Response Letter

Dear Dr. Genthon,

We sincerely thank you for your insightful comments and valuable suggestions on our manuscript “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 the title and the wording throughout the manuscript to better reflect the updated observation period. Since the MRR record has now been extended to February 2026, **the study covers two years, from March 2024 to February 2026.** Accordingly, the title has been changed to **“Two-year MRR observations at Great Wall Station, Antarctic Peninsula region”**, and the Abstract and related text have been updated consistently. The precipitation and snowfall occurrence statistics have also been recalculated using the extended dataset.

Second, we have **expanded the descriptions of the observational site, local meteorological instruments, precipitation gauge, and MRR instrumental setup**. The revised manuscript now provides more complete information on the site elevation, sensor types, installation heights, relative humidity reference, precipitation gauge setting, gauge wind-shielding condition, and MRR sampling configuration, including temporal resolution, range-gate spacing, number of range gates, spectral bins, Doppler velocity resolution, and the lowest usable range gate.

Third, we have **reorganized and improved Figure 1 and added Appendix A to the main manuscript** to provide additional information on the local topographic environment around Great Wall Station. In addition, to further address the referee’s concern regarding ERA5 grid-point selection and spatial representativeness, we **provide additional explanatory material in this response letter (Figure R1 and Table R1)** to clarify the spatial context of Great Wall Station and the spatial representativeness of the ERA5 grid point. The revised Figure 1 now shows the ERA5 grid points, the ERA5 grid point nearest to Great Wall Station, which is ocean-dominated, and the corresponding ERA5 grid box.

Fourth, we have **revised the discussion of precipitation occurrence and snowfall reflectivity profiles.** We clarified the meaning of “relative occurrence” and specified that the occurrence statistics are based on the lowest usable MRR range gate. We also added a discussion of the possible influence of radar range-dependent sensitivity on height-dependent precipitation occurrence. These changes make the interpretation of Figure 2 more precise and cautious.

Fifth, we have **substantially revised the discussion of wind-speed effects on snowfall reflectivity profiles.** Following your comments, we changed the title of Section 3.2 from **"Signatures of blowing snow" to "Wind-speed effects on snowfall reflectivity profiles", so that the section now focuses on the dependence of snowfall reflectivity profiles on near-surface wind speed, rather than directly identifying blowing-snow signals.** Following your suggestion, we also provide additional analyses in Appendix B, including reflectivity statistics stratified by season and wind-speed regime (Figure B1), as well as the wind-speed–visibility distribution (Figure B2). These additional analyses allow us to discuss the possible influence of blowing snow more cautiously in the main text, while explicitly acknowledging the uncertainty caused by the lowest usable MRR range gate and seasonal differences in surface snow conditions.

Sixth, we have **strengthened the description and uncertainty assessment of the local $\boldsymbol{Z_e}$–$\boldsymbol{S}$ relationship**. We added more information on the gauge observations and the screening procedure used to identify snowfall-only 12 h accumulation cases. We also added an uncertainty estimate for the fitted Z_e–S relationship using the regression RMSE in log space, shown as a shaded envelope in Figure 3a. The revised manuscript now also discusses gauge undercatch and other potential sources of uncertainty more clearly.

We believe that these revisions have substantially improved the rigor, transparency, and completeness of the manuscript. We sincerely appreciate your careful review and valuable 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.

Referee 1:

Comments

1. L1 Don't understand "first-year" suggest to remove "first-year", just MRR observation etc

Please see our response to Comment 2.

2. L9 This is a year and half. Just mention "first observation"?

Response:
We thank the referee for this helpful suggestion. In the revised manuscript, the study period covers **March 2024 to February 2026**, and the title has been revised to "**Two-year MRR observations at Great Wall Station, Antarctic Peninsula region**". The statements in Abstract and other places have been revised accordingly.

3. L11 This is not "surface", but lowest meaningful radar gate. "Near surface"?

Response:
We agree with the referee's comment. We have revised **"surface"** to **"near-surface"**.

4. L11 0.32 0.23 need to clarify. Suggest 32 / 23% of time?

Response:
We agree with the referee's comment. This sentence has been revised as: **"Quality control was applied to the raw MRR data, from which near-surface precipitation and snowfall were identified during 32% and 21% of the observation time, respectively."**

5.L49 delete "Madeleine,"

Response:
Thank you for your correction. We have revised the relevant content accordingly.

6. L53. in fact, "how reanalyses… represent snowfall" is a misuse of terminology, as precipitation itself is not (re)analysed (data assimilation etc) is a model product. For instance, Roussel et al hint at this when they report studying "predictions from weather forecasting model" rather than analyses of precipitation

Response:
We agree with the referee's comment. This sentence has been revised as: **"During the YOPP-SH special observing campaign at DDU, Roussel et al. (2023) combined gauge and MRR observations to assess the ability of several atmospheric models and**

meteorological reanalysis products to simulate snowfall occurrence.”

7. L65 “first-year”

Response:

We have revised the corresponding wording in the manuscript. The sentence has been updated to: **“In this study, we address this gap using a two-year record of MRR observations collected at Great Wall Station.”**

8. L67 Considering potential land/sea and topographic influences on precipitation and blowing snow, a close up on Great Wall's close environment including topography contour lines would be appropriate. Also, since this is compared with ERA5, showing the corresponding ERA5 grid box on the map would be useful.

Response:
Thank you for pointing out this issue. We have **revised Figure 1a and added more geographic information to the inset map.** Specifically, we now show the surrounding ERA5 grid points (black dots), the ERA5 grid point nearest to Great Wall Station (green cross), its corresponding ERA5 grid box (black dashed box), and the nearest oceanic ERA5 grid point (orange cross).

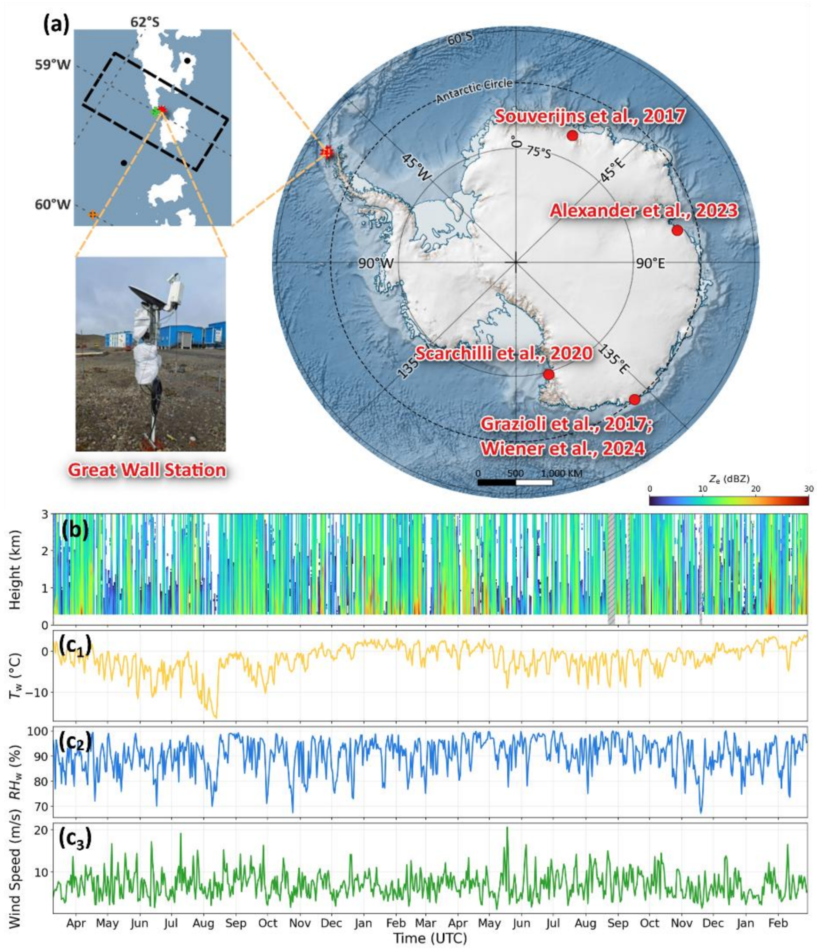

Figure 1 (a) Location of Great Wall Station and the deployed Micro Rain Radar (MRR), together with the automatic weather station (AWS). In the upper-left inset, black dots denote the ERA5 grid points; the green cross marks the ERA5 grid point nearest to Great Wall Station; the orange cross indicates the nearest oceanic ERA5 grid point; and the black dashed box outlines the corresponding ERA5 grid box. (b) 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. (c_1) Daily-mean wet-bulb temperature T_w (yellow solid line). (c_2) Daily-mean relative humidity with respect to liquid water RH_w (blue solid line). (c_3) Daily-mean wind speed (green solid line). In (a), established MRR sites are marked with red dots, and scholars who used MRR data from the corresponding sites are annotated.

Meanwhile, we have clarified the selection of the ERA5 grid point in the description of Section 2.3. The revised text now states:

"Through the comparative analysis of ERA5 grid points, we found that the grid point nearest to Great Wall Station is the optimal choice for representing the snowfall characteristics at the station, irrespective of its surface type. The detailed topographic map around Great Wall Station (Fig. A1) also shows that there is no obvious elevated terrain or ridge between the station and the nearest ERA5 grid point. Accordingly, in Section 3.3, the detailed comparison between the model or reanalysis results and the observations is carried out for this nearest grid point."

In addition, to address the referee's concern regarding possible topographic influences on precipitation and blowing snow, **we added Appendix A, which presents a detailed topographic map of the area surrounding Great Wall Station, including terrain contour lines**. The figure also shows the location of the selected nearest ERA5 grid point. As shown in Figure A1, there is no obvious elevated terrain or ridge between Great Wall Station and the selected nearest ERA5 grid point. We therefore consider that using the ERA5 grid point nearest to Great Wall Station for comparison with the MRR observations is the most appropriate choice.

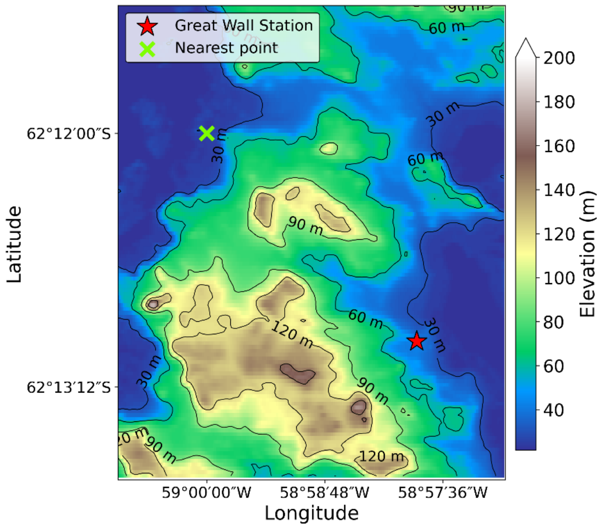

Figure A1 Detailed local topographic map in the vicinity of Great Wall Station. Great Wall Station is marked by a red star, the nearest ERA5 grid point is marked by a green cross, and the black lines represent elevation contours.

9. L75 Which relative humidity? With respect to liquid even below 0°C (met standard)?

Response:

We thank the referee for this important clarification. The relative humidity recorded by the automatic weather station is reported with respect to liquid water (i.e., RH_w), following standard meteorological convention, including at temperatures below 0 °C. We have added this clarification in the manuscript and revised the corresponding sentence accordingly.

10.L77 Do we need the wet bulb temp? Would temperature + relative humidity be enough?

Response:

Yes. The wet-bulb temperature (T_w) is derived from temperature, relative humidity and pressure. Here, we decided to use T_w, because it directly denotes the location where melting starts (Mittermaier and Illingworth, 2003; Stull, 2011; Li and Moisseev, 2020). To minimize the influence of near-surface partial melting, we used T_w to identify snowfall.

11. L78 Some more instrumental description is needed: what is site elevation asl? which instrument / manufacturer? What height above surface, Is relative humidity from humicap (in which case probably with respect to liquid at all temps)? What anemometer and what height above the surface? Etc. This is not part of PANDA described in Ding et al. so met station description therein does not necessarily applies

Response:

Sorry for the confusion. In the revised manuscript, we have specified the details of instrumentation details as follows.

"Atmospheric pressure is measured by a PTB220 barometric pressure sensor installed inside the cabinet of the automatic weather station data acquisition unit. Air temperature and relative humidity are measured by an HMP45D temperature and humidity sensor placed in a Stevenson screen at a height of 2 m above the ground, with relative humidity defined with respect to liquid water. Wind speed and wind direction are measured by an XFY3-1 wind speed and direction sensor installed at a height of 10 m above the ground. 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 precipitation observations do not distinguish between solid and liquid precipitation, all cases were carefully screened in the subsequent fitting analysis of Z_e–S in Section 3.3."

12. Fig 1a Further close up on Great Wall immediate surroundings incl topography and ERA5 grid box being compared with would be useful, probably more than a picture of the MRR itself: replace?

Response:

We thank the referee for this helpful and valuable suggestion. We agree that a clearer close-up view of the surroundings of Great Wall Station is important, particularly for illustrating the representativeness of the ERA5 grid point used for comparison. Accordingly, **we have revised Figure 1a and added Appendix A to the manuscript (see our response to Comment 8).** Specifically, more information has been added to the inset of Figure 1a, including the surrounding ERA5 grid points, the ERA5 grid point nearest to Great Wall Station, and the corresponding ERA5 grid box. In addition, the detailed local topographic map in the vicinity of Great Wall Station shown in Appendix A (Fig. A1) better documents the terrain conditions and the basis for the ERA5 grid-point selection.

We have retained the photograph of the MRR instrument because it helps document the location and installation environment of the MRR system at Great Wall Station. We hope that the revised Figure 1a, together with the topographic map in Figure A1, now provides a clearer representation of the local terrain, observational environment, and ERA5 grid-point selection.

13. Fig 1 b_1 This is probably liquid wet bulb temperature even below 0 °C (met convention)? and this would be RH wrt liquid? Please specify

Response:

Yes. Due to the revision of Figure 1, the original T_w panel (Fig. $1b_1$) has now been changed to Fig. $1c_1$. Here, T_w refers to wet-bulb temperature calculated with respect to liquid water, including at temperatures below 0 °C. Meanwhile, the relative humidity shown in Fig. $1c_2$ is also relative humidity with respect to liquid water. We have added an explicit clarification in the manuscript and revised the corresponding figure caption and labels accordingly, as shown in Figure 1:

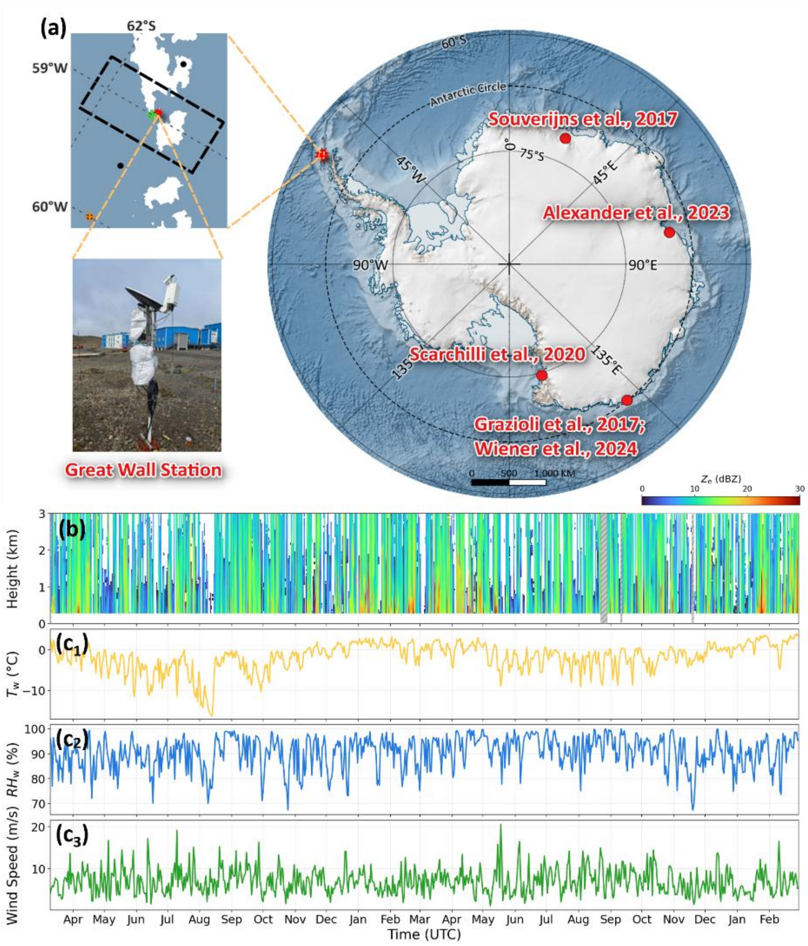

Figure 1 (a) Location of Great Wall Station and the deployed Micro Rain Radar (MRR), together with the automatic weather station (AWS). In the upper-left inset, black dots denote the ERA5 grid points; the green cross marks the ERA5 grid point nearest to Great Wall Station; the orange cross indicates the nearest oceanic ERA5 grid point; and the black dashed box outlines the corresponding ERA5 grid box. (b) 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. (c_1) **Daily-mean wet-bulb temperature T_w (yellow solid line). (c_2) Daily-mean relative humidity with respect to liquid water RH_w (blue solid line).** (c_3) Daily-mean wind speed (green solid line). In (a), established MRR sites are marked with red dots, and scholars who used MRR data from the corresponding sites are annotated.

14. L105 mark ERA5 "grid box" on expanded figure 1a. What is mean surface elevation in this grid box? What land/sea fraction, to which extent this is representative of the local characteristics of Great Wall / met station immediate surroundings, MRR elevation etc?

Response:

We sincerely thank the referee for this helpful and important comment. To better describe the representativeness of the selected ERA5 grid box, we have marked the corresponding ERA5 grid box in the enlarged Figure 1a (see our response to Comment 8). We also further examined the spatial context and ERA5 grid-point selection. Owing to the length limitation of the Brief Communication format, these related materials are provided in this response letter rather than in the main text.

Figure R1 shows the locations of the candidate ERA5 grid points around Great Wall Station, including the nearest grid point, the nearest oceanic grid point, and the nearest terrestrial grid point. For the finally selected nearest ERA5 grid point, Table R1 provides the mean surface elevation within the corresponding grid box (0.5 m) and the land fraction (22.7%, i.e., 77.3% ocean). This grid point is located only 2.6 km from Great Wall Station. To assess its representativeness more rigorously, we compared the three candidate ERA5 grid points in Table R1, including their coordinates, distances from Great Wall Station, mean surface elevations, land–sea mask values, surface accumulation errors, and vertical distribution deviations.

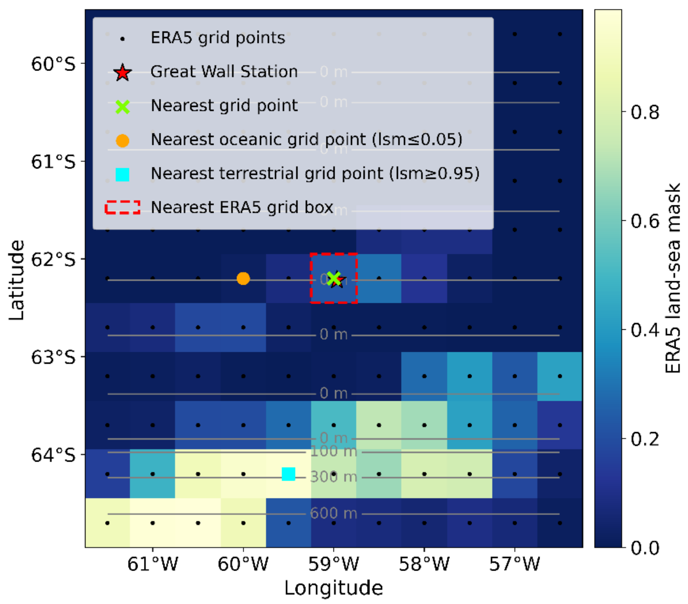

Figure R1 Selection of ERA5 grid points around Great Wall Station. The background shading represents the ERA5 land–sea mask (lsm), and the grey contours indicate geopotential height. The figure shows the location of Great Wall Station (red star), the grid point nearest to Great Wall Station (green cross) together with its corresponding ERA5 grid box (red dashed box), the nearest oceanic grid point (orange circle), and the nearest terrestrial grid point (blue square).

Table R1 Coordinates, distance from Great Wall Station, ERA5 surface altitude, land–sea mask (lsm), surface accumulation error, and vertical deviation for the three selected ERA5 grid points.

Grid point	Coordinates	Distance / altitude (lsm)	Surface accumulation error (%)	Vertical distribution bias (%)
Nearest	62.2° S, 59.0° W	2.6 km, 0.5 m (22.7% land)	-36.7	2.76
Nearest oceanic	62.2° S, 60.0° W	53.7 km, 0.5 m (1.6% land)	-39	2.33
Nearest terrestrial	64.2° S, 59.5° W	222.2 km, 269.1 m (96.3% land)	101.6	4.15

In addition, we added Appendix A (see our response to Comment 8) to the main manuscript, in which a high-resolution DEM is used to provide a detailed local topographic map of the area surrounding Great Wall Station, together with the location of the selected nearest ERA5 grid point (Figure A1). As shown in these materials, Great Wall Station is located in a coastal lowland area, the surrounding terrain is generally gentle, and the highest nearby elevations do not exceed approximately 150 m. More importantly, there is no obvious elevated terrain or ridge between Great Wall Station and the selected nearest ERA5 grid point. From the comparison among different grid points, the nearest terrestrial grid point is much farther from the station and exhibits substantially larger errors. The nearest oceanic grid point performs slightly better in terms of the vertical-structure metric, but it is located considerably farther from Great Wall Station. Taken together, the nearest grid point provides the best overall balance between geographical representativeness and consistency with the MRR observations.

Therefore, we consider this nearest ERA5 grid point to be the most appropriate choice for comparison with the local MRR and meteorological observations.

15. Figure 2 "Relative occurrence" this is relative to what? Presumably, 1 is 100% - of what?

Response:
Sorry for the confusion. Panels (b) and (c) are calculated conditionally on snowfall cases, i.e. only time steps identified as snowfall at the lowest usable MRR range gate (referred to here as the near-surface gate) are included in the sample. Therefore, the **"relative occurrence"** is normalized by the total number of snowfall time steps identified at this near-surface gate. Accordingly, a value of **1** corresponds to **100% of the near-surface snowfall cases**. We have revised the last sentence of the figure caption accordingly to read:

"For each regime, the median Z_e is shown by the black solid line, the interquartile range (25th, 75th percentiles) by the light-grey shading, and the 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."

16. L134 but presumably temperature is warmer below / phase more likely liquid at lower levels?

Response:
We sincerely thank the referee for this important comment. The original wording may give the impression that Figure 2a reflects the thermodynamic evolution of precipitation phase with height. In fact, **Figure 2a shows the occurrence probability, defined as the fraction of all observational time steps at each height for which a given precipitation category is detected by the radar**. The snowfall and wet-snow/rain categories are separated using the wet-bulb-temperature criterion (T_w ≤ 0 °C for snowfall and T_w > 0 °C for wet snow/rain). Therefore, **the larger snowfall occurrence in the lower layers means that snowfall is detected more frequently than wet snow/rain in the lower layers over the full observation period, rather than implying that lower levels are thermodynamically more favorable for snowfall or less favorable for liquid precipitation.** We have revised the relevant text to clarify the statistical meaning of Figure 2a and to avoid this potential misunderstanding. Specifically, the following sentence has been added to Section 3.1:

"Here, the occurrence frequency is defined as the fraction of all observational time steps at each height for which a given precipitation category is detected by the radar."

17. L155 Mc Murdo is presumably much colder than KGI (?), thus less melting, surface snow more mobilizable. Is blowing snow often observed at KGI? Should the study be seasonal due to snow melt more frequent in summer limiting surface snow erosion by wind? On Figure 1, picture shows fully snow-free surface, which does not occur at other sites mentioned here

Response:

We thank the referee for this important and insightful comment. We agree that the environmental conditions at King George Island differ substantially from those at colder Antarctic sites such as McMurdo or East Antarctic stations. Compared with other sites located on the Antarctic Ice Sheet, Great Wall Station is situated at a lower latitude, where melting and snow-free surface conditions may occur more frequently, especially in summer. Such conditions may reduce the availability of loose surface snow for wind erosion and resuspension. The snow-free surface shown in Fig. 1a is an example of such summer surface conditions and does not represent the surface state during the entire observation period. Following your comment, we have discussed the possible influence of blowing snow at Great Wall Station more cautiously in the revised manuscript. Specifically, **we changed the title of Section 3.2 from "Signatures of blowing snow" to "Wind-speed effects on snowfall reflectivity profiles"**. This revision shifts the focus from directly identifying blowing-snow signals to examining how snowfall reflectivity profiles vary under different near-surface wind-speed conditions.

Regarding whether blowing snow occurs at Great Wall Station, we further checked the manually recorded weather phenomena during the study period. Because blowing snow may occur together with solid precipitation, some uncertainty may exist in the manual weather-phenomenon records. Nevertheless, among the strong-wind cases included in Fig. 2c$_4$, namely cases with wind speeds ≥13 m s^{-1}, many were characterized by both strong surface winds and reduced visibility, and a considerable fraction of these cases was manually recorded as blizzard and/or blowing snow. Therefore, we consider that blowing snow does occur at Great Wall Station, although its influence should not be interpreted by direct analogy with colder Antarctic sites that are more persistently snow-covered.

We also agree with the referee that seasonality should be considered, because summer melting and snow-free surface conditions may limit the erosion of surface snow by wind. Following your suggestion, we have added Appendix B and summarized the relevant results in the main text, including an examination of the wind-speed dependence of snowfall reflectivity profiles in different seasons and a two-dimensional histogram of surface wind speed (Figure B1) and visibility for the selected snowfall profiles (Figure B2). The results show that the seasonal statistics are broadly consistent with the main-text results. Overall, the figure shows that the reflectivity profiles exhibit only weak variation when wind speed is below 10 m s^{-1}; reflectivity below approximately 1.5 km is slightly enhanced for wind speeds of 10–13 m s^{-1}; and reflectivity below approximately 1 km decreases markedly when wind speed reaches ≥ 13m s^{-1}. This low-level reflectivity reduction is most evident in summer.

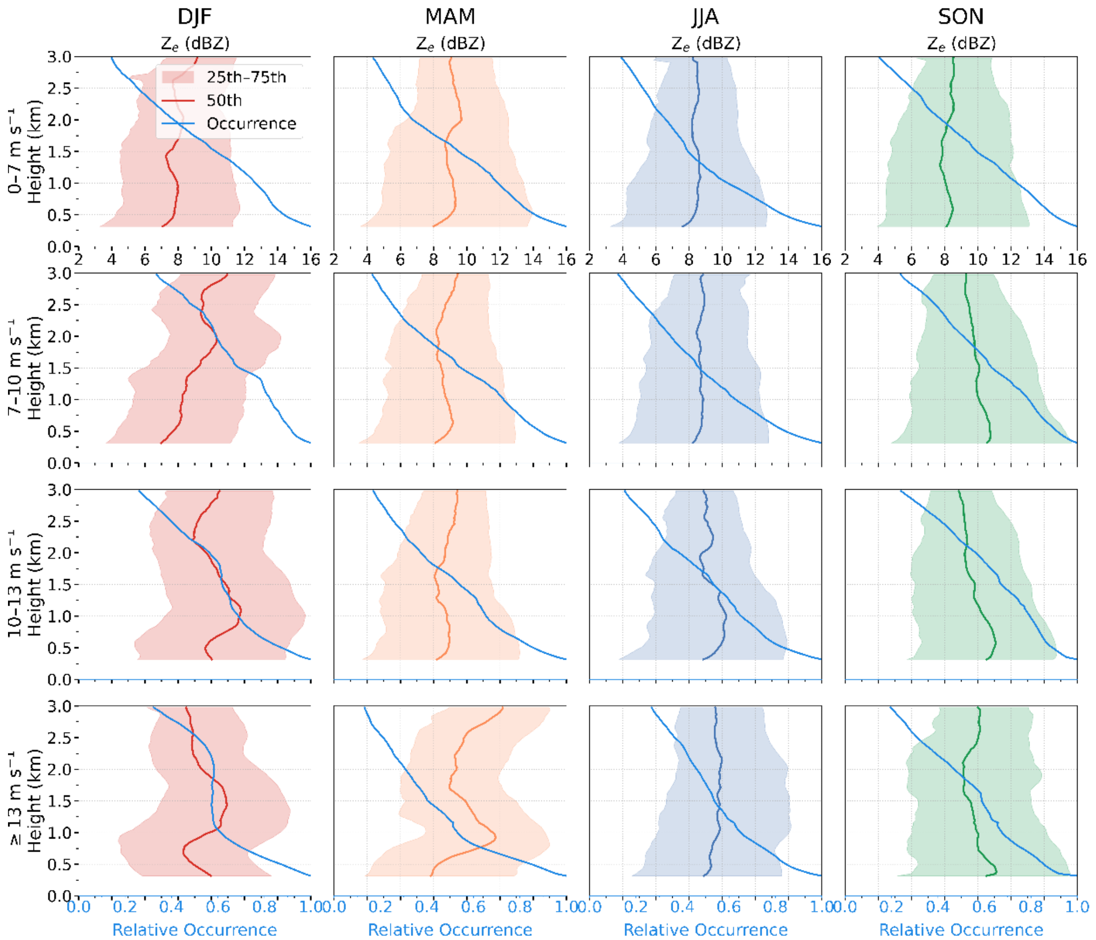

Figure B1 Seasonal median profiles of equivalent radar reflectivity under different wind-speed conditions for summer (DJF, red), autumn (MAM, orange), winter (JJA, dark blue), and spring (SON, green). Solid lines denote the median $\boldsymbol{Z_e}$ profiles, and the shaded areas indicate the interquartile 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.

To further examine the possible influence of blowing snow, we also added a two-dimensional histogram of surface wind speed and visibility for the selected snowfall profiles (Figure B2). We found that, under strong-wind conditions, a large fraction of the cases is associated with visibility below 8 km. Because blowing snow requires mobilizable snow particles at the surface, the number of snowfall cases in summer is the smallest among the seasons. Nevertheless, many summer snowfall cases occur under surface wind speeds of 10–17 m s^{-1}, with visibility below 7 km. This suggests that the low-level reflectivity decrease observed in summer is likely related to blowing-snow conditions.

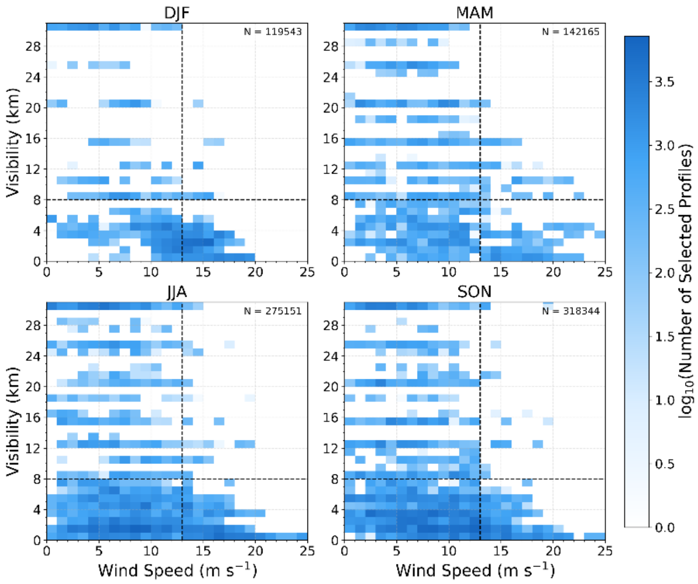

Figure B2 Two-dimensional histograms of surface wind speed and visibility for snowfall profiles in different seasons. ***N*** denotes the number of snowfall profiles included in the statistics for each season. The vertical black dashed line indicates a wind speed of 13 m s^{-1}, and the horizontal black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

Because blowing snow requires mobilizable snow particles at the surface, the number of snowfall cases in summer is the smallest among the seasons. Nevertheless, we found that many summer snowfall cases occur under surface wind speeds of 10–17 m s^{-1}, with visibility below 7 km. This suggests that the low-level reflectivity decrease observed in summer is likely related to blowing-snow conditions.

At the same time, we have added an uncertainty statement in Section 3.2. The revised manuscript emphasizes that the main purpose of this section is to discuss the variation of snowfall reflectivity profiles under different wind-speed conditions, while blowing snow is considered only as a possible cause of the low-level reflectivity decrease. Because of the lowest usable MRR range gate and the seasonal variability in surface snow conditions, this interpretation remains uncertain. The revised Section 3.2 now states:

"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 revised Section 3.2 describes the observed changes 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 the Referee for the careful review and constructive suggestion, which helped us account for the seasonal differences that were not sufficiently considered in the original manuscript and improve the completeness and rigor of the discussion.

18.L173 Assuming a weak catabatic contribution, strong winds at Great Wall are likely associated with passing storms and significant amounts of synoptic precipitation. Could liquid precipitation aloft freezing in the lower levels as it falls also contribute to Ze increasing in the lowest 1 - 2 km?

Response:
This is a valid concern. **To assess this possibility, we further examined all MRR cases showing a melting-layer signature, i.e. cases indicative of liquid precipitation aloft. We found that, for the vast majority of these cases, the corresponding surface wet-bulb temperature was above 0 °C**. As illustrated by the two example cases shown below (Fig. R2), we also present one case with both strong wind conditions and liquid precipitation aloft (27 January 2025); however, the red curve of surface T_w in the figure shows that the wet-bulb temperature remained above 0 °C, and this case was therefore also excluded before the statistical analysis. Under our snowfall-classification criterion based on $T_w \leq 0$ °C, such cases are generally not included in the snowfall sample. Although a very small number of marginal cases with slightly negative wet-bulb temperatures may still have been included, their occurrence is rare and is unlikely to have a material influence on the overall statistics. **On this basis, we consider that refreezing of liquid precipitation aloft is unlikely to be the dominant cause of the observed low-level reflectivity enhancement in the snowfall sample.**

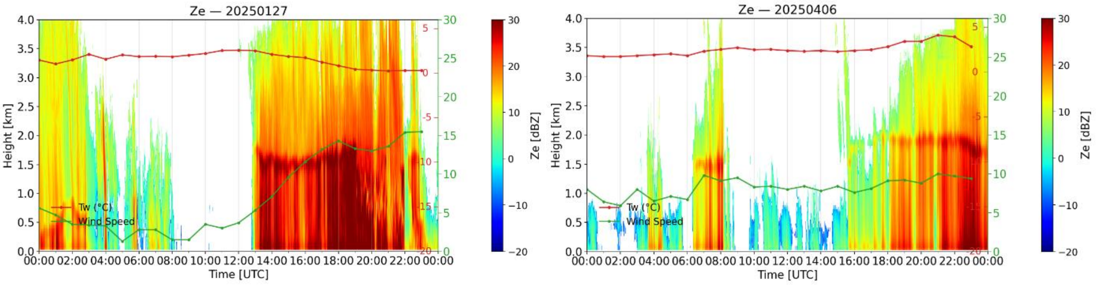

Figure R2 Examples of two precipitation events with melting-layer signatures on 27 January 2025 and 6 April 2025. The color shading shows the equivalent radar reflectivity (Z_e, dBZ) as a function of time and height above ground level. The red solid line denotes the surface wet-bulb temperature (T_w, °C), and the green solid line denotes the wind speed (m s^{-1}).

19. L176 Again, missing info on local obs / instrum / setting

Please see our response to Comment 21.

20. L186 how? Missing info

Please see our response to Comment 21.

21. L195 but are there local gauge obs? This is not stated / described.

Response to Comments 19, 20, and 21:

We sincerely thank the referee for these helpful and important comments. The original manuscript did not provide sufficient information on the local observations, instrumentation, and measurement setting used for the site-specific Z_e–S fitting, nor did it explain clearly how the 12 h snowfall accumulation was obtained and screened. To address these points, **we have revised both Section 2.1 and Section 3.3, and we have also clarified the related description in the Figure 3 caption.**

In Section 2.1 (Great Wall Station), we now provide a more complete description of the local meteorological instruments and precipitation observations. In particular, we specify that precipitation was measured manually using a standard weighing rain gauge (TQ-SDM6, HY Sounding Inc., Beijing, China) installed at 1.5 m above the ground, and that the 12 h accumulated precipitation is defined as the total precipitation recorded over the preceding 12 h at 00:00 and 12:00 UTC. The revised text now reads:

"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."

In Section 3.3, we have added a clearer explanation of how the 12 h snowfall accumulation used in the fitting was identified from the routine gauge observations. Because the gauge records do not directly distinguish rainfall from snowfall, the 12 h precipitation measurements were not used directly as snowfall accumulation. Instead, snowfall-only cases were identified using a multi-step screening procedure. The added and revised parts of the manuscript are as follows:

"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 particular, strong horizontal winds can resuspend previously deposited snow, leading to biased gauge accumulations and, consequently, biased regression. Previous studies have noted that blowing-snow effects become non-negligible for wind speeds exceeding 7 m s^{-1} when deriving Z_e–S relationships (Scarchilli et al., 2020; Wiener et al., 2024)."

Through these revisions, we hope to make clearer the source and measurement setting of the local observations, the derivation of the 12 h precipitation data, and the specific procedure used to isolate snowfall-only cases before constructing the local Z_e–S relationship.

22. L196 but this is surface wet bulb, could liquid precip occur higher from liquid water clouds?

Response:
We sincerely thank the referee for this important and insightful comment. This is a valid concern. Screening based only on surface T_w cannot, in principle, completely rule out the possible presence of liquid or supercooled liquid water aloft. This issue is important for the reliability of the samples used to derive the local Z_e–S relationship, and it prompted us to further examine the relevant cases and the screening procedure more carefully.

In Section 3.3, our purpose in using T_w as a screening criterion was not to demonstrate that liquid water was completely absent at all heights, but rather to identify, as far as possible, 12 h cases that can be regarded as surface snowfall-only accumulation for constructing a more robust local Z_e–S relationship. Surface $T_w \leq 0°C$ generally indicates snowfall at the surface, although freezing rain represents a possible exception. Freezing rain can mainly form in two ways:

1) Melted raindrop falling in sub-freezing environment. In this case, we could see the melting layer of snow (a layer of enhanced radar reflectivity). **However, by checking the radar images, we found that such cases were very rare. We therefore consider that this situation does not significantly affect our results.**

2) Formation of supercooled drizzle from supercooled clouds. This is one of the basic unsolved questions in cloud physics. Drizzle formation from liquid clouds is already difficult, and it is expected to be even more limited under sub-freezing conditions. In the few reported cases, the corresponding radar reflectivity is below ~10dBZ, indicating a negligible rain rate

(Li et al., 2021). Therefore, we consider that these situations are unlikely to significantly affect our results.

To further identify snowfall-only samples as far as possible, we applied a multi-step screening procedure, and the corresponding criteria have now been added to the revised manuscript (please see our response to Comment 21). In addition, we checked all 47 cases ultimately used in the fitting and did not find the situation raised by the referee.

Based on the above analysis, we acknowledge that T_w alone cannot theoretically exclude the possibility of liquid water aloft in all marginal situations. However, **after applying the screening procedure and examining the MRR observations, we did not find evidence that such cases occurred in the final samples used for the fitting in this study. We therefore consider that such conditions do not significantly affect our results.**

23. L202 one needs info: what instruments? Gauge may record precip but not accumulation

Response:
We thank the referee for this important comment. We understand the referee's concern that the gauge provides routine precipitation measurements rather than a direct measurement of snowfall accumulation, and that the instrumentation and observational setting therefore need to be described more clearly.

To address this point, **we have expanded the description in Section 2.1 to specify the instrument and measurement setting (please see our response to Comment 11 and 21).** In the revised manuscript, we now state that precipitation was measured manually using a standard weighing rain gauge (TQ-SDM6, HY Sounding Inc., Beijing, China) installed at 1.5 m above the ground, and that the 12h accumulated precipitation is defined as the total precipitation recorded over the preceding 12 h at 00:00 and 12:00 UTC.

We have also clarified in Section 3.3 that the gauge observations themselves do not distinguish between rainfall and snowfall. Therefore, the 12 h precipitation measurements were not used directly as snowfall accumulation. Instead, snowfall-only cases were identified through the screening procedure described in the revised manuscript, including the wet-bulb-temperature criterion, radar-coverage requirement, minimum-accumulation threshold, and wind-speed restriction. In this way, **only 12 h cases that can be regarded, as far as possible, as surface snowfall-only accumulation were retained for the local Z_e–S fitting.**

We hope these revisions make clearer both the measurement basis of the gauge observations and how the 12 h snowfall accumulation used in the fitting was derived from the local observations.

24. L212 could there be topographic effects that maximize precip at the MRR and gauge

sites and cannot be capture by ERA5 due to resolution?

Response:

We sincerely thank the referee for this important and insightful comment. Accordingly, we have **added a discussion of the local topographic setting and the representativeness of the ERA5 grid point in Appendix A, as well as in our responses to Comments 8 and 14.** Specifically, we now provide a detailed topographic map of the area surrounding Great Wall Station in Figure A1, where Great Wall Station is marked by a red star, the nearest ERA5 grid point is marked by a green cross, and the black lines represent elevation contours. This figure shows that there is no obvious elevated terrain or ridge between Great Wall Station and the selected nearest ERA5 grid point that could substantially affect the precipitation observations.

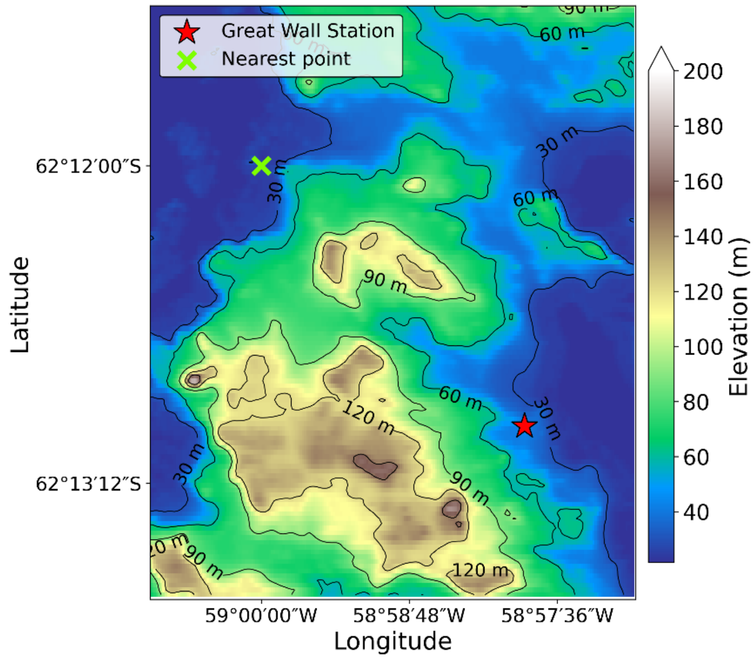

Figure A1 Detailed local topographic map in the vicinity of Great Wall Station. Great Wall Station is marked by a red star, the nearest ERA5 grid point is marked by a green cross, and the black lines represent elevation contours.

In addition, as discussed in our response to Comment 14, we compared the nearest ERA5 grid point with the nearest oceanic and terrestrial grid points. The results indicate that the nearest grid point provides the best overall balance between geographical representativeness and consistency with the MRR observations. Therefore, although we cannot completely rule out sub-grid-scale local effects unresolved by ERA5, the available topographic analysis does not indicate a pronounced local topographic enhancement of precipitation at the MRR and gauge sites relative to the selected ERA5 grid box. We therefore consider the ERA5 grid point nearest to Great Wall Station to be the most appropriate choice for comparison with the local observations.

25. L218 there are also spatial representativeness issues

Response:
We sincerely thank the referee for this important comment. Spatial representativeness is indeed an important consideration when comparing local observations with ERA5. In our responses to Comments 8 and 14, we have provided a detailed discussion of ERA5 grid-point selection and representativeness.

Specifically, we compared the ERA5 grid point nearest to Great Wall Station with the nearest oceanic and terrestrial grid points in terms of distance from Great Wall Station, land–sea mask, surface altitude, surface cumulative snowfall error, and consistency of the vertical snowfall structure with the MRR observations. The results show that the nearest ERA5 grid point provides the best overall balance between geographical representativeness and agreement with the local observations. We have also added the corresponding ERA5 grid box in Figure 1a, together with the detailed topographic analysis shown in Figure A1, to further document the local setting and the representativeness of the selected grid point. Therefore, although some sub-grid-scale representativeness limitations remain unavoidable because of the coarse spatial resolution of ERA5, we have considered this issue in the grid-point selection and selected the most appropriate ERA5 grid point for comparison with the MRR observations.

26. L224 compare observed and 10-m ERA5 winds to evaluate catabatic contribution bias?

Response:
We thank the referee for this constructive and insightful suggestion. However, Great Wall Station is located on King George Island, far from the interior of the Antarctic Ice Sheet, and does not have the typical inland-to-coastal steep topographic gradient that favors persistent katabatic outflow. The near-surface wind field at Great Wall Station is mainly influenced by the westerlies and frequent synoptic cyclone activity, rather than by persistent gravity-driven downslope flow. Therefore, a comparison between observed near-surface winds and ERA5 10 m winds may not provide a clear diagnostic of the relatively weak katabatic influence at this site.

In the present study, our interpretation that katabatic influence at Great Wall Station is relatively weak is based primarily on the geographical setting of the station, the regional meteorological background, and the vertical structure of snowfall observed by the MRR. Consistent with this environmental setting, the MRR observations at Great Wall Station do not show a pronounced katabatic signature comparable to those reported at Antarctic continental or coastal sites more strongly affected by katabatic outflow, such as DDU or Zhongshan Station. Nevertheless, we agree with the referee that, if multi-source wind observations combined with reanalysis data become available in the future, a more systematic assessment of the local wind regime at Great Wall Station would be a very valuable direction for future work.

27. L245 Are there radiosondes at Great Wall, the statistics of which could be compared with Dumont d'Urvilles's and contrast katabatics at the 2 sites?

Response:

We sincerely thank the referee for this important and valuable suggestion. A comparison of radiosonde statistics between Great Wall Station and Dumont d'Urville would indeed be highly useful for investigating the differences in katabatic influence between the two sites. **Unfortunately, owing to limited observational conditions and logistical constraints in Antarctica, Great Wall Station does not have a sufficiently continuous radiosonde dataset for the study period to support a robust statistical comparison. We are therefore unable to address this point in the present manuscript.** Nevertheless, we greatly appreciate this suggestion and regard the comparison of radiosonde-derived thermodynamic and wind profiles between Great Wall Station and continental Antarctic sites as an important direction for future work.

28. L250 but also synoptic disturbance / low level precipitation?

Response:

We sincerely thank the referee for this important and insightful comment. We recognize that, under strong-wind conditions at Great Wall Station, synoptic disturbances and the associated low-level precipitation processes may in principle contribute to the observed radar signatures. **However, as explained in our responses to the related comments above (especially Comments 18 and 22), we attempted to minimize contamination from liquid precipitation or melting-layer cases in the snowfall samples.** Specifically, our snowfall screening excludes any 12 h window containing valid radar samples with $T_w > 0°C$, and only radar samples satisfying both valid reflectivity and $T_w \leq 0°C$ were retained in the subsequent analysis. In addition, we further examined all MRR cases showing melting-layer signatures and found that the vast majority of such cases were associated with surface wet-bulb temperatures above $0°C$, and were therefore generally excluded before the statistical analysis. We also checked the final cases used in the fitting and did not find the situation raised by the referee. **Therefore, although synoptic disturbances may accompany strong-wind events at Great Wall Station and may influence snowfall structure, contamination from liquid precipitation or melting-layer processes was minimized as far as possible in the samples used in this study.**

29. L258 but needs some discussion about spatial representativeness / local contrasts that may induce significant spatial variability of precipitation sub-ERA5 grid scale

Response:

We sincerely thank the referee for this important comment. We recognize that spatial representativeness issues and local contrasts may indeed introduce substantial precipitation variability at scales smaller than the ERA5 grid box. **In our previous responses to related comments, especially Comments 8 and 14, we have already provided a relatively systematic discussion of ERA5 grid-point representativeness.** Specifically, we revised Figure 1a to indicate the selected ERA5 grid box, added Appendix A to the main manuscript, and provided Figure R1 and Table R1 in this response letter to further document the possible sub-grid-scale influences of land–sea distribution and local topography. **By comparing the grid-point information and the local topographic setting around Great Wall Station, we have explicitly considered the representativeness of the selected grid point. We consider the nearest ERA5 grid point to be the most appropriate available choice for comparison with the local observations.**

30. L269 not consistent with the title "first-year" observation...

Response:
As discussed above, two-year observations have been analyzed. The sentence has been modified as follows:

“Given that the present analysis is limited to a two-year record, future work should extend the time series and pursue coordinated analyses that integrate longer-term MRR...”

31. L275 Please provide link to English site / version. This is fully in chinese.

Response:
We sincerely thank the referee for this valuable suggestion. Following the referee’s comment, we rechecked the available data-access pages and found an English ScienceDB data page that includes part of the automatic weather station observations from Great Wall Station.

Therefore, in the revised manuscript, we have added this English data page as an accessible English reference for the published Great Wall Station surface observation dataset. Additional data may also be made available upon request to the corresponding authors. The revised Data availability statement now reads:

“Surface observations at Great Wall Station can be accessed through the English ScienceDB data page (https://www.scidb.cn/en/detail?dataSetId=4d8df6c116fa43e4a9c1e164a9f47b3b&version=V2). Additional Great Wall Station observational data can also be made available from the corresponding authors upon request.”

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