

Thank you very much for your valuable comments. I will respond point-by-point to the main and technical comments raised by the reviewers.

This manuscript presents a methodology for monitoring the calibration of differential reflectivity (ZDR) in X-band phased-array weather radars (XPAR) using a very limited dataset and compares the results with observations from an S-band polarimetric radar (SPOL). While the framework incorporates four correction stages to mitigate ZDR error sources, the validation against S-band observations is problematic. S-band data carries inherent limitations as a benchmark, and using it as ground truth does not sufficiently substantiate the accuracy or reliability of the resulting ZDR.

Response:

Thank you for raising this critical issue. We agree that the adjacent S-band polarimetric radar (SPOL) cannot be treated as absolute ground truth and still has inherent limitations, though operationally maintained S-band radars represent the best-available reference for radar calibration practices in China.

It is worth noting that alternative validation approaches reported in international literature also come with intrinsic drawbacks. For example, Sanchez-Rivas and Rico-Ramirez (2022) used birdbath vertical-profile (VP) scans and disdrometer-derived ZDR for C-band radar validation. Nevertheless, the disdrometer-based method itself has notable limitations:

1. Disdrometers provide point-scale ground observations, whereas radar performs volume-averaged sampling. There is a mismatch in spatial representativeness; our XPAR even has a fine spatial resolution of $30\text{ m} \times 30\text{ m}$.
2. Raindrops may undergo evaporation, coalescence and breakup while falling from the radar sampling height aloft down to the ground surface.
3. Deriving ZDR from drop-size-distribution (DSD) measurements relies on assumptions regarding raindrop shape, canting angle and temperature, which introduces extra uncertainties in T-matrix scattering simulations.
4. Ground-based disdrometer measurements cannot account for the impacts of radar beam blockage.

Constrained by hardware configurations, our XPAR system does not support 90° birdbath vertical scans. Moreover, there are no colocated and synchronous disdrometer observations within our study area, nor are C-band radars with birdbath scanning available for comparison. Under these practical constraints, cross-comparison against an operationally well-maintained SPOL is a feasible evaluation strategy. As documented in Ho et al. (2025), the US phased-array radar Horus also adopted the nearby parabolic-dish KTLX radar as a reference for polarimetric assessments. Importantly, KTLX is not absolute ground truth either and serves only for relative cross-comparison.

Consistent with these published studies, the objective of this work is to take advantage of the high spatiotemporal resolution of XPAR observations and examine whether the corrected XPAR ZDR can achieve reasonable observational consistency and approach the measurement quality of SPOL. This work provides useful insights for the further development of XPAR techniques. For current Chinese weather radar networks, operationally calibrated SPOL provides the most reliable radar-based reference that we can access. Similar to Reference 1 and Reference 2, we perform cross-comparison against

35 SPOL rather than claiming it as absolute ground truth for XPAR correction. In the absence of gold-standard datasets such as KTLX-style references or C-band birdbath measurements, SPOL represents a practical validation option. Future work will explore supplementary validation datasets should they become accessible. Therefore, we have supplemented numerous datasets and experiments for inter-comparison between corrected XPAR and SPOL observations.

40 **Major comments::**

1. While the proposed methodology is promising, its validation relies on a minimal sample size, raising significant questions regarding its overall robustness. Why did the authors evaluate this framework on such a limited dataset? A single case study spanning only a few hours is insufficient to demonstrate the effectiveness, long-term stability, and applicability of the proposed framework. The authors must provide a clear, acceptable justification for this decision and validate their approach
45 against a larger, more diverse dataset over an extended observation period.

Response: The datasets used in this study were collected on 27 March 2023 and from 13 June to 18 June 2023. These include the dataset for Bias- ZDR correction (Table 3) and the dataset for isolation correction (Table 4). We have supplemented observations from additional sites in 2023 as well as data acquired in 2024. We adopted XPAR observations from multiple sites at different times. These XPAR data feature high spatiotemporal resolution, so the total data volume is considerable.
50 Data from diverse times and sites were used to guarantee the stability of the dataset. The statement that only a few hours of data were used is inaccurate. Only parts of each day featured light or moderate rainfall: Bias-ZDR correction requires light rain samples, while isolation correction relies on moderate rain samples. Periods with no precipitation or sparse echoes were excluded. Moreover, continuous echoes are required for isolation correction to capture its variations with elevation angle and time, which imposes constraints on data selection.

55 To address concerns regarding the dataset, we added observations from multiple sites and times in 2023 to improve dataset stability, demonstrating that the algorithm performs reliably and effectively for various XPAR systems. Meanwhile, we supplemented multi-day datasets from a certain month in 2024. The correction performance of Bias-ZDR and isolation correction is shown in Tables 3 and 4, which also verifies the feasibility and long-term stability of the algorithm.

Corrections were successfully obtained for all these time periods. After the algorithm was validated, it was applied to squall-
60 line cases. We concluded that ZDR correction exerts positive effects on the initiation, evolution and dissipation of squall lines.

2. The proposed framework outlines four primary stages to generate reliable ZDR values. However, each stage presents critical methodological gaps or validation weaknesses that need to be addressed:

65 (a) System bias: in their literature review, the authors outline several established methodologies to address system bias, including (i) 90deg vertical (birdbath) scans, (ii) Quasi-Vertical Profiles (QVPs) collected during light rain, and (iii) observations within dry snow. However, the manuscript fails to justify why none of these standard approaches were adopted,

nor does it provide a comparative analysis between the proposed method and these established techniques. The authors should clarify this choice and ideally benchmark their approach against at least one standard method.

70 Response: 90° scan configuration is not available for many radars; therefore, the maximum elevation angle is used as a substitute. The extraction of dry-snow data is challenging due to contamination by wet snow, ice crystals and other hydrometeors, making it difficult to obtain pure dry-snow samples (see line 287). Reproducing Quasi-Vertical Profiles (QVPs) is also nontrivial.

As additional experiments have been supplemented in this manuscript, we compare the performance of the proposed Bias-
75 WZDR method with ZDR correction results derived from the maximum elevation angle, as shown in Figs. 6–7, together with quantitative statistics listed in Table 3.

We also explain why only a few hours of light-rain data were selected from a single day: light rain only occurred during this period, while no raindrops were present at other times. Moreover, the XPAR radars used were deployed at different sites. Each XPAR performs a volume scan every 60 s or 92 s, and the XPAR dataset has a large dimension of $12 \times 400 \times 1400$.

80 These experiments demonstrate the effectiveness of the proposed method. To further strengthen the persuasiveness, experiments from 2024 have been added. Meanwhile, the correction performance at the 20.7° elevation angle is supplemented for comparison in Figs. 20 and 21, with corresponding descriptions added in the text following the figures. Here we clarify the data revisions in Table 3. During re-evaluation, we found that the initial ZDR bias($Z_{DR_bias}(dB)$) at some sites was mistakenly interpreted as the corrected value, which led to discrepancies. This error has been fixed. We re-
85 determined and recalculated the Bias-wZDR (for ZH between 18–20 dBZ), as well as the ZDR bias after Bias-wZDR correction.

(b) The procedure for handling differential attenuation lacks clarity. Specifically, it is unclear how specific attenuation (A_H) was computed (or if it was accounted for at all). At X-band frequencies, both attenuation and differential attenuation are non-
90 negligible. A more rigorous, fully described correction procedure is essential for an X-band framework.

Response: This study adopts the classic Z_{DR} - K_{DP} integrated attenuation correction method. A_H is calculated using Equation (2), and A_{DP} is further derived from A_H via Equation (3). The corrected Z_{DR} is then obtained using A_{DP} . Here, A_{DP} represents the specific differential attenuation per unit distance, and $2 \int_0^r A_{DP}(s)ds$ denotes the total two-way cumulative differential attenuation along the radar radial path. This formulation follows a well-established approach documented in
95 existing literature. (Wang, X.: Data quality control and precipitation classification research of X-band dual-linear polarization radar, MSc thesis, Chengdu University of Information Technology, Chengdu, China, <https://doi.org/10.27716/d.cnki.gcdxx.2019.000113>, 2019).

(c) Cross-polarisation isolation degradation compensation specific to phased-array systems. For this reviewer, this stage
100 represents the most novel component of the proposed framework, particularly regarding its application to phased-array

systems. Unfortunately, because the evaluation is restricted to a brief dataset covering only a few hours, it is impossible to properly verify the effectiveness, stability, or long-term reliability of this compensation technique.

Response: Yes, this is indeed the novel algorithm proposed in this study. Regarding the dataset, we provide the following explanation. The selected periods are 13–18 June 2023 and 27 March 2023. Each column in Table 4 represents one precipitation event. The dataset for isolation calculation requires moderate rain with sufficient echo coverage. For any given day, moderate rain usually lasts for a short duration, or it only occurs within one time window, while the rest of the day features no rain or light rain. To enhance the robustness of our results, we supplemented datasets collected at other sites and at different times in 2023. These multi-site and multi-time observations demonstrate the effectiveness and stability of our algorithm. Datasets from 2024 are also incorporated to further confirm that the proposed algorithm is valid and feasible.

(d)Correction for anomalous radial interference. The filtering solution presented for radial interference appears ad hoc and lacks technical robustness. The approach feels like a simplistic shortcut to remove problematic data rather than a well-supported, objective filtering algorithm. The authors need to provide theoretical or empirical justification for this step.

Response: The method adopted in this study is indeed a classical approach, which is practical and simple. Since the abnormal radial bins in our dataset are relatively straightforward and easy to filter, sophisticated methods such as neural networks and fuzzy logic were not employed. In Line 240, we supplemented the filtering parameters and formulas for abnormal radial bins, together with the dataset selected for the statistical distribution of abnormal radial bins (Table 2). The filtering results shown in Figure 4 were also added.

Technical comments:

1. Figure and tables organisation. Figure captions lack structural consistency across the manuscript. For example, Figure 17 embeds timeframes and sub-figure labels directly into the main title, whereas Figure 18 adopts a clearer structure by separating the main title from the sub-figure descriptions. All figure captions must follow a uniform, standardised format throughout the manuscript. Such problems appear throughout the manuscript.

Response: Figures with multiple legends (Figures 14 and 15) in the manuscript have been reformatted to follow the layout of Figure 18, ensuring consistent and clear presentation of all panels.

2.Table Titles: Table titles throughout the paper need refinement for clarity (e.g., the title for Table 3 is overly vague). On the other hand, the table on page 20 lacks a title and numbering, and the values are clearly incorrect (a bias of 19967 dB is unrealistic). Such problems appear throughout the manuscript.

Response: I have revised the ambiguous titles throughout the manuscript to improve clarity. The caption of Table 3 was changed from “XPAR System Bias Correction” to “ZDR System Bias Before and After Correction for XPAR at Different Stations and Observation Periods”. In addition, Table 5 has been newly added. The previously mislabeled outlier entry

corresponds to sample size; the incorrect table header has been corrected. The erroneous description on Figure 16 was also revised.

3. Similarly, some figures are repetitive and not easy to follow.
Response: The repeatability plots and captions for Figures 9–12 have been optimized in the revised manuscript; see the updated Figure 9.

4. Mathematical expressions across the manuscript should strictly adhere to standard academic formatting and journal guidelines. The introducing text following equations (e.g., the use and formatting of "where") is inconsistent. For instance Lines 280, 286 or 294 uses different styles.

Response: The descriptions of parameters for all equations have been revised to adopt the where format; please refer to the tracked manuscript.

5. Variable Definitions: Please carefully audit the text to ensure every variable appearing in an equation is explicitly defined upon its first appearance. For instance, in equations 2-3 non-mathematical symbols are used, and λ is left undefined.

Response: We have revised the definitions of λ_1 and λ_2 . In Equations (2) and (3), non-mathematical symbols were removed by replacing the Chinese character for “or” with the English word “or”. We have also supplemented the definitions and relevant citations for variables in Equations (2) and (3). The variable descriptions are presented using the where format to maintain consistent notation explanation across all equations.

6. Ensure all timestamps and dates follow a standard, consistent format throughout the paper (e.g., ISO format or standard UTC presentation).

Response: All time values within tables and their captions are revised to follow a consistent ISO standard for UTC time.

7. Reference List: The reference section must be reordered alphabetically and formatted strictly according to the journal’s author guidelines.

Response: All references have been re-sorted alphabetically by the first author’s surname, and three new references have been added.

8. Line 89. Please add a proper reference for the method based on scans taken at 90 degree.
Response: As mentioned in the manuscript, the birdbath scan corresponds to a 90° elevation angle. To maintain consistency throughout the paper, the term “90° elevation angle” in Line 89 has been replaced with “birdbath scan (90° elevation angle)”, and a reference has been added after this statement.

9. Lines 136. This paragraph disrupts the flow of the section and should be rephrased to improve logical continuity and readability

170 Response: This paragraph has been revised at column 145. Descriptions of the initiation, mature development, and dissipation stages of the squall-line, as well as the significance of ZDR in these processes, have been added.

10. Line 145. This paragraph presents concluding remarks, which are inappropriate for the Introduction/Literature Review section and should be relocated.

175 Response: We have revised the concluding statement here and moved it to the opening paragraph of Section 3 Experimental Results to introduce the objectives of this experiment. Meanwhile, at the end of the introductory text starting with “ZDR plays a critical role in...”, we emphasize that ZDR correction enables us to characterize squall-line events and observe ZDR variations throughout the initiation, mature development, and dissipation stages of squall-lines, which is of great importance for quantitative precipitation estimation (QPE) and hydrometeor-phase identification.

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11. Line 209. This sentence is incorrect. ZDR system bias detection is not limited to the highest elevation angle scan.

Response: Thank you for pointing out this issue. The original sentence at Line 235, “Conventional weather radars typically employ the natural target method for ZDR system bias correction, which uses the mean ZDR at the highest elevation angle as the overall system bias,” was too absolute. As stated in the cited work of Ryzhkov et al. (2005), ZDR bias correction can also be performed using observations at elevation angles of 40–60°. Accordingly, we have revised this statement.

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12. Line 223-235. The procedural sequence appears out of order: shouldn't the process begin with the determination of the melting layer (ML) height, given that light-rain data selection is restricted to regions below the ML bottom? Furthermore, please consistently use the term "melting layer" instead of "zero-degree layer."

190 Response: The zero-degree layer has been replaced with the melting layer. Besides, lines 270–300 show the results after reordering. Indeed, the height of the melting layer should be determined first.

13. Figure 4. There are no axes labels (latitude and longitude).

Response: Axis labels for the X and Y axes (longitude and latitude) have been added.

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14. Figure 5. Axis labels are incorrect; please use standard labels such as "Range [units]" and "Height [units]"

Response: Figure 5 has been modified in accordance with the comments.

15. Eq. 7. Please use a more adequate citation.

200 Response: This expression has been revised.

16. Line 267. The term 'La' is duplicated

Response: I have replaced the repeated occurrence of "La" with "Ls" at line 351.

205 17. Figures 8-12 may look better in one combined plot, using different line styles and markers.

Response: The four original figures have been combined into a single panel, as shown in Figure 9.

The revised manuscript with marked changes is provided herein. Given that some figures and tables have been added or removed, inserting new items would require renumbering all subsequent tables and figures. For this reason, we have not yet

210 adjusted the numbering of all tables and figures pending final confirmation.