BIOGEOCHEMICAL PARTITIONING BETWEEN THE LIQUID WATER AND ICE PHASES DURING FREEZE-DOWN IN ANTARCTIC AND ARCTIC LAKES

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INTRODUCTION

The freezing or maintenance of thick ice cover on seasonally and perennially frozen lakes, respectively, plays a major role in the physical, chemical and biological properties of these lakes. The partitioning of chemical and biological constituents between the water and ice, during freezing, can produce concentrated brines beneath the overlying ice and influence the biogeophysical properties of the ice itself. As water molecules freeze they create a crystalline lattice that repels most of the solutes and particulate matter that were dissolved or suspended in the water. The materials that become trapped in the ice typically concentrate in localized inclusions or in liquid vein networks which develop between the ice grains. Despite much contemporary interest in the habitability of icy systems at Earth's poles, little is known about how constituents partition between the liquid and solid phase. We conducted controlled freezing experiments using water from Arctic and Antarctic lakes to investigate chemical and biological segregation between ice and water during progressive freezing.

OBJECTIVES AND HYPOTHESES

Overarching Objective: To understand the biogeochemical dynamics and biological response to phase changes during formation and growth of ice covers under seasonal and perennial freezing regimes.

Hypotheses:

1. In a physical response, solutes will be incorporated into the ice based on their respective affinities: $Cl^- > F^- \sim NH_4^+ > NO_3^- > Na^+ \sim K^+ > Ca^{2+} > SO_4^{2-}$ (Eichler et al., 2001).
2. In a biological response, microbial communities from Arctic and Antarctic lakes will incorporate into the ice phase in a similar manner.

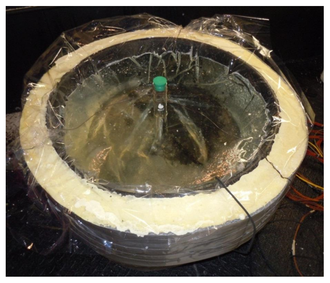

Figure 1. The simulated lake experimental setup

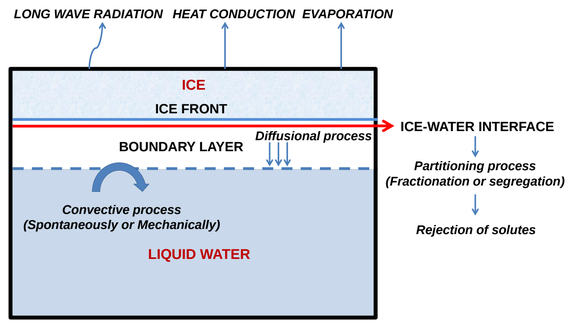

Figure 2. Conceptual model of ice cover formation.

RESULTS

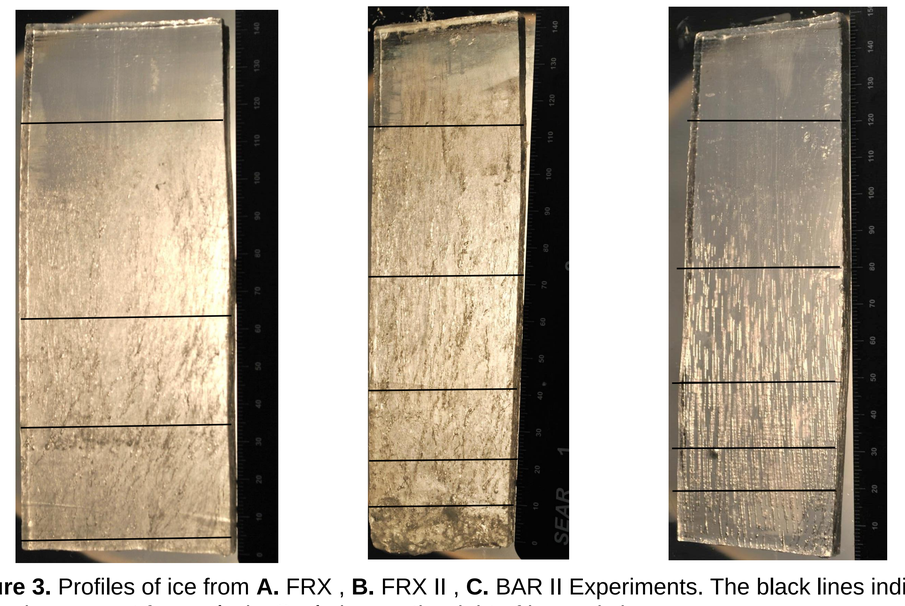

Figure 3. Profiles of ice from **A.** FRX , **B.** FRX II , **C.** BAR II Experiments. The black lines indicate where ice was cut for analysis. Scale bar on the right of image is in cm.

Segregation Coefficient: The effective exclusion of solutes from the solid phase and retained in the liquid phase.

$$K_{eff} = C_{ice}/C_{bulk\ water}$$

A higher K_{eff} indicates the ice accepts the solute in the ice matrix, where as a lower value indicates the solute is repelled from the ice matrix and stays in the liquid phase.

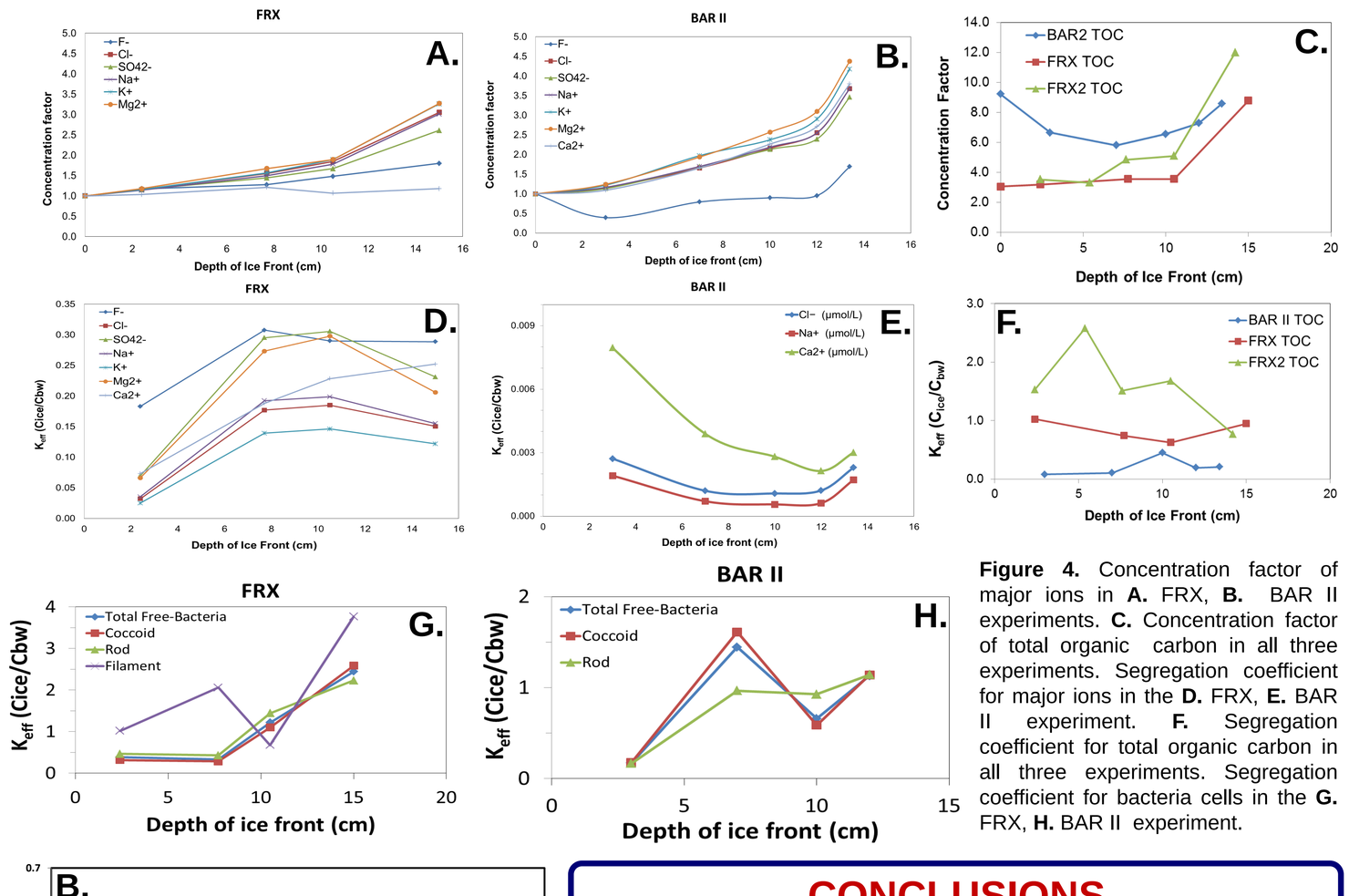

Figure 4. Concentration factor of major ions in **A.** FRX, **B.** BAR II experiments. **C.** Concentration factor of total organic carbon in all three experiments. Segregation coefficient for major ions in the **D.** FRX, **E.** BAR II experiment. **F.** Segregation coefficient for total organic carbon in all three experiments. Segregation coefficient for bacteria cells in the **G.** FRX, **H.** BAR II experiment.

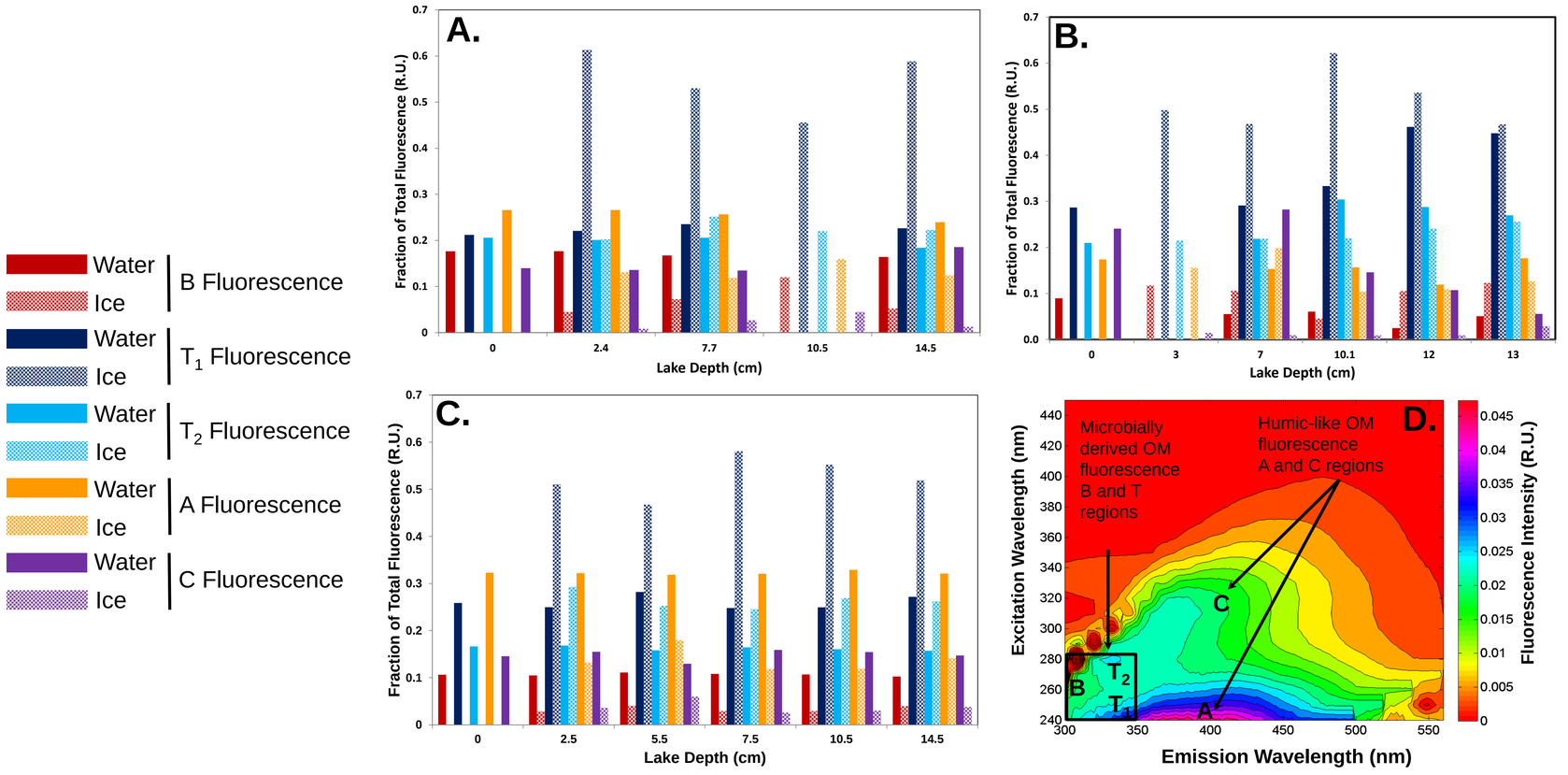

Figure 5. Excitation Emission Matrix Fluorescence Spectroscopy (EEMS) reports fluorescence intensity measured over a range of excitation and emission wavelengths. We employ the fluorophores labelled as A, C, B, and T as proposed by Coble (1996). Organic matter fluorophores can be subdivided into two regions based on reactivity. B and T (Tyrosine- and Tryptophan-like) fluorophores are more labile than A and C (humic-like) fluorphores, which are more resistant to further degradation. **A.** Fraction of total fluorescence for each of the 5 selected fluorophores in the liquid and water phases of FRX experiment. **B.** Fraction of total fluorescence for each of the 5 selected fluorophores in the liquid and water phases of BAR II experiment. **C.** Fraction of total fluorescence for each of the 5 selected fluorophores in the liquid and water phases of FRX II experiment. **D.** An example excitation/emission intensity plot for the T0 water of the FRX experiment with the 5 fluorphores labeled.

CONCLUSIONS

1. The physical structure of ice differs between Arctic and Antarctic lakes, which is likely due to the geochemistry of each lake.
2. Individual ions become incorporated into the ice in a predictable manner based on the chemical affinities for the ice matrix.
3. There may be differences in bacterial incorporation into the ice matrix based on the freezing regime to which the organisms are adapted.
4. Microbially derived, labile organic matter is more readily incorporated into the ice than recalcitrant organic matter, which is segregated into the liquid phase.

These data allow us to describe microhabitats in ice and liquid water based on the biogeochemical partitioning observed.

Acknowledgements

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