Supplementary Materials for

Saltwater exposure accelerates ice grain growth and may increase fracture vulnerability

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Supplementary text

Calculation of liquidus curves.

Our results revealed that the grain-growth parameter k for saline ice can be expressed by

$$k_{im}(f_M, V_L, T) = \exp(A * (1 - f_M) \ * \ (V_L + 1)^B) * k_{pure} * \exp\left(-\frac{Q}{RT}\right), \quad \textit{(Eq. S1)}$$

$$V_L(x, T, Te) = \frac{T_L(x) - T}{T - Te}, \quad \textit{(Eq. S2)}$$

where x is chloride salinity as a weight fraction, $T_L(x)$ is the liquidus temperature at a given composition, T is temperature in Kelvin, Te is the eutectic temperature of a chloride system in Kelvin, $k_{0_{pure}}$ is 6.19 x 10^{-8} m^4/s and Q is 68 ± 47 kJ, following (Wang et al., 2024). An example of calculating the melt fraction and] V_L, the vertical lever (McCarthy et al., 2019) is shown in Figure S1B.
The liquidus temperature at a given composition is calculated following a modified method from (Lamas et al., 2022), such that

$$T_L(x_m, T) = 273.15 - 1.998v\, x_m - bx_m^{1.5} - cx_m^2, \quad \textit{(Eq. S3)}$$

where x_m is concentration in molality, v is the number of ions per mol of the salt inclusion, and b and c are observationally derived.
We use the following parameters for the three salts considered in our models:

	v	*b*	*c*
NaCl	2	-1.45	0.75
KCl	2	-1.6	0.75
MgSO4	2	-2.2	0.65

lightly modified from (Lamas et al., 2022) to more accurately replicate experimentally-derived eutectic points (Fortes & Choukroun, 2010) as shown in Figure S5.

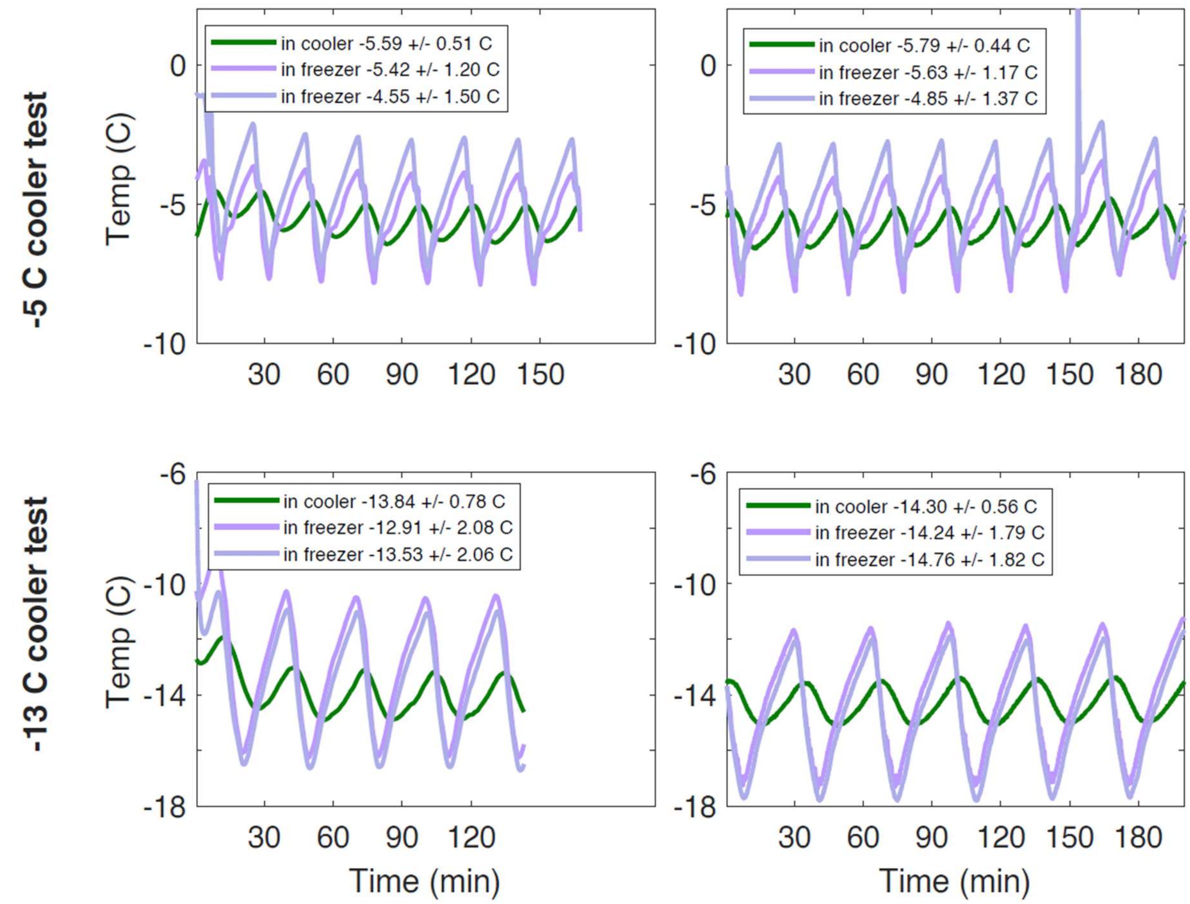

Fig. S1.
Freezer testing. Green line in all cases represents the temperature within a custom-built cooler. Two tests were conducted in each freezer, represented by each column.

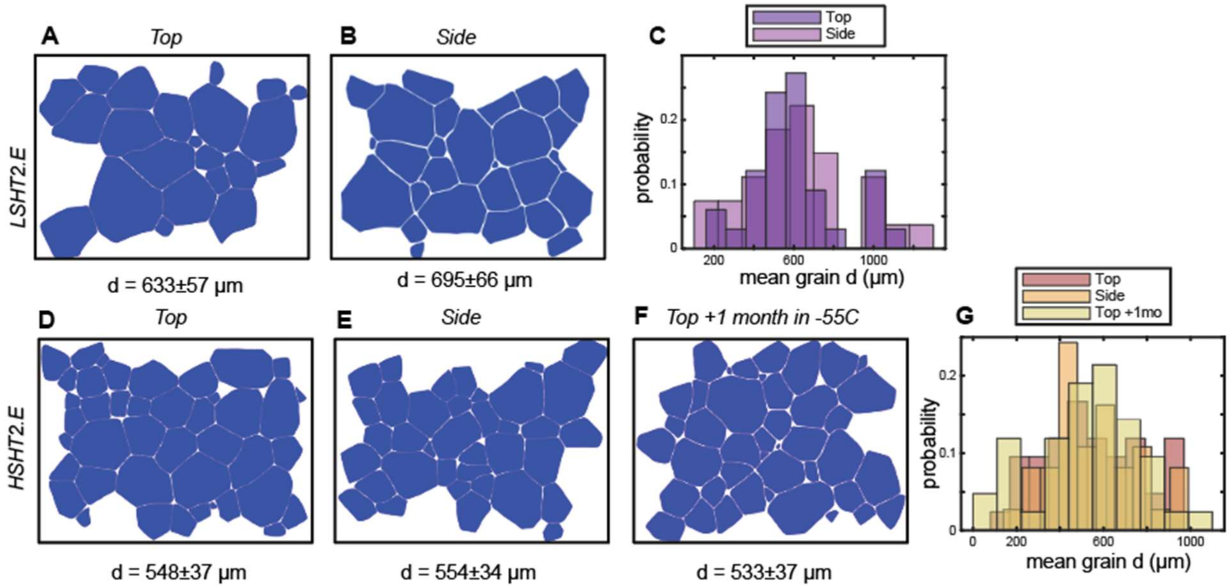

Fig. S2.

Comparison of grain size from multiple angles of sample. Tracings from (**A**) top of sample LSHT2.E, (**B**) side of sample LSHT2.E, and (**C**) histogram of grain sizes from A-B. (**D**) Tracings from top of sample HSHT2.E, (**E**) tracings from side of sample 2.E, (**F**) tracings from side of sample HSHT2.E after a month of being left in the -55 freezer, where no grain growth should have occurred, (**G**) histogram of grain sizes from D-F.

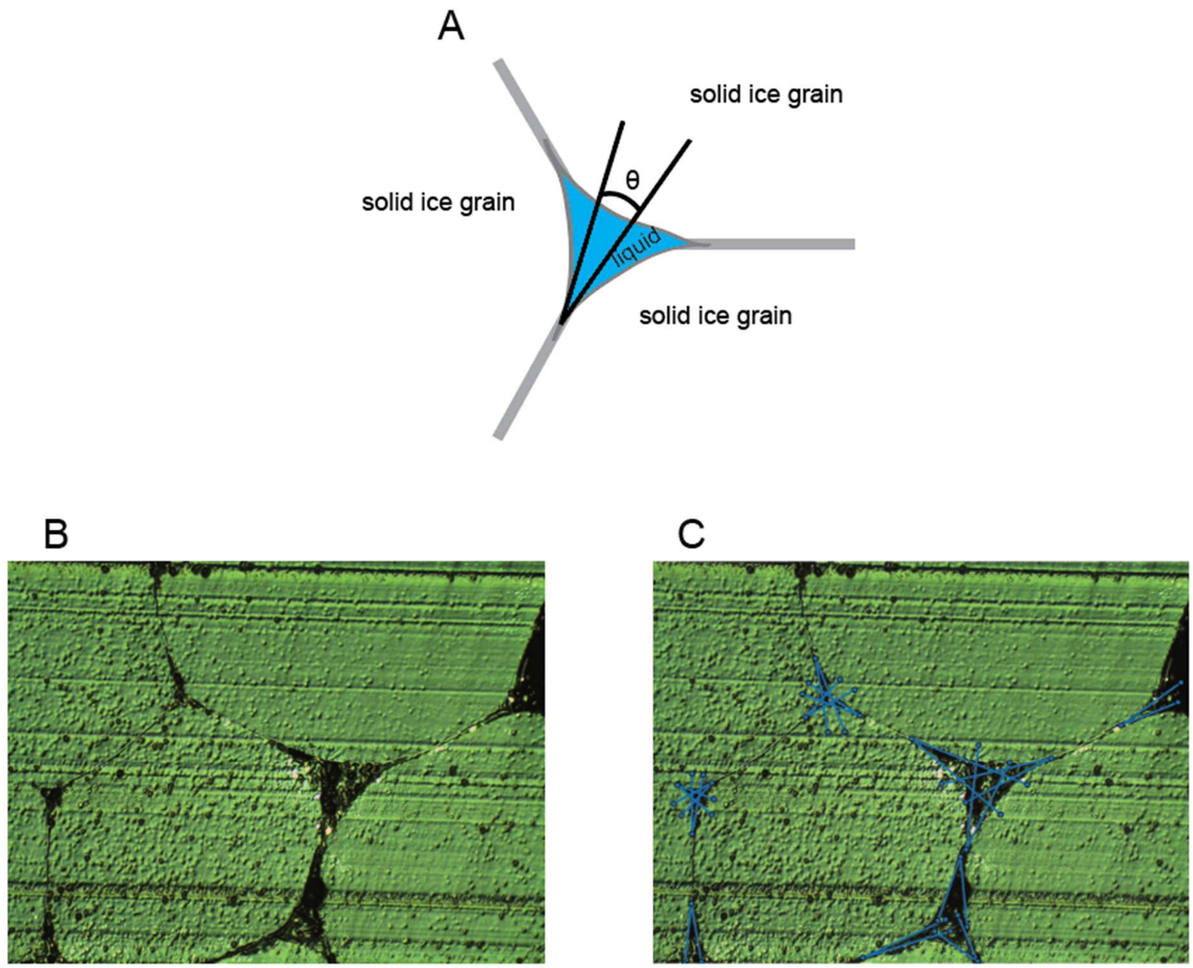

Fig. S3.
(**A**) Schematic of dihedral angle measurement in a theoretical system. (**B**) 10x image of LSLT2.E (**C**) Dihedral angle measurements of image.

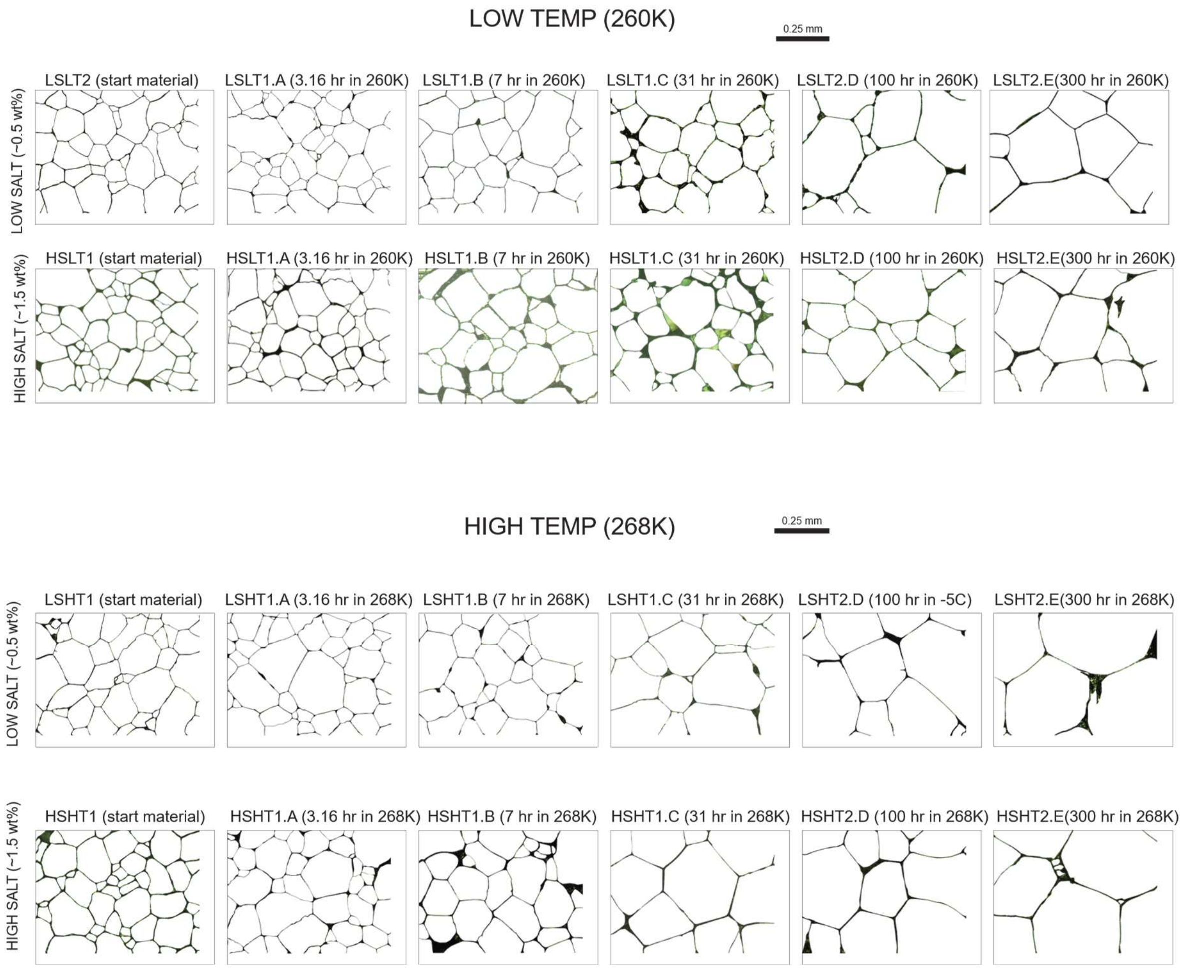

Fig. S4.

Traced grain boundaries from experimental grain growth series at low (top, 260K) and high (bottom, 268K) temperature. All grains are shown at same magnification.

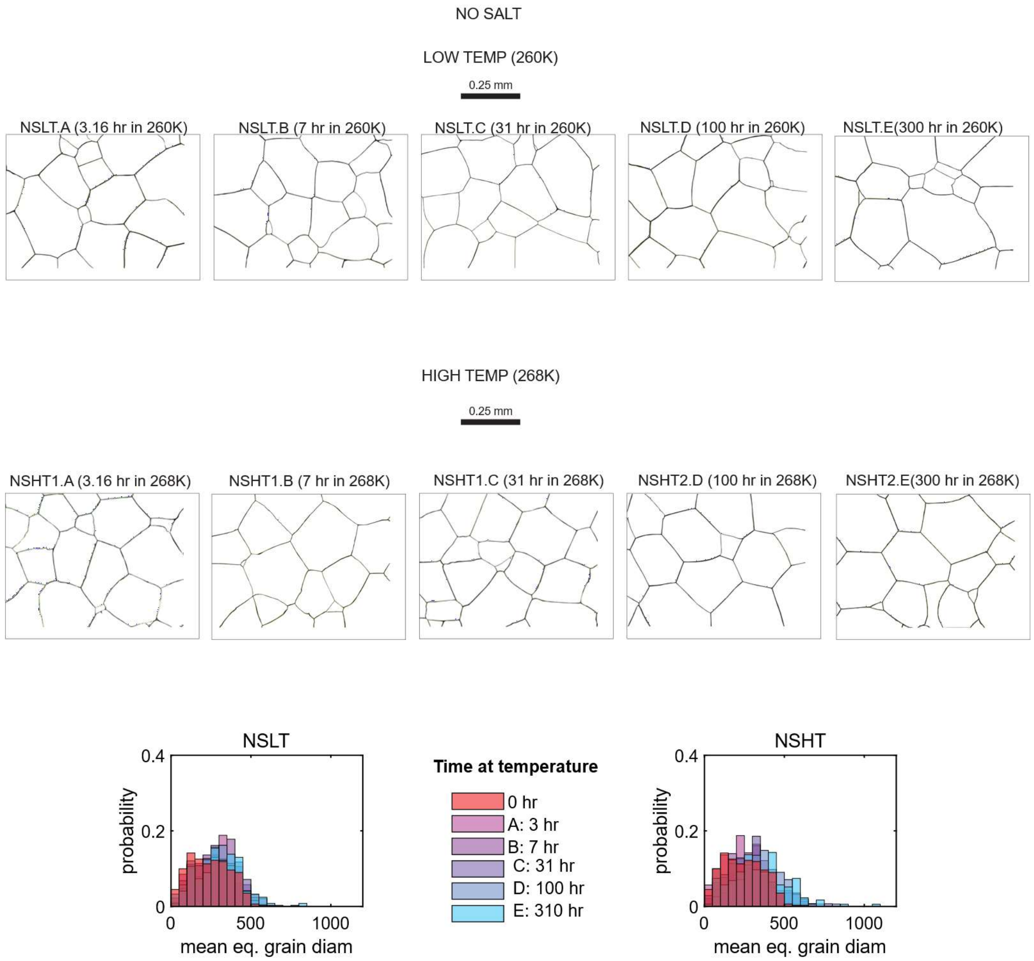

Fig. S5.

Traced grain images from no-salt experiments at low (260K, top) and high (268K, bottom) temperatures. Histograms from both experimental series are shown in the last row.

$$k_{im} = \exp(A * (1 - f_m)(V_L + 1)^B) * k_{0_{pure}} * \exp(\frac{-Q}{RT})$$

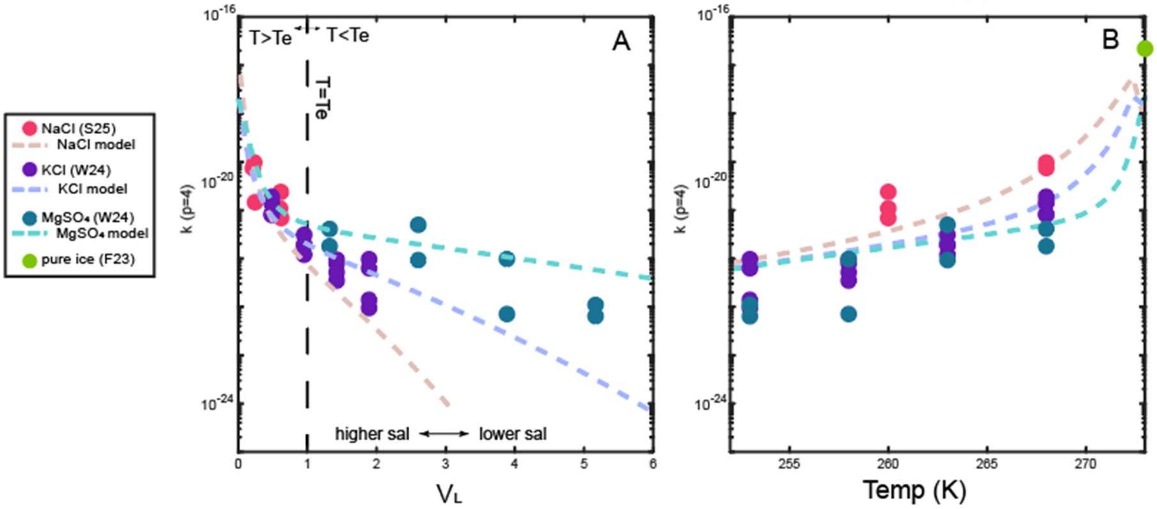

Fig. S6.
Modeled equation (6) from main text applied to three different H_2O-salt systems. S25 indicates this work, W24 and F23 from (Fan et al., 2023; Wang et al., 2024), respectively. (**A**) k_{im} as a function of vertical lever (Fig. S1). (**B**) k_{im} as a function of temperature.

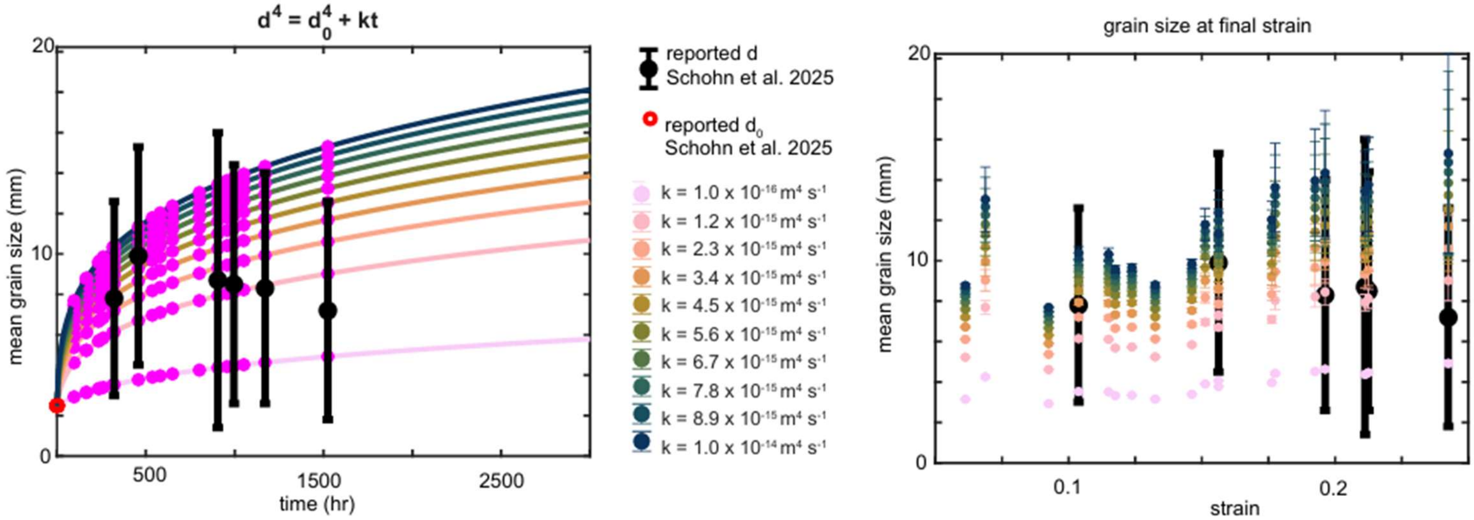

Fig. S7.
Reported final grain sizes (black) from Schohn et al, 2025, against theoretical grain-growth curves with variable range of *k* values and *p*=4.

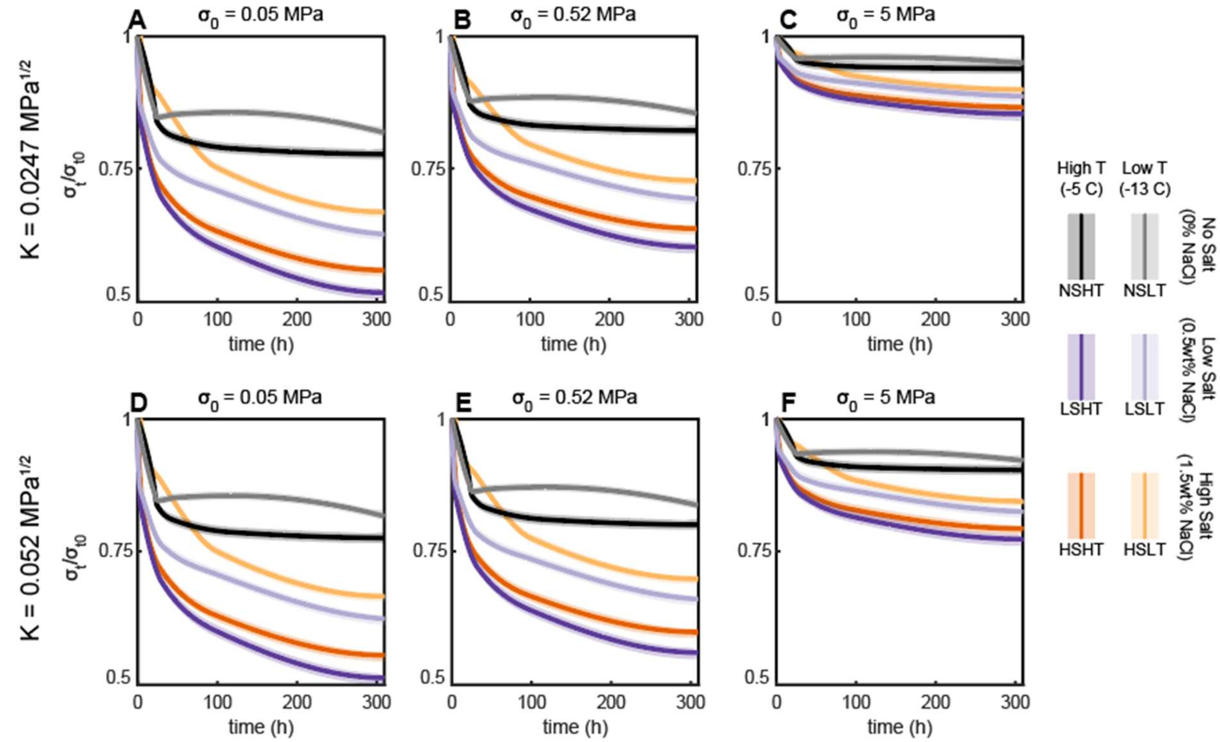

Fig. S8.

Effective tensile strength of ices exposed to warm water or saltwater, using a value of (**A- C**) K = $0.0247 \mathrm{MPa}^{\frac{1}{2}}$, on initial tensile strength (σ_0) values of (**A**) 0.05 MPa, (**B**) 0.52 MPa, and (**C**) 5 MPa, and normalized to the strength before water infiltration, or (**D - F**) K = $0.052 \mathrm{MPa}^{\frac{1}{2}}$, on initial tensile strength (σ_0) values of (**D**) 0.05 MPa, (**E**) 0.52 MPa, and (**F**) 5 MPa. Each line shows a mean value with one standard deviation above and below.

100

LOW TEMPERATURE (268 K)							
	LOW SALT						
	LSLT1	LSLT2	LSLT1.A	LSLT1.B	LSLT1.C	LSLT2.D	LSLT2.E
Duration (hr)	-	-	*3.16*	*7*	*31.6*	*100*	*310*
mean deq (µm)	193.3	183.7	198.2	206.3	266.13	311.5	405.9
error	4.9	5.74	5.27	6.5	11.9	15.4	20.7
n grains	883	738	880	692	274	332	334
best p	4.34						
k (p = 4)	2.43×10^{-20}						

	HIGH SALT						
	HSLT1	HSLT2	HSLT1.A	HSLT1.B	HSLT1.C	HSLT2.D	HSLT2.E
Duration (hr)	-	-	*3.16*	*7*	*31.6*	*100*	*310*
mean deq (µm)	138.4	138.4	143.9	165.9	195.9	257.2	359.8
standard error	7.3	7.27	4.6	7.13	6.4	10.9	19.1
n grains	284	284	941	446	735	374	315
best p	3.09						
k (p = 4)	1.07×10^{-20}						

	NSLT.A	NSLT.B	NSLT.C	NSLT.D	NSLT.E
Duration (hr)	*3.16*	*7*	*31.6*	*100*	*310*
mean deq (µm)	272.7	283.9	276.3	269.8	296.8
standard error	13.2	10.3	10.1	10.5	11.7
n grains	359	568	591	492	490
best p	15				
k (p = 4)	n/a				

HIGH TEMPERATURE (268 K)							
	LOW SALT						
	LSHT1	*LSHT2*	*LSHT1.A*	*LSHT1.B*	*LSHT1.C*	*LSHT2.D*	*LSHT2.E*
Duration (hr)	-	-	3.16	7	31.6	100	310
mean deq (µm)	165	177.9	208.5	230.5	325.75	442.8	615.2
standard error	6.08	6.86	6.15	10.1	18.5	27.9	35.2
n grains	714	582	727	337	229	225	226
best p	3.52						
k (p = 4)	9.51×10^{-20}						

	HIGH SALT						
	HSHT1	*HSHT2*	*HSHT1.A*	*HSHT1.B*	*HSHT1.C*	*HSHT2.D*	*HSHT2.E*
Duration (hr)	-	-	3.16	7	31.6	100	310
mean deq (µm)	141.7	132.9	184.9	221.1	305.9	374.6	524
standard error	8.22	5.05	7.8	8.1	12.1	20.4	29.2
n grains	274	710	372	372	310	299	262
best p	4.31						
k (p = 4)	6.82×10^{-20}						

	NSHT.A	*NSHT.B*	*NSHT.C*	*NSHT.D*	*NSHT.E*
Duration (hr)	3.16	7	31.6	100	310
mean deq (µm)	274.4	290.7	305.4	334.3	330.5
standard error	13	18.3	15.3	17.4	16.7
n grains	333	230	333	273	336
best p	12.79				
k (p = 4)	n/a				

Table S1.

Summary of experimental grain growth data on ice with (HS, LS) and without (NS) saltwater present.