Response to reviewers

We would like to thank both reviewers for their well-considered responses. We have modified the manuscript following their suggestions as outlined below:

Reviewer 1

Specific comments:

p. 1834, l6-7
We have modified the text as suggested. The descriptions now read:

"... shortwave radiation receipt persistently close to the theoretical site maximum during cloud free days (mean annual 295 W m^{-2}; summer hourly maximum 1354 W m^{-2})..."

"... and low precipitation rates (mean annual 45 mm w.e.). Snowfall occurs sporadically throughout the year and is related to frontal events in the winter and convective storms during the summer months (MacDonell et al., 2013)."

p. 1838, l7-10
We did not use the snow density of 285 kg m^{-3} used by Mölg et al. (2008). We followed Cuffey and Paterson (2010) and instead used a fresh snow density of 60 kg m^{-3}. We have included this value in text:

"From the smoothed surface change measurements, the solid precipitation rates in the mass balance model were calculated using a fresh snow density of 60 kg m^{-3} (Cuffey and Paterson, 2010)."

In addition, the snowpack density evolves over the course of the run (so only the parameter "fresh snowfall density" is constant; snowpack density is a prognostic variable).

p. 1838, l22-23
Sentence modified as suggested.

p. 1858, Table 1
We have modified Table 1 as suggested. The albedo value is included in the table.

p. 1839, l24 to p. 1840, l3
The roughness lengths obtained from the eddy covariance measurements are stated in text. We collected these data from close to the AWS, and have now stated this in text. The sentence now reads:

"The values of z_{0m} and z_{0h} for an ice surface are from unpublished short-term eddy covariance measurements taken 20 m from the G-AWS during March 2010..."

We agree that the treatment of the roughness lengths are incredibly important, especially in an area where sublimation dominates the ablation regime. With this in mind, we are currently preparing a paper to describe the eddy covariance results from the planar surface on Guanaco Glacier in detail, and to compare these with results from a penitente-covered area on another glacier surface, and so do not want to reproduce that work here. As part of that investigation we are also investigating the effect of the form of the bulk equation on modelled results.

p. 1848-1849: Section 5.2

We reduced the number of variables. As suggested we removed the u and v wind variables as well as air pressure. We left the different short wave radiation components, because it is instructive to understand if the correlation seen between sublimation and the net short wave radiation is mainly driven by variations in incoming radiation, and/or changes in albedo. The later plays an important role at the site in driving the net short wave radiation balance, and hence sublimation rates, as discussed in the text.

As suggested we also computed the correlation with the vapour pressure deficit. The correlation is r=0.44 with the raw data and 0.41 once the seasonal cycle removed. The correlation is lower than with the vapour pressure, so we chose not to include it as it does not bring new information. As for correlating with long wave radiation we only included the incoming long wave (LWI) as the focus is to relate varying meteorological conditions with sublimation rates. LW* would include the complex effect of surface temperature, which responds to the whole energy balance.

p. 1850, l9 to p. 1851, and Figure 6

The caption has been corrected to state that coloured lines represent days with melting.

p. 1850, l25

Sentence modified as suggested.

p. 1851, l6-7

Sentence modified as suggested.

p. 1851, l23

Sentence modified to read: "...subsurface temperature occasionally..."

p. 1851, l27 to p1852, l4

The text has been modified to state:

The vapour pressure (Figure 8b) is also noticeably higher while the wind speed is much reduced (Figure 8d) during days with melting, which explains the reduced sublimation rates (or for hours when the surface melts, reduced evaporation) and the excess energy available for warming and melting the surface.

Reviewer 2

General comments

Social importance and impossibility of extrapolation
In the Discussion section we have included reference to the potential role of penitentes on this glacier. We are hesitant to expand this as to accurately portray the contribution of penitentes to the wider catchment, detailed modelling of the effect of penitentes on the energy balance is required. This work is currently underway, but is outside the scope of this paper.

Subsurface model (p. 1840, l8-11; Fig. 7; p. 1844, l2-6; p. 1851, l16-17; p. 1851, l23-24)
The subsurface heat flux sub-model is well described in Mölg et al. (2008), which is referenced in text. This flux incorporates both the conductive heat flux in the subsurface (*QC*), and the energy flux from shortwave radiation penetrating through the subsurface (*QPS*). The calculation of QPS is described in the last paragraph of the model section, and follows the method outlined by Bintanja and van den Broeke (1995) and Mölg et al. (2009). Incorporating QPS is necessary in radiation dominated environments, such as those experienced at Guanaco Glacier.

The depth of the lower boundary is already included in the last paragraph of the model section of the Methods. We have added the fixed temperature at that depth, which comes from measurements, which are now described in text:

" The temperature at 15.0 m depth is fixed at -6.5ºC, which is a stable temperature taken from five long-line manual temperature measurements collected at Guanaco Glacier between November 2008 and April 2011."

Specific comments

p. 1839, l8
The sentence has been expanded to state:

"In this study, *QP* is ignored because all of the precipitation falls as snow and precipitation intensity is low, which means that heat addition due to precipitation is likely to be negligible."

p. 1838, l17-18

We agree with the reviewer, and it is also stated in other SEB studies, that e=1 is an assumption, although the most widely accepted one. However, the uncertainty in the LW-out measurement usually introduces higher uncertainty in the derived Tsurf than the uncertainty in e (e.g., van den Broeke et al., 2005). Thus we are explicitly addressing the LW-out measurement in the sensitivity analysis, and not e, in order to reveal the largest potential error in the Tsurf calculation.

p. 1841, l5-7
There are no penitentes in the region of the G-AWS, and so no information regarding penitentes has been included here.

p.1841, L. 14-16
We have modified the text to read:

"As most ablation events following snowfalls are relatively well reproduced, there are no detectable losses caused by wind erosion of the snowpack."

Additionally, Gascoin et al. (2012) state that in this area, "glaciers do not gain or lose much mass by wind transport, while outside glaciers, wind erosion is significant", we have expanded reference to this work in the text:

"This is inline with Gascoin et al. (2012) who show that glaciers in the region represent preferential snow deposition areas, and that glaciers do not lose much mass by wind transportation."

p. 1850, l16-17

As we describe in the text, the 'effective' cloud cover is not a real cloud cover index, such as those relying on direct observations of clouds. This effective cloud cover only measures the attenuation effect that clouds have on the incoming solar radiation at the point where it is measured (AWS), which is commonly used in energy balance modelling since it relies on readily available solar radiation. So we agree with the reviewer that n_eff is not a direct indicator of clouds for the whole area, but it was not meant to be. n_eff will be inherently very variable at the hourly timescale due to partly cloudy conditions. At the >daily timescale however, we expect n_eff to be a good indicator of cloud conditions in the area.

References

Bintanja, R., and van den Broeke, M.R.: The surface energy balance of Antarctic snow and blue ice, J. Appl. Meteorol., 34, 902–926, 1995.

Cuffey, K.M., and Paterson, W.S.B.: The Physics of Glaciers, fourth edition, Elsevier: Oxford, 2010.

Gascoin, S., Lhermitte, S., Kinnard, C., Borstel, K., and Liston, G.E.: Wind effects on snow cover in Pascua-Lama, Dry Andes of Chile. Adv. Water Resour., DOI:10.1016/j.advwatres.2012.11.013, 2012.

Mölg, T., Cullen, N., Hardy, D.R., Kaser, G., and Klok, L.: Mass balance of a slope glacier on Kilimanjaro and its sensitivity to climate, Int. J. Climatol., 28, 881–892, 2008.

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