Supplement of Atmos. Chem. Phys., 19, 1027–1039, 2019
https://doi.org/10.5194/acp-19-1027-2019-supplement

Atmospheric Chemistry and Physics
Open Access
EGU

Supplement of

Ice nucleating particles in the marine boundary layer in the Canadian Arctic during summer 2014

Victoria E. Irish et al.

Correspondence to: Allan K. Bertram (bertram@chem.ubc.ca)

Supplemental information

S1 Calculation of n_s-values of Niemand et al. (2012) and DeMott et al. (2016)

At -25, -20, and -15 °C, the exponential function from Niemand et al. (2012) predicts n_s-values of 307263 cm^{-2}, 39092 cm^{-2}, 1810 cm^{-2}, respectively. Errors were calculated from the 95 % prediction band.

A linear fit was applied to the n_s-values reported in DeMott et al. (2016) for laboratory conditions only. At -25, -20, and -15 °C, the n_s-values were 123 cm^{-2}, 10 cm^{-2}, and 1 cm^{-2}, respectively. Data for laboratory bloom conditions were not accounted for in this study as the reported chlorophyll *a* concentrations during the bloom experiment in DeMott et al., (2016) were much higher than average monthly chlorophyll *a* concentrations during this cruise. Errors were calculated from the 95 % prediction band of the linear fit.

S2 Calculation of the n_s-values for mineral dust on July 21st and 25th

We calculated n_s-values for mineral dust, $n_s(MD)$, from the CCSEM-EDX measurements and measurements of the total aerosol surface area of particles. Specifically, $n_s(MD)$ was calculated with the following equation:

$$n_s(MD) = \frac{[INP(T)]}{Fraction_{MD}.SD_{total}}, \quad \text{(S1)}$$

where $[INP(T)]$ is the measured concentration of the INPs as a function of temperature, $Fraction_{MD}$ is the fraction of the surface area associated with mineral dust determined from the CCSEM-EDX measurements, and SD_{total} is the surface area of the total aerosol particles determined with an aerodynamic particle sizer (APS; TSI, Inc. Model 3021). The APS measurements are discussed below as well as the method of determining SD_{total} from the APS measurements.

The APS was positioned on top of the bridge, next to the MOSSI and approximately 10 m in front of the ship's smokestack. The APS sampled through a louvered TSP inlet coupled directly to the inlet of the APS using a 16" straight vertical stainless steel tube (¾" inner diameter). The height of the TSP inlet was approximately 15 m above sea level. The total sampling flow rate of the APS was 5 L min^{-1}. The APS determined the number size distribution of particles with aerodynamic diameters between 0.5 – 20 µm. Since a dryer was not used prior to sampling with the APS, the APS measurements correspond to wet aerodynamic particle diameters ($D_{wet,aer}$). When calculating n_s-values for mineral dust, we assumed that the ratio of the surface area of mineral dust to the surface area of sea salt measured with the CCSEM-EDX in the range of 0.5 to 5 µm is applicable to the range of 0.5 to 20 µm measured by the APS.

For an upper limit to SD_{total} we calculated the total surface area using the wet aerodynamic diameter from the APS and the following equation:

$$SD_{total} = \int \pi D_{wet,aer}^2 dN, \quad \text{(S2)}$$

where N is the number concentration measured by the APS.

For a lower limit to SD_{total} we used Eq. S2, but instead of the wet aerodynamic diameter, we used the dry physical diameter. The dry physical diameter ($D_{dry,phy}$) was calculated from the wet aerodynamic diameter using the following equation (Khlystov et al., 2004):

$$D_{dry,phy} = \frac{D_{wet,aer}}{\sqrt{\frac{\rho_{wet}}{\chi \rho_o}}}, \quad \text{(S3)}$$

where ρ_{wet} is the particle density at sampling RH, ρ_o is the unit density of 1 g cm^{-3} and χ is the dynamic shape factor that accounts for a non-spherical particle shape. In Eq. S3, we assumed a dynamic shape factor of 1, and ρ_{wet} was calculated using the following equation:

$$\rho_{wet} = \rho_{water} + (\rho_{dry} - \rho_{water}) \frac{1}{gf^3}, \quad \text{(S4)}$$

where ρ_{water} is the density of water, ρ_{dry} is the density of the dry particles, and gf is the hygroscopic growth factor. For gf we used 2.3 based on an average ambient RH of 93 % and sea spray aerosol with an assumed organic content of 30 % (DeMott et al., 2016; Ming and Russell, 2001). For the density of the dry particles, we used a value of 1.87 g cm^{-3}, also based on sea spray aerosol with an assumed 30 % organic mass content (DeMott et al., 2016; Ming and Russell, 2001).

DATE	Time mid-sample (UTC)	Longitude (°)	Latitude (°)
14th July	12:51	-61.085	67.240
15th July*	17:33	-64.847	69.359
16th July*	21:52	-71.117	71.702
17th July	19:29	-79.464	73.982
18th July	20:37	-81.018	73.569
19th July	16:18	-83.976	74.110
21st July	14:21	-92.225	74.237
22nd July	12:23	-94.859	74.324
23rd July	14:41	-94.526	74.547
24th July	21:48	-94.912	74.620
25th July	19:50	-86.998	74.428
26th July*	17:13	-75.270	73.926
27th July	17:47	-63.609	73.281
28th July*	22:08	-57.885	73.261
29th July	13:40	-61.610	75.402
30th July	19:59	-72.193	76.260
31st July*	17:15	-73.272	76.317
1st August	16:44	-76.097	76.340
2nd August	20:03	-72.689	78.934
3rd August	12:41	-64.180	81.367
4th August	14:57	-69.213	80.150
5th August	22:47	-71.690	79.078
7th August	12:50	-78.381	74.701
8th August	14:22	-96.151	74.191
9th August	14:10	-98.507	74.421
10th August	16:27	-96.235	72.926
11th August	14:07	-99.243	70.090
12th August	14:11	-105.472	68.971

Table S1: Dates, times, and locations of sampling.

*Indicates dates included in the DeMott et al. (2016) study.

.

Date	Total number of particles analysed	Fraction of total number of particles classified as sea salt	Fraction of total number of particles classified as dust	Surface area of total number of particles classified as dust (μm^2)	Surface area of total number of particles classified as sea salt (μm^2)
21st July	2180	0.09	0.01	25	632
25th July	1004	0.50	0.11	32	357
29th July	516	0.32	0.08	22	805

Table S2: Results from the CCSEM-EDX analysis. Results correspond to particles in the diameter range of 0.15 - 0.5 µm.

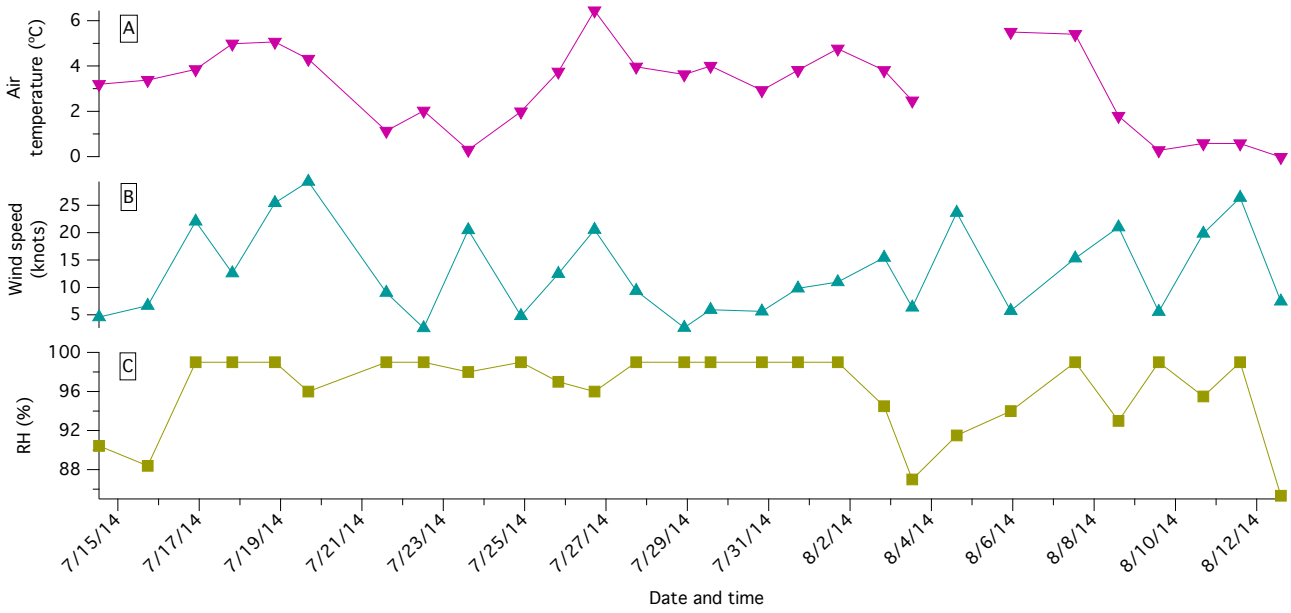

Figure S1 - Air temperature (A), wind speed (B), and RH (C) during sampling.

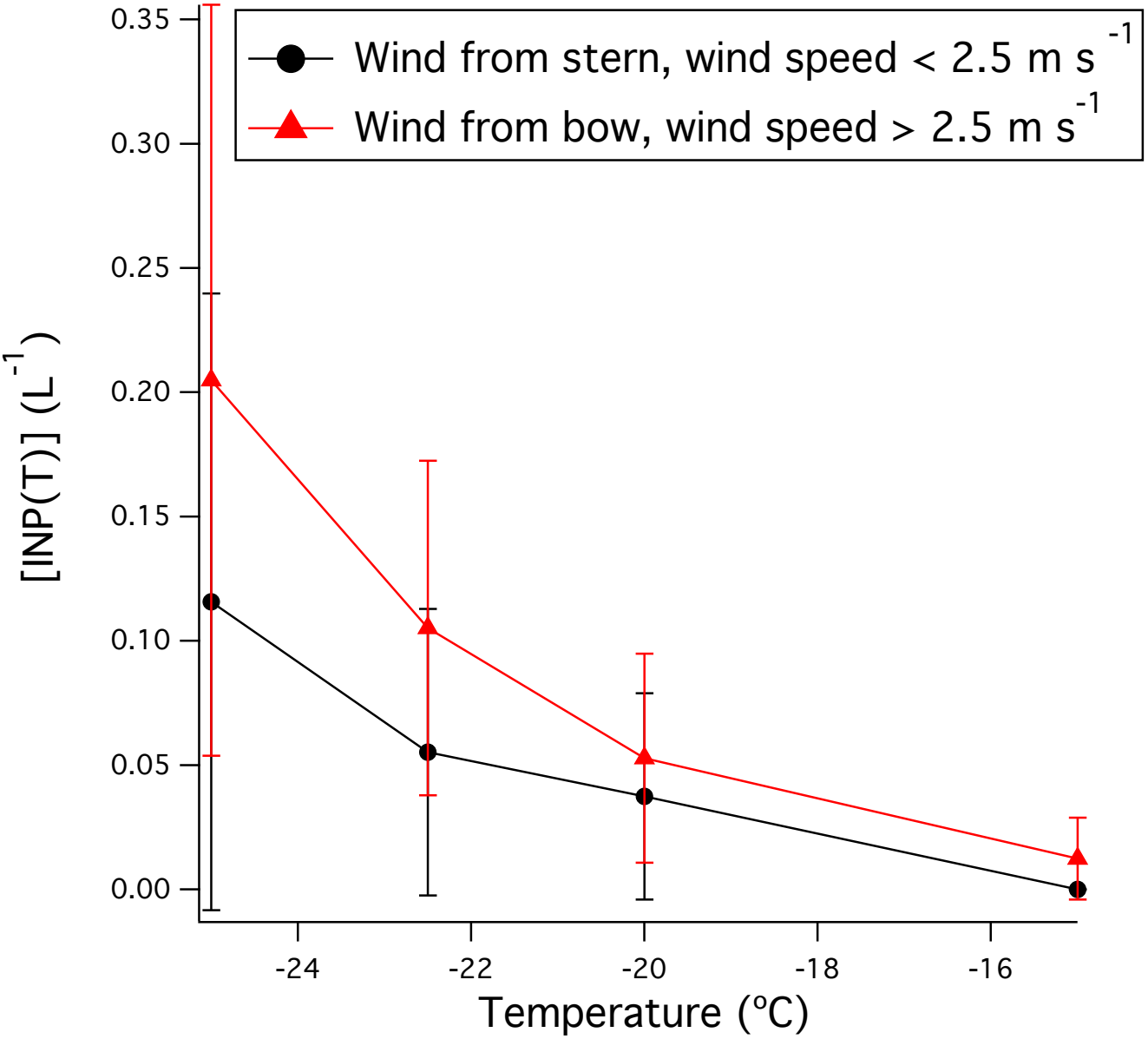

Figure S2: Comparison of *[INP(T)]* (L^{-1}) when the wind direction measured on the ship was coming from the bow of the ship (between 0-90° and 270-360°, where 0°/360° = bow of ship) and when the minute average wind speed was higher than 2.5 m s^{-1} (in red) to the *[INP(T)]* (L^{-1}) when the wind direction was from the stern of the ship (between 90°-270°) or when the minute average wind speed was less than 2.5 m s^{-1} (in black). Error bars represent the 95 % confidence interval.

Figure S3: WRF domain used in FLEXPART.

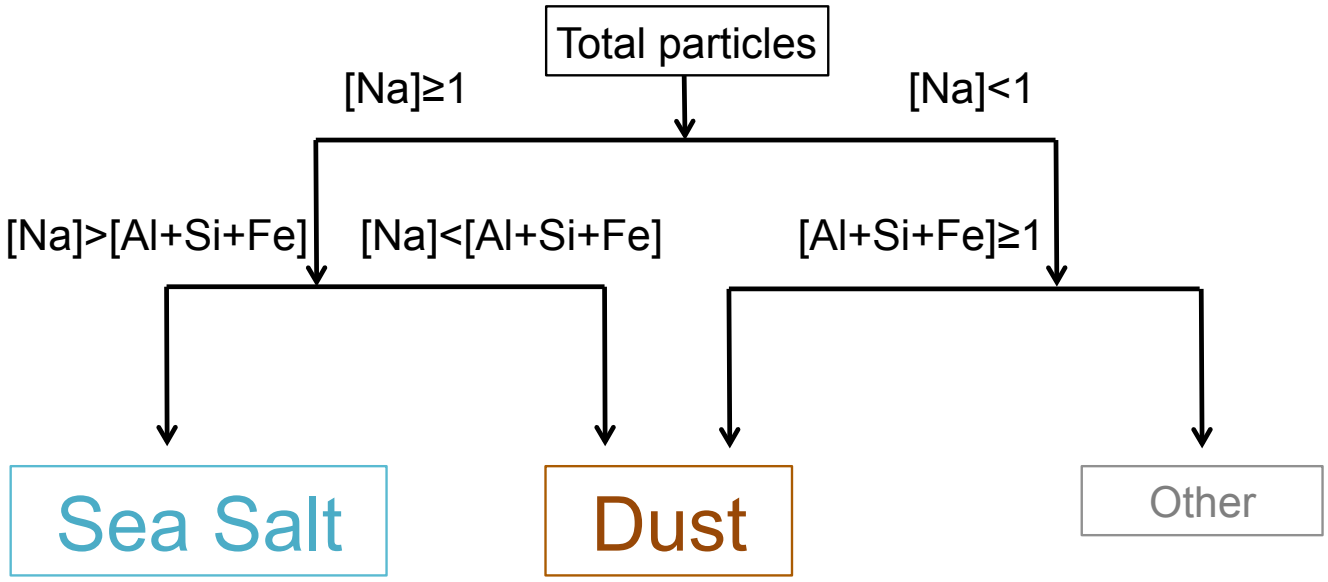

Figure S4: CCSEM-EDX particle classification scheme used in the current study. Numbers represent atomic percentage.

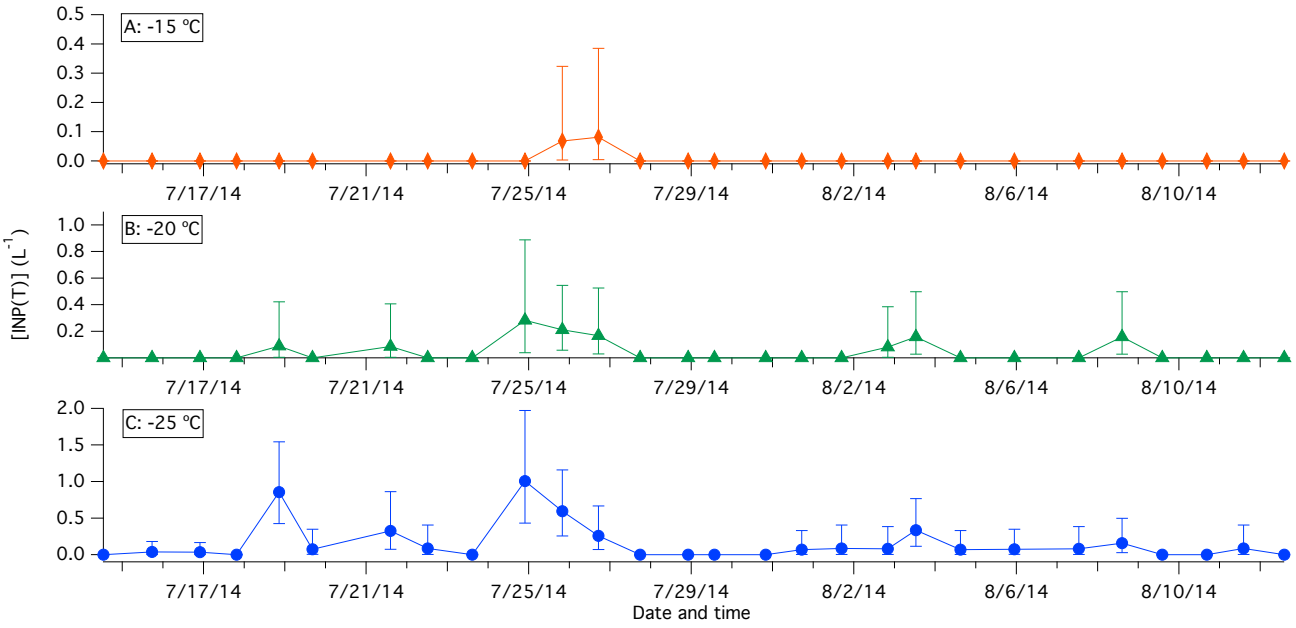

Figure S5: Time series of *[INP(T)]* (L^{-1}) at A) -15 °C, B) -20 °C, and C) -25 °C. Error bars were calculated using nucleation statistics following Koop et al. (1997).

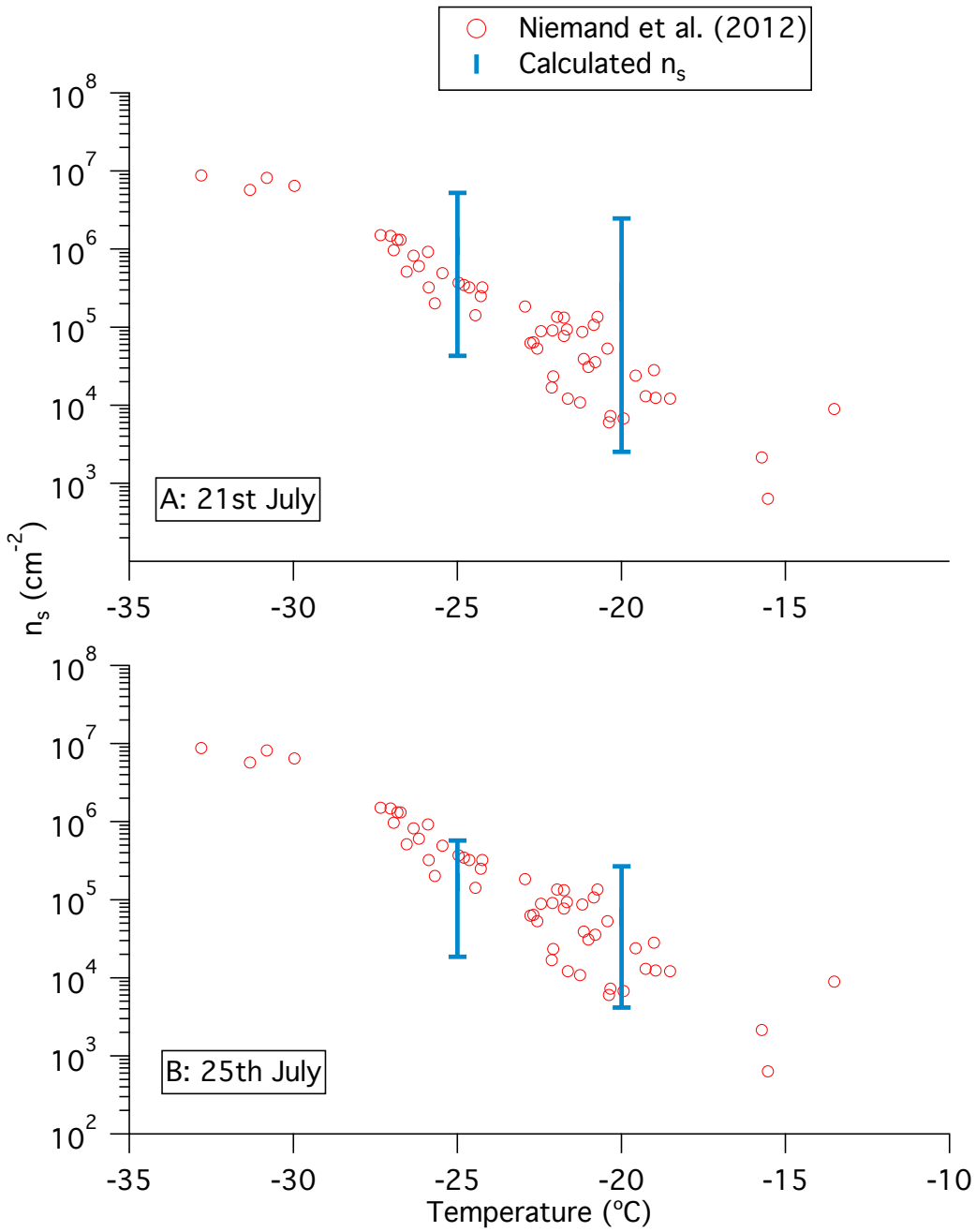

Figure S6: Plot of n_s-values for mineral dust particles as a function of temperature for A) the 21st July, and B) the 25th July. The uncertainties in the n_s-values include the uncertainties in the INP measurements and the uncertainties in the total surface area of the particles measured by the APS as discussed in Section S2.

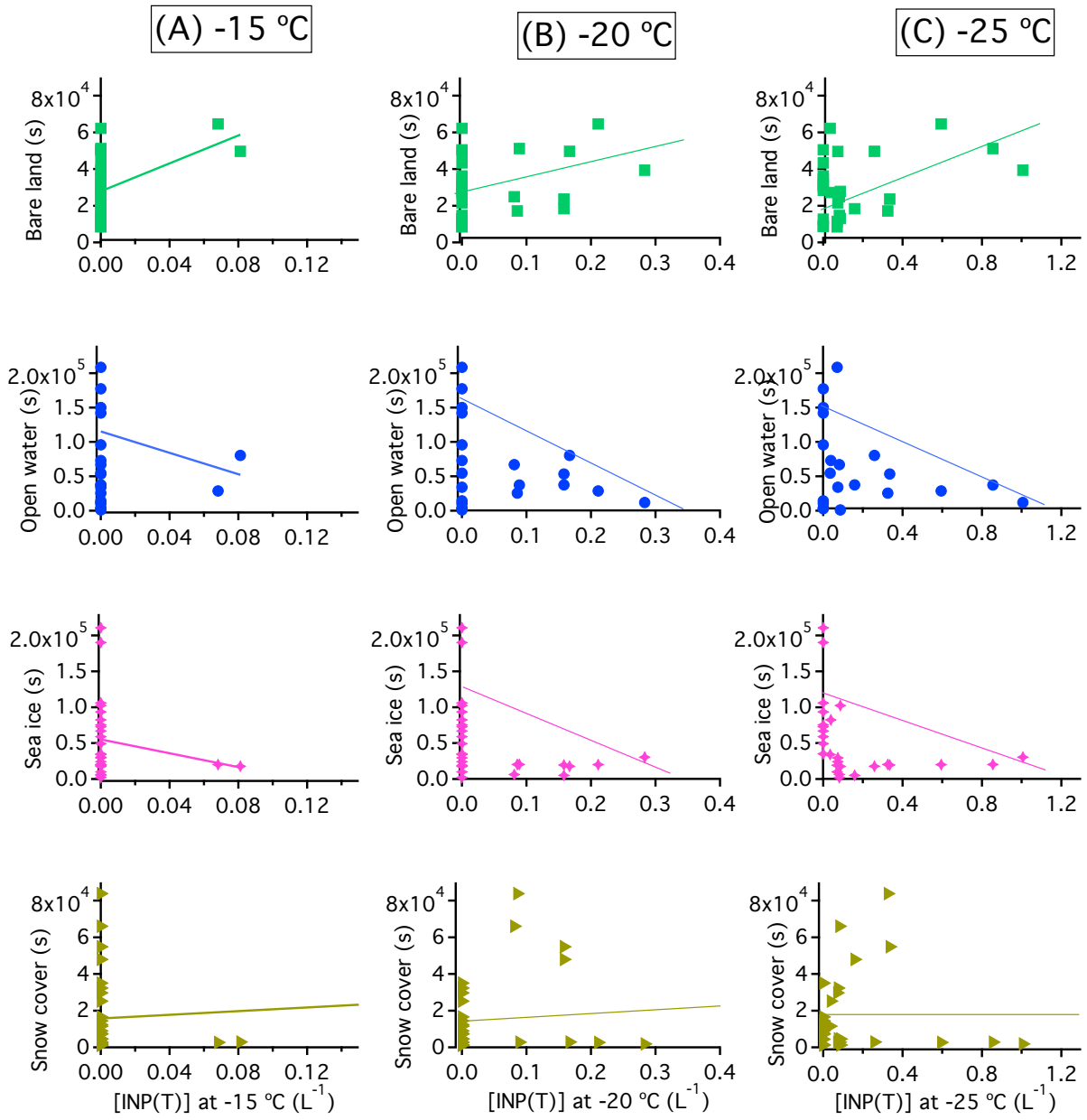

Figure S7: Plots for correlation analyses between the time the air mass spent over different surface types within 0-300 m of the surface and [INP(T)] at A) -15 °C, B) -20 °C, and C) -25 °C. A summary of the statistics from the correlation analysis can be found in Table 1.