Response to reviewer 2

General comments:
In this work, it is investigated the presence of von Kármán (VK) vortices and Kelvin-Helmholtz (KH) instabilities in Large-Eddy Simulation (LES) when the common distributed drag force approach is used to represent plant canopies. Three different simulations were performed: one with horizontally homogeneous drag force, and two with a different set of patched areas with drag force. Four different types of data analyses were used to characterize the presence of coherent structures in the LES flow field, namely proper orthogonal decomposition, Shannon entropy, mutual information content and synchronization analysis. In these analyses, several features were pointed out as indicators of the presence of coherent structures. It is concluded that a weak signature of these coherent structures is present in the drag force formulation of plant canopies.
Overall, the motivation of the work is interesting (how realistic the drag force formulation of canopy in LES is), but this work presented a superficial and unconvincing evaluation of the signature of coherent structures in the simulation. Also, it is not provided any comparison of the LES results with data from a real canopy, which in my view is highly needed. I would like to point out some specific issues and questions that could help to improve the work.

We thank the reviewer for the constructive comments. We have improved the manuscript based on Your suggestions.

Specific comments:

1. **Abstract: it is already clear from the abstract that the work has more motivation than actual results or conclusions. After improving the content of the manuscript, the abstract should focus more on the results and conclusions of the work.**

Thanks for pointing out. We have modified the abstract accordingly.

2. Introduction: a good description of the canopy layers, coherent structures and drag formulation is given, but the review on the current state of the art is poor. Paragraph between the lines 18 of page 2 and 5 of page 3 is a clear example. How do all of these works have contributed to the understanding of the canonical structure of homogeneous canopy? What did they find, and what didn't they find? Which gaps are these? More specifically, what kind of information regarding the signature of coherent structures in the canopy did they find, that could help to interpret your results? Is this the very first work testing how realist the drag force formulation is? Given how many times it has been used, I highly doubt that, but if this is the case, you should state it clearly.

We have expanded this section according to these recommendations. In our opinion, this is the first work testing the distributed drag formulation in numerical simulations. Other numerical works use this formulation and takes the KH and VK structures as granted as they are shown by experiments involving real canopy obstructions. We have improved the discussion to reflect these.

3. Methodology: I am not convinced by this "weak and more generic" or "weak and loose" definitions of VK and KH motions. What are the basis for them? Have they been

used as surrogate for coherent structures before? I believe there will be an enhanced motion in these directions due only to the difference in the flow caused by the drag, even if there is no coherent structure (which should be captured by the drag formulation). I expect, for example, that this weak signature may represent purely local fluxes that has little to do with coherent structures. Is there a way to differentiate purely local flux to the true coherent structure signature? I believe this is a difficult task, but if you are claiming that there is some weak signature of coherent structures in the drag formulation, I believe you should be able to show this better.

It is a widely accepted fact in atmospheric and engineering applications that velocity inflections are associated with KH type instabilities. From literature review it appeared to us that the presence of KHI is somewhat taken for granted in for canopy turbulence. For example, the well-known review paper Fininigan 2000 summarizes results from Raupach 1996 which calculated mean streamwise separation of coherent eddies near canopy top and presented a conceptual model which looks like figure 1.

Figure 1: Conceptual diagram of KHI as shown in Finnigan 2000.

They also conclude that although these structures evolve throughout the stages of turbulence development, the streamwise wavelengths are preserved. This motivates our current work in the sense that we want to confirm the presence of such structures directly from the velocity signals instead of the more abstract turbulence statistics that are usually found in the literature.

Similarly for the VK structures, it is an accepted fact that they evolve in a horizontal place across the flow behind the obstacle and for canopy turbulence, this is taken for granted although it is only the lab experiments with real obstacles that observe these. We wanted to examine how realistic are these assumptions for the drag formulation. The so called weak definitions are thus not found in the literature, and we construct them in the paper. What we mean is we want a more direct evidence from the velocity records themselves. We describe this in more clearly and also remove the terms 'weak definition' to avoid confusion.

4. Results: I'm very confused about how it is possible to have VK vortices in the horizontally homogeneous case. What is the mechanism of creation of them, if there is no discontinuity in the horizontal plane? How do you know these are not just "regular"

turbulent motion (not created by coherent structures), but instead these are coherent structures? I would expect no VK vortices in the horizontally homogeneous case, and maybe something similar to VK vortices in the patches case due to the discontinuity (even though I believe in reality they are created by the complete blocking of the flow by plant trunks, and may not form from the reduced flow by a patch with drag). The KH vortices, yes, they are created by the inflection point which is present in the drag formulation, so they can be present in all cases (although in different ways based on the intensity of the inflection point). In order to differentiate "regular" turbulent motion from coherent structures, maybe a simulation without canopy could be used. Those snap-shots of Figure 3 do not show me anything. I cannot even see what is different inside the squares with the "VK?" from the rest of the plot. And if it is not conclusive, why show it?

Thanks for this comment. We were motivated by these exact same question - that for horizontally homogeneous canopies there are no discontinuity, although the VK motions are still used in the conceptual model. That is why we did the patch configurations to provide the discontinuity and variations of wake spaces to see if they produce a clearer signature of VK motions. That is why we looked for even weak signatures of u-v covariations as visually we could not find any strong signature as one would see in real experiments. This is explained better in the text. In simulations without canopy no such signature are found and we have included an appendix with results from a simulation without any canopy.

5. Overall, in order to argue that any feature is due to the canopy presence, it is good to compare it with the case without canopy. Also, it is highly needed a direct comparison of LES results with cases in the literature where the coherent structures were really present. For example, you should compare LES statistics with results from wind tunnel or field data where a real canopy was present, and point out which features are present in the LES and which are not. Only after that, you could show these new analyses that (I believe) nobody has done before, and show how they improve the interpretation of your results. So far I have no way of telling what are you actually showing with these new analyses, and if the features that you found are actually any weak signature of coherent structures or something else. I think that you reached the conclusion that those features are from coherent structures too fast and without enough evidence.

We have included an appendix with results from a no-canopy run and a section using data from a real canopy. The time and space averaged turbulent statistics as seen in figure 4 are already comparable to existing literature.

Conclusions: if there are significant differences between the drag model and the real case, it should be discussed what are the implications of these differences for all the studies that are done with LES.

Agreed. We have expanded the discussion in this direction.