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Interactive Comment

Interactive comment on "Limitations of using a thermal imager for snow pit temperatures" *by* M. Schirmer and B. Jamieson

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Interactive Comment

Reviewer's comments are in *italics*, our responses are in normal text.

My recommendation is that because much of the results and discussion is still qualitative (not quantitative), the authors should carefully explain their opinion about the causes of the warm/cold crusts. As the authors discussed in the text (4. Discussion section), while the proposed heterogeneous surface energy process due to the pit wall roughness can explain one aspect of mechanisms producing the warm/cold crusts found in the previous studies, the effect of possible internal snow temperature gradient on the warm/cold crusts phenomena cannot be eliminated completely by examining only the data presented in this study. In particular, the warm crust found by Shea et al. (2012c, Fig. 6) seems to be even warmer than before the cooling of the air temperature. That is, the finding of Shea et al. (2012c) contradicts the assimilation process of the pit wall to the air temperature proposed in this study. To eliminate the possibility proposed by Shea et al. (2012c) you should evaluate the effects of both surface energy process and internal snow gradient quantitatively. I think that the contradiction itself is considered to indicate the current limitation of using the thermal imager for this kind of study and thus the question should be open for discussion in future studies.

We really appreciate the reviewer's thorough interpretation of Fig. 6. in Shea et al.

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Discussion Paper

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(2012c) in comparison with our proposed assimilation process. Indeed, the warming of the crust in this example cannot be explained with a slower cooling of the crust compared to adjacent snow layers. In a temperature assimilation process we also would expect to see a warmer crust relatively to adjacent layers at 9 am. But we would expect the whole extent of the picture to be much colder at 9 am compared to 6 am, because of the assimilation with the colder air temperature even after some seconds of exposure. Oppositely, in Fig. 6 in Shea et al. (2012c) the layers around the crust have more or less the same temperature, while the crust temperatures increase as air temperatures strongly decrease (from 6 am to 8 am). However, we have some evidence that this negative correlation is not correct and is maybe a result of wrong colorbars in this Fig. 6 in Shea et al. (2012c). We tried to assess the original thermal photos, which are still available in our team. We also interpreted the publication by the same authors as Shea et al. (2012c). This publication is a poster based on the same dataset as in their Fig. 6 (March 3, 2011), which can be downloaded here:

http://www.ucalgary.ca/asarc/2012/shea-c-jamieson-b-birkeland-k/web-article/life-shallow-snowpack

This poster is also added as a supplement figure.

In this poster the bottom row of thermal images shows the whole shallow snow depth of March 3, 2011 with approximately 60 cm snow depth. The location of the crust is approximately at the depth of the arrows, best visible at 9 am. For a similar extent as in Fig. 6 above and below the crust it can be seen that there is no negative correlation of snow and air temperatures: The adjacent layers are warmer at 6 am, colder 9 am and again warmer at 11 am. A warm crust in such a case can also be explained with a less fast assimilation process. This observation is backed up with the original photos. We have some uncertainty that the found photos are exactly the same as used for Fig. 6 in Shea et al. (2012c) (after 3 years), which is the reason for us not to publish them as a supplement. We agree that for an elimination of the processes proposed by Shea et al. (2012c) a more quantitative investigation of surface energy and internal processes is

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needed. To our knowledge these processes cannot be measured separately. Thus, we changed our formulations in the Discussion (fomerly line 10ff p.5240) and Conclusions section (formerly line 20ff, p. 5245) into more careful statements.

Specific comments P5235, L17-18 The authors mentioned that "When integrating over the used camera's spectrum, the grain type differences may be diminished." However, a recently published paper (Hori et al., 2013, Applied Optics, 10/2013; 52(30):7243-55) estimated possible biases in measured temperatures with a FLIR thermal imager. Their results indicates that even if the emissivity effects are integrated over the camera's spectrum the grain type differences are not necessarily diminished but remains depending also on the photographic (viewing) angles when measuring the surface of snow cover under clear sky conditions.

We thank the reviewer pointing us to this recent study. We added a citation in the Introduction section, and modified the sentence mentioned by the reviewer. We also added this study in the Discussion section mentioning the found warm interstitial microcavities in a snow surface of melt forms.

In general, when explaining field observations, the place, date, and weather conditions (e.g., clear/cloudy, air temperature, windy or not) should be addressed to enable readers to interpret the measurement results correctly.

We added details about our field observations in general and in more detail for the one which is presented in the results section (2.1.1 Snow pits section).

P5237, L19 (3.1 Snow pits) The authors present only thermal image of snow pits in Fig.2 here. It will be helpful for readers to add a photograph (not thermal image) of the pit wall and/or describe the dimension (depth of concaves) of the shovel scours and the crust layer in the text in order to understand how much is the effect of the surface energy process on the heterogeneous temperature profile.

We took photos from our snow pits also made visual videos as described in (2.1.1

Snow pits). However, even with image post processing these photos do only show a smooth pit wall and the reader gets no further information on the dimensions of the shovel scours. The crusts and individual holes in the crusts become visible but not the depth of the holes. We chose to add a descriptions with words instead (section 3.1 Snow pits). For the specimens used in the cold lab we were able to make photos which will give the reader an idea of the dimensions of the surface roughness and provided them in the paper.

Technical comments P5235, L16 “deg. C” should be “deg.” Changed as suggested

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Interactive comment on The Cryosphere Discuss., 7, 5231, 2013.