BRIEFING NOTE

Rafting of Growing Antarctic Sea Ice Enhances In-Ice Biogeochemical Activity in Winter

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Objective – A briefing note/policy brief aims to provide a concise outcome-based synopsis of recent research or expert opinion that may inform decision making and activities by authorities, NGOs and NPOs. The policy note series aims to complement the academic peer reviewed literature published by NRF-SAEON, and highlight key messages from high-level engagements.

**Key Recommendations:**

1. South Africa must continue to study and sample sea ice in the Antarctic Marginal Ice Zone. Our contributions are providing crucial data and knowledge about severely understudied region, often the only datasets that exist for this region are coming from South African led expeditions.
2. Future sea ice model development should move away from the single-layer model and consider sea ice as an active environment during winter that is composed of multiple layers with distinct biogeochemical environments.

## Executive Summary:

The Antarctic marginal ice zone (AMIZ) is a region of intense air-sea interactions where sea ice begins to form during winter. It is generally assumed that little to no biological activity occurs in winter sea ice, with the chemical and biological composition of the ice instead set by seawater that is incorporated during ice formation. We sampled young ice (YI) and first-year ice (FYI; collectively, growing sea ice) in the Atlantic AMIZ in winter 2019, the first such collection from this region. Our measurements of sea-ice crystal structure and oxygen isotopes suggest that the FYI formed from repeated breaking and piling up of younger ice. This idea is supported by model experiments showing that the FYI was the result of more than just temperature-driven thickening of YI. Additionally, our measurements and modelling of nutrients and chlorophyll in the ice strongly suggest that the biological community was active during winter. Our findings challenge the assumption that winter sea ice is biologically inactive and suggest that the biological and chemical signatures of YI are conserved as growing ice is broken up and reformed. The results of our study will help to improve and validate future modeling efforts.

**Study description:**

Sea ice samples were collected during the South African led Southern oCean seAsonaL Experiment (SCALE; https://scale.org.za/) aboard the *R/V S.A. Agulhas II.* Sampling sites were located along the Good Hope transect between 57°S and 58.5°S, 150 km apart (***Figure 1***). The study employed protocols and techniques that were developed by the sea ice team at the University of Cape Town (UCT) by adapting existing techniques that are employed in the Arctic for the Antarctic. These adapted techniques leverage the skills and infrastructure available to South Africans and the captain and crew of the *R/V S.A. Agulhas II*. Once collected, sea ice cores were transported back to UCT where they were processed and analysed. The aim of this study was to characterise the physical and biogeochemical properties of the sea ice found in the Antarctic Marginal Ice Zone.

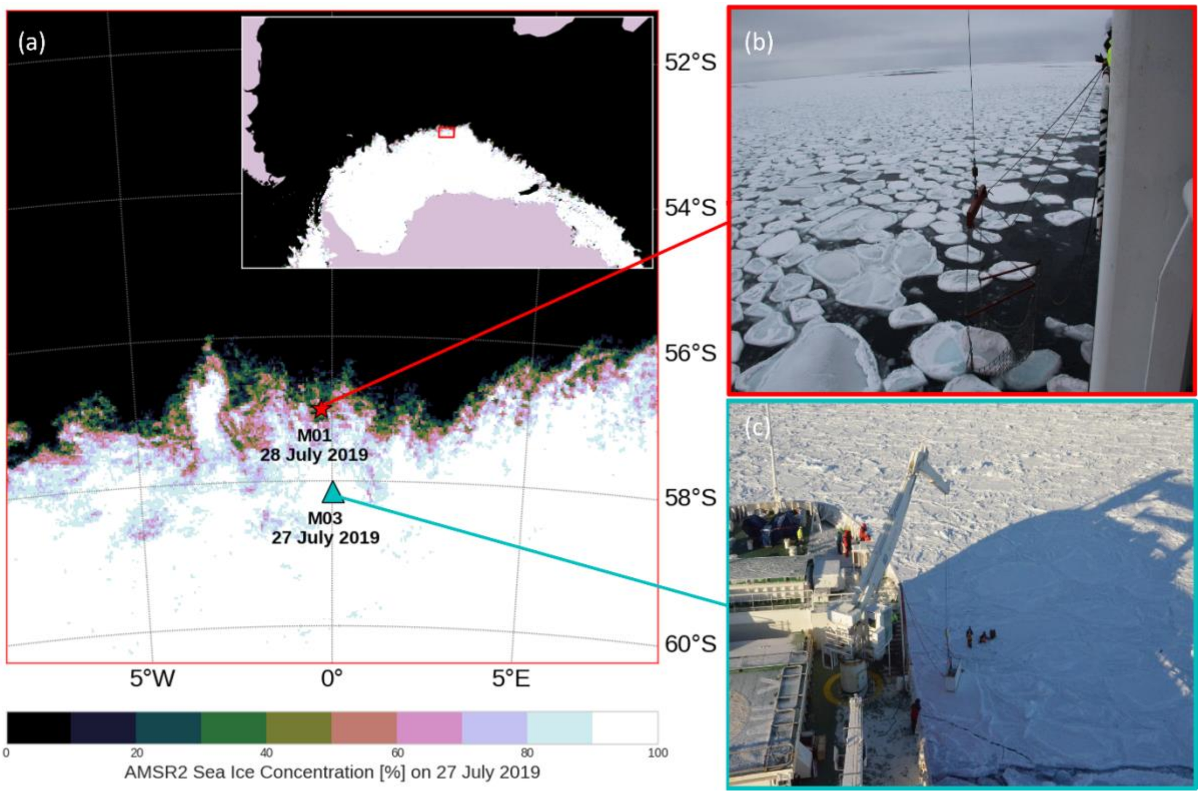


**Figure 1. (a) Map of the station locations and (b, c) station conditions during the SCALE 2019 winter expedition. The red star indicates station M01 (YI station) and the corresponding image in the red block (b) shows the conditions at the station on the day of sampling. The blue triangle indicates station M03 (FYI station) and the corresponding image in the blue block (c) shows the conditions at the station on the day of sampling. The map (a) is overlaid with the satellite-derived sea-ice concentration for 27 July 2019 taken from the AMSR2 satellite product.**

**Study findings:**

Measurements of sea-ice temperature, salinity, crystal structure, stable isotopes, chlorophyll, and nutrient concentrations were used to investigate the winter sea-ice habitat and decipher the conditions under which the ice formed and grew. Model simulations support the hypothesis that nutrient accumulation in advancing sea ice cannot be explained by passive seawater entrainment and thermodynamics alone. Our data confirm that winter sea ice is biogeochemically active and accumulates remineralized nutrients. We further propose that mechanical thickening enhances the reservoir of nutrients during the ice growth season. The biogeochemical transition from YI to FYI does not appear to be a linear progression of thickness with habitat space reduction as sea ice consolidates. Instead, FYI bulk biogeochemistry results from multiple cycles of rafting of YI, which conserves the biogeochemical properties of YI in the FYI, ultimately increasing the overall nutrient and chlorophyll content (***Figure 2***).

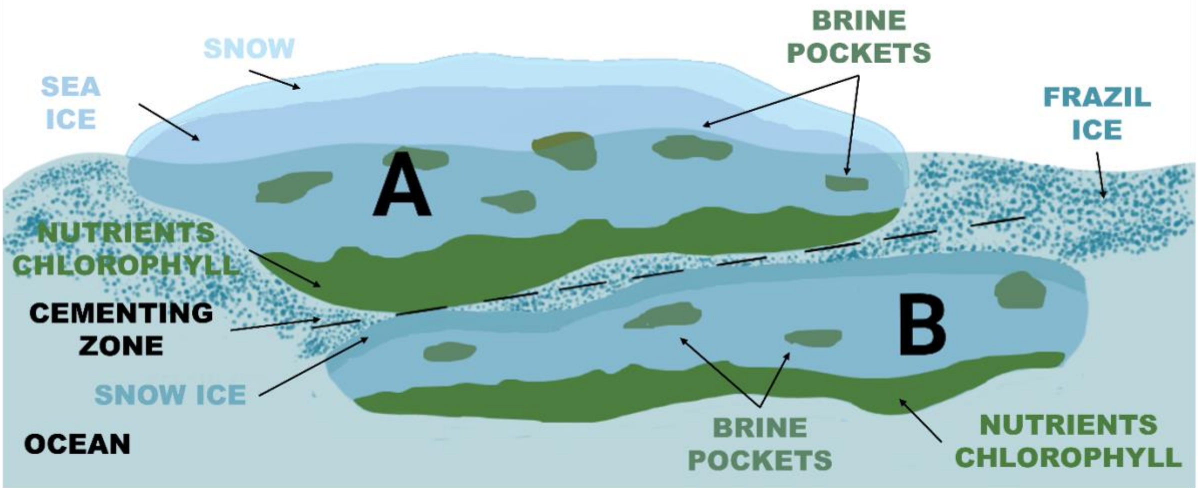


**Figure 2. Schematic of the proposed rafting mechanism that results in the enhancement of nutrient- and chlorophyll concentrations in first-year winter sea ice in the Antarctic marginal ice zone.**

### Study implications and recommendations:

Our study challenges two widely accepted notions:

1. That sea ice is biogeochemically inactive during winter.
2. The transition from young ice to first year ice is a linear process that is dominated by thermodynamic thickening of the sea ice.

Our study instead suggests:

1. Winter sea ice is biogeochemically active and acts as a reservoir of concentrated nutrients during the ice growth season.
2. The transition from YI to FYI is a product of multiple cycles of breaking and rafting that conserves the biogeochemical signal of the YI.

The implications for the evidence provided by our study will help guide model development for the Antarctic. Existing sea ice models consider sea ice as a single, homogenous layer, this assumption influences how sea ice biogeochemistry is modelled and as our study shows, often underestimates the biogeochemical environment. Our findings suggest that sea ice should be considered as multiple layers with unique biogeochemical environments that are modified through rafting processes as the ice transitions from YI to FYI. Our study supports the growing need for Antarctic-specific modelling efforts as opposed to continuing to use Arctic-based numerical models and principles to simulate the Antarctic region. This approach does not work due to the fundamental differences between the two polar regions and should be avoided in future models. In addition to this, our study also contributes new data concerning the physical and biogeochemical properties of growing sea ice in the Antarctic Marginal Ice Zone and motivates for the continued sampling and data collection in this severely understudied region.