

Response to Reviewer Comments

Manuscript: "Precursor dynamical factors in the local lower atmosphere of Warm-Sector Heavy Rainfall over South China: Evidence from Wind Profiler Radar Observations"

Manuscript number: **egosphere-2025-2955**

5 Response to Reviewer 2

RC2.1 (General Comment)

10 | *The authors investigated the precursor dynamical factors in the local lower atmosphere of Warm-Sector Heavy Rainfall (WSHR) over South China. ... However, this paper should be improved with much more work, including clarifying the data quality of wind profile radar observations, explaining some confusing issues, and determining the mechanisms contributing to the WSHR from the results in this study. Notably, this article requires thorough proofreading.*

15 | **Response:** We sincerely thank Reviewer 2 for the detailed and constructive evaluation. We agree with all general criticisms and have addressed them comprehensively: (1) Data quality: WPR data quality control is now described in full in Sect. 2.1. (2) Confusing issues: All identified ambiguities in terminology, figure labels, and physical descriptions have been resolved (see specific responses below). (3) Mechanism determination: Three distinct regional mechanisms are supported by quantitative diagnostics: Spearman correlations, Mann–Whitney U tests, and ERA5-based Δw and CAPE analyses, all with explicit p-values. (4) Proofreading: The entire manuscript has been carefully proofread; all grammatical errors and technical inconsistencies identified by the reviewer have been corrected.

20 RC2.2 (Line 61)

| *How to define the onset of WSHR events? And the "vertical profiles" is unclear. Please clarify.*

25 | **Response:** The onset definition is now given explicitly in Sect. 2.2: WSHR event onset is the first hour at which the sub-regional mean precipitation rate $\geq 1.0 \text{ mm h}^{-1}$ for ≥ 3 consecutive hours. The original sentence containing "vertical profiles" has been removed in the revised Introduction; the instrument description now reads "continuous vertical sampling from the surface to 5–6 km" (Sect. 5.2), and specific altitude ranges are given where relevant throughout the manuscript.

RC2.3 (Lines 65–67)

| *Please consider rewriting this sentence, as it is overly long and difficult to read. Many sentences in this paper are recommended to be rewritten as short, simple sentences (e.g., lines 17–22).*

30 | **Response:** The specific sentence at Lines 65–67 ("The wind profiler radar provides the horizontal wind speed...") has been rewritten ("Wind profiler radars continuously measure horizontal wind and vertical velocity profiles in the lower and middle troposphere at high temporal and vertical resolution (Liu et al., 2020), making them well suited to resolving the pre-onset wind field evolution associated with mesoscale weather systems") in the revised manuscript. The long compound sentence in lines 17–22 has been
35 | similarly restructured throughout the Introduction into shorter declarative sentences.

RC2.4 (Line 71)

| *"lower level" is an unclear description. Please clarify.*

40 | **Response:** The phrase "lower level" no longer appears in the revised Introduction, as the relevant passage has been entirely rewritten. Elsewhere in the manuscript, specific altitude ranges are used throughout (e.g., "below 2 km" in the wind field description of Sect. 4.1; "below 3 km" in the VWS discussion).

RC2.5 (Line 76)

| *"BLH". The abbreviation should be defined at its first occurrence.*

Response: "Boundary Layer Height (BLH)" is now defined at its first occurrence (line 24). All other abbreviations have been checked and defined at first use.

45 RC2.6 (Line 82)

How did the authors combine the observations from wind profile radars and automatic weather stations? Please clarify. Please consider evaluating the data quality of the wind profile radars. It is vital to understand the limitations/flaws of such data.

50 **Response:** Sect. 2.1 now describes in full how the two datasets are combined and how WPR data quality is assessed. WPR and AWS data serve complementary roles: WPR data provide vertical wind profiles for computing the five dynamical indices, while AWS hourly precipitation records are used for event identification. The two datasets are combined through a representative-station assignment rule: for each identified event, the WPR station nearest to the rainfall-weighted precipitation centroid (within 100 km, same sub-region) is designated as the representative station, linking the precipitation-based event record to
55 a specific WPR observation time series. WPR data quality control follows three steps: (1) removal of records flagged by instrument quality flags; (2) physical range checks (altitude ≤ 6000 m, horizontal wind $0-40$ m s^{-1} , vertical velocity -10 to $+10$ m s^{-1}); (3) two-dimensional median filter (± 2 time steps, ± 2 height gates), setting deviating values to missing. Known limitations—restricted vertical range (0–6 km), ground clutter below ~ 0.5 km, and hydrometeor-induced bias near onset—are stated in Sects. 2.1 and 5.3.

60 **RC2.7 (Line 83)**

"the f electromagnetic". What is meaning of "f"?

Response: This typographic error has been removed. The sentence has been rewritten to avoid this phrasing entirely.

RC2.8 (Line 100)

65 *The caption of Figure 1. Profile or profiler? Please check this carefully throughout the paper.*

Response: "The profiler" (instrument) and "profile" (vertical data record) have been carefully distinguished throughout. Fig. 1 caption now correctly reads "wind profiler radar network". All occurrences of "profile" that were used to mean "profiler" have been corrected.

RC2.9 (Line 101)

70 *"subsurface" should be "impermeable subsurface".*

Response: The sentence containing "impermeable subsurface" has been removed. Fig. 1 now refers to "urban built-up areas in 2020" as defined by the He et al. (2022) dataset, which is more physically appropriate to the context of this study.

RC2.10 (Line 111)

75 *The limitations and sources of potential error in these calculations should be stated.*

Response: Limitations and error sources have been addressed at two levels in the revised manuscript. At the data level, the QC procedure described in Sect. 2.1 documents the known biases and their mitigation. At the method level, the main limitations for each index are acknowledged in Sect. 2.3: the LLJI precision is limited by WPR horizontal wind measurement uncertainty ($\sim 1-2$ m s^{-1}) and the inability to resolve
80 winds below 0.5 km AGL due to ground clutter (Sect. 2.3.1); the lower VWS limit of 0.5 km is adopted to avoid ground clutter contamination and is further supported by the VWS maxima observed throughout the entire sample of full 226-events and typical BLJ core heights over coastal South China (Du and Chen, 2018), as stated in Sect. 2.3.2; ALI values near and after onset should be interpreted with caution due to hydrometeor fall-speed contributions ($\sim 0.5-2$ m s^{-1} ; Sect. 2.3.3); and the BLH residual uncertainty of
85 $\pm 300-500$ m after validation is stated in Sect. 2.3.4. Broader methodological limitations—including the absence of null-case comparisons and the potential for hydrometeor contamination of vertical velocity near onset—are discussed in Sect. 5.3.

RC2.11 (Line 123)

Please clarify the meaning of "D".

90 **Response:** D in the LLJI formula (Eq. 7, Sect. 2.3.1) denotes the lowest altitude at which the wind speed reaches 12 m s^{-1} in a given time period. This definition is now stated explicitly in the text following Eq. (7): "where V is the maximum wind speed below 2 km altitude and D is the lowest altitude of the 12 m s^{-1}

95 wind speed in a given time period. When the maximum wind speed does not reach 12 m s^{-1} , D is set to the altitude of the maximum wind speed." The divergence computed in Sect. 2.3.5 uses a distinct symbol and is defined separately with units of s^{-1} .

RC2.12 (Lines 126–127)

What did the authors want to explain via this description "thereby allowing the hydrometeors in the updraft to separate from the updraft."? If authors want to describe the tilted updrafts, I suggest to rewrite this sentence.

100 **Response:** The sentence has been rewritten for physical accuracy:

105 Revised text: "Strong VWS tilts the convective updraft, enabling precipitation particles to fall out of the updraft region, thereby reducing hydrometeor loading on the updraft and sustaining its buoyancy. Strong VWS also enhances the entrainment of dry cold air into the middle layer, strengthening the downdraft and cold outflow near the ground, which forces the inflowing warm, moist air to rise more intensely." (Sect. 2.3.2)

RC2.13 (Line 162)

Please check these terms.

110 **Response:** The BLH estimation section (Sect. 2.3.4) has been fully rewritten with consistent and precise terminology: "vertical velocity standard deviation (σ_w)", "boundary layer height (BLH)", "gradient criterion ($\Delta\sigma_w/\Delta z$)", "strict threshold" and "relaxed threshold". All terms are defined in the first use.

RC2.14 (Lines 206–208)

The authors should note that the described phenomenological characteristics should be accompanied by corresponding figures.

115 **Response:** All phenomenological descriptions in the revised Sect. 4 are now directly linked to specific figures. The composite wind field evolution (Sect. 4.1) is illustrated in Fig. 6; the VWS vertical structure in Fig. 7; the temporal evolution of all indices in Fig. 8; stratified composites in Fig. 10. Cross-references to the corresponding figures have been added at each relevant point.

RC2.15 (Table 1)

The meanings of number in first row should be explained.

120 **Response:** Table 1 has been removed from the revised manuscript. The information contained (event start times, representative stations, maximum rainfall intensities, and regional assignment) has been superseded by the objective event identification algorithm described in Sect. 2.2 and the statistical overview in Figs. 2–3.

RC2.16 (Figure 4)

125 *The information in this figure is difficult to discern; it is recommended that the figure be redrawn and zoomed in.*

130 **Response:** The original Fig. 4 showed synoptic-scale geopotential height and wind fields at 850 hPa for each of the eight individual cases (8 sub-panels). In the revised manuscript, this figure has been replaced by revised Fig. 5, which presents composite mean geopotential heights and wind fields at 500, 850, and 925 hPa for the three sub-regions (9 panels arranged as 3 rows \times 3 columns). The composite approach provides a cleaner representation of the typical synoptic environment for each region and is more readable than the eight individual case maps.

RC2.17 (Lines 239–240)

135 *The authors are encouraged to explain how did you get the Figure 7. And more details should be clarified for this sentence.*

Response: The original Fig. 7 showed VWS in a two-dimensional triangular format (x-axis = high altitude, y-axis = low altitude) for each of the eight individual cases. This figure has been replaced in the revised manuscript by revised Fig. 7, which shows composite VWS vertical profiles averaged over $t = -3$

140 to 0 h for all events in each sub-region. VWS is calculated between adjacent 60 m range gates from quality-controlled WPR profiles and then composited between events (median with 25th–75th and 10th–90th percentile ranges). This approach provides a statistically representative description of the pre-onset VWS vertical structure across all 226 events. The averaging window ($t = -3$ to 0 h) was chosen to capture the most active pre-onset evolution while minimising contamination by convective-scale disturbances after onset. A full description is now given in Sect. 4.1.

145 **RC2.18 (Lines 240–242)**

"There is strong... onset of precipitation." The authors should clarify where the information comes from.

Response: This statement has been replaced with a direct reference to the supporting figure. The revised Sect. 4.1 states that two features are shared across all three regions: "(i) a progressive strengthening of low-level winds in the hours before onset, and (ii) a transition from near-zero to positive vertical velocity anomaly beginning 1–3 h before onset," with explicit reference to Fig. 6.

RC2.19 (Lines 245–247)

How to explain the differences between Figures 6b, e, g, h and Figures 6a, c, d? The corresponding wind direction is southerly in Figure 6g but that is southwester in Figure 6h.

155 **Response:** The original Figs. 6a–h showed individual case wind fields, and the differences between panels primarily reflected the seasonal transition associated with the onset of the South China Sea monsoon: panels corresponding to the pre-monsoon cases showed a predominantly south flow, while the post-monsoon cases showed a southwest flow as the monsoon was established. The wind direction contrast between south (pre-monsoon western region) and southwest (post-monsoon eastern region) reflects this seasonal shift. In the revised manuscript, individual case panels have been replaced by composite time–height cross-sections for each sub-region (revised Fig. 6), which clearly shows the regional wind structure typical of all 226 events. The monsoon-phase stratification is now addressed through the stratified composite analysis in revised Fig. 10a–b.

RC2.20 (Figure 7)

165 *This Figure is difficult to understand. Please provide more details for clarification.*

Response: The original Fig. 7 displayed VWS between all possible altitude pairs in a two-dimensional triangular matrix, with the upper-level altitude on the x-axis and the lower-level altitude on the y-axis. While this format provides a comprehensive overview of cross-level shear at a glance, it proved difficult to interpret in the context of this study and offered limited analytical value for identifying the physically relevant shear layers. This figure has been completely replaced in the revised manuscript. The revised Fig. 7 shows composite VWS vertical profiles (median \pm percentile ranges) averaged over $t = -3$ to 0 h for all three sub-regions. The two analysis layers (Layer 1: 0.5–1.5 km; Layer 2: 1.5–3.0 km) are marked directly on the figure with gray bands. The caption specifies the computation method, averaging window, and the meaning of the shading. The rationale for all layer bounds is explained in Sect. 4.1.

175 **RC2.21 (Line 267)**

Why do authors select this range, 0.5–1.5 km? As they shown, the maximum values occurred at 0–1 km height. Please clarify.

Response: The choice is justified in Sect. 2.3.2 and reiterated in Sect. 4.1. The 0.5 km lower bound is adopted because WPR measurements below ~ 0.5 km AGL are subject to ground clutter and strong frictional variability, making them unreliable across the event sample. The true near-surface VWS maximum is therefore excluded not because it is unimportant, but because it cannot be measured reliably with this instrument network. The 1.5 km upper bound encompasses the BLJ core, which typically resides near 0.5–1 km over coastal South China.

RC2.22 (Figure 8)

185 *The authors should carefully check their results (e.g., the 25%–75% quantiles are presented, but the mean values are absent), and the median values are encouraged to be shown in this figure.*

Response: The revised Fig. 8 now shows: (1) composite median (solid line); (2) bootstrap 95% CI of the median (dark shading, 1000 resamples, bias-corrected and accelerated); (3) interquartile range (light shading).

190 **RC2.23 (Line 298)**

| "2 hours". Why did authors use the 2 hours before the onset of WSHR? Please clarify.

Response: The four pre-onset periods ($t = -6$ to -4 h, -4 to -2 h, -2 to -1 h, -1 to 0 h) are now justified in Sect. 2.4. The boundaries are motivated by the composite wind field analysis (Sect. 4.1, Fig. 6), which identifies $t \approx -2$ h as the onset of the most active pre-onset wind field evolution phase across all regions. The innermost period (-1 to 0 h) also represents a practically relevant nowcasting time for WSHR.

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RC2.24 (Lines 316–317)

| Including the 95% confidence interval in Figure 11 would improve the clarity of the figure.

Response: The original Fig. 11 (composite mean temporal evolution of LLJI, VWS, ALI, and BLH across three regions) has been replaced in the revised manuscript by the revised Fig. 8, which shows composite medians with both bootstrap 95% CI (dark shading) and interquartile range (light shading), as described in the response to RC2.22 above. The revised Fig. 11 now shows composite wind speed profiles for strong- and weak-rainfall events (a different analysis), with IQR shading. The original Fig. 11 content is fully represented in revised Fig. 8.

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RC2.25 (Lines 318–319)

| "VWS values...before the onset." Where is the information from? Figure 11d and e did not show this feature. In addition, the higher VWS is absent from Figure f. Following above context, the "0.5–1 km" should be "0.5–1.5 km".

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Response: "0.5–1 km" has been corrected to "0.5–1.5 km" throughout. The VWS characterisation is now supported by explicit reference to Fig. 8d–f (composite temporal evolution) and Fig. 9 (Spearman rank correlation heat map), rather than the original Fig. 11. The original panels (d) and (e) of Fig. 11 showed individual time series that were difficult to interpret; the revised composite approach in Fig. 8 provides a clearer picture of the regional VWS structure.

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RC2.26 (Lines 321–322)

| The increased ALI over central region is true but the trend of ALI over western region is unclear.

Response: The ALI description has been revised. The text in Sect. 4.2 now reads: "The ALI (Fig. 8g–i) is episodic, with intermittent pulses in western and central GD but no sustained build-up; eastern GD remains low and flat." No systematic pre-onset trend in ALI is identified in any region.

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RC2.27 (Lines 330–332)

| A question: Is the trend of VWS significant or not?

Response: This question touches on an important distinction between two different aspects of the VWS analysis, which we now address explicitly in the revised manuscript. **Temporal trend of VWS:** VWS at both layers shows no systematic change across $t = -6$ to 0 h in any region; bootstrap 95% CIs of the median overlap substantially at all time steps (Fig. 8d–f). The revised text states explicitly: "Neither layer shows a systematic change in the hours preceding onset." Thus VWS does not build up or intensify as onset approaches. **Relationship between VWS magnitude and rainfall intensity:** This is a separate question, addressed in Sect. 4.3. Although VWS does not trend over time, different events have different pre-onset VWS levels. In central GD, events with higher pre-onset VWS at 0.5–1.5 km tend to produce more intense rainfall (Spearman $r = 0.28$ – 0.35 over three consecutive periods, Fig. 9b). These two findings are not contradictory: the absolute magnitude of VWS reflects the steady-state urban friction effect on the BLJ, which discriminates between strong and weak events without necessarily evolving in the hours before onset.

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RC2.28 (Lines 333–335)

| *"The ALL...formation." Which region did authors describe?*

235 **Response:** The ambiguous multi-region sentence has been replaced with a region-specific description in Sect. 4.2: "The ALI (Fig. 8g–i) is episodic, with intermittent pulses in the western and central GD but without sustained build-up; eastern GD remains low and flat." This makes clear which regional behaviour is being described at each point.

RC2.29 (Line 335)

| *"BLH, LLJI...the onset are positively." It should be negative.*

240 **Response:** The original sentence stated that BLH, LLJI and VWS 2–3 hours before onset are positively correlated with precipitation in central GD, and then become negatively correlated 90 minutes before onset. This was based on the sliding window correlation (SWC) analysis of 8 events in the original manuscript. The entire SWC analysis has been replaced in the revised manuscript. In central GD, VWS at 0.5–1.5 km shows a positive correlation with rainfall intensity that persists across three consecutive
245 periods ($r = 0.28$ – 0.35 , all $p < 0.05$; Fig. 9b). BLH and LLJI do not show significant correlations in central GD in any pre-onset period.

RC2.30 (Lines 338–339)

250 | *"Moreover, convergence of wind speed, weaker VWS, inhibited lifting and lower BLH are observed 90 minutes prior to the onset." How did authors get the information about convergence of wind speed here? And why the convergence of wind speed will inhibit lifting? Please clarify.*

Response: This sentence was part of the sliding window correlation (SWC) analysis based on 8 events, which described an apparent sign reversal at 90 minutes before the onset of central GD. The entire SWC analysis and the associated interpretation have been removed from the revised manuscript. The revised Sect. 4.3 focuses on period-averaged Spearman rank correlations, which show that the absolute magnitude
255 of VWS at 0.5–1.5 km—rather than its temporal change—is the relevant predictor of rainfall intensity in central GD. The concept of a "convergence of wind speed" inhibiting lifting does not appear in the revised manuscript.

RC2.31 (Lines 341–342)

260 | *"Overseeing...to precipitation." This is not convinced enough, especially for the 2-3 hours leading time.*

Response: The sentence has been replaced with explicit quantitative evidence from revised Fig. 9. In Sect. 4.3, the text now reads: VWS at 0.5–1.5 km in central GD is significantly correlated with rainfall intensity at $t = -4$ to -2 h ($r = 0.28$, $p < 0.05$), $t = -2$ to -1 h ($r = 0.25$, $p < 0.05$), and $t = -1$ to 0 h ($r = 0.35$, $p < 0.05$). The persistence in three consecutive pre-onset periods provides the statistical basis for the 2–3 h
265 leading-time claim.

RC2.32 (Lines 344–345)

| *The trend of VWS is unclear during this period, i.e., the VWS decreased during 90–120 minutes.*

Response: As addressed in RC2.27 and RC2.30, the original SWC analysis and the associated 90-minute sub-window interpretation have been removed from the revised manuscript. VWS does not exhibit a
270 systematic temporal trend in any region (revised Sect. 4.2 and Fig. 8d–f). The 90–120 minute finding was an artifact of the small sample size and has not been reproduced with the 226-event dataset.

RC2.33 (Figure 12 caption)

| *For avoiding the confusing, this lag time should be a negative value.*

275 **Response:** The original Fig. 12 showed the sliding window correlation (SWC) of precursor signals with precipitation as a function of lag time (in minutes). In the revised manuscript, this figure has been replaced by revised Fig. 9, which shows the Spearman rank correlation heat map between pre-onset index values and maximum accumulated rainfall for all three sub-regions. The SWC framework and its associated lag-time axis have been removed entirely; correlations are now computed over four discrete non-overlapping pre-onset periods ($t = -6$ to -4 h, -4 to -2 h, -2 to -1 h, -1 to 0 h. **RC2.34 (Lines 350–**

280 351)

| *"the water vapor fluxes over the three regions" should be "over"*

Response: Corrected.

RC2.35 (Line 357)

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| *The authors should not ignore the magnitude of water vapor in the lower altitude (i.e., 1000–800 hPa).*

Response: The 1000–850 hPa layer is now explicitly specified in the revised caption of Fig. 14: "IVT is integrated between 1000 and 850 hPa." The composite moisture flux fields in revised Fig. 14 cover the full 1000–500 hPa range in the vertical cross-section panels, making the dominant role of the low-level layer visually apparent.

290 **RC2.36 (Line 374)**

| *"radiation" should be "divergence"*

Response: Corrected.

RC2.37 (Line 375)

| *"which may be related to the ...jets." Please further explain the mechanisms.*

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Response: In the revised manuscript, the mechanism for central GD is explained in Sect. 4.4 as follows: within the large-scale convergent environment where southwest flow from the Indian Ocean meets southeast flow from the western Pacific subtropical high, the low-level VWS—strongest in central GD among the three regions—likely reflects frictional deceleration of the BLJ as it crosses the urban surface of PRD. This deceleration enhances the convergence beneath the BLJ core, which promotes sustained upward motion. The case study in Sect. 4.5 provides direct observational support: the divergence profile computed using the triangle method (Fig. 16b) shows a convergence peak of $-10.1 \times 10^{-5} \text{ s}^{-1}$ at 1.2 km in the triangle containing the urban station, paired with upper-level divergence at 2–3 km, establishing a low-level convergence–upper-level divergence couplet already 2 h before onset.

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RC2.38 (Lines 375–376)

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| *"There is...stronger convection." If the CAPE value is got from the moment of rainfall onset, it cannot be used to indicate the convection intensity right now.*

Response: Agreed. In the revised manuscript, CAPE values are pre-onset values, averaged over $t = -6$ to -2 h before rainfall onset (ERA5). This is clearly stated in the text and in the caption of revised Fig. 13: "Pre-onset CAPE (ERA5, averaged over $t = -6$ to -2 h) for strong-rainfall (red) and weak-rainfall (blue) events."

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RC2.39 (Line 377)

| *"there is sufficient water vapor". I am not sure whether the authors mean that there is sufficient water vapor throughout the vertical zone or not.*

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Response: The vague phrase "sufficient water vapor" has been removed. The vertical distribution of moisture is now shown directly in revised Fig. 14, which presents composite ERA5 moisture flux cross-sections (1000–500 hPa) and IVT fields (1000–850 hPa) for all three regions based on 226 events. The figure makes clear that moisture flux is concentrated in the low-level layer in all three regions.

RC2.40 (Lines 380–384)

| *How did the authors conclude these results? Where is the evidence? Please clarify.*

320

Response: The original conclusions in this passage were based on the water vapour budget decomposition analysis (original Eq. 13 and Fig. 14), which has been removed from the revised manuscript as it was based on selected individual cases and lacked statistical robustness. In the revised manuscript, the regional mechanism conclusions are supported by: (1) ERA5 composite moisture flux fields (revised Fig. 14); (2) the Δw diagnostic linking LLJI intensification to upper-level ascent in western GD ($r = 0.37$, $p = 0.006$;

325 revised Fig. 12a) and documenting upper-level suppression in eastern GD ($r = -0.43$, $p = 0.001$; revised
Fig. 12c); (3) pre-onset CAPE comparisons between strong and weak events (revised Fig. 13; median 841
vs. 636 J kg^{-1} , $p = 0.036$ for eastern GD); and (4) the triangle-method divergence analysis in the case
study (revised Fig. 16b). Each conclusion in Sect. 5.1 is now linked to specific figures and p-values.

RC2.41 (Figure 14 caption)

330 | *The authors are encouraged to describe more details to clarify this Figure.*

Response: The original Fig. 14 showed vertical profiles of water vapour budget decomposition terms and
CAPE values for three regional representative cases. This figure has been replaced in the revised
manuscript by revised Fig. 14, which shows composite ERA5 water vapour flux fields based on all 226
335 events: vertical cross-sections of moisture transport flux along a regional transect (upper panels) and
spatial distributions of vertically integrated water vapour transport (lower panels). The revised Fig. 14
caption now specifies: the location of transect (purple line in the lower panels); the amplification factor
for vertical velocity ($\times 50$ for visibility); the unit ($\text{kg m}^{-2} \text{ s}^{-1}$); the IVT integration limits (1000–850 hPa);
and the averaging window ($t = -6$ to -2 h before onset).

RC2.42 (Line 403)

340 | *"70 minutes". The authors need to describe more about the X-axis in Figure 15.*

Response: In the revised manuscript, Fig. 15 shows the temporal evolution of LLJI, VWS, ALI, and BLH
at the four profiler sites (LG, HD, CH, ZC) as time-series line plots at 30-minute resolution. The x-axis is
defined in the caption as "hours relative to the rainfall onset time of the 20 April 2019 event (marked by
the red dashed line)". References to specific minute counts have been replaced with hour-based
345 descriptions (e.g., "approximately 1.5 h before onset").

RC2.43 (Line 404)

| *"The ALI...". The Figure 15c shows it is named "ARI". It is confused.*

Response: "ARI" was a typographic error. It has been corrected to "ALI" in both the figure label and
caption.

RC2.44 (Lines 405–406)

| *"The maximum ALI at Luogang is the largest among the four sites, indicating that the vertical
motion of the atmosphere is closely related to the subsurface." I think the causal link here is
reversed.*

Response: The reviewer is correct. The revised text in Sect. 4.5 now reads: "The ALI at Luogang (Fig.
355 15c) is comparable to Conghua but generally exceeds Huadu and Zengcheng, reflecting stronger vertical
motions over the urban surface." This correctly attributes the elevated ALI to the urban surface properties
rather than implying the reverse.

RC2.45 (Figure 15)

| *The authors should note that the boxes of these figures are not appropriate.*

360 **Response:** The revised Fig. 15 presents time-series line plots for each of the four profiler sites (LG, HD,
CH, ZC), showing the temporal evolution of LLJI, VWS, ALI, and BLH from $t = -6$ h to $t = +3$ h at
resolution of 30-minutes with the time of onset of rainfall marked by a red dashed line.

RC2.46 (Lines 418–419)

| *"there is...SLJ". Is this feature for each panel in Figure 16?*

365 **Response:** The original Fig. 16 showed horizontal wind field time–height diagrams for all four stations on
20 April 2019. In the revised manuscript, this figure has been replaced by the vorticity and divergence
profile analysis (revised Fig. 16.), and the wind field temporal evolution is now presented in revised Fig.
15. Regarding the reviewer's question: in the 1–2 hours before onset, three of the four stations (Luogang,
Conghua, and Zengcheng) show a southerly low-level jet below approximately 3 km with wind speeds
370 exceeding 10 m s^{-1} , while Huadu does not exhibit this feature. Among the three stations with a clear jet

signal, Luogang shows systematically stronger wind speeds..

RC2.47 (Figure 16)

For each Figure, it is recommended that the information for the X- and Y-axes be described.

375 **Response:** The original Fig. 16 (wind field time–height diagrams) has been removed from the revised manuscript (see RC2.46). The revised Fig. 16 now shows vorticity and divergence vertical profiles computed using the triangle method. The revised Fig. 16 caption now specifies the computation method, the units (10^{-5} s^{-1}), and the meaning of the dotted horizontal lines in panel (b) marking the convergence–divergence transition height.

RC2.48 (Figure 17)

380 *Please clarify more information about this Figure.*

Response: The original Fig. 17 showed mean VWS for 3-hour in triangular format for the four stations, which has been removed from the revised manuscript. The relevant spatial information (urban vs. suburban VWS contrast) is now captured by the divergence analysis in revised Fig. 16b, which quantitatively demonstrates the convergence peak at the urban-containing station triplet.

385 RC2.49 (Lines 439–441)

"The vorticity...urban area." Where did the authors define the urban area in the caption of Figure 18?

390 **Response:** The spatial definition of urban and suburban stations is now provided explicitly in Sect. 4.5: "Luogang (LG, 59287) is located within the urban core of Guangzhou, while Huadu (HD, 59284), Conghua (CH, 59285), and Zengcheng (ZC, 59294) are in the surrounding suburban areas (Fig. 1)." The urban core boundary follows the 2020 urban built-up area dataset of He et al. (2022), shown in Fig. 1.

RC2.50 (Sections 5 and 6)

Section 5 and 6 should be combined, which named "Conclusion and discussion".

395 **Response:** Done. Sections 5 and 6 have been merged into "5 Conclusions and Discussion" with three sub-sections: 5.1 Summary, 5.2 Comparison with previous studies, and 5.3 Limitations and future work.

RC2.51 (Author contributions)

According to the list of authors, the contributions of all authors are not fully listed here.

400 **Response:** The Author Contributions section has been completely rewritten to include all eleven authors: "WL performed the main data analysis and prepared the manuscript. ZH developed the precursor index calculations. SX contributed to data processing. LS, XB and LY provided important scientific comments and suggestions throughout the study. SL, YY (Yang Yang), CL and JW contributed to the manuscript revision. SL provided expertise on wind profiler radar data quality assessment. YY (Yuanjian Yang) conceived of the study, provided overall scientific guidance, and supervised the project. All authors reviewed and approved the final manuscript."

405 RC2.52–RC2.58 (Technical corrections)

"WVS" should be "VWS" (Lines 23, 287, 319). Line 65 punctuation. Line 86 "Th" → "The". Lines 92–94 grammatical mistake. Line 97 punctuation. Lines 105–106 capitalisation. Line 133 missing period. Lines 150–151, 176, 222 formatting issues. Figure 9 caption formatting. "Author contributions.s" → "Author contributions".

410 **Response:** All technical corrections have been implemented: "WVS" corrected to "VWS" globally (find-and-replace verified manually); all punctuation, capitalisation, grammatical, and formatting issues identified have been corrected; "Author contributions.s" corrected to "Author contributions".

Additional Corrections Identified During Revision

415 In addition to the reviewer comments, we identified and corrected the following issues proactively during revision:

1. Variable sample sizes across figures. Sample sizes differ between figures because different analyses impose different data-availability thresholds after quality control. A clarifying statement has been added to Sect. 2.4: "Sample sizes vary slightly across figures because each analysis requires continuous WPR data over a different time window; events with substantial data gaps in the required window are excluded. Exact counts are reported in each figure caption."
420

We hope that the revised manuscript, together with this detailed response, satisfactorily addresses all concerns raised by the reviewers and the editor. We remain fully available to provide any further clarifications or revisions that may be required.

425

Sincerely,

The Authors