RESPONSE TO RICHARD L.H. ESSERY
TO MANUSCRIPT tc-2021-56-RC1

Title: Evaluating a prediction system for snow management
Authors: Pirmin Philipp Ebner et al.

We thank Richard L.H. Essery for his positive feedback, constructive comments and suggestions. To your comments:

Comment #1: L9: Specifically, the comparison with Sentinel-2 data is for snow-covered area.

[ANSWER] We will rephrase the sentence:

"*… more than 80 % for snow-covered area compared to the Sentinel-2 data .”*

Comment #2: L10: Redistribution of snow by skiers would not directly lead to a reduction in average snow depth. This may be a significant omission in simulations, but the statement in the abstract seems more confident than the discussion in the paper.

[ANSWER] Maybe this sentence in the abstract was misleading. We actually meant that due to the redistribution of snow by skiers the variability of snow depth increases regarding the quite fine 10 m x 10 m resolution. This variability is of course visible in the GNSS snow depth measurements but are not simulated in the model. Therefore, we rephrased this sentence to:

L10: "*Potential sources for local differences of the snow depth between the simulations and the measurements are mainly due to the impact of snow redistribution by skiers or spontaneous local adaptions of the snow management, which were not reflected in the simulations*."

Comment #3: L24: What is “early winter” in this context?

[ANSWER] We refer “early winter” to October/November. We will change the sentence:

"*… to early winter (October/November) demand for perfect …”*

Comment #4: L29: What do these national percentages represent? Can a link be provided for Lalli et al. 2019?

[ANSWER] The percentages represent the covered snow pistes with technical snow production. We will add a link for Lalli et al. 2019 and change the sentence to:

"Regarding pistes covered with snow originating from snow production, *Italy (90 %) …"*

Comment #5: L51: Monti et al. (2016) discusses initialization of a model with manual snow profiles, not remote sensing.

[ANSWER] Correct, we will delete this reference in this context.

Comment #6: L69: This is the width of the elevation bands, not the elevation bands themselves.

[ANSWER] Thanks for pointing this out. We will change the sentence:

"*… divided into a number of elevation bands with width ranging from 50 to 400 m."*

Comment #7: L88: The snow management configurations in Table 1 are incomprehensible without reading Hanzer et al. (2020). Brief descriptions and reasons for selecting them should be given to make this paper more self-sufficient.

[ANSWER] We will change this sentence and add more information:

L88: *"… configurations for each ski resorts are shown in Table 1 and are selected to be comparable with the snow management configuration of each ski resort based on individual discussions with the ski resorts managers. In general, the basis for snow production is relying on resource saving assumptions, the features of the locally installed snow-making system as well as the opening and closing of each ski resort. The configurations where selected for each ski resort as follows and are described in more detail in Hanzer et al. (2020):*

- *Configuration 2: No snow production; simulations are based on a natural snow only configuration, however with grooming activity*

- *Configuration 7: Snow production with a minimum required SWE of 150 kg m-2 using fans and a wet-bulb temperature of maximum -4°C*
- *Configuration 11: Snow production with a minimum required SWE of 150 kg m^{-2} using lances and a wet-bulb temperature of maximum -4°C*
- *Configuration 23: Snow production with a minimum required SWE of 250 kg m^{-2} using fans and a wet-bulb temperature of maximum -4°C*
- *Configuration 31: Snow production with a minimum required SWE of 250 kg m^{-2} using lances and a wet-bulb temperature of maximum -6°C"*

Comment #8: L102: The SRU is a clever concept similar to the familiar HRU of hydrology, but it seems from the Supplementary Material that there is much more to the definition of SRUs than the slicing into elevation ranges described here.

[ANSWER] Correct but we decided not to include the whole SRU definition in the main paper. Therefore, we moved the detailed definition into the Supplementary Material part. However, we will add a reference to the Supplementary Material in the main text and will add the following sentence:

L108: "Local snow managements play a major role in this as explained in more detail in the Supplementary Material A1."

Comment #9: L158: In short, GNSS snow depth data were available for all pilot resorts except La Plagne.

[ANSWER] We will change this sentence accordingly.

Comment #10: L184: The 0-1 range of SP has already been stated.

[ANSWER] We will delete the sentence in Line 178-179.

Comment #11: L210: i = 0,…,N would be N+1 pixels

[ANSWER] Thanks, we will correct this.

Comment #12: L213: https://doi.org/10.1029/2010EO450004

[ANSWER] We will change this sentence:

L213: "*A negative MD value indicates an overestimation and a positive MD value indicates an underestimation of the snow …"*

Comment #13: L226: Agreement between observations and models that the pistes are almost fully snow covered in the middle of the season is not surprising (these are ski resorts, after all!). A more interesting question, and a more important one for snow management, might be how much better the models perform in early and late season compared with simulations without snow management.

[ANSWER] It is indeed more interesting to focus on the beginning (in particular) and the end of the season. We therefore emphasize these phases now a bit more but maintain the focus on the influence of snow management on the whole season. Our focus is on the complete ski resort with snow management. Even if we do not perform such an analysis, we can justify the goodness of the model without snow management based on our analysis for natural snow outside the pistes, mainly shown in Figure A1, B1 and C1 and in Table 3. The overall accuracy for natural snow is around 80 %. If we apply the snow management, we could further increase the overall accuracy. Based on this we can conclude that our models perform better also in early and late season compared with simulations without snow management.

We will add the following sentence:

L226: *"The overall accuracy for natural snow is around 80 %. If we apply the snow management, we could further increase the overall accuracy. Based on this we can conclude that our models perform better, also in early and late season, compared with simulations without snow management."*

Comment #14: L263: If slopes were not groomed, how are GNSS measurements available to quantify the model error? How does the lack of grooming lead to strong increases in RMSD?

[ANSWER] GNSS measurements were available a day after this big snow fall event, therefore, we still could quantify the error. It is not the lack of grooming

but an overestimated snowfall in the model, which leads to an increase in RMSD (see Line 264). We will change the sentence to:

L263: "*As a result, a large part of the ski area was closed and many slopes were no longer groomed at this date*."

Comment #15: L278-279: Is something missing from this sentence? It does not seem to make sense.

[ANSWER] We will change the sentence to:

Line278: "… in coarser clusters tends to mask the variability in the error in terms of …"

Comment #16: L281: Figure 7 is referred to before Figure 6

[ANSWER] Thanks for pointing this out, we will change Figure 7 and 6.

Comment #17: Figure 3: It seems counterintuitive that the brightest colour is the lowest snow persistence.

[ANSWER] We would like to keep it as it is as we would like to assign the colour white to '0' regarding the SPI as we did assign 0 also to the difference, although it might be somehow counterintuitive.

Comment #18: Figure 4: Having a zero line that is not in the centre of a radar plot is confusing. Absolute errors might be better, or at least highlight the zero line.

[ANSWER] We will change Figure 4 and highlight the zero line (same for Figure C1).

Comment #19: Figure 5: Having RMSD and MD on the same figure but with different axes is very confusing and makes it difficult to tell at a glance if an error is small or large. Using a single axis would compact the error range but would be much clearer (this is common in evaluations of weather forecast errors)

[ANSWER] We will change Figure 5 as shown below. In our opinion, the separation in solid lines for RMSD and dashed lines for MD should be now clear enough by adding more information for clarification also in the figure subtitle. Moreover, we included information on simulated and measured SD below, as

we believe this helps to better interpret MD and RMSD in the course of time over the season with varying SD.

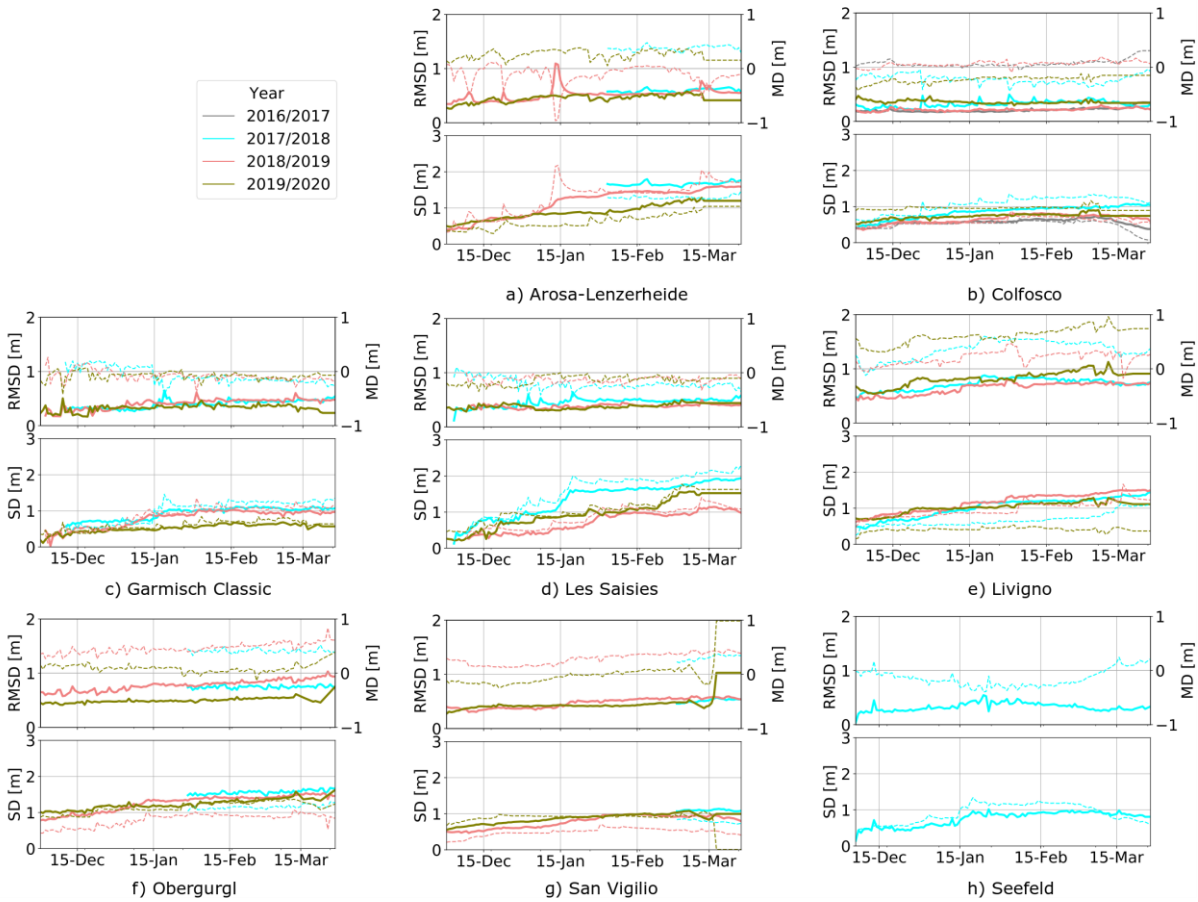

Figure 5: Root mean square deviation (RMSD) (upper subplots: solid line, left axis) and mean deviation (MD) (upper subplots: dashed line, right axis) averaged over space between GNSS measured snow depth (SD) (lower subplots: solid line, left axis) and simulated SD (lower subplots: dashed line, right axis) over time for the ski resorts. Within the period 2016-2020 we considered all valid GNSS measured snow depth data which were available.

Comment #20: Figure 6: What is the nature of the large measured snow depth between 1400 m elevation? Is there a bump in the snow surface or a dip in the ground surface that is not resolved by the 10 m model?

[ANSWER] Indeed, there is a bump in the snow depth measured by the GNSS. It is due to a dip in the ground surface which was filled with snow to level the piste leading to a higher measured snow depth.

We will add the following sentence in the caption of figure 6:

Figure 6: "*The nature of the large measured snow depth by GNSS at around 1400 m elevation is due to a dip in the ground surface which was filled with snow to level the piste. This led to a higher GNSS measured snow depth compared to the simulations.*"

Comment #21: Figure 7: Little variation is seen in MD between resolutions. Text in 4.3 discusses reduction in RMSD, so that might be a better variable to show.

[ANSWER] Thanks for pointing this out. We will add information on RMSD and change Figure 7 to:

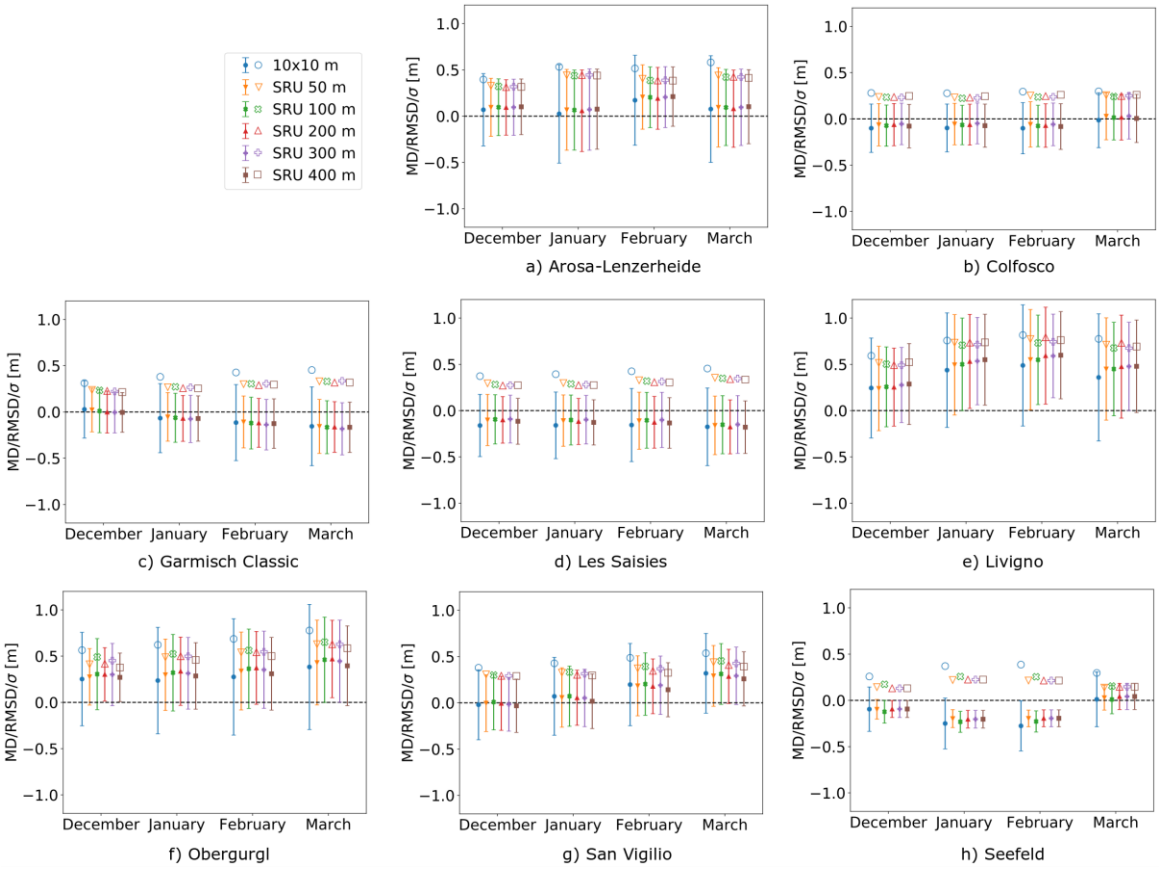

Figure 7: Overview of the root mean square deviation (RMSD, hollow symbols), global average (MD, filled symbols) and standard deviation (σ, extend of error bars) between simulated and GNSS measured snow depth considering all the time steps and displayed for each SRU resolution. The presented data are analysed for the four months December, January, February and March where GNSS data were available.

Comment #22: Table C1: Why does the column for Sentinel-2 contain statements about errors in snow depth?

[ANSWER] Thanks for pointing this out. It is not “snow depth” but “snow covered area” – we will change this.

The authors