When does VPD drive or reduce ET?

Adam (with Pierre and Changjie)

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When does VPD drive or reduce ET?

- **Hydrometeorologists** would say that an increase in VPD (increase in **atmospheric demand**) would drive an **increase in ET**.
- However, **plant physioligists** know that plants have evolved to use stomata to conserve and regulate water use. So **stomata closure** in response to increases in VPD may **decrease ET**.

The question is, which effect dominates with an increase in VPD: plant response (decrease in ET) or atmospheric demand (increase in ET)?

- It should be a function of plant type and the environment:
  - Plants that are evolved to conserve water will tend to reduce ET with increases in VPD.
  - However the environment can overwhelm plant response: at some threshold (i.e. very high VPD) the atmospheric demand should dominate and plants will not be able to consernve water, no matter how much they have evolved to do so.

We will try an analytical approach to this question:

We can use Penman-Monteith (PM) to estimate ET:

$$ET = \frac{\Delta R + g_a \rho_a c_p D}{\Delta + \gamma(1 + \frac{g_a}{g_s})},$$

But in:

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

A is a function of ET. So ET in PM is really an implicit function of itself.

Remove dependence of ET on A

Zhou et al. 2016 shows that uWUE:

$$uWUE = \frac{GPP \cdot \sqrt{D}}{ET}$$

is conserved across space and time (within PFT).

So we can use uWUE to remove dependence of g_s on A:

$$g_s = \frac{\mathrm{LAI}}{\mathrm{LAI}_{ref}} \frac{R\ T}{P} 1.6 \left(1 + \frac{g_1}{\sqrt{D_s}}\right) \frac{uWUE\ ET}{c_s\ \sqrt{D}}$$

Derive new form of PM

If we plug in our new expression for g_s we can solve for ET to get a new form of PM:

$$ET = \frac{\Delta R + \frac{g_a\ P}{T}\left(\frac{c_p D_s}{R_{air}} - \frac{\mathrm{LAI}_{ref}}{\mathrm{LAI}} \frac{\gamma c_s \sqrt{D}}{R* \ 1.6\ \mathrm{uWUE}\ (1 + \frac{g_1}{\sqrt{D}})}\right)^1}{\Delta + \gamma}$$

Now, we can take derivatives, and:

$$\frac{\partial\ ET}{\partial\ D} = \frac{g_a\ P}{T(\Delta + \gamma)}\left(\frac{c_p}{R_{air}} - \frac{\mathrm{LAI}_{ref}}{\mathrm{LAI}} \frac{\gamma c_s}{1.6\ R*\ \ \mathrm{uWUE}}\left(\frac{2g_1 + \sqrt{D}}{2(g_1 + \sqrt{D})^2}\right)\right)$$

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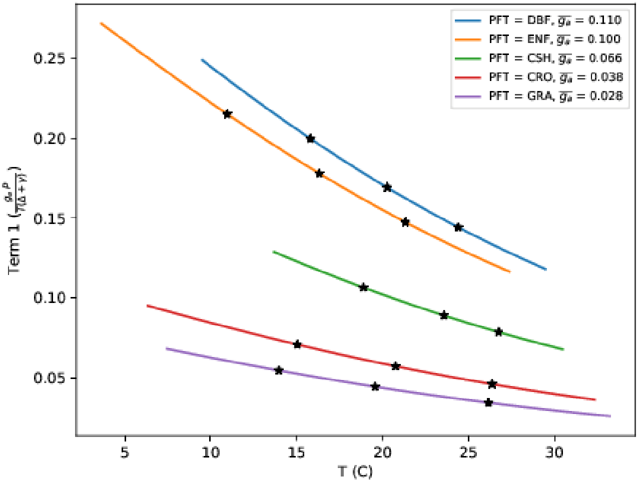
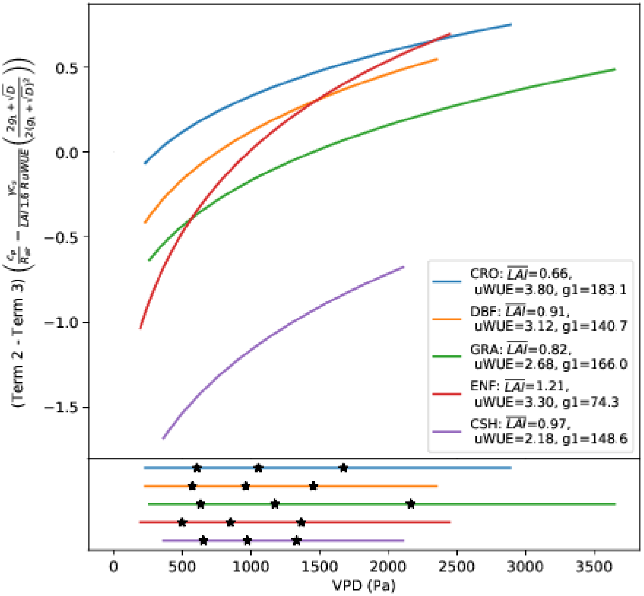
[1] note that all terms are known, except for $\frac{\mathrm{LAI}_{ref}}{\mathrm{LAI}}$

Scaling Term

$$\frac{\partial\ ET}{\partial\ D} = \frac{\mathbf{g_a\ P}}{\mathbf{T}(\mathbf{\Delta} + \gamma)} \left(\frac{c_p}{R_{air}} - \frac{\mathrm{LAI}_{ref}}{\mathrm{LAI}} \frac{\gamma c_s}{1.6\ R * \quad \mathrm{uWUE}} \left(\frac{2g_1 + \sqrt{D}}{2(g_1 + \sqrt{D})^2} \right) \right)$$



"Sign" Term


(Term 2 - Term 3)
0.5
0.0
−0.5
−1.0
−1.5
CRO: $\overline{LAI}$=0.66, uWUE=3.80, g1=183.1
DBF: $\overline{LAI}$=0.91, uWUE=3.12, g1=140.7
GRA: $\overline{LAI}$=0.82, uWUE=2.68, g1=166.0
ENF: $\overline{LAI}$=1.21, uWUE=3.30, g1=74.3
CSH: $\overline{LAI}$=0.97, uWUE=2.18, g1=148.6
0
500
1000
1500
2000
2500
3000
3500
VPD (Pa)

References

Zhou, Sha et al. (2016). "Partitioning evapotranspiration based on the concept of underlying water use efficiency". In: *Water Resources Research* 52.2, pp. 1160–1175. DOI: 10.1002/2015wr017766. URL: https://doi.org/10.1002%2F2015wr017766.