Response letter to comments by the editor

We would like to thank Ylva Sjöberg for her time to offer constructive comments to our manuscript.
Our responses are written in blue font.

Line numbers in the **revised manuscript** that contain changes are given in red font.

General comment:

Thank you for submitting a revised version of your manuscript (tc-2021-60) together with responses to the comments for reviewers #3 and #4. I find that you have addressed almost all concerns from the reviewers very well and that the manuscript is near a final publication in TC. However, I have a few minor comments remaining before publication and have therefore decided that minor revisions are needed on your manuscript. These should not require much work from you and I hope we can therefore soon see your very nice contribution to this topic published in TC.

Specific comments:

1. Section 2.1: clarification is needed about what data is in the end used to run the model (resolution, processing, length, variables). Specify that (if!) it is the locally observed daily values of air temperature, relative humidity, wind speed, and shortwave radiation that was used for simulations together with the processed (as described) precipitation data (averages?) for the full (?) years of 2013 to 2019. Also, that a set of spinup data was produced from this data (as described).

Response: We added more information about the forcing dataset used to run the model, such as resolution of the original data as well as of the final dataset, variable names and the length of the full forcing dataset. In the end of Section 2.1 we describe how we created the forcing data set for the simulations.

Changes: L109-129: The observational weather data to drive the model (hereinafter referred to as the forcing dataset) is derived from an automatic weather station located in Adventdalen (78.2°N 15.87°E) operated by the University Center in Svalbard, which measures air temperature, incoming short- and longwave radiation, relative humidity, and wind speed. Precipitation measurements are retrieved from the long-term weather station at Longyearbyen airport (9 km west of the Adventdalen weather station; 78.24°N 15.51°E) operated by the Norwegian Meteorological Institute. Precipitation is retrieved as daily values representing daily cumulative rain- or snowfall. Air temperature, relative humidity, and wind speed are measured in one-second intervals, radiation in five-minute intervals, and represent instantaneous values. The time period of measurements used in this study is 2013 to 2019 and measurements are aggregated into daily sums or averages. To create the forcing dataset, mean values of each variable for every day of the year (day-of-year average) between 2013 and 2019 are calculated to obtain a representation of current average weather conditions. Further data processing involves the classification of precipitation as rain if mean daily air temperatures are above 0°C, and as snow if air temperatures are below 0°C. An adjustment for precipitation undercatch in Svalbard has been suggested to be 1.85 for snow and 1.15 for rain (Førland and Hanssen-Bauer, 2000), and therefore precipitation is multiplied by these respective factors. This results in an average annual sum of 330 mm for the period 2013–2019. The annual sums of rain (160 mm) and snow (170 mm w.e.) are then redistributed to equal daily amounts during the rain- and snow period, respectively. The mean annual air temperature for the calculated averages over this time period is -2.8°C. Thereby, the resulting forcing data set consists of daily values based on the average for each day of the year between 2013 and 2019 for wind speed, air temperature, incoming shortwave radiation, relative humidity, incoming longwave radiation, rain precipitation, and snow precipitation (Fig. S1). This yearly cycle of average weather data is then repeated 100 times (corresponding to 100 annual cycles) to create the forcing dataset needed to initialize and run the simulations, as described in Section 2.2.2.

2. As it currently reads, it is unclear that you did not use the averaged (spinup) data to run the simulations, which was likely the cause of some of the comments from reviewer 3.

Response: Thank you for the feedback. We made an effort to clarify in section 2.2.2 how we conduct the spinup and that the last year of the spin-up runs is used for the analysis of the results.

Changes: L211-219: In the (final) fourth step, the resulting state from the 1D single column spin-up model is mapped to each of the 33 columns of the hillslope transect model. Thereafter, the same forcing dataset (Section 2.1) is used again to run the simulations, now in the full domain allowing for all lateral and vertical dynamic processes to occur. The full model is run for 100 annual cycles, corresponding to 100 years of simulation. The first 99 years are considered as spin-up, to obtain an annually periodic steady- state for the entire surface-subsurface hillslope system in the 2D model domain. The final year of the simulation (year 99 to year 100) is then considered as the simulation result, used for analysis in this study. Thus, it is equivalent to a representation of the hydrothermal state of the subsurface corresponding to the current 2013–2019 average weather conditions. The initialization procedure is repeated for each model case considered, to ensure effects of hillslope inclination and wetness conditions are embedded in the final simulation results.

3. This unclear description in the input data leads to further confusion in section 2.2.2 (about the spinup procedure). Specifically:
L200 be specific about which data is used
L205 be specific about which data is used and that this is part of the spinup.

Response: We have improved the description in Section 2.1 (comment 1 above) to better describe the data and data processing. Therefore, we have included a reference to Section 2.1 in this section (in Section 2.2.2). We also added a brief repetition of the key information about the forcing dataset in Section 2.2.2, and restructured the paragraph describing the last step (4th step) of the spin-up to make it clearer.

Changes: Section 2.1 and L206-210: In the third step, the forcing dataset (Section 2.1) is used to bring the thermal-hydraulic conditions of the column model into an annual steady state. The annual steady state is achieved by repeating the forcing data set for 50 annual cycles, corresponding to 50 years of simulation, after which inter-annual temperature differences throughout the column are less than 0.01°C. This procedure is necessary to obtain a physically consistent system which can be used as initial condition for the main simulation runs.

4. L258-260: This sentence needs some revision. First, there is a grammar issue (“flat cases freezes” and “slopes freezes”). Second, what is meant by “the active layer slopes”?

Response: Changed “flat cases” to “flat case”. Line 259 refers to the active layer in the slopes. Added “in the”.

Changes: L269-270: While the flat case freezes uniformly, the active layer in the slopes freezes faster uphill and slower downhill, causing those temperature differences.

5. Small grammar detail: The formulation “has found to…” is found in several places in the text (e.g. L29, L155, and L170). Please change to a more grammatically accurate formulation, such as “has been found to” or “was found to”.

Response: Changed irritating formulation to grammatically accurate formulation according to the comment.