Response Letter

Dear Referee,

We sincerely thank you for your insightful comments and valuable suggestions on our manuscript EGUSPHERE-2026-862 (originally entitled "First-year MRR observations at Great Wall Station, Antarctic Peninsula region"). Your comments have been very helpful for improving the clarity, rigor, and overall presentation of the manuscript. In response to your suggestions, we have carefully revised the manuscript and added new analyses and supplementary materials where appropriate.

The major revisions are summarized as follows:

First, **we have revised and shortened the Introduction to make it more concise and better suited to the format of a short communication.** We reduced general background information that has already been covered in the cited literature and focused more directly on the added value of MRR observations in the Antarctic Peninsula region. The revised Introduction now more clearly explains how the Great Wall Station MRR observations complement previous Antarctic MRR deployments, rather than simply replicating similar observational efforts elsewhere on the continent.

Second, **we have reorganized Figure 1 to improve the alignment and consistency of the temporal scales among the time-series panels.** The meteorological variables from the automatic weather station and the MRR equivalent radar reflectivity are now presented using consistent daily-mean time axes, which makes the relationship between the radar observations and local atmospheric conditions clearer. Although we retained the map and site photographs within Figure 1 because of the figure-number limitations of the short communication format, we optimized the panel layout to improve readability and reduce interference with the time-series comparison.

Third, **we have expanded the description of the MRR instrumental setup in Section 2.2.** The revised manuscript now provides key operating parameters of the MRR, including the native temporal resolution, number of range gates, range-gate spacing, maximum observational height, Doppler spectral bins, maximum unambiguous Doppler velocity, Doppler velocity bin spacing, and the lowest usable range gate used in the snowfall statistics. These additions make the instrumental description more complete and better aligned with the focus of the manuscript.

Fourth, **we have revised the interpretation of precipitation occurrence in Figure 2 by adding a discussion of range-dependent radar sensitivity and detectability.** We now clarify that the occurrence frequencies derived from Z_e represent precipitation detectable by the MRR, and that weak echoes at higher range gates may fall below the detection threshold. Therefore, the decrease in precipitation occurrence with height should not be interpreted solely as a physical reduction in precipitation frequency. This revision makes the discussion of height-dependent occurrence more cautious and technically accurate.

Fifth, **we have substantially revised Section 3.2 to avoid overinterpreting the wind-stratified reflectivity profiles as direct evidence of blowing-snow contamination. Following your comment, we changed the section title from "Signatures of blowing snow" to "Wind-speed effects on snowfall reflectivity profiles"**. The revised section now focuses on how snowfall reflectivity profiles above the lowest usable MRR range gate vary under different near-surface wind-speed conditions. We also provide additional material in Appendix B, including analyses of reflectivity profiles stratified by season and wind-speed regime, as well as wind-speed–visibility distributions. These additions allow us to discuss possible blowing-snow influence more cautiously, while explicitly acknowledging the uncertainty caused by the lack of reliable MRR measurements below approximately 300 m and by seasonal differences in surface snow conditions.

Sixth, **we have strengthened the description of the precipitation gauge observations and the derivation of the local Z_e–S relationship. The revised manuscript now provides more detailed information on the precipitation gauge, its installation height, lack of a dedicated wind shield, and possible wind-induced undercatch. We also clarified the screening procedure used to identify snowfall-only 12 h accumulation cases from the routine gauge observations.** In addition, following your suggestion, we estimated the uncertainty of the fitted Z_e–S relationship using the regression RMSE in log space and added this uncertainty as a shaded envelope in Figure 3a. These revisions improve the transparency and rigor of the local snowfall retrieval analysis.

Seventh, we have revised the Data availability statement in response to your recommendation. We fully agree that the two-year MRR dataset collected at Great Wall Station is an important observational resource. We are preparing the processed and quality-controlled MRR dataset for release through an appropriate open-access data repository after acceptance of the manuscript. The revised Data availability statement also provides access information for the Great Wall Station surface observations and ERA5 data.

We sincerely appreciate your careful review and constructive suggestions, and we kindly request your re-evaluation of the revised manuscript. In this response letter, the referee's comments are reproduced first, followed by our point-by-point responses. Our response is presented in blue, and any changes in the revised manuscript are underlined.

The authors are thankful to the reviewers for their valuable comments. Our detailed point-by-point responses are provided below.

Referee2:

The manuscript presents preliminary results of the deployment of a Micro Rain Radar in the Antarctic Peninsula region. The manuscript describes the measurements conducted and provides statistics of precipitation occurrence (and, though uncertain, quantification) in the region, based on the MRR measurements and on reanalysis. The topic is interesting for the readership of the journal, although not novel in terms of methods and instruments. I recommend the author to better define the added value of this work, by focusing on how it complements and not just replicates similar installation efforts on the continent.

Response:
We thank the reviewer for constructive comments on this work. With the very good comments from two reviewers, we have substantially improved the focus, transparency, and scientific rigor of the manuscript in the revised manuscript. In particular, as discussed in the Introduction, it is very difficult to obtain such precipitation profiling observations in Antarctica. Our work fills in a critical gap in understanding precipitation formation over KGI. We also compared our observations to other MRR observations (MRR observations in Antarctica are very rare due to the harsh environment), and we do see some differences to other Antarctica sites (possibly due to the impact of katabatic winds in other sites). Therefore, our observations are definitely not similar to previous studies. We will also release the MRR data in the published version of this work.

Comments

1.- I wonder whether, given the fact that this is a short communication, the Introduction section should be reduced. Most of the considerations presented in the Introduction are already present in the cited literature. I would go more to-the-point regarding the added value of MRR measurements in this context and what has been already done (with respect to this instrument) in this environment.

Response:
We sincerely thank the Referee for your constructive suggestion and careful review of our manuscript. Following your comment, we have revised the Introduction to make it more concise and more directly focused, in line with the format of a short communication. Specifically, **we merged and shortened the original opening paragraphs, reduced general background information that has already been well covered in the cited literature, and streamlined the discussion of the limitations of existing Antarctic precipitation**

observations.

In the revised manuscript, the Introduction now moves more directly to the added value of Micro Rain Radar (MRR) measurements in Antarctic precipitation studies. We emphasize that MRR observations can provide continuous, high-temporal-resolution vertical profiles of precipitation, which are valuable for complementing satellite observations and for independently evaluating accumulated precipitation estimates from models and reanalysis products. We have also clarified the previous MRR-based studies conducted in Antarctica in the second paragraph, and then highlighted the remaining observational gap addressed by the present study at Great Wall Station.

We sincerely appreciate your valuable guidance, which has helped us improve the focus, logical flow, and overall quality of the manuscript.

2.- Figure 1. I would like to see this figure reorganized in a way that the temporal scale is well aligned in all the plots. Consider putting the map and the pictures in a separate figure.

Response:
We sincerely thank the Referee for the careful review of our manuscript and for pointing out the issue with the organization of Figure 1. We greatly appreciate this constructive suggestion. Following the Referee's comment, we have revised Figure 1 to improve the consistency and alignment of the temporal scales among the time-series panels. **In the revised Figure 1, the MRR equivalent radar reflectivity and the meteorological variables recorded by the automatic weather station at Great Wall Station, including temperature, relative humidity, and wind speed, are now presented with consistent and well-aligned time axes. In particular, the original radar reflectivity profile has been replaced by a daily-mean reflectivity profile so that it corresponds more directly to the daily-mean automatic weather station data.** This revision makes the relationship between the radar observations and the local atmospheric conditions at Great Wall Station clearer. The revised Figure 1 is shown below.

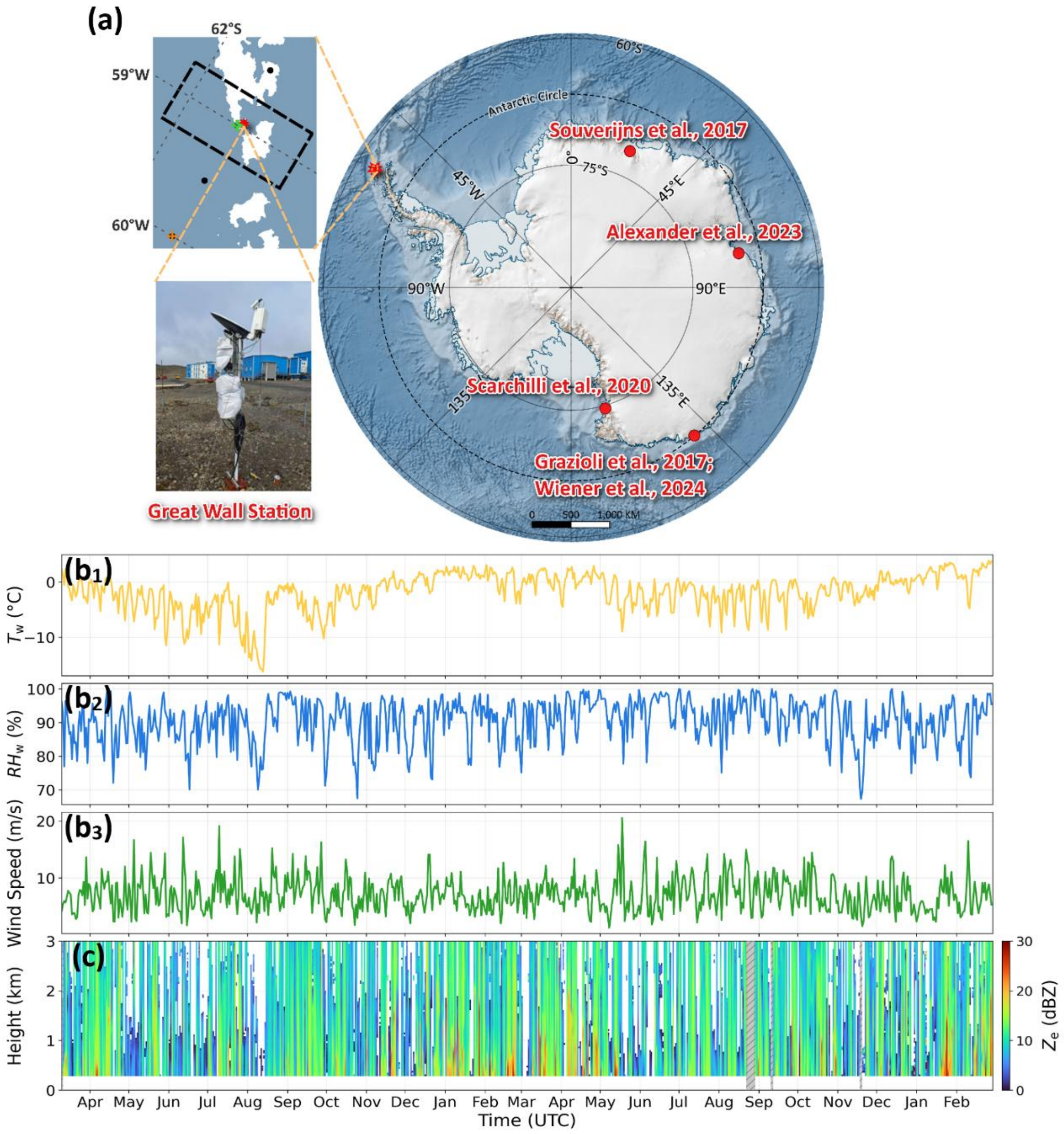

Figure 1 (a) Location of Great Wall Station and the deployed Micro Rain Radar (MRR), together with the automatic weather station (AWS). In the upper-left inset, black dots denote the ERA5 grid points; the green cross marks the ERA5 grid point nearest to Great Wall Station; the orange cross indicates the nearest oceanic ERA5 grid point; and the black dashed box outlines the corresponding ERA5 grid box. (b1) Daily-mean wet-bulb temperature T_w (yellow solid line). (b2) Daily-mean relative humidity with respect to liquid water RH_w (blue solid line). (b3) Daily-mean wind speed (green solid line). (c) Daily-mean Equivalent radar reflectivity (Z_e) at Great Wall Station from March 2024 to February 2026. Grey hatched areas indicate periods of missing data. In (a), established MRR sites are marked with red dots, and scholars who used MRR data from the corresponding sites are annotated.

We also carefully considered the suggestion to place the map and site photographs in a separate figure. However, because the short communication format limits the total number of figures, we retained the map and photographs within Figure 1. To address the original layout issue, we reorganized the positions of these panels and optimized the overall arrangement. In this way, the geographical location of Great Wall Station, the ERA5 grid information, and the observational setting can be presented more clearly, while avoiding interference with the comparison among the time-series panels.

We sincerely appreciate this valuable suggestion, which has helped us improve the clarity and overall presentation quality of the figure.

3.- Section 2.2: please provide more information about the instrument setup (temporal resolution, range gate spacing, Doppler spectra resolution, etc) as this is the main focus of the paper, according to the title

Response:
We sincerely thank referee for this important suggestion, which helped us improve the description of the Micro Rain Radar instrument setup. Following your comment, **we have revised Section 2.2 by adding the main operating parameters of the MRR, including the native temporal resolution, number of range gates, range-gate spacing, maximum observational height, Doppler spectral bins, maximum unambiguous Doppler velocity, Doppler velocity bin spacing, and the lowest usable range gate used for snowfall statistics.**

Specifically, the following information has been added to Section 2.2:

"During the observation period, the MRR was operated with a native temporal resolution of 10 s, 128 range gates, and a range-gate spacing of 35 m, …… the lowest usable range gate for snowfall statistics was approximately 300 m above ground level."

We sincerely appreciate this valuable suggestion, which has made the description of the instrument configuration more complete and clearer, and has improved the rigor of the manuscript.

4.- Figure 2, and comments about it in the text. Can you please comment about precipitation occurrence with respect to the decrease in sensitivity / detectability as a function of range of weather radars?

Response:
Dear Referee, we sincerely thank you for your careful review and for raising this important point regarding the range-dependent sensitivity and detectability of weather radars. Your suggestion has helped us improve the interpretation of the precipitation occurrence results shown in Figure 2.

Following your comment, we have revised Section 3.1 by adding a discussion on how the MRR-derived occurrence frequency may be affected by the decrease in radar sensitivity with increasing range. In the revised text, **we clarify that the occurrence frequency derived**

from Z_e represents precipitation detectable by the MRR, and that weak echoes at higher range gates may fall below the detection threshold. Therefore, the decrease in occurrence frequency at higher altitudes should not be interpreted solely as a physical reduction in precipitation frequency.

The revised text is shown below:

"It should be noted that these occurrence frequencies can be affected by the range-dependent sensitivity of the radar. Since the MRR is vertically pointing, increasing range corresponds to increasing height above the instrument. With increasing range, weak echoes are more likely to fall below the detection threshold, and precipitation occurrence at higher range gates may therefore be underestimated. Consequently, the decrease in occurrence at higher altitudes should not be interpreted solely as a physical reduction in precipitation frequency. To reduce the influence of noisy range gates and potential range-dependent underdetection, the occurrence analysis was restricted to the reliable height range of the MRR, excluding the lowest range gates affected by near-field effects and possible ground contamination, as well as the noisiest upper range gates."

Your insightful suggestion has helped us provide a more cautious interpretation of the height-dependent precipitation occurrence and improve the robustness of the discussion related to Figure 2.

5.- Section 3.2: as the station is not situated in a Katabatic-wind region (as stated in 3.1), I have some reserves on the stratification of data according to surface measurements, without telling the reader something more about the overall vertical structure of the atmosphere. As radar measurements below 300 m are not available, how can we imagine an influence / contamination between blowing snow and radar observations?

Response:
We sincerely thank referee for this precise and insightful comment. We fully understand your concern regarding the use of surface meteorological observations to stratify radar profiles, especially considering that Great Wall Station is not located in a typical katabatic-wind region and that MRR observations below approximately 300 m were not included in this study.

During the MRR observation period, continuous and reliable radiosonde data were not available at Great Wall Station. Therefore, we are unable to provide an observation-based description of the full vertical atmospheric structure for all selected cases. Following your suggestion, we have revised Section 3.2 to further clarify this limitation and to avoid overinterpreting the wind-stratified reflectivity profiles as direct evidence of blowing-snow contamination in the radar observations. In particular, we changed the section title from **"Signatures of blowing snow"** to **"Wind-speed effects on snowfall reflectivity profiles"**, so that this section now focuses more on how snowfall reflectivity profiles vary under different near-surface wind-speed conditions. We also revised the analysis of reflectivity profiles under high-wind conditions. The revised Section 3.2 now reads:

“By contrast, for wind speeds of 10–13 m s^{-1} (Fig. 2c3), a marked enhancement of low-level reflectivity emerges. When wind speed exceeds 13 m s^{-1} (Fig. 2c4), a pronounced reduction in Z_e occurs below 1 km, accompanied by an abrupt decrease in the relative frequency of snowfall occurrence at 1 km—from about 70% in Fig. 2c3 to roughly 60%—and, toward lower altitudes, a noticeably steeper vertical gradient in the occurrence profile.”

To further explain and examine the possible causes of the reflectivity-profile changes, we additionally analyzed the wind-speed dependence of snowfall reflectivity profiles in different seasons (Fig. B1) in Appendix B. The results are consistent with the overall reflectivity variations. The newly added explanatory text is as follows:

“Overall, the seasonal results are consistent with those shown in Figs. 2c$_1$–c4. Under wind speeds of 0–7 m s^{-1} and 7–10 m s^{-1}, the equivalent radar reflectivity profiles show only limited variation. When wind speed increases to 10–13 m s^{-1}, reflectivity below approximately 1.5 km is slightly enhanced compared with that in the 0–10 m s^{-1} regimes. When wind speed further increases to ≥13 m s^{-1}, reflectivity below approximately 1 km decreases markedly compared with the preceding wind-speed regime. This low-level reduction in reflectivity under wind speeds ≥13 m s^{-1} is most evident in summer (DJF, red).”

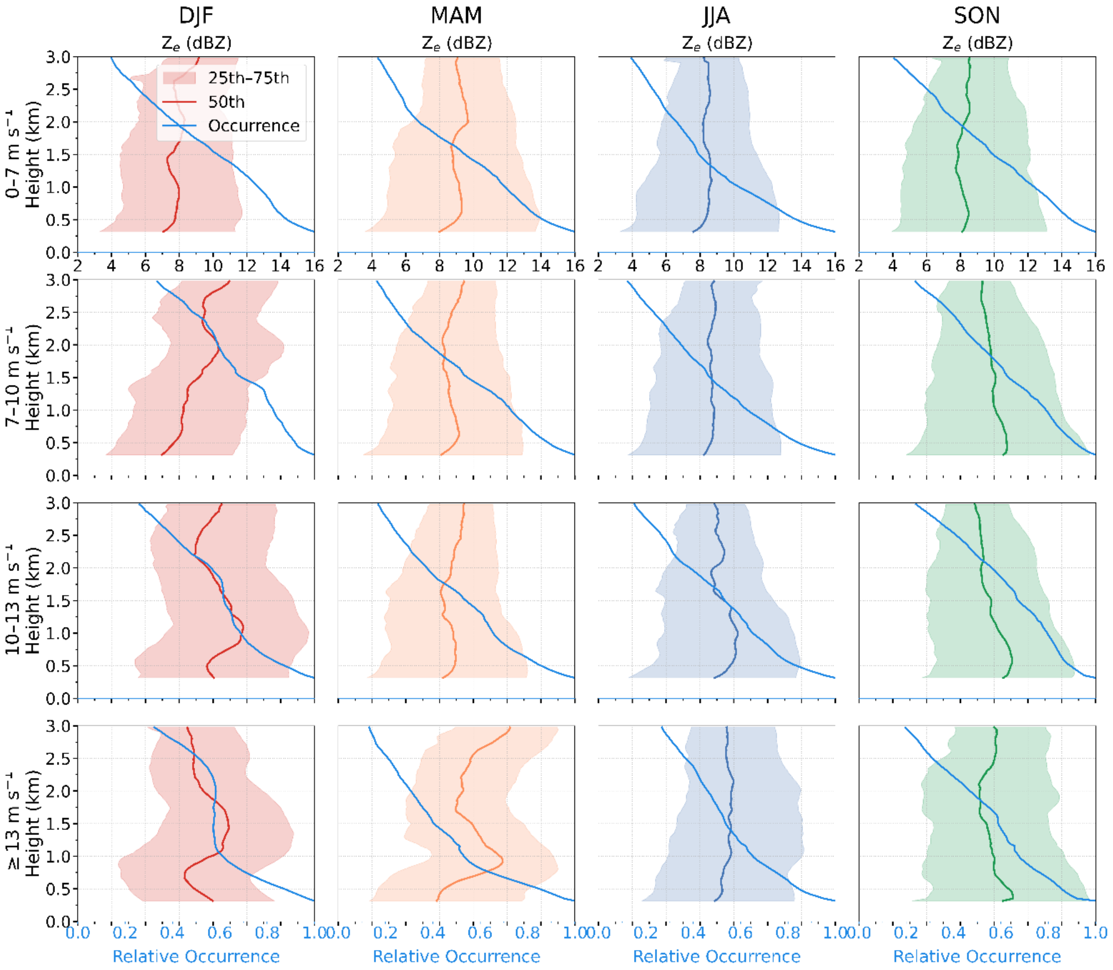

Figure B1 Seasonal median profiles of equivalent radar reflectivity under different wind-speed conditions for summer (DJF, red), autumn (MAM, orange), winter (JJA, dark blue), and spring (SON, green). Solid lines denote the median Z_e profiles, and the shaded areas indicate the interquartile range between the 25th and 75th percentiles. The light-blue solid line shows the height-dependent relative occurrence of snowfall, normalized by the total number of snowfall cases identified at the lowest usable MRR range gate.

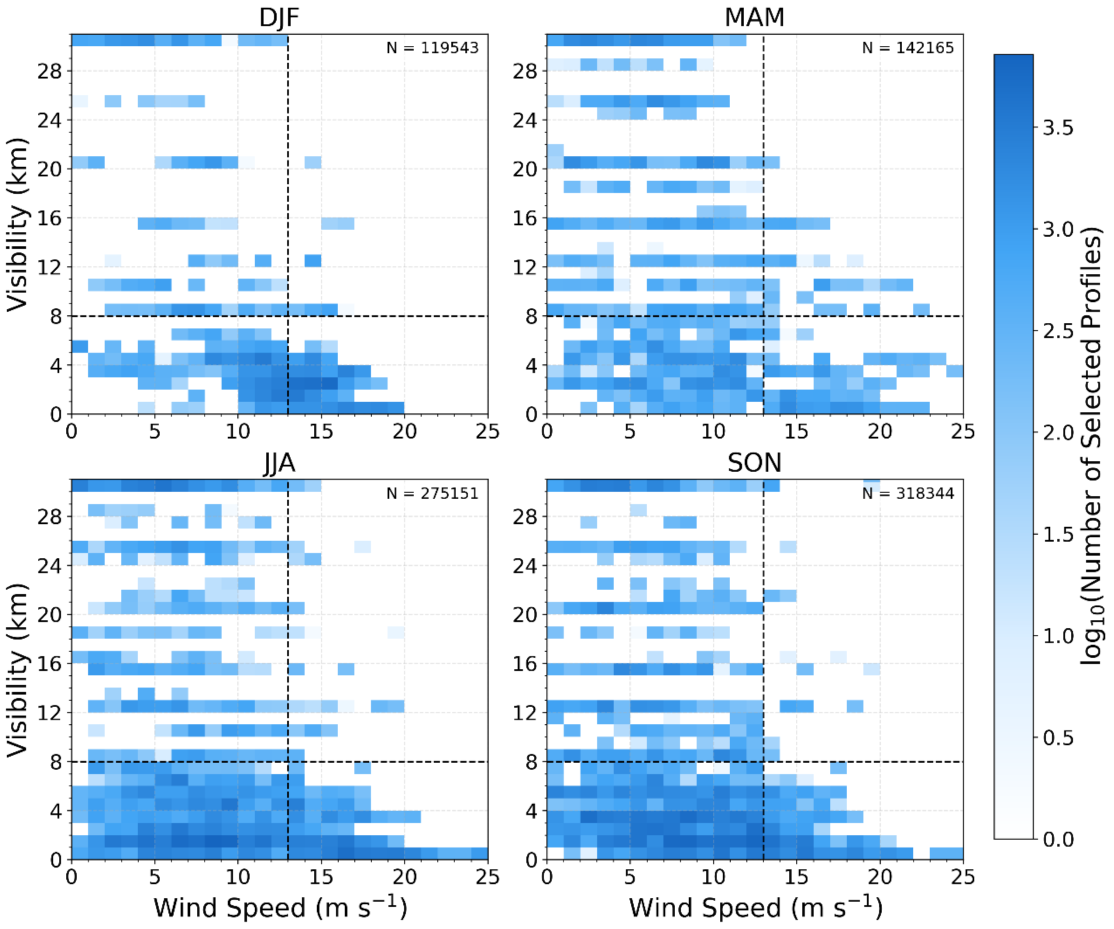

Figure B2 Two-dimensional histograms of surface wind speed and visibility for snowfall profiles in different seasons. ***N*** denotes the number of snowfall profiles included in the statistics for each season. The vertical black dashed line indicates a wind speed of 13 m s^{-1}, and the horizontal black dashed line indicates a visibility of 8 km.

We also compared the selected snowfall profiles with the available surface wind-speed and visibility observations. The resulting two-dimensional histogram (Fig. B2) shows that, when wind speed exceeds 13 m s^{-1}, many snowfall cases are associated with reduced visibility, generally below 8 km; some manually recorded weather phenomena were also classified as blizzard or blowing snow. This high-wind and low-visibility feature is particularly evident in summer. Because strong wind and reduced visibility are typical meteorological characteristics of blowing snow, the supplementary results provide partial support for the interpretation that the decrease in low-level reflectivity under strong-wind conditions may be related to blowing-snow influence. However, we also explicitly clarify in the revised manuscript that, because the lowest usable MRR range gate is approximately 300 m, near-surface blowing snow cannot be directly resolved by the radar; meanwhile, seasonal differences in surface snow conditions and in the availability of mobilizable snow particles may also affect the wind-speed range over which blowing snow occurs. Therefore, we present this interpretation as a possible mechanism rather than as direct evidence of blowing-snow contamination in the MRR observations.

Accordingly, we added the following limitation statement to Section 3.2:

"However, this interpretation remains subject to uncertainty, as MRR measurements below 300 m were excluded from the statistics due to their limited reliability, while seasonal differences in surface snow conditions and the availability of mobilizable snow particles may also affect the wind-speed range over which blowing snow occurs. Therefore, the decrease in low-level Z_e under wind speeds ≥13 m s^{-1} is interpreted here as a feature possibly related to strong-wind and blowing-snow-related processes."

Through these revisions, the manuscript no longer treats the wind-stratified profile changes as direct evidence of blowing-snow influence on the radar observations. Instead, the revised Section 3.2 describes them as features of snowfall reflectivity profiles above the lowest usable MRR range gate that vary with near-surface wind speed, with blowing snow discussed only as a possible contributing process. We sincerely thank you for the careful review of our manuscript and for your valuable suggestion, which helped us improve the rigor and robustness of the related discussion.

6.- Section 3.3. Here more information is needed about the gauge used to measure precipitation and its siting and wind sheltering. As this is supposedly the ground reference, it should be described more thoroughly, also to understand if it may significantly undercatch or not. Given the extreme spread of the points observable in Fig. 3 (a) and Fig 3 (b), the authors should try to provide an estimate of uncertainty of the Z-S relation and put some error bars around the estimates derived from them.

Response:
Dear Referee, we sincerely thank you for this important and constructive comment, and for pointing out the missing information in our original manuscript. We fully understand that, since the gauge observations are used as the ground reference for deriving the local Z_e–S relationship, the precipitation instrument, its siting, wind shielding condition, and possible wind-induced undercatch need to be described more thoroughly.

Following your suggestion, we have **expanded the description of the local meteorological and precipitation observations in Section 2.1. In the revised manuscript, we now provide more detailed information on the surface meteorological instrumentation at Great Wall Station, including the sensors used for pressure, temperature, relative humidity, wind speed, and wind direction, as well as their installation heights.** We also added the following description of the precipitation gauge and visibility observations:

"Precipitation is measured manually using a standard weighing rain gauge (TQ-SDM6, HY Sounding Inc., Beijing, China), which is installed at a height of 1.5 m above the ground. The 12-hour accumulated precipitation is defined as the total precipitation recorded over the preceding 12 h at 00:00 and 12:00 each day. The gauge is not equipped with a dedicated wind shield. Therefore, wind-induced undercatch may occur under windy Antarctic conditions and is acknowledged as a potential source of uncertainty. Visibility is also identified manually by observers in the meteorological room of the scientific building. The meteorological observation field is located northwest of the meteorological room.”

Since the gauge observations themselves do not distinguish between liquid and solid precipitation, the gauge measurements were not used directly as snowfall accumulation without additional screening. **In Section 3.3, we further describe the screening criteria used to identify snowfall-only cases.** The revised text reads:

“Snowfall case selection was based on routine gauge precipitation observations, in which precipitation was recorded twice daily at 00:00 and 12:00 UTC, representing the accumulated precipitation over the preceding 12 h, without distinguishing between rainfall and snowfall. To identify cases containing snowfall only, the following screening was applied. For each 12 h time window (00:00–12:00 UTC and 12:00–24:00 UTC), a case was retained only when the corresponding radar file was available, the 12 h gauge accumulation was valid and no less than 1.0 mm, and the radar temporal coverage within the 12 h window was at least 80%. In addition, to minimize contamination by liquid precipitation, the 12 h accumulation window is required to contain no time steps with wet-bulb temperature $T_w > 0$°C. Cases containing any valid radar sample with $T_w > 0$°C were excluded. Only radar samples satisfying both valid reflectivity and $T_w \leq 0$°C were used in the subsequent analysis.”

In addition, we sincerely thank the Referee for suggesting that we provide an uncertainty estimate for the Z_e–S relationship. This suggestion was very helpful for improving the rigor of the manuscript. **Following your suggestion and the approach of Wiener et al. (2024), we calculated the RMSE of the residuals between the observed $\ln(Z_e)$ values and the fitted $\ln(Z_e)$ values, and used it as the uncertainty estimate of the fitted relationship.** This uncertainty is now shown in Figure 3a as a blue shaded envelope around the locally fitted relation.

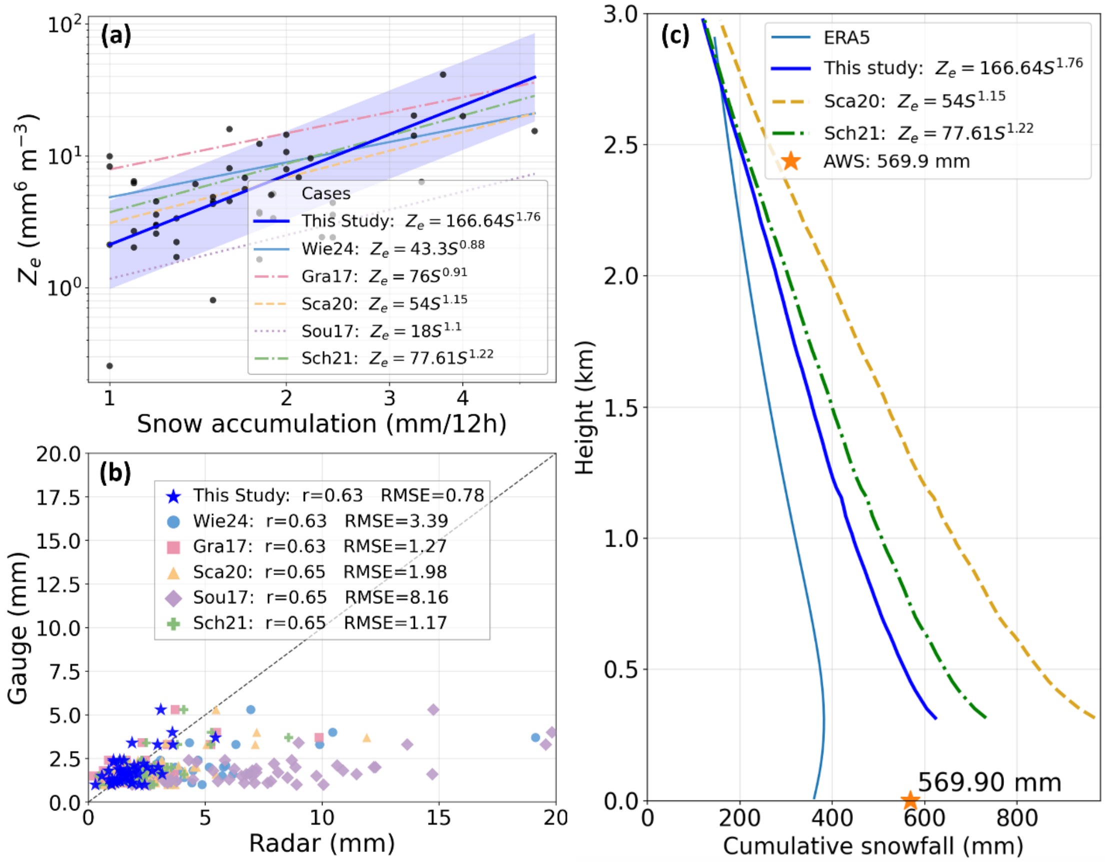

Figure 3 (a) Scatterplot of MRR equivalent reflectivity (linear units) versus 12 h snowfall accumulation from a standard weighing rain gauge (black dots), together with the $\boldsymbol{Z_e}$–$\boldsymbol{S}$ relationship derived using DE regression (solid blue line). The blue shaded region represents the regression RMSE estimated in $\mathbf{ln}\ (\boldsymbol{Z_e})$ space. Also shown are published $\boldsymbol{Z_e}$–$\boldsymbol{S}$ relations from Wiener et al. (2024) (light-blue solid), Grazioli et al. (2017) (red dashed), Scarchilli et al. (2020) (yellow dashed), Souverijns et al. (2017) (purple dashed) and Schoger et al. (2021) (green dashed). (b) Comparison between 12 h snowfall accumulation estimated from MRR reflectivity using the same $\boldsymbol{Z_e}$–$\boldsymbol{S}$ relations as in (a) and the time-scheduled precipitation amounts recorded by the automatic weather station (scatterplot). (c) Cumulative snowfall profiles from ERA5 and from the MRR-based retrieval using the locally fitted relation (solid blue), together with profiles computed using the relations of Scarchilli et al. (2020) (yellow dashed) and Schoger et al. (2021) (green dashed).

The following explanation has been added to Section 3.3:

"Following Wiener et al. (2024), we estimated the uncertainty associated with the fitted Z_e–S relationship using the regression RMSE in log space. Specifically, the residuals between the observed $\ln (Z_e)$ values and the fitted $\ln (Z_e)$ values were used to calculate the regression RMSE. The blue shaded region in Figure 3a represents the range $\ln (Z_{e,\mathrm{fit}}) \pm$ RMSE, converted back to linear Z_e units. This uncertainty envelope illustrates the substantial scatter in the Z_e–S fitting and provides a visual estimate of the uncertainty of the locally derived relationship."

Through these revisions, we hope that the ground reference observations, their measurement setting, the potential uncertainty related to wind-induced undercatch, and the uncertainty of the locally derived Z_e–S relationship are now described more clearly. We sincerely appreciate this valuable suggestion, which helped us improve the rigor and transparency of Section 3.3.

7.- Data availability: I recommend to make data available in an appropriate repository. As the manuscript added value is mostly about the MRR data themselves rather than physical interpretations or new insights, I believe that data should be made public.

Response:
Dear Referee, we sincerely thank you for this valuable suggestion. We fully agree that the two-year MRR dataset collected at Great Wall Station represents an important observational resource, providing continuous vertical measurements of precipitation in the Antarctic Peninsula region.

Following your recommendation, we plan to make the processed MRR dataset publicly available through the **National Arctic and Antarctic Data Center** after acceptance of the manuscript. Since the raw MRR data require additional processing, quality control, and formatting before they can be released as a user-friendly data product, this preparation will require some additional time. We will ensure that the final released dataset is provided as a user-friendly data product to facilitate future use by the community.

We sincerely appreciate this suggestion, which will help improve the accessibility and long-term scientific value of the observations presented in this study.

Minor comments:

- A possibly relevant literature item is: https://doi.org/10.1049/SBRA557G_ch10

Response:
We sincerely thank the referee for recommending this highly relevant literature item. This reference provides valuable and systematic insights that are helpful for improving the context and quality of our manuscript. Following the referee's suggestion, we have carefully read this work and cited it in the revised Introduction. The added reference helps enrich the background discussion and provides useful guidance for our future work. We sincerely appreciate the referee's valuable recommendation.