"L-band vegetation optical depth as an indicator of plant water potential in a temperate deciduous forest stand" by Nataniel Holtzman et al.

Reply to Reviewer 2

In this manuscript, the relationship between VOD and plant water potential is analysed using an L-band radiometer and in situ measurements of stem xylem and leaf water potential and dielectric constants. In addition to the relationship in general, the authors investigate diurnal changes of VOD and the sensitivity of VOD to the stem and leaf water potential, respectively. The authors provide a comprehensive overview of basic plant hydraulics, the applied VOD retrieval and all conducted measurements. A weakness of the study is the limited number of in situ samples especially from leaves, but the authors are aware of that and describe the associated uncertainties. Despite the low number of samples, the findings presented in the manuscript are interesting and contribute to a better understand the variables which affect VOD over temperate forest.

Response: We thank the reviewer for their thoughtful review.

#266f: In the second half of September, VOD, stem dielectric constant and potential drop significantly. I saw that you refer to this later but consider mentioning it already here.

Response: We thank the reviewer for this suggestion, and added a mention at line 266: "The minimum values of VOD, stem water potential, and soil moisture are all achieved during the same few days in mid-September (Supplemental Figure 2)."

Figure 3c: Do you have an idea why one of the stem water potential curves is very close to leaf water potential on July 10?

Response: The stem water potentials were measured on 3 trees within the footprint of the radiometer, while the leaf water potentials were measured on a different set of 5 trees next to the tower but not in the footprint. Although leaf potentials are generally lower than stem potentials on the same tree in daytime due to being more directly affected by transpiration, it is plausible that a leaf potential from one tree may be similar to a stem potential from another tree. We will add a clarifying sentence to the figure caption: "Note that stem water potential and leaf water potential were measured on different sets of trees."

Figure 4: The VOD curve presents the average from April-October. You show in the supplement Fig. 3 that the VOD from July 9-12 does not differ much from the April-October average apart from the absolute values. Have you considered showing both figures in the main part of the manuscript, or adding the July-VOD to Fig. 4? In my opinion this would add information, as April-October is almost the entire growing season, whereas in mid-July not many LAI/biomass-related dynamics occur in temperate forest.

Response: We thank the reviewer for the helpful suggestion. Indeed, a combined figure showing the early July VOD diurnal cycle along with the April-October one works well, as shown below. We will include this figure in the main manuscript and delete Supplemental Figure 3.

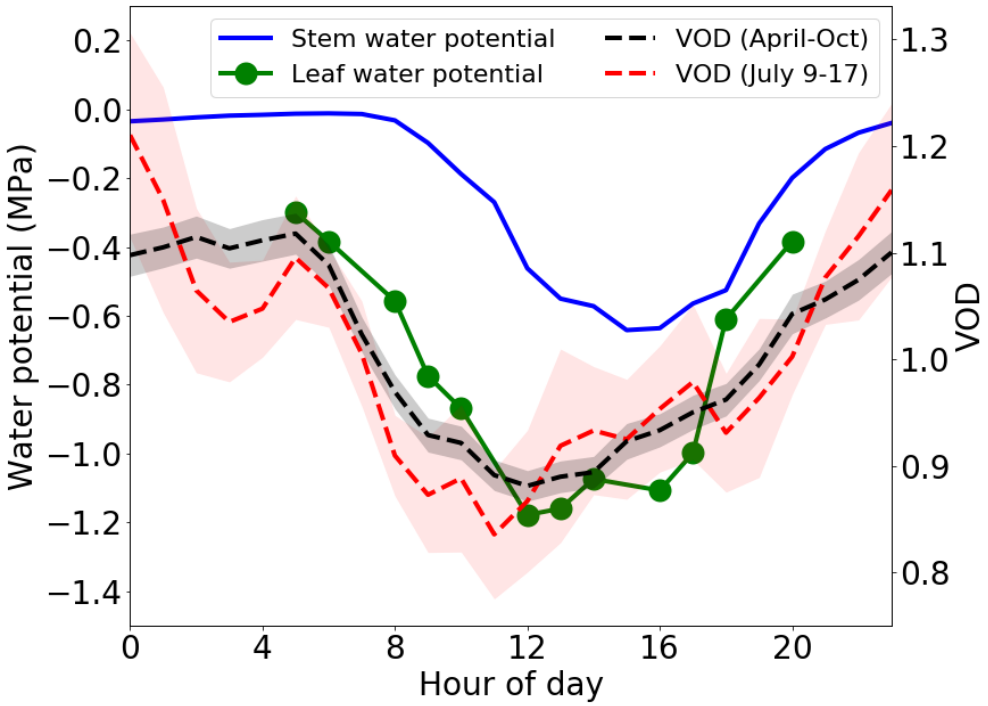


Figure 4. Average diurnal cycles of VOD and plant water potential. Shaded area is a range of 1 standard error for VOD.

#296f/Figure 5a: The VOD-leaf water potential relationship also seems to break down, but during morning and evening hours and at a leaf potential around -0.5 MPa. Can you elaborate on this?

Response: We agree with the reviewer that there is more noise in the VOD-leaf water potential relationship above -0.5 MPa than below it. On the other hand, it is possible that there would be more noise below that water potential as well if we had measured leaf water potential on more days; it is difficult to make conclusions with the small sample size we have.

Furthermore, the relationship has no statistical change in slope at -0.5 MPa. We verified this lack of a breakpoint by fitting the following model that represents a piecewise linear relationship:

$$VOD = \beta_0 + \beta_1\psi + \beta_2\mathbb{I}[\psi > -0.5] * (\psi - (-0.5))$$

The last term contains an indicator function that is 1 when water potential is greater than -0.5 MPa and 0 otherwise. This term is constructed so the model will still be continuous at -0.5 MPa regardless of a change in slope. The R-squared of this model is 0.58, the same as that of the original simple linear model without a breakpoint; thus adding the breakpoint does not make the model more accurate. The piecewise model also has a less negative Akaike information criterion

value compared to the simple linear model (-45.5 compared to -47.5) which indicates that the simple linear model is to be preferred in a model selection context.

Figure 5/6: You obtain a much better relationship in Fig. 6c than in 5a, just by leaving out the measurements during which you did not measure the leaf dielectric constant (R=89 vs. R=76, no "break down"/vertical linear relationship at -0.5 MPa in Fig. 6c). Can you explain if there is any reason for this? When did you measure the leaf dielectric constant, when not - just randomly?

Response: This is a good observation. Leaf permittivity was measured during July 9, 10, and 11, but not measured on July 12 due to the sensor being used for a different experiment that day.

#324f/Figure 7: I agree that there is a linear relationship over the entire growing season. But when looking at the individual months, there is a clear difference in the slope and distinctiveness of the relationship. You address this in the discussion, but maybe briefly address it already here. E.g., add the R values for each month. Are the monthly differences due to weather, e.g. soil moisture? Or rather due to the gaps between the three installations (but then you would only have it in the leaf water potential). Or due to phenological processes in the trees? You could also show the scatterplots using symbols for the three months and colours for soil moisture values.

Response: We have added a table (shown below) in the supplemental information with both Pearson and Spearman correlations for each separate month, for each of the three scatter plots in figure 7.

We have added the following to the discussion section 4.1 at line 401:

> "Looking at the three installations separately, the highest correlations between all 3 pairs of variables are found in September (Supplemental Table 1). This may be due to dry conditions at that time creating a wider range of stem water potential and stem dielectric values, providing increased signal during September for the same amount of noise."

As discussed in the last two paragraphs of section 4.1, we attribute changes from month to month in the form of the VOD-stem dielectric relationship to changes in the individual tree containing the dielectric probe that were not representative of the whole stand. We also attribute changes in slope in the VOD-stem water potential relationship to the trees simply reaching especially low water potentials late in the growing season, at which point the pressure-volume curve (and thus the water potential-VOD curve) may become more non-linear.

Stem water potential and stem dielectric

Period	R	ρ
All	0.65	0.47
July	0.53	0.58
Aug	0.40	0.28
Sept	0.66	0.51

Stem dielectric and VOD

Period	R	ρ
All	0.68	0.60
July	0.31	0.36
Aug	0.33	0.41
Sept	0.74	0.69

Stem water potential and VOD

Period	R	ρ
All	0.65	0.54
July	0.32	0.31
Aug	0.66	0.53
Sept	0.71	0.64

Supplemental Table 1. Pearson correlations (R) and Spearman rank correlations (ρ) for the three pairs of variables shown as scatter plots in Figure 7, for all data and individually for each of the three periods that the stem psychrometers were installed (corresponding to three months).

Can you include e.g. SMAP VOD over the area (morning and evening overpasses if available) and (briefly) show main differences/similarities to your in situ VOD?

Response: This is a very good suggestion, which was also made by Reviewer 1. We have added a comparison to a SMAP VOD product, discussed as follows, and plotted the corresponding data in the revised Supplemental Figure 2 (shown below).

In the methods section at lines 239-244 we added the following:

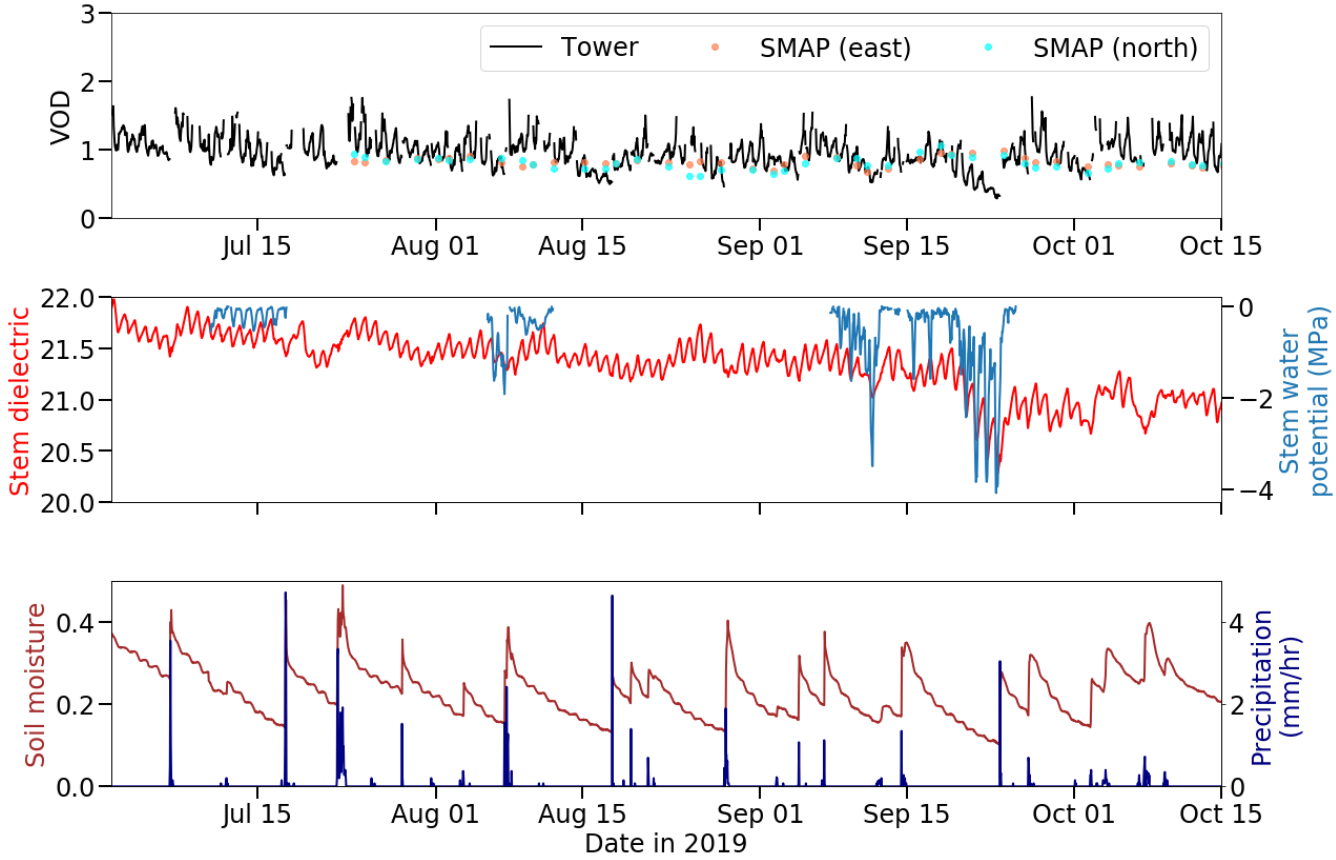
> "Finally, we compared our tower-based single-channel VOD retrievals with VOD retrieved from SMAP satellite data using the multi-temporal dual-channel algorithm (MT-DCA) (Konings et al., 2017). The spatial resolution of this SMAP dataset is 9 km. The SMAP pixel containing the Harvard Forest tower site is masked out in the MT-DCA data, as are the adjacent pixels to the west and south, because of proximity to a water body (the Quabbin Reservoir). Thus, we compared our tower-based VOD to the MT-DCA VOD from the adjacent SMAP pixels to the east and north of the tower site."

In the results section at lines 278-286 we added the following:

> "As illustrated in Supplemental Figure 2, the magnitude of VOD retrieved from the tower-based radiometer using the single-channel algorithm is similar to VOD retrieved from the

SMAP satellite over nearby pixels using the MT-DCA. This close match adds to our confidence that our retrieved VOD is in a realistic range for the Harvard Forest site. However, VOD from the tower radiometer shows more detailed temporal dynamics than what is seen from SMAP. For example, between August 7 and August 15 the tower VOD first increases and then decreases, following the changes in stem dielectric. In contrast, SMAP VOD shows little change over that time period, likely due to spatial heterogeneity within the SMAP footprint that does not affect the tower radiometer footprint."

Unfortunately, evening VOD retrievals from the multi-temporal dual-channel algorithm are not available.



Supplemental Figure 2. Time series of VOD, stem xylem dielectric constant at 70 MHz, stem xylem water potential, soil moisture, and precipitation at Harvard Forest.

We also thank the reviewer for catching several typographical errors in the manuscript. These errors have now been fixed as follows:

#71-72: check sentence structure

Line 71 now reads "Momen et al. (2017) compared fluctuations in satellite-based X-band VOD to *in situ* leaf water potential measurements in three forest and woodland sites"

#152: they/the, parentheses

Line 152 now reads “Depths are approximate, as the sensing volume varies depending on soil moisture status and signal magnitude: it is strongest close to the sensor and decreases away from a sensor.”

#322: consider turning around “Fig. 5” and “Fig. 6”, or use a different wording than “: : : because the former” - it’s a bit confusing to the reader which figure the second half of the sentence refers to

Line 322 now reads “The VOD-leaf potential correlation in Fig. 6 is different from that in Fig. 5, because Fig.6 is limited to leaf water potential observations that coincided with a leaf dielectric constant observation.”

#451: Fig. 3 and 4 instead of 5 and 6?

Line 451 now reads “Between 5 AM and 8 AM, stem xylem potential stays high while VOD and leaf potential begin to decrease, as shown in Figs. 3 and 4.”

#461: sensitivity

Line 461 now reads “Nevertheless, the relatively larger sensitivity of VOD to leaf water potential than to stem water potential is notable because most of a tree’s mass is in its trunk.”