Dear anonymous reviewer 2,

We are grateful for your helpful an detailed comments which allowed us to improve our manuscript.

The text in *italic* contains your original comments, the normal text represents our responses to your comments whereas the text in **bold font** shows the modifications made to the manuscript.

Responses to your general comments:

1. *Equation (5) is a gross approximation. It depends on* k_0^3 *and* L^3. *The dependence is basically Rayleigh scattering. Experimental data of* κ_s *(equation 8) shows that such dependence are too strong. Recent models have much agreement with measurements.*

   The introduction has been modified to justify the use of the Strong Fluctuation Theory (SFT):

   P4883, line 10: **The snowpack permittivity is calculated based on the Strong Fluctuation Theory (SFT) introduced by Stogryn (1984). The SFT has been tested and verified in the literature (Wang et al., 2000, Tsang et al., 2007). It is also used in the DMRT model of multilayer snowpack developed by Longepe et al. (2009). This model is capable of simulating the interaction of electromagnetic waves with a layer of snow based on the physical parameters (thickness, optical diameter, snow density). The advantage of this model is the simple implementation and its moderate computation time, which is crucial in order to run the data assimilation process, where the electromagnetic model is repeatedly executed multiple times.**

2. *The SFT model has very small cross polarization*

   In this study, we assumed that the snow particles are of spherical shape. Therefore the backscattering coefficient of the cross-polarization channels (HV and VH) cannot be properly calculated. The manuscript has been updated with the discussions on the limitations of this model:

   P4889, line 20: **The assumption of spherical particles can simplify the modeling problem, however it prevents the simulations of the backscattering coefficient over cross-polarization channels (HV and VH).**

   P4899, line 12: **This system however, has some limitations, like the inability to simulate and assimilate under wet snow conditions due to the hypothesis used in the EBM. Another important hypothesis made in this study concerns the spherical shape of snow grains. This assumption highly simplifies the modeling problem, but on the other hand prevents the simulations over cross-polarization channels (HV and VH). The discussion on how to resolve these limitations should be addressed in another study on the modeling of electromagnetic waves interactions with a snowpack.**

3. *Figure 6 has data of snow depth up to 700 cm. A single scattering approach is inadequate.*

   There was a mistake in equation (19) defining snow optical thickness, figure 6 and equation (19) have been corrected as follow:

$$\tau = \sum_{k=1}^{n} \kappa_e^k d^k$$

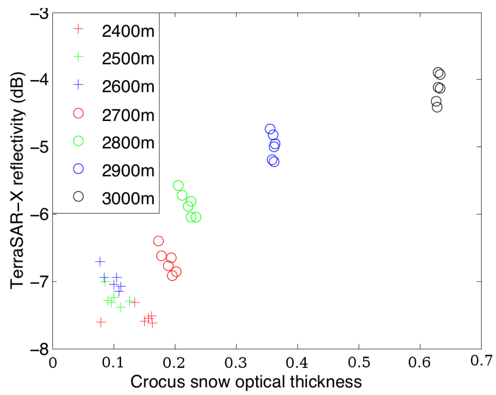

Figure 6. TerraSAR-X reflectivity plotted as function of optical thickness derived from Crocus output. Each point correspond to a date of acquisition TerraSAR-X

The optical thickness depends on both snow depth and the extinction coefficient of snowpack, and shouldn't be mistaken for snow depth only.

4. *Only 1 channel HH and dozens of parameters from Crocus. The choice of B and R are crucial. Such choices should be discussed in details*

   The values of **R** and **B** are described in the manuscript in the data assimilation section. The matrix **B**, which represents the error of Crocus, is inferred from the model results and sensitivity (P4986, line 17-25, P4987, line 1-12). The matrix **R** in our case is actually a scalar since we only have one backscattering coefficient in HH polarization. Therefore the value of **R** is the deduced from the radiometric uncertainty of TerraSAR-X data (0.5 dB) and the error of the Electromagnetic Backscattering Model (inferred from the sensitivity of the EBM).

   The manuscript has been modified in order to clarify this aspect: P4897, line 13: **In this case study, SAR data are only available for the HH channel, therefore the error covariance matrix R reduces to a scalar, deduced from the radiometric uncertainty of TerraSAR-X (0.5 dB) and the error of the Electromagnetic Backscattering Model (inferred from the sensitivity of the EBM). The calculations at several altitudes over the Argentière glacier gives the average value of R** $= 0.03$.

5. *The better match only means updating the profile match the radar data better. It does not mean the retrieved/updated profile is the true profile in view of the large number of parameters in the Crocus.*

   Agreed.

   The study provides a process to assimilate the remote sensing data into the snowpack model Crocus.

We needs further validation from in-situ measurements in order to verify whether the result obtained from data assimilation is closer to field measurements than open loop simulated snow properties. Our perspective is to take more in-situ measurements, as for now the modifications made by assimilation process are compatible with the physical evolution of snowpack, and this is indicated in the conclusion of the manuscript. Moreover the temporal convergence of the guess profile toward the assimilated one is a very encouraging aspect. Future study will concentrate on the validation of the assimilation process using in-situ measurements and 3-D SAR images (Ferro-Famil et al., 2012).

References

Ferro-Famil, L., Leconte, C., Boutet, F., Phan, X., Gay, M., and Durand, Y. (2012). Posar: A vhr tomographic gb-sar system application to snow cover 3-d imaging at x and ku bands. In *Radar Conference (EuRAD), 2012 9th European*, pages 130–133.

Longepe, N., Allain, S., Ferro-Famil, L., Pottier, E., and Durand, Y. (2009). Snowpack characterization in mountainous regions using c-band sar data and a meteorological model. *Geoscience and Remote Sensing, IEEE Transactions on*, 47(2):406 –418.

Tsang, L., Pan, J., Liang, D., Li, Z., Cline, D., and Tan, Y. (2007). Modeling active microwave remote sensing of snow using dense media radiative transfer (dmrt) theory with multiple-scattering effects. *Geoscience and Remote Sensing, IEEE Transactions on*, 45(4):990 –1004.

Wang, H., Pulliainen, J., and Hallikainen, M. (2000). Extinction behavior of dry snow at microwave range up to 90 ghz by using strong fluctuation theory. *Progress In Electromagnetics Research*, 25:39–51.

Sincerely yours,
Xuan-Vu Phan
on behalf of all co-authors.