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The Cryosphere Discussions

Interactive comment on "Simulating melt, runoff and refreezing on Nordenskiöldbreen, Svalbard, using a coupled snow and energy balance model" *by* W. J. J. van Pelt et al.

I C Willis (Referee)

iw102@cam.ac.uk

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General Points

This is a good paper involving a lot of very thorough work and deserves to be published in TC. It uses a full surface energy balance model coupled to a physically based subsurface model dealing with conduction / refreezing to calculate the surface mass balance of a large (193km^2) glacier on Spitsbergen. It is forced by a Regional Climate Model (RACMO) and the mass balance model is thoroughly parameterised and initialised using available data. A particularly novel aspect of the work is the way in which it deals with the energy/mass balance of the slush layer within the snowpack.

The first part of the results section of the paper discusses the "standard run" (1989-2010) and describes and explains spatial patterns of long-term average mass balance, refreezing and runoff across the glacier (Fig 4), and elevation profiles of these quantities, in addition to precipitation, melt, and sublimation / riming (Fig 5). Patterns of the energy balance components across the glacier are also discussed (Fig 6). Time-series of these quantities are also discussed both over the long term (1989-2010) (Fig 7 &Fig 8a & b) and short-term (within a melt season (Fig 8 c & d; Fig 9)). This part of the paper is particularly successful. The second part of the results section performs what have become quite standard sensitivity experiments (sensitivity to model parameters, initialisation, and climate variables). The crux of this analysis is contained within Table 2 and Fig 13. The sensitivities of mass balance, refreezing and ELA to air temperature and precipitation (Fig 15) are then used to project these quantities through the 21^{st} century assuming a linear change in climate between 2010 and 2085 for the IPCC A1B emission scenario (Fig 16). I accept that this is a useful thing to do, although this methodology is gradually being superseded by one involving the use of downscaled time dependent output from GCMs of future climate to drive glacier mass balance models into the future.

The paper is long (with 16 Figures) and I would encourage the authors to consider removing one or two sections (and Figures). The last paragraph of Section 6.3 (and Fig 14) is an obvious candidate.

The Conclusions and Discussion could be shortened – the first 5 long paragraphs are really a summary of the whole paper and largely repeat a lot of what has been said. Could this be abbreviated to bullet points? The last two paragraphs only are what I would call "discussion" and usefully discus the key finding in the context of other work.

I would like to see slightly more thought given to the role of calving on the mass balance of this glacier. It is rather hastily dismissed as unimportant on the basis that the glacier largely became land terminating part way through the 1989-2010 period.

TCD
6, C186–C194, 2012

When I printed the paper, the text/numbers on several of the Figures was too small to be read clearly.

There are a few minor issues / typographical errors I hope could be dealt with fairly quickly too, listed below.

Minor Points / Typographical Errors

Throughout. You could say “melt season” instead of “melting season”. Melt season is much more widely used.

P213. L3. Arnold et al, 1996 would be another good reference here (one of the first of its type).

Arnold, N, Willis, I.C. Sharp, M.J., Richards, K.S. and Lawson, W.J. 1996. A distributed surface energy balance model for a small valley glacier: I. Development and testing for Haut Glacier d’Arolla, Valais, Switzerland. Journal of Glaciology 42, 77-89.

P213. L6. Could do better than referencing Paterson’s text book here.

P213. L20-21. Section on basal dynamics seems a little contrived / unnecessary here.

P214. L25. Refer to Fig 1 after . . . . .Lomonosovfonna

P215. L6-10. What resolution is the DEM?

P215. L17 & 20. delete “above sea level” (everyone reading the paper should know what a.s.l. means.

P216. L19-24. The sentences “The mean observed. . . GPR measurements” need to be rewritten to make things clearer. It is not immediately obvious what has been done here. Also, is 191mm an annual precipitation rate? What is meant by “mean maximum precipitation?” The word “yearly” should be deleted as the pptn is already expressed as a rate per year. Quote the mean accumulation rate found by Palli et al (2002) rather than just saying it was “similar” to 540mm a^{-1}.

TCD

6, C186–C194, 2012

P217. L16. Better to say “data logger problems” rather than “short circuiting in the system”.

P217. L27-8. Say “. . . .measurements have been made at. . . . . .readings are done. . . .”

P218. L1. Say “Snow pits were dug. . . .”

P218. L3-4. Consider moving the sentence “Furthermore, ...height.” to before the previous one. i.e. explain generally what is done each year since 2006, then describe extra data not done every year.

P218. L22-24. Definition of specific mass balance is not quite right. Is this at a point? Over a grid cell? Or averaged over the whole glacier? Either way, units should be m w.e. a^{-1}, not m w.e. m^{-2} as stated.

P218. L25-26. Say “Ice melt only influences the mass budget if the meltwater runs. . . ”

P223. L20. I think it should be “. . . are assigned. . . ”

P225. L5. “Finding”

P225. L10. “ . . . position (Davies and McKay, 1989). . . ”

P225. L25. The incoming long wave radiation flux depends. . . ”

P226. L7. say “data logger problems” rather than “short circuit problems”

P228. L17. “. . . altitude of -12^{o}C. . . ”

P229. L14. “. . . ELA is 600m. . . ”

P229. L16. Why not state how the calculated mass balance compares to the measured balance for the years for which there are measurements? Or if this is to be done later in the paper, state the section here.

P229. L20-21. You say that the glacier “has almost fully retreated on land over the course of the simulation period” But where was it at the start of the period? Pre-

sumably it had an active calving front? Just because the glacier almost became land terminating at some point over the last 20 years does not necessarily imply calving is negligible. A better discussion of the likely calving contribution is needed here, perhaps by comparison with other Svalbard glaciers where this has been calculated?

P230. L6-7. Comma after "glacier". Delete "per unit area" and "annual". Add "a^{-1}" to discharge units.

P230. L9. Say "elevation profiles" rather than "height profiles". Could delete "defining".

P230. L16. Delete "approximately"

P230. L18-20. Say "...The sum of all the incoming and outgoing fluxes (Fig 6a) decreases with..."

P230 L21. Delete "at the surface"

P230. L29 / p231. L1. The sentence that straddles these pages doesn't quite make sense to me. Suggest rewrite.

P231. L4/5. Delete sentence "As mentioned....precipitation"

P231. L7. Say "...variations in both summer melt and winter accumulation"

P231. L10-11. delete "in annually averaged temperatures". Also, what is meant by "not clear" with respect to the summer temperatures? It would be better to test to see if the slope of the regression line through the annual and the summer data are significantly different to zero or not. Then you could state that the annual trend is significant and the summer trend is not (assuming this is actually what you find).

P231. L19. Change "significant" to "important" to avoid confusion with notions of statistical significance.

P231. L14-20. Wouldn't it also make sense to quote the correlation between annual mass balance and winter precipitation here too?

TCD
6, C186–C194, 2012

P231. L22. Say "...variability results mainly from..."

P231. L22-25. Should the word "affect" read "affects"? If so, with this change, the sentence is clear. Otherwise the sentence should be reworded to explain precisely what annual snowfall and air temperature control.

P231. L29 / P232 L1-2. This is confusing. Too many things are being discussed at once. Consider deleting or rewording.

P231. L13. "...at the melting..."

P231. L22. "...2010 is shown..."

P231. L23-24. "...amount of runoff; when the snow pack is all gone, all available...immediately, inducing a clear..."

P232. L26-27. Delete reference to Morteratschgletscher here. What effect does the snowfall event have on the mass budget of Nordenskiöldbreen? This is surely more relevant here!

P233. L 3. say "flow line" not "cross section" wrt Fig 1.

P233. L10. Say "measure of" or "proxy for"

P233. L22. Delete "extrema in"

P233. L24. say "these fluxes" not "the latter fluxes"

P233 L26-27. Say "Discrepancies between observed and simulated SWin result mainly from..., which also accounts for discrepancies between observed and simulated LWin"

P234. L11. "you say the situation at S1 and S2 "could be" related to windblown snow. But there could be other explanations? If so these should be stated 9and dismissed if there is evidence).

P234. L14-15. It should be "compare....with" not "compare...to"

TCD
6, C186–C194, 2012

P234. L15. “For this purpose..” Also, why only seven profiles used in the comparison? Seven out of how many? Why were these 7 chosen?

P234 L16. “adopted” is the wrong word”. Just say “used” ?

P234 L19-20. Delete “In comparison to. . . ..density”. Then say “The mean measured snow density of 367 kg m-^{3} is. . . higher than simulated.”

P234 L24. “model’s sensitivity”

P235 L7-8. Delete “Especially”. Then say “The sensitivity. . . ..is particularly high. . . .”

P235 L21. “For this purpose”

P235. L22. Was the initial water content in the snowpack set to zero for the standard run too? Might be worth reiterating this if it was said earlier. Or explaining why initial conditions were different here than for the standard run.

P235. L24-5. Should this say “. . . by 3K increases the mass balance by 27 mm w.e. a^{-1} after one year and by 60 mm w.e. a^{-1} between 2-6 years after the start of the experiment.” ?

P237. L2-4. Say “. . . .change can be offset by a 32%.....perturbations. On the other hand In the case of. . . .”

P237. L8-9. Say “Conversely” rather than “On the other hand”

P237. L11-12. “Reduced increase” This is hard to understand. Similarly “pronounced effect” is vague. I think you need to refer to Table 2 more frequently throughout this paragraph and explain these sensitivities a little more clearly.

P237. L 16-23. This section is already long (the whole paper is very long) and this paragraph could be cut. It would also mean Fig 14 could be cut.

P239. L9. delete apostrophes from 60’s and 70’s and say “1960s and 1970s”

P239. L17-18. Delete “w.r.t. the period 1990-2010” (as this was stated above). Say

"...mass loss between 1910 and 2085 is 29m w.e....."

P239. L24. Delete "an increase in"

P239. L25-27. Say "....climate, the effect of warming and enhanced precipitation on refreezing will, to a large extent, counteract each other"

P239. L28. "..in the case.."

P240. L7. Delete "it should be noted"

P240. L9-11. say "We regard the mass balance – dynamics – surface elevation feedback as.....omission from our modelling; the presented...are likely, therefore, to be somewhat...."

P241. L8. say "Conversely" not "On the other hand"

P241. L15. delete "disregardance of" and add "not considered by the model" to the end of the sentence.

Figures.

Fig 5. Suggest "Elevation profiles" rather than "Height profiles"

Fig 7. The order in which a, b, c and d are discussed in the text is different to how they are presented. Consider reordering Figures d to b, b to c and c to d.

Fig 9. Impossible to see difference between two shades of blue on the graph. Also, suggest 1 Apr, 1 May rather than Apr/1, May/1, etc.

Fig 10 caption. " ..along the main flow line marked..."

Fig 11. Add a) b) c) and d) to Figure and refer to these in Figure caption (rather than upper right panel, etc). Add time period over which observations are made to the Fig caption.

Fig 13. Difficult to se difference between reds and between blues (although I accept it is

TCD
6, C186–C194, 2012

fairly obvious than the more extreme curves are for the more extreme climate variables)

Fig 14. x axis units should be "(m w.e. a^{-1})" I assume.

Fig 15. Caption "....mass balance, refreezing and ELA..."

Interactive comment on The Cryosphere Discuss., 6, 211, 2012.