**HESS-2024-78 Leveraging a Disdrometer Network to Develop a Probabilistic Precipitation Phase Model in Eastern Canada**

# Response to anonymous referee 1

We would like to thank the reviewer for their helpful contribution to the article. Please note that additions to the article are shown in bold. The lines in this document refer to the previous version of the manuscript and may be subject to change in the revised version.

## 1 General comments

This study of predicting the phase of precipitation is rather regional, but it is worthwhile for the large amount of novel data used and different conclusions on the importance of humidity to earlier studies in other regions. My comments are minor or technical.

Thank you, your kind words are greatly appreciated.

## 2 Specific comments

### 2.1 Considering that there are several types of disdrometer, it might be worth getting the word "radar" into the title.

This is a good point, thank you. We propose the new title:

Lines 1-3: *Leveraging a **radar-based** disdrometer network to develop a probabilistic precipitation phase model in eastern Canada*

### 2.2 Line 21: Specify which reanalysis data are in PGP_full (thickness, temperature lapse rate and surface pressure).

Thank you, we agree that it would be beneficial to detail which variables are used for each model. We suggest to the following change:

Lines 20-21: *PGP_basic is based on 2-m air temperature and site elevation, while PGP_hydromet integrates relative humidity, **surface pressure and precipitation rate**. The PGP_full dataset **includes all the previous data, along with additional reanalysis data, that is, 1000-850 hPa layer thickness, and temperature lapse rate.***

### 2.3 Line 71: The difference in computational resources between threshold and curvilinear functions is trivial in application.

This is a fair point, we suggest removing the corresponding part of sentence, resulting in the following:

Lines 73-74: *Furthermore, these types of methods can be refined into curvilinear functions, which would theoretically yield to a more accurate phase identification (Feiccabrino et al., 2013).*

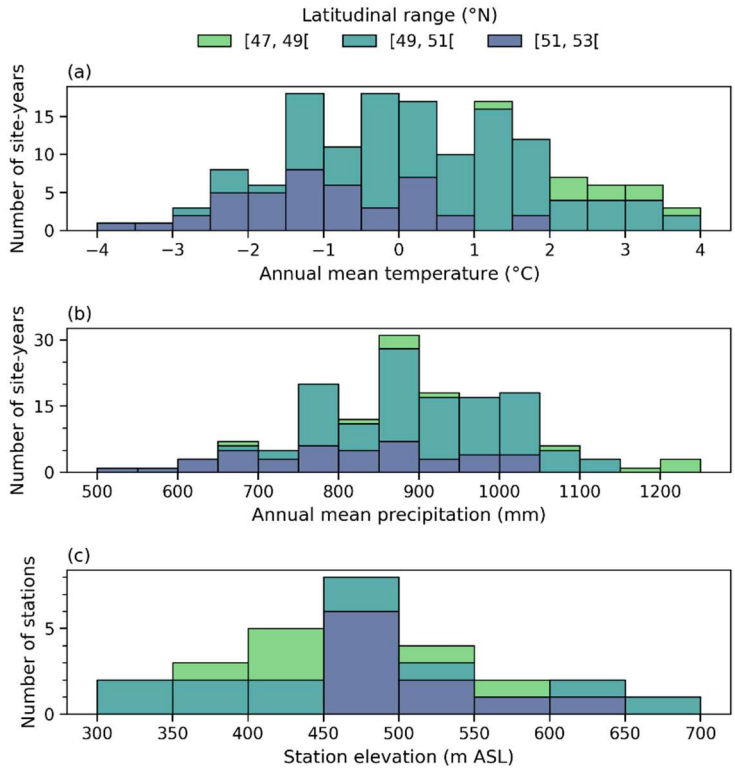
2.4 Line 189: The WMO definition of freezing rain is supercooled liquid drops that freeze on impact with the ground. Is this what the WS100 records as "freezing rain"? How does its diameter-fall velocity relationship differ from warm rain?

Regarding the instrument's definition of freezing rain, considering that the instrument outputs files that use WMO codes and that freezing rain is the term used in official documentation, we assume it corresponds to the WMO definition.

As for the diameter-fall velocity relationship of freezing rain, this is a good point and would be pertinent information to add. Unfortunately, after verification with the company manufacturing the disdrometer (Ott HydroMet), the specific details of this relationship are proprietary information that they keep confidential at his time.

2.5 Figure 2: Picking up some hints in the text, would scatter plots of these variables be interesting?

There is not enough data and spatial variability to truly have an interesting trend for scatter plots. However, we suggest adding a color scale for different latitudinal ranges, to supplement the figure interpretation. Here is the modified figure and the corresponding caption:



Lines 199-200: *Figure 2: Distributions of the (a) annual mean temperature, (b) annual mean precipitation and (c) elevation at the study sites**, separated by latitudinal range.***

Additionally, we propose modifying the following line to better fit the information in the figure:

Lines 175-176: *The southernmost sites (<**49**°N) receive **more** precipitation **on average**, with an annual mean of 1002 mm. **However, the variability observed at these sites is much greater than that observed elsewhere.***

2.6 Line 240: Thickness does not indicate the travel time unless the hydrometeor fall velocity is also known.

This is a good point; we propose removing the corresponding part of the sentence:

Lines 239-242: *The layer thickness between the two pressure levels is correlated with the mean temperature of the **and** is also commonly used in operational meteorological models (Feiccabrino et al., 2015).*

2.7 Line 264: Aggregation of freezing rain with snow rather than rain is common in previous studies and is justified by the hydrological influence, but it seems to be a misclassification of the phase of the hydrometeors.

We acknowledge that this aggregation could constitute a misclassification of the phase. However, the goal of this study is to provide a phase model for hydrological purposes, where freezing rain is generally not considered. For example, SWAT (Arnold et al., 2012) is widely used and lumps freezing rain with snow for snow accumulation. Thus, the important distinction for such a model is whether the precipitation increases the solid or liquid content of the snowpack, without regard if it contributes as fresh snow or an ice layer.

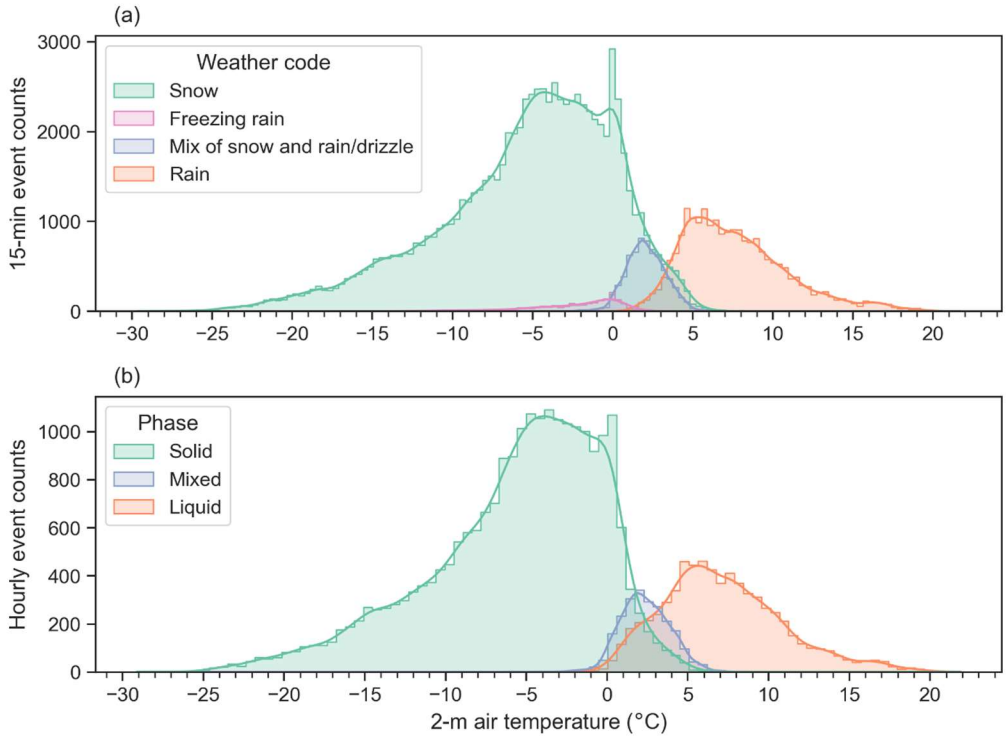
Furthermore, as it is by far the rarest precipitation phase, we judged that this aggregation would not impact significantly the results. The instances where freezing rain occurred consist of 6.4% and 3.6% of the solid and mixed phase precipitation data points, respectively. Freezing rain accounts for approximately 3% of the total winterly precipitation amounts. While this aggregation could affect the prediction of mixed-phase events that include freezing rain, it is such a small portion of the dataset that the effect is likely to be minimal.

2.8 Figure 3: After reading the text many times, I think that the “mix of snow and rain/drizzle” in Figure 3a combines what the disdrometers class as “mix of snow and rain/drizzle” (which gets aggregated with the liquid phase in 3b) and hours with 15-minute periods classed as both snow and rain (which remain classed as “mixed” in 3b). But I am not confident in that interpretation (and I have no idea why the peak in snowfall close to 0C

appears to go down slightly when classed as solid precipitation). Please don't make the reader work so hard on something simple.

The information conveyed in Figure 3 should indeed be made clearer, thank you for pointing this out. We propose the following modifications to the figure:

1. The upper part shows the 15-min precipitation data points that are used in the aggregation along an interpolated 15-min 2-m air temperature.
2. Adding "15-min" and "Hourly" to the count labels to clearly indicate the difference between Figures 3a and 3b.




Lines 278-279: Figure 3: ***Event*** *counts of (a) the* ***15-min*** *precipitation phase identified by the disdrometers and (b) the aggregated* ***hourly*** *precipitation phases according to the 2-m air temperature.*

We also propose the following modifications to the text supporting the figure:

Lines 280-280: *Figure 3****a shows the phase occurrence of the coupled 15-min precipitation data along an interpolated 15-min 2-m air temperature. The phase occurrence in Figure 3b*** *shows that* ***it is mostly the*** *mixed and liquid precipitation* ***distributions that are affected by the aggregation****, and that the very few freezing rain events that are aggregated with snow events result in the snow and solid phase distributions being very similar.*

2.9 Figure 9: The colours do not convey any information, so I would not use them.

While this is true in the case of this figure, we deemed it important to keep the colour scheme consistent between Figures 8 and 9 to quickly identify the different models.

2.10 Line 572: What is "Improving PGP models' ability to accurately predict the mixed phase is manifold" meant to mean?

This sentence is indeed rather vague and superfluous. We suggest rewording the paragraph:

Lines 571-575: ***The scoring scheme for permutation importance must be carefully selected according to the model and the use case. In this instance,*** *the PGP models tend to overpredict the mixed phase, which also negatively impact their ability to predict the other phases. In turn, this also affects the models' partitioning error,* ***which indicates that their overall performance is reliant on accurate phase classification****. For these reasons, the chosen scoring scheme for the permutation importance is the weighted F1 score, to consider* ***the classification of*** *the imbalanced* ***phase dataset****.*

2.11 Figure 10: The diagonal is redundant. Removing it would allow making the rather small labels a bit bigger. The colour scale should have a label.

Both points are valid. Including the diagonal does not add information and will be removed. Regarding the color scale, it is true that the reader should be able to understand that it indicates the correlation between variables without reading supporting text, so it will be added.

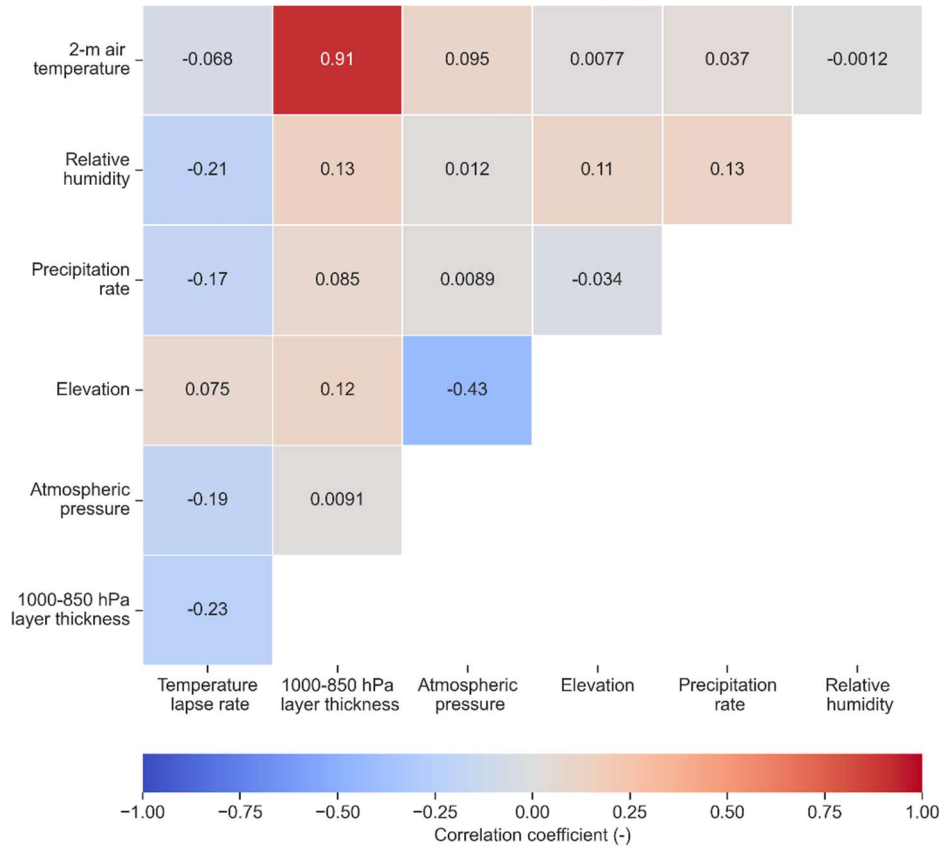



Figure 10: Correlation matrix of PGP_full input variables pairs.

## 2.12 Line 825: Why exclude snowfall when there is not already snow on the ground?

This is a good point, and the reasoning was not well explained here. The criterion was introduced to retain events where the SWE was greater than the instrument's lower measurement limit of 15 mm. We suggest the following changes:

Lines 824-825: *This filtering step aimed to exclude short events and events that occurred either in warmer conditions, where phases other than rain are uncommon, or in the absence of a snow cover* ***detectable by the instrumentation in place****.*

## 2.13 Appendix C: Does equation C4 not give the temperature for unventilated hydrometeors? The ice bulb temperature may be a more appropriate predictor (or there may be little difference due to the high relative humidities in this study).

It is indeed the equation for the temperature for unventilated hydrometeors. The description of the equation could benefit from a little more detail. We suggest adding the following:

Lines 855-866: ***Based on the mass balance of a sublimating ice sphere, the temperature of an unventilated hydrometeor*** $T_i$ *is calculated iteratively with the following function:*

Ice bulb temperature may indeed be an appropriate predictor for drier climates. Among other predictors, the wet bulb (rather than ice bulb) temperature was tested in this study, as multiple studies have successfully done so. However, as hypothesized by the reviewer, the high relative humidities meant that there was very little gain in performance.

# 3 Technical comments

## 3.1 Line 74: "yield a more accurate"

Thank you, this will be corrected.

## 3.2 Line 86-89: "it" becomes "they" over the course of this sentence.

Thank you, "they" will be replaced by "it".

## 3.3 Line 107: "Therefore" seems incorrect at the start of this sentence.

This is true, it will be corrected.

## 3.4 Line 168: "elevations range"

Thank you, it will be corrected.

## 3.5 Line 207: "with sensors"

Thank you, it will be corrected.

## 3.6 Line 208: Delete "ground".

We assume that this comment refers to the unnecessary addition of level in "above ground level" and will correct it.

## 3.7 Line 238 (and subsequently): Prevent automatic capitalization of the first word after a display equation when there is not a new sentence.

Thank you for pointing this out, it will be corrected.

## 3.8 Line 314: "harshly penalizes a poor score in either" has already been said.

This part of the sentence will be removed, as it is indeed redundant.

3.9 Line 316: “the model partitioning performances are”

Thank you, this typo will be removed.

3.10 Line 359: “the predicted phase is either solid or liquid,”

Thank you, it will be corrected.

3.11 Line 453: “PGP_basic overpredicts the mixed phase”

Thank you, the sentence will be changed.

3.12 Line 512-513: Spurious line break

Thank you, it will be removed.

3.13 Line 658: “importance of 1000-850 hPa layer thickness”

The sentence will be modified accordingly.

3.14 Line 679: “such as laser disdrometers”

Thank you, this will be corrected.

3.15 Line 686: “at a site sheltered from the wind”

This will be corrected, thank you.

# 4 References in this document

Arnold, J. G., Moriasi, D. N., Gassman, P. W., Abbaspour, K. C., White, M. J., Srinivasan, R., Santhi, C., Harmel, R. D., van Griensven, A., Van Liew, M. W., Kannan, N., and Jha, M. K.: SWAT: Model Use, Calibration, and Validation, Transactions of the ASABE, 55, 1491-1508, https://doi.org/10.13031/2013.42256, 2012.