Stomatal optimization under rising CO_2

Ecohydrological Consequences

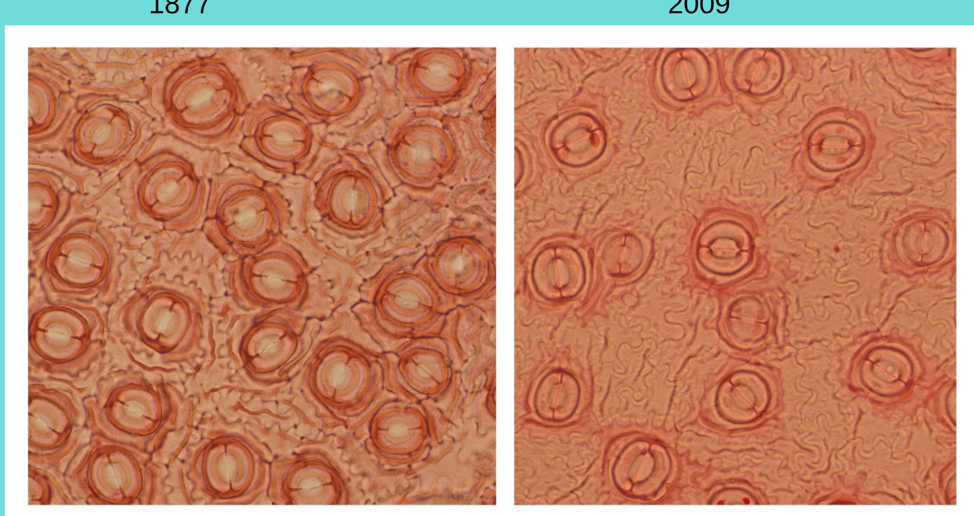
Stefan C. Dekker[1] and Hugo J. de Boer

Universiteit Utrecht

With Emmy Lammertsma | Rike Wagner | Martin Wassen | Maarten Eppinga
Utrecht University, Faculty of GeoSciences, Environmental Sciences
s.c.dekker@uu.nl

Data: Size and Density of stomata

Geometry **measured under microscope...**

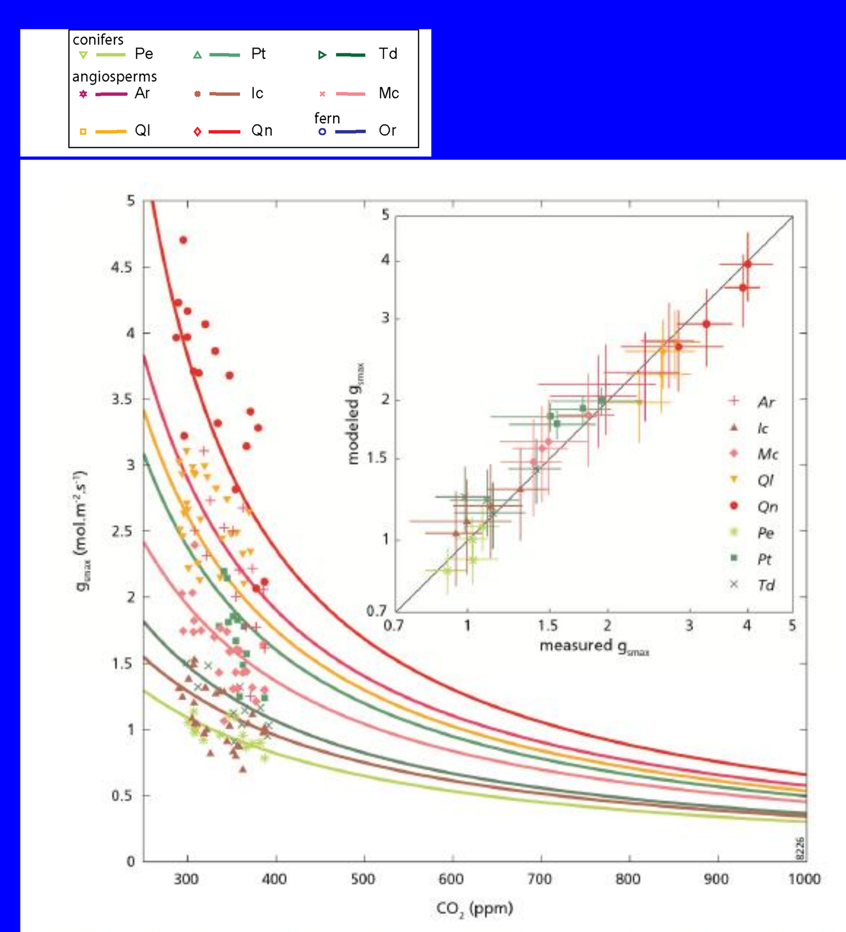


Example of leaf fragment of from 1877 to 2009 *Ilex Cassine*

Structural adaptation of stomatal conductance

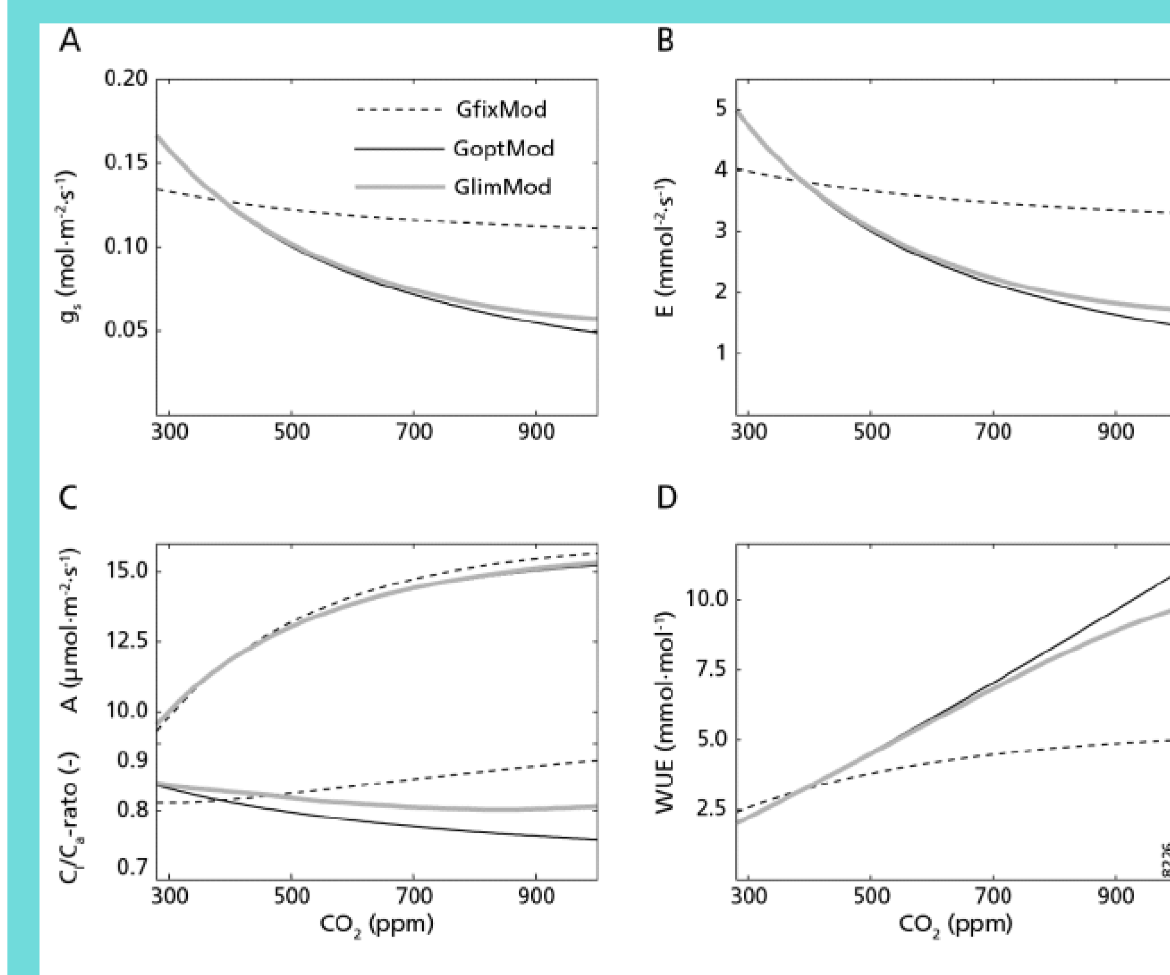
Maximal stomatal conductance (g_{smax}) is a function of: stomatal density (D), maximal pore size (a_{max}), pore depth (l) and diffusivity (d_w):

$$g_{s\max} = \frac{d_w \cdot D \cdot a_{\max}}{l + \frac{\pi}{2}\sqrt{a_{\max}/\pi}}$$



Structural adaptation of maximum stomatal conductance for 8 species. Stomatal optimizaton model based on maximization of carbon gain with minimum water loss

Ecohydrological consequences

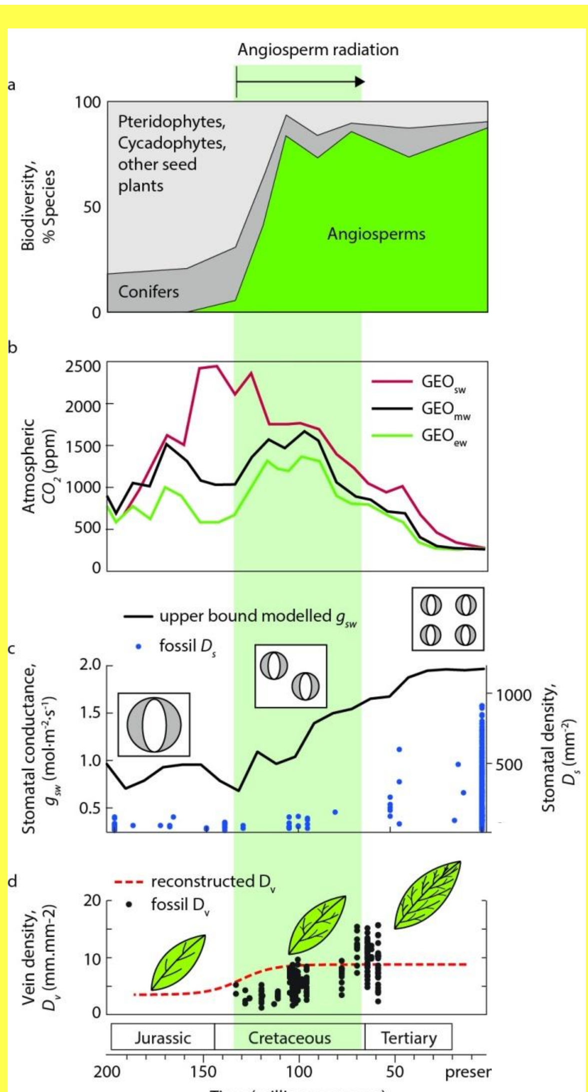


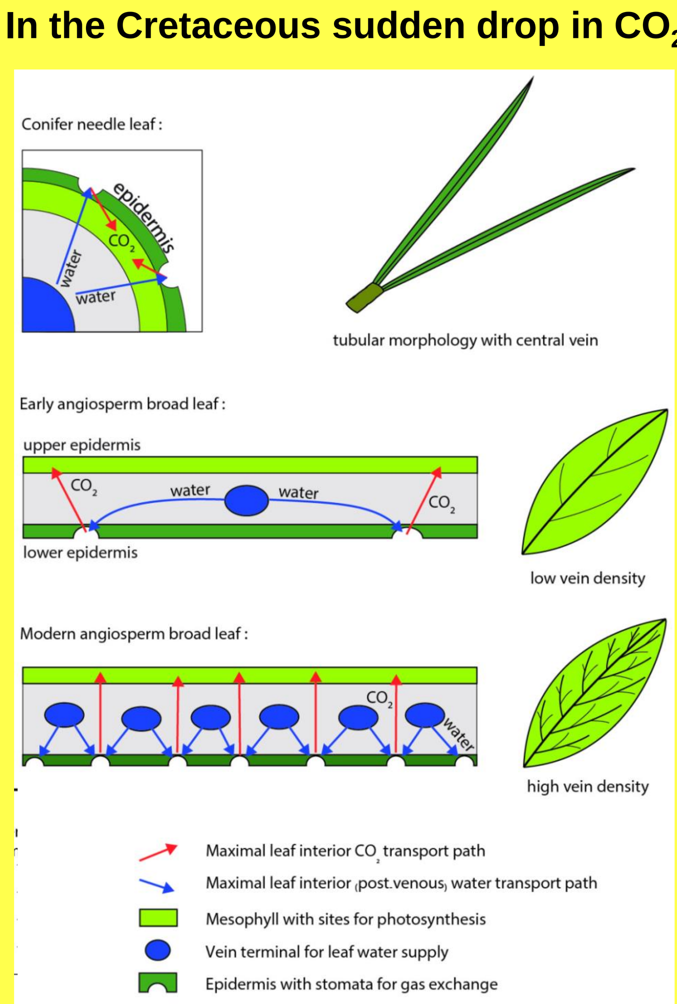
Modeled canopy fluxes for energy limited systems.

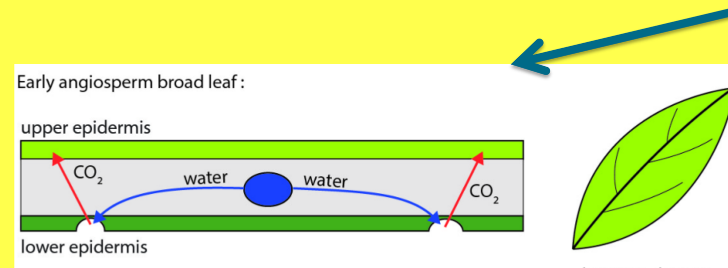
GfixMod:	Only dynamic adaptation of stomatal conductance
GoptMod	With structural optimizaton.
GlimMod	Limits of phenotypic plasticity

Evidence for sudden shift?

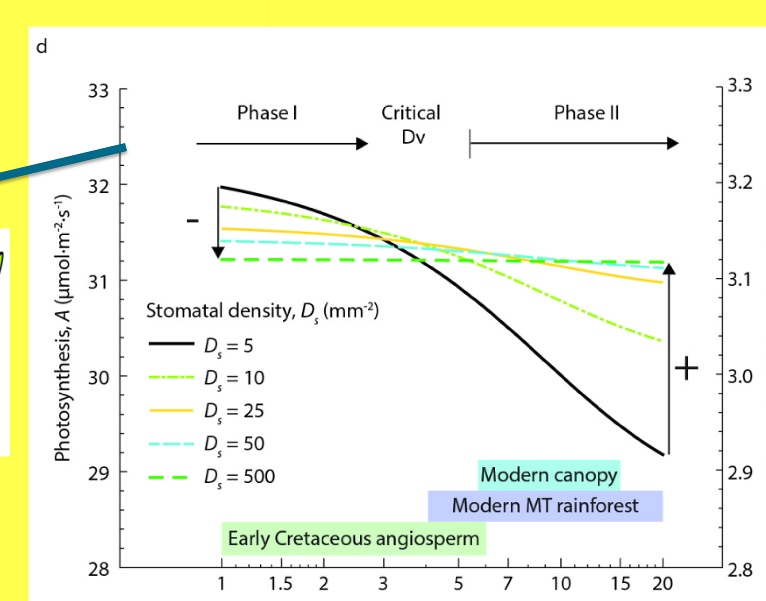
In the Cretaceous sudden drop in CO_2 and increase in angiosperms

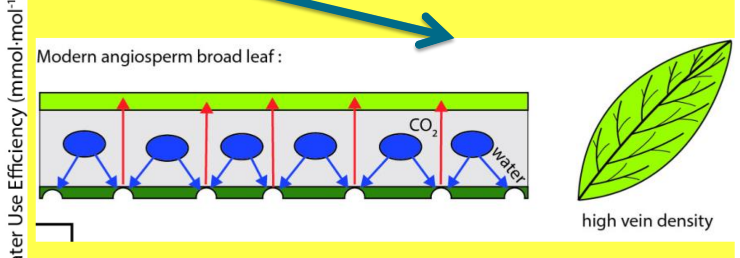






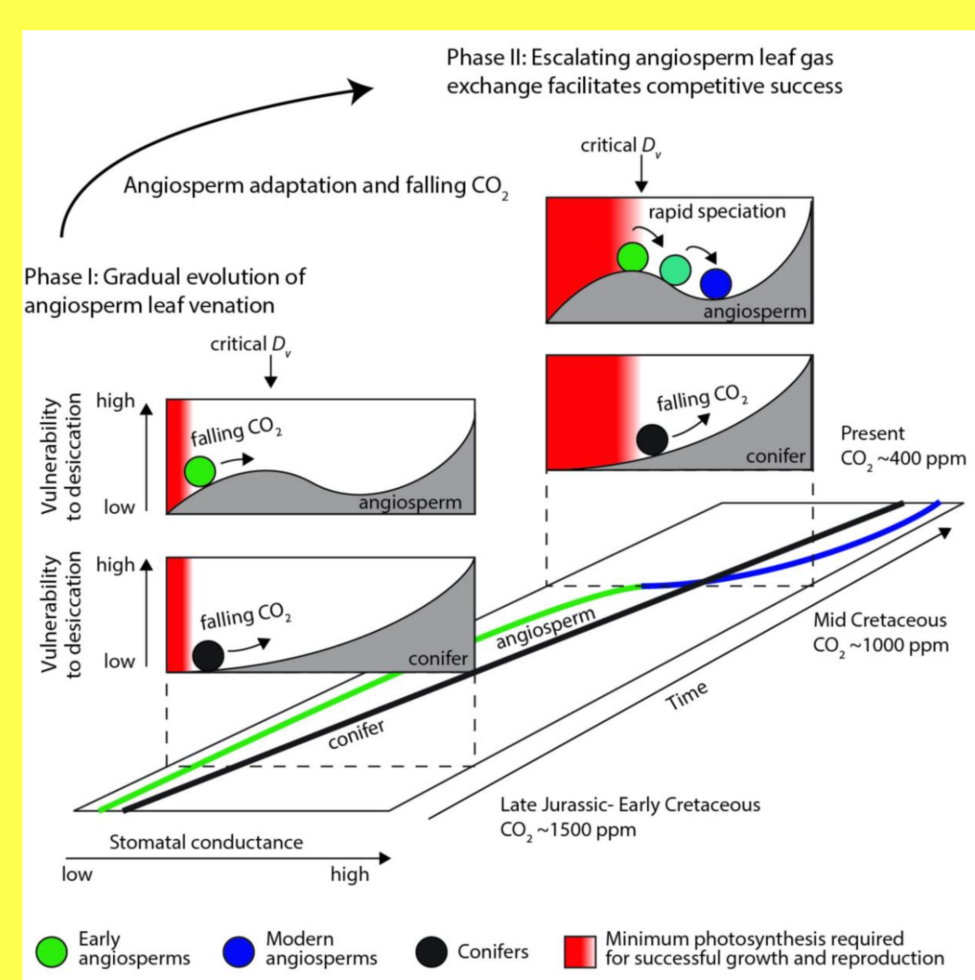
Falling CO_2
→ More water transport needed
→ More veins and stomata
→ Lower photosynthesis





After passing Critical D_v
→ Water transport length lower then CO_2 length
→ With more stomata more Carbon gain → higher Photosynthesis

Conifer:	**Water transport costs always the same**
Broadleaf:	**Water transport costs differ due to differences in stomata and veins**



Conceptual overview how crossing critical vein density (Dv) facilitated angiosperm revolution

Conclusions

Vegetation becomes more efficient in their water use efficiency

30% reduction of transpiration for double CO_2 due to structural adaptation.

Questions

Competitive advantage between species foreseen?

Ecohydrological consequences in water limited systems?

Limits of the phenotypic plasticity of vegetation?

faculty of Geosciences

Boer H.J. de, Eppinga, MB, Wassen MJ and Dekker SC, 2012. A critical transition in leaf evolution sparked the Cretaceous angiosperm revolution. *Nature Communications*
de Boer HJ, Lammertsma EI, Wagner-Cremer F, Dilcher DL, Wassen MJ , Dekker SC. 2011. Climate forcing due to optimization of maximal leaf conductance in subtropical vegetation under rising CO_2. *PNAS, 108:4041–4046.*
Lammertsma EI, de Boer HJ, Dekker SC, Dilcher DL, Lotter AF, Wagner-Cremer F. 2011. Global CO_2 rise leads to reduced maximum stomatal conductance in Florida vegetation. *PNAS* 108:4035–4040.