# Responses to reviewer 2

We would like to thank the anonymous reviewer 2 for taking the time to proofread and provide insightful comments on the manuscript. We will do our best to address all comments in the revised version so as to improve the overall quality of the manuscript in line with the reviewer's recommendations. Our responses are reported below in blue.

This paper describes new modeling of Greenland snow and ice in the ORCHIDEE surface model. It is well written and pleasant to read. The work is substantial and certainly deserves to be published. The idea of using MAR as a forcing and comparing it to its outputs is very pertinent. Nevertheless, it seems to me that certain modeling choices need to be discussed and model validation a little improved.

## Major comments:

1 - For Figures 1 to 4, you give the raw distributions of MAR and each simulation. But to show differences would be also interesting. In addition, for the others (Figure 5 to 8), you give the differences, but not the raw distributions. As it is possible for you to have additional information, it would be nice to provide all the details, i.e. both the raw distributions and the differences for each variable analyzed (and thus for each figure 1 to 8).

We guess that the reviewer means Figures 2 to 5 instead of Figures 1 to 4, as Figure 1 is the flowchart showing how the new snow scheme works. Figures 2 to 4 display the raw distribution of runoff, sublimation and refreezing for MAR and the four ORCHIDEE simulations. Figure 5 represents the raw SMB distribution of MAR (panel a) and the SMB differences between the ORCHIDEE runs and MAR outputs (panels b, c, d and e). The choice of plotting the SMB differences was motivated by the fact that SMB differences with MAR were not clearly visible with the raw distributions. We recognize that this representation is a little confusing, especially as the title of the figure only refers to panels (b, c, d and e) and the previous Figures 2 to 4 show the raw spatial distributions of runoff, sublimation and refreezing. Therefore, in the revised manuscript, we will rearrange Figure 5 (MAR SMB) for better consistency and we will provide the raw SMB distributions for MAR and ORCHIDEE simulations in the Supplement. We will also add the spatial distributions of the differences in runoff, sublimation refreezing as well as the raw SMB distributions (see Fig. S1 to S4 at the end of this response).

Figures 6 and 8: The albedo differences are only for panels b, c, d, e (Fig. 6) and b, c, d, e, f (Fig.8). Figs 6a and 8a represent the summer albedo coming from the MAR simulation and MODIS retrievals respectively. Following your recommendations, we will add figures in the Supplement showing the raw distributions of the ORCHIDEE albedo (Fig. 5) and will change the titles of Fig. 6 and Fig. 8 to avoid confusion.

2 - By the way, regarding this validation, why not provide the PDF of each quantity, i.e. compare the MAR (or MODIS) PDF with the ORCHIDEE PDFs ? When you look at Figures 1 to 8, it's hard to see whether one version is much better than another. An objective method of comparison is missing. Comparing PDFs could be a solution but there is perhaps another ways.

Following your suggestion, we plotted the PDFs for SMB, runoff, sublimation, refreezing and albedo to see what additional information they could bring to the analysis.

As ORCHIDEE has been forced by MAR outputs, the simulated ORCHIDEE SMB is very close to the SMB MAR in the GrIS interior. In other words, SMB differences mainly occur at the periphery of the ice sheet due in great part to differences in runoff and to a lesser extent in refreezing. As a result, plotting the PDFs for SMB, runoff and refreezing does not lead to very clear conclusions, since the MAR and ORCHIDEE PDFs are very close to each other. To better highlight the differences between both models, we have chosen to keep only the grid points for which the altitude is less than 1600 m. This altitude threshold corresponds to the maximum extent of areas experiencing ablation in the OPT-12L experiment. It is important to note that model outputs for sublimation have not been filtered at 1600 m, as sublimation/condensation occurs over the entire Greenland ice sheet, hence all grid points have been considered.

These distributions show that negative SMB values in the STD-3L experiment are less frequent than in the MAR signal and, conversely, that positive values are more common (Figs. S6 and S7, in the Supplementary Section). Moreover, positive SMB values are greater in the STD-3L experiment than in MAR. The same remarks can be made about STD-12L and ASIM-12, despite the differences with MAR being less pronounced. By contrast, the MAR and OPT-12L distributions are almost similar as shown by the Cramer Von Mises (CVM, Anderson, 1962; see also Table S1) statistical test and the related p-value (= 0.11).

Regarding runoff, sublimation and refreezing, the peaks of the distributions in the STD-3L, STD-12L and ASIM-12L experiments are shifted towards values lower than in the MAR distribution. These results were expected as the amount of runoff and, therefore, of refreezing are smaller in ORCHIDEE-ICE. In the same way, negative values found in the sublimation distributions correspond to a larger amount of condensation. Conversely, the SMB, the runoff and sublimation distributions of the OPT-12L experiments have significant similarities with the corresponding MAR distributions.

However, only the SMB OPT-12L distribution has a p-value greater than 0.05. This can be explained by the fact that ORCHIDEE -ICE was forced by MAR outputs and, as such, part of the SMB signal (i.e., accumulation) comes from MAR even in the ablation areas whose elevation is most often less than 1600 m. Nevertheless, values of the CVM tests clearly show that scores are improved between the STD-3L and the OPT-12L experiments (see Table S1), despite the fact that the obtained p-values (almost zero) cannot allow to conclude about the similarities between MAR and ORCHIDEE-ICE distributions (except for the OPT-12L SMB). These results confirm our previous conclusions presented in the main text and deduced from Figures 2 to 5 and Table 2.

We agree with the fact that the original version of the manuscript lacked statistical tests. However, as these tests do not provide new insights, we plan to include the above comment, the PDF figures and the CVM tests (Table S1) in the Supplementary Section.

We will also provide the PDF for the albedo (see Fig. S8 and Table S2), although the ORCHIDEE-ICE distributions exhibit large differences with both the MAR and MODIS distributions, the former being shifted towards lower albedo values. An exception concerns ASIM-12L and MODIS. This result was expected as the albedo parameters used in ASIM-12L have been calibrated against MODIS retrievals.

Please note that the Supplementary Material can be found at the end of this reply.

Table S1: CVM test values for the SMB, runoff, sublimation and refreezing PDFs of the ORCHIDEE-ICE experiments compared to the corresponding MAR distribution. The corresponding p-values are reported in brackets.

| Experiments | SMB | Runoff | Sublimation | Refreezing |
|---|---|---|---|---|
| STD-3L | CVM = 25.09<br>[3.20 $10^{-9}$] | CVM = 34.25<br>[6.36 $10^{-9}$] | CVM = 170.62<br>[5.55 $10^{-8}$] | CVM:53.85<br>6.70 $10^{-9}$ |
| STD-12L | CVM = 12.73<br>[3.07 $10^{-9}$] | CVM = 15.81<br>[4.66 $10^{-9}$] | CVM = 162.01<br>[6.36 $10^{-9}$] | CVM = 22.82<br>[7.64 $10^{-9}$] |
| ASIM-12L | CVM = 6.16<br>1.37 $10^{-11}$ | CVM = 8.08<br>1.37 $10^{-11}$ | CVM = 368.87<br>1.23 $10^{-7}$ | CVM = 35.59<br>1.15 $10^{-8}$ |
| OPT-12L | **CVM = 0.33**<br>**[0.11]** | CVM = 4.60<br>[3.04 $10^{-11}$] | CVM = 41.41<br>[1.78 $10^{-8}$] | CVM = 13.01<br>[4.40 $10^{-9}$] |

Table S2: CVM test values and the related p-values for the ORCHIDEE-ICE albedo compared to MAR and MODIS. Last line: CVM and p-values for the MAR albedo distribution compared to the MODIS distribution.

| Experiments | Albedo vs MAR | Albedo vs MODIS |
|---|---|---|
| STD 3L | CVM = 363.18<br>[1.00 $10^{-7}$] | CVM = 327.89<br>[8.26 $10^{-8}$] |
| STD-12L | CVM = 362.59<br>[9.82 $10^{-8}$] | CVM = 326.92<br>[7.95 $10^{-8}$] |
| ASIM-12L | CVM = 122.77<br>[5.66 $10^{-8}$] | CVM = 4.16<br>[2.06 $10^{-10}$] |
| OPT-12L | CVM = 320.44<br>[1.10 $10^{-7}$] | CVM = 296.28<br>[7.24 $10^{-8}$] |
| MAR | | CVM = 138.06<br>[4.22 $10^{-8}$] |

3 - It seems that spatial statistics (correlation, etc.) are missing for each field analyzed. In other words, two or three objective criteria to determine whether in Figure 2 (for example) the OPT-12L spatial distribution (e) is better than the others compared to MAR (a). That is, each panel (b, c , d, e) should have its spatial correlation (spatial rmse, etc.) with MAR. The fact that, for example, the spatial distribution of OPT-3L refreezing (Figure 3e) is closer to MAR (Figure 3a) is not trivial to see with the naked eye. Anyway, I hope this comment is understandable. You lack objective statistical criteria in your assessment of all the figures showing comparisons of spatial distribution. The simple Table 2 obtained via a spatial average is not enough.

We agree with the reviewer on the fact that the comparison of the raw distributions is not always trivial. This is why we will add the scatter plots displayed below (see Fig. 1). The different points represent the daily values over the period 2000-2019 for each of the grid points. We believe that these new plots provide new insights and make the comments of our results more robust. In addition, we computed the areal mean biases (Tables 2 and 3) and the spatial RMSE (Table 2). Note that new information is provided in the new Table 2.

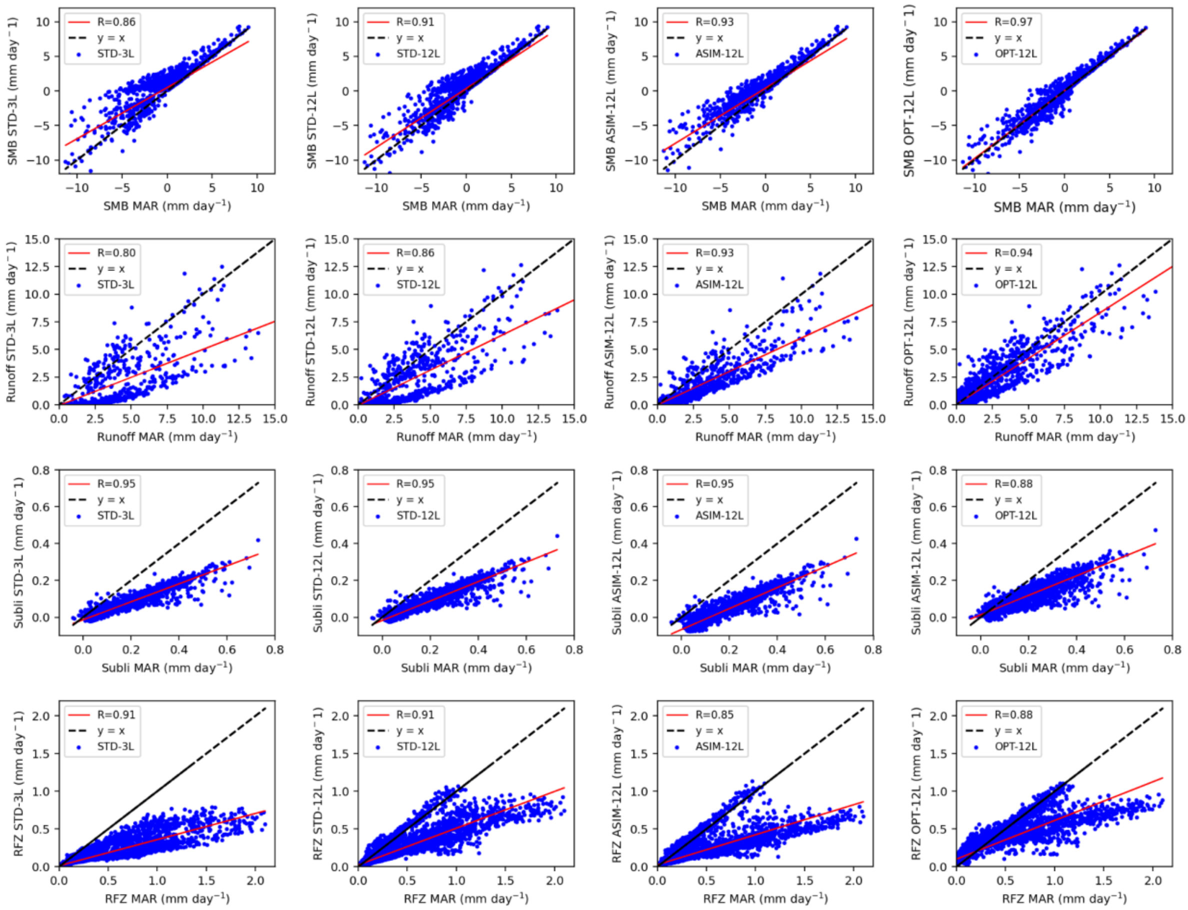

Figure 1: Representation of the simulated SMB (1st row), runoff (2nd row), sublimation (3rd row) and refreezing (4th row) simulated with ORCHIDEE-ICE as a function of the same MAR variables: STD-3L (1st column), STD-12L (2nd column), ASIM-12L (3rd column) and OPT-12L (4th column). The different points represent the daily values over the period 2000-2019 for each of the grid pointsThe regression line is displayed in red (R is the regression coefficient) and the line y = x is in black.

Table 2 (revised): Simulated values of SMB, runoff, sublimation and refreezing (in Gt $yr^{-1}$) integrated over the entire Greenland ice sheet and averaged over the 2000-2019 period (column 2) and corresponding values (in mm $day^{-1}$) of the root-mean-square error (RMSE, column 3), areal-mean bias (column 4) and spatial RMSE (column 5) with respect to MAR outputs.

| Experiments | SMB (Gt $yr^{-1}$) | RMSE (in mm $day^{-1}$) | Areal mean bias (in mm $day^{-1}$) | Spatial RMSE (in mm $day^{-1}$) |
|---|---|---|---|---|
| **MAR** | **286** | | | |
| STD-3L | 504 | 0.976 | 0.351 | 3.05 |
| STD-12L | 450 | 0.786 | 0.264 | 2.81 |
| ASIM-12L | 466 | 0.706 | 0.290 | 2.60 |
| **OPT-12L** | **301** | **0.464** | **0.024** | **2.53** |
| ERA5-12L | 352 | | | |
| Experiments | Runoff (Gt $yr^{-1}$) | RMSE (in mm $day^{-1}$) | Areal mean bias (in mm day-1) | Spatial RMSE (in mm $day^{-1}$) |
| **MAR** | **375** | | | |
| STD-3L | 152 | 1.107 | - 0.357 | 3.16. |
| STD-12L | 205 | 0.922 | - 0.272 | 2.90 |
| ASIM-12L | 217 | 0.829 | - 0.254 | 2.64 |
| **OPT-12L** | **336** | **0.592** | **-0.063** | **2.54** |
| ERA5-12L | 273 | | | |
| Experiments | Sublimation (Gt $yr^{-1}$) | RMSE (in mm $day^{-1}$) | Areal mean bias (in mm $day^{-1}$) | Spatial RMSE (in mm $day^{-1}$) |
| **MAR** | **82** | | | |
| STD-3L | 33 | 0.021 | - 0.081 | 0.20 |
| STD-12L | 33 | 0.026 | - 0.079 | 0.20 |
| ASIM-12L | 5 | 0.050 | - 0.124 | 0.23 |
| OPT-12L | **52** | **0.050** | **- 0.049** | **0.27** |
| ERA5-12L | 89 | | | |
| Experiments | Refreezing (Gt $yr^{-1}$) | RMSE (in mm $day^{-1}$) | Areal mean bias (in mm day-1) | Spatial RMSE (in mm $day^{-1}$) |
| **MAR** | **186** | | | |
| STD-3L | 72 | 0.336 | - 0.183 | 1.25 |
| STD-12L | 104 | 0.269 | -0.131 | 1.13 |
| ASIM-12L | 90 | 0.313 | - 0.155 | 1.18 |
| **OPT-12L** | **158** | **0.240** | **-0.046** | **1.32** |
| ERA5-12L | 141 | | | |

**Table 3 (revised):** Albedo RMSE values (column 1) and areal mean bias (column2) for the MAR, STD-3L, STD-12L, ASIM-12L and OPT-12L experiments compared to MODIS. Columns 3 and 4: same as columns 1 and 2 respectively for the ORCHIDEE-ICE experiments compared to MAR. All values are averaged over the 2000-2017 period.

| Experiments | RMSE (w.r.t MODIS) | Areal mean bias (w.r.t MODIS) | RMSE (w.r.t MAR) | Areal mean bias (w.r.t MAR) |
|---|---|---|---|---|
| MAR | 0.076 | - 0.005 | | |
| STD-3L | 0.098 | - 0.047 | 0.055 | - 0.042 |
| STD-12L | 0.097 | - 0.051 | 0.058 | -0.047 |
| OPTinit-12L | 0.072 | 0.001 | 0.051 | 0.006 |
| OPT-12L | 0.111 | - 0.008 | 0.092 | - 0.047 |

4 - The modeling choices made could have been discussed. In particular, the parametrization of snow albedo. Moreover, I don't understand why this new parametrization compared to Wang et al. (2013) is in section 2.1 (existing parm) and not rather in section 2.2 (new param). This new parametrization is a bit outdated today when there are more robust parametrizations in land surface models accounting for spectral albedo and solar absorption calculation as in CLM with SNICAR (Flanner and Zender 2006) or ISBA-ES (Decharme et al. 2016). What's more, this more robust representation already exists for ES (Decharme et al. 2016). Why not use it ? This choice is debatable in view of the importance of albedo on the SMB. Please discuss about that.

This parameterization of the snow albedo is used in the standard ORCHIDEE model since the paper of Wang et al. (2013), this is why it is in section 2.1. We will make it clearer in the revised version. We chose to drop the snow albedo ES parameterization after an exercise of intercomparison on sites and at a global scale against satellite data, which shows a better agreement with the simpler model, probably because it takes indirectly the vegetation impacts into account through the dependence of aging coefficients to plant functional types. We agree that over ice sheets, this choice is debatable, but we are presently carrying out developments in parallel around a new snow spectral albedo model accounting for aerosols (light absorbing particles). However, this new model (Krishnakumar et al., 2024) is still under evaluation and is not available for this work. Its implementation in our ORCHIDEE-ICE model is the subject of very near future work.

**Other comments:**

1 - Independent MAR observations of the Greenland SMB based on GRACE data could have been used in section 5.3 (Schlegel et al. 2016, Wang et al. 2024).

The GRACE space mission provides observations of variations in Earth gravity and therefore on variations in mass changes. For the Greenland ice sheet, mass changes result from SMB variations and from dynamic ice discharges. Determining mass changes related to ice dynamics requires the use of a dynamic ice sheet model forced, for example, by the simulated SMB. In fact, this is the approach followed by Schlegel et al (2016) who used the SMB computed with the MAR and RACMO models and the ISSM ice-sheet model. This is also the approach we intend to follow in the future within the framework of the coupling between the IPSL climate model and the GRISLI ice sheet model developed in our lab.

However, to address your comment and compare our results to observations independent from MAR, we used the 353 SMB measurements from the PROMICE (Programme for the Monitoring of the Greenland ice sheet) database (Machguth et al., 2016) and we computed the mean bias, the regression coefficient between PROMICE observations and model results and the RMSE. Results are reported in the table below.

As expected, MAR performs better than ORCHIDEE-ICE when compared with PROMICE. However, our results for the OPT-12L experiment are of the same order of magnitude as the MAR ones. Moreover, these results clearly indicate a strong reduction of both the bias and the RMSE in OPT-12L compared to the three other ORCHIDEE-ICE experiments.

These results will be discussed in Section 5.3 as requested.

**Table 4 (new)**: Comparison of the simulated SMB in MAR, STD–3L, STD-12L, ASIM-12L and OPT-12L with the SMB observations from the PROMICE network.

| Experiments | Bias (mWE) | Correlation | RMSE (mWE) |
|---|---|---|---|
| MAR | 0.14 | 0.86 | 0.82 |
| STD-3L | 0.94 | 0.67 | 1.70 |
| STD-12L | 0.68 | 0.73 | 1.43 |
| ASIM-12L | 0.74 | 0.75 | 1.33 |
| OPT-12L | 0.30 | 0.77 | 1.13 |

2 - From what I understand, some parameterizations that are in section 2.1 are new compared to Wang et al. (2013), and should therefore be in section 2.2.: snow fraction, albedo

As explained in our response to your Major Comment 4, this parameterization of the albedo has been modified since the paper of Wang et al. (2013). This is the same situation for snow fraction (see Eq. 6 in the manuscript). Both parameterizations were already implemented in the ORCHIDEE version used for CMIP6 simulations. This is why they are reported in Section 2.1 and not in Section 2.2 which only describes the new developments we made to apply the snow scheme to the ice sheets. In Section 2.1 (lines 134-135) we also specify: *"In this section, we provide an extensive description of the snow model including the main differences with the original ISBA-ES version (Wang et al., 2013)".*

3 - On the implementation of the ice layer (section 2.2.2), why didn't you use ES directly to model this. On line 293, you say that snow density is limited to 750kg/m³. But if you had raised this limit to 900 or 950kg/m³, it seems to me that all the "snow" equations converge to "ice" equations, at least that's what comes out when we compare equation 26 to 20, 27 to 21, etc. In theory, if ES is done right, snow that has reached a certain density should be able to become ice. It would then be sufficient to initialize the height and density of the snowpack accordingly (e.g. the last 6 layers with an ice density and a total height of 100m for example). I don't know if it's possible but this could be discussed.

The value of 750 kg $m^{-3}$ was chosen in the original ES version (and it has not been changed in ORCHIDEE-ICE) because compaction becomes slower above densities between 550 and 800 kg $m^{-3}$ (Maeno and Ebinuma, 1983). A critical value of 730 kg $m^{-3}$ has even been advanced by Maeno (1978). The slower compaction is due to the progressive disappearance of air spaces between the snow particles. When the snowpack attains such high densities, the transformation of firn into ice slows down dramatically. For example, Schwander and Stauffer (1984) report that in Greenland, the process does not exceed 80 years but ranges between ~20 and ~ 600 years in Antarctica, depending on the stations. As a result, to reduce the spin-up duration, we chose to prescribe ice layers. These are considered as an infinite reservoir and they are only used to compute the amount of the potential ice ablation.

It is also worth mentioning that at the edges of the ice sheet, snow can be fully removed through seasonal melting giving rise to bare ice. In turn, ice can melt if the energy is sufficient. In real life, ice loss is replaced by the upstream ice flow. However, in the absence of a dynamic ice sheet model, this ice flow is not accounted for.

4 - Line 629 - 632: I understand here that the improved runoff modeling in OPT-12L would not be due to bias compensation. Well, I'm really not sure. What I understand from looking at your results is that to improve runoff compared to MAR, you need to set an albedo lower than MAR (Figure 6e), which inevitably induces a surface temperature (and surely an internal temperature of the snowpack) that is too high (Figure 7e) compared to MAR. I have the impression that this is also what Figure (8f) reveals. So, to obtain the same runoff than MAR, ORCHIDEE-ICE have to simulate a lower albedo than MAR to capture more energy. If it is true, it is perhaps due to the non-representation of solar absorption by snow or a poor simulation of snowpack density.

We recognize that this sentence implies something that is not quite right. What we had in mind was that the RMSE decreases between STD-3L and OPT-12L. So, if there is error compensation, it decreases from one experiment to the next. According to our RMSE values for SMB, runoff, sublimation and refreezing, the OPT-12L experiment better compares to MAR than any other ORCHIDEE-ICE experiment. Other statistical tests you requested confirm this statement, at least for SMB and runoff. For refreezing, the OPT-12L spatial RMSE has the highest value although the areal-mean bias has the lowest one (see new Table 2). In the same way, the regression line coefficient of the sublimation (see previous scatter plots) reflects a larger mismatch with MAR. In these cases, we agree on the fact that there is actually "compensation of errors". As these new statistical tests will be presented in the revised manuscript, these limitations will be also mentioned in the Discussion section. To avoid confusion, we will also remove the lines 630-631 from the original version stating that "the improvement in the runoff computation over the whole of the GrIS does not result from compensation biases".

On the other hand, we acknowledge that our model has missing mechanisms such as the transmission of solar absorption which leads to a too high temperature of the snowpack and biases in the snow density (see next response). We are fully aware of these limitations and we propose to extend the discussion to mention these aspects. However, we would like to remind you that our primary objective in this paper was to present the state-of-the-art performance of our model and its ability to represent the SMB and its components under prescribed conditions (i.e., prescribed albedo parameters leading to lower albedo). As mentioned above, a more physically based albedo scheme is currently under development and will be implemented in ORCHIDEE-ICE in the near future.

5 - This last remark also underlines the fact that other important variables concerning the internal properties of the snowpack could be shown/analyzed, such as the temperature and density of the simulated snowpack compared with MAR, etc. This would enable a better understanding of the processes involved in the improvements related to one or another process claimed by the authors.

As you pointed out, ignoring solar absorption leads to a warmer snowpack (in ORCHIDEE-ICE) compared to MAR. However, this is only true for temperatures below ~ -10°C as shown in Figure 2 below. Indeed, temperatures above this threshold present a relatively good agreement with the simulated MAR temperatures at 1 and 2 meter-depth. As a result, runoff should not be so much impacted. Moreover, a more surprising result is that the temperature profile does not seem to be too much affected by the choice of the albedo parameterization (i.e., values of the albedo parameters), thereby limiting the impact on runoff.

Warmer temperatures in a given snowpack may modify the snow microstructure and the water vapor transfer between snow particles, as well as snow density. This process is parameterized in the snow model through the second term of Eq. (17). However, it becomes rapidly negligible for density above 150 kg $m^{-3}$. It is therefore likely that the effect of this parameterization on the albedo is not very significant at depths above 1 m as snow density exceeds 300 kg $m^{-3}$ (see Figure 2). Nevertheless, in a future study, it should be interesting to investigate thoroughly the extent to which snow temperature is affected by the parameterization of water vapor transfer.

The differences in the simulated densities between MAR and ORCHIDEE are mainly related to high values simulated by MAR (Fig. 3). For example, snow density at 2 m depth does not exceed 600 kg $m^{-3}$ in OPT-12L, while it reaches values up to 800 kg $m^{-3}$ in MAR. Similar remarks can be made for 5 meter-depth (not shown). This result can be explained by the choice of a lower maximum snow density value used in ORCHIDEE-ICE (750 kg $m^{-3}$) and by the fact that snow metamorphism is not explicitly represented in our snow model. This limitation will be pointed out in the revised manuscript.

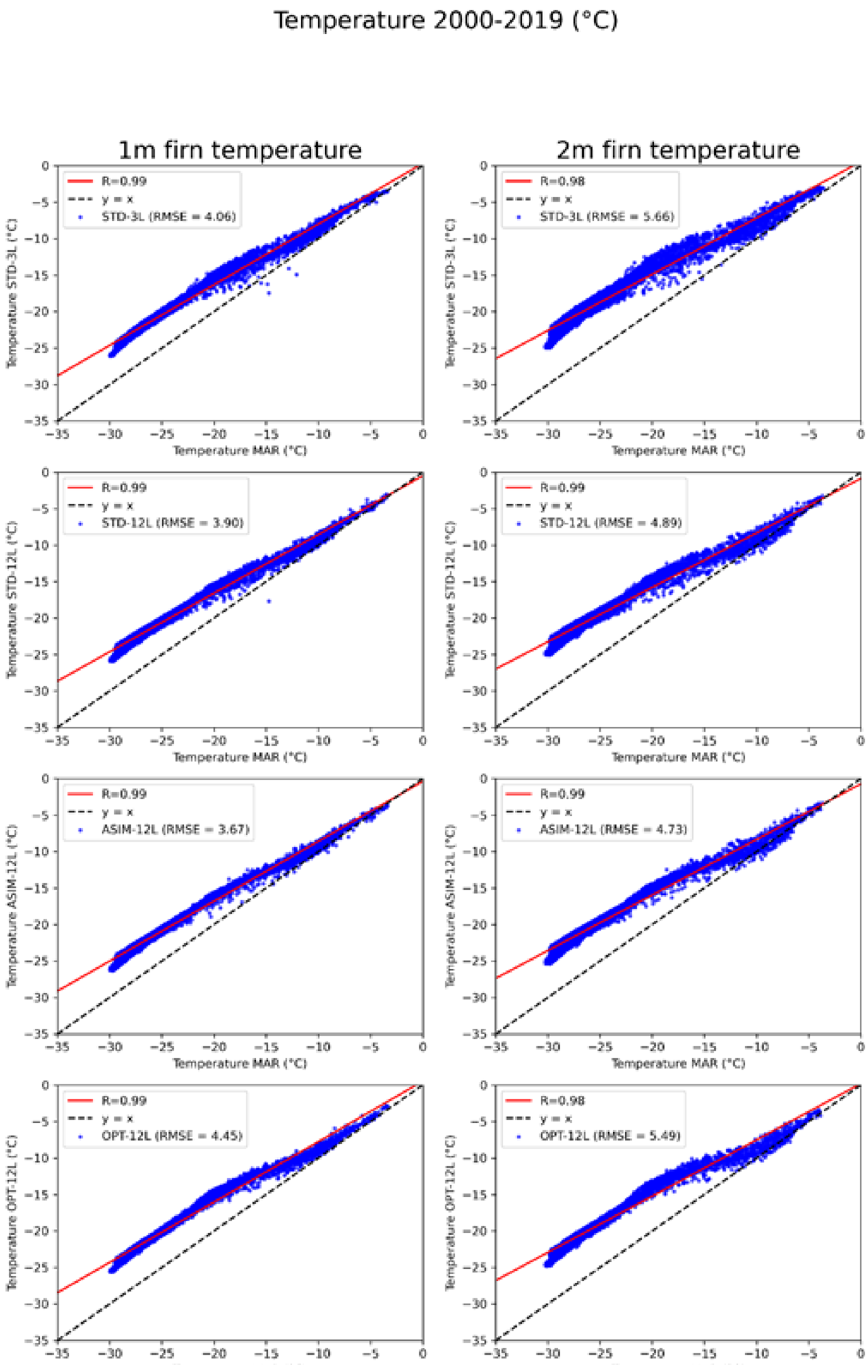


Figure 2: Representation of the ORCHIDEE-ICE simulated snow temperatures at one-meter (left) and two-meter depth (right) as a function of MAR. The different points represent the daily values over the period 2000-2019 for each of the grid points. The regression line is displayed in red (R is the regression coefficient) and the line y = x is in black.

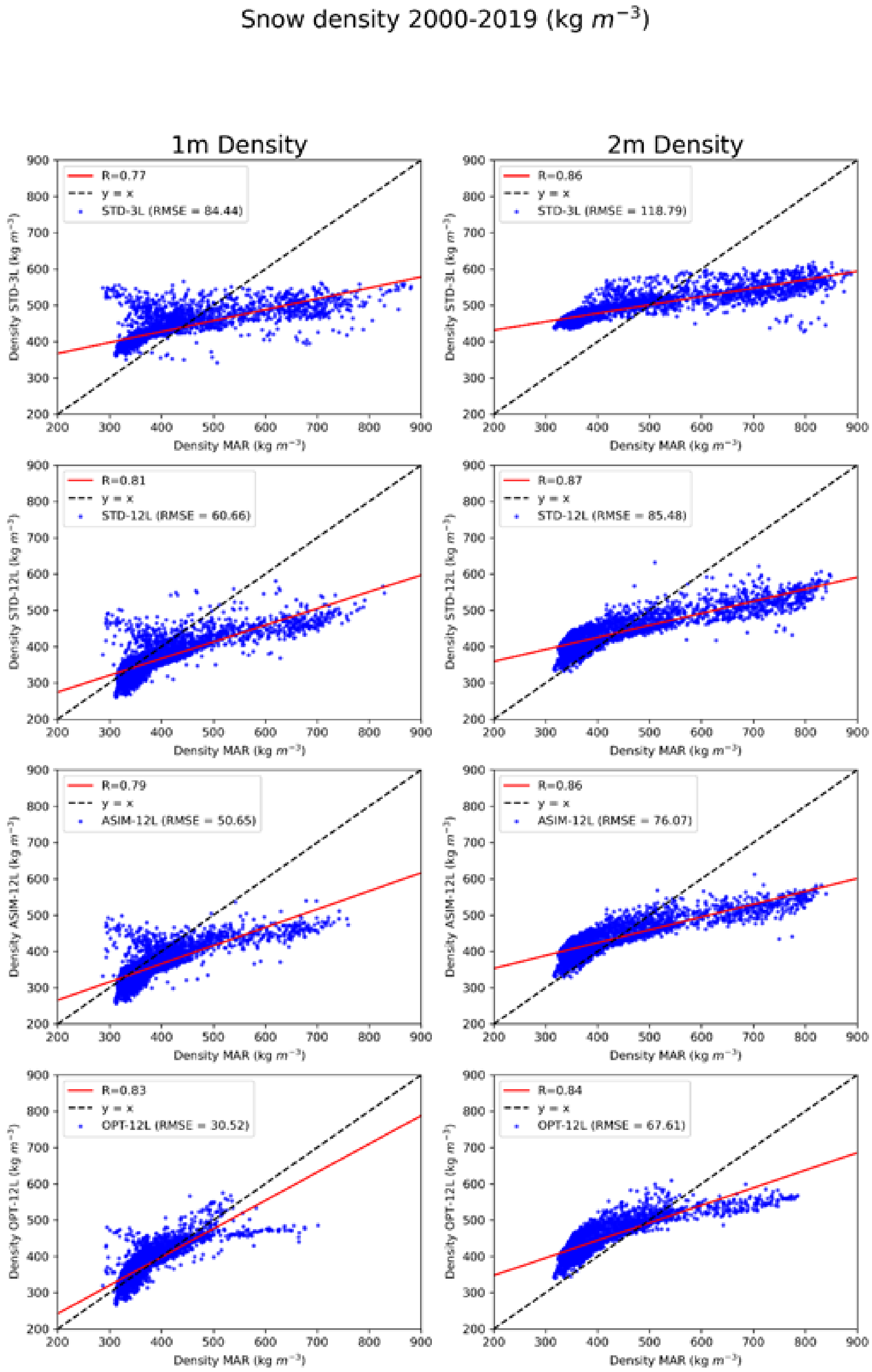


Figure 3: Representation of the ORCHIDEE-ICE simulated snow densities at one-meter (left) and two-meter depth (right) as a function of MAR. The different points represent the daily values over the period 2000-2019 for each of the grid points. The regression line is displayed in red (R is the regression coefficient) and the line y = x is in black.

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# Supplementary Materials

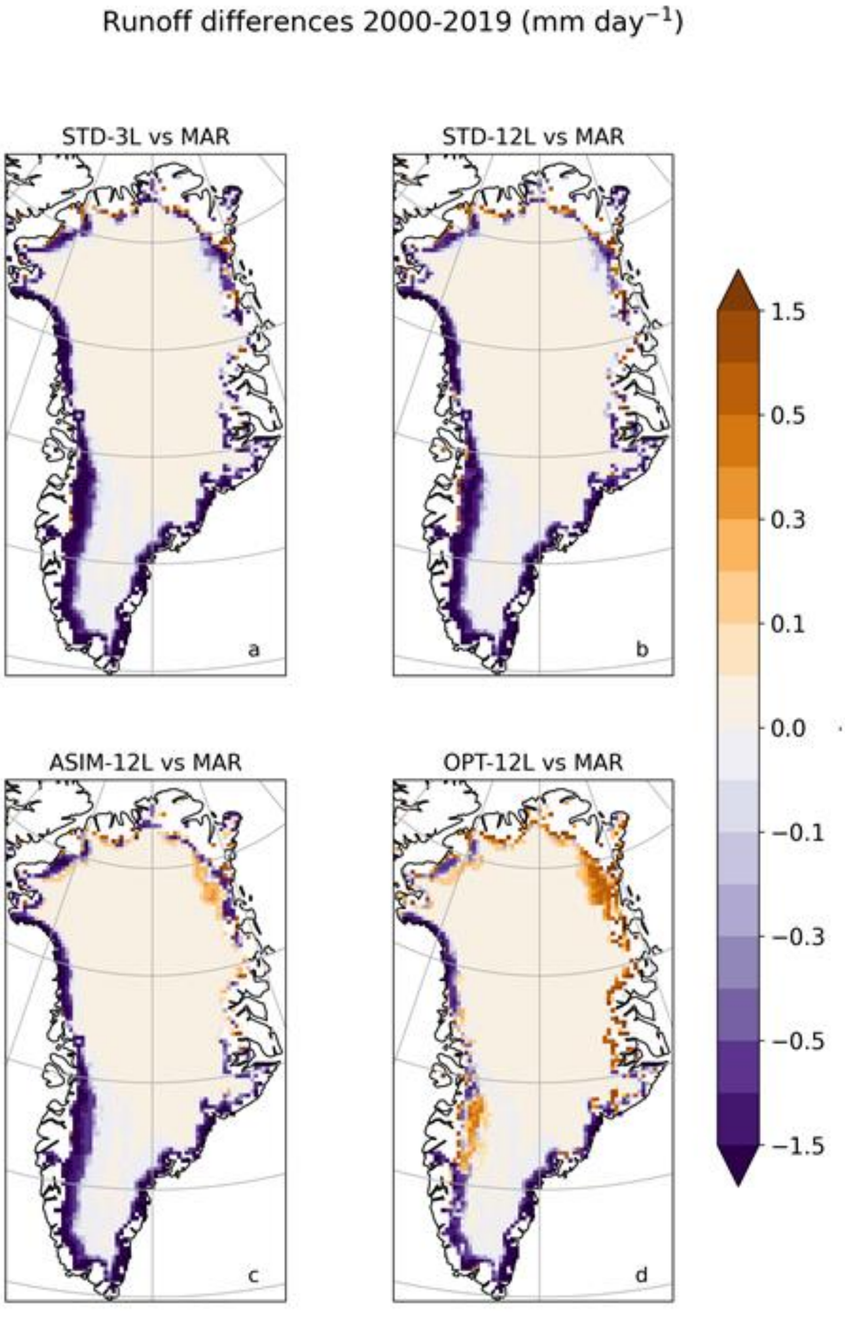


Figure S1: Spatial distribution of the differences in the simulated runoff (in mm day$^{-1}$) between MAR and and the ORCHIDEE-ICE experiments: STD-3L (a), STD-12L (b), ASIM-12L (c) and OPT-12L (d).

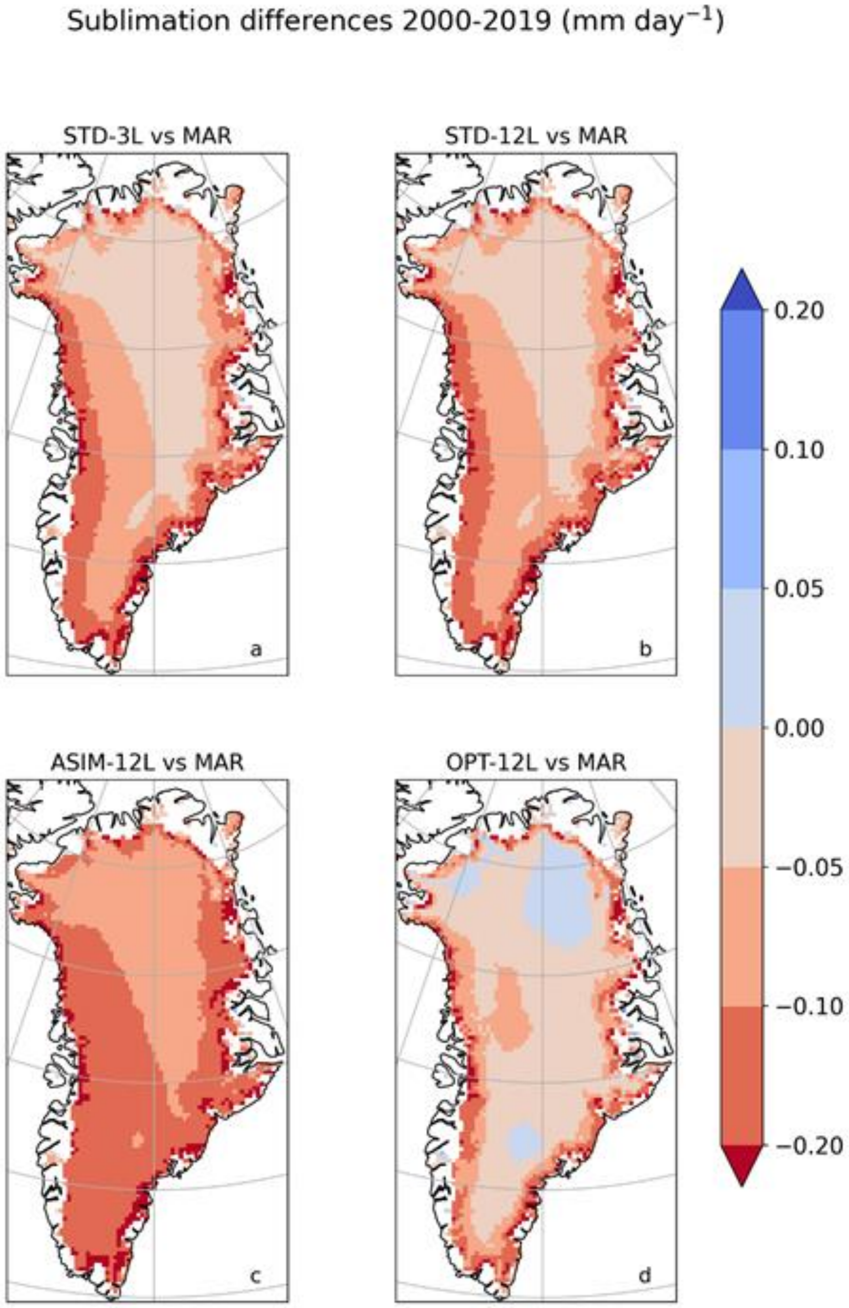


Figure S2: Same as Figure S1 for sublimation.

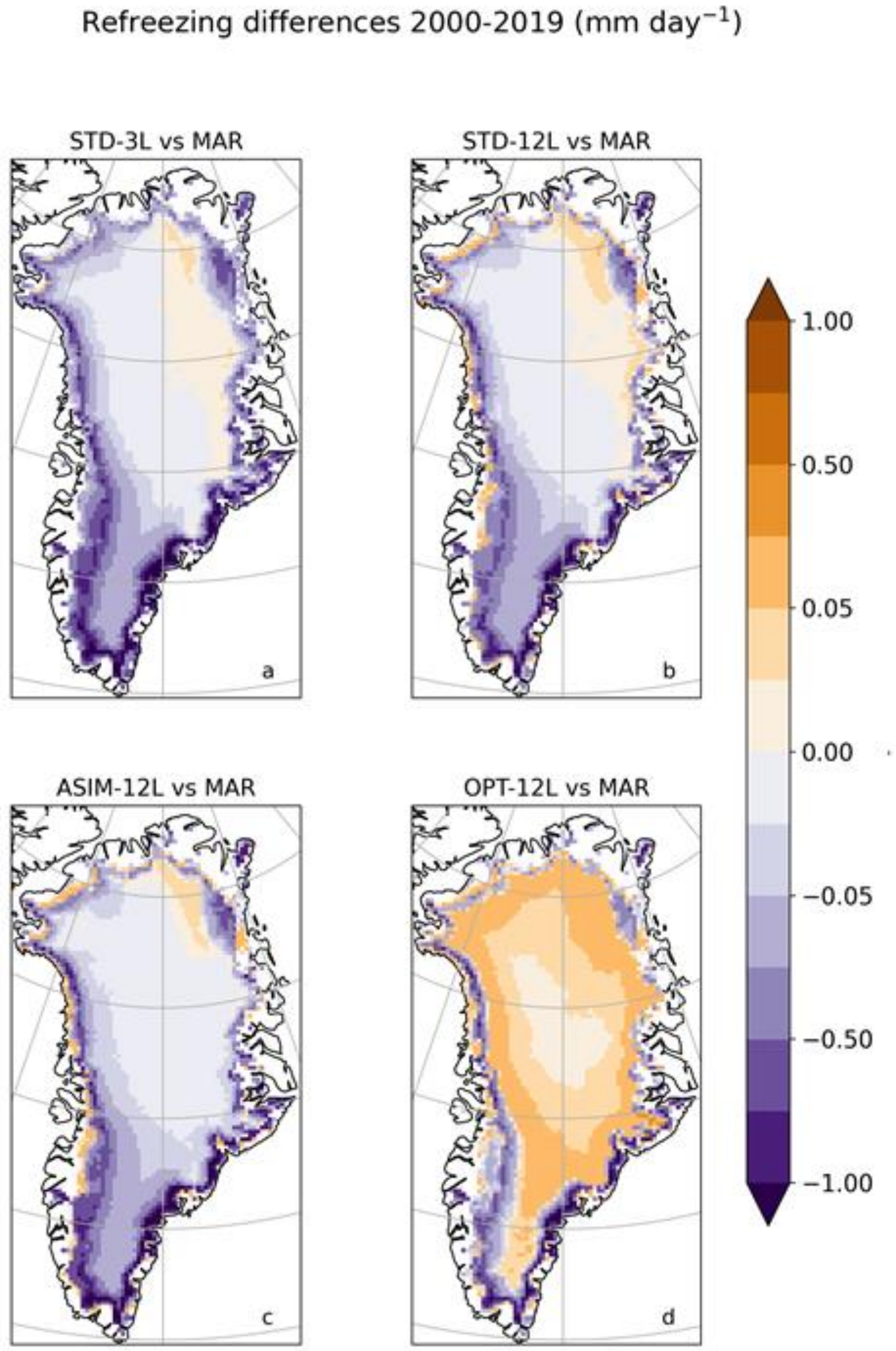


Figure S3: Same as Figure S1 for refreezing.

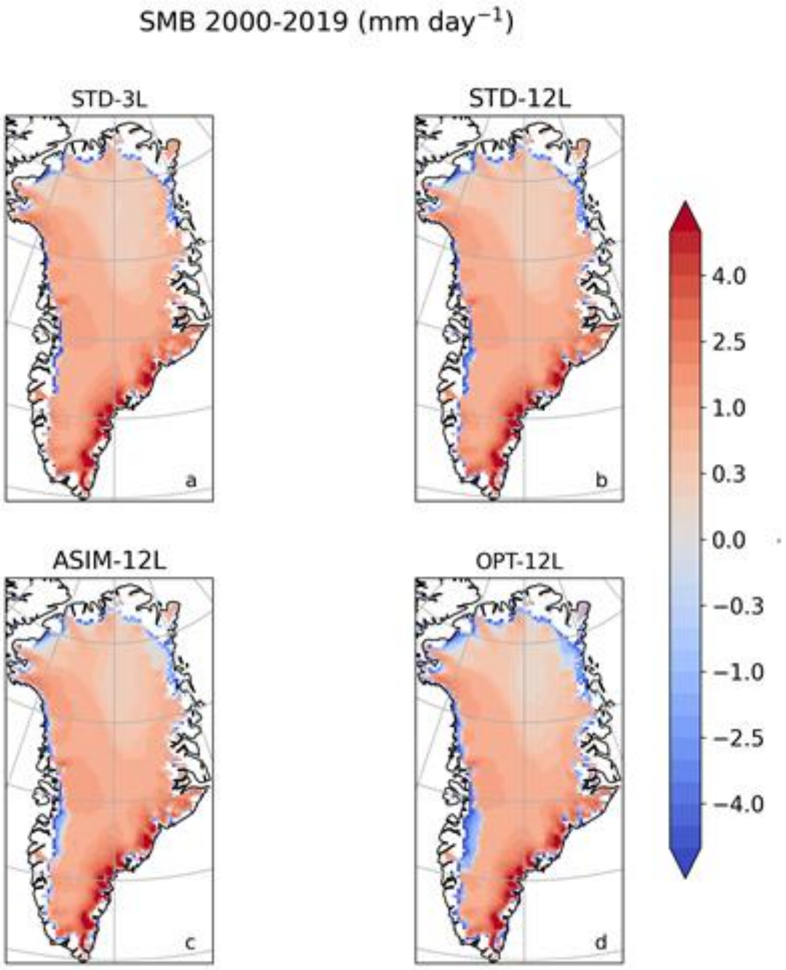


Figure S4: Spatial distribution of the simulated SMB (in mm day$^{-1}$) averaged over the 2000-2019 period for the STD-13L (a), STD-12L (b), ASIM-12L (b) and OPT-12L experiments.

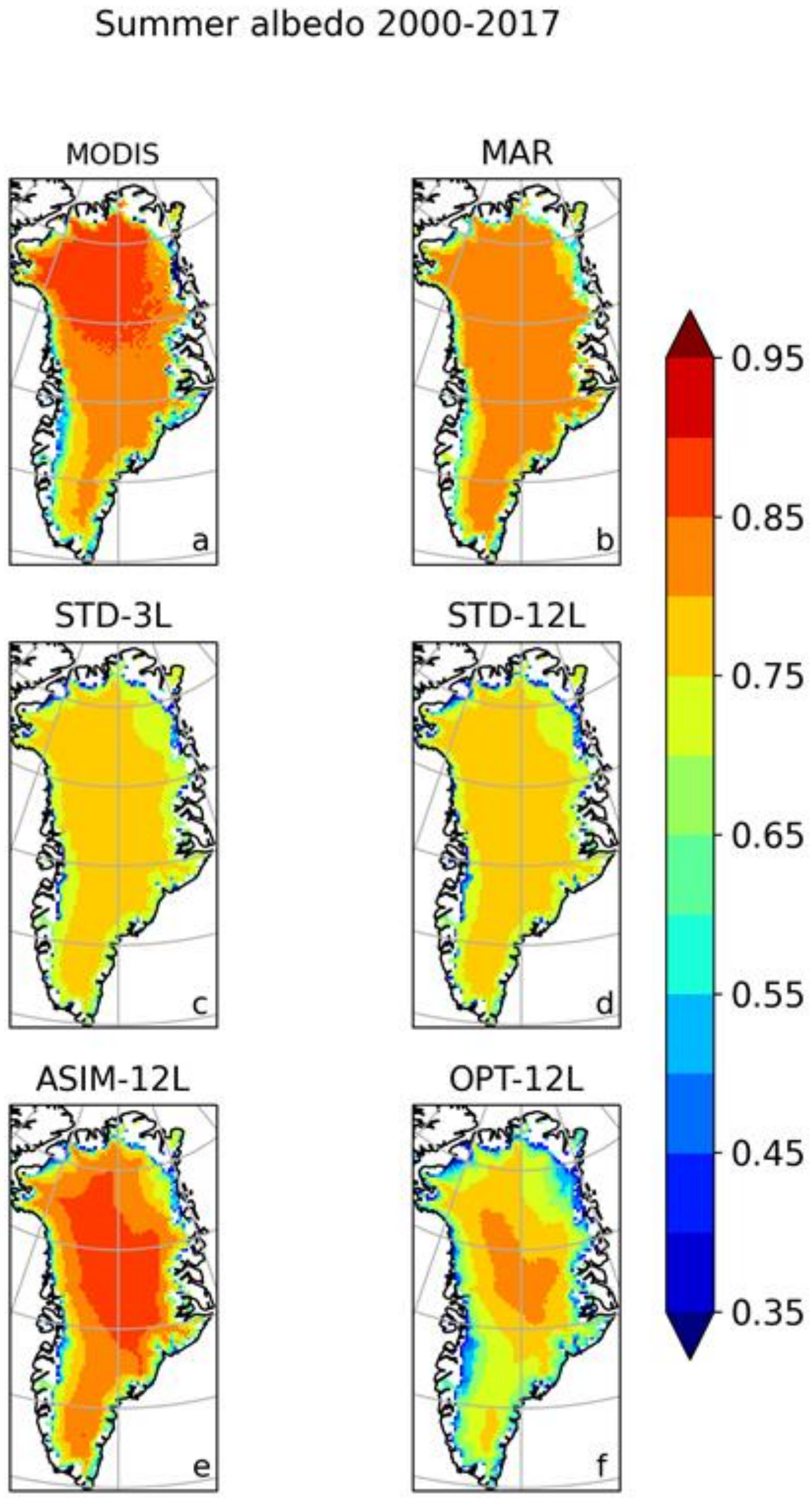


Figure S5: Spatial distribution of the summer (June-July-August) averaged over the 2000-2017 period for MODIS (a), MAR (b), STD-3L (c), STD-12L (d), ASIM-12L (e) and OPT-12L (f).

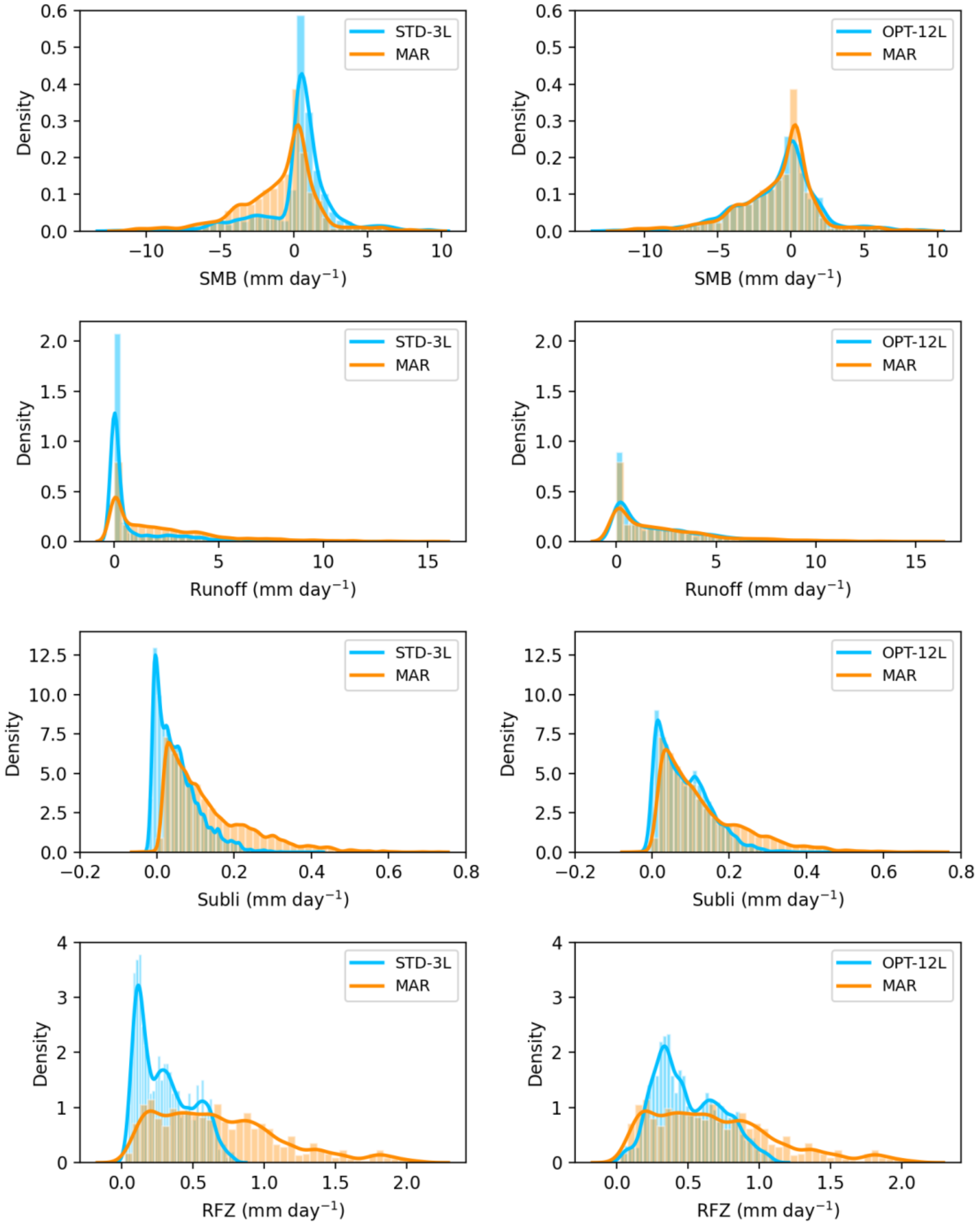


Figure S6: Probability density function of the STD-3L and OPT-12L experiments compared to the MAR distributions for SMB, runoff, sublimation and refreezing.

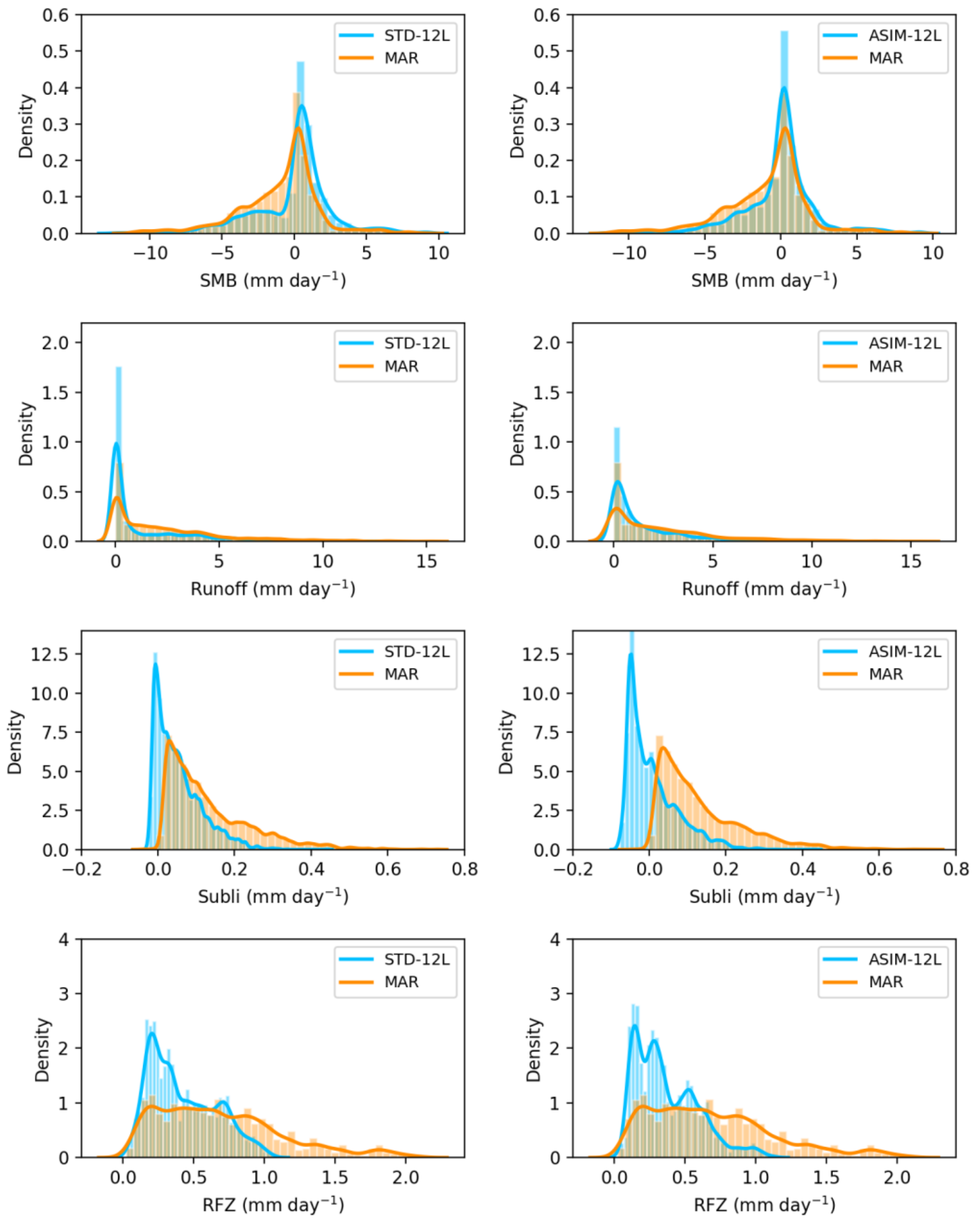


Figure S7: Probability density function of the STD-12L and ASIM-12L experiments compared to the MAR distributions for SMB, runoff, sublimation and refreezing.

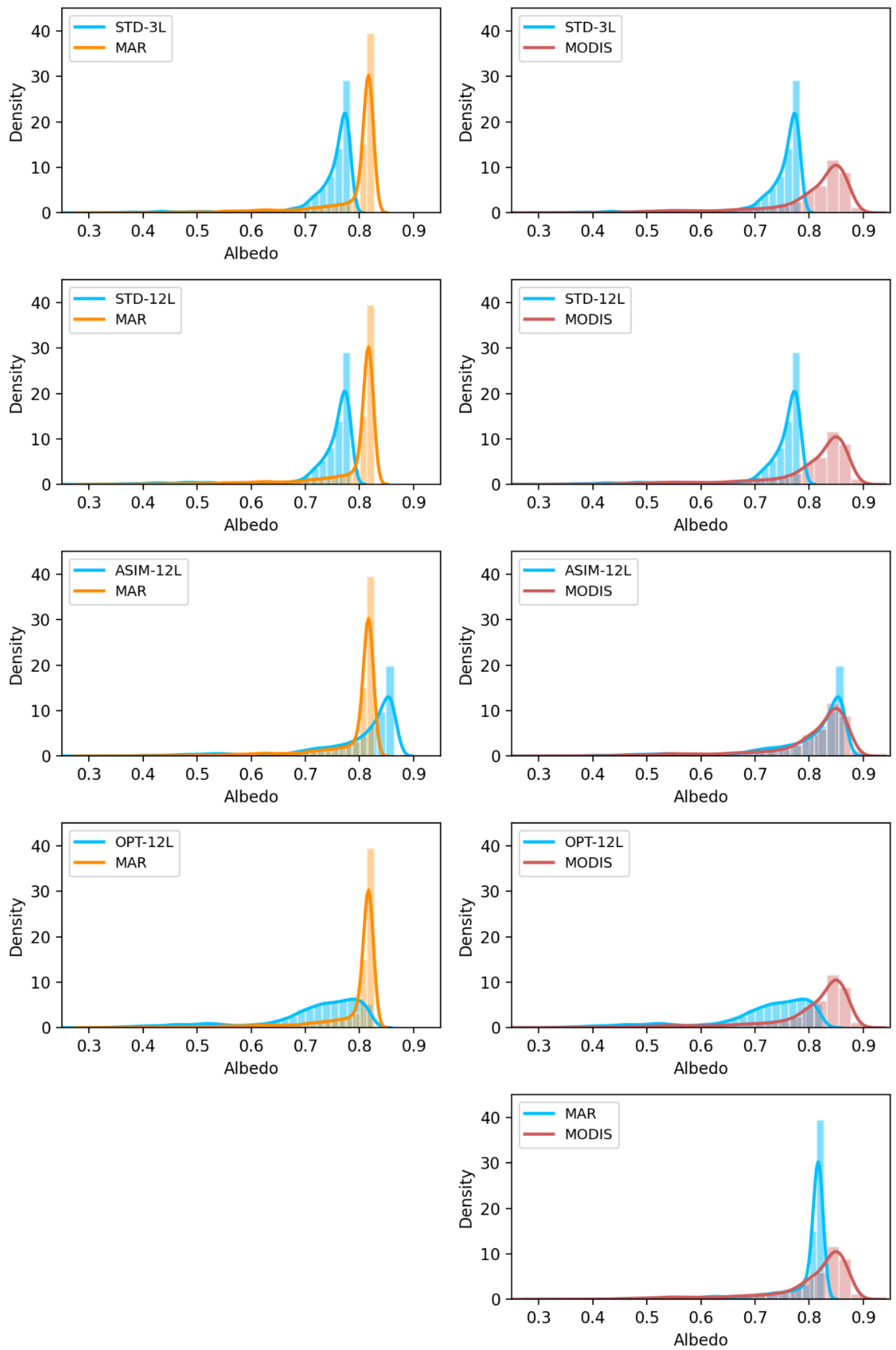


Figure S8: Probability density function for the simulated albedo of the ORCHIDEE-ICE experiments compared to MAR.