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Hydrology and Earth System Sciences Discussions



# *Interactive comment on* "CREST-Snow Field Experiment: analysis of snowpack properties using multi-frequency microwave remote sensing data" *by* T. Lakhankar et al.

**Anonymous Referee #1**

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Comments to Authors

This manuscript describes ground-based passive microwave radiometer measurements over a winter season, and uses a physical snowpack model to provide snow inputs to a snow emission model. The radiometer measurements are relatively unique, and the ability to couple physical snow and snow emission models is important in the context of satellite retrievals and land surface modeling applications. As outlined below, however, the manuscript fails to deliver on the promising experiment setup:

1. The Introduction does not present any clearly stated objectives or hypothesis to test.

This results in a very descriptive paper with little quantitative analysis.

2. There are numerous cases of conceptually incorrect statements regarding snow metamorphism and the microwave emission/scattering properties of terrestrial snow, and there is confusion regarding melt metamorphism versus temperature gradient metamorphism. Examples include: -Page 8107 line 19: “Further, as a time progress smaller grains locked together to form bigger grains.” Is this referring to melt metamorphism? ‘Locked together’ is a strange word choice. -Page 8107 lien 25: Do you really think soil properties ‘dominate’ winter season microwave emission? If so, how could we use these measurements to look at snow? -Page 8112 line 16: “The diurnal variation of brightness temperature during the snow accumulation phase was smaller due to slow snow metamorphism compared to the later winter period.” The diurnal variation in Tb is likely due to temperature and snow wetness processes not grain metamorphism. -Page 8113 line 15: “The increase of the brightness temperature at 89GHz immediately after the snowfall event is due to the greater microwave scattering of the fresh snow as compared to soil or aged snow.” Greater microwave scatter related to increased Tb? Page 8114 line 18: “Snow metamorphism, which transforms smaller grains into larger grains, is slow when below freezing temperatures persist.” What about temperature gradient metamorphism? Prolonged cold temperatures drive this process. . .

3. Details are missing on some aspects of the radiometer measurements. Given the beam width, incidence angle, and height, what are the dimensions of the measurement footprint? How was the radiometric stability of the instruments evaluated during the course of the measurements? Was there any calibration drift? If so, how was this corrected? Was there any post-processing of the measurements?

4. There are some critical gaps in the field measurements. How were the grain size and density measurements made? Were grain size and density really only measured on a single day (10 March 2011) as stated on page 8111 line 6? If so, this means all the statements throughout the manuscript on the impact of grain size and density on brightness temperature are speculative and not quantitative. A lot of descriptive



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statements lack any evidence from snow measurements. For example: -page 8113 line 1 “The reduction of TB in 89GHz band at both vertical and horizontal polarization was primarily associated with the change in surface temperature accompanied with the change in snow grain size.” -page 8113 line 20 “This reduction is apparently related to changes in the snowpack properties particularly to the increase of the grain size.” Were any grain size measurements made during these periods? If so, they must be presented quantitatively to avoid speculative statements like these.

5. An additional section is needed on the implementation of SNTHERM and HUT. Coupling physical snow models with snow emission models is not a trivial task, and many research groups are currently addressing this issue. It is difficult to take physical snow model output (for example, grain size) and feed it directly into a snow emission model, so more details are needed here. It also appears that the SNTHERM simulations, with the exception of temperature, were not validated at all with observations. In addition to temperature, HUT requires grain size, SWE, and density inputs. If these were taken straight from the SNTHERM simulations with no validation how do you know these values were reasonable? How can uncertainty in the Tb simulations be attributed to the model inputs versus the model parameterizations? HUT also requires surface roughness and surface dielectric inputs. How were these determined?

6. The strong 37V response to ice layers (section 4.1.3) is not consistent with previous studies and warrants further attention. I would check: Rees, A., J. Lemmetyinen, C. Derksen, J. Pulliainen, and M. English. 2010. Observed and modelled effects of ice lens formation on passive microwave brightness temperatures over snow covered tundra. Remote Sensing of Environment. 114: 116-126. Lemmetyinen, J., J. Pulliainen, A. Rees, A. Kontu, Y. Qiu, and C. Derksen. 2010. Multiple layer adaptation of the HUT snow emission model: comparison with experimental data. IEEE Transactions on Geoscience and Remote Sensing. 48: 2781-2794.

7. I suggest re-thinking the snow categories in Section 4.2. The ‘aged snow’ category in particular should include some consideration of grain shape, i.e. rounded versus



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faceted, or some consideration of the layered nature of snowpacks which typically contain both old and new snow layers.

8. Figure 4: I was struck by the lack of response of the 37 GHz measurements to snow depth, even when the snowpack was close to 40 cm and relatively cold. This is quite unexpected. Is there any explanation for this?

9. Figure 8: A lot of temporal averaging was performed before comparing the simulations and observations. What does a statistical analysis of more instantaneous measurements and simulations look like?

Editorial Comments

The manuscript requires a thorough edit for many minor grammatical/word choice errors.

Remove all mention of non-metric units (i.e. inches).

Page 8108 line 19: "Previous snow field experiments (Chang et al., 1981; Elder et al., 2009; Hewison and English, 1999; Langlois et al., 2007; Macelloni et al., 2005) that have used microwave radiometers to study snowpack microwave emission properties." Not a complete sentence.

Section 3.2: details on the data logger are not necessary.

Section 4.1 and throughout the manuscript: the term 'subfreezing' is not typical. Are you referring to processes in the snowpack or the top soil layer?

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 8105, 2012.