



Supplement of

Kinetic grain growth in firn induced by meltwater infiltration on the Greenland Ice Sheet

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S1. Methods – Site-Specific Simulation

Microstructural properties ascribed to the site-specific simulation firn column are provided in Table S1.

Table S1: Initial microstructure parameters of the site-specific simulation firn column. Values are uniform across the entire profile initially.

Parameter	Value
Grain radius, all layers (mm)	0.8†
Bond radius, all layers (mm)	0.25
Dendricity, all layers	0
Sphericity, all layers	0.5
Microstructure parameter ('mk', categorical)	1 (indicates that snow has become faceted)

† A grain radius of 0.8mm produces firn grains with sizes slightly smaller than those reported by McDowell et al. (2023)

S2. Methods – Synthetic Simulations

Information regarding initial conditions and forcings for the two synthetic simulations are found in Table S2 and Figure S1.

Table S2: Firn profile initial conditions and meteorological forcings, spin-up period for synthetic simulations.

Initial Conditions – Microstructure	Value
Grain radius (mm)	0.75
Bond radius (mm)	0.5
Dendricity	0 ('old' snow)
Sphericity	0.6
Microstructure marker ('mk')	1 (meaning grains have become faceted')
Stress change rate	0
Site Information	Value
Site altitude	1998m
Site coordinates	69.872469, -47.036429
Meteorological Forcings	Value
Shortwave radiation (W m^{-2})	2
Longwave radiation (W m^{-2}) †	300
Precipitation (m yr^{-1})	0.4-0.5, occuring randomly
Windspeed (m s^{-1})	3
Wind direction	20
Relative humidity	0.61

† A LWR value of 300 W m^{-2} was used as it allowed for the deep firn temperature profile at the end of the 50-year spin-up to become vertical at -16.5°C. Firn temperature profiles at CP-1998m (and at other sites along our study transect) are typically vertical at depth and reflect the MAAT at the site (-16.5°C) (Saito et al., 2024).

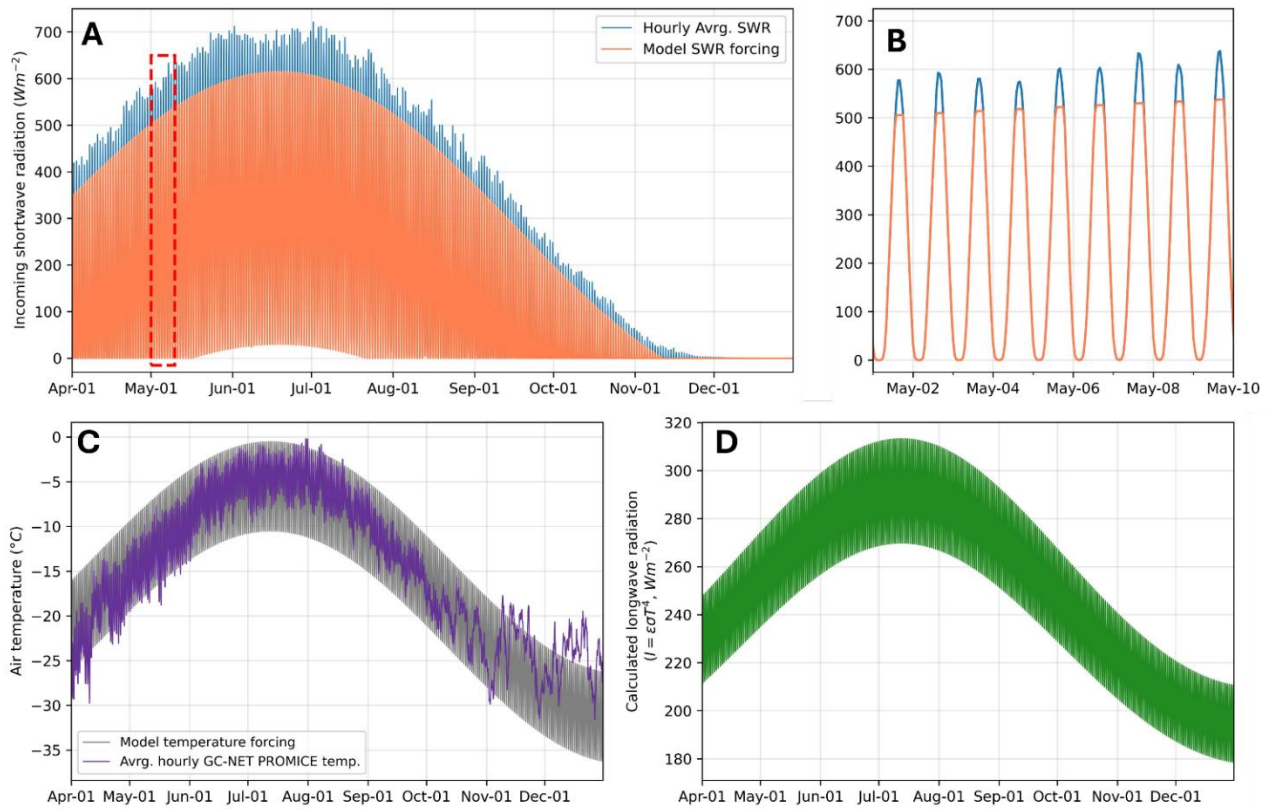


Figure S1: Meteorological forcings employed in the synthetic Wetting Front and Preferential Flow (Piping) simulations. Forcings span from April 1st – December 31st. A) Measured hourly average shortwave radiation values from 1995-2020 at the GC-NET PROMICE weather station, site CP-1998m (blue line). Model SWR forcings were created by trimming local maxima and minima with two envelopes (orange line). The data within the red dashed box are shown in B), a close-up of diurnal fluctuations in the shortwave radiation data/model forcing. C) Measured hourly average air temperature data from 1995-2020 (purple line), also from the CP-1998m weather station. Averages were fit with a sinusoid with a secondary, diurnally fluctuating sinusoid (grey line) to capture approximate air temperature fluctuations throughout the year. Using the sinusoidal air temperature forcings, we directly calculated longwave radiation (D) from temperature using the Stefan-Boltzmann Law.

S3. Results

Site-by-site characteristics, as well as overall site averages, of the two meltwater-induced faceting modes, wet layer onset and preferential flow/piping, are found in Table S3.

Table S3: Duration, timing, and depths of observed wet layer onset and preferential flow/piping Critical Temperature Gradients (CTGs, $\geq|\pm 10|$ °C m⁻¹) at various sites. Only those sites experiencing either form of CTG are included.

Site I.D.	Msrmt. year	Wet layer CTG date range †		Wet lyr. CTG duration (hrs)‡	Wet lyr. CTG depth ranges (m)		# of piping CTG events•	Piping CTG duration (hrs)‡	Piping CTG depth ranges (m)	
Site Averages	-	-	-	263.94	0.67	3.31	-	45.47	2.42	6.06
H3-1540m	2008	6/13/2008	7/16/2008	198	1	3.25	1	19.00	2.00	4.75
H2-1555m	2008	6/9/2008	7/20/2008	253	0.25	5.00	1	22.00	4.00	5.25
H1-1680m	2008	6/14/2008	7/17/2008	83	0.50	2.25	1	22.50	2.50	5.25
H163-1660m	2008	6/14/2008	7/12/2008	76	0.75	3.00	1	12.00	2.25	4.25
H165-1680m	2008	6/14/2008	8/19/2008	56.5	0.50	3.00	1	12.50	2.25	5.25
T1-1710m	2008	6/14/2008	8/4/2008	100.5	0.25	3.75	1	18.50	2.00	3.75
T2-1750m	2007	6/28/2007	8/4/2007	191.5	0.75	5.00	1	96.50	3.50	17.0
T3-1818m	2007	6/25/2007	8/9/2007	86.5	1.50	3.50	2	120.50	4.00	5.25
T3-1818m, 15m core	2022	7/5/2022	9/9/2022	960	0.13	3.50	1	110.00	1.50	4.50
T3-1818m, 25m core	2022	7/6/2022	9/11/2022	407.5	0.25	4.50	2	42.00	1.75	9.00
T4-1878m	2007	7/3/2007	8/1/2007	268.5	0.75	3.00	1	4.50	1.00	9.00
T4-1878m	2022	7/6/2022	8/5/2022	260	0.25	1.25	1	3.00	0.75	3.00
T4-1878m	2023	7/9/2023	7/23/2023	155	1.50	3.75	1	2.00	5.00	6.00
T5-1928m	2023	7/10/2023	7/22/2023	157.5	0.75	4.00	1	190.00	2.25	7.75
CP-1998m	2007	6/25/2007	7/28/2007	603	0.75	2.25	-	-	-	-
CP-1998m	2023	7/6/2023	7/18/2023	226.5	1.25	2.75	1	44.00	2.50	4.75
UP18-2102m	2023	7/8/2023	7/29/2023	504	0.25	2.50	1	8.50	1.50	2.25

† Date ranges encompass the minimum and maximum dates in which CTGs associated with wet layer onset were observed. CTGs were not necessarily observed continuously over the specified range.
‡ Temperature gradient durations are the cumulative time in which temperature gradients associated with each scenario were observed within their respective date ranges. Gaps where CTGs were not observed were not included in duration calculations.
• Observation dates denote the first date in which CTGs associated with breakaway infiltration were observed.

References

Saito, J., Harper, J., and Humphrey, N.: Uptake and Transfer of Heat Within the Firn Layer of Greenland Ice Sheet's Percolation Zone, J Geophys. Res. Earth. Surf., 129, <https://doi.org/10.1029/2024JF007667>, 2024.

McDowell, I. E., Keegan, K. M., Wever, N., Osterberg, E. C., Hawley, R. L., and Marshall, H. P.: Firn Core Evidence of Two-Way Feedback Mechanisms Between Meltwater Infiltration and Firn Microstructure From the Western Percolation Zone of the Greenland Ice Sheet, *J. Geophys. Res. Earth Surf.*, 128, <https://doi.org/10.1029/2022JF006752>, 2023.