Answer to **RC2**: 'Comment on nhess-2023-40', Anonymous Referee #2, 13 Jun 2023

1 Overview

In this manuscript, the authors present the performance of an additive logistic regression model called “AR-ChaMo” that is able to predict the probability of lightning and hail occurrence. AR-ChaMO model for hail is compared with two documented convective indices and results show that AR-ChaMo outperforms them.
While the manuscript is well-written and the presented results are very interesting, and of great importance, I would suggest some major revisions to be made before the manuscript is accepted for publication.

2 Major comments

- The study is based on the additive logistic models developed by Rädler et al. (2018) but they were based on the much coarser ERA-Interim reanalysis dataset and in the current manuscript, in Section 3, it mentioned that ERA5 was used to train the models with additional parameters. While in Rädler et al. (2018) it reads in their Section 6 “*This model may be improved further by using additional predictor parameters. Such parameters may include low-level moisture, lapse rates, lifted condensation level, or height of the melting level.”,* it seems that the authors of the current manuscript have taken into account this suggestion but they do not present their calculations. In addition, Battaglioli et al. (2023) study has not been published yet, and several aspects of the approached used are not currently accessible. The table with some acronyms of the parameters used is not sufficient in order to publish a method and make it reproductible by the scientific community.

Authors: Thank you for raising this point. We understand that the current paper is heavily based on Battaglioli et al. 2023 (Journal of Applied Meteorology and Climatology). The JAMC paper has been conditionally accepted and is now undergoing the last round of reviews. For reasons we are not aware of, the review process has been extremely slow (6 months between submission and receiving the reviews), this has caused delays in the publication of Battaglioli et al. 2023.

We have decided to upload the manuscript as a preprint. It can be accessed at the following link: https://www.preprints.org/manuscript/202308.0314/v1

The Battaglioli et al. 2023 paper presents a thorough description of the model selection procedure that yielded the final lightning, hail > 2 cm and hail > 5 cm models out of 172 possible predictors. Nonetheless, to account for the reviewer’s comment, an addition to the section 2.1 paragraph has been included citing the different metrics and procedure used for model selection: “model selection procedure based on an ingredients-based approach (Doswell et al. 1996), the Deviance Explained (Wood 2006) and the Bayesian Information Criterion (BIC, Schwarz 1978) scores. Out of 172 available parameters from the ERA5 reanalysis, the model selection procedure with

Deviance Explained (the higher, the better) and BIC (the lower, the better) yielded a 5-dimensional lightning model and a 4-dimensional conditional hail model".

With this addition we aim to provide the reader with a clearer view of the metrics and the procedure used for model selection. Rather than repeating the whole procedure in detail, the reader is directed to the Battaglioli et al. 2023 manuscript (now available).

While the study is dealing with both hail and lightning forecasting, the latter is not discussed at all in the Introduction. Please expand this section and use more references for lightning forecasting. Ideally, other approaches for lightning forecasting should be discussed and compared, similar to hail.

Authors: Thank you for pointing this out. The introduction has now been heavily edited to consider the reviewer's comment. A description of lightning forecasting techniques in the literature has been added and 18 references to lightning-related papers have been added to the section. We now believe the introduction describes both lightning and hail thoroughly. For a more detailed view of the edits, we refer to the updated manuscript.

- The Significant Hail Parameter (SHP) is able to distinguish environments with very large hail (>=5 cm) and with small hail. How did you compare your model's result with SHP given that you used ESWD data with hail >=2 cm? Please consider adding a few more graphs either in main text or as an appendix to visually compare examples for large hail forecasts with SHP, CAPESHEAR, and AR-ChaMo.

Authors: Thank you for raising this point. Indeed SHP is meant to delineate very large hail to large hail. Nonetheless SHP represents a skillful predictor for large hail in Europe (Czernecki et al. 2019). For this reason, it was selected as a possible composite parameter to compare with ARhail. Other parameters e.g., the Large Hail Parameter (LHP) were considered for testing, but the limited vertical resolution of the ECMWF reforecast data made it impossible to calculate.

To address the second part of the comment we produced forecasts for the 15th of June 2019 and three initialization times (T-12h, T-108h, T-180h) - as for AR-CHaMo - but for the 1-dimensional logistic models based on SHP and CAPESHEAR. The 12 hour forecasts plots (now Figure 3 and Figure 4) have been added to the main text along with a discussion of the main differences with the AR-CHaMo output in Section 4.1: "To compare the AR-CHaMo forecast with that of existing composite parameters, we produced probabilistic hail forecasts for the same timestep and initialization time based on two 1-dimensional logistic models trained using SHP (Figure 3) and CAPESHEAR (Figure 4). The SHP model is in agreement regarding the Germany-Poland-Czechia and south-eastern France regions, but compared to AR-CHaMo, yields high hail probabilities also across regions where no hail was reported e.g., the Balkans

and Eastern Europe. The CAPESHEAR model, on the other hand, identifies well the south-eastern France region but places the highest probability of hail across northern Germany and northern Poland away from the highest density of hail reports to the south. "

The plots for the longer lead times have been included in the manuscript, in the Appendix.

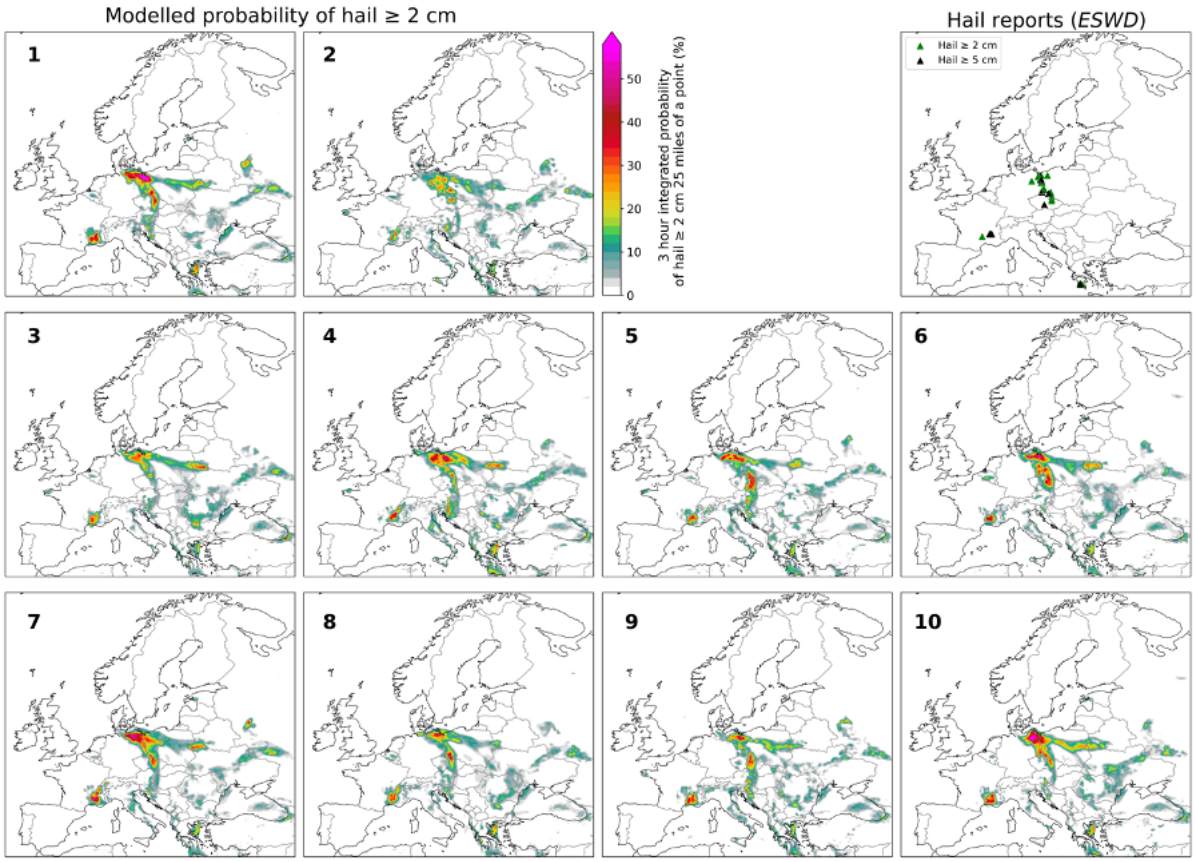

Figure 3: Probabilistic forecast of hail 2 cm occurrence on the 15th of June 2019 at 12:00 UTC (initialized on the 15th of June 2019 at 00:00 UTC) for the individual ensemble members. Hail reports between 12:00 UTC and 15:00 UTC are shown as triangles (green for hail 2 cm but 5 cm, black for hail 5 cm) in the right-top panel.

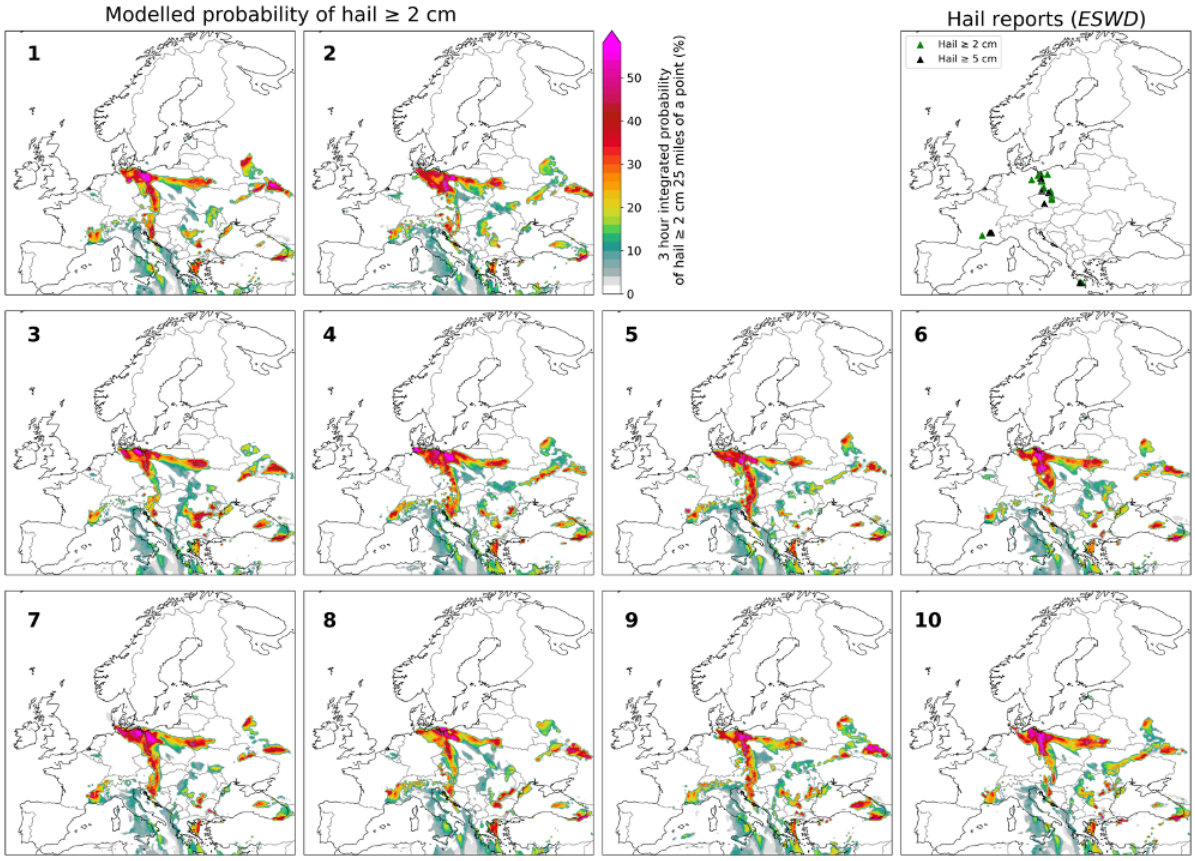

Figure 4: Probabilistic ensemble forecast of hail occurrence based on a 1D logistic SHP model for the 15th of June 2019 at 12:00 UTC (initialized on the 15th of June 2019 at 00:00 UTC). Hail reports between 12:00 UTC and 15:00 UTC are shown as triangles (green for hail 2 cm but 5 cm, black for hail 5 cm) in the right-top panel.

3 Minor comments

1. Acronyms are used without explicitly defining them, even in the Abstract (i.e., ECMWF, CAPE, etc).

   Authors: We have added the definition before the acronyms in the Abstract and throughout the text.

2. Wet Bulb Zero Height is mentioned in the Abstract but it is not mentioned anywhere else. Was it used?

   Authors: In Table 2 we changed 0° height with Wet Bulb Zero Height since the latter was the one used in the final model.

3. In Line 66 Table 1 should be Table 1c.

   Authors: Thank you for the comment. As mentioned already for reviewer #1, Table 1 is correctly mentioned here. The problem is that Table 1 was not correctly copied in the Preprint. Now this has been corrected.

4. Rädler et al. (2019) should be Rädler et al. (2018).

Authors: Yes, good point. This has been changed accordingly.

5. Lighting should be lightning in Lines 80 and 171.

   Authors: Thank you, we corrected "lighting" to "lightning" throughout the text.

6. I am not totally sure, but the time convention is 00z or 0000 UTC or 00:00 UTC, and not 00 UTC as it is used now. Please double check and modify accordingly.

   Authors: Thank you for pointing this out. We changed all time instances to the format "00:00 UTC".

7. In Line 135: J/kg – J kg^{-1}

   Authors: Changed accordingly.

References:

1. Rädler, A. T., P. Groenemeijer, E. Faust, and R. Sausen, 2018: Detecting Severe Weather Trends Using an Additive Regressive Convective Hazard Model (AR-CHaMo). J. Appl. Meteor. Climatol., 57, 569–587, https://doi.org/10.1175/JAMC-D-17-0132.1
2. Battaglioli, F., Groenemeijer, P., Púčik, T., Taszarek, M., Ulbrich, U., and H. Rust, 2023: Logistic modelling of (very) large 315 hail occurrence in Europe and the United States (1950-2021)

3. Czernecki, B., M. Taszarek, M. Marosz, M.Półrolniczak, L. Kolendowicz, A. Wyszogrod zki, and J. Szturc, 2019: Application of machine learning to large hail prediction—The importance of radar reflectivity, lightning occurrence and convective parameters derived from ERA5. Atmos. Res., 227, 249–262, https://doi.org/10.1016/j.atmosres.2019.05.