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

General comments:

The authors are discussing one of the critical issues in lidar measurements, namely the error associated with lidar measurements. In particular, this contribution is focusing on the fundamental assumption of flow homogeneity which is the cornerstone of horizontal wind reconstruction techniques. This work split the error into two parts, which are very promising in understanding and deeply analysing the source of errors.

Having said that, this work lacks in many places, especially the discussion section, providing deep insights about the predicted results. Moreover, the newly introduced error classification has been ignored in many of the result subsections. That has been reflected on the conclusion section as well.

Here is a list of general suggestions and points which could improve the manuscript:

- Improve the description of the model setups in order to improve the reproducibility of the work.
- Provide an insightful explanation to the predicted trends in the error.
- Add where it is possible as a ratio of the total error, the two error parts.
- Add where it is possible more than one model results.
- 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 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.
- Although the error estimation is relative to the model full predicted wind vector, a validation of the model setups will be beneficial. The hill case is well studied in the literature, and there is a great chance to find data for some of the modelled cases in this work.

The specific comments section is reflecting most of the above comments. In general, the manuscript language could be improved in some places, but nothing major. The citation format is not consistent across the paper, for instance sometime it takes the form of Author (Year) or (Author, year) or (Author (year)). Please follow the journal format and be consistent across the manuscript. Same applies on the figures, for instance -2% dashed line is missed in some plots.

Specific comments:

0. Abstract:

The abstract could be improved by including some key results of the study, such as the error increase value due to one or two parameters. Also, adding the conclusion about the error due to the cone angle, since it is one of the main finding of the study and explains the contradictions in the literature.

L11: influencing factor on or of

L14: reformulate to make it more clear

L15: remove ,eg.,

1. Introduction:

L32: Group citation should be in chronological order

L34: I guess you mean the horizontal wind vector/speed reconstruction

L42: chapter -> section

L47: This statement is quite general, the assumption is not valid when there is a significant spatial changes between the measurement points. Therefore within the same complex site, it will depend on the position of the profiler lidar and the cone angle.

L49:L51: it is not clear if you are comparing Anotoniou et al. (2007) with Smith et al. (2006), and what is the main contradiction between the two. Please reformulate.

L52: This 5-10% error reported by Courtney et al. (2008) is common in complex terrain, please elaborate from that study why? Otherwise it is not clear for the reader why reducing the cone angle from 30deg -> 15deg is necessary.

L59: It is great to mention this contradiction but please elaborate more and mention why there was no significant increase in the error.

L67: not dependent -> independent . I agree with this conclusion but with larger cone angle, there is a higher change to capture inhomogeneous flow.

L71: why is it independent of height ?

L86: do you mean RANS CFD here? Please be more specific, CFD is a general term.

L114: Group citation should be in chronological order

L123: Group citation should be in chronological order

L135: Indeed stability has a significant impact on wind profiles and turbulence levels even in flat terrain, but it is not obviously clear to the reader at this point how it could influence the lidar accuracy. Please elaborate more.

L137: is another factor -> do you mean ‘are another factors’ ?

L145: Group citation should be in chronological order

2. Methods

I suggest to have some subsections here, at least two, one for the model and one for the lidar error.

L178: forest parameters are not necessarily surface parameters, for instance a typical forest model parameters have to be mapped as volume values.
L191: Group citation should be in chronological order
L196: Isolated one sentence should not be a separate paragraph. Please reformulate it.
L200: The literature is full of similar cases for Gaussian and Cosine hills and the similarity parameters are well established. Please give a background about this case and cite the appropriate literature. Also add the mathematical formula of the hill or cite the source.
L200: H and L should be formatted as math for consistency.
L222: win flow → wind flow
L240: The used models are steady, aren't they? Add this to the description of the models
L241: Add the forest parameters, (low, medium and high) are very general terms
L241: is the forest applied uniformly above the ground? Or limited to the hill. Please elaborate more on the forest model setup.
L247: This was done for a low roughness case, ……. It is not clear what do you mean here.
L249: exemplaryly ?
L250: The model description lack any information about the used meshes. For instance, in addition to the mesh horizontal resolution and domain size, the first cell size is an important parameter especially with high roughness values.
L255: One could start a subsection here.
L286: chapter → section
L303: Eq(6), is this assumption applied in this work?
L311: equation 6 → equation 5?
L313: Are equation (9) and (1) equivalent? In other terms, if one estimated the error based on Eq(1) and Eq(9) will get the same value or not? Have the authors tested that?
L313: Is the same approach applicable om three-dimensional flow? If so, it would be beneficial to end this part with the general formulation.

3. Results and discussion
L323: exemplaryly →exemplary?

<u>Subsection 3.1:</u>
Fig 4: for the right hand side figures a, b, c, it is more reasonable (and more common for such case) to use normalized x, and y axis with respect to L or H. Also the choice of y-coordinate is confusing since the vertical component is considered z-dir in the rest or the paper.
L378: speep-up → speed-up
L378: what about the error variation due to the model? Each model has a different error prediction and it would be good to show it for this case.
Subsection 3.2:
L380: Add to the text the used model, it is not enough to mention it in the figure caption only.

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.
L395: is the predicted flow of all cases and models fully attached? Although it could happened downstream directly above the ground, it may influence the measurement heights.

Subsection 3.3
I have similar comments as above, why it is limited to one model here. Especially, potential flow is symmetric and does not show the expected diverse behavior in the curvature and speed-up errors.

Subsection 3.4
L425: as the above mentioned comments, without including the other models in comparison to the potential flow, it would be hard to isolate the influence of the roughness. The increase in the max error here is not because of the roughness only.
L436: This subsection lacks any explanation for why the error decrease which increasing the roughness values. Probably it is related to turbulence mixing.
L436: it would be interesting to see the influence of roughness on the ratio of the two errors.

Subsection 3.5
As mentioned in my comments on the method section, the forest parameters are not clear. Did you use the same LAD or LAI?

L445:446: epsilon is not math format
Fig8: I do not see the point of including the forest and stability in the same figure.
Fig8: there is no explanation for this behavior, why the error decrease with increasing the forest height, or why both 20m and 30m cases have the same max error.
L451: again this section focuses on the total error and does not show the two error parts which are the main promise of this work.

Subsection 3.6
It is not mentioned what are the model parameters behind these stability classes. For instance, Table 3 includes three stable conditions, which on is included here?
Same comments as before, what is the effect of thermal stratification on the two errors? Any insights why does the error decrease with moving towards stable condition?

4. Conclusion

It is highly advised to revisit this section once applying the above comments. It could benefit also from adding more insights about this future work, it could be a subsection or one paragraph.