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Photosynthesis limiting regimes

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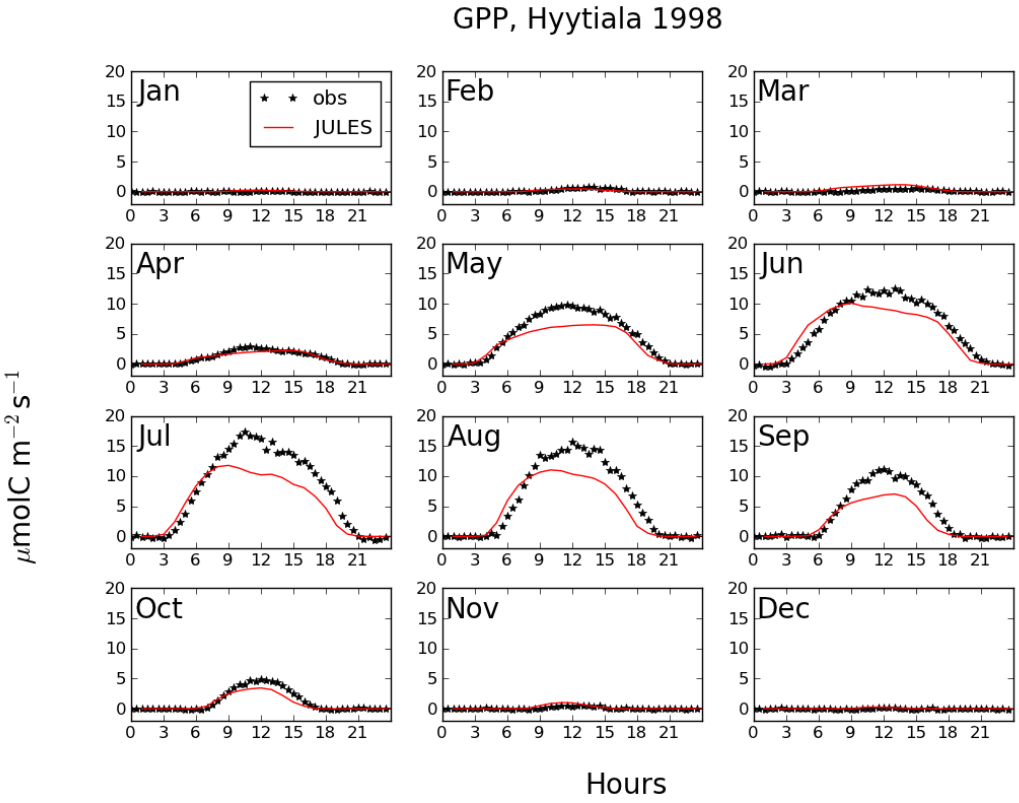
Plants and environmental factors

- Plants are living organisms
- Plant processes affects carbon, water and energy cycles.
- Diurnal and seasonal cycles are controlled by
  - environmental factors
  - genotype



Photosynthesis limiting regimes

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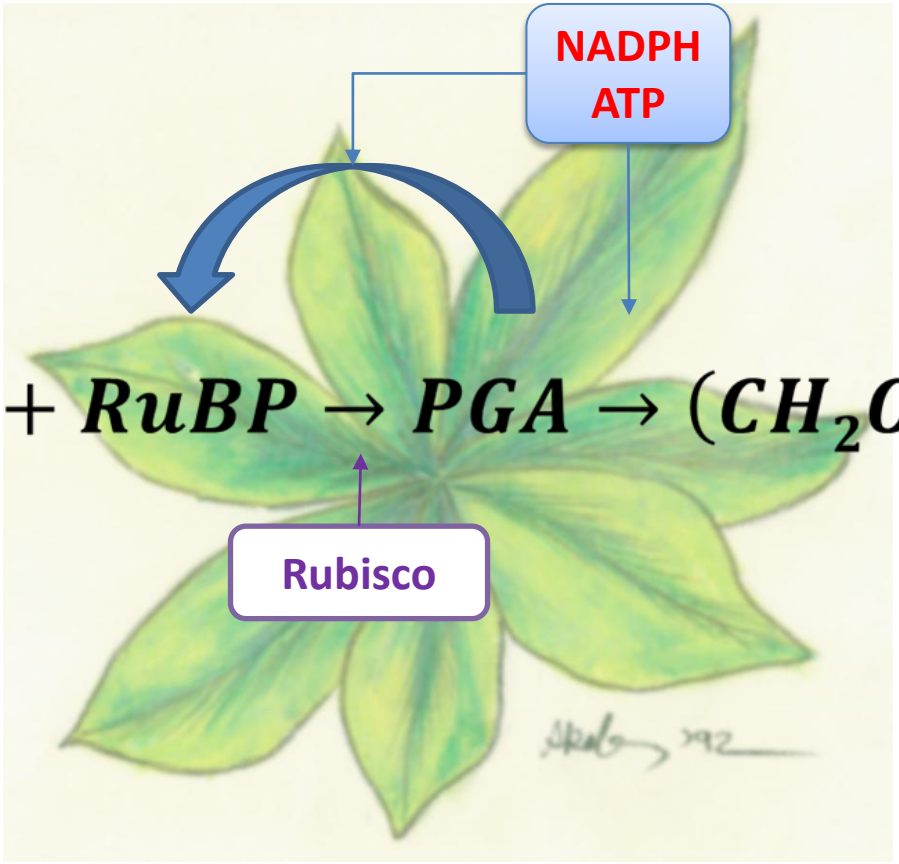
1. CO_2 limited regime (Rubisco)



2. Light limiting regime (RuBP regeneration)

$$CO_2 + RuBP \rightarrow PGA \rightarrow (CH_2O) + O_2$$

3. Export limited regime

RuBP: Ribulose 1,5 bisphosphate
Rubisco: Ribulose bisphosphate carboxylase /oxygenase
PGA: Phosphoglyceric acid

Photosynthesis limiting regimes

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1. CO_2 limited rate

$$Wcarb = \begin{cases} V_{cmax}\left(\dfrac{c_i - \Gamma}{c_i + K_c + \left(1 + \dfrac{O_a}{K_o}\right)}\right) & for\ C_3 \\ V_{cmax} & for\ C_4 \end{cases}$$

V_{cmax}: max rate of carboxylation of Rubisco
c_i: Internal CO_2 partial pressure
O_a: Partial pressure of O_2
Γ: Compensation point
K_c, K_o: Michelis-Menten parameters

2. Light limited rate

$$W_{lite} = \begin{cases} \alpha(1-\omega)I_{par}\left(\dfrac{c_i - \Gamma}{c_i + 2\Gamma}\right) & for\ C_3 \\ \alpha(1-\omega)I_{par} & for\ C_4 \end{cases}$$

α: Quantum efficiency of photosynthesis
I_{par}: Incident photosyntetically active radiation
ω: leaf scattering coefficient

3. Rate of transport of photosynthetic products (C_3) and PEPCarboxylase limitation (C_4)

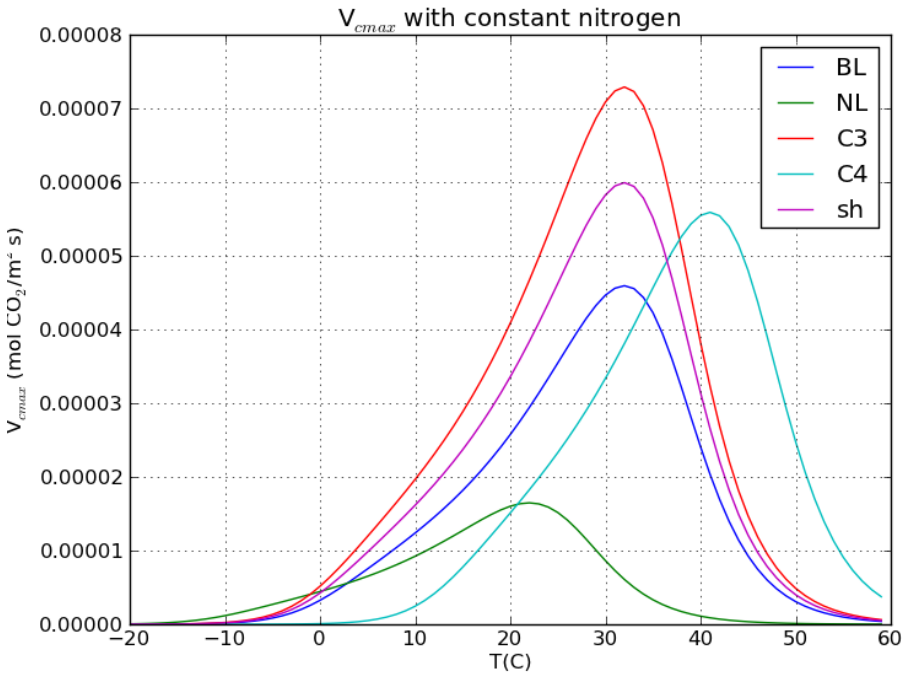
$$We = \begin{cases} 0.5\,V_{cmax} & for\ C_3 \\ 2 \times 10^4 V_{cmax}\left(\dfrac{c_i}{P_*}\right) & for\ C_4 \end{cases}$$

P_*: Surface air pressure

Clark D. B. et al. (2011)

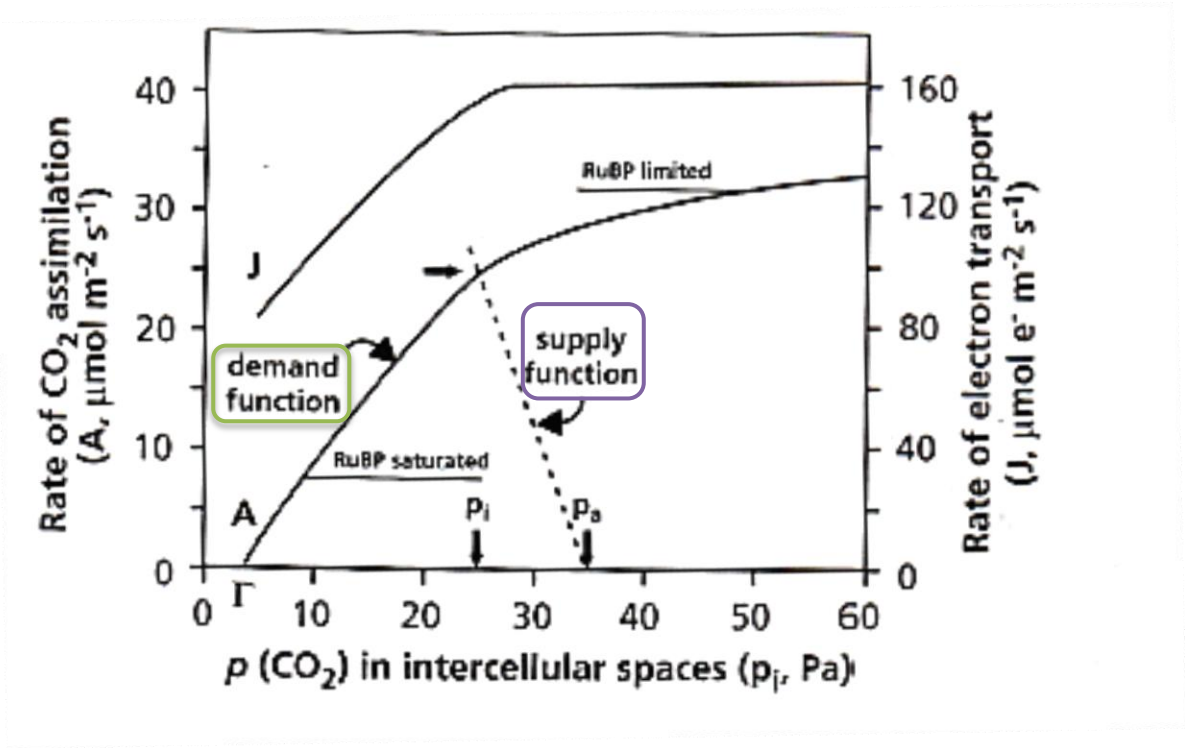
Other factors affecting photosynthesis

4. Soil water availability
5. Nutrient availability
6. Temperature



V_{cmax}, Γ, K_c, K_o depend on temperature

The CO_2 response curve

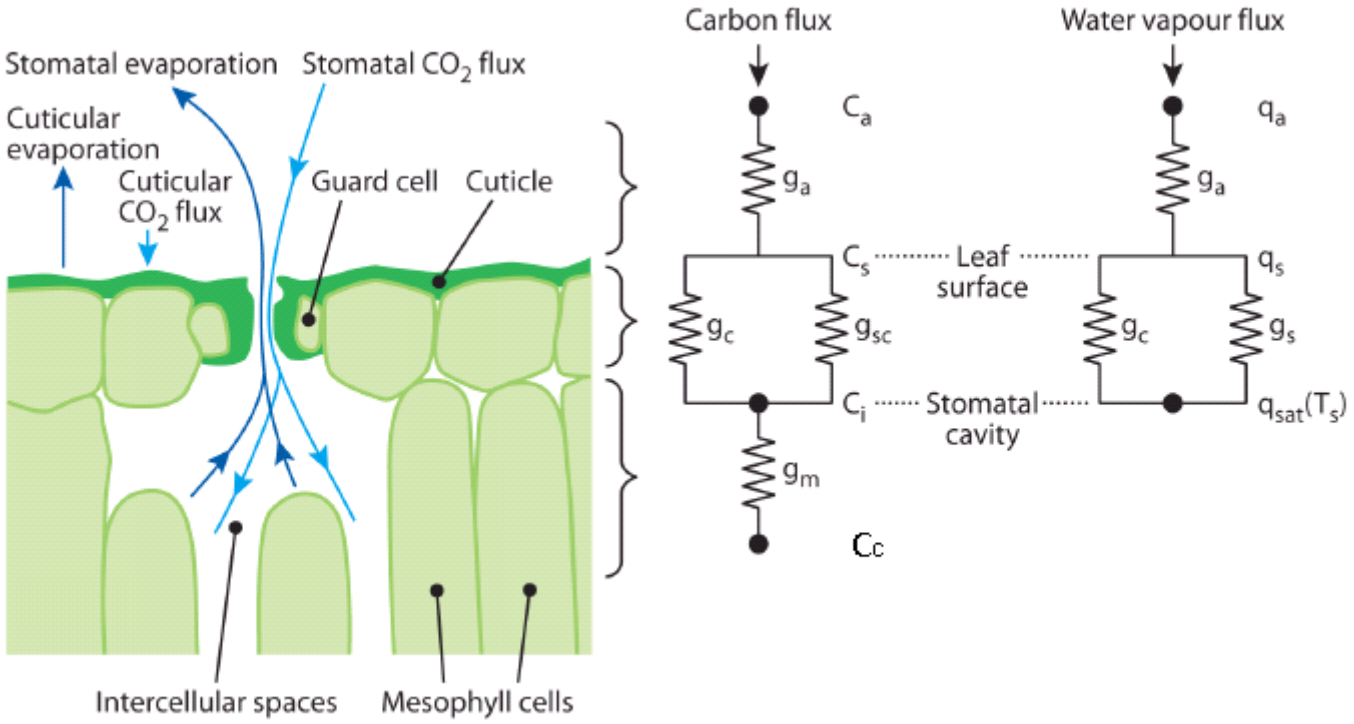


Demand function: Determined by the processing of CO_2 in the chloroplasts

Supply function: Determined by the diffusion of CO_2 to the chloroplasts

Figure: Lambers, Plant Physiological Ecology

Gas exchange at leaf level



A-g_s models

$$g_{sc} = \frac{A_n(PAR, C_a, T \ldots)}{C_s - C_i}$$

$$g_s = 1.6 g_{sc}$$

Under which conditions does each limiting regime dominate?

JULES **photosynthesis scheme at the leaf level** was run for:

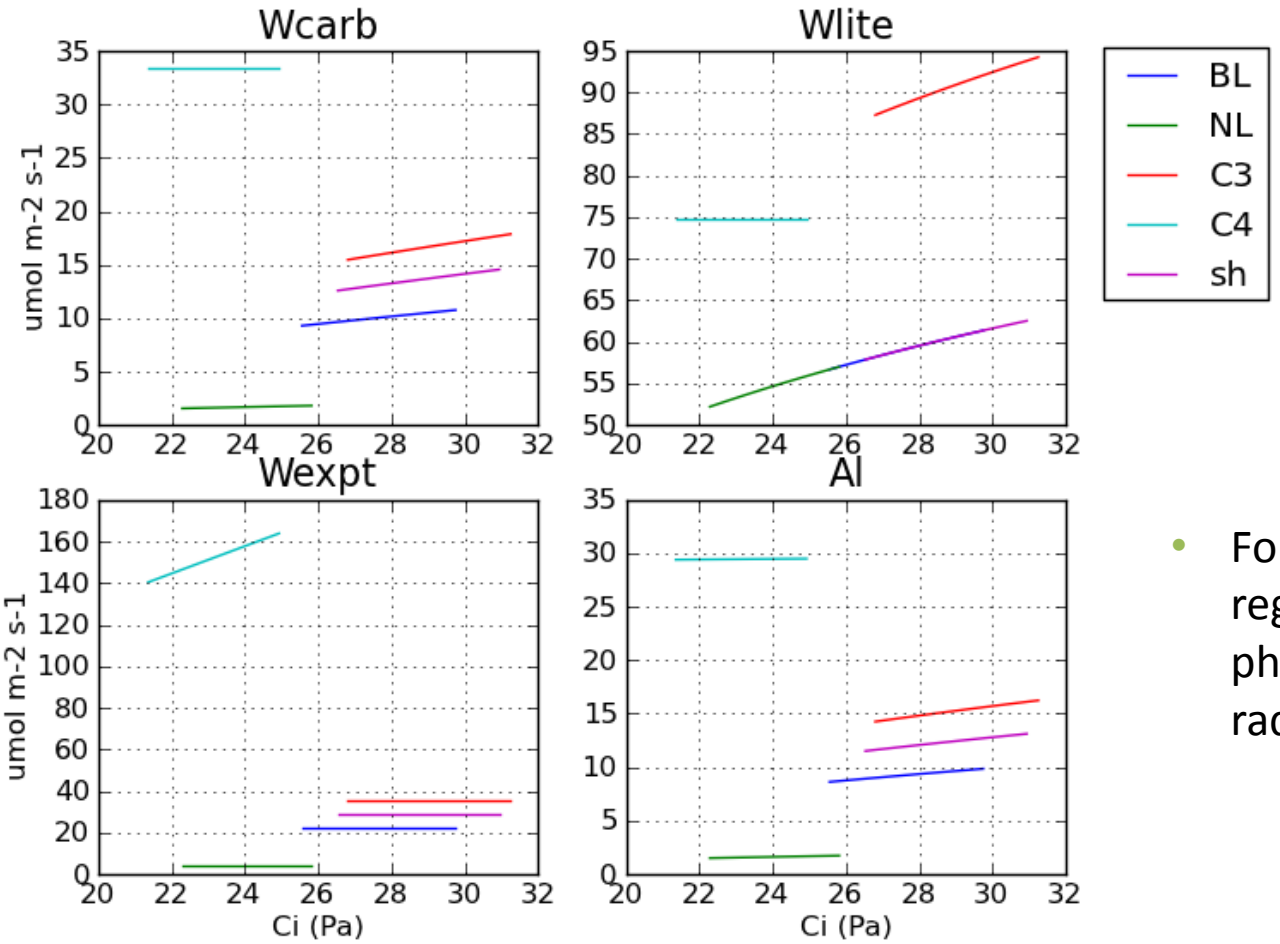
- Leaf temperature [0 -50 °C]
- Photon flux density [0 -1600 µmol m^{-2} s^{-1}]
- Atmospheric CO_2 [340 -400 ppm]
- All PFTs

$$g_{sc} = \frac{A_n(T, PPFD, C_a, \ldots)}{C_s - C_i}$$

No restrictions on soil water availability (β=1)

Aerodynamic conductance set to a constant value (g_a=0.075 m s^{-1})

CO_2 response curve and Plant Functional Types

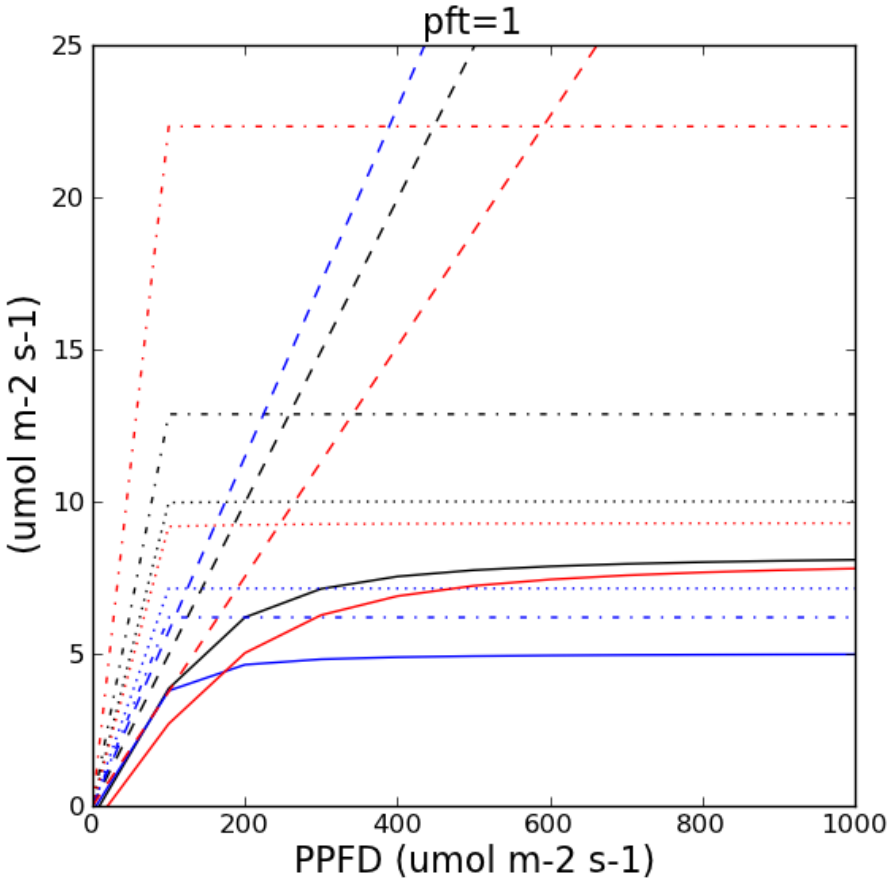


T leaf = 30°C

PPFD = 1500 µmol m^{-2} s^{-1}

- For all PFTs CO_2 limiting regimes dominates photosynthesis at high radiation

Light response curve



Light limited

Carbon limited

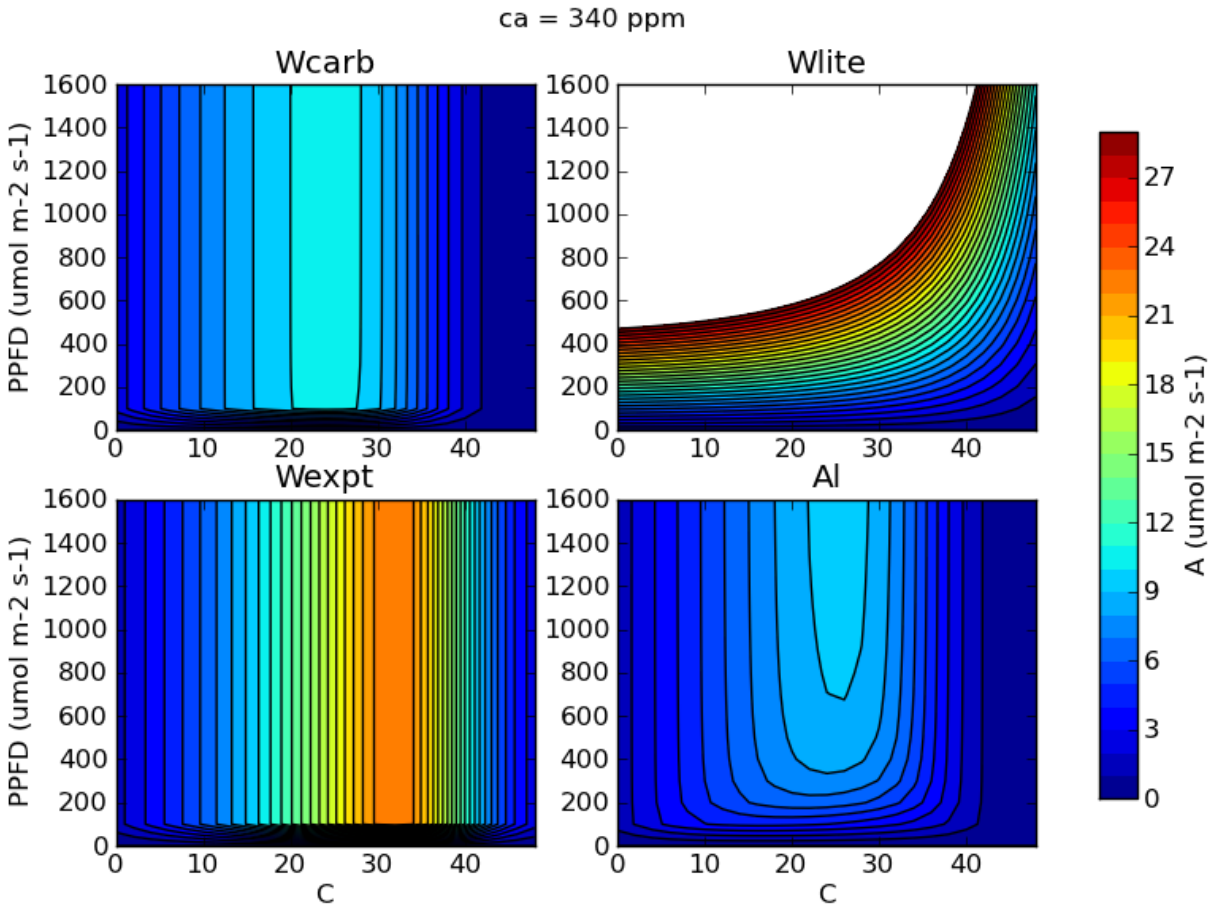
Export limited (T<10°C)

Light limited: For low light intensities A increases linearly with irradiance. Light limited regime dominates for a longer period for higher temperatures

CO_2 limited: At high irradiance, photosynthesis becomes light saturated, and is limited by the carboxylation rate

Export limited: Only becomes limiting for temperatures below 10 °C

PPFD-Leaf T (Broadleaf)

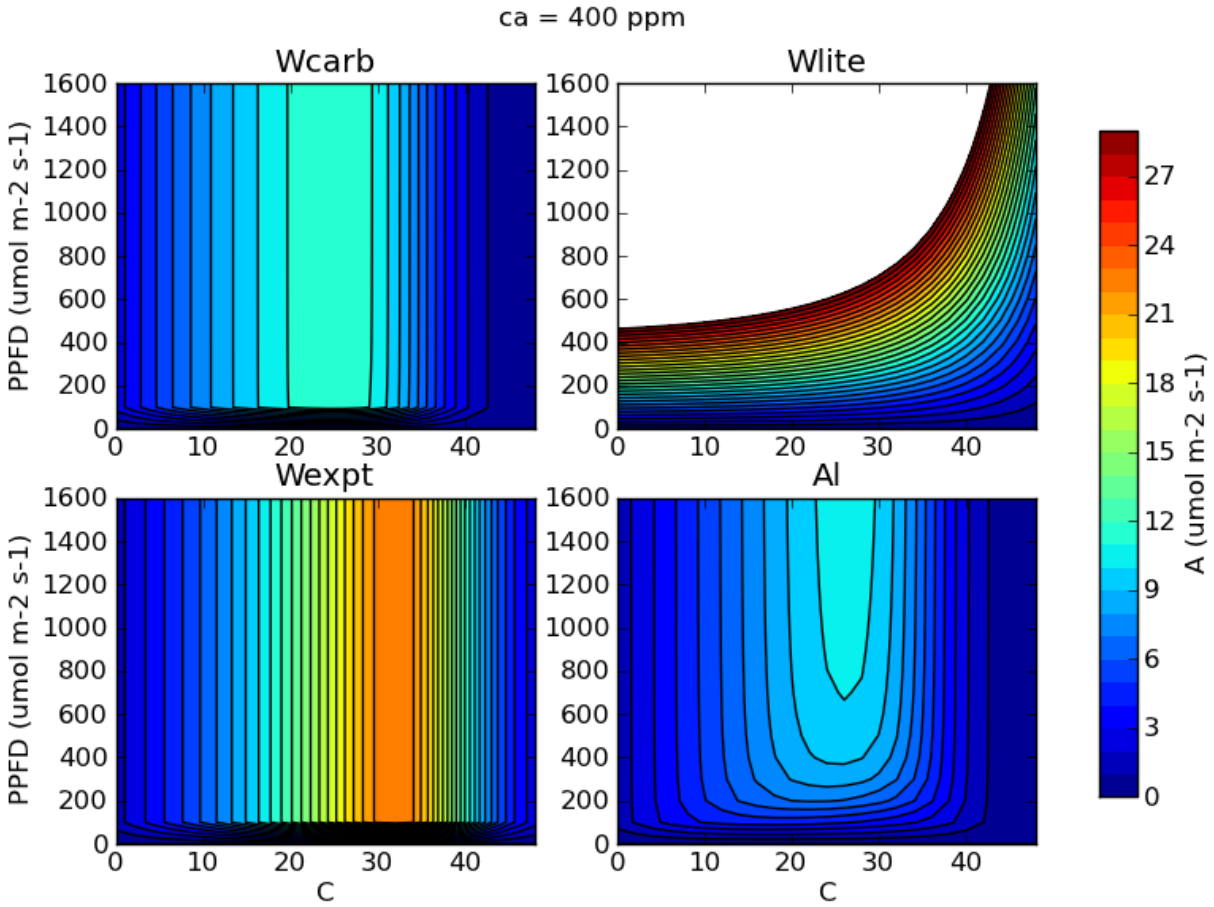


CO_2 limited regime dominates the total photosynthetic rate

Light limiting regime limits for low radiation

Export limited regime slightly limits for low temperatures

PPFD-Leaf T (Broadleaf)



An increase in ambient CO_2 increases mainly the CO_2 assimilation for the CO_2 limiting regime, resulting in increased influence of light limiting regime

PPFD-Leaf T (C4 grass)

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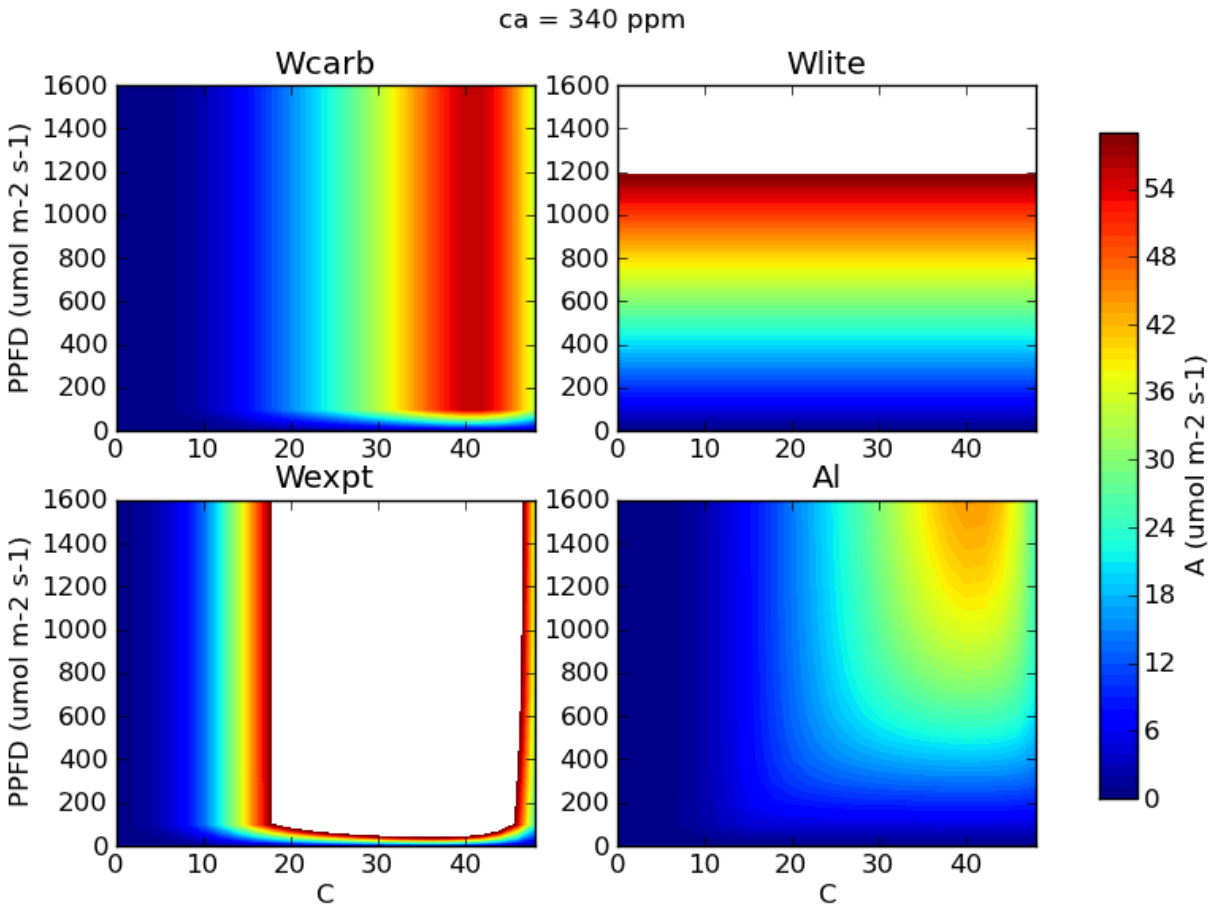
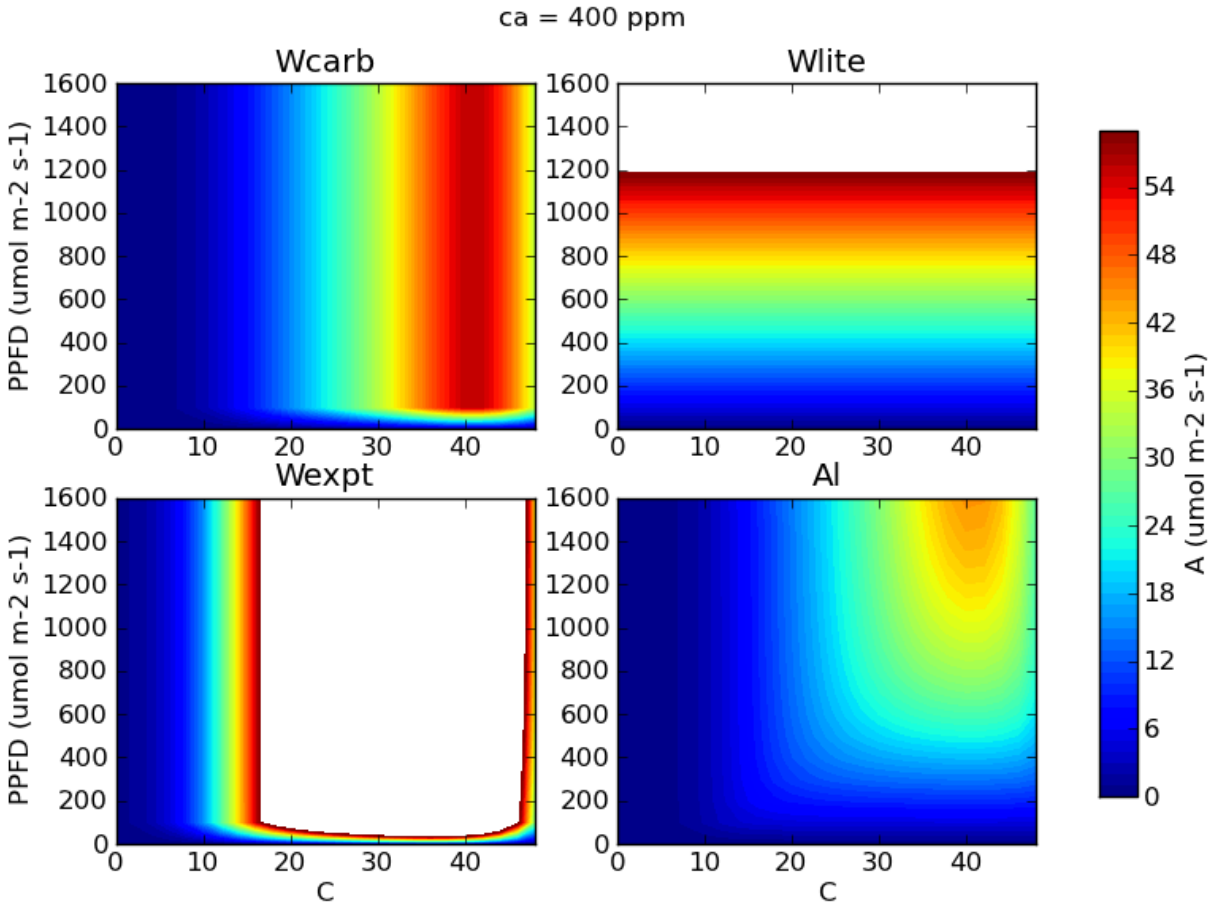


Light limiting regime does not vary with temperature

CO2 limiting regime dominates less than for C3 photosynthesis

PPFD-Leaf T (C4 grass)



For C4 photosynthesis, an increase in ambient CO_2 only affects Wexpt

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Overview

- The influence of environmental factors in photosynthesis is accounted for in models by limiting regimes

  - CO_2 limiting regime - Represents the main limitation
  - Light limiting regime - Dominates at low irradiances
  - Export limiting regime- Only is important for low temperatures

- An increase in atmospheric CO_2

  - In C3 species increases the carboxylation rate, which results in a increased influence of light limiting regime, and higher leaf photosynthetic rate
  - In C4 species does not change the influence of limiting regimes and does not change the leaf photosynthetic rate.

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Thank you

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