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Interactive comment on "Dynamics of canopy stomatal conductance, transpiration, and evaporation in a temperate deciduous forest, validated by carbonyl sulfide uptake" *by* Richard Wehr et al.

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Response of Authors Wehr et al. (hereafter W) to Anonymous Referee #2 (hereafter AR2):

AR2: This is an excellent paper that I enjoyed reading, which shows novel application (!) of COS flux measurements to estimate canopy scale conductance. This is a welcome deviation from the current focus on using COS as tracer for CO2 uptake and GPP, to address another critical uncertainty in ecosystem research. The paper is well written and provides a rigorous treatment of the topic. The results on the seasonal pat-

terns in conductance and the ET partitioning, including the "counter- intuitive" trends is interesting and intriguing. I have a few comments that can be ad- dressed in minor revisions before formal publication in BC, which is fully warranted.

W: We thank the referee for taking the time to improve our manuscript, and for these kind words.

AR2: – while the estimates of total canopy conductance with COS is straight forward, estimating stomatal conductance is more tricky and is not necessarily well constrained by COS alone. It seems the uncertainties in the modeling of the wide range of the additional parameters is somewhat played down and more indications of the uncertainties involved should be made. –In that sense, the statement that agreement between two methods validate both is a bit strong. I think its "reassuring" (but we should remain cautious)...

W: Indeed, there are sources of substantial systematic uncertainty in the OCS-flux method (mainly the CA activity) and in the water-flux method (mainly the assumptions about evaporation), and they are unfortunately difficult (perhaps even impossible) to rigorously quantify because they are mostly model structural uncertainties rather than measurement uncertainties. That is precisely the motivation for the article, for seeking validation. A key point of the paper is therefore that the two methods give the same answer for stomatal conductance even though very few sources of uncertainty are shared between them. In other words, our conclusions are not subject to the uncertainties in one method or the other, but rather to the uncertainties they have in common. That point is made on p.10, lines 23-30:

"Although our transpiration and evaporation estimates are not direct measurements, only three sets of assumptions are common to both of the methods by which we derived those estimates from our measurements: (1) the assumptions involved in the eddy covariance method, which seem to fail at dawn as discussed in Sect. 3.2; (2) the boundary layer resistance model described in Sect. 2.5, to which our estimates are insensitive (within plausible bounds); and (3) the application of stoma-scale gas transport equations at the canopy scale, which neglects biological and environmental heterogeneity within the canopy but is a sufficiently good approximation to allow the observed temporal patterns of canopy OCS uptake to be precisely predicted from the observed heat and water vapor exchange, as shown in Sect. 3.1. Given the close agreement between the two otherwise independent methods (Sect. 3.2), our estimates of transpiration and evaporation should be accurate."

Hopefully the new flow chart attached to our response to Referee #1 will help readers to see what information goes into each method.

Regarding in particular "modeling of the wide range of the additional parameters", there are 3 modeled parameters involved in going between total canopy OCS conductance (i.e. the OCS measurements) and stomatal conductance: (1) the boundary layer conductance, (2) the mesophyll conductance, and (3) the biochemical conductance. The first two are estimated to be about 3X larger than the peak stomatal conductance, which is therefore not sensitive to them (a point that we will emphasize in our revised manuscript). For example, based on the conductances shown in Fig. 3, the total resistance at midday is about 40% gs, 40% gCA, 10% gm and 10% gb; so a 10% bias in gm or gb would cause only a 2.5% bias in gs. The biochemical conductance (i.e. CA activity) is the overwhelming source of uncertainty, since it is simply assumed–but again, confidence is obtained by agreement between the diel and seasonal patterns obtained from the two largely independent methods.

AR2: –In particular, I found the discussion on the estimation of the biochemical conductance interesting, but perhaps incomplete. There is little reference to the literature available on the topic, both COS (e.g. Berry et al 2103, Stimler et al 2011, etc.), in much of the CO2- 18O literature where similar aspects had to be addressed, and other physiological studies. Ultimately, perhaps CA poses little resistance to COS uptake at all...

W: Thank you for pointing out the lack of supporting literature for our discussion of CA activity, which was an oversight on our part. The salient point for the present manuscript seems to be that the literature on the topic does not give us any means to estimate CA activity. We will therefore change the methods section on CA activity to begin as follows: "The one term in Eq. (1) that is not constrained by measurements, empirical models, or established theory is the biochemical conductance associated with carbonic anhydrase activity, gCA. Apparent CA activity depends on the amount of CA enzyme and on where it is located relative to the intercellular air spaces, but little is presently known about either of those things (Berry et al., 2013)."

AR2: –Although the focus on conductance is commendable, the total ignorance of CO2 exchange (e.g. Fig. 1) is problematic and should clearly be addressed. This are important constraints on COS estimates, and information on COS/CO2 relationships from such study will be very valuable to other COS studies. In fact, it could also be interesting to check if the COS-based g is valid for CO2 exchange, and perhaps to use results on COS-based T, and CO2 to look at seasonal trends of WUE.

W: As the referee is no doubt aware, the total OCS conductance g in Eq. (1) is not strictly valid for CO2 because CO2 uptake is not only a matter of diffusion and CA activity, but also of Rubisco and especially light, as discussed on page 2, lines 12-13. In other words, the leaf relative uptake (LRU, commonly discussed in the OCS literature) is not constant. However, it may be approximately constant–perhaps enough for certain applications–and there is of course much interest in using OCS as a proxy for GPP. So, although this article is about stomatal conductance and ET (not GPP or even OCS per se), we will insert this new, short section on the GPP-OCS relationship for interested readers:

"3.3 Gross Primary Productivity and Leaf Relative Uptake

The success of Eq. (1) in predicting canopy OCS uptake supports the theoretical expectation that canopy OCS uptake is dependent on the atmospheric OCS mixing ratio, the diffusive conductance, and CA activity–and is therefore not directly related to GPP, which depends also on the enzyme Rubisco and on light. There is nonetheless widespread interest in using OCS uptake as a proxy for GPP. So for interested readers, we show how GPP and OCS uptake compare over the diel cycle and over the growing season in Figs. NEW and NEW, using both isotopic and standard partitioning methods for estimating GPP as described in Wehr et al. (2016). We include a common metric for comparison, the leaf relative uptake (LRU): LRU is defined as the ratio of the canopy OCS uptake to GPP, divided by the ratio of the atmospheric OCS concentration to the atmospheric CO2 concentration. Figs. NEW and NEW show that, as expected, LRU is inversely correlated with PAR, as PAR can directly limit uptake of CO2 but not of OCS."

Drafts of the two new figures mentioned are attached to this comment.

Wading into water-use efficiency, while interesting, would be considerably off-topic, and we would prefer not to do so. Intrinsic WUE using the same water-flux-based estimates of stomatal conductance as here has already been reported in Wehr et al., Seasonality of Temperate Forest Photosynthesis and Daytime Respiration, Nature 534, 680-683, doi:10.1038/nature17966, 2016.

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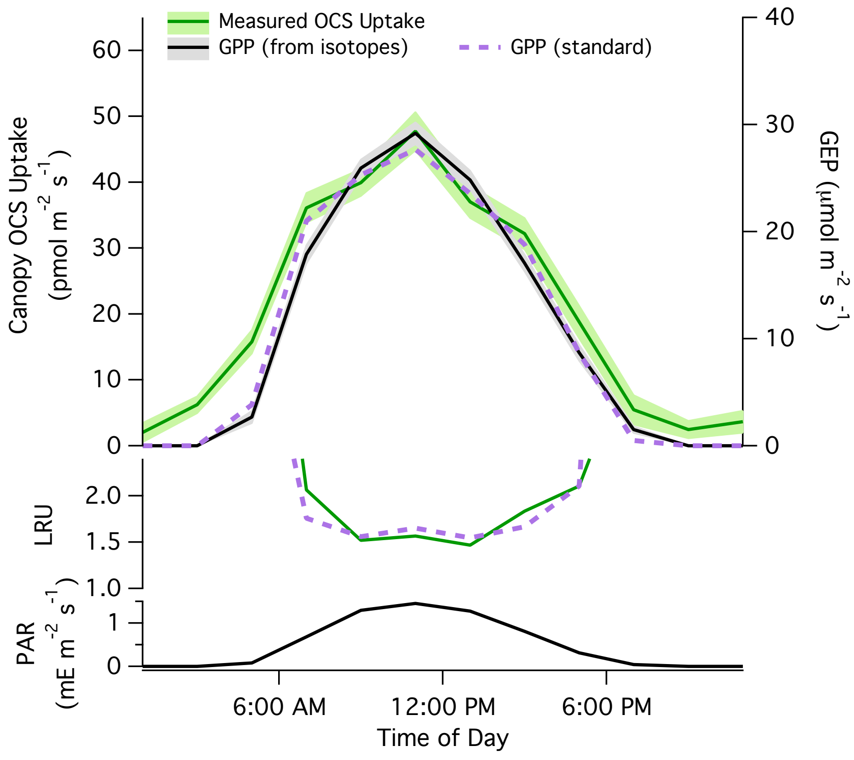

Fig. 1. Diel cycle of GPP and leaf relative uptake

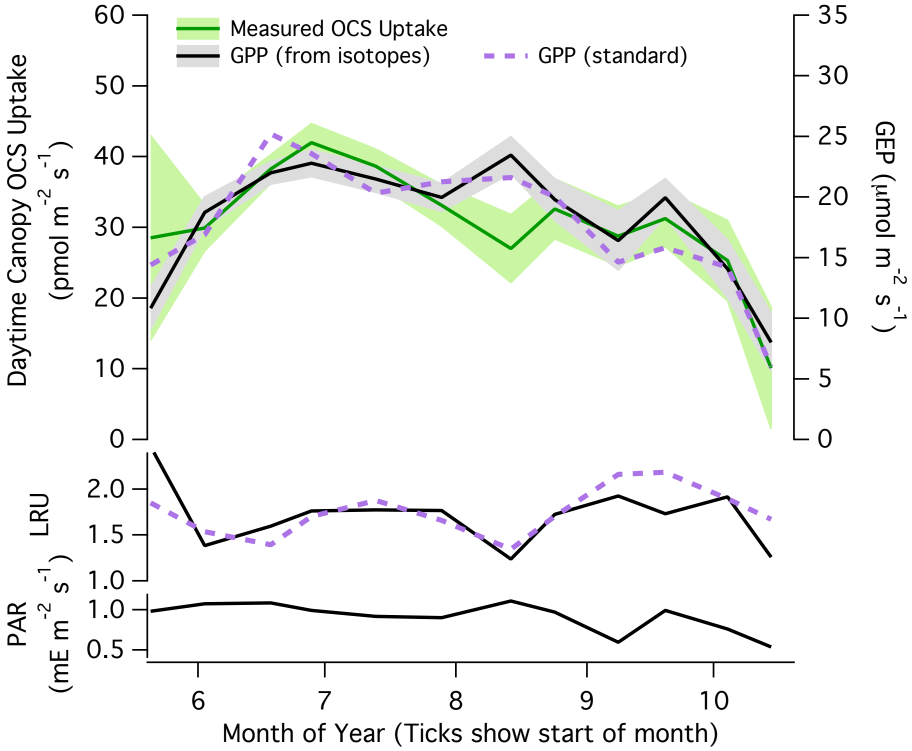

Fig. 2. Seasonal cycle of GPP and leaf relative uptake