

Supplement of Atmos. Chem. Phys., 19, 7775–7787, 2019
<https://doi.org/10.5194/acp-19-7775-2019-supplement>
© Author(s) 2019. This work is distributed under
the Creative Commons Attribution 4.0 License.



Supplement of

Revisiting properties and concentrations of ice-nucleating particles in the sea surface microlayer and bulk seawater in the Canadian Arctic during summer

Victoria E. Irish et al.

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

The copyright of individual parts of the supplement might differ from the CC BY 4.0 License.

Supplemental information

S1 Non-colligative effects of seawater on freezing temperatures

5 Two ml of a microlayer sample stored at $-80\text{ }^{\circ}\text{C}$ for less than 6 months (station 4) was mixed with 2 ml of a solution of Instant Ocean salt in ultrapure water. Instant Ocean is a commercially available sea salt replica used regularly by aquariums to mimic ocean composition (Atkinson and Bingman, 1997). The microlayer sample was mixed with three different concentrations of the Instant Ocean solution (26, 55, and 77 g of salt per kg of water) to make three salinity-altered microlayer samples. The freezing temperatures of the three salinity altered microlayer samples and the freezing temperatures of the three Instant Ocean solutions were measured and are shown in Figure S6.

10












Station	Photos	Notes	Station	Photos	Notes
1		Foggy. Rippled sea surface with a small swell. Beaufort scale (BS) approx. 3-4. Wind speed 3.8 m/s.	7		A lot of ice and icebergs. Starting to spit rain. Overcast. Polar bears in vicinity. Wind speed 0.3 m/s.
2		Sunny. Next to ice island. Icebergs approx. 100m away. BS approx. 2. Wind speed 6.1 m/s.	8		Overcast. Ice bits around. BS ~1. No polar bears...yet. Wind speed 3.5 m/s.
3		Partly sunny. Light winds. A few icebergs approx. 200m away. Can see land. Wind speed 6.6 m/s.	9		Sunny, ice bits, 1/10 th ice. BS 0. Clouds 1/9 th cirrus. Wind speed 1.3 m/s.
4		Can see Greenland. Overcast, rippled sea surface and a bit of a swell. BS ~2. Wind speed 0.7 m/s.	10		BS ~4, sunrise, clear skies, most wavy conditions yet. Wind speed 6.9 m/s.
5		Sunny, slight swell, rippled surface. BS ~3/4. Wind speed 2.8 m/s.	11		BS ~3, sunrise, mostly cloudy. Wind speed 5.6 m/s.
6		Sunny, rippled waves. Icebergs more than 2miles away. BS 2. Wind speed 4.4 m/s.			

Table S1. Conditions at sampling stations.

	Bulk T ₅₀ -value		
	r	p	n
Heterotrophic bacterial abundance	-0.53	0.047	11
Total phytoplankton abundance (0.2 - 20 µm)	0.48	0.067	11
Salinity	-0.83	0.001	11
Temperature	0.36	0.151	10

Table S2. Correlations between biological and physical properties of bulk seawater and T₅₀-values in 2016. Values in bold indicate results that are statistically significant.

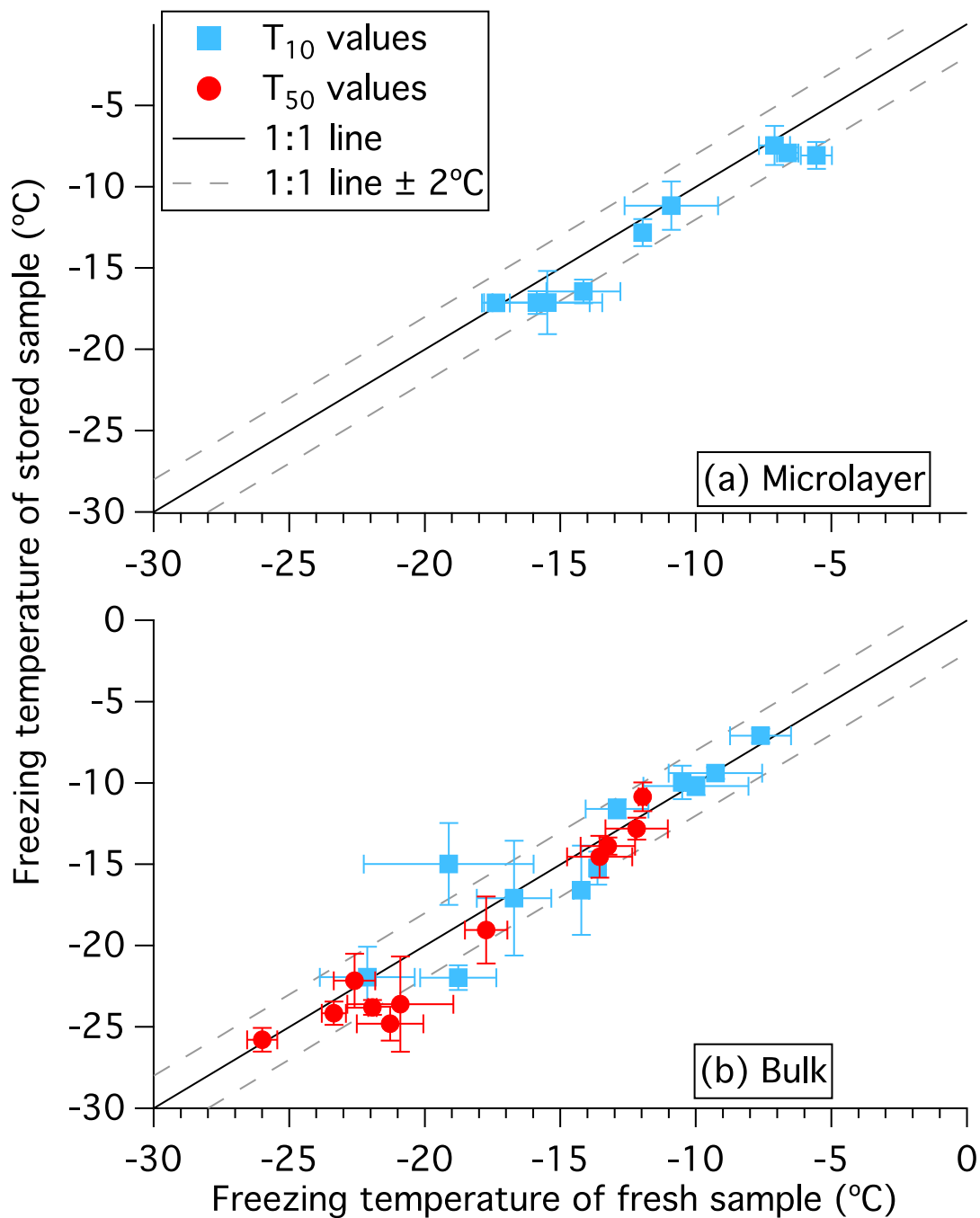


Figure S1. Plots comparing the T₅₀-values and T₁₀-values for duplicate fresh and stored (at -80 °C for up to six months) samples. (a) Microlayer samples and (b) bulk seawater samples. Data points are the average T₅₀-values and T₁₀-values from three experiments. Error bars are the 95% confidence interval for three repeat experiments. With experimental variability, all microlayer and bulk seawater samples lie within the 1:1 line ± 2 °C.

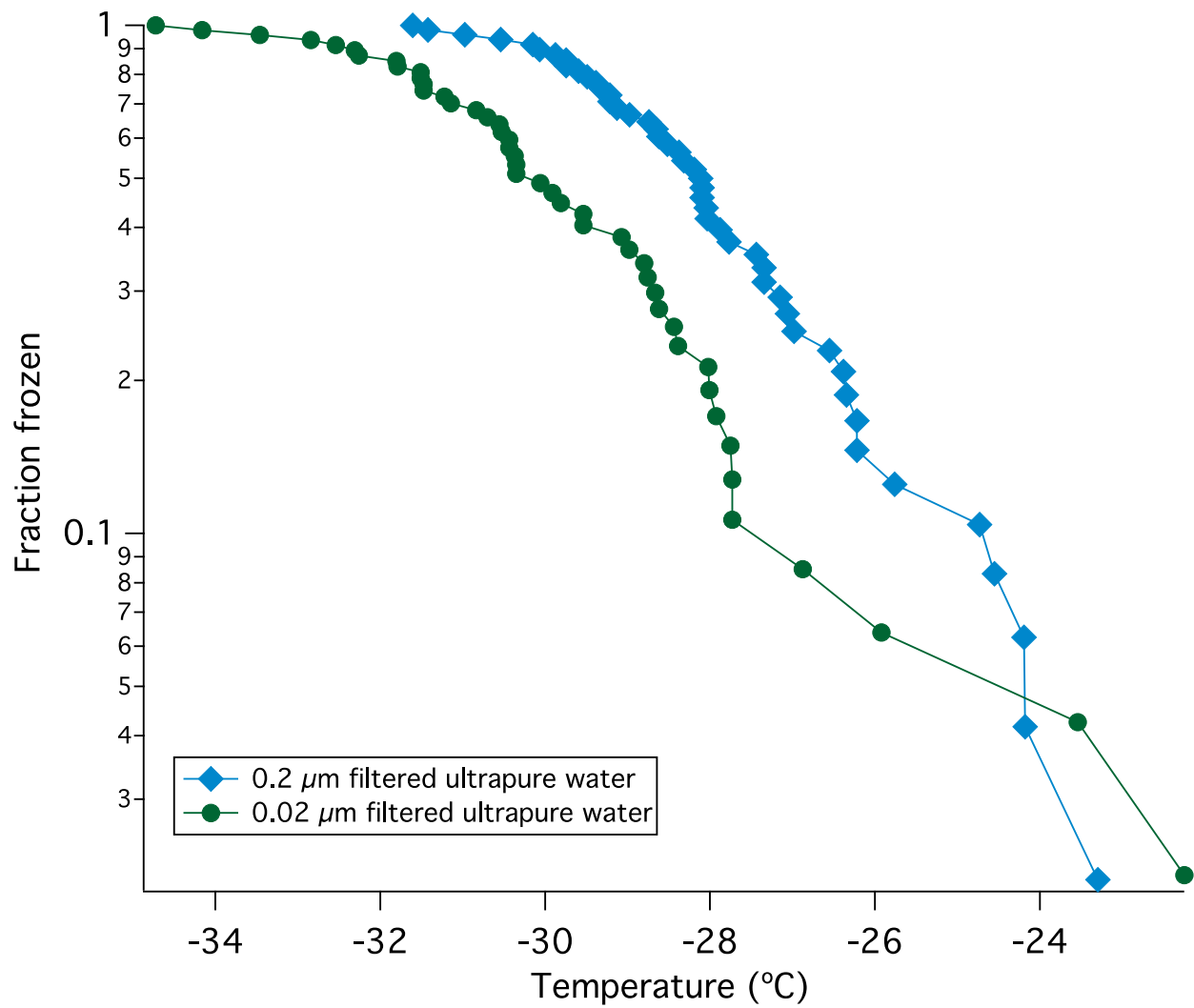


Figure S2. Plot comparing the frozen fraction curves of ultrapure water passed through filters with pore sizes of 0.2 and 0.02 μm .

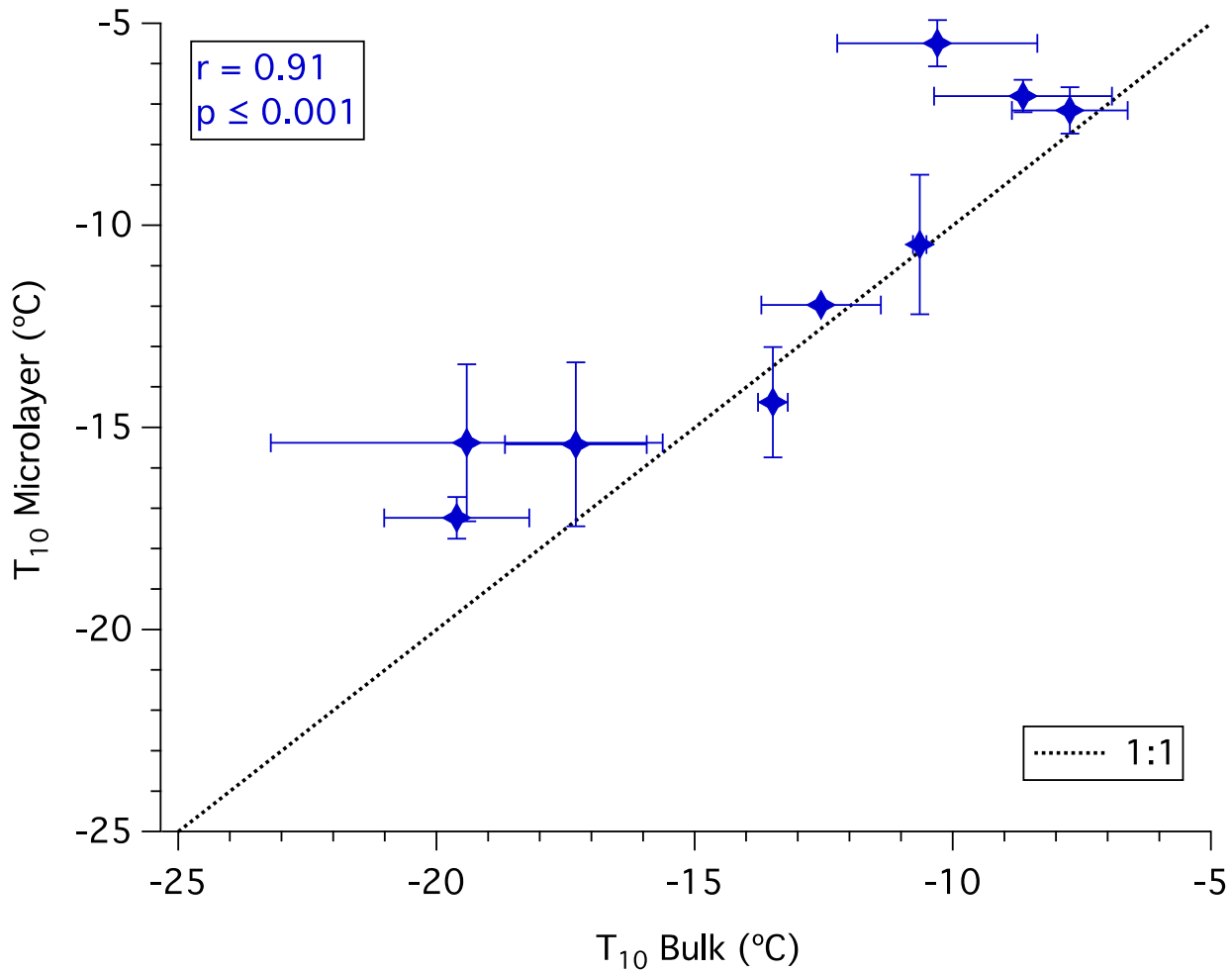


Figure S3. Relationship between T_{10} -values for microlayer and bulk seawater samples with a 1:1 line for reference. Data points are the average T_{10} -values from three repeat experiments. Error bars are the 95% confidence interval for three repeat experiments. Only freezing data that was at warmer temperatures than the field blanks are included.

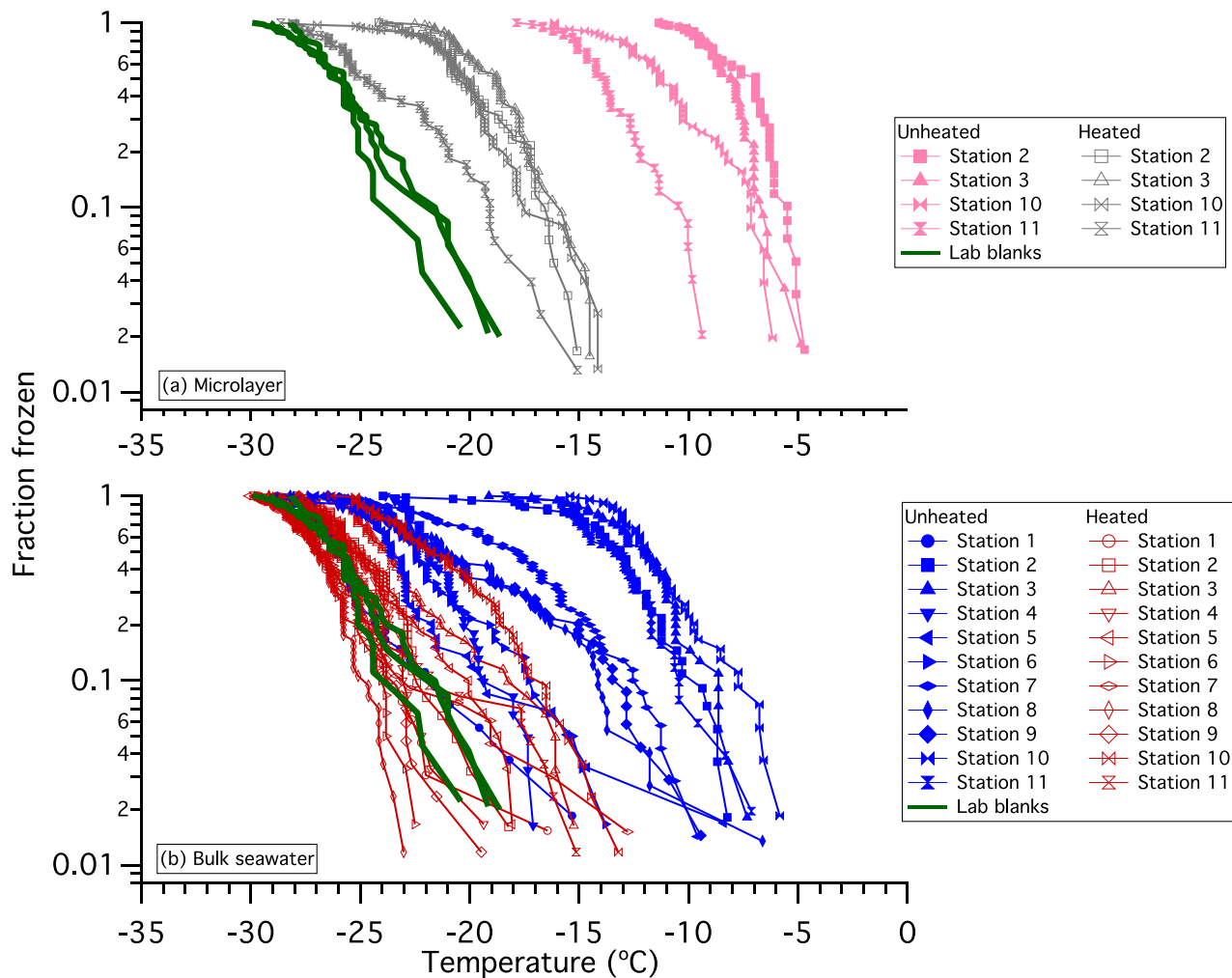


Figure S4. Effect of heating on the fraction frozen curves for unfiltered samples from (a) the microlayer and (b) bulk seawater. Each data point corresponds to one droplet freezing event. All data have been corrected for freezing point depression.

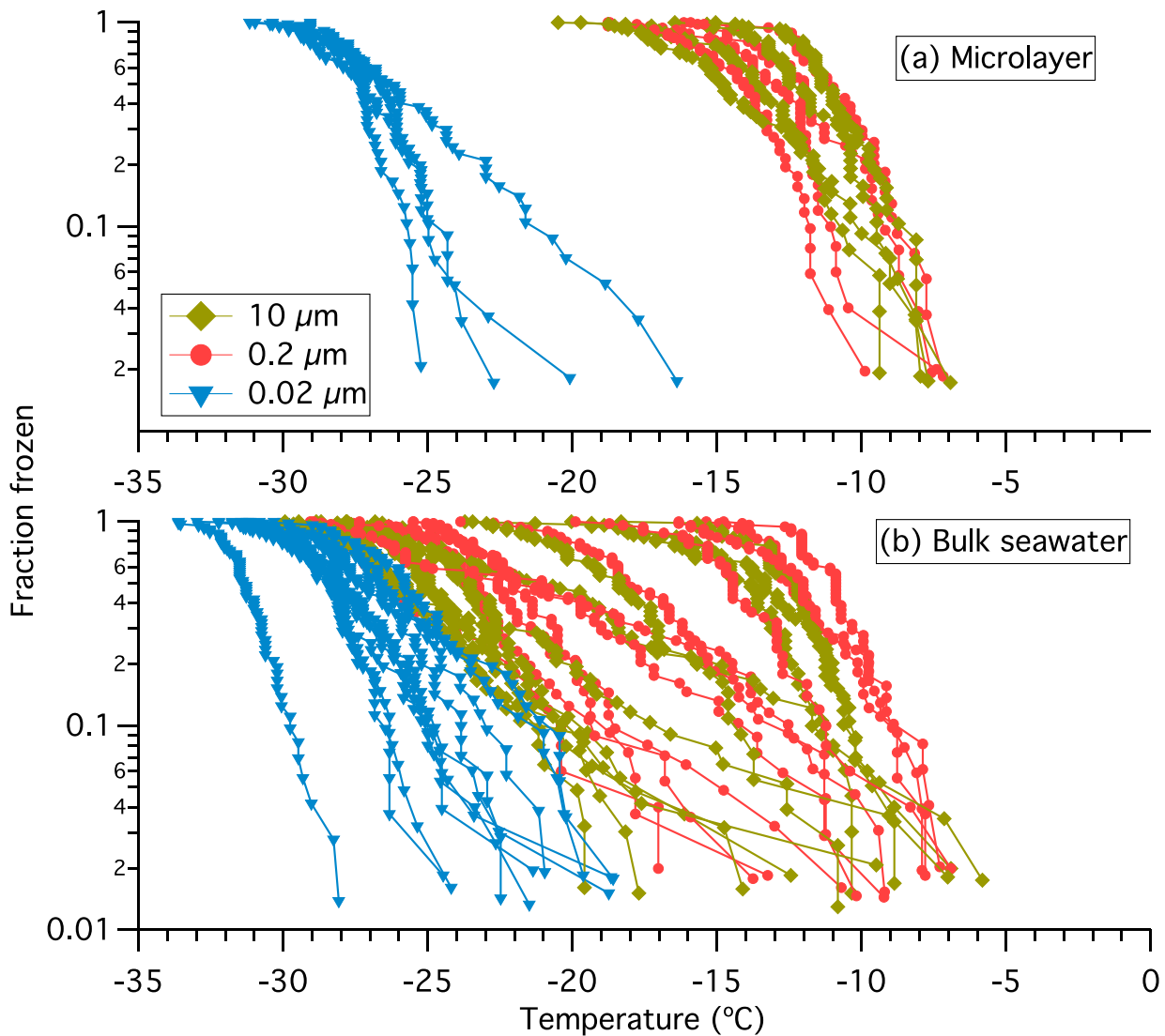


Figure S5. Fraction of droplets frozen as a function of filter pore size in (a) microlayer samples and (b) bulk seawater samples. Filter pore sizes used in the experiments were 10 μm (yellow diamonds), 0.2 μm (red circles) and 0.02 μm (blue triangles). All data have been corrected for freezing point depression.

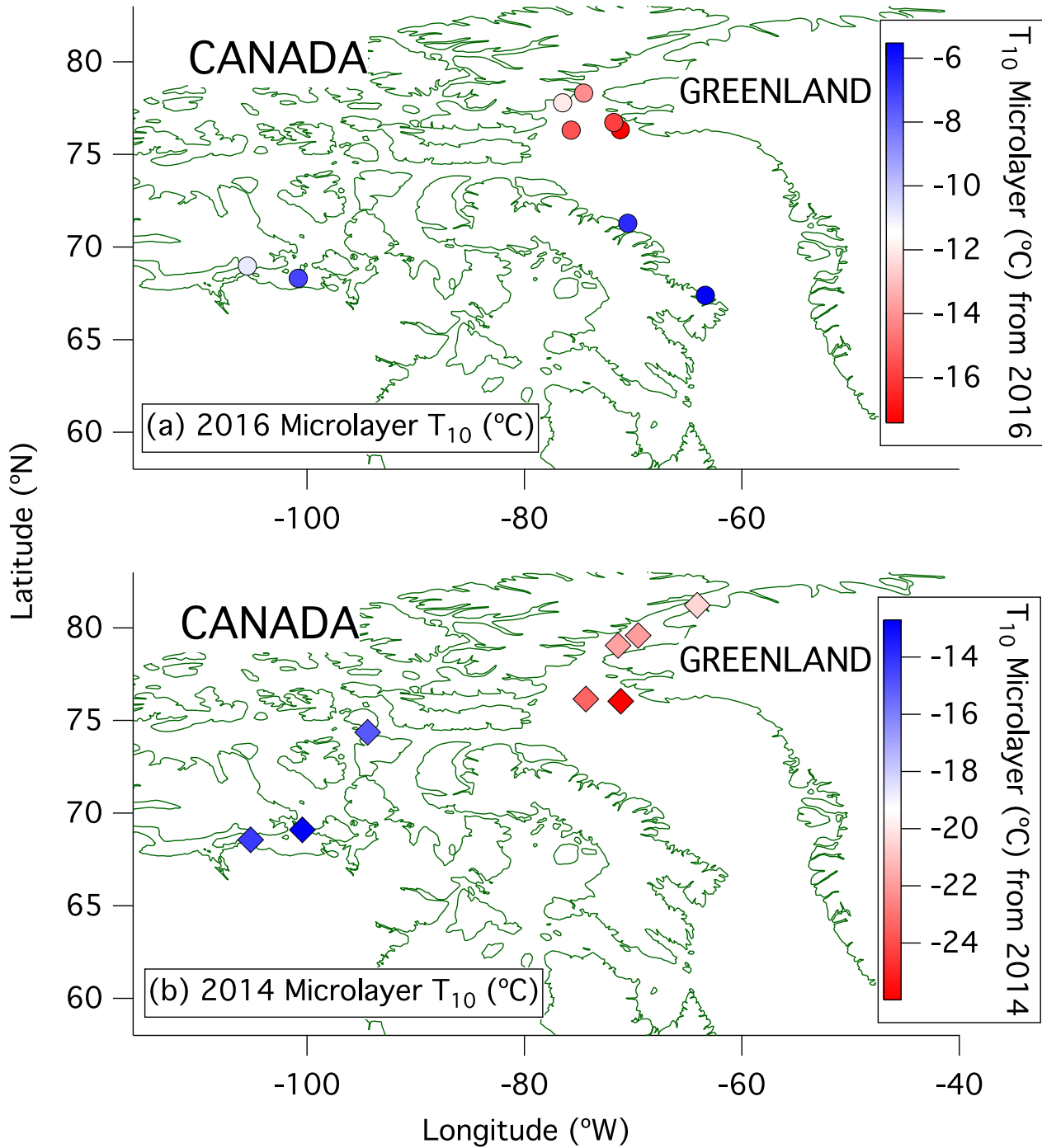


Figure S6. Spatial patterns of T_{10} -values in (a) 2016, and (b) 2014 for the microlayer.

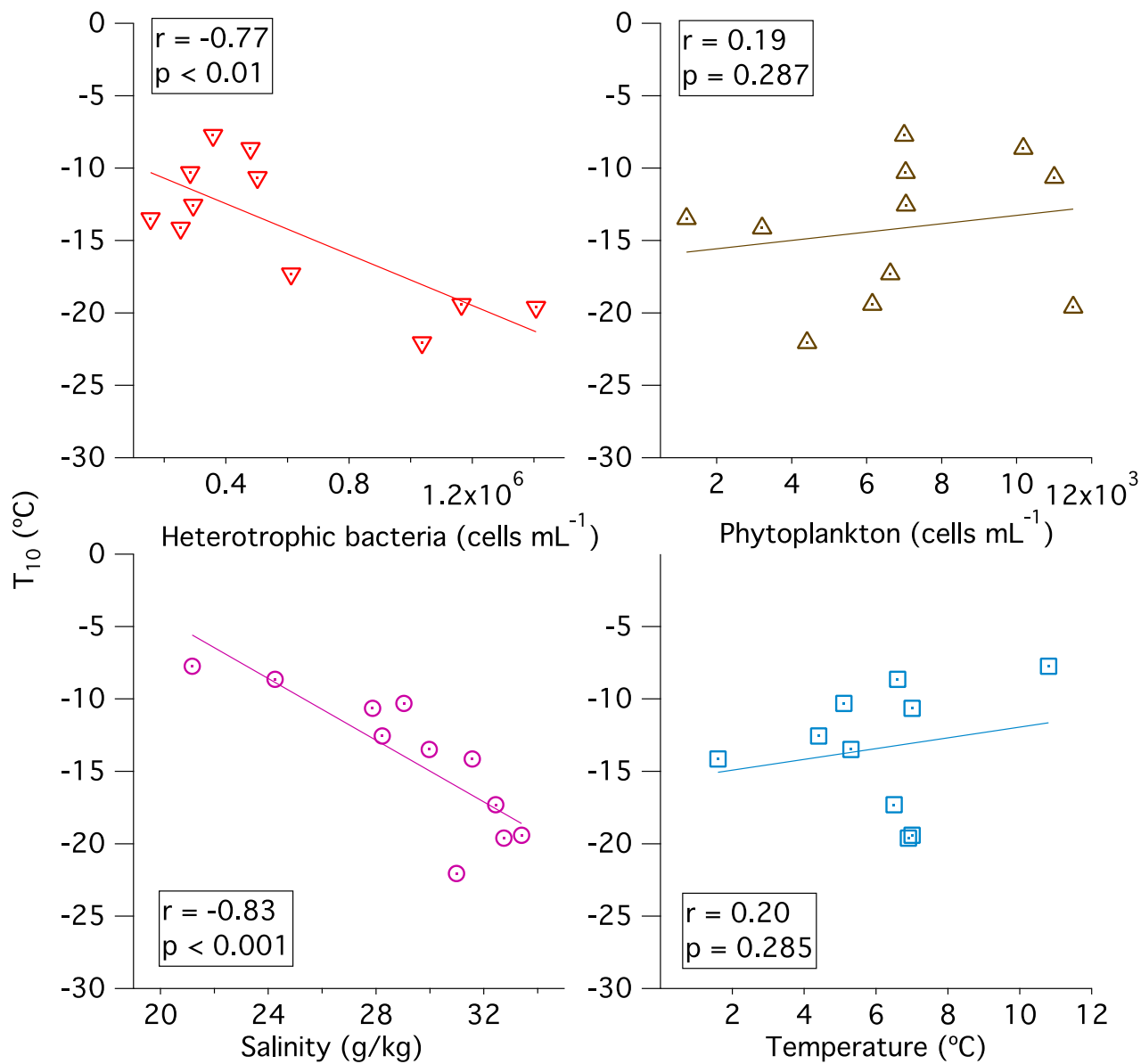
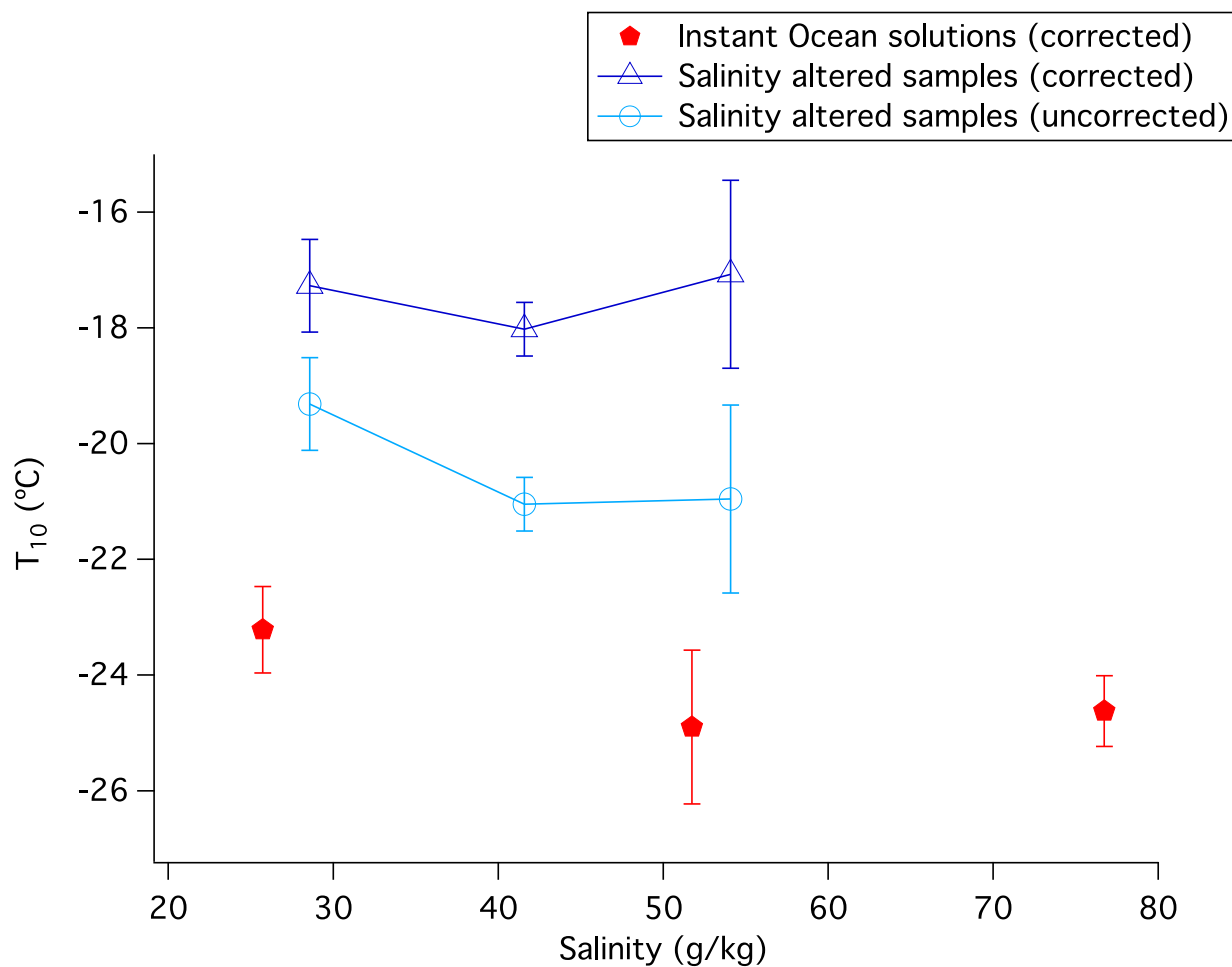


Figure S7. Relationships between T_{10} -values, and biological or physical properties of bulk seawater during the 2016 expedition. Phytoplankton include 0.2-20 μm photosynthetic eukaryotes and cyanobacteria.



5 **Figure S8.** Plot of the T₁₀-values of the microlayer sample from station 4 as a function of salinity. The salinity was adjusted by adding solutions of Instant Ocean in ultrapure water to the samples. Data points represent averages and error bars represent the 95 % confidence intervals of 3 repeat experiments. Light blue circles represent T₁₀-values uncorrected for freezing point depression. Dark blue triangles represent T₁₀-values after correcting for freezing point depression by the presence of salts as described in Section 2.3.3. Red pentagons represent T₁₀-values for solutions of Instant Ocean in ultrapure water, after correcting for freezing point depression.

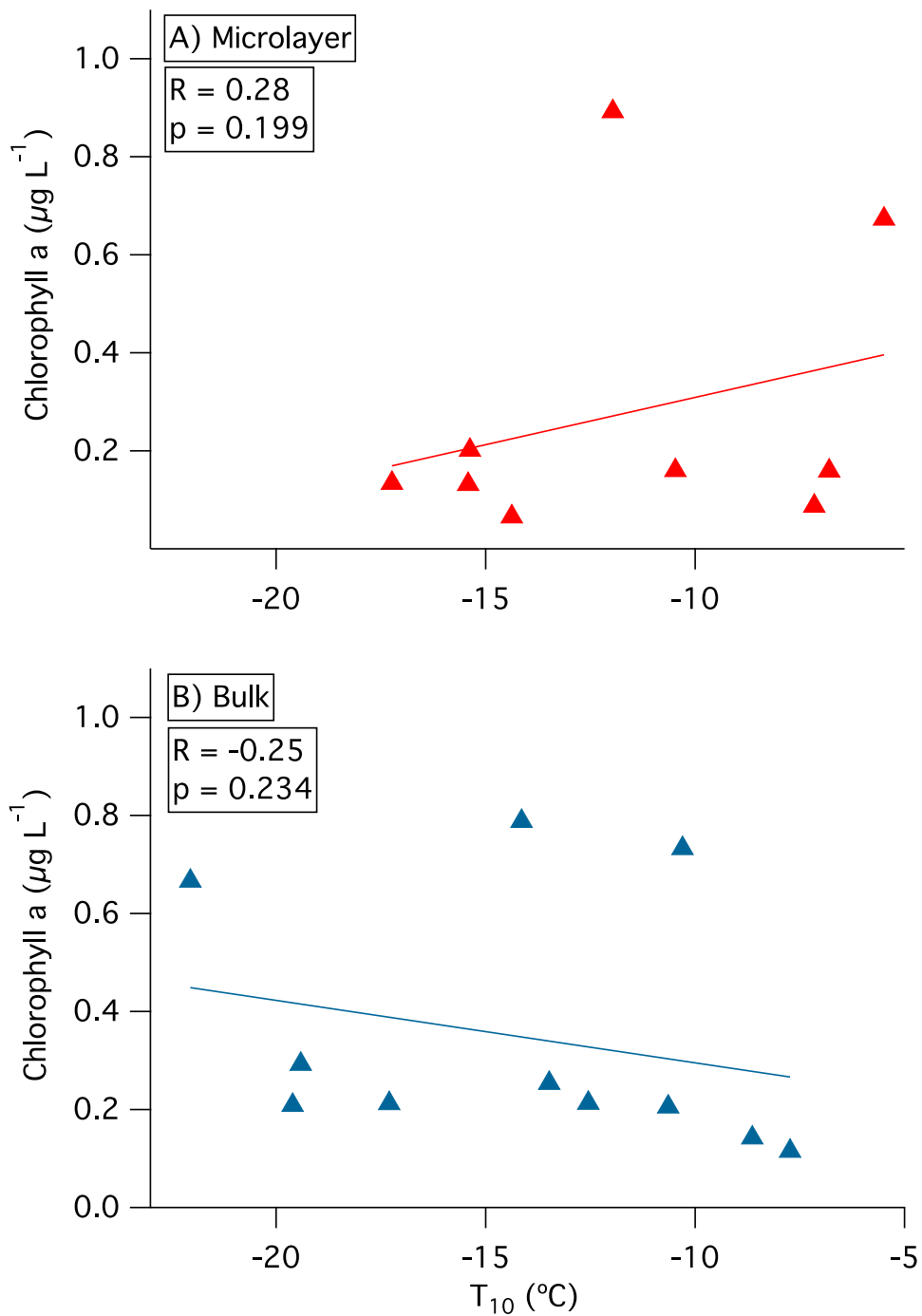


Figure S9. Relationship between our measured chlorophyll *a* concentrations and the T_{10} -values of microlayer and bulk seawater for 2016.

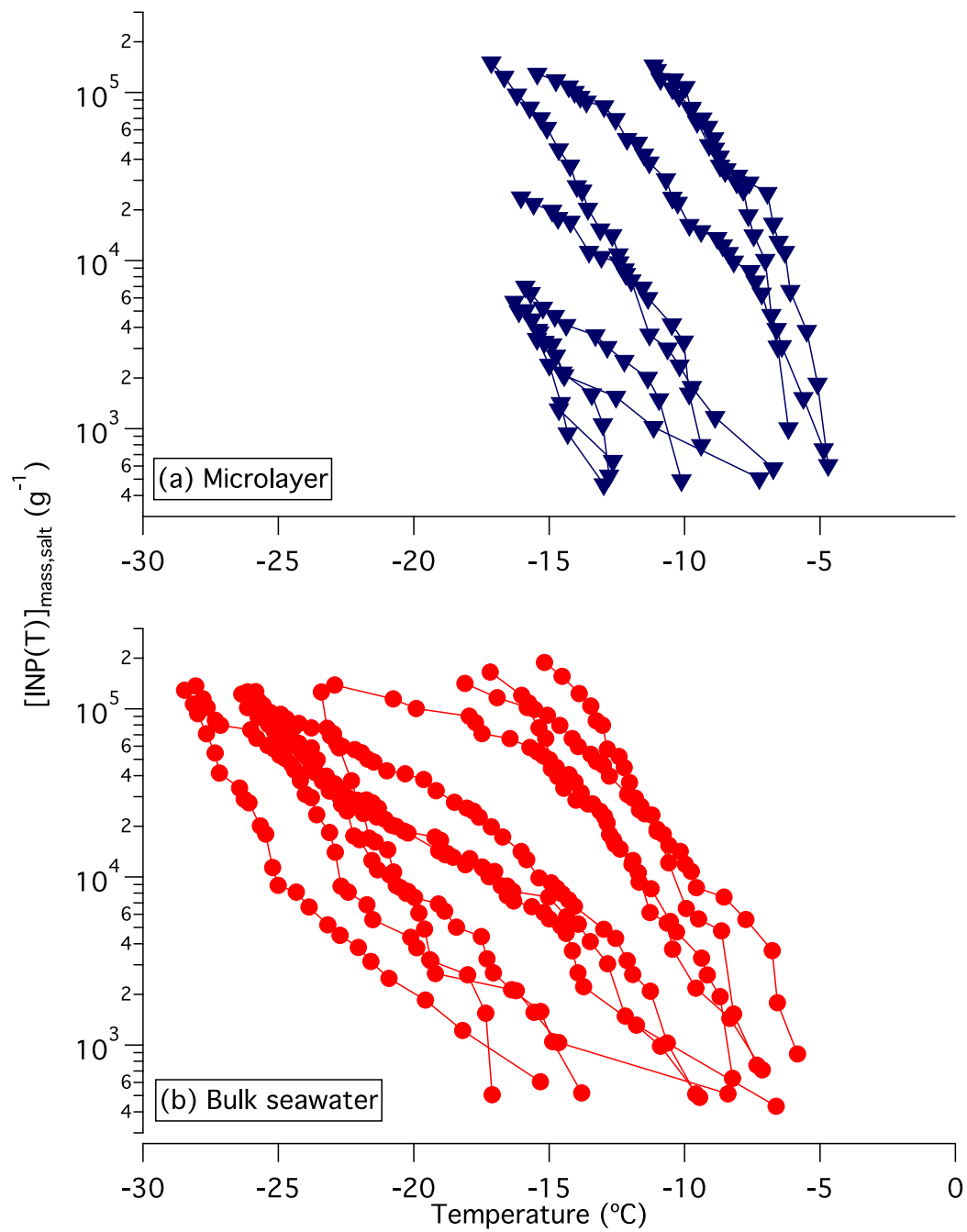


Figure S10. Plot of the concentration of INPs in the liquid per unit mass of sea salt, $[INP(T)]_{mass,salt}$, as a function of temperature for (a) the microlayer, and (b) bulk seawater.

References

- Atkinson, M. J. and Bingman, C.: Elemental composition of commercial seasalts, *J. Aquaric. Aquat. Sci.*, 8, 39–43 [online] Available from: <http://www.rudyv.be/Aquarium/sels.pdf>, 1997.
- 5 Burgers, T. M., Miller, L. A., Thomas, H., Else, B. G. T., Gosselin, M. and Papakyriakou, T.: Surface water $p\text{CO}_2$ variations and sea-air CO_2 fluxes during summer in the Eastern Canadian Arctic, *J. Geophys. Res. Ocean.*, 122, 9663–9678, doi:10.1002/2017JC013250, 2017.