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Response to the referee and short comments on

Sensitivity of a distributed temperature-radiation index melt model based on a four melt season AWS record from Hurd Peninsula glaciers, Livingston Island, Antarctica

by

U.Y. Jonsell, F.J. Navarro, M. Bañón, J.J. Lapazaran and J. Otero

The two referees' comments do in some instances confluence and in most cases we agree with them and have made the corresponding changes to improve the manuscript. We do not fully understand a few comments, as is outlined below.

We address the comments, which overall were of specific nature, one by one.

Referee 1

3229-14.
r was not correctly explained in the text or in the list of symbols. We have simply changed the text to explain that it is the correlation coefficient usually employed with the linear data fits.

3234-24-26
Yes, it is correct that it is possible to make other combinations giving similarly good fit (low rms) of the calibration run (2008/09) and we refer to other papers commenting on this. The set of parameters used are based on 1) lowest rms of the validation data; 2) that the ratio between δ_{snow} or δ_{ice} is about the same as the ratio between typical snow and ice albedo, thus reflecting the physical basis behind using dual set of δ; 3) giving the best fit (lowest rms) for the three validation periods (Figure 5). This last criterion does not involve any tuning of the parameters in the validation runs, but only an accept or reject decision. We have clarified this in the manuscript and included the temperature-index model parameters in a new table, as suggested.

3235-20.
A short explanation of the general principle behind the effects of clouds and its coupling to the long- and short-wave energy fluxes is added in the MS as follows:

The generally negative coupling between L_{in} and S_n is mainly an effect of their different response to cloud cover as in general clouds absorb and scatter a great portion of the incoming short-wave radiation, preventing it to reach the ground, but emit long-wave radiation to the ground as a function of their temperature.

Figure 7 and the corresponding text in 3.1:
The comment made us change our approach and originate the discussion from the seasons with most contrasting standard deviation for L_{in} and S_n. Therefore part 1 of Figure 7 is changed to illustrate season 2008/09 and the corresponding reasoning to explain the contrast is changed and more adequately expressed. The main observation is that the larger amoun of days with more extreme negative mean L_{in} occurring in 2009/10 are not associated with days with low daily mean A, which makes the coupling between L_{in} and A weaker in 2009/10.

The **technical corrections** are all implemented.

Referee 2
Title:
Referee has indeed a point and we changed the title to:
Sensitivity of a distributed temperature-radiation index melt model based on AWS observations and surface energy balance fluxes, Hurd Peninsula glaciers, Livingston Island, Antarctica

3222-20
The sentence has been changed according to the referee's suggestion.

3223-29/3244-1 and 3224-3
It was indeed intended to cite references addressing different processes. It was written in a very compact form to avoid a lengthy introduction. However, the reviewer is right in that this can induce to misinterpretation, so we have replaced the former sentences (p. 3223, l. 29 - p. 3224, l. 5) below

The impact of the warming in the region on glacier dynamics (Rott et al., 1996; Rignot et al., 2004; Scambos et al., 2004; Pritchard and Vaughan, 2007), glacier extent (Rau et al., 2004; Cook et al., 2005), mass balance and melt rates (Braun and Hock, 2004; van den Broeke, 2005; Turner et al., 2005, 2009; Vaughan, 2006) are key scientific questions for understanding the contribution of grounded ice losses from this region to future sea level rise.

with the new, more complete, version that follows

"The impact of this regional warming on surface mass balance and melt rates has been analyzed by several authors (e.g. Braun and Hock, 2004; van den Broeke, 2005; Turner et al., 2005, 2009; Vaughan, 2006). Additionally, atmospheric warming, together with warmer ocean temperatures, have been pointed out as drivers, through different physical processes, of the disintegration of some ice shelves on the northeastern coast of the AP (MacAyeal et al., 2003; Shepherd et al., 2003; van den Broeke, 2005; Cook and Vaugham, 2010), with subsequent acceleration of the inland glaciers feeding the ice shelves (Rott et al., 1996; Rignot et al., 2004; Scambos et al., 2004), and also of the widespread retreat of marine glacier fronts of the AP over the past half-century (Cook et al., 2005). An overall tendency of retreating ice fronts has also been observed in studies analyzing, over the period 1986-2002, both marine-terminating and land-terminating glaciers in the region (Rau et al., 2004). A widespread acceleration trend of glaciers on the AP west coast has been observed as well from repeated flow rate measurements within 1992-2005, and attributed to a dynamic response to frontal thinning (Pritchard and Vaughan, 2007). On the northeastern side of the AP, however, the rate of recession of ice-shelf tributary glaciers has slowed down markedly during the last decade as compared to the previous one (Davies et al., 2011). All of these observations, and their underlying physical processes, are key for understanding the contribution of grounded ice losses from this region sea level rise, that has been currently estimated as 0.22±0.16 mm a^{-1} (Hock et al., 2009)."

3230-24

We have added typical figures for Z_{0T} and Z_{0e} *(*Z_{0T} $1.3\times10^{-4} \pm 0.06$ m and Z_{0e} $1.6\times10^{-4} \pm 0.10$ m)

3233-22

We have changed the terminology according to the suggested UNESCO-IASC glossary throughout the text.

3234

We believe that the referee is aiming at the snow-rain transition. Anyhow, this figure and that of lapse rate and how lapse rate was calculated is added to the revised manuscript:

"The temperature at a specific grid cell, T_{xy}, is given by the AWS temperature record with an offset based on altitude difference and air temperature lapse rate (*dT/dZ*). Braun and Hock (2004) showed the dependence of *dT/dZ* and melt rates with the synoptic weather pattern and recommended to avoid the use of a constant lapse rate. We did not find conclusive correspondence between *dT/dZ* and wind direction, wind speed or θ_d that could be indicative of different weather patterns and which could be used to differentiate *dT/dZ* among our of model runs for distinct seasons. Consequently we applied a constant *dT/dZ* based on the temperature difference between JCI and AWS during season 2009/10, that yielded −7.0±0.5 K km^{-1}, with the range being one standard deviation. This value is within the normal range of reported lapse rates in the AP region (Braun and Hock, 2004). In the evaluation of the calibration run of the model, we analyze the model sensitivity to perturbations of a constant *dT/dZ.*"

And we added in the discussion on the sensitivity of the calibration run:

"A change in *dT/dZ* is equivalent, for the model results, to a change in ablation gradient. A change of *dT/dZ* by ±0.2 K km^{-1} in the calibration run changed b_{sfc} by ±5 %. As the average T_{air} is close to zero and the AWS is located close to the ELA, the area-integrated change in melt due to a more negative *dT/dZ* will to some extent balance out the larger changes in individual grid cells, but will result in changed rms of the difference between measured and modelled melt for the stakes. A 0.2 K km^{-1}

increase of *dT/dZ* raised the rms of the calibration run to 160 mm w.e., while a corresponding decrease in fact lowered the rms slightly."

3234-22

See response to referee 1 comment on 3234-24-26

3236

We do not fully understand this comment. We do not present annual balances. We use b_{sfc} as the surface balance during the period of measurement (different for each season). It consists mostly of ablation but with some summer snow falls contributing and making it a balance. b_{sfc} should not be confused with annual balance $b_{a.}$ In the MS we considered for convenience the resulting figure (mostly melt) as a positive entity. As it possibly becomes clearer we changed it to a negative entity throughout the revised MS. We have also made a clarification in the explanation in the list of symbols and in the text reagarding b_{sfc}.

Rückamp et al. (2011) indeed talk of large variability of accumulation, but they speak of winter accumulation, and they do not correlate it with any general circulation pattern. This is done by Braun et al. (2001) -as the referee points out- but does not explain the interannual variability shown in Fig. 6.

3237-1

We have changed and used consistently mm w.e.

3238-1

We have added in text the threshold temperature for determining if precipitation is considered as new snow or rain (run-off) and in the sensitivity analysis section we have added the results of perturbating this threshold by 0.5 K.

3236-1

A discussion on this theme involving the most relevant references from King George Island studies is now included and reads as follows:

"A high sensitivity of the mass balance to changes in T_{air} for glaciers on the nearby KGI was pointed out by Knap et al. (1996) from the results of running a simple ice-flow model forced by an energy-balance model, after perturbating T_{air}, until a new equilibrium state was reached. An energy-balance model based on single-point measurements on Ecology glacier, KGI, produced an increase in ablation by 15% in response to a 1 K temperature increase (Bintanja, 1995). This considerably lower sensitivity as compared to our results can be explained by almost constantly positive temperatures over the 30-day period of Bintanja's study. Thus, the effect of the 0°C threshold will be considerably lower. A contrasting situation is probably behind the lower sensitivity –as compared to ours– (27% increase in ablation as a response to a 1 K air temperature increase) obtained by Braun and Hock (2004) when applying a distributed energy balance model to the western part of KGI ice cap. In this case, the hypsometry of the ice cap indicates that a great part of the area was for most of the six week study period well below 0°C. An additional explanation of the higher sensitivity found in our study is that the two KGI studies mentioned above were performed during limited time periods in December and early January, which is before the usual period of strongest seasonal melt.”

3236-20
See comment on 3234 of referee 1

3247
Suggested change regarding the order of columns in Table 2 is implemented.

3255.
The figure size will be increased as much as possible in the final production.

Short comments by Mauri S. Pelto

3226-4
We do not think it is that relevant to add a temperature range from King George Island in this section.

3230-14 or 3226-1
It is true that the peaks in Figure 8 correspond to warm events with high turbulent fluxes indicative of moist warm winds. In the end of section 3.1 we have added the following paragraph:

”The high peaks in melt (Fig. 8) coincide with high turbulent fluxes, driven by high relative humidity and positive $T_{air.}$ Backward trajectory analyses using the NOOA Hysplit trajectory model (http://ready.arl.noaa.gov/HYSPLIT_traj.php) show these events to be associated with air masses rapidly moving in from NW. The indication of higher melt from the ultra sonic ranger is possibly at least partly an effect of the compaction of the snow during the wet conditions, and partly an effect of SEB and temperature-index model not allowing accounting for the additional melt effect of rain and fog.”

3231-25
We are thankful for providing the suggestion of the reference discussing penetration of short-wave radiation into the snow pack as a motivation of the criterion for onset of melt (A positive and $T > -0.5$ºC). The reference is now included.

3234-17
The dots in Figure 5 indicate the stakes that at the end of the modelling period were treated as ice or snow. We have added in Table 2 the number of stakes that were observed as being standing in ice at the end of the time period of modelling.

We are not sure if some of the line references are correct. Nevertheless, we have added, in the section on physical setting (with reference to the parallel surface mass balance observation paper (Navarro et al., 2012) that is to be submitted shortly) average figures on AAR, ELA and ablation. We do not give any typical duration of bare ice on the glaciers as that (as shown by the AAR variability) varies much between individual seasons.

The updated Figure 7 and Figure 9 are also uploaded.

We are cordially thankful to the two volunteer referees and Mauri Pelto for their comments that have greatly improved the manuscript.

Authors via
Ulf Jonsell