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Geoscientific
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Discussions

Interactive comment on "Simulation of the microwave emission of multi-layered snowpacks using the dense media radiative transfer theory: the DMRT-ML model" *by* G. Picard et al.

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We would like to thank the reviewer for her/his detailed comments. We addressed them below. A number of sections have also been clarified in the manuscript to address both reviewers' questions. The manuscript has certainly been much improved by addressing them.

** p. 3656, eqn. 5-7: It is not very clear how those equations are obtained, they should be properly referenced.

Precise references of the equation in Shih et al. 1997 and Tsang et al. 2001 have been added. The form of our equations 5-7 are not strictly the same as in the refer-

ences (it follows the DMRT-ML codes), but the derivation is very simple with common electromagnetic formula relating the propagation number and the effective dielectric constant.

** p. 36655, l20: Is there an explanation for reducing the grain size from 1.75 mm to 0.83 mm? How are the grain sizes defined in the model, and in the original measurements?

Reducing the grain size aims at showing that the large difference in imaginary part of the dielectric constant can be compensated by a reasonable change in the grain size parameter. Measurements of the grain size in the field being problematic, an error by a factor 2 is not uncommon. Hence, the agreement between the model and the data can be obtained with the formulation of the dielectric constant by Matzler and Wegmuller 1987 (which is expected to be more accurate than the value used in Kong et al. 1979 since it is more recent) and with a reasonable grain size (0.83 mm). However, we cannot ascertain the grain size of 1.75mm is unrealistic. For this reason, we remove the sentence "Such a grain size value appears more common than 1.75 mm \citep{domine_2008}. ".

The end of the paragraph has been reformulated as follow: However, the imaginary part of the ice dielectric constant used by Kong et al. (1979) was an order of magnitude higher than the one obtained with the more recent Equation 2 from Matzler and Wegmuller (1987). With the latter parameterization, the brightness temperatures simulated using the same grain size of 1.75 mm are much lower (dash line in Fig. 3b) leading to a strong disagreement with the observations. Modeling results and observations can be re-conciliated by using a smaller radius of 0.83 mm (solid line in Fig. 3b). This new simulation yields results very close to those of the original simulation and observations.

Note: the text was incorrect, the imaginary part with Matzler et Wegmuller. 1987 formulation is 10 times lower than the value used in Kong et al. 1979.

** In general, you only briefly indicate the problems that are associated with the definition of snow grain sizes. Since brightness temperatures are very sensitive to grain size, this problem should be more thoroughly evaluated.

These problems are important but difficult and they are addressed in several dedicated articles. In the DMRT theory, the grain size is well defined and since the present paper focuses on a DMRT-based model, the definition of grain size in the paper is not ambiguous. Since natural snow is not composed of perfectly spherical grains, the issues arise when this theory is used with measured grain size, which is the subject of several articles with DMRT-ML (e.g. Brucker et al. 2011, Roy et al. 2012).

Even though the question of the grain size is not addressed in depth in this paper, it is mentioned :

- In Section 3.2 "In practice, the choice of the distribution is difficult and is related to the more general issue of the representation of snow by a collection of spherical grains."

- In Section 3.4 "In practice, choosing a realistic value of stickiness to represent natural snow is difficult. There is currently no means to estimate this value either from field measurements, 3D images of snow micro-structure or snow evolution model outputs. As for choosing a grain size distribution, the core of the problem is the representation of snow by spheres."

- In section 4. "The representation of snow grain in the DMRT theory by spherical particles is also a conceptual difficulty."

In the Section 3.2, we have changed the term "grains" to "spheres" to avoid confusion.

We have also added a sentence in the conclusion: "The error found between predicted and observed brightness temperatures ranged between 2 and 13 K, which gives the magnitude of accessible errors but which depends on the methodology used for the comparison. In particular, the choice of the relationship to relate the measured grain size to the grain size metric relevant to the DMRT theory is critical and no ideal solution

exists yet."

** p. 3667: The criterion for the validity of the Rayleigh approximation given by Ulaby (Microwave Remote Sensing) is 2π a $\sqrt{\varepsilon}$ / λ < 0.5. This is much more strict than the criterion given here. Is it possible that the unrealistic values shown in Fig. 5 are a consequence of the resulting inaccuracy in the scattering efficiency?

The criteria that we derived from Figure 4 is indeed less strict that the criteria on the Rayleigh approximation. It is possible that this results from the fact that our calculation was done with QCA-CP formula with a density approaching 0 and that it is slightly different from the original Rayleigh approximation. We decided to remove any reference to the Rayleigh approximation and to keep the terms "low frequency" and "small scatterer". We have also changed the legend in Figure 4.

The values in Figure 5 obtained for large grains are lower that those found in Antarctica (and probably elsewhere) but it does not mean the calculation is wrong or the approximation is invalid. It may be that such large grain sizes in the upper part of the snowpack are rare in the nature, which would explain why such low brightness temperature values can not be found.

** p. 3669: Please check the description of Fig. 8. It does not seem to be consistent with the plot you show.

Corrected: cyan → black

** p. 3671, 3672 and 3673: You repeatedly cite Roy et al (2012), but the paper is not available yet. Please consider replacing or removing this reference. The paper is ready for publication and should be available in the coming months.

** p. 3671: You compare measurements with results from your model. For such a comparison, it would be very helpful to have some information about the setup of your model.

The setup is different in the different studies and cannot be explained in a few sentences which is explained in the text “Hence, the results of the comparisons and the errors estimated in these studies depend on the methodology and are meaningless out of the context of each study.”. The objective of the section 4 is to draw general points from our previous comparisons that may be useful for DMRT-ML users. The text also gives an order of magnitude of the achievable accuracy, but this value depends on the details of the methodology. Basically, it depends on the number of parameters considered as unknown and that requires calibration by optimization with respect to the observations. This unfortunately reduces the strength of these validations but is due to the impossibility to measure all the variables required to run the model (grain size, soil parameters mainly). It is essential that the reader interested by this section refers to the cited papers which give the details of the setup and the limitation of these comparisons.

** Fig. 10/11: Currently, it is not entirely clear what the authors want to show in those figures. Maybe it would be better to directly compare measurements and model results, even though the methods of deriving the field data are different?

It was a deliberate choice to present the results in a different view from that in the other studies for the reason that the direct comparison is meaningless out of the context of these particular studies due to the parameter calibration. In this paper, we presented the results in the H-V polarisation space – arguably not as clear as a direct comparison – because we believe that the different methodologies applied in the different studies (in short, the parameter calibration is different) does not significantly affect the relationship between the polarizations so that the Figures 10/11 are informative and relatively independent of the different methodologies that cannot be described in this paper.

Technical corrections ** p. 3650, l10: direct measurements are only possible

** p. 3651, l4: no particular model ... systematically reproduces

** p. 3653, l5: the result is the brightness temperature emerging

** p. 3653, l22: Please check the citation (brackets).

** p. 3655, l22: a means to account for

** p. 3657, l24: between individual snow layers (?)

** p. 3659, l17: Please check the sentence structure.

** p. 3664, l20: Kirchhoff

All these comments have been addressed.

** p. 3666, l4: Please check the sentence structure.

Reformulated as follows:

"This method takes into account multiple scattering within and between the layers which is an asset with respect to the iterative method (Tsang et al., 1985; Jin, 1994; Ishimaru, 1997) for which the number of calculated order of scattering is limited. It also computes the energy propagation in an unlimited number of directions (or “streams”) as opposed to the two-stream (Pulliainen et al., 1999) or six-stream (Wiesmann and Matzler, 1999) methods whose formulations are based on a fixed and small numbers of directions."

** p. 3667, l6: Please check the sentence structure/grammar.

The sentence is simplified: “In practice, the choice of the distribution is difficult and is related to the more general issue of the representation of snow by a collection of spherical grains.”

** p. 3667, l16: dashed blue curve

done

** p. 3668, l9: the proximity of the grains

done

** p. 3669, l5: using a method called bridging (?)

The citation and the term bridging have been moved to the next sentence:

"A second option is to interpolate the scattering and absorption coefficients using polynomials fitted with anchor points taken in both domains where the theory is valid. This option called ”bridging” (Dierking et al., 2012) is appealing because it yields continuous relationships as a function of the density."

Interactive comment on Geosci. Model Dev. Discuss., 5, 3647, 2012.