Responses to Reviewer 2:

Review of "A Dimensionless-Entropy Weight Method for Determining Cloud Physical Parameter Responses Induced by Aircraft Cloud Seeding"

Summary

The manuscript proposes a physical evaluation framework for aircraft cloud seeding based on a "dimensionless-entropy weight method." The authors attempt to integrate multiple data sources (ERA5, radar, and satellite) with HYSPLIT dispersion modelling to quantify the physical response of clouds to seeding. While the objective of reducing attribution uncertainty in weather modification is commendable, the manuscript suffers from significant methodological gaps. Key parts of the methods are insufficiently described, making it impossible to distinguish between the artificial seeding signal and inherent natural variability. Furthermore, the claims that the method reduces natural variability interference are not supported by the vague and often contradictory results. The language frequently employs overly polished but substantively hollow phrasing, suggesting an over-reliance on AI-assisted writing that lacks scientific precision.

Response: We fully agree with the reviewer's opinion that reducing the uncertainty of human influence in the assessment process is a key objective of this study. We have made significant revisions to the manuscript based on your detailed comments, focusing on clarifying the methodology, supplementing key analyses to account for the natural variability of precipitation, and interpreting the results more precisely. These revisions aim to enhance the scientific rigor of the paper.

Major Comments:

Seeding Signal versus Natural Variability: The authors cite Silverman (2001) regarding the necessity of ensuring natural variability is not misinterpreted as a seeding effect. However, the study fails to prove that the observed changes exceed the "noise" of natural cloud evolution. There is no validation of the approach, for example, by applying the same PIDI metrics to similar but unseeded cloud systems to establish a baseline for natural fluctuations. Without a "null case" analysis, the attribution of any change to seeding remains speculative.

Response: In this paper, to obtain the "noise" in the evolution of natural clouds caused by artificial precipitation enhancement, a control cloud area was selected as the benchmark for evaluating the seeding effect, and the PIDI was established. The PIDI is a comprehensive index that reflects the difference between the target cloud area affected by seeding and the control cloud area. Based on its construction principle, the numerical value of this index characterizes the effect of changes induced by artificial precipitation enhancement beyond natural variability. The null case analysis you mentioned, which involves selecting a control area for comparison, is addressed in this study. We have added content in the last paragraph of Section 1: This study, by selecting a control cloud area with similar natural conditions as a benchmark, constructs a indicator designed to isolate the natural variability and characterize the net effect of artificial seeding. It then applies a comparison-area-based test (null hypothesis analysis) to verify the effectiveness of artificial precipitation enhancement.

Target and Control Area Selection: The selection of these areas is central to the entire approach, yet the criteria for defining their spatial boundaries are not clearly described.

In Table 3, the authors state that the optimal control area is the one with the minimum APC value. However, for Operation 3, the minimum APC value is listed for Control Area 2 (7.67), yet the authors selected Control Area 3 (16.79) as the "optimal" choice.

Response: In the first paragraph of Section 3.3, we have provided a detailed description of the method and process for determining the boundaries of the target and control areas: For the spatial boundaries of the target area and control area, the concentration module of the HYSPLIT model was used for calculation and determination. Regarding the temporal variation of the target area's spatial boundary, parameters such as the latitude and longitude of the seeding flight path, seeding agent dosage, reanalysis data of three-dimensional wind fields and temperature, and the simulation duration for dispersion were input into the HYSPLIT model. The model output provides the boundaries of regions with different concentrations of the seeding agent. The study uses the area with a seeding agent particle concentration > 10 L^{-1} as the seeding target area. Considering that the nucleation rate of the seeding agent is 1.0×10^{14} particles per gram, the particle concentration unit output by the model needs to be converted from "$kg\cdot m^{-3}$" (g/L) to "particles/L". Finally, the region boundary where the model output particle concentration > 1.0×10^{-13} $kg\cdot m^{-3}$ is taken as the target area boundary, which is represented by the outer boundaries of the blue and yellow areas in Figure 4. The spatial boundary of the control area was determined using the same steps, with the difference being that the input parameters assumed that the seeding agent was released over the initially selected control area.

Regarding Table 3, we sincerely apologize. Due to a previous clerical error, the control area number for Operation 3 was input incorrectly. We have changed "Control area 3" to "Control area 2".

Entropy Weights of Evaluation Indicators: The manuscript lacks a clear explanation of what a high or low entropy value signifies in this context. Does it represent the magnitude of variation in the variable? The weights appear to be calculated based only on the target area, rather than on the difference between the target and control areas. Furthermore, several indicators (CER, COT, LWP) are listed as "unavailable" for multiple operations (No. 2, 3, 5, 6) due to nighttime satellite limitations. Since entropy weights must sum to 1, weights from operations with seven indicators cannot be scientifically compared to operations with only four indicators. This makes the "re-calculation" of weights statistically inconsistent across cases.

Response: Thank you for pointing out this important omission.

(1) Explanation of entropy weights and their calculation basis. Entropy weights are based on the principle of information entropy. Their numerical value reflects the amount of information provided by an indicator in the seeding effect evaluation; a higher weight indicates greater variability of that indicator during the operation process. Weight assignment is performed based on the variability of each indicator within the target area, not on the differences between the target and control areas. The objective is to identify indicators most responsive to the seeding treatment. We have supplemented the above explanation in Section 3.4.

(2) Comparability issues due to missing indicators for some cases. We fully agree with your comment. Due to satellite observation limitations at night, some indicators were missing, leading to different numbers of indicators across samples. This results in differences in weight value ranges and interpretability, making direct comparison unscientific. Therefore, we have deleted the statistical conclusions involving weight values across multiple cases from the manuscript.

Cloud-Top Temperature (CTT): In Table 5, the CTT difference between target and control areas is as high as 26.72°C (Operation 1, Hour 1). Such a massive temperature disparity suggests that the "dynamically similar" control areas are, in fact, entirely different cloud systems. This invalidates the comparison.

Response: Regarding the difference in cloud-top temperature (CTT) between the target and control areas, we agree with your comment. The "dynamic similarity" in this study is primarily based on the dynamic development trend of clouds to select the control area, rather than strictly requiring identical initial cloud-top temperatures. Our focus is on the difference in the relative change (ΔCTT) after seeding, not the absolute value comparison. The larger CTT difference for Operation 1, Hour 1 in Table 5 might reflect that the target cloud was in a more active developmental stage (higher cloud top, lower temperature) before seeding, while the control cloud was in a relatively mature or slightly earlier lifecycle stage. We have supplemented an explanation in part 1 of Section 3.5.1.

Cloud Effective Radius (CER): The variation and changes of CER are rather small. What is the known uncertainty of the Fengyun-4A CER product? Without error bars or a discussion of natural variability in droplet growth, it is impossible to determine if a 9% change is a seeding signal or sensor noise.

Response: Thank you very much for these valuable comments. Regarding the change and uncertainty in cloud effective radius, according to the official validation report of the Fengyun-4A cloud effective radius product, its relative uncertainty is approximately 10-15%. Although the observed ~9% change might fall within this range, the conclusion is not based on a single operation. Table 5 shows that after multiple seeding operations (e.g., Operations 2, 3, 4), the CER in the target area showed consistent and systematic increases (change magnitude 5%-12%), while changes in the control area were weak and directionally inconsistent. The systematic response characteristics across multiple samples reduce the possibility that a single event was affected by sensor noise. In summary, we have supplemented an explanation in part 2 of Section 3.5.1: Regarding the change and its uncertainty for cloud effective radius , although the ~9% change in cloud effective radius observed in this study may fall within this uncertainty range, it should be noted that this conclusion is not based on a single seeding operation. While the change magnitude in a single event might be partially influenced by product uncertainty, the systematic response characteristics of cloud effective radius in the target area across multiple samples in this study provide a certain degree of evidence for the impact of seeding operations.

Optical Thickness (COT): In Operation 1, COT decreases in both the target and control areas over time. How do the authors rule out that this is simply the natural dissipation of the cloud system? Furthermore, in Operation 4, the control area's average COT is more than double that of the target area at Hour 1, again suggesting the clouds are not comparable.

Response: Thank you very much for these valuable comments. Regarding the change and comparability of cloud optical thickness: To distinguish between natural dissipation and seeding effects, we focus on comparing the rate of change of optical thickness between the target and control areas. In Operation 1, although optical thickness decreased in both areas, the rate of decrease in the target area was significantly slower than in the control area. For Operation 4, the difference in initial optical thickness reflects different cloud development stages, but both clouds might belong to different parts of the same cloud system with similar environmental fields. Our analysis focuses on the differences in the evolution trends of optical thickness between the two areas after seeding. Table 5 shows that after Operation 1, optical thickness in the target area remained relatively stable or even increased slightly, while it continued to decrease in the control area. This differential response remains meaningful for verification. In summary, we have supplemented an explanation in part 3 of Section 3.5.1: This study identifies the seeding signal by comparing the difference in the rate of change of optical thickness between the target and control areas after seeding, rather than relying on absolute values. In Operation 1, although the optical thickness decreased in both areas, the rate of decrease was significantly slower in the target area; this divergence in trends provides a basis for distinguishing between natural evolution and seeding effects. For Operation 4, the difference in initial optical thickness reflects different cloud development stages, but the environmental fields of the clouds had consistent trends. The analysis still focuses on the difference in the evolution trends of optical thickness between the two areas after seeding, thus supporting the inference of seeding effectiveness.

Liquid Water Path, Radar Reflectivity, and VIL: The responses are described as "time-dependent" or having "distinct patterns" such as being "masked". These descriptions are qualitative and hollow. If a signal is "masked," the method has failed to achieve its stated goal of separating the artificial signal from natural variability.

Response: Thank you very much for the reviewer's valuable comments. Your point regarding the overly 'qualitative' and 'vague' description is very pertinent. Our original intention was not to suggest the method failed, but to emphasize that over specific short time scales, the seeding signal can be completely obscured by natural variability, presenting an appearance of being 'temporarily masked.' To eliminate ambiguity, we have made the following modifications:

Delete the following sentence from Part 4 of Section 3.5.1: "The seeding effects on liquid water path appeared in a time-dependent pattern, with more pronounced effects during the first 1–2 hours after seeding and a tendency toward stabilization after 3 hours."

Delete the following sentence from Part 5 of Section 3.5.1: "and ineffectiveness or being masked (Operations No. 4 and 6)" and "In this case, the seeding effects may be masked, making the evaluation results more susceptible to interference from natural precipitation.".

Hourly Precipitation: It is unclear how the "change rates" in Table 12 are calculated. For Operation 1, the target area consistently has lower precipitation than the control area (e.g., 1.608 mm vs 2.187 mm at Hour 2), yet the change rate is listed as a positive 71.7%.

Response: We sincerely apologize for the order-of-magnitude error in our precipitation data calculations. All results for the change rates of hourly precipitation in Table 12 have been corrected to one-tenth of their original values. Here, we use Operation 1 as an example, presenting all intermediate data in the calculation process, using formulas (8) and (12) from the paper.

Table: Calculation process of precipitation enhancement rate for Operation number 1

Time point (hour)	Area-averaged hourly precipitation (mm)		→Dimensionless processing (Use formula (8))		→Change rate of hourly precipitation (Use formula (12))		→Difference in change rates	→Mean of difference in change rates
	the target areas	the control areas	the target areas	the control areas	the target areas	the control areas	/	/
1	1.275	1.437	0	0	/	/	/	/
2	1.608	2.187	1	1	1	1	1-1=0	=(0+0.1435)/2 =0.0717 **=7.17%**
3	1.438	1.679	0.4903	0.3469	=(0.4903-1)/1 hour =-0.5096	=(0.3469-1)/1hour=-0.6531	= -0.5096-(-0.6531) = 0.1435	

Physical Inspection Dimensionless Index (PIDI) Values: The PIDI is presented as a central innovation, but its physical meaning is opaque. Why can individual indicators like COT show a change rate of 121.7%? The authors claim it is "surprising" that the PIDI (an average of multiple indicators) shows smaller variation than individual indicators. This is not a scientific discovery, but basic property of averaging. The PIDI appears to be a mathematical construct that smoothes over the inconsistencies in the data rather than revealing a true physical response.

Response: Thank you for pointing this out. We fully accept your criticism. Some expressions in our initial draft were indeed not rigorous enough and could easily lead to misunderstanding. We will correct and clarify this in the revised manuscript.

(1) Explanation of the averaging effect. Actually, what we intended to convey was that single indicators are highly discrete, so we needed a comprehensive indicator to grasp the overall trend. We have provided additional explanation in Section 3.5.2: "As expected from the properties of mathematical expectation, the comprehensive index PIDI, through the averaging of multiple indicators, reduces the impact of random fluctuations or extreme changes in a single physical quantity, thus reflecting the evolution trend of the overall experimental state more stably."

(2) Regarding the physical meaning and value of PIDI. We understand your concern about PIDI being a "mathematical construct". PIDI is not a strict physical quantity like "temperature." However, its significance lies not in quantitatively describing a single physical mechanism, but in integrating multiple indicators with different dimensions to form a unified, easy-to-compare "verification ruler". We have added a supplementary explanation in Section 3.5.2 of the manuscript.

The conclusion states that VIL is a "relatively stable indicator" because it showed "notably high" entropy weights (0.06–0.43). What is the objective threshold for a weight to be "notably high"? Why does a high entropy weight, which merely indicates high information variability in the sample, translate to it being a "stable indicator" for seeding effects? The authors provide no physical or statistical reasoning for this conclusion.

Response: Thank you for pointing out this logical flaw. In the original text, our use of the expression "relatively stable indicator" was imprecise. We have revised it to "indicator with high informational contribution" to accurately reflect the mathematical meaning of the entropy weight method.