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Interactive comment on "Modelling the late-Holocene and future evolution of Monacobreen, northern Spitsbergen" *by* J. Oerlemans

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First of all, I thank the referee for the extensive comments and the many valuable suggestions to make the paper more clear and transparent. I will defintely take these into account in a revised version.

I am puzzled, however, by the slightly cynical remarks on scientific contents / questions. These remarks are a bit scattered through the document, and therefore I want to organize my initial response into four topics: (i) Scientific rationale, (ii) Why a minimal model, (iii) Calibration, (iv) The effect of surging.

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(i) «Scientific rationale» The question of glacier response to climate warming is a central question in 'global warming science'. The issue has been tackled by different kind of models as I have described in the paper. Although simulations have been done for some of the ice caps in Svalbard (notably Austfonna), to my knowledge nobody has attempted to deal with the large complex glacier systems in Spitsbergen. The reason is obvious: the geometry is complicated, many of the glaciers are tidewater glaciers and surge as well, and overall there is very little data on bed geometry and mass balance conditions. Trying to model these glacier systems is therefore, in my judgement, a major scientific challenge. As far as I know, nobody has attempted to model the evolution of a complex glacier system like Monacobreen over a longer time span, so, frankly, I would rate my work as 'scientifically new and original'.

(ii) «Why a minimal model ?» 'Minimal' refers to the fact that the mechanics of the glacier are treated in a simple way and the model as such has no spatial resolution in the sense that numerical models have. The glacier length is the basic state variable. Adding tributaries as buckets or adding a parameterization of calving and surging does not make the model less minimal in its fundamental approach. To use a comprehensive numerical model for Monacobreen is currently not feasible. The amount of input data needed would be enormous, and the formulation of boundary conditions would involve a lot of ambiguity. Also, it is unlikely that such a model would produce surges of the right duration and amplitude, unless they are strongly imposed like in the minimal model. The reproducibility of results obtained with a minimal model is another point I want to emphasize. Anyone can code the model and have it running within a few days. I agree with the referee that some of the results, notably the e-folding response time and climate sensitivity, should be discussed in more detail in the paper.

(iii) «Calibration» Since glaciers have a memory, a projection for the future cannot be done without without a proper simulation of the past evolution. In my judgement this point has not always obtained sufficient attention. Although for Monacobreen (and most other glaciers in Spitsbergen) the information on past changes is limited, the facts can

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still impose strong constraints. There is abundant geological and geomorphological evidence that Monacobreen achieved its largest size at the end of the Little Ice Age. It is not at all trivial that a model reproduces this maximum Holocene glacier stand around 1900. The case that in this paper the maximum stand can be reproduced is a significant result (apparently due to the quality of the forcing function and the suitability of the model). The correct amplitude and timing of the surge has to be included, because otherwise the starting state for the future evolution evolution would not be optimal. It is not fair to state that the minimal model has 65 parameters! Almost all of these describe the geometry and are therefore not tuning parameters. This view would imply that a numerical model with 60000 grid points would have 60000 parameters (bed elevation)!. In the model I have carefully restricted the number of tuning parameters to make it match with the information available. In fact, the two parameters describing the surge are directly taken from the observations - they are thus fixed. Except for E_0 and E_1, all other parameters (like the calving parameter) have been taken from earlier studies (which does not imply that they have no uncertainty, but they are not used as tuning parameters). With respect to the bed profile: the values of lambda has not been tuned to give the correct front position. However, slight variations in this parameter were considered as described in the discussion. The bathymetry in the fjord shows irregularities (mainly moraines), but it unlikely that such irregularities extend underneath Monacobreen because its surface is so smooth. The fact that the model reproduces the maximum stand around 1900 as well as the correct rate of retreat after the last surge is a major achievement and not directly forced by the calibration. I regret that the referee does not acknowledge this is any way.

(iv) «The effect of surging» The referee states "I don't think you can conclude that the surface mass balance effect is small (especially since your equation for H_m is unlikely to hold during a surge since it assumes a quasi-steady glacier profile)". Here I do not agree. First of all, the relation between the mean ice thickness and glacier length does not assume a steady-state profile. However, more importantly, the mass balance perturbation depends only on the change in the MEAN surface elevation, not

on its spatial distribution (because the balance rate is a linear function of altitude). So when the change in glacier length is known/prescribed from observations, the change in mean surface elevation automatically follows from mass conservation. This is implicit in the model formulation and in my view an elegant way of dealing with the effect of surges (more explicitly discussed in my paper on Abrahamsenbreen (Oerlemans et al., 2015)). So I think that the conclusion about a minor effect of surging on the long-term evolution of Monacobreen is firm (and in fact a consequence of the small surge amplitude: the change in length is only about 5 % of the total glacier length).

Reference: J Oerlemana and W J J van Pelt: A model study of Abrahamsenbreen, a surging glacier in northern Spitsbergen. The Cryosphere, vol 9, 767-779 (2015).

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