Reply to interactive comment on Haszpra et al. "How well do tall tower measurements characterize the CO_2 mole fraction distribution in the planetary boundary layer?" by Referee#2

First of all, we would like to thank the reviewer for his/her comments and suggestions, which have helped us to improve the manuscript, and for his/her opinion finding our work worthy to be published in AMT. Below you will find our detailed point-by-point response to the comments and suggestions in italic:

- I think figure captions need to be improved. In general the figures contents are well described in the paper text, but not enough in the figure captions. They are too much short for a good comprehension. I think on the lack of a plain description of what means "tower height" (maybe describing it as "virtual tower top height" or "aircraft measuring points height used as virtual tower top heights"). Another example is the description of Y-axis as "estimation height" that could be "height of the top of virtual towers relative to the PBL (%)".

  Accepting the Reviewer's arguments the captions of the figures have been completed with the explanations of the terms used (see below). We determine on the basis of aircraft measurements how well a tower of z height can estimate the CO_2 mole fraction at H height. We speak about hypothetical physical towers the top of which is simulated by the aircraft with and without the application of the virtual tall tower concept. Although, the hypothetic physical tower can be considered as a 'virtual' tower but this term could be mixed with the virtual tall tower concept that is a mathematical model. To avoid any confusion we reserved the term 'virtual' exclusively for the mathematical model called virtual tall tower concept.

  The extended figure captions are as follows:

  Fig. 1. The median bias between the true CO_2 mole fraction and the estimated one as a function of the height of the hypothetic tower (tower height) ***simulated by the aircraft or the existing tower*** *and the relative height within the PBL for which the mole fraction is extrapolated ('estimation height') from the measurements at the top of the* ***hypothetic*** *tower (μmol mol^{-1}). Negative sign means underestimation by the measurements. Left: summer; right: winter. Bottom panels show the 12 UTC PBL-height statistics for all days during the period of 2006-2008 and for the days of the flights.*

  Fig. 2. Empirical frequency distribution of the differences between the CO_2 mole fraction measured at ***the top of a tower of*** *a given height (tower height)* ***simulated by the aircraft or the existing tower*** *and the mid-PBL CO_2 mole fraction determined from the aircraft vertical profiles for summer (left) and winter (right). Whiskers represent the lowest value still within 1.5 interquartile range (IQR) of the lower quartile and the highest value still within 1.5 IQR of the upper quartile, respectively.*

  Fig. 3. Empirical probability of the cases when the bias ***between the true CO_2 mole fraction and the estimated (extrapolated) one*** *does not exceed 0.5 μmol mol^{-1} (left) or 1.0 μmol mol^{-1} (right) as the function of the height of the* ***hypothetic*** *tower and the estimation height relative to the height of the PBL in summer (top) and winter (bottom).*

Fig. 4. The median bias between the true CO_2 mole fraction and the estimated one using the VTT concept as a function of the height of the hypothetic tower (tower height) ***simulated by the aircraft or the existing tower*** *and the relative height within the PBL for which the mole fraction is extrapolated ('estimation height') from the measurements at the top of the* ***hypothetic*** *tower ($\mu mol\ mol^{-1}$). Negative sign means underestimation by the measurements. Left: summer; right: winter.*

Fig. 5. Difference of the median biases of the estimations applying and not applying the VTT concept ($\mu mol\ mol^{-1}$) ***as a function of the height of the hypothetic tower (tower height) simulated by the aircraft or the existing tower and the relative height within the PBL for which the mole fraction is extrapolated ('estimation height') from the measurements at the top of the hypothetic tower****. Positive sign indicate that the application of the VTT concept improves the estimation. Left: summer; right: winter.*

Fig. 6. Empirical probability of the cases when the bias ***between the true CO_2 mole fraction and the estimated one*** *does not exceed 0.5 $\mu mol\ mol^{-1}$ (left) or 1.0 $\mu mol\ mol^{-1}$ (right) at the application of the VTT concept as the function of the height of the* ***hypothetic*** *tower and the estimation height relative to the height of the PBL in summer (top) and winter (bottom).*

- I suggest improving the figure 2 captions too. The asymmetric frequency distributions are full of interest as they represent atmospheric (PBL) structure, and I am sure much more work can be done on them in the future.

  The caption to Fig. 2 has been improved as it can be seen above. It is not easy to model the concentration distribution within the PBL. We fully agree with the Reviewer: tall tower and aircraft measurements would provide an indispensable background for model development and validation. It is a pity that aircraft measurements have been ceased almost everywhere over Europe due to the lack of funding.

- Finally it is to say aircraft campaigns often measure many air masses in the PBL horizontal transects: advection, plumes, and different convection patterns form structures we can find there. Do you think this methodology can be applied on these transects?

  The present study is about the vertical representativeness of the measurements. The dominant factor is the vertical concentration gradient within the PBL that depends on the mixing in the PBL (convection, mechanical turbulence). Vertical extrapolation of the tower top measurements in any way may fail if there is substratification in the PBL. We suppose, a similar methodology could be applied for the study of the horizontal (or 3-D) representativeness using transect aircraft measurements. In this case the heterogeneity of the source/sink field around the tower sampled by the aircraft can be critical. Such a study may give valuable contribution to the model based footprint calculations of the tower measurements.