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Interactive comment on "Assessment of heat sources on the control of fast flow of Vestfonna Ice Cap, Svalbard" *by* M. Schäfer et al.

Anonymous Referee #3

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1 General statement

The manuscript entitled "Assessment of heat sources on the control of fast flow of Vestfonna Ice Cap, Svalbard" by Schäfer and colleagues investigates the influence of the ice thermal regime on the initialization and sustainability of fast flow regimes of several outlet glaciers of the Vestfonna Ice Cap. They use the Elmer/Ice software with a thermo-mechanical coupling based on the Full-Stokes equations to reproduce the glacier configuration and initialize their model using data assimilation of surface velocities to infer basal friction for different years. They first assess the importance of the different heat sources on the ice thermal regime and compare their results with measurements along a deep borehole. They then run simulations for about 13 years

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under different scenarios and compare the evolution of the velocity with observations. They conclude that basal friction is not solely driven by temperature changes but that other parameters such as hydrology or sediments also play a significant role.

The manuscript is supported by previous work based on the Elmer/Ice framework as well as work from the same author on the Vestfonna Ice Cap (Schäfer et al.,2012. The authors present here additional results on this ice cap and provide many different experiments and scenarios to assess the impact of the different heat sources. Simulations include deformation heat, basal friction heat or heat released during refreezing of melt water, some are based on steady-state assumptions and others are run as transient models. The focus of the paper is not always clear and the abstract does not really represent the content of the manuscript. Some very common equations are detailed in the manuscript while others that are not widely used are not provided. I also found myself sometimes confused between the experiments and the thermal model used in some simulations. All these aspects are detailed in the Specific comments section below. I therefore think that the text should be clarified, shortened and better focused in order to improve the quality of the manuscript and the pertinence of the conclusions.

2 Specifics comments

The abstract does not really reflect the content of the text and the conclusions of the manuscript. The first part, which deals with general aspects and previous studies, is rather long and should be reduced as this kind of information should be provided in the introduction section. I think that it would be better to focus on the conclusions reached in this study. It is also not clear whether the authors investigate the influence of heat on basal friction or the influence of basal friction on ice thermal regime.

The model section is very detailed for some aspects that are fairly common and already presented in Schäfer et al. (2012) (e.g., Arrhenius law, evolution of free surface) but not

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so detailed when it comes to the latent heat induced by firn heating and P_{max} model. A shorter description of the model with emphasizes on new or improved parts would help clarify this section.

The simulation section sometimes only provides simulation description and sometimes also includes discussion of the results. This section is not very clear and could be better organized. I would like for example to have a very short description of all the simulations performed in the introduction of the section and then go into the details as it is done in the manuscript. I think that adding name, similarly to what is done with 1995ss, that summarize the set-up for all experiments and a table with the description of all simulations would greatly clarify this section.

3 Technical comments

p.5099 l.15: Add reference for surging glaciers

p.5101 l.22: Add reference for Elmer/Ice software

p.5102 l.10: situated → located

p.5102 l.18: What is the coverage of ground based and airborne radar? What is the distance between flight lines? How are these data combined to provide a two-dimensional map of bedrock elevation?

p.5103 l.28 and followings: Can the authors quantify the acceleration?

p.5104 l.2-5: This sentence is not very clear, it would help to rephrase it.

p.5104 l.14: How is the surface temperature changed? How often?

p.5104 l.18: How does the surface temperature coincide with measurements?

p.5105 l.10: What do the authors use for the surface accumulation? Do they include

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melt water run-off as they have a percolation and meltwater refreeze model?

p.5106 eq. 2 and 3: These equations are common knowledge and do not need to appear in the manuscript. Same for eq.5

p.5106 l.13: What is the climate mass balance? Where does it come from?

p.5107 eq.7: no m needed here

p.5107 eq.9: How is the temperature kept below melting point ($T < T_{pm}$)? What initial value is used for the temperature T?

p.5108 l.3: What is the link between u_b, τ_b and $v_{\|}$, $\tau_{\|}$ on p.5106?

p.5108 l.8: Can the authors please provide the equation of the P_{max} model?

p.5109 l.8: There are earlier citations for the regularization term.

p.5110 l.14: What kind of elements are used in the two-dimensional and three-dimensional mesh (triangles, rectangles, ...)? What type of finite elements are used (linear, quadratic, ...)?

p.5111 l.4-7: Rephrase this sentence

p.5111 l.11: I would actually start this section with a brief summary of all the simulations performed, with names and a table that lists them.

p.5112 l.1: It is not very clear what the authors do with the thermal part during the spin-up? Do they use the initial steady-state and keep it constant during the spin-up? Do they compute a new thermal steady-state at each time step (updated with ice thickness and velocity)?

p.5112 l.11: reasonable → reasonably

p.5112 l.18: this whole introduction of section 4.1 is not clear: it starts with a description of the relaxation but does not go into the details, so it is a little confusing.

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p.5112 l.22-25: This sentence is not very clear, should be rephrased.

p.5113 l.27: How do they explain this better fit?

p.5114 l.7: Why do the authors use zero surface mass balance and not a more realistic value?

p.5114 l.10: Why do the authors evaluate the change on vertical velocity and not rate of thickness change (or surface elevation) change?

p.5114 l.12: I do not understand why the mesh is changing? It should rather be the surface elevation here.

p.5115 l.9: It is not clear from this paragraph if a new thermal steady-state was recomputed.

p.5115 l.25: How do the authors deduce this from the temperature profile?

p.5116 l.5: Consider adding a definition of ice lenses

p.5117 l.16: Why do the authors start from the thermal steady-state? Why not use the simulation that best fits the measurements?

p.5117 l.24: It is quite confusing that in the section, the authors sometimes just very quickly describe the experiment (e.g., subsection 4.3) and sometimes discuss the settings and some results with a lot of details (e.g., subsection 4.2). The authors should homogenize the different parts of this section.

p.5118 l.7: I am quite confused by this statement ("The temperature evolution shows high sensitivity to such an inversion"). If the authors start from a thermal steady-state, the temperature should not evolve much.

p.5119 l.2: What year was the profile measured?

p.5120 l.15: It is not clear what parameterization the authors are referring to here.

p.5121 l.4: importance of friction heating on what?

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p.5122 l.10: What kind of errors?

p.5122 l.20-23: Rephrase

p.5124 l.26-29: This paragraph is not very clear, should be rephrased.

Fig.1: What exactly is uxy, should be defined. What do the diamonds on the figure indicate? White color seems to indicate both very high velocities and no data. Southwest part in 2011 looks really weird.

Fig.4: What are the units? Are the authors referring to the end of initialization or relaxation?

Fig.5: Is the temperature in this figure corrected for T_{pm}

Fig.7: It would be good to have the 18m equilibrium line to compare with the 13m one.

Fig.8: Should be β (not beta)

Fig.9: All the temperatures should either be in K or C.

4 References

Schäfer, M., T. Zwinger, P. Christoffersen, F. Gillet-Chaulet, K. Laakso, R. Pettersson, V. Pohjola, T. Strozzi, and J. Moore, Sensitivity of basal conditions in an inverse model: Vestfonna ice cap, Nordaustlandet/Svalbard, The Cryosphere, 6, doi:10.5194/tc-6-771-2012, 2012.

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