The Cryosphere

Discussions

EGU

Open Access

Interactive comment on "Relationships between Snowfall Densities and the Main Types of Solid Hydrometeors Deduced from Measured Size and Fall Speed, for snowpack modeling applications" *by* M. Ishizaka et al.

Anonymous Referee #2

Received and published: 16 June 2016

In this study the authors establish a quantitative relationship between the density of freshly fallen snow and the main type of hydrometeors. Hydrometeors are classified trough measurements of their fall speed and size using the Center of Mass Flux (CMF) criteria as defined by Ishizaka et al. (2013). From this relationship the authors introduce a new quantity, the so called "CMF-density", which they relate to the measured density of the freshly fallen snow for aggregate snow and graupel. Finally, the authors discuss potential use of this relationship for snowpack modeling. With this analysis the authors investigate a very interesting approach of estimating snow density of freshly fallen snow, which has the potential to improve current snowpack models. The rela-

tionship might further be used to better forecast new snow height of snowfall events, as snow height is strongly dependent on the density of the freshly fallen snow. I have two general comments on the paper, the first concerns the relationship between snow density and "CMF-density" and the second concerns the application of the relationship for snowpack modeling. These general issued should be assessed in advance of publishing in The Cryosphere. Furthermore, I list specific comments and technical corrections, which can help to improve the scientific quality of the paper. Additionally, I strongly recommend to improve figure captions and the English with assistance of a native speaker.

General comments

1. The authors establish the relationship of the density of freshly fallen snow to "CMF-density" based on 14 and 9 snowfall events for the aggregate group and the graupel group, respectively. The relationships are thus based on a rather small sample of snowfall events. The authors state "The curves fairly represent the relationship between real density and "CMF-density", although the values scatter around the curves to some extent." (P8 L18-19). However, uncertainty bounds of the curves are lacking and thus, this statement is rather vague. It is important to get a justification of the robustness of the curves. A possibility to establish the uncertainty of the relationships is to perform a "leave one out cross validation" on the data. Another possibility would be to validate the results by a different sample of measurements for aggregate snow and graupel, respectively. However, the second might be difficult to achieve as only a certain amount of measurements may be taken during one season.

2. The title of the paper has the reader waiting for an application of the established relationships for snowpack modeling. The aspect of the applicability of the rela-

tionships for snowpack modeling is however only discussed in a perspective way for possible applications in the future. The authors mention that the relationships between "CMF-density", which may be determined from fall speed and size measurements of hydrometeors, and the density of freshly fallen snow may provide an improvement on the estimation of snow density in current models, where the initial density of snow is modeled based on meteorological conditions, while the type of hydrometeors is not considered. As the paper title states "..., for snowpack applications" I would very much recommend that the authors show a comparison of the performance and improvements of the new method of snow density estimation compared to currently employed methods in numeric snowpack models.

Specific comments

- It is informative how you derive the uncertainty of the error in your density estimation based on the reading error. However, you do not mention the uncertainty of your scale, which might have a similar impact as the reading error depending on the accuracy/uncertainty of the scale. If this uncertainty is negligible, please state.

- In section 2.4 "Estimation of errors in density measurements" you further give the derivation how you estimate densification of the snowpack, even though you finally state that for your application densification is negligible. Your paper would benefit by moving the whole derivation (P5 L10 -24) to the supporting material. Furthermore, equations (4) and (5) have to be revised.

- The first section of the results 3.1 "Classification of snowfall events" states how you classify your groups. In my opinion this should go to the methods section, as this section gives your methodology how you separate the groups but no results.

C3

- The analysis is restricted to snowfall events lasting about 1-2 hours (allowing for densification of the snowpack to be neglected) and to two snow types: aggregate snow and graupel. A discussion about the applicability of the method for different snow types and longer lasting events would be interesting.

- Figure Captions: all of your figures are sparsely described. Please, give more specific figure captions! Furthermore, I recommend to that figure captions are autonomous, i.e. define abbreviations. Example: "Figure 2: The distributions of measured sizes and fall speeds (crosses), and the integrated CMFs (white circle) of different types of snowfalls. a) corresponds to event A13 (aggregate type) and b) to event G4 (graupel type). Both cases are listed in Table 1. The two lines show the relationships of size and fall speed for conical graupel as described by Locatelli and Hobbs (1974) and densely rimed aggregate as described by Ishizaka (1995)."

- When you refer to previous sections specification of section is helpful for the reader.
  - e.g. P6 L19: "... originating from the reading errors (Section 2.4)."
  - e.g. P7 L8: "... criteria previously mentioned." -> "... criteria mentioned in Section X.X.", X.X = number of section.

Technical corrections

- P1 L31: plactical -> practical

- P2 L21-22: Try to eliminate one-sentence paragraphs.

- P3 L12: "The winter temperature, around 0°C..." Is this the mean winter temperature?

C4

- P3 L28: "CCD" Please define this abbreviation.

- P8 L25: "SI" -> S1

- P10 Summary: The summary should be autonomous and abbreviations should be defined.

- I recommend to rephrase the following sentences to make them more precise:
    - P4 L19: "If different snow types, ..."
    - P7 L21: "It is found that the densities..."

- Missing/spare spaces:
    - P1 L24: "...hydrometeors.As a result..." -> "...hydrometeors. As a result..."
    - P4 L10: "... aggregate type (A13)and graupel..." -> "... aggregate type (A13) and graupel..."
    - P7 L21: "...density is , the larger..." -> "...density is, the larger..."

Language

There are numerous lingual issues. I will mention some which will likely need to be changed. I strongly recommend to improve the English by assistance of a native speaker. Abstract (and later on in the paper): snows -> snow, hydrometeors types -> hydrometeor types, snowfalls -> snowfall events

C5