**Supplement**

**Underway *p*CO2 measurement challenges in the high Arctic**

The vessel is totally unheated for 10 months of the year and is completely frozen for most of that time. Since winter temperatures drop below -40°C in Cambridge Bay, it is necessary to remove the whole system between field seasons. To avoid damage to the equipment, the fresh install of the system can only proceed in July once the temperature is persistently above freezing and the *RV Martin Bergmann* has been taken off its trailer. Transportation of compressed gas cylinders to Cambridge Bay is extremely prohibitive as they are designated as dangerous goods and can only be transported by cargo plane; this restriction meant that only small cylinders with a liquid volume of ~7 L could be used on the *RV Martin Bergmann*. Rather than frequently shipping gas cylinders North at great financial expense, standards were run less frequently and flushed for shorter periods of time than during other oceanographic research cruises. These logistical challenges have only been circumvented with considerable assistance from our local technicians who live in Cambridge Bay.

The summer field season for oceanographic work in ice-free seas is very short; drifting surface ice is prevalent throughout July and can even persist regionally into August (such as in Queen Maud Gulf and in Icebreaker channel). As the *RV Martin Bergmann* is not an icebreaker and does not have a reinforced hull, the field season cannot safely begin until the sea ice has cleared from the region. Outside of the main channels, large parts of the Canadian Arctic Archipelago bathymetry is unmapped which can be dangerous even with an experienced crew skippering a vessel with a relative short draft like the *RV Martin Bergmann*. The functional limitations of a small vessel also proved challenging. For example, even though the atmospheric air inlet tubing was flushed for 5 minutes at an air flow of 100 ml min-1 it proved difficult to find a position for the air inlet on the ship that provided a reliable clean air signal for atmospheric CO2. As well, the underway seawater inlet was located halfway along the port side of the ship to minimise turbulence from the ship’s propellers at the aft of the vessel, even with this precaution the *RV Martin Bergmann* is a small ship and it is likely that surface stratification is perturbed by the ship. Lastly, with a full complement of 4 crew and 5 scientists, the *RV Martin Bergmann* can remain at sea for ~12 consecutive days without requiring refuelling and restocking. Given the sparseness of communities in the region, resupplying is a limitation on sampling time and the range of the ship.

Table S1: Summary table of the cruises where the underway *p*CO2 system was deployed on *RV* *Martin Bergmann*.

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| --- | --- | --- | --- |
| Survey year | Cruise dates | Cruise ID | Cruise programme |
| 2016 | 1st – 11th August | MB16001 | MEOPAR |
| 2017 | 2nd – 10th August | MB17001 | MEOPAR |
| 2017 | 16th August – 15th September | MB17002 | K3S |
| 2018 | 31st July –August 8th | MB18001 | MEOPAR |
| 2018 | 16th –22nd August | MB18002 | K3S |
| 2019 | 9th –10th August | MB19001 | MEOPAR |
| 2019 | 13th –21st August | MB19002 | K3S |

Table S2: Summary table of changes in the pCO2 system configuration in each of the four surveyed years.

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| --- | --- | --- | --- | --- |
| Survey year | 2016 | 2017 | 2018 | 2019 |
| Standard xCO2 values | 255.1  409.9  566.4 | 0  255.1  409.9 | -  -  566.4 | 0  250  450 |
| System spanned with N2 and standard before field season |  | Yes | Yes | Yes |
| Interval between standards (hr) | 4.5 hr | 4 hr / 12 hr | 12 hr | 6 hr |
| Interval integration/flush through time (minutes) | 5 minutes | 5 minutes | 7 minutes | 10 minutes |
| Data logged differently to described in text | CR3000 insitu temperature logged to data logger | - | - | TSG insitu temperature logged to TSG file  Sunburst latitude and longitude logged to sunburst files |
| Instrument replacements | - | - | - | Pump replaced with a Red Lion RJSE-75SS 115V 3/4 HP Stainless Steel Sprinkler Utility Pump.  Tubing length extended from 2m to 5m. |
| Insitu temperature sensor (yes/no) | Yes | No – Insitu temperature determined by regression between CTD temp at 1m and equilibrator temperature. The equation for this was y= 0.8512x -0.50.RMSD= 0.49°C. | No – Insitu temperature determined by regression between CTD temp at 1m and equilibrator temperature. The equation for this was y= 1.1875x -3.30. RMSD= 0.64°C. | Yes |

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| Figure S1: Temperature regressions between rosette CTD temperature and equilibrator temperature (T (equ)) used to derive SST (1m) in 2017 and 2018. The equation for the linear regression fit and the RMSD values of this fit are shown as text labels. |

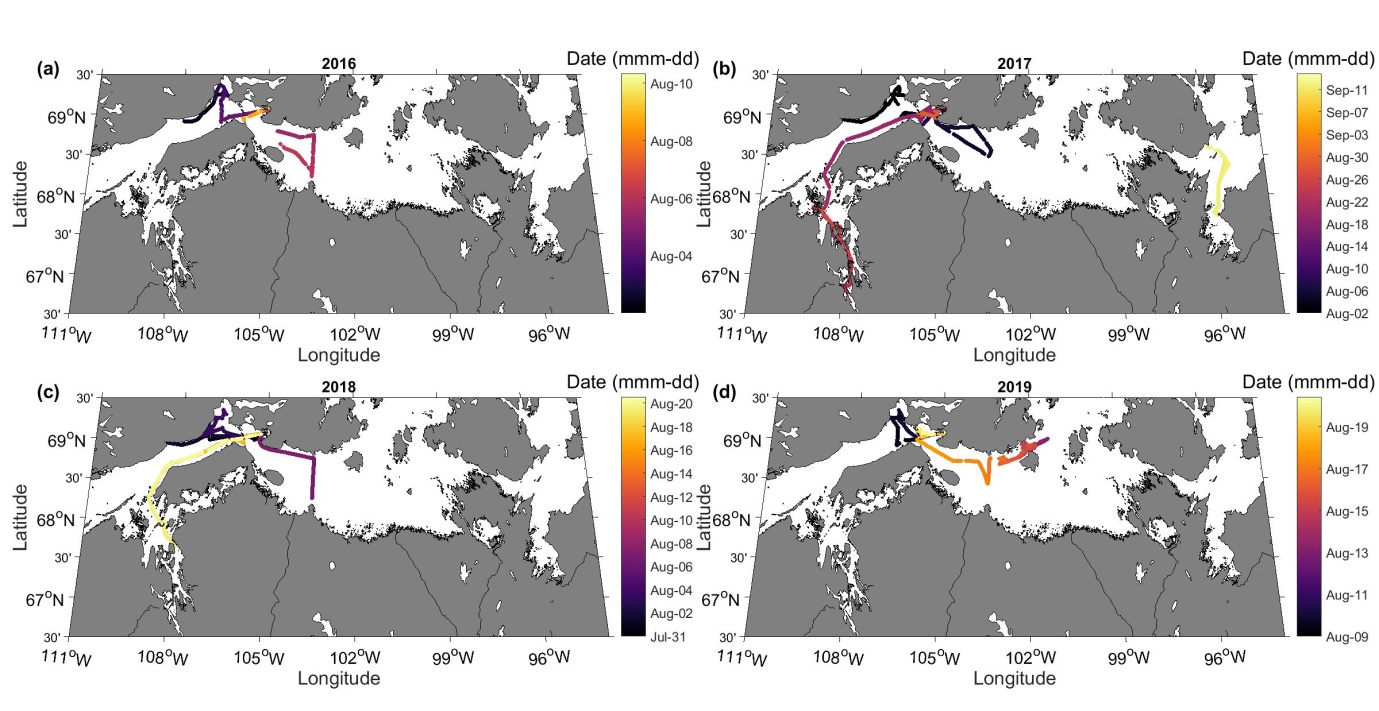
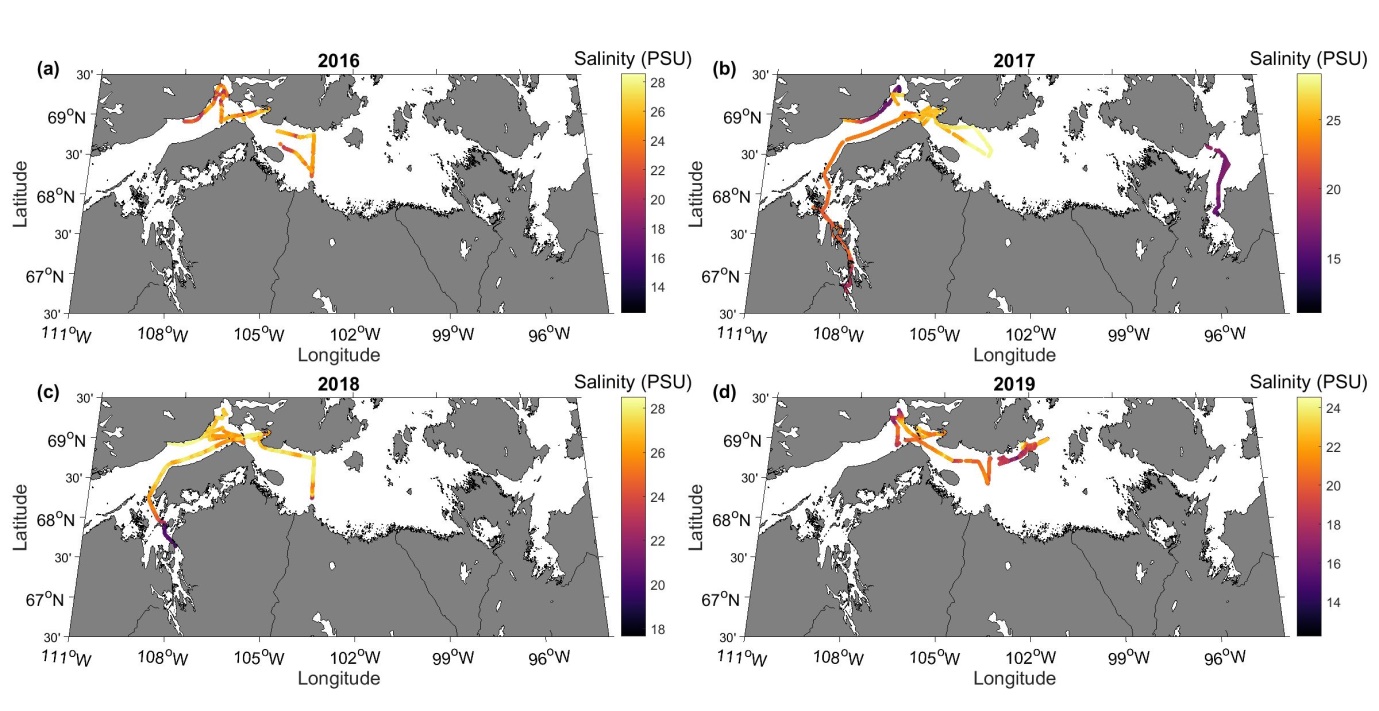


Figure S2: Maps of the cruise time for (a) 2016 (b) 2017 (c) 2018 (d) 2019.

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| Figure S3: Maps of SST (1m)for (a) 2016 (b) 2017 (c) 2018 (d) 2019. |



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| Figure S4: Maps of the sea surface salinity for (a) 2016 (b) 2017 (c) 2018 (d) 2019. |

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| Figure S5: Maps of the *p*CO2 (sw) for (a) 2016 (b) 2017 (c) 2018 (d) 2019. |
| Figure S6: Maps of fluorescence (a) 2016 (b) 2017 (c) 2018 (d) 2019. |