Discussion of “A Large-scale Validation of Snowpack Simulations in Support of Avalanche Forecasting Focusing on Critical Layers”

Author response to community comment 1

Herla et al.

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1 Responses to community comment #1 (Ron Simenhois)

1.1 General Comments

1.1.1 Kudos

Comment: *This is a well-written and interesting manuscript with impressive results. Below are a few general comments on the manuscript.*

Author Comment: Thank you very much for the kudos, and thank you for reaching out with your ideas of improving the manuscript! We really appreciate it!

1.1.2 Influence of the slab

Comment: *This work focuses on identifying weak layers for avalanche forecasting. However, a large body of research highlights the importance of both the weak layer and slab for avalanche formation. I believe the manuscript will benefit from a short discussion about why this work focuses on weak layers only.*

Author Response: Thanks for this suggestion! As you mention, at any given grid point and any given time, the snowpack instability depends on weak layer and slab characteristics. We actually take both of these characteristics into account when computing the stability of each layer in our data set. Please refer to comment 1.1.4 for a more detailed response and for how we made this more explicit in the revised manuscript.

This said, the general focus of our study is indeed on the weak layer. Since the slab is primarily a function of precipitation (Richter et al. 2020), research that contributes to our understanding of the modeled slab would rather look at simulated snowfall. Horton and Haegeli (2022) did exactly that for the same model chain that this paper uses. We added the following statement to the Introduction to create the mentioned link between snowfall validation research and the slab:

> Regional-scale validation studies of simulated snowfall further contribute essential information to the valuation of snowpack simulations for avalanche forecasting, particularly with respect to snow surface avalanche problems (e.g., storm snow problems) and characteristics of the slab, which is primarily influenced by precipitation (Richter

et al. 2020). Nevertheless, the existing research does not paint a comprehensive picture yet: to our knowledge no large-scale study exists that created a specific link between simulated layers and known critical avalanche layers.

In our analysis, the slab is most impactful in Sect. 4.3.3, where we compare temporal trends of modeled and reported instability. For situations with poor agreement, we cannot disentangle whether the weak layer or the slab is the main culprit. We added a comment to Sect. 5.2 "Limitations", where we discuss this challenge:

> Lastly, any temporal comparisons between simulations and assessments are additionally impacted by uncertainties in snowfall frequency and magnitude, which in turn impact weak layer and slab characteristics alike. Again, it often remains unclear which data source is closer to reality when new snow amounts differ (Lundquist et al. 2019; Horton and Haegeli 2022).

1.1.3 Dry slab avalanche forecasting

Comment: *The authors mention that this work aims to help with dry avalanche forecasting toward the end of the manuscript. It will add to the manuscript's clarity if this is mentioned earlier.*

Author Response: Agreed. We added statements in the Abstract and Introduction that will clarify this early during the reading.

> These simulations contain information about thin, persistent critical avalanche layers that are buried within the snowpack and are fundamental drivers of dry slab avalanche hazard.
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> [...]
>
> Overall, our study quantifies the capabilities of an operational weather and snowpack model chain to represent critical avalanche layers that are prone to cause dry slab avalanches, which contributes to making snowpack simulations more transparent and applicable for operational applications.

1.1.4 Weak layer characteristics

Comment: *This work concentrates on snowpack layers' grain type (persistent weak layers). Other weak layer characteristics that may or may not be more important than grain type, like depth, hardness, grain size, etc., are only mentioned toward the end as potential for future work. Again, I think the manuscript will benefit from a short discussion of why these weak layer characteristics are not part of this work.*

Author Response: In a first instance, we use grain type to identify layers that will cause persistent avalanche problems and will therefore be of concern substantially longer than non-persistent critical layers (e.g., storm snow). Once we had identified these persistent layers, a variety of weak layer and slab characteristics was indeed used to assess their modeled instability. We added explicit statements to Sect. 3.1.2 (Pre-processing simulations) to clarify this.

> [...] the model learned to predict the probability of layer instability ($p_{unstable}$) from a set of six simulated predictor variables. These predictor variables included characteristics of both the weak layer and the slab, namely the viscous deformation rate, the critical cut length, the sphericity and grain size of the weak layer, the skier penetration depth, and the cohesion of the slab. [...]

> [...] our process-based approach used a combination of three indices to assess the instability of a layer: a) the relative threshold sum approach RTA (Monti and Schweizer 2013; Monti et al. 2014), b) the multi-layered skier stability index SK38 (Monti et al. 2016), and c) the critical crack length r_c (Richter et al. 2019). Each of these indices consists of a variety of weak layer and slab characteristics, such as macroscopic properties (e.g., layer depth), microstructural properties (e.g., grain type and size), and mechanical properties (e.g., shear strength). [...]

This said, it is correct, though, that the presentation of our results is very much influenced by grain type. Not by personal choice, but informed by our CTree analyses, where grain type emerged as a strong explanatory variable. Now, you could ask why we didn't include any other weak layer characteristics other than grain type and grain size at the time of burial. We added an explanation to Sect. 3.2, where we explain our choice of explanatory variables:

> We included the following potential explanatory variables in our analyses, which contained both direct layer attributes as well as more contextual information:
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> - grain type (and grain type search routine)
> - grain size of the simulated layer at burial
> - data quality class
> - month of burial
> - number of associated avalanche problem days
> - simulated length of the dry spell before burial
> - season
> - region and elevation band.
>
> Since the CTree analysis required the explanatory variables to remain constant over the lifetime of the layer, we did not include any other specific weak layer or slab variables.

To sum up, the added explanations should make it more transparent for the future reader that a variety of weak layer and slab characteristics are indeed considered in our methodology, but that those have not been considered as potential explanatory variables of the CTree analysis.

References

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