Response to review:

We would like to thank the reviewer for the comments.

Response to comments:

For this section the authors response are shown in black, where the reviewers comments are in blue. Quotes (“”) and *italic font* show changes to the manuscript.

Overall, this is an interesting modeling paper that describes the improvements in the Crocus(V7) snowpack model. The current modification improves the modeling of the water storage in the snowpack, and once further validated, could be an invaluable contribution to the state of art in snowpack modeling. Below I have a couple questions and minor suggestions, most of which are editorial.

Abstract L15. Pendular and funicular regime (scientific jargon). Need to explain that first.
We added to the abstract to further explain the jargon.

“Snow layers often reached a point where the ice crystals surface area is completely covered by a thin film of water (the transition between pendular and funicular regimes), where feedback is expected to be nonlinear..”

Section 2. First paragraph. I am confused. Is it a three models coupled system (SURFEX, ISBA, and Crocus)? If yes, then title should be changed.
The Crocus model has been developed as a standalone model. However, Crocus is often run coupled with two other models (SURFEX and ISBA). Crocus was coupled to “Interactions between soil, biosphere and atmosphere” (ISBA), for a wider range of bottom boundary conditions (Vionnet et al 2012, Noilhan and Planton, 1989). ISBA is coupled to SURFEX for a similar reason regarding the upper boundary.

Because the changes are all contained in the Crocus model we feel the title should include Crocus, but have added SURFEX to the title. We have adapted the 1st paragraph on section 2 of the revised manuscript to make connections between the models more obvious.

The current formulation of the Richards equation 1 does not account for presence of ice and air in snowpack. How do authors think the results would change by introducing them in the equation 1?
The Richards equation does account for ice, air and water in the snowpack via the water retention curve and the hydraulic conductivity. Both of these parameterizations are based on the snow layers dry density (ice vs air) the snow grains size (distribution of ice and air) and θ, the water content.

P4. L30. h should it be H?
Equation 2. shows the relationship between H and h.

“*H is the hydraulic head, which is the sum of the pressure head (h) and the elevation (z), which is negative because z is positive downward (Eq. 2).”*

$H = h - z$ Equation 2

P5. L2,5. The notation is confusing pressure head (h), and retention curve h(theta)?

We took out h(θ), to avoid confusion. The water retention curve relates head values (h) to water content values (θ) and vice-versa.

P5. L10. Equation 3. If it is water retention curve function then should be h(theta)
Equation 3 shows θ(h) which is the inverse function of h(θ). We use the relations θ(h) and h(θ) in our routine. The Van Genuchten (1980) (VG) parameterization is used for the relation between water content and pressure head which can be seen in Fig.2 . Figure 2 shows for a given grain size and snow layer density there is a one to one relation between h and θ. We now use only "θ" and "h", to make notation clearer.

When water percolates through the snow layer and freezes at the bottom. The pressure and volume at the bottom grid cell increases due to ice formation. How does the model handle the increase in pressure due to ice formation?
This behavior described by the reviewer can be seen in the Filefjell results (Fig. 6 D of the revised manuscript). In the Filefjell case the ice layer at the bottom of the snowpack becomes very dense. The model will eventually crash due to extreme values of the suction and conductivity if the density becomes too great.

I assume "increase in pressure" means increase in suction (negative pressure), since this model does not deal with positive pressures (no pooling of water). Regardless of the terminology it is the pressure gradient (dh/dz) what matters for water percolation. It is not obvious what will happen when one layer becomes denser. The hydraulic conductivity and the water retention curve will both be affected by the change in density and also the change in θ because the pore spaces decrease.

In general it is not well understood how water interacts with crust layers it has been reported to act as a barrier layer but also a conduit (Jordan, 1995). Better parameter sets are needed for crust layers as stated in section 6.5.
We feel very dense layers will not be problematic if new parameter sets for crusts are developed and feedback from the snow compaction routine is updated for high water contents.

It would be interesting to plot pressure head changes with time on Figures 8 and 9.
The saturation (S defined in equation 6) is the major factor in a snow layers pressure head. This can be seen in Fig. 2. Snow density and grain size have a smaller effect on the pressure head of the snow pack. Because the pressure changes so drastically with regards to S (or θ), we feel it is better to show how θ changes with time and the density evolution instead of changes in h. The histogram in Fig. 2 shows how pressure head acts at different water contents, this is particularly interesting to see that the saturation is always < 20% for the simulated forcing.

Section 6.6. Authors are referring to the different routines, like 'C13' and so on. It is confusing to read those notations and have no idea where they come from. For clarity, I suggest to make a chart including all the important routines.
C13 and B92 are parts of the SNOWCROMETAMO routine shown in figure 1. We make this clearer in section 6.5 by describing the relationship between C13, B92 and the routine SNOWCROMETAMO. We also refer to figure 1.

"The water retention curve and hydraulic conductivity functions are not designed for use on crust layers. Furthermore, Crocus' snow metamorphism routine (SNOWCROMETAMO, Fig. 1) does not work well for

crust layers, because dense crusts do not have individual grains, but rather a solid ice layer with bubbles. There is a choice of routines in SNOWCROMETAMO, the B92 (Brun et al. 1992) and the C13 routines. The B92 routine uses sphericity and dendricity. The C13 routine uses optical diameter, which is used as an approximation for visual grain size in the Richards routine."

There are figures, like Figure 11, which have the same legend. I suggest to make one legend, and put A) and B) as a subtitle or place the text inside the figure

Figure 11 (Fig. 9 in revised manuscript) has been updated with A and B and the time step duration printed inside the plot area.

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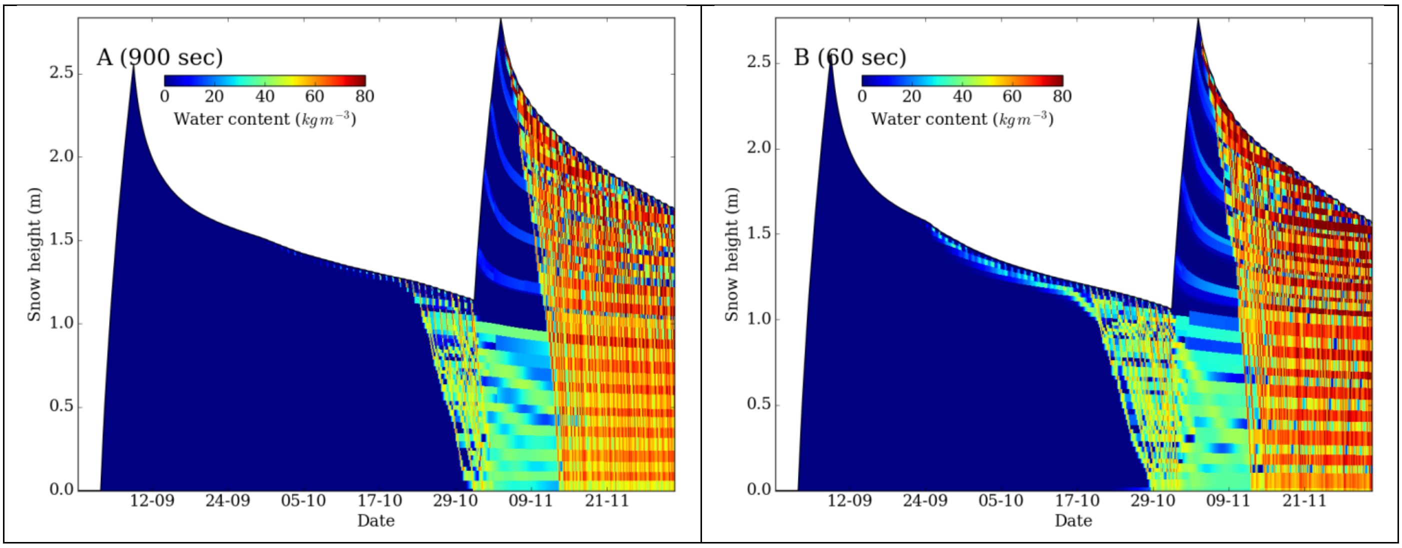

Figure 9: Water percolation in the simulated data set scenario with different time steps: A) T_{Crocus}= 900 s (15 min), B) T_{Crocus}= 60 s both plots use the free-flowing bottom boundary with pre-wetting set to θ_{min} = 10^{-5}. The 60s simulation has water at the bottom of the snowpack 4 days before the 900 s simulation. "

References

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