Responses to comments from Referee #3

MANUSCRIPT: acp-2018-944

TITLE: From weak to intense downslope winds: origin, interaction with boundary-layer turbulence and impact on CO2 variability

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MAIN CHANGES IN THE MANUSCRIPT:

o Title.

o Abstract and motivating aspects.

o Denomination: katabatic → downslope.

o Further information about data postprocessing in Sect. 2.2.

o New Sect. 4 in the revised manuscript: analysis of the heat and momentum budgets, profiles and the estimation of the jet-maximum height for three representative events.

o Summary and conclusions.

o Appendix A (footprint estimation) and B (assessment of the thermal profile).

o Removed figures (numbers from the old manuscript): Fig. 7, Fig. 10, Fig. 11 and Fig. 12.

o Merged figures (numbers from the old manuscript): Figs. 4 and 5, Figs. 8 and 9.

o New figures (numbers in the revised manuscript): Fig. 7, Fig. 8, Fig. 9, Fig. 10, Fig. A1 and Fig. B1.

o Slightly modified figures (numbers in the revised manuscript): Fig. 1 and Fig. 11.

o Wording and English revision.

General Comments:
The manuscript investigates katabatic flows on the basis of occurrences observed during one summer season at the foothills of the Guadarrama Mountain Range in Spain. The data set has been split up into weak, moderate and intense events, based on the observed maximum wind speed observed during each individual case and is then analyzed under various aspects. The study shows distinc differences between the different classes of katabatic flow, the number of intensive katabatic flow cases is, however, very low (3) and rises thus questions on the statistical significance of the reported results. The paper is in general well structured and includes a good literature overview on the subject. The figure layout is in general rather inhomogeneous over the paper and should be reworked. Several of the figures are in addition hard to read, mainly due to small labels and legends. Finally, the manuscript requires a thorough makeover by a native English speaker. Main points in this context the rather complicated sentence structures, unconventional wording obviously taken from the dictionary (e.g. emplacement instead of site/location), missing commas, the improper use of prepositions and articles, and grammatically incomplete sentences. I have marked a quite a few, but far from all, instances in my specific comments.

We thank Referee #3 for his/her comments about the article. We agree that the number of intense flows is small, but anyway, some of the most important conclusions about the nature and characteristics of the downslope flows (note that we have changed their denomination from katabatic to downslope), are drawn from the analysis of representative individual events and not from the statistical parameters of the distributions. In any case, this new database could be enlarged in time by including further measurements. Furthermore, we have revised the figures and modified them in order to be legible and clear enough. Finally, a native speaker has revised English along the manuscript, providing language corrections and improvements, apart from those given by the referees. It must be noted that Sect. 4.2 and 5.1 have been eliminated from the old manuscript and new sections have been added in the new manuscript (Sect. 4, Appendix A and B). Below, we provide point-by-point responses to the specific queries from the referee. The modifications undertaken in the manuscript can be checked up both from the revised manuscript and the tracked-changes version.

Specific comments:

1) P1, L1: "on the dynamics" instead of ""in the dynamics"

We thank Referee#3 for all the language corrections and improvements suggested. The manuscript has been accordingly corrected.

2) P1, L5: insert comma after "moderate and intense"

Inserted.

3) P1, L9: insert "flow" after "katabatic"

Inserted.

4) P2, L26: "at contrasting" instead of "in contrasting"

Changed.

5) P2, L28: insert comma after "model"

Inserted.

6) P2, L33: "In contrary" instead of "At contrary"

Changed.

7) P3, L8 and 11: "emplacement" is rather uncommon, better "site or location"?

It has been changed to both location and site.

8) P3, L15-16: "on the concentration" instead of "in the concentration"

Changed.

9) P3, L16: remove "the" before "CO2

Changed.

10) P3, L16: "in coastal areas" instead of "at local areas"

Changed.

11) P3, L27: sentence incomplete; "the role of: ....., in CO2 mixing ratios" ; should be "in controlling/affecting CO2 mixing ratios"

Completed.

12) P3, L34: insert "concentrations" after "CO2"

Inserted.

13) P4, L23: "a relatively" instead of "an relatively"

Changed.

14) P4, L23-24: "immediately besides" is quite strange; better "close to"?

It has been changed to "close to".

15) P4, L29-30: "needleleaved evergreen tree cover", sounds complicated; isn't it just "coniferous"?

This name was obtained from the database and maps of land-use types from Land Cover CCI from ESA. In any case, in order to clarify, we have added "coniferous" in brackets.

16) P4, L34: replace "inexistent" by "absence of"

As the native speaker suggested, it has been changed to "non-existent".

17) P5, L8: formatting error "CO2" subscript

Changed.

18) P6, L5: insert "concentrations" after "CO2"

Inserted.

19) P6, L7: "Forty were selected as days: : :: : :.." The sentence is grammatically poorly formulated and hard to read. Please rephrase

It has been changed to "Forty events with the formation of a thermally-induced downslope flow were selected from the analysed summer period with available data (94 days in total)".

20) P7, L2: insert "the criteria" after "meet"

It has been accordingly changed.

21) P7, L2 (and other instances): replace "minutal" by "minute"

Replaced.

22) P7, L4: replace "weak" by "low"

Replaced.

23) P7, L29: there is no Figure 5a)

The former Fig. 5 has been eliminated, so this sentence is not present anymore.

24) P8, L34: Why are you presenting a 4th-order polynomial fit; any physical reasoning for this? A simple trend could also be seen from a linear regression, and the two peaks resulting from your fit seem to be rather arbitrary; Thus I see a big danger of an over-interpretation of non-existing features in the corresponding paragraphs on page 9, L1-13 (see also my comment on Figure 7)

As commented in the response to the Specific Major Comment 7 from Referee#2, the reason for using the fourth-order fit was to justify the bimodal behaviour. However, due to the vague relationship between the variables presented, that figure and the associated explanation have been removed from the manuscript. A short comment about this vague correlation has been included in the revised manuscript (Lines 21-24 on Page 9).

25) P9, L17-18: "....., the shear associated with the katabatic flow increases, and the downslope flow strengthens progressively." I do not understand the direct link between this two statements; How can increase in shear strengthen the downslope flow? Might also be a misunderstanding from my side, but then the sentence should be rephrased.

That sentence has been changed to "If the downslope flow arrives when the stratification is still unstable and the surface thermal inversion (hereinafter measured from θ_v) is not formed yet, the downslope flow strengthens progressively" (Page 9 Lines 33-34).

26) P9, L20: insert "the" before "surface"

Inserted.

27) You should define the calculation of VTKE already here, and not two lines under.

As suggested by the referee, it is defined two lines above.

28) P10, L2: insert comma after the parenthesis with the wind speed.

Inserted.

29) P10, L10: "increases linearly"; I could also see a square root dependency here

Given the wonder from Referee#3, we have represented in green the linear fit (Fig. Ia) and the square-root fit (Fig. Ib) over the scatter plot of V_{TKE} vs U when $U > 1.5$ m s^{-1}, together with the value of r^2. The correlation is very similar for both plots (the rounded r^2 is equal), indicating that it is not clear whether the dependency is linear or square root. Therefore, we have changed the mentioned sentence to: "increases approximately at a linear rate with U" (Line 28 on Page 10).

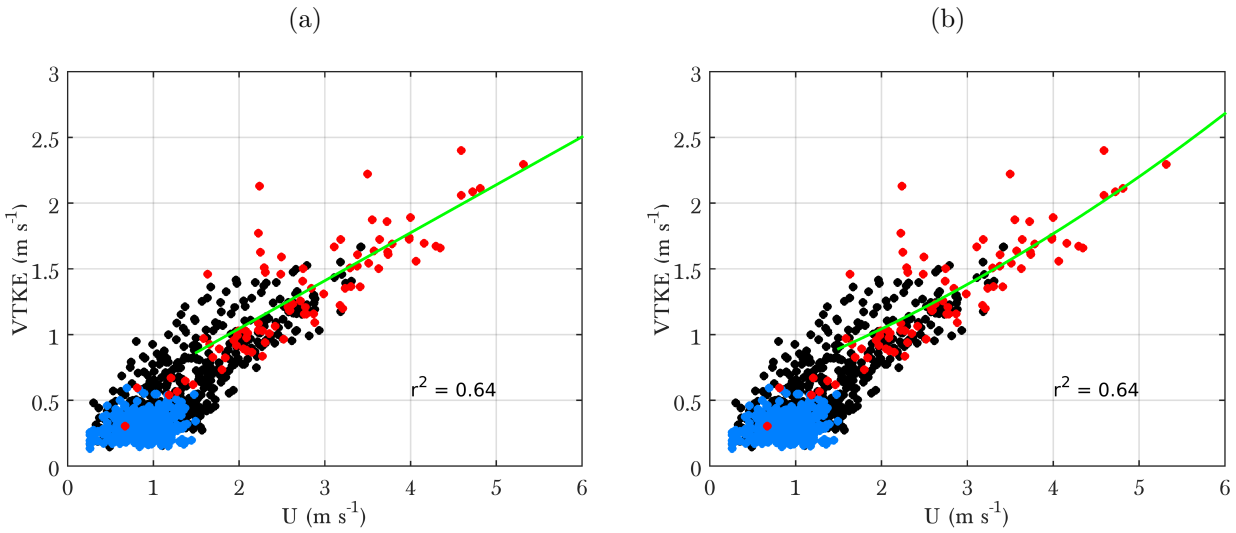

Figure I: *Same as Fig. 7b from the manuscript including in green (a) the linear fit, (b) the square-root fit, and the value of the square of the multiple correlation coefficient (r^2) for the fit .*

30) P10, L29: replace "on" by "for" or "during"

That sentence is eliminated from the revised manuscript.

31) P10, L32: insert comma after "night"

Inserted.

32) P11, L17: Sentence has to start with an upper case letter; "Van Hooijdonk: : :.."

Corrected.

33) P11, L25-26: "intense and weak katabatics cluster into two clearly distinct regimes"; at 8 m I still see a considerable amount of black and red data points for SC¡3 with distinct elevated VTKE levels; can you explain/comment on this.

We thank the referee for this comment but Fig. 10 has been eliminated from the manuscript, as well as the associated text.

34) P12, L4: put "by definition" between commas.

That sentence has been eliminated from the manuscript.

35) P12, L17: replace "related with" by "related to"

Replaced.

36) P13, L7-8: start the sentence with "In contrary, U remains: : :.."

Changed.

37) P13, L12: insert comma after "takes place"

Inserted.

38) P13, L25: replace "so doing" by "doing so"

Changed.

39) P14, L9: insert comma after "SBL"

Inserted.

40) P14, L20: insert comma after "nearly 0"

Inserted.

41) P14, L21: insert comma after "assumption"

Inserted.

42) P14, L22: insert comma after the reference

The comma has been inserted before "following the methodology", since we think it is better for the meaning we want to express.

43) P14, L25: insert comma after "equation"

Inserted.

44) P 15, L8-10: this sentence has to be rephrased, maybe even better split in to or three! In particular complicated is the part ": : :by the presence upwind of a land use component of forest: : :: : :: : :"

That sentence has been changed to: "This positive CO_2 advection is probably induced by the presence of a land use composed of forest, mosaic trees and shrubs upwind, towards the downslope direction. Given the increased plant respiration and soil flux, greater CO_2 concentrations are accumulated close to the surface during the night" (Lines 8-10 on Page 17).

45) Some small inconsistencies in the references a. Boundary Layer Meteorol. vs Boundary-Layer Meteorol.; I believe the latter one is the usual b. A few journal abbreviations are not terminated by a period; e.g. Borge et al. and Plaza et al. c. Presentation of doi or not for articles

We thank the referee for pointing out these inconsistencies. Journal abbreviations and citations along the manuscript have been revised and accordingly corrected. The DOI of all articles has additionally been included.

46) Page 22, Table 1; inaccurate caption, I suggest: "Specification of the values measured and the devices : : :: : :"; the specification of a value is not technical!

Changed.

47) Page 24, Table 3; add number of occurrences for each class in the table; maybe also an idea to place the measurement frequency directly in the table for each sensor instead of using the footnote solution.

As suggested by the referee, the number of occurrences of each type are included in Table 3, and the sampling rate is also included in Table 1.

48) Page 25, Figure 1a; the location names are difficult to read; use larger fonts and bold style; in addition have the degree symbols in the axes labels an underscore that should be removed.

The figure has been accordingly modified.

49) Page 27, Figure 3: I suggest to split this figure in 3 separate ones for the weak, moderate and intensive cases; as it is presented now you loose a lot of information by the averaging; I would also like to see the 40 individual profiles in this plots, e.g. as grey lines in the background.

We thank the referee for his/her suggestions about this figure. However, we prefer to keep it as it is for various reasons. First, one of the main purposes for including this figure is to represent the frequency distribution of the wind speed, show the differences between the levels at the onset and when the maximum intensity is achieved, and motivate the classification into the three types. Therefore, we think that at this point of the manuscript it is preferable to keep this figure as it is. Second, if we plot the 40 individual profiles in the background, the figure becomes fuzzy and unclear. Instead, we plotted the individual profiles for three representative events in Figs. 8–10. In this way, we compare in a clear way the structure of the downslope flows for the three types.

50) Page 31, Figure 7: I cannot see that the applied 4th-order fitting makes any sense; do you have any physical reasoning for your choice.

Please, see response to Comment 24 above.

51) Page 34, Figure 10: labels/legends too small.

This figure has been withdrawn from the manuscript.

52) Page 35, Figure 11: a) use different line styles for 4 and 8 m (in particular important for the intense event in red); why have you selected 21:00 as last time you present; from the time series it looks like that is more a transition phase, while e.g. 22:00 appears to be a more stationary situation; b), d), f): I suggest to use a common x-axis span at least for the wind speed

Thank you for these suggestions. This figure has been split into Figs. 8, 9 and 10 in the new manuscript. Different line styles are used for the different times represented. On the other hand, 2100 has been changed to 2230 UTC to represent a moment in which the SBL is already well developed. Besides, a common x-axis is used for all the panels in Figs. 8–10.

53) Page 36, Figure 12: axis labels too small!

This figure has also been eliminated from the manuscript: the evolution of the thermal stratification is shown in Figs. 8–10a; the time series of the wind shear is not needed either given that the friction velocity is also represented in Figs. 8–10a; and finally, the surface energy balance involves a great uncertainty, and hence, its interpretation is challenging.

54) Page 37, Figure 13: use different line styles for 4 m and 8 m

To better distinguish the two levels, instead of using different line styles, the level of 4 m is represented with the markers filled and the level of 8 m with the markers empty.