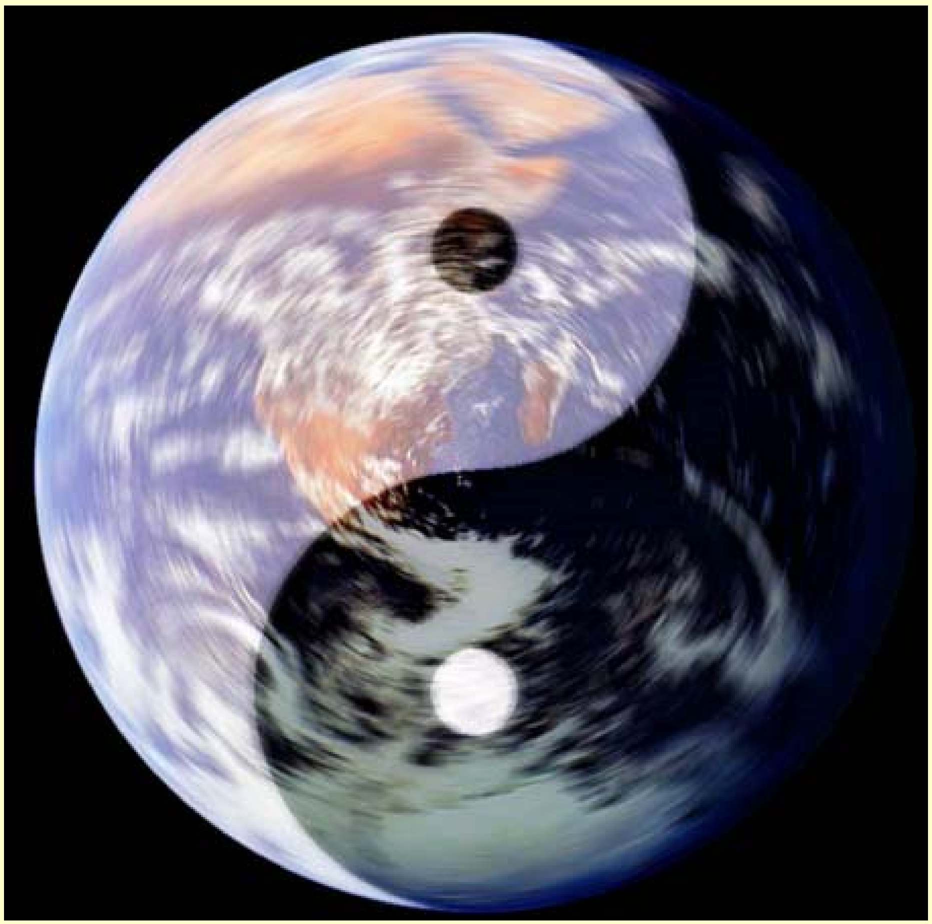
Plant water loss: via Stomata

Leaf openings through which CO_2 is taken in and water is lost

Scott Saleska

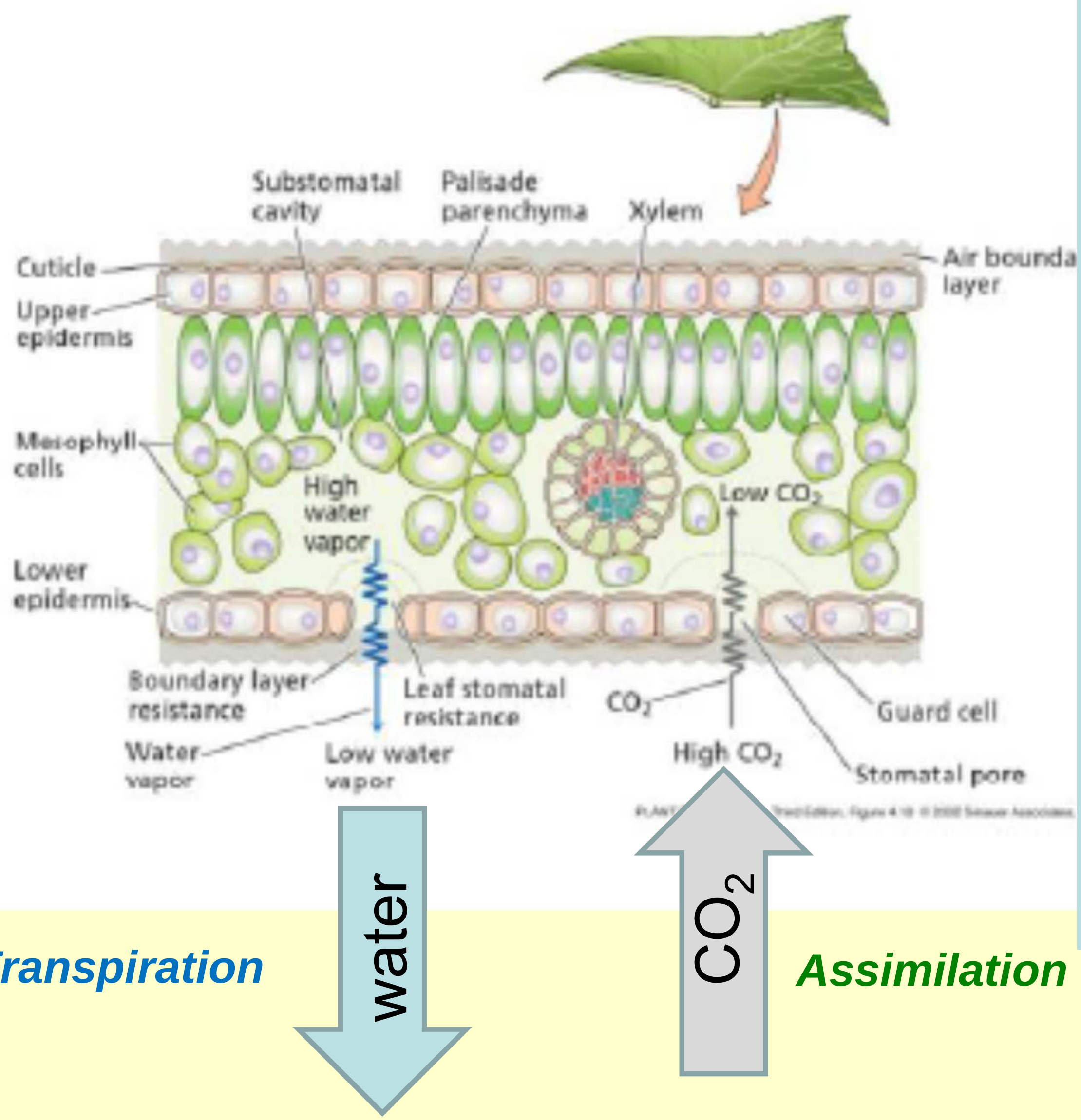
University of Arizona



water

carbon

Fundamental trade-off: Carbon-in ←→ water-out



Transpiration

Assimilation

Global terrestrial water-use efficiency (WUE) for carbon:

WUE = GPP / evapotranspiration
= 100 PgC/yr / 71,000 Pg H2O/yr
= 1.4 mmol C fixed / mole water lost

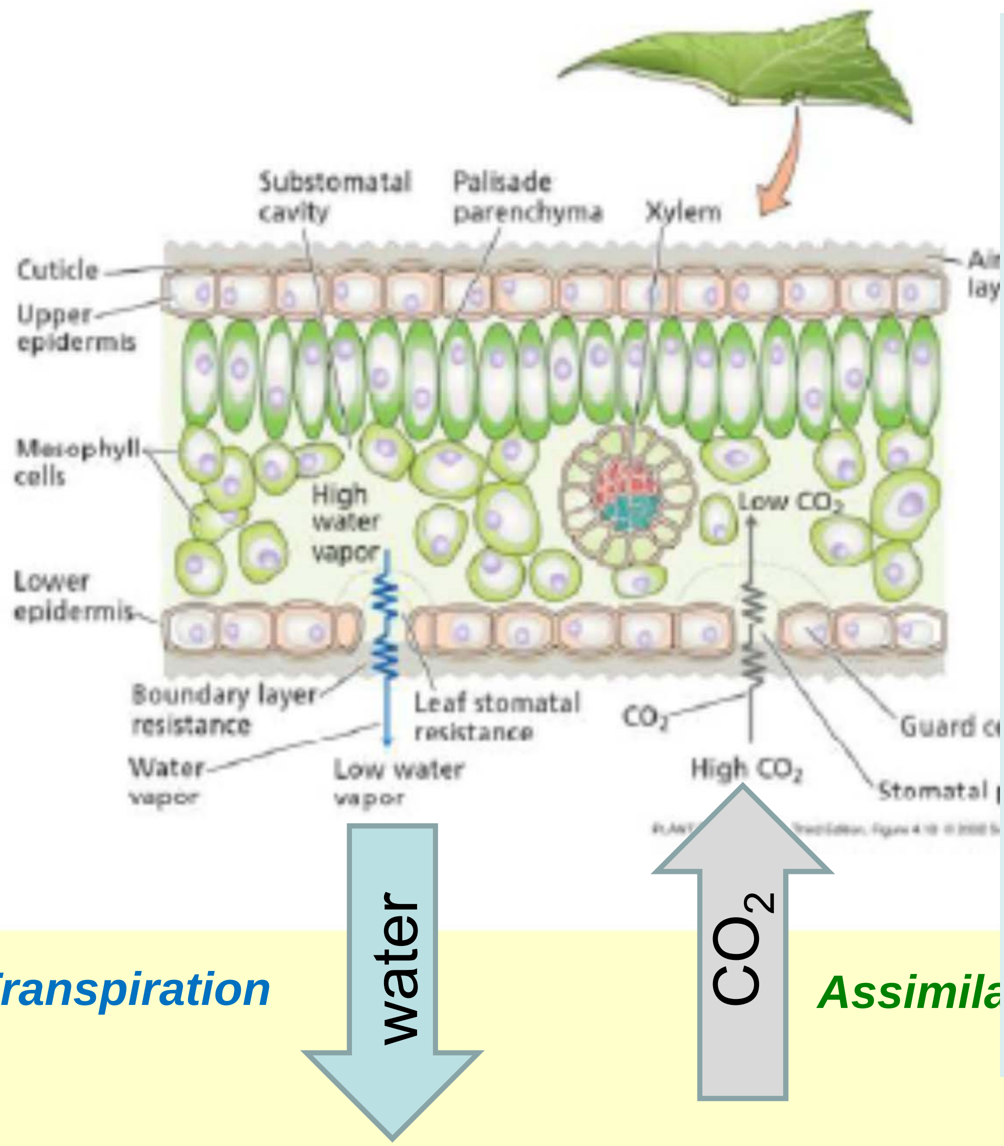
→ ~ 700X more water than carbon

Main plant need for water is **not** as an ingredient

(as in CO2 + H2O → CH2O + O2),

but to meet evaporative demand here, at the leaf

Fundamental trade-off: Carbon-in ←→ water-out



Transpiration

Assimila

Important unknown questions:

- What is the global transpiration flux?
  (Jasechko et al. 2012 vs. Coenders et al. 2013: is it 90% or 50-60% of terrestrial Evapotranspiration?)

- What is the long-term trend in Water Use efficiency (WUE)?

+2.7%/yr (eddy flux network, Keenan et al) v
+0.5%/yr (tree ring isotopes, Frank et al)

The fate of vegetation under climate change droughts may depend on this…

Test Roisin Commane's Hypothesis:

OCS IS A BETTER TRACER OF STOMATAL CONDUCTANCE THAN IT IS OF GPP

Dynamics of canopy stomatal conductance, transpiration, and evaporation in a temperate deciduous forest, validated by carbonyl sulfide uptake

Richard Wehr[1], Róisín Commane[2], J. William Munger[2], J. Barry McManus[3], David D. Nelson[3], Mark S. Zahniser[3], Scott R. Saleska[1], and Steven C. Wofsy[2]

Rick Wehr

Roisin Commane

Test Roisin Commane's Hypothesis:

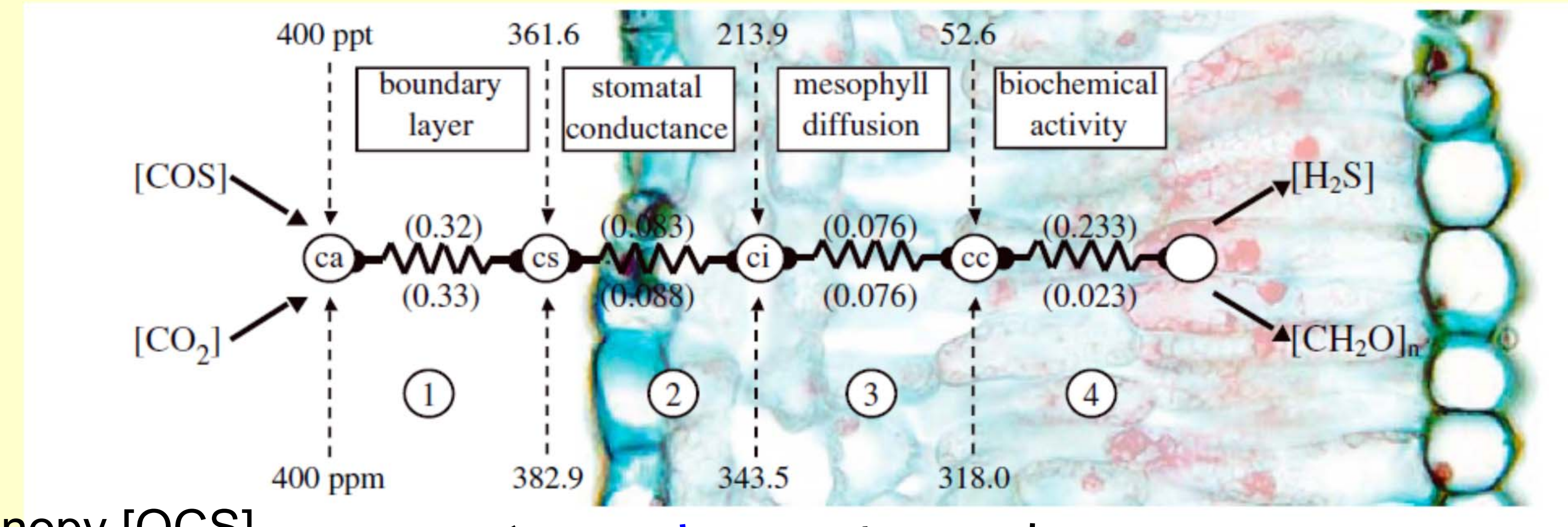
OCS IS A BETTER TRACER OF STOMATAL CONDUCTANCE THAN IT IS OF GPP

<u>Strategy: address first part (OCS as tracer of stomatal conductance)</u>

Can we predict OCS flux, given stomatal conductance (derived from water flux) ?

Can we predict stomatal conductance, given OCS flux? (no water flux needed)

Canopy scale conductance via OCS flux measurements



Berry et al. 2013

Canopy [OCS]

$$F = gC_n; \quad g = \left(g_b^{-1} + g_s^{-1} + g_m^{-1} + g_{CA}^{-1}\right)^{-1}$$

OCS uptake

g_s (H_2O) = 1.94 g_s; g_b(H_2O) = 1.56 g_b (Stimler et al. 2010)

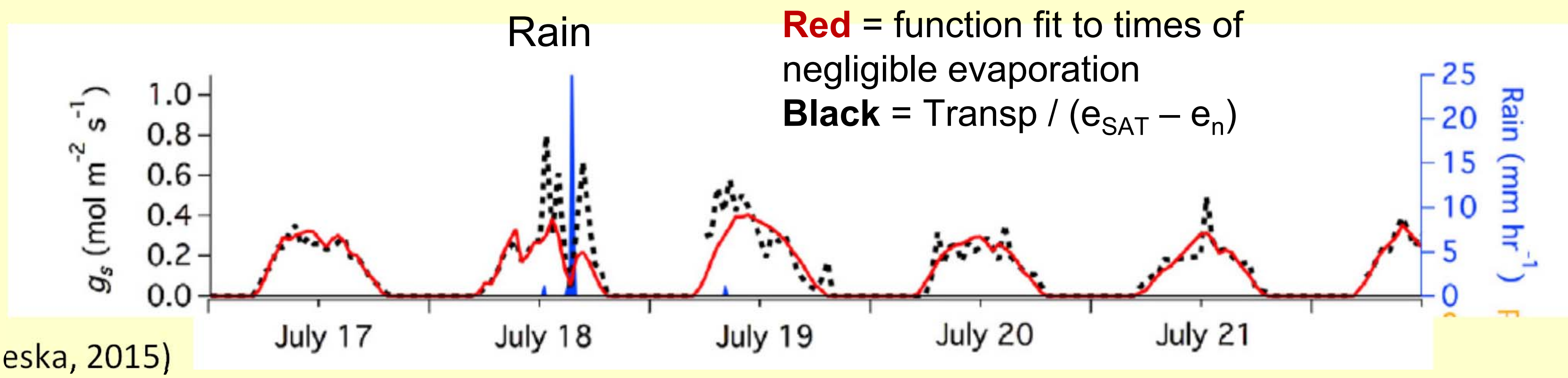
Transpiration flux:

$$F_{H2O} = g_{H2O} \, [e_{SAT}(T_{leaf}) - e_n]/RT_n$$

(Wehr, Commane et al. 2017)

Canopy scale conductance via OCS flux measurements

Step 1: Predict OCS flux from **water-flux derived g_s**, using an empirical function for g_s



(Wehr & Saleska, 2015)

$$g_s = \mathrm{LAI}(b_0 e^{b_1 \mathrm{LVD}} e^{b_2 \chi})\mathrm{PAR}$$

LVD = leaf vapor deficit
= e_{SAT} (Tleaf) - e_n

Fit b_0, b_1, b_2 to measured Transpiration when evap negligible

Transpir-ation flux:

$$F_{H2O} = g_{H2O}\,[e_{SAT}(T_{leaf}) - e_n]/RT_n$$

Canopy scale conductance via OCS flux measurements

Step 1: Predict OCS flux from water-flux derived g_s, using an empirical function for g_s

Simple model

stomatal conductance

$$F = g C_n; \quad g = \left(g_b^{-1} + g_s^{-1} + g_m^{-1} + g_{CA}^{-1}\right)^{-1}$$

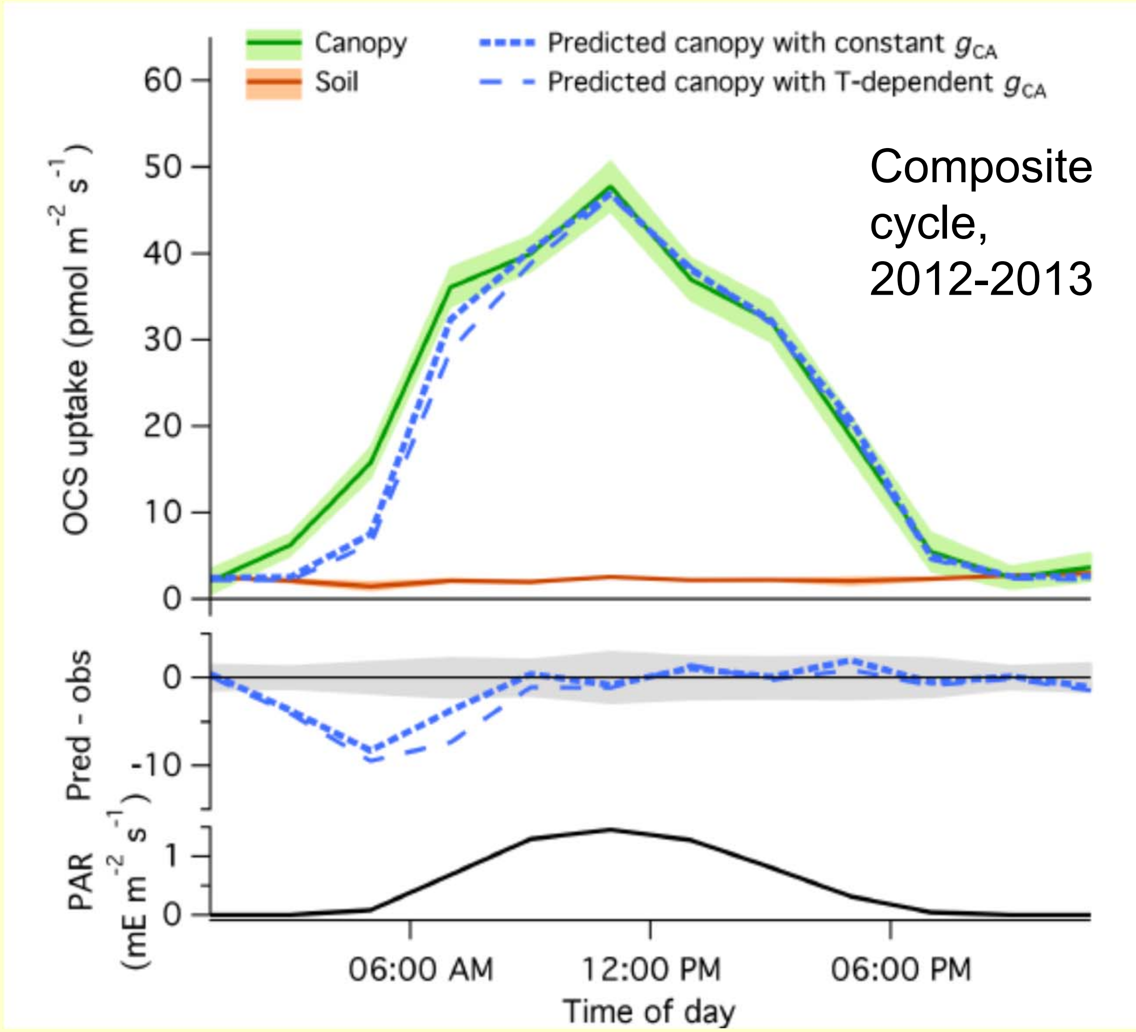
OCS flux

[OCS]

Boundary layer

Mesophyll (empirical Temp function)

"biochemical conductance" (constant or T-dependent)



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$$F = gC_n; \quad g = \left(g_b^{-1} + g_s^{-1} + g_m^{-1} + g_{CA}^{-1}\right)^{-1}$$

- F: OCS flux
- C_n: [OCS]
- g_b: Boundary layer
- g_s: stomatal conductance
- g_m: Mesophyll (empirical Temp function)
- g_{CA}: "biochemical conductance" (constant or T-dependent)

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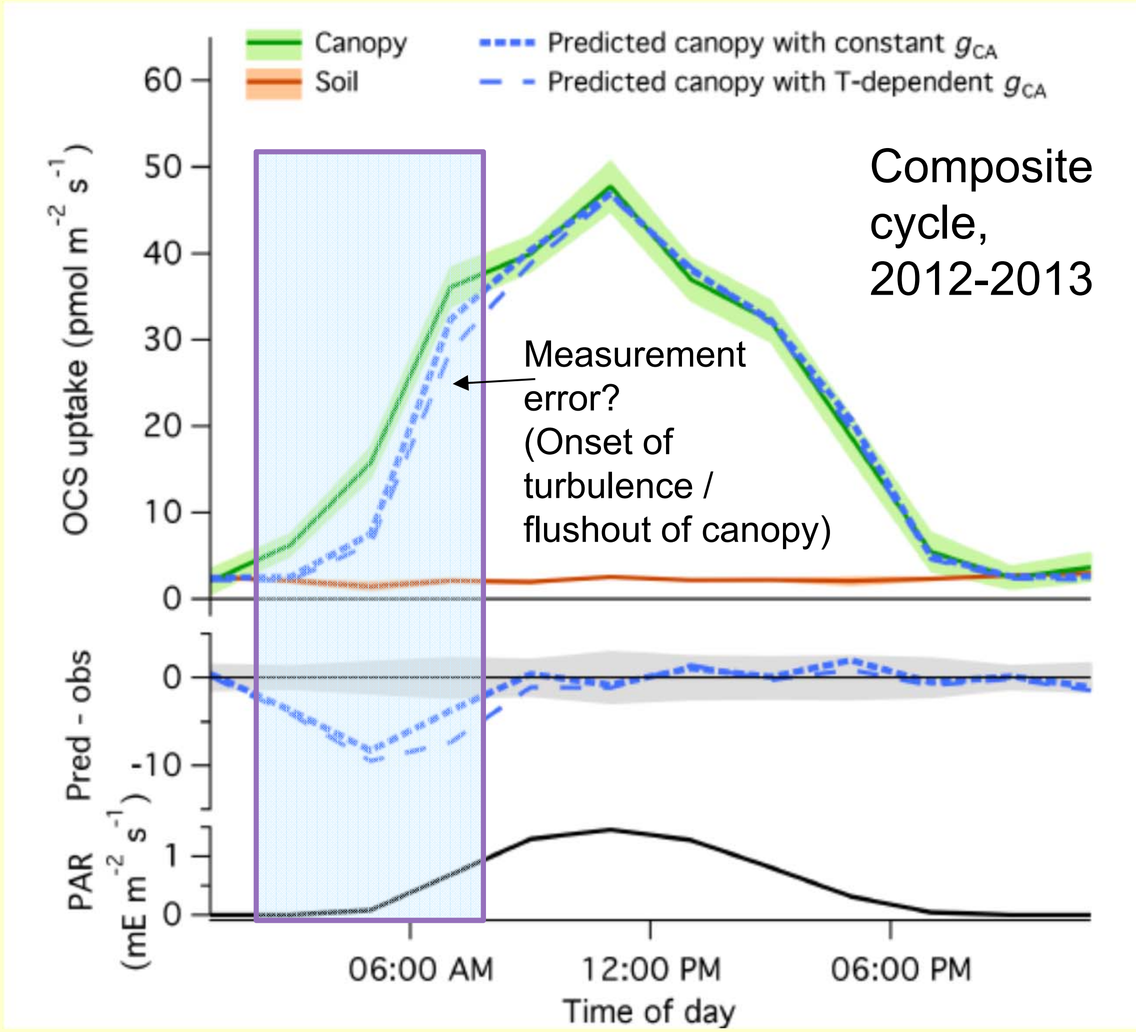
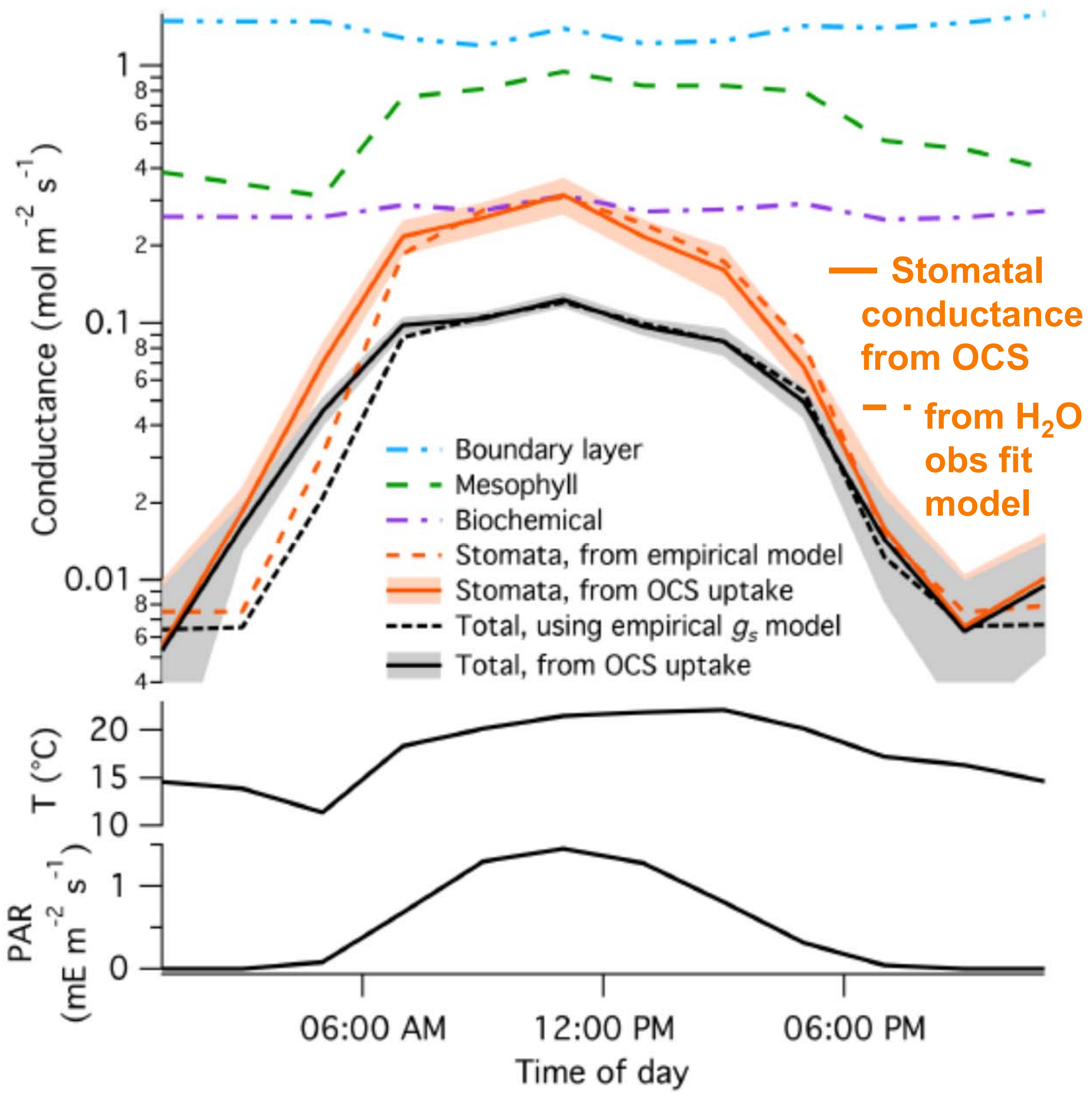
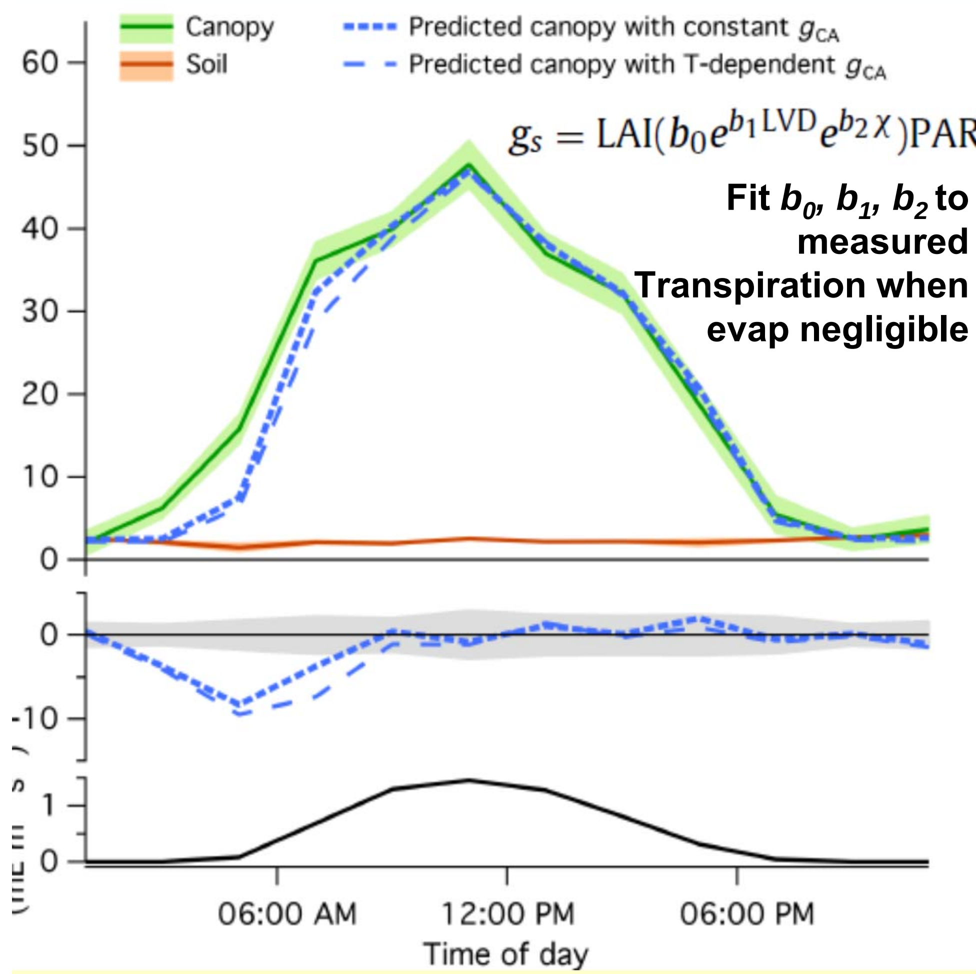


(Wehr, Commane et al. 2017)

Step 2: Predict stomatal (and total) conductances from OCS fluxes





Composite cycle, 2012-2013

(Wehr, Commane et al. 2017)

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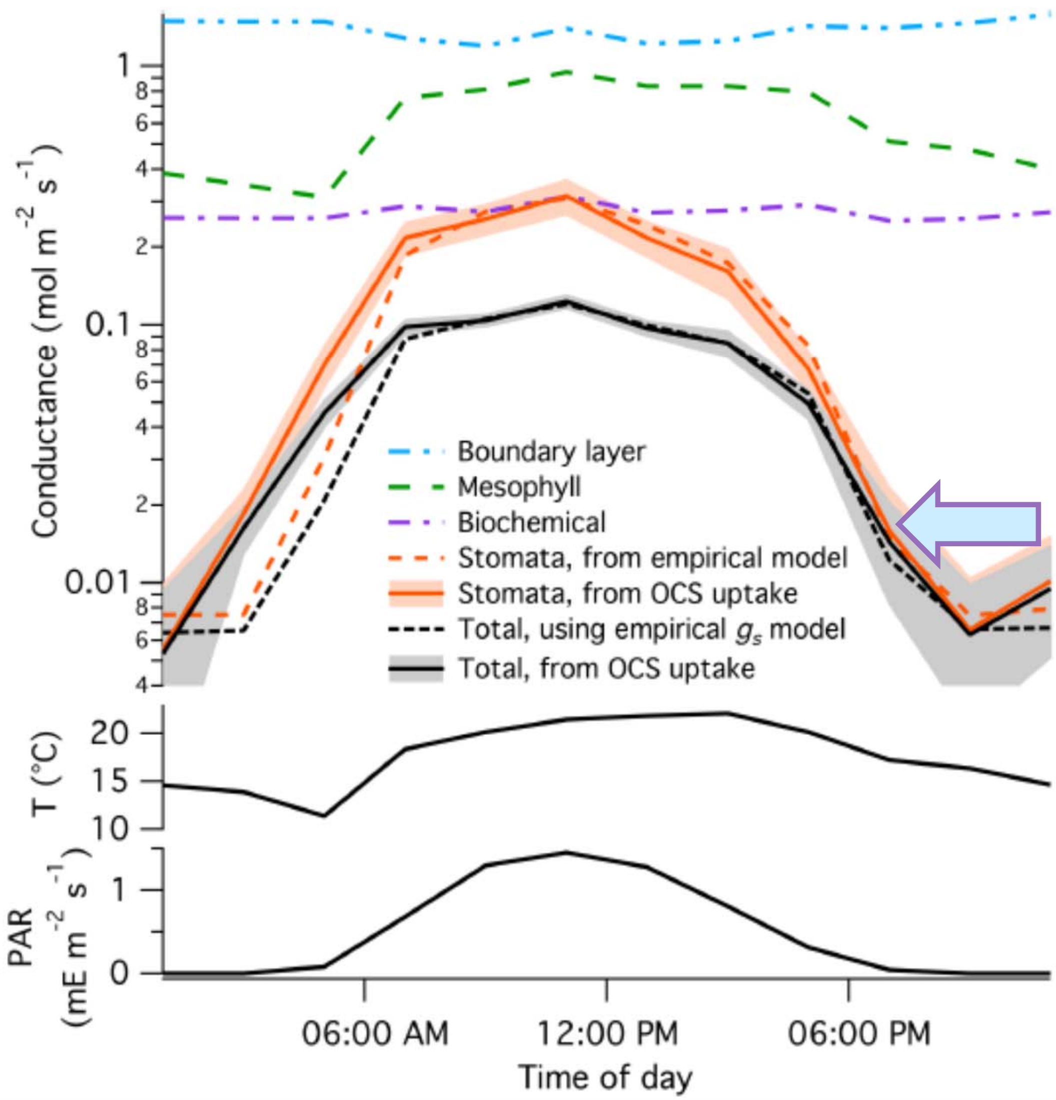


Composite cycle, 2012-2013

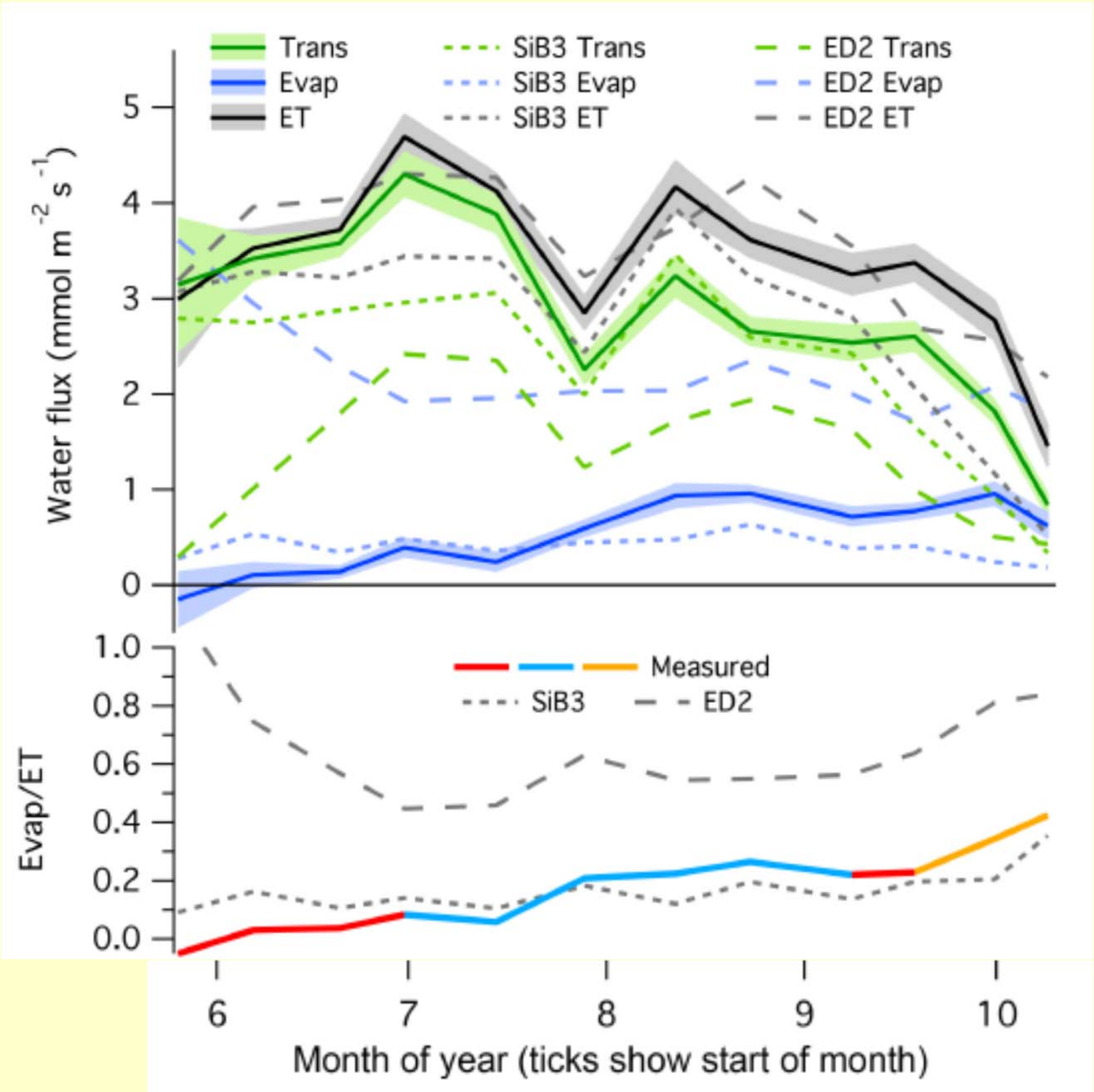
OCS fluxes a very good tracer of stomatal & total canopy conductance

OCS (ie g_s) ≠ GPP,
But g_s is part of GPP

(Wehr, Commane et al. 2017)

Application: allows transpiration-Evaporation partitioning via OCS flux measurements

Composite cycle, 2012-2013



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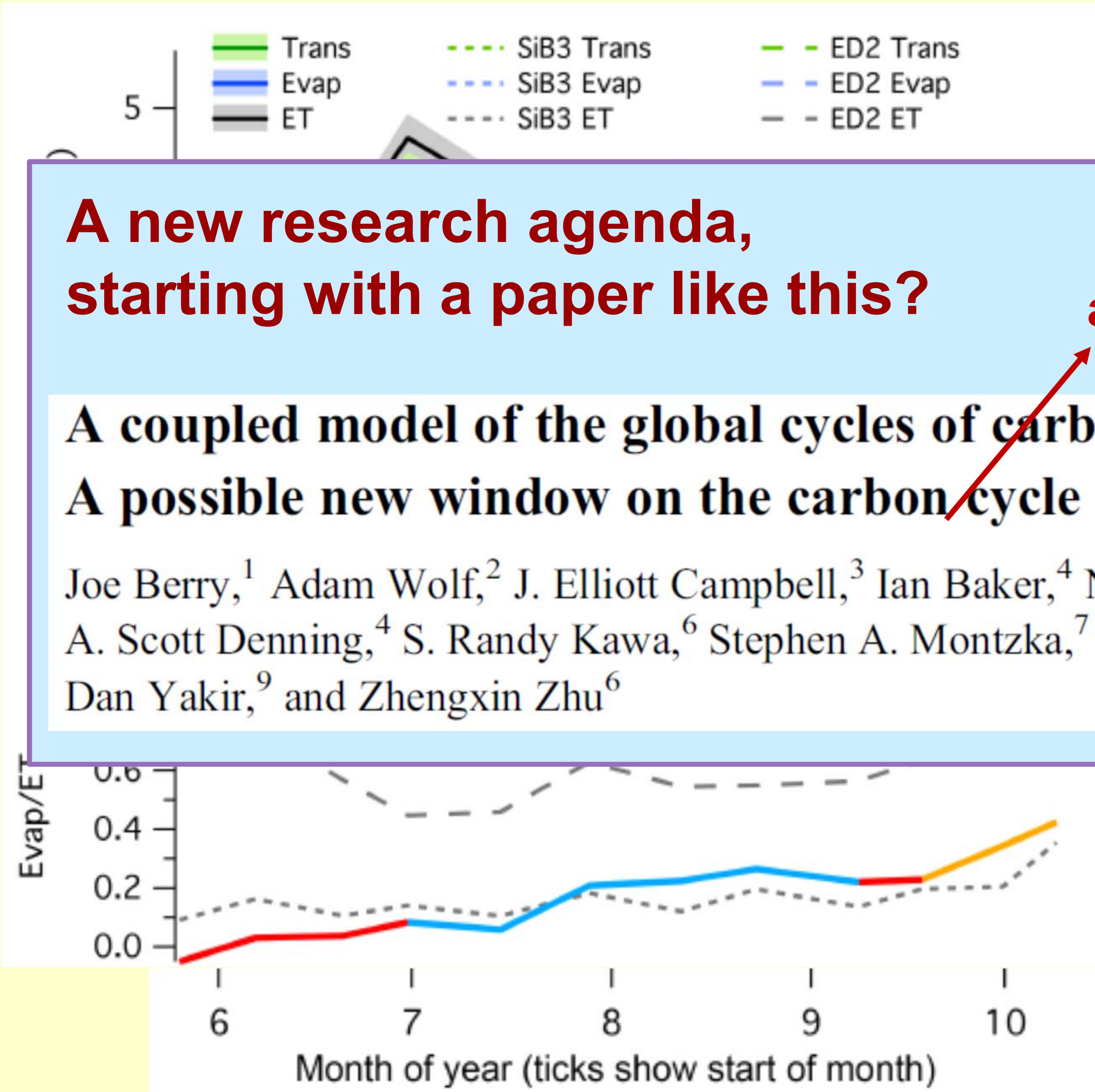

A new research agenda, starting with a paper like this?

and water?

A coupled model of the global cycles of carbonyl sulfide and CO_2: A possible new window on the carbon cycle

H_2O?

Joe Berry,[1] Adam Wolf,[2] J. Elliott Campbell,[3] Ian Baker,[4] Nicola Blake,[5] Don Blake,[5] A. Scott Denning,[4] S. Randy Kawa,[6] Stephen A. Montzka,[7] Ulrike Seibt,[8] Keren Stimler,[9] Dan Yakir,[9] and Zhengxin Zhu[6]