Interactive comment on "Using GNSS-based vegetation optical depth, tree sway motion, and eddy-covariance to examine evaporation of canopy-intercepted rainfall in a subalpine forest" *by* S. P. Burns et al.

Reply to Referee #1

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The comments by Referee 1 are greatly appreciated. We have listed the comments by Referee 1 below in italics, followed by our responses.

Burns et al. measured warm season ET, VOD and tree sway in Colorado subalpine forest to was to track evaporation of intercepted water. They found that a canopy intercepted water can take a tremendous amount of time to evaporate and thus can contribute to ET at the site especially on dry days after a rain event. This work well describes VOD and tree sway as a method of measuring evaporation of canopy interception.

This is an accurate summary of our manuscript and the goals of the study.

Under the category "Comments":

To help distinguish these VOD measurements from more common measurements excluding, I suggest to specify in the acronym that this is VOD plus intercepted water. For example, VOD underscore "int" to distinguish from studies where VOD refers to water only within the tissues.

Though we appreciate the concept of making this distinction, the practical logistics of applying it are a bit difficult, and (in our opinion) could lead to confusion. For example, there are several plots that show VOD in both dry and wet conditions (e.g., Figs. 2 and 3) as well as plots that show VOD in only dry conditions (Fig. 5). So, it would be inaccurate to label the VOD in dry conditions as VOD_{int}. We think it is clear that the focus of our study is on how VOD is affected by wet conditions and leave it to the reader to distinguish when the forest surfaces are wet and/or dry.

line 66: Please clarify what the "small pockets" are referring to.

The "small pockets" were referring to the tracheids within the xylem that move the water in a conifer tree. In an attempt to clarify this text, we changed the words "small pockets" to "tracheids within the xylem that are on the order of 5 to 80 μm in diameter and less than 5 mm long". We also added a new reference to Hacke et al. (2015) which contains this information. The sentence has been re-written as,

> "This is because intercepted water forms a water layer which attenuates and reflects microwave signals more than internal water found within the xylem tubular structures; for conifers, tree water is primarily found within xylem tracheids that are on the order of 5 to 80 μm in diameter and less than 5 mm long (e.g., Tyree and Ewers, 1991; Hacke et al., 2015)."

line 75: Parentheses missing around GNSS

The parentheses have been added.

line 95: The inclusion of the CLM analysis while exciting comes up abruptly here and the importance of this analysis could be integrated sooner. Suggest to reference Burns et al 2018 or specific the concepts from that paper that will be expanded upon here.

This is a good point. We added some context for the Burns et al. (2018) study. The original paragraph was:

> "Though the focus of our study is on observations, we also wanted to compare the VOD and tree sway observations with land-surface model results. To achieve this, we used the Community Land Model CLM4.5 (e.g., Oleson et al., 2013). This expands on previous work with CLM4.5 at US-NR1 by Burns et al. (2018) to include modeled canopy surface water content (which we expect to be comparable with the VOD and tree sway frequency measurements)."

The revised paragraph is:

> "Though the focus of our study is on observations, we also wanted to compare the VOD and tree sway observations with land-surface model results. In Burns et al. (2018) the Community Land Model CLM4.5 (Oleson et al., 2013) components of the latent heat flux (transpiration, canopy evaporation, and soil evaporation) were compared with the measured ecosystem-scale latent heat flux. Since the VOD and tree sway frequency measurements are related to canopy water content (and thus canopy evaporation), we compared these observations to CLM4.5-modeled canopy surface water content."

We will also consider moving the location of the CLM4.5 comparison within the Introduction.

line 163: Suggest to replace "use the concept" with "assume"

We agree and changed "use the concept" to "assume".

Figure 3, 8: It would be helpful to please clarify in the results why there is not diurnal cycle of VOD where VOD peaks in the morning and decreases into the afternoon even on the dry days. This is common finding in Holtzman et al. 2021 Biogeosciences and Yao et al. 2024 Geophysical Research Letters. Later on VOD does increase due to rain but do the trees not dehydrate when transpiring through the day?

The finding that VOD had no diel cycle in dDry conditions was a surprise. This is highlighted in Fig. 5 which is only data from the dDry days (so there should be minimal effect of precipitation). In Figs. 5c and 5e both the tree sway frequency data and tree bole moisture sensors show a diel cycle that suggests transpiration effects on the tree water content. Clearly VOD (in Fig. 5d) does not have a diel cycle in these conditions. We address this with the following text at the end of Sect. 3.2:

> "There is an important implication from the dDry periods (when most of the ET is transpiration, not evaporation). Though ε_a had a dDry diel cycle with a clear early-morning maximum and late afternoon minimum, VOD had relatively small variation without any apparent pattern (Fig. 5). This suggests that, at our site, VOD changes were largely controlled by water on the canopy *surfaces*, not the the internal water content of the trees. In contrast, tree sway frequency had a diel pattern on dDry days (Fig. 5c) that was similar to that of ε_a (Fig. 5e), suggesting that tree sway frequency was more affected by internal tree water content changes than VOD. Ciruzzi and Loheide II (2019) has also shown that tree sway motion is affected by changes in internal tree water content. Other possible factors could be an effect of the temperature diel cycle on tree sway frequency, or too much noise in the VOD measurements to capture a diel cycle in internal tree water content."

In the last sentence we report a few possible reasons that we did not find a clear diel signal in the VOD data during dDry conditions. However, taking a closer look at the diel cycle in Holtzman et al. (2021) (their Fig. 4) and Yao et al. (2024) (their Fig. 2) we note that have diel VOD ranges of 0.85 to 1.1 and 0.62 to 0.7, respectively. Both of these studies are from deciduous forests in the eastern USA. At the US-NR1 subalpine forest, our diel range in VOD for dry conditions is on the order of 0.36 to 0.38 (see Fig. 5d). Therefore, another possible reason for the lack of diel cycle in VOD in dry conditions is the lower water content of the subalpine forest trees compared to deciduous trees in a more humid/wet environment. We will add a note with the ranges of the Holtzman/Yao diel cycle somewhere within our manuscript as a possible reason for the lack of a VOD diel cycle in dry conditions. We welcome any additional comments/ideas by reviewer 1 related to this.

336-337: Please describe the B0, G1, A1, and F2 cases here or in the methods sections for reference to the reader.

The meaning of B0, G1, A1, and F2 are described at the end of Sect. 2.3. On line 336-337, we have added a reference back to Sect 2.3 so this information can be easily found.

419: This is does not seem like a novel finding given your reference to the common method of removing these data in the introduction. Please clarify the novelty here.

We agree that our study builds on previous suggestions (e.g., Holtzman et al., 2021; Yao et al., 2024) that time periods following precipitation affect VOD. However, in Holtzman et al. (2021), they suggested that the canopy wetness did *not* affect VOD (i.e., Sect. 3.3 in Holtzman, et al. is entitled, "**Canopy interception fails to influence VOD**"). And, in Section 4.4, they write,

"More research is needed to better understand how VOD sensitivity varies between water internal and external to the canopy.".

So, Holtzman et al. (2021) did not make a conclusive statement on this issue. Yao et al. (2024) showed how wet periods affected the canopy (i.e., their Fig. 2c), which they used this as evidence to avoid wet periods. In contrast, we are stating these "wet" periods are valuable for looking at canopy evaporation and specify how long it takes for the canopy to dry out (which is the novel information added by our study). We agree that these subtle points in Holtzman and Yao should be clarified in our manuscript. If there are other studies that have specifically looked at this issue that we have not included within our manuscript, please let us know about them. We will modify our text to better highlight this point.

477: suggest to replace leaf with needles for clarity.

Good point. We changed "leaf" to "clumped needles".

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