Supplementary Material for:

# Exploring the potential of forest snow modelling at the tree and snowpack layer scale

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## Contents:

**S1: Additional validation of the FSMCRO simulations**

To complement section 3.1 of the main article, additional comparisons of observed snow depth distributions to simulations obtained with FSMCRO and FSM2 are shown in Figures S1 and S2. Figure S1 includes the same sites in Laret, Switzerland, as Figure 2 in the main article, but presents a mid-winter survey. Figure S2 shows a survey carried out in Sodankylä, Finland, during late spring. Summary and error statistics for both Laret surveys (Figure S1 and Figure 2 of the main article) are reported in Table S1. Metrics are computed over all points of all three plots and testify comparable performances of FSMCRO and FSM2.

Snow patterns simulated at Laret are consistent between FSMCRO and FSM2 and largely replicate the observed snow depth signal, despite both models tendentially overestimating snow depth at the south-exposed canopy edge.

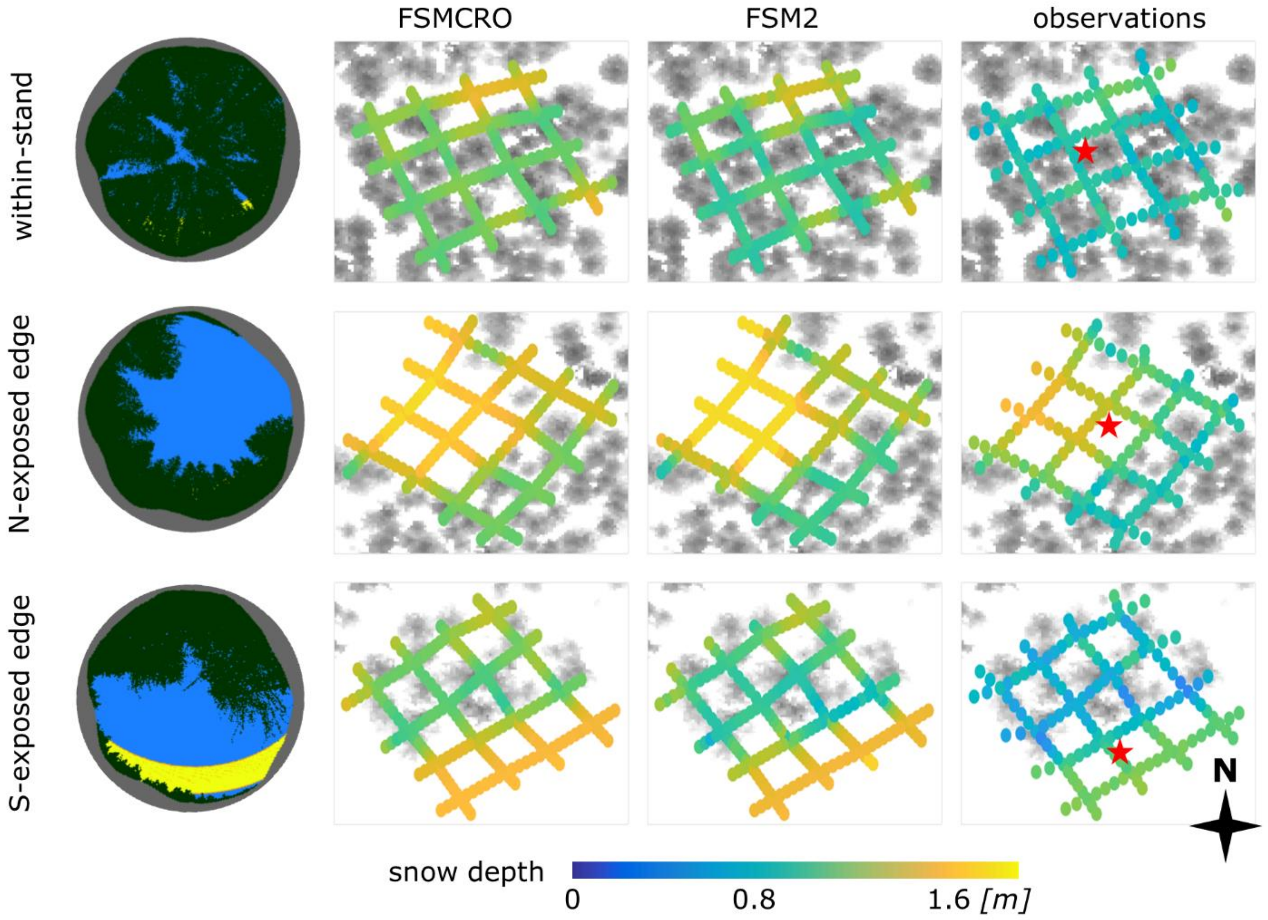


**Figure S1: Snow distribution observed on 10 February 2019 at three 50m x 50m forest plots in Laret and simulated with FSMCRO and FSM2, data from (Mazzotti et al., 2020b). Hemispherical images taken at the position of the red star are shown for each site, including canopy structure (grey/black), terrain (gray) and the solar tracks between 1 October and 10 February (yellow). These images exemplify the characteristics of the contrasting within-stand, north-, and south-exposed canopy edges locations.**

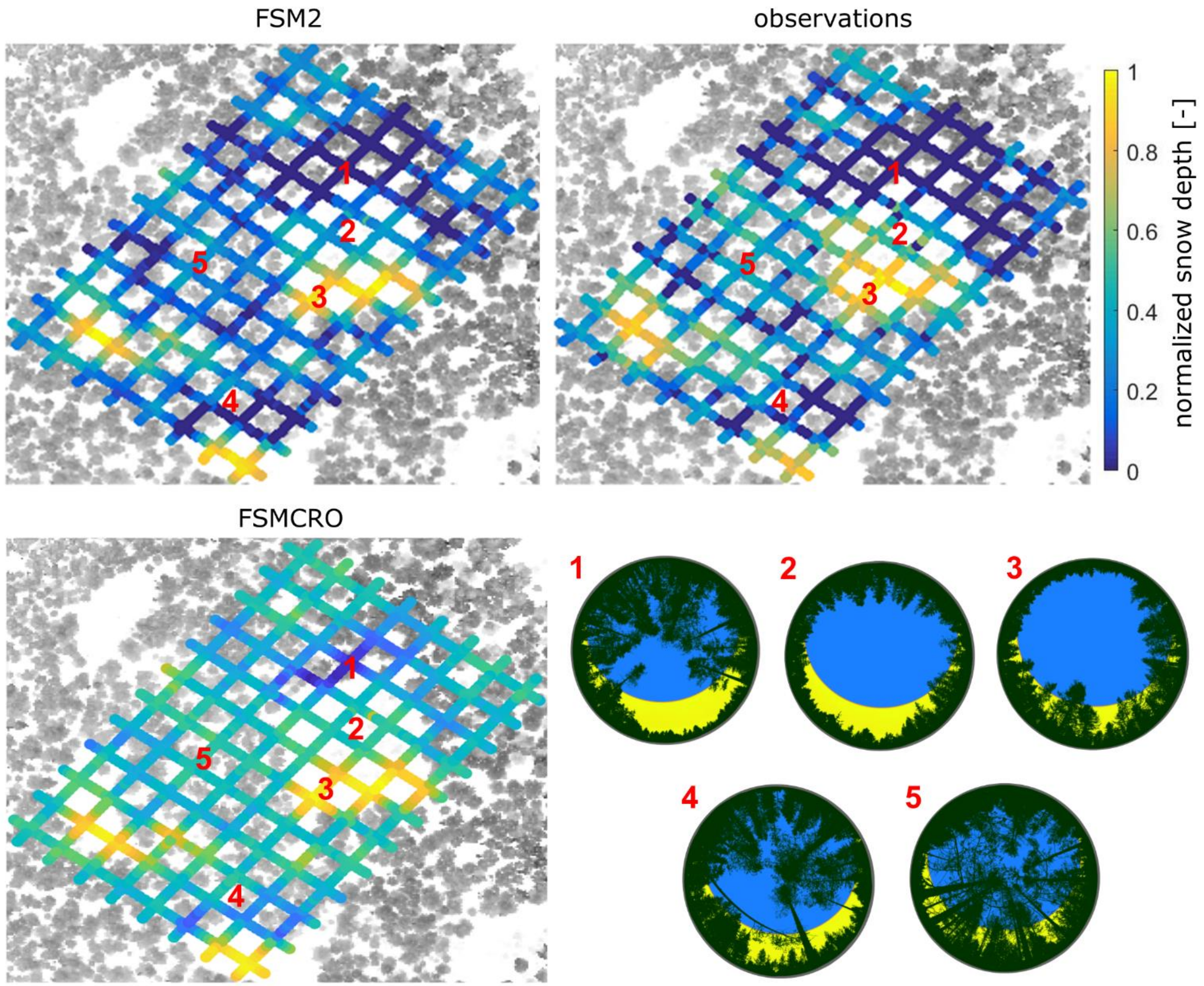


**Figure S2: Snow distribution patterns observed at the Sodankylä grid on 30 April 2019 (top right), and simulated with FSM2 (top left, see Mazzotti et al., 2020b) and FSMCRO (bottom left). The canopy on the site is shown in gray. Hemispherical images with the corresponding solar tracks for the entire season in yellow (1 October to 31 May) are shown for five characteristic locations within the site (1: South-exposed canopy edge; 2: Large canopy gap; 3: North-exposed canopy edge; 4: Small canopy gap; 5: closed canopy).**

Figure S2 complements the evaluation at Laret with data from a boreal site. Following Mazzotti et al. (2020b), we here focus on relative distribution patterns in terms of normalized snow depths (i.e., normalized by the maximum value of the set of observations and modelled snow depths, respectively). Albeit contrasts are less pronounced, patterns simulated by FSMCRO are in line with FSM2 simulations and observations. The gradient across the large forest gap is well visible, with snow depth minima along the south-exposed canopy edge (position 1), intermediate snow amounts in the middle of the gap (2), which are similar to snow depths in smaller gaps and close canopy (4, 5), and snow depth maxima along north-exposed canopy edge (3). Partial melt-out is much more advanced in the observations and FSM2 simulations than in FSMCRO results, suggesting that the relatively poorer performance of FSMCRO might be primarily caused by a too low melt rate in general.

| | **10 February 2019** | | | **17 April 2019** | | |
|---|---|---|---|---|---|---|
| **Summary statistics** | FSMCRO | FSM2 | observations | FSMCRO | FSM2 | observations |
| Mean [m] | 1.29 | 1.21 | 1.00 | 0.64 | 0.82 | 0.61 |
| Median [m] | 1.25 | 1.17 | 0.97 | 0.75 | 0.57 | 0.64 |
| Standard deviation [m] | 0.15 | 0.20 | 0.19 | 0.37 | 0.33 | 0.32 |
| Coefficient of variation [-] | 0.12 | 0.17 | 0.19 | 0.57 | 0.40 | 0.53 |
| Interquartile range [m] | 0.25 | 0.29 | 0.25 | 0.33 | 0.31 | 0.40 |
| 5th percentile [m] | 1.11 | 0.96 | 0.73 | 0.28 | 0.00 | 0.00 |
| 95th percentile [m] | 1.58 | 1.66 | 1.35 | 1.48 | 1.24 | 1.35 |

| | **10 February 2019** | | | **17 April 2019** | | |
|---|---|---|---|---|---|---|
| **Error metrics** | FSMCRO-OBS | FSM2-OBS | FSMCRO-FSM | FSMCRO-OBS | FSM2-OBS | FSMCRO-FSM2 |
| BIAS [m] | 0.29 | 0.21 | 0.08 | 0.18 | -0.03 | 0.21 |
| RMSE [m] | 0.31 | 0.24 | 0.11 | 0.26 | 0.19 | 0.23 |
| Pearson's R [-] | 0.85 | 0.85 | 0.96 | 0.86 | 0.86 | 0.97 |

**Table S1: Summary statistics of snow depth observations and simulations with FSMCRO and FSM2 at Laret for the two surveys shown in Figure 2 of the main article and Figure S1, and goodness-of-fit metrics computed for FSMCRO and FSM2 relative to observations and between FSMCRO and FSM2. FSM2 data is from Mazzotti et al. (2020b).**

## S2: Snow stratigraphy along a forest transect: temperature and density profiles

Figures 4 and 5 in the main article show snow grain type and SSA profiles along a discontinuous forest crossing a large canopy gap at the Sodankylä site, to visualize the spatio-temporal variability of these variables in heterogeneous canopy. Figure S3 and S4 below complement these by additionally showing snow temperature and density profiles for the same transect and timesteps and attest strong spatiotemporal variability for these variables as well.

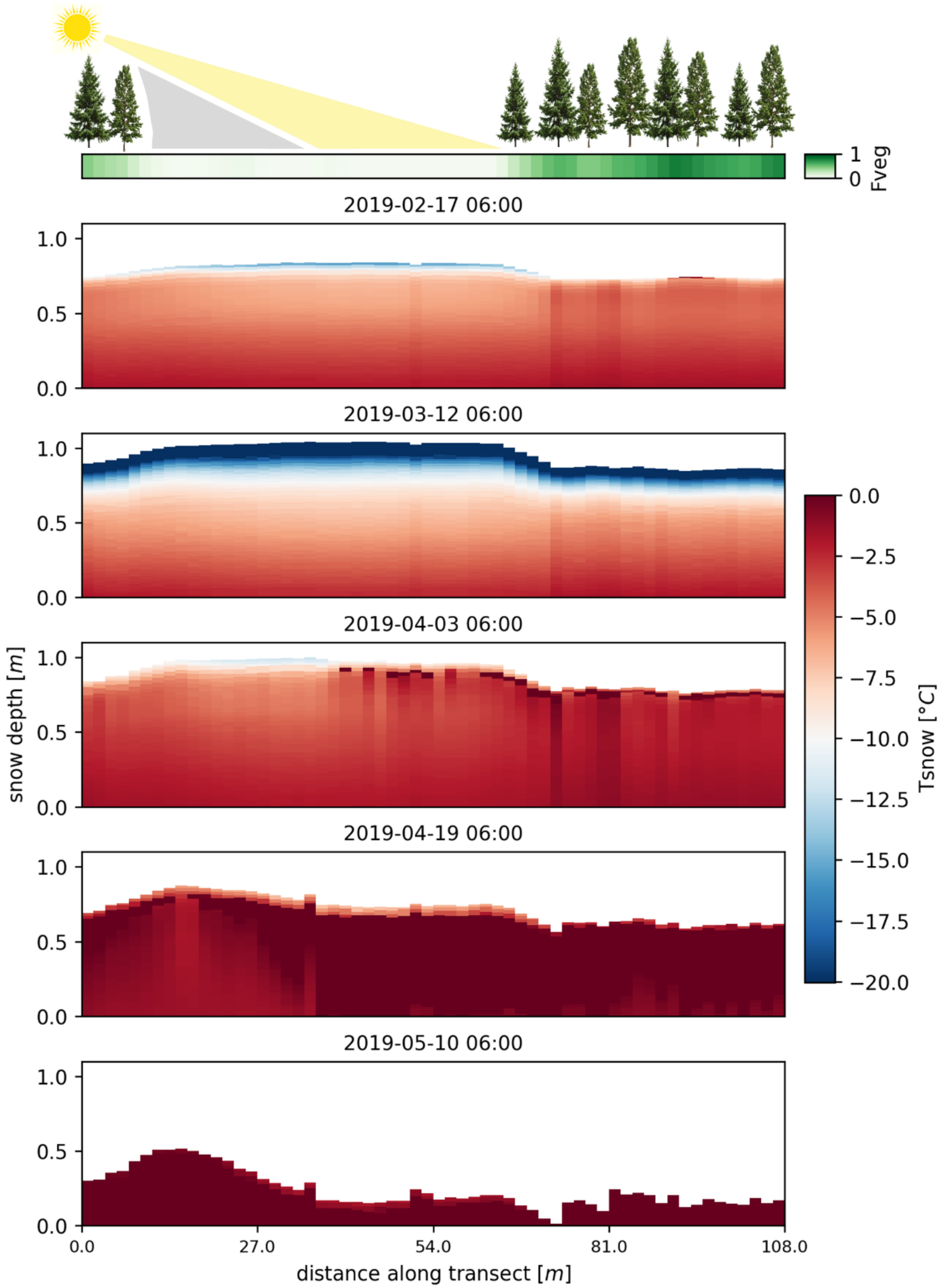


**Figure S3: Snow temperature at the layer scale along the discontinuous forest transect at Sodankylä from Figures 4-6 in the main article for five different dates covering the three-month period between mid-February and mid-May (same as in Figures 4-5). Canopy structure along the transect is visualized in terms of local canopy cover fraction, Fveg.**

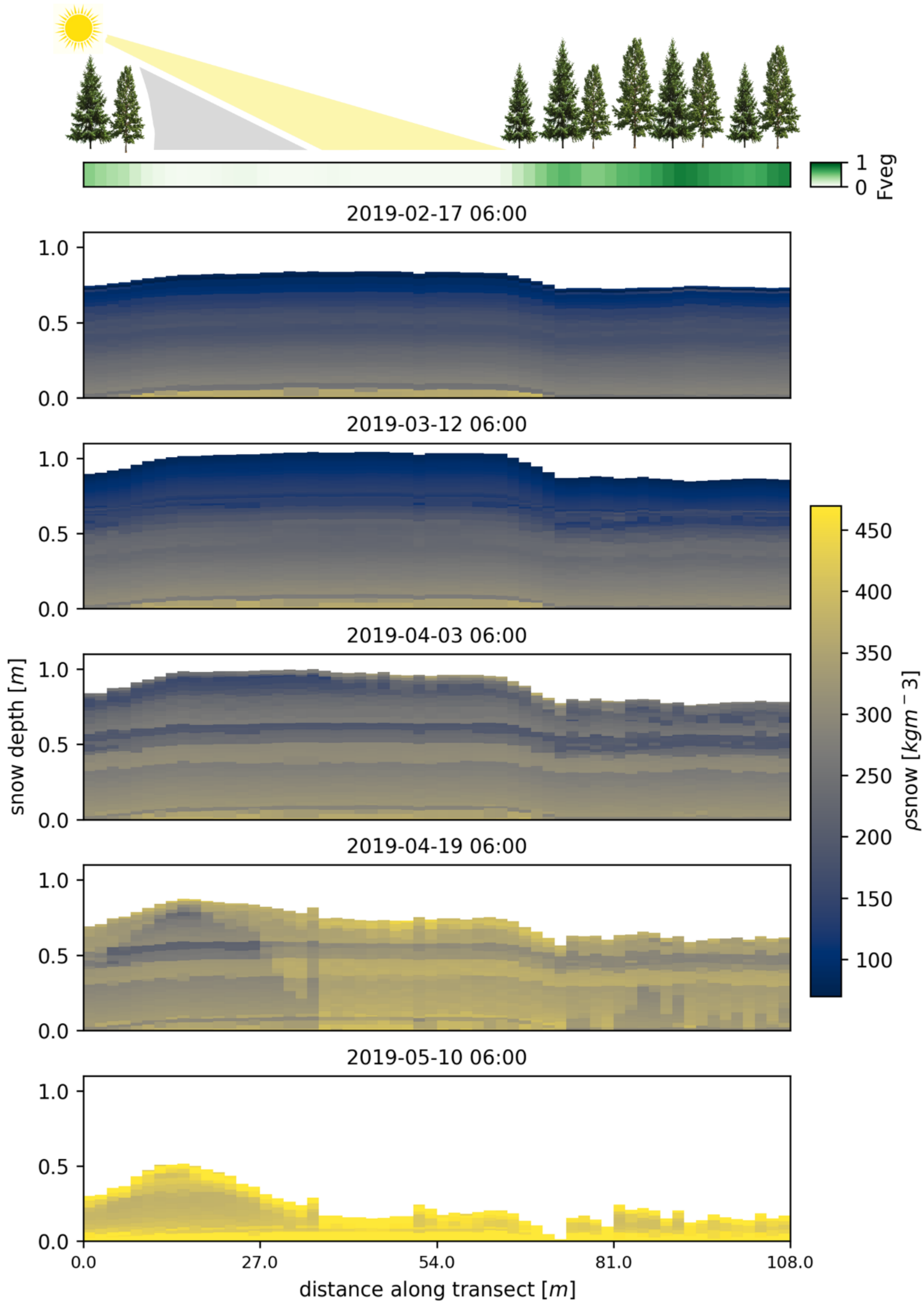


**Figure S4: Snow density at the layer scale along the discontinuous forest transect at Sodankylä from Figures 4-6 in the main article for five different dates covering the three-month period between mid-February and mid-May (same as in Figures 4-5). Canopy structure along the transect is visualized in terms of local canopy cover fraction, Fveg.**