Modeling diurnal photosynthetic rate of Andean tree species

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What is the effect of climatic drivers of photosyntehsis on Andean tree species?

H1: **VPD** limits photosynthesis via stomatal closure

H2: **Temperature** limits photosynthesis via biochemical restrictions

H3: **Radiation** limits photosynthesis via leaf temperature increase

All hypotheses predict negative relationship between variable and photosynthesis

Doughty and Goulden (2008); Smith et al., (2021)

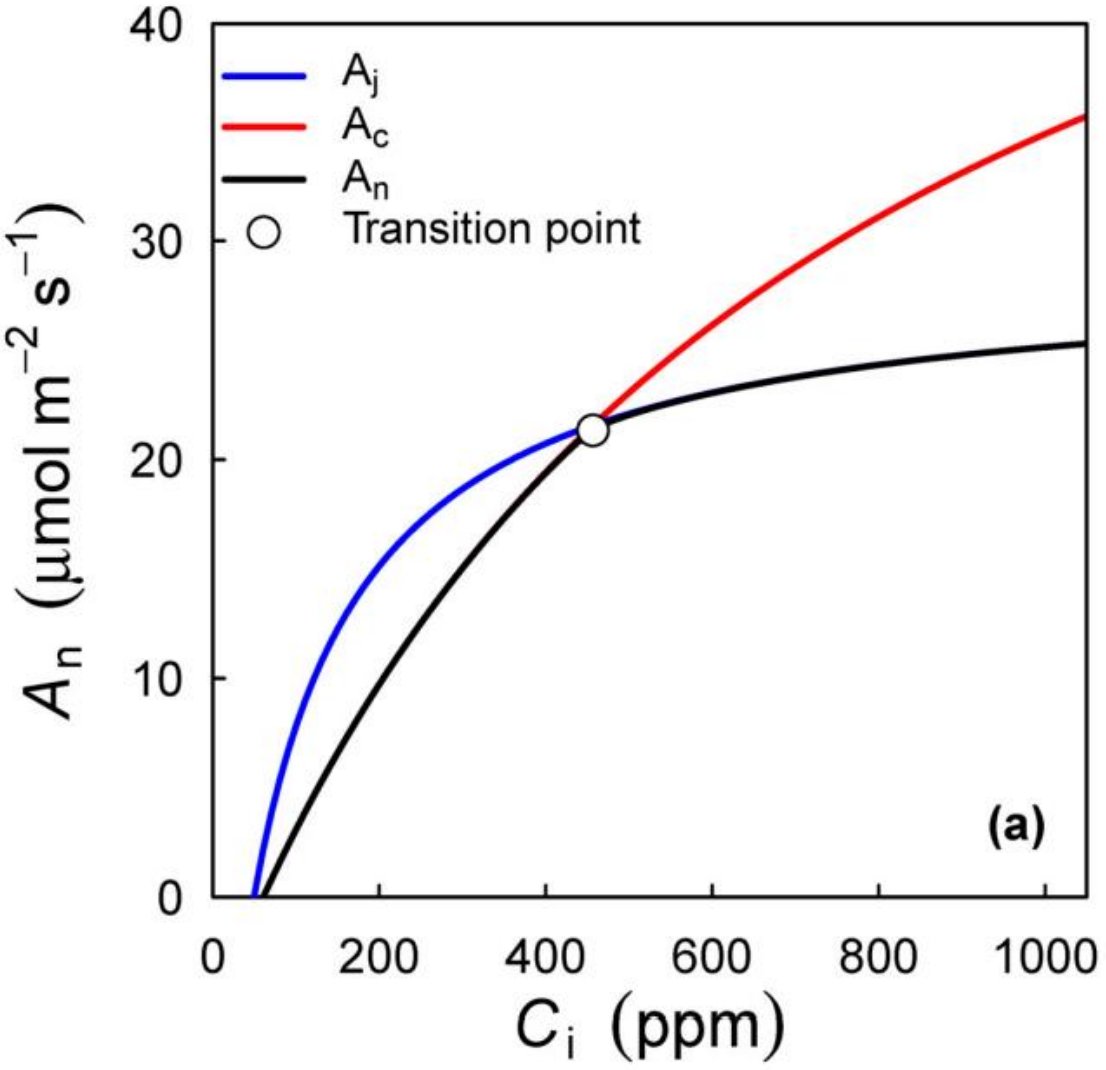
Experimental setup

	Site 1 (14°C)	Site 2 (22°C)
Andesanthus lepidotus	6	2
Clethra fagifolia	6	6
Clusia multiflora	6	3
Miconia theizans	6	6
Quercus humboldtii	6	6
Weinmannia pubescens	6	2

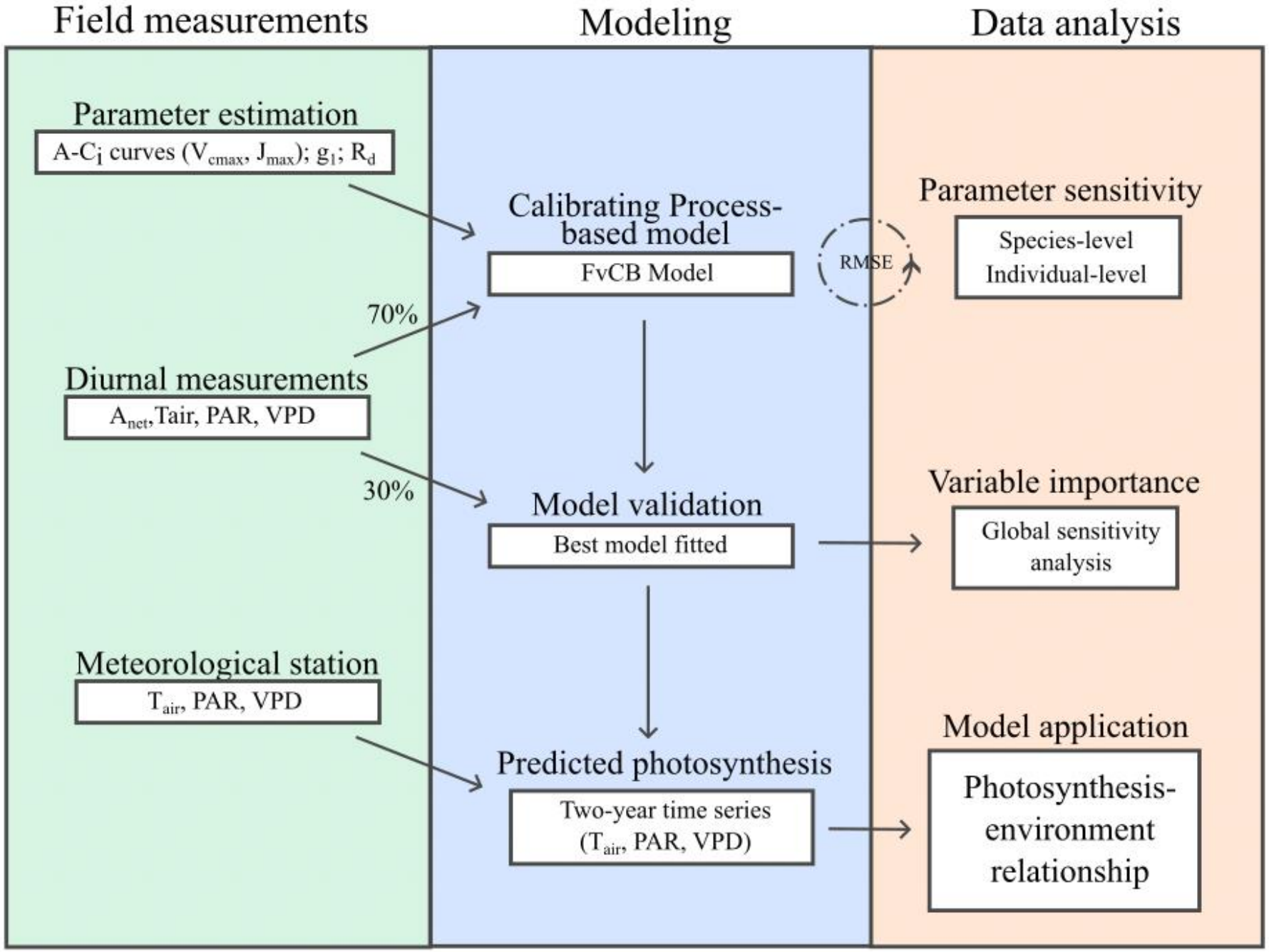
For this study, we measured multiple of individuals **six cold-affiliated** species in two sites

Modeling Photosynthesis using the Farquhar–von Caemmerer–Berry (FvCB) model

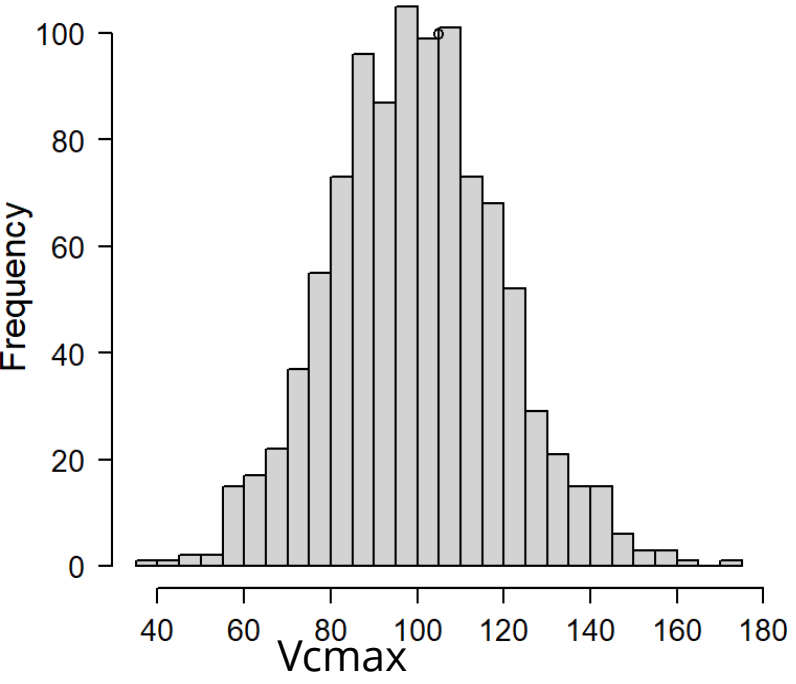
From photosynthetic CO_2 response measurements (A-Ci curves) was derived **Photosynthetic capacity (Vc_{max} , J_{max})** and Leaf dark respiration (R_d) parameters

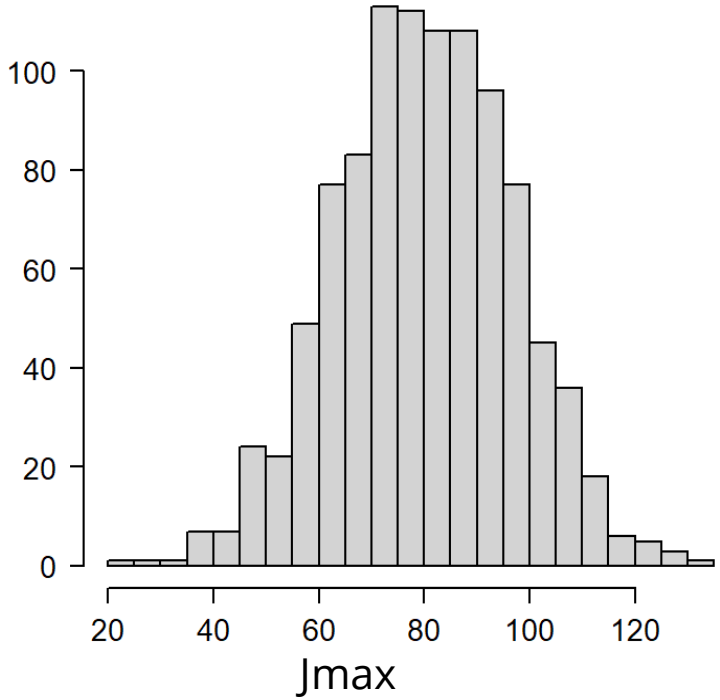


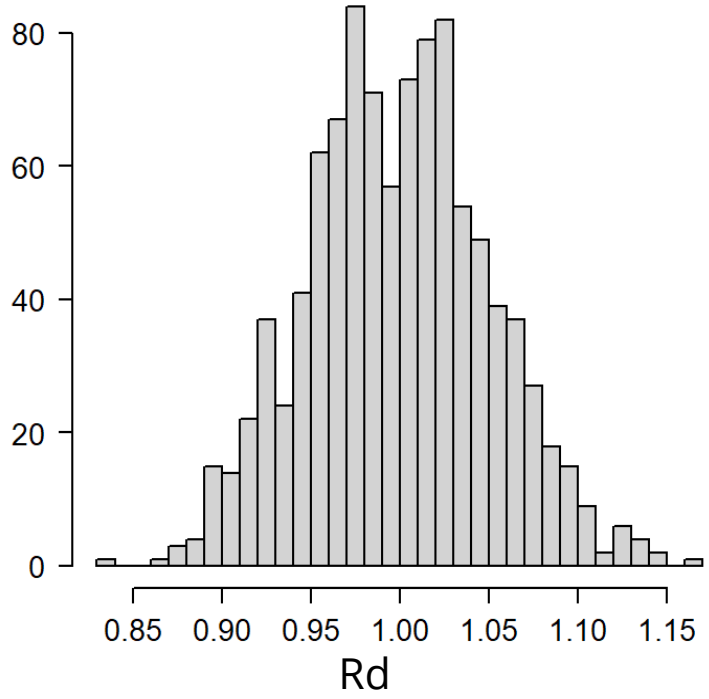
Using *plantecophys* R package; Duursma (2015)


Field measurements
Modeling
Data analysis
Parameter estimation
A-Ci curves (Vcmax, Jmax); g1; Rd
Calibrating Process-based model
FvCB Model
RMSE
Parameter sensitivity
Species-level
Individual-level
70%
Diurnal measurements
Anet,Tair, PAR, VPD
30%
Model validation
Best model fitted
Variable importance
Global sensitivity analysis
Meteorological station
Tair, PAR, VPD
Predicted photosynthesis
Two-year time series (Tair, PAR, VPD)
Model application
Photosynthesis-environment relationship

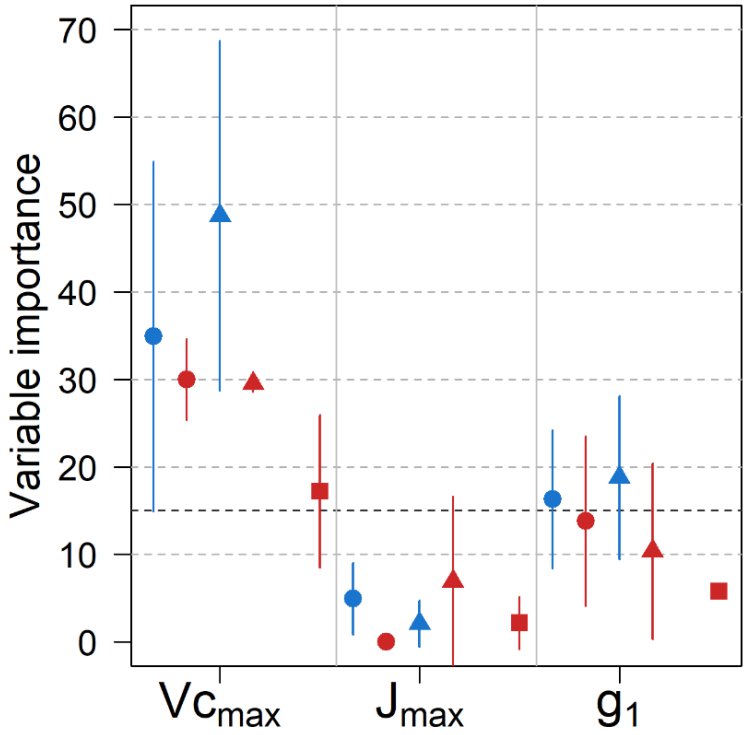
Intraspecific variability of photosynthetic parameters

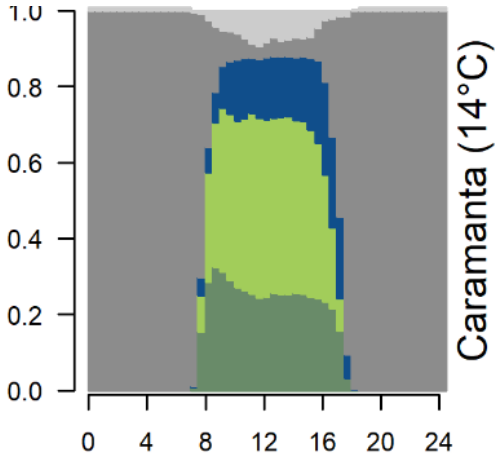


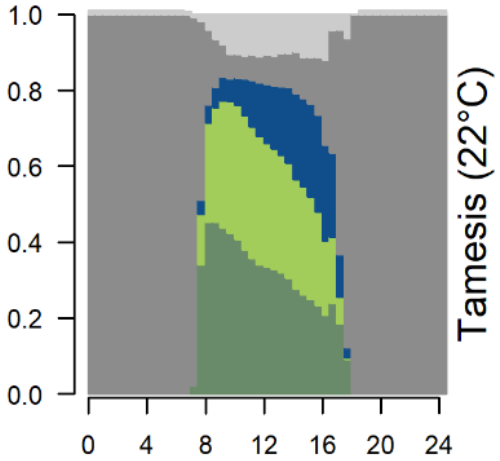


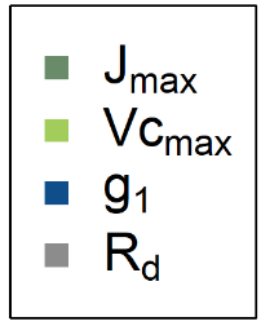


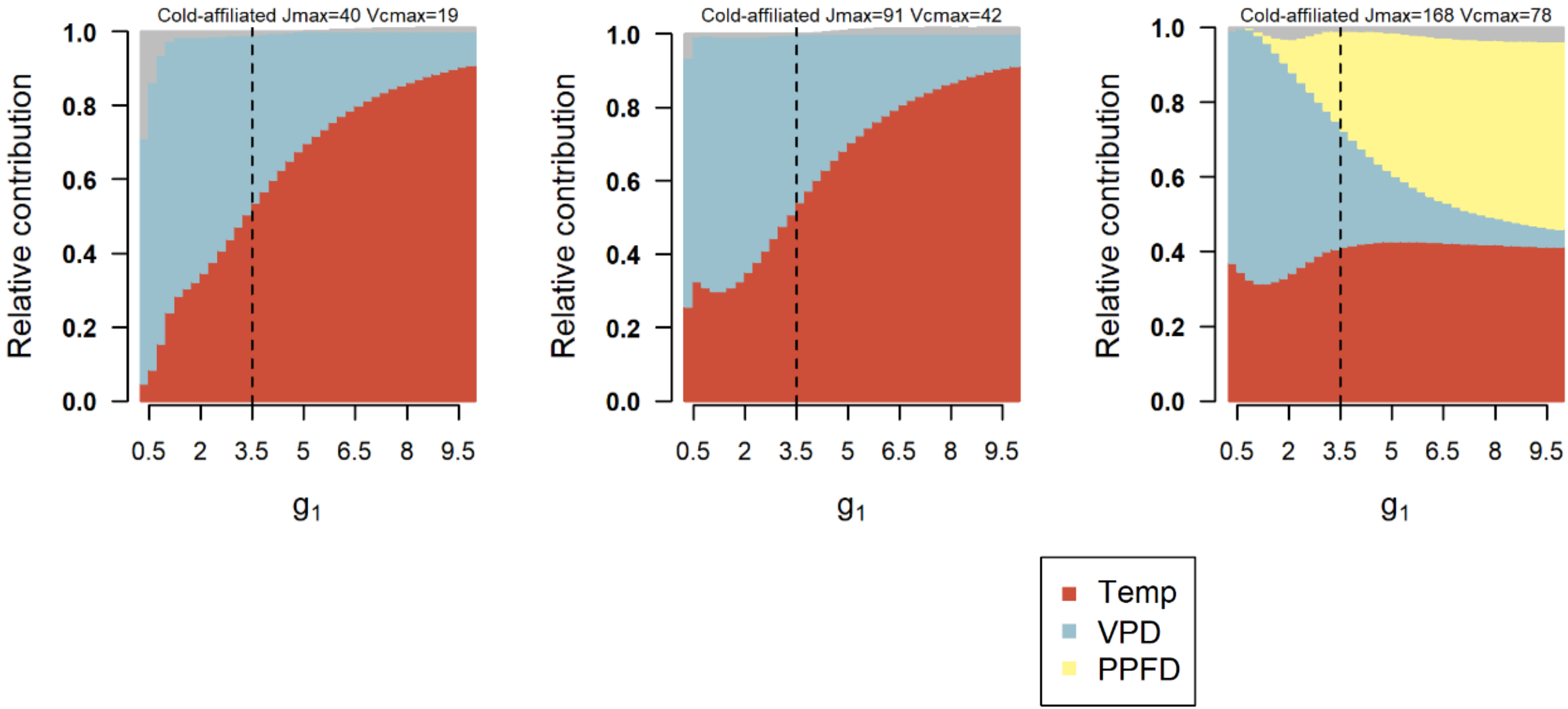
Relative contribution of each parameter to photosynthesis





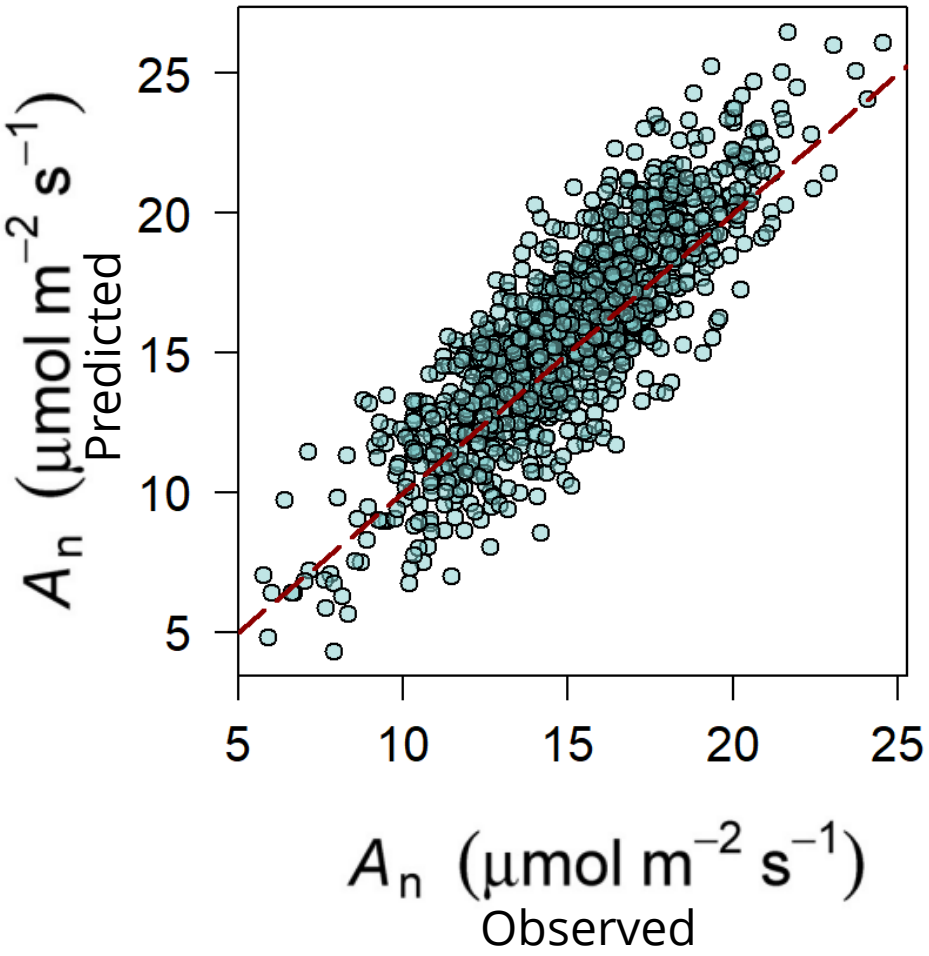




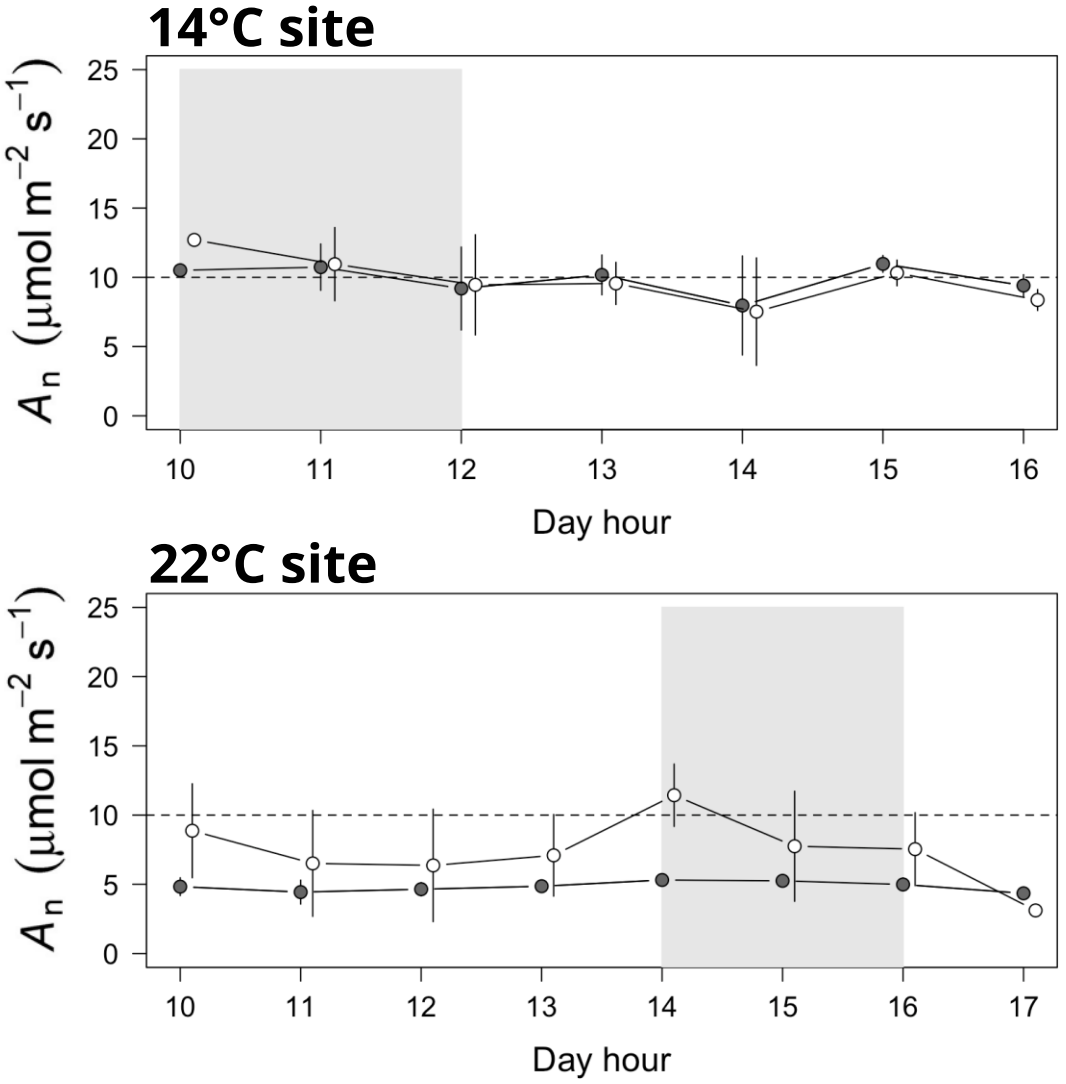

Cold-affiliated Jmax=40 Vcmax=19
Cold-affiliated Jmax=91 Vcmax=42
Cold-affiliated Jmax=168 Vcmax=78
Relative contribution
1.0
0.8
0.6
0.4
0.2
0.0
0.5
2
3.5
5
6.5
8
9.5
g1
Temp
VPD
PPFD

Model evaluation at two sites for six cold-affiliated species

Quercus humboldtii



$R^2 = 0.87$

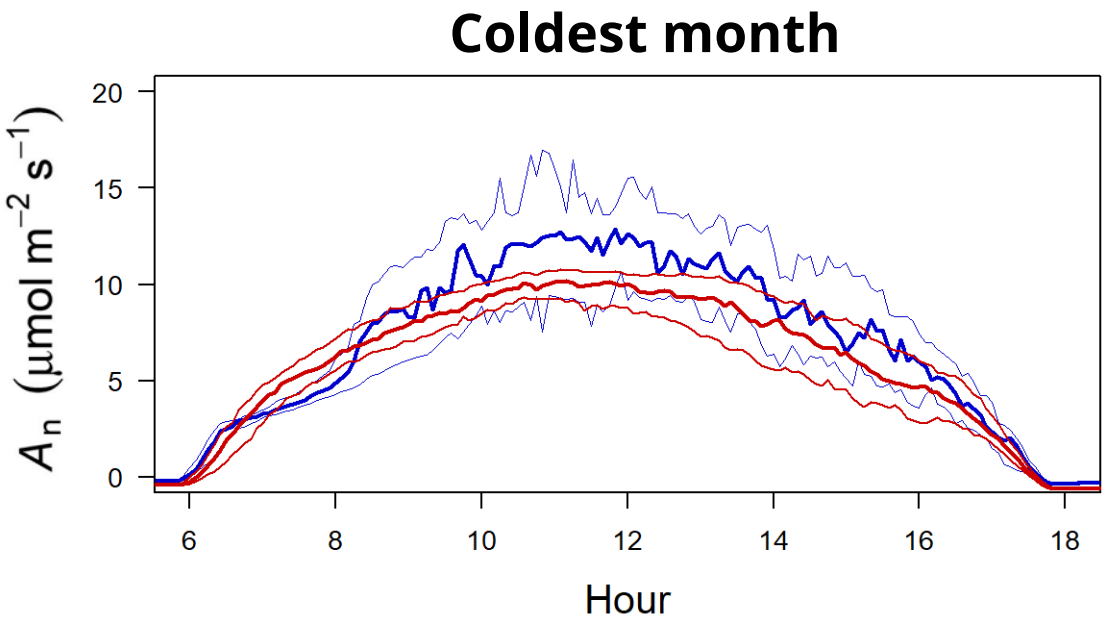


Observed Predicted

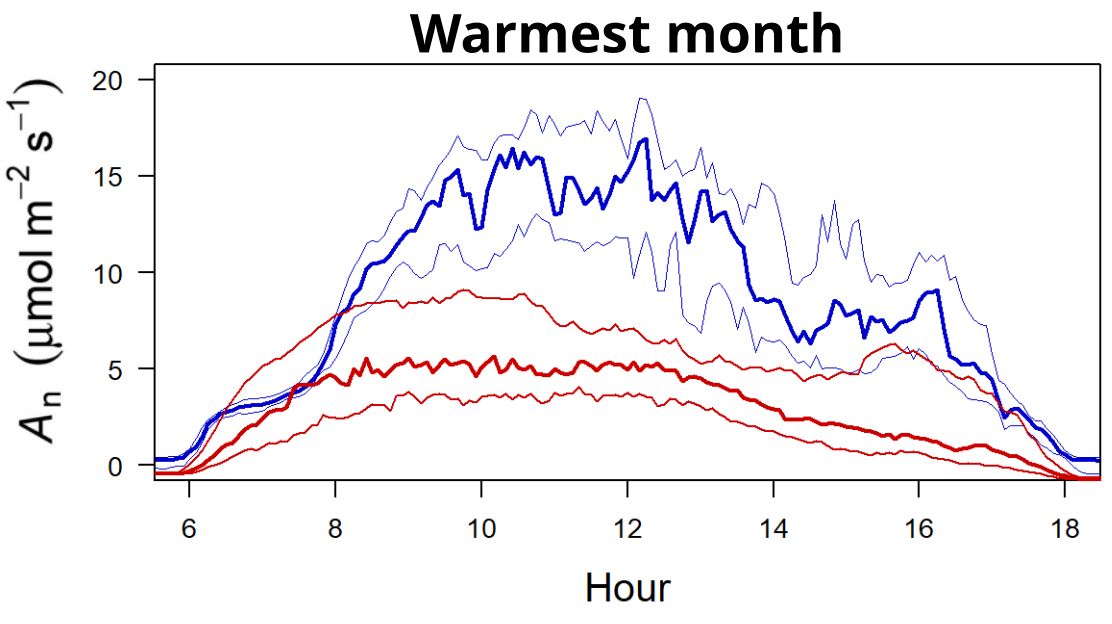
Simulated photosynthesis over two years

Site 1 (14°C)

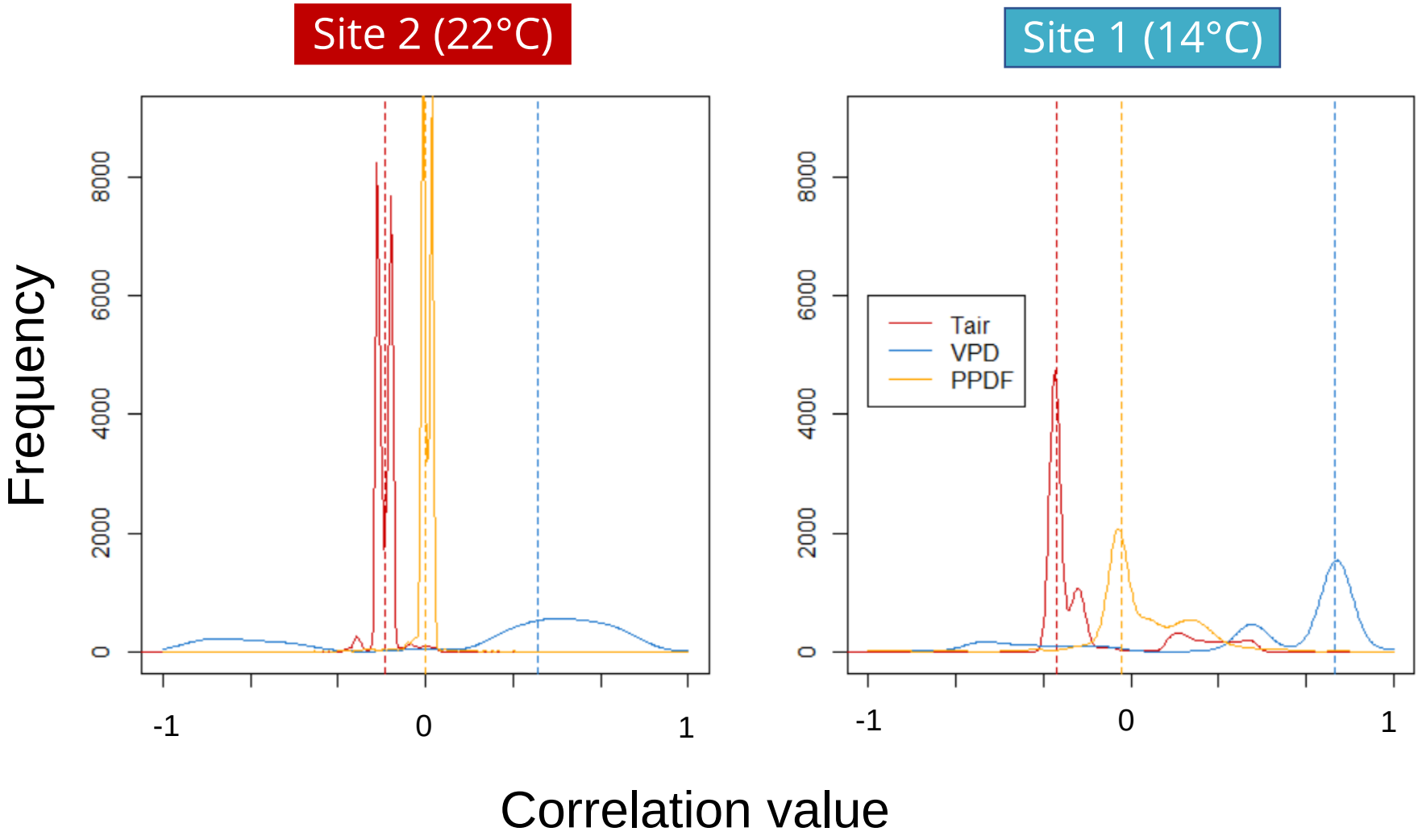
Site 2 (22°C)



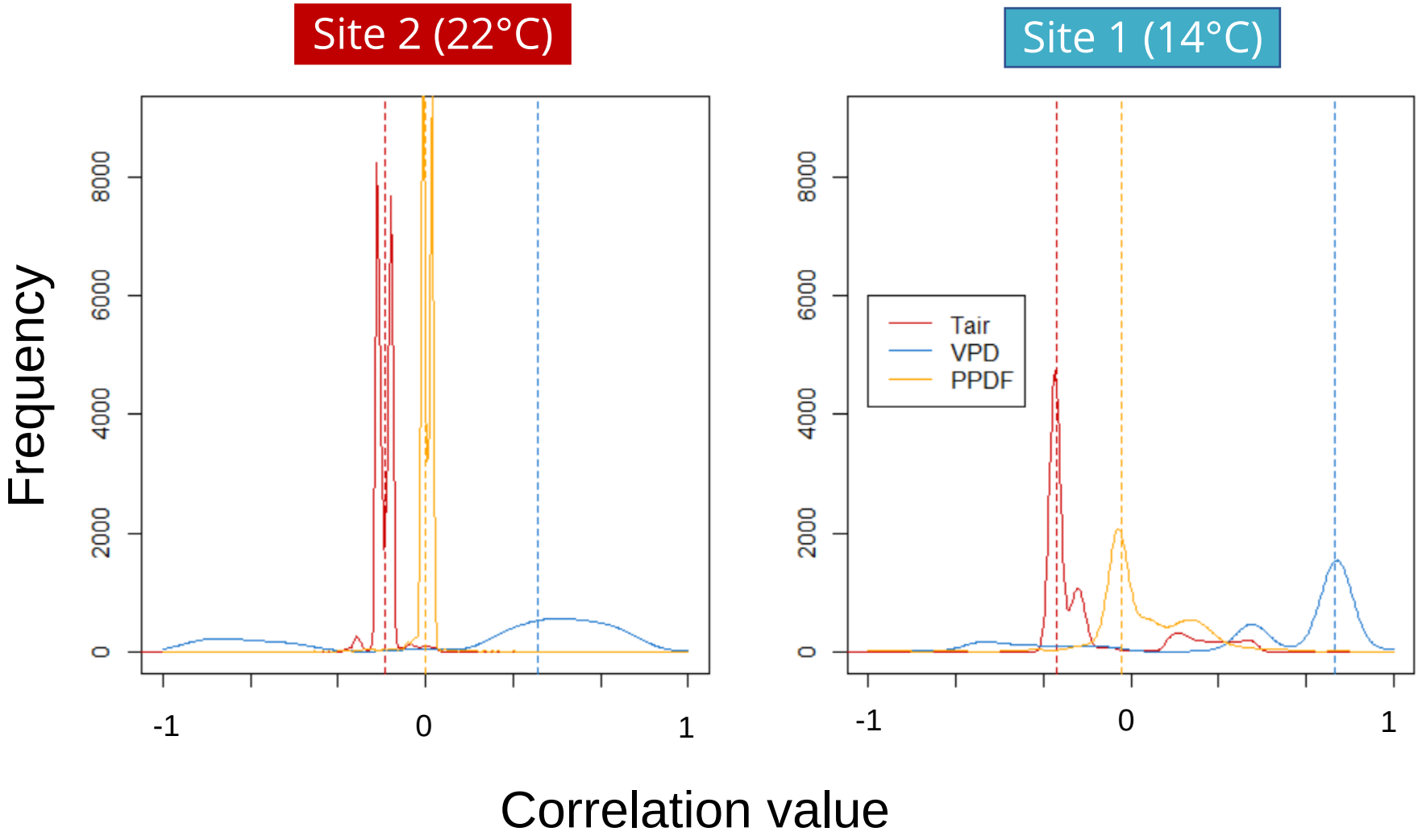
Photosynthesis is similar in the coldest month in both sites



Photosynthesis is higher in 14°C site than 22°C in the warmest month in both sites. The effect of temperature in afternoon reduce drastically photosynthesis.



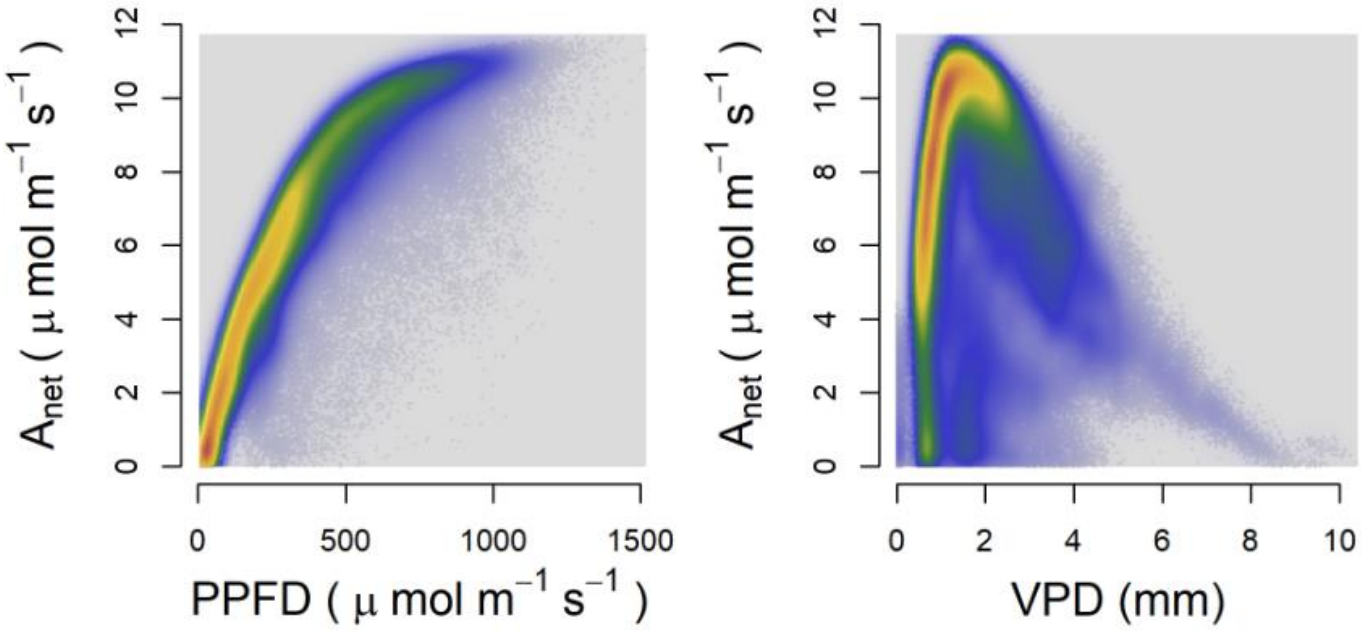
Correlation values were obtained employing a **cross-correlation wavelet** analysis, useful to interpret time series

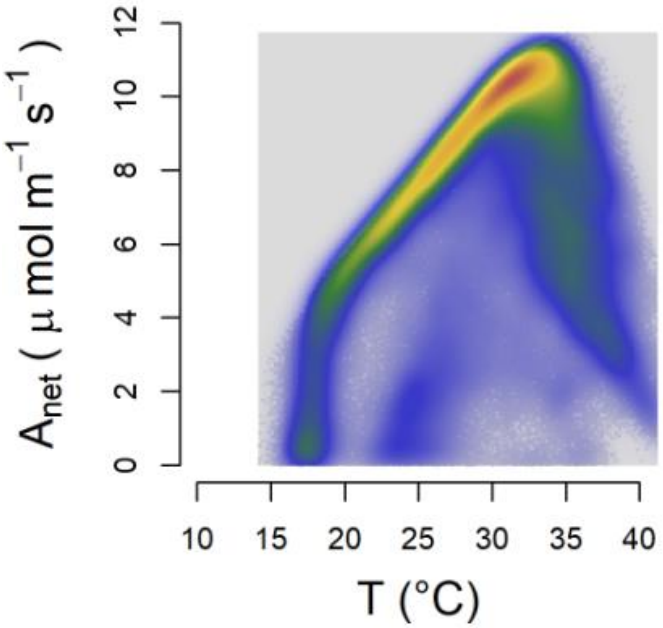


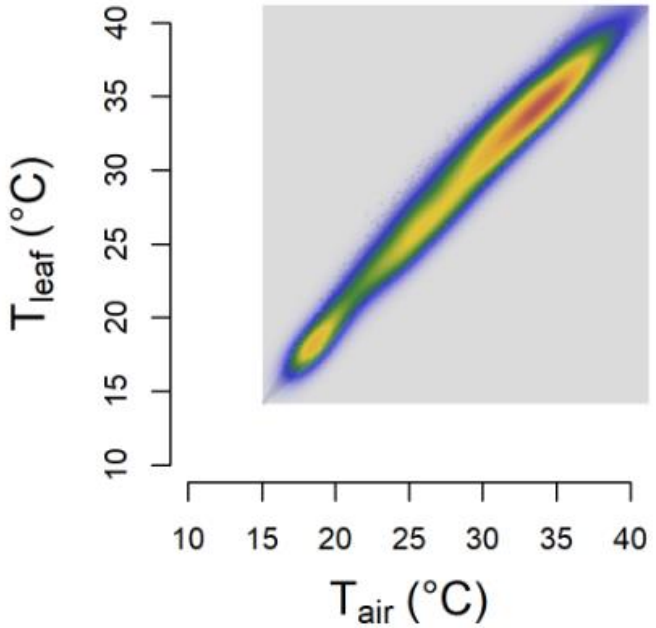
H1:VPD
H2:Temperature
H3: Radiation

Temperature has a **negative effect** on photosynthesis, that could be related to high temperatures in the afternoon

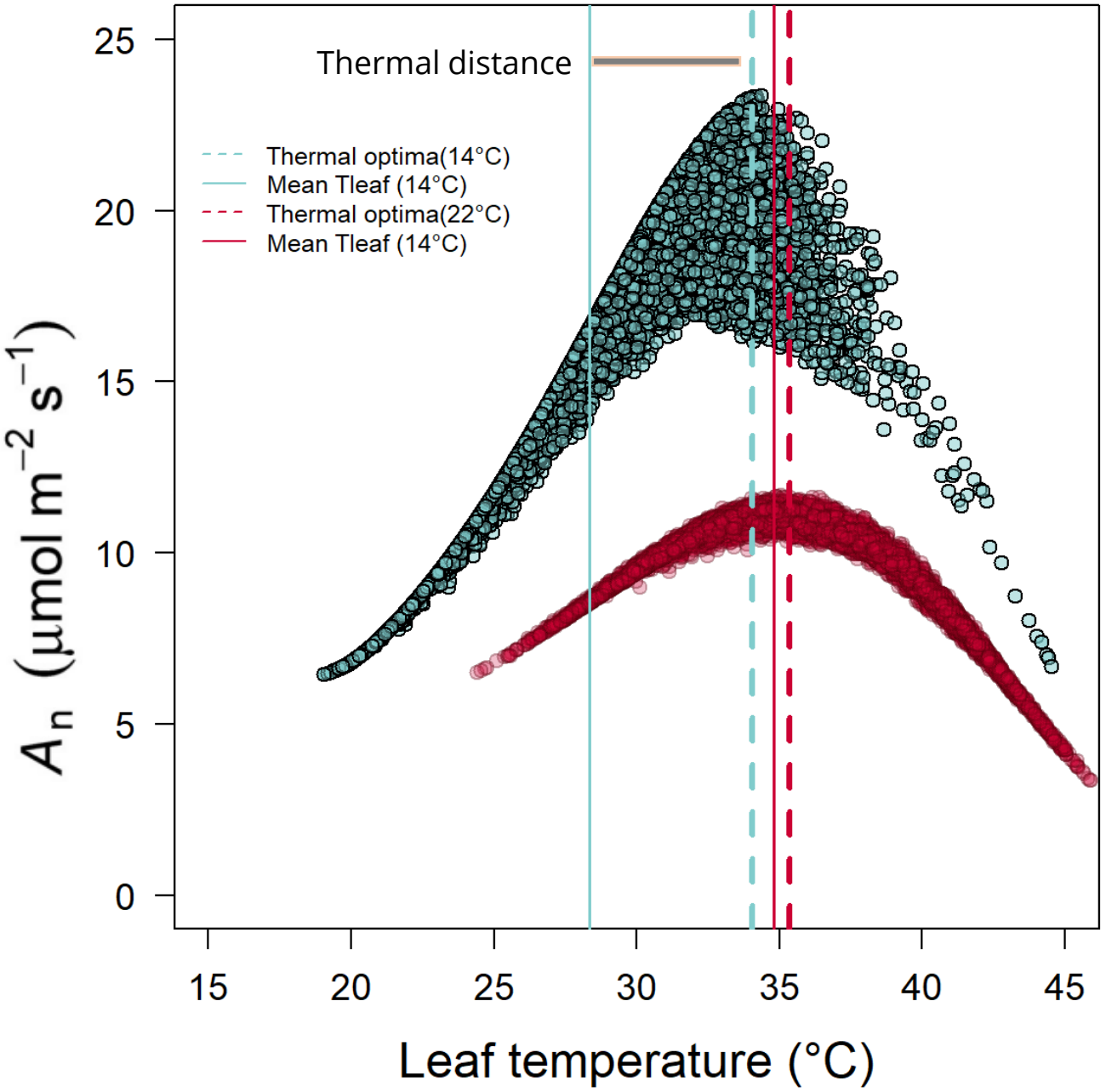
Correlation values were obtained employing a **cross-correlation wavelet** analysis, useful to interpret time series



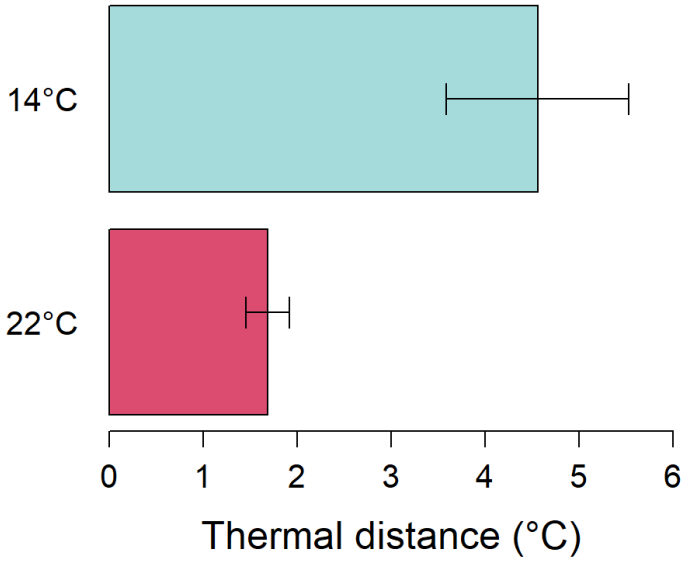




Photosynthesis data density from two years allows us detect the most represented and máximum values



Six cold-affiliated species



Thermal optima is higher than leaf temperature average, suggesting a **broad tolerance** capacity of the cold-affiliated tree species

Take-home messages

- Diurnal data of photosynthesis are useful to calibrate FvCB model, however intraspecific variation is a challenge to parameterize it correctly.

- Simulated leaf temperature is below thermal optima in highlands (14°C) and close to thermal optima at 22°C.

- Simulated leaf temperature optima is always higher than estimated leaf temperature optima.

Acknowledgment

- Montane-acclim project
- University of Exeter
- NERC fund

Thank you for your attention!

https://andeantreewarming.wordpress.com

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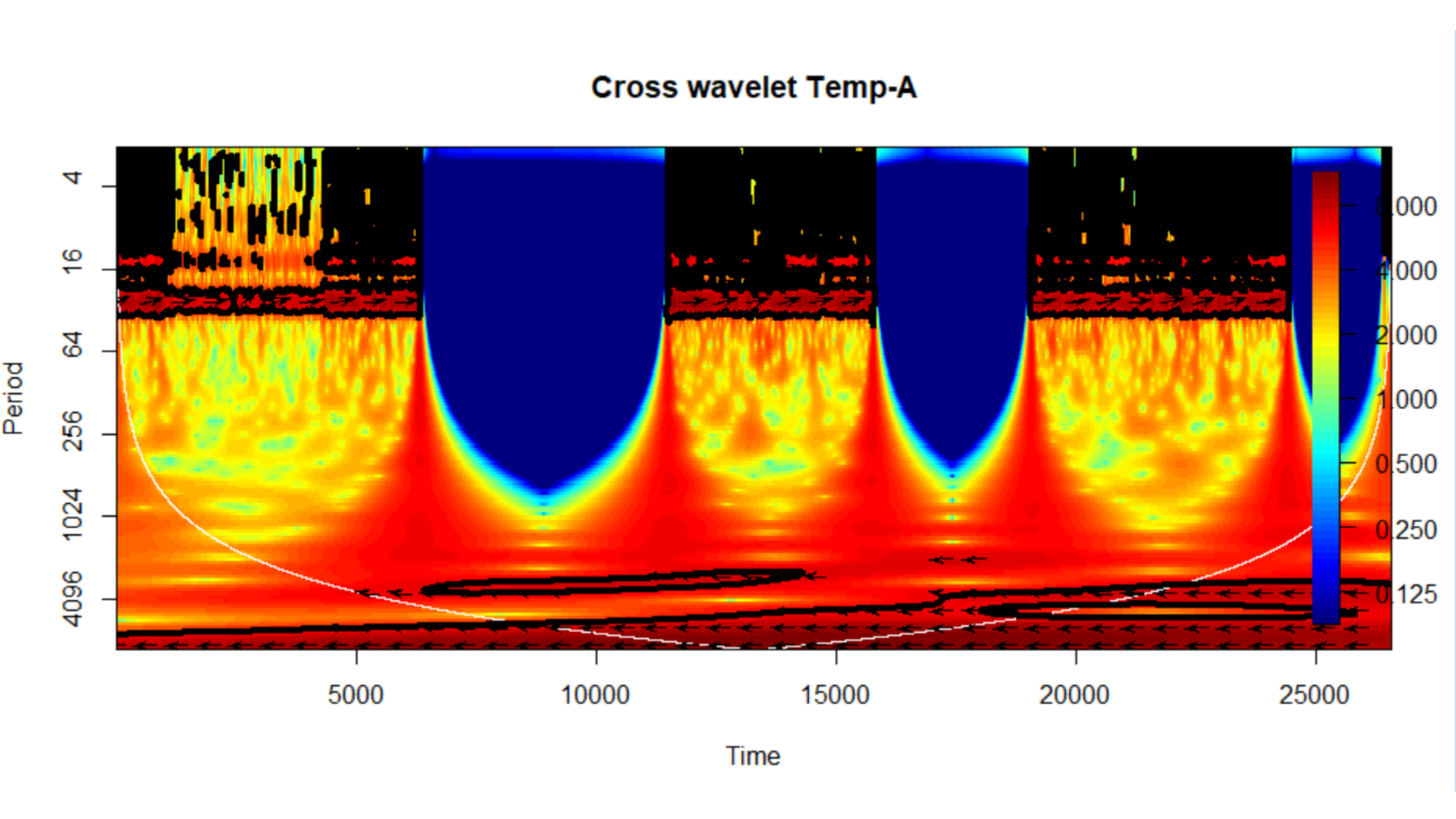
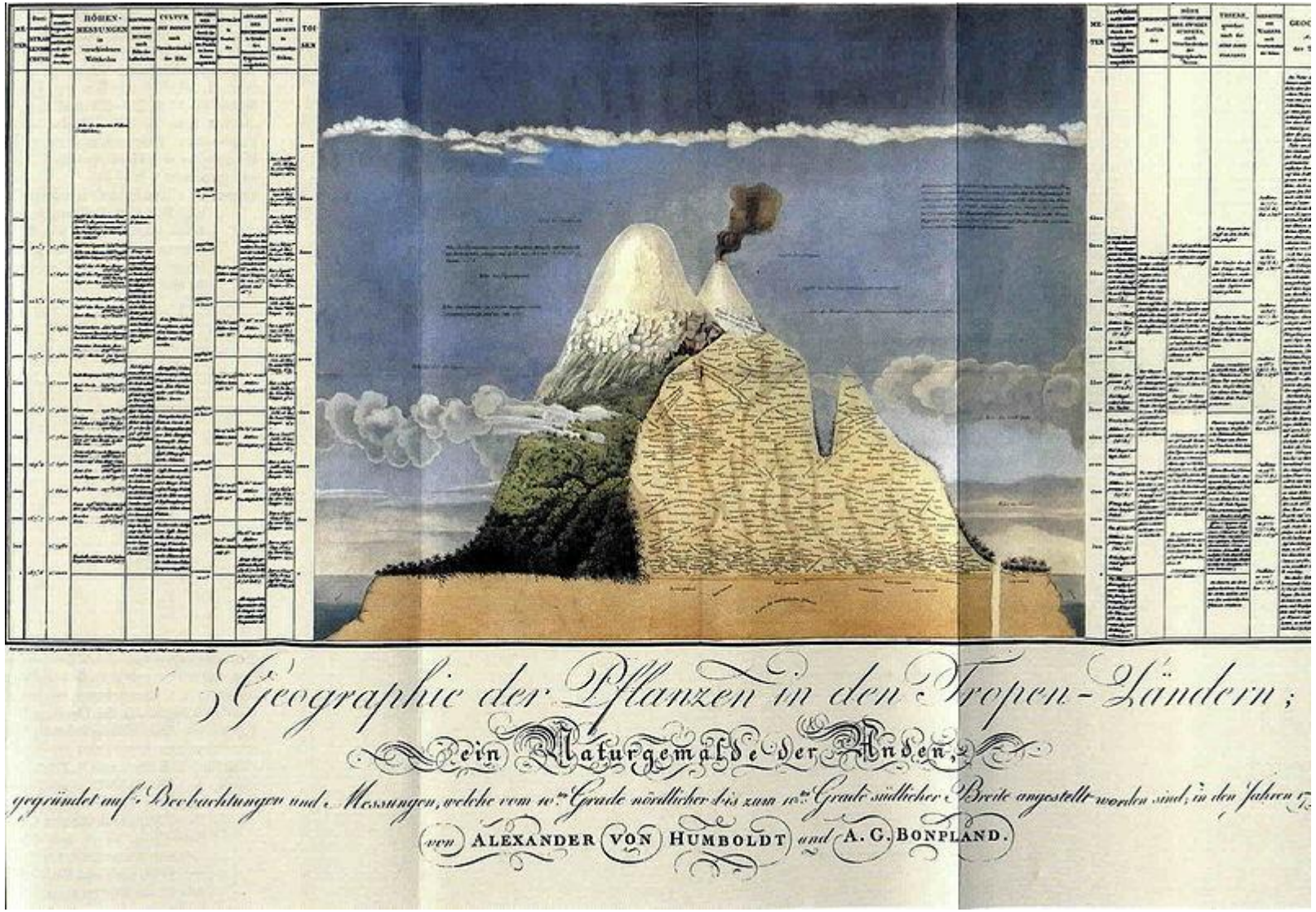

Cross wavelet Temp-A
Period
4
16
64
256
1024
4096
5000
10000
15000
20000
25000
Time
8.000
4.000
2.000
1.000
0.500
0.250
0.125



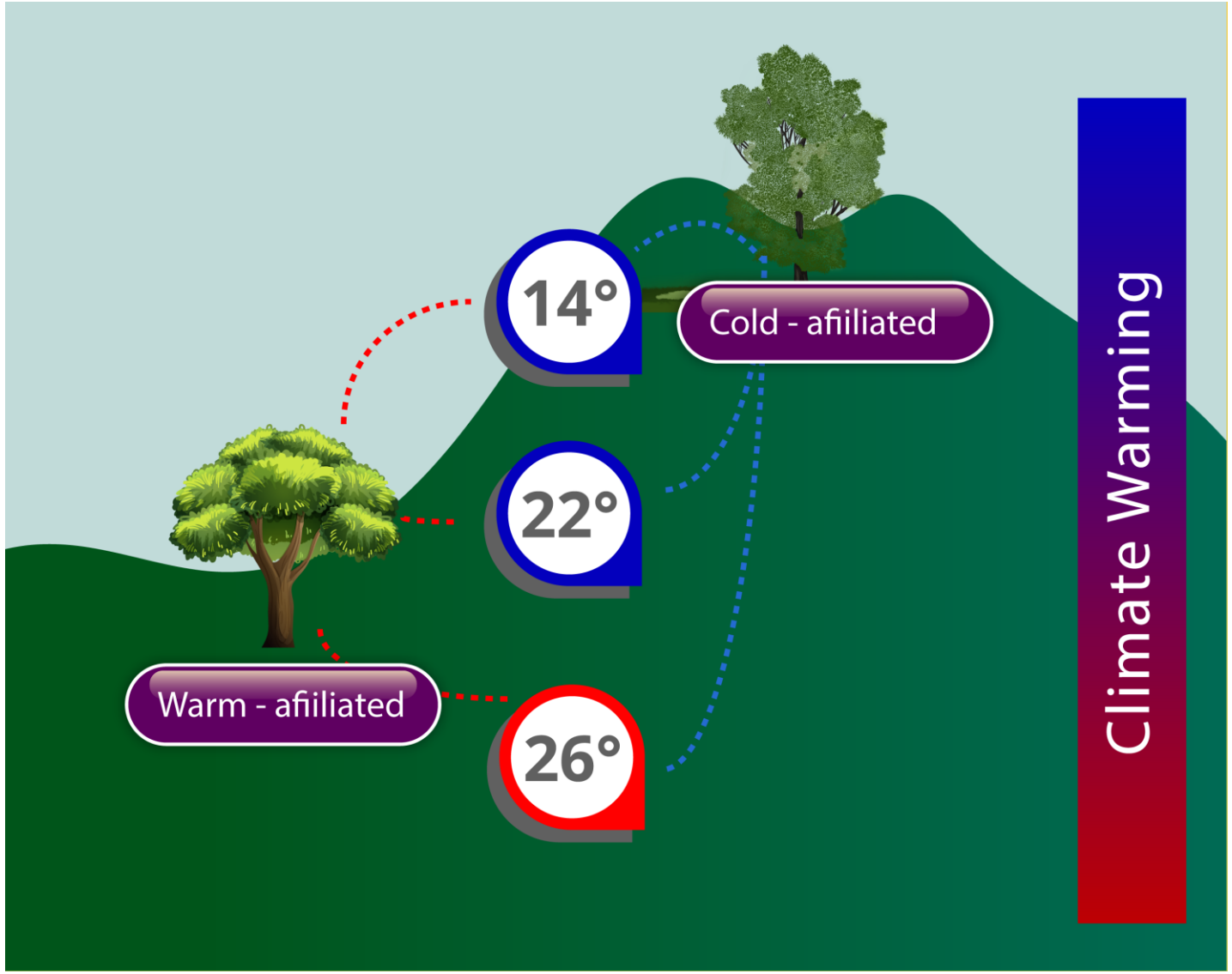
Tropical Andes is the highest global biodiversity hotspot and an important carbon sink

Temperature increase resulting from anthropogenic activities is affecting tropical mountains

Range contraction of cold-affiliated species will modify forest productivity

Humboldt and Bonpland 1807; Henderson et al., 1991 Myers et al. 2000; Duque et al., 2021;Feleey et al., 2011; Duque et al. 2015; Fadrique et al. 2018

Montane-acclim project



This is a transplant experiment focused in understanding thermal performance of tropical Andean tree species under warmer conditions

In this project, we planted more than 1000 plants in which were measured survival, growth, leaf traits and some physiological parameters related to **photosynthesis** and respiration.