Report from 2022 cruise on Le Commandant Charcot to 90N

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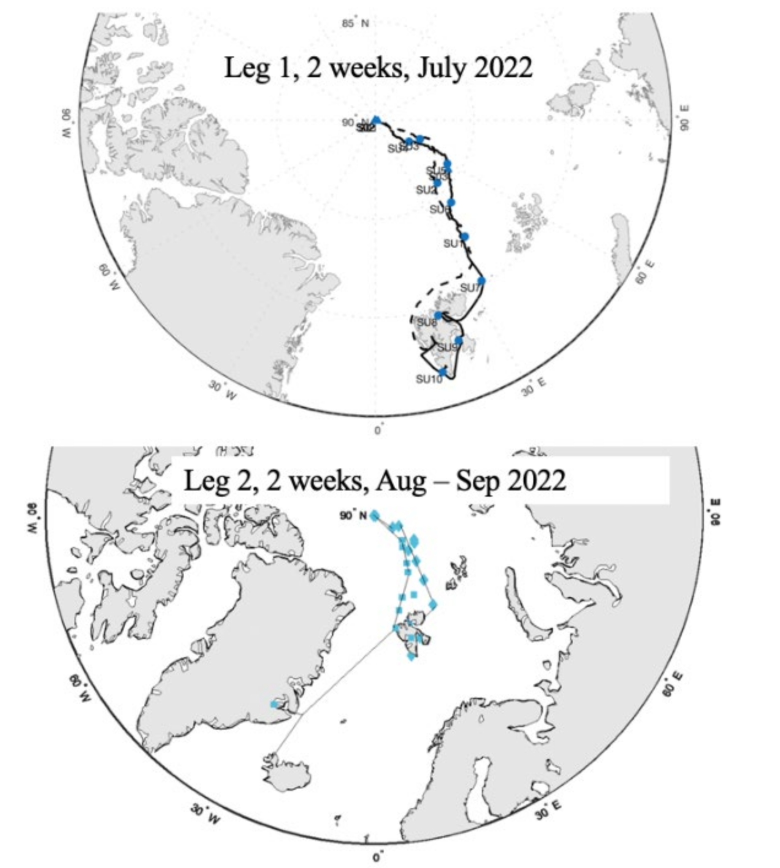
The Arctic Ocean (AO) is changing in a rapid pace, with most apparent changes observed in the extent, thickness and other properties of its sea ice cover. These changes occur before we gathered sufficient ecological information on many taxa that inhabit the AO and therefore our ability to predict and understand the biological consequences of the changing AO environment is limited (CAFF report 2017, Macias-Fauria and Post 2018). The scarcity in data is particularly apparent for the Central AO (CAO) where logistical challenges and high costs of operation have hampered sampling efforts. It has been long thought that the CAO is barren of life due to the year-long ice cover, cold temperatures and limited resources (light and nutrients) for primary producers. The handful of studies that examined abundances, distributions and composition of primary producers in this region, suggest that although biomass is low, there exist diverse communities of phytoplankton and sea ice algae, but ecological knowledge on many of these species is lacking (CAFF report). Many outstanding questions remaining about sea ice and its control on phytoplankton biomass and species composition in the CAO, and there is a large uncertainty regarding the future trajectory of this ecosystem, in part because very little data exists to characterize even its current state. A key question is whether the CAO will become a new 'oasis' for phytoplankton or maintain its present characteristics of a low biomass, 'oligotrophic' ocean (Damm et al. 2010). On one hand, thinning of sea ice and an expansion lead area on the pack ice allow light to penetrate seawater. On the other hand, leads expose the ocean to the cold air and can enhance mixing. Mixing deepens the mixed layer depth which could result in light limitation if the mixed layer exceeds the photic depth but could alleviate nutrient limitation by mixing nutrient rich water with surface nutrient-depleted waters. It is difficult to detect, model or predict long term changes when short-term variability in phytoplankton abundance and community composition has not been fully characterized. Most of the phytoplankton studies in the CAO were conducted on platforms that drifted in the pack ice making it difficult to separate spatial and temporal patterns. Furthermore, vast areas of the CAO are 'invisible' to ocean color satellites for most of the year, and under ice ecosystems in the Arctic are primarily sampled only in situ, which happens infrequently. Increased knowledge on primary producers in this region, in relation to sea ice dynamics and nutrients, is crucial and timely in view of the 16-year international agreement, signed in 2021, to ban commercial fishing in the CAO until a better understanding of the ecosystem properties dynamics is gained.

Background

A Sea change at the bottom of the Arctic food web

Phytoplankton and sea ice algae form the first link in Arctic marine food webs and play important roles in biogeochemical processes in the AO. Their net production is regulated by the availability of light and nutrients, which in the AO is strongly influences sea ice dynamics. As a consequences of climate change, sea ice has transformed over the last four decades. Negative anomalies in sea ice concentration and extent are now being observed throughout the year, and the timing of melt onset and fall freeze-up are shifting. Arctic sea ice becomes thinner and now mostly comprises of first- and second-year ice (reviewed in Stroev and Notz 2018). First year ice does not have the same mechanical properties as multiyear ice and can become fragmented more easily by winds, currents, and waves. The presence of melt ponds further weakens ice structure, while also adding positive feedback to melting through increased albedo. [add about melt ponds]. Furthermore, areas (mostly over Arctic shelves) that were once covered by sea ice are now ice free in summer. Some models predict that by 2050 the entire AO will be ice free by summer (Notz and SIMIP Community 2020). With albedo varying from roughly 0.8 for snow covered sea ice in the spring to ~0.35 or less for ponded ice during summer melt (Light et al., 2022), and < 0.1 for the open ocean, changes in sea ice conditions have important implications to the intensity and spectral composition of the light available for photosynthesis. In addition, sea ice dynamics affect ocean-atmosphere interactions, the stratification and mixing of the upper water column and therefore the supply of nutrients needed for cells to meet their metabolic demands and undergo cell division. **The goal of the cruise was to collect as many observations as possible along a gradient of sea ice concentration and thickness in transit to 90N and back.**

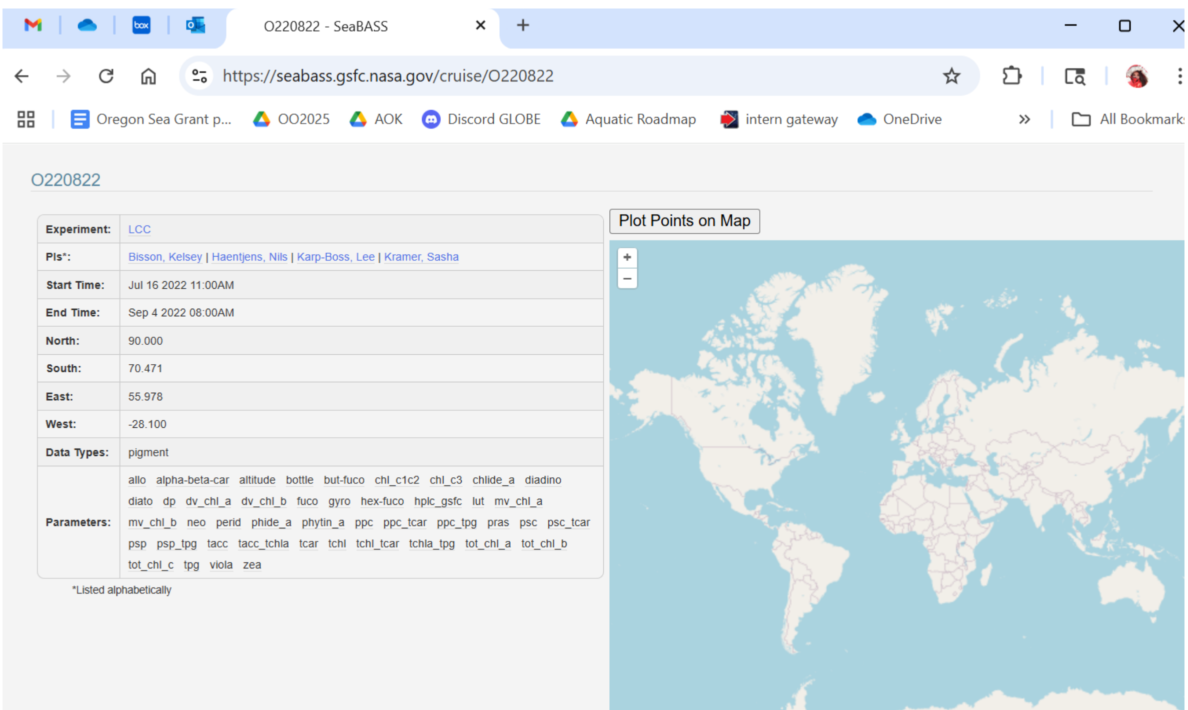
Cruise description



Our team embarked on Le Commandant Charcot throughout Summer 2022 on two separate legs. Our Arctic sampling plan involved sampling the water column in ice-covered regions under a gradient of sea ice thickness and light conditions. Leg 1 commenced in July whereas Leg 2 commenced in August. Both cruises transited to 90N along a sea ice transect from Svalbard. Leg 2 had additional stops in eastern Greenland on the way to Reykjavik. Because the cruise was not strictly a scientific one, field work was limited by the logistics of the ship and passenger activities. In total, leg 1 comprised 10 CTD casts from the stern of the ship, continuous underway optics when the ship was transiting through open water, 51 discrete particulate organic carbon (POC) measurements, 42 discrete nutrient samples, 27 discrete pigment (HPLC) samples, and 22 samples for genomics, Additionally, 1 ice core at 2 depths was drilled at 90N. Leg 2 had 8 CTD casts and some additional (~10) CTD casts within compact sea ice from a zodiac boat. 119 POCs, 129 nutrient, 107 HPLC, and 102 genomics samples were taken. 4 ice core samples at 2 depths from 3 separate ice stations were analyzed. On both legs a total of 63 samples within sea ice (either compact or non-open water with leads) were analyzed on the imaging flow cytobot (IFCB). 50 of these samples include triplicates and 13 include duplicates.

In addition to descriptive sampling along a gradient of sea ice concentration and latitude, 2 natural ‘experiments’ were conducted. First, ice core sampling and ice physical descriptions (grain size, snow density, freeboard, thickness, snow depth, albedo) were conducted at 90N on both legs. Samples were taken below sea ice under varying ice thicknesses within a 50m radius. Ice cores were melted and analyses for taxonomy using the IFCB. Second, a sea ice experiment was conducted at 85N to sample water (through 9 stations and CTD casts with a niskin capture at 0m and 10m) at different sea ice types (frazil, nilas) through a zodiac trip. Simultaneous ice cores were drilled with samples for sea ice algae at 0-3cm and 3-10cm. Samples were taken for POC, genomics, HPLC, and IFCB analysis. The overall goal was to sample a range of sea ice conditions within a small area (1km) to compare phytoplankton communities across a range of conditions (9 stations total) within a consistent sampling area to measure spatial heterogeneity.

We hosted the data on NASA’s SeaBass server which is publicly available. Of note, ours is the first collection of data products at 90N, which caused some delays in data posting as the server needed to be appropriately configured to accommodate the geographic North Pole.



https://seabass.gsfc.nasa.gov/experiment/LCC/

There is no current funding to pursue the science on its own, but these data are being used in ongoing funded efforts as context and biodiversity in the CAO.

References:

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