Overview

This manuscript describes the methodology of finding the optimal solution for a combination of parameters used in an analytical model of downburst outflows. This methodology is then applied to a particular case of downburst that occurred in Rumania in the summer of 2021. It is clear to me that the authors are knowledgeable in this field and the description of the method and results is very comprehensive. Perhaps even too comprehensive in some instances. While I have a number of comments below, I consider most of them to be minor. I believe the manuscript is well suited for this journal and it is most certainly a topic of importance in downburst research and wind engineering.

Authors greatly appreciate the remarks received from the Reviewer 1, which are very pertinent and stimulating for improving the paper. We will make our best to take all the comments received into consideration, providing adequate and precise answers to all of them. All our answers and comments are reported in red colour and the manuscript will be modified according to them.

Specific comments from Reviewer 1:

1. Begin instead of begins.

   Corrected as suggested.

2. Is the scale of less than a kilometer related to a downburst or thunderstorm? It should be related to a downburst, but it is not clear based on how the sentence is structured.

   Reworded for clarity to explicitly specify that it refers to a downburst.

3. Xhelaj et al. is not the proper reference. I suggest the authors write “Xhelaj et al. (2020) presented…” The reader is automatically informed that the research was published in 2020.

   Modified as suggested to include the year of publication.

4. L46 and elsewhere. I believe that “et” should not have a dot.

   Checked and corrected throughout the manuscript.

5. L22–L72. This paragraph is well written, but it is too long. Please split this large paragraph into 2–3 smaller paragraphs to increase readability of this section. For example, L56 (goals of this research) can be the beginning of a separate paragraph.

   The paragraph is split to enhance readability, as recommended.

6. I suggest rewriting this sentence as follows: …was produced during the passage of an intense mesoscale convective system in the form of a bow echo over the town of Sânnicolau Mare.

   Sentence has been rewritten as suggested for improved clarity.

7. Some parts of the manuscript can be shortened. For example, the definition of thunderstorms in L100 is probably not needed. Even if needed, that general discussion should be in the introduction.

Similarly, L103 and the difference between downburst and atmospheric boundary layer winds is probably not needed as well.

Removed the definition of thunderstorms in L100 and adjusted L103 to maintain relevance while being concise.

8. Figure 1. Labels in panel (b) should be of higher resolution and the red dot that indicates the tower location should be larger.

   Enhanced label resolution and increased the size of the red dot as indicated.

9. Figure 2. In principle, I have no problems with this figure but is it really that the researchers don't have their own photograph of the tower and have to use Google Street View? I suggest replacing this figure with their own photograph.

   Replaced with an original photograph of the tower.

10. Figure 3b. It is very interesting to note that the squall line seems to be stratiform parallel, which is one of the rarest types of squall lines. See Markowski and Richardson (2010) and references therein on squall lines. The authors, of course, do not need to pursue this comment further, it's just an interesting observation from this reviewer.

    Acknowledged the interesting observation. It is also added to the manuscript. Thank you very much for the suggestion.

11. Figure 5a. Tmin = 14.5 degC should not be over the line. There is plenty of space to move it elsewhere.

    Relocated the Tmin = 14.5 degC label as advised.

12. L171–174. Downburst is a wind event and hail is hailstones falling from the cloud. If hailstones cause the damage, that is not the same as caused by wind (i.e., downburst). One might rephrase this to state that the downburst was also associated with hail that caused substantial damage. Then the reader knows that the damage was not wind-driven but hail-driven.

    Thank you for your valuable feedback on the distinction between wind and hail impacts in our manuscript. We recognize the importance of clearly differentiating these factors. Accordingly, we have modified our text to emphasize that while the primary focus is on the wind aspect of the downburst, it was concurrently associated with hail. This hail, potentially influenced by the strong downburst winds, contributed to the extensive damage observed. This revision will ensure a comprehensive understanding of the event, highlighting that the observed damage was a result of both wind and hail interactions during the downburst.

13. Figure 6. Indicate the North direction in this figure.

    Added a North direction indicator to the figure.

14. Table 1. The units should not be italicized.

    Units in Table 1 have been corrected to normal font.

15. This sentence is the same statement as the previous sentence, which is that Figure 7 shows the convergence pattern of the objective function.

    Removed the redundant sentence for conciseness.

16. Figure 7. The mean convergence curve does not converge at about 70 iterations. Indeed the envelop curves seem to converge at about that value, but not the mean and standard deviation curves.

    Clarified the discrepancy in the mean and standard deviation convergence curve description.

    "The envelope curves in Figure 7 indicate convergence around 70 iterations. However, this does not directly correspond to convergence in the mean (m_F) and standard deviation (s_F) curves. While these curves show a trend towards stabilization, their convergence is less distinct and does not align precisely with the behavior of the envelope curves."

17. Remove the comma after 1024.

    Comma after 1024 has been removed.

18. Symmetry rather than simmetry.

    Corrected "simmetry" to "symmetry."

19. (2) The word and should not be italicized.

    Corrected the italicization of "and."

20. Probably an incorrect reference format. Please double-check.

    Reviewed and corrected the reference format.

21. Rewrite to “The hierarchical tree in Figure 9 (i.e., dendrogram) is constructed following the Wards’ method (Ward, 1963).” and then delete the following sentence because it contains the same information.

    Reworded as suggested for clarity.

22. Figure 9. Indicate in the figure caption that the three colors serve to visualize three identified clusters.

    Updated the caption to include information about the color coding of clusters.

23. Discussion about Figure 10. When this method is applied to other problems in engineering and/or atmospheric sciences, is clustering that represents ~60% of the total variance an acceptable value? In other words, this problem is related to finding the optimal combination of downburst parameters, and Figures 9 and 10 show that the clustering of solutions in the present way explains ~60% of variance among all solutions. If one looks at other (similar) problems in meteorology, engineering, earth sciences, etc., does one observe a similar level of model confidence? A few references on this subject might help.

Thank you for your feedback on the variance explained by clustering in our study. We recognize that the ~60% variance explained may seem modest, but in the complex field of atmospheric science, and specifically in downburst studies, this level is often both substantial and meaningful. The inherent variability and unpredictability of meteorological data make such a level of explanation significant, especially considering our methodology is based on anemometric data from a single location near Sannicolau Mare.

Literature in related domains, like the work of Bogensperger and Fabel (2021) (Bogensperger, A., Fabel, Y. A practical approach to cluster validation in the energy sector. *Energy Inform* **4** (Suppl 3), 18 (2021). https://doi.org/10.1186/s42162-021-00177-1), underscores the challenges in comparing clustering results and the context-specific nature of cluster validation indices. These studies align with our findings, suggesting that the acceptable level of variance explained is highly dependent on the study's specific goals and context.

In our opinion, the present clustering effectively captures key patterns and relationships within the data, contributing valuable insights to the understanding of realistic downburst spatiotemporal evolution. Including more patterns does not increase substantially the knowledge of this phenomenon's variability, as indicated in Fig. 10 by the very low contribution to the explained variance of the red bins, because further cutting produces patterns that are very similar to each other. Therefore, we believe the ~60% variance explained in our analysis represents a robust and insightful understanding of downburst characteristics.

Added references and discussion in the manuscript to address the query about the ~60% variance.

24. Section 5.1 and other sections. Please separate your sections into multiple paragraphs. Having one paragraph that covers more almost one whole page reduces the readability of your manuscript.

    Divided long sections into shorter paragraphs for better readability.

25. Related to my previous comment, this manuscript should be shorter. I think that the level of English is satisfactory, but certain parts of the manuscript can be shortened.

    Reviewed and condensed certain sections without losing critical content.

26. How does the k-means algorithm work to improve the partitioning? What is the mechanism by which k-means algorithm moves the clusters from being overlapped to disjoint (Figure 11)?

    In our study, the k-means algorithm is utilized to refine the initial partitioning of clusters determined through Ward's method. Starting with the initial partition, the algorithm iteratively recalculates the center of mass for each cluster and reassigns solutions based on their proximity in Euclidean space. This process continues until the improvement in the ratio of between-cluster variance to total variance falls below a threshold. This method ensures more distinct and consistent clusters by increasing this ratio, thereby reducing overlap and enhancing separation. This is an optimization method for clustering and at the end of the process the hierarchical structure from Ward's method is somehow modified (optimized) in the final partition.

    Provided a more detailed explanation of the k-means algorithm's function in the manuscript.

27. Table 4. Define p1, p2, and Vk in the caption of this table.

    Defined p1, p2, and Vk in the table caption.

28. Table 4 and the associated text. Explain what is the weight of a variable in the context of your analysis and the quality of representation (projection)?

    In Table 4 of our manuscript, the weight of a variable indicates its contribution to a principal component (PC1 and PC2 considered). It's computed as the squared correlation coefficient between the variable and the principal component, normalized by the total of such squared correlations for that principal component.

    The quality of representation of a variable on a principal component is determined by the squared Pearson correlation coefficient between the variable and the principal component vector. Standardization simplifies this to the squared correlation.

    A more detailed explanation of the weight of a variable and quality of representation is implemented in the manuscript.

29. Rewrite the first sentence in this line for better English.

    Revised the sentence for better English.

30. Figure 17 and associated discussion. This is very nice. Is it possible to constrain your space of solutions by fixing some of the parameters using the observations (e.g., direction of damage, translation speed and direction of the cloud, etc.). In L545–546 you conclude that one needs to conduct many simulations, but wouldn't make more sense to constrain simulations with known values of parameters rather than letting all parameters take arbitrary values?

    Thank you for your insightful suggestion on constraining the solution space, as mentioned in your comment about Figure 17. We agree that incorporating specific known parameters, like downburst translation direction from radar data and ABL wind speed and direction determined for example through change point analysis (as detailed in Xhelaj et al., 2020), would indeed refine our approach. By incorporating these constraints, the solution space becomes more representative of the actual event, enhancing both the accuracy and the efficiency of our simulations. However, it is important to note that this procedure can be done only if radar data (or other kinds of data) is also available. In some cases, like the present one, only anemometric data is available.

    This approach aligns with the methodology outlined in our manuscript, particularly in the section 5.4 discussing parameter optimization and data utilization. We appreciate this valuable suggestion, and we will change our conclusions in section 5.4.

31. I think the title should more highlight the main topic of this paper and that's the application of the Teaching Learning Optimization Algorithm to your analytical model. You are using an objective method to find the optimal solution from the space of all solutions and the particular downburst is just a case study that you used to validate your method. A title such as "The Application of Teaching Learning Optimization Algorithm to Analytical Model of Downburst Outflows" might better capture the main topic of this paper, but I leave it up to the authors to decide.

    Thank you for your suggestion regarding the title of our paper. We agree with you that "phase space" is not very clear to let the reader understanding the content of this paper. After careful consideration, we have decided to revise the title to reflect the core focus of our work more accurately. The new title will be:

“Application of the Teaching Learning Optimization Algorithm to an Analytical Model of Thunderstorm Outflows to analyze the variability of the downburst kinematic and geometric parameters”

We believe this revised title emphasizes the application of the Teaching Learning Optimization Algorithm within our analytical framework, underscoring its role in downburst outflow modeling. Thanks again for the suggestion!