# Influence of along-valley terrain heterogeneity on exchange processes over idealized valleys

## Reply to Reviewers' Comments
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# 1 Introduction

We thank both referees and the editor and acknowledge their efforts to improve our manuscript. After a thorough study of their comments we tried to include all aspects as far as possible. We revised the upvalley wind and mass flux analysis and recalculated the trajectories. Changes in the text are written in red colour in the manuscript.

In the following, comments of the reviewers are written in italic type and marked with numbers. Corresponding replies of the authors are labeled with "⇒".

# 2 Comments of Referee #2

### General evaluation

*The manuscript "Influence of along-valley terrain heterogeneity on exchange processes over idealized valleys" by Wagner et al. presents a series of high-resolution numerical simulations to answer the question of how and how much valley geometries influence the transport of air masses originating over the adjacent plain into the valley atmosphere. Furthermore, subsequent exchange with the free troposphere is discussed. The applied numerical methods are sound and the manuscript is well organized and written and is easy to follow. My remaining concerns focus on the included trajectory analysis and a few minor motivating and more technical points. After these points have been dealt with the manuscript will be fit for publication in ACP.*

**Major comments**

*There are two issues about the trajectory analysis which I would like to be addressed by the authors.*

1. *If I understand correctly your trajectories are computed based on the 10 minute (instantaneous?) WRF-ARW output fields and are not forced by additional (parameterized) turbulent motions. Which would mean that you are missing part of the non-resolved (temporal or spatial) turbulent mixing. However, in section 3.3 you are using the analysis of trajectory positions to discuss exchange between the PBL and the free troposphere. For this exchange I would think that the unresolved turbulence might still be of some importance. How do you justify neglecting it.*

⇒ Thanks for this suggestion. We have recomputed all trajectories based on a 5 minute output interval of instantaneous wind fields and justified the neglect of subgrid-scale turbulent diffusion in the text. The general distribution of parcels in terms of height and along-valley position is conserved (see Fig. 1 in this document). However, the new data indicate less diffusion of parcels and the percentage of parcels, which are located above the reference boundary layer heights is reduced for the PLAIN simulation and cases with wide valleys (e.g., W30, W40). This means that nearly all parcels of these simulations stay below the entrainment layer height PLAIN-PBL3 (see Fig. 2 in this document). We agree that effects of subgrid-scale turbulent diffusion are not included in this trajectory computation, but think that it can be used to study mesoscale upslope and upvalley winds in this investigation. We added this information in the text (L463-L468).

Concerning the mass flux analysis we removed Fig. 9e, as we think that it did not provide additional information.

2. *Your trajectories are initialized in the center of the domain in a relatively small box compared to the valley widths (ratio 0.2). How representative are these trajectories then for the total inflow into the valley? Wouldn't a wider box make more sense, in order to cover most of the inflow? This problem seems to be most obvious when looking at the wide valley geometries (W40N, W40NI) where basically all current trajectories remain in the valley atmosphere and don't make it up the slopes. Personally I think that this leads to the wrong conclusion in the following that for these valley geometries no vertical export takes place. I agree it might be smaller than in the narrow valley cases but it will still be present along the slopes, but is simply missed by the current trajectory approach. I would encourage that you either repeat the trajectory calculations with a wider release box or that you discuss the limitations of the current approach in more detail.*

⇒ The trajectory box is indeed small and does not represent the whole inflow into the valley. However, we computed the mass fluxes into and out of the valley to demonstrate the mass exchange in dependence of the valley geometry. By computing the trajectories we wanted to study how parcels from the surface are transported into the valley and kept the box-width to valley-width ratio of 0.2 constant for wide (e.g. W40) and narrow (e.g. REF)

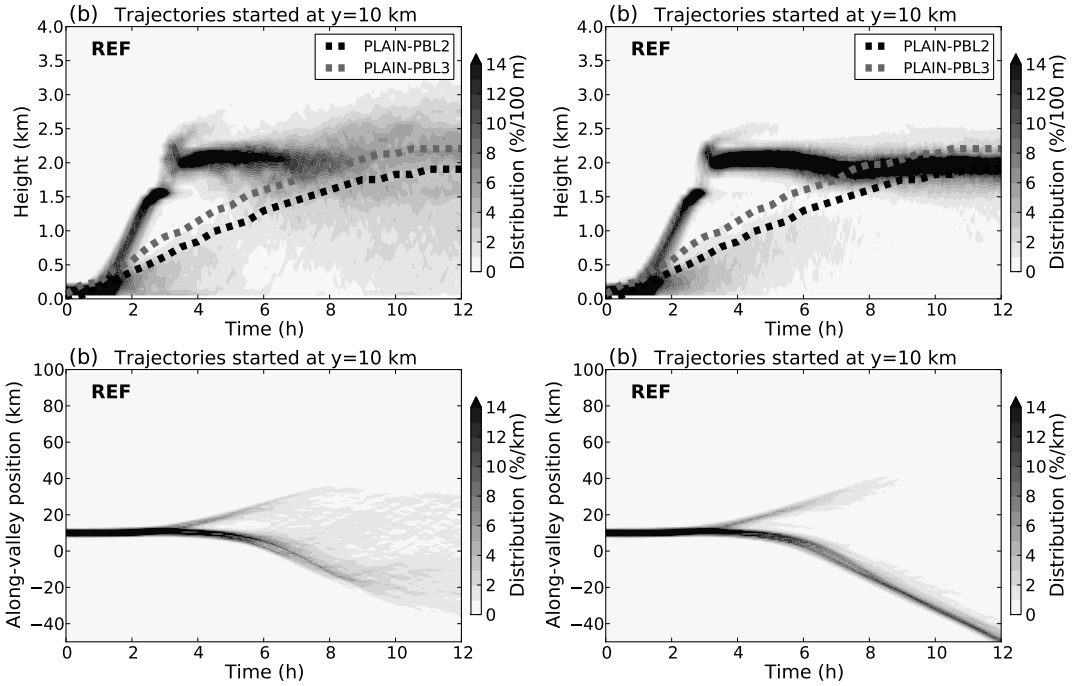


Figure 1: Evolution of parcel height and along-valley distribution for trajectories started at $y = 10$ km based on a 10 (left panels) and 5 minute (right panels) output interval.

valleys. We performed additional calculations for the REF and W40NI cases with parcels started in a larger box, whose cross-valley extent is equal to the valley width (see Fig. 3 in this document). For this larger box (marked with "L_BOX") the vertical transport is increased as more parcels are advected directly towards the slopes (see Fig. 4 in this document). In our opinion, it is, however, not helpful to use such a box for parcels started within the valley (e.g., at $y = 10$km), as a major part of the parcels would then be released at the slope and on the mountain crests. Therefore, we kept the smaller boxes and added this information in the text (L505-L515).

**Minor comments**

1. *P417: In the introduction you motivate why there might be a need for a vertical exchange parameterization in complex terrain for common NWPs. However, present (even operational) NWPs are getting closer to the 1 km margin and are already able to resolve even more narrow valleys. Will there still be a need for a parameterization and will we get the parameterization before computational improvements allow kilometer scale operational simulations? There will always be a remaining unresolved sub-grid orography contribution, but does this still need a parameterization considering the large number of influence factors and unknowns?*

⇒ We agree that such parameterizations will probably not be needed in mesoscale models, but we think that they are important for global NWP and climate models. We added two sentences in the introduction (L60-L67).

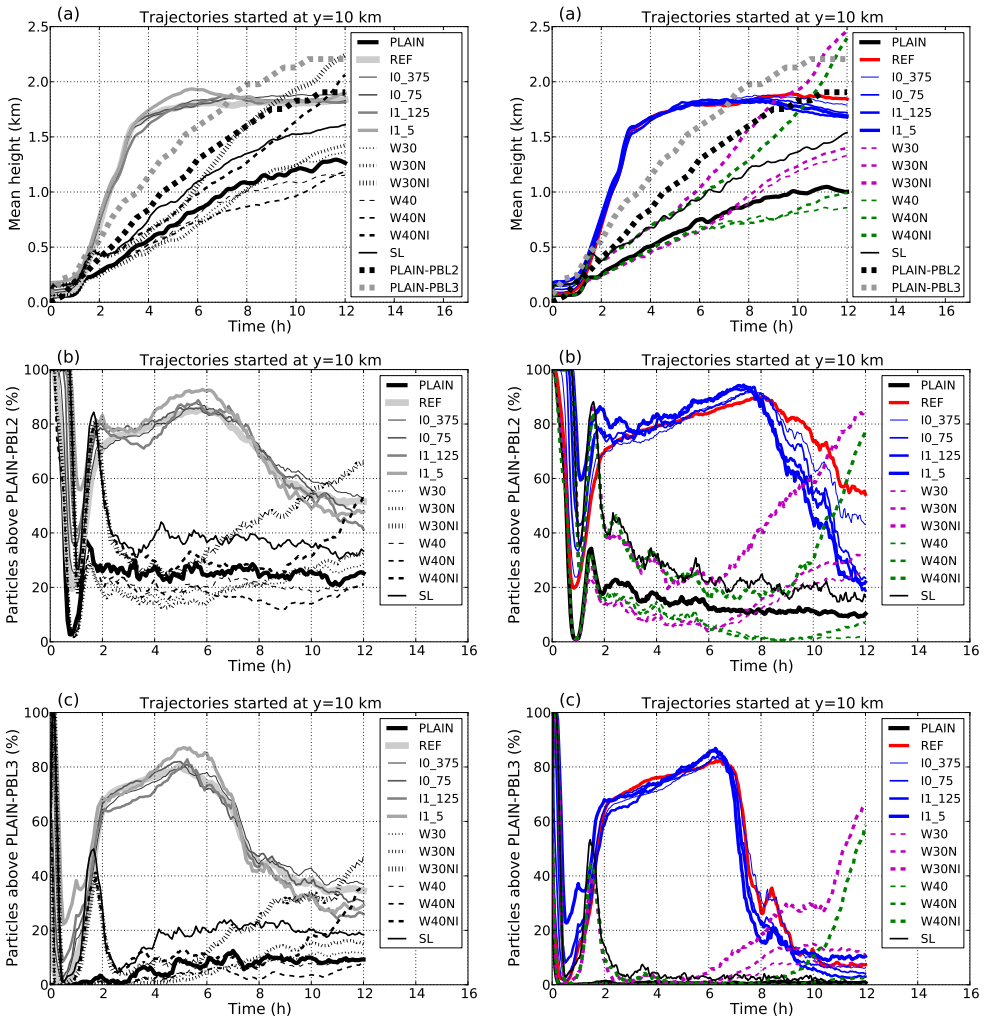


Figure 2: Time series of mean trajectory height (upper panels) and fraction of parcels, which are located above PLAIN-PBL2 (lower panels) based on a 10 (left panels) and 5 minute (right panels) output interval.

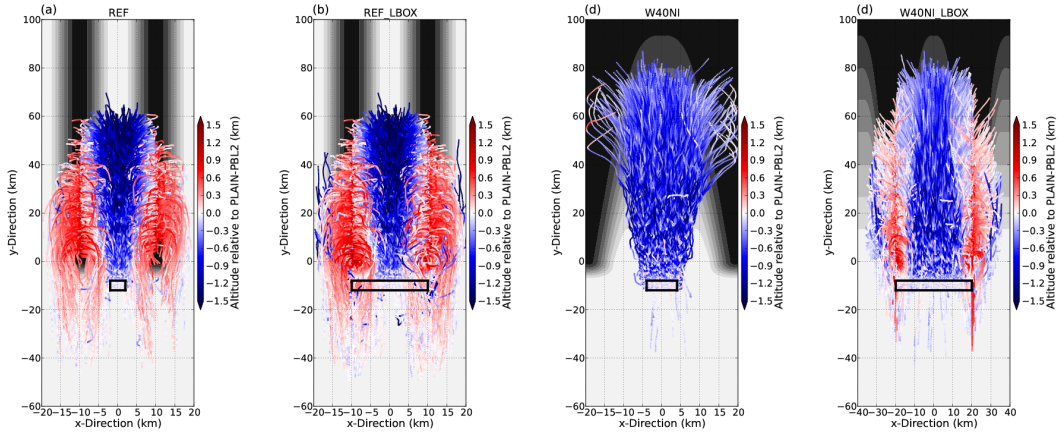


Figure 3: Trajectories for different start boxes for REF, REF_LBOX, W40NI, W40NI_LBOX (crom left to right).

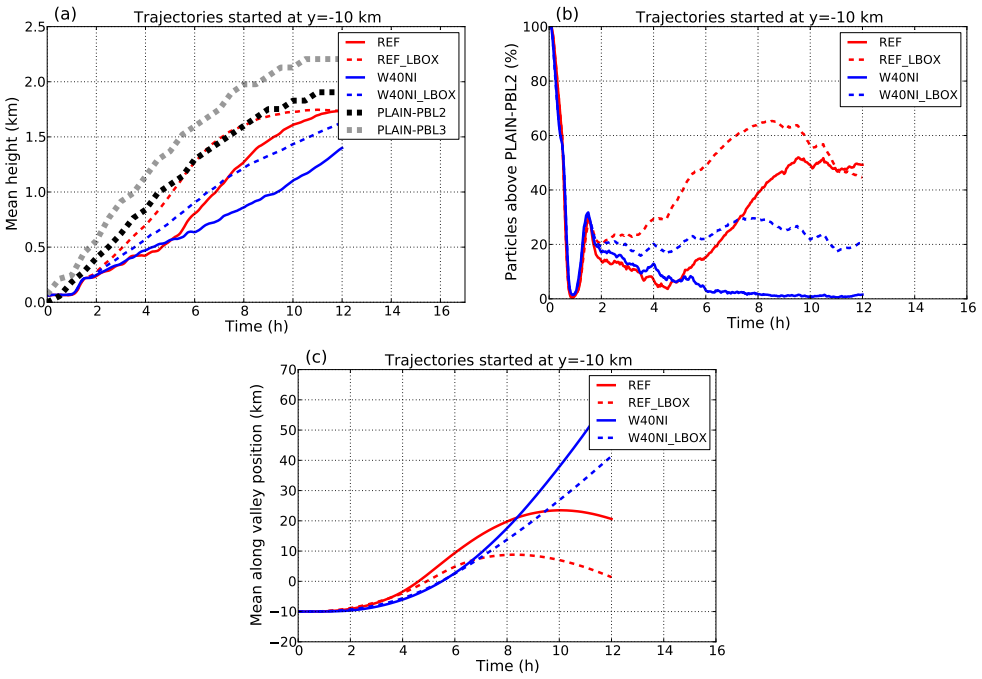


Figure 4: Time series of (a) mean trajectory height, (b) fraction of parcels, which are located above PLAIN-PBL3 and (c) mean along-valley position of parcels started at $y$ = -10 km for the REF, REF_LBOX, W40NI and W40NI_LBOX cases.

2. *P417: Is there additional evidence that tilting and narrowing valley are the more realistic valley geometries compared to homogeneous along-valley geometries. Some examples are given later on page 421. But this information would be useful as motivation as well.*

⇒ We now mention examples for real valleys with inhomogeneous along-valley geometries in the introduction (L85-L92).

3. *P417: Can you summarize some more details on previous findings using homogeneous along-valley geometries. Especially concerning important influence parameters like stability, ridge height, etc. that are not discussed in this study. Then in the discussion: Is it possible to put your results more into context with these previous studies? Basically trying to answer a question like: What are the most important influence factors that a parameterization will need to consider: tilting valleys, ridge height, stability, etc.?*

⇒ We added additional studies for valley width, depth and slope inclination in the introduction (L76-L82).

4. *P418: It is not exactly clear if WRF was used in LES mode or not. Only the mentioning of the LES simulations in the author's previous works suggests the use of the LES mode.*

⇒ We added the LES mode information (L114-L115). Further information on the horizontal mesh size of 200 m is also given in L160-L167.

5. *Figure 4: It is very difficult to distinguish the different isolines of potential temperature and along-valley wind speed. I suggest to omit the latter since it is displayed in more*

*detail in Figure 5 as well. Also it is not explained in the caption what the arrows, which are barely visible, illustrate.*

⇒ We agree and changed the line colour for upvalley wind contours to magenta and removed the arrows.

6. *Figure 6-9, 13, 14: Again, it is very difficult to distinguish all the line plots for all the different sensitivity runs. The use of different colors instead of line type and thickness would largely improve these figures.*

⇒ We agree and use coloured lines in the corresponding figures now.

**Technical comments**

1. *P18L22: "Extention" should be "extent".*

⇒ We agree and corrected the expression.

# References