Some notes on the simple SPAC deployment

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1 Photosynthesis Model

This basically consists of four parts:

1. Medlyn model for maximum conductance
2. SPAC-based down-regulation of g_s to regulate ψ_l
3. Transport of CO_2 into the intercellular space
4. Photochemistry

We were interested in whether GPP and $\frac{C_i}{C_a}$ can increase with increasing VPD in well-watered cases. To start with, given the well-watered stipulation, we can ignore (2) and just focus on Medlyn and how it couples with C_i, etc.

Medlyn:

$$g_s\left[\frac{mol}{m^2 s}\right] = g_0 + \left(1 + \frac{g_1}{\sqrt{D}}\right)\frac{A}{C_a} \tag{1}$$

The Medlyn paper models photosynthesis as:

$$A = \frac{J}{4}\frac{C_i - \Gamma^*}{C_i + 2\Gamma^*} - R_d \tag{2}$$

Where J is the rate of electron transport, C_i is the intercellular CO_2 concentration and $\Gamma*$ is the CO_2 compensation point. We'll neglect respiration in our simplified model.

Assuming steady-state, photosynthesis has to be matched by the flux of carbon through the leaf's surface, which I'll call F_{CO2}

$$F_{\mathrm{CO2}} = g_s\left(C_a - C_i\right) \tag{3}$$

When VPD increases, Medlyn requires that g_s decrease. If you want to achieve the same F_{CO2} you have to lower C_i to compensate with a larger gradient. However, that compensation will inhibit photochemistry, because A is an increasing function of C_i. As a result, (with all else equal) the equilibrium resulting from the lower g_s will reduce C_i, but in such a way that the increase in $C_a - C_i$ will ***always*** be smaller than the decrease in g_s. The Medlyn paper shows that if we assume $g_0 = 0$ and assume that only VPD is changing, that $\frac{C_i}{C_a}$ decreases monotonically with D according to:

$$\frac{C_i}{C_a} = 1 - \frac{1.6\sqrt{D}}{g1 + \sqrt{D}} \tag{4}$$