Supplementary Information: Global patterns of forest autotrophic carbon fluxes

Rebecca Banbury Morgan   Valentine Herrmann   Norbert Kunert
Ben Bond-Lamberty   Helene C. Muller-Landau   Kristina J. Anderson-Teixeira

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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
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			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
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	R-squared value
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	Delta AICc	Marginal R squared
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. 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 stem	MAT	Lin	15.87	0.24
ANPP foliage	MAT	Lin	11.05	0.58
BNPP root	T Seas	Log	3.01	0.36
BNPP fine root	ATR	Log	2.11	0.19
R auto	T Seas	Log	1.62	0.65
	ATR	Log	1.62	0.60
R root	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	0.6200	0.660	Lin	Lin	37	NPP
		MAT	0.6200	0.700	Log	Lin	37	NPP
		T Seas	0.6500	0.700	Log	Log	37	NPP
NPP	ANPP	Latitude	0.5200	0.480	Log	Log	158	NPP
		MAT	0.3000	0.440	Log	Lin	158	ANPP
		T Seas	0.4700	0.430	Lin	Lin	158	NPP
	BNPP	Latitude	0.4900	0.340	Log	Lin	116	NPP
		MAT	0.4100	0.220	Log	Log	116	NPP
		T Seas	0.4900	0.410	Log	Log	116	NPP
ANPP	ANPP foliage	Latitude	0.3200	0.450	Log	Log	96	ANPP foliage
		MAT	0.3600	0.500	Lin	Lin	96	ANPP foliage
		T Seas	0.2700	0.420	Lin	Lin	96	ANPP foliage
	ANPP stem	Latitude	0.3500	0.130	Lin	Lin	176	ANPP
		MAT	0.4200	0.170	Lin	Lin	176	ANPP
		T Seas	0.2900	0.089	Lin	Lin	176	ANPP
GPP	R auto	Latitude	0.6400	0.340	Null	Null	11	GPP
		MAT	0.6900	0.340	Null	Null	11	GPP
		T Seas	0.6400	0.320	Null	Null	11	GPP
BNPP	R root	Latitude	0.0130	0.390	Null	Null	9	R root
		MAT	0.0830	0.350	Null	Null	9	R root
		T Seas	0.0093	0.630	Null	Null	9	R root

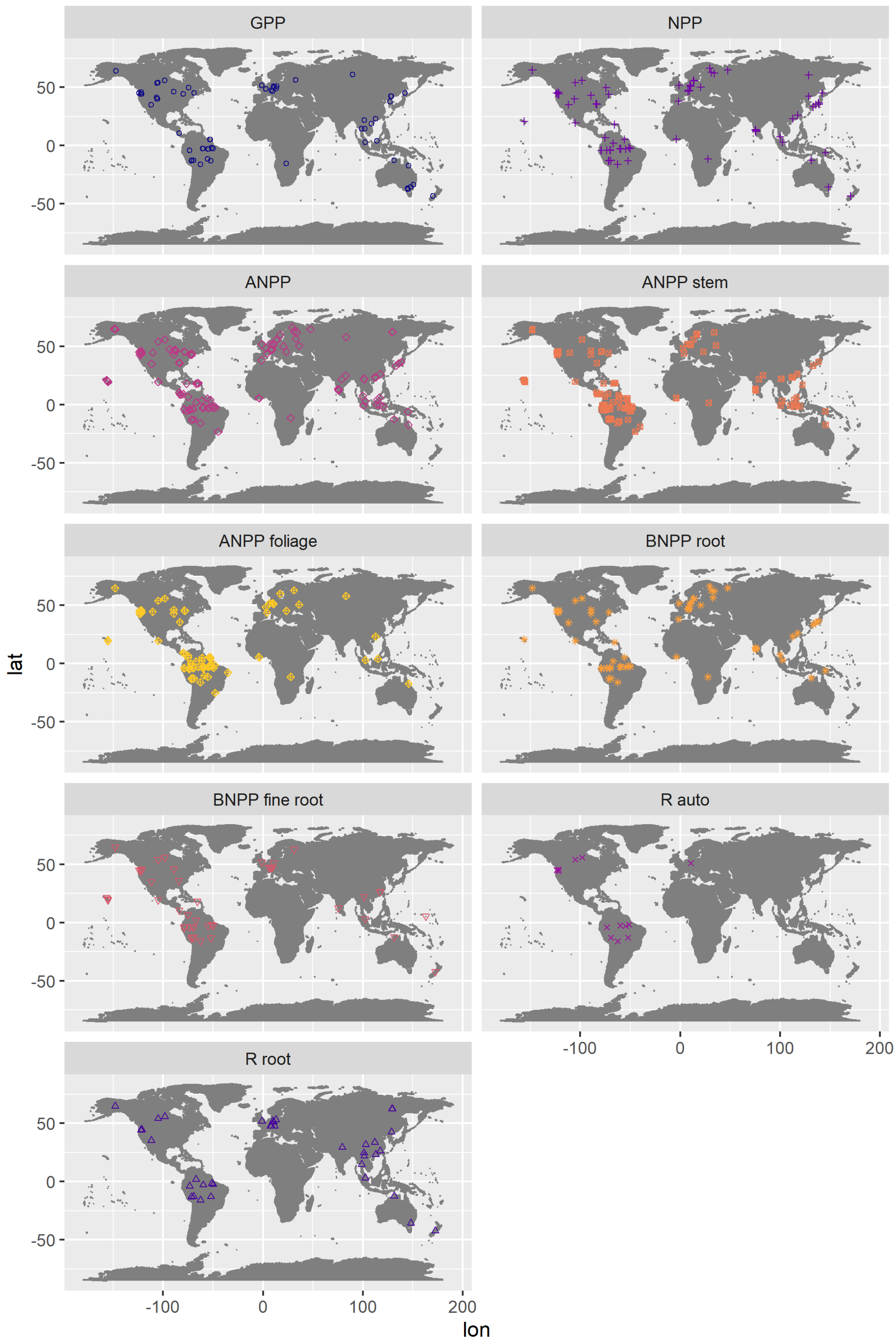

Figure S1: Maps showing distribution of samples for the nine forest C fluxes analyzed here

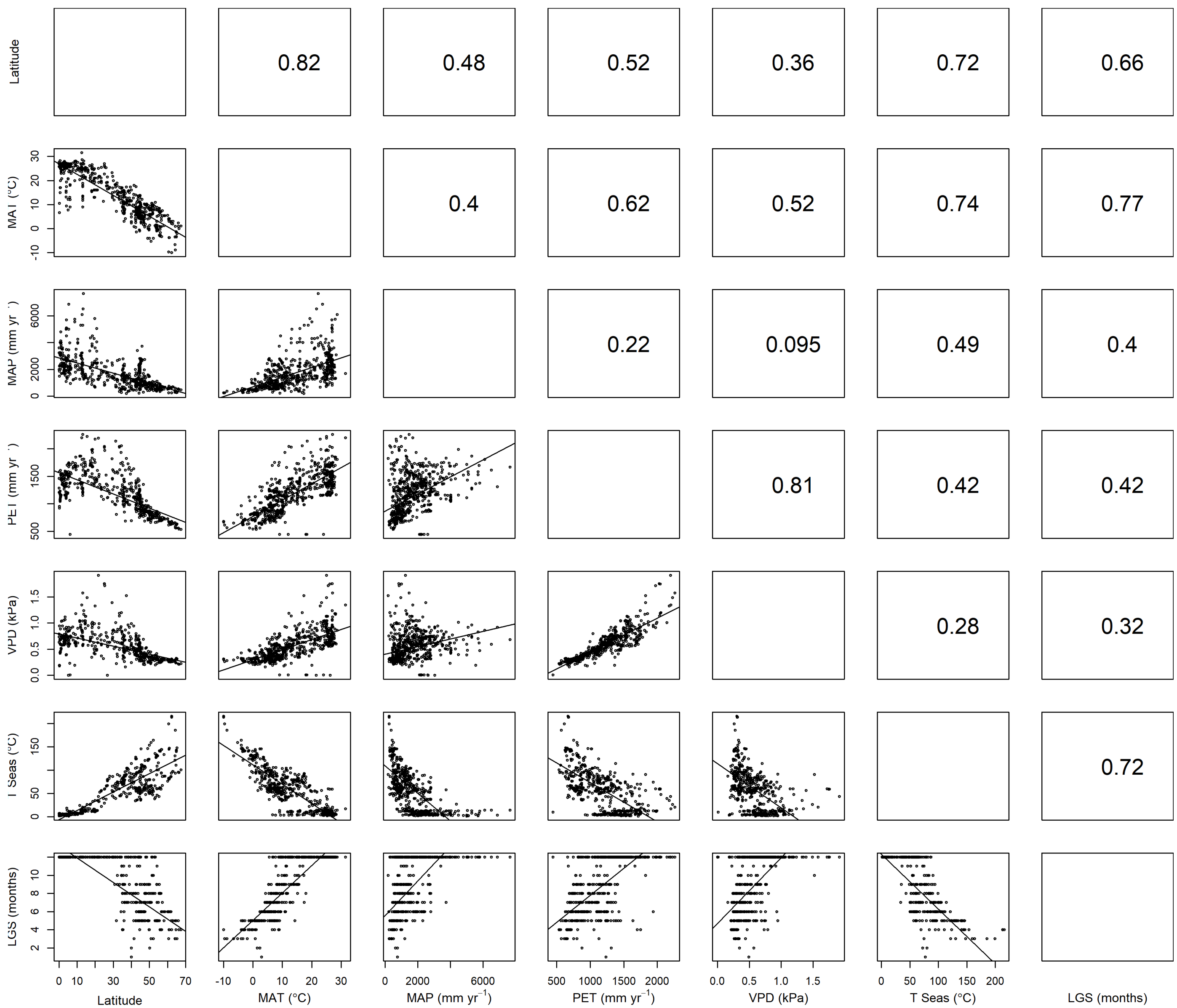

Figure S2: Correlations among latitude and climate variables

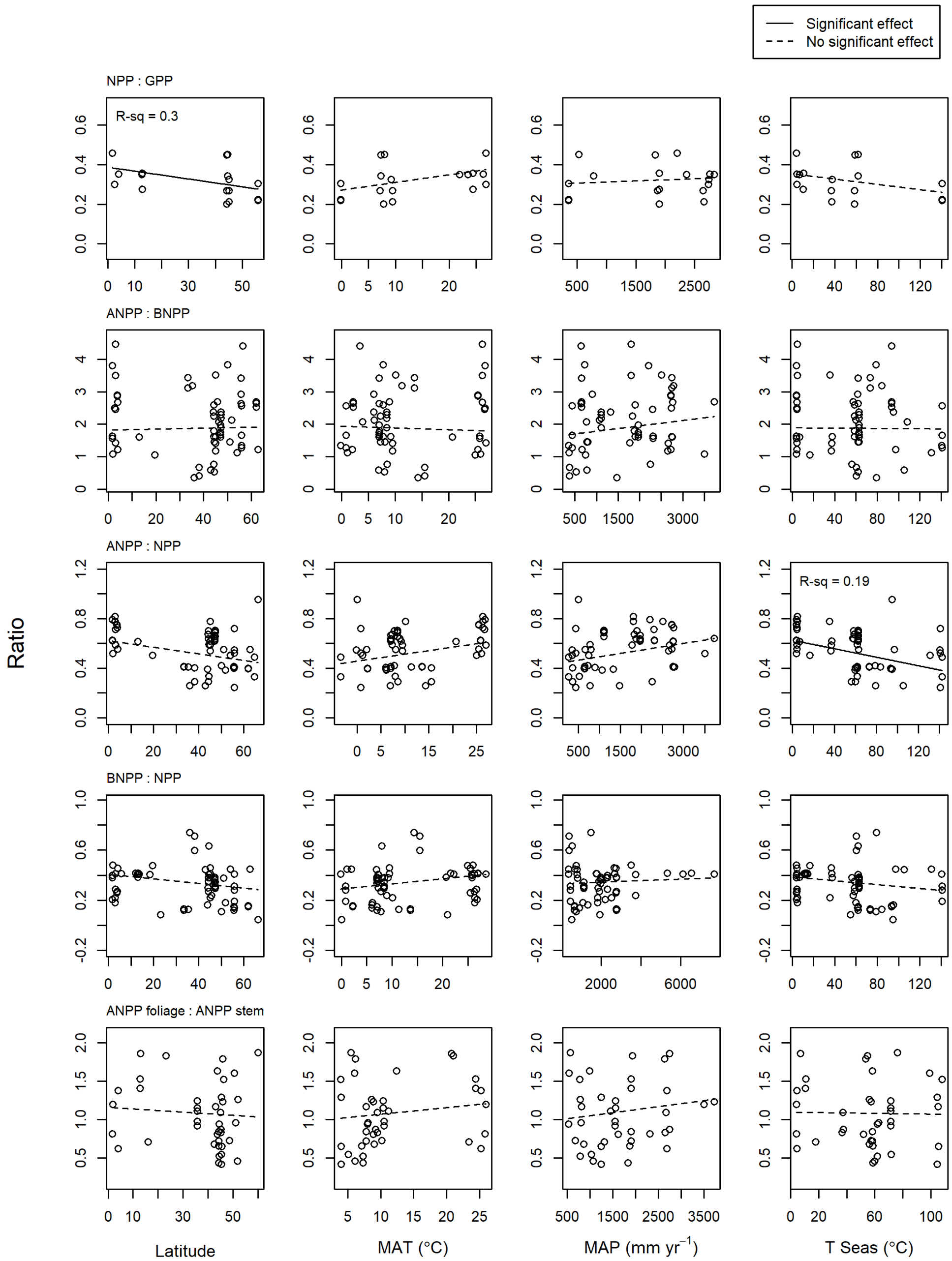

Figure S3: Ratios among forest C fluxes as a function of latitude and climate variables

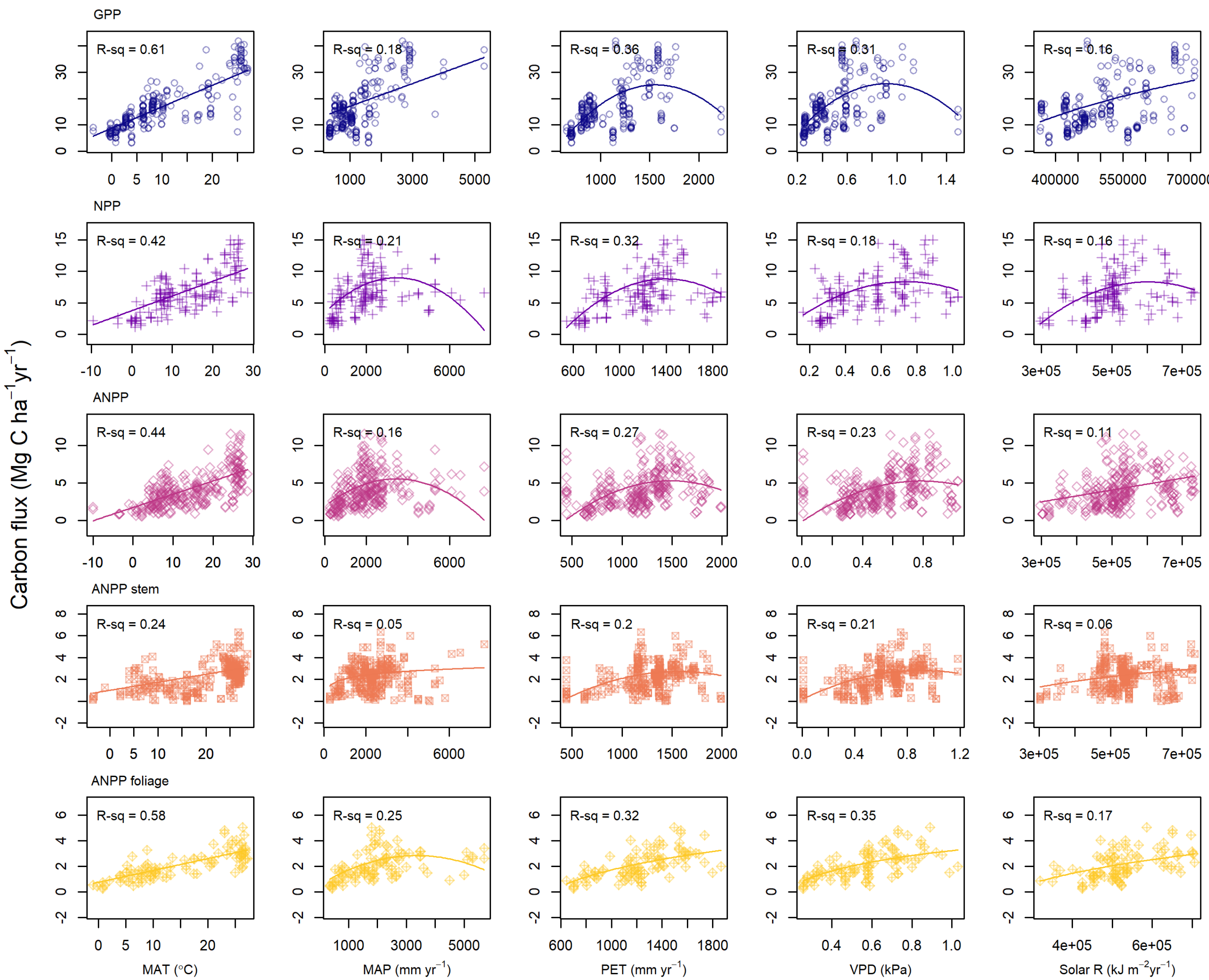

Figure S4: Individual plots of forest C fluxes in relation to mean annual climate, part 1.

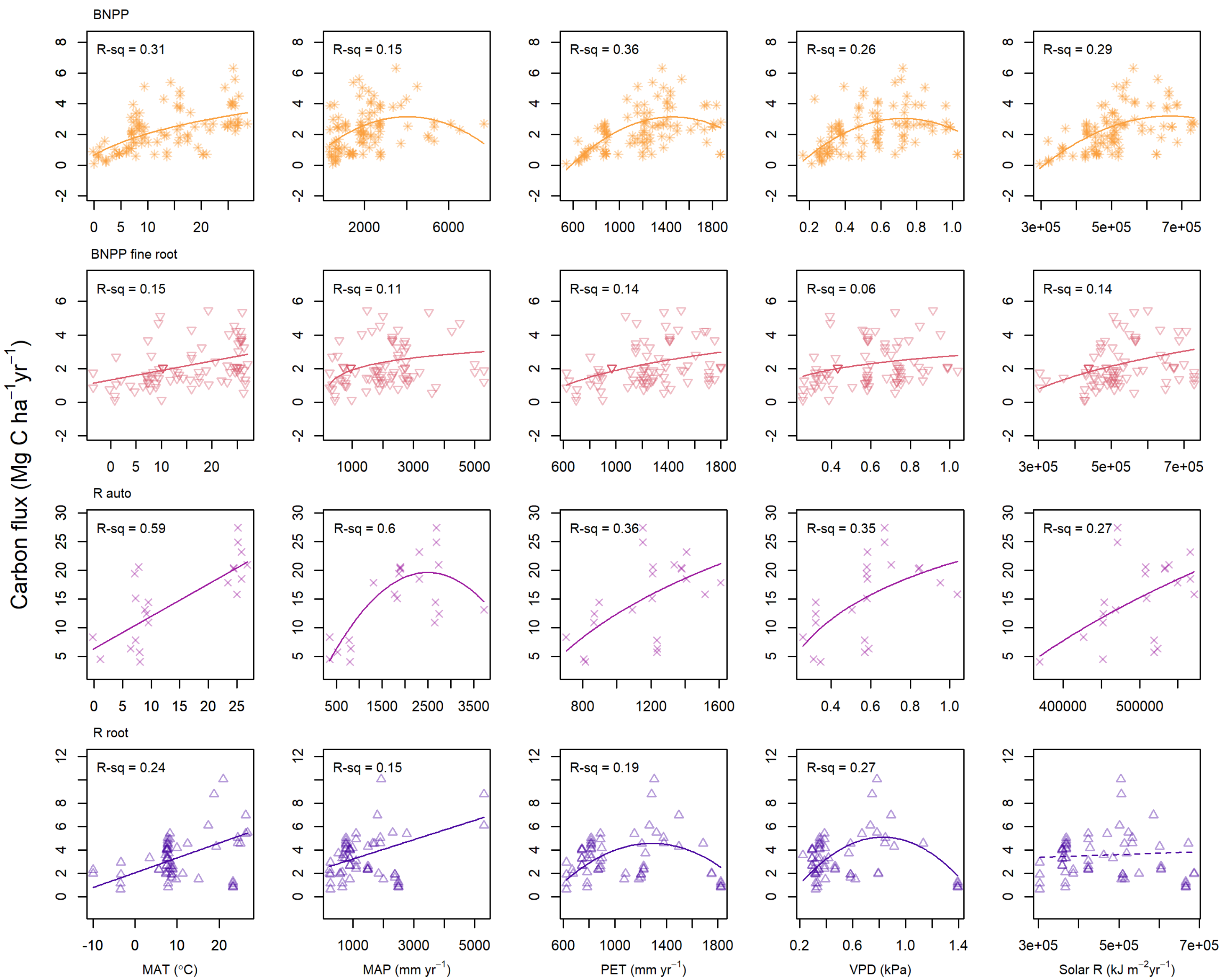

Figure S5: Individual plots of forest C fluxes in relation to mean annual climate, part 2.

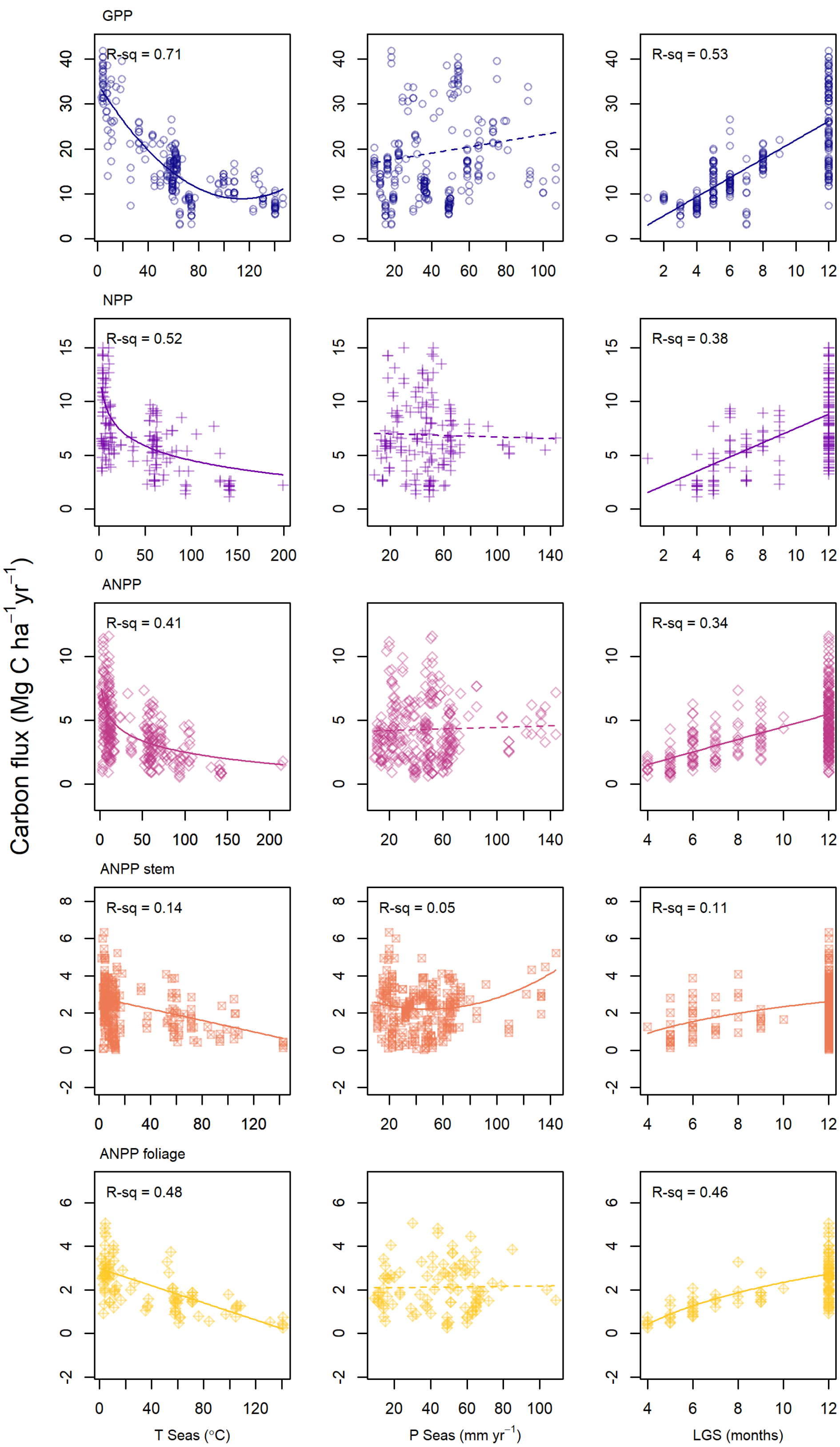

Figure S6: Individual plots of forest C fluxes in relation to mean climate seasonality, part 1.

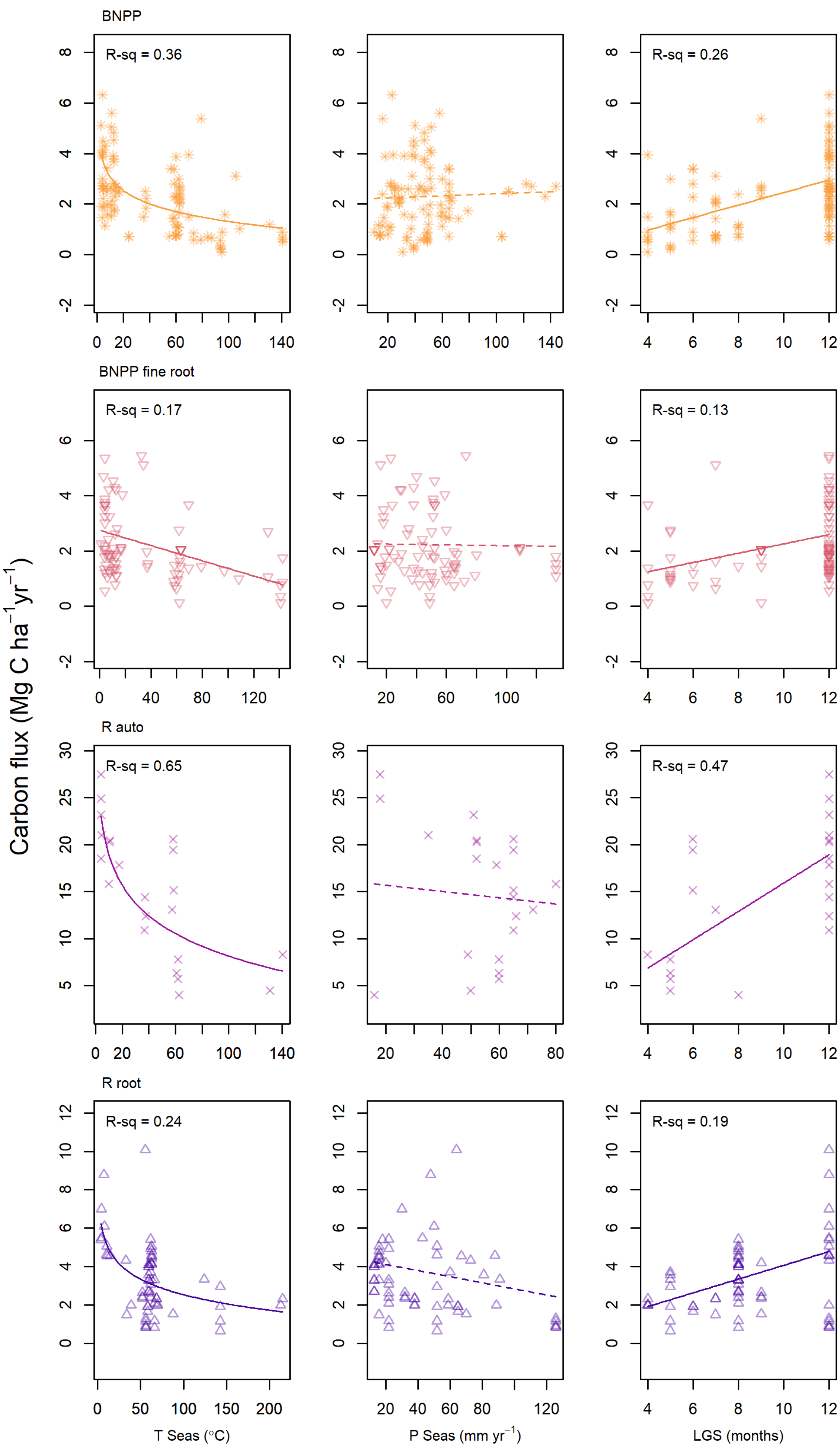

Figure S7: Individual plots of forest C fluxes in relation to mean climate seasonality, part 2.

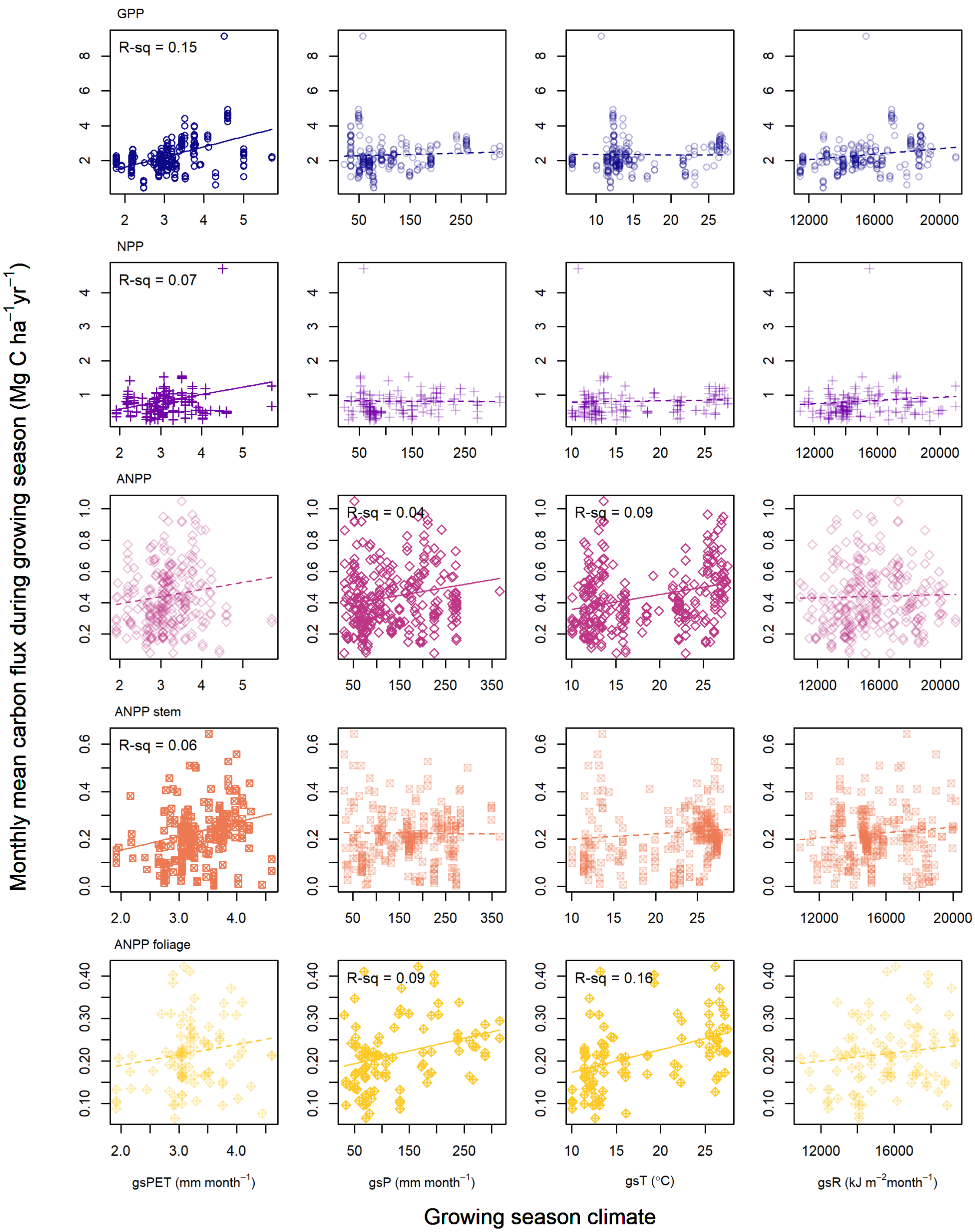

Figure S8: Growing season length-standardized forest C fluxes in relation to mean growing season climate, part 1.

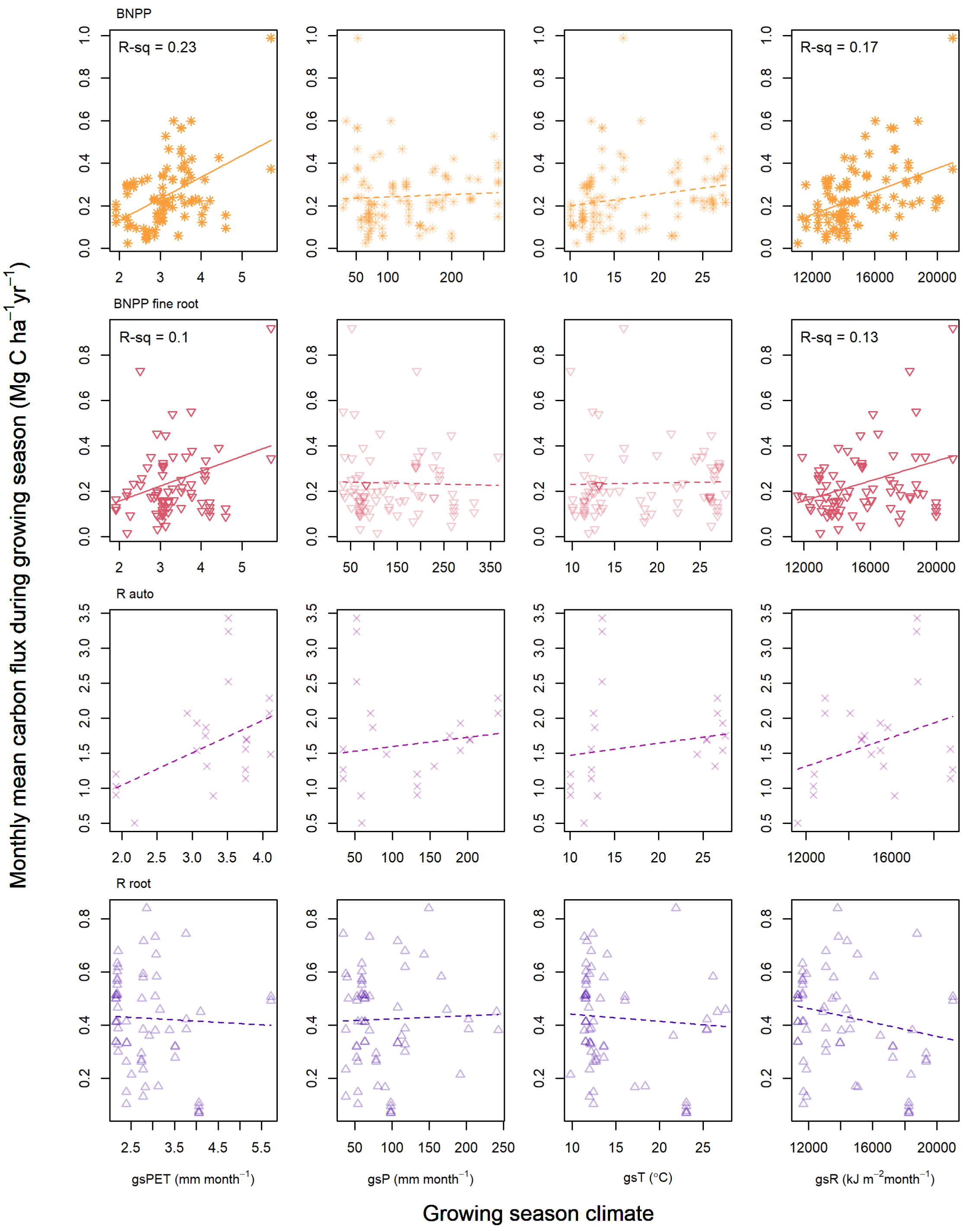

Figure S9: Growing season length-standardized forest C fluxes in relation to mean growing season climate, part 2.

References

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