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Comment on bg-2022-96

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Community comment on "Technical note: Common ambiguities in plant hydraulics" by Yujie Wang and Christian Frankenberg, Biogeosciences Discuss.,
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This manuscript propagates some common misconceptions about plant water relations, concerning the roles of diffusion vs advection (and water potential vs pressure) in xylem water transport, and the meaning and relevance of the gravitational potential term in the formal definition of water potential.

- line 39-40: "Water potential gradients drive water flow through permeable media such as xylem conduits"

This is incorrect, except on extremely small scales. Water potential describes the tendency for water to move between adjacent phases (regions of internally uniform thermodynamic states) due to the net, or average, movement of individual water molecules. In other words, it predicts where water molecules will diffuse. It does not describe the movement of coherent bodies of water under the action of body forces (advection). Water potential gradients thus drive liquid water movement only at spatial scales where diffusion is faster than advection. Those scales are extremely small, and can be quantified using the Peclet number, which is the ratio of advective to diffusive transport velocities. The Peclet number equals $V \cdot X / D$, where V is the advective velocity, X is the distance and D is the molecular diffusivity (of water in liquid water, in this case; about $2.4 \times 10^{-9} \text{ m}^2 \text{ s}^{-1}$). If the Peclet number is greater than 1, advection dominates; if it is less than 1, diffusion dominates. For example, consider water moving in the xylem at a velocity of 1 cm/hr ($2.8 \times 10^{-6} \text{ m/s}$), which is quite low but not negligible. In this case the Peclet number is unity for X around 0.9 mm; that is, for distances over a millimeter, advection dominates and thus pressure gradients are the more relevant driver of water movement. (For more typical midday sap velocities of $\sim 10\text{-}50 \text{ cm/hr}$, the Peclet number is unity for X around 20-90 microns.) Thus, advection dominates xylem water transport in nearly all cases, so the statement quoted above is precisely incorrect.

- lines 44-46: "For instance, for a 100 m tall tree with no transpiration, leaf water potential is equal to soil water potential; however, leaf xylem water pressure would be approximately 1 MPa more negative than xylem pressure at the tree base;"

It is nominally correct, but misleading and pointless, to say that leaf water potential would be equal to soil water potential in this example. While it is true that chemical potential (and water potential, by its conventional definition) contains a gravitational potential term,

that term is never relevant to plants on Earth. This is because gravitational potential never varies substantially at the spatial scales where water potential drives water movement. (The reason gravity does matter for water transport is addressed in my next comment, #3.)

We measure water potential because it tells us something about the physiologically relevant condition of water in a given tissue; and in the case of leaves, because it gives us an estimate of the pressure in the xylem water at that location – which is useful for predicting both long-distance water transport and xylem embolism. Any measurement of water potential (including by psychrometry) would give you a value of -1 MPa for the leaf in this example. The fact that this leaf's water had more potential energy than that of a leaf near the ground would not do the leaf any good, in terms of dealing with the negative consequences of its actual water status.

If we want to be at once rigorous, practical, and clear with our definitions, we should probably redefine water potential to exclude the influence of fields (like gravity) that never vary, in practice, at the spatial scales where water potential is a relevant driver of water movement. (There's nothing stopping us from redefining it. It was an arbitrary definition to begin with.)

- Continuing from the above "...and using pressure drop here to derive flow rate will be incorrect when there is height change"

This is a red herring. Nobody uses pressure drop alone to derive flow rate in such a case (or if they do, it's rare - I've never seen it done in cases where the height change is very large). They properly subtract the gravitational head (the force per unit area caused by the weight of the water column). A simple force balance analysis for the xylem water is what leads to the actual flow equation (with flow being proportional to the pressure difference minus the gravitational head).

- lines 51-53: "Leaf water potential is often estimated using the pressure chamber method (Scholander et al., 1964; Boyer, 1967). However, the term "potential" is not accurate here, as the pressure chamber method gives the applied pressure at the free meniscus of the cut end."

This is sophistic. Plant physiologists all understand that the pressure bomb gives the pressure in the xylem water (or, we hope, a decent estimate of it). They refer to it as "water potential" because (a) the xylem water generally has very low solute content, so its pressure is approximately equal to its water potential (ignoring the pointless gravitational term as discussed above), and (b) in the equilibrated leaf, the living cells' water potentials will be equal to that of the xylem water. Again, in this case, bringing up the gravitational component of water potential adds more confusion than clarity and is meaningless in practice.

- lines 104-105 and Equation 11. "A common mistake when using plant hydraulics-based models is that one does not follow the original model formula or hypothesis"

Ironically, Equation 11 is not in fact the Sperry et al (2017) model. It defined Theta as

Theta = $(k_{cmax} - k_c(P_c)) / (k_{cmax} - k_{crit})$.