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 #4

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The comments by Referee 4 are greatly appreciated. We have listed the comments by Referee 4 below in italics, followed by our responses.

This research investigates promising and novel techniques to predict rainfall interception and, thus indirectly, canopy evaporation. The authors use L-band microwave active microwave attenuation data (vegetation optical depth) from a GNSS doublet and tree sway data measured by a an accelerometer placed on the trunk of a tree canopy. The study is set in an subalpine, high elevation needleleaf forest in in Colorado/USA. The authors demonstrate the ability of both proxies to correlate with onset and drydown of precipiation events, evapotranspiration and modeled interception storage from different land surface model (CLM4.5) parametrizations. The data sets and analysis presented by the authors allow for the conclusion that these techniques are promising tools to measure interception storage and that they hold potential to supplement/validate land surface models that are known to have high uncertainties in interception fluxes the their parametrization of the canopy, and uncertainties in EC water flux measurements during rain events. This study is of great quality. However, the authors should address the comments below before publication.

This is an accurate summary of our study and we appreciate the positive comments that our study is of "great quality". The comments by Referee 4 focus on the footprint analysis and details about the VOD measurements. To reply in a timely manner, we only address two of the specific comments below. The other comments will be addressed in our complete responses to all reviewer comments that will be included in the paper revisions.

Under the category "Major comment":

Please elaborate on the robustness of tree sway motion being able to represent interception storage without the need to account for wind speed as a possible confounding factor. In this context, it would be valuable to find sway motion data as a function of wind speed—e.g. in fig. 10 and at least in one of the plot over time—to clarify on this relationship and include this missing piece of information.

Based on mechanical theory, tree sway frequency f_{sway} acts like a damped harmonic oscillator; therefore, is does not depend on wind speed. This is highlighted in Sect.3 of Raleigh et al. (2022) who show that f_{sway} is described by:

$$f_{sway} \propto \frac{1}{2\pi} \left(\frac{K}{m} \right)^{0.5}, \tag{1}$$

where K is the flexural rigidity and m is the mass of the tree. As precipitation accumulates on the tree leaves and branches, m changes which alters f_{sway}. We will further address this aspect of our study more explicitly in our revised manuscript.

Under the category "Minor comments":

Comments 1–4 will be addressed at a later time.

5. 433/4: The size of the EC footprint has not been explicitly mentioned in the text. Also, which footprint size of VOD as your referring to in this statement? To make a statement about the footprint size (a very relevant discussion) the referee suggests to state that although the footprint sizes between all technique partly or greatly differed, the good correlations could be found etc.

We thank Referee 4 for noticing this shortcoming. Shortly after making the submission, the lead author realized that though we make reference the ET flux footprint, we did not include any specific details about it. We appreciated that this oversight was noticed by Referee 4, and will include the following information in the revised manuscript. First, we will cite Chu et al. (2021) who show a footprint climatology and suggest that the US-NR1 footprint has a size of around 500 m^2, but depends on wind direction and atmospheric stability. A more explicit view of the US-NR1 footprint is shown below for five different atmospheric stability conditions in Fig. R1 for winds from the west, and in Fig. R2 for winds from the east. For comparison purposes, we include the larger VOD footprint from Fig. 1 on the same plot. The tower footprints have been calculated using the simple footprint model of (Kljun et al., 2015). For the revised manuscript, we plan to include similar plots in the supplemental figures and improve the details about the ET flux footprint within the text. One important difference between the VOD and flux footprints is that the VOD footprint does not vary with wind direction or atmospheric stability.

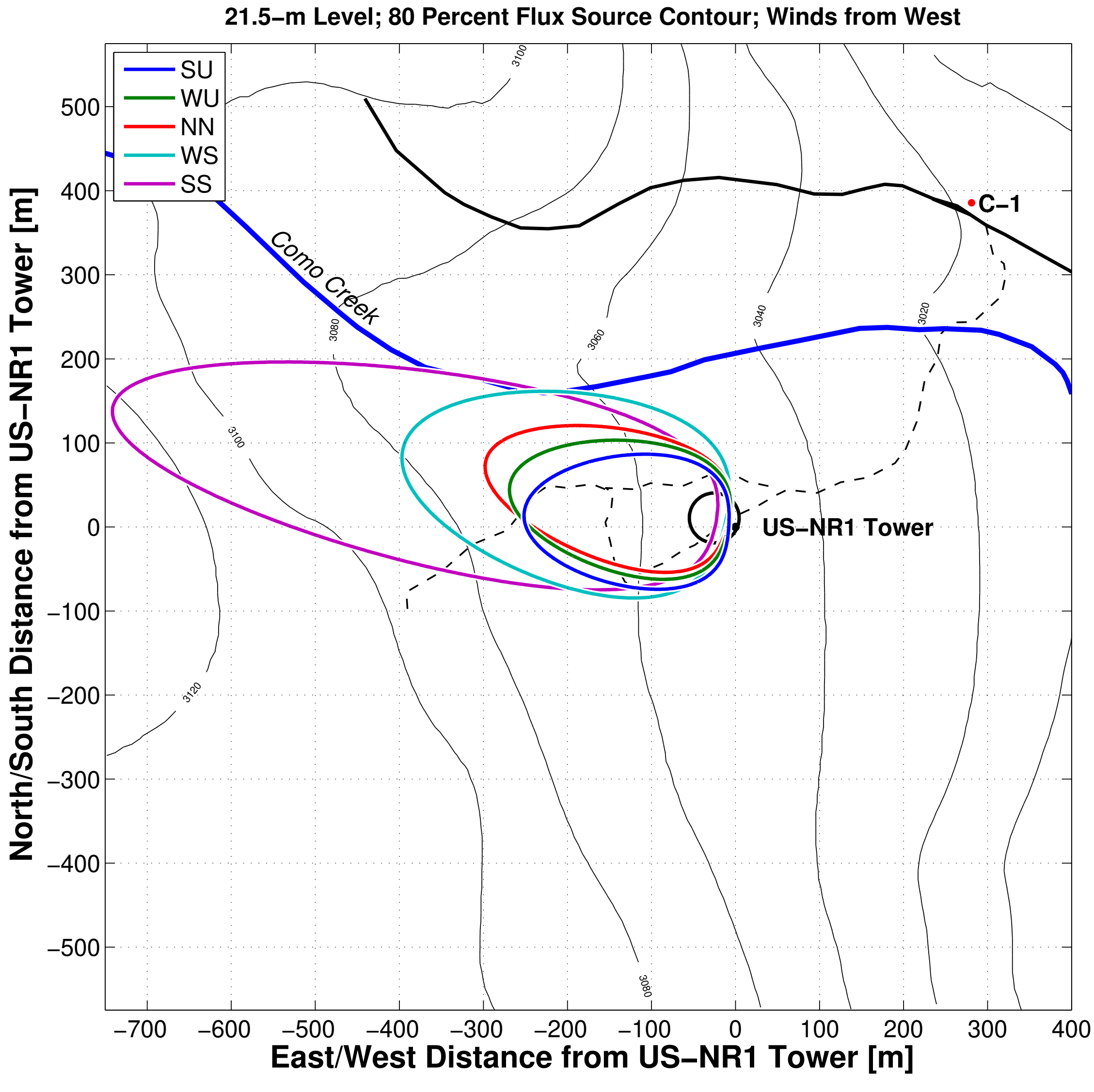

Figure R1: Contours of the 80% flux footprint are shown for winds from the west for different stability classes (SU, strongly unstable; WU, weakly unstable; NN, near-neutral; WS, weakly stable; SS, strongly stable). Footprints are calculated based on Kljun et al. (2015) and shown as distance [meters] from the main US-NR1 flux tower. The larger VOD footprint from Fig. 1 is shown as a black circle.

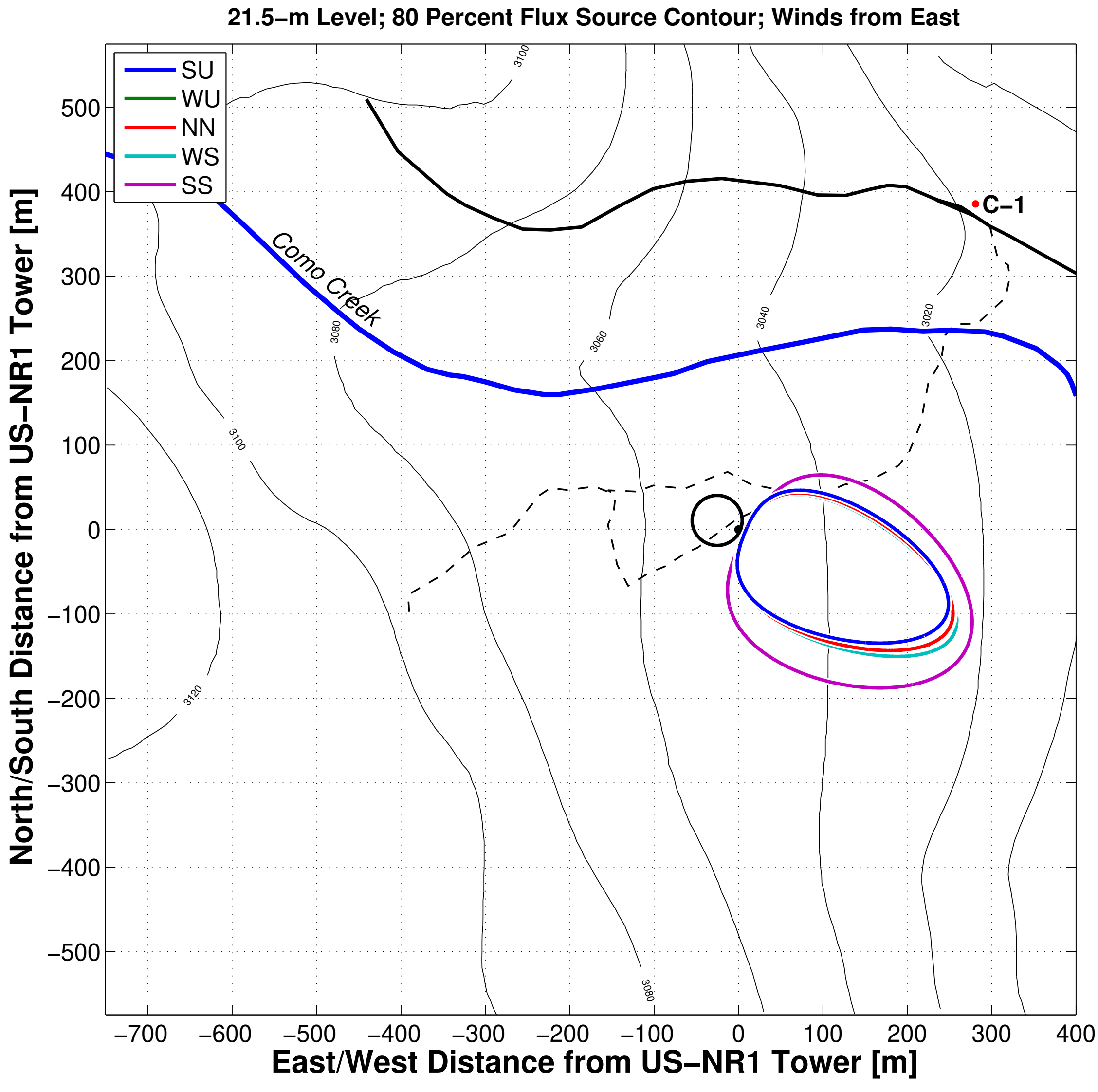

Figure R2: As in Fig. R1, but for winds from the east.

References

Chu, H., Luo, X., Ouyang, Z., Chan, W. S., Dengel, S., Biraud, S. C., Torn, M. S., Metzger, S., Kumar, J., Arain, M. A., Arkebauer, T. J., Baldocchi, D., Bernacchi, C., Billesbach, D., Black, T. A., Blanken, P. D., Bohrer, G., Bracho, R., Brown, S., Brunsell, N. A., Chen, J., Chen, X., Clark, K., Desai, A. R., Duman, T., Durden, D., Fares, S., Forbrich, I., Gamon, J. A., Gough, C. M., Griffis, T., Helbig, M., Hollinger, D., Humphreys, E., Ikawa, H., Iwata, H., Ju, Y., Knowles, J. F., Knox, S. H., Kobayashi, H., Kolb, T., Law, B., Lee, X., Litvak, M., Liu, H., Munger, J. W., Noormets, A., Novick, K., Oberbauer, S. F., Oechel, W., Oikawa, P., Papuga, S. A., Pendall, E., Prajapati, P., Prueger, J., Quinton, W. L., Richardson, A. D., Russell, E. S., Scott, R. L., Starr, G., Staebler, R., Stoy, P. C., Stuart-Haëntjens, E., Sonnentag, O., Sullivan, R. C., Suyker, A., Ueyama, M., Vargas, R., Wood, J. D., and Zona, D.: Representativeness of eddy-covariance flux footprints for areas surrounding AmeriFlux sites, Agricultural and Forest Meteorology, 301-302, 108 350, doi:10.1016/j.agrformet.2021.108350, 2021.

Kljun, N., Calanca, P., Rotach, M. W., and Schmid, H. P.: A simple two-dimensional parameterisation for Flux Footprint Prediction (FFP), Geosci. Model Dev., 8, 3695–3713, doi:10.5194/gmd-8-3695-2015, 2015.

Raleigh, M. S., Gutmann, E. D., Van Stan, J. T., Burns, S. P., Blanken, P. D., and Small, E. E.: Challenges and capabilities in estimating snow mass intercepted in conifer canopies with tree sway monitoring, Water Resources Research, 58, doi:10.1029/2021WR030972, 2022.