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

[1] Hijmans et al. (2005) [2] Fick et al. (2017) [3] Harris et al. (2017) [4] Abatzoglou et al. (2018)

Table S2. Model form, delta 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).

	Latitude			MAT			MAP			T Seas			P Seas			ATR			Solar R			AI		
Carbon Flux	Model	R-sq	dAIC	Model	R-sq	dAIC	Model	R-sq	dAIC	Model	R-sq	dAIC	Model	R-sq	dAIC	Model	R-sq	dAIC	Model	R-sq	dAIC	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
Autotrophic respiration	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
Root respiration	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			Max VPD			WSM			LGS		
Carbon Flux	Model	R-sq	dAIC	Model	R-sq	dAIC	Model	R-sq	dAIC	Model	R-sq	dAIC	Model	R-sq	dAIC	Model	R-sq	dAIC	Model	R-sq	dAIC	Model	R-sq	dAIC
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
Autotrophic respiration	-	-	-	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
Root respiration	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	Significant interactive effect	Significant additive effect	Significant effect of MAT	p-value	R-squared value
GPP	FALSE	TRUE	TRUE	<0.0001	0.66
NPP	TRUE	TRUE	TRUE	0.018	0.48
ANPP	FALSE	TRUE	TRUE	0.0349	0.45
ANPP woody stem	TRUE	TRUE	TRUE	0.021	0.26
ANPP foliage	FALSE	FALSE	TRUE	<0.0001	0.59
BNPP root	FALSE	FALSE	TRUE	<0.0001	0.29
BNPP fine root	FALSE	FALSE	TRUE	0.002	0.15
Autotrophic respiration	FALSE	TRUE	TRUE	0.041	0.71
Root respiration	FALSE	FALSE	TRUE	0.001	0.25

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

Fixed effect	AIC value	Delta AICc	Marginal R squared
GPP			
MAT	126.42617	0.000000	0.6196780
Growing season length	140.80589	14.379717	0.5411935
None	178.96179	52.535617	0.0000000
NPP			
MAT	174.88249	0.000000	0.5156614
Growing season length	191.53714	16.654650	0.4006999
None	216.16976	41.287265	0.0000000
ANPP			
MAT	249.50512	0.000000	0.2925950
Growing season length	254.20763	4.702509	0.2612187
None	268.94008	19.434966	0.0000000
ANPP woody stem			
MAT	235.95797	0.000000	0.1548800
Growing season length	237.28992	1.331943	0.1370243
None	243.13700	7.179027	0.0000000
ANPP foliage			
MAT	484.87610	0.000000	0.4462629
Growing season length	520.96482	36.088722	0.3497750
None	560.34915	75.473049	0.0000000
BNPP root			
MAT	184.54480	0.000000	0.5921282
Growing season length	204.92685	20.382054	0.4644116
None	237.46554	52.920743	0.0000000
BNPP fine root			
MAT	540.19217	0.000000	0.2429540
Growing season length	566.36955	26.177388	0.1060029
None	578.65529	38.463119	0.0000000
Autotrophic respiration			
MAT	45.25818	0.000000	0.6271133
Growing season length	50.35515	5.096972	0.5041004
None	56.16877	10.910597	0.0000000
Root respiration			
MAT	133.53500	0.000000	0.2507631
Growing season length	135.92632	2.391311	0.1990489
None	141.78719	8.252190	0.0000000

Table S5. Best models by carbon flux. Models where delta AIC </= 2 are presented

Carbon flux	Climate variable	Model type	dAIC	R squared
GPP	T Seas	Poly	6.55	0.71
NPP	MAT	Lin	0.21	0.42
	T Seas	Log	0.21	0.52
ANPP	MAT	Lin	21.40	0.44
ANPP foliage	MAT	Lin	11.05	0.58
ANPP stem	MAT	Lin	15.87	0.24
BNPP root	T Seas	Log	3.01	0.36
BNPP fine root	ATR	Log	2.11	0.19
Autotrophic respiration	T Seas	Log	1.62	0.65
	ATR	Log	1.62	0.60
Root respiration	T Seas	Log	0.76	0.24
	ATR	Log	0.76	0.22
	MAT	Lin	1.30	0.24

Table S6. Pairwise comparisons between carbon fluxes

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

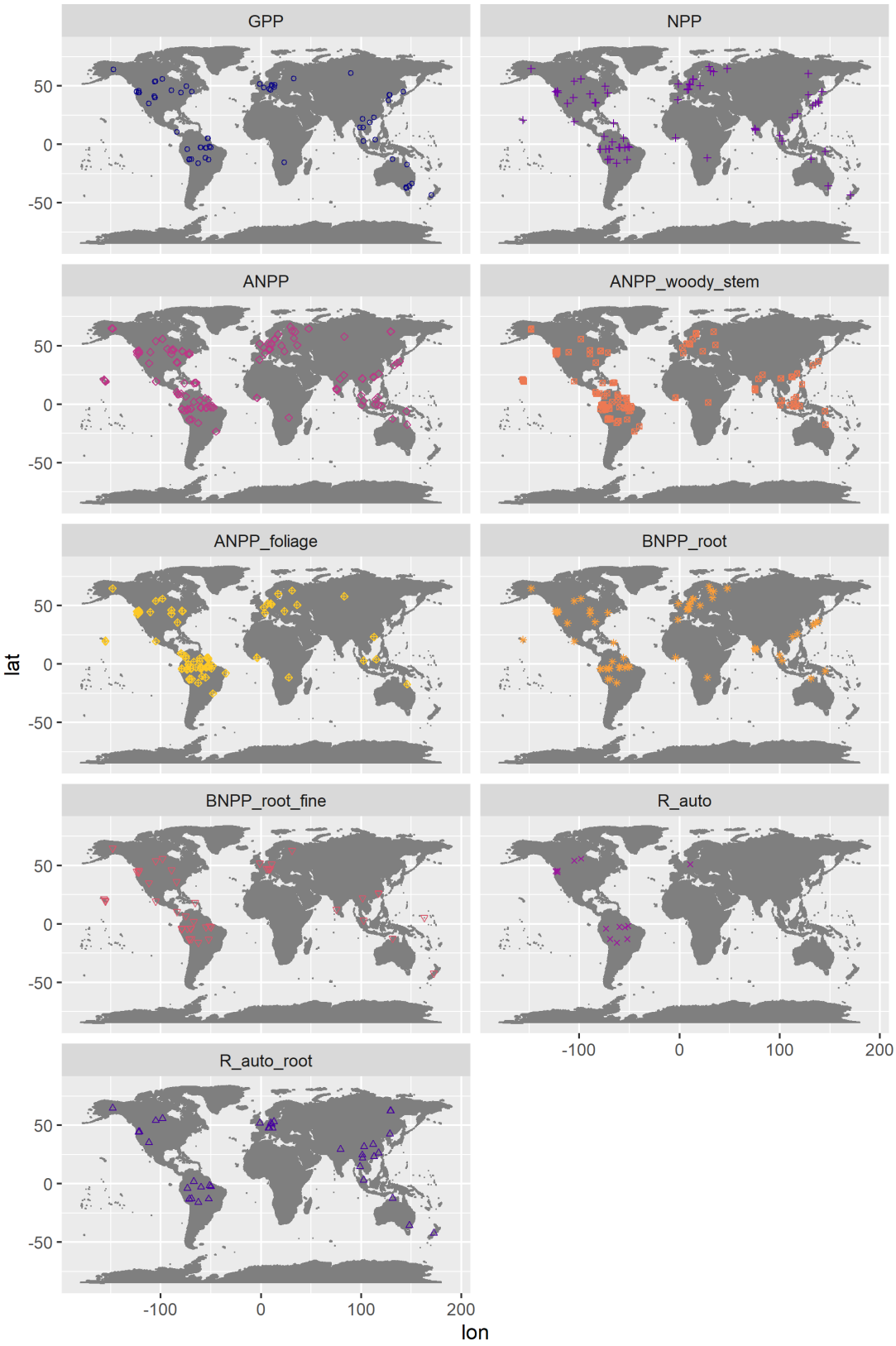

Figure S1: Maps showing distribution of samples for the nine forest C fluxes analyzed here

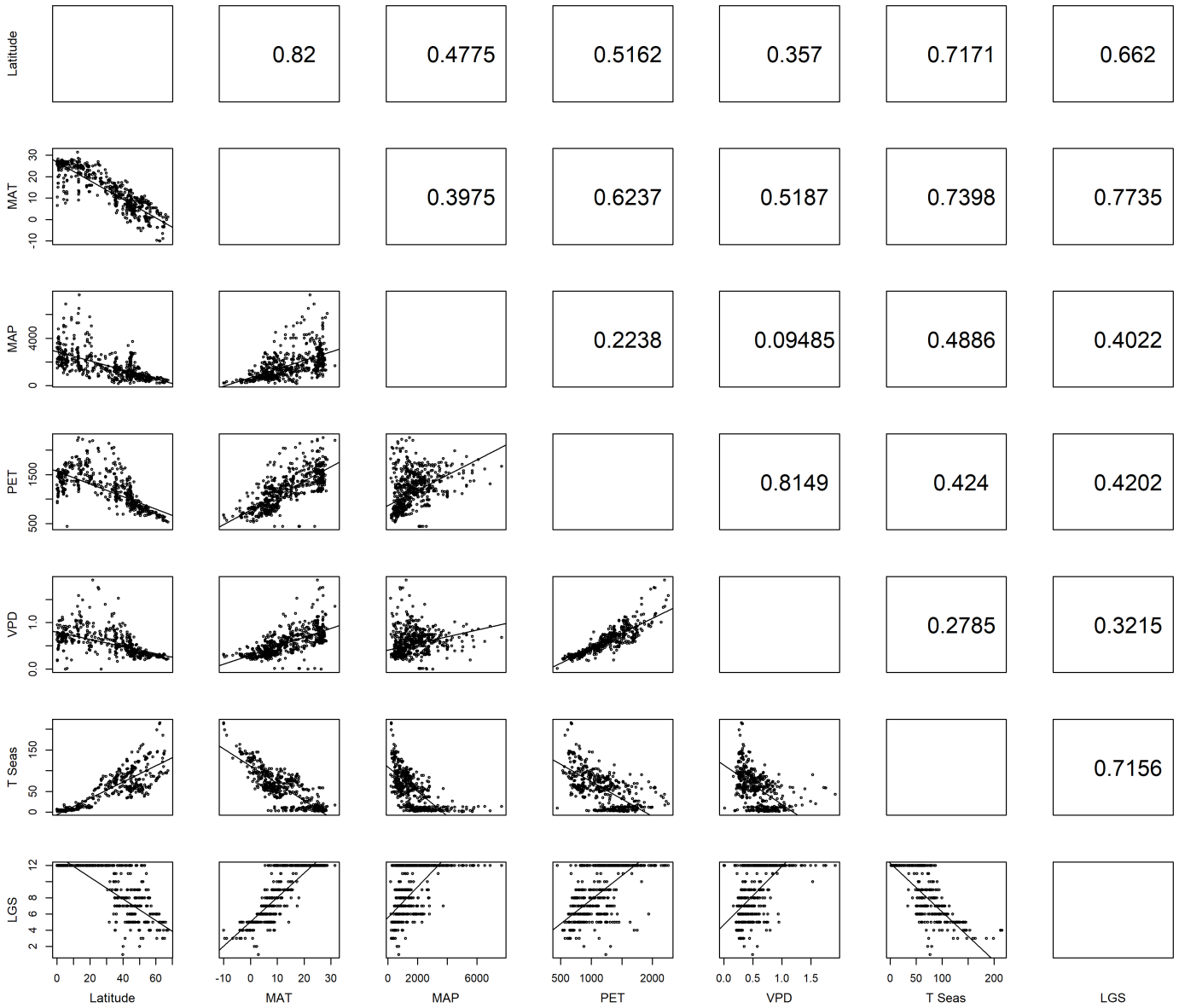

Figure S2: Correlations among latitude and climate variables

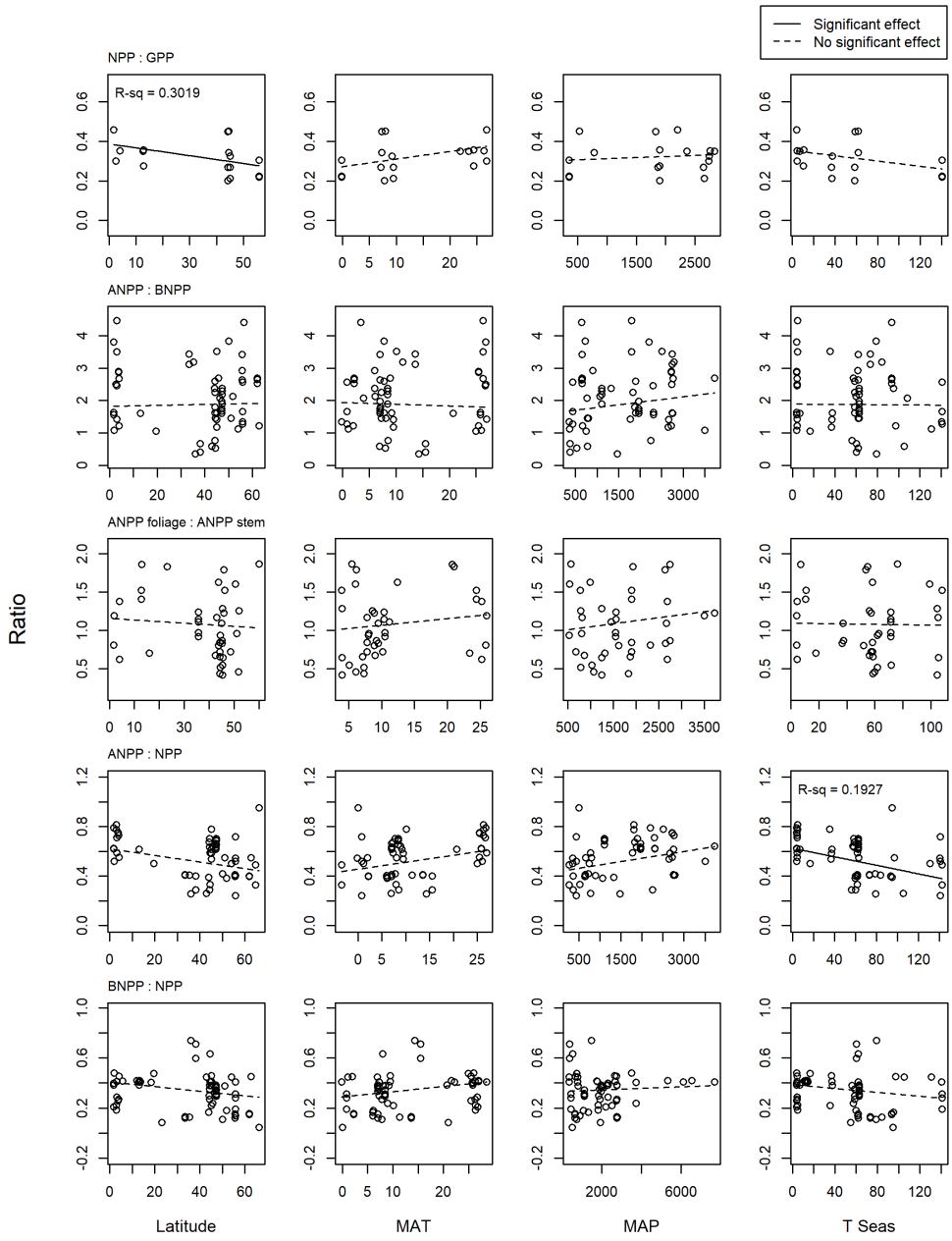

Figure S3: Ratios among forest C fluxes as a function of latitude and climate variables

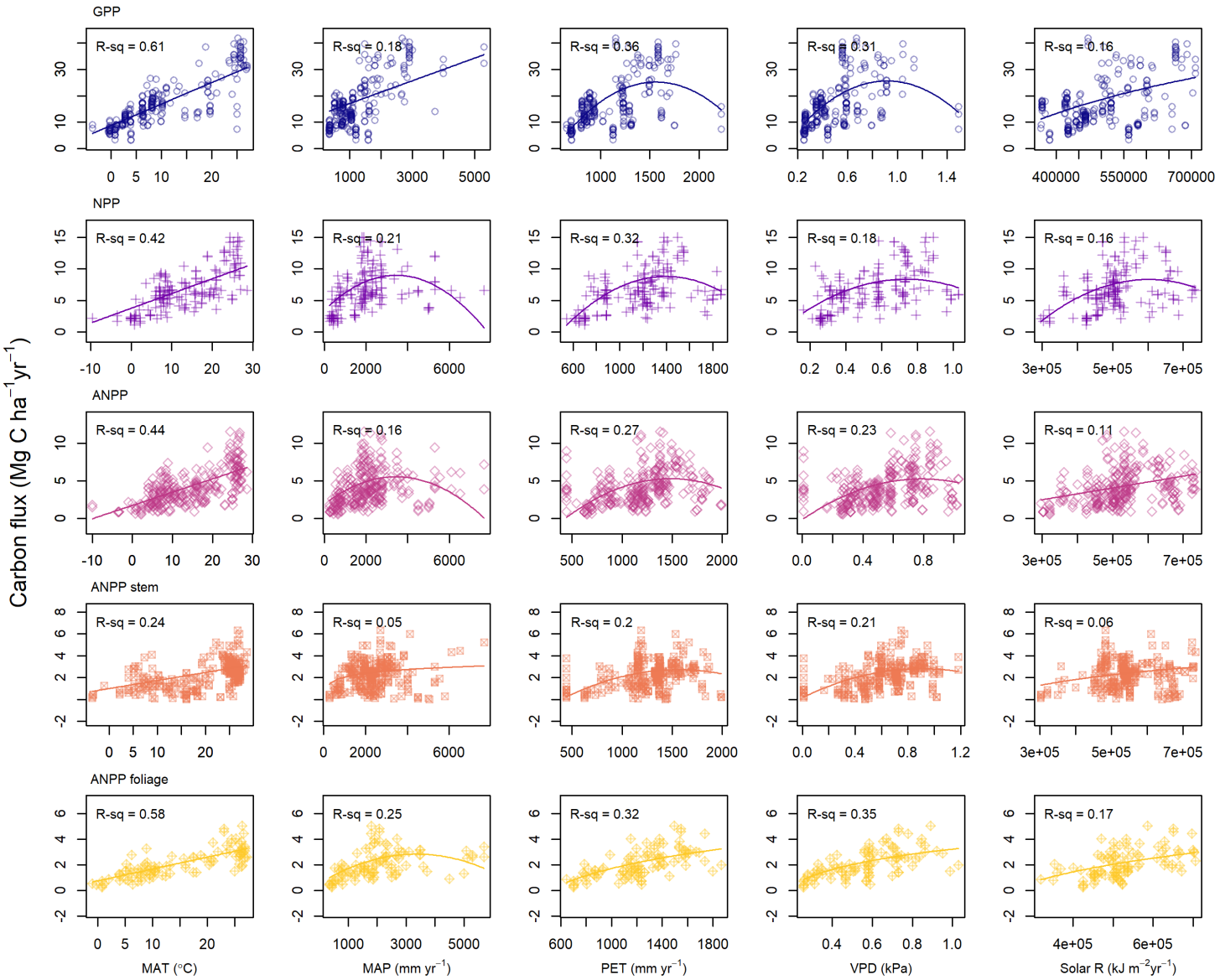

Figure S4: Individual plots of forest C fluxes in relation to mean annual climate, part 1.

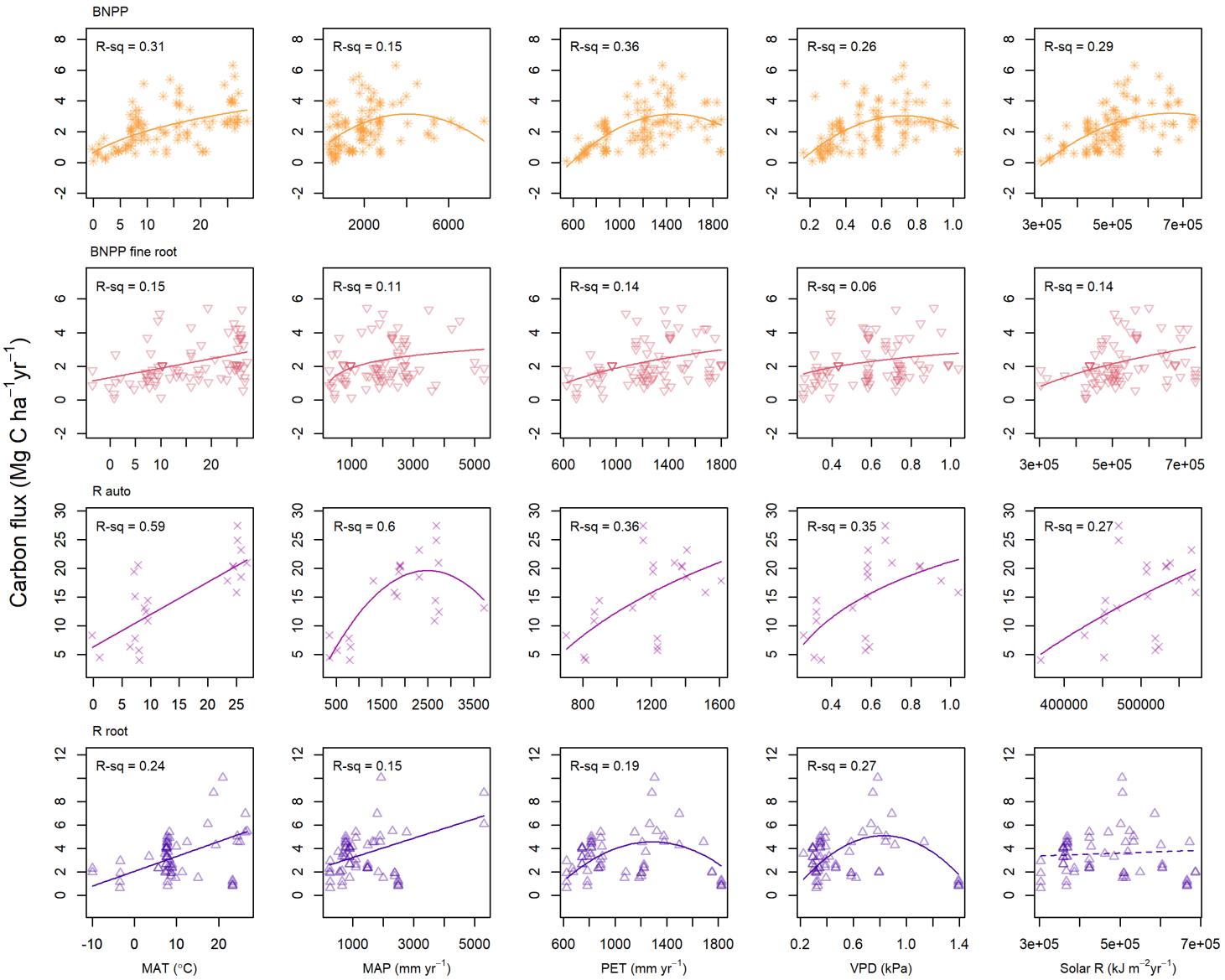

Figure S5: Individual plots of forest C fluxes in relation to mean annual climate, part 2.

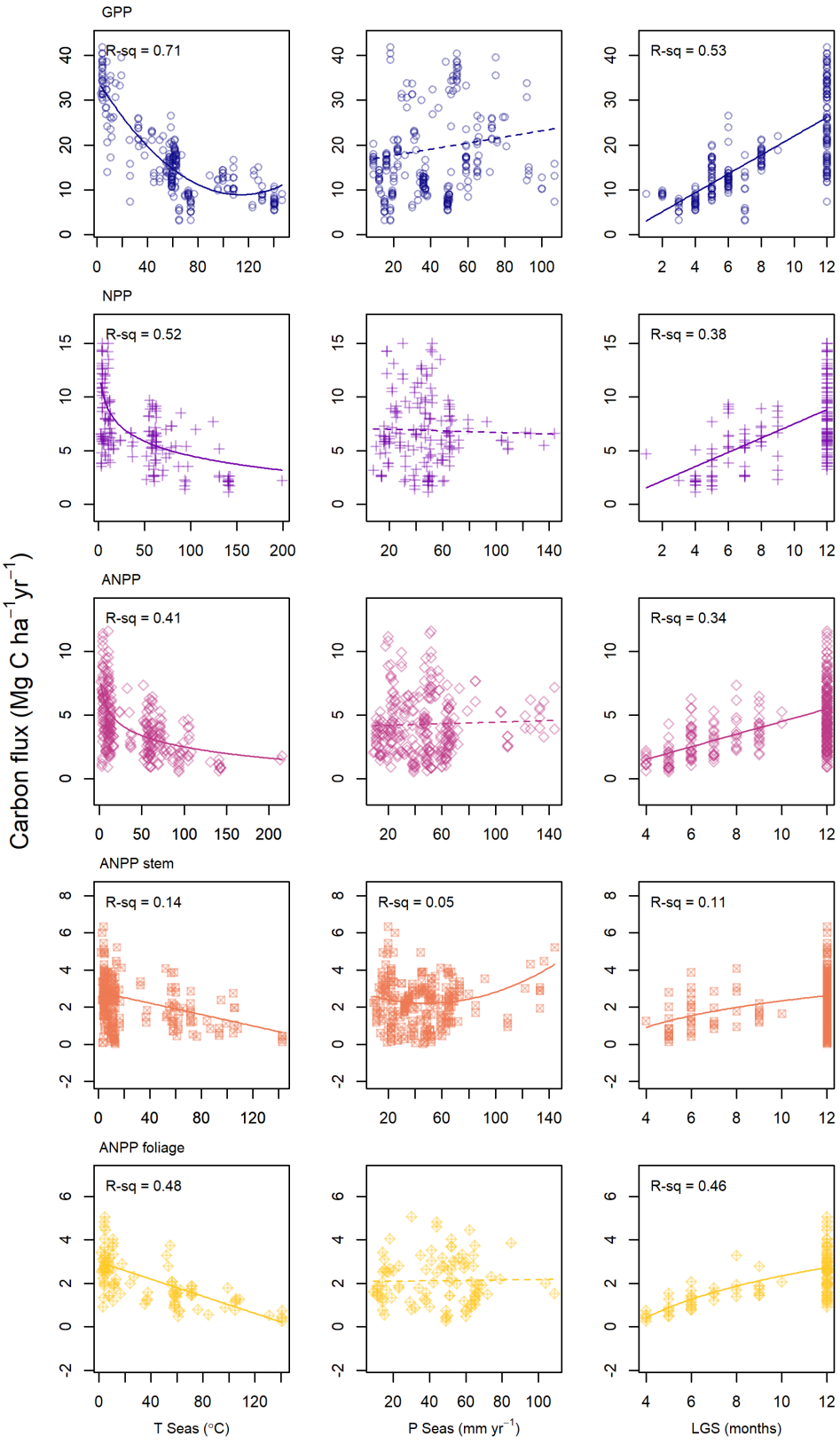

Figure S6: Individual plots of forest C fluxes in relation to mean climate seasonality, part 1.

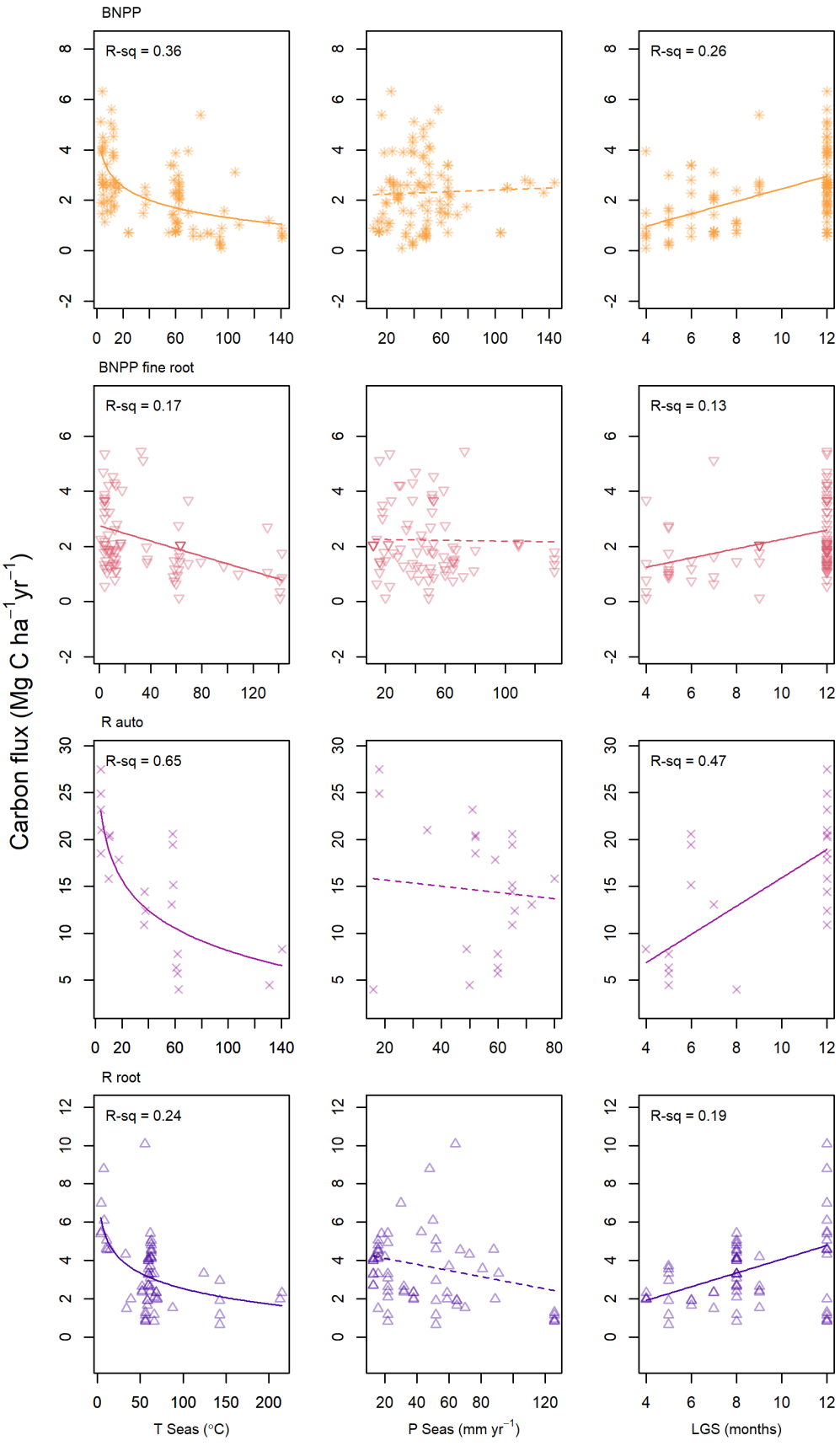

Figure S7: Individual plots of forest C fluxes in relation to mean climate seasonality, part 2.

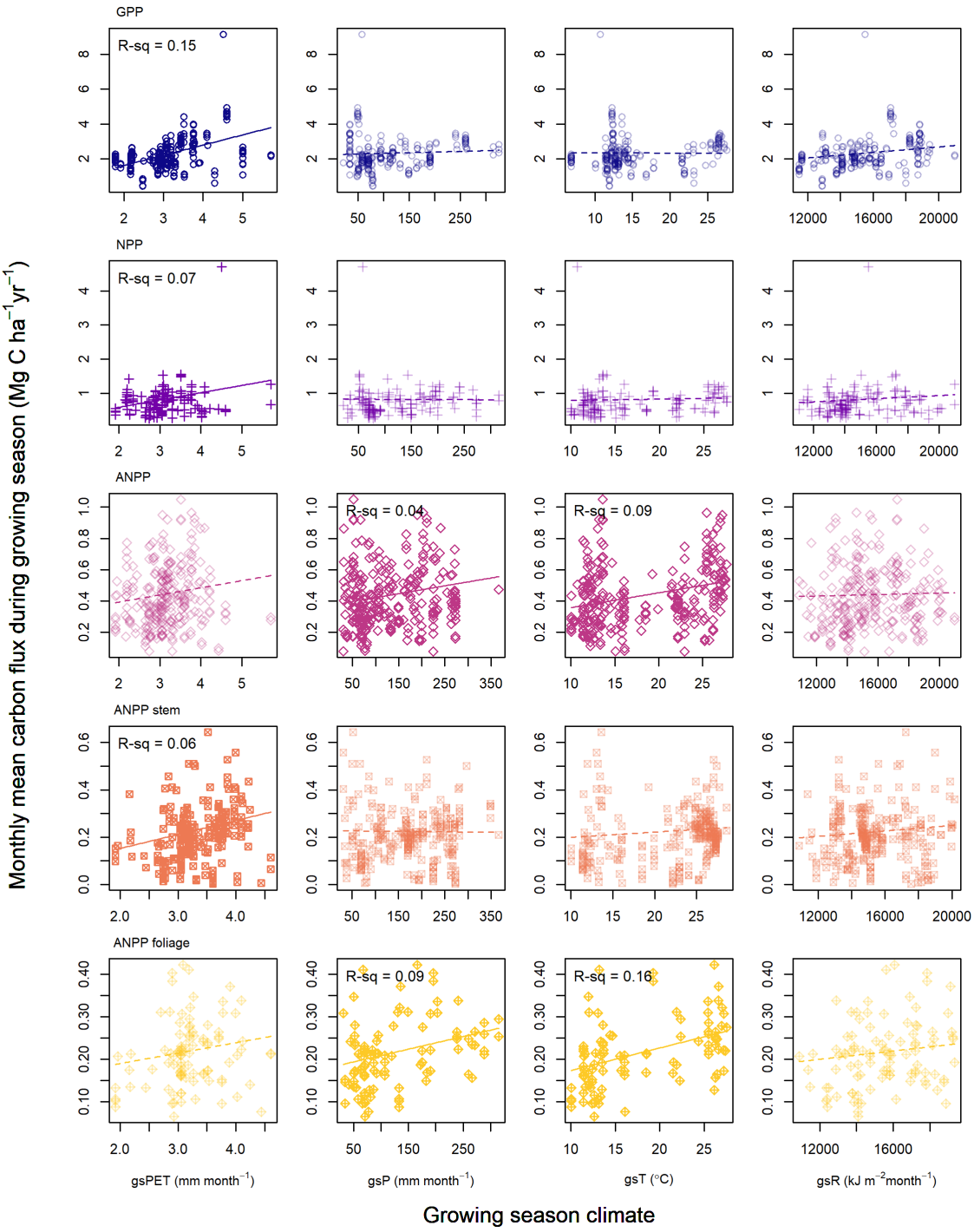

Figure S8: Growing season length-standardized forest C fluxes in relation to mean growing season climate, part 1.

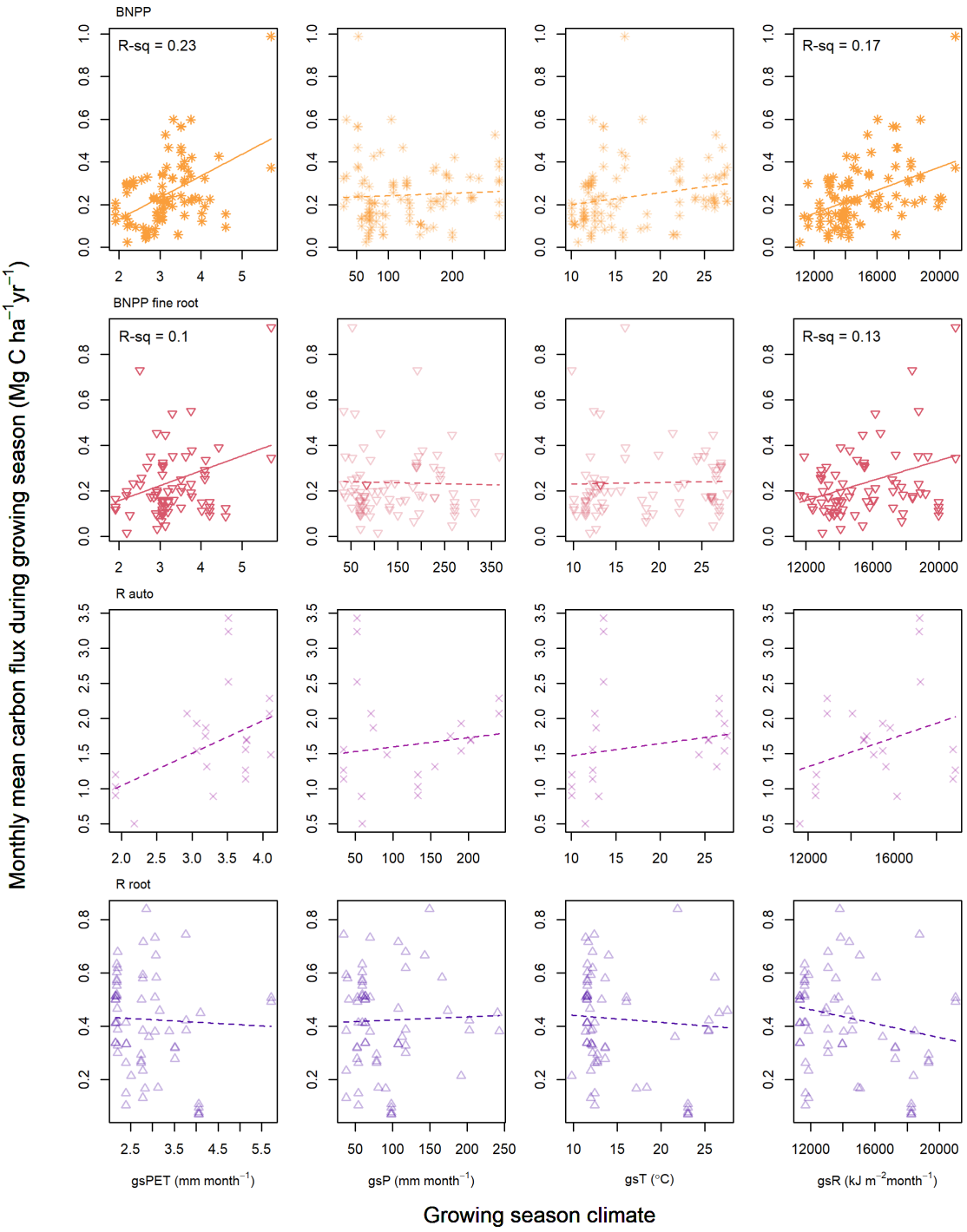

Figure S9: Growing season length-standardized forest C fluxes in relation to mean growing season climate, part 2.

References

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