The Cryosphere Discuss., 5, C2063–C2071, 2012
www.the-cryosphere-discuss.net/5/C2063/2012/


The Cryosphere Discussions

# *Interactive comment on* "Brief communication "Modeled rain on snow in CLM3 warms soil under thick snow cover and cools it under thin"" *by* J. Putkonen et al.

**J. Putkonen et al.**

jaakko.putkonen@engr.und.edu

Received and published: 5 March 2012

We are grateful for the insightful comments provided by Dr. Fierz (Referee #2). Below are our responses to the specific suggestions.

REFEREE COMMENT: General Remarks The problem addressed in this brief communication is undoubtedly of importance. The main outcome is a snow depth threshold for cooling/warming of the ground in higher latitudes of the Northern Hemisphere (NH) due to Rain On Snow (ROS) events. Furthermore, the methodology used seems quite inappropriate. Indeed, applying the same large precipitation event (and air temperature increase of 30 K in one day?) over each pixel alike will not reveal more than carefully



performed test runs with differing initial conditions in one point. From the present study, influence of other factors such as meteorological conditions, state and structure of the snowpack, and snow cover duration can hardly be disentangled from the alleged snow depth "signal". This makes me strongly feel that the threshold mentioned above is hardly supported by the data shown in Figure 3.

Finally, for a brief contribution, there is quite a number of imprecision in the text and the quality of the figures is not yet at its best (sloppy labeling, for example). I therefore recommend rejecting the paper but would encourage the authors to perform a much more detailed analysis of ROS events first and apply then the knowledge gained on a simulation over the NH. This would imply, however, that a realistic modeling of ROS in those regions can be performed. A few points in detail (page, line)

AUTHORS' RESPONSE: We are grateful for the insights and constructive comments provided by Dr. Fierz (Referee #2). We realize from the above comment that we need to do a better job in explaining the intentions of this manuscript within the constrained space of the Brief Communication. The motivation of this manuscript is to highlight more in a qualitative sense than quantitative the counterintuitive thermal response of the seasonally snow covered lands to ROS when certain conditions are met. It is clear that this manuscript is more of a starting point for further research than the final answer. We fully agree that there are many more parameters at play here than simply just the snow depth. However, we suggest that since the result is rather robust across a wide geographic area the snow must be one of the more important factors (within the natural variability of the initial conditions).

We intend to continue the research with much more detailed analyses, but those results will of course not fit in a Brief Communication. Also, we found the current results so intriguing that we wanted to bring them to the attention of the wider community at this discovery stage.

We hope that with these caveats and incorporated comments and suggestions this

manuscript will be acceptable for publication.

REFEREE COMMENT: 2560, 12-17: I would argue that you should do a careful analysis without “modeling” the full NH first, disentangling the contributions from various factors. The main challenge in applying a ROS to the NH will be to model the latter. After all, none of your “cooling” pixel may ever be hit by a ROS event of this magnitude, or vice versa, or any combination of both.

AUTHORS’ RESPONSE: It is certainly a prudent approach to analyze and model all the important processes at a given site/pixel before embarking on a hemisphere wide analysis. We have done such analyses in our field site in Spitsbergen and are fully aware of the challenges and complexities of the atmosphere/snow/soil system. However such detailed analyses (and field work) done for every pixel would be too time consuming to be practical. Here we use a totally different approach of a large scale model that has if not perfect at least well studied and understood components. We are using this model to tease out general behavior that we would never be able to find with the detailed analysis of every pixel as we did in Spitsbergen. We suggest that conceptual/theoretical work (such as this) complements detailed observations based field work by guiding us to new field areas and especially important and informative aspects of the processes.

REFEREE COMMENT AND OUR REPSONSE: 2561, 7: Based on the CLM3 documentation, we agree with the Ref that the thinnest snow layers are at the snow/atmosphere boundary. We will correct this error.

REFEREE COMMENT: 2561, 8: Darcy’s law is valid for saturated snow, which is hardly the case for subfreezing snow before the first wetting. It is an oversimplification! Anyway, it seems CLM3 does not use that scheme in snow (see p 103 ff of Tech Notes)!

AUTHORS’ RESPONSE: We agree with referee comment and will correct that note in the text.



AUTHORS’ CORRECTION: 2562, 6: ’In order to compare the thermal insulation provided by the snow pack across model pixels, it is useful define the snow pack thermal resistance ():’ i.e. replace ’between’ with ’across’.

REFEREE COMMENT: 2562,13: I agree that it cannot be the purpose of a brief communication to describe a model in detail and you give the appropriate reference (by the way, why did you not use CLM4?). However, I would expect that what is said about the model be done carefully and correctly (see below for a few examples).

AUTHORS’ RESPONSE: We welcome all suggestions to improve our presentation and are eager to incorporate those to our manuscript. The modeling was done before CLM4 came out.

REFEREE COMMENT: 2562, 22: “By artificially introducing a rain on snow event on the order of 50mm in a one day period” This may be the main crux of this contribution.

AUTHORS’ RESPONSE: As noted above, our intention is to find out more in a qualitative sense how the system behaves under typical conditions in various parts of the northern hemisphere when ROS occurs. Whether or not the ROS event is of this size or occurs at this given date or what was the thermal history of the site, we still expect this simulation to reveal something fundamental about the system that warrants further research. Furthermore, we found the reported thermal behavior so counterintuitive that we expect the wider community to benefit of these ideas already in their early stages.

REFEREE COMMENT: 2563, 5-10: Note that there is hardly no compaction during and after the ROS event; it is comparable to the “control case”. Thus in this case the main increase in density is due to the refreezing of around 95 % of the rain water. This would not be the case if the snowpack would be quite warmer initially and initial snow depth plays a role too.

AUTHORS’ RESPONSE: We agree and acknowledge that there is much research to be done to fully resolve the above mentioned relations.

REFEREE COMMENT: 2563, 12: “The ROS event is shown by air temperature (TBOT), which was raised to freezing for four days surrounding the rain fall” Thus rain with a temperature of 0 _C falls on a subfreezing snowpack at about -40 _C? It is well known that such an event very efficiently warms a subfreezing snowpack indeed. However, is this scenario realistic (40 _C air temperature raise in one day)? What would happen if the snow temperature was near the freezing point before the event?.

AUTHORS’ RESPONSE: We have observed an air temperature increase of similar magnitude [about 27 degrees Celcius] in our field site in Spitsbergen (see Figure 1. in Putkonen and Roe. 2003. GRL Vol 30, no 4, 1188), followed in a few days by a large ROS event.

REFEREE COMMENT: 2563, 15-16: “even though the average snow temperature (not shown) is below freezing.” When is this the case? The snowpack needs to be isothermal at 0 _C to allow percolating water reaching the ground surface. The state of the snowpack before the ROS is thus crucial to the advancement of the warming and wetting front. Not taking the influence of such factors in more details weakens your analysis even more.

AUTHORS’ RESPONSE: We appreciate the referee pointing out a section that requires clarification. Our intention was/is to convey the idea that when the liquid water is present under the snow pack (for days and weeks) the air temperature again drops below freezing point (and thus the mean temperature of the snow pack is below freezing). This is a common phenomenon observed for example in our field site in Spitsbergen.

REFEREE COMMENT: 2564, 24-28: I have hard times to follow that argumentation to justify the methodology used in this contribution.

AUTHORS’ RESPONSE: We are making an obvious point that our modeled ROS is never going to happen exactly as modeled. However, as observed in various parts of the Arctic large ROS occurs every now and then. Our modeling reveals possible response of the permafrost system to such an event.



REFEREE COMMENT: 2565, 20: “enhanced heat flux” What causes this enhanced heat flux? A wetted snowpack is isothermal and shows no temperature gradient.

AUTHORS’ RESPONSE: Thank you for pointing out a poorly worded section. The sentence should state that due to the wetting event the thermal conductivity of the snow is higher than it is for the reference case without a wetting event. Therefore the heat flux through the snow pack in the months following the wetting event is enhanced.

REFEREE COMMENT: 2565, 27: “to timing and duration of the snow cover” I would argue that this factor is of importance for any pixel.

AUTHORS’ RESPONSE: We agree. We are just trying to make a point that in the areas that see the least snow cover for short periods of time. The timing and small changes in the absolute amount of snow seem to be the most important.

Minor points

REFEREE COMMENT: 2558, 18: Replace “Brown et al.” by “Brown and Romanovsky”.

AUTHORS’ RESPONSE: Will do

REFEREE COMMENT: 2559, 5: Is 1998 recent?

AUTHORS’ RESPONSE: Will do

REFEREE COMMENT: 2559, 20: “slow”? I would argue that this depends on the cold content of the snowpack just prior to the event (cold and dry vs almost isothermal near the melting point) as well as on the weather conditions following the event.

AUTHORS’ RESPONSE: Noted

REFEREE COMMENT: 2560, 26: “such as” why not name all four PFTs as three are already! 2561, 7: “with thinnest layers at the soil/snow boundary.” Are you sure? According to the TD of CLM3 it is the other way round, which is what I would expect anyway!

AUTHORS' RESPONSE: CLM3 has more than 4 PFTs, but selects the 4 dominant ones on a cell by cell basis. Change text starting at line 25 to: "Vegetation in each cell is modeled by the four plant functional types (PFTs) that dominate there, ...'. may make this clearer. This is not an aspect of CLM3 that we intended to manipulate.

REFEREE COMMENT: 2561, 8: Darcy's law is valid for saturated snow, which is hardly the case for subfreezing snow before the first wetting. It is an oversimplification! Anyway, it seems CLM3 does not use that scheme in snow (see p 103 ff of Tech Notes)!

AUTHORS' RESPONSE: Will correct this.

REFEREE COMMENT: 2561, 19: "incoming solar radiation" What about long wave radiation?

AUTHORS' RESPONSE: Incoming atmospheric longwave radiation is derived by the offline CLM routines from the air temperature and dew point temperature.

REFEREE COMMENT: 2562, 6: I suggest to replace "between the" by "to each"

AUTHORS' RESPONSE: Will correct this.

REFEREE COMMENT: 2562, 10: "Thermal conductivity is calculated" Did you replace the conductivity used in CLM3 by Sturm's equation too?

AUTHORS' RESPONSE: No, we used CLM3 as it is.

REFEREE COMMENT: 2563, 10: Use "control case" throughout the text. For example, see caption to Fig. 2 ("base case")

AUTHORS' RESPONSE: 2563, 10: valid point - we should change the Fig. 2. caption to use 'control case' instead of 'base case'.

AUTHORS' RESPONSE: Will correct this.

REFEREE COMMENT: 2563,18: "due to a limited snow fall" I do not understand the argument here. What is due to this limited snowfall? Which snowfall?



AUTHORS' RESPONSE: We can use the same wording as used in Fig 2 caption? 'there was no significant snow fall for a month after the modeled ROS event'. Which hopefully makes it clearer.

REFEREE COMMENT: 2564, 6: "defined" arbitrarily!

AUTHORS' RESPONSE: Ref is bothered by the use of 'defined', but what would be better: chose, selected. This practice of setting a more or less arbitrary boundary to separate commonly occurring events from extreme ones is rather common in atmospheric science.

REFEREE COMMENT: 2564, 9: Replace "> -1 _C" by "< -1 _C" (correct in Fig. 3). Why not using kelvins?

AUTHORS' RESPONSE: Referee is correct, fig 3, TSOIAvgDiff (mean season average soil temperature with ROS) >0.5 <-1 In text 'season average temperature difference' >0.5 C >-1.0 C (this should be <) It seems to us that since this paper is all about freezing and thawing Celcius scale is more intuitive.

REFEREE COMMENT: 2564, 10: To speak of "natural" in this modeling context sounds odd!

AUTHORS' RESPONSE: we should call it a 'control case' instead?

REFEREE COMMENT: 2564, 15: Replace "depth" with "depth range" AUTHOR RESPONSE: yes 'depth range' is better 'and the depth range where ... is 0.35m-0.15m'.

REFEREE COMMENT: 2564, 21-23: Rather arbitrary in my view!

AUTHORS' RESPONSE: No, this is based on our results that are shown in this manuscript.

REFEREE COMMENT: Figures

The quality is far from overwhelming and the labeling often very bad. This definitely

needs improvement. Also, do not use model variable names such as TBOT for air temperature or SNOWDP for snow depth HS. AUTHORS' RESPONSE We will explore ways to improve the figures and make them more legible.

---

Interactive comment on The Cryosphere Discuss., 5, 2557, 2011.