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

Response to Dr. James Feiccabrino

We are grateful to Dr. Feiccabrino for his valuable input, which has clearly contributed to the improvement of our manuscript. 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

My recommendation (old standard) would be accept with minor corrections.

I overall enjoyed reading through the article and commend the writers for a well written thorough overview of the state of precipitation phase determination in hydrological or hydro-met models. They did a very good job of stating the problem (why it's important, and reviewing past work on the issue). They have an interesting and well thought out method and do a good job explaining their results and how it fits into the current state of work on the issue. They also attempt to identify why some results don't agree with all previous work and how it could be used for future studies. I would consider this a solid write-up.

I really liked how you explained the difference in outcomes between your study and other studies citing RH as an important factor for precipitation phase determination lines 605 - 609, and 641-644. I wish more papers included notes like this.

Thanks for the positive feedback, it is much appreciated.

2 Major corrections

2.1 Lines 530-539 are an exact copy of lines 513-521. One of these paragraphs should be deleted, and may affect the final location of Table 4.

Thank you, the paragraph on lines 513-521 will be removed, and Table 4 will be left as is.

2.2 Line 254 - (ECCC, 2024) is the reference used, but does not appear in that form in the reference list. I believe this is the reference on line 932, but there is no easy way to link the reference in the article to the reference named "climate glossary".

This is a good point. After consideration, we propose replacing the reference with the relevant section in the WMO guide to instruments and methods of observation (WMO, 2018), as it is a more general reference than the ECCC climate glossary.

Lines 249-253: *A first filter was applied, where hourly precipitation rates < 0.2 mm h^{-1} were considered erroneous trace amounts,* ***following the standard WMO methodology (WMO, 2018)****.*

Please see the section at the end of this document for the full reference.

2.3 Line 225 - Hersbach 2023 is missing et al., in the article reference.

Thank you for this observation, this will be fixed.

3 Minor Corrections and things to consider (not necessary changes)

3.1 Line 72 - grammar - consider switching "while occurring" with "that occur"

Thank you for the suggestion, this will be corrected.

3.2 Line 205 - grammar - you are missing a word in "The weather stations measure hourly air temperature and relative humidity ___ sensors mounted at 2 m above ground level" some possibilities are rewording or filling ___ with (using/from...)

Thank you, we propose modifying the sentence as follows:

Lines 205-207: *The weather stations measure hourly air temperature (model CS109, Campbell Scientific) and relative humidity (model HMP155a, Campbell Scientific)* ***with*** *sensors mounted at 2 m above ground level.*

3.3 Line 201 - it could be cleaner for the reader if you edited to make "from weather stations near the disdrometer stations" the last statement in the paragraph lines 201-209, moved it to the beginning of the next paragraph lines 210-219. As is, it leaves the reader wondering How close is near? - However, not a major issue since the answer is found in the next paragraph.

This is a good point. We suggest removing the part that mentions the distance between sites, as it is unnecessary in the context of the paragraph, and that the following paragraph provides more details about the distance:

Lines 201-203: *The meteorological observations in this study* ***come from*** *weather stations, operated by Hydro-Quebec and SOPFEU, the province's wildfire prevention organisation.*

3.4 Line 220 - Formatting - Table 1 seems to be the last two words of the previous paragraph rather than needing a new line.

Thank you, the formatting will be corrected.

3.5 Lines 419 - 423 as it relates to Figure 6d - Something to check. It seems a bit odd, but possible that the mean precipitation rate 0.9mm is higher than the medians of 0.8mm, 0.7mm, and 0.6mm for mixed phase, liquid phase, and solid phase respectfully. It can be a correct statement, but figure 6d makes this less likely given the very low numbers of heavy precipitation events depicted in the chart... It's not highly important to the paper, but does look a bit off.

The values presented have been double checked and are as presented in the manuscript. This result is probably due to the significant weight of the lower precipitation values, which make the median lower than the mean, rather than higher precipitation values that result in a mean greater than the median.

3.6 Line 452 - grammar - "the most the mixed phase" - perhaps PGP_basic has the greatest overprediction in mixed phase (plenty of options, but right now the grammar is incorrect).

Thank you, it will be corrected.

3.7 Lines 566 - 568 - wording is a bit tricky, no issues with the beginning " The layer thickness is affected by environmental temperatures, as air density is inversely proportional to its temperature" however the end needs to indicate temperatures increasing or decreasing to finish the thought "which increases the distance between two pressure levels." A suggestion would be "... temperature. Therefore, as temperatures increase, the distance between two pressure levels also increases".

Thank you, we propose modifying the sentence to follow this suggestion:

Lines 566-568: *The layer thickness is affected by environmental temperatures, as the air density is inversely proportional to its temperature*. ***Therefore, as temperatures increase, the distance between two pressure levels also increases.***

3.8 Line 679-680 - grammar (missing word) - "options such __ laser disdrometers", looks like it should be "such as".

Thank you, it will be corrected.

3.9 Line 766 - 767 - I would suggest consulting co-authors to make sure this is the final consensus on why "The longer time-step may lead to a lower critical threshold because the energy needed to melt the precipitation can be supplied over a longer period", I can't attach this thought with anything in the paper and would not personally agree with this statement.

This is a good point, and the reasoning will be reworded for clarity. The goal of this statement was to express CT differences could be due to the validation data's timestep, the sentence will be reworded.

In the case of both Jennings et al. (2018) and Dai (2008), the validation data are at a 3-h time step and the CT is lower than this study's solid CT_S. Additionally, Jennings et al. (2018) showed even greater differences, as they separated the data into relative humidity and surface pressure bins, whereas Dai (2008) lumped all overland data together. Following this result, one could argue that the CT would decrease for longer timesteps, where mixed-phase precipitation due to a phase change is more likely to occur and requires overall colder temperatures for solid precipitation. Figure R1 illustrates the evolution of CT_S from the dataset, which has been resampled to increasingly longer time steps. The longer the timestep, the colder CT_S becomes. The CT_S for humid conditions (i.e., greater than 90% relative humidity) are slightly colder and show a decrease similar to the full data curve.

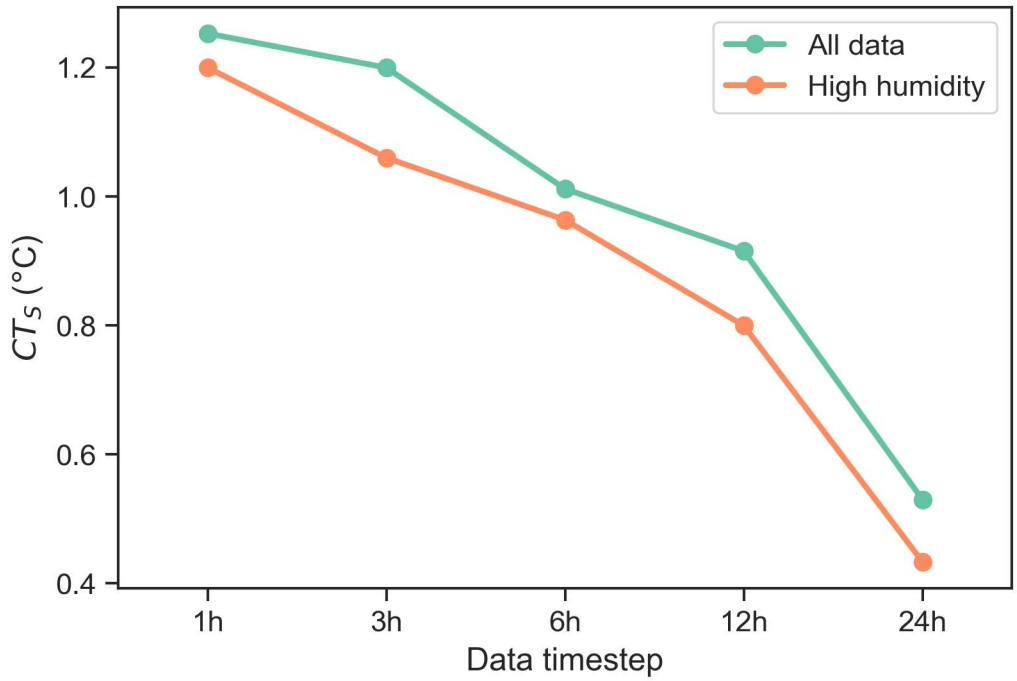

Figure R1: CT_S according to resampled data timestep, for the full dataset and high humidity data points (> 90% relative humidity).

As a matter of fact, the 3-hourly CT_S decreases to 1.2°C and is in line with the value for all overland observations from Dai (2008). When accounting for humid conditions, CT_S further decreases to 1.1°C. A noticeable difference remains however, especially compared to Jennings et al. (2018), even when accounting for the timestep and relative humidity range. The difference could come from the phase identification errors of both validation data sources, as it seems that the disdrometers used identify solid precipitation at warmer temperatures than the other studies mentioned.

We propose first refining slightly the comparison with the results in Behrangi et al. (2018) to show the difference between CT_S and their CT_a for humid conditions:

Lines 743-746: *One of the main conclusions of the study was that the wet-bulb temperature model is more robust than the dry-bulb temperature model because the CT_a can vary significantly from site to site.* ***As such, the CT_a for humid conditions would be approximately equal to the mean value minus the standard deviation, resulting in 1.18°C. The CT_a for humid conditions is thus much closer to the CT_S of 1.3°C in this study. Additionally, the*** *upper limit* ***of the CT_a of*** *2.16°C* ***in Behrangi et al. (2018)*** *closely matches the P_m of this study.*

Then we suggest a change at the end of the paragraph containing the problematic sentence that is the source of the reviewer's concern:

Lines 764-767: ***The greater difference between these CT_a and CT_S could be due to several reasons. First, the 3-hourly CT_a should theoretically be lower than the hourly CT_a. As the timestep increases, the occurrence of mixed-phase precipitation increases due to the higher likelihood of a phase transition. Second, the different types of validation data could explain why CT_a is generally lower than CT_S. Phase identification errors, particularly near the solid-liquid phase transition, could differ between direct observations and radar disdrometers.***

Finally, we propose a small addition to the following lines to reflect the previous modifications:

Lines 768-769: *Overall, the radar-based disdrometer measurements are similar to the findings of previous studies,* ***although with generally slightly warmer conditions of occurrence for solid precipitation. However,*** *more research is needed to properly quantify the uncertainties associated with this type of disdrometer.*

3.10 Line 792 - 793 - should double check this, might be 850-1000mb height difference according to figures 10 and 11 - "According to the input variable importance analysis, *atmospheric pressure* was the second most important hydrometeorological variable for phase classification" - It is the second greatest reanalysis variable (bright blue in figure 11) but the 4th most important variable if considering all data in Figure 11. This statement could be correct depending on the intended meaning of "hydrometeorological variable".

This is indeed ambiguous. We propose adding “near-surface” to the sentence for precision:

Lines 792-793: *According to the input variable importance analysis, atmospheric pressure was the second most important* ***near-surface*** *variable for phase classification.*

3.11 Lines 811 - 814 (Appendix A) - Longitude and Latitude, some values are given to 5 decimal points and others to 6, usually these values all have similar accuracy. I would suggest either rounding to 5 decimals, or if it is dropping a sixth decimal if = to 0, reformatting to show the 0 to show all coordinates having accuracy to 6 decimal points.

This is a good point, a zero will be added in the instances where there are only 5 decimal points.

4 References to be added to the manuscript

WMO: 6.1.2 Units and scales, in: Measurement of Meteorological Variables, 2023 edition ed., edited by: WMO, Guide to instruments and methods of observation, Volume 1, WMO, Geneva, 574, 2018.

5 References used in this document

Behrangi, A., Yin, X., Rajagopal, S., Stampoulis, D., and Ye, H.: On distinguishing snowfall from rainfall using near-surface atmospheric information: Comparative analysis, uncertainties and hydrologic importance, Quarterly Journal of the Royal Meteorological Society, 144, 89-102, https://doi.org/10.1002/qj.3240, 2018.

Dai, A.: Temperature and pressure dependence of the rain-snow phase transition over land and ocean, Geophysical Research Letters, 35, https://doi.org/10.1029/2008GL033295, 2008.

Jennings, K. S., Winchell, T. S., Livneh, B., and Molotch, N. P.: Spatial variation of the rain-snow temperature threshold across the Northern Hemisphere, Nat Commun, 9, 1148, https://doi.org/10.1038/s41467-018-03629-7, 2018.