

# Response to Reviewers' Comments

We sincerely appreciate the insightful comments and constructive suggestions from both reviewers. Your feedback has been instrumental in enhancing the scientific rigor, clarity, and academic standardization of our manuscript. Below is a detailed, section-by-section response to each comment, along with corresponding revisions marked in the revised manuscript using track changes.

## *1. Response to Reviewers' Comments on the Abstract*

### ① Reviewer 1's Comments

- **Comment:** The abstract is overly technical with distracting numerical values, lacking clear novelty and broader implications.

- **Revision & Rationale:** We streamlined the abstract by removing non-essential numerical data (e.g., 34.7 m/s, 14.9°C, 5.4 hPa) to focus on core contributions rather than result-specific details. We explicitly stated the novelty by contrasting our multi-source high-resolution data integration (radar, surface observations, lightning, video, field surveys) with early cases like the "Eastern Star" (relying only on macro meteorological data and disaster records), highlighting innovation in full-chain disaster mechanism analysis. To address broader implications, we added a concluding sentence: "The results provide critical scientific support for optimizing early warning systems and emergency responses to similar ship capsizing disasters in inland waterways," linking the case study to disaster prevention and risk management. We simplified jargon by revising "verifying the coupling disaster-causing mechanism of dynamic attenuation and microphysical transport" to "revealing the coupled dynamic-microphysical disaster mechanism" to improve readability while retaining scientific accuracy. Finally, we restructured the abstract into a logical flow: Background → Research gap → Novel approach → Key findings → Broader implications, using concise sentences and transition words (e.g., "However," "Compared to") to enhance coherence.

### ② Reviewer 2's Comments

- **Comment:** Lack of explicit research gap, unclear rationale for multi-source data integration, weak links between data and mechanisms, and missing generalizability.

- **Revision & Rationale:** We defined the research gap by adding: "Existing studies mostly rely on macro meteorological data, lack high spatiotemporal resolution ground monitoring support, and struggle to integrate multi-source data (meteorological information, on-site images, disaster traces), making it impossible to fully characterize the full-chain link from meteorological processes to disaster consequences." To justify data integration, we explained the complementary roles of each dataset: "Weather radar captures microburst dynamics; surface observations reflect near-ground conditions; lightning monitoring indicates

convection intensity; video surveillance and field damage surveys verify disaster traces, enabling holistic full-chain analysis." We strengthened data-mechanism links by adding causal connections: "Radar strong echo core analysis reveals the trigger of near-ground divergent wind fields; ZDR column data indicates ice-phase particle transitions that reinforce sinking motion; video/field data confirm the consistency between wind field evolution and disaster traces." To enhance generalizability, we retained the concluding implication sentence to extend the study's impact to regional maritime traffic safety and disaster risk management.

## ***2. Response to Reviewers' Comments on the Introduction***

We systematically revised the introduction to address reviewers' concerns about structure, clarity, novelty, and logical coherence:

**1. Streamlined definitions and classifications:** Merged repetitive downburst descriptions into a concise opening, integrating Fujita's (1976) definition and correcting the typo to clearly distinguish microbursts (4 m–4 km) from macrobursts (4–40 km), as well as wet vs. dry subtypes. Overly detailed aviation-specific content (e.g., 100 m AGL definition) was relocated to the methodology section to maintain focus on inland waterway hazards.

**2. Clarified research gap:** Explicitly highlighted the critical limitation of prior studies: "Current research on inland waterway wet microburst disasters lacks integrated analysis of radar, lightning, video, and ground-based observations, hindering understanding of the full-chain disaster-causing process."

**3. Strengthened case-mechanism links:** Embedded maritime disaster cases (e.g., "Eastern Star") with causal explanations: "Wet microbursts pose extreme risks to inland waterway navigation due to their sudden onset, strong winds, and reduced visibility, as exemplified by the 2015 'Eastern Star' capsizing, where insufficient multi-source data integration limited mechanistic understanding."

**4. Condensed research aim:** Revised to a concise, targeted statement: "This study investigates the formation, evolution, and disaster-causing mechanisms of the 2025 wet microburst using multi-source high-resolution data, filling gaps in integrated multi-source analysis for inland waterway wet microburst disasters and providing scientific support for maritime traffic safety early warning."

**5. Improved readability:** Split long paragraphs into logical sections (definitions, hazard examples, research motivation, study aim) and corrected grammatical errors (e.g., "capsized" to "capsizing") and ambiguous numerical statements.

## ***3. Response to Reviewers' Comments on Data Description/Weather Conditions***

To enhance clarity, accuracy, and academic standardization, we made the following targeted revisions:

1. **Simplified complex sentences:** Split information-dense sentences (e.g., line 77) into logically structured short sentences, separating data time range selection, extraction details, and research objectives to avoid information overload.

2. **Clarified data characteristics:** Explicitly stated that all 1-minute resolution data (wind speed/direction, temperature, pressure, rainfall) are instantaneous values without averaging, and noted that gust and regular wind data follow consistent recording standards with no special distinction methods.

3. **Standardized figure references:** Systematically checked and adjusted all figure numbering to ensure consecutive consistency, and integrated references naturally into corresponding data description or result analysis paragraphs to improve text fluency.

#### ***4. Response to Reviewers' Comments on the Results Analysis Section***

We retained the integrated structure of description and analysis to maintain readability, while implementing revisions to strengthen mechanistic interpretation and quantitative precision:

##### **1. Revised subheadings to emphasize mechanisms:**

○ Original: "Evolution Characteristics of Weather Radar Detection" → Revised: "Weather Radar Detection Characteristics and Dynamic-Microphysical Mechanism Analysis of Downbursts"

○ Original: "Evolution Characteristics of Wind, Temperature, and Pressure at Ground Automatic Stations" → Revised: "Evolution Characteristics of Surface Meteorological Elements and Cold Pool Outflow Response Analysis"

○ Original: "Characteristics of Lightning Activity" → Revised: "Analysis of Lightning Activity Characteristics and Dynamic-Charge Coupling Mechanisms"

These revisions align with Reviewer 1's suggestion to link observational phenomena to physical mechanisms explicitly.

##### **2. Replaced qualitative descriptions with quantitative metrics:**

○ Original: "Typical extremely strong wind characteristics" → Revised: "Wind force reached Level 12 (instantaneous wind speed of 34.7 m/s, corresponding to the Beaufort scale for hurricane-force winds)"

This addresses Reviewer 2's request for quantitative clarity, providing a universally interpretable reference for wind intensity.

##### **3. Quantified temporal offset between dynamic and thermal responses:**

Added a mechanistic explanation based on high-resolution observations: "According to ground meteorological station data, the temperature began to drop after 08:30, with the thermal response lagging behind the dynamic response (wind

direction reversal) by approximately 3 minutes. This temporal offset reflects the physical process of cold pool propagation: the leading edge of the cold pool first induces wind field divergence, followed by the advection of cold air to drive near-surface cooling."

#### **4. Explained cloud-to-ground lightning suppression with literature support:**

Supplemented the lightning subsection with a physical mechanism and citation: "The dominance of cloud flashes (85.1%) can be attributed to two key effects of the cold pool: (1) The high-density cold air forms a stable stratification near the surface, which blocks the conduction path of negative charges from the cloud base to the ground; (2) Strong downdrafts suppress upward air currents, reducing the vertical transport of charges and further inhibiting the formation of effective cloud-to-ground discharge channels (Shi et al., 2025)."

A new reference was added to the bibliography:

Shi, T., Yang, Y. J., Lu, G. P., Zheng, Z. F., Zi, Y. C., Tian, Y., Liu, L., & Lolli, S. (2025). Urban morphology modulates thunderstorm process and associated cloud-to-ground lightning activity over Beijing metropolitan region. *Atmospheric Chemistry and Physics*, 25, 9219–9234. <https://doi.org/10.5194/acp-2024-3>

#### **5. Response to Reviewers' Suggestion on Quantitative Correlation Analysis**

We greatly appreciate the valuable suggestion to conduct quantitative correlation analysis between radar observations, surface characteristics, lightning activity, and disaster losses. This recommendation aligns with our long-term research goals, and we plan to address it in future work as follows:

##### **1. Data Expansion and Multi-Source Fusion**

**Spatial-temporal data integration:** Integrate ground meteorological station data along the upstream movement path of the convective system to capture spatial-temporal variations in downburst impacts. This will allow us to analyze the evolution of downburst characteristics across different locations and time periods.

**Multi-source data fusion:** Combine radar, lightning, and ground-based observations with "Sky Eye" surveillance video to verify the consistency between meteorological parameters and disaster traces. This multi-source approach will provide a more comprehensive understanding of the relationship between downburst events and their impacts.

##### **2. Quantitative Modeling of Downburst Momentum and Temperature Characteristics**

**Momentum calculation methodology:** We will adopt the momentum flux integration method proposed by Stull (1988), with modifications for gust effects following Holmes (2001):

$$M = G \int \rho \cdot v^2 \cdot dt$$

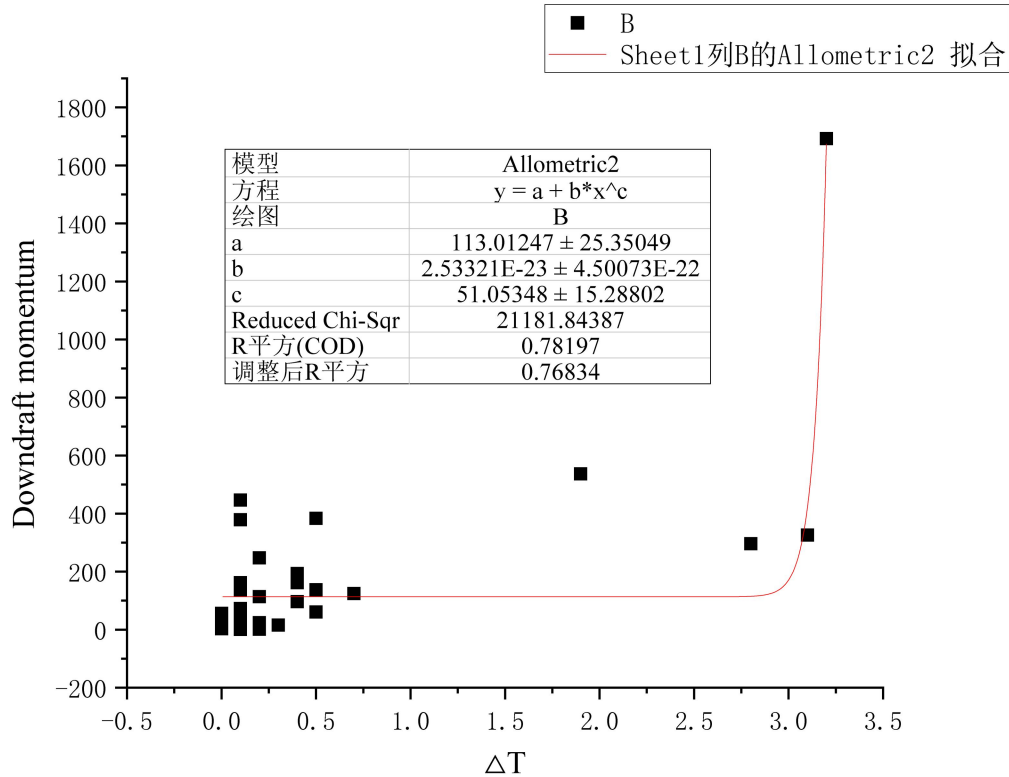
where:

- $G$  is the gust factor (1.15–1.20)
- $\rho$  is air density calculated from surface pressure and temperature data using the ideal gas law:

$$\rho = \frac{P}{R_d \cdot T}$$

- $P$  is minute-level atmospheric pressure (Pa)
- $T$  is minute-level absolute temperature (K, i.e., Celsius temperature + 273.15)
- $R_d = 287\text{J}/(\text{kg} \cdot \text{K})$
- $v$  is minute-level wind speed (m/s).

**Preliminary analysis and future plans:** We have conducted a preliminary analysis using data from a single ground station to explore the relationship between temperature drop characteristics and downdraft momentum. As shown in Figure X, the scatter plot of minute-level temperature drop (x-axis) versus downdraft momentum (y-axis) shows no significant correlation. This suggests that using data from a single station may not capture the full spatial-temporal complexity of downburst events. In future work, we will expand our analysis to include multiple stations along the downburst path to better understand the relationship between temperature evolution and downdraft momentum.



### ***Final Revisions***

In addition to the section-specific revisions above, we have:

- Systematically checked and corrected grammatical errors and typos throughout the manuscript.
- Standardized reference formatting to comply with the journal’s guidelines.
- Marked all revisions in the manuscript using track changes for easy identification.

We believe these revisions have significantly improved the quality of our manuscript and addressed all reviewers’ concerns. We look forward to your further feedback and are happy to provide additional clarifications if needed.

Thank you again for your time and expertise.

Sincerely,

The Authors