Review of: Kaas and Emeis, The five main influencing factors on lidar errors in complex terrain (revised).

The authors would like to thank the referee very much again for reading the revised version of the manuscript and providing additional, valuable feedback and suggestion on how to further improve it.

In the following, we have answered to all of the referee's questions, comments and suggestions. We also state how we use the feedback in the revised version of the manuscript.

General

The revised version of the paper is excellent. Both the structure and the language have been lifted to a level that do justice to the technical content. The addition of the discussion section has in particular added the insight that was missing from the previous version.

I have only a couple of smaller suggestions (and these should be the last!):

- The authors have incorporated my comments concerning the (lack of) accuracy of cup anemometers in complex terrain. I would suggest that they go one step further and give us some numbers since this really puts all the lidar/mast comparisons in a somewhat different light. E.g the Windsensor cup anemometer (high quality and widely used) has class numbers of 1.32A and 3.71B. A typical standard uncertainty (68% confidence level) on a mast would therefore be 1.4% @ 10 m/s in flat terrain (class A) and 2.4% @ 10 m/s in complex terrain class B. Double these numbers for the more typically used 95% confidence limit!
- The development of section 2.3 Lidar error correction could be even better (but I do understand it now). In particular I would suggest that the authors develop firstly the equations for the ideal homogeneous case (same flow at both sensing positions). Actually this equation first appears in a box in figure 3. I think it would help the general understanding to develop this first then demonstrate how this gives the wrong answer when the flow is no longer truly homogeneous.

Thank you very much for you general feedback on the revised version of our manuscript and for the effort you put in reading this version. We are glad to hear that we have mostly met your expectations based on your comments and feedback on the first version.

- We understand your wish to add more detailed information on the uncertainty of cup anemometers in flat and complex terrain. We have therefore added an example with classification numbers for a Thies First Class cup anemometer from the literature. We have also calculated the standard uncertainty including calibration and mounting uncertainties.
- We have extended the development of our correction equations and added that flat terrain case. We agree that this will help the reader to follow and understand the situation in complex terrain.

More detailed comments follow:

P2, L40 (suggestion) 'to test lidars at these sites to assess their applicability' -> 'to examine the accuracy of lidars at such sites'

Thank you, we have changed the sentence according to your suggestion.

P3, L93 '…FCR over-corrects for the lidar error' – its probably within the measurement uncertainty.

Thank you. We have slightly revised this paragraph. We think it becomes clear now that the fact that FCR tends to over-correct in complex terrain has been found in several studies. However, we agree that in the mentioned case, the over-correction could be within the uncertainty margins of the measurement and have added this to the text.

P6, L183-189. Are you suggesting using the raw lidar data to check the flow model that you will then use to correct the lidar? Maybe this is getting dangerously circular??

Thank you for your comment. We agree that the paragraph reads a bit misleading and have therefore slightly rephrased it. We also agree that it is a challenge to avoid circularity when using the lidar data for model validation and then the model for lidar error correction. We have proposed to use additional data for model validation wherever possible before doing the lidar correction in the revised version to make it clearer.

P10, L283 'The flow inclination'…….'therefore introduces an error component' – this reads as if it's the flow inclination itself that gives the error. I'm sure the authors don't believe this! Please re-word so that its clear it's the change in inclination angle – here developing the homogeneous case first would help the understanding (my main comment #2).

Thank you for your comment. We agree that this reads misleading and have slightly rephrased the paragraph in the new version.

P11 Figure 3 – see my main comment #2. The equation in the box just pops out of nowhere!

Thank you. As already stated above, we have extended the development of our equations and the mentioned equation is now part of the text.

P12, l313 – you need $\beta=-\alpha$, not $\alpha=\beta$! Else the numerator of eq(6) becomes zero!

Thank you, we have corrected this in the revised version.

P12 generally – maybe just take the symmetric case for ε_S as well (you get $\Delta u/u_L$ if I understood this correctly).

Thank you, we have added the symmetric case in the revised version to make it more complete.

P21 Discussion – maybe one important point that you miss here is that both error components have the same sign (is this ever not true?).

Thank you for your comment. This should always be true and we agree that we have missed this information in the discussion. We have added a short sentence to clarify this fact.

Review: The five main influencing factors on lidar errors in complex terrain, wes-2021-26

The authors would like to thank the referee very much again for reading the revised version of the manuscript. We thank you for providing us additional, valuable feedback and suggestion on how to further improve it.

In the following, we have answered to all of the referee's questions, comments and suggestions. We also state how we use the feedback in the revised version of the manuscript.

The manuscript has improved considerably compared to the initial version in many aspects. The authors responded to all comments and updated the article accordingly. I am glad to see the paper on this level now. However, there are few points are overlooked or may be were not very clear in my first review:

General comments:

- Although turbulence plays an essential rule in atmospheric flow, it is ignore in this analysis. Examining turbulent intensity and/or turbulent kinetic energy could give some insights about the predicted results.
    - The turbulence level which is influenced with the five factors investigated here could shed some light on the difference between different cases. The speed-up factor could be very sensitive to the turbulence intensity.
- The current study depends on steady state flow models which quite understandable for the scope and the applications of this work, but the authors could at least discuss this effect. In the end, Lidars do not measure stationary wind conditions.
    - This point hasn't addressed. The highest fidelity model used in this work is steady RANS which is for stationary isotropic turbulence which is far off the wind conditions measured by the Lidar. The point here, if one predict the error as proposed, has to be very careful when applying the correction.

Thank you very much for your general feedback and comments. We understand your point regarding the effects of turbulence and instationarity on the actual lidar measurements. We also agree that the five factors we have investigated significantly influence the turbulence in the wind flow.

In the end of the conclusions and outlook section we have briefly discussed the possibility to use more advanced, i.e. non-stationary flow models in order to better explain the scattered results of lidar measurement errors in 10-minute statistics. With such a model we could also analyze instationary effects such as recirculation of detached flow. However, the correction factors resulting from the three models used in this study are meant to be applied to 10-minute statistics time series. They will mainly help to reduce the mean errors and not the error of a single data point.

Analyzing turbulence for the three different models (and for more advanced models) would be an interesting task and worth another, separate study. However, we would rather like to keep our analysis close to the model parameters that are available to the model user. This will help the reader to better understand how to parameterize the models for a good lidar error estimation. We have discussed the effects of roughness elements and forest on turbulence and the flow field with regards to the relevant literature in line 125. From there on it would be possible to study the effects of the different influencing factors on turbulence as well for the interested reader. We hope that we could answer your comments to your satisfaction although we have decided not to include more detailed results on turbulence or turbulent kinetic energy in the model results.

Specific comments:

L380: I think this subsection is essential for this study because it shows the two error parts. So it is essential to show the effect of the model on the error distribution. For example, the speed-up error ratio (with respect to the total) should be relatively higher in RANS model compared to potential flow model. Showing the ratio of each part across the three models will enrich the discussion.
Thank you very much for your comments.

(We are happy to hear that especially the separation of the total error into its two parts is getting so much positive feedback. Detailed results on this can be found in the dissertation of the main author. Considering your feedback, we have decided to include a paragraph that discusses the error parts for the two other models in the newly introduced 'Discussion' section. We have thought about adding more result figures, which show the different error parts or ratios for the different model (and for different parameterizations). However, we have come to the descision that this will lengthen the manuscript too much. We would therefore like to keep the already included figures and discuss the other models in the text.)

Regarding showing the two parts of error which was mentioned more than once in the first review round, I agree with the author that it would be too much to show it for all models for the five parameters. I find Figure 7 very interesting, it shows the different behaviour of the two parts and the order of each one. I think it would be a missed opportunity to not show a similar plot for the other factors.

Thank you very much for your comment. We agree that it would be interesting to show even more and detailed results on this. However, we still think that this would extend the content of the study too much and would like to stick to the already included figures and results.

L178 models repeated

Thank you, we have corrected this in the revised version.

L240 A constant horizontal resolution of 10 m was used in the proximity of the lidar location and the minimum resolution is 25 m - It is not clear what that does mean

Thank you, we have rephrased the section in order to improve the description of the mesh resolution. What we meant is that we have placed a so-called 'mapping' area in the inner region of the mesh around the lidar location. The mapping has a constant resolution of 10 m. Then the grid is becomes less resolved towards the outer boundary until a minimum resolution of 25 m is reached.

L555 forest parameter influence on error - This conclusion isn't very clear. From modelling perspective, there is no doubt that if the site has forested area, it must be included in the model with the right parameters. In Klaas (2015), since measurements were available, it was clear the right forest parameter reduce the gap between the model and the measured data which is expected. This work shows that increasing forest height reduce the error which a good point stress on. Typically a forsted site is considered to be complex and this study finding states that forest does not add error compared to less forested site. That make the L27(abstract) and here kind of misleading to some readers.

Thank you very much for your comments and suggestions. We understand your concerns and read the mentioned section again. However, we think that in the abstract it becomes clear that forest on the one hand contributes to the complexity of the site and the flow. On the other hand, this increased complexity – surprisingly – leads to reduced lidar errors. This in counterintuitive because – as your mention – forest is considered to increase the complexity of a given site. We have added this to the discussions section to underline this finding.