Global variation in NPP: Bivariate and multiple regression analyses in R

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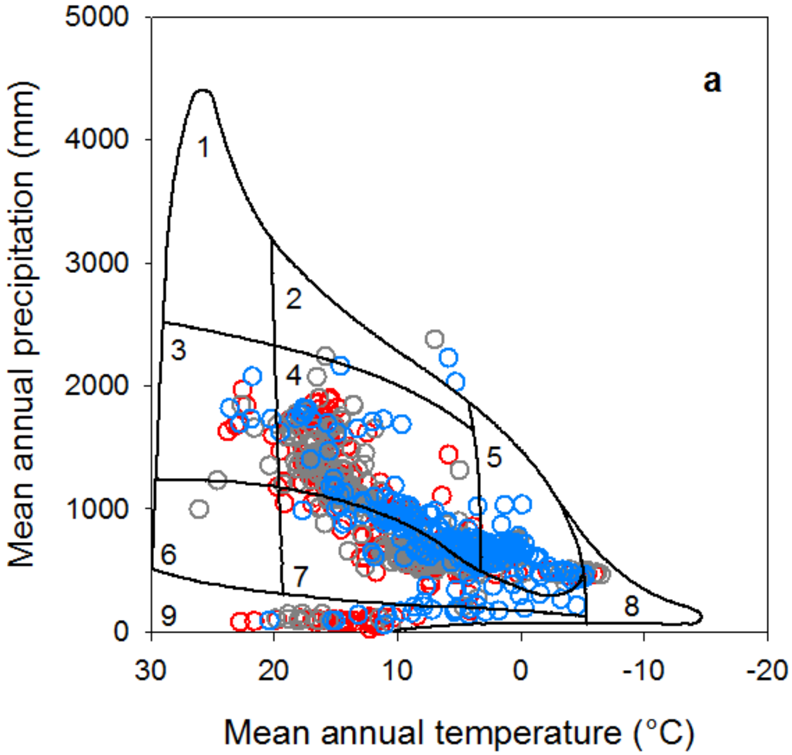
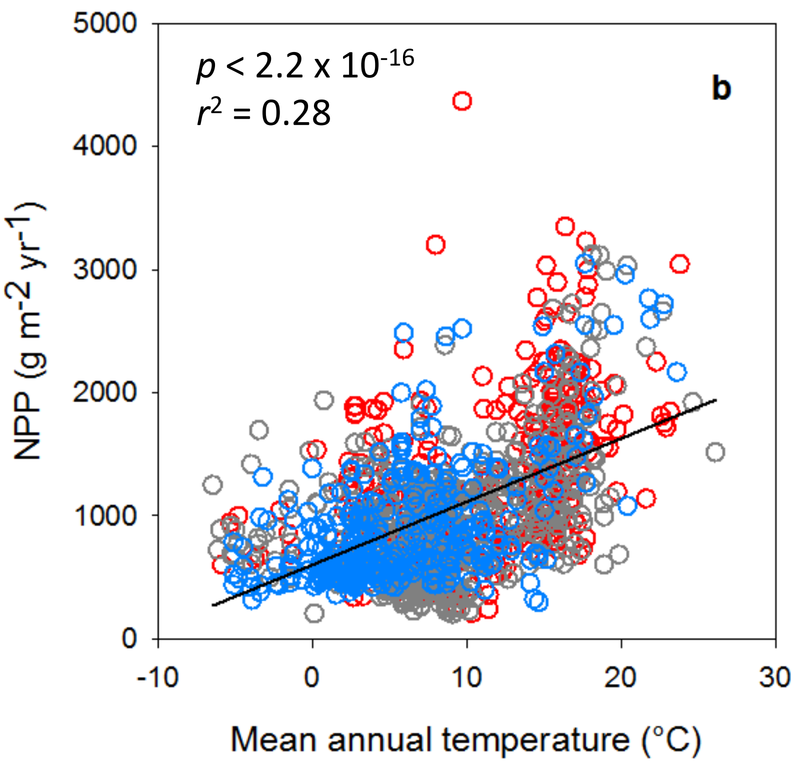
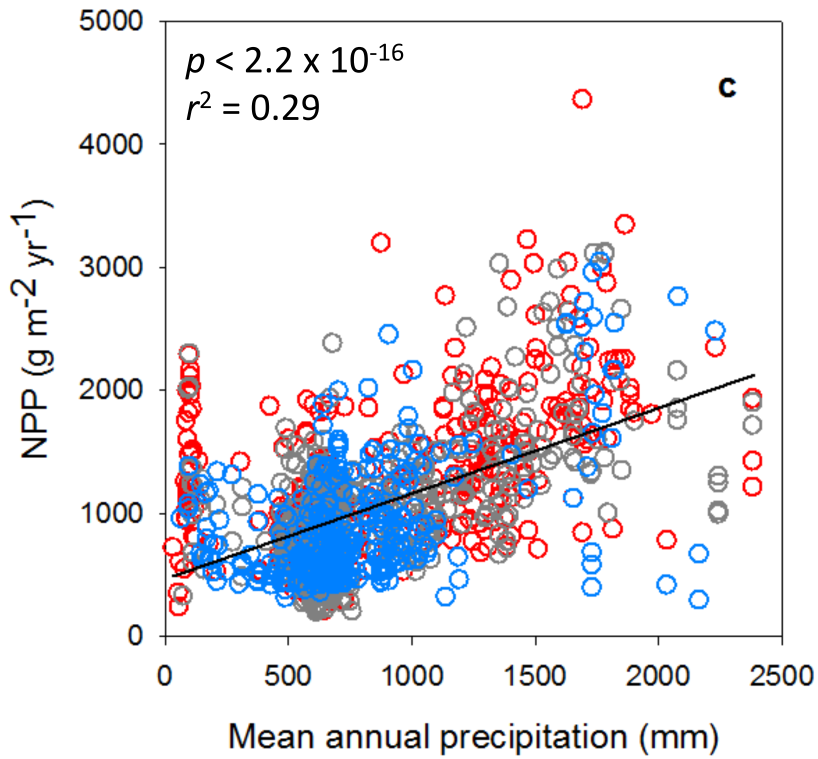
Whittaker “climate space” diagram



1, tropical rainforest.
2, temperate rainforest.
3, tropical seasonal forest.
4, temperate forest.
5, tiaga.
6, savanna.
7, woodland/shrubland.
8, tundra.
9, desert.
Red, 0 – 40 years;
grey, 41 – 80 years;
blue, 81 – 350 years.

Bivariate regression: NPP on MAT and MAP



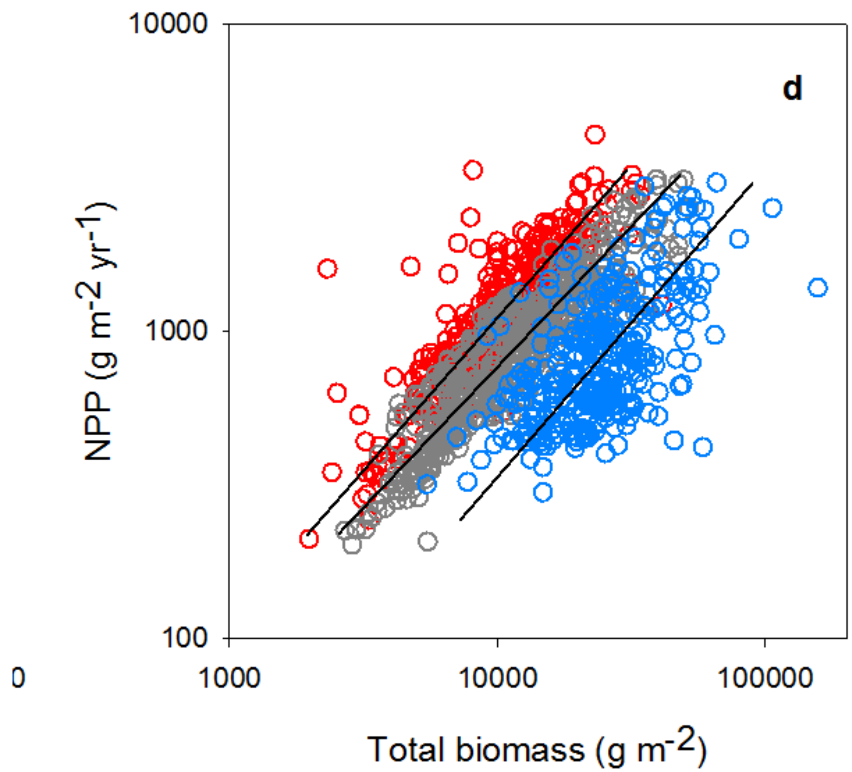


A general mass-scaling model of NPP

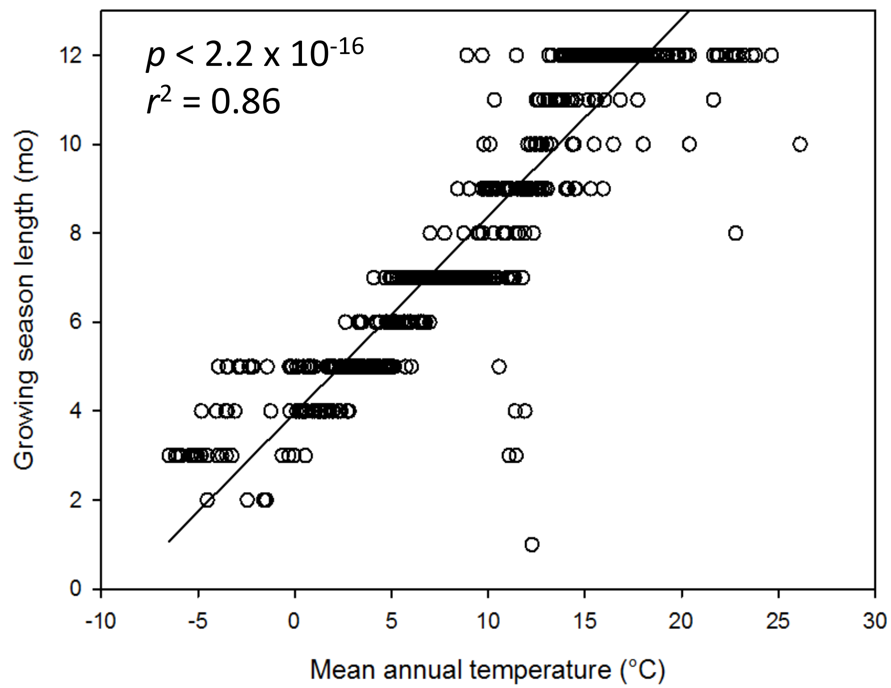
$$NPP = CM_{tot}^{\alpha}$$

NPP – net primary productivity (g m^{-2} yr^{-1})
C – proportionality constant ($g^{1+\alpha}$ m^{-2} yr^{-1})
M_{tot} – total stand biomass (g)
α – mass-scaling exponent (dimensionless)

Bivariate regression: Model II SMA regression



Relationship between NPP and MAT may be confounded by growing season length!



A metabolic scaling theory of woody plant production: Annual net primary productivity

$$NPP = P^{\alpha_P} l_{gs}^{\alpha_{l_{gs}}} a^{\alpha_a} e^{-E/kT} g_1 \frac{c_n}{A} \left[\frac{5c_m^{\ 8/3}}{3c_n} \right]^{\alpha} M_{tot}^{\alpha}$$

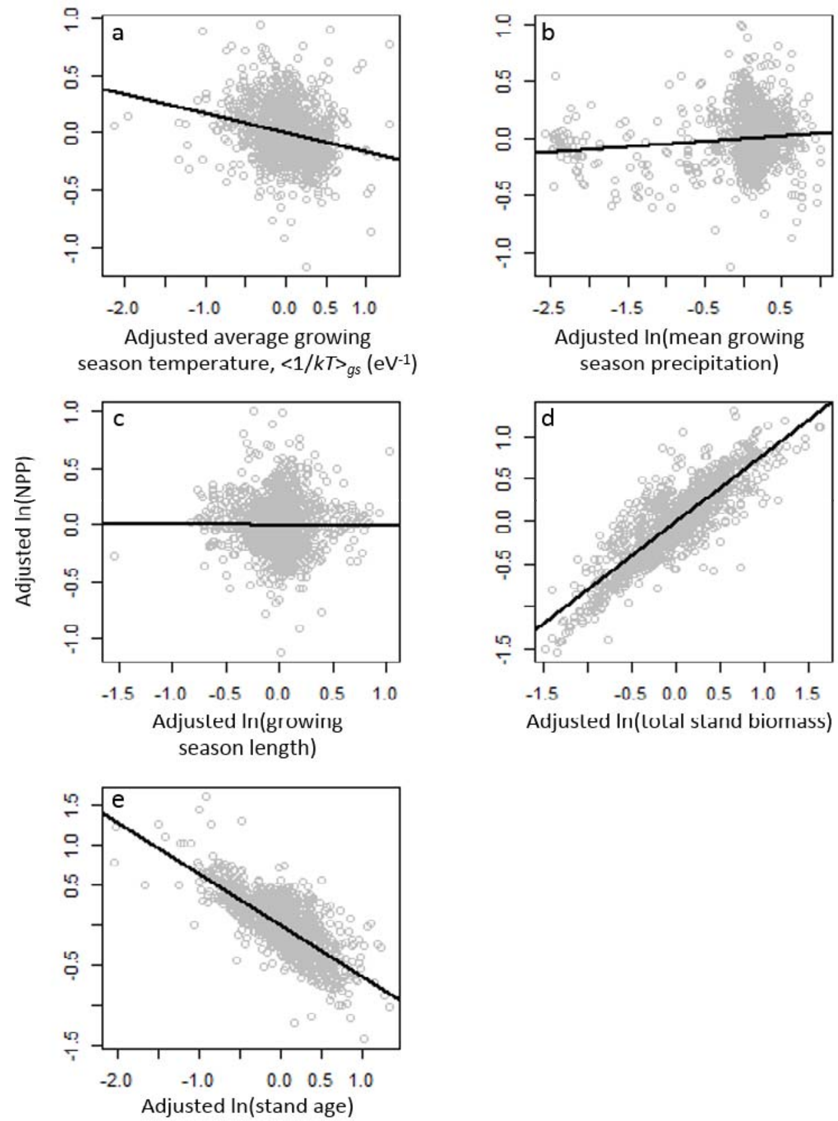
Linearize as

$$\ln\left(NPP\right) = \beta_{0,1} + \alpha_P \ln\left(P\right) + \alpha_{l_{gs}} \ln\left(l_{gs}\right) + \alpha_a \ln\left(a\right) - \frac{E}{kT} + \alpha \ln\left(M_{tot}\right)$$

where intercept $\beta_{0,1} = \ln(g_1) + \ln\left(c_n / A\right) + \ln\left(\left[5c_m^{8/3} / 3c_n\right]^{\alpha}\right)$

Most variation explained by biomass and age only!

- Full model $R^2 = 0.80$
  - Biomass partial $r^2 = 0.74$
  - Age partial $r^2 = 0.58$
  - Temp partial $r^2 = 0.06$
  - GS length partial $r^2 = 0.00$
  - Precip partial $r^2 = 0.00$



Partial residual plots:

1. Compute the residuals of regressing the response variable against the independent variables but omitting X_i
2. Compute the residuals from regressing X_i against the remaining independent variables
3. Plotting the residuals from (1) against the residuals from (2).

A metabolic scaling theory of woody plant production: Annual net primary productivity

$$\frac{NPP}{l_{gs}} = P^{\alpha_P} a^{\alpha_a} e^{-E/kT} g_2 \frac{c_n}{A} \left[\frac{5 c_m^{\ 8/3}}{3 c_n} \right]^{\alpha} M_{tot}^{\alpha}$$

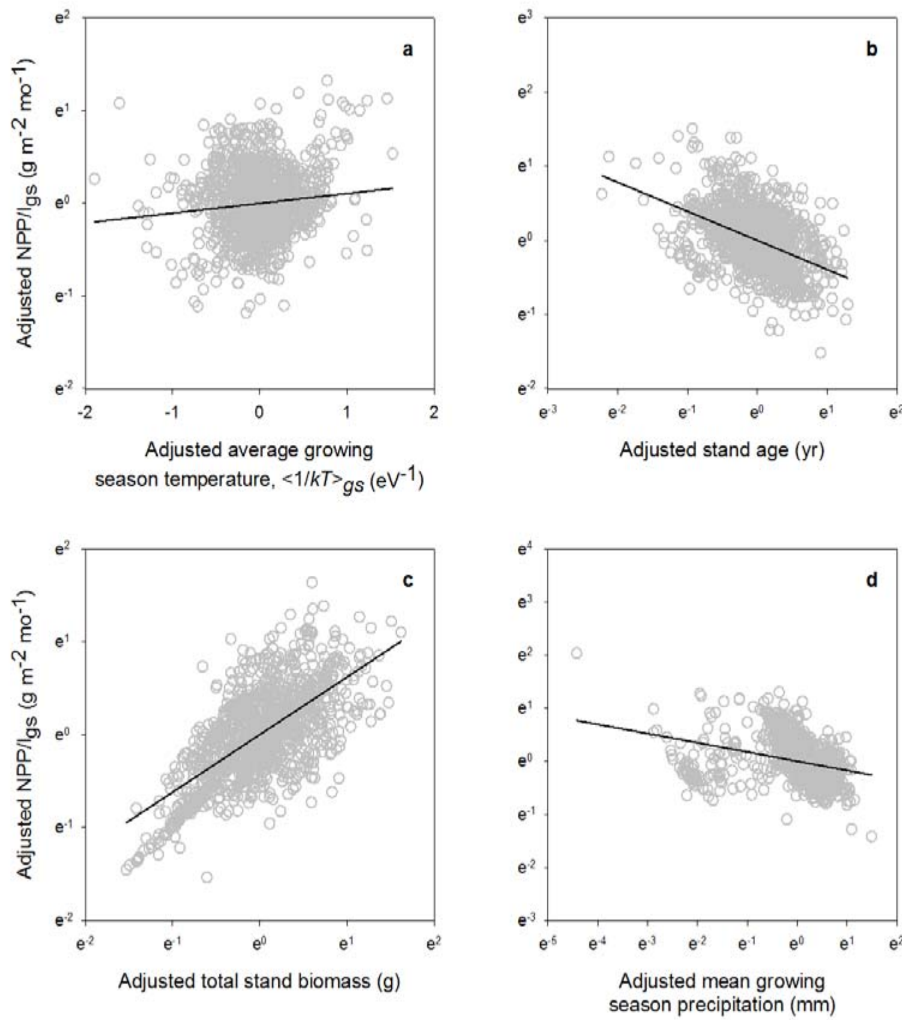
Linearize as

$$\ln\left(\frac{NPP}{l_{gs}}\right) = \beta_{0,2} + \alpha_P \ln(P) + \alpha_a \ln(a) - \frac{E}{kT} + \alpha \ln(M_{tot})$$

where intercept $\beta_{0,2} = \ln(g_2) + \ln(c_n / A) + \ln\left(\left[4 c_m^{8/3} / 3 c_n\right]^{\alpha}\right)$

Most variation explained by biomass and age only!

- Full model $R^2 = 0.80$
    - Biomass partial $r^2 = 0.45$
    - Age partial $r^2 = 0.21$
    - Temp partial $r^2 = 0.02$
    - Precip partial $r^2 = 0.10$



Dependent variable	Covariate	Coefficient	Estimate	SE	t	p-value	Partial R^2
NPP (g m^{-2} yr^{-1})		β_0	8.24579	0.78843	10.459	$< 2 \times 10^{-16}$	0.0843
	$\alpha_{l_{gs}}$ $<1/kT>_{gs}$	E	0.16640	0.01957	-8.501	$< 2 \times 10^{-16}$	0.0573
	a	α_a	-0.64156	0.01586	-40.456	$< 2 \times 10^{-16}$	0.5794
	l_{gs}		-0.01314	0.02577	-0.510	0.6102	0.0002
	M_{tot}	α	0.79987	0.01397	57.248	$< 2 \times 10^{-16}$	0.7339
	P_{gs}	α_P	0.04740	0.01147	4.133	3.84×10^{-5}	0.0142
NPP/l_{gs} (g m^{-2} mo^{-1})		β_0	-3.05016	1.11337	-2.740	0.00624	0.0035
	$<1/kT>_{gs}$	E	-0.11603	0.02761	4.202	2.84×10^{-5}	0.0146
	a	α_a	-0.39132	0.02203	-17.766	$< 2 \times 10^{-16}$	0.2098
	M_{tot}	α	0.62029	0.02002	30.978	$< 2 \times 10^{-16}$	0.4466
	P_{gs}	α_P	-0.17351	0.01516	-11.443	$< 2 \times 10^{-16}$	0.0992

Simpler model is more parsimonious but explains roughly same variation in NPP as full model!

Versus $R^2 = 0.80$
for full model