Supplement of

Modelling snowpack on ice surfaces with the ORCHIDEE land surface model: Application to the Greenland ice sheet

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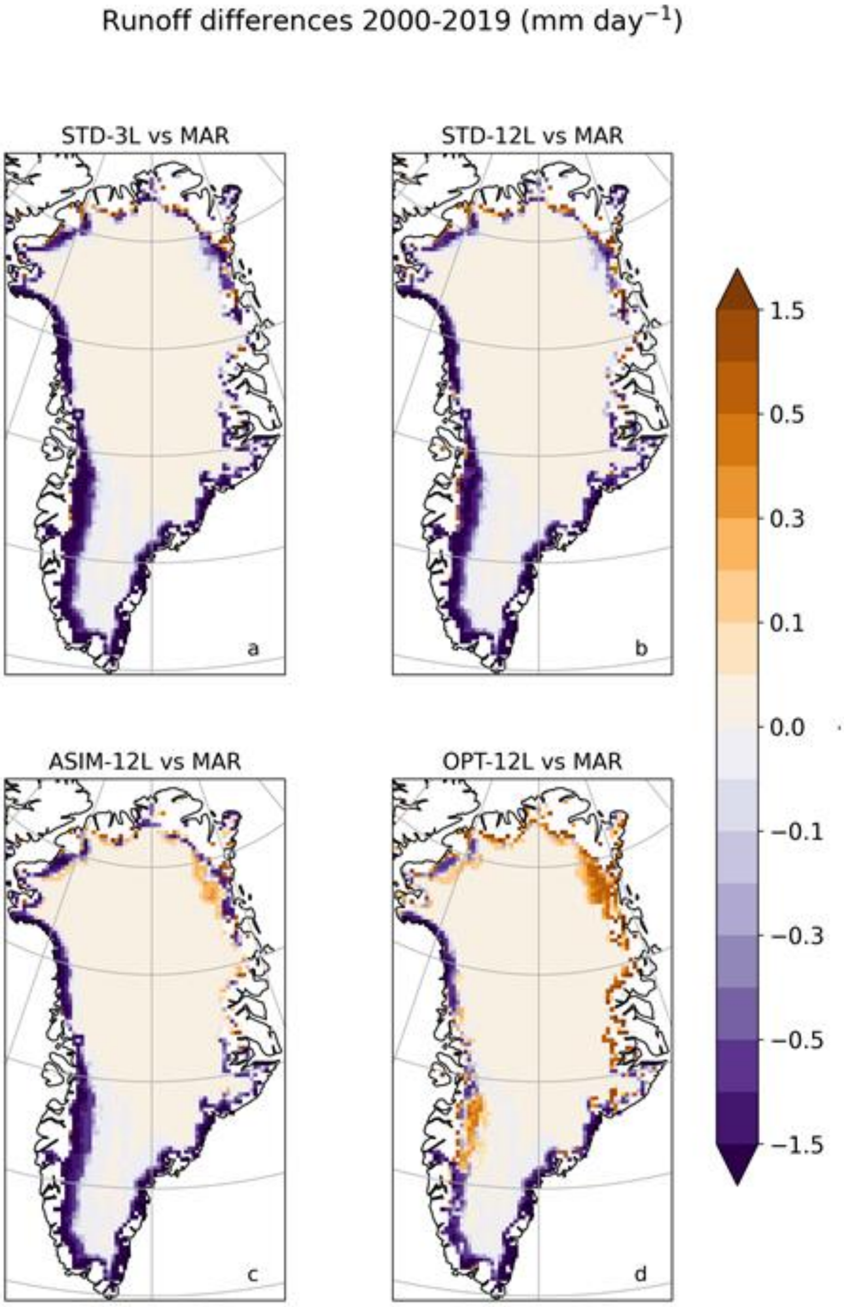

Figure S1: Spatial distributions of the differences in the simulated runoff (in mm day^{-1}) between MAR and the ORCHIDEE-ICE experiments: STD-3L (a), STD-12L (b), ASIM-12L (c) and OPT-12L (d).

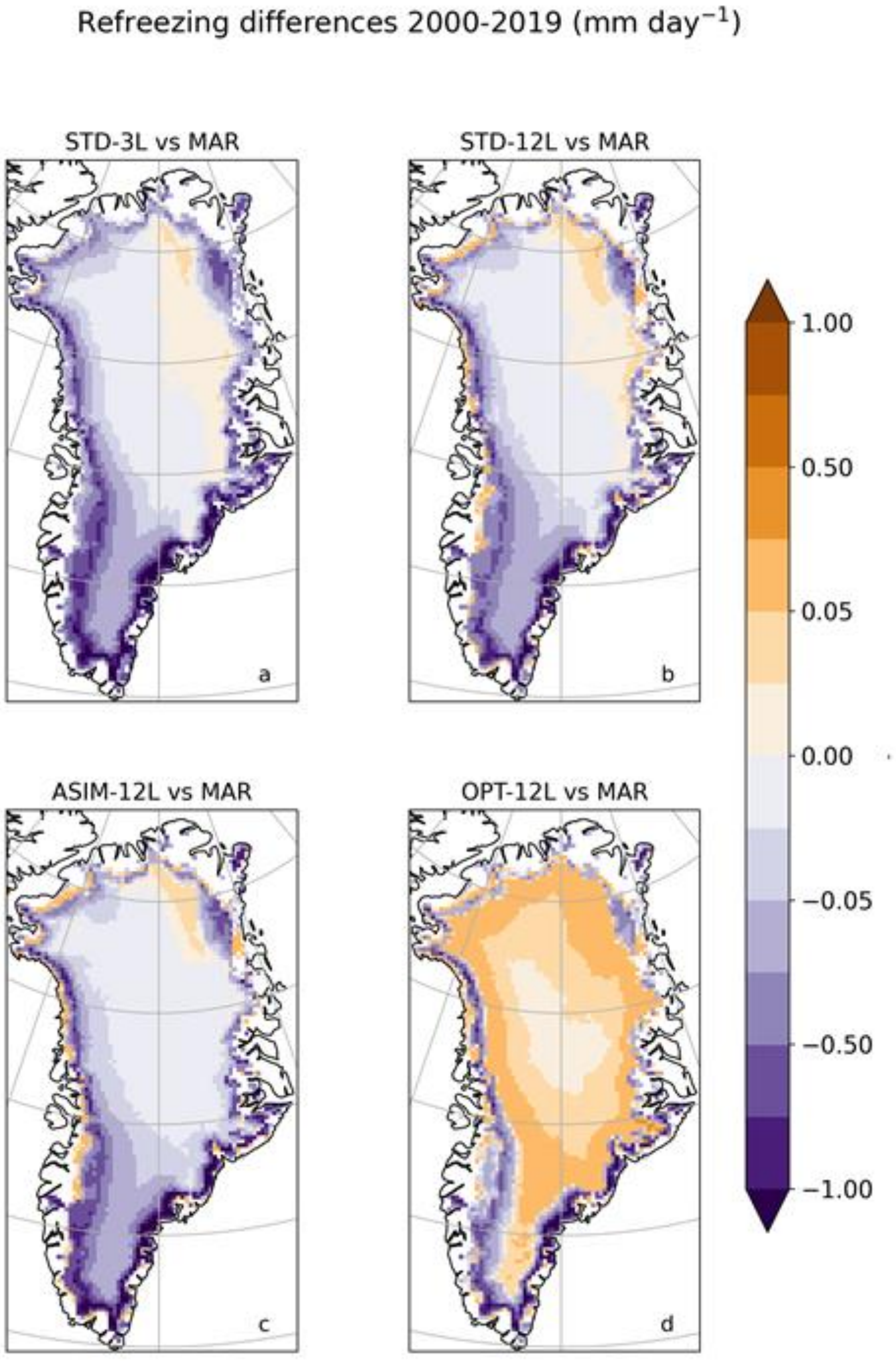

Figure S2: Same as Figure S1 for refreezing.

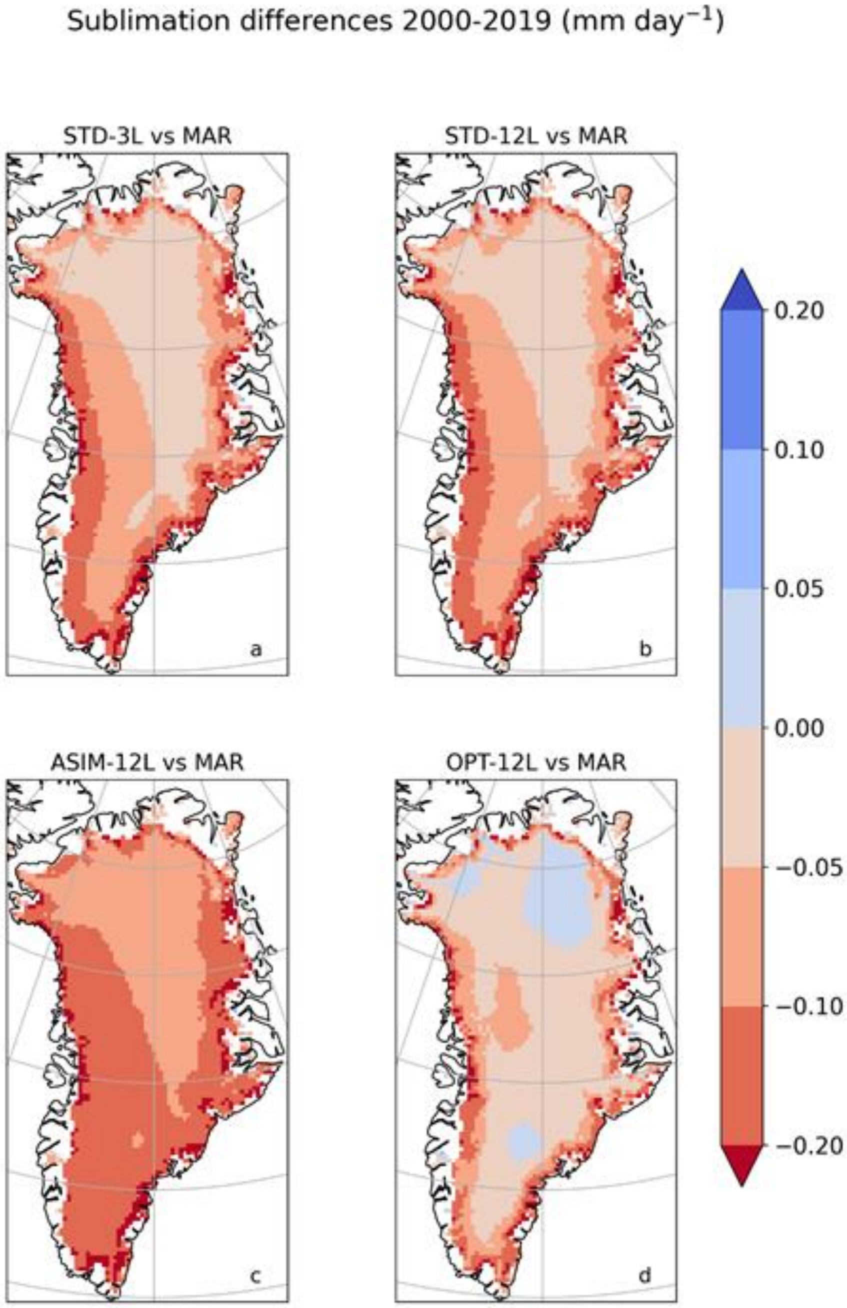

Figure S3: Same as Figure S1 for sublimation.

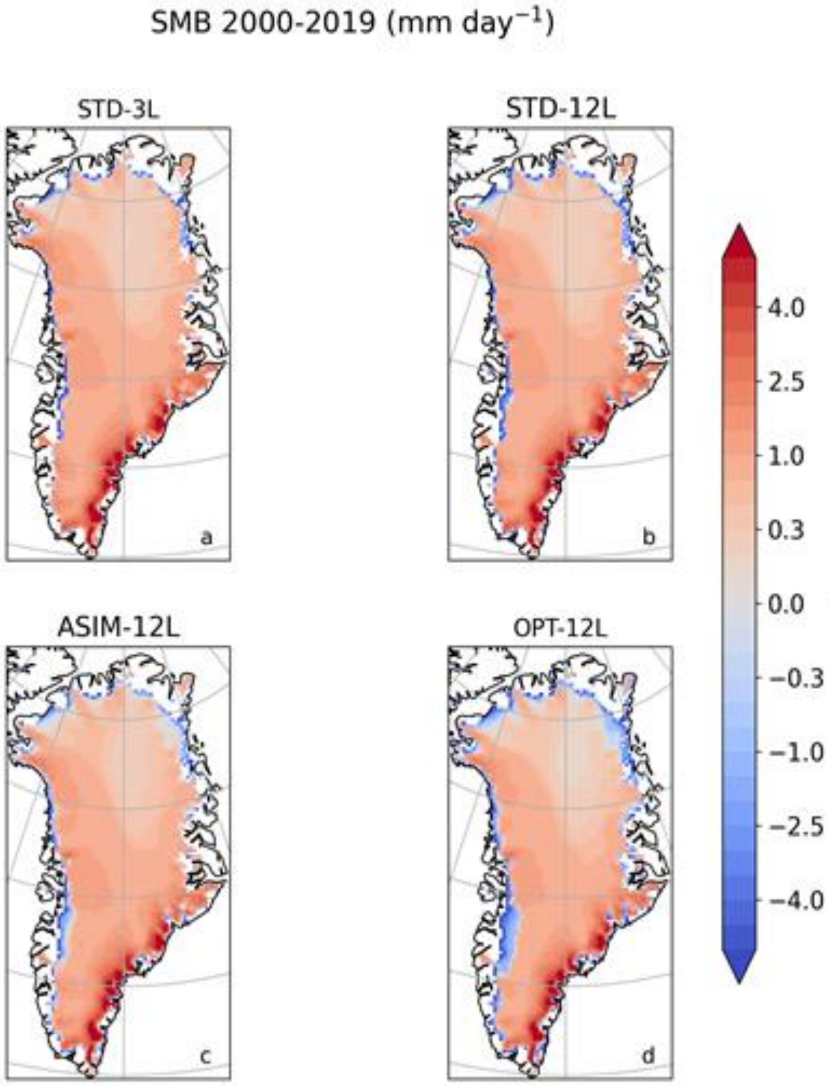

Figure S4: Spatial distribution of the simulated SMB (in mm day^{-1}) averaged over the 2000-2019 period for the STD-13L (a), STD-12L (b), ASIM-12L (b) and OPT-12L experiments.

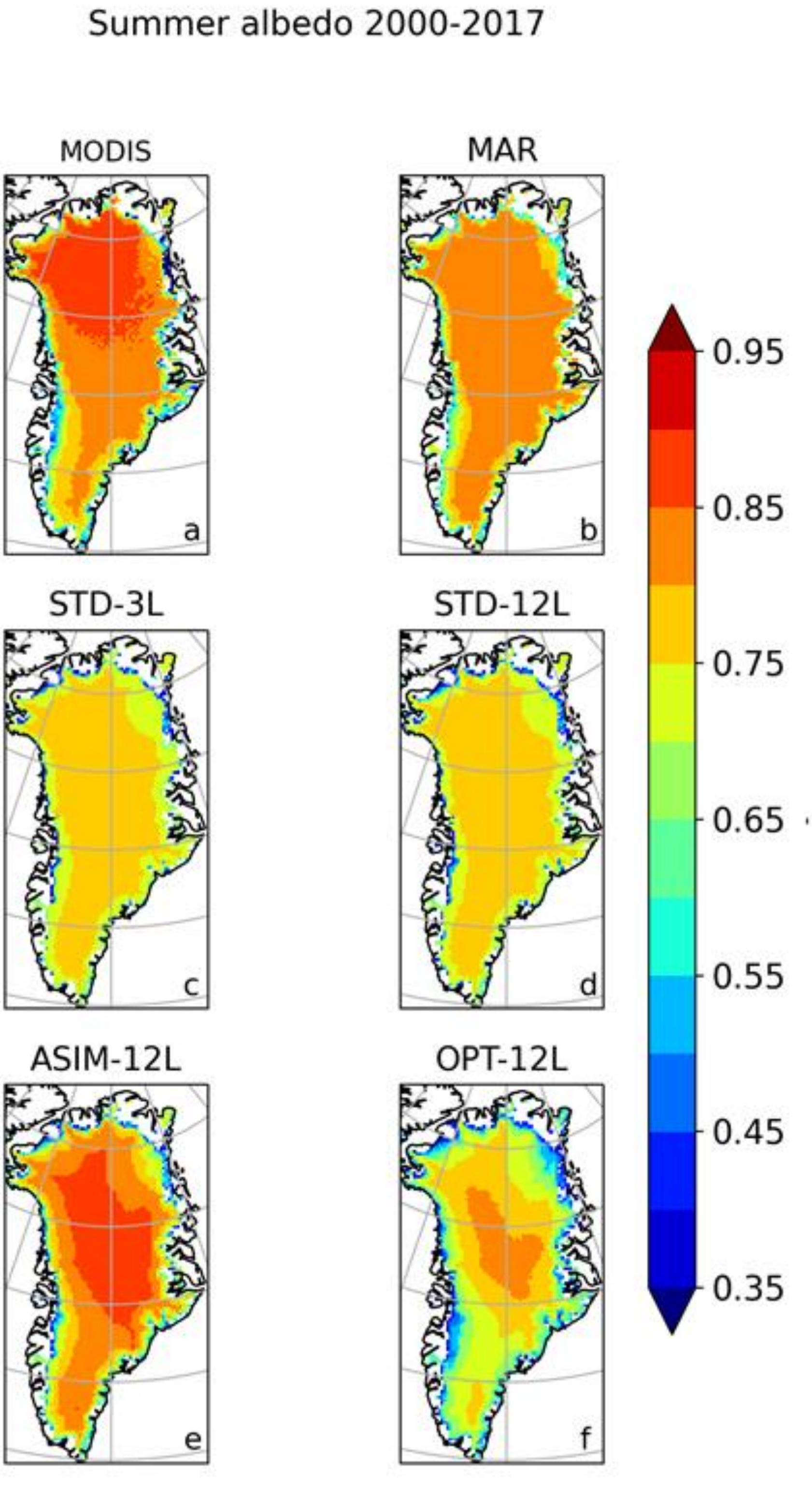

Figure S5: Spatial distribution of the summer (June-July-August) averaged over the 2000-2017 period for MODIS (a), MAR (b), STD-3L (c), STD-12L (d), ASIM-12L (e) and OPT-12L (f).

Probabilty density functions

Figures S6 and S7 display the probability density functions (PDF) for SMB, runoff, sublimation and refreezing compared to the MAR distributions.

As ORCHIDEE-ICE has been forced by MAR outputs, 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 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. 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 information reported in Table 2.

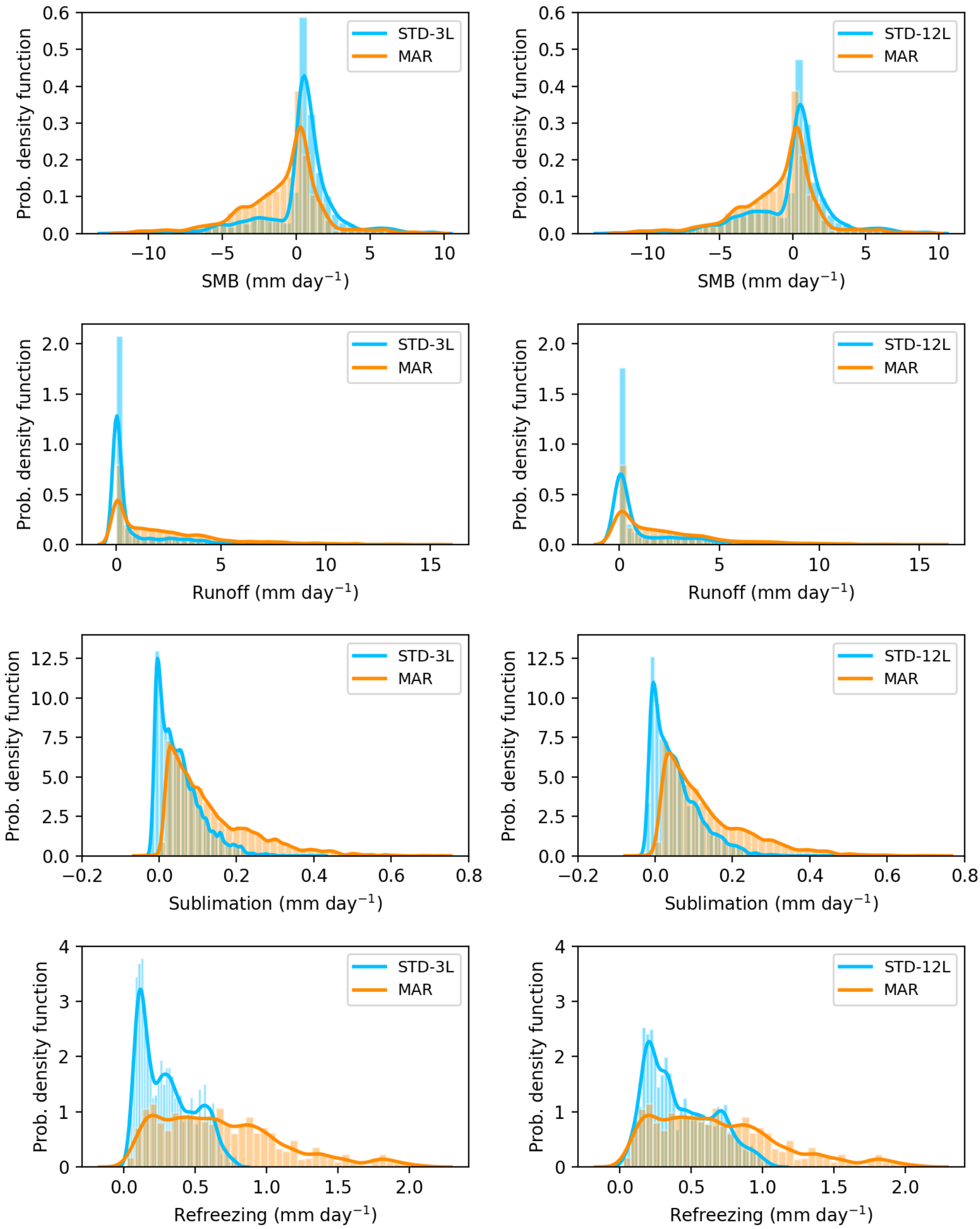

Figure S6: Probability density functions of the STD-3L and STD-12L experiments compared to the MAR distributions for SMB, runoff, sublimation and refreezing. As ORCHIDEE-ICE has been forced by MAR, the main differences in SMB, runoff and refreezing mainly occur at the periphery of the GrIS. Therefore, we kept only the grid points having an altitude is below 1600 m. This threshold corresponds to the maximum extent of areas experiencing ablation in the OPT-12L experiment. For sublimation, grid points have not been filtered.

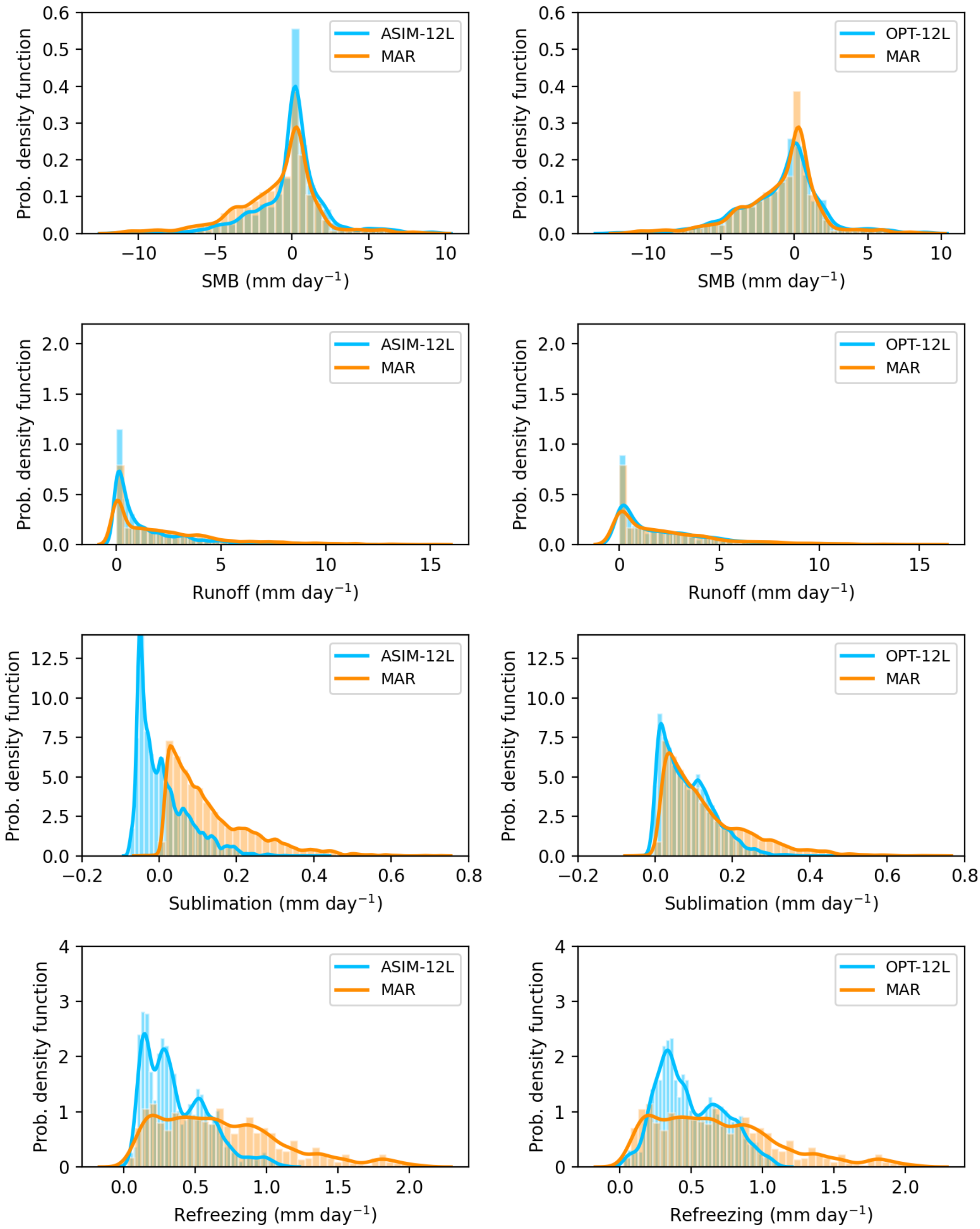

Figure S7: Same as Figure S6 for the ASIM-12L and the OPT-12L experiments

Table S1: CVM test values for the probability density functions of SMB, runoff, sublimation and refreezing 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 [$3.20\ 10^{-9}$]	CVM = 34.25 [$6.36\ 10^{-9}$]	CVM = 170.62 [$5.55\ 10^{-8}$]	CVM:53.85 $6.70\ 10^{-9}$
STD-12L	CVM = 12.73 [$3.07\ 10^{-9}$]	CVM = 15.81 [$4.66\ 10^{-9}$]	CVM = 162.01 [$6.36\ 10^{-9}$]	CVM = 22.82 [$7.64\ 10^{-9}$]
ASIM-12L	CVM = 6.16 $1.37\ 10^{-11}$	CVM = 8.08 $1.37\ 10^{-11}$	CVM = 368.87 $1.23\ 10^{-7}$	CVM = 35.59 $1.15\ 10^{-8}$
OPT-12L	**CVM = 0.33** **[0.11]**	CVM = 4.60 [$3.04\ 10^{-11}$]	CVM = 41.41 [$1.78\ 10^{-8}$]	CVM = 13.01 [$4.40\ 10^{-9}$]

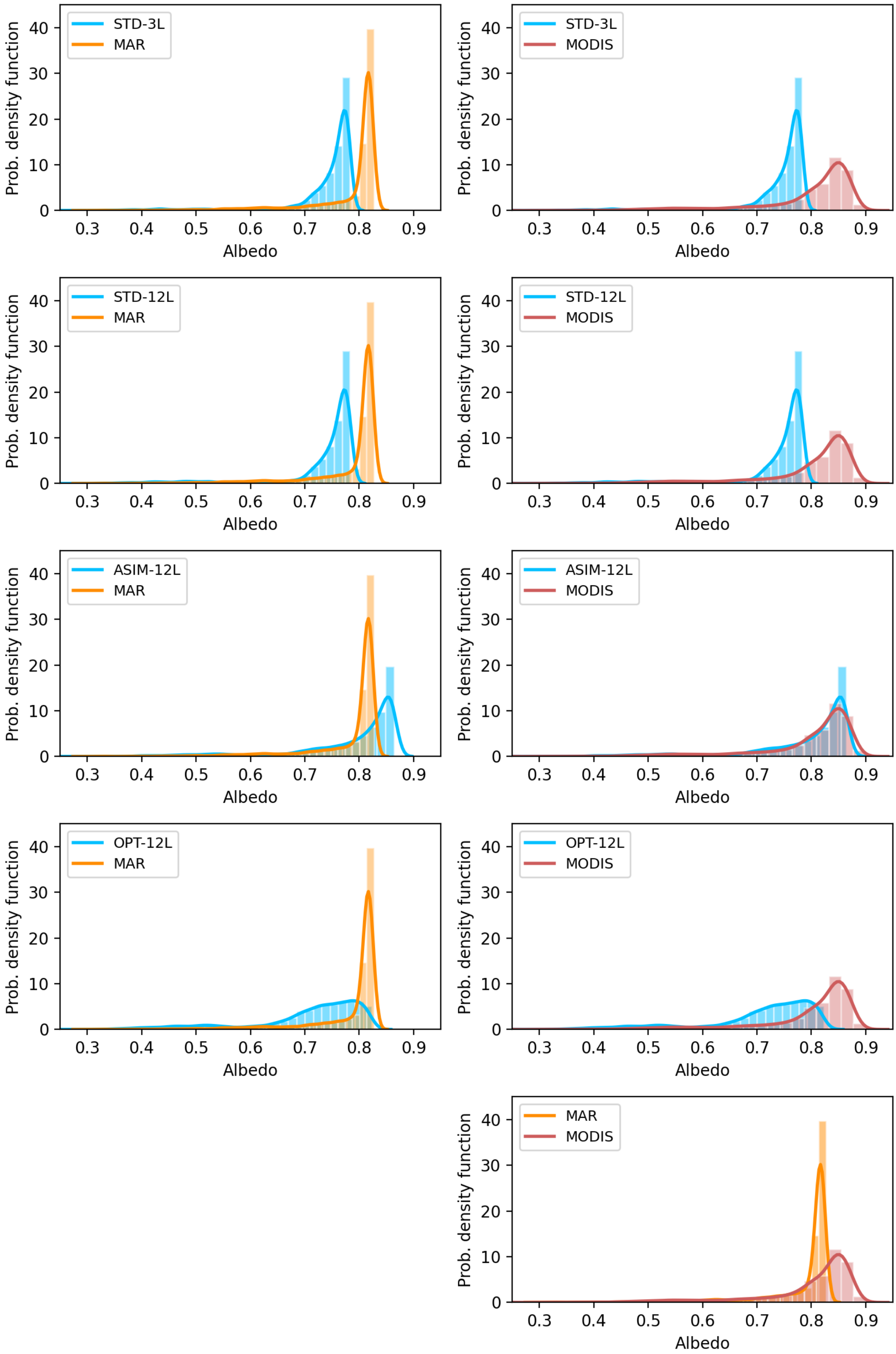

Figure S8: Probability density functions for the simulated albedo compared to MAR (left) and MODIS (right).

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 [$1.00\ 10^{-7}$]	CVM = 327.89 [$8.26\ 10^{-8}$]
STD-12L	CVM = 362.59 [$9.82\ 10^{-8}$]	CVM = 326.92 [$7.95\ 10^{-8}$]
ASIM-12L	CVM = 122.77 [$5.66\ 10^{-8}$]	CVM = 4.16 [$2.06\ 10^{-10}$]
OPT-12L	CVM = 320.44 [$1.10\ 10^{-7}$]	CVM = 296.28 [$7.24\ 10^{-8}$]
MAR		CVM = 138.06 [$4.22\ 10^{-8}$]