Response to Referees – Daytime along-valley winds in the Himalayas as simulated by the WRF–model

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We thank the reviewers for their constructive comments on our submitted manuscript. We have copied the comments of the reviewers in black here and include our response to each individual comment in blue. In the revised submission the Supplementary Figures A1–A4 have been relabeled as Supplementary Figures S1–S4.

Referee report 1

Thanks to the authors for the new addition of section 2.1, which clearly justifies the choice of this time period for analysis. Both this and the alterations to the text make the aims of the paper clearer. I also found the new cross-sectional diagrams in A3 and A4 very interesting, especially given the lack of 'textbook' cross-valley circulation at many locations.

I have a few small comments:

1. As I understand from line 111, the 17 th December is now removed from all analysis, therefore the manuscript should refer to a 4-day period, rather than a 5-day period. Since we consider the time period from 18LT on the 17th December, the wording of "5–day period" was used in the previous revision as technically there are 5 different dates. However, in the revised manuscript we have changed this to a "4–day period" since we only consider 4-day time periods (i.e. the white areas in Figure 6), that are the main aim of the study.
2. As model spin-up is a computational artifact, it is standard practice not to show it in results and therefore I'd recommend it's removed from all graphs in the manuscript (line 535). As the 17 th December is not discussed in the analysis, I suggest it is removed from all graphs entirely for clarity. Thank you for the suggestion. For clarity, the spin-up period is excluded in all of the timeseries figures.
3. Conclusions: As 17 th December is not discussed in the results, discussion of this day should be removed from the conclusions (line 594: only north-westerlies have been discussed on the 18 th December in the results). This sentence referred to by the reviewer discussed the northerlies and north-westerlies during the remaining six hours of the 17th (after the spin-up 06-18 local time) and the early morning hours of the 18th. We have carefully revised the text to make sure the period of model spin-up is not considered in the conclusions.

4. Figures A3 and A4: these are very interesting, thank you for the addition! As the numbers are a little small, an addition in the figure caption of 'solid lines are positive values and dashed lines are negative values' would be helpful for clarity. Thank you, the figure caption is now revised.

5. 91 typo: coincided → coincide This is now corrected.

6. 140: As using a spin-up period is standard practice in numerical modelling, this paragraph could be shortened to just state the spin-up period and reference Bonekamp 2018. Based on the referee comments on the first submission, we feel the first general sentence about model spin-up is relevant. Also there is only one sentence that could be deleted and we think the paragraph is not too long as it is. Therefore, we have not made any revision in the manuscript concerning this point.

7. 211: Typo, repetition of 'WRF-simulation' This is now corrected.

8. Figure 7: I would recommend adding that the wind velocity has been multiplied by -1 (e.g. m s $^{-1}$ (multiplied by -1)) to the y-axis label on the western slope, to make sure this important point is not missed. We added text boxes below each column in this figure stating that the positive (negative) values refer to up-slope (down-slope) winds. We think this is clearer, and less confusing, than adding information on the y-axis of the panels showing the western slope.

Referee report 2

The authors have resolved some major issues related to the methodology and interpretation of the results to meet the main objectives of this manuscript.

We thank the reviewer for valuable ideas how to extend the range of the wind analysis and build credibility of our study. Here we gather first a general response on their main points and give specific comments below.

Our current study is the first step in understanding thermally driven winds in the Himalayas and also the transport of aerosol by these winds. As a starting point, in this study, we focus heavily on the valley topography driven differences in the daytime up-valley winds. Unfortunately, the simulation used in this study under review was performed on our super computing system quite a long time ago and since then major system updates have occurred. This means that the exact model configuration is currently not available and hence it is very difficult for us to extend this simulation. We do however fully acknowledge that due to our short time period our conclusions are subject to uncertainties and we have carefully revised the manuscript to state this. Finally, we would state that in our ongoing and future work we are attempting to resolve some of these uncertainties. Currently, we are studying thermally driven winds and aerosol transport processes at the same location in the Himalayas by means of a 1-month long high-resolution simulation with fully coupled meteorology and air-chemistry. However, the results from this longer simulations constitute future work and are beyond the scope of this current paper.

While the following issues still persist:

Major comments

1. The explanation for the longer model run and spin-up period (12 h) is acceptable for such a case study as the objective of this study is to investigate the local valley circulations that are induced by topography and profoundly affected by variations in the synoptic-scale flows. However, the synoptic scale wind flow in Figure 1 is shown to vary enormously throughout the period and wind patterns significantly changed from one day to the other (17-18 December) and are not rather appropriate for the analysis, in order to get the true representation of valley flows. It would have been the best choice to look into the days-in-continuation where the synoptic flows are not changing to a greater extent i.e. few days before and after the slight change, to ensure that synoptic flows are not random but systematic. Since the variable synoptic scale flows appear to affect the intensity of local valley circulations, which could be investigated separately. Figure 1 shows the synoptic scale winds in the outer domain of the simulation. The actual study area is in the North-Eastern part of Nepal (Nepal borders are marked on red in the Figure 1). If only the wind in this smaller area is considered, we think it is somewhat of an overestimation to state that the synoptic-scale wind varies enormously during the study period 18-21 Dec. We do agree that the synoptic-scale wind differs on the 17th but we do not consider this day in our analysis. However, as stated above, we have revised the manuscript to be clear that our results are subject to uncertainties and we state that as future work, longer simulations

are needed to fully assess the impact of the synoptic-scale flow on the thermally driven winds.

2. The cross valley circulations are primarily originating as a result of anabatic and katabatic flows and dominant during the daytime in the weak mean flow conditions. This could be a better way to investigate and define the cross valley circulations and differentiate among them. Therefore, the justification for selecting this period is not sufficient. If similar synoptic flow conditions are chosen, then the differences in the day-night valley circulations will be only due to the thermally driven processes. In this study we focus on the daytime along-valley winds and therefore the cross-valley winds are not analysed and discussed in depth in the manuscript. Detailed analysis of the cross-valley winds will be included in the future work.

3. To be more specific, as evident from Figure 1(discarding 17-18 Dec) that after 21 December for the next few days, the synoptic-scale flow does not change much. The selection of this period will support the third main aim of this study which is related to investigating the cause of the differences in local winds. Further, the influence of the synoptic-scale flow (e.g., 15 to 18 December when the wind direction changes) on along-valley flow will add more value. This work is really good contribution to the mountain meteorological studies. The combined effect of the synoptic scale flow and the valley topography on the local along-valley winds would be indeed interesting and as stated above, we plan in the future to perform longer simulations, with coupled chemistry, to better address this question.

Specific comment:

1. Line 152-153: It is suggested to quote the name of the valleys in Figure 2b. This is now added in the figure caption.