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First, we would like to thank the reviewers for comments which were useful in producing an improved manuscript. Important new elements were brought to the manuscript in order to: 1) better describe the model and the simulations; 2) make the motivation of the study clearer; 3) Put the results in context of microwave emission models. We thus added a figure (Fig.10) showing the results in terms of simulated optical radius (R_{opt} derived from the simulated SSA), which corresponds to the parameter used as input in the microwave snow emission model. We discuss the error of R_{opt} in this context. Furthermore, small adjustments were brought to CLASS-SSA and Figures 4 to 10 were corrected:

- Minimum SSA is changed from $5 \text{ m}^2 \text{ kg}^{-1}$ to $8 \text{ m}^2 \text{ kg}^{-1}$ for dry snow. The limit of $8 \text{ m}^2 \text{ kg}^{-1}$ is based on proposed values by Taillandier et al., (2007). That change has minor effects in term of comparison with measured SSA. It however had an impact on R_{opt} calculations (see Fig.10). The limit of $8 \text{ m}^2 \text{ kg}^{-1}$ was also confirmed by our field works conducted this winter (2013) in Canadian Arctic and Alaska, where very large depth hoar (up to 0.5 cm of maximum diameter) gave minimum values around $8 \text{ m}^2 \text{ kg}^{-1}$ with our IRIS measurements.
- The maximum dry snow density is set to the maximum density calculated by CLASS instead of 300 kg m^{-3} . This also had minor effect on SSA simulations but is more coherent with the CLASS model (see R2-C6).
- In the temperature gradient calculation, we considered the air temperature instead of snow surface (skin) temperature modeled by CLASS. In fact CLASS sometimes gives very cold surface temperature (up to 20°C colder than air temperatures), while the measured surface temperature (Traceable 2000 digital temperature probe) rarely give differences between air temperature and snow surface temperature higher than 3°C at Churchill, SIRENE and St-Romain. It appears that the air temperature is more representative of the upper snow layer than the skin surface snow temperature to calculate the gradient needed for the SSA evolution.

We responded to all reviewers' comments. Editing comments were all corrected, but not included in this document. To facilitate the reading, we identified the Reviewer's comments (blue) and modification added to the manuscript (italic)

In blue: Reviewer's comments. To better identify the questions, we added reference symbols: R= Reviewer #; C = Comments #;

In black: Answers to reviewer

In black and italic: Modification added to manuscript

Anonymous Referee #1

SUMMARY:

This manuscript presents an offline model for the temporal evolution of snow specific surface area (SSA), driven by meteorological data from five sites in Canada and France. The offline model is incorporated in the CLASS one-layer snow model that has widely been used in climate models. Research into SSA evolution has exploded in recent years, and the research presented here is an interesting, albeit somewhat unusual approach to finding a simple way to incorporate SSA evolution in an existing snow model. The subject is appropriate for *The Cryosphere*, a journal that is evolving as a main platform for SSA-related research.

GENERAL COMMENTS:

R1-C1: As I mentioned above, I find the chosen approach somewhat unusual. The few attempts to incorporate SSA evolution in the literature use multi-layer models (Lawrence, 2010, Kuipers Munneke 2011). There is an obvious reason for this: SSA evolution depends on local temperature, local density, and on local temperature gradients (Flanner and Zender, 2006). This is easily taken into account in a multi-layer model. The incorporation of an SSA model in a single-layer snow model is thus a bit odd. Indeed, the authors have to make quite a few assumptions to knit a multi-layer SSA model to a snow model in which crucial parameters like temperature are only known in one level. To me it seems that the authors have made it a bit difficult for themselves by sticking to a single-layer model, rather than taking one of the many multi-layer snow models that are around in this study field (Bartelt 2002, Bougamont 2005, Ettema 2010, Niwano 2012, CROCUS) and implement it in CLASS.

There are several multi-layer thermo-physical state-of-art snow models available, such as Crocus, SNOWPACK or SNTHERM, among others as suggested by the reviewer (the suggested references are added, see also the very detailed review by Essery et al., 2013). We work with the three mentioned models as benchmarks (see Langlois et al., 2009). However, to completely change the snow model within the CLASS scheme is challenging without changing the model structure (for easy operational implementation at the Canadian Centre for Climate Modeling and Analysis (CCCma)). Moreover, depending on the goal of the study, a simplified snow model could provide accuracy in agreement with the objective. The SNOWMIP experiment has shown that for SWE estimates, 1-layer models such as CLASS performed relatively well (see Etchevers et al, 2002 ; Brown et al., 2006; and Rutter et al., 2009). Brown et al. (2006) stated that : « A preliminary assessment of snow water equivalent (SWE) rms error for the 23 models participating in SnowMIP showed that CLASS was one of the better single layer snow models included in the comparison. CLASS performance was comparable to the multi-layer CROCUS snowpack model in the evaluations carried out in this study. ». For hydrological applications, a 1-layer model could also provide good results for runoff simulations from spring snowmelt (see Frigon et al., 2007 and 2008 ; Music et al., 2009). We added a sentence in the introduction to put CLASS in the context of one layer versus multi-layer snow models:

Line 92-99: *Even if one layer snow models are less physically correct than multi-layered models (Brun et al., 1992; Bartelt et al., 2002; Bougamont et al., 2005, Ettema et al., 2010, Niwano et al., 2012) the SnowMIP experiment has shown that CLASS performed relatively well (Brown et al. 2006; Rutter et al., 2009). Furthermore, in climate and meteorological models, the errors in*

snow simulations are often related to the precipitation inputs. Hence, in these contexts, a more complex multi-layer model would not necessarily produce better results.

A multi-layer snow model could be important to resolve the diurnal temperature cycle within the snowpack. However, in the North during the winter, this cycle is in most cases, less pronounced than over temperate or mountainous regions (Leathers et al., 1998). During the day, snow cover affects the surface radiation balance through its high albedo. Incoming solar radiation that would normally be absorbed at the earth's surface is reflected, decreasing the daily maximum temperature. Using a linear gradient throughout a dry and relatively shallow snowpack (below about 1 to 1.5 m depth) appears thus as a satisfactorily hypothesis in most cases over Northern areas. Kondo and Yamazaki (1990) demonstrate that a linear temperature profile can be considered with a good approximation. The representation of the energy exchange across the upper portion of the snowpack is important mainly during the melting period (e.g. Franz et al., 2008). Thus, we think that it is realistic to reconstruct the snow layers for the SSA evolution estimates using a linear snow temperature gradient model. This point is discussed below (answer [R1-C7](#)).

The main objective of this paper is the development of a microwave brightness temperature (T_b) assimilation tool in a snow model (see modification added in the text below: [R1-C2](#) to clarify the objective of this paper). For such a retrieval approach, a single layer snow model appears as a strong advantage, because no hypotheses must be made on the adjustment of the several layers. It can be shown that different combinations of snow layer characteristics (depth, bulk density and grain size) could give the same T_b . Takala et al. (2011) recently developed a relatively powerful methodology (root mean square errors below 40 mm for cases when SWE<150 mm) for retrieving SWE from brightness temperature as a function of the characteristics of a single-layer snow pack (depth, bulk density and grain size).

We thus think that our approach, even if using a simpler 1-layer model, still remains a valuable approach for SWE estimates with the objective of using a satellite data assimilation scheme. Few sentences were added in that sense (see below: [R1-C2](#)).

We also added that this study also contribute to validate the SSA evolution model developed by Taillandier et al. (2007) using new sets of very accurate in-situ SSA measurements (at Col-de-Porte, France and over different Canadian sites).

Line 172-174: The study also provide an additional validation of the Taillandier et al. (2007) equations using new sets of accurate in-situ SSA measurements for different environment.

Essery, R., Morin, S., Lejeune, Y., Bauduin-Ménard, C., A comparison of 1701 snow models using observations from an alpine site, *Advances in Water Resources* (2013), doi: <http://dx.doi.org/10.1016/j.advwatres.2012.07.013>

Etchevers P., Martin E., Brown R., Fierz C. Lejeune Y., Bazile E., Boone A., Dai Y-J, Essery R., Fernandez A., Gusev Y., Jordan R., Koren V., Kowalczyck E., Nasonova R., Pyles D., Schlosser A., B.Shmakin A., Smirnova T. G., Strasser U., Versegny D., Yamazaki T., Yang Z.-L., SnowMiP, 2002: An intercomparison of snow models : first results. *Proceedings of the International Snow Science Workshop*, Penticton, Canada, 29 sep-4oct 2002, 8 p.

Franz et al., (2008)) KJ, Hogue T, Sorooshian S. Operational snow modeling: addressing the challenges of an energy balance model for National Weather Service forecasts. *J Hydrol* 2008;360(1–4):48 66, doi:[10.1016/j.jhydrol.2008.07.013](https://doi.org/10.1016/j.jhydrol.2008.07.013).

Frigon, A., Slivitzky, M., Caya, D. & Roy, R. (2007) Construction of hydro-climatic projections and first-order estimation of their associated uncertainties from regional climate model simulations: Application to water management of hydropower reservoirs in Quebec. *La Houille Blanche* **6**, 97–103. doi: [10.1051/lhb:2007089](https://doi.org/10.1051/lhb:2007089).

Frigon, A., Slivitzky, M. & Music, B. (2008) Comparaison du couvert de neige du Modèle régional canadien du climat (MRCC) avec des données sur grille à l'échelle des 21 bassins versants du Québec/Labrador. Available from Ouranos Consortium, 550 Sherbrooke St. West, 19th Floor, Montreal, QC H3A 1B9, Canada.

Music B., A. Frigon, M. Slivitzky, A. Musy, D. Caya, R. Roy (2009). Runoff modelling within the Canadian Regional Climate Model (CRCM): analysis over the Quebec/Labrador watersheds. International Association of hydrological Sciences (IAHS) Red Book series publ., 333, 183-194.

Takala, M., et al., Estimating northern hemisphere snow water equivalent for climate research through assimilation of space-borne radiometer data and ground-based measurements, Remote Sensing of Environment (2011), doi:10.1016/j.rse.2011.08.014

R1-C2: From what I understand, the motivation for developing this simple offline model is to be able to assimilate passive microwave brightness temperatures in CLASS to improve estimates of snow parameters. It is however unclear to me how this assimilation is going to be carried out. What quantities are assimilated and how will a single-layer snow model benefit from this assimilation? Plus, what is the specific role of SSA in the assimilation procedure? Perhaps, the authors have good reasons to use the CLASS model in particular, but this is not apparent in the manuscript.

We first developed more on the need of snow grain size in passive microwave applications in the first paragraph:

Line 58-63: Thus, snow grain size must be considered in microwave snow emission models (MSEM) for the retrieval of snow properties from satellite passive microwave observations (Langlois et al., 2012; Huang et al., 2012; Pardé et al., 2007). *Hence, in passive microwave applications, prior information such as snow grain size from a snowpack physical model is required for SWE estimates (Durand et al., 2012).*

It has been shown that SSA is reliable for passive microwave emission modeling. We added a paragraph in the introduction on the use of SSA in microwave snow emission model (MESM) for snow grain representation and its implication for assimilation:

Line 113-120: *Recent studies have shown that SSA offer a reliable representation of snow grains in the context of microwave emission snow modeling (MESM) (Roy et al., 2013, Montpetit et al., 2013, Brucker et al., 2010). These studies showed that a scaling factor on R_{opt} derived from SSA is required to well simulate brightness temperatures to palliate for oversimplification of snow grain representation in models. From a good representation of snow grain in snowpack microwave emission, it is possible to determinate which part of the signal is attributable to snow grain and which is attributable to other snow characteristic of interest like SWE.*

We also clarified that the model is developed for passive microwave applications at the end of the introduction:

Line 170-172: *The model is developed in a perspective of passive microwave applications for SWE retrievals at a large scale, but could be used for other applications like snow albedo estimates.*

In the discussion section, we added a new section on the conversion of SSA to R_{opt} in the perspective of implementation in microwave snow emission model (Not in this document to minimize the size: see Sect.4.3). R_{opt} shows good correspondence with measurements (see the

new Fig. 10). From these R_{opt} values, we also give an estimation of the generated error on brightness temperature (T_B) simulations with DMRT-ML (Picard et al., 2013).

We also added explanations on model application (Sect. 4.43), we developed on the use of CLASS-SSA for SWE retrievals from satellite-borne sensors. More specifically, we explained that MESM are used to retrieve snow parameters by minimizing simulated and measured T_B . From that, different approaches can be considered (inversion, assimilation)

Line 648-665: *The proposed model opens opportunities to couple CLASS with MESM for improving SWE estimates.* Data assimilation offers the potential to merge information on snow variables from satellite observations and land-surface model simulations. CLASS-SSA was developed mainly for passive microwave T_B assimilation in CLASS to improve estimates of snow parameters. The model employed in this study provides a good estimate or “first guess” of the snow grain size and a description of the snow type at a given time during the snow season. *Inversion approaches, where snow parameters (snow depth, snow density) are retrieved by minimizing the differences between simulated and measured brightness temperatures (Langlois et al., 2013; Vachon et al., 2010; Pardé et al., 2007) will benefit from SSA simulations by taking into account the important effect of snow metamorphism on the microwave signal.* The “first guess” could also be used as a state initial condition in more complex data assimilation system approaches (Touret et al., 2011 ; Durand et al., 2009; Reichle, 2008) because the grain-size parameterization is no longer the dominant source of uncertainty. Grain size can be considered as one of many sources of uncertainty, but with a known likely errors or variation. *Hence CLASS-SSA can be applied to improve SWE estimates at large scale from satellite-borne passive microwave information.*

Furthermore, we outline that CLASS is the operational land surface scheme of the Canadian GCM (at the Canadian Centre for Climate Modeling and Analysis) (Scinocca et al., 2008) and of the Canadian Regional Climate Model at Ouranos, Montréal (see Frigon et al., 2008, 2008; Music et al., 2009). We also added application of the model for hydrological and meteorological purposes in the Model application section in Sect 4.3.

Line 672-678: *The proposed methodology could also be implemented a hydrology land-surface scheme (HLSS) such as the one developed in the framework of Environment Canada's community environmental modeling system : MESH. MESH evolved from the WATCLASS model which links a hydrological routing model (WATFLOOD) (Pietroniro et al., 2006) to the Canadian Land Surface Scheme (CLASS). It is used as a basis for coupling horizontal surface hydrology (river routing) with both weather and climate atmospheric models (see discussion by Teutschbein and Seibert, 2010).*

On the other hand, the authors find good agreement between simulated and observed SSA at five study sites (except for wet snow conditions). Moreover, the authors are to be commended for their careful and extended discussion of potential model errors and implications of certain assumptions for the model results (section 4).

R1-C3: All in all, I get the impression that this model was developed with a rather specific application in mind. I think it is ok to publish the model separately from any (future) application, but then the model paper should set out with a clear motivation about the approach that is adopted. At the moment, I have no clear picture of why this project was carried out in the way it

was done. I would recommend to rewrite the manuscript in such a way that the motivation for this study becomes apparent to the reader, and in fact a central driver for the development of the model. This likely constitutes quite a major overhaul of the paper. On the other hand, after such a rewrite of the manuscript, it will serve as a perfect launching pad for future papers about the assimilation studies that will be carried out by it.

See R1-C2

R1-C4: Finally, I think that section 4 would benefit from some more structure, and perhaps some more subheaders to allow for easier reading.

We structured the discussion in four sections:

4.1 Sources of errors

4.2 Comparison with other models

4.3 R_{opt} analysis for MESM

4.4 Model applications

MINOR POINTS:

R1-C5 (page 5258 line 23): this part is not clear. What is meant by "In the case of the density correlation"?

We clarify :

Line 136-138: Jacobi et al. (2010) implemented these last two approaches in the Crocus multi-layer snow model (Brun et al., 1992). *With the model based on snow type and snow density (Domine et al., 2007), SSA was overestimated in surface snow, ...*

R1-C6 (page 5262 eq.4) : have the feeling that this equation is cast in an odd form. Why not
 $SSA(t+dt) = SSA(t) + \Delta SSA(t+dt)$?

We changed the term $\Delta SSA(t+\Delta t)$ for ΔSSA to avoid confusion. The form of the equation is correct. Equation (4) calculate a ΔSSA for a given timestep for given snow temperature and temperature gradient ($SSA_{initial}$ is constant). The calculated ΔSSA is then substracted to the model SSA. We clarified in the text:

Line 260-268: According to Eq. (2) and Eq (3) the rate of SSA decrease for a given time step (ΔSSA) depends on snow age, snow temperature, temperature gradient and $SSA_{initial}$. Based on Jacobi et al. (2010), we calculate the ΔSSA from Eq. (2) and (3) according to:

$$\Delta SSA = SSA(t + \Delta t) - SSA(t) \quad (4)$$

where Δt corresponds to the time step (0.5 hours). The ΔSSA is then subtracted from the model's previous SSA value.

R1-C7 (page 5269 line 8): Would it not have been possible to include a very simple thermodynamical scheme in the multi-layer SSA model to calculate a realistic temperature profile? This is one of the issues why I do not really understand why not a more complete multi-layer model was used. Thermodynamics is really only a diffusion equation plus a source term in case of refreezing: such an implementation would have taken away the need for the rather crude assumption of a linear temperature profile.

The developed approach is as simple as possible for easy operational implementation at the Canadian Centre for Climate Modelling and Analysis (CCCma). Furthermore, the difficulty in modeling the multi-layer thermodynamics in CLASS-SSA is to ensure a coherency with CLASS 1-layer thermodynamics. We then chose to consider a linear temperature profile which is a satisfactorily hypothesis in most cases over Northern area. We added this point in the Sect. 4.1:

Line 504-510: *However, in the North during winter, this diurnal temperature cycle is generally in most cases less pronounced than over temperate or mountainous regions (Leathers et al., 1998). Furthermore, using a linear gradient throughout a dry and relatively shallow snowpack (below about 1 to 1.5 m depth) appears thus as a satisfactorily hypothesis in most case over Northern areas. Kondo and Yamazaki (1990) demonstrate that a linear temperature profile can be can be successfully employed in a snowmelt model.*

Anonymous Referee #2

SUMMARY:

This paper presents the development of a model for snow surface area (SSA) implemented within the one-layer Canadian Land Surface Scheme (CLASS). The new model (called CLASS-SSA) is then used to simulate the temporal evolution of SSA at five sites with different climatic and snow regimes (alpine, Arctic and sub-Arctic). CLASS-SSA generally reproduces accurately the SSA in dry snow conditions (RMSE of 4.9 m² kg⁻¹ for the average SSA) but shows limitations in wet snow conditions. The paper concludes that CLASS-SSA may be used to validate satellite microwave brightness temperature assimilations along with other aspects or processes associated with snowpacks. The paper is generally well-written and scientifically sound although some aspects of the methodology are unclear. I recommend publication following some major revisions as outlined in my report.

GENERAL COMMENTS :

R2-C1: Some aspects of the CLASS-SSA model development remain unclear. For instance, the approach of adding a new snow layer every time snowfall occurs remains ambiguous. At what time interval are snowfalls and hence new snow layers established in CLASS-SSA? Is there a minimum depth of snow required to establish a new snow layer? What is the maximum number of snow layers possible in the model? If a multilayered structure for snow is used in CLASS-SSA, why not simulate the prognostic variables (snow water equivalent or SWE, snow depth, density and temperature) for each layer in the snowpack? Is the heat content of the snowpack also simulated in CLASS?

We clarify and explain the choice of the timestep in the CLASS-SSA model description (section 2.1):

Line 184-186: *CLASS has been designed to run at a time step of 30 minutes or less, to ensure numerical stability the modeled prognostic variables (Verseghy, 2009). In this study, CLASS is run at a time step of 30 minutes.*

In the same section, we also detailed on how new snow layers are added

Line 201-203: The CLASS-SSA model adds snow layer when snowfall occurs. *Consecutive precipitation (precipitation occurring during two or more consecutive time steps) is however considered as the same layer.* The fact that we considered a unique layer for consecutive precipitation limited the number of layers and also removes the effect of the precipitation input timestep (ex: NARR=3H and Col de Porte = 1H) on the number and depth of added layers.

We thus also clarify that NARR precipitation is on a timestep of three hours, while other NARR inputs are interpolated:

Line 350-352: *As NARR provide data on a three-hour time step, the variables were interpolated to a 30-minutes time step, except for precipitation which maintained a three-hours interval.*

We set the maximum number of layer at 200 in the code, which is sufficient in the context of seasonal snow. That number of layers could however easily be changed if needed. We do not think it worth mentioned it in the text as it does not affect the simulations.

Prognostic variables are not simulated to keep the model as simple as possible of eventual operational needs. Furthermore, for an “offline” model, the difficulty remains in keeping the coherency with the 1 layer CLASS model (same state variables). See also R1-C1 and R1-C7.

R2-C2: Further information on the simulations needs to be provided in the paper. For instance, what variables from the North American Regional Reanalysis (NARR) are used to force the CLASS simulations? Are the NARR data interpolated to each site of interest? What are the specific periods for which the model is run? What timestep is used in the simulations? What in situ meteorological variables at Col de Porte are used in the application of the model there?

In Section 2.1, we first clarified the needed input data in CLASS:

Line 187-191: In our case, the meteorological data used to drive the CLASS model (*precipitation rate, air temperature, wind speed, air humidity, and incoming shortwave and longwave radiation*) were derived from in-situ measurements or from the North American Regional Reanalysis (NARR) data (Mesinger et al., 2006) (*more details on driving data are provided in Sect. 2.2*).

In Section 2.2, where we described the input data used for each site, we clarify which and how the NARR data were used as well as the periods for which the model were run:

Line 346-355: NARR data (Mesinger et al., 2006) (*2 m air temperature and air humidity, 10 m wind speed, surface shortwave and longwave radiation*) were used to force the CLASS model at the first four sites. Langlois et al. (2009) show that the NARR product delivers reliable input data for snowpack modeling. *Forcing data from the NARR nearest neighbor pixel of each site was employed. As NARR provide data on a three-hour time step, the variables were interpolated to a 30 minutes time step, except for precipitation which maintained a 3-hours interval.* To initialize the starting conditions, the CLASS model was run for the year prior to the winter in this study: *from October 1 2009 to June 1 2011 at SIRENE and St-Romain; from October 1 2008 to June 1 2010 at Churchill.*

The CLASS time step was also clarified (see R2-C1)

We also added the meteorological variables used at Col de Porte and clarified the precipitation time interval:

At the Col de Porte site, meteorological variables (*air temperature, humidity, windspeed, precipitation and incoming shortwave and longwave radiation*) recorded with an hourly time resolution throughout the snow season of 2009-2010 (from 20 September 2009 to 10 May 2010) were interpolated to a 30-minute time-step and used to drive the CLASS model (see Morin et al, 2012b for more details on the Col de Porte meteorological data).

R2-C3: Are there time series of automated in situ snowpack properties (e.g., snow depth measurements) available for any of the five sites to validate the CLASS snowpack

simulations?

We added 2 figures (4 a and b) that show CLASS snow depth simulations compared with Ultrasonic measurements at SIRENE and Col de Porte:

Line 377-383: *Comparisons between continuous ultrasonic snow depth observations at SIRENE and Col de Porte also show that errors in diagnosing precipitation phase at the beginning of the snow season lead to an offset of snow depth (overestimation at SIRENE) (Fig. 4a). That sensitivity to precipitation phase in CLASS is also demonstrated in Langlois et al. (submitted). Figure 4b shows that underestimation of melt events at the beginning of the season also lead to positive offset in the snow depth.*

R2-C4: The discussion focuses on aspects of the CLASS-SSA model that may lead to errors in the simulation of SSA. Have the authors performed any sensitivity tests with CLASS-SSA to test the impacts on the simulations of, for example, a vertical gradient of temperature in snow or the use of an alternative forcing dataset? If the NARR data are used to drive the CLASS-SSA model at Col de Porte, how different are the SSA results?

A vertical gradient will have a major effect mainly at Churchill sites where temperature gradient is the main forcing phenomenon for SSA decrease. Fig. 4 shows that for a high $TG_{\text{threshold}}$, the RMSE rises at these sites because of SSA overestimation (metamorphism underestimation). In fact, a high $TG_{\text{threshold}}$ is similar to vertical temperature gradient.

The NARR data are not available at Col de Porte. The Col de Porte site is included because of the important SSA database available. However, as the objective of the paper is to drive CLASS-SSA at large scale, it was important to validate the model with input available at large scale (NARR). We specified that point in Sect 2.1.

Line 191-193: *The use of NARR data is motivated by the necessity to run the model at a large scale in the perspective of passive microwave space-borne applications.*

SPECIFIC COMMENTS

R2-C5 (p. 5260, line 25): Rephrase the repetitive text “model SWE with the SWE simulated”.

We changed the sentence:

Line 184-185: Thus, prior to each time step, a correction factor is applied to the SWE value of every snow layer to fit the multilayer model SWE *with the CLASS simulation*.

R2-C6: Why is the maximal snow density set to 300 kg m⁻³? This seems somewhat low, particularly for late season, wet snow or for possible ice layers within the snowpack.

As mentioned in the introduction, the maximum density is set the maximum density calculated by CLASS instead of 300 kg m⁻³. This had minor effect on SSA simulations but is more coherent with the CLASS model.

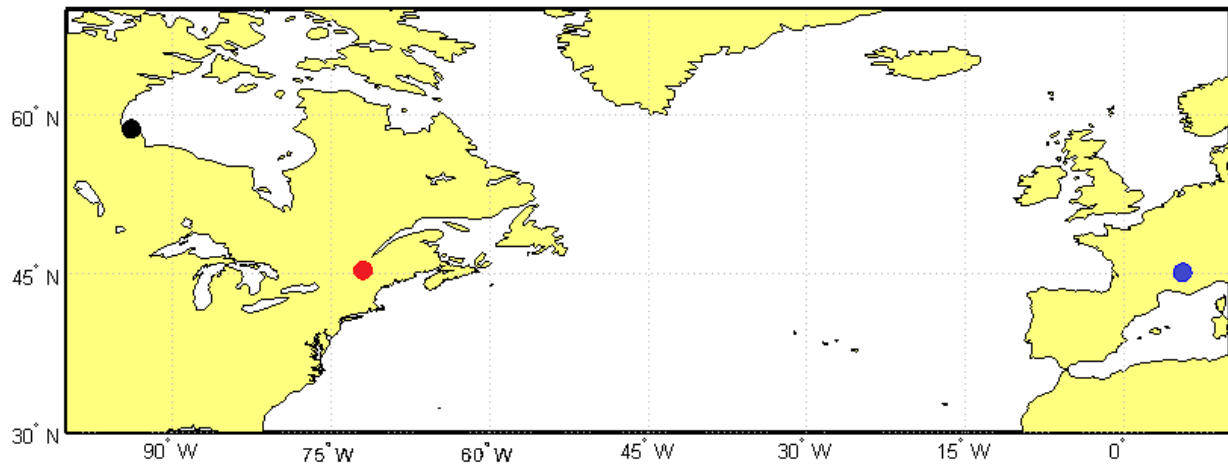
Line 223-226: On the other hand, if the sum of the snow depths for all the layers is higher than the snow depth simulated by CLASS, a correction is applied to all the layers, but the density of any layer cannot exceed maximum snow density estimated by CLASS.

R2-C7: A map identifying all of the study sites would be useful for readers unfamiliar with the regions of interest. In addition, providing a general climatology (e.g., for winter air temperature, snowfall, maximum snow accumulation, etc.) for each site would provide useful context to the reader.

In the site description section (Sect. 2.1), we added this climatological information for Churchill and Sherbrooke stations. For Col de Porte, we added the Morin et al. 2012b paper, which well described the site and the measurements. However, we did not add a map of the different sites (see below).

The sites were at the *Site interdisciplinaire de recherche en environnement extérieur* (SIRENE) experimental station at the Université de Sherbrooke (45.37 °N, 71.92 °W) and at St-Romain (45.45 °N, 71.02 °W; 80 km northeast of Sherbrooke) in Québec, Canada. *Mean January temperature at Sherbrooke is -11.9° C and the cumulated precipitations are 294.3 cm generally from November to April (National Climate Data, Environment Canada). Temperatures are generally slightly colder at St-Romain and accumulated snowfall higher because of the altitude (≈ 150 m over Sherbrooke).* Two other sites were located close to the Churchill Northern Study Centre (58.73 °N, 93.81 °W) in Manitoba, Canada: one in an arctic dry fen (tundra) and the other in a taiga environment (black spruce forest). *Churchill has a subarctic climate with mean January temperature of -26.7° C and cumulated snowfall of 191cm generally from October to May (National Climate Data, Environment Canada).* The data were collected during the Canadian CoReH2O Snow and Ice (CAN-CSI) campaign in the winter of 2010, which included four periods of intensive field sampling (January, February, March, and April). Further details of the campaign are provided in Derksen et al. (2012). The last is the meteorological research station Col de Porte (CDP; 45.17 °N, 5.46 °E), near Grenoble, France, in the French Alps at an elevation of 1325 m. Measurements were carried out during the winter of 2009-2010 (see Morin et al., 2012a and b for more details).

Below is the site location map. However, as we put the Latitude and the Longitude of each sites in the text we do not think that it worth adding that figure in the text. We did not add this map because this does not really bring critical supplementary information in the context of this paper. These sites can be easily found using Google Map!



R2-C8 (p. 5266, line 2): Should this be “and measured SWE”?

The given phenomena affect the SWE, which in turn impact snow depth. We clarify:

Line (374-377): However, other phenomena such as blowing snow and interception by vegetation could lead to differences between the simulated and measured SWE (*consequently snow depth as well*).

R2-C9 (p. 5279, line 11): Insert “Sensing” after “Remote”.

“IEEE T. Geosci. Remote” is the standard in The Cryosphere.

R2-C10 (Figure 3-5-6): For which year are the comparisons valid?

We specified the winter when snowpit measurements were made for each sites in the site description (Section 2.2). We think that it would overload the caption or/and the figures to put years of simulations.