

**RESPONSE TO P.A.B. Bartlett
TO MANUSCRIPT tc-2021-56-RC2**

Title: Evaluating a prediction system for snow management

Authors: Pirmin Philipp Ebner et al.

We thank P.A.B. Bartlett for his positive feedback, constructive comments and suggestions. To your comments:

Comment #1: Line 32-34: Have any authors or ski resorts conducted a cost-benefit analysis for making snow that melts over various periods of time? Early season production of artificial snow may very well melt, leading to loss of the snow-cover, but this is likely weighed against income derived by the resort being able to remain open for a period of time. I suspect many resorts have some criteria and that a decision to make artificial snow is based on the likelihood that it will last long enough to recoup the cost. I don't expect these questions to be answered in this paper, but I wonder if examples of such information exist such that they might inform the discussion.

[ANSWER] We found some information to answer this question in a study of Köberl et al. (2021) which is under review but should be accepted soon. We will add the following sentences:

Line 34: "Based on a study by Köberl et al. (2021, under review) the "uncertainty surcharge" of snow produced due to imperfect knowledge about upcoming weather and snow conditions paired with high risk aversion is likely to represent a noticeable share of total snow production and related water consumption as well as of total snow management operating costs. Depending on the pilot ski resort, respondents expect that perfect knowledge would reduce the amount of technical snow needed by 10% to 45%, the amount of water needed by 10% to 40%, and total snow management operating costs by 5% to 20%. Hence, there seems to be room for services that are able to improve the ski resorts' current ability to anticipate weather and snow conditions."

We will add this in the revised manuscript.

Köberl, J, François, H., Cognard, J., Carmagnola, C., Prettenthaler, F., Damm, A., and Morin. S.: The demand side of climate services for real-

time snow management in Alpine ski resorts: some empirical insights and implications for climate services development, Climate Services, under review, 2021.

Comment #2: Line 64: Change “snow-covered maps” to “snow-cover maps”.

[ANSWER] We will change it.

Comment #3: Line 67: Change “unit” to “units”.

[ANSWER] We will change it.

Comment #4: Line 88: Change “The used snow management configurations for” to “The snow management configurations employed for”.

[ANSWER] We will change it.

Comment #5: Line 106: Aggregating as a post-processing step simplifies the presentation but not the computation. Has it been tested whether similar results are obtainable employing these aggregated areas for the simulations?

[ANSWER] No, we didn't perform simulations on the aggregated areas since this would require a completely new model setup. As the Sentinel-2 and the GNSS snow depth data are given as rasterized data, we decided to perform the simulations similar and aggregate the simulated snow depth in a post-processing step. Another reason is that we would not be able to capture a realistic shape of the pistes, which are often quite narrow (approx. 10 m), with a coarser resolution as with Amundsen and Alpine3D we use models which rely on raster cells for calculation. Therefore, in our opinion it makes more sense to aggregate the 10 m x 10 m raster cells alongside the 'real' piste shapes with the altitudinal band concept we chose for aggregation.

Comment #6: Line 152: Change “This technique relies on differential GNSS signals and takes measurements without snow depth on the slopes as a reference into account.” To “This technique relies on differential GNSS signals, comparing the snow-free (i.e. zero snow depth) reference signal with those obtained during the snow season, to obtain snow depth.

[ANSWER] We will change it.

Comment #7: Line 156: Snowsat and Leica are not defined.

[ANSWER] Snowsat and Leica are companies providing GNSS snow-depth measurements from the grooming machine. We will rephrase the sentence:

“... data were provided by the companies SNOWsat and Leica Geosystems AG and were ...”

Comment #8: Line 169: Change “constrains” to “constraints”.

[ANSWER] We will change it.

Comment #9: Line 187: Change “Additionally” to “In addition”.

[ANSWER] We will change it.

Comment #10: Figure 4: Are the bold vertical lines in each plot of Figure 4 the intra-model means? This should be defined in the graph pane or in the caption.

[ANSWER] The bold vertical lines are the intra-model means. We will add this in the caption..

Comment #11: Line 278: Is this averaging effect desirable? Instead of "allows minimizing the error", would "tends to mask the error" be a more accurate description of what is happening? Later, it is discussed that there may be a benefit to this, but I would still use “mask” perhaps as “tends to mask the variability in the error”.

[ANSWER] Thanks for this good suggestion. Indeed, we don't want to “minimize the error” but to find out what is happening. We will change the sentence to:

“... in coarser clusters tends to mask the variability in the error in ...”

Comment #12: Why is Figure 7 presented before Figure 6? I would rename the figures.

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

Comment #13: Line 309: Remove “it”.

[ANSWER] We will remove it.

Comment #14: Line 315: Change “use” to “uses”.

[ANSWER] We will change it.

Comment #15: Line 321: Change “in average” to “on average”.

[ANSWER] We will change it.

Comment #16: Line 325: Change “e.g., rapid snow melt inside the catchment are hardly to be matched correctly by the models” to “e.g., the ensuing rapid snow melt inside the catchment is difficult to simulate accurately”.

[ANSWER] We will change it.

Comment #17: Line 337-338: This is not a sentence.

[ANSWER] We will change the sentence:

“The GNSS data can only be used as ground observation with some restrictions.”

Comment #18: Line 352-354: The authors should define some accuracy requirements for the snow models to meet the needs of the ski resorts.

[ANSWER] Unfortunately, we can't really add some accuracy requirement in this case. For the ski resort it is more important that they can reach at least the minimum snow depth (with a certain probability!?) before season opening and hold it. But we can say that the accuracy of all three snow models is generally sufficient (see Hanzer et al. (2020)) because the uncertainty coming from the meteorological/climatological input is much larger.

Comment #19: Line 357: I would not include the errors in the S and SW facing pistes with snow redistribution. These errors are caused by more rapid ablation because these pistes are exposed to high solar radiation during the warmest part of the day. I wouldn't classify that as redistribution although both are important.

[ANSWER] We will change this point to:

“... (2) snow redistribution by the groomers;”

and we will add an additional point:

“... (3) rapid ablation (e.g. south, south-west exposed pistes) due to high solar radiation;”

Comment #20: Line 393-394: I suspect that the ski resorts would know the minimum snow depth required. The research should attempt to determine whether the models can simulate snow depth with sufficient accuracy to enable the resort managers to maintain the optimum and minimum viable snow depth in a more efficient way.

[ANSWER] This is correct and currently an additional publication is in preparation investigating this question for specific ski areas. Detailed studies for each ski resort are needed but this was not within the scope of this paper. We will add the following sentence and include a reference to the paper:

Line 397: *“However, further studies to determine whether the models can simulate snow depth with sufficient accuracy to enable the resort managers to maintain the optimum and minimum viable snow depth in a more efficient way, are needed and will be attempted in the future (Köberl et al. 2021).”*

Köberl, J, François, H., Cognard, J., Carmagnola, C., Prettenthaler, F., Damm, A., and Morin. S.: The demand side of climate services for real-time snow management in Alpine ski resorts: some empirical insights and implications for climate services development, Climate Services, under review, 2021.

Comment #21: Overestimation of snow depth and S and SW facing pistes could be addressed by having the incoming radiation adjusted for slope and aspect. I am not asking for this to be done in this paper, but it would be an obvious improvement for the next paper.

[ANSWER] In all models the adjustment of the incoming radiation for slope and aspect is already implemented. It seems like that the snow redistribution of the skier plays a major role but further validations on ski pistes are needed.

The authors