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Sensitivity of the surface energy budget to drifting snow as simulated by MAR in coastal Adelie Land, Antarctica

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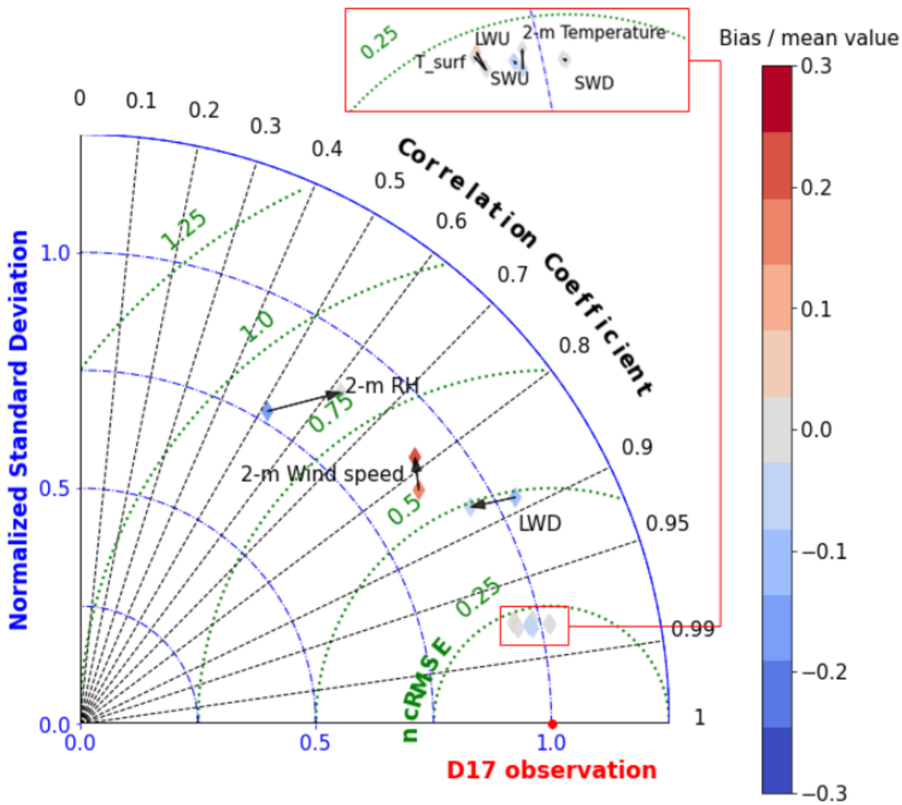

Figure S1. Taylor diagram at D17 enables visualization of modifications between simulations, using observations as a reference. The radial distance from the origin accounts for the normalized standard deviation (standard deviation of the simulated variable divided by the observed standard deviation). Correlation coefficient is represented by the angular distance from the horizontal. Normalized and centered root mean squared error (ncRMSE) is represented by a green circle centered on the red point. A simulation matching perfectly observations would stand on the red point. The colorbar indicates the mean bias divided by the mean value of observations. The arrows point from MAR-nDR simulations to MAR-DR simulations. 2 m RH designates 2 m relative humidity and T_{surf} designates surface temperature. Surface temperature is computed using LWD and LWU.

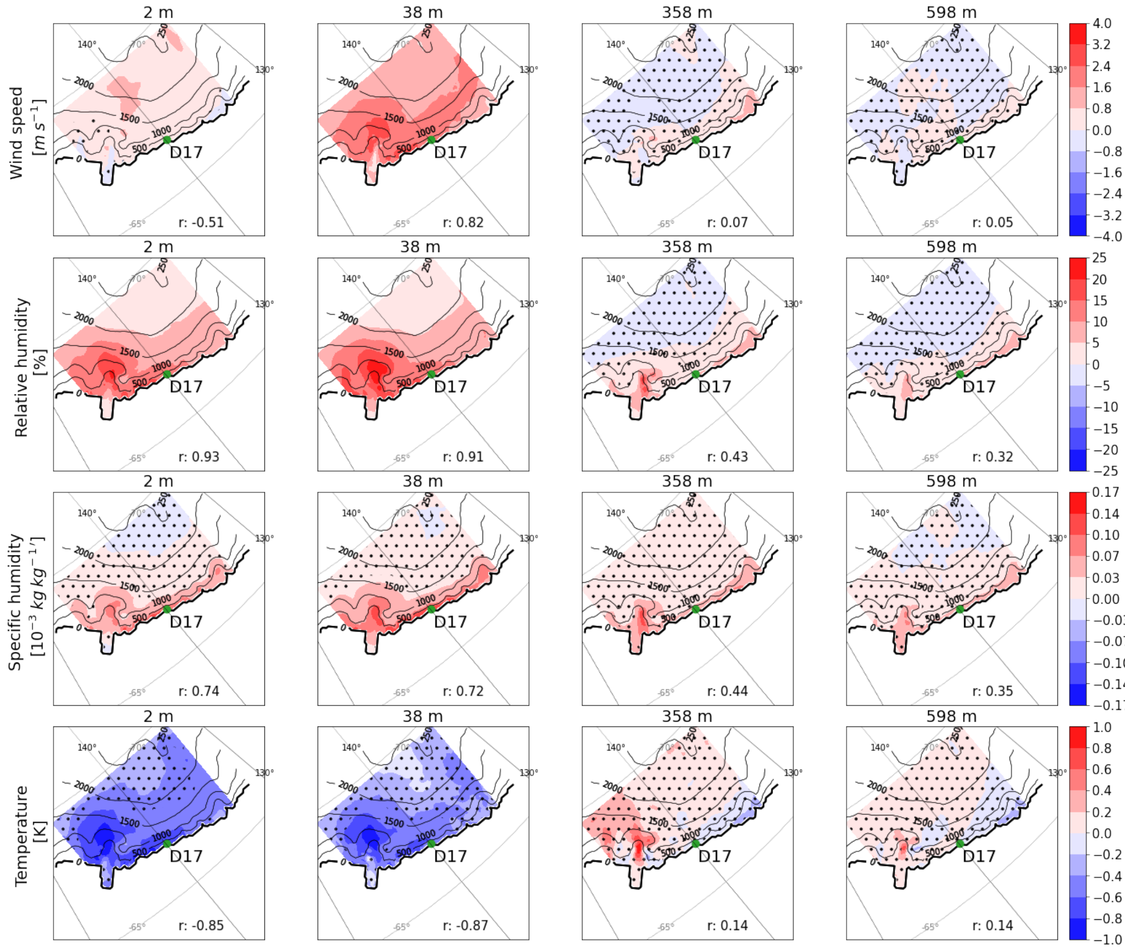

Figure S2. Annual mean (2010-2018) near-surface and surface variables modifications between MAR-DR and MAR-nDR over the integration domain at different vertical levels in the low atmosphere. Within each panel, r indicates the Pearson correlation coefficient between the snow mass transport anomaly and the considered variable. Dotted area designate areas where modifications are lower than interannual variability (taken as the standard deviation computed from annual means).

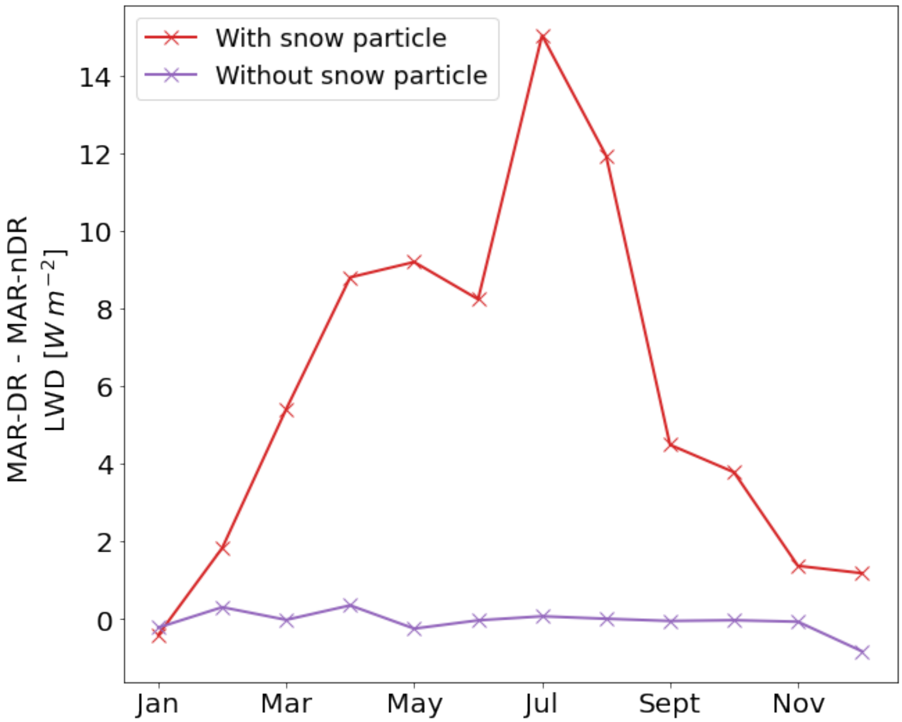

Figure S3. Time series of LWD modifications between MAR-DR and MAR-nDR at D17 for the year 2017. Two model configurations are compared here: the reference simulation, referred as “With snow particle” includes the snow particle ratio in the LWD computation, oppositely to the “Without snow particle” configuration. LWD modifications between MAR-DR and MAR-nDR are highly influenced by the presence of snow particles in the atmosphere.

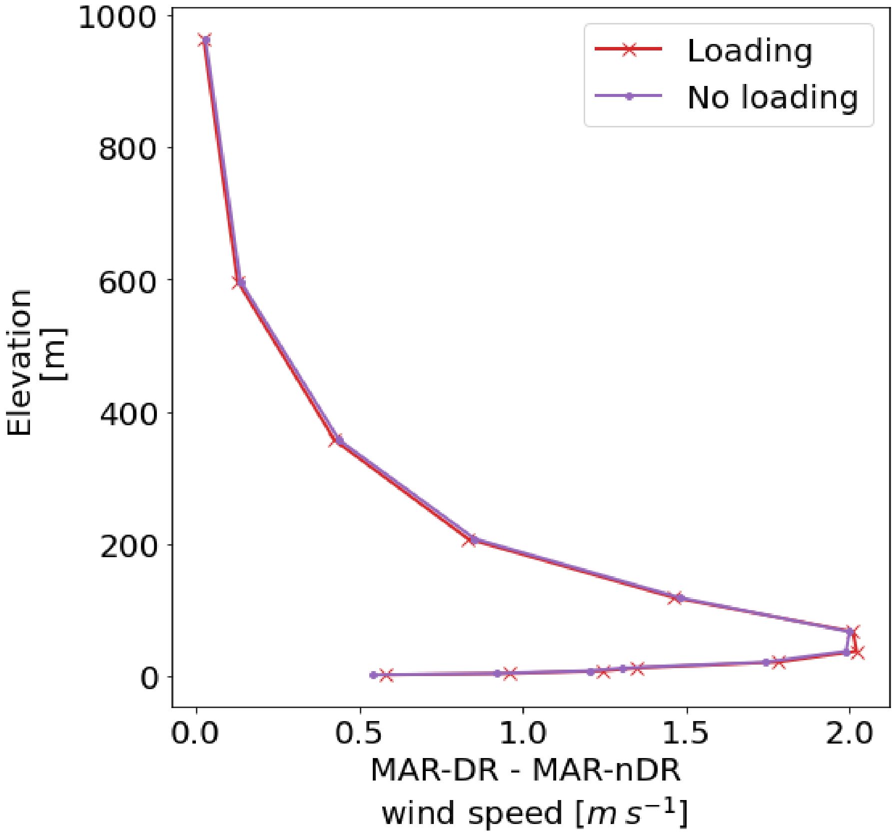

Figure S4. Vertical profile of wind speed modifications between MAR-DR and MAR-nDR at D17 for the year 2017. Two model configurations are compared here: the reference simulation, referred as "Loading" includes the contribution of snow particles to air density, oppositely to the "No loading" configuration. The mass of snow particles is only responsible for limited wind speed modifications when the drifting-snow scheme is activated in MAR.

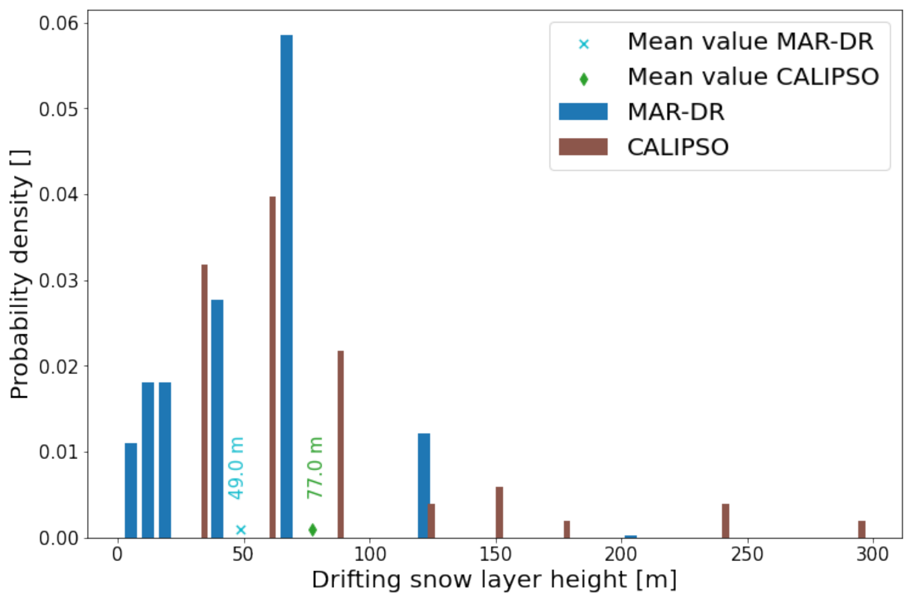

Figure S5. Distribution of drifting-snow layer heights as simulated by MAR-DR (after the filtering process described in Sect. 2.4) and as observed by CALIPSO (Palm et al., 2011). The MAR-DR algorithm for detecting drifting-snow layer height is calibrated on CALIPSO observations. On the 2010–2018 period and after the filtering process, MAR-DR simulates a mean drifting-snow layer height of 49 m while CALIPSO detects for specific occurrences a mean value of 77 m.

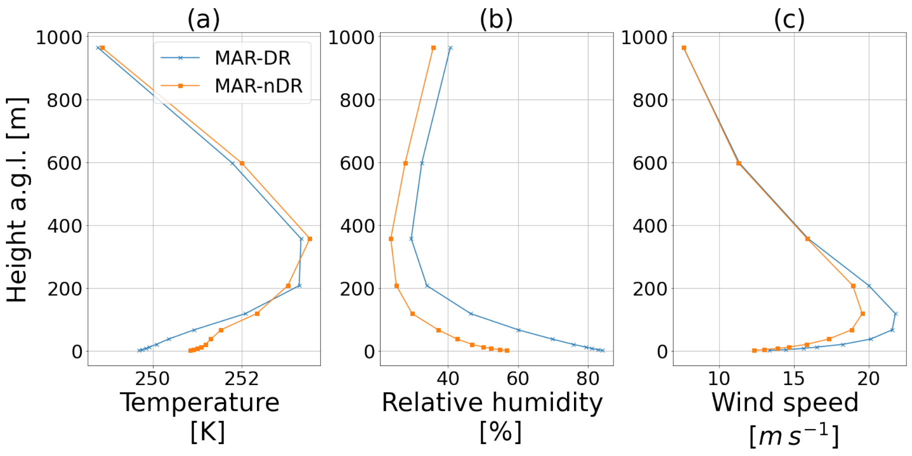

Figure S6. (a) Temperature, (b) relative humidity and (c) wind speed mean profiles calculated during a drifting-snow event between the 1st and the 3rd of October 2017 at D17. Temperature variations are small in the katabatic layer (0.017 K m-1 on the first 100 m a.g.l.), relative humidity peaks near the surface, and wind speed increases with elevation in the katabatic layer

S0.1 Metrics

We define ncRMSE the normal and centered root mean square error as follows:

$$\text{ncRMSE} = \frac{1}{std_{obs}} \times [\frac{1}{N}\sum_{i=1}^{n}((m_i - \overline{m}) - (o_i - \overline{o}))^2]^{1/2} \quad \text{(S1)}$$

with n the total number of observations, m the simulated value, o the observed value, $\overline{m}$ the simulated mean value, $\overline{o}$ the observed mean value and std_{obs} the observed standard deviation.

S0.2 Potential temperature deficit

We define ncRMSE the normal and centered root mean square error as follows:

Mahrt (1982) and van den Broeke and van Lipzig (2003) propose a framework to decompose the downslope momentum budget terms along a low inclination straight slope. This strategy is well suited for studying katabatic wind regimes (e.g., van den Broeke et al., 2002; van den Broeke and van Lipzig, 2003; van Angelen et al., 2011) and thus the influence of drifting snow on the katabatic forcing at D17. KAT (eq. S7) designates the downslope momentum budget term related to the katabatic pressure gradient force, 0is the background potential temperature, g is the standard acceleration due to gravity (9.81 ms^{-2}) and α is the slope.

$$\text{KAT} = \frac{g}{\Theta_0} \times \Delta_\theta \times \sin\alpha \quad \text{(S2)}$$

KAT results from a potential temperature deficit between the air potential temperature and the background potential temperature, representative of a potential temperature out of the gravity flow Mahrt (1982). The latter is obtained by the usual assumption of a linear behavior of potential temperature from the free atmosphere down to the lowest model vertical level. Mean vertical profile of are reported on Fig. S7 at D17. Drifting-snow sublimation cools the low atmosphere and increases temperature deficits in MAR-DR. This results in an increased katabatic forcing in the computation of the momentum budget in the model, and favors increasing wind speeds in the downslope direction (eq. S2).

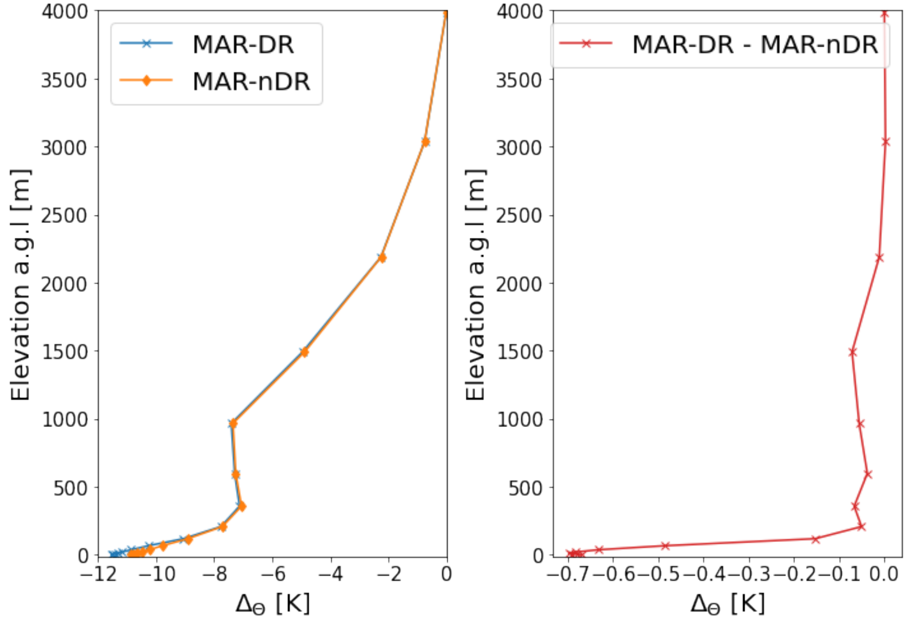

Figure S7. Sensibility of mean Δ_θ to the drifting-snow scheme computed with half-hourly outputs between 2010 and 2019. Δ_θ is the potential temperature perturbation due to the presence of a gravity (katabatic) flow and is calculated accordingly to van den Broeke and van Lipzig (2003). Δ_θ decreases in MAR-DR due to drifting-snow sublimation and subsequent cooling of the atmosphere, and is responsible for the enhanced katabatic forcing in the lower boundary layer.

References

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