Supplementary Material

Snow model comparison to simulate snow depth evolution and sublimation at point scale in the semi-arid Andes of Chile

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S1 Meteorological observations

Table S1.1: Available observations, sensor height from the ground and the manufacturers and type of the corresponding sensor at Tapado AWS.

Measurement	Unit	Height (m)	Brand/type	Uncertainty given by manufacturer
Accumulated precipitation	mm	1.5	Geonor/T-200B 1000mm	0.1% Full Scale
Air pressure (Pa)	hPa	3.5	Vaisala/PTB110	±1.0hPa
Air temperature (TA)	°C	3.5	Vaisala/HMP45C	±0.3°C at 0°C
Incoming LW radiation ($L_{\downarrow}$)	W m^{-2}	3.5	Kipp and Zonen/CNR4	10% (95% confidence level)
Incoming SW radiation ($S_{\downarrow}$)	W m^{-2}	3.5	Kipp and Zonen/CNR4	5% (95% confidence level)
Outgoing LW radiation ($L_{\uparrow}$)	W m^{-2}	3.5	Kipp and Zonen/CNR4	10% (95% confidence level)
Reflected SW radiation ($S_{\uparrow}$)	W m^{-2}	3.5	Kipp and Zonen/CNR4	5% (95% confidence level)
Relative Humidity (RH)	%	3.5	Vaisala/HMP45C	±2% RH (0 to 90% RH) ±3% RH (90% to 100% RH) and ±0.05% RH/°C
Wind speed (WS)	m s^{-1}	5.4	RM Young/5103	±0.3 m/s
Wind direction (WD)	°	5.4	RM Young/5103	±3°
Snow depth (SD)	m	3.5	Campbell/SR50A	±1 cm
Water equivalent (SWE, thallium, Tl)	mm	3.5	Campbell/CS725	±15 mm from 0 to 300 mm ±15% from 300 to 600 mm
Water equivalent (SWE, potassium, K)	mm	3.5	Campbell/CS725	±15 mm from 0 to 300 mm ±15% from 300 to 600 mm

S2 Precipitation perturbations

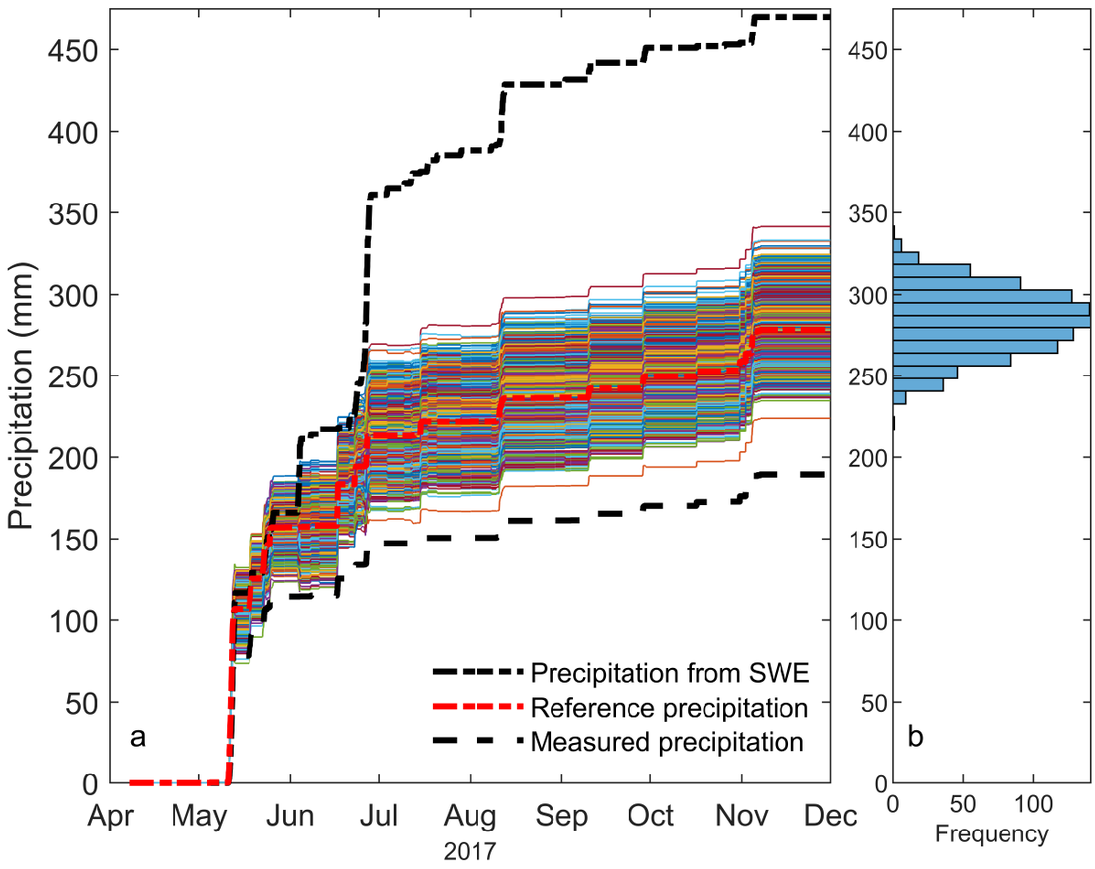

Figure S2.1: The a) distribution of 1000 perturbed precipitation sets. b) The amount of precipitation accumulated at the end of the season is normally distributed around the reference precipitation (red curve).

S3 Analysis of roughness lengths

The selection of the roughness length has been done by running the model 100 times with roughness lengths evenly distributed on a logarithmic scale between 10^{-4} and 10^{-2} m. Figure SS3.1 displays 100 runs for the snow depth and SWE of both SNOWPACK and SnowModel. Lower roughness lengths increase the correlation with the observations and decrease the RMSE. The end of the snow season is between 16 and 20 September for different roughness lengths for SnowModel, where the earliest date corresponds to a roughness length of 10^{-2} m. SNOWPACK simulates an end of season between 23 September and 14 October, and thus the influence of z_0 is smaller for SnowModel than for SNOWPACK. As roughness lengths lower than 1 mm are not realistic in the study area, the best R^2 and $RMSE$ are not considered with the z_0 uncertainty but a roughness value of 1 mm is kept as reference (MacDonell et al., 2013; Pellicciotti et al., 2005).

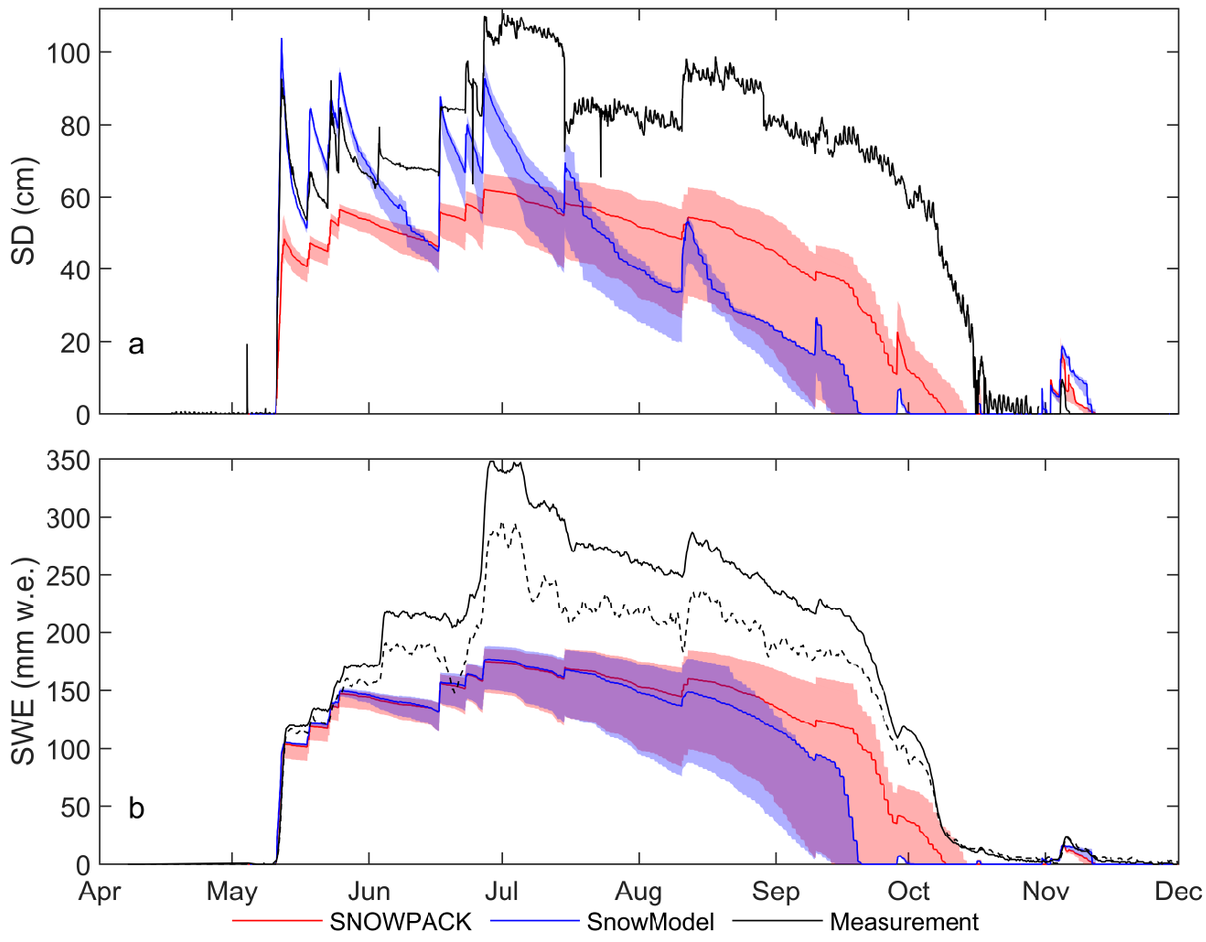

Figure S3.1: Measured (black) and simulated (colour) SD and SWE based of 100 runs with roughness lengths between 10^{-4} and 10^{-2} m. The reference run of both models is the bold coloured curve. The shaded areas correspond to the a) SD and b) SWE of SNOWPACK (red) and SnowModel (blue).

S4 Albedo and fresh snow density parameterizations

Table S4.1: Fresh snow density parameterizations SNOWPACK

Lehning (old)	$\rho_{fs} = 70 + 30\,TA + 10\,TSS + 0.4\,RH + 30\,WS + 6\,TA\,TSS - 3\,TA\,WS - 0.5\,RH\,WS$
Lehning (new)	Lehning et al. (2002, eq.(2)) with $\alpha = 90$
Zwart	Zwart (2007)
Bellaire	$\rho_{fs} = exp(3.946 + 0.07703\,TA + 0.0001701\,HH + 0.02222\log(WS) - 0.05371\,TA\log(WS))$ HH is the altitude above sea level
Pahaut	Vionnet et al. (2012, eq(1))

Table S4.2: Albedo parameterizations SNOWPACK. The exact equations can be found in SNOWPACK's code.

Lehning (0)	Statistical model of surface snow albedo based on measurements from Weissfluhjoch study plot
Lehning (2)	Statistical model of surface snow albedo based on measurements from Weissfluhjoch study plot
Schmucki (GSZ)	Statistical model based on $S_{\downarrow}$ and $S_{\uparrow}$ at 4 Swiss stations and the grain size
Schmucki (OGZ)	Statistical model based on $S_{\downarrow}$ and $S_{\uparrow}$ at 4 Swiss stations and the optical equivalent grain size

Table S4.3: Fresh snow density parameterizations SnowModel

Default	Gascoin et al. (2013, eq. (1))
Lehning (old)	$\rho_{fs} = 70 + 30\,TA + 10\,TSS + 0.4\,RH + 30\,WS + 6\,TA\,TSS - 3\,TA\,WS - 0.5\,RH\,WS$ with $\rho_{fs} = 50$ if $\rho_{fs} < 50$ and $\rho_{fs} = 158.8$ if $\rho_{fs} > 158.8$
Lehning (new)	Lehning et al. (2002, eq.(2)) with $\alpha = 90$ and $\rho_{fs} = 50$ if $\rho_{fs} < 50$ and $\rho_{fs} = 158.8$ if $\rho_{fs} > 158.8$

Table S4.4: Albedo parameterizations SnowModel

Default	$\alpha = 0.9$ for $TA < 0$ $\alpha = 0.6$ for $TA > 0$ $\alpha = 0.15$ for no snow
Time-evolution	Strack et al. (2004, eq.(3-4))

S5 Statistics of model calibrations

Table S5.1: *RMSE* of calibrations of SNOWPACK. *Lehning 0*, *Lehning 1*, *Schmucki GSZ* and *Schmucki OGS* are the albedo parameterizations as named in the model and *Lehning (old)*, *Lehning (new)*, *Bellaire*, *Zwart* and *Pahaut* are the fresh snow density parameterizations. The calibrations chosen as reference is given in bold.

	Lehning 0	Lehning 1	Schmucki GSZ	Schmucki OGS
Lehning (old)	**0.094**	-	0.130	0.117
Lehning (new)	0.104	-	0.135	0.111
Bellaire	0.121	0.137	0.134	0.138
Zwart	0.109	0.143	0.133	0.134
Pahaut	0.105	-	0.136	0.137

Table S5.2: R^2 of calibrations of SNOWPACK. *Lehning 0*, *Lehning 1*, *Schmucki GSZ* and *Schmucki OGS* are the albedo parameterizations as named in the model and *Lehning (old)*, *Lehning (new)*, *Bellaire*, *Zwart* and *Pahaut* are the fresh snow density parameterizations. The calibrations chosen as reference is given in bold.

	Lehning 0	Lehning 1	Schmucki GSZ	Schmucki OGS
Lehning (old)	**0.851**	-	0.693	0.778
Lehning (new)	0.814	-	0.656	0.827
Bellaire	0.735	0.380	0.601	0.614
Zwart	0.799	0.452	0.680	0.691
Pahaut	0.812	-	0.612	0.643

Table S5.3: *RMSE* of calibrations of SnowModel. *Default* and *Strack (Strack et al., 2004)* are the albedo parameterizations as named in the model and *Default*, *Lehning (old)* and *Lehning (new)* are the fresh snow density parameterizations. The calibrations chosen as reference is given in bold.

	Default	Strack
Default	0.153	**0.123**
Lehning (old)	0.156	0.125
Lehning (new)	0.153	0.125

Table S5.4: R^2 of calibrations of SnowModel. *Default* and *Strack (Strack et al., 2004)* are the albedo parameterizations as named in the model and *Default*, *Lehning (old)* and *Lehning (new)* are the fresh snow density parameterizations. The calibrations chosen as reference is given in bold.

	Default	Strack
Default	0.778	**0.776**
Lehning (old)	0.778	0.773
Lehning (new)	0.777	0.773

S6 Snow density of calibrations

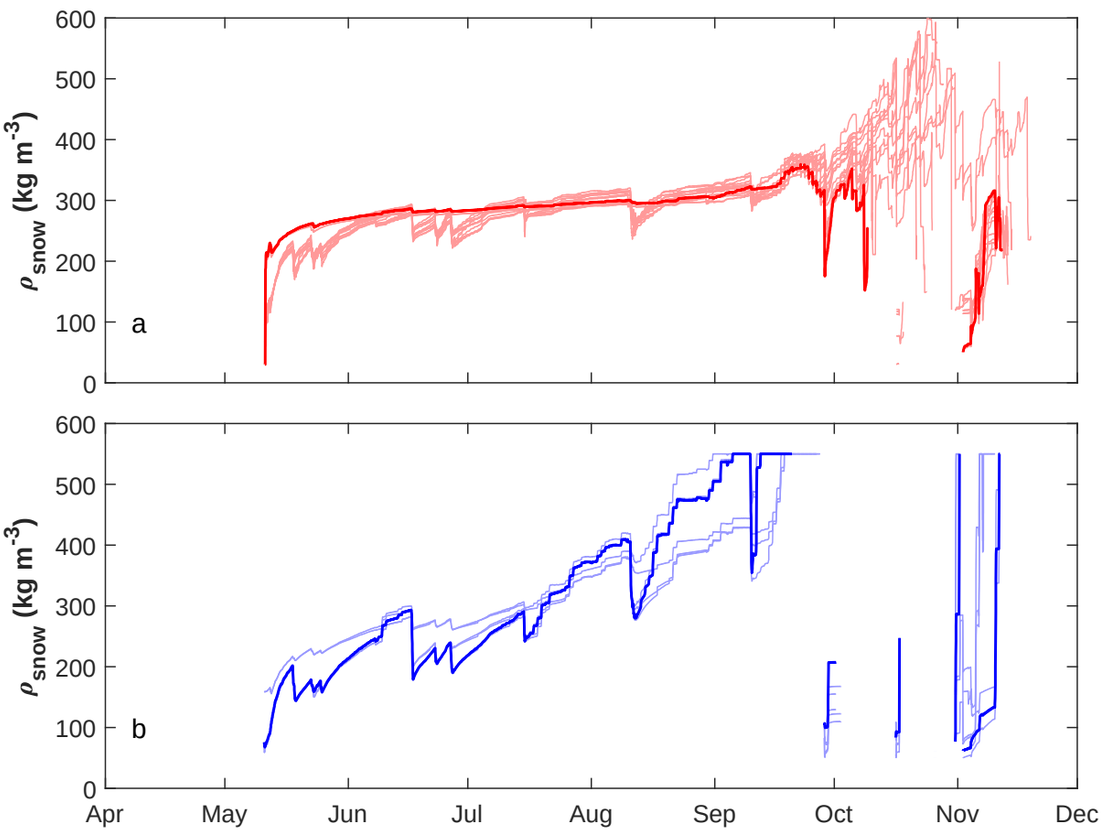

Figure S6.1: Snow density simulations of the complete snowpack for a) 20 calibrations for SNOWPACK (red) and b) 6 calibrations for SnowModel. The reference runs are bold. Snow density measurements were unavailable.

References

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