The Cryosphere Discuss.,
doi:10.5194/tc-2016-194-RC2, 2016

Interactive comment on "Seasonal evolution of a ski slope under natural and artificial snow: detailed observations and modelling" *by* Pierre Spandre et al.

F. Wolfsperger (Referee)

wolfsperger@slf.ch

Received and published: 2 November 2016

general comments

Spandre et al. present unique data on the mass balance of snowmaking which firstly quantifies the net water losses (10 to 50%) with high validity. The findings are highly relevant for ski resorts and the snow making industry as well as for the scientific community as several publications describe snow making models without taking account mass losses.

The design of the study and the methods are adequate: An area of a ski piste is monitored from the first snowfalls to the complete melt of the snowpack by measuring

the snow surface (ground was measured too) and snow density at several points in time to quantify the snow mass on the ground of single snow making events as well as the total snow accumulation and its redistribution throughout the season. The water flow of the snow making system was recorded continuously providing the used water mass and led to the snow-water-mass ratio.

The GNSS method was properly validated comparing to TLS method. The propagation of uncertainties into the snow volume calculation was considered but some statistical methods were unsuited (see below). SAFRAN-crocus model chain was run with precipitation correction, a snowmaking and grooming module. In the methods section, the authors miss to clearly outline the use of model in their study. The explanation comes later in the result section: First, the model was used to answer the question how good (how much snow over time of season) the piste would have been - a) without snowmaking and b) without snowmaking and without grooming compared to c) the observation. Second, the model was used to determine the mass losses of snow making throughout the whole season by comparing the measured total amount of snow with the simulated amount of snow excluding the produced MM snow in the model. Third, mass losses are implemented into the snow making module of the model to best meet the measured seasonal snow mass evolution of the piste evolution.

The weakness of the manuscript becomes obvious: Two different objectives are mixed up leading to a confusing structure. a) To determine snowmaking mass losses, two approaches are presented: one by measurements of single snowmaking events, the other analyzes the whole season and uses modeling and measurements. b) Conclusions on the seasonal evolution of the ski slope are more a side product of a).

In the introduction, the relevance of the study was also argued by the snow making efficiency and not by the seasonal evolution of the piste which is pretty known, even among practitioners as DGPS-snow heights measurements are state of the art (in a few resorts). If focus should be on the seasonal evolution of the snow pack, additional parameters should be presented like the mentioned albedo influencing factors dirt or

SSA, snow wetness etc.

So, to overcome those problems I would recommend minor revisions: - changing the title that it fits to the relevant finding of the study - restructure methods and results *WRR(mass loss) by observations of single snowmaking events *WRR by observation & modelling of seasonal snow accumulation *indirect WRR estimation: best fit of modelled snow accumulation to observations

specific comments

p1, l.13: . . .we also addressed thermodynamic effects. . . Eisel did this with an oversimplified formulation p4: an overview on the test site would be nice (from above) p7, l.5: Shapiro Wilk Test is suitable for n<=2000 (Royston, 1982). I guess with n>8000 or >16000 the test would never accept H0 (accepting it's not different to normality) p.9, l.9-11: and (1): which uncertainties are combined how? (sorry, didn't get it. . .) p.10, l.6: . . .relative error of 4%... wouldn't call this error. It's rather natural variability of MM snow. Better: . . . showed a weak variation of 4% (sigma) p.10, l.2-9: generally snow density is quite a sensitive term when determining snow mass as MM snow density can vary from 350 to 600 kg/m3 mainly driven by liquid water content depending on meteo and snow producer props (flow. . .) and water temp. LWC can also vary along the snow pile. Lower snow quality adjustment at the snow maker simply increases the water flow and usually leads to higher LWC and so density. Taking an average density about all experiments has to be justified (well, you did with sd=4%)but it would also be nice to explain why density could vary. May also give some information on where at the pile density was measured (e.g max height). I see this point p.12, l.21: . . .is very consistent. . .maybe show difference of total snow making hours - looks like a few days and more than 10% p. 13, Fig.4: classes would be better started with >-3.5°C your start threshold p.13: how many snowmakers were used and which type? p.14: Fig 4a) at N side of the pile two "lines"(snow accumulations) are visible. Is there an explanation. How the center of pile was defined (max height?) p.14: Fig 4b)Not sure if geometric patterns can be recognize by the visualization. Error bars should be de-

scribed (A(R)*SD ?) p.15: Tab6: why is sigma of water flow constant? why there is no sigma for total water vol. p.16: why is the groomed piste so much better - it has the same snow mass, right? just a smaller volume by compacting? SSA and so albedo should be higher without grooming? wind drift? thermal cond? p.18: maybe define a WRR(R_max) with R_max = dv/dR =0 p.19: Tab.8 sigma is not explained p.19: better explain how WRR and its uncertainty is calculated with Formula where simulated and measured mass terms should be indexed p.19: l.6-12: I would prefer a table for these results p.19: l.18: see general comments: what is the aim? methods explained with results. p.21: Tab.9: what is Nu? RMSE is not showing if snow mass is smaller or larger p.21: 12ff: explanations on the physics of snow making are missing and why the eisel approach is trusted or maybe not. p.22: would prefer wind drift for mechanical effects. p.23: speed of droplets depends on pressure not on flow. The effect might be due to smaller droplets (less mass and impulse) connected to different nozzles. Quality acts on water flow sometimes droplet size, so better freezing due to less mass concentration in the snow cloud. p.25, l.4: see Mott et al., 2011 p.25ff, l.27: 0.5m grid, most of the conclusion is a summary

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