ARCTIC 2022 – IMPLEMENTED PROJECTS

NITRAC

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ABSTRACT

Introduction

Because of polar amplification, the effect of climate change is most pronounced in polar regions, particularly the Arctic, where sea ice extent has been decreasing by 13.2% per decade (McMillan et al. 2016). Sea-ice retreat and increased meltwater flux is leading to profound perturbations of marine ecosystems, impacting light availability (Arrigo et al., 2008), water-column stratification, and nutrient inventories/biogeochemistry (Arrigo et al., 2012; 2017; Boetius et al., 2015). We propose to deploy high-resolution underway instruments to study how glacial melt influences the flow of energy and matter across Arctic oceanic ecosystems.

Objective 1 : How does ice melt influence net community production in the Arctic ?

The rapidly melting Arctic glaciers and sea ice release freshwater and nutrients to the ocean surface, likely enhancing primary productivity at the ocean surface. Very little is known about the factors limiting growth in Arctic waters, with some studies arguing for the potential for iron limitation (Arrigo et al. 2017) while others providing evidence for macronutrient limitation (Kanna et al 2018) (Hopwood et al 2018). To address this question, we propose to estimate NCP from sea-to-air fluxes of biogenic oxygen, as measured from underway high-frequency measurements of dissolved O2/Ar. pCO2 and O2/Ar will be measured with the latest generation of Equilibrator Inlet Mass Spectrometers (EIMS) (Cassar et al, in prep.).

Our work also has multiple synergies with the other group who will be on the Charcot. Dr. Marion Fourquez will be conducting measurements of O2 and CO2 flux. Our underway high-resolution estimates of biological O2-based net community production will be of direct relevance to Dr. Fourquez's observations.

Objective 2: Does using high frequency and real-time measurements reveal significant BNF in the Arctic, proving past assumptions about BNF incorrect?

Biological nitrogen (N2) fixation (BNF), the microbially-catalysed reduction of atmospheric N2 to ammonium, is a central pathway for new nitrogen, influencing terrestrial and oceanic fertility and the global carbon cycle. BNF therefore has profound biogeochemical implications, yet we have poor constraints on its magnitude and controlling factors, due to unexplored niches and methodological limitations. By tackling both of these issues, this

proposed work will improve the representation of BNF in our projections of a changing climate. Because BNF is an energetically expensive process, it was believed that nitrogen fixers would only have an advantage in nitrogen depleted, warm, oligotrophic waters (Zehr et al 2020). However, recent groundbreaking research has found evidence of BNF in the polar oceans (Shioaki et al 2018, Shiozaki et al 2020, Harding et al 2018), which would have important implications in light of the amplified effects of climate change in polar regions.

We propose to explore Arctic BNF by deploying the very first method to allow underway high-frequency and near real-time measurements of BNF (Cassar et al. 2018). We hypothesize that BNF in the Arctic is biogeochemically significant, but sporadic and patchy. Previous studies have been unable to capture data with high enough resolution to determine if the BNF occurs at significant levels. Using the method we've developed, we can collect more data on a single cruise than exists in the literature.

Prior to the cruise, PI Cassar will be in the Arctic studying N2 fixation in mosses and lichens in Alaska, Greenland and Svalbard. We also propose to sample mosses and lichens for the study of terrestrial BNF whenever the Charcot stops at terrestrial sites. Mosses and lichens are often the dominant source of new nitrogen in Arctic terrestrial ecosystems. The opportunistic sampling will allow us to increase the return on investment for the study of both terrestrial and marine environments. We will have permits to sample these ecosystems.

Methods

There is increasing evidence that biological events at the ocean surface are episodic and spatially heterogeneous, and that discrete observations cannot capture this patchwork. The methods we have developed allow us to sail with a biogeochemical compass to constrain the fluxes of energy and matter at unprecedented resolution (Cassar et al. 2009, Cassar et al. in prep., Huang et al. 2013, Huang et al. 2015, Cassar et al. 2012, Cassar et al., 2018). Our sampling does not require any additional ship-time, and samples are collected while the vessel is in transit.

O2/Ar: Ecosystem energetic-Redox balance, biological O2, and Net Community Production: Because of the central role O2 plays in biological redox reactions at the ocean surface, the biological O2 budget reflects the net energetic balance of ecosystems. Ecosystems where the photochemical energy input is greater than the loss of potential energy have a positive internal energy balance. Our measurements estimate NCP at high resolution, where NCP is equal to gross primary production minus community respiration. Equilibrator Inlet Mass Spectrometry (EIMS): Seawater from the ship's underway system will be pumped through a gas equilibrator, the headspace of which will be connected to a quadrupole mass spectrometer for continuous pCO2 and O2/Ar ratio measurements, from which the biogenic O2 supersaturation will be estimated. From the O2/Ar supersaturation, the piston velocity, and the O2 concentration at saturation, NCP will be calculated as in Cassar et al. (2009), correcting for vertical mixing using N2O observations using the calculation methods presented in Cassar et al. (2014).

N2 fixation: Our real-time method will allow us to capture the sensitive variations that lead to the heterogeneity in BNF to further elucidate the biogeography of marine N2 fixation. Flow-through Acetylene Reduction Assays by CRDS (FARACAS): In our real-time method, underway seawater goes through a flow-through incubation chamber for acetylene reduction estimates of N2 fixation. We will use the underway line with the Charcot's peristaltic pump, which is less damaging to cells than the centrifuge pump. Prior to the chamber, high-purity acetylene is continuously added to the flowing seawater. Downstream of the incubation chamber, a contactor cell is used to strip the ethylene out of solution and into the CRDS (Cassar et al. 2012, Cassar et al. 2018).

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