Response to reviewer 3

General Comments:
The paper evaluates the performance of a canopy model using a drag formula in the large eddy simulation (LES). Particularly, the existence of two key features –Kelvin Helmholtz (KH) waves and von Karman (VK) vortices – over the three canopy configurations are examined in this work. Several innovative approaches (proper orthogonal decomposition, Shannon entropy, Mutual information and synchronization analysis) are introduced to analyze the LES data. The conclusion confirms the existence of both phenomena in canopy flow simulations. However, overall, the analyses based on new approaches are incomplete and lack physical interpretation.

We thank the reviewer for the constructive comments and suggestions. We have improved the manuscript based on these recommendations.

Specific Comments:
Major (The authors need to well address these comments before the paper can be published):

1. **The paper lacks some important information about the description of analysis approach. These include the lack of (i) the physical interpretation of mutual information content (MIC), (ii) the mathematical equation and physical meaning of synchronization analysis, and (iii) the approach to split the large scale and small scale in MIC analysis.**

This is pointed out by reviewer 1 as well. We have added discussions on all of them in the text and appendix.

2. **The description of LES setup is incomplete. For example, the paper doesn't pro- vide some key parameters of two patched configurations (e.g. the separation between patches) and the reason to select those key parameters. The reasons to choose different locations of virtual towers between two patched configurations are not given – Why the number of virtual towers inside selected canopy patches are different between these two configurations? The detailed description of initial conditions is missing.**

This was also pointed out by reviewer 1 and we have added discussions on all of these points.

3. The use of virtual tower to mimic observations in lab or field experiment is interesting, but weakened by the lack of comparison with data from observations. This makes the conclusions much weaker, especially due to the use of innovative analysis approaches without any validation. The use of those approaches need to answer the following questions before being applied in a such case: can KH waves and VK vortices be interpreted using these approaches in a real case? and if they can, whether these phenomena can be observed in LES results?

This is a great point and also pointed out by reviewer 2. We have added appendices and discussions to compare with no -canopy simulations and real canopy data.

4. The KH and VK phenomena can be identified from many traditional approaches including quadrant analysis, skewness analysis, variable-interval time averaging, wavelet transform, two-point space-time correlation tensor, etc. (a good review about these approaches is in Finnigan (2000)). However, these methods are not being used in cur- rent analysis. Why? For example, the following questions is critical: can KH and VK be identified using traditional approaches in current simulations? compared to these traditional approaches, what are the advantages of using these innovative methods? If there are no advantages a a, why bother?

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.

5. The turbulent flow should be more or less symmetric with respect to the central plane of each canopy patch in streamwise direction. Thus, the turbulent flux <uv> should be

more or less zero at the virtual towers located on these planes. However, in Figure 4, the turbulent flux <uv> is non-zero in all three cases. This phenomenon is not explained.

This is because we do not employ any spatial averaging. This discussion is added in the text.

6. Some panels of figures are not analyzed in current manuscript and should not appear in the paper. These panels include the length scale of u in Figure 4 and third column of Figure 5.

Removed.

Minor:

1. **The resolution of Figure 3 and Figure 5 are too low in current manuscript which make them difficult to view. Meanwhile, the ranges of coordinates and color bar in both figures are not the same from case to case.**

Improved.

2. The title of section 4.3 is already included in title of section 4.2 and need to be corrected.

Corrected.

3. The index i shouldn't be used repetitively in equation 'pi=. . .' in page 7 line 7.

Corrected.

4. New variable V in page 11 line 8 need to be defined before being used.

Corrected.

5. Some other text typos and format problem associate with units need to be corrected.

Checked and corrected.