ARCTIC 2022 – IMPLEMENTED PROJECTS

Underway Measurements of Essential Marine Biogeochemical Variables in the Arctic

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ABSTRACT

Current understanding of the Arctic Ocean's response to climate change is limited by a lack of observational data. Many essential climate variables (identified by the World Meteorological Organization as critical to characterizing Earth's climate) are rarely measured in the Arctic. For example, vast areas of the Arctic Ocean have no reported dissolved CO2 observations (Bakker et al., 2016, 10.5194/essd-8-383-2016). Similarly, the Argo float program, which provides in situ measurements of essential climate variables, has no significant presence in the Arctic (Jayne et al, 2017, 10.5670/oceanog.2017.213).

One approach to this 'observational hole' is the use of underway sensors aboard ships transiting the Arctic. These instruments sample water continuously from a vessel's seawater intake, providing measurements of physical, chemical, and biological variables along the cruise track. When operating on vessels transiting large spatial extents or conducting repeated voyages along a scheduled route, underway sensors can dramatically increase knowledge of near-surface ocean processes.

Underway sensors have been crucial in advancing our understanding of Arctic Ocean greenhouse gas exchange, ocean acidification, and primary production. From limited observations of dissolved carbon dioxide (pCO2), it has been suggested that the Arctic is a stronger sink for atmospheric CO2 than most low-latitude oceans (Bates & Mathis, 2009, 10.5194/bg-6-2433-2009). However, large regional variations have also been observed (e.g. Ahmed & Else, 2019, 10.1029/2019GL083547), and it is unclear how the Arctic carbon sink will be impacted by climate change (e.g. Else et al., 2013, 10.1002/grl.50268). Certain Arctic regions are also an important source of other greenhouse gases like methane (CH_4) and nitrous oxide (N_2O) (Fenwick et al., 2017, 10.1002/2016JC012493). As ice melts and river runoff intensifies, the surface waters of the Arctic ocean are expected to be particularly susceptible to ocean acidification (Niemi et al., 2021, 10.3389/fmars.2021.600184). Underway systems can be used to track the progress of ocean acidification, and identify vulnerable regions in relation to surface hydrographic conditions. One of the biggest questions in Arctic marine ecosystem science is how phytoplankton – the base of the Arctic foodweb – will respond to sea ice loss. Satellite remote sensings studies have suggested an increase in phytoplankton primary production (Arrigo & van Dijken, 2015, 10.1016/j.pocean.2015.05.002), but underway systems (e.g. Izett & Tortell (2021, 10.1002/lom3.10440)) are a

necessary tool for validating satellite primary production algorithms, and providing greater insights into phytoplankton physiology (Sezginer et al., 2021, 10.1371/journal.pone.0256410).

Our research team has significant experience deploying underway sensors on Arctic and Antarctic research vessels to measure gas exchange, ocean acidification, and primary productivity. Unfortunately, ship time on research vessels is always a scarce resource, and to facilitate a step-change in data quantity, we need to begin deploying instruments on commercial ships. The design of Le Commandant Charcot's makes it an ideal vessel to make this leap. We propose to instrument Le Commandant Charcot with a suite of innovative underway instruments that will allow us to:

1) Determine pCO2 and concentrations of other greenhouse gases (CH4 and N2O) in undersampled areas.

2) Measure pH and other carbonate system variables to build baseline data on ocean acidification state, and identify regions that may be vulnerable to acidification.

3) Measure phytoplankton primary productivity and physiology in the changing Arctic Ocean.

To achieve these objectives, we propose installing our equipment on the ship's dedicated scientific water sampling line, near the existing thermosalinograph. We will measure pCO2 using a membrane-type equilibrator system (SuperCO2, Sunburst Sensors LLC) coupled to an infrared gas analyzer (LI-840, LI-COR Inc), while N2O and CH4 will be measured using a gas extraction module coupled to a cavity ring-down spectrometer (Los Gatos Research Inc.). Dissolved oxygen and pH will be measured with a flow-through CTD (Ocean Seven 315 On Line module, Idronaut S.r.l). Gas measurements will be calibrated using compressed air standards with known mixing ratios. Seawater samples will be collected from the scientific sampling line regularly, preserved, and returned to Canada to calibrate pH sensor and fully characterize ocean acidification parameters. To measure primary production we will deploy an O2/N2 measurement system, which uses a combined oxygen optode and gas tension device. A fast repetition rate fluorometer (FRRF) will also be installed to examine phytoplankton physiology and primary productivity. The method exposes water samples to rapid pulses of intense light and analyzes rapid fluorescence "transients" to derive quantitative estimates of photosynthetic parameters, including photochemical quantum yields, and photosynthetic electron transport rates.