Supplementary Information: Global patterns of forest autotrophic carbon fluxes

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Table S1. Climate variable definitions, sources, and abbreviations

Abbreviation	Climate variable	Units	Definition	Time span	Source
MAT	Mean annual temperature	$^{\circ}\mathrm{C}$	Annual mean temperature, from primary literature or WorldClim if not reported	1970 - 2000	Primary literature; WorldClim ¹
MAP	Mean annual precipitation	${ m mm~yr^{-1}}$	Annual mean precipitation, from primary literature or WorldClim if not reported	1970 - 2000	Primary literature; WorldClim ¹
T Seas	Temperature seasonality	$^{\circ}\mathrm{C}$	Standard deviation (variation) of monthly temperature averages	1970 - 2000	$WorldClim^1$
P Seas	Precipitation seasonality	%	Coefficient of variation of mean monthly precipitation x 100	1970 - 2000	$WorldClim^1$
ART	Annual temperature range	$^{\circ}\mathrm{C}$	Maximum temperature of warmest month - minimum temperature of coldest month	1970 - 2000	$WorldClim^1$
Solar R	Solar radiation	${ m kJ~m^{-2}~yr^{-1}}$	Solar radiation	1970 - 2000	$WorldClim2^2$
Cloud	Cloud cover	%	Cloud percentage cover	1901 - 2014	CRU time-series dataset v 4.03^3
AFD	Annual frost days	$days yr^{-1}$	Number of freeze days annually	1901 - 2014	CRU time-series dataset v 4.03^3
AWD	Annual wet days	days yr^{-1}	Number of days with precipitation >0.1 mm annually	1901 - 2014	CRU time-series dataset v 4.03^3
PET	Potential evapotranspiration	$\mathrm{mm}\ \mathrm{yr}^{-1}$	Mean annual potential evapotranspiration	1950 - 2000	Global Aridity Index and Potential Evapotranspiration Climate Database ⁴
AI	Aridity		MAP/mean annual PET	1950 - 2000	Global Aridity Index and Potential Evapotranspiration Climate Database ⁴
VPD	Vapour pressure deficit	kPa	Mean monthly vapour pressure deficit	1958 - 2015	$TerraClimate^5$
Max VPD	Maximum vapour pressure deficit	kPa	Maximum monthly vapour pressure deficit	1958 - 2017	Derived from TerraClimate data
WSM	Water stress months	months yr^{-1}	Number of months annually with MAP $<$ PET	1970 - 2000	Derived from WorldClim data
LGS	Length of growing season	months yr^{-1}	Number of months annually with mean minimum temperature $> 0.5^{\circ}\mathrm{C}$	1901 - 2014	Derived from CRU data
gsT	Growing season temperature	$^{\circ}\mathrm{C}$	Mean growing season temperature	1901 - 2014	Derived from CRU data
gsP	Growing season precipitation	$_{ m month^{-1}}^{ m mm}$	Mean monthly precipitation during growing season months	1901 - 2014	Derived from CRU data
gsPET	Growing season PET	$_{ m month^{-1}}^{ m mm}$	Mean monthly potential evapotranspiration during growing season months	1901 - 2014	Derived from CRU data
gsR	Growing season solar radiation	$_{\rm month^{-1}}^{\rm mm}$	Mean monthly solar radiation during growing season	1901 - 2014	Derived from CRU data

 $^{^{\}ast}$ The WorldClim version used was the most recent available at the time of analysis 1 Hijmans et al. (2005) 2 Fick et al. (2017) 3 Harris et al. (2017) 4 Abatzoglou et al. (2018)

Table S2. Model form, Δ AIC, and R² for each climate variables as a single fixed effect in models for each C flux. Model forms include first-order linear (Lin), second-order polynomial (Poly), and logarithmic (Log).

]	Latitud	e		MAT			MAP			T Seas	3		P Seas	8		ATR			Solar I	3		AI	
Carbon Flux	Model	\mathbb{R}^2	Δ AIC	Model	R-sq	dAIC																		
GPP	Lin	0.64	54.9	Lin	0.61	52.5	Lin	0.18	33.3	Poly	0.71	69.5	-	-	-	Poly	0.69	63.0	Log	0.16	8.9	-	-	-
NPP	Log	0.50	44.3	Lin	0.42	41.5	Poly	0.21	16.7	Log	0.52	44.3	-	-	-	Log	0.49	42.3	Poly	0.16	12.5	Lin	0.04	2.8
ANPP	Lin	0.44	63.4	Lin	0.44	80.5	Poly	0.16	19.7	Log	0.41	58.7	-	-	-	Log	0.37	51.9	Lin	0.11	12.3	Lin	0.05	2.1
ANPP stem	Lin	0.18	22.2	Lin	0.24	38.5	Log	0.05	7.3	Lin	0.14	17.6	Poly	0.05	5	Lin	0.12	13.6	Log	0.06	6.8	Lin	0.07	4
ANPP foliage	Lin	0.50	37.7	Lin	0.58	52.9	Poly	0.25	13.3	Lin	0.48	34.1	-	-	-	Lin	0.50	36.1	Log	0.17	10.1	Lin	0.11	6.8
BNPP root	Lin	0.34	22.9	Log	0.31	21.0	Poly	0.15	6.2	Log	0.36	26.6	-	-	-	Log	0.33	23.6	Poly	0.29	18.8	-	-	-
BNPP fine root	Lin	0.17	8.0	Lin	0.15	7.2	Log	0.11	5.4	Lin	0.17	8.4	-	-	-	Log	0.19	10.9	Log	0.14	7.2	Log	0.06	2.4
R auto	Lin	0.65	13.1	Lin	0.59	10.9	Poly	0.60	8.6	Log	0.65	13.1	-	-	-	Log	0.60	11.5	Log	0.27	2.4	Poly	0.48	3.7
R root	Log	0.22	8.8	Lin	0.24	8.3	Lin	0.15	6.8	Log	0.24	9.5	-	-	-	Log	0.22	8.8	-	-	-	Lin	0.16	7.3

		Cloud			AFD			AWD			PET			VPD	·	N	Iax VF	D		WSM			LGS	
Carbon Flux	Model	\mathbb{R}^2	Δ AIC																					
GPP	-	-	-	Log	0.54	50.0	Lin	0.11	5.7	Poly	0.36	19.7	Poly	0.31	15.9	-	-	-	-	-	-	Lin	0.53	38.2
NPP	Lin	0.06	3.6	Lin	0.40	38.5	Lin	0.11	7.3	Poly	0.32	24.3	Poly	0.18	15.3	-	-	-	Lin	0.04	4	Lin	0.38	28.4
ANPP	Poly	0.09	7.1	Log	0.41	61.6	Lin	0.17	18.7	Poly	0.27	24.5	Poly	0.23	21.4	Poly	0.06	2.2	Poly	0.06	3	Lin	0.34	44.0
ANPP stem	Poly	0.09	5.4	Log	0.17	22.3	-	-	-	Poly	0.20	14.0	Poly	0.21	17.7	Log	0.14	7.5	-	-	-	Log	0.11	12.6
ANPP foliage	-	-	-	Lin	0.53	43.4	Lin	0.15	7	Log	0.32	24.2	Log	0.35	30.0	Poly	0.07	4.9	Poly	0.17	7.8	Log	0.46	32.9
BNPP root	-	-	-	Lin	0.28	19.1	Poly	0.11	3.4	Poly	0.36	23.2	Poly	0.26	13.9	-	-	-	-	-	-	Lin	0.26	14.7
BNPP fine root	-	-	-	Lin	0.16	9.2	Lin	0.08	2.7	Log	0.14	7.1	Log	0.06	1.9	-	-	-	-	-	-	Lin	0.13	5.8
R auto	-	-	-	Log	0.57	9.4	Null	0.26	0.6	Log	0.36	4.8	Log	0.35	4.3	-	-	-	Null	0.3	1.5	Lin	0.47	5.8
R root	Log	0.16	1.9	Log	0.19	7.3	Lin	0.17	3.5	Poly	0.19	1.7	Poly	0.27	6.7	-	-	-	Lin	0.14	6.1	Lin	0.19	5.9

Table S3. Joint effects of MAT and MAP on forest C fluxes

Carbon flux	MAT	MAT + MAP	MAT x MAP	\mathbb{R}^2
GPP	0.0e+00	8.2e-05	0.140	0.66
NPP	0.0e+00	4.5e-01	0.018	0.48
ANPP	0.0e+00	3.5e-02	0.460	0.45
ANPP stem	0.0e+00	8.3e-01	0.021	0.26
ANPP foliage	0.0e+00	4.7e-01	0.410	0.59
BNPP root	3.3e-06	9.6e-01	0.056	0.29
BNPP fine root	2.1e-03	2.3e-01	0.091	0.15
R auto	1.6e-04	4.1e-02	0.340	0.71
R root	1.1e-03	1.1e-01	0.110	0.25

Table S4. Comparison of growing season length and MAT as predictors of forest C fluxes

Fixed effect	AIC value	Δ AIC	Marginal R ²
GPP			
MAT	126.43	0.00	0.62
Growing season length	140.81	14.38	0.54
None	178.96	52.54	0.00
NPP			
MAT	174.88	0.00	0.52
Growing season length	191.54	16.65	0.40
None	216.17	41.29	0.00
ANPP			
MAT	249.51	0.00	0.29
Growing season length	254.21	4.70	0.26
None	268.94	19.43	0.00
ANPP stem			
MAT	235.96	0.00	0.15
Growing season length	237.29	1.33	0.14
None	243.14	7.18	0.00
ANPP foliage			
MAT	484.88	0.00	0.45
Growing season length	520.96	36.09	0.35
None	560.35	75.47	0.00
BNPP root			
MAT	184.54	0.00	0.59
Growing season length	204.93	20.38	0.46
None	237.47	52.92	0.00
BNPP fine root			
MAT	540.19	0.00	0.24
Growing season length	566.37	26.18	0.11
None	578.66	38.46	0.00
R auto			
MAT	45.26	0.00	0.63
Growing season length	50.36	5.10	0.50
None	56.17	10.91	0.00
R root			
MAT	133.54	0.00	0.25
Growing season length	135.93	2.39	0.20
None	141.79	8.25	0.00

Table S5. Best models by carbon flux. Where \triangle AIC values </=2 all models with a \triangle AIC value </=2 are presented

Carbon flux	Climate variable	Model type	$\Delta {\rm AIC}$ relative to null model	Δ AIC relative to next best model	\mathbb{R}^2
GPP	T Seas	Poly	69.5	6.55	0.71
NPP	MAT	Lin	41.5	0.21	0.42
	T Seas	Log	44.3	-	0.52
ANPP	MAT	Lin	80.5	21.4	0.44
ANPP stem	MAT	Lin	38.5	15.87	0.24
ANPP foliage	MAT	Lin	52.9	11.05	0.58
BNPP root	T Seas	Log	26.6	3.01	0.36
BNPP fine root	ATR	Log	10.9	2.11	0.19
R auto	T Seas	Log	13.1	1.62	0.65
it auto	ATR	Log	11.5	-	0.60
	T Seas	Log	9.5	0.76	0.24
R root	ATR	Log	8.8	-	0.22
	MAT	Lin	8.3	-	0.24

Table S6. Pairwise comparisons between carbon fluxes

C flux variable 1	C flux variable 2	Climate variable	\mathbb{R}^2 variable 1	\mathbb{R}^2 variable 2	Model type variable 1	Model type variable 2	Number of plots	Variable with higher R ²
		Latitude	0.62	0.66	Lin	Lin	37	NPP
GPP	NPP	MAT	0.62	0.70	Log	Lin	37	NPP
		T Seas	0.65	0.70	Log	Log	37	NPP
		Latitude	0.52	0.48	Log	Log	158	NPP
	ANPP	MAT	0.30	0.44	Log	Lin	158	ANPP
		T Seas	0.47	0.43	Lin	Lin	158	NPP
NPP		Latitude	0.49	0.34	Log	Lin	116	NPP
	BNPP	MAT	0.41	0.22	Log	Log	116	NPP
		T Seas	0.49	0.41	Log	Log	116	NPP
	ANPP stem	Latitude	0.35	0.13	Lin	Lin	176	ANPP
		MAT	0.42	0.17	Lin	Lin	176	ANPP
ANDD		T Seas	0.29	0.09	Lin	Lin	176	ANPP
ANPP		Latitude	0.32	0.45	Log	Log	96	ANPP foliage
	ANPP foliage	MAT	0.36	0.50	Lin	Lin	96	ANPP foliage
		T Seas	0.27	0.42	Lin	Lin	96	ANPP foliage
		Latitude	0.64	0.34	Null	Null	11	GPP
GPP	R auto	MAT	0.69	0.34	Null	Null	11	GPP
		T Seas	0.64	0.32	Null	Null	11	GPP
·	·	Latitude	0.01	0.39	Null	Null	9	R root
BNPP	R root	MAT	0.08	0.35	Null	Null	9	R root
		T Seas	0.01	0.63	Null	Null	9	R root

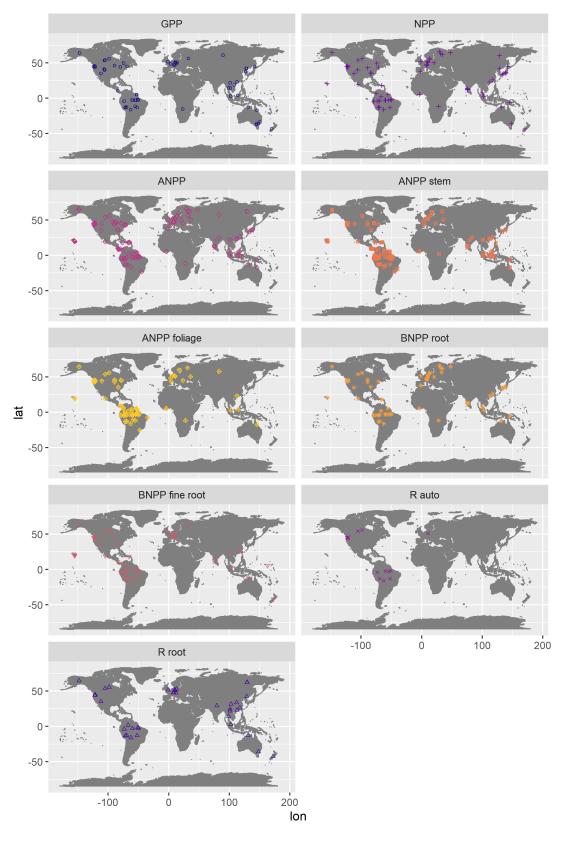


Figure S1: Maps showing distribution of samples for the nine forest C fluxes analyzed here

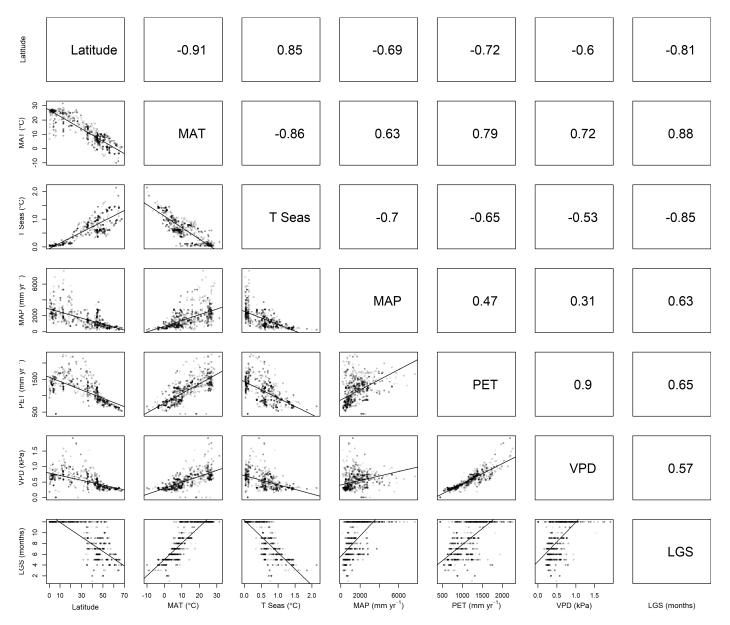


Figure S2: Scatterplots and Pearson's R values for relationships between latitude and climate variables

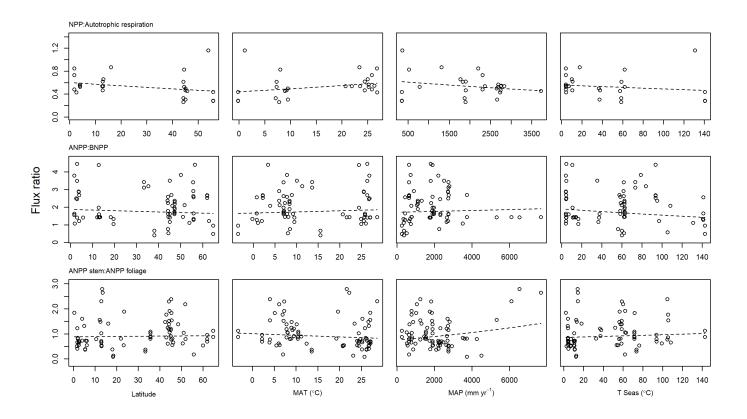


Figure S3: Ratios among forest C fluxes as a function of latitude and climate variables

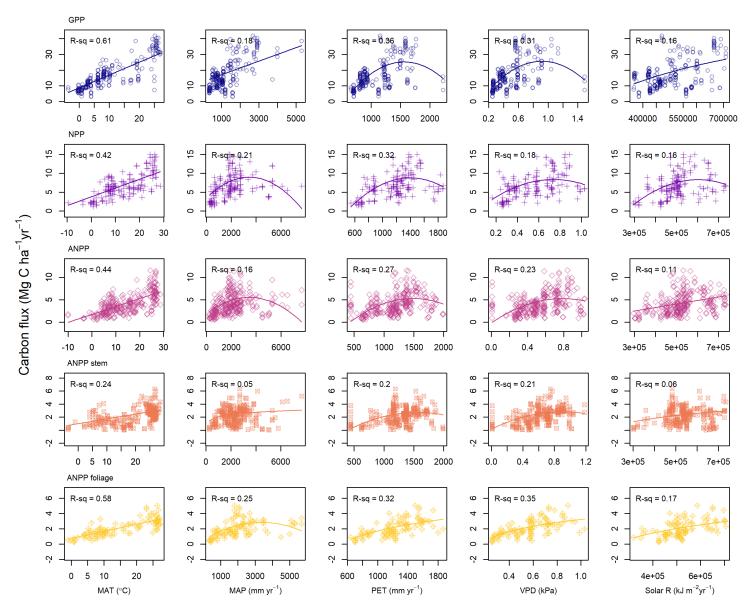


Figure S4: Individual plots of forest C fluxes in relation to mean annual climate, part 1.



Figure S5: Individual plots of forest C fluxes in relation to mean annual climate, part 2.

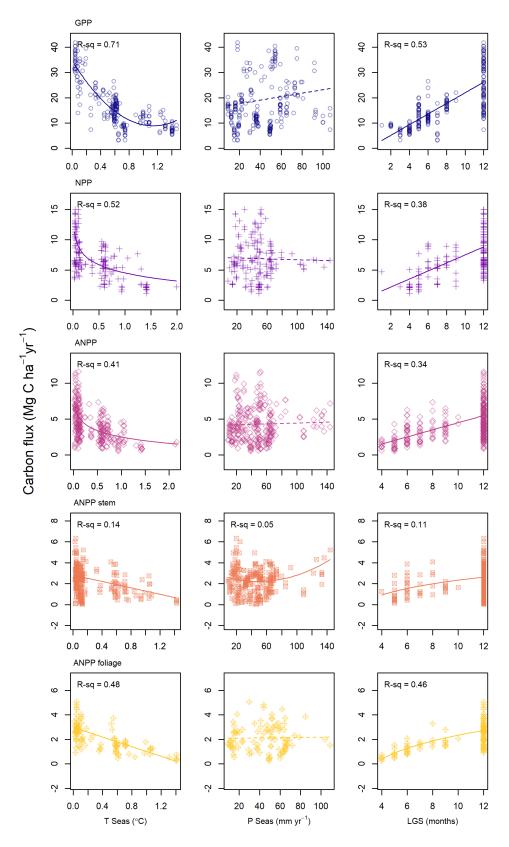


Figure S6: Individual plots of forest C fluxes in relation to mean climate seasonality, part 1.

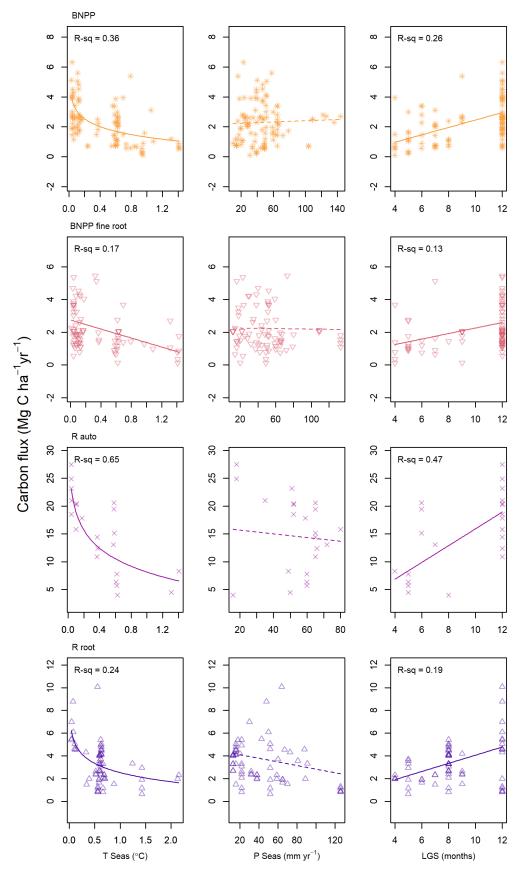


Figure S7: Individual plots of forest C fluxes in relation to mean climate seasonality, part 2.



Figure S8: Growing season length-standardized forest C fluxes in relation to mean growing season climate, part 1.



Figure S9: Growing season length-standardized forest C fluxes in relation to mean growing season climate, part 2.

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