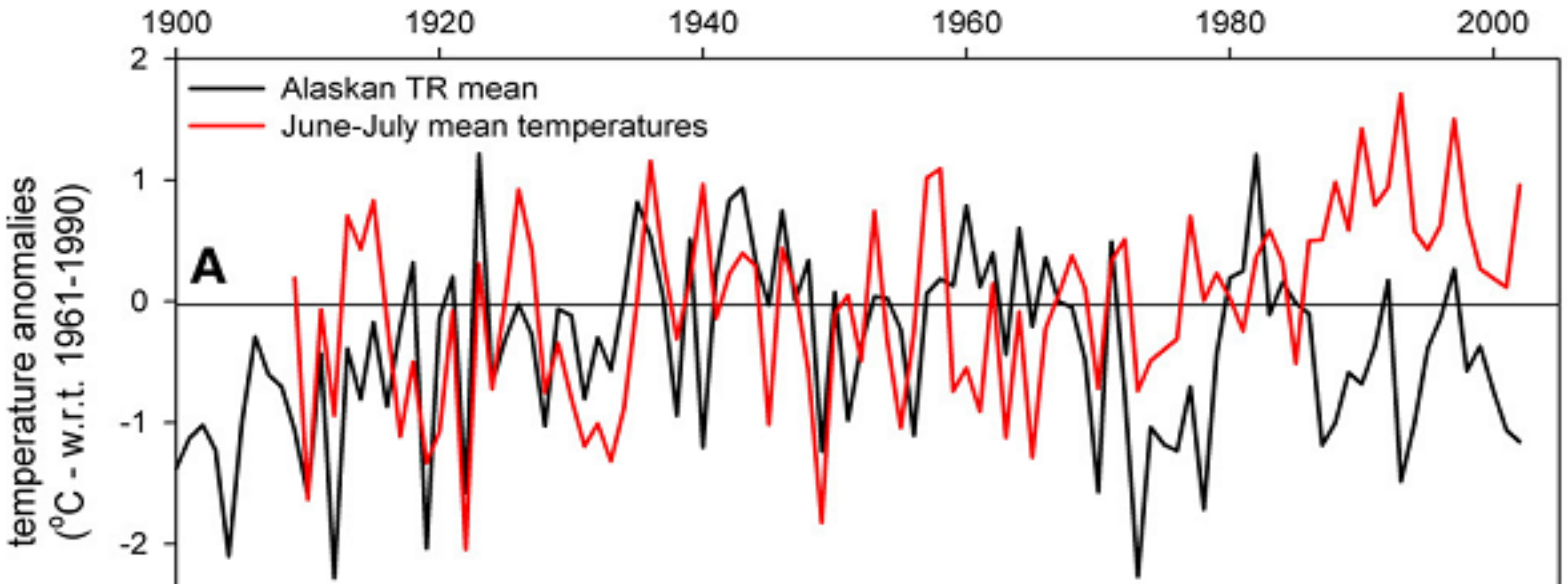
Exploring the 'Divergence' Problem Using a Simple Process-based Model of Tree Growth

Guangqi Li[1], Sandy P. Harrison[1], I. Colin Prentice[2]

1 University of Reading; 2 Imperial College London

1 Divergence problem

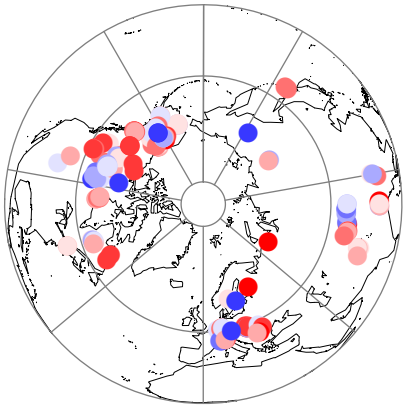


D'Arrigo et al (2007)

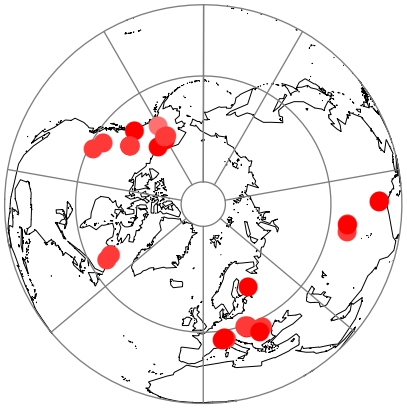
Divergent tree ring width with temperature in some of the northern sites (Briffa et al. 1995, Jacoby and D'Arrigo 1995, Briffa et al. 1998, Vaganov et al. 1999, Barber et al. 2000)

1 Divergence explore in ITRDB for Picea

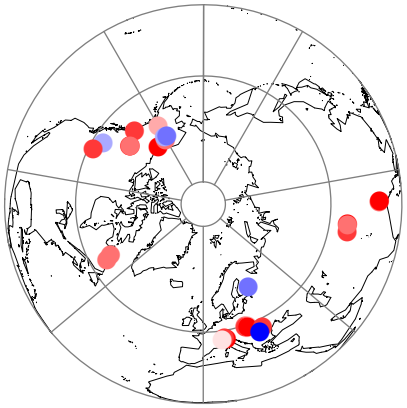
All Picea sites



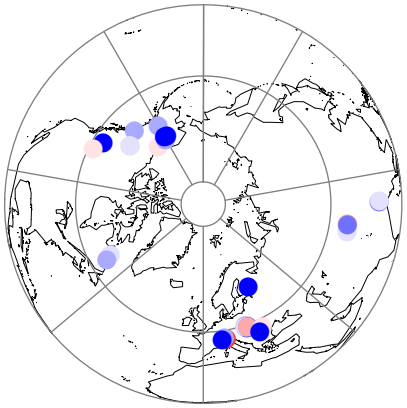
1940-1970



1971-2000

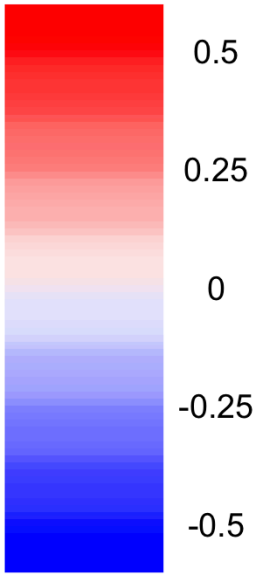


Difference latter - former



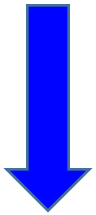
Summer temperature strength

"Summer Temperature Limiting Sites"

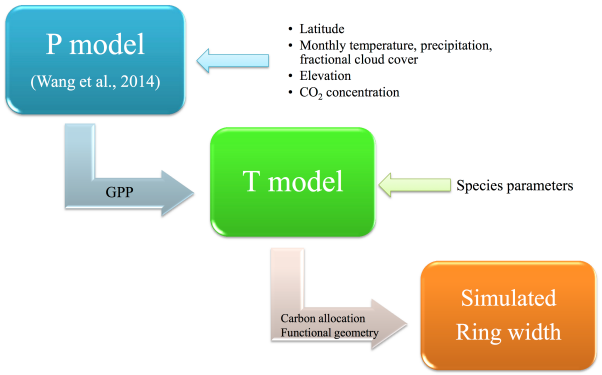


temperature

strength of temperature

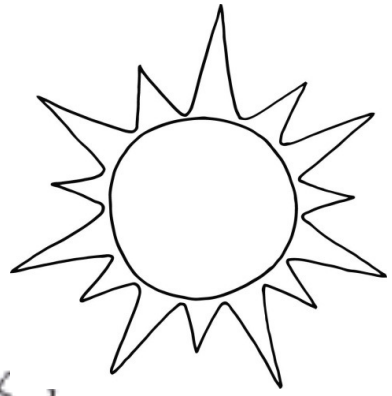


2 Tools for analysis - PT model



$$GPP = \Phi_0 \, (PAR_0 \times fAPAR) \;\; (c_i - \Gamma^*)/(c_i + 2\Gamma^*)$$

(Wang et.al, 2014)



latitude, elevation
monthly T, P, S, CO_2

- ✓ Light
- ✓ Moisture
- ✓ CO_2
- ✓ Others

GPP

P model

T model

Foliage mass
Foliage respiration
Foliage turnover

Carbon allocation

$$P = P_0 \, A_c \, (1 - \exp(-kL))$$
$$P_{net} = y(P - R_m) = y \, (P - W_{\bullet s} \, r_s - \zeta \, \sigma \, W_f \, r_r)$$
$$P_{net} = dW_s/dt + (1 + \zeta \, \sigma) \, dW_f/dt + (1/\tau_f + \zeta \, \sigma/\tau_r) \, W_f$$
$$dW_s/dt = y \, A_c \, [P_0 \, (1 - \exp(-kL)) - \rho_s \, (1 - f_c/2) \, H \, r_s/c - L \, \zeta \, r_r] - L \, (\pi c/4a) \, [aD \, (1 - H/H_m) + H] \, (1/\sigma + \zeta) \, dD/dt - L \, A_c (1/\sigma\tau_f + \zeta/\tau_r)$$

Stem mass (Ring width)
Sapwood respiration

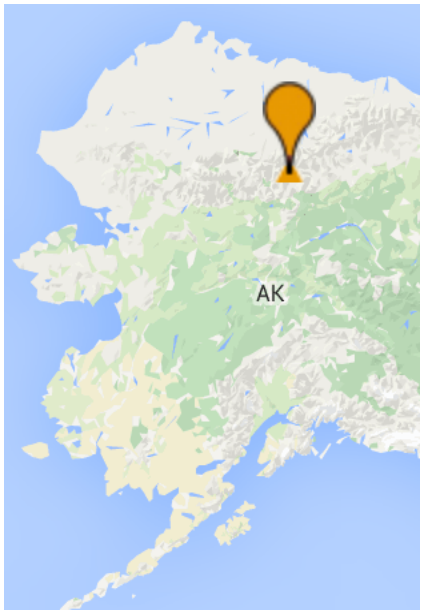
Functional geometry

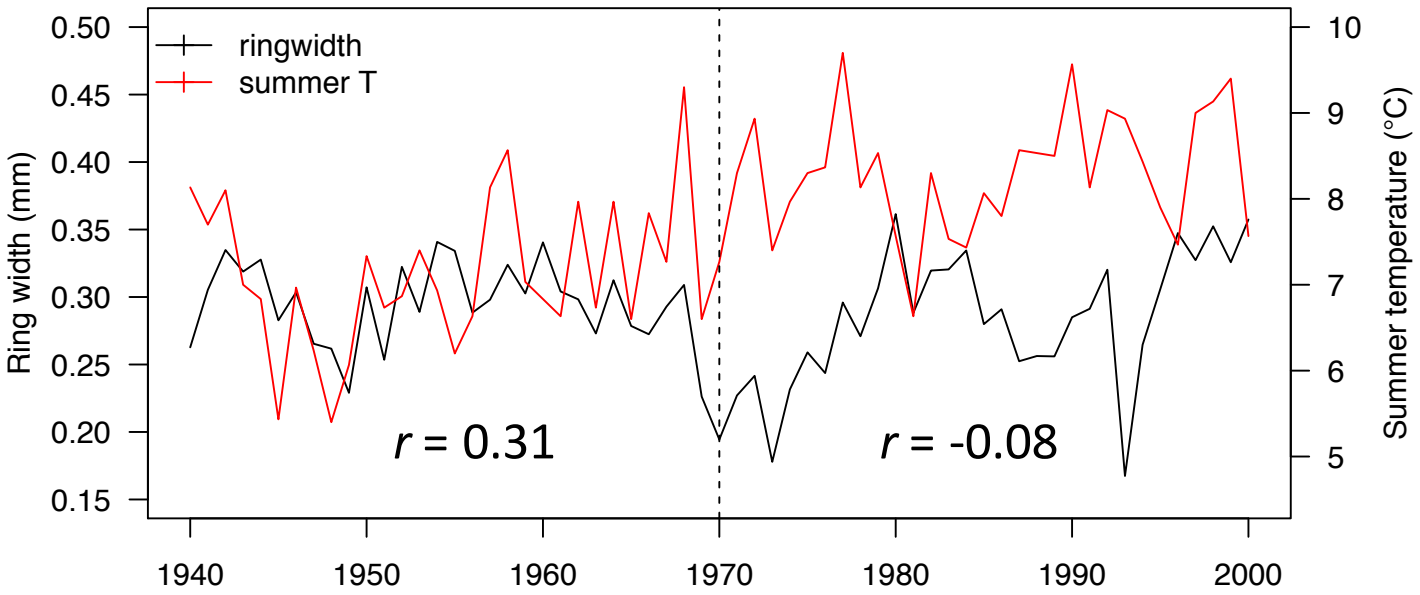
$$H = H_m \, [1 - \exp \, (-aD/H_m)]$$
$$A_c = (\pi c/4a) \, DH$$
$$f_c = (1 - z^*/H) = H/aD$$
$$W_s = (\pi/8) \, \rho_s \, D^2 H$$
$$W_{\bullet s} = L \, A_c \, v_H \, \rho_s \, H_f$$

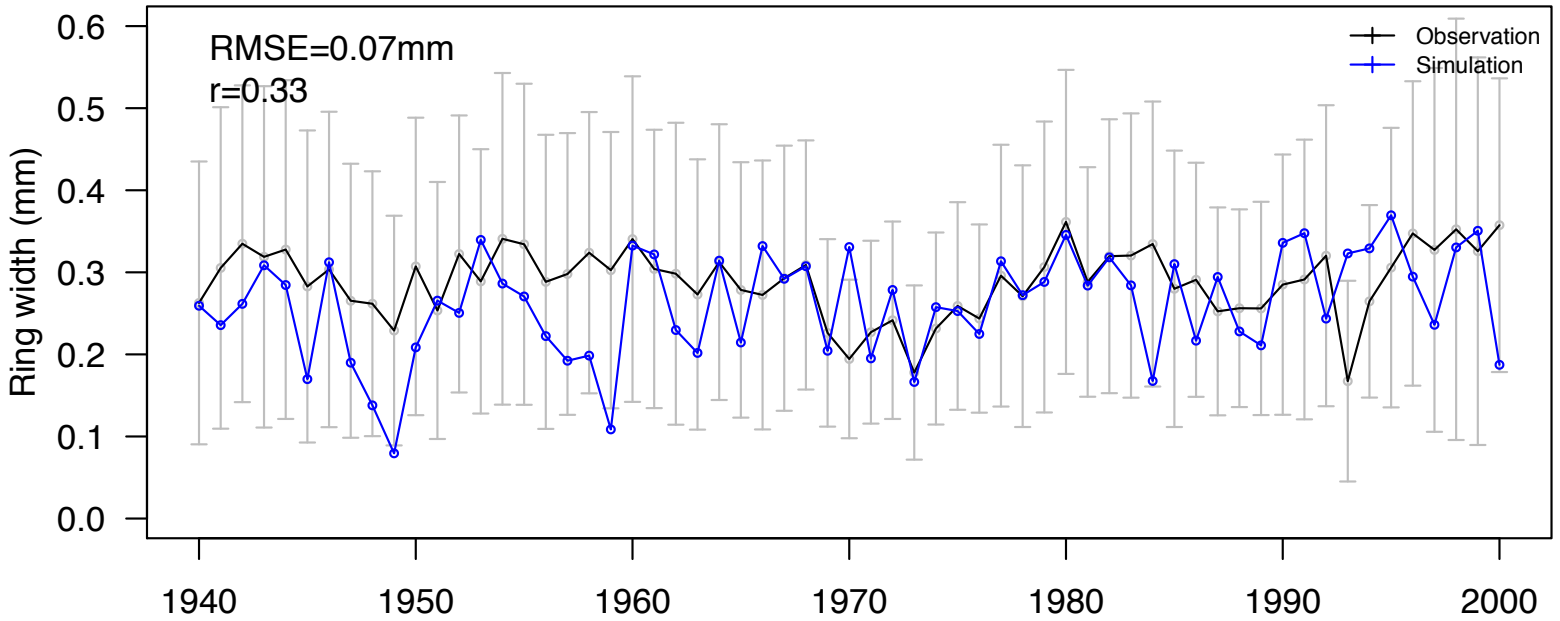
Root mass
Fine root respiration
Fine root turnover

Species parameter

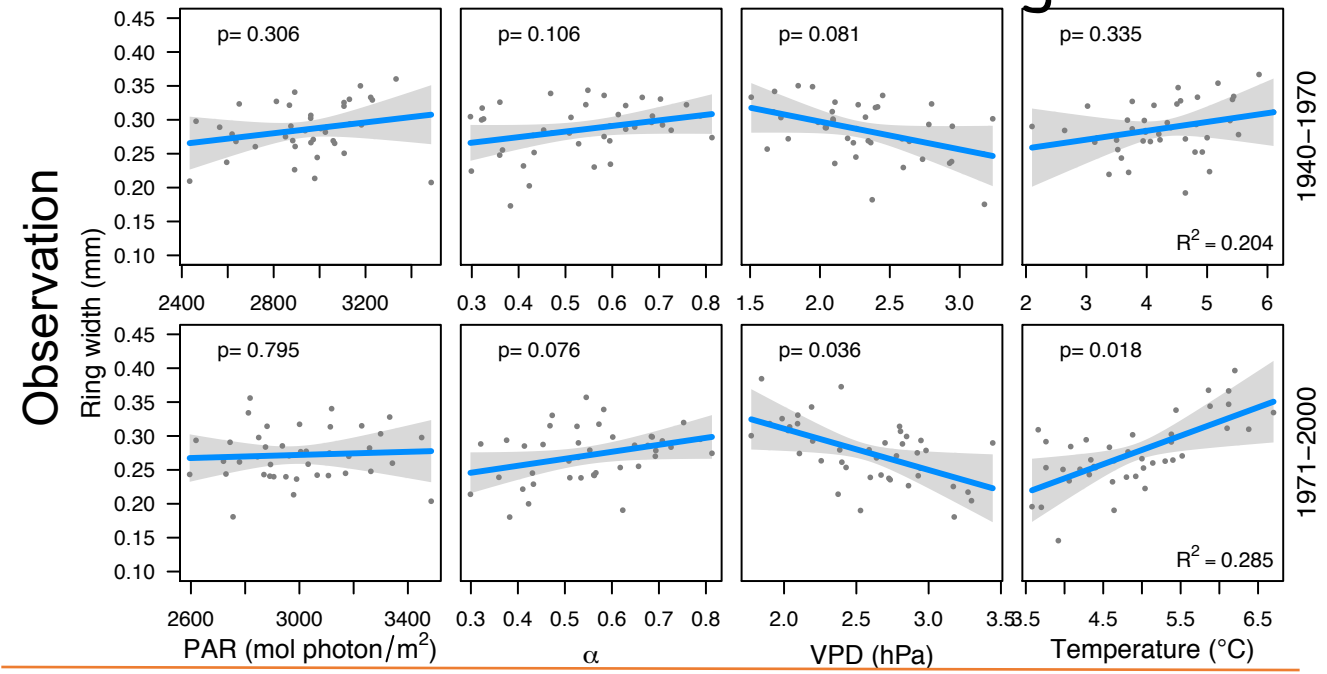
3 PT model application for a divergence site

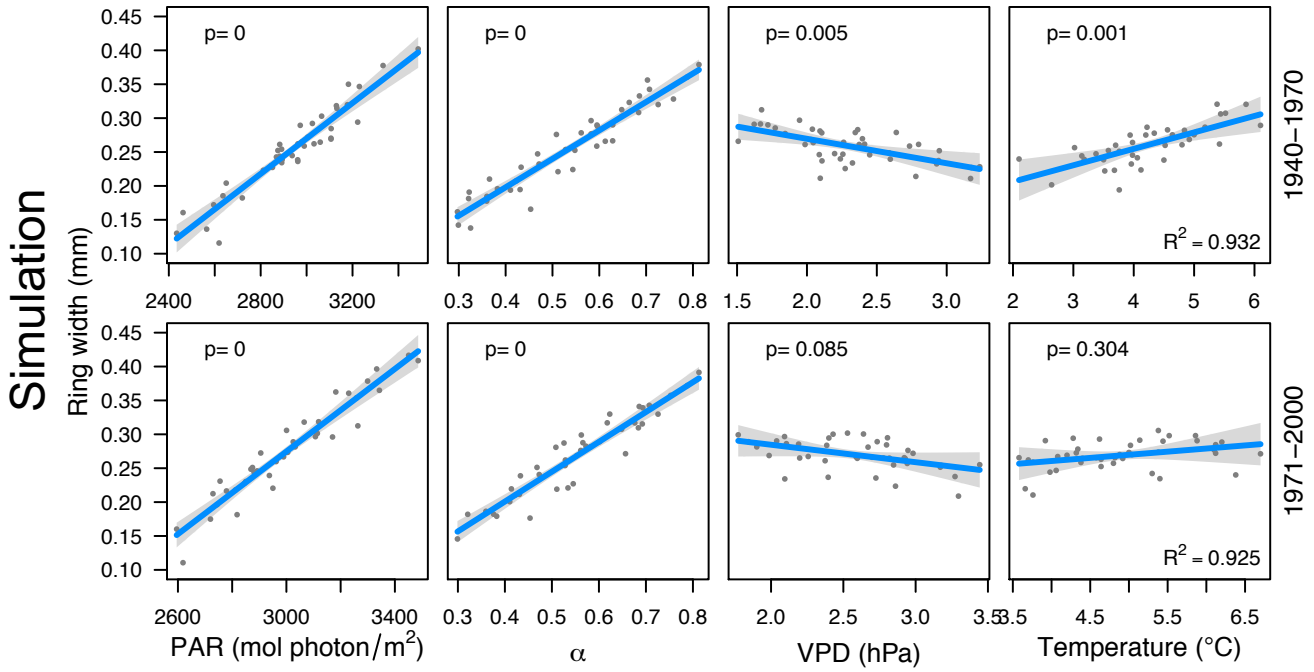






4 Climate controls on tree ring width





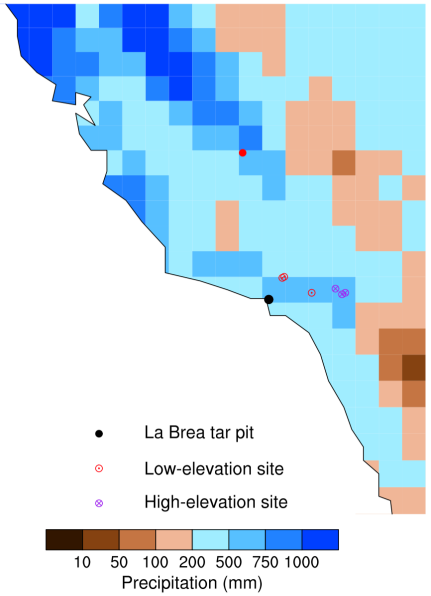
Both two periods show

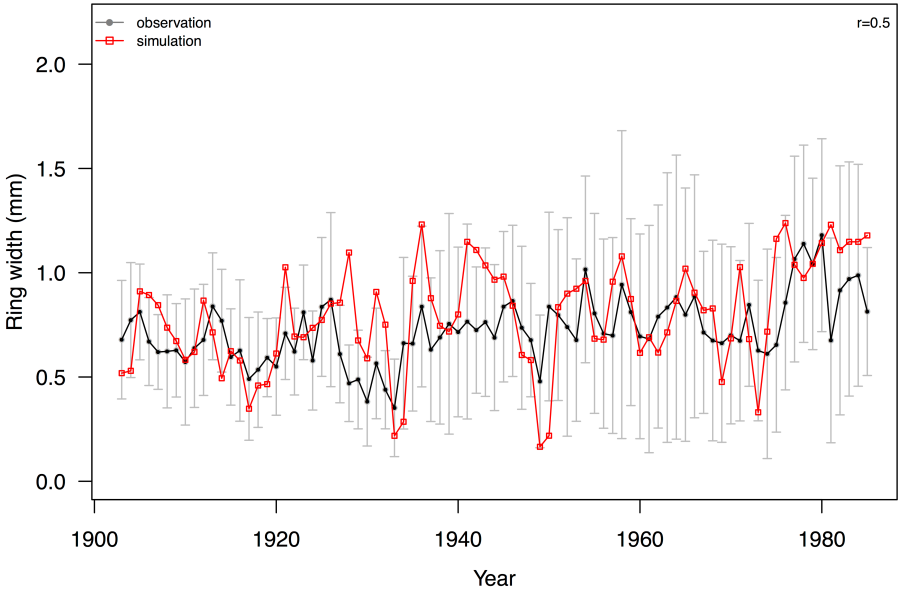
- Positive effect from **PAR** and **α**
- Negative effect from **VPD**

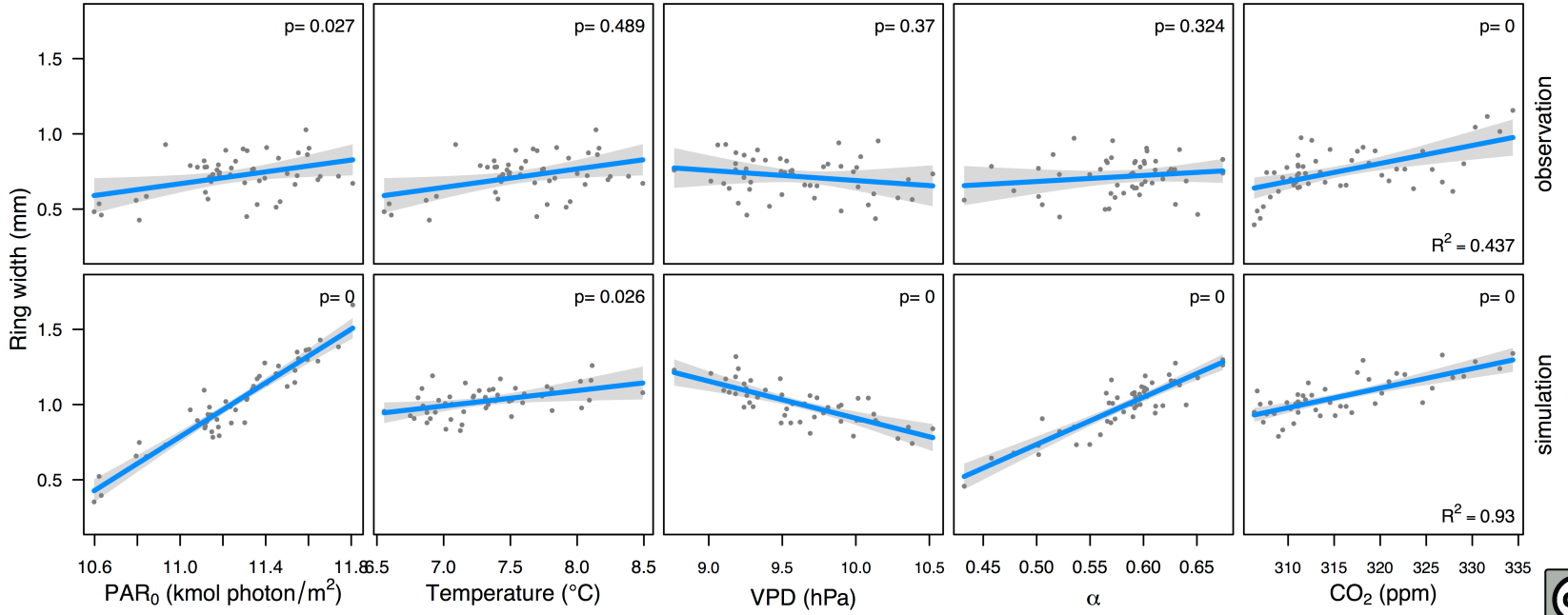
Simulation has the similar responses to the major climate factors as observation (**PAR, α, VPD**)

Temperature sensitive — *Juniperus occidentalis*, California, USA

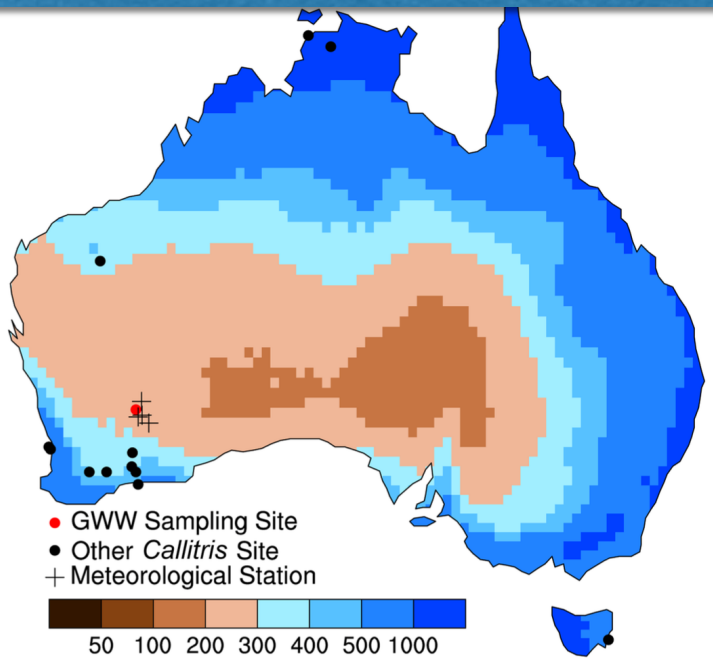
Non-divergent

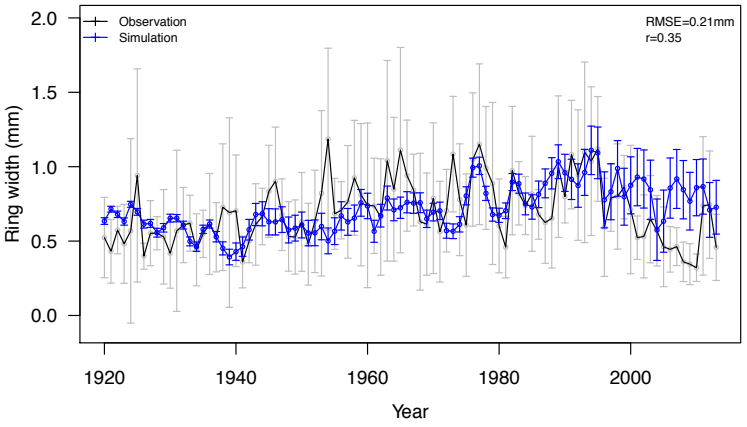


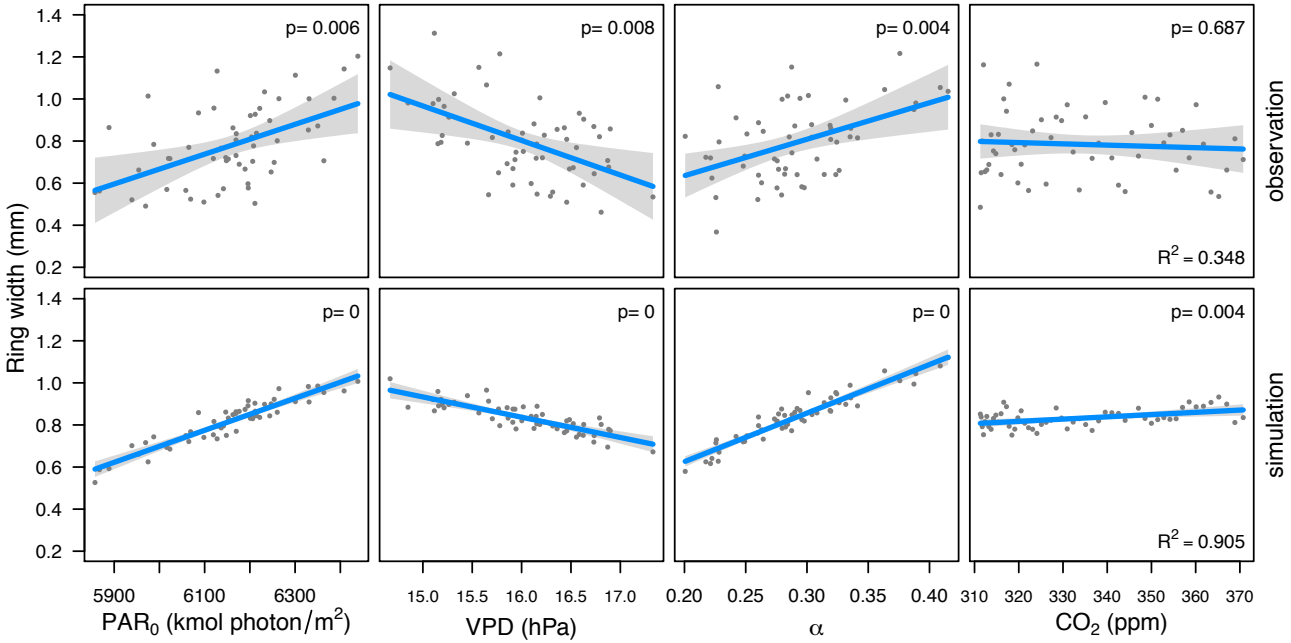




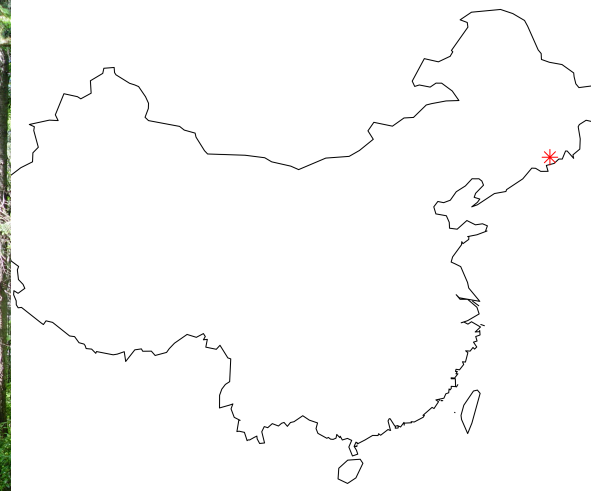
Moisture sensitive – *Callitris columellaris*, GWW, Australia

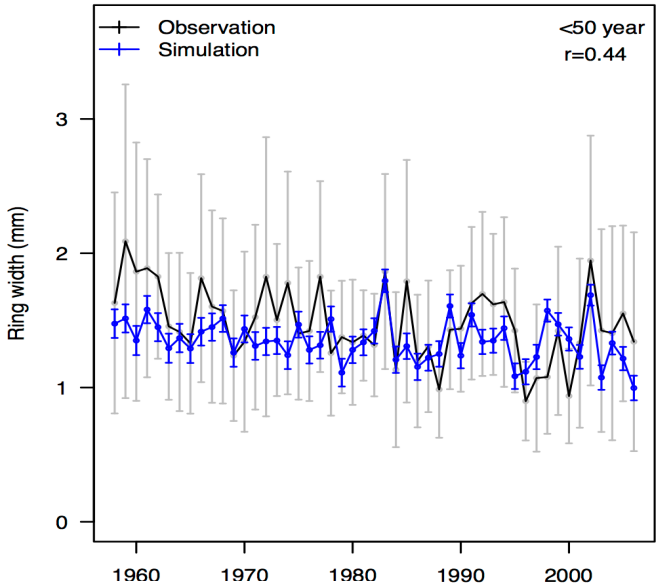


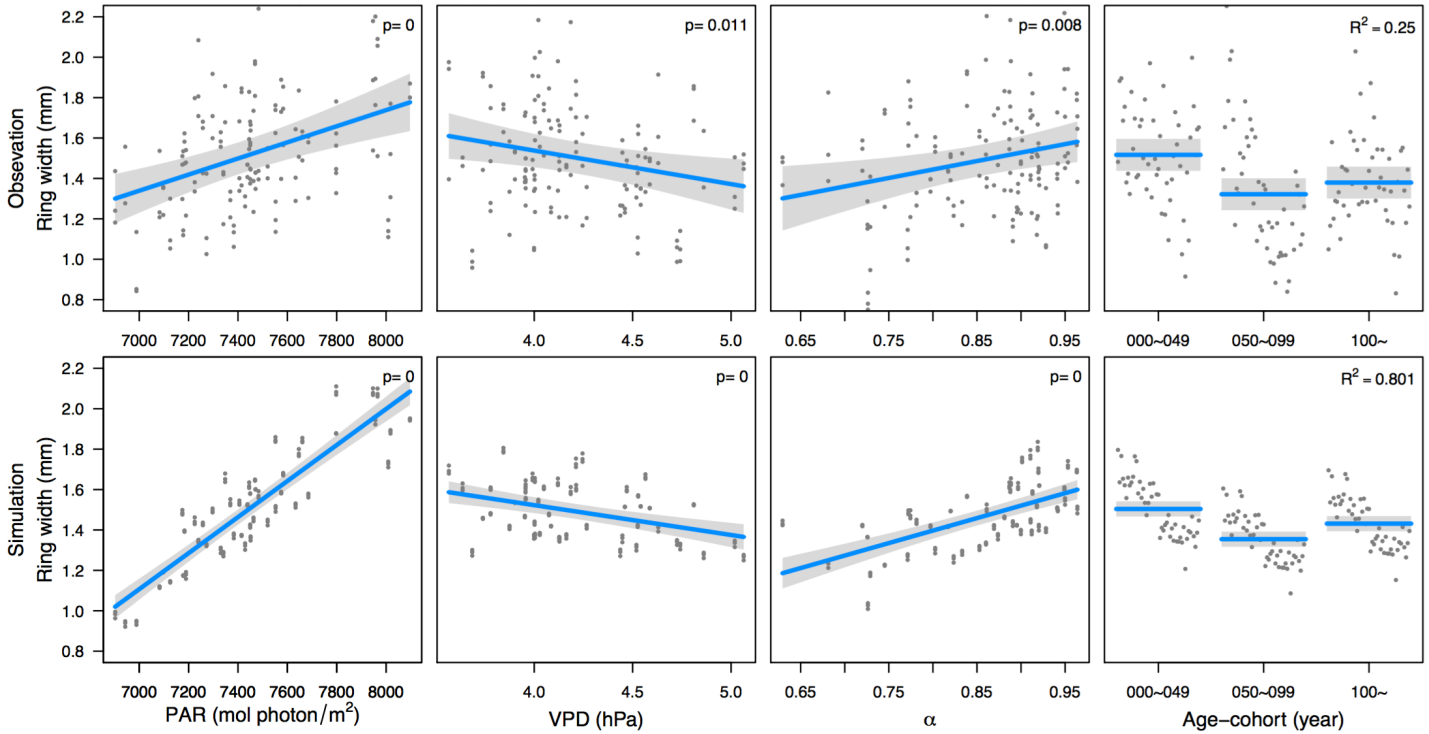




Mild climate - *Pinus koraiensis*, Changbai Mountain, China

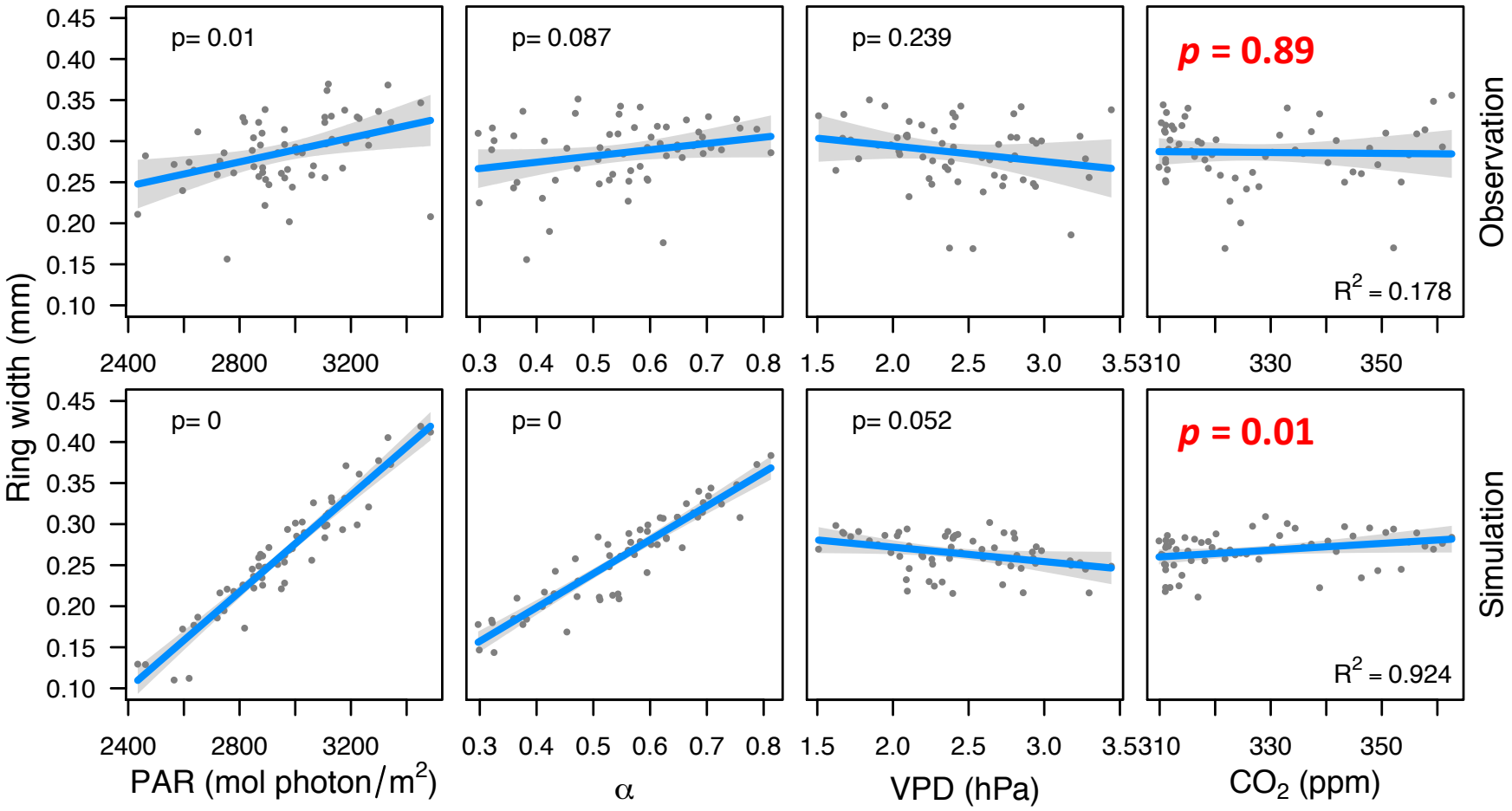






5 Effect of CO_2 on tree growth

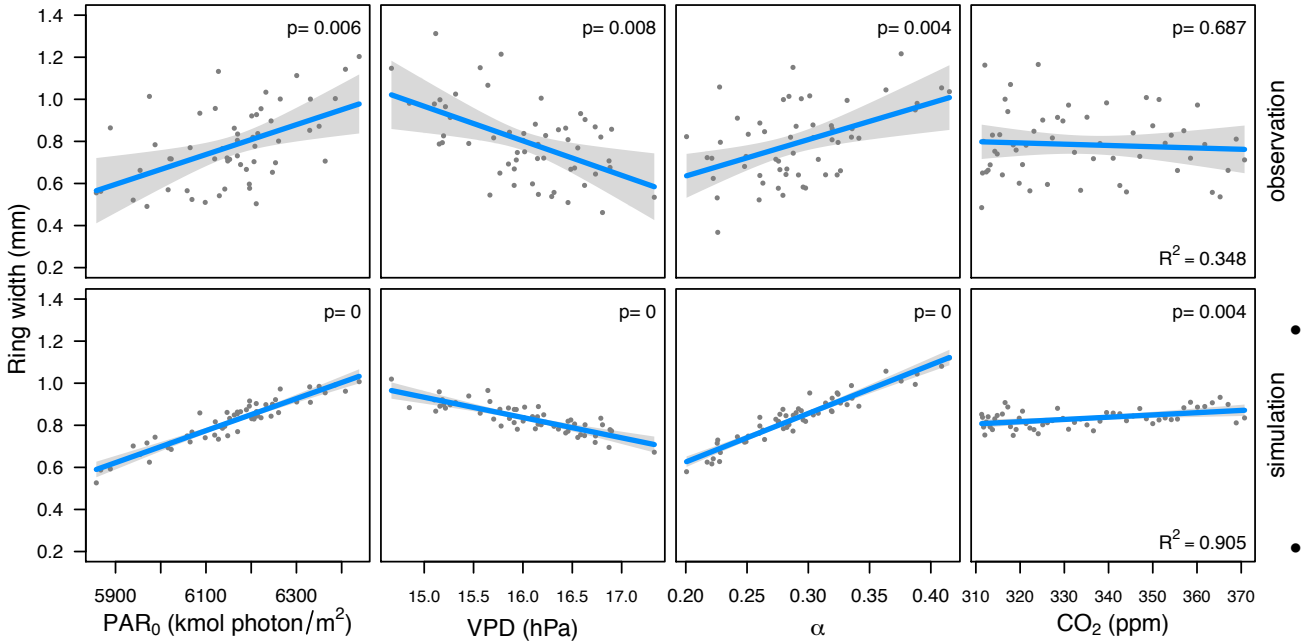
AK104, Alaska, USA

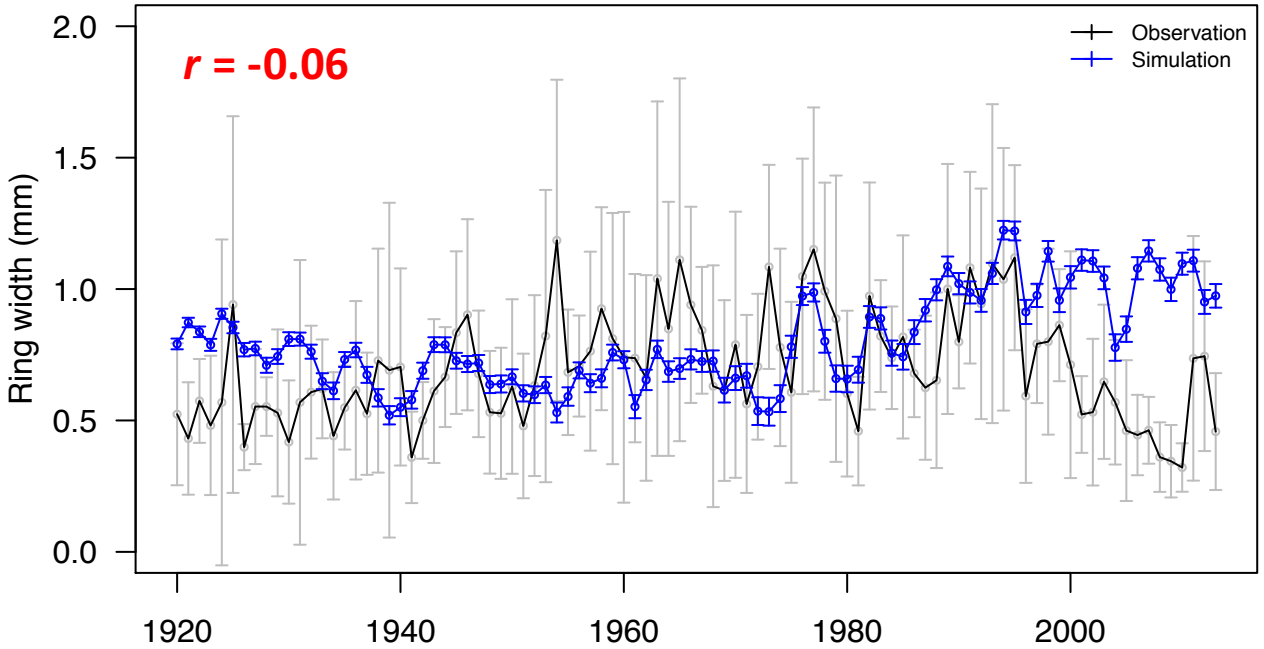


- Model simulate a **significant positive** CO_2 response;
- CO_2 effect is **missing** (flat and insignificant) in observation.

5 Effect of CO_2 on tree growth

GWW, West Australia

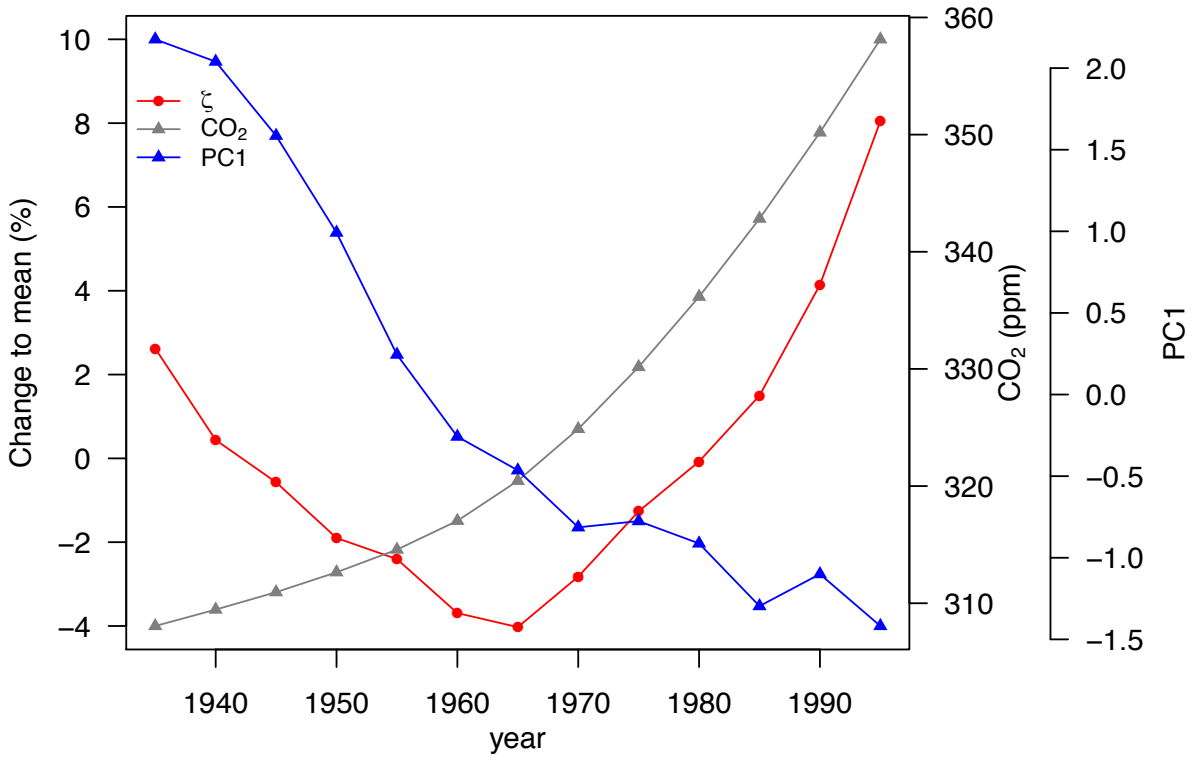




- Controls on simulation and observation similar, ***except*** **[CO_2]**
- Positive effect from **PAR** and **α**
- Negative effect from **VPD**
- No effect from **[CO_2]** for observation, but model simulates significat [CO_2] response.

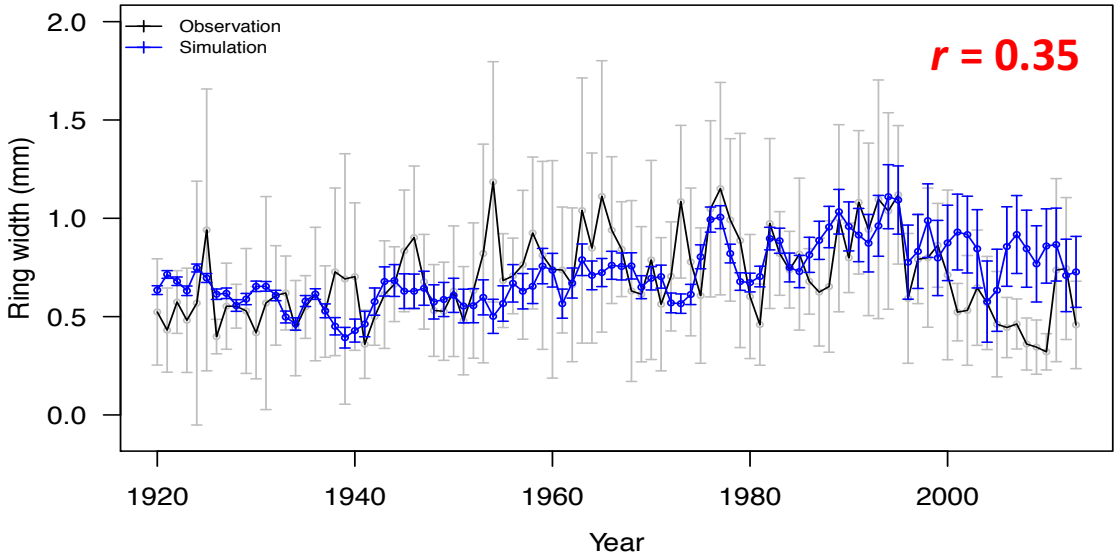
5 Effect of CO_2 on tree growth

Possible reason for missing [CO_2] signal



[CO_2]

Root to shoot ratio



- Carbon allocation is the results of both **climate change** and **CO_2 rising**
- Time-dependent carbon allocation parameter improves simulation

Take home messages

- Tree growth is controlled by multiple factors, and 'divergence' just illustrates this.
- Changes of climate and CO_2 affect allocation.
- Solution to 'divergence' problem is site specific.
- Interpretation of tree rings should account for controls on tree growth and carbon allocation realistically.