Supplement of

Dry snow initialization and densification over the Greenland and Antarctic ice sheets in the land surface model ORCHIDEE

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1 Snow thermal conductivity equation

Snow thermal conductivity is expressed in ORCHIDEE (Charbit et al., 2024) as follows:

$$\Lambda_{snow} = a_\Lambda + b_\Lambda \cdot \rho_{snow} \tag{S1}$$

Where $a_\Lambda = 0.02 \mathrm{W\,m^{-1}\,K^{-1}}$ and $b_\Lambda = 2.5 \cdot 10^{-6} \mathrm{W\,m^{-5}\,K^{-1}\,kg^{-2}}$.

2 Snow heat capacity equation

Snow heat capacity is expressed in ORCHIDEE as follows:

$$\mathrm{Cap}_{snow} = a_{\mathrm{cap}} \cdot \rho_{snow} \tag{S2}$$

Where $a_{\mathrm{Cap}} = 2.106 \cdot 10^{3} \mathrm{J\,K^{-1}\,kg^{-1}}$.

3 Albedo scheme Chalita and Le Treut (1994)

$$\alpha_{snow} = a_{\mathrm{aged}} + b_{\mathrm{dec}} \cdot \exp(-\frac{\tau_{snow}}{\tau_{dec}}) \tag{S3}$$

Where a_{aged} represents the albedo of old snow covered surface (after aging), b_{dec} is defined in order that the sum of a_{aged} and b_{dec} represents the fresh snow albedo, τ_{snow} is the snow age and τ_{dec} represents the snow age decay rate in days.

The parameterized snow age, τ_{snow} is expressed as following:

$$\tau_{snow}(t+dt) = \tau_{snow}(t) + f_{age} \tag{S4}$$

where t represent time and dt the model time step. The term, f_{age}, which represents the effect of low temperatures on metamorphism is shown:

$$f_{age} = \frac{(\tau_{snow} + (1 - \frac{\tau_{snow}}{\tau_{max}}) \cdot dt) \cdot exp(-\frac{P_{snow}}{\delta_c}) - \tau_{snow}(t)}{1 + g_{temp}(T_{soil})} \tag{S5}$$

where T_{max} is the maximum snow age, P_{snow} is the snowfall amount during the model time step dt, δ_c is the critical snowfall depth required to reset the snow age.

$$g_{temp}(T_{soil}) = [\frac{max(T_0 - T_{soil}, 0)}{\omega_1}]^{\omega_2} \quad \text{(S6)}$$

where ω_1 and ω_2 are tuning constants.

4 Albedo parameters

Table S1. Albedo values used for the ORCHIDEE simulations

Parameter	Desciption	GrIS ASIM12L	GrIS OPT12L	AIS
A_{aged}	Old snow albedo	0.553	0.58	0.75
B_{dec}	Sum with A_{aged} for the fresh snow albedo	0.32	0.28	0.08
δ_c	Snowfall depth required to reset snow age [m]	0.783	1.0	1.0
τ_{dec}	Snow age decay rate [d]	6.911	2.0	6.9
ω_1	Tuning constant	3.037	3.0	3.0
ω_2	Tuning constant	3.974	6	6
τ_{max}	Maximum snow age (d)	56.183	54	54
α_{ice}	Ice albedo	0.476	0.420	0.420

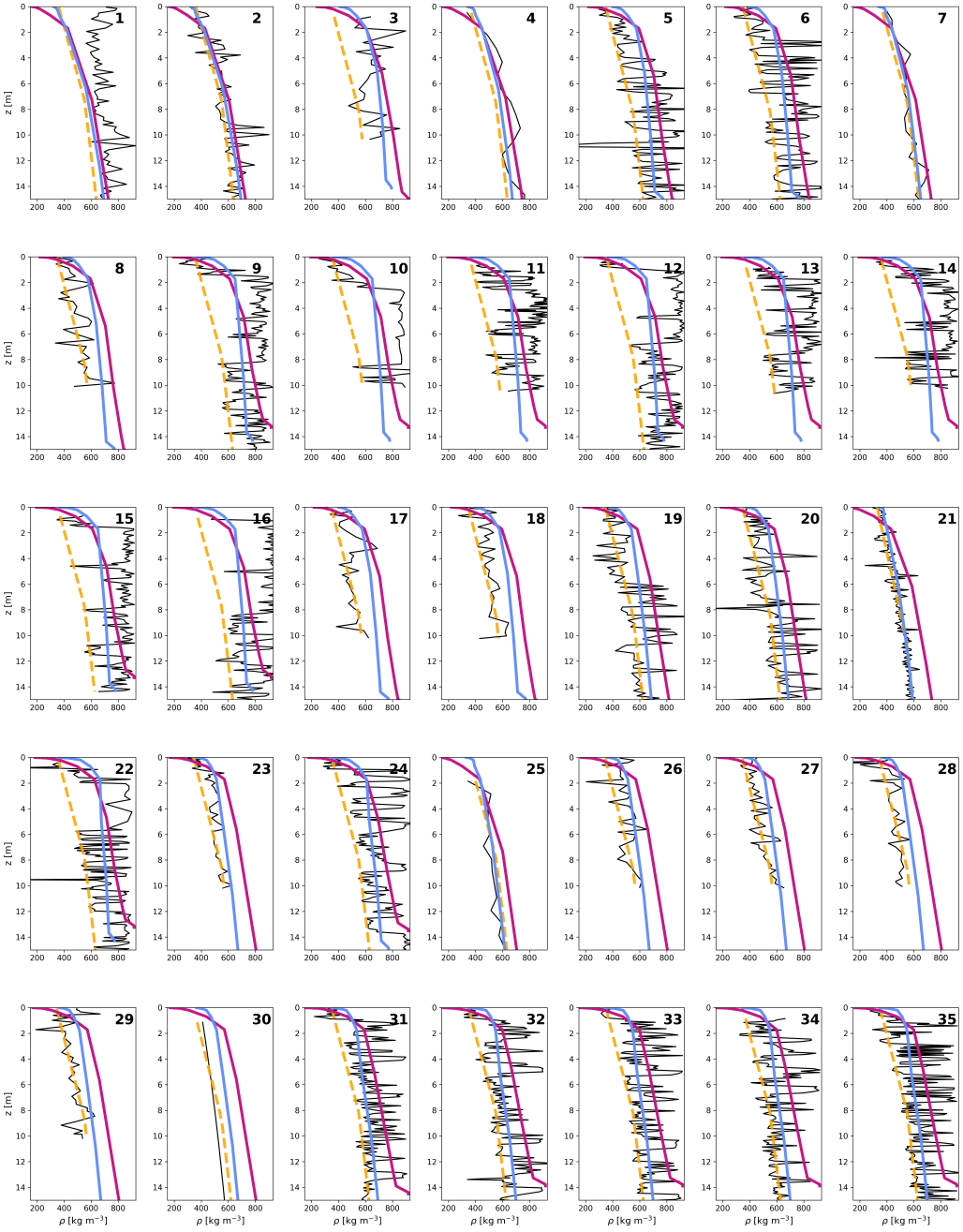

Figure S1. Density profiles in Greenland. Dark lines represents observed density profiles, orange dashed line the initialization profile, the purple curve the density profile before developments and calibration (OR OLD) and in blue the updated density profile (OR NEW).

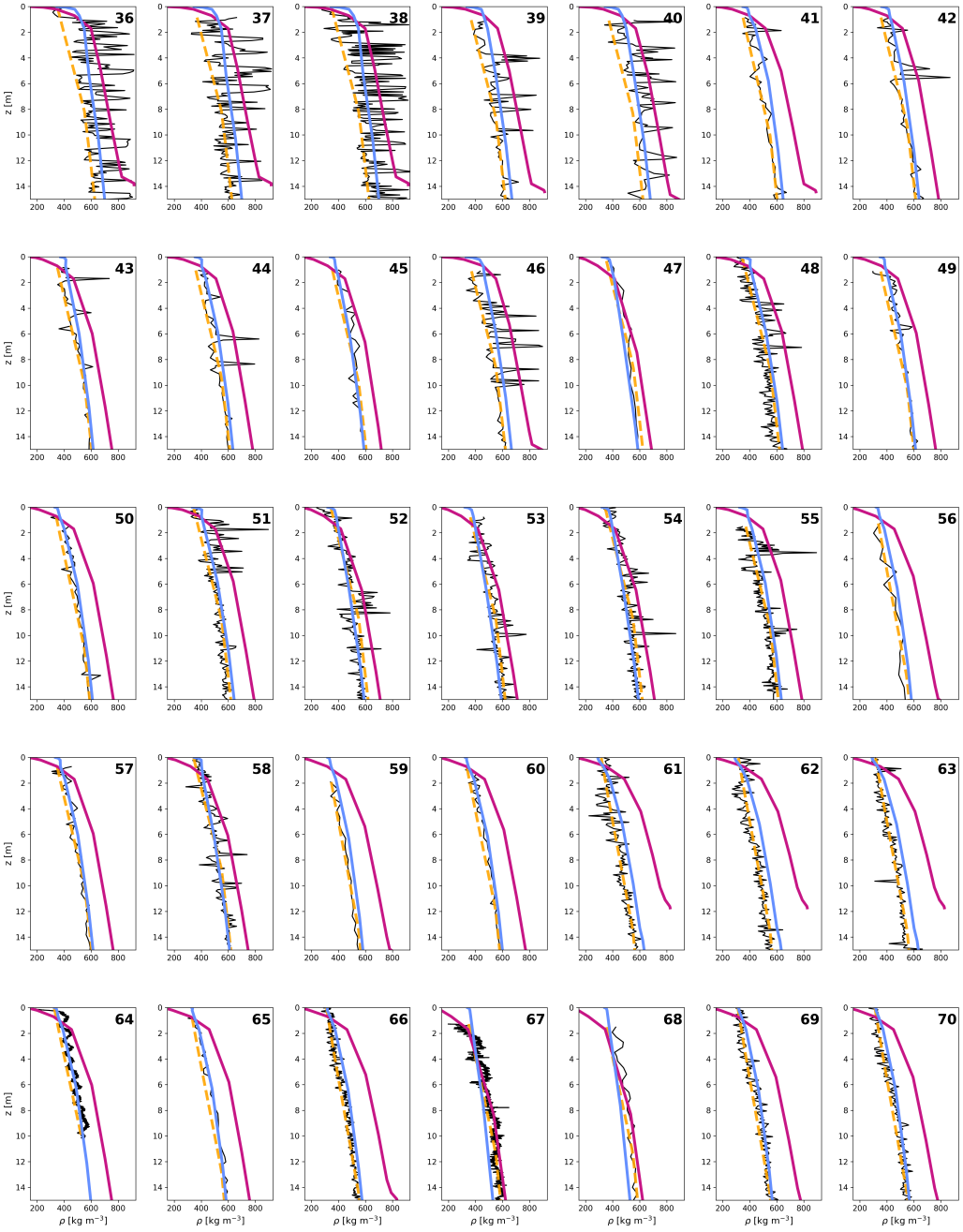

Figure S2. Density profiles in Greenland. Dark lines represents observed density profiles, orange dashed line the initialization profile, the purple curve the density profile before developments and calibration (OR OLD) and in blue the updated density profile (OR NEW).

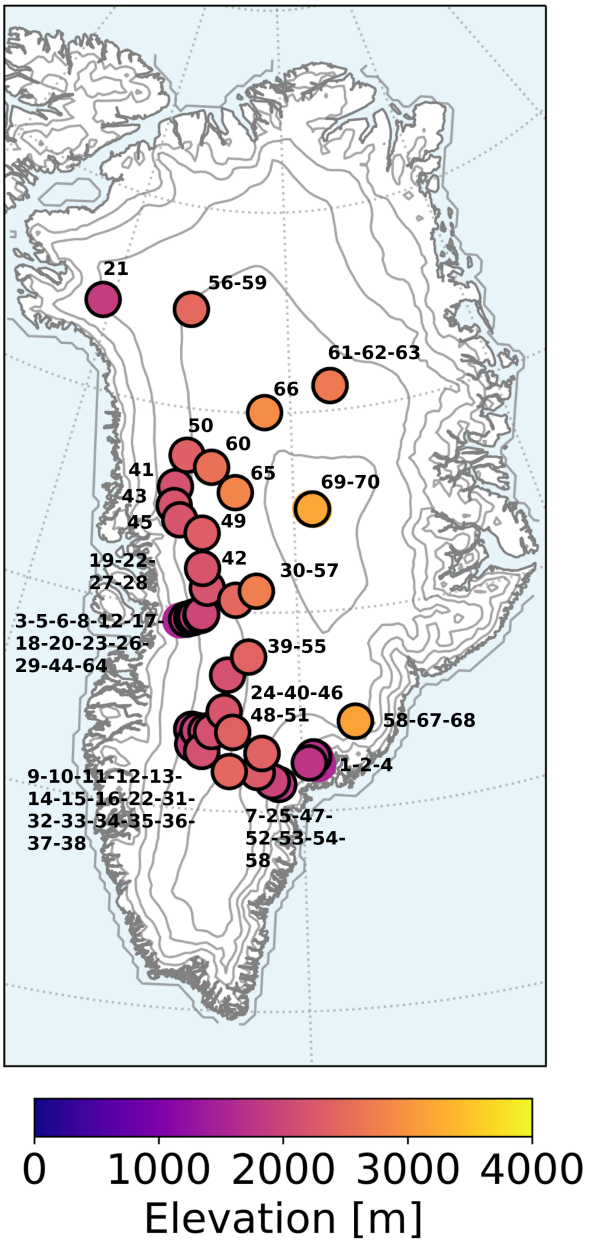

Figure S3. Locations of the numeroted density profiles in Greenland presented in Figures S1 and S2. The locations are represented as a function of their surface elevation.

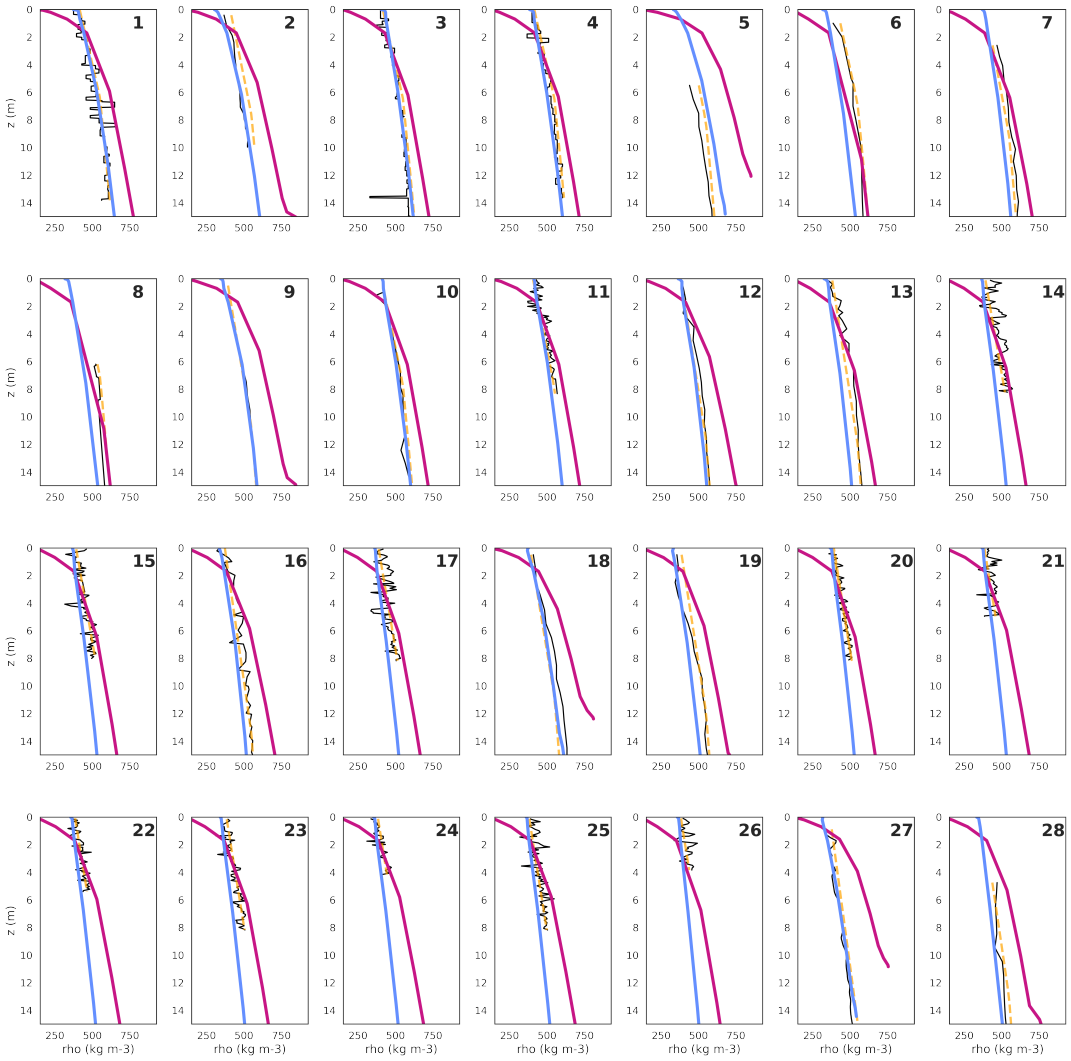

Figure S4. Density profiles in Antarctica. Dark lines represents observed density profiles, orange dashed line the initialization profile, the purple curve the density profile before developments and calibration (OR OLD) and in blue the updated density profile (OR NEW).

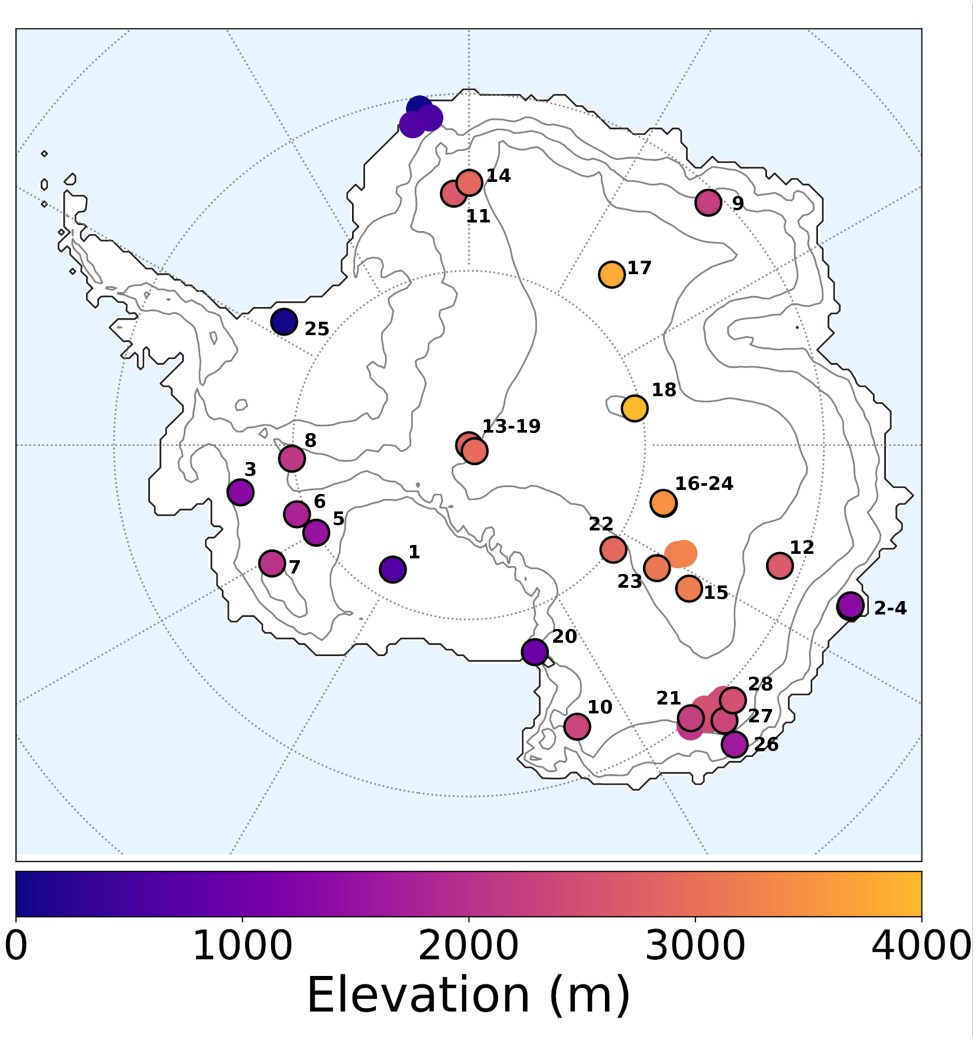

Figure S5. Locations of the numeroted density profiles in Antarctica presented in Figure S4. The locations are represented as a function of their surface elevation.