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The Cryosphere Discussions

Interactive comment on "Measured and modelled sublimation on the tropical Glaciar Artesonraju, Perú" *by* M. Winkler et al.

M. Winkler et al.

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We appreciate the contribution of the three referees very much, and also want to thank M. Pelto and J. E. Sicart for their short comments. The suggestions doubtlessly increased the quality of the paper. In particular, the integration of Tab. 1 and Fig. 1 as well as the more precise description of the error estimation will be helpful for the readers of the paper. Below we reply to the questions and suggestions of the referees and M. Pelto. (For the comments on J. E. Sicart's critics please look above at AC S415.)

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1 Author comment on SC S297 'Addressing Sublimation'

ad 1.) and 2.) As others, this paper shows that glacier surface roughness strongly influences sublimation. On the other hand, sublimation alters the surface characteristics (e.g. penitentes growth). Neither the description of this feedback mechanism nor answering question 2.) is this work's purpose. To find out more about this, one must measure surface roughness and sublimation independently.

ad 3.) and 739-28: The revised Fig. 2 (now Fig. 3) shows the threshold conditions.

ad 740-1: Sublimation and evaporation only occur if the vapour pressure is higher at the surface than in the air. In this case the vapour pressure gradient is positive downward, which means that Q_L is negative. For the definition of Q_L see e.g. Kuhn (1989, his Eq. (5)).

ad 740-20: "long-term mean" was changed to "longer-term mean" in the revised version, indicating that it was calculated for a longer period than the 2-day mean measured by Cullen et al. (2007) using eddy covariance instrumentation. Actually, it is a mean over 19 months including wet and dry seasons.

ad 741-15: An additional sentence addressing this question was added.

ad 742-20: We suppose that there would not have been a significant impact. The advantage of having fewer rims per area would cancel out with the disadvantage of only having fewer pots due to timing problems.

sections 2.3 and 3.2: We incorporated sections 2.3 and 3.2 in order to extend from the measuring series to a longer time period, and in future versions of the ITGG model we want to incorporate the findings. A pointer corresponding to that issue was inserted in the introduction.

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ad 749-6 and 749-10-15: See comment on question 3.) and 739-28. Distinct threshold conditions cannot be given because it is always a combination of surface features and atmospheric conditions that influences sublimation.

ad 750-15: The changes in the previous Fig. 2 (Fig. 3 in the revised version) answer the question. No respective changes were added to Fig. 5 (now Fig. 6) because there are no wind and humidity records available for this period.

ad 751-15-19: See comment on questions 1.) and 2.).

Cullen, N. J., Mölg, T., Kaser, G., Steffen, K., and Hardy, D. R.: Energy-balance model validation on the top of Kilimanjaro, Tanzania, using eddy covariance data, Ann. Glaciol., 46, 227-233, 2007.

Kuhn, M.: The response of the equilibrium line altitude to climate fluctuations: theory and observations, in: Glacier fluctuations and climatic change, edited by Oerlemans, J., Glaciology and quaternary geology, 407-417, Kluwer Academic Publishers, 1989.

2 Author comment on RC S312 'Tropical Sublimation'

ad 741-8: An overview picture was inserted in the revised version. For a detailed map see Juen (2006) or Juen et al. (2007).

ad 747-13: The sentence was changed.

ad 747-14f: We have extended on the error estimation.

ad 747: A new Tab. 1 was added to overview the results of the sublimation measurements and the respective atmospheric conditions.

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ad 748f: We prefer to not add another table here, because there was only one roughness length combination for P^- and one for P^+ chosen. It is stated that the emissivity ϵ is a very sensitive parameter and respective numbers are given. The criterions (I, II and III), which were used to find the optimal roughness length combinations, are arbitrarily chosen and there is no physical meaning behind them. Only criterion (I) was sensitive to changes in the roughness lengths, so it was the only criterion used to determine them. That information is now given more clearly in the results section.

Technical comments: Changes made.

Juen, I.: Glacier mass balance and runoff in the tropical Cordillera Blanca, Perú, Ph.D. thesis, Institute of Geography, University of Innsbruck, Austria, 2006.

Juen, I., Kaser, G., and Georges, C.: Modelling observed and future runoff from a glacierized tropical catchment (Cordillera Blanca, Perú), Global Planet Change, 59, 37-48, 2007.

3 Author comment on RC S343 'Comments on Paper Winkler et al.'

ad 742-22: There was definitely no possibility for meltwater flowing into the pots. To make this clear, a sentence was added.

ad 744-6: Yes, we refer to the operating principle of the recording device, which is described in the respective reference mentioned in the text.

ad 749-4-6: The meltwater was ponding "on the flat parts of the surface" of the tongue, but not in the pots. This information was added to the section: Measurement site and methods.

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Technical comments: Changes made.

4 Author comment on RC S366 'Comments on Paper Winkler et al.'

ad 438-1: We inserted "...and mass balance..." in the revised manuscript. Sublimation is decisive because it reduces melting efficiently (due to its 8.5-times higher latent heat). Still, on most days with ablation more mass is lost by melting than by sublimation, but the loss by melting would be much higher if there was no sublimation. Note also that sublimation is driven by the vapour gradient between surface and air, whereas melting is exclusively a residual if all other energy fluxes provide a surplus.

ad 439-1: We changed the sentence to "Tropical glacier mass balances provide valuable information about climate and climate change in tropical mountain areas, ...".

ad 740-19: See above at 1 Author comment on SC S297, 740-20.

ad 741-1-5: We agree that (2) is not a real aim of the paper and removed it. Still, we prefer to keep aim (4) (now (3)). The sublimation measurements give an independent possibility to find optimal roughness parameters for the glacier surface at that time. As direct measurements of the roughness lengths are rare on tropical glaciers, we would like to keep (4) (now (3)) as one goal. Actually, the surface roughness parameterisation for tropical glaciers in the bulk method was improved by this study because the approach taken provides numbers of possible roughness lengths.

ad 741-15: See above at 1 Author comment on SC S297, 741-15.

ad 742-27: See above at 3 Author comment on RC S343, 742-22.

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ad 743-21: A sentence addressing this was added.

ad 744-5-10: During hours with a melting surface ($T_S = 0°$C) LW_{out} measured by the RBS is constant at about 315 Wm^{-2}, at the SEBS it is often higher than 320 Wm^{-2}, which is not possible over ice. This pattern mostly occurs at clear-sky conditions, when direct solar radiation warms the sensors. When it is overcast, also the SEBS measurements are constant during hours with melting. We added "...when direct solar radiation warms the sensors.".

ad 746-17: See page 740, lines 21-29 in the discussion paper. The parameterisation was made with the Zongo data series since there were no suitable data sets available for Artesonraju. By doing so it was assumed that the inter-relation between all moisture related variables are similar in both, the Cordillera Real (Zongo) and the Cordillera Blanca (Artesonraju). This does not mean that the seasons are similar.
Finding a good parameterisation for Glaciar Artesonraju using only precipitation data seems to be difficult. Incorporating wind speed might be a solution as Fig. 5 in the discussion paper (now Fig. 6) indicates.

ad 747-14: We have extended on the error estimation including the subsurface heat flux.

ad 748-20: Section title is changed to "Results for sublimation and melting from the process-based model".

ad 749-15: This statement was removed because it is not needed in the paper. Clarifying this issue is complicated and was done in Winkler (2007).

ad 750-4: Yes. We inserted the values in brackets now.

ad 750-10: See answer to 746-17. Simply using other limits would not improve the parameterisation.

ad 751-16: The roughness lengths represent a parameterisation of the surface roughness in the bulk theory. In this study a quantification of the roughness lengths for these specific conditions was made. We do not claim that we present a "new way" to parameterise surface roughness.

Figure 1 and references for maps were added.

The differences between smooth and rough is now addressed in the caption of Fig. 3, which was Fig. 2 in the discussion paper.

Technical comments: Changes made.

Winkler, M.: Die Rolle der Sublimation in der Energie- und Massenbilanz des tropischen Glaciar Artesonraju, Master's thesis, Institute of Meteorology and Geophysics, University of Innsbruck, Austria, 2007.

Interactive comment on The Cryosphere Discuss., 2, 737, 2008.