Stomatal Behaviour:

Scaling from Leaf to Ecosystem

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Bringing knowledge to life
HAWKESBURY INSTITUTE FOR THE ENVIRONMENT

The credit also goes to…

For valuable discussions:

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Lucas Cernusak

Peter Isaac

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For the flux data sets:

Le Brey, Sorø, Hyytiälä, Harvard EMS & Tumbarumba sites

(all through FluxNet data portal)

This talk is about…

- A proof of concept demonstration.
- A stomatal model based on the optimal stomatal behaviour theory.
- Scaling stomatal behaviour from leaf to ecosystem.

The overall goal is…

- To seek for your experts' opinions and suggestions!
- To find out data availability, and the possibility for collaborations.

Optimal stomatal behaviour theory:

- **Stomata should act to maximize carbon gain (*A*) while minimizing water loss (*E*).**

Cowan & Farquhar (1977)

$$g_s = A\left(\sqrt{\frac{1.6\lambda}{(C_a - \Gamma)D}}\right)$$

molH$_2$O mol^{-1}C: the marginal water cost of carbon gain.

Coupled with biochemical C3 photosynthesis model

Medlyn et al. (2011)

$$g_s = g_0 + 1.6\left(1 + \frac{g_1}{\sqrt{D}}\right)\frac{A}{C_a}$$

(i) $g_1 \propto \sqrt{\Gamma \times \lambda}$

(ii) *A linear relationship between* g_s *and* $\frac{A}{C_a\sqrt{D}}$

The instantaneous transpiration use efficiency (ITE):

$$E = \frac{g_s \times D}{P_{atm}}$$

$$ITE = \frac{A}{E} \approx \frac{C_a \times P_{atm}}{1.6\left(D + g_1\sqrt{D}\right)}$$

(i) *ITE is predicted to decline with increasing D*

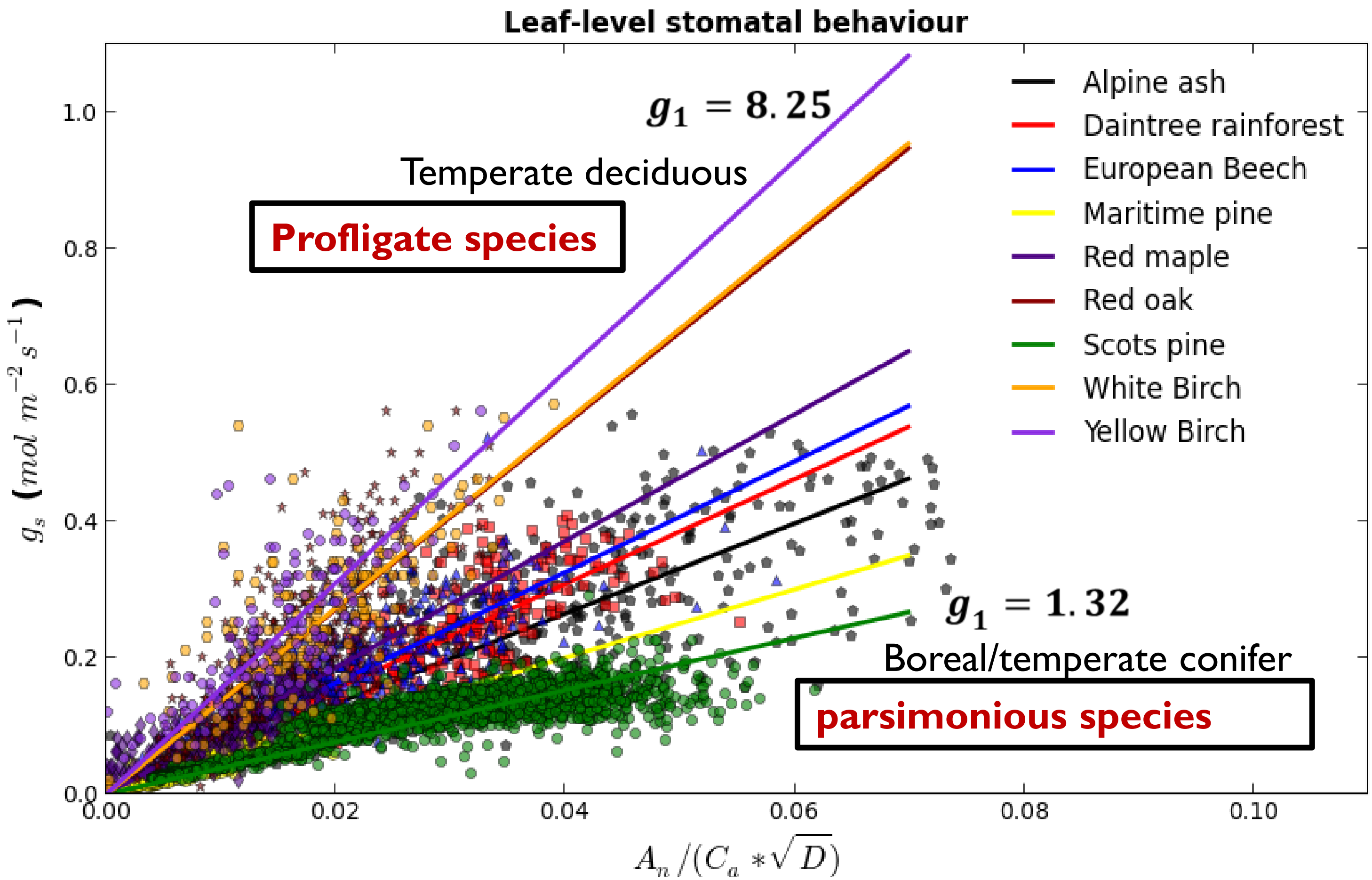
(ii) *Higher* g_1 *will have a low ITE*

What does different g_1 mean among species?

- $$g_s \approx 1.6\left(1 + \frac{g_1}{\sqrt{D}}\right)\frac{A}{C_a}$$

(i) $g_1 \propto \sqrt{\Gamma\lambda}$

(ii) A linear relationship between g_s and $\frac{A}{C_a\sqrt{D}}$

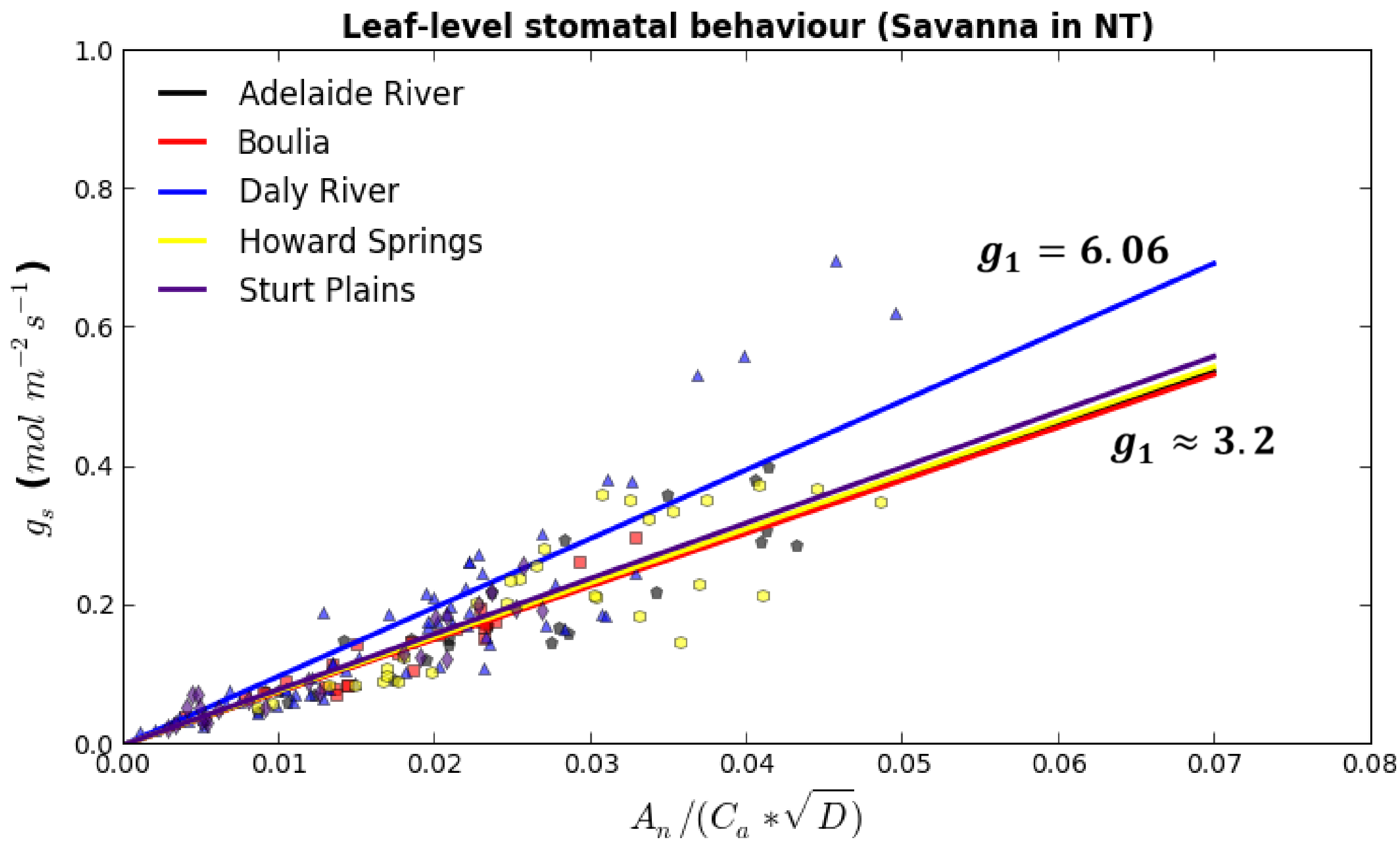


g_1 for the same species from different sites

- $$g_s \approx 1.6\left(1 + \frac{g_1}{\sqrt{D}}\right)\frac{A}{C_a}$$

(i) $g_1 \propto \sqrt{\Gamma\lambda}$

(ii) A linear relationship between g_s and $\frac{A}{C_a\sqrt{D}}$



Do the differences in leaf-level behaviour influence ecosystem-level water use efficiency?

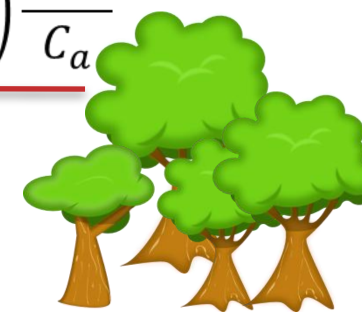
We would expect the stomatal model to scale to the canopy because it is linear in *A*.

$$g_s = g_0 + 1.6\left(1 + \frac{g_1}{\sqrt{D}}\right)\frac{A}{C_a}$$

Leaf-level

$$G_s = g_0 L + 1.6\left(1 + \frac{g_1}{\sqrt{D}}\right)\frac{GPP}{C_a}$$

Ecosystem-level



How does this translate to ecosystem evapotranspiration (ET) ?
…depends on:

(i) Canopy roughness
(ii) Soil evaporation
(iii) Understory plant structure
(iv) Wet canopy evaporation

Data sets to test!

Sites & dominated species

1. Scots pine (*Pinus sylvestris*) – Hyytiälä, Finland
2. Maritime pine (*Pinus pinaster*) – Le Bray, France
3. Beech (*Fagus sylvatica*) – Sorø, Denmark
4. Red maple+oak (*Quercus rubra* & *Acer rubrum*) – Harvard Forest, MA, USA
5. Alpine ash (*Eucalyptus delegatensis*)– Tumbarumba, Australia

Leaf-level data type

Half-hourly auto-cuvette data

Diurnal spot measurements

Ecosystem-level data type

Half-hourly flux data from FluxNet data portal

Only use the data points when…

1. Both leaf v.s ecosystem level measurements conducted at the same time.
2. PAR > 500 ($\mu mol\ m^{-2}s^{-1}$)

Leaf & ecosystem stomatal behaviour

$$g_s = g_0 + 1.6\left(1 + \frac{g_1}{\sqrt{D}}\right)\frac{A}{C_a}$$

Leaf-level

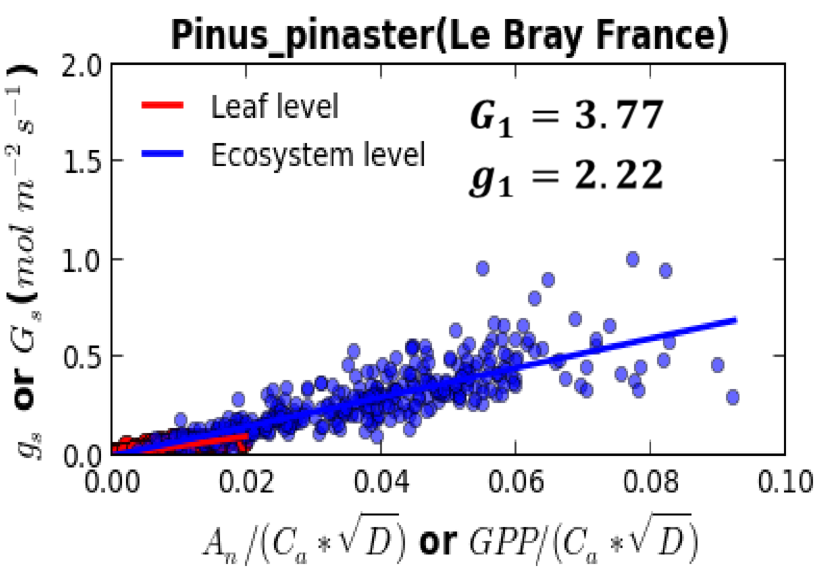
$$G_s = g_0 L + 1.6\left(1 + \frac{g_1}{\sqrt{D}}\right)\frac{GPP}{C_a}$$

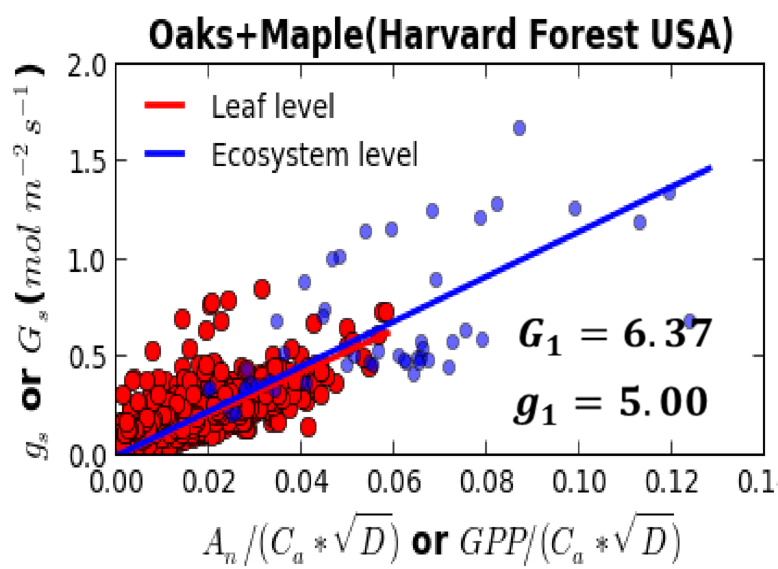
Ecosystem-level

A linear relationship between:

g_s vs. $\frac{A}{C_a\sqrt{D}}$

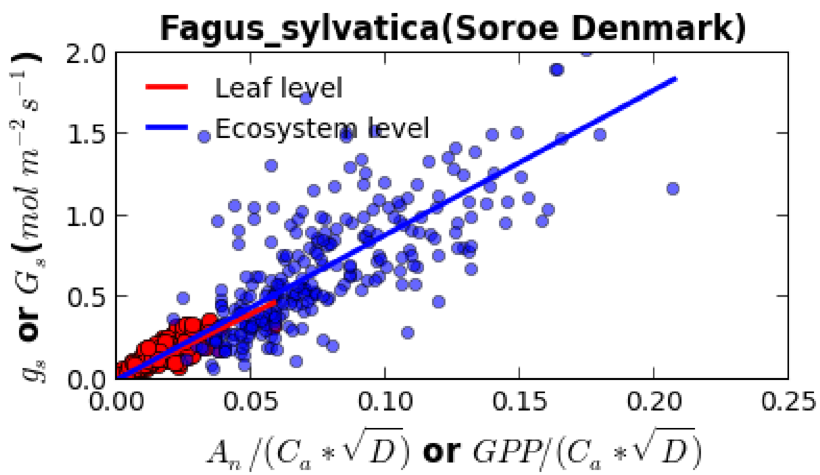
G_s vs. $\frac{GPP}{C_a\sqrt{D}}$





Leaf & ecosystem stomatal behaviour: yearly adjustments

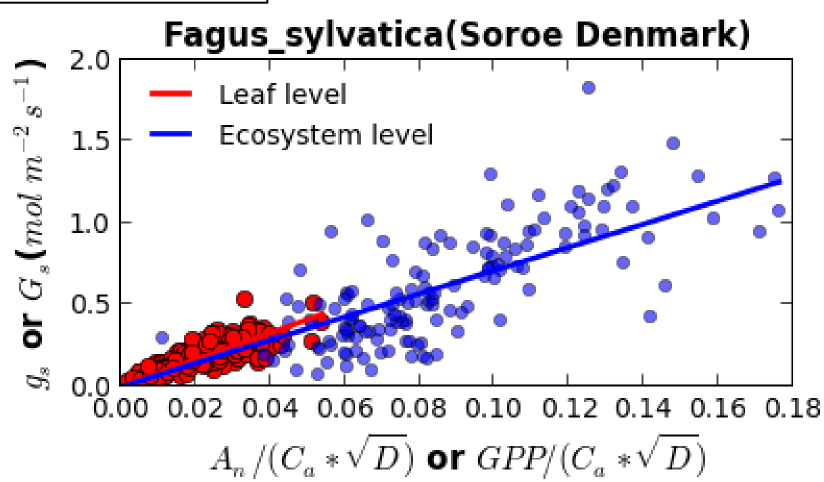
Year 1999 summer



$G_1 = 4.38$

Precipitation: 897 mm

Year 2000 summer

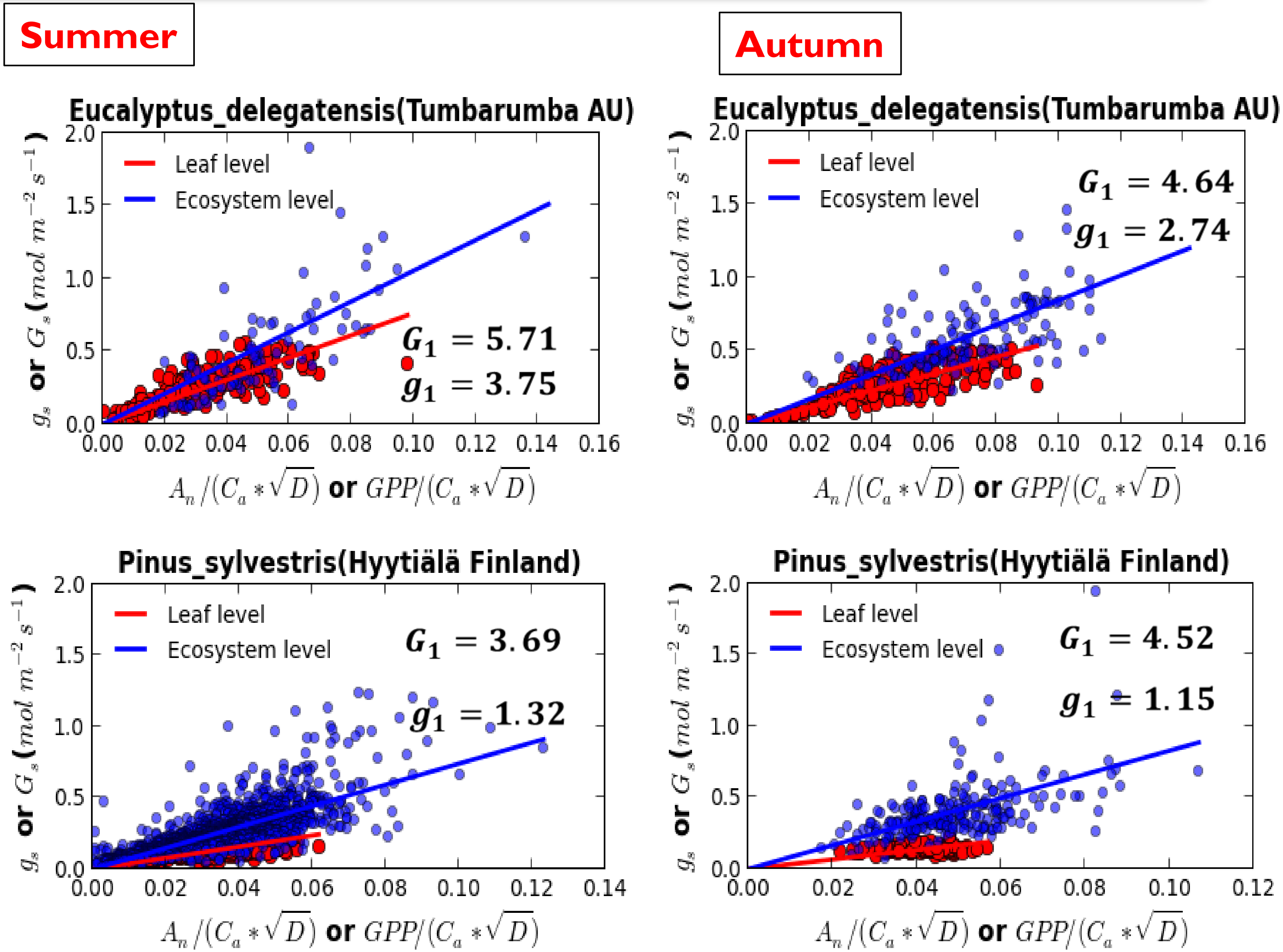


$G_1 = 3.14$

Precipitation: 632 mm

(~30% decrease)

Leaf & ecosystem stomatal behaviour: seasonal adjustments



Compare leaf and ecosystem level *ITE* vs. *D*

$$ITE = \frac{A}{E} \approx \frac{C_a \times P_{atm}}{1.6\left(D + g_1\sqrt{D}\right)}$$

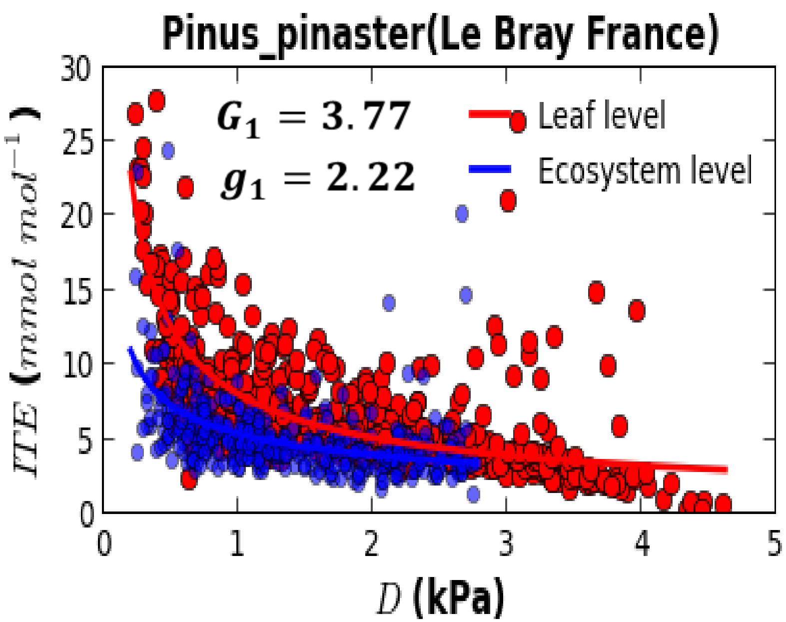
Leaf-level

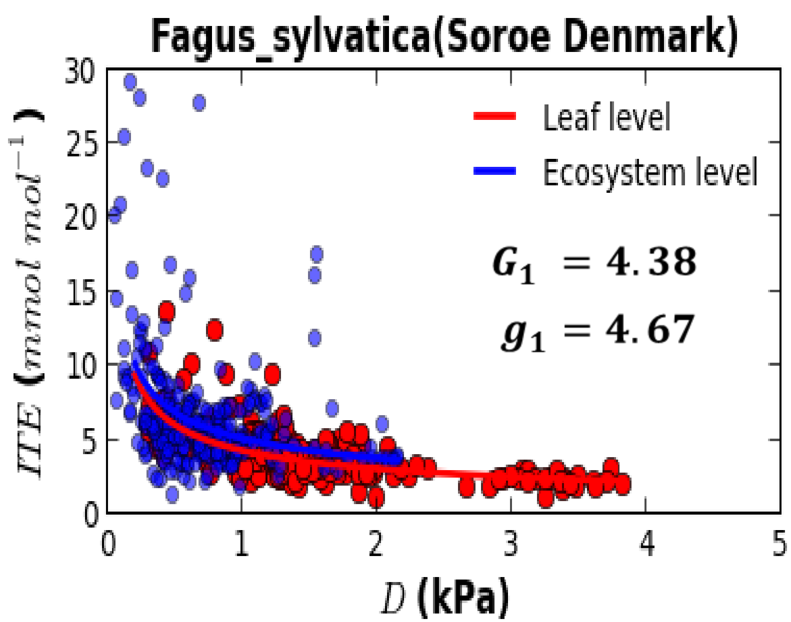
$$ITE = \frac{GPP}{ET} \approx \frac{C_a \times P_{atm}}{1.6\left(D + G_1\sqrt{D}\right)}$$

Ecosystem-level

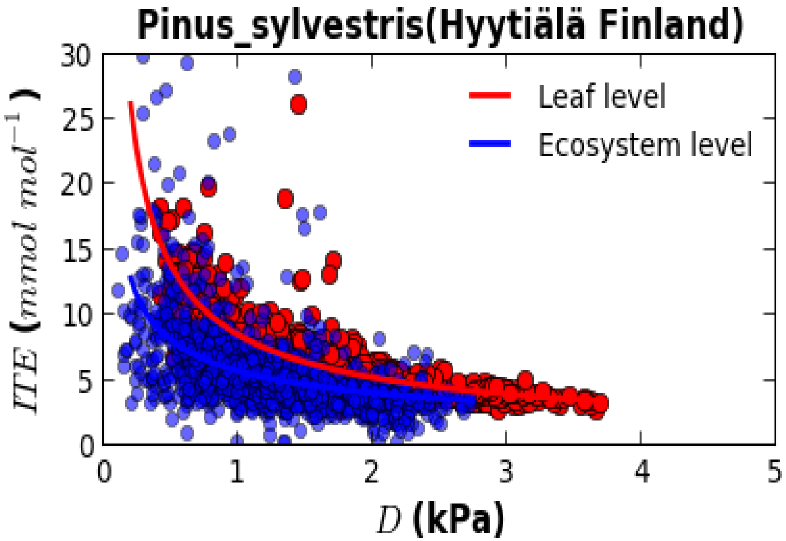
(i) ITE is predicted to decline with increasing D

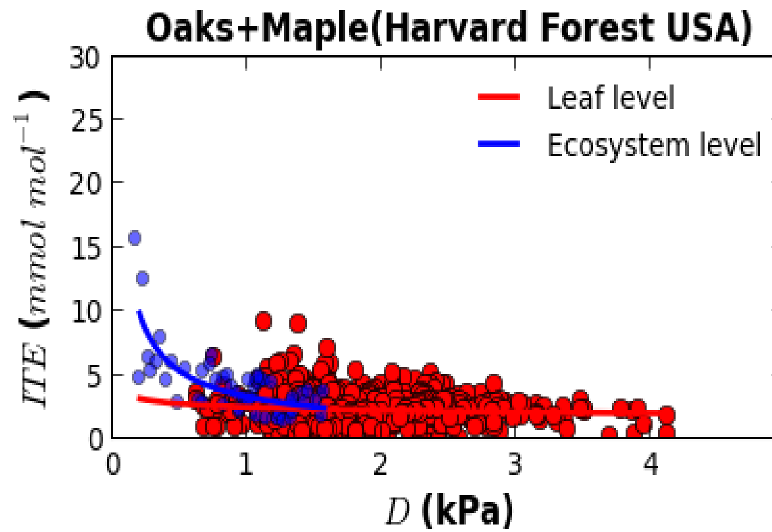
(ii) Higher g_1 will have a low ITE



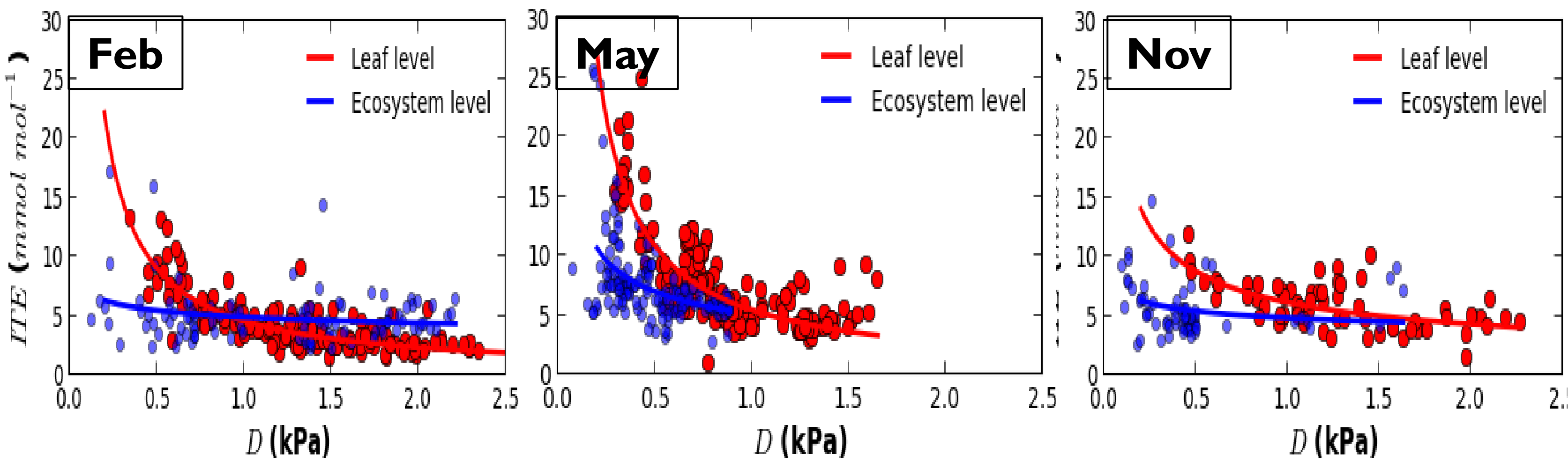


Compare leaf and ecosystem level *ITE* vs. *D*





Eucalyptus delegatensis **(Tumbarumba, AU)**



Future improvement & questions

We'd like to do the same analysis on Ozflux sites!

Some essential data/questions:

1. Diurnal leaf scale gas exchange measurements.
2. Standardised GPP estimation (*Jason & Peter, we are betting on you!*)
3. What's the best way to estimate canopy *D*?
4. How about canopy wetness sensor?
5. Correlation with LAI.
6. A better understanding on species phenology.

Be part of the Stomatal Behaviour Synthesis project!

http://bio.mq.edu.au/stomata/