Dear Referee #1,

thank you for your comments.

We will first address the major comment regarding the position of the single- and multi-layer version of the model and then we will report the reply to the minor comments.

The aim of the model is to integrate the different processes involved in the transformation of snow into firn. The choice to present both model versions in the new manuscript was driven by the consideration that the model is intended to be used in two different contexts: (1) with the multi-layer version it is possible to assess the evolution of firn under climate changes, since the model uses as input meteorological forcings (i.e., precipitation, temperature and wind speed) rather than snow accumulation and density. In this sense, the presented model expands available firn densification models, including an explicit representation of snow; (2) on the other hands, a simpler representation of the firn component results in a more straightforward integration in hydrological models. In the former case it is important to have as output a depth-density profile, while in the second an average firn density with which to estimate SWE may be enough.

Reflecting on the issue you pointed out, we decided to add a comparison between the two model versions that may relate the results of the two versions. It is in fact important, when adopting a simpler schematization, to be aware of the resulting approximation. For this purpose, we report here a comparison between the average firn density obtained from the single-layer version and the one obtained averaging the results of the multi-layer one (Fig.s RC1.1-2). In the figures, each group of bars represents a different run of the single-layer version of the model. On the x-axis it is reported the starting year of each simulation or equivalently the age of the oldest part of the firn column. The age of the most superficial part, or the ending year of the simulation, is different for the two cores: 2015 for CG15 and 2013 for KCC. The length of the bars is equal to the depth of the firn column obtained from the single-layer version or summing the depths of the individual layers of the multi-layer version. Dots, instead, represent the average density of the firn column, again as obtained from the single-layer version or averaging the density of each individual firn layer obtained with the multi-layer version, weighted for their depth.

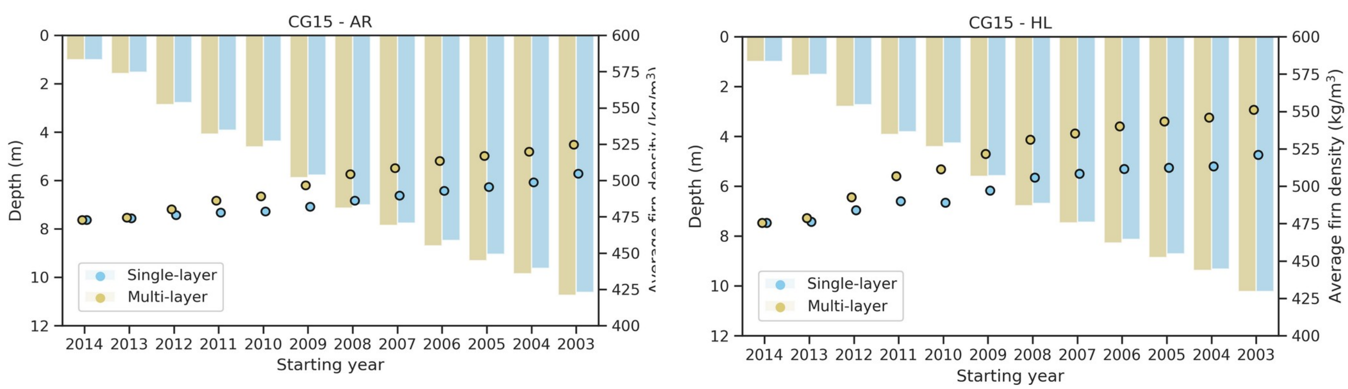

Figure RC1.1: Firn density and depth obtained from the single-layer version of the snow-firn model and averaging the results of the multi-layer version, for ice core CG15, using the model for firn densification of Arnaud et al. (2000) (left panel) or Herron and Langway (1980) (right panel).

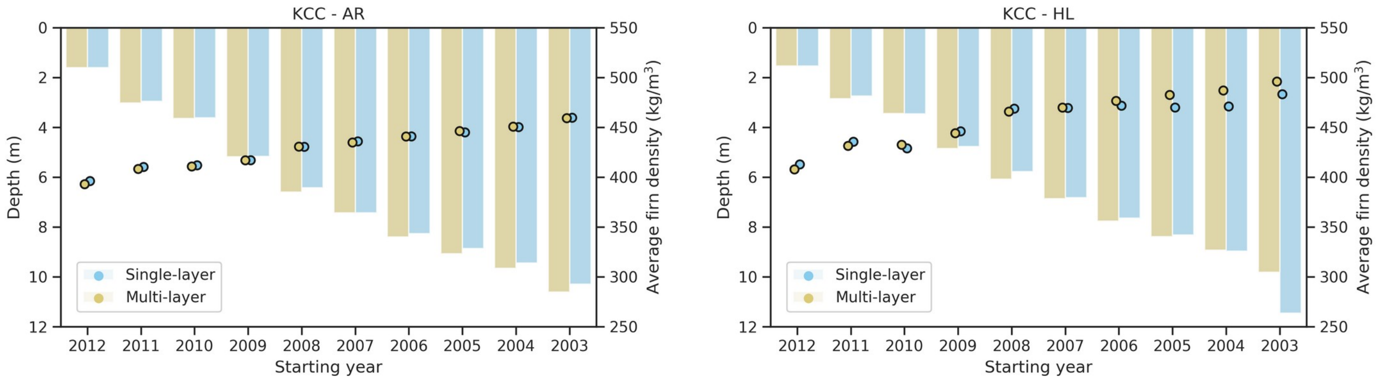

Figure RC1.2: Firn density and depth obtained from the single-layer version of the snow-firn model and averaging the results of the multi-layer version, for ice core KCC, using the model for firn densification of Arnaud et al. (2000) (left panel) or Herron and Langway (1980) (right panel).

Here the replies to the minor comments:

1. *L293-296 Why did you use the optimized values in the Japan site despite the studied field site being in Europe? If it is because Japan is the only place where the parameters of e could be adjusted, it should be written clearly. Also, it may lead to problems using a and e optimized at different locations in a single equation.*

A series of SWE or snow density with which to calibrate the parameter “e” was not available at Colle Gnifetti, but we may look for available SWE/snow density series in the Italian Alps and recalibrate the parameter in a site closer to the study site.

2. *L333-337, L377-389 From this result, the accuracy among several models are compared. Overall, the one that is calculated at high density seems to be suitable. Do you have any ideas to improve the model accuracy of the density profile more?*

In most of the ice cores reported in Fig. 4 of the manuscript it is possible to see a bend in the profile in correspondence of 20 - 30 m of depth. The reason of this could be a combination of ice flow and the upstream-effect, i.e. changes in snow accumulation upstream (P. Bohleber, personal communication, 26 April 2021). These effects are not likely to be reproduced by a 1D model like the ones we used. However, several effects may influence the observed variability in depth-density profiles.

The application of the steady-state firn densification models to other cold alpine sites may possibly provide further information about the ability of Arnaud et al. (2000) or Herron and Langway (1980) models to reproduce depth-density profiles in sites with characteristics at the limit of the ones of polar regions. Thus, allowing to better separate the mismatch due to non 1D effects or non-stationarity from the mismatch due to the parameters calibration of firn densification models.

3. *L350-352, L468-470 In 1D simulations, I think the purpose of considering erosion is to avoid overestimation of the amount of new snow and underestimation of density. Do you have any verification of the amount of the erosion?*

At our knowledge, there are no measurements of wind erosion at Colle Gnifetti, therefore the only quantitative verification is the one coming from ice cores. Qualitatively, the erosion of winter snow is confirmed also by some temporary snow measurements performed in sites close by, like Colle Sesia.

4. *L355-366 In Fig. 4, the density profile was reproduced using a multi-layer model. On the other hand, what is the purpose of the validation of the density of one-layer model with averaged observed density. Also, I think quantitative comparison about the accuracy between one-layer and multi-layer model.*

The aim was to assess the accuracy of a simpler model in reproducing the average firn density in order to have a description of the snow water equivalent contained in firn and that will be potentially released under increasing temperatures. Following your comments, we added a comparison between the firn depth and density obtained directly from the single-layer version or averaging the results of the multi-layer one. This to answer the question, which approximation is introduced estimating the snow water equivalent of firn with a single-layer model for firn rather than a multi-layer one.

5. *L457-461 I understand that you lowered the temperature for snow melt to match the observed density. However, I wonder if it can change a fixed value in natural science such as the melting point in the simulation. It is still understandable if you are assuming the influence of unknown factors such as salinity. Please describe why you used melting point as an adjustment.*

By adjusting the melting temperature, we were trying to assess the uncertainty associated with a wrong estimation of the surface temperature of snow. The latter was, in fact, set equal to air temperature, while melting may occur also for air temperatures lower than zero or not occur for air temperatures higher than zero. The amount of melting varies greatly over the site; Mattea et al. (2021) estimated a mean annual melt between less than 1 cm w.e. yr -1 on the steepest slopes of the Signalkuppe that increases to 17 cm w.e. yr^{-1} at the saddle point and to about 23 cm w.e. yr^{-1} on the Zumsteinspitze slope. Since the snow-firn model estimates annual melt amounts closer to the lower limit obtained by Mattea et al. (2021) and the CG15 core is located near the saddle point, we tried to assess the influence of a possible wrong estimation of melting.

Mattea, Enrico, et al. "Firn changes at Colle Gnifetti revealed with a high-resolution process-based physical model approach." *The Cryosphere Discussions* (2021): 1-30.

6. *L482-484 I understand that a simple one-layer model is more convenient to integrate into a hydrological model, but it is a rough validation compared to the multi-layer model. If you are planning to use the one-layer model in the final integrated model, the multi-layer results should be fed back to the one-layer model in some way, otherwise the multi-layer comparison will be meaningless. Do you have any plans to connect the multi-layer results with the one-layer model in some way?*

In Fig.s RC1.1-2 we reported a comparison of the results of the two model versions that can provide information about the accuracy that we are losing moving from one version to the other, therefore giving additional information on the performances of the single-layer version.