 0.001				
Movement	0.59	16238.15	< 0.001				
60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.66	245215.03	< 0.001	0.93	0.93	0.91	258
ln MI	0.77	219098.10	< 0.001				

Recent Area	0.85	132211.70	< 0.001
ΔArea	0.72	14352.42	< 0.001
Movement	0.45	30592.89	< 0.001

Table S15 | Summary of the Generalised Additive Models (GAMs) with species richness as the response variable and climate and its deep-time geographic dynamics as explanatory variables for recent climatic conditions that first appeared in the Mid-Pliocene (3.3–3.0 Ma), across multiple climatic space resolutions. Summary statistics of GAMs fitted with species richness as the response variable. Explanatory variables include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence (i.e. Mid-Pliocene) to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence (i.e. Mid-Pliocene) to the recent period. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.74	124085.91	< 0.001				
ln MI	0.69	80856.61	< 0.001				
Recent Area	0.56	109540.94	< 0.001	0.94	0.94	0.93	140
ΔArea	0.22	497.03	< 0.001				
Movement	0.48	9512.98	< 0.001				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.78	171294.45	< 0.001	0.94	0.95	0.93	212

ln MI	0.66	127666.29	< 0.001				
Recent Area	0.81	32466.22	< 0.001				
ΔArea	0.60	10527.97	< 0.001				
Movement	0.45	15544.55	< 0.001				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.74	248967.86	< 0.001				
ln MI	0.64	180867.76	< 0.001				
Recent Area	0.71	57224.37	< 0.001	0.93	0.93	0.92	307
ΔArea	0.52	20857.56	< 0.001				
Movement	0.42	26931.11	< 0.001				
60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.73	229332.72	< 0.001				
ln MI	0.64	227880.25	< 0.001				
Recent Area	0.84	69952.47	< 0.001	0.90	0.89	0.88	411
ΔArea	0.63	22303.51	< 0.001				
Movement	0.40	32335.03	< 0.001				

Table S16 | Summary of the Generalised Additive Models (GAMs) with species richness as the response variable and climate and its deep-time geographic dynamics as explanatory variables for recent climatic conditions that first appeared in the Last Glacial Maximum (LGM, 22–18 ka), across multiple climatic space resolutions. Summary statistics of GAMs fitted with species richness as the response variable. Explanatory variables include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence (i.e. LGM) to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence (i.e. LGM) to the recent period. Different GAMs were constructed based on climatic

spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.87	29297.00	< 0.001				
ln MI	0.86	10462.70	< 0.001				
Recent Area	0.85	4936.89	< 0.001	0.86	0.79	0.74	96
ΔArea	0.53	435.82	< 0.001				
Movement	0.54	6219.60	< 0.001				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.90	33161.67	< 0.001				
ln MI	0.86	7298.11	< 0.001				
Recent Area	0.88	9135.40	< 0.001	0.93	0.94	0.91	146
ΔArea	0.61	2011.42	< 0.001				
Movement	0.61	3888.90	< 0.001				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.86	43972.48	< 0.001				
ln MI	0.80	6645.51	< 0.001				
Recent Area	0.86	8718.15	< 0.001	0.89	0.88	0.84	197
ΔArea	0.62	2742.06	< 0.001				
Movement	0.39	6989.94	< 0.001				
60 equal interval resolution							

Predictor	Concurvity	χ^2	*p*-value	Deviance	R_{pred}^2	R_{adj}^2	N
T_m	0.87	55468.33	< 0.001				
ln MI	0.77	9558.44	< 0.001				
Recent Area	0.86	14550.80	< 0.001	0.89	0.88	0.85	255
ΔArea	0.57	2113.34	< 0.001				
Movement	0.31	13362.34	< 0.001				

Table S17 | Relative importance of explanatory variables in Generalised Additive Models (GAMs) with species richness as the response variable and climate and its deep-time geographic dynamics as explanatory variables. Summary of the relative importance of each explanatory variable in GAMs fitted for all recent climatic conditions, as well as separately according to their first appearance. Species richness is the response variable. Explanatory variables include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence to the recent period. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. The method for calculating the relative importance of each explanatory variable is described in the Methods section of the main text.

30 equal interval resolution						
Geological period	**T_m**	**ln MI**	**Recent Area**	**ΔArea**	**Movement**	**Unexplained**
All periods	19.68%	19.19%	26.77%	9.34%	20.05%	4.97%
Eocene (*ca.* 50 Ma)	20.93%	28.68%	23.22%	9.76%	9.07%	8.33%
Mid-Pliocene (3.3–3.0 Ma)	18.15%	25.46%	27.45%	2.45%	20.21%	6.29%
Last Glacial Maximum	29.47%	24.21%	16.96%	11.09%	4.26%	14.01%

(LGM, 22–18 ka)

40 equal interval resolution						
Geological period	**T_m**	**In MI**	**Area**	**ΔArea**	**Movement**	**Unexplained**
All periods	20.24%	18.24%	25.90%	9.24%	19.25%	7.13%
Eocene (*ca.* 50 Ma)	23.53%	25.84%	25.23%	10.18%	10.57%	4.65%
Mid-Pliocene (3.3–3.0 Ma)	17.59%	25.68%	26.08%	6.47%	18.62%	5.56%
Last Glacial Maximum (LGM, 22–18 ka)	28.99%	21.79%	22.54%	14.51%	5.17%	7.00%
50 equal interval resolution						
Geological period	**T_m**	**In MI**	**Area**	**ΔArea**	**Movement**	**Unexplained**
All periods	19.80%	17.71%	25.36%	9.86%	18.75%	8.52%
Eocene (*ca.* 50 Ma)	21.89%	24.49%	26.06%	11.10%	10.51%	5.94%
Mid-Pliocene (3.3–3.0 Ma)	18.11%	24.24%	22.87%	9.50%	18.66%	6.62%
Last Glacial Maximum (LGM, 22–18 ka)	30.20%	21.19%	19.61%	13.88%	4.25%	10.86%
60 equal interval resolution						
Geological period	**T_m**	**In MI**	**Area**	**ΔArea**	**Movement**	**Unexplained**
All periods	19.85%	16.96%	24.59%	9.85%	19.12%	9.63%
Eocene (*ca.* 50 Ma)	22.60%	24.90%	24.78%	10.14%	10.14%	7.44%
Mid-Pliocene (3.3–3.0 Ma)	15.84%	22.54%	23.56%	9.80%	17.84%	10.44%
Last Glacial Maximum (LGM, 22–18 ka)	28.87%	20.58%	19.49%	13.07%	6.84%	11.15%

Table S18 | Summary of Generalised Linear Models (GLMs) with species richness as the response variable and climate and its deep-time geographic dynamics as explanatory variables. Summary of both linear GLMs and quadratic GLMs incorporating second-order polynomial terms to account for non-linear relationships, developed for all recent climatic conditions, as well as separately according to their first appearance. Species richness is the response variable. Explanatory variables include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence to the recent period. Different GLMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. The table reports key model statistics, including deviance, McFadden's R^2, Akaike information criterion (AIC) and sample size (N) for each model.

Geological period	Model	Deviance	McFadden's R^2	AIC	N
All periods	Linear	2865670.43	0.58	2869198.44	342
	Quadratic	1051793.47	0.85	1055331.47	
Eocene	Linear	1196024.18	0.43	1197042.33	88
(ca. 50 Ma)	Quadratic	355709.28	0.83	356737.43	
Mid-Pliocene	Linear	669166.38	0.65	670670.58	140
(3.3–3.0 Ma)	Quadratic	126914.60	0.93	128428.79	
Last Glacial Maximum	Linear	147733.41	0.48	148620.13	96
(LGM, 22–18 ka)	Quadratic	64219.10	0.77	65115.82	

Table S19 | Coefficients of explanatory variables in Generalised Linear Models (GLMs) with species richness as the response variable and climate and its deep-time geographic dynamics as explanatory variables. Summary of the coefficients (Estimate and *p*-value) of explanatory variables in both linear GLMs and quadratic GLMs incorporating second-order polynomial terms to account for non-linear relationships, developed for all recent climatic conditions, as well as separately according to their first appearance. Species richness is the response variable. Explanatory variables include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence to the recent period. Different GLMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals.

Geological period	Model	Coefficient	T_m	T_m^2	ln MI	ln MI^2	Recent Area	Recent Area^2	ΔArea	ΔArea^2	Movement	Movement^2
All periods	Linear	Estimate	3.24×10^{-2}	– –	1.78×10^{-1}	– –	5.21×10^{-7}	– –	-4.11×10^{-8}	– –	8.70×10^{-5}	– –
		p-value	< 0.001	– –	< 0.001	– –	< 0.001	– –	< 0.001	– –	< 0.001	– –
	Quadratic	Estimate	1.27×10^{-1}	-3.94×10^{-3}	1.22×10^{-1}	-4.05×10^{-2}	1.51×10^{-6}	-2.81×10^{-13}	4.03×10^{-8}	-3.64×10^{-15}	2.05×10^{-4}	-1.35×10^{-8}
		p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Eocene (ca. 50 Ma)	Linear	Estimate	3.55×10^{-3}	– –	9.83×10^{-2}	– –	3.88×10^{-7}	– –	1.05×10^{-7}	– –	8.71×10^{-5}	– –
		p-value	< 0.001	– –	< 0.001	– –	< 0.001	– –	< 0.001	– –	< 0.001	– –

	Quadratic	Estimate	3.94×10^{-1}	-9.90×10^{-3}	1.77×10^{-1}	-3.11×10^{-1}	7.32×10^{-7}	-1.33×10^{-13}	1.50×10^{-7}	-1.83×10^{-14}	-2.11×10^{-4}	5.30×10^{-9}
		p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Mid-Pliocene (3.3–3.0 Ma)	Linear	Estimate	3.66×10^{-2}	– –	1.87×10^{-1}	– –	1.54×10^{-6}	– –	-1.62×10^{-7}	– –	1.20×10^{-4}	– –
		p-value	< 0.001	– –	< 0.001	– –	< 0.001	– –	< 0.001	– –	< 0.001	– –
	Quadratic	Estimate	1.43×10^{-1}	-4.23×10^{-3}	1.78×10^{-1}	-3.00×10^{-2}	3.87×10^{-6}	-2.16×10^{-12}	2.53×10^{-8}	-3.59×10^{-15}	2.20×10^{-4}	-1.42×10^{-8}
		p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.14	< 0.001	< 0.001
Last Glacial Maximum (LGM, 22–18 ka)	Linear	Estimate	7.04×10^{-2}	– –	1.07×10^{-1}	– –	1.19×10^{-6}	– –	2.25×10^{-7}	– –	-5.49×10^{-5}	– –
		p-value	< 0.001	– –	< 0.001	– –	< 0.001	– –	< 0.001	– –	< 0.001	– –
	Quadratic	Estimate	6.88×10^{-2}	-1.16×10^{-3}	-3.17×10^{-1}	-1.08×10^{-1}	3.86×10^{-6}	-2.54×10^{-12}	-9.89×10^{-9}	-5.62×10^{-14}	5.59×10^{-5}	-5.16×10^{-9}
		p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	0.38	< 0.001	< 0.001	< 0.001

Table S20 | Summary of the Generalised Additive Models (GAMs) with species turnover as the response variable and climate and its deep-time geographic dynamics as explanatory variables for all recent climatic conditions across multiple climatic space resolutions. Summary statistics of GAMs fitted with turnover component of β-diversity as the response variable. Explanatory variables include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence to the recent period. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.65	63.00	< 0.001				
ln MI	0.54	7.31	0.11				
Recent Area	0.84	122.41	< 0.001	0.74	0.77	0.75	297
ΔArea	0.63	2.28	0.13				
Movement	0.46	61.57	< 0.001				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.66	114.00	< 0.001				
ln MI	0.51	17.04	< 0.05				
Recent Area	0.76	159.96	< 0.001	0.72	0.75	0.73	464
ΔArea	0.55	7.96	< 0.001				

Movement	0.49	93.95	< 0.001				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.67	107.91	< 0.001				
ln MI	0.55	18.51	< 0.01				
Recent Area	0.76	119.50	< 0.001	0.64	0.65	0.63	638
ΔArea	0.58	14.60	< 0.001				
Movement	0.49	58.31	< 0.001				
60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.66	127.13	< 0.001				
ln MI	0.53	40.57	< 0.001				
Recent Area	0.77	94.97	< 0.001	0.57	0.63	0.62	830
ΔArea	0.57	2.57	0.14				
Movement	0.46	70.44	< 0.001				

344 **Table S21 | Summary of the Generalised Additive Models (GAMs) with species turnover as**
345 **the response variable and climate and its deep-time geographic dynamics as explanatory**
346 **variables for recent climatic conditions that first appeared in the Eocene (*ca.* 50 Ma), across**
347 **multiple climatic space resolutions.** Summary statistics of GAMs fitted with turnover component
348 of β-diversity as the response variable. Explanatory variables include: T_m (°C), recent (1901–1989)
349 temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area
350 (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in
351 total land area occupied by a climatic condition from its earliest occurrence (i.e. Eocene) to the
352 recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence
353 (i.e. Eocene) to the recent period. Different GAMs were constructed based on climatic spaces
354 defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis
355 divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2

356 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2)

357 and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.78	14.00	< 0.05				
ln MI	0.85	15.94	< 0.001				
Recent Area	0.91	61.21	< 0.001	0.89	0.86	0.82	82
ΔArea	0.80	0.63	0.43				
Movement	0.73	19.84	< 0.001				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.77	81.62	< 0.001				
ln MI	0.86	9.20	< 0.05				
Recent Area	0.87	49.77	< 0.001	0.77	0.76	0.71	127
ΔArea	0.75	1.83	0.31				
Movement	0.74	18.76	< 0.001				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.72	22.73	< 0.001				
ln MI	0.82	1.43	0.23				
Recent Area	0.82	45.56	< 0.001	0.52	0.60	0.54	184
ΔArea	0.71	3.20	0.07				
Movement	0.65	9.09	< 0.001				
60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.72	63.45	< 0.001				
ln MI	0.79	6.74	0.13	0.60	0.66	0.61	236
Recent Area	0.85	21.21	< 0.001				

ΔArea	0.73	0.05	0.82
Movement	0.54	43.59	< 0.001

Table S22 | Summary of the Generalised Additive Models (GAMs) with species turnover as the response variable and climate and its deep-time geographic dynamics as explanatory variables for recent climatic conditions that first appeared in the Mid-Pliocene (3.3–3.0 Ma), across multiple climatic space resolutions. Summary statistics of GAMs fitted with turnover component of β-diversity as the response variable. Explanatory variables include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence (i.e. Mid-Pliocene) to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence (i.e. Mid-Pliocene) to the recent period. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.80	10.01	< 0.05				
ln MI	0.75	12.77	< 0.01				
Recent Area	0.82	46.59	< 0.001	0.76	0.77	0.74	128
ΔArea	0.63	0.89	0.66				
Movement	0.52	33.66	< 0.001				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.80	47.19	< 0.001	0.85	0.84	0.82	198

ln MI	0.68	71.69	< 0.001				
Recent Area	0.82	15.10	< 0.001				
ΔArea	0.65	4.91	0.10				
Movement	0.49	68.29	< 0.001				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.76	2.36	0.12				
ln MI	0.67	27.29	< 0.001				
Recent Area	0.74	40.08	< 0.001	0.61	0.63	0.60	267
ΔArea	0.60	1.12	0.29				
Movement	0.45	68.67	< 0.001				
60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.75	0.56	0.54				
ln MI	0.67	54.01	< 0.001				
Recent Area	0.85	32.17	< 0.001	0.59	0.60	0.58	368
ΔArea	0.67	0.92	0.34				
Movement	0.42	115.65	< 0.001				

373 **Table S23 | Summary of the Generalised Additive Models (GAMs) with species turnover as**
374 **the response variable and climate and its deep-time geographic dynamics as explanatory**
375 **variables for recent climatic conditions that first appeared in the Last Glacial Maximum (LGM,**
376 **22–18 ka), across multiple climatic space resolutions.** Summary statistics of GAMs fitted with
377 turnover component of β-diversity as the response variable. Explanatory variables include: T_m (°C),
378 recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture
379 index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period;
380 ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence
381 (i.e. LGM) to the recent period; Movement (km), geographic shift of a climatic condition since its
382 earliest occurrence (i.e. LGM) to the recent period. Different GAMs were constructed based on

climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.88	10.47	0.07				
ln MI	0.85	22.07	< 0.001				
Recent Area	0.85	67.36	< 0.001	0.83	0.83	0.80	78
ΔArea	0.58	10.75	< 0.001				
Movement	0.60	17.49	< 0.001				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.91	14.54	< 0.05				
ln MI	0.84	10.54	< 0.05				
Recent Area	0.90	60.04	< 0.001	0.78	0.80	0.77	117
ΔArea	0.68	0.78	0.38				
Movement	0.56	6.53	< 0.05				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.89	32.01	< 0.001				
ln MI	0.79	19.57	< 0.001				
Recent Area	0.87	106.63	< 0.001	0.79	0.80	0.77	160
ΔArea	0.65	6.32	< 0.05				
Movement	0.38	25.18	< 0.001				
60 equal interval resolution							

Predictor	Concurvity	χ^2	*p*-value	Deviance	R_{pred}^2	R_{adj}^2	N
T_m	0.88	37.93	< 0.001				
ln MI	0.77	42.87	< 0.001				
Recent Area	0.87	58.25	< 0.001	0.81	0.78	0.75	194
ΔArea	0.63	5.23	< 0.05				
Movement	0.34	31.93	< 0.001				

Table S24 | Summary of the Generalised Additive Models (GAMs) with phylogenetic diversity as the response variable and climate and its deep-time geographic dynamics as explanatory variables for all recent climatic conditions across multiple climatic space resolutions. Summary statistics of GAMs fitted with Faith's phylogenetic diversity[2] as the response variable. Explanatory variables include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence to the recent period. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.64	197.55	< 0.001				
ln MI	0.56	139.60	< 0.001				
Recent Area	0.84	48.21	< 0.001	0.85	0.85	0.84	333
ΔArea	0.62	41.54	< 0.001				
Movement	0.41	37.37	< 0.001				

40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.61	325.36	< 0.001				
ln MI	0.53	237.09	< 0.001				
Recent Area	0.76	55.06	< 0.001	0.83	0.83	0.82	516
ΔArea	0.55	41.80	< 0.001				
Movement	0.42	40.35	< 0.001				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.67	382.79	< 0.001				
ln MI	0.49	247.36	< 0.001				
Recent Area	0.76	86.85	< 0.001	0.82	0.82	0.81	734
ΔArea	0.55	40.24	< 0.001				
Movement	0.40	57.51	< 0.001				
60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.63	472.51	< 0.001				
ln MI	0.47	340.21	< 0.001				
Recent Area	0.77	133.54	< 0.001	0.81	0.81	0.81	968
ΔArea	0.56	54.97	< 0.001				
Movement	0.39	102.72	< 0.001				

Table S25 | Summary of the Generalised Additive Models (GAMs) with phylogenetic diversity as the response variable and climate and its deep-time geographic dynamics as explanatory variables for recent climatic conditions that first appeared in the Eocene (*ca.* 50 Ma), across multiple climatic space resolutions. Summary statistics of GAMs fitted with Faith's phylogenetic diversity[2] as the response variable. Explanatory variables include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in

total land area occupied by a climatic condition from its earliest occurrence (i.e. Eocene) to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence (i.e. Eocene) to the recent period. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.76	92.73	< 0.001				
ln MI	0.86	130.50	< 0.001				
Recent Area	0.91	10.64	< 0.05	0.94	0.94	0.92	87
ΔArea	0.79	10.77	< 0.05				
Movement	0.66	0.10	0.88				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.75	89.69	< 0.001				
ln MI	0.82	114.57	< 0.001				
Recent Area	0.87	60.67	< 0.001	0.90	0.90	0.88	136
ΔArea	0.72	0.20	0.65				
Movement	0.66	1.01	0.40				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.70	99.30	< 0.001				
ln MI	0.80	130.64	< 0.001				
Recent Area	0.83	83.61	< 0.001	0.89	0.89	0.87	194
ΔArea	0.70	1.58	0.21				
Movement	0.59	3.99	0.09				

60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.66	127.88	< 0.001				
ln MI	0.77	166.98	< 0.001				
Recent Area	0.85	95.08	< 0.001	0.87	0.87	0.86	257
ΔArea	0.72	3.04	0.08				
Movement	0.46	5.36	0.22				

Table S26 | Summary of the Generalised Additive Models (GAMs) with phylogenetic diversity as the response variable and climate and its deep-time geographic dynamics as explanatory variables for recent climatic conditions that first appeared in the Mid-Pliocene (3.3–3.0 Ma), across multiple climatic space resolutions. Summary statistics of GAMs fitted with Faith's phylogenetic diversity[2] as the response variable. Explanatory variables include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence (i.e. Mid-Pliocene) to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence (i.e. Mid-Pliocene) to the recent period. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.74	73.23	< 0.001				
ln MI	0.69	53.54	< 0.001	0.83	0.83	0.81	140
Recent Area	0.56	119.42	< 0.001				

ΔArea	0.22	4.61	0.13				
Movement	0.48	8.07	< 0.05				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.78	253.68	< 0.001				
ln MI	0.65	223.38	< 0.001				
Recent Area	0.81	48.73	< 0.001	0.88	0.88	0.86	210
ΔArea	0.61	2.53	0.40				
Movement	0.45	0.82	0.37				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.74	392.41	< 0.001				
ln MI	0.64	320.08	< 0.001				
Recent Area	0.71	31.27	< 0.001	0.85	0.85	0.84	305
ΔArea	0.52	28.10	< 0.001				
Movement	0.42	3.24	0.24				
60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.73	266.27	< 0.001				
ln MI	0.63	236.90	< 0.001				
Recent Area	0.84	69.56	< 0.001	0.81	0.81	0.80	407
ΔArea	0.64	13.99	< 0.01				
Movement	0.39	8.88	< 0.05				

Table S27 | Summary of the Generalised Additive Models (GAMs) with phylogenetic diversity as the response variable and climate and its deep-time geographic dynamics as explanatory variables for recent climatic conditions that first appeared in the Last Glacial Maximum (LGM, 22–18 ka), across multiple climatic space resolutions. Summary statistics of GAMs fitted with Faith's phylogenetic diversity[2] as the response variable. Explanatory variables include: T_m (°C),

436 recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture
437 index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period;
438 ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence
439 (i.e. LGM) to the recent period; Movement (km), geographic shift of a climatic condition since its
440 earliest occurrence (i.e. LGM) to the recent period. Different GAMs were constructed based on
441 climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with
442 each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model
443 include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance),
444 predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into
445 each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.91	60.30	< 0.001				
ln MI	0.88	8.68	0.05				
Recent Area	0.95	9.26	< 0.05	0.72	0.72	0.66	90
ΔArea	0.72	0.00	0.99				
Movement	0.62	3.91	0.30				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.90	92.99	< 0.001				
ln MI	0.87	7.79	0.12				
Recent Area	0.89	31.31	< 0.001	0.77	0.77	0.73	137
ΔArea	0.65	0.10	0.75				
Movement	0.61	11.60	< 0.05				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.87	119.01	< 0.001	0.70	0.71	0.67	187

ln MI	0.79	8.16	0.09				
Recent Area	0.86	31.75	< 0.001				
ΔArea	0.64	0.57	0.45				
Movement	0.39	10.83	< 0.05				
60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.87	181.31	< 0.001				
ln MI	0.76	10.83	< 0.05				
Recent Area	0.86	68.59	< 0.001	0.74	0.74	0.72	245
ΔArea	0.59	0.77	0.38				
Movement	0.31	38.22	< 0.001				

Table S28 | Summary of the Generalised Additive Models (GAMs) with relative phylogenetic diversity as the response variable and climate and its deep-time geographic dynamics as explanatory variables for all recent climatic conditions across multiple climatic space resolutions. Summary statistics of GAMs fitted with relative phylogenetic diversity (calculated as the residuals from regressing phylogenetic diversity against species richness) as the response variable. Explanatory variables include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence to the recent period. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution

Predictor	Concurvity	χ^2	*p*-value	Deviance	R_{pred}^2	R_{adj}^2	N
T_m	0.64	157.07	< 0.001				
ln MI	0.56	56.06	< 0.001				
Recent Area	0.84	15.17	< 0.001	0.53	0.53	0.49	333
ΔArea	0.62	2.94	0.45				
Movement	0.41	17.34	< 0.001				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.61	250.31	< 0.001				
ln MI	0.53	114.22	< 0.001				
Recent Area	0.76	19.89	< 0.001	0.56	0.56	0.53	516
ΔArea	0.55	12.51	< 0.05				
Movement	0.42	36.63	< 0.001				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.67	383.95	< 0.001				
ln MI	0.49	179.03	< 0.001				
Recent Area	0.76	64.01	< 0.001	0.55	0.55	0.53	734
ΔArea	0.55	12.45	< 0.05				
Movement	0.40	28.34	< 0.001				
60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.63	478.01	< 0.001				
ln MI	0.47	218.37	< 0.001				
Recent Area	0.77	53.55	< 0.001	0.52	0.52	0.50	968
ΔArea	0.56	19.31	< 0.01				
Movement	0.39	54.78	< 0.001				

Table S29 | Summary of the Generalised Additive Models (GAMs) with relative phylogenetic diversity as the response variable and climate and its deep-time geographic dynamics as explanatory variables for recent climatic conditions that first appeared in the Eocene (*ca.* 50 Ma), across multiple climatic space resolutions. Summary statistics of GAMs fitted with relative phylogenetic diversity (calculated as the residuals from regressing phylogenetic diversity against species richness) as the response variable. Explanatory variables include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence (i.e. Eocene) to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence (i.e. Eocene) to the recent period. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.69	192.95	< 0.001				
ln MI	0.82	118.19	< 0.001				
Recent Area	0.80	11.44	< 0.05	0.81	0.81	0.78	87
ΔArea	0.73	1.16	0.29				
Movement	0.53	7.65	< 0.05				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.75	221.22	< 0.001				
ln MI	0.82	221.46	< 0.001	0.83	0.83	0.80	136
Recent Area	0.87	8.93	0.06				

ΔArea	0.72	5.32	0.20				
Movement	0.66	3.72	0.06				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.70	318.68	< 0.001				
ln MI	0.80	232.70	< 0.001				
Recent Area	0.83	15.48	< 0.001	0.77	0.77	0.74	194
ΔArea	0.70	0.58	0.45				
Movement	0.59	2.71	0.24				
60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.66	252.31	< 0.001				
ln MI	0.77	157.38	< 0.001				
Recent Area	0.85	5.59	< 0.05	0.69	0.69	0.66	257
ΔArea	0.72	9.25	0.12				
Movement	0.46	1.98	0.35				

Table S30 | Summary of the Generalised Additive Models (GAMs) with relative phylogenetic diversity as the response variable and climate and its deep-time geographic dynamics as explanatory variables for recent climatic conditions that first appeared in the Mid-Pliocene (3.3–3.0 Ma), across multiple climatic space resolutions. Summary statistics of GAMs fitted with relative phylogenetic diversity (calculated as the residuals from regressing phylogenetic diversity against species richness) as the response variable. Explanatory variables include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence (i.e. Mid-Pliocene) to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence (i.e. Mid-Pliocene) to the recent period. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with

each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.79	54.18	< 0.001				
ln MI	0.75	69.90	< 0.001				
Recent Area	0.81	5.19	< 0.05	0.73	0.73	0.69	140
ΔArea	0.59	36.49	< 0.001				
Movement	0.51	1.17	0.28				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.78	120.94	< 0.001				
ln MI	0.65	105.55	< 0.001				
Recent Area	0.81	17.03	< 0.001	0.74	0.74	0.71	210
ΔArea	0.61	42.19	< 0.001				
Movement	0.45	15.69	< 0.001				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.74	160.61	< 0.001				
ln MI	0.64	103.56	< 0.001				
Recent Area	0.71	47.79	< 0.001	0.70	0.70	0.67	305
ΔArea	0.52	35.96	< 0.001				
Movement	0.42	16.54	< 0.001				
60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**

T_m	0.73	194.06	< 0.001				
ln MI	0.63	114.24	< 0.001				
Recent Area	0.84	34.78	< 0.001	0.65	0.65	0.62	407
ΔArea	0.64	52.50	< 0.001				
Movement	0.39	17.71	< 0.001				

Table S31 | Summary of the Generalised Additive Models (GAMs) with relative phylogenetic diversity as the response variable and climate and its deep-time geographic dynamics as explanatory variables for recent climatic conditions that first appeared in the Last Glacial Maximum (LGM, 22–18 ka), across multiple climatic space resolutions. Summary statistics of GAMs fitted with relative phylogenetic diversity (calculated as the residuals from regressing phylogenetic diversity against species richness) as the response variable. Explanatory variables include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence (i.e. LGM) to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence (i.e. LGM) to the recent period. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Reported metrics for each model include concurvity, χ^2 and *p*-value for each explanatory variable, and explained deviance (Deviance), predicted R^2 (R_{pred}^2) and adjusted R^2 (R_{adj}^2) of each GAM model, and the sample size (N) fitted into each model.

30 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.91	3.38	0.23				
ln MI	0.88	5.27	< 0.05				
Recent Area	0.95	4.64	< 0.05	0.14	0.14	0.08	90
ΔArea	0.72	0.01	0.94				

Movement	0.62	0.08	0.78				
40 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.90	40.20	< 0.001				
ln MI	0.87	35.50	< 0.001				
Recent Area	0.89	5.96	0.08	0.45	0.46	0.37	137
ΔArea	0.65	0.05	0.83				
Movement	0.61	6.64	0.14				
50 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.87	41.92	< 0.001				
ln MI	0.79	42.50	< 0.001				
Recent Area	0.86	2.06	0.15	0.33	0.34	0.28	187
ΔArea	0.64	0.01	0.92				
Movement	0.39	3.08	0.08				
60 equal interval resolution							
Predictor	**Concurvity**	**χ^2**	***p*-value**	**Deviance**	**R_{pred}^2**	**R_{adj}^2**	**N**
T_m	0.87	74.10	< 0.001				
ln MI	0.76	55.39	< 0.001				
Recent Area	0.86	17.00	< 0.001	0.39	0.39	0.34	245
ΔArea	0.59	4.51	0.35				
Movement	0.31	4.73	< 0.05				

509 **Table S32 | Spatial auto-correlation test for Generalised Additive Models (GAMs)**
510 **incorporating bioclimatic variables and the geographic extent of climate at multiple climatic**
511 **space resolutions.** Summary of spatial autocorrelation tests for the residuals of GAMs fitted across
512 different geological periods. Species richness is the response variable. Explanatory variables
513 include recent (1901–1989) temperature index (T_m, °C) and natural-log-transformed moisture index
514 (ln MI, unitless), and total land area occupied by each climatic condition (Area, km^2) in different

geological periods. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Potential spatial autocorrelation was assessed using Moran's *I* test on the residuals of each GAM. Moran's *I* index and corresponding *p*-value of each GAM are presented in the table.

30 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
Eocene (*ca.* 50 Ma)	0.26	< 0.001
Mid-Pliocene (3.3–3.0 Ma)	0.29	< 0.001
Last Glacial Maximum (LGM, 22–18 ka)	0.33	< 0.001
Mid-Holocene (*ca.* 6 ka)	0.30	< 0.001
Pre-industrial (pre-1850)	0.28	< 0.001
Recent period (1901–1989)	0.32	< 0.001
Mean	0.30	< 0.001
40 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
Eocene (*ca.* 50 Ma)	0.33	< 0.001
Mid-Pliocene (3.3–3.0 Ma)	0.34	< 0.001
Last Glacial Maximum (LGM, 22–18 ka)	0.40	< 0.001

Mid-Holocene (*ca.* 6 ka)	0.40	< 0.001
Pre-industrial (pre-1850)	0.34	< 0.001
Recent period (1901–1989)	0.38	< 0.001
Mean	0.39	< 0.001
50 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
Eocene (*ca.* 50 Ma)	0.38	< 0.001
Mid-Pliocene (3.3–3.0 Ma)	0.39	< 0.001
Last Glacial Maximum (LGM, 22–18 ka)	0.43	< 0.001
Mid-Holocene (*ca.* 6 ka)	0.41	< 0.001
Pre-industrial (pre-1850)	0.36	< 0.001
Recent period (1901–1989)	0.40	< 0.001
Mean	0.40	< 0.001
60 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
Eocene (*ca.* 50 Ma)	0.36	< 0.001
Mid-Pliocene (3.3–3.0 Ma)	0.35	< 0.001

Last Glacial Maximum (LGM, 22–18 ka)	0.40	< 0.001
Mid-Holocene (*ca.* 6 ka)	0.39	< 0.001
Pre-industrial (pre-1850)	0.34	< 0.001
Recent period (1901–1989)	0.37	< 0.001
Mean	0.38	< 0.001

Table S33 | Spatial auto-correlation test for Generalised Additive Models (GAMs) with species richness as the response variable and climate and its deep-time geographic dynamics as explanatory variables. Summary of spatial autocorrelation tests for the residuals of GAMs fitted for all recent climatic conditions, as well as separately according to their first appearance. Species richness is the response variable. Explanatory variables include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence to the recent period. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Potential spatial autocorrelation was assessed using Moran's *I* test on the residuals of each GAM. Moran's *I* index and corresponding *p*-value of each GAM are presented in the table.

30 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
All periods	0.17	< 0.001
Eocene	0.01	0.38

(*ca.* 50 Ma)		
Mid-Pliocene (3.3–3.0 Ma)	0.10	< 0.05
Last Glacial Maximum (LGM, 22–18 ka)	0.04	0.22
40 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
All periods	0.24	< 0.001
Eocene (*ca.* 50 Ma)	–0.14	0.99
Mid-Pliocene (3.3–3.0 Ma)	0.06	0.07
Last Glacial Maximum (LGM, 22–18 ka)	–0.05	0.80
50 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
All periods	0.27	< 0.001
Eocene (*ca.* 50 Ma)	–0.02	0.58
Mid-Pliocene (3.3–3.0 Ma)	0.03	0.17
Last Glacial Maximum (LGM, 22–18 ka)	0.01	0.39
60 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
All periods	0.23	< 0.001
Eocene (*ca.* 50 Ma)	–0.01	0.59

Mid-Pliocene (3.3–3.0 Ma)	0.02	0.22
Last Glacial Maximum (LGM, 22–18 ka)	–0.05	0.87

Table S34 | Spatial auto-correlation test for Generalised Additive Models (GAMs) with species turnover as the response variable and climate and its deep-time geographic dynamics as explanatory variables. Summary of spatial autocorrelation tests for the residuals of GAMs fitted for all recent climatic conditions, as well as separately according to their first appearance. Turnover component of β-diversity is the response variable. Explanatory variables include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence to the recent period. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Potential spatial autocorrelation was assessed using Moran's *I* test on the residuals of each GAM. Moran's *I* index and corresponding *p*-value of each GAM are presented in the table.

30 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
All periods	0.07	< 0.05
Eocene (*ca.* 50 Ma)	–0.17	0.98
Mid-Pliocene (3.3–3.0 Ma)	–0.05	0.79
Last Glacial Maximum (LGM, 22–18 ka)	0.02	0.34

40 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
All periods	0.06	< 0.05
Eocene (*ca.* 50 Ma)	–0.07	0.85
Mid-Pliocene (3.3–3.0 Ma)	0.02	0.28
Last Glacial Maximum (LGM, 22–18 ka)	–0.08	0.87
50 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
All periods	0.01	0.27
Eocene (*ca.* 50 Ma)	–0.05	0.82
Mid-Pliocene (3.3–3.0 Ma)	0.10	< 0.01
Last Glacial Maximum (LGM, 22–18 ka)	–0.03	0.66
60 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
All periods	–0.02	0.82
Eocene (*ca.* 50 Ma)	–0.10	0.99
Mid-Pliocene (3.3–3.0 Ma)	–0.01	0.62
Last Glacial Maximum (LGM, 22–18 ka)	–0.11	0.99

Table S35 | Spatial auto-correlation test for Generalised Additive Models (GAMs) with phylogenetic diversity as the response variable and climate and its deep-time geographic dynamics as explanatory variables. Summary of spatial autocorrelation tests for the residuals of GAMs fitted for all recent climatic conditions, as well as separately according to their first appearance. Faith's phylogenetic diversity[2] is the response variable. Explanatory variables include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence to the recent period. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Potential spatial autocorrelation was assessed using Moran's *I* test on the residuals of each GAM. Moran's *I* index and corresponding *p*-value of each GAM are presented in the table.

30 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
All periods	0.25	< 0.001
Eocene (*ca.* 50 Ma)	0.04	0.24
Mid-Pliocene (3.3–3.0 Ma)	0.11	0.02
Last Glacial Maximum (LGM, 22–18 ka)	–0.07	0.83
40 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
All periods	0.34	< 0.001
Eocene (*ca.* 50 Ma)	0.11	< 0.05

Mid-Pliocene (3.3–3.0 Ma)	0.01	0.39
Last Glacial Maximum (LGM, 22–18 ka)	–0.05	0.81
50 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
All periods	0.32	< 0.001
Eocene (*ca.* 50 Ma)	0.12	< 0.01
Mid-Pliocene (3.3–3.0 Ma)	0.14	< 0.001
Last Glacial Maximum (LGM, 22–18 ka)	–0.00047	0.46
60 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
All periods	0.31	< 0.001
Eocene (*ca.* 50 Ma)	0.14	< 0.001
Mid-Pliocene (3.3–3.0 Ma)	0.04	0.12
Last Glacial Maximum (LGM, 22–18 ka)	0.05	0.10

562 **Table S36 | Spatial auto-correlation test for Generalised Additive Models (GAMs) with relative**
563 **phylogenetic diversity as the response variable and climate and its deep-time geographic**
564 **dynamics as explanatory variables.** Summary of spatial autocorrelation tests for the residuals of
565 GAMs fitted for all recent climatic conditions, as well as separately according to their first
566 appearance. Relative phylogenetic diversity (calculated as the residuals from regressing
567 phylogenetic diversity against species richness) is the response variable. Explanatory variables

include: T_m (°C), recent (1901–1989) temperature index; ln MI (unitless), recent natural-log-transformed moisture index; Recent Area (km^2), total land area occupied by a climatic condition in the recent period; ΔArea (km^2), change in total land area occupied by a climatic condition from its earliest occurrence to the recent period; Movement (km), geographic shift of a climatic condition since its earliest occurrence to the recent period. Different GAMs were constructed based on climatic spaces defined by the recent climatic conditions (T_m and ln MI) at four resolutions, with each climatic axis divided into 30, 40, 50 or 60 equal intervals. Potential spatial autocorrelation was assessed using Moran's *I* test on the residuals of each GAM. Moran's *I* index and corresponding *p*-value of each GAM are presented in the table.

30 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
All periods	0.39	< 0.001
Eocene (*ca.* 50 Ma)	0.01	0.38
Mid-Pliocene (3.3–3.0 Ma)	0.18	< 0.001
Last Glacial Maximum (LGM, 22–18 ka)	–0.10	0.91
40 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
All periods	0.45	< 0.001
Eocene (*ca.* 50 Ma)	0.02	0.34
Mid-Pliocene (3.3–3.0 Ma)	0.27	< 0.001
Last Glacial Maximum (LGM, 22–18 ka)	–0.00021	0.45

50 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
All periods	0.48	< 0.001
Eocene (*ca.* 50 Ma)	0.06	0.08
Mid-Pliocene (3.3–3.0 Ma)	0.29	< 0.001
Last Glacial Maximum (LGM, 22–18 ka)	0.11	< 0.01
60 equal interval resolution		
Geological period	**Moran's *I***	***p*-value**
All periods	0.44	< 0.001
Eocene (*ca.* 50 Ma)	0.02	0.28
Mid-Pliocene (3.3–3.0 Ma)	0.19	< 0.001
Last Glacial Maximum (LGM, 22–18 ka)	0.11	< 0.01

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References

1. Cai, L. *et al.* Global models and predictions of plant diversity based on advanced machine learning techniques. *New Phytol.* **237**, 1432–1445 (2023).
2. Faith, D. P. Conservation evaluation and phylogenetic diversity. *Biol. Conserv.* **61**, 1–10 (1992).
3. Rafiqpoor, D., Kier, G. & Kreft, H. Global centers of vascular plant diversity. *Nov. Acta Leopoldina NF* **92**, 61–83 (2005).
4. Kier, G. *et al.* Global patterns of plant diversity and floristic knowledge. *J. Biogeogr.* **32**, 1107–1116 (2005).
5. Kreft, H. & Jetz, W. Global patterns and determinants of vascular plant diversity. *Proc. Natl. Acad. Sci.* **104**, 5925–5930 (2007).
6. Brummitt, N., Araújo, A. C. & Harris, T. Areas of plant diversity—What do we know? *Plants, People, Planet* **3**, 33–44 (2021).
7. Sabatini, F. M. *et al.* Global patterns of vascular plant alpha diversity. *Nat. Commun.* **13**, 4683 (2022).
8. Govaerts, R., Nic Lughadha, E., Black, N., Turner, R. & Paton, A. The World Checklist of Vascular Plants, a continuously updated resource for exploring global plant diversity. *Sci. data* **8**, 215 (2021).
9. Weigelt, P., König, C. & Kreft, H. GIFT–A global inventory of floras and traits for macroecology and biogeography. *J. Biogeogr.* **47**, 16–43 (2020).
10. Steinig, S.; Abe-Ouchi, A.; de Boer, A.M.; Chan, W.-L.; Donnadieu, Y.; Hutchinson, D.; Knorr, G.; Ladant, J.-B.; Morozova, P.; Niezgodzki, I.; Poulsen, C.J.; Volodin, E.M.; Zhang, Z.; Zhu, J.; Lunt, D. J. Deep-Time Model Intercomparison Project (DeepMIP) Eocene model data version 1.0. *NERC EDS Cent. Environ. Data Anal.* (2024) doi:10.5285/95aa41439d564756950f89921b6ef215.
11. Hurrell, J. W. *et al.* The community earth system model: a framework for collaborative research. *Bull. Am. Meteorol. Soc.* **94**, 1339–1360 (2013).

12. Lunt, D. J. *et al.* DeepMIP: Model intercomparison of early Eocene climatic optimum (EECO) large-scale climate features and comparison with proxy data. *Clim. Past* **17**, 203–227 (2021).
13. Delworth, T. L. *et al.* GFDL's CM2 global coupled climate models. Part I: Formulation and simulation characteristics. *J. Clim.* **19**, 643–674 (2006).
14. Bentsen, M. *et al.* The Norwegian Earth System Model, NorESM1-M–Part 1: description and basic evaluation of the physical climate. *Geosci. Model Dev.* **6**, 687–720 (2013).
15. Kageyama, M. *et al.* PMIP4-CMIP6: the contribution of the Paleoclimate Modelling Intercomparison Project to CMIP6. *Geosci. Model Dev. Discuss.* **11**, 1033–1057 (2018).
16. Danabasoglu, G. *et al.* The community earth system model version 2 (CESM2). *J. Adv. Model. Earth Syst.* **12**, e2019MS001916 (2020).
17. Kelley, M. *et al.* GISS-E2. 1: Configurations and climatology. *J. Adv. Model. Earth Syst.* **12**, e2019MS002025 (2020).
18. Miller, R. L. *et al.* CMIP6 historical simulations (1850–2014) with GISS-E2. 1. *J. Adv. Model. Earth Syst.* **13**, e2019MS002034 (2021).
19. Andrews, M. B. *et al.* Historical simulations with HadGEM3-GC3. 1 for CMIP6. *J. Adv. Model. Earth Syst.* **12**, e2019MS001995 (2020).
20. Semmler, T. *et al.* Simulations for CMIP6 with the AWI climate model AWI-CM-1-1. *J. Adv. Model. Earth Syst.* **12**, e2019MS002009 (2020).
21. Mauritsen, T. *et al.* Developments in the MPI-M Earth System Model version 1.2 (MPI-ESM1. 2) and its response to increasing CO2. *J. Adv. Model. Earth Syst.* **11**, 998–1038 (2019).
22. Yukimoto, S. *et al.* The Meteorological Research Institute Earth System Model version 2.0, MRI-ESM2. 0: Description and basic evaluation of the physical component. *J. Meteorol. Soc. Japan. Ser. II* **97**, 931–965 (2019).
23. Cao, J. *et al.* The NUIST Earth System Model (NESM) version 3: description and preliminary evaluation. *Geosci. Model Dev.* **11**, 2975–2993 (2018).

24. Seland, Ø. *et al.* Overview of the Norwegian Earth System Model (NorESM2) and key climate response of CMIP6 DECK, historical, and scenario simulations. *Geosci. Model Dev.* **13**, 6165–6200 (2020).

25. Eyring, V. *et al.* Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization. *Geosci. Model Dev.* **9**, 1937–1958 (2016).

26. Bi, D. *et al.* Configuration and spin-up of ACCESS-CM2, the new generation Australian community climate and earth system simulator coupled model. *J. South. Hemisph. Earth Syst. Sci.* **70**, 225–251 (2020).

27. Tatebe, H. *et al.* Description and basic evaluation of simulated mean state, internal variability, and climate sensitivity in MIROC6. *Geosci. Model Dev.* **12**, 2727–2765 (2019).

28. University of East Anglia Climatic Research Unit; Harris, I.C.; Jones, P.D.; Osborn, T. CRU TS4.09: Climatic Research Unit (CRU) Time-Series (TS) version 4.09 of high-resolution gridded data of month-by-month variation in climate (Jan. 1901- Dec. 2024). *NERC EDS Cent. Environ. Data Anal.* (2025).

29. Fick, S. E. & Hijmans, R. J. WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas. *Int. J. Climatol.* **37**, 4302–4315 (2017).