The Cryosphere Discuss.,
doi:10.5194/tc-2016-6-RC1, 2016

The Cryosphere Discussions
Open Access
EGU

Interactive comment on "Surface Energy Balance Sensitivity to Meteorological Variability on Haig Glacier, Canadian Rocky Mountains" *by* S. Ebrahimi and S. J. Marshall

Anonymous Referee #1

Received and published: 25 February 2016

General Comments

The manuscript explores the sensitivity of surface energy balance components to summer climate perturbations for site over a small mountain glacier in the Canadian Rocky Mountains. Theoretical sensitivity is calculated using mean summer conditions, while empirical sensitivity is established using daily variability from 11 years of in-situ data. The paper also presents a reconstruction of summer melt from reanalysis data for the later part of the 20th Century. The paper is generally well written with well-presented figures and a logical progression through the results.

However, there are significant shortcomings in the methods that limit the usefulness of the results in address the key questions posed. In particular, it is well established

Printer-friendly version

Discussion paper

that feedbacks are important mechanisms in determining glacier sensitivity to climate, in particular those between air temperature, precipitation and albedo (Oerlemans and Fortuin, 1992). For this reason, models assessing the sensitivity of melt (or mass balance) to climate perturbations require, 1. Driving data that covers the full range of meteorological conditions through multiple seasons, 2. A model that includes formulations for surface energy balance components that allow for important feedbacks (i.e. dynamic albedo, variation of incoming longwave with air temperature and humidity, dynamic surface temperature to include variations in refreezing/sub-surface conduction, 3. Study periods that include the full season to include air temperature/ precipitation / albedo feedbacks.

The authors reflect on most of these points throughout the results/discussion, but fail to adequately address them in the methods chosen. This undermines the results and ultimately reduces the interpretations that can be made from the data. The use of theoretical sensitivity based on mean summer conditions does not meet the criteria above and is subject to many assumptions implicit in the formulae used. It may provide an efficient way to assess the sensitivity over a large number of glaciers (and elevations on each glacier), but it would have to be carefully compared to the sensitivity assessed using realistic meteorological forcing across the full season over a large number of glaciers. Similarly, the use of reanalysis data perturbations could provide a useful method to derive sensitivity, again if the method could be shown to work for a number of glaciers in a variety of geographic settings. Unfortunately, the results of the NARR reanalysis driven surface energy balance conflict with the in-situ data here, so little can be interpreted from the seemingly accidental good model performance.

If the authors can work to robustly test their methods at a number of sites, and carefully redefine the focus of the work as presenting a new method for efficiently assessing sensitivity then it may be acceptable. If the authors wish to remain focused on the climate sensitivity of this particular glacier, then they need to employ methods appropriate to the task and put their results more carefully in the context of previous efforts to under-

stand climate sensitivity.

Specific Comments

Ln 27 – The abstract needs to be clearly state what the results of NARR analysis indicated.

Ln 40 – Interesting choice of the words ‘banal’ and ‘trivial’. Perhaps these apply to the general public but likely not the readers of the current journal. Please revise.

Ln 45 – The introduction needs to present a more thorough review of the atmospheric controls on glacier mass balance, in particular the link between air temperature and mass balance (melt) on extratropical glaciers discussed in papers such as Oerlemans (2005) and Sicart et al. (2008) and references therein.

Ln 66 – “capture the impact of shifts” perhaps add “in other climate variables such as”.

Ln 75 – while perhaps not commonplace, surface energy balance – mass balance models have been used extensively to investigate glacier-climate interactions and sensitivity (Gerbaux et al., 2005; Greuell and Smeets, 2001; Klok and Oerlemans, 2004; Mölg et al., 2008). Please revise.

Ln 85-90 – The introduction needs to more clearly define what is being examined – the sensitivity of surface energy balance components, or melt, or mass balance? – and over what time period – the sensitivity of melt to summer meteorology or annual climatology? The results should then align with the objective defined. Certainly inter-annual variations in air temperature will impact the fraction of rain vs snow and thus the winter accumulation and from this the albedo and melt through the timing of the snow-ice transition. If the authors wish to examine the sensitivity of mass balance or melt to climate change it is imperative that modelling is conducted over full seasons.

Ln 143 – It is contradictory to state a sophisticated model is ’needed’ if you go on to use a parameterization that does not perform these calculations. Perhaps it would be accurate to state that one needs to take into account the profile of lower tropospheric

water vapour, cloud and temperature. Ln 206-214 – This paragraph appears to be out of place. Please move to introduction.

Ln 240 – It is ambiguous how the diurnal cycle of is parameterized. Please explain.

Ln 261 – Theoretical sensitivity – As discussed in the general comments, a robust assessment of sensitivity needs to consider the full range of meteorological variation. The results of the theoretical and empirical sensitivity differ in important ways and thus, the theoretical sensitivity cannot be said to add anything beyond the standard of modelling the full season. Either this section needs to be removed, or developed further into a distinct methodology that is validated at a number of sites.

Ln 468 - Please explain why daily time steps were used when the computational cost of hourly sub-hourly steps is not great? Much important information is lost at a daily time step, even with a parameterized diurnal cycle and further discussion of the effects on the results is warranted.

Ln 478 – Please state what fraction of data are missing/gap filled, in particular the incoming longwave data.

Ln 492 – The feedbacks need to be clearly explained here, as equation 14 indicates there will be positive feedbacks that will enhance the variation of incoming longwave with humidity.

Ln 517 – It is essential that incoming longwave vary with humidity for an assessment of sensitivity to be robust. By using measured and parameterized data this becomes ambiguous and parameterized data should be used exclusively.

Ln 517 – You have the opportunity to include the effects of humidity on incoming shortwave radiation (through equation 9). As you note, this can overwhelm influence on incoming longwave radiation (Ln 319). The inclusion of this effect would be novel application of the empirical model.

Ln 524 – Your results indicate the feedbacks are important (Ln 541) and your conclu-

sions should echo this more strongly.

Ln 560 – This assumption is likely to be incorrect and the effect of subsurface heat fluxes needs to be considered (e.g. Pellicciotti et al. (2009).

Ln 574-576 – Further explanation of this method is needed i.e. how did you treat variations in moisture - as changes in qv or in RH? If the former, then perhaps you will overestimate the actual variation as qv variations at lower altitudes will be larger.

Ln 586 – This statement seems to contradict the previous statement that most important radiative inputs are not well correlated on an inter-annual basis and that the variance of the shortwave does not correspond with the in-situ. As there is distinct seasonal variations in air temperature and solar radiation, these variables are heavily auto-correlated and a more meaningful correlation would remove the seasonal trend before correlating variables between NARR and in-situ data.

Ln 629 – As biases in NARR results only happen to cancel and thus produce correct estimates of melt energy, these results cannot be considered robust enough to provide a meaningful interpretation of the inter-annual variations in the surface energy fluxes. Either the interpretations need to be carefully explained in this light, or further work is needed to demonstrate acceptable model skill.

Ln 654 – The approach presented in this paper has already been fairly well established in the literature (see comment for Ln 75) and so some additional novelty needs to be displayed here.

Ln 763-765 – Further explanation of the differences between theoretical and empirical sensitivities is needed.

Ln 770-771 – The trends in energy fluxes need to be more closely tied into the results of the sensitivity study.

References

Gerbaux, M., Genthon, C., Etchevers, P., Vincent, C., and Dedieu, J. P.: Surface mass balance of glaciers in the French Alps: distributed modeling and sensitivity to climate change, Journal of Glaciology, 51, 561-572, 2005.

Greuell, W. and Smeets, C. J. P. P.: Variations with elevation in the surface energy balance on the Pasterze (Austria), Journal of Geophysical Research, 106, 31717-31727, 2001. Klok, E. J. and Oerlemans, J.: Modelled climate sensitivity of the mass balance of Morteratschgletscher and its dependence on albedo parameterization, International Journal of Climatology, 24, 231-245, 2004.

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

Oerlemans, J.: Extracting a climate signal from 169 glacier records, Science, 308, 675-677, 2005.

Oerlemans, J. and Fortuin, J. P. F.: Sensitivity of glaciers and small ice caps to greenhouse warming, Science (New York, N.Y.), 258, 115-117, 1992.

Pellicciotti, F., Carenzo, M., Helbing, J., Rimkus, S., and Burlando, P.: On the role of subsurface heat conduction in glacier energy-balance modelling, Annals of Glaciology, 50, 16-24, 2009. Sicart, J. E., Hock, R., and Six, D.: Glacier melt, air temperature, and energy balance in different climates: The Bolivian Tropics, the French Alps, and northern Sweden, Journal of Geophysical Research, 113, 2008.

Interactive comment on The Cryosphere Discuss., doi:10.5194/tc-2016-6, 2016.

Printer-friendly version

Discussion paper