

Interactive comment on “Winter tourism and climate change in the Pyrenees and the French Alps: relevance of snowmaking as a technical adaptation” by Pierre Spandre et al.

Pierre Spandre et al.

samuel.morin@meteo.fr

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1 General comments

In this paper results from snowpack modeling tailored to ski resort operations and potential impacts of climate change are presented. From a regional perspective it is one of the view climate impact analyses for the ski industry in France, one of the most important ski markets in the world which has so far been under-researched. The applied model was already introduced elsewhere, but to my knowledge this is the first application for assessing the future perspectives of the ski industry. It is an important

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contribution as snowmaking - an important adaptation strategy - was included. I have some question in the methods section (see comments below) and I suggest to include a paragraph in the discussion section on the “take-home message” of the paper. Apart from % changes illustrated in the results section, is it possible to evaluate the (near or longer term) future for skiing tourism in France and the Spanish Pyrénées? Is climate change a serious challenge, or manageable?

We thank Robert Steiger for positive feedback and constructive suggestions. Please find below our replies to the specific points of the review comment. We have not included a "take-home message" section in the Discussion, but the Conclusion was refined to better convey the key results from this study, in terms of snow reliability. The revised conclusion highlights that snow reliability is not the only driver for ski resorts sustainability.

2 Specific comments

Specific comments p. 3, l. 2: Damm et al. (2017) did not include snowmaking in their assessment, so the reference does not match your statement “...and the snowmaking requirements so as to compensate the loss over Europe (Damm...)”.

We agree with this comment and have revised the sentence so that this error is corrected.

p.4, l.5: what is the justification for using the village elevation?

This statement in the manuscript refers to our method to compute the village elevation

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in the ski resorts, based on the location of housing infrastructure. We indeed compute the elevation of the village, which corresponds to the locations where tourism housing infrastructures are located. Snow conditions in the immediate vicinity of housing infrastructure are critical for ski resort managers, because this is where tourists access the ski area, at the lower part of major ski lifts. A previous study (Spandre et al., 2016, J. Outdoor Tour. Recreat.) has demonstrated that ensuring appropriate snow conditions at the village elevation is a critical motivation for snow management in ski resorts, hence the focus on this elevation band.

p. 4, l.7-15: It is not clear to me what data was available in which region and which data you had to estimate. I understand that all data (village elevation, min/max elev., ski lift power and surface area) was available for France. As seen in Fig 1 you then estimated ski lift power (?) based on the surface area you drew from OSM and on the linear model derived from French ski resorts? Then you also had to estimate the elevations of Spanish/Andorran ski areas? Why that if you had OSM data? How can you explain the outliers in the OSM/BD stations figure?

We have clarified the wording of this part of the document to avoid ambiguities. Had the study only concerned French ski resorts, we would not have used OpenStreetMap (OSM) data. STRMTG data (detailed ski lifts characteristics) and high resolution digital elevation models and IGN data, used for the work on estimating the village elevation, were not available to use over Spain and Andorra. Based on OSM data for French ski resorts, we have analyzed the relationship between ski resorts surface area and ski resorts indicators such as ski lift power, and we have used this relationship to infer this information for ski resorts in Spain and Andorra, assuming that the general relationship established over a wide range of French ski resorts from the Alps and Pyrenees is most likely to hold in Spain and Andorra, where no major structural difference exists with French ski resorts. We have not analyzed specifically the outliers, because the

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deviations to the main regression line where generally small compared to the full elevation range - this could be investigated in a future study.

p. 5, l. 12: can you add some data on Spain as well? (the ski areas in this study represent xy% of ski lift infrastructures of Spain)

We have added more information on the share of the Spanish and Andorran ski tourism infrastructure covered in our study.

p. 6, l. 11: 150 kg/m² -> if it is density it should be kg/m³ ; this is an uncommon density for technical snow for base layer snowmaking, typically it is around 400 kg/m³

The values provided in the text are indeed snow water equivalent values (SWE), expressed in their native physical unit kg per unit surface area (kg m⁻²). SWE is sometimes referred to using mm w.e., because liquid water density is 1000 kg m⁻³. Using managed snow density of 500 kg m⁻³, 150 kg m⁻² correspond to 30 cm snow depth. We have clarified this in the revised manuscript.

p. 8, l. 21-23: please explain why the village elevation is relevant in your assessment. Later on you refer to the “lowest elevation of the ski area”, this would be a clear explanation.

As explained above, the village elevation corresponds to the mean elevation of tourism housing infrastructure. It does not necessarily correspond to the lowest elevation of the resort, because quite often, in the case of high elevation ski resorts, the lower elevation of the ski resorts is found below the tourism housing infrastructure.

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p. 9, l. 2. "snowmaking is limited to the lowest elevation and for a minority of seasons" -> I don't understand this sentence. How is snowmaking limited to a minority of seasons? Does that mean that snow is only produced in some years?

We have clarified this statement, which now reads, in the revised manuscript : "Snow-making is generally employed only at the lowest elevations, and it makes a difference only for a minority of seasons where natural snow conditions are too scarce." Indeed, here we emphasize on the fact that the 3 categories 1, 2 and 3 correspond to situations where snowmaking does not play a major role in determining the snow reliability of the ski resort.

p. 11, l. 4: "to decrease in the Pyrenees, up to 15%" -> here the sentence structure confused me a bit because "decrease" is followed by a positive number and in the same sentence there is 15% another time, but as increase. Maybe consider to split this sentence in two?

We agree and have reworded the sentence as follows: "The production of machine made snow at the snow reliability line is projected to remain steady or to decrease in the Pyrenees, up to 15% compared to the reference period. In the Alps, the production of machine made snow is projected to increase for all scenarios up to 15%."

p. 11, l. 5: what do you mean by "either in the Northern or Southern Alps"?

We have removed this part of the sentence, which was not necessary because it only meant to insist that similar changes were observed in the South and North of the

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French Alps - which the meaning of the revised sentence captures, see above.

Fig. 4/Discussion: how can you explain that the systematic bias is not existent in the Southern Alps?

We have no specific explanation for this observation. That the distribution in ski resorts reliability categories is the same for past climate conditions using SAFRAN reanalysis and adjusted historical climate simulations is most likely a coincidence due to the combination of ski resorts elevations and snow simulations. Because this figure directly stems from counting ski resorts belonging to a given categories, it is most likely that the same distribution is found between the two cases, even though there are discrepancies between meteorological information of the SAFRAN and adjusted climate simulations. That there is a difference between the two can be viewed on Figure 3, which shows differences for all mountain regions, including the Southern Alps.

Interactive comment on The Cryosphere Discuss., <https://doi.org/10.5194/tc-2018-253>, 2018.

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