Reviewer #2 second round of comments – Major revisions

Report #1

Submitted on 28 Jan 2024
Anonymous referee #2

Anonymous during peer-review: Yes No

Anonymous in acknowledgements of published article: Yes No

Checklist for reviewers

1) Scientific significance Does the manuscript represent a substantial contribution to scientific progress within the scope of this journal (substantial new concepts, ideas, methods, or data)?	Excellent **Good** Fair Poor
2) Scientific quality Are the scientific approaches and applied methods valid? Are the results discussed in an appropriate and balanced way (consideration of related work, including appropriate references)? Note that papers do not necessarily need to be long to be scientifically sound.	Excellent Good **Fair** Poor
3) Presentation quality Are the scientific results and conclusions presented in a clear, concise, and well structured way (number and quality of figures/tables, appropriate use of English language)?	Excellent Good **Fair** Poor

For final publication, the manuscript should be

accepted as is

accepted subject to technical corrections

accepted subject to minor revisions

reconsidered after major revisions

rejected

Were a revised manuscript to be sent for another round of reviews:

I would be willing to review the revised manuscript.

I would not be willing to review the revised manuscript.

Thank you to the reviewers for constructive comments. Our responses to the reviewer comments are below.

Responses to Reviewer #2:
I'm happy with most answers to my questions and general improvements to the manuscript. However, there are still three major issues (numbered below) that needs to be addressed before I can recommend publication.

1. **The sawtooth-like features in Fig. 2d are not adequately explained. In their answer to my question (number 3 under specific comments), the authors say that these features do not impact the result of the study. I am not convinced, and I don't understand from the author's explanation how they appear. If they are an artefact of how the data are interpolated or derivatives are calculated (as indicated in the answer), then I think the method needs to be changed to one that does not introduce such artefacts. Gradients are an essential part of this paper and artificial gradients shouldn't be accidentally introduced by the method. In any case, please explain in the text how the data are interpolated to the 10 m vertical grid (is it linear interpolation or something else?) and how the derivatives are calculated. If the authors insist that the current method is sound, then they need to mention the reason for the sawtooth-like features in the text and explain why they do not impact the results.**

- For this study, the only gradient of importance is the absolute minimum gradient of the profile. In the specific example of Figure 2d, there are two noticeable gradients (near 0.5 km and 2.1 km), the latter of which has a value of −200 N-units km^{-1}. Both are a result of sharp moisture gradients. The sawtooth features above the minimum gradient are nearly four times smaller than the value that is used to define the PBLH; further, if they do not qualify as ducting and therefore if the moisture induced refractivity gradients were absent, the profile would not be used in the study.
- The non-linear vertical grid in ERA5 can create artificial steps in the refractivity profile at very fine scales. It is unwise to perform too much smoothing to remove the features, since it would low-bias the PBLH/ducting height in addition to resulting in the loss of a significant number of cases where the refractivity gradient exceeds the ducting threshold.
- The quality control process that is outlined at the beginning of Section 3 defines the minimum gradient as the largest magnitude negative gradient of the profile; further, the minimum gradient threshold value is −157 N-units km^{-1}. It can be seen in Figure 2c and 2d that any minor value that is introduced as a result of the calculation of the derivative does not impact the location or presence of the absolute minimum gradient in any way.
- The 'deriv' function part of the IDL library (https://www.nv5geospatialsoftware.com/docs/DERIV.html) and "uses a three-point (quadratic) Lagrangian interpolation to compute the derivative of an evenly-spaced or unevenly-spaced array of data."
- The interpolation is performed at the beginning of the analysis and is a quadratic interpolation that filters NaN values so as not to create data from an undefined point. The first step identifies the beginning and the end of the input height array so values are not extrapolated beyond the value of the original domain. Second, the original refractivity and height profiles are used as input values and the uniform height profile (surface to 100

km with resolution of 10 m) is used to interpolate the refractivity profile to the same resolution.

- The following text will be added to the end of Section 2.2 where the interpolation of both data sets is discussed:
    - "In the case of both data sets, quadratic interpolation is used to translate the refractivity profiles from their raw height value to a uniform height profile which is necessary for a sound statistical comparison."
- The following text detailing the gradient calculation will be added to the beginning of Section 2.3:
    - "The refractivity gradient profile is calculated by differentiating the 10 m interpolated refractivity profile with respect to height. The height array is an evenly spaced array from the surface to 100 km with a vertical resolution of 10 m, it is the array that is used for the interpolation process."
- The following text acknowledging the "sawtooth-like" structure above the minimum gradient will be added to the end of Section 2.3:
    - "Note that the weak gradients seen above the minimum in the ERA5 refractivity gradient (Fig. 2d) are a result of the vertical derivative being calculated from the interpolated ERA5 refractivity profile and do not appear for larger interpolation intervals suggesting that the non-linearity of the ERA5 vertical grid at this height affects the vertical gradient. These features of approximately 15 N-units km^{-1} magnitude are only noticed in the plotting and do not impact the results of the study, as only the moisture-induced minimum gradient values are large enough in magnitude to exceed the minimum gradient threshold."

2. **I still do not understand how it is possible to get such narrow ducting thickness for ERA5. In their answer to my question (number 5 under specific comments), the authors explain that it is because the data are interpolated to a 10 m vertical grid. However, that should not increase the underlying resolution. In particular I am concerned when I see the gradient profile in Fig. 2d with the sawtooth-like features that appear to be artificial (due to the vertical derivative being calculated from the interpolated profile). Couldn't these features result in a wrong and too narrow ducting thickness? Could they also influence the results in Fig. 6?**

- The narrow ducting thickness can occur as a result of a gradient value that narrowly exceeds the ducting threshold of −157 N-units km^{-1}. In the case of such an occurrence, it is plausible that the resulting ducting layer could be interpreted with a thickness of only 10 m as the quadratic interpolation could limit a 10 m vertical resolution profile to one point. The authors justify this as acceptable because the interpolated value is providing a more realistic ducting layer thickness. As an example, an ERA5 profile that is not interpolated can have a minimum gradient value of −160 N-units km^{-1} and if the raw profile resolution at that point is 50 m, one could argue the ducting layer thickness is 50 m. However, a 50 m ducting layer thickness could be just as artificial as the reviewer is claiming for a 10 m thickness. In this example the 10 m interpolation is a more accurate assessment of the ducting layer because it allows for estimation based on a uniform height profile and not for an assumption of thickness to be made solely by the non-linear model layers.
- The "sawtooth–like features" have been discussed at length in point 1 above.

3. **I still think the paper would be better without section 3.3.3. But if it is kept, I have the following questions and recommendations: a) How come the linear regression line in Fig. 10a has a slope larger than 1.0 and that most points are above the line in the lower part given that there are a number of outliers well above the diagonal? This seems counter-intuitive. Please check that it is correct. b) I suppose the linear regressions in Figs. 10 and 11 are done with the variables on the x-axes as independent variables and those on the y-axes as dependent variables. So in Fig. 10 it is the PBL height, and in Fig. 11 it is the peak N-bias that is considered as the independent variable. However, in this context, PBL height and peak N-bias are not actual independent variables. Likewise, height if peak N-bias, minimum gradient, and sharpness parameter are not dependent variables as a function of some independent variable. To me, linear regression makes little sense in this case. The reason that it makes little sense is that if you were to interchange the axes, thereby treating the other three variables as independent, you would get different regression lines. I'm not referring to the mirroring in the diagonal. The lines become profoundly different with different slopes and intercepts (see e.g., https://www.reddit.com/r/statistics/comments/12s21os/q_why_doesnt_flipping_the_axes_of_a_scatterplot/). It may not be by much (it depends on the scatter), but enough to question the purpose of the linear regression when you don't have an actual independent variable. Please consider not including the regression lines in these figures.**

- Section 3.3.3 has been removed.

Besides these issues, there are still many mistakes in the text. Some of them I did not catch in my first review, others have appeared in new sentences. I list them all below.

- line 58: **One ";" too many (between Ao et al. and Guo et al.). Commas are missing before the years.**
    - This was changed in response to the reviewer's comment on line 187 that the in-text citation order was not chronological.

- line 115: **I think it should be 'the' refractivity field. But I'm not sure the sentence makes sense using 'which'. The sentence in the original manuscript makes better sense to me, but here parts that before made sense has been left out.**
    - The last sentence has been restored to the original version: "Finally, ducting is prevalent throughout the domain over which the observations were captured creating an opportunity to perform an analysis over a natural cross-section of X (zonal) and Z (vertical) dimensions."

- lines 119-120: **In their answer to me comment on the use of the word 'reanalysis' here (number 3 under technical corrections), the authors write that "the word reanalysis has been removed ...". However, it doesn't seem to have been implemented in the revised manuscript. Please revise.**
    - The word 'reanalysis' has been removed, apologies for the redundancy.

- line 138: **'Seidal' should be 'Seidel'.**
    - Thank you for catching this error, the authors meant no disrespect to Dr. Seidel by the misspelling, and the change has been made.

- line 139: **A 'the' is missing before 'gradient method'.**
    - This line has been removed, please see response to line 140 below.

- line 140: **It seems that the definitions of N'_min and N'_RMS got lost. It is in the answer to one of my questions in the first review (number 1 under specific comments).**
    - The omission of the definitions for N'_{min} and N'_{RMS} was unintentional. However, since the authors have decided to take the reviewer's advice and remove Section 3.3.3 from the manuscript, discussion of the variables is no longer needed.
    - The sentence beginning on line 142 "To assess the robustness…" and continuing to line 145 "… to 5 km as follows:" as well as Eq. (2) on line 146 have been removed.

- line 142: **I am not sure what it means that "Each refractivity gradient profile can then be filtered...". I think you mean that one could filter out (remove from the study) those profiles where the sharpness parameter is not large enough, but that you did not do that in this study. Is that right?**
    - The reviewer is correct, that was the intended message with that sentence. The reviewer is also correct that 'filter' was not used in this study. Since this is the case, the line "Each refractivity gradient profile can then be filtered to identify the PBLH values with sharpness parameter exceeding a specific threshold, thus increasing the robustness of PBLH detection" has been removed from the paragraph.

- line 151: **Remove 'near surface' in this sentence.**
    - The text 'near surface' has been removed.

- line 164: **Would it be better to say more directly: "The ducting layer height is defined as the height of the top of the ducting layer"?**
    - Yes, that seems to be a much simpler way to state the definition, the text has been changed.

- line 166 and Fig. 2: **I think that 'N-units x 1/10' is still the incorrect unit. The authors answer to my comment on this (number 5 under technical corrections) is understood, but a correction does not seem to have been implemented in the revised manuscript. In their answer 12 to reviewer #1, the authors use deca N-units (deca means 10). I think that would be more correct. Alternatively, one could add numbers indicating the N-units on a second x-axis on top of the panels in question.**
    - Thank you for bringing the point to our attention. When the initial changes were made, the '1/10 x N in N-units' was unintentionally left incorrect as it was not realized that '1/10 x N in N-units' was contradictory.
    - Referring to the previous comment (number 5 in reviewer #2's technical correction), the author's do not feel a second axis is necessary but the units can be clarified by listing refractivity units as '*N*-units/10' for this specific figure since the refractivity values are on the order of 10^2 below 3 km altitude.

- References for refractivity in figure 2 (main text and caption) have been changed to '*N*-units/10'

- line 187: **Comma should be semicolon between 1973 and Fjeldbo. Is it a new rule in AMT to put the latest publication first in lists of citations? Usually it is the other way around (oldest first).**
  - Comma was replaced with a semicolon.
  - In-text citations have been reordered chronologically.

- line 201: **Perhaps (N_rds) should be (N_MAGIC) to be consistent with Fig. 3.**
  - Agreed. N_{rds} has been changed to N_{MAGIC}.

- line 204: **Perhaps skip (N_Abel - N_Obs)/N_obs here and in the Fig. 3 caption. It is not explained what N_Obs is, but I think things could be said without the use of symbols here. The Fig. 3 caption would have to be modified a bit.**
  - $((N_{Abel}-N_{Obs})/N_{Obs})$ has been removed from line 206.
  - Caption for Figure 3 has been modified to the following"
    - "End-to-end simulation results for MAGIC radiosonde launched at 0530 UTC on 20121002 showing: (a) N_{MAGIC} (solid red) and N_{Abel} (blue dashed) from surface to 4 km; (b) PBLH adjusted *N*-bias; (c) refractivity gradient and (d) bending angle vs. impact parameter. Panels e-h show end-to-end simulation results for the colocated ERA5 profile."

- lines 200-204: **These lines could be more complete in telling what is in Figure 3, for example something like: 'Figures 3a and 3e show refractivity profiles from the radiosonde (N_MAGIC) and the collocated ERA5 (N_ERA5) data as well as their corresponding Abel refractivity retrievals (N_Abel). The refractivity gradients are shown in Figures 3c and 3g. The PBLH is marked by a horizontal dotted line. The peak bending angles in Figures 3d and 3h are consistent with the sharp refractivity gradients (impact height typically being a few km larger than the height). Figure 3b shows the fractional N-bias (in percent) between the simulated Abel retrieved RO refractivity profile and the radiosonde, whereas Figure 3f shows the same for the ERA5 profile.'**
  - The reviewer's rearrangement of these lines results in a better explanation of the information presented in Figure 3. The original text has been changed to the following:
    - "Figures 3a and 3e show refractivity profiles from the radiosonde (N_{MAGIC}) and the colocated ERA5 (N_{ERA5}) data as well as their corresponding Abel refractivity retrievals (N_{Abel}). The refractivity gradients are shown in Figures 3c and 3g. The derived PBLH is marked by a horizontal dotted line. The peak bending angles in Figures 3d and 3h are consistent with the sharp refractivity gradient. Figure 3b shows the fractional *N*-bias (in percent) between the simulated Abel retrieved RO refractivity profile and the radiosonde, whereas Figure 3f shows the same for the ERA5 profile."

- line 206 (and 321): **Is 'normalized' really the right word to use here? Would it be more right to say that '... each N-bias profile is displayed as a function of an adjusted height being the height minus the derived PBLH.'?**
    - The authors feel that ‘normalized’ is an acceptable word to use; however, the reviewer’s suggestion offers more clarity.
    - Removed ‘normalized’ and added ‘…displayed as a function of an adjusted height, which is the height minus the derived…’
    - Change made on line 206 and line 321 (line 324 in track changes version)

- line 218: **Remove the minus in front of '120' or skip the 'E' (don't have both). The same can be said about the longitudes given in sections 3.3.2 and 3.3.3. Please revise.**
    - Directional notations have been removed from all latitude and longitude references and the authors will maintain consistent use of positive latitude (North) and longitude (East) and negative latitude (South) and longitude (West).

- line 236: **Perhaps here '... MAGIC radiosondes (rds) ...' to be consistent with Fig. 4.**
    - Thank you for catching this, ‘(rds)’ has been added for consistency.

- line 243: **Add 'the' in front of 'gradient method'.**
    - Added ‘the’ in front of ‘gradient method’.

- line 246: **Comma instead of period before 'while'.**
    - The period has been changed to a comma.

- lines 246-247: **Please support with references regarding trade-wind inversion and mixing layer.**
    - Added citations, “Ao et al., 2012; Xie et al., 2012; Riehl, 1979” as references for use of ‘ducting layer’ and ‘trade-wind inversion’
    - Added citation, “Xie et al., 2006” as reference to ‘mixing layer’

- lines 249-250: **Refer to section 2.1 instead of repeating numbers.**
    - Text from line 247 beginning with “Note the radiosonde…” to line 250, ending with “…within 2-3 km” has been deleted and replaced with the following:
        - “Due to the difference in vertical sampling noted in Section 2.1, the ERA5…”

- line 276: **"All parameters are interpolated to a 10 m vertical grid." How do you interpolate these parameters? They are not functions of height. I'm not sure this new added sentence makes any sense.**
    - The reviewer is correct; the sentence does not make any sense. The reference was meant to notify the reader that the mentioned parameters were calculated from interpolated refractivity profiles.
    - The sentence has been removed.

- line 279: **Should 'is' be 'as'?**
    - Yes. Changed ‘is’ to ‘as’.

- line 302: **'bars' and 'bar'. Please be consistent.**
    - Changed ‘bar’ to ‘bars’.

- line 347: **Could it be just "peak height" instead of "its peak N-bias occurring height"?**
    - Yes. “N-bias occurring” has been removed.

- line 350: **Comma instead of period before 'whereas'.**
    - Punctuation has been changed.

- line 353: **Please improve the syntax of this sentence: "Overall, the N-bias in ERA5 are smaller than radiosonde in all bins."**
    - Syntax has been improved to the following:
    - “Overall, the *N*-bias values for the ERA5 data set are less than the *N*-bias values calculated from the radiosonde data set for each longitude bin.”

- line 357: **"Note that the ...". However, it is not possible to see the numbers from the figure. Perhaps just skip "Note that".**
    - “Note that” has been removed from line and replaced with “The”.

- line 358 **(and other places): 'PBL height' -> 'PBLH'.**
    - All references to PBL height have been changed to PBLH except where first defined in the Abstract (line 13) and main text of the introduction (line 33).

- line 359: **I think I know what you want to say, but this does not make sense: "... shows greater difference than the height of peak N-bias ...". Please revise.**
    - Paragraph from lines 357 to 361 has been revised to the following:
    - “Note that the PBLH is above the height of the peak *N*-bias for both data sets. The MAGIC data shows a maximum difference of 100 m (−137.5˚) and a minimum difference of ~15 m (−152.5˚) while the ERA5 PBL height shows greater values for maximum difference (230 m at −142.5˚) and minimum (45 m at −157.5˚).”

- lines 393-394: **Numbers here are still wrong/not updated compared to table 1. However, it seems that they do correspond to the curves in Fig. 9a. For example, the easternmost points in Fig. 9a are slightly above 6 (blue) and 8 (red), whereas the median numbers in Table 1 are slightly below 6 and 8, respectively. Please verify that the numbers in Table 1, in the text, and in the figures are correct and consistent. Please also indicate that the numbers in Table 1 are in percent (I assume they are).**
    - The reference “Fig. 9a and Table 1” on line 394 should not have included Table 1. The reviewer is correct in noting that the numbers reference points in Figure 9.
    - Table 1 is a supplement to Figure 8 and should not have been noted here. Thank you for bringing this to the author’s attention.
    - The reference to Table 1 has been removed from line 394.

    - The numbers listed Table 1 are percentages and referenced correctly from lines 339-360.
    - Table 1 has been updated for clarity, the caption for Table 1 has been updated as well.

- lines 409-411: **A revised sentence here reads: "The reason for the lower correlation value in MAGIC data is attributed to outlier cases when the radiosonde N-bias profiles with a double peak at which the larger magnitude bias is located" This is grammatically wrong. Please revise.**
    - In response to major point #3, section 3.3.3 has been removed.