Analysis of the phase space of the downburst that occurred on 25 June 2021 in Sânnicolau Mare (Romania) – First Review

The authors have applied a previously developed analytical model for simulating downburst wind fields to an event that occurred in western Romania. Because the model is under constrained by the available observations, a spectrum of solutions is produced based on random initialisations. The authors use statistical clustering to define three dominant sets of solutions, and use a damage survey to determine which cluster of solutions is most plausible. The cluster with the highest agreement with the damage patterns also contains the solution with the lowest objective loss function, and it is concluded that this loss function is therefore potentially an appropriate measure of model fit, while the authors do acknowledge that this needs to be tested for more cases. A principal component analysis is also performed to determine which model variables explain most of the variability in the solution space.

Overall, I think the manuscript is currently good to fair in quality and would be suitable for publication subject to revisions, as outlined in comments below. I would classify the nature of these revisions as major.

My review is structured as follows:

- Firstly, some general points are outlined in relation to the EGUsphere review criteria.
- Secondly, some "Overall/general comments" and concerns are stated, including some suggestions to improve the manuscript.
- Thirdly, some "Specific comments" are made. These are mostly suggestions to improve the presentation, grammar, readability, or clarity of the manuscript.

EGUsphere review criteria

Scientific Significance: The main scientific contribution of the manuscript is to improve the interpretation of the analytical downburst model. However, while the set of model solutions has been thoroughly explored, it is acknowledged that the analysis of only one downburst case limits the applicability of the results. Apart from this, the use of the hail damage survey for evaluating the model solutions is very interesting and fairly novel in my opinion.

Scientific quality: The scientific and statistical methods used by the authors are sound and well established, I have no issues with the technical aspects of the paper. However, I think the authors could do a better job to discuss and place their work within the broader literature of downburst modelling (see comments below).

Presentation quality: The manuscript is fairly well presented, and the figures/tables are nice and clear. I thought at times that there were actually too many details, and that some information could be removed to help with readability (I will list some examples below). In addition, I think the English grammar and language could be improved somewhat (I appreciate this is challenging given the author is not a native English speaker).

Overall/general comments

1. I think the damage survey aspect of the paper is very interesting, but it would be good to have some further details on this, including if there are any notable uncertainties. For example, is it difficult to relate hail damage to near-surface wind velocity?

2. I have a general concern whether this analytical model of a translating downdraft can represent complex mesoscale circulations that can induce severe winds, such as a rear inflow jet related to the bow echo. It is good to see that the hail damage estimate agrees with the general pattern suggested by the model, but I think it would be good to discuss this further in the manuscript, by noting it as a limitation and/or linking to other studies that have investigated the wind field patterns of bow echoes (and if they look like translating downbursts or not).

3. I think this paper lacks a little in discussing the results within the broader literature. How does the model and results fit with previous studies that have done downburst modelling? Similarly, have previous studies used hail trajectories to evaluate a downburst wind field?

Specific comments

1. Title: The title is a little unclear without having read the article. “Phase space” could refer to several things. It would be good to make it clear in the title that this is a study exploring an analytical model representation of a downburst.

2. L8 and elsewhere: Pluralisation issues - should be “measurement challenges”. Similarly on line 38, should be “Since downburst events have high frequencies of occurrence…”.

3. L38 and onwards: This paragraph is very long with many ideas – should be separated into multiple paragraphs.

4. L40: “unstable”

5. Introduction: The introduction is very technical at times in terms of describing the analytical model and TLBO approach, this could probably be moved to data/methods. Instead (and related to general comment 3), it would be good to have some background on the “analytical model” – what is it based on, what are the constraints, outputs, etc, and a discussion of similar models – how does this work fit within the broader literature?

6. Figure 4: What do the red/orange/yellow colours indicate? Time of strike?

7. L188: Repeated sentence.

8. L207 and elsewhere: grammar issues. “The TLBO algorithm ~~it~~ is an iterative…”

9. Table 2: I wonder if some of the variables in the analytic model could be constrained further by other data sources. For example, the storm speed/direction could potentially be estimated by storm tracking from radar or satellite, while the ABL wind speed and direction could be estimated from reanalysis.

10. L269: MDA acronym does not need to be defined anymore.

11. L275: I’m not sure whether this is a good reason to exclude storm direction as a variable to analyse. Can a transform be done from degrees to a periodic function? E.g. https://stats.stackexchange.com/questions/148380/use-of-circular-predictors-in-linear-regression

12. The language can be made simpler in many parts. E.g.: on L285: “The focus of the MDA lies in examining the data matrix from both the solution and variable perspectives, aiming to identify similarities among solutions based on their variables. In essence, the goal is to establish a typology of solutions by identifying groups that exhibit homogeneity in terms of variable similarity” could be simplified to “The focus of the MDA is to apply statistical clustering to identify similar analytic solutions” (please correct me if I have misinterpreted this sentence, but hopefully this example is useful).

13. Section 4.3: I appreciate the nice explanation of normalisation, but I think it is fairly standard practice in statistical modelling, and can probably be simplified. This is just a suggestion in relation to “presentation quality” (see review criteria above). Similarly on line 446: the expected average contribution calculation could probably be assumed rather than explained fully.

14. L327: Damage “survey” rather than “campaign”?

15. L345: “where”.

16. L384: “found”.

17. Table 4: Please define the symbols used for the column headings. This will make it easier to read.

18. I think Section 5.3 could potentially be shortened somewhat. The key point seems to be that a certain set of variables are more important for explaining the variability in the solution space by PCA, and this result could be presented in a more concise way.

19. L407: Table 4 also presents…

20. Table 6: Are these representative cluster solutions based on solutions closest to the mean using all dimensions, or just X_c0 and Y_c0 as in Figure 14?

21. Figure 15: Exactly how is the simulated wind speed on this plot calculated for comparison with observations? Is it the addition of the radial velocity solution and the storm translation speed or ABL wind speed?

22. Figure 5 and 15: Y-axis label should be wind speed rather than velocity?

23. L496: “field”.

24. L517: I think this is a key point that nicely sets up some of the goals of the paper, consider mentioning it earlier (unless it was already mentioned, and I missed it)