Respond to reviewer #2: Q/C (Question/Comment);R(Response)

Thank you so much for dedicating significant time to read and comment on our manuscript, and the level of scrutiny you exercised. We appreciate your detailed comments and recommendation for the manuscript. Here, in the open discussion period, we would like to address your main concerns and keep responding to all your remaining comments to the final revision.

Line 112:

Q/C: Why10 min instead of the usual 30 min perturbation time scale?

R: According to Vickers et al. (2009) for the sun-lit daytime flux period using a perturbation time scale of 10 min reduces the random sampling error significantly compared to 30 min. Reducing the perturbation time scale from 30 to 10 min increases the systematic error only by a few percent, which is small compared to other sources of uncertainty. While 30 min is often used in the literature, it is often not the optimal choice. It depends on a study's objectives. Our intention was to extract the turbulent flux (as opposed to other non-turbulent contributions to the mass and heat exchange) while limiting its overall uncertainty. To this end, 10 min is an excellent choice.

Line 171:

Q/C: what is the role of TKE on it?! It should be the result of the convective heat flux and associated with windspeed, shouldn't it?!

R: The convective heat loss from coned fibers scales with TKE; please refer to figure 5 in Lapo et al. (2020). TKE by definition, is proportional to the squared turbulent velocity perturbations. Yes, TKE enhances the heat loss from the heated coned fibers and is the reason why a difference in fiber temperatures is sensed.

Line 192:

Q/C: Why not?! Could you comment on it?!

R: Rotation angles in weak-wind environments such as forest canopies are often much larger compared to those above strong-wind short-statured vegetative canopies and may introduce additional uncertainty rather than helping to fulfill the theoretical requirement of Reynold'a second postulate. In the roughness sublayer the flow – by definition – responds to the presence of individual flow obstacles, including tree trunks, stems, and undergrowth, which often leads to a significant wind direction dependence of the rotation angles. Here, we decided not to use any rotation for the quadrant analysis for those reasons but have not conducted a detailed investigation of the resulting uncertainties. We may do so for the final round of revisions and include the results in the manuscript if important implications arise.

Line 251:

Q/C: Could you explain why this option was chosen?!

R: We increased the length of the shroud from 1.5 m at EBG (Part 1) to 3 m for the forest environment (Part 2) because the minimum resolvable scale with fiber-optic cable and DTS device used in this experiment is 30 s (Freundorfer et al. 2021). In the preparatory phase of the experiment, our analyses yielded a mean magnitude of the vertical wind speed perturbations of 0.1 ms^{-1} for the Waldstein subcanopy site; hence a shroud length of at least 30 s * 0.1 ms^{-1}= 3 m seemed optimal to sample the passing eddies by FODS. The turbulence spectrum in rough forest canopies is dominated by organized turbulent motions resulting in more low-frequency turbulence compared to short-vegetated grasslands; hence the integral length scale is larger. This adjustment seemed necessary to capture to main energy-containing eddies.

Line 262:

Q/C: So, if you found this, what are the reasons to publish the paper/results?! Only to show the idea?! I did not understand the real application. Could you please describe it better?!

R: We think there is a misunderstanding here. In the first part of the study, we designed and tested the shroud aimed at observing the vertical flow using FODS in the forest environment; and it failed for the reasons reported. However, we believe reporting this failure has merit as often one learns more from failure than from success. We want to emphasize that failure is always part of scientific work, and the community can also learn from failures. The general fluid dynamics and engineering approach though is physically plausible and could have yielded quantitative results. However, in the second part of the study, we report on a significant finding from an alternative, unshrouded section of the fiber-optic cable, which we tested in comparison. Here, FODS could observe the vertical turbulent flow even without a shroud during the weak wind situation, specifically at the height where the minimum horizontal wind speed in the sub-canopy occurs. This is a significant finding propelling the FODS technique from measuring only first-order to meaningful second-order statistics, including vertical fluxes.

Line 352:

Q/C: is this conclusion associated with the observations made at **line** 262?

R: The reported failure is related to the first part of the study in which the shroud did not yield meaningful results, while the reported conclusion relates to the second part of the paper, where the coned fibers could observe the coherent structures without a shroud. In our revisions, we will clarify this misunderstanding; thanks for bringing this to our attention.

Line 540:

Q/C: I was expecting to have ejection/sweeps not occurring at the same time,... But at this Figure 6, there are a lot of time interval that both occurs at the same time. See it (as an example), before 5:10 and 5:20 h,

R: As you have mentioned, the sweep and ejection phases are not happening simultaneously at any one location, while they do, of course, in a sufficiently larger fluid volume as the sweep-ejection phases are continuous cycles of the mixing-layer scale vortices. The illustration of 1h of high-resolution data leads to believe that they do co-occur at the single measurement location. We will adjust the time axis during final revisions.

Line 575:

Q/C: why the sensible heat flux is mostly positive during nighttime?! Please, explain it

It occurs due to typical counter-gradient fluxes in the sub-canopy induced by non-colocated heat sources with cooling at the top of the canopy and warming from the forest floor and subcanopy. It is a known phenomenon in forest canopies, see e.g. Denmead & Bradley (1985) .

Counter-gradient flux definition with AMS Glossary:

A flux of some variable opposite to the mean gradient of that variable. For example, if temperature decreases upward, then a counter-gradient heat flux would be downward, from cold to hot. While this appears to violate a law of thermodynamics that states heat flows from hot to cold, those laws are found not to be violated when nonlocal motions (air parcels moving across finite distances) are considered. Flux is not caused by, nor related to, the local gradient when coherent structures are present.

References:

Vickers, D., Thomas, C., & Law, B. E. (2009). Random and systematic CO2 flux sampling errors for tower measurements over forests in the convective boundary layer. agricultural and forest meteorology, 149(1), 73-83.

Denmead, O. T., & Bradley, E. F. (1985). Flux-gradient relationships in a forest canopy. In The forest-atmosphere interaction (pp. 421-442). Springer, Dordrecht.