Journal: NHESS
Title: Heavy snow loads in Finnish forests respond regionally asymmetrically to projected climate change
Authors: I. Lehtonen, M. Kämäräinen, H. Gregow, A. Venäläinen and H. Peltola
MS No.:nhess-2016-184
MS Type: Research Article
Iteration: First review
Referee #1

We are grateful to the Referee for the positive feedback and good suggestions which will certainly improve the manuscript. Our replies to the comments are given in "Italics" after the comments given in the beginning of this document.

"General comments"
Dear authors, congratulation to this - in general - scientifically sound and well-written paper. It is about an interesting topic in climate change effects on snow loads in Finnish forests, nicely fits to the scope of the journal, represents state-of-the-art research and is in correct English. I recommend publication after some improvements. The paper could mainly benefit from (i) adding a more detailed description of the methods, and (ii) providing more quantitative measures of uncertainty, particularly for the humidity/rime load calculations.

Thank you for these encouraging views. Description of the methods is in the current manuscript version rather short as we refer to an earlier study where the snow-load calculation methods have been described in detail. Nevertheless, this part could be expanded in order to provide for the readers a more deepen idea of the used methods without a need to take a look on the previous paper. Measuring quantitatively the uncertainty related particularly to the humidity/rime load calculations is not a straightforward issue. Basically, we have estimated quantitatively the uncertainty related to our projections by comparing the results based on different climate models. This range of model-based uncertainty is presented in Figs 2 and 6. It is visible that the uncertainty related to the humidity and rime load projections itself is not larger than the uncertainty related to projections in other weather variables or snow load components. However, we admit that the applied bias-correction method is not necessarily as applicable for relative humidity in freezing temperatures as for other variables and this potentially induces to the rime load projections uncertainty that is hard to measure.

"Specific comments"
- The paper could be improved in its methodological part by adding a paragraph on the two methods, G08 and FMI, respectively. In general, both methods should be explained in a detail that better supports the understanding of the results.

We agree that a more detailed explanation of the methods would be beneficial as then readers would not need necessarily to dig the information from the cited previous papers.

- It would be good to explain why You actually do present the G08 method, because its results mostly correlate with dry snow loads which have little importance with respect to forest damage. If it turns out that this is of minor importance for the paper, You can consider to completely skip the G08 methods and all its results, and only mention it in the introduction. The interested reader won't probably miss it.

The main reason for presenting the results for G08 method is that in the previous work of Kilpeläinen et al. (2010) this method was used and they got the result that snow loads and snow-induced forest damage in Finland are likely to decrease in the future due to global warming. As our main conclusion is quite different, we wanted to demonstrate that by using the same method, we would have got actually almost identical results, so the difference between our results is most likely due to the methodological differences, not due to the different climate change scenarios, for instance.

- You should explain the FMI method with sufficient detail, and provide a meaningful measure of uncertainty for the effect of a changing (modelled and corrected/downscaled) humidity on the riming process which You state is the most important factor leading to heavy crown snow loads. The difference of humidity relative to ice and/or water appeared to be the reason for a 20 % difference in calculated maximum rime load. You should make an attempt to separate this effect from the one originating in a changing climate.

The problem here is that although after correcting the bias both in temperature and relative humidity simulations, both variables have a realistic distribution (for relative humidity in subzero temperatures this holds exactly only when considering the relative humidity with respect to ice), but the humid and dry days in the model are not necessarily distributed similarly as observed regarding the temperature distribution. There are no easy solution for this. It appears that after bias correction climate model results tend to overestimate the situations with combined temperature and relative humidity conditions favouring the rime formation. It is moreover noteworthy that in many climate models relative humidity values in cold temperatures are more or less unreliable having physically unjustified values with relative humidity exceeding 100% that raises worries considering their usefulness. To conclude, we are more suspicious of our results related to the rime loads than other snow-load components. However, we assume that in climate model results the same deficiencies are present both in the calibration period (1981-2010) and scenario periods and thus the projected changes are originating from the climate change signal. We moreover note that our projections for heavy rime loads and heavy wet snow loads indicate increases and decreases roughly over the same areas reinforcing the idea where the risk for snow-induced forest damage is likely to increase.

- You should also justify in more detail the temporal scale transition from 3-hourly to daily (at least by providing an example).

There are an example in the cited literature dealing this issue which could be shortly discussed here as well.

- The role of the thresholds defined by Lehtonen et al. (2014) to determine the number of the two types of risk days is not entirely clear: on the one hand, You state that they may not be suited for the whole

country, on the other hand You provide their values with two decimal places (probably table 2 should be modified). I would be good to explain how these thresholds were determined, and how/why they can be applied in Your study (risk days of heavy riming vs FMI-modelled heavy riming).

This could be discussed in more detail.

- You should give a short explanation in the introduction how trees are damaged by snow loads (the process(es), and how they are related to the relevant snowfall events; are there observations?), and You should give some more information about the tree species related damage risk in a changing climate.

These issues could be discussed in more detail in the introduction.

"Technical corrections"
- Page 2, line 20: dot (".“) missing between "Finland“ and "In both studies“

Thank you for noting this.

- Page 15,
capture of fig. 2: s, c and n should also be denoted for southern, central and northern (like in the capture of fig. 6).

We agree with this.

- Page 18, fig. 5: scale bar of panel section (f) is too small. Values in the map seem to not correspond with the (colors and values of the) scale bars.

Thank you for noting this.

Good luck

Thank you