BERING STRAIT NORSEMAN II 2022 MOORING CRUISE REPORT

Research Vessel Norseman II, Norseman Maritime Charters

Nome-Nome, 8th - 19th September 2022

Rebecca Woodgate, University of Washington (UW), *woodgate@uw.edu*
Cecilia Peralta-Ferriz, John Guthrie, Laramie Jensen, Katy Christensen, Robert Daniels, Marie Zahn
(2022 Science Team)

Funding from NSF Arctic Observing Network Program PLR-1758565 & PLR-2153942

Chief Scientist: *Rebecca Woodgate,*
University of Washington (UW), USA.
1013 NE 40th Street, Seattle WA, 98105
Email: woodgate@uw.edu
Tel: +1-206-221-3268;

Co-PI (1758565 & 2153942):
Cecilia Peralta-Ferriz, UW

Related PIs:
Marine Mammal Recorders:
Kate Stafford, Oregon State University (OSU), USA
Trace Metal/Nutrient Sampling:
Laramie Jensen, Randi Bundy, Ryan McCabe, UW
Underway Marine Mammal Survey
Kate Stafford, OSU, USA & Kristin Laidre, UW

Research vessel Norseman II during 2019 Nome on-load [Credit: Woodgate].

As part of the Bering Strait project funded by NSF-AON (Arctic Observing Network), in September 2022 a team of US scientists undertook a ~ 11 day cruise in the Bering Strait and southern Chukchi Sea region on the US vessel Norseman II, operated by Support Vessels of Alaska, Inc..

The primary goals of the expedition were:

1) **recovery of 3 moorings** carrying physical oceanographic (Woodgate & Peralta Ferriz) and whale acoustic (Stafford) instrumentation. These moorings were deployed in the Bering Strait region in 2021 from the Norseman II. The funding for the physical oceanographic components of these moorings comes from NSF-AON.

2) **deployment of 3 moorings** in the Bering Strait region, carrying physical and biogeochemical oceanographic (Woodgate & Peralta-Ferriz) and whale acoustic (Stafford) instrumentation. The funding for the physical and biogeochemical oceanographic components of these moorings comes from NSF-AON.

3) a set of **CTD sections** studying water properties in the region, with some **sampling for nutrients and salinities** (Woodgate & Peralta-Ferriz),

4) collection of **trace metal/nutrient water samples** using a pumped system at selected CTD casts (Jensen)

5) collection of accompanying ship's **underway data**, viz. surface water temperature and salinity, ADCP velocity data and meteorological data (Woodgate & Peralta-Ferriz),

6) **underway marine mammal survey** (Stafford & Laidre)

The cruise loaded and offloaded gear and people in Nome, Alaska.
As a Covid precaution, the science team undertook social distancing pre cruise, including masking during flights to Alaska and masking when with others inside, and a set of pre-cruise Covid tests.

Key Statistics:

2 moorings recovered, 3 moorings deployed,
111 CTD casts on 4 CTD lines, with 169 nutrient samples and 20 salinity samples
trace metal/nutrient water samples taken on 35 stations

SCIENCE BACKGROUND

The ~50m deep, ~ 85km wide Bering Strait is the only oceanic gateway between the Pacific and the Arctic oceans.

The oceanic fluxes of volume, heat, freshwater, nutrients and plankton through the Bering Strait are critical to the water properties of the Chukchi [*Woodgate et al.*, 2005a]; act as a trigger of sea-ice melt in the western Arctic [*Woodgate et al.*, 2010]; provide a subsurface source of heat to the Arctic in winter, possibly thinning sea-ice over about half of the Arctic Ocean [*Shimada et al.*, 2006; *Woodgate et al.*, 2010]; are ~ 1/3rd of the freshwater input to the Arctic [*Aagaard and Carmack*, 1989; *Woodgate and Aagaard*, 2005]; and are a major source of nutrients for ecosystems in the Arctic Ocean and the Canadian Archipelago [*Walsh et al.*, 1989]. In modeling studies, changes in the Bering Strait throughflow also influence the Atlantic Meridional Overturning Circulation [*Wadley and Bigg*, 2002] and thus world climate [*De Boer and Nof*, 2004].

Quantification of these fluxes (which all vary significantly seasonally and interannually) is critical to understanding the physics, chemistry and ecosystems of the Chukchi Sea and western Arctic, including sea-ice retreat timing and patterns, and possibly sea-ice thickness. The Bering Strait oceanic heat flux has been found to be the best predictor of Chukchi sea ice retreat [*Serreze et al.*, 2016]. Understanding the processes setting these fluxes is vital to prediction of future change in this region, in the Arctic, and beyond. The Bering Strait is the only Arctic gateway where observations currently show significant interannual change [*Østerhus et al.*, 2019].

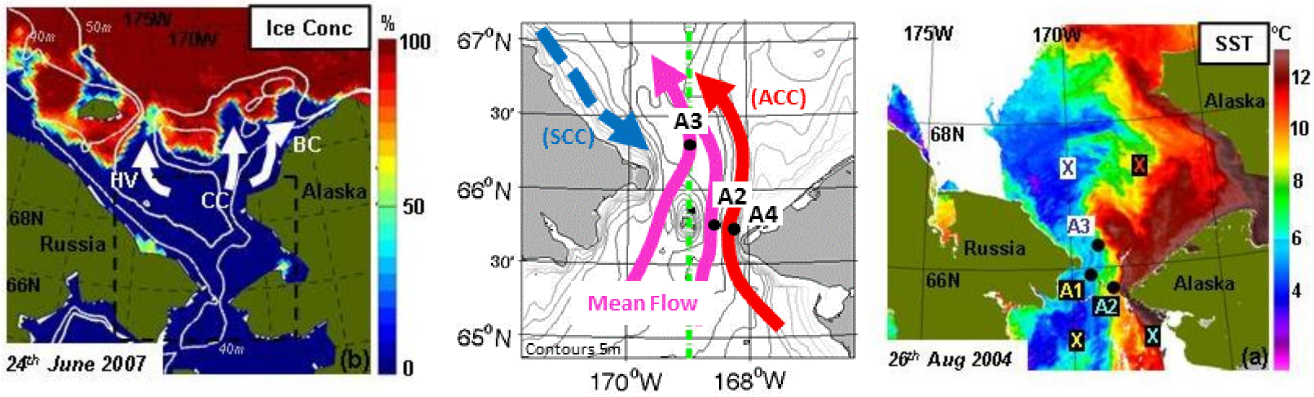

Figure 1: (Left) *Chukchi Sea ice concentration (AMSR-E) with schematic topography. White arrows mark three main water pathways melting back the ice edge [Woodgate et al., 2010].*

(Middle) *Detail of the Bering Strait, with schematic flows and mooring locations (black dots – A2, A3, A4). The main northward flow passes through both channels (magenta arrows). Topography diverts the western channel flow eastward near site A3. The warm, fresh Alaskan Coastal Current (ACC) (red arrow) is present seasonally in the east. The cold, fresh Siberian Coastal Current (SCC) (blue dashed arrow) is present in some years seasonally in the west. Green dashed line at 168º58.7'W marks the US-Russian EEZ (Exclusive Economic Zone) boundary. Note all moorings are in the US EEZ. Depth contours are from IBCAO [Jakobsson et al., 2000]. The Diomede Islands are in the center of the strait, shown here as small black dots on the green dashed line marking the US-Russian boundary.*

(Right) *Sea Surface Temperature (SST) MODIS/Aqua level 1 image from 26th August 2004 (courtesy of Ocean Color Data Processing Archive, NASA/Goddard Space Flight Center). White areas indicate clouds. Note the dominance of the warm ACC along the Alaskan Coast, and the suggestion of a cold SCC-like current along the Russian coast [Woodgate et al., 2006].*

Since 1990, year-round moorings have been maintained almost continually year-round in the Bering Strait region, supported by typically annual servicing and hydrographic cruises [*Woodgate et al.*, 2015; *Woodgate*, 2018]. These data have allowed us to quantify seasonal and interannual change [*Woodgate et al.*, 2005b; *Woodgate et al.*, 2006; *Woodgate et al.*, 2010; *Woodgate et al.*, 2012; *Woodgate*, 2018; *Woodgate and Peralta-Ferriz*, 2021], and assess the strong contribution of the Alaskan Coastal Current (ACC) to the fluxes through the strait [*Woodgate and Aagaard*, 2005; *Woodgate*, 2018]. These data also show that the Bering Strait throughflow increased ~50% from 2001 (~0.7Sv) to 2011 (~1.1Sv), driving heat and freshwater flux increases

[*Woodgate et al.*, 2012], with more recent fluxes also being high (e.g., 2014, 1.2Sv, [*Woodgate*, 2018; *Woodgate and Peralta-Ferriz*, 2021], see Figure 2).

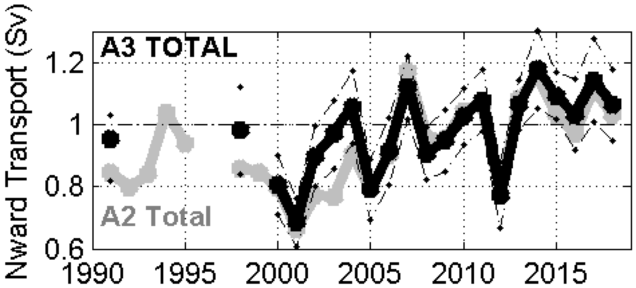

Figure 2: *Annual mean (x-axis, time in years) of Bering Strait mooring data from 1991 to 2018, showing transport for the whole strait, as estimated from A2 (grey) or A3 (black).*

Analysis [*Woodgate*, 2018] indicates this long term trend is driven by large scale changes between the Pacific and the Arctic oceans, with no significant trends in the winds in the strait. Thus, satellite-sensed data sets (winds, SST) prove insufficient for quantifying long-term variability, indicating interannual change can still only be assessed by in situ year-round measurements [*Woodgate et al.*, 2012]. The work to be accomplished on this cruise will extend this mooring time-series to mid-2022.

In addition, this cruise aims to provide a high resolution survey of the water properties of the strait and southern Chukchi Sea in early-summer. A particular goal is to quantify the early season heat and salt content of the waters, which have been unusually warm and fresh in the last 4 years (see Figure 3).

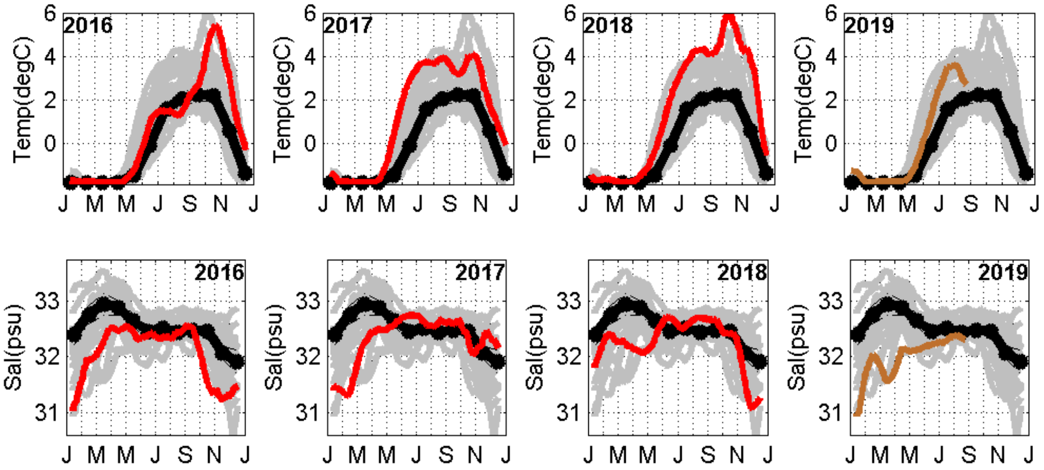

Figure 3: *30 day smoothed near-bottom A3 temperature* ***(top)*** *and salinity* ***(bottom)****, data for recent years* ***(columns)****, showing labeled year in color, climatology [Woodgate et al., 2005b] in black, and all prior years (1990-present) in grey. X-axis labels show month (J=January,etc.), [Woodgate and Peralta-Ferriz, 2021].*

The winter freshenings observed are particularly remarkable and suggest Pacific waters are entering the Arctic 50m shallower than before, and no longer refreshing the cold layer which historically protected the sea ice from warmer Atlantic waters below. The impacts of this on Arctic climate are currently unclear.

In a new addition to the project this year, we will also initiate year-round biogeochemical measurements on the moorings, particularly to quantify the flux of oceanic nutrients through the strait. This effort will be supported by water sampling for nutrients during the cruise, to gain an understanding of the spatial variability of oceanic nutrients in the region. In addition to physical oceanographic goals, our work also supports long term marine mammal acoustic monitoring in the Strait (PI: Stafford).

International links: Maintaining the time-series measurements in Bering is important to several national and international programs, e.g., the Arctic Observing Network (AON), started as part of the International Polar Year (IPY) effort in 2007; various NSF, ONR and NPRB projects and missions in the region. For several years, the work was part of the RUSALCA (Russian-US Long Term Census of the Arctic). Some of the CTD lines are part of the international Distributed Biological Observatory (DBO) effort. The mooring work also supports regional studies in the area, by providing key boundary conditions for the Chukchi Shelf/Beaufort Sea region (a current focus on ONR Arctic programs); a measure of integrated change in the Bering Sea, and an indicator of the role of Pacific Waters in the Arctic Ocean.

2022 CRUISE SUMMARY:

The 2022 mooring cruise was scheduled in September, to allow hydrographic sampling of the fall season.

By summer 2022, pre-cruise Covid precautions were well established for UNOLS and equivalent cruises, viz testing ~10 days before travel, social distancing subsequently until the cruise commences, testing pre travel, masking and similar precautions during travel, and testing immediately prior to boarding. One science team member tested positive at the first of these tests, but as the CDC recommended isolation period is less than 10 days and the member in question tested negative before travel and before joining the ship, they were not excluded from the cruise.

The science team flew commercial to Nome on **Tuesday 6th Sep 2022**, and continued to social distance (eating only takeouts, masking when near anyone indoors). Cruise preparations (checking and starting instrumentation, building instrumentation into frames, picking up air cargo, etc.) continued through **Wednesday 7th Sept 2022**. On the am of **Thursday 8th Sept**, all the 7 science party tested negative for Covid (double tests) and joined the ship.

With a poor forecast for the 9th Sept likely precluding working in the strait, after onload, the ship remained at dock to allow for setup in comparative calm. This included reterminating the CTD cable, and installing all instruments in the CTD frame. We sailed around 6pm, and early evening performed a test CTD cast, which found issues with the CTD termination, which took to 1am to resolve.

Weather on the **9th Sept** was too bad to attempt work in the strait. We steamed to near Tin city, a settlement just S of the strait, where we had shelter from the strong southward winds, and there performed more CTD test casts, including fixing bottle closing issues and training in tag line operations for the CTD.

On **Saturday 10th Sept**, weather was good enough to attempt mooring recoveries, starting at A2-21. We anticipated possible issues with this mooring as it was deployed with an iscat without a weak link in 2021 and thus may have been moved by ice. As detailed below, ranging on the mooring solicited no response, even though (as demonstrated by activating communications at mooring A4 from A2) releases can be communicated with at a distance of at least 15km. We instigated a search pattern, moving N and (after a while S) and stopping to range, but failed to establish any communications with A2-21. As light was limited, midafternoon, we moved instead to mooring A4-21, which released and was recovered smoothly. We deployed the replacement mooring A4-22, and ran ADCP lines across the strait moving northwards through the night to be onsite at A3-21 for the morning.

On **Sunday 11th Sept**, ranging on site A3-21 showed it to be 1nm off position, and it was successfully located to the SE of the deployed position. Although release was confirmed, the mooring required 3 draggings to come free from the anchor. From examining the recovered mooring components and data, we conclude a ~20m deep ice keel slid the mooring ~1nm over a 5hr period on the 25th Jan 2022 (average speed 10cm/s, average direction 150deg, same as the mean ~southward flow), the ice catching on the deeper of the floats of the iscat system, and applying a weak enough force so as to not pull through the double weak links of the miscat. Replacement mooring A3-22 was redeployed that afternoon, and we returned southwards, continuing the acoustic search for A2-21, a search that ran through the night, visiting latitudes also south of the strait proper, all without success.

On **Monday 12th Sept**, we used all reasonable daylight hours for dragging operations, both around the original deployment site of A2-21, and at a position (the "maybe" point, ~0.8nm at 231deg from A2-21 deployment) where the N2 Captain saw something mooring like on the ship's echosounder. This produced no concrete success, although at some times the drag obviously caught on something, but slipped off before it could be brought to the surface. Around 5:45pm, as it became too close to nightfall to drag safely (visibility being essential for this work), we steamed instead to BS22, to run the BS CTD and pumping line overnight. At station BS17.5, a shark was spotted swimming around the CTD in the dark.

On **Tuesday 13th Sept**, we resumed dragging operations, comprehensively sweeping out an area of diameter 0.7km around the mooring site, again with snaggings, but no obvious success. Reasonably convinced the mooring was not in this area, we then prepared to deploy the replacement A2-22, steaming an echosounder search pattern to the south during this preparation. A2-22 was successfully redeployed late afternoon. With the worst storm in the region in 50 years predicted for the weekend, we steamed rapidly north to complete other cruise goals before the weather hit.

The A3line was started that night, completed by **Wednesday 14th** morning. We then steamed NW to the CCL line, and ran the CCL line and DI lines south, completing those by ~730 on **Thursday 15th** morning, and immediately starting the rerunning of the BS line. Poor weather forced us to break off this line at BS18.5 early afternoon, and as it was necessary to transit to Port Clarence in a timely manner to hide from the storm, this concluded all over-the-side operations for the cruise. We arrived at Port Clarence, a natural harbor between the Bering Strait and Nome, around **midnight on Thursday 15th** night.

Even in the shelter of Port Clarence, with some land protection and very little fetch, the storm was impressive. **Friday 16th** winds were to 40 knots. **Saturday 17th Sept** am we dragged anchor and were forced to jog for the rest of the day, with winds peaking at 74 knots and large seas. The City of Nome experienced flooding which reached the airport, and it became very clear we would be unable to dock on our scheduled date of Sunday 18th Sept. On **Sunday 18th** am, though still rough and windy, the weather had come down enough for us to head slowly towards Nome, which we reached **Monday 19th** am, when fortunately the wind turned sufficiently to allow us to come to dock. Flood had damaged the road to the port however, making off load of gear impossible. Thus, it was arranged the ship would transport our gear to Homer, and the science team left the ship on foot to the higher ground, for the flight back to Seattle.

The Norseman2 left Nome that evening, arrived Homer **Monday 26th Sept** and offloaded our gear, which was containered to Seattle, arriving finally **27th Oct 2022**.

Weather, and the necessity for an extensive acoustic and dragging search for A2, both greatly limited the hydrographic survey portion of the cruise, and we had insufficient time to visit the CS line (which is one of the DBO lines). That said, a reasonable survey of the Bering Strait region was still accomplished, with the new SUNA nitrate measurement on the CTD. A total of 111 CTD casts were taken on 5 lines, with 169 nutrient samples taken on 4 of these lines, and pumped trace metal samples (also with nutrients) on 35 stations, including the Bering Strait repeat. Salinity samples were taken for a bottle closing investigation, which (as detailed below) showed our bottle closing protocol (a 10s pause before closing) was giving representative samples of the CTD depth.

Various colleagues on national and international ships assisted later in the season with acoustic or multibeam search for A2-21. Our thanks go to the following:

Steven Roberts, Bob Pickart , Ethan Roth on the Sikuliaq
Luc Rainville, Ben Jokinen on the Sikuliaq
Motoyo Itoh on the Mirai
Ryan McCabe, Catherine Berchok, Phyllis Stabeno on the Dyson
Carin Ashjian, Seth Danielson , Jackie Grebmeier on the Healy
Mike Dempsey on the Laurier
Robert Levine, Erica Escajeda, UW students

As detailed below, neither method produced unequivocal results, although the mutlibeam did give some inconclusive leads. At the time of writing, we plan a Norbit survey on our Norseman 2 cruise in 2023 to better survey the region, although without working releases, the missing mooring may prove extremely hard to locate.

Summary of CTD lines.

BS *(Bering Strait)* (US portion) – the main Bering Strait line, run at the start and at nearly the end of the cruise. This line has been occupied by past Bering Strait mooring cruises. US portion only run here. This line was previously ~ 2nm resolution. On both runnings of this section, we used the more recent station spacing of ~1nm to better resolve the structure in the strait. Previous runnings of this line have included two stations (BS23 and BS24) which fall south of the main line near Prince of Wales, extending the line along (rather than across) isobaths. Neither BS23 and BS24 were taken during this cruise**. CTD nutrient samples were taken on both runnings of this line in 2022. Pumped samples for trace metals/nutrients were taken on both runnings of this line in 2022.**

DLS and DLN *(Diomede Line)* (previously one line DL) – two consecutive lines running north from the Diomede Islands to A3, the southern portion DLS (stations DL1-12) at 1nm spacing, the northern portion DLN (stations DL13-A3) was previously run at 2.5nm spacing, but on this cruise a station spacing of 1.25nm was used. Run both at the start and end of the cruise, although the second running is complete due to bad weather. These lines study the hypothesized eddying and mixing region north of the islands. **CTD nutrient samples were taken on this line in 2022.**

AL *(A3 Line)* (US portion) – another previously-run line (previously run at ~ 1.7nm resolution, run this cruise once at 0.85nm resolution), just north of the Strait, running from the Russian coast, through the mooring site A3, to where the main channel of the strait shallows on the eastern (US) side. US portion only run here, and extended by 6.6nm to map the transition to shallower water**. Run with trace metal/nutrient sampling, and CTD nutrient sampling.**

Parts of **CCL *(Chukchi Convention Line)*** (US waters) – a line running down the convention line from the end of the LIS line towards the Diomedes (also run in 2003, 2004, 2011, 2012, 2013, 2014, 2015, 2016, 2017 and 2018), typically incorporating a rerun of the high resolution DL line at the southern end, run variously at 10nm (typical) or 5nm (rarely) resolution. Run only in parts in 2021. Run in part in 2022

Re-run of BS line with trace metal/nutrient sampling, and CTD nutrient sampling

Summary of ADCP/Underway data lines

The ship's ADCP recorded for the duration of the cruise, and between lines steams were often positioned to give more useful underway information. The following were targeted underway surveys:

After A4 recovery east to shallow waters and then back to A2 and BS11, then NE across the strait, and NW back across the strait to A3.

After completing AL line in the east, NW to the CL line

See maps for details of these lines.

Prior lines not taken on this cruise:

CS *(Cape Serdtse)* (US portion) – another cross strait line (~ 3.9nm resolution), run here from the US-Russian convention line (~168° 58.7'W) to Point Hope (US), but originally starting at Cape Serdtse-Kamen, in Russian waters. Also repeated during the cruise, both runnings adding stations to make station spacing ~1.9nm. First running done with trace metal/nutrient sampling in 2021. Not run in 2022.

NPH *(North Point Hope)* (US waters) - a line run before in 2016, and 2019, crossing from north of Point Hope to the WNW, at 1.25nm spacing near the coast, and 2.5nm spacing after NPH5, to chart the Alaskan Coastal Current transformation on its route along the Alaskan Coast. Extended in 2019 to the Convention Line (CCL). Run twice this cruise. First running westward only to station NPH13, second running (eastward) of complete line from CCL. Not run in 2022.

CD *(Cape Dyer)* (US waters) - a line new in 2016, taken also in 2017 and 2019, running west-east towards the Alaskan Coast, midway between Point Hope and Cape Lisburne, set just south of some apparent topographic irregularities, also to chart the Alaskan Coastal Current transformation on its route along the Alaskan Coast. Extended in 2019 to the Convention Line, but run in 2021 only from CD 14 to the coast. Not run in 2022.

LIS *(Cape Lisburne)* (US waters) – from Cape Lisburne towards the WNW, a previous RUSALCA line, run by us also in 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018 and 2019 and close to the CP line occupied in previous Bering Strait cruises in 2003 and 2004 (station spacing ~ 3.6nm). Note that due to the Quintillion cable, station Lis 9 is replaced by 2 new neighboring stations, Lis 8.5 and 9.5 . Run once during the 2021 cruise. Run with trace metal/nutrient sampling in 2021. Not run in 2022.

DLa and DLb – two other high resolution lines (1nm resolution), mapping the eddying/mixing region, parallel to DLS, allowing for a 2-dimensional mapping of the region.

AS – a line sampled only once before (2011) (although sometimes run for underway data), running from the eastern end of AL back towards the western end of the CS line, taken at variously 4nm or 2nm spacing (closer stations over steeper topography).

NNBS *(North North Bering Strait)* – a new line run only three times before (2015, 2017, 2019) west-east across the eastern strait, south of A3 and north of NBS, run at ~ 1.8nm resolution, to better map the Alaskan Coastal Current north of the Strait proper.

NBS *(North Bering Strait)* – an east-west cross-strait line ~ 8nm north of the Bering Strait line, run in previous years, with ~ 1.7nm resolution.

MBS *(Mid Bering Strait)* – an east-west cross-strait line ~ 10nm north of the Bering Strait line, run in previous years, with ~ 1.7nm resolution, with higher resolution near the coast

SBSnn – a previous line new in 2014, run only in 2014, 2015, 2017 and 2019, and then often only in part, just south of the strait, crossing the Alaskan Coastal Current before it enters the strait proper (previously and this year run at 2.2nm resolution, run in 2019 at 1.1nm resolution). This year run with the same alignment (i.e. from BS22 as used since 2019, and thus denoted SBSnn. (Previous SBS line started at BS24).

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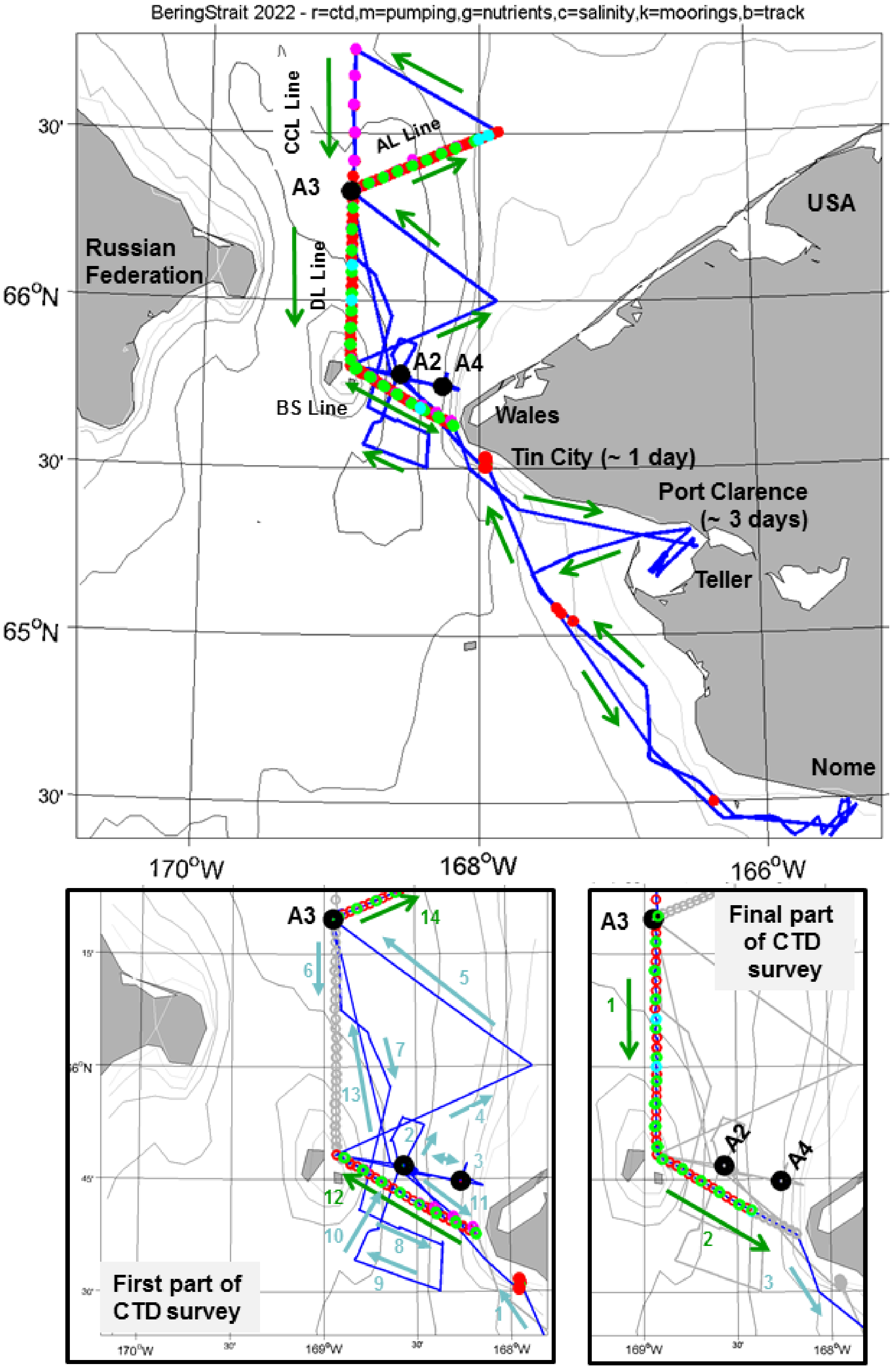
Listing of target CTD positions

References

Event Log (To be added on revision)

BERING STRAIT 2022 CRUISE MAP: *Ship-track, blue. Mooring sites, black. CTD stations - without (red) and with (cyan) salinity or (green) nutrient and (except 3 stations mid DL line) trace metal pumping. Pink, CTD and trace metal stations only. Consecutively numbered arrows show direction of travel (on this figure, green marking CTDing lines, cyan marking transit). Depth contours every 10m from IBCAO (International Bathymetric Chart of the Arctic Ocean [Jakobsson et al., 2000]. Lower panels give detail of strait region at the start (left) and end (right) of the cruise. (See next page for daily detail.)*



Bering Strait 2022
Mooring Cruise
Norseman II
By day
from 7am local

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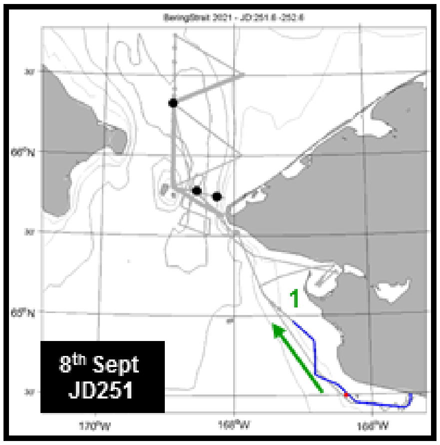

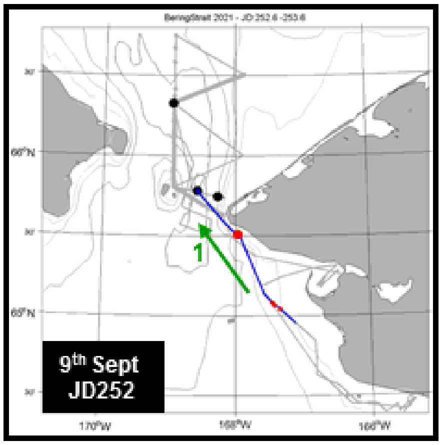

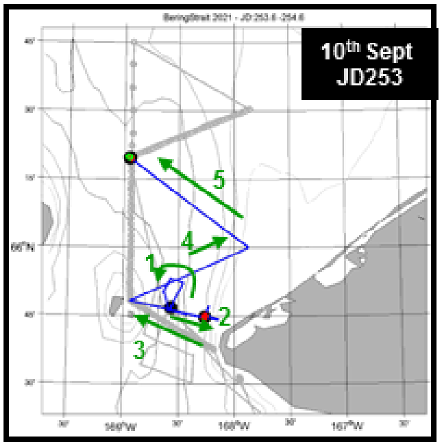

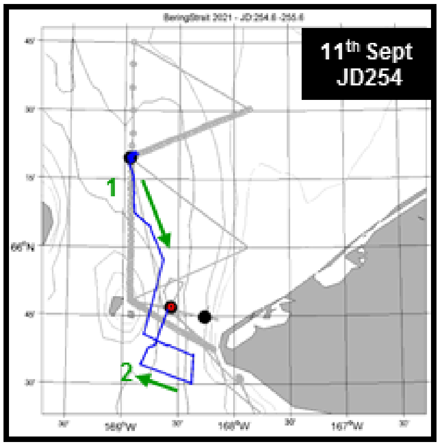

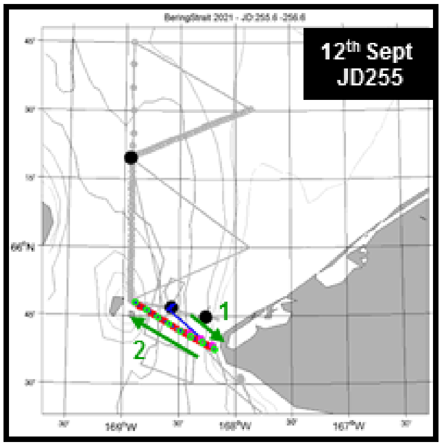

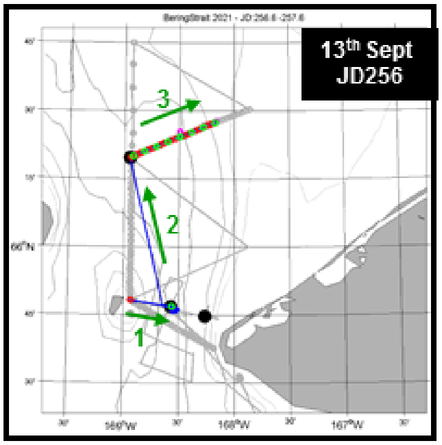

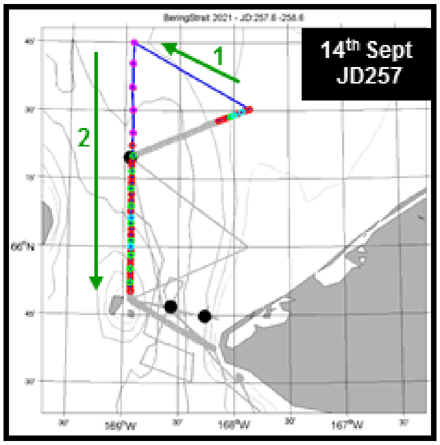

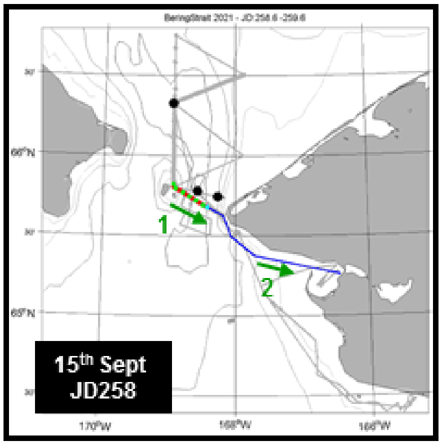

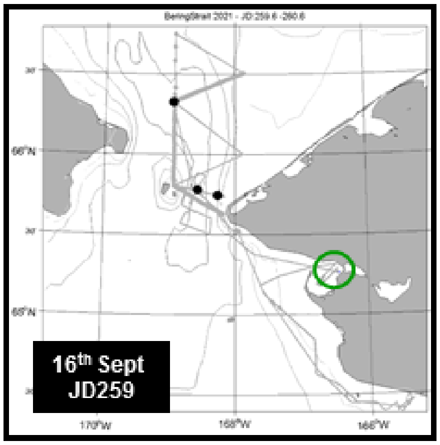

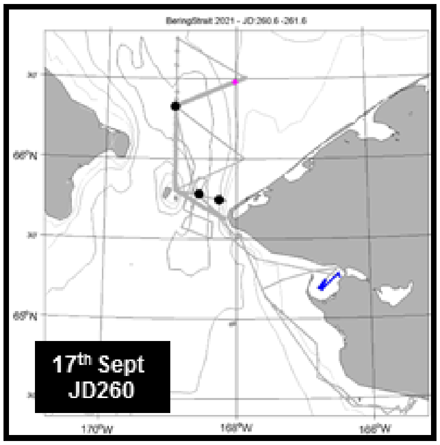

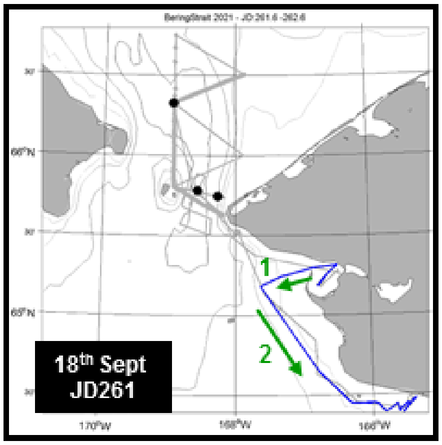

BERING STRAIT 2022 SCIENCE PARTICIPANTS

1. Rebecca Woodgate	UW	*Chief Scientist and UW PI*
2. Cecilia Peralta-Ferriz	UW	*Co-Chief Scientist and UW Co-PI*
3. John Guthrie (M)	UW	*UW research scientist*
4. Laramie Jensen (F)	UW	*UW postdoc & lead of trace metal/nutrient sampling*
5. Katy Christensen (F)	UW	*UW graduate student & lead of CTD measurements*
6. Robert Daniels (M)	UW	*UW mooring technician*
7. Marie Zahn (F)	UW	*UW graduate student & lead of marine mammal studies*

UW – University of Washington, US

Cabin Allocations:
Main deck (Cabin 4) - Katy and Marie
Lower deck, port aft (Cabin 8) - Rebecca
Lower deck, starboard aft (Cabin 7) - Cecilia and Laramie
Lower deck, starboard forward (Cabin 5) - John and Robert

BERING STRAIT 2022 NORSEMAN II CREW

1. Casey C. (M)	SVA	*Captain*
2. Brennan Carney (M)	SVA	*Mate*
3. Jim Wells (M)	SVA	*Boson*
4. Chris S (M)	SVA	*Chief Engineer*
5. Chris L (M)	SVA	*Cook*
6. Mike L eiffeste (M)	SVA	*Lead Deck*
7. Chris K. (M)	SVA	*Deck*
8. Josh C. (M)	SVA	*Deck*

SVA – Support Vessels of Alaska, Inc. , https://www.supportvesselsofalaska.com

Ship contract arranged by:

CPS Polar Field Services, partner of Battelle ARO
Adelaide Rosic, adelaide@polarfield.com

BERING STRAIT 2022 CRUISE SCHEDULE (Times: Alaskan Daylight Time (UTC-8), 24hr format)
(Wind directions are wind source .. so S Wind = wind from South)

20th July 2022	*Shipment of container of UW equipment to Homer*
19th Aug 2022	*Barge arrived in Nome and container offloaded*
26th Aug 2022	*Start of pre-cruise Covid precautions* *Fri 26th August - (10 days pre travel) all team do Covid antigen test* *Start pre-cruise safety measures and symptom tracking* *Mon 5th August - (1 day pre travel) all team do observed Covid antigen test*
Tues 6th Sept 2022	*UW Science period fly commercial to Nome.* *Continue covid pre-cruise safety measures* *Pre-cruise preparations with gear at Northland and Aurora*

Thursday 8th Sept 2022 (Cruiseday1, JD 251)	*UW Science team do Covid antigen test before joining ship* **UW Science team join Norseman2 0900** Set up CTD, **Sail ~ 1800 local** into poor forecast. CTD tests. Two reterminations of CTD cable
Friday 9th Sept 2022 (Cruiseday2, JD 252)	Poor weather, steam towards Tin City and hold there for weather CTD and water sampling test casts, fix leaking bottles
Saturday 10th Sept 2022 (Cruiseday3, JD 253)	On site at A2-21, early AM but no acoustic response. Ran search pattern to N and S Successfully ranged on A4 from A2 1521 On site at A4-21, **pre recovery CTD** 1549 **Released A4-21, all on deck 1600** Prep A4-22 1858 **Deployment A4-22, at depth 1904** 1926 **Post deployment CTD** Run ADCP lines (east to end of line, back through A2 to BS11, NE across strait to NBS10, NW across strait to A3
Sunday 11th Sept 2022 (Cruiseday4, JD 254)	0803 On site at A3-21, early AM **pre recovery CTD** ~0830 Start ranging on A3-21, find is moved 1nm SE (150deg) Started dragging operations (3 draggings necessary to snag mooring) **Recovered A3-21, all on deck 0915** Prep A3-22 1513 **Deployment A3-22, at depth 1519** 1530 **Post deployment CTD** Return south towards A2, ranging for missing A2-21. Run search pattern S of the strait through the night with no success.
Monday 12th Sept 2022 (Cruiseday5, JD 255)	Early AM Start dragging operations at site of A2-21 No success despite multiple snags and draggings Start dragging operations at "maybe" point, site ~1nm SW of A2-21

	where unusual feature spotted on ship's echosounder ~1745 Break off dragging operations without success, steam to BS22 **2004 Start BS line running west,** with nutrient sampling and trace metal pumping
Tuesday 13th Sept 2022 (Cruiseday6, JD 256)	**0710 Complete BS line,** steam to A2 ~0830 Start dragging operations at A2, ~1200 Break off dragging operations to prep A2-22, during prep run search pattern S of A2-21 site 1607 **Deploy A2-22, at depth 1618** 1632 **Post deployment CTD** Weather forecast (worst storm in 50 years due Sat) poor, so steam to A3 **2104 Start AL line, heading east** with nutrient sampling and trace metal pumping
Wednesday 14th Sept 2022 (Cruiseday7, JD 257)	~0200 SUNA issue **0938 Finish AL line**, steam NW to CCL 8.5, ranging en route **1351 Start CCL line heading S,** with trace metal pumping **2006 End CCL line at A12.5, start DI line heading S** with nutrient sampling and some trace metal pumping
Thursday 15th Sept 2022 (Cruiseday8, JD 258)	**0728 End DL line** **0752 Start BS line, heading SE** with some nutrient sampling and trace metal pumping **1347 Break off BS line after BS18.5 due to bad weather** Steam to Port Clarence to shelter from storm Arrive Port Clarence and anchor around midnight
Friday 16th Sept 2022 (Cruiseday9, JD 259)	All day at anchor in Port Clarence, winds 20-40knots
Saturday 17th Sept 2022 (Cruiseday10, JD 260)	~ 0500 local, drag anchor Jog in Port Clarence for rest of day, peak winds 74knots, ~ 1700 weather starts coming down, but winds still > 40 knots
Sunday 18th Sept 2022 (Cruiseday11, JD 261)	~ 1000 decide possible to head to Nome, Leave Port Clarence, heading for Nome.
Monday 19th Sept 2022 (Cruiseday12, JD 262)	Wind turns enough in night to allow docking at Nome ~0830 Causeway damaged in floods. Extract items from container at Northland on foot Mid AM Science party walks out to get cab to airport and flight to Seattle Gear now to be offloaded in Homer. N2 leaves Nome Mon evening

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Monday 26th Sept 2022	N2 arrives Homer, Offload of ship, and loading of Container for Seattle
Tuesday 27th Sept 2022	Pick up of Container for Seattle
Wed 12th-Fri 14th Oct 2022	Container delivered Seattle, but wrong container
Thursday 27th Oct 2022	Correct container delivered in Seattle

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Bering Strait 2022 Mooring cruise TOTALS

10.75 days at sea (away from Nome) ~1800 8th Sept – 0830 19th Sept 2022
11 days on ship (including on/offload) ~0900 8th Sept – 1100 19th Sept 2022

Moorings recovered: 2
Moorings deployed: 3
CTD casts: 111 (plus 14 test casts) on 5 lines
Trace metal/nutrient Pumping stations: 35
Nutrient samples taken: 169 on 4 lines
Salinity samples taken: 20 (for bottle closing investigation)

SCIENCE COMPONENTS OF CRUISE

The cruise comprised of the following science components:

- Mooring operations – 3 attempted mooring recoveries (2 successful), 3 mooring deployments.

- CTD operations - 111 casts on 5 lines (UW instrumentation, measuring temperature, conductivity, oxygen, fluorescence, turbidity and SUNA nitrate with pressure)

- Water sampling from the CTD rosette - 169 nutrient samples taken on 4 lines to map spatial variability of nutrients and 20 salinity samples taken at isolated station to investigate bottle flushing.

- **Pumped Water sampling for trace metals/nutrients** - 41 stations where samples taken with pumped system.

- Underway sampling – ship-based equipment of 300kHz hull-mounted ADCP; SBE21 underway Temperature-Salinity recorder, an SBE38 temperature sensor, and some meteorological data (air temperature, pressure, humidity, wind direction and wind speed).

- Moored Marine Mammal Observations (acoustic instruments on the moorings)

Recovered A3 moorings and the deployed A3 mooring carried Marine Mammal Acoustic Recorders from Kate Stafford, UW.

MOORING OPERATIONS (Woodgate/Daniels, assisted by others)

Background: The moorings serviced on this cruise are part of a multi-year time-series (started in 1990) of measurements of the flow through the Bering Strait. This flow acts as a drain for the Bering Sea shelf, dominates the Chukchi Sea, influences the Arctic Ocean, and can be traced across the Arctic Ocean to the Fram Strait and beyond. The long-term monitoring of the inflow into the Arctic Ocean via the Bering Strait is important for understanding climatic change both locally and in the Arctic. Data from 2001 to 2018 suggest that heat and freshwater fluxes are increasing through the strait [*Woodgate et al.*, 2006; *Woodgate et al.*, 2010; *Woodgate et al.*, 2012; *Woodgate et al.*, 2015; *Woodgate*, 2018; *Woodgate and Peralta-Ferriz*, 2021], with 2012 being a year of low flow, but 2013 to 2016 returning to higher flow conditions [*Woodgate*, 2015; *Woodgate et al.*, 2015; *Woodgate*, 2018]. The data recovered this cruise will indicate if recent years show further increase or a return to older conditions.

An overview of the Bering Strait mooring work (including data access) is available at http://psc.apl.washington.edu/BeringStrait.html. Data are also permanently archived at the National Oceanographic Data Center, now renamed the National Centers for Environmental Information (https://www.nodc.noaa.gov/ or https://ncei.noaa.gov).

A map of mooring stations is given above. Three UW moorings were to be recovered on this cruise. These moorings (all in US waters –A2-21, A4-21, and A3-21) were deployed from the Norseman II in July 2021, with mooring funding from NSF-AON (PIs: Woodgate and Peralta-Ferriz, *PLR1758565*).

Three UW moorings (A3-22, A2-22, A4-22) were deployed on this 2022 Norseman II cruise under funding from NSF-AON (PIs: Woodgate and Peralta-Ferriz, *PLR2153942*). All these deployments were replacements of recovered moorings at sites occupied since at least 2001 (A4) or 1990 (A2 and A3). Analysis of past data suggests data from these three moorings are sufficient to give reasonable estimates of the physical fluxes of volume, heat and freshwater through the strait, as well as a useful measure of the spread of water properties (temperature and salinity) in the whole strait [*Woodgate et al.*, 2015].

All moorings (recovered and deployed) carried upward-looking ADCPs (measuring water velocity in 2m bins up to the surface, ice motion, and medium quality ice-thickness); lower-level temperature-salinity sensors; and iscats (upper level temperature-salinity-pressure sensors in a trawl resistant housing designed to survive impact by ice keels). Both the recovered and deployed A3 moorings also carried marine mammal acoustic recorders. The A3-22 mooring also carried, instead of an iscat, the “Miscat”, a multiple instrument version of the iscat, designed to allow instruments to be lost sequentially from nearer the surface. For a full instrument listing, see the table below.

Our new NSF grant supports also biogeochemical measurements on the moorings. Thus A2-21 and A3-21 carried also SUNA optical nitrate sensors, SBE37-ODO optical sensors for dissolved oxygen and WETLABS FLNTUSB optical sensors for fluorescence and turbidity. An additional WETLABS FLNTUSB sensor was also deployed on A4-22.

This coverage should allow us to assess year-round stratification in and fluxes through the strait, including the contribution of the Alaskan Coastal Current, a warm, fresh current present seasonally in the eastern channel, and known to be a major part of the heat and freshwater fluxes [*Woodgate and Aagaard*, 2005; *Woodgate et al.*, 2006; *Woodgate et al.*, 2015; *Woodgate*, 2018]. The ADCPs (which give an estimate of ice thickness and ice motion) allow the quantification of the movement of ice through the strait [*Travers*, 2012]. The marine mammal recording time-series measurements should advance our understanding of the biological systems in the region. The biogeochemcial sensors aim to return the first year-round measurements of nitrate in the strait, with accompanying key biological parameters.

Calibration Casts: Biofouling of instrumentation has been an on-going problem in the Bering Strait. Prior to each mooring recovery, a CTD cast was taken to allow for *in situ* comparison with mooring data. Similarly, CTD casts were taken at each mooring site immediately after deployment. These post-deployment casts will allow us to assess how effective this process is for pre-recovery calibration. Since the strait changes rapidly, and CTD casts are by necessity some 200m away from the mooring and may be as long as 1hr separated in time from the mooring reading, it is inevitable that there will be differences between the water measured by the cast and that measured by the mooring. **Action item: On recovery, check the post deployment casts to see how reliable the comparison is.**

This year (as in 2017, 2018, 2019 and 2021), an on-deck calibration tank was also used for recovered instruments. This is discussed below.

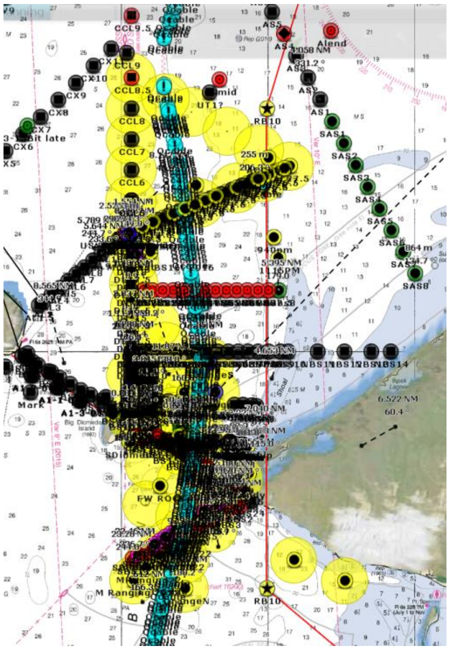
2022 Recoveries and Deployments:

Our standard procedure for mooring recoveries was the following:

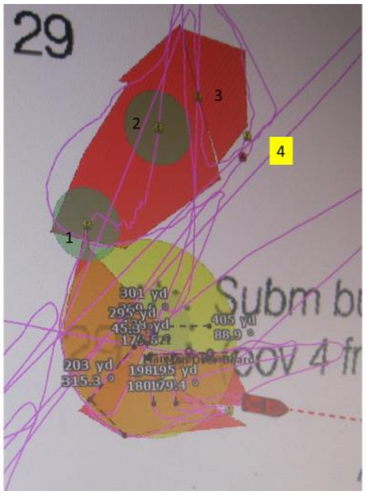
First a pre-recovery CTD cast was taken starting at a safe (~200m) distance from the mooring position and drifting way. Next, for ranging, the ship positioned ~ 200m away from the mooring so as to drift towards the mooring site. Ranging was done from the port mid corner of the aft deck of the ship, with the hydrophone connecting to the deck box inside at the aft end of the port laboratory. **Action item: Re check position as regards to ship's propellers.** Once the ship had drifted over the mooring and the acoustic ranges had increased to >70m, the mooring was released**.** This procedure was followed to prevent the mooring being released too close (or underneath) the ship since in previous years the moorings have taken up to 15min to release. **Action item: Be sure to distinguish between slant and horizontal range during soundings.** As site A3 is ~0.6nm from the Russian border, prior to ranging on A3, the Norseman II's small boat was prepared for launching, to cover the eventuality that if the mooring had to be dragged, the mooring would surface and drift towards Russian waters before the ship was able to recover it. **Action item: Continue to prepare for small boat operations at site A3.**

On all moorings, we use double releases, with springs to assist the mooring release. For the all moorings, our usual routine is to communicate and range with one release and then attempt to release the other release (to test both instruments).

The first mooring attempted was **A2-21**, which was deployed with an iscat but missing the weak link. Thus we expected the mooring might be dragged by the ice. Thus, to avoid accidently catching the mooring during the pre-recovery CTD, we started with ranging instead of the CTD cast. Unfortunately, ranging (on either release) gave no response. This was extremely unusual. Finding no response locally, we proceeded 5nm in the direction of the mean flow (NNE), stopping every 1nm to range again. We then moved 3nm ~west, and returned ~south, again stopping to range. Finally we tried 1nm to the south in the direction of the mean flow, again without success. With hindsight, this survey spacing was over pessimistic. We later proved the releases could hear and respond to signals from at least 15km (as we could activate and get responses from a release on A4 when at site A2 - with the transducer was at ~30-40m depth, responses to range were obtained roughly every other interrogation). This suggested acoustically we had already searched a large area, and thus, so as to not waste the light and good weather on searching which could be done by night, by midafternoon, we proceeded instead to A4-21. Subsequent ranging effort by us (and by others) also failed to produce any response from the A2-21 releases. We used a standard routine of enable, and 3 range attempts with the transducer at ~40m or 10m above bottom in shallower water throughout the cruise. From the second half of the cruise, we also sent the disable command as the last communication. Only at one place did we obtain a reply. That gave wildly different ranges to sequential interrogates, and would also reply to an interrogate at any frequency. We concluded whatever it was, it was not the mooring. Figure right shows in yellow a 4nm radius around all ranging locations. Likely the ensonified area is twice this. This suggests the mooring has to have moved more than many 10s of miles, or the releases are not working



After the rest of the mooring work was complete, we spent 2 days dragging at site A2 and at a position (the “maybe” point, marked as 65 46.3146N 168 35.6770W ~0.8nm at 231deg from A2-21 deployment) where the N2 Captain saw something mooring like on the ship’s echosounder during our transit to SSE. (Note this position is not exactly on the ship track, and likely was marked by hand on the chart when the unusual item was noticed on the echosounder, and thus the actual target could be some way 200+m NNE of the marked point. All efforts to run exactly over the maybe point again were unsuccessful, and nothing unusual was sighted on any of them. Our mooring strategy was to lay out ~ 1200ft of cable in a U shape, starting up stream and off to the side of the target, and looping round downstream off the target and off to the other side, then the ship drift should drag the chain and hooks over the target position. Frequently this caught on somethings, often enough to pull the ship back towards the point as the trawl was hauled in. This strategy has in the past brought anchors to the surface. However, none of the dragging brought anything to the surface this year. Our conclusion was there were several “sticky points” worth checking again, though around A2 they are likely old anchors.



2. Moved that to
65 47.2702
168 33.9946

1: drew something
up to:
65 47.0646
168 34.4211

3. Moved that
to
65 47.3436
168 33.7521

4. Moved that
to 65 47.2669
168 33.4736

And then looked
at maybe point

1. Maybe point
65 46.3146
168 35.6770

2. Moved to
65 46.3877 and 168 35.7112

Finally, we convinced ourselves that the mooring was no longer at A2-21 site, and thus we redeployed A2-22 at the same location.

The Sikuliaq was kind enough later in the season to attempt to revisit these points using their multibeam system. There were various overheating issues which limited their ability to scan. They did demonstrate that at 10knots they were unable to find the newly deployed mooring in real time but at 5knots they could find it 75% of the time, but only if it was within 50m of the ship. Post processing the data met with better success in finding the existing mooring. Weather prevented a fuller survey, but they found nothing at the maybe point. A possible target was identified some 200m from the maybe point at lat: 65.773868N 168.595823W, however, revisiting that point some weeks later, they did not refind the target. While this is not good news, the effective swath ended up being so small, it is also not conclusive proof of absence of the mooring.

At the time of writing . At the time of writing, we plan a Norbit survey on our Norseman 2 cruise in 2023 to better survey the region, although without working releases, the missing mooring may prove extremely hard to locate. **Action item: Arrange for mooring search for 2023.**

Mooring **A4-21** responded immediately to the interrogate commands, and was released exactly according to plan.   Mooring **A3-21** responded immediately to interrogate, but gave a range of ~ 2km, and increasing, indicating the mooring was to the S of the original position. Triangulation yielded a new position of 66 18.78N 168 55.74W. Although the releases confirmed release the mooring did not surface and had to be dragged, being successfully recovered on the 3rd dragging operation. From examining the recovered mooring components and data, we conclude a ~20m deep ice keel slid the mooring ~1nm over a 5hr period on the 25th Jan 2022 (average speed 10cm/s, average direction 150deg, same as the mean ~southward flow), the ice catching on the deeper of the floats of the iscat system, and applying a weak enough force so as to not pull through the double weak links of the miscat. **Action item: Invest in better dragging gear.**

In all cases, once the mooring was on the surface, the ship repositioned, bringing the mooring tightly down the starboard side of the ship. One boat hook and a pole with a quick releasing hook attached to a line were used to catch the mooring, typically on a pear link fastened to the chain between the float and the ADCP or on eyes welded to the float surface. The line from the hook was then passed back to through the stern A-frame, and tied with a "cat's paw" knot to a hook from the A-frame. This portion of the mooring was then elevated, allowing the second A-frame hook to be attached lower down the mooring chain, and tag lines to be attached if necessary. The iscat, if present, was recovered by hand at a convenient point in this operation, prior to recovery of most of the mooring. Then the entire mooring was then elevated, using both hooks from the aft A-frame, and recovered onto deck. Recovery work was done by a deck team of 4 crew of the Norseman II – one on the A-frame controls, three on deck with on overhead safety lines ("dog runs") down each side of the deck (one of these working forward of the deck on tag lines), assisted by UW personnel further forward on the aft deck. Once on deck, the moorings were photographed to record biofouling and other issues. **Action items: Be sure to add pear-link to the chain between float and ADCP. Prepare loops of line for threading through chain/shackles to provide a lifting point. High A-frame or crane very helpful for recovery. Also helpful to review mooring movies at start of cruise. Bring extra tires for the recovered floats.**

The A-frame of the Norseman II is atypically high (~ 26ft less block attachments). While this is extremely useful in fair weather, it allows for swinging of the load in rougher seas. **Action item: Continue to use tag line options for recovery in rougher weather.**

Good visibility (at least ~1nm) is required for mooring recoveries since the mooring may delay releasing due to biofouling, or the mooring may require dragging, as in previous years. Given the proximity of A3 to the US-Russian border, small boat operations may also be necessary during a dragging operation to prevent the surfaced mooring drifting out of US waters. For these reasons, it was decided typically not to commence a new mooring operation after 5pm local time. **Action item: Continue to include weather days in the cruise plan; plan also for small boat operations (including sending a battery powered release unit), considering especially if small boat operations could be used in fog. Assess causes of foggy conditions, in order to predict best strategy for finding workable visibility.**

Biofouling was moderate to light on the 2021 moorings. The ADCP heads were entirely covered with barnacles, but salinity cells were clear. Bryozoan growth was limited - instead barnacles were plentiful. The releases had some biofouling, but significantly less than on the rest of the moorings.

The lower float of the miscat on A3-21 was recovered, but showed obvious bending damage just above the float, presumably from ice.

Mooring deployments were done through the aft A-frame, using the A-frame hooks for lifting. The height of the Norseman II A-frame was extremely advantageous for these deployments. Lacking such an A-frame, alternative ships might consider lifting the mooring with the crane, rather than the A-frame. The mooring was assembled completely within the A-frame. The ship positioned to steam slowly (~1 to 2knots) into the wind/current, starting between 500m and 600m from the mooring site. **Action item: This distance (greater distance in strong current) works well.** At the start of the deployment, the iscat was deployed by hand and allowed to stream behind the boat, which steamed at ~ 2knots, fast enough to maintain headway and to trail the mooring behind the ship, but not so fast as to damage the equipment being towed or pull equipment off the deck. **Action item: Feed the iscat tether unwound to the person spooling it off the deck.** The first pick (from one of the hooks of the aft A-frame) was positioned below the ADCP, except in the case of A4, where the first pick was below the top float. The second pick (from the other hook of the aft A-frame) was lower down on the mooring allowing all the mooring except the anchor to come off the deck during the lift. Then, the A-frame boomed out to lower these instruments into the water. Tag lines were used to control the instruments in the air. **Action item: use deck cleats to fair tag lines. Be sure to position the lift point on the float so it does not cause the float to roll off.** The first pick was released by a mechanical quick release, which was then repositioned to lift the anchor. (Previous years have shown that if the first pick was insufficiently high, the releases would still be on deck when the first package was in the water. The releases would then slip off the deck inelegantly. It was found that a higher lift of the instruments, and using both hooks of the A-frame, allowed the releases also to be lifted from the deck and then hang nicely behind the ship once the ADCP was placed in the water.) The anchor was lifted into the water just prior to arriving at the site. Positioning of this final pick very close to the anchor prevents the releases being pulled back over the lip of the ship when the anchor is lifted. **Action item: Make final pick as close as possible to the anchor.** When the ship arrived on site, the anchor was dropped using the mechanical quick release. Positions were taken from a hand-held GPS on the upper aft deck, some 5m from the drop point of the mooring. **Action item: Continue to bring own GPS unit. Note that due to mooring fall back, actual mooring position may be ~ 10m from this position in the opposite direction to the steaming direction during recovery.** This information is noted on the mooring diagrams.

A team of 4-5 crew did the deployments, with one person on the A-frame, 3 on the "dog runs' assisting the instruments up into the air, and other members of the crew/science team assisting with tending the tag lines during lifting.

Action items: design pick points into the moorings for recover; continue to put 2 rings on the anchors for tag lines. Consider using chain, not line for the moorings (saves on splicing and gives extra pick points); Compute the best pick point, such that the releases are lifted free of the deck, rather than slipped over the edge.

Deployment Instrumentation issues: This year, to avoid needing a long preparation period in Nome, much of the instrumentation was started in Seattle and shipped on delayed start. (Note SBE37IM will not accept a delayed start longer than 30 days.) Exceptions were the new biotopics instruments which were only delivered after the shipment was left. These were started in Nome.

Iscat housings and tethers were assembled in Seattle, and ADCPs incorporated into the ADCP frames, leaving the only assembly work to be done in Nome/at sea the placing of the floats on the ADCP frames and the testing of the releases. **Action item: Consider in future if starting instruments in Seattle is a safe way of saving time in Nome. Note that releases could also be deck checked ashore to save time at sea.**

The new biogeochemical instruments presented several issues. Those more than a standard learning curve will be added to this report at a later date. Action item: **Add biooptics notes**.

Recovered Data and Instrumentation issues: Data recovery on the moorings was generally very good.

- ISCAT SBE37IMS AND LOGGERS: Of the 2 iscats/miscat deployed on the recovered moorings:

- from **A4-21**, the top SBE37 sensor was not recovered. The logger recorded data until 15th Feb 2022, though there were common data gaps of 1hr and in Jan 2022, there is a gap of more than 2 days. The data record contained many spurious characters, requiring over 500 edits to align columns. **Action item: Investigate**
- from **A3-21,** only the bottom SBE37 sensor of the miscat system was recovered. The logger returned data until 15th Dec 2021 for the upper sensor and until 3rd Aug 2022 for the lower sensor. The logger battery was only 6.2V on recovery (starting voltage 9.6v). Likely the logger record is not complete as the battery was too drained. **Action item: Use Lithium battery on miscat in the future**. Nonetheless, this is the first successful deployment of the miscat system**.**

Preliminary results (before any correction for biofouling or post cruise calibration) are plotted below.

- *ADCPs:* The two recovered ADCPs were running on recovery and gave complete data records. These instruments were deployed with lithium batteries (and no external battery pack) and a conservative recording schedule and were expected to last the two years. The ice track records have been roughly investigated, and show the large ice keel which moved A3. **Action item: Check the sea ice data.**

Preliminary results are plotted below.

- *SBEs:* A SBE37 was recovered from each mooring. Neither instruments were pumped. Both instruments were running on recovery and returned full data records with only minor problems, viz. the memory of 23154 on A4-21 was not completely wiped before deployment (1 record uncleared). **Action items: Send for calibration.**

Preliminary results (before any correction for biofouling or post cruise calibration) are plotted below.

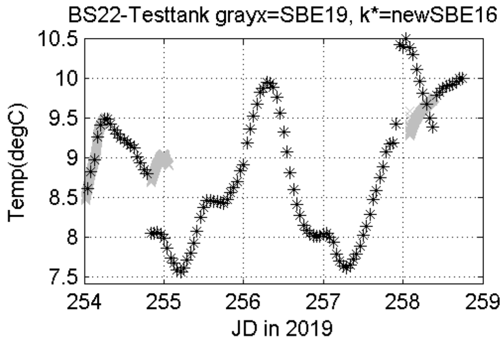
Post recovery tank calibrations: As an addition calibration test, uncleaned post-recovery SBE instruments were placed, for various periods after recovery in a large-plastic bin filled with salt water in conjunction with three recently calibrated SBE instruments:

- SBE19 #924, borrowed from the APL equipment pool and last calibrated in Jan/Feb 2018
- SBE16 # 1698, brought as a mooring spare and last calibrated in October 2021
- (No SBE37IM spare was went on this cruise).

The intent was to ascertain to what extent cleaning after recovery changes the readings on the SBE instruments. The preliminary test with this system was in 2016, and had significant limitations, likely relating to the instruments being horizontal, trapping air bubbles or biofouling, or coming out of the water on the rolling ship, or possibly due to interactions between instruments. This year, as in 2017 and 2018 and 2019 and 2021, the tank was designed to a) allow all instruments to be vertical and b) to include a pump to circulate water within the tank.

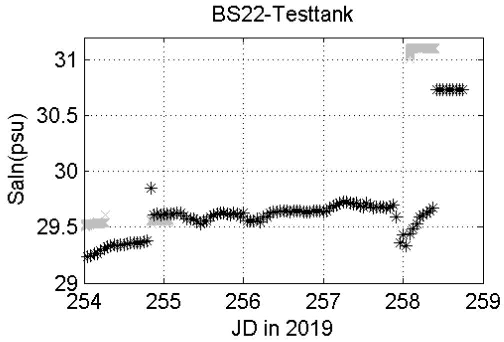
Once instruments were recovered from the moorings, they were placed in the tank for various periods of several hours, such as to obtain at least 6 readings. Since recovered instrumentation was recording either hourly (SBE16s) or every 5min (SBE37), this allows a good comparison with the calibration CTD, set at 5 second data, and somewhat with the SBE16 recording hourly. Instruments were then cleaned and placed again in the tank for at least another 6 readings. The instruments will next be returned to the manufacturer for post cruise calibration. **Action item: Keep CTD upright. Do test before and after cleaning. Use both mooring spares**. **Track CTD time (only ~ 28hrs per battery set). Check CTD pump is working.**

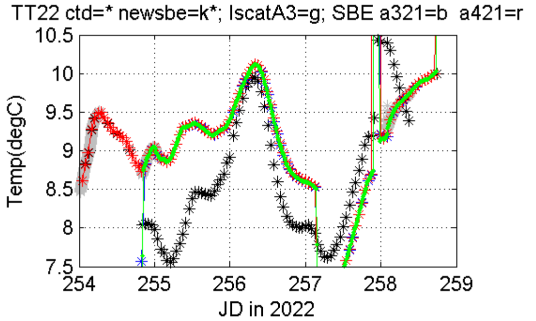
Preliminary results are shown below. Three time periods were recorded. JD254-254.3, JD 254.8- 255.1, JD 258.1-258.4.Three SBE instruments were recovered (A4-21SBE, A3-21SBE, A3-21iscatlower

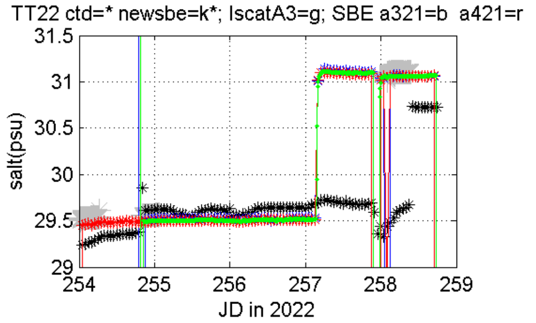


This preliminary plot compares the testank SBE19 (gray) with the newly calibrated SBE16 (black).

For unexplained reasons, this comparison is very poor. There is only 1 period when they are working in the tank at the same time (254-254.2). Here the SBE16 is 0.3 to 0.2 psu fresher than the pumped CTD. And around 258.4, when the salinity is stable, even though the time overlap is small, the SBE16 is also much (0.35psu) fresher.

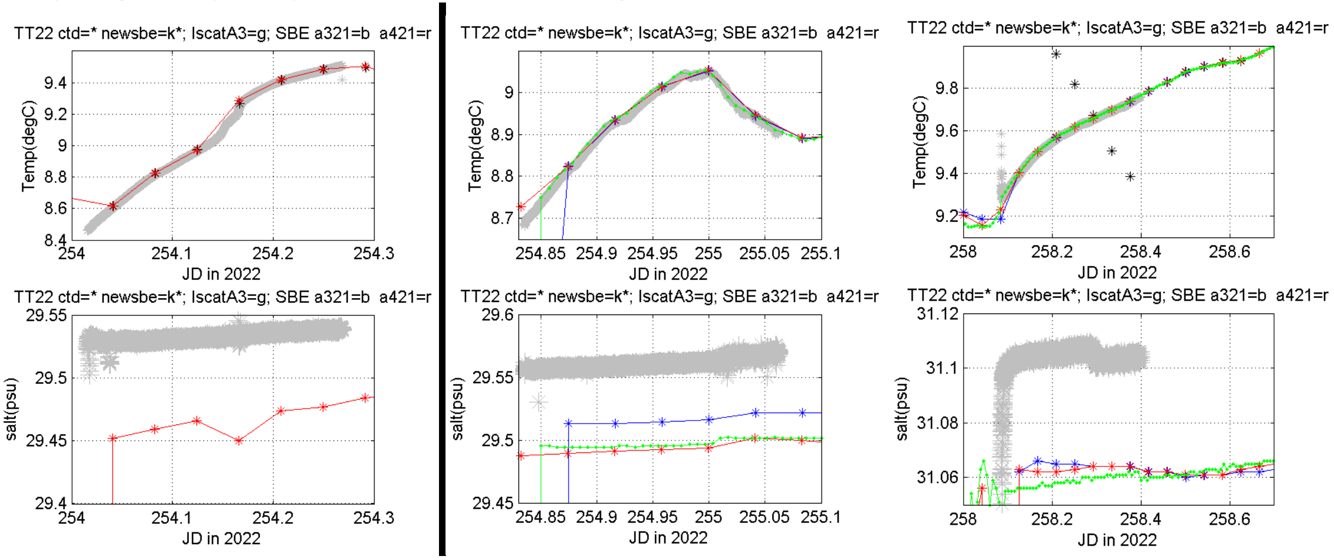






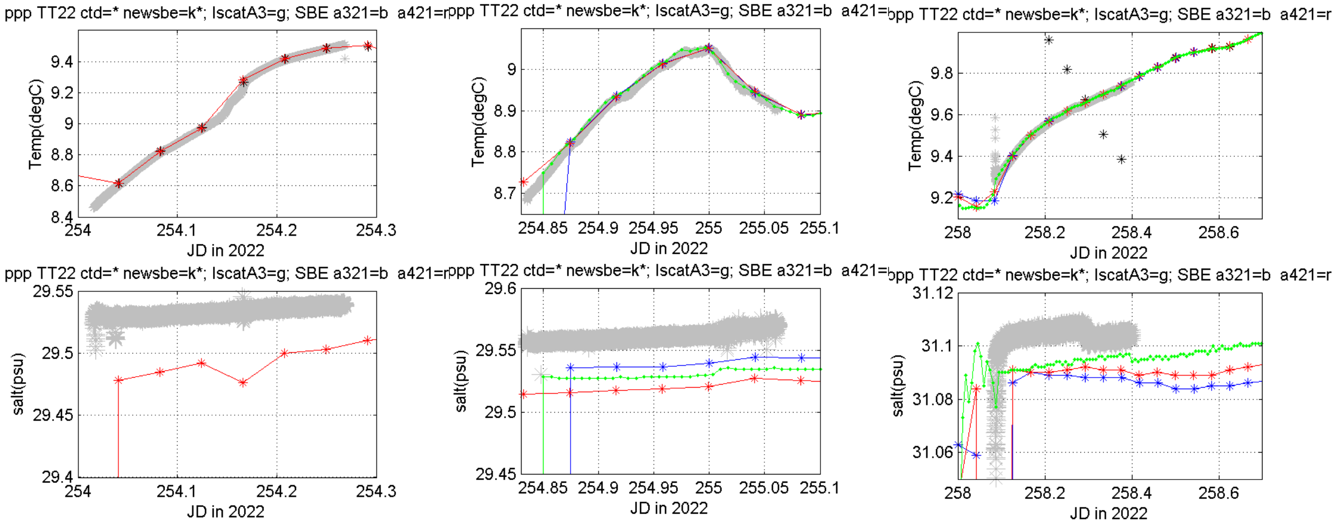
Moreover, the recovered instruments (colours, right) show much better agreement both with themselves and with the SBE19

Comparing now by time period, we see the following:



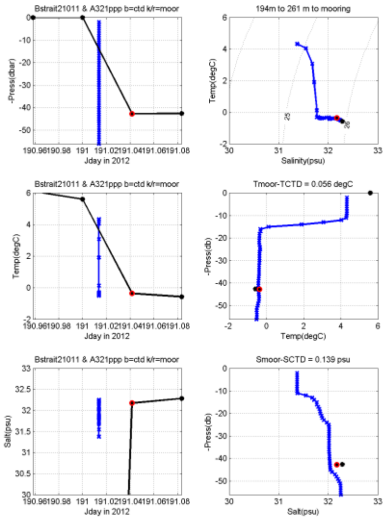
Before cleaning, the recovered instruments are ~ 0.06psu or less fresher than the SBE19
After cleaning, the recovered instruments are ~ 0.04psu fresher than the SBE19, and now show less spread also amongst themselves

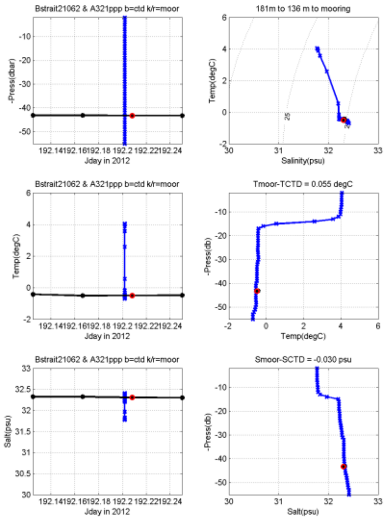
April2023, same plots with postcals:

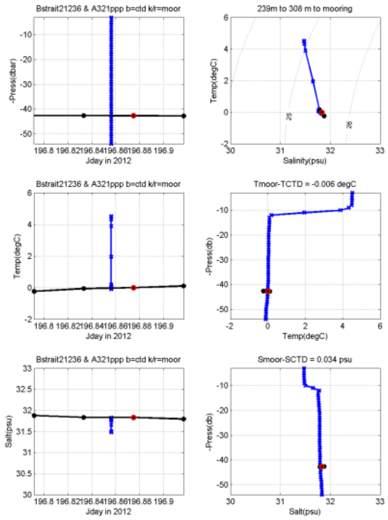


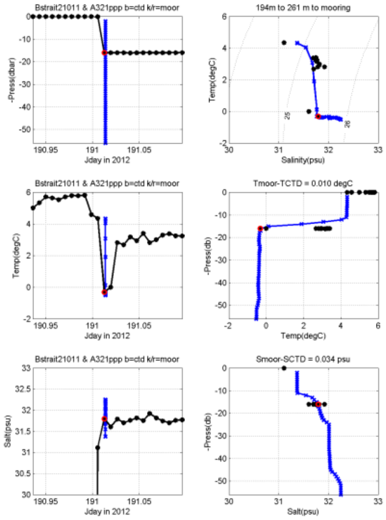
Before cleaning, postcaled instruments are within 0.05psu, and cleaned are within 0.01psu.
Relevant numbers here are pre cleaning.
A3-21sbe are about 0.02psu too fresh
A3-21isc are about 0.03psu too fresh
A4-21sbe are about 0.04psu too fresh

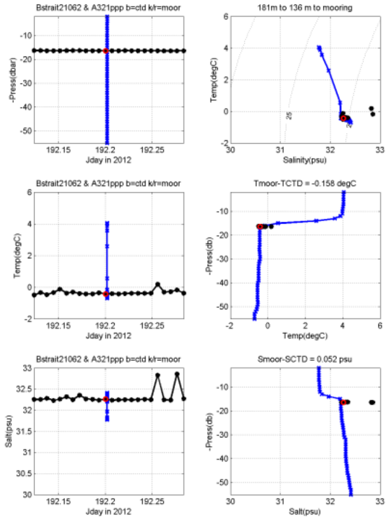
CTD calibration casts run with postcals taken:7 relevant to deployment

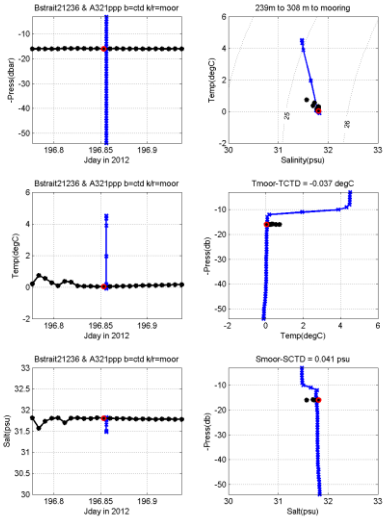


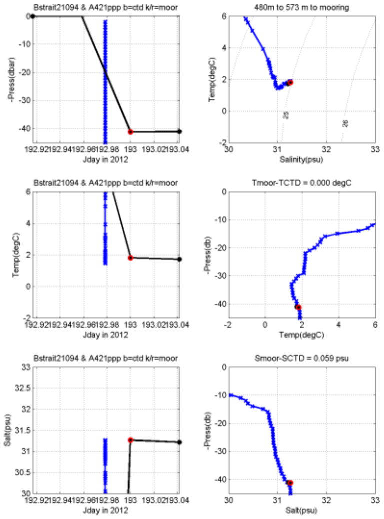






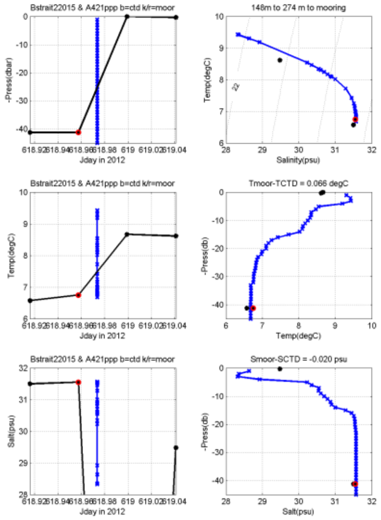




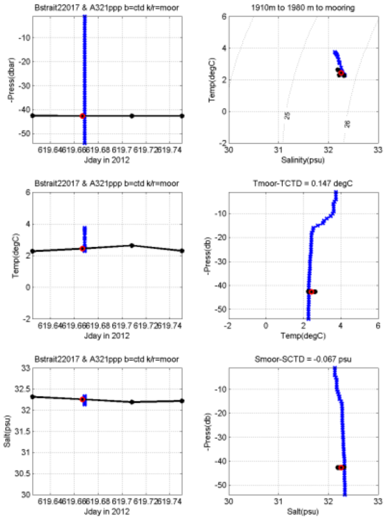


3 relevant to recovery:

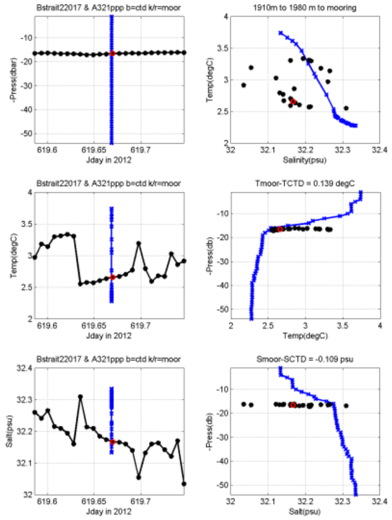
A4sbe .. possibly relevant



A3sbe .. but ~2km away



A3isc but far, & on gradient



Summary of cal casts:

```
%********SUMMARY CAL CASTS*** run Apr2023 with postcals *****
%Mooring  CTDYr CTDNum DISTSt&E(m) Press(db)  Mooring-CTD for
%                                              T(degC)   S(psu)
% -- DEPLOYMENT - SBEs
A321ppp Bstrait21 011    194  261    42.7     0.056    0.139
A321ppp Bstrait21 062    181  136    43.2     0.055   -0.030
A321ppp Bstrait21 236    239  308    42.7    -0.006    0.034
A421ppp Bstrait21 094    480  573    41.2     0.000    0.059
% -- DEPLOYMENT - Iscats
A321ppp Bstrait21 011    194  261    16.0     0.010    0.034
A321ppp Bstrait21 062    181  136    16.4    -0.158    0.052
A321ppp Bstrait21 236    239  308    16.0    -0.037    0.041
%
% -- RECOVERY - SBEs
A321ppp Bstrait22 017   1910 1980    42.6     0.147   -0.067
A421ppp Bstrait22 015    148  274    41.2     0.066   -0.020
% -- RECOVERY - Iscats
A321ppp Bstrait22 017   1910 1980    16.6     0.139   -0.109
```

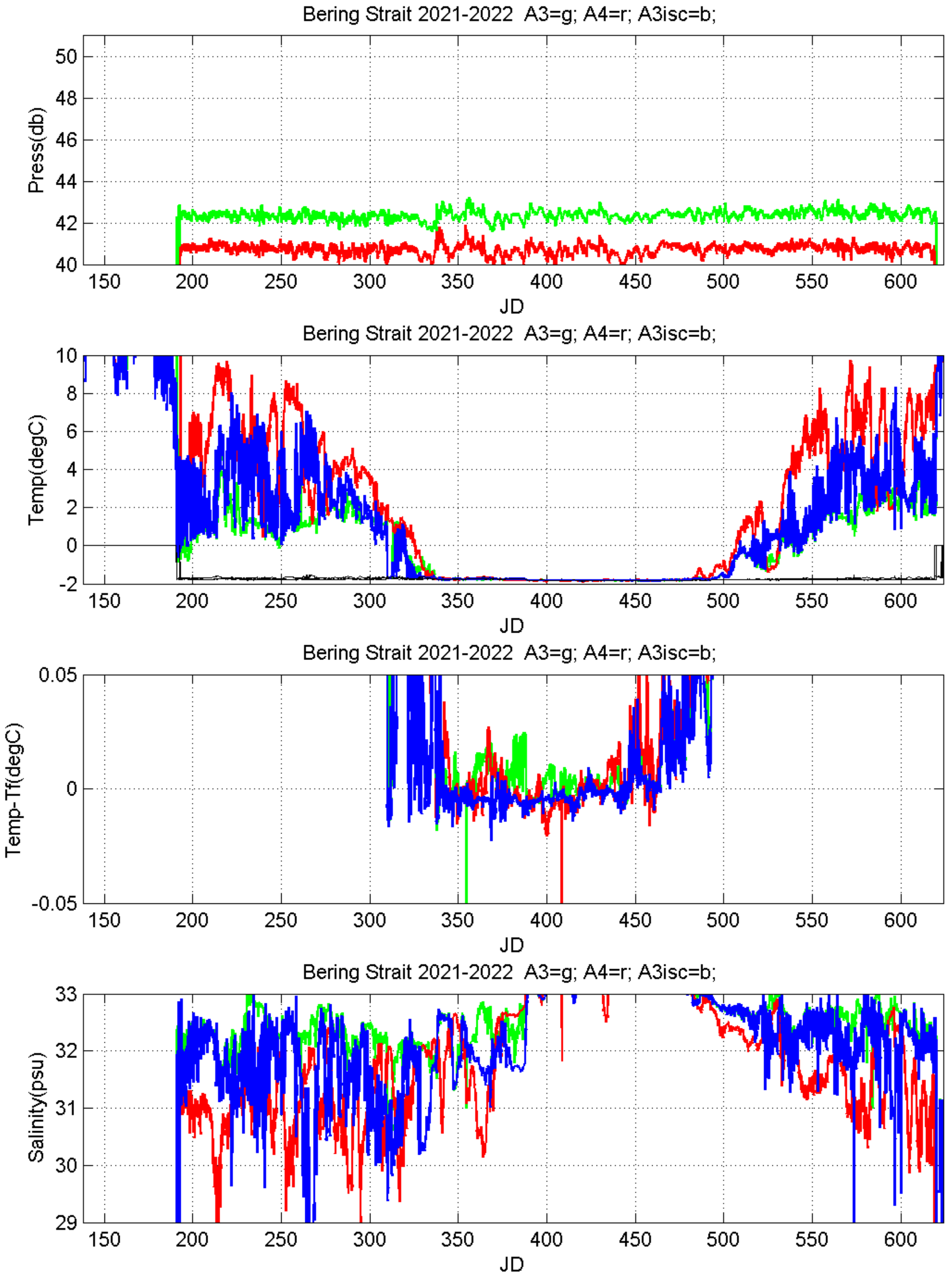
Conclude:

- even on deployment, inconclusive agreement. And thus really not very useful for recovery.
- do suggest moorings are drifting fresh.
- testtank seems more reliable

ACTION ITEMS:

- why is SBE1698 so far off? Do test tank in Seattle to check
- note cleaning changes salinities by ~ 0.02psu
- wait for post cals.

Post cals relative to T freezing:



SUMMARY OF SALINITY CORRECTIONS for 2021-2022 data with postcals – May 2022

2021-22	**A221sbe**	**A221iscat**	**A321sbe**	**A321iscatL**	**A321iscatU**	**A421sbe**	**A421iscat**
Note	Not recovered	Not recovered	Sbe37	Recovered	LOST	Sbe37	LOST
SAcc from Manufact	*0.05psu*	*0.008psu*	*0.008psu*	*0.008psu*	*0.008psu*	*0.008psu*	*0.008psu*
1) ppp			0.02psu	0.03psu		0.025psu	
2) testtank With ppp			0.02psu too fresh	0.03psu too fresh		0.04psu too fresh	
3) Rec CTD			inconcl.	inconcl.		inconcl.	
4)Next yr			Not avail.	Not avail.		Not avail.	
5)Iscat/SBE			Seems ok	Seems ok		Seems ok	
6)Other moorings			Seems ok	Seems ok		Seems ok	
7) Tfreeze			Seems ok	Seems ok		Seems ok	
CONCLUDE			**ppp 0.02 psu fresh Correct for in Scorr**	**ppp 0.03 psu fresh Correct for in Scorr**		**ppp 0.04 psu fresh Correct for in Scorr**	

Recall
Freezing temperature for 33psu = -1.808degC
Freezing temperature for 33.02psu = -1.809degC
Freezing temperature for 33.04psu = -1.810degC
So these salinity changes are not going to rise above the noise in our estimates of Tfreezing

Other Recovered/Deployed Instrumentation: Other instruments on the moorings were recovered/deployed for other groups. These instruments are:

Recoveries: An ***Aural Marine Mammal Acoustic*** sensor on A3 was deployed by Kate Stafford, (UW). This instrument was cleaned and data storage returned to Seattle for analysis.

Deployment: ***Marine Mammal Acoustic*** only 1 sensor (placed on A3) was deployed this year. This instrument is deployed for Kate Stafford, UW.

Details of mooring positions and instrumentation are given below, along with schematics of the moorings, photos of the mooring fouling, and preliminary plots of the data as available.

BERING STRAIT 2022 MOORING POSITIONS AND INSTRUMENTATION

ID	LATITUDE (N) (WGS-84)	LONGITUDE (W) (WGS-84)	WATER DEPTH /m (corrected)	INST.
2021 Mooring Deployments				
A2-21	65 46.849	168 34.089	55 (with3mdraft)	ISCAT, ADCP, SBE16
A2-21 RECOVERY	A2-21 was no recovered on this cruise. Investigation and dragging at this site failed to find any proof it was still at this position			
A4-21	65 44.737	168 15.767	49 (with 3mdraft)	ISCAT, ADCP, SBE16
A3-21	66 19.636	168 56.993	58 (with3mdraft)	MISCAT, ADCP with SBE16, new MMR
A3-21 RECCOVERY	A3-21 was recovered ~ 1nm SE of this position. Best estimate of recovered position is 66 18.78N, 168 55.74W. Data suggest dragged by ice between 0903 and 1433 on 25th Jan 2022			

ID	LATITUDE (N) (WGS-84)	LONGITUDE (W) (WGS-84)	WATER DEPTH /m (corrected)	INST.
2022 Mooring Deployments				
A2-22	65 46.850	168 34.103	56	ISCAT, ADCP, SBE37ODO, FLNTUSB, SUNA SBE16
A4-22	65 44.743	168 15.781	49	ISCAT, ADCP, SBE16, FLNTUSB
A3-22	66 19.628	168 56.930	58	MISCAT, ADCP with SBE16, SBE37ODO, FLNTUSB, SUNA new MMR

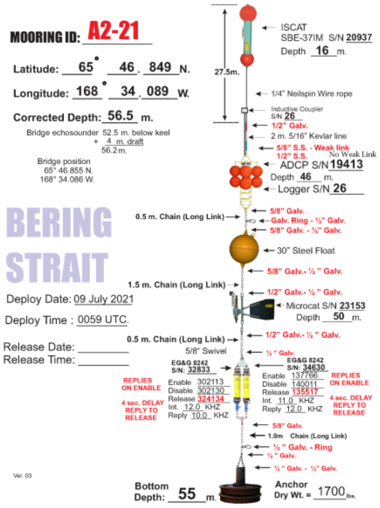
ADCP = RDI Acoustic Doppler Current Profiler
ISCAT = near-surface Seabird TS sensor in trawl resistant housing, with near-bottom data logger
MISCAT = ISCAT with two near-surface sensors (one at ~ 8m, one at ~ 16m)
SBE16 = Seabird CTD recorder, SBE37 = Seabird CTD recorder
MMR=Marine Mammal Recorder (new=new APL version)
SBE37ODO = Seabird CTD and dissolved oxygen recorder
FLNTUSB = Wetlabs fluorescence and turbidity recorder
SUNA = Seabird optical SUNA nitrate sensor

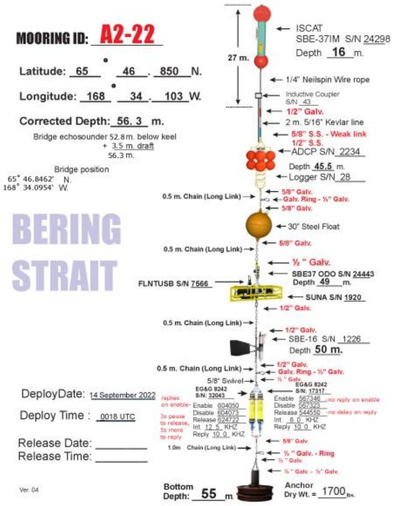
For 2021 deployments, water depths are assuming a ship's draft of 4m.
For 2022 deployments, water depths are assuming a ship's draft of 3.5m.

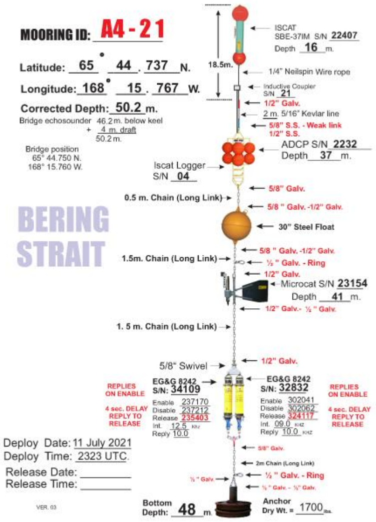
BERING STRAIT 2022 SCHEMATICS OF MOORING RECOVERIES AND DEPLOYMENTS

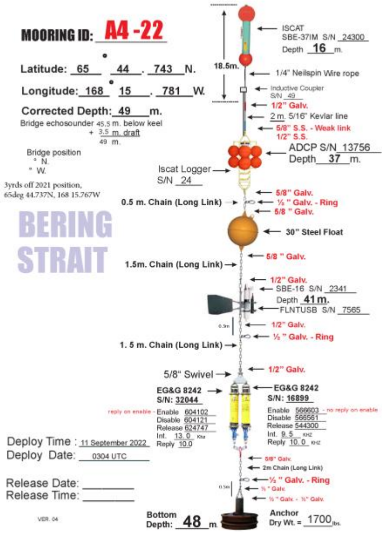
RECOVERED **STILL TO BE RECOVERED** **DEPLOYED**

= in the eastern channel of the Bering Strait

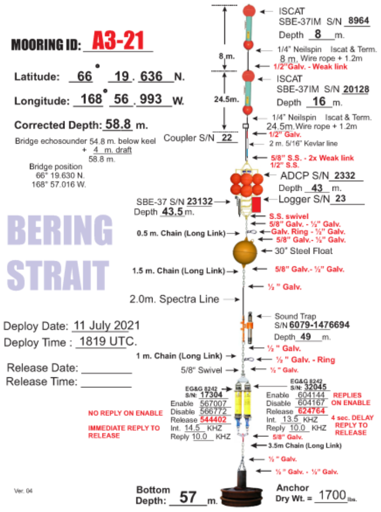

MOORING ID: A2-21
Latitude: 65° 46.849 N.
Longitude: 168° 34.089 W.
Corrected Depth: 56.5 m.
Bridge echosounder 52.5 m. below keel + 4 m. draft 56.2 m.
Bridge position 65° 46.855 N. 168° 34.086 W.
Deploy Date: 09 July 2021
Deploy Time : 0059 UTC.
Release Date: ________
Release Time: ________

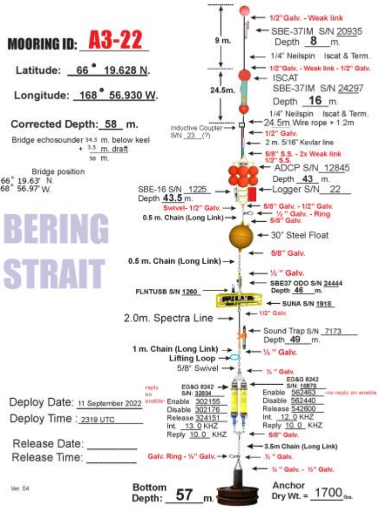

MOORING ID: A2-22
Latitude: 65° 46. 850 N.
Longitude: 168° 34. 103 W.
Corrected Depth: 56. 3 m.
Bridge echosounder 52.8 m. below keel + 3.5 m. draft 56.3 m.
Bridge position 65° 46.8462' N. 168° 34.0954' W.
DeployDate: 14 September 2022
Deploy Time : 0018 UTC
Release Date: ________
Release Time: ________


MOORING ID: A4 - 21
Latitude: 65° 44. 737 N.
Longitude: 168° 15. 767 W.
Corrected Depth: 50.2 m.
Bridge echosounder 46.2 m. below keel + 4 m. draft 50.2 m.
Bridge position 65° 44.750 N. 168° 15.760 W.
Deploy Date: 11 July 2021
Deploy Time: 2323 UTC.
Release Date: ________
Release Time: ________


MOORING ID: A4 -22
Latitude: 65° 44. 743 N.
Longitude: 168° 15. 781 W.
Corrected Depth: 49 m.
Bridge echosounder 45.5 m. below keel + 3.5 m. draft 49 m.
Bridge position ° N. ° W.
3yrds off 2021 position, 65deg 44.737N, 168 15.767W
Deploy Time : 11 September 2022
Deploy Date: 0304 UTC
Release Date: ________
Release Time: ________

= at the climate site, ~ 60km north of the Strait


MOORING ID: A3-21
Latitude: 66° 19. 636 N.
Longitude: 168° 56. 993 W.
Corrected Depth: 58.8 m.
Bridge echosounder 54.8 m. below keel + 4 m. draft 58.8 m.
Bridge position 66° 19.630 N. 168° 57.016 W.
Deploy Date: 11 July 2021
Deploy Time : 1819 UTC.
Release Date: ________
Release Time: ________


MOORING ID: A3-22
Latitude: 66° 19.628 N.
Longitude: 168° 56.930 W.
Corrected Depth: 58 m.
Bridge echosounder 54.5 m. below keel + 3.5 m. draft 58 m.
Bridge position 66° 19.63' N. 168° 56.97' W.
Deploy Date: 11 September 2022
Deploy Time : 2319 UTC
Release Date: ________
Release Time: ________

BERING STRAIT 2022 RECOVERY PHOTOS

A4-21 Recovery

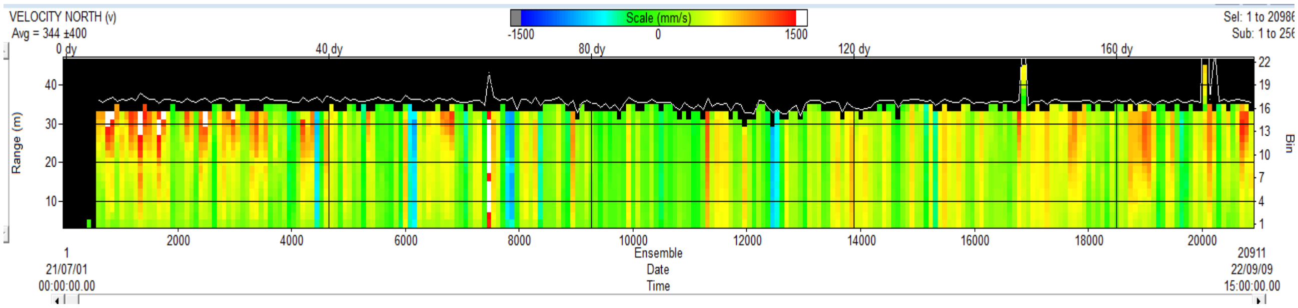
A3-21 Recovery

NORTHWARD VELOCITY from Bering Strait 2021-2022 ADCPs

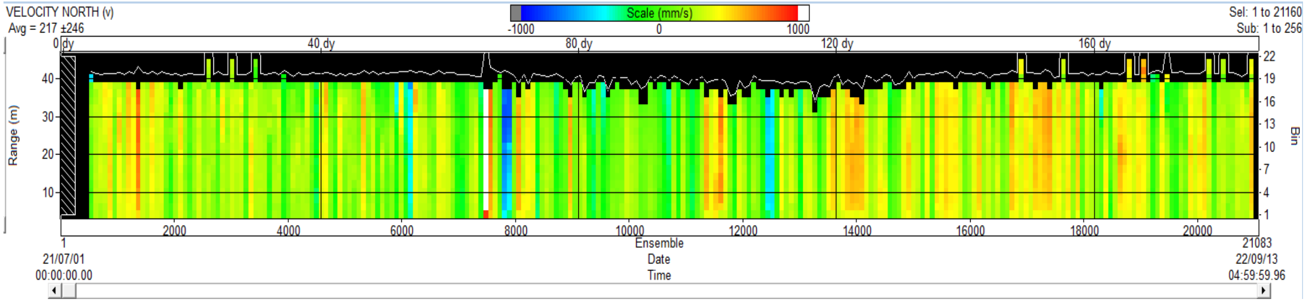
A2-21-19413

Not recovered on this cruise

A4-21-2232

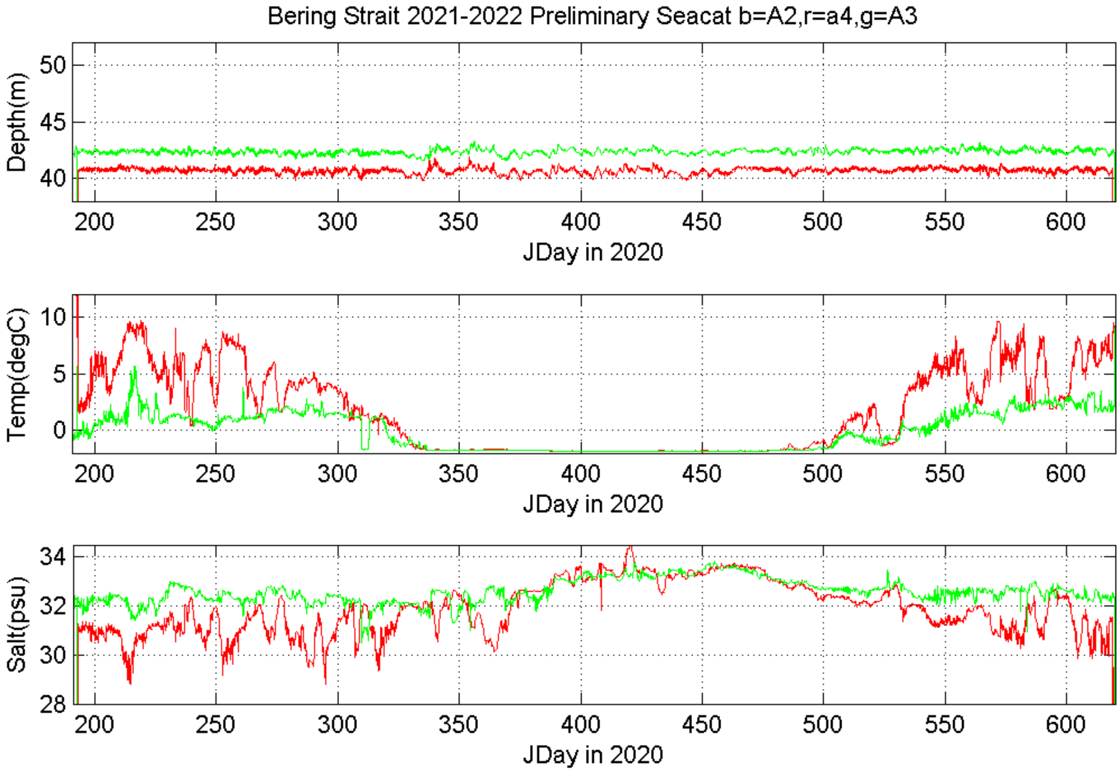


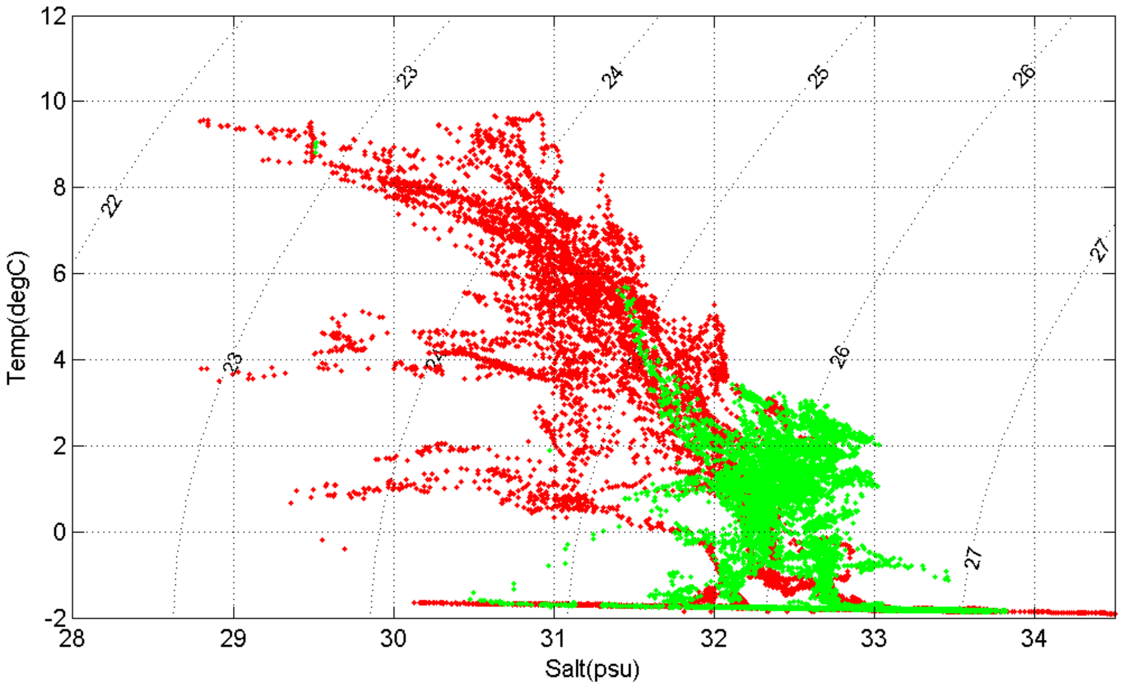
A3-21 2332 (Note different scale)



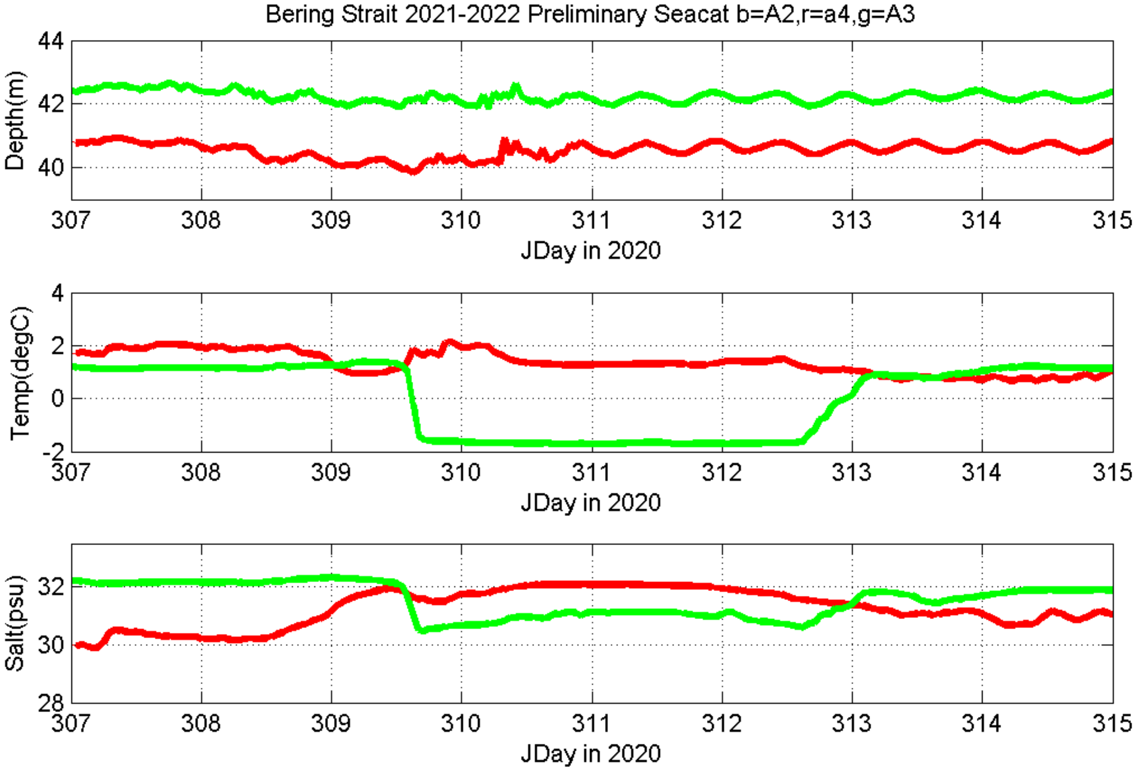
BERING STRAIT 2021-2022 SBE PRELIMINARY RESULTS (Ax21 data)

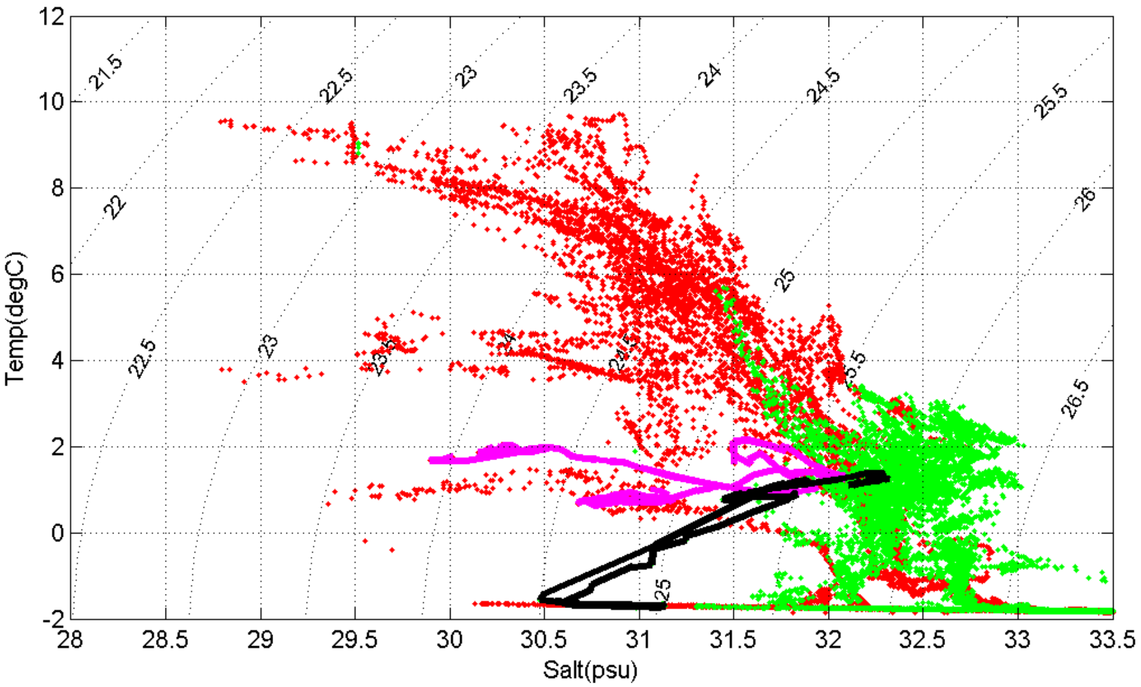
– all lower level TS Sensors (note A2 missing)





Note the curious cold event around day 310 to 313 (5th to 8th Nov)



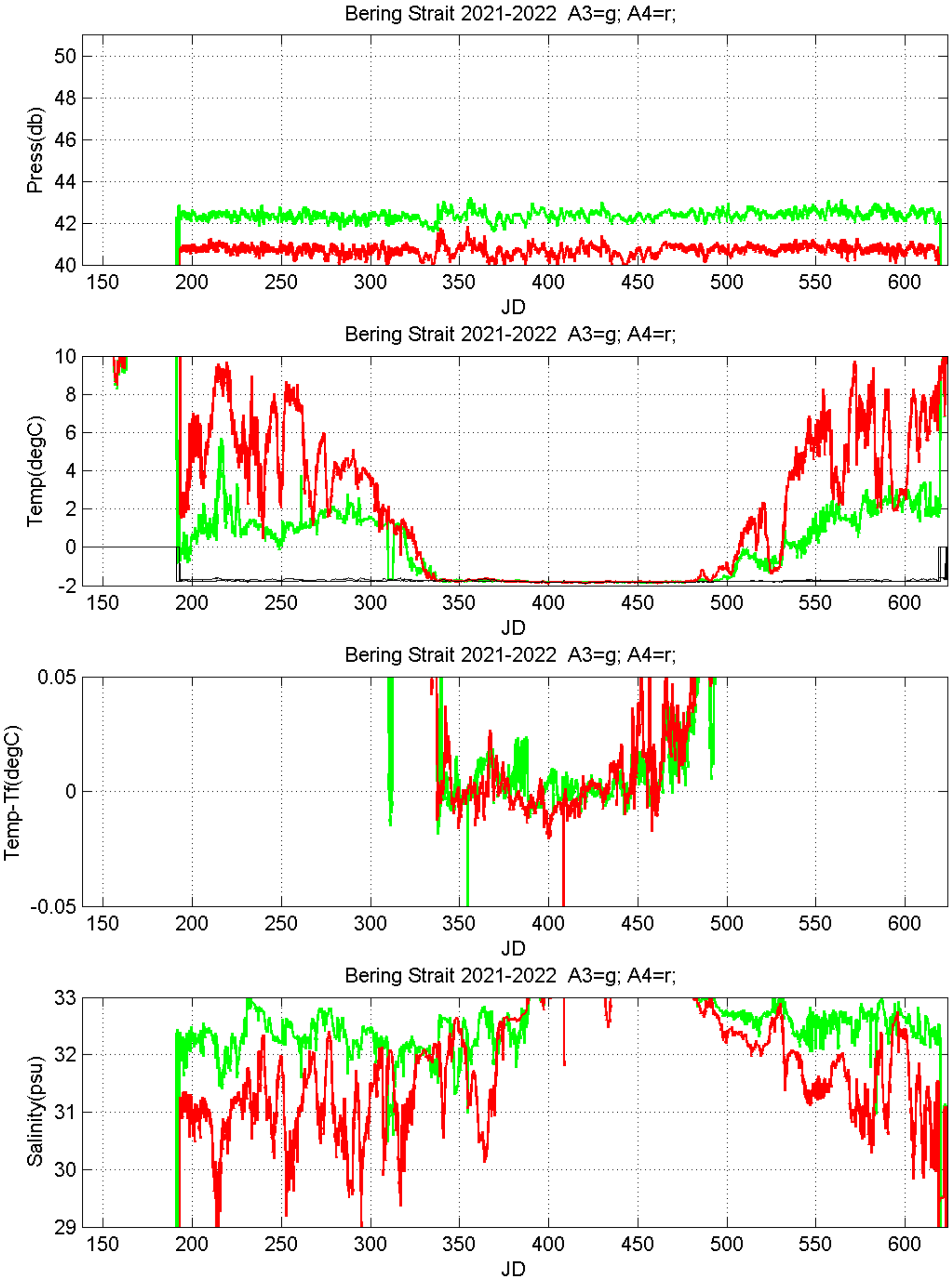


BERING STRAIT 2021-2022 SBE PRELIMINARY RESULTS (Ax21data)

– all lower level TS Sensors

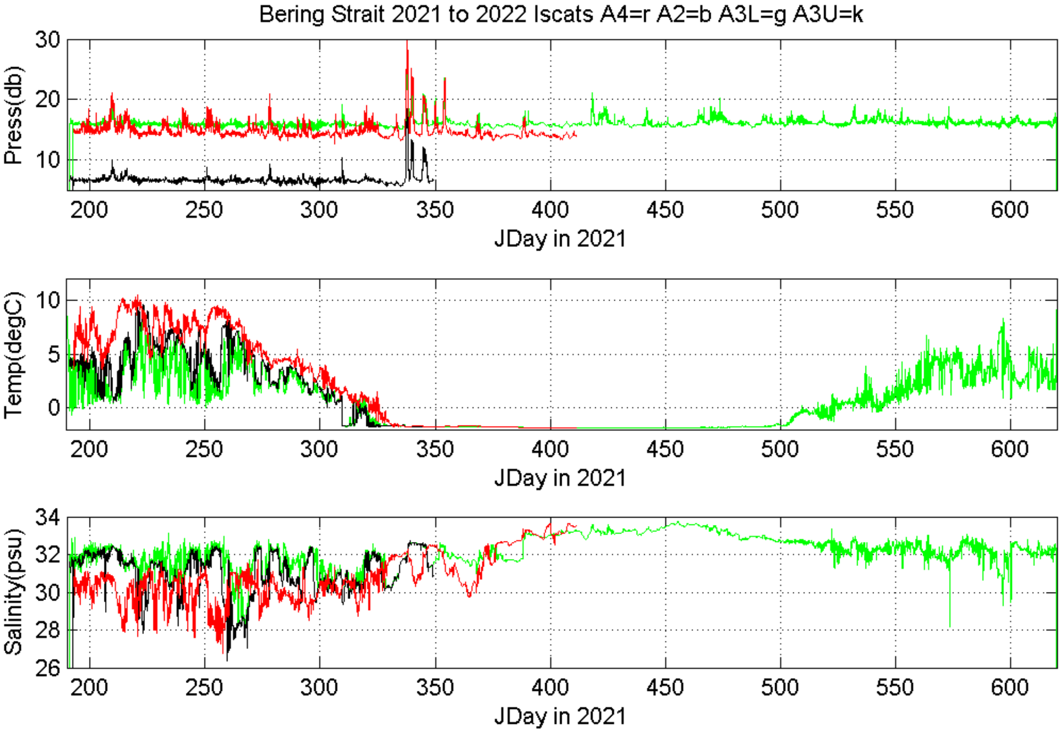
Comparison to freezing temperature

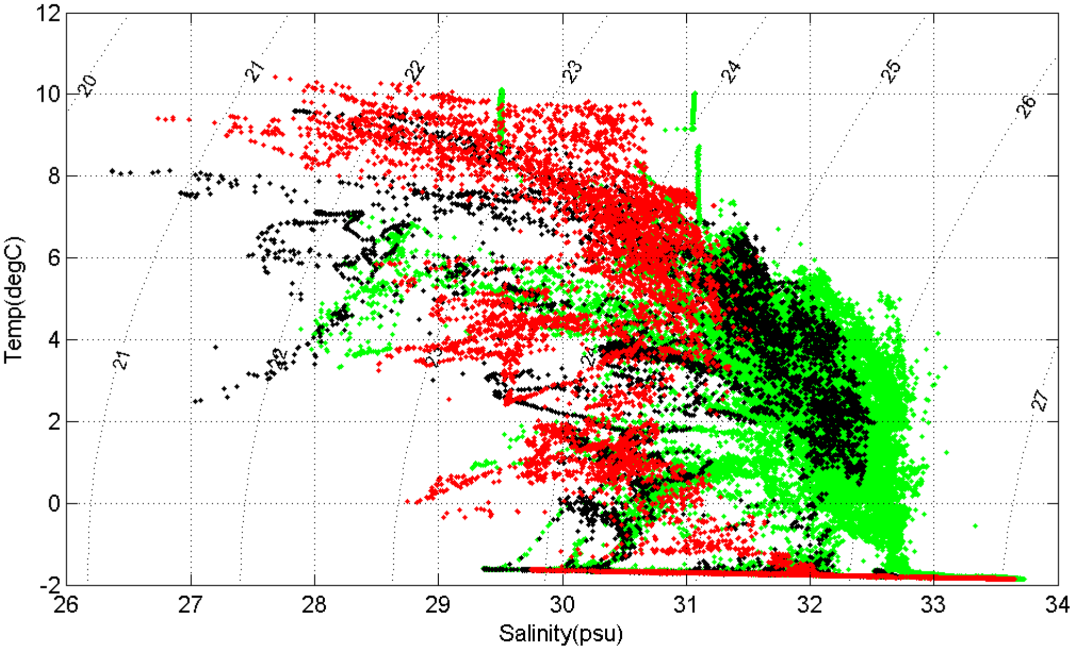
T-Tfreezing being near zero suggests winter salinities are not significantly biofouled



BERING STRAIT 2021-2022 ISCAT PRELIMINARY RESULTS

– all upper level TS Sensors





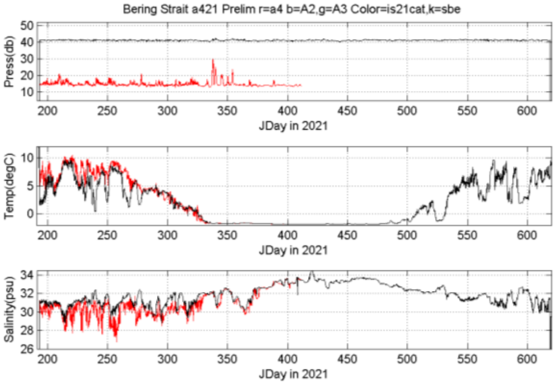
(includes testtank data)

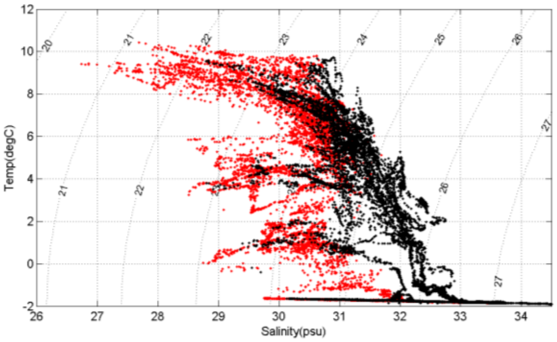
BERING STRAIT 2021-2022 ISCAT and SBE PRELIMINARY RESULTS (Ax21data)

–upper and lower TS sensors by mooring

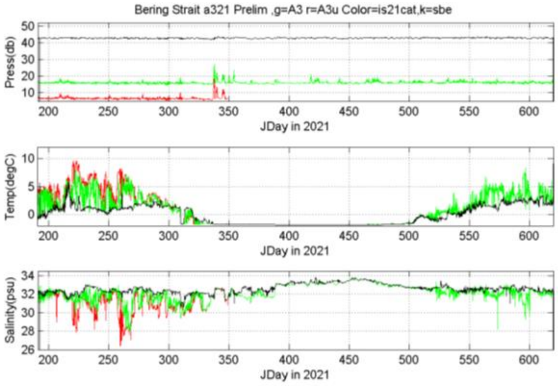
A2-21

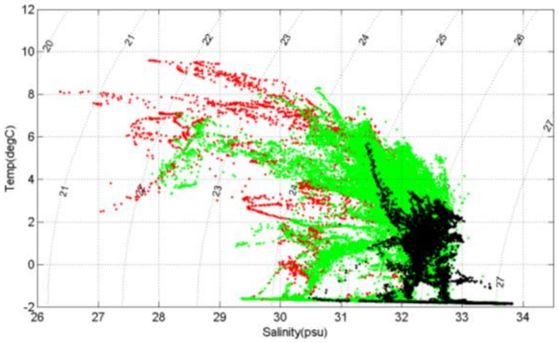
A4-21





A3-21





CTD OPERATIONS (Whole Science Team,)

As in previous years, in 2022 the moorings were supported by annual CTD sections. This year, these sections were run with a CTD rosette system to allow bottle samples to be taken. This is in addition to the separate pumped system was used to take trace metal and nutrient samples.

The CTD rosette system used on this cruise was loaned from APL-UW and, used the same instrumentation as in previous years, other than the altimeter was replaced with a SUNA nitrate sensor with external battery pack (which required the space of one of the bottles of the rosette). The transponder broke its mounts during the cruise and was removed from the rosette. **Action item: Fix transponder mounts. Find better mounting for SUNA and battery pack**. Serial numbers and calibration dates are given here. Note the system was sent for calibration after the cruise. **Action item: Update with new calibrations once received**. The full package consisted of:

one SBE9+ with pressure sensor
(SN26451 – calibration 17th June 2019)
two SBE3 temperature sensors
(T1 = SN0843 – calibration 28th Jan 2021)
(T2 = SN0844 – calibration 28th Jan 2021)
two SBE4 conductivity sensors
(S1 = SN0484 – calibration 11th Feb 2021)
(S2 = SN0485 – calibration 2nd Feb 2021)
two SBE43 oxygen sensors
(Ox1 = SN1753 – calibration 4th Feb 2021)
(Ox2 = SN1754 – calibration 4th Feb 2021)
one Wetlabs FLNTURT fluorescence/turbidity sensor (SN1622 – calibration 11th March 2010)
on SUNA nitrate sensor (SN1916 -new summer 2022, reference update pre cruise)
two Seabird pumps (believed to be SN50340, SN55236, but not confirmed)
one EG&G transponder (D-CAT SN31892, Interrogate: 11.0kHz, Reply: 13.5kHz)

The temperature, conductivity and oxygen probes were paired as last year, viz:

	Temperature	**Conductivity**	**Oxygen**	**Pump**
Primary	#843	#484	#1753	SN NA
Secondary	#844	#485	#1754	SN NA

With the rosette system, the sensors are mounted horizontally below the rosette. Care must be taken that they are installed the correct way around as the rosette frame is not symmetric, and only in one orientation are the sensors protected by the cage. **Action item Check mounting before shipping from Seattle**.

The CTD was connected to a conducting wire winch on the ship. This winch (Rapp Hydema NW, SOW 160 5000m capacity, with 3 conductor 0.322"diameter wire), was new on the Norseman II in 2014. Chris Siani, APL, assisted with wiring and CTD tests of this system while the ship was in Seattle in April 2014. In 2022, we found the termination had been changed by the prior cruise. We reterminated, but the test cast failed however, and eventually this was traced to a leak in the termination. A second retermination was successful. **Action item: Bring several termination kits.**

The winch was connected to an SBE11 deckbox, which in turn was linked via serial ports and USB-serial connectors to a dedicated PC, running the software package Seasave v7. Data were recorded in standard hexadecimal SBE format, incorporating NMEA GPS input from the Norseman II forward GPS (since the aft-Aframe GPS was giving the wrong date). **Action item: Check the ship is carrying a spare GPS antenna.**

An event log (copied attached at the end of this report) was maintained on the CTD computer, including comments on data quality and other issues. The log, the data files, and a screen dump of the end-of-cast Seasave image were copied to a thumb drive as a backup after each cast, and regularly (every few casts) transferred ashore via google drive for analysis.

The CTD console was set on the port side of the interior lab. The package was deployed through the aft A-frame using a special block supplied by the ship. Although a Pentagon ULT unit had been mounted inside by the CTD console for lowering and raising the CTD, in practice, the winch driving was done by a crew member on deck, directed by the CTD operator using radio commands. This was deemed more efficient given the shortness of the casts (50m or less).

As in previous years, in 2021 the crew operated the winch from a remote console on the deck by the A-frame. The lowering (and raising) rate we seek is ~30 or 40m/min. There is no readout of winch speed at the remote console and winch drivers had to estimate speed either from the sound of the winch or from feedback from the scientist in the lab. **Action item: Be sure to calibrate in winch speed early in the cruise, preferably with some scale on the winch so the speed is consistent between operators. Update ship's winch so as to provide a speed readout by the remote console. Also, train CTD driver to check winch speed on read-out beside CTD console both for lowering and raising.**

For the casts done during mooring operations, the CTD was hand-carried forward after each cast to the port-forward corner of the aft-deck, to clear the aft-deck for mooring work. Once all the mooring work was complete, the CTD package was kept on the aft deck.

Once mooring work was complete, CTD operations were run 24hrs, using a team (per watch) of 1 science team member driving the CTD, and 4 personnel (2 ship, 2 science) on deck - one (ship's crew) driving the winch, one ship's crew on starboard tag line, one scientist on port tagline and one scientist catching the rosette from the middle of the deck . Since the aft doors were open so as to not lift the CTD too high, all personnel on deck wore harnesses and were attached to the "dog runs" overhead wires. **Action item: Consider if mid deck person is required in good weather, and if rosette could be lifted over the rail rather than work with aft doors open**.

The efficiency of the crew made for very speedy CTD operations, and combined with the fast winch speed, resulted in commendably fast times for running line, though significantly slower than using the non-rosette system. If pumped samples were to be taken, this operation followed on immediately after the CTD cast without the ship repositioning. **Action item: Make sure the CTD is recovered and out of the water before the pump system is deployed, otherwise ship's manoeuvrability is compromised**.

Prior to each cast the turbidity sensor was cleaned by rinsing with soapy water and freshwater and wiping. **Action item: Bring syringe with better fit for flushing the CTD cell.**

Ship's draft was estimated at 2m, and this should be taken into account in viewing the data. Also given that sea states were often significant and the altimeter on the CTD (which usually rarely functioned) was not used this year, some casts stop 5m-6m above the bottom.

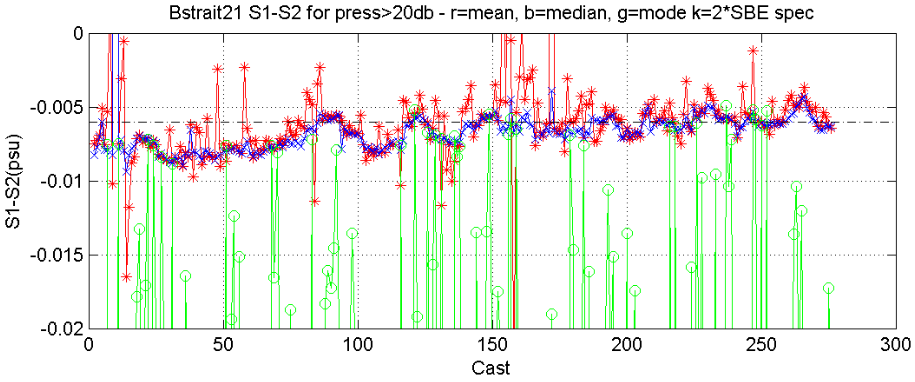
A new addition this year was the SUNA nitrate sensor. As this requires significant current on start up, it was powered by an external, rechargeable battery, as per a design from Seth Danielson. When the CTD powers on, this activates a relay in the external battery which turns on power to the SUNA. Two battery packs were constructed so one could be charging while one was in use. **Action item: Add charging information here**. The SUNA returned a voltage to SeaSave, which gives a rough estimate of nitrate. Proper calibration of this data stream is still required. **Action item: Process SUNA data once CTD data final.**

Overall, CTD data this year are exceedingly clean, although the following issues were encountered:

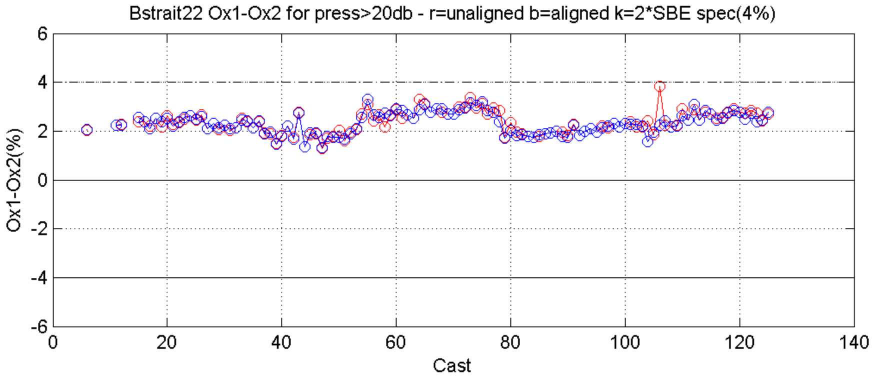
1) SUNA issue. For casts 57 to 66 inclusive, SUNA data sent to SeaSave are poor, as the voltage returned to SeaSave appeared to fall to zero. Checking the system found no errors, other than perhaps slight dampness in the plug. The SUNA was appeared still to be recording internally correctly, so CTD operations were continued and from cast 67 onwards, the SUNA data stream to Seasave recovered. **Action item: Investigate**

2) Offset between Salinity sensors. Prior years found an offset in salinity between the two sensors on the CTD. This year, a much larger offset was found (with S1 reading fresher as in prior years). This indicates the system is overdue for recalibration.

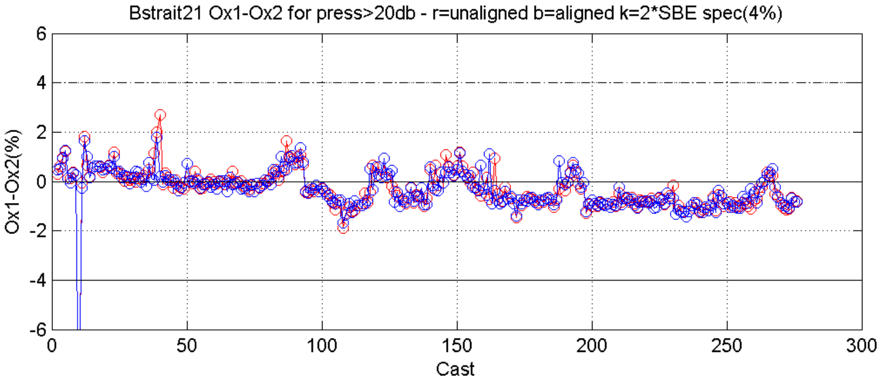
last year for comparison



3) Offset between Oxygen sensors. Once aligned in post processing, differences between oxygen sensors were within manufacturer's specifications, although greater than last year, suggesting calibration is also due.



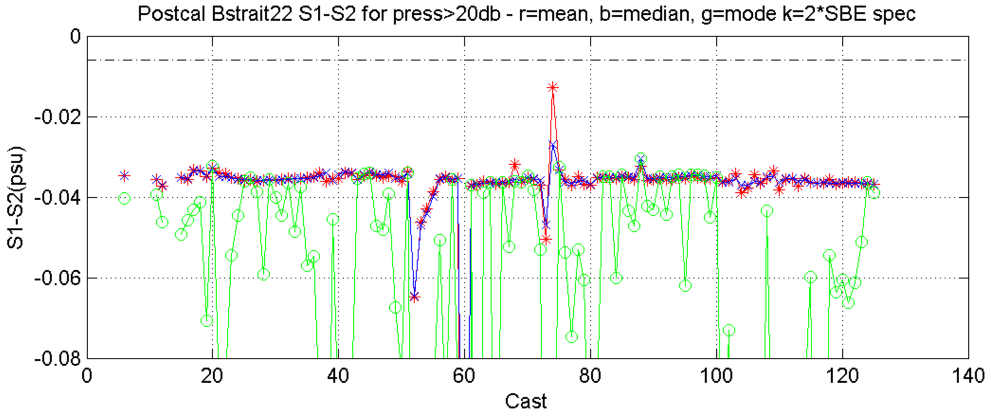
last year for comparison



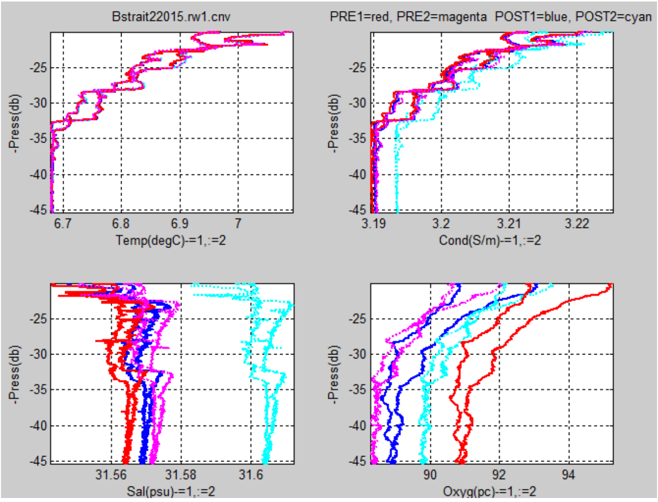
6) Other cast issues:
To be added once post cruise calibrations have been performed.

==== April 2023 Update

Post cruise calibrations were performed by the manufacturer after the cruise. Using these resulted in a salinity difference between sensors of ~0.035psu.

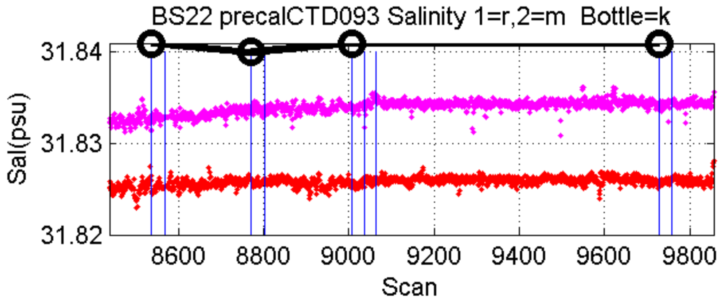

Postcal Bstrait22 S1-S2 for press>20db - r=mean, b=median, g=mode k=2*SBE spec

Even in the converted data before further processing, it was clear that the postcal on the secondary channel was producing unrealistic salinities. Here a typical cast, precals as red (system1) and magenta (system 2), postcals as blue (system1) and cyan(system2).


Bstrait22015.rw1.cnv
PRE1=red, PRE2=magenta POST1=blue, POST2=cyan

Salinity samples taken to check bottle firing allow us to confirm this.

E.g., Cast 93 comparison of bottle salinities suggest:
Precal system1 (r) ~ 0.015psu fresh
Precal system2 (m) ~0.05psu fresh.


BS22 precalCTD093 Salinity 1=r,2=m Bottle=k

The postcal for salinity 1 gives closer agreement with the bottle samples, and thus the postcal will be used for the final data for salinity 1..
However the postcal for salinity 2 takes it further from the bottle samples, and thus the precal will be used for salinity 2 final data.

Note that postcal oxygens agree better than precals. Thus postcals will be used for final oxygen data.

NOTES ON BERING STRAIT 2022 CTD PROCESSING Rebecca Woodgate (based on 2019processing)
**Feb2024 Notes updating for SUNA processing.

Cals to be used for final data:

one SBE9+ with pressure sensor
(SN26451 – calibration 17th June 2019) (PRE CAL)
two SBE3 temperature sensors
(T1 = SN0843 – calibration 2nd Dec 2022) (POST CAL)
(T2 = SN0844 – calibration 28th Jan 2021) (PRE CAL)
two SBE4 conductivity sensors
(S1 = SN0484 – calibration 6th Dec 2022) (POST CAL)
(S2 = SN0485 – calibration 2nd Feb 2021) (PRE CAL)
two SBE43 oxygen sensors
(Ox1 = SN1753 – calibration 15th Nov 2022) (POST CAL)
(Ox2 = SN1754 – calibration 11th Nov 2022) (POST CAL)
one Wetlabs FLNTURT fluorescence/turbidity sensor (SN1622 – calibration 11th March 2010)
on SUNA nitrate sensor (SN1916 -new summer 2022, reference update pre cruise,
but in this file only approximate numbers as linear rather than full calibration)

**Feb2024 - although hex files are still this raw data, final processed CTD files now contain corrected SUNA data as per notes below.

Summary Notes by cast:

Casts 0-4, and 7-8 were runs on deck only.
Cast 5-6, and 9-14 were to test bottle firing
First science cast of the cruise was cast 15.
Last cast of the cruise was cast 125.
Casts 26, 37 and 55 – have times of corrected SUNA data drop out. In full resolution data, these are marked with a dummy value of -99. Unfortunately this value is not recognized by the Seasave bin averaging program as a and thus bin averages of these bins are erroneous. However, for these files, the resultant values are all negative and thus can easily be identified..
Cast 60 - Salinity and oxygen bad on upcast - bottle data will be off, but up and down casts seem similar In temp, so use that.
Cast 65 - Oxygen system 1 data bad on up cast, System 2 ok

Notes on SUNA data in the original SeaSave files:

Suna data in the raw CTD files are based on a very simple linear calibration and must be considered as only approximate. SUNA data will be post processed and higher quality data will be archived separately.
Known SUNA issues

- **Cast 57 - Suna down and upcasts very different,**
- **Cast 58,59 - some SUNA zeros**
- **Cast 60-65 - just zero**
- **Cast 66 = partly back**
- **Cast 67 onwards - ok**

**** Feb 2024 note – these SUNA 'zero' issues (which result in a SUNA reading of -7.5, due to the calibration values) are only an issue of the data flow to the SBE9-11 system – the SUNA data recovered internally on the SUNA are not zero. The corrected values have been placed in the finally processed CTD files.**

Details of processing steps

Overview:

Start with files from SeaSave for each cast, i.e.,
Bstrait22nnnn.hex and Bstrait22nnnn.hdr

Then run through 9 steps (8 of them with SBEDataProcessing program from Seabird).

001_DatCnvBStrait2022_allvarswithSUNA
Start matlab tests
002_DatCnvBStrait2022_CTDforprocesswithSUNA_FINAL
003_FilterBStrait2022_CTDforprocesswithSUNA_FINAL
Copy files to testoxalign

In main

004_AlignCTDBStrait2022_CTDforprocessOx2withSUNA_FINAL
005_CellTMBStrait2022_CTDforprocess_FINAL
006_LoopEditBStrait2022_CTDforprocess7m4m18p5mndp_FINAL
Check soak with matlab
007_DeriveCTDBStrait2022_CTDprocess_FINAL

In testoxalign

004_AlignCTDBStrait2022_CTDforprocessOx3withSUNA_FINAL
(change advance in data set up and file name)
004_AlignCTDBStrait2022_CTDforprocessOx4withSUNA_FINAL
004_AlignCTDBStrait2022_CTDforprocessOx5withSUNA_FINAL
005_CellTMBStrait2022_CTDforprocess_FINAL
006_LoopEditBStrait2022_CTDforprocess7m4m18p5mndp_FINAL
007_DeriveCTDBStrait2022_CTDprocess_FINAL
Run matlab tests to decide on ox aligns.

In main, once ox aligns set, complete with

008_W_FilterCTDBStrait2022_CTDforprocess_MF17_FINAL
009_BinAvgBStrait2022_CTDforprocess_FINAL
009_BinAvgUBStrait2022_CTDforprocess_FINAL
Run matlab tests to check data

This completes the CTD data processing, pre SUNA correction.

Once SUNA data are available (which requires the corrected CTD data processed above), run the SUNA postprocessing (matlab) which takes the output from W-Filter and corrects the SUNA data from the raw recorded in Seasave, to the UCI corrected version.

Rerun the bin averages.

009_BinAvgBStrait2022_CTDforprocess_FINALwithCorSUNA

Finally, extract bottle data information and merge with bottle data (in matlab)

<u>Full details of 2022 processing</u>

=== 1) First make up a file to be used for quick plotting. This contains all variables, but is not corrected in any way.

IN SBEDATA PROCESSING, RUN: DATA CONVERSION
(PSA file for this = 001_DatCnvBStrait2022_allvars.psa)
Inputs are: BStrait22nnnn.hex and BStrait22nnnn.hdr

*In FILE SETUP
-- CHECK box on match instrument to configuration file
-- Choose input file (should be .HEX) and directory
-- Name append .rw1
-- Choose output directory
*In DATA SETUP
-- Convert data from:UP and downcast *(Last year we just did down as we were firing no bottles. Here we do both, noting that upcasts may differ because of water being swept up with the CTD.)*
-- Create file types: data (.CNV) only *** NOW Cast and bottle data ... *** USING .BL File
...—Merge Header file
-- Select output variables... for 2019 we use
-- 1) Pressure, Digiquartz (db)
-- 2) Temperature (ITS-90, degC)
-- 3) Temperature,2 (ITS-90, degC)
-- 4) Conductivity (S/m)
-- 5) Conductivity, 2 (S/m)
-- 6) Oxygen raw, SBE 43 (Volts)
-- 7) Oxygen, SBE 43 (saturation)
-- 8) Oxygen raw, SBE 43, 2(Volts)
-- 9) Oxygen, SBE 43, 2(saturation)
-- 10) Fluorescence WET Labs WET star (mg/m^3)
-- 11) Upoly 0, FLNTURT
12) Scan Count % This was done in 2018, but not recorded in the write up
-- 13) Salinity, Practical (PSU)
-- 14) Salinity, Practical, 2 (PSU)
-- 15) Time, NMEA (seconds)
-- 16) Latitude (deg)
-- 17) Longitude (deg)
-- 18) Altimeter (m) *** NOW USER POLY 2 FOR APPROXIMATE SUNA DATA
-- 19) Pump Status
-- Source for start time in output .cnv header: Select NMEA time
*In MISCELLANEOUS
-- Keep all defaults. Note the Oxygen is Window size (2s), Apply Tau Correction, Apply Hysteresis.

But now we want
A) to replace Alt with SUNA ...in col 18
b) to do bottle file also. ... so ---- do bottle and data
--- source is bl file

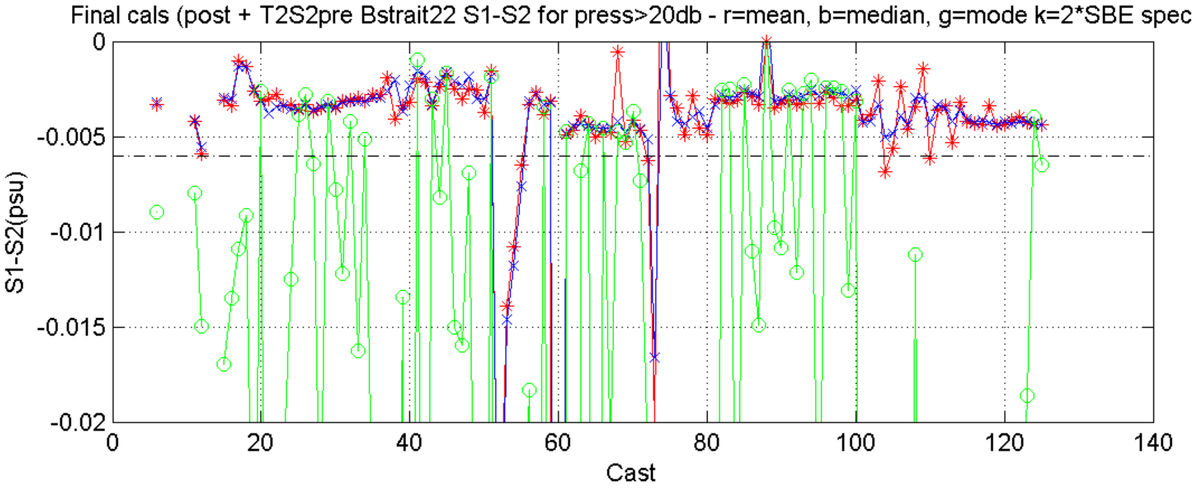
THIS GIVES files called: BStrait22nnn.rw1.cnv

=== 2) Do first basic quality control by plotting everything in Matlab
Matlab master code = **testplotsBStrait2018RW.m** which calls subroutine **CTDQCpump.m**
Inputs are: BStrait18nnn.rw1.cnv

Checks here include:
--- that the pump comes on
--- that the altimeter is working
--- that T1=T2, S1=S2 and Ox1=Ox2
--- preliminary identification of spikes and other issues.

.. mostly ok

- **SUNA**
  - **- Cast 57 - Suna down and upcasts very different,**
  - **- Cast 58,59 - some SUNA zeros**
  - **- Cast 60-65 - just zero**
  - **- Cast 66 = partly back**
  - **And then ok**
- **Cast 60 - Salinity bad on upcast - bottle data will be off**
- **Cast 65 - system 1 data bad**



Now sensors agree to within specs.

=== 3) Now work through the 7 steps (002-009)of SBEDataConversion. Start by applying the calibrations to get the converted files, but this time excluding all the derived variables.
IN SBEDATA PROCESSING, RUN: DATA CONVERSION
(PSA file for this = DatCnvBStrait2022_CTDforprocess.psa)
Inputs are: BStrait22nnnn.hex and BStrait22nnnn.hdr

*In FILE SETUP
-- CHECK box on match instrument to configuration file ** Do not check box, as using postcal/precal file
-- Choose input file (should be .HEX) and directory
-- Name append NONE
-- Choose output directory
*In DATA SETUP
-- Convert data from:UP and downcast *(Last year as here, we do both, noting that upcasts may differ because of water being swept up with the CTD.)* **** ADD WiTH BOTTLES AND ** ADD .BT FILE*
-- Create file types: data (.CNV) only
...—Merge Header file
-- Select output variables... for 2018 we use
-- 1) Pressure, Digiquartz (db)

-- 2) Temperature (ITS-90, degC)
-- 3) Temperature,2 (ITS-90, degC)
-- 4) Conductivity (S/m)
-- 5) Conductivity, 2 (S/m)
-- 6) Oxygen raw, SBE 43 (Volts)
-- 7) Oxygen raw, SBE 43, 2(Volts)
-- 8) Fluorescence WET Labs WET star (mg/m^3)
-- 9) Upoly 0, FLNTURT
-- 10) Scan Count
-- 11) Time, NMEA (seconds)
-- 12) Latitude (deg)
-- 13) Longitude (deg)
-- 14) Altimeter (m) ** REPLACE WITH SUNA (UPoly2)
-- 15) Pump Status
** 16) BOTTLES FIRED
-- Source for start time in output .cnv header: Select NMEA time
*In MISCELLANEOUS
-- Keep all defaults. Note the Oxygen is Window size (2s), Apply Tau Correction, Apply Hysteresis.

THIS GIVES files called: BStrait22nnnn.cnv and BStrait22nnn..ros

=== 4) Second step of SBEDataProcessing. Apply a time filtering to the data.

This step allows us to time-filter (i.e., smooth) the data. Routine allows us to select two filters, A and B. In 2014, we used A = 0.5 sec and B=0.15 sec, but in 2015 this appeared to remove too much variability.
Manual for the SBE9plus suggests to not filter Temperature and Conductivity, but to filter pressure at 0.15s. So set A=0, and B=0.15 and then only filter pressure *(this is now the same as 2015, but different to 2014).*
Note these filters should be applied to the raw data (e.g., Ox voltage, Conductivities), not the derived data (e.g., salinity, oxygen saturation, etc).

IN SBEDATA PROCESSING, RUN: FILTER
(PSA file for this = FilterBStrait2022_CTDforprocess.psa)
**** Could filter SUNA here, but decide not to, as SUNA data will be processed properly separately**
Note that bottle data will be reextracted later.

Inputs are: BStrait22nnnn.cnv
*In DATA SETUP
-- Lowpass filter A(sec): 0.0 *(was 0.5 in 2014, but this seemed too smooth in 2015, so used 0, as here)*
-- Lowpass filter B(sec): 0.15 *(This is as per the manual for SBE9plus)*
--> SPECIFY FILTERS
-- Pressure: Lowpass filter B
-- Temperature: None
-- Temperature, 2: None
-- Conductivity: None
-- Conductivity,2: None
-- Oxygen raw: None
-- Oxygen raw,2: None
-- All others: None ... including SUNA
*In FILE SETUP
-- Name append = A00B15 *... this indicates data was filtered (Note: makes only small changes to the data)*

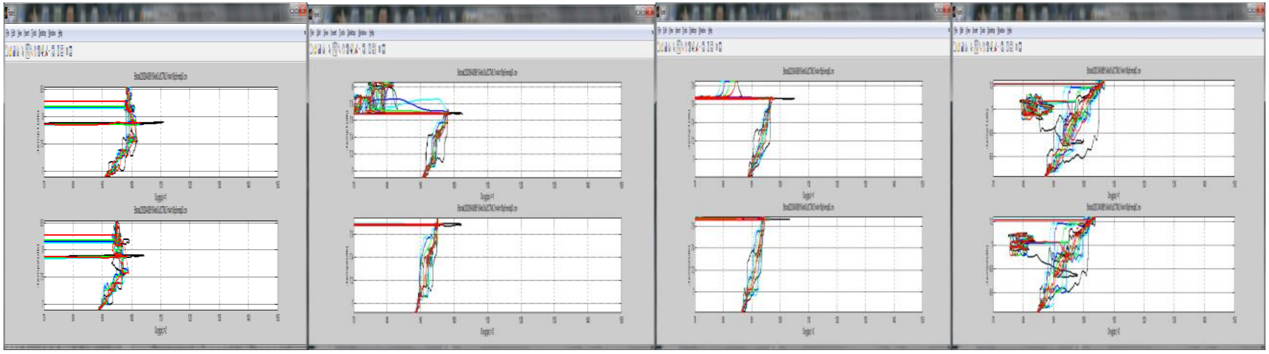
THIS GIVES files called: BStrait22nnnnA00B15.cnv

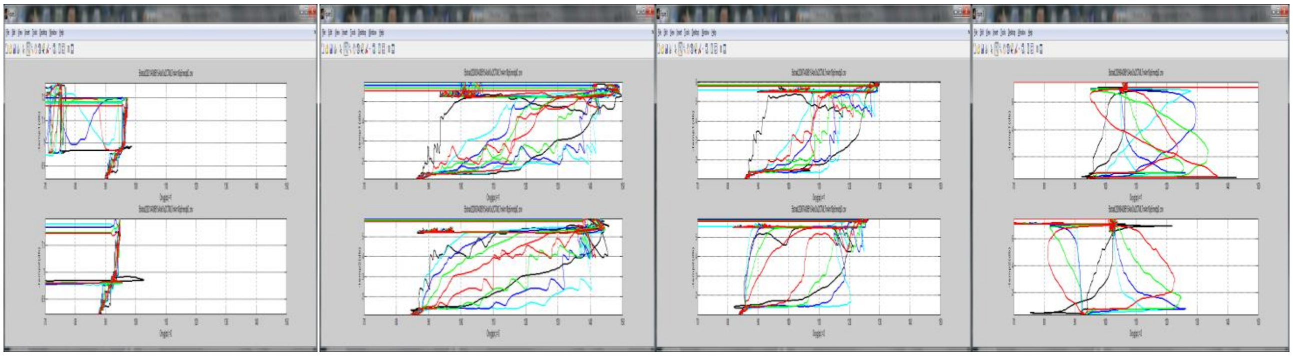
=== 5) Third step of SBEDataProcessing. Align the timeseries in time.

This step is to compensate for the delay between the water passing the various sensors in the pumped pathway. For the SBE9plus, the manuals suggest that
- the temperature advance relative to pressure =0
- that the salinity advance relative to pressure is 0.073s, but this advance is set in the SBE11plus by factory settings, and thus for this program we use conductivity advance =0. ***Action item: Check this is what is set in the SBE11 plus.***
- that the oxygen advance should be between +2and +5. This should be done on the Oxygen voltage.

IN SBEDATA PROCESSING, RUN: ALIGN
(PSA file for this = AlignCTDBStrait2022_CTDforprocessOx2.psa)
Inputs are: BStrait22nnnnA00B15.cnv
*In DATA SETUP
--> Enter Advance values
-- Oxygen: 2 *(as recommended in SBE9+ manual (2 to 5), and tests suggest in 2014 and 2015)*
-- All others: 0
*In FILE SETUP
-- Append added = AdvOx5
THIS GIVES files called: BStrait22nnnnA00B15AdvOx2.cnv

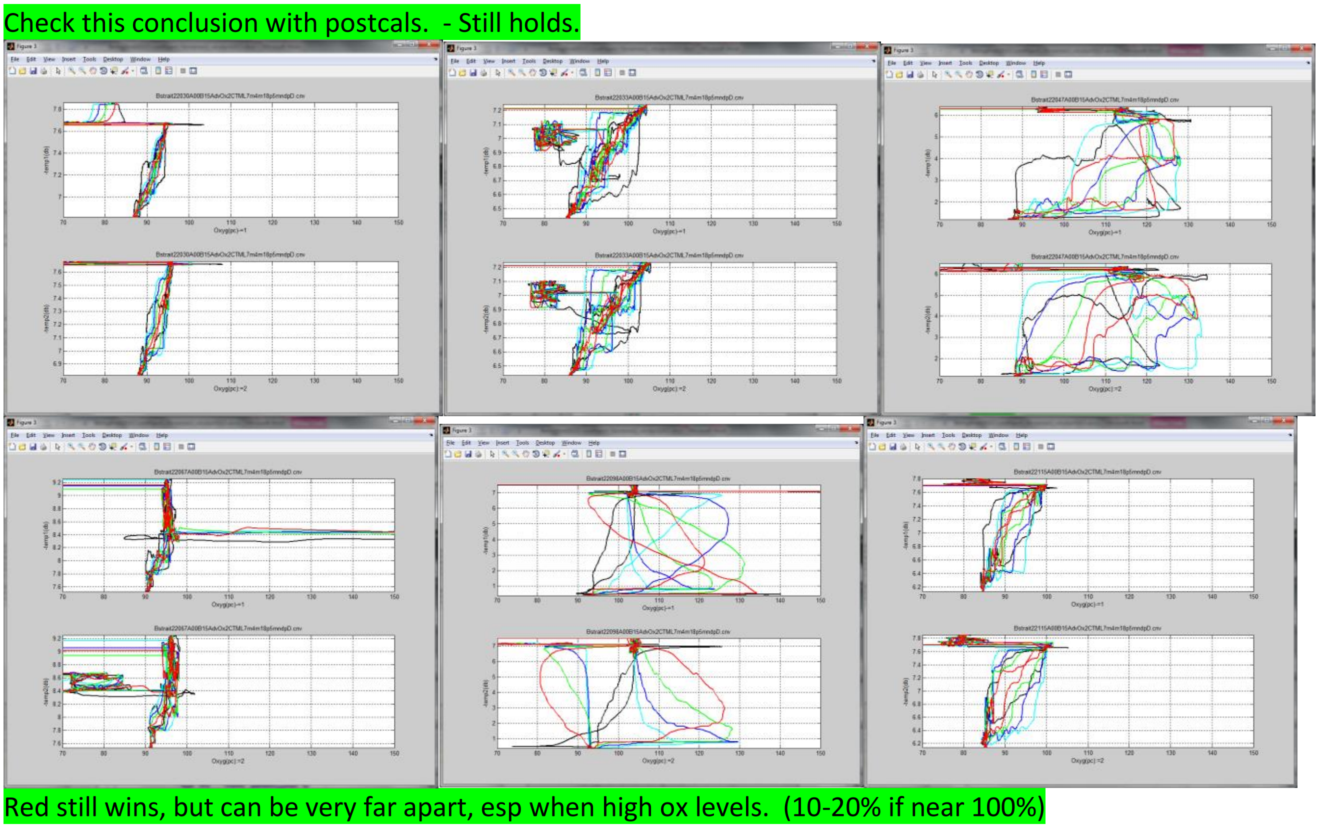
So, of these, it is suggested we investigate the various oxygen options. This we run this step with various values for the oxygen advance (2-5) and, by plotting oxygen against temperature, see which advance value gives the most consistent reading comparing the up and down casts.
This is using the precals: R=2,g=3,b=4,c=5





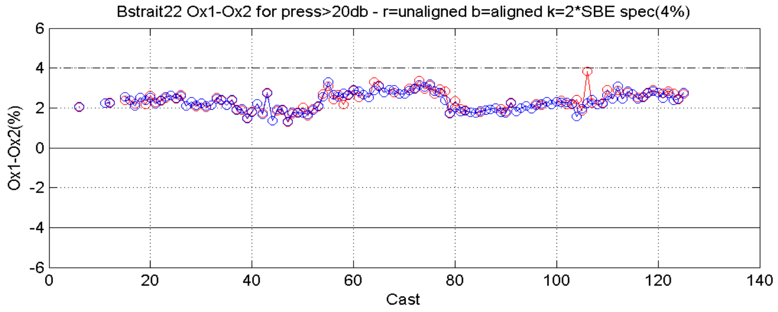
Previous years have segregated casts into which colors are good. Here 2 is the best (red) and will use that, as in prior years, though not 2020. Note the CTD is mounted horizontal this year. \

Check this conclusion with postcals. - Still holds.

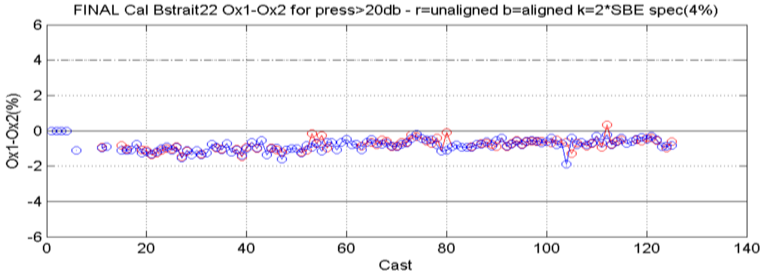


Red still wins, but can be very far apart, esp when high ox levels. (10-20% if near 100%)

How do the oxygen sensor compare?



With Precals, difference between Oxygen sensors was ~2%, within instrument specs, although not as good as 2021 (drifting from +1 t -1% during the cruise).



With final calibrations (both postcruise), the sensors agree to about 1%, much better than then instrument specs (2% each).

Finally conclude:
- at this stage will use Ox1, as it shows slightly less spread than Ox2.
- alignment is generally best at +2.
- recognize that up and down casts may differ by 5%-10% .
- agreement between sensors ~ 1%, well within manufacturer's specs (twice 2% saturation)

=== 6) Fourth step of SBEDataProcessing. Correct for thermal mass of the cell

This is a standard SBE correction to compensate for thermal mass of the cell. Assumes the pump is at 3000 rpm. ***Action Item: Check this.*** Then manual suggests for SBE9+ Alpha=0.03, 1/beta=7.

IN SBEDATA PROCESSING, RUN: CELL THERMAL MASS
(PSA file for this = CellTMBStrait2022_CTDforprocess.psa)
Inputs are: BStrait22nnnnA00B15AdvOx2.cnv

*In DATA SETUP (correct both Primary and Secondary values)
-- Thermal anomaly amplitude [alpha]: 0.03 *(suggested for SBE9+)*
-- Thermal anomaly time constant [1/beta]: 7 *(suggested for SBE9+)*
*In FILE SETUP
-- Append added = CTM

THIS GIVES files called: BStrait22nnnnA00B15AdvOx2CTM.cnv

== 7) Fifth step of SBEDataProcessing. Remove pressure loops from the casts.

This step is to take out pressure looping, stalls in lowering, and the surface soak. To run this, you must have filtered the pressure first (as we did above). This does not remove any data, it just marks looped data with a bad data flag of -99e-26.

In 2015, we instigated a 5m depth for the initial surface soak, returning after that soak to the surface to start the downcast. Thus the used values were L5m2m6m (soak, min, max) and were used including deck pressure, and that seemed to work well with this routine. Prior years just used a 2m soak depth and that might be less successful with this routine.

In 2016 the soak was about 4m .. checks show this works with this routine and these settings.

In 2017, soak is about 7m, but sometimes much deeper. Previous settings (L5m2m6m) did not work well with this data set. After investigation, we learn the following:

- likely best not to include the deck pressure as offset - our system is never on while in air, and thus this will just introduce a non-intuitive offset.
- the max must be deeper than the deepest soak, yet shallower than the maximum depth of the shallowest cast. In 2017, the shallowest casts were (Cast1 and 2, tests, and thus not considered; 113(19.6m), 114(19.6m), 115(19.5m), 117(18.7m). Our deepest soaks were cast 20(18.25m), cast 31(16m). Thus, we set max to be 18.5m
- the min must be deep enough to separate the going-in-the-water oscillations from the soak. 2m and 3m were found to be too shallow in 2017, but by inspection 4m works well.

Finally settings for 2017 were thus: 7m soak, min 4m, max 18.5m. (Note if you specify max and min, the program is not supposed to use soak depth at all.)

In2018 these settings gave a good result and were used without further testing.

In 2022 and 2022, we again adopted these settings

IN SBEDATA PROCESSING, RUN: LOOP EDIT
(PSA file for this = LoopEditBStrait2022_CTDforprocess.psa)
Inputs are: BStrait22nnnnA00B15AdvOx2CTM.cnv

Must run filter on pressure first. Flag surface soak with -9.99e-26 ..

*In DATA SETUP
-- Minimum ctd velocity (m/s) = 0.25
--> Check box Remove Surface soak
-- Surface soak depth (m) = 7
-- Minimum soak depth (m) = 4
-- Maximum soak depth (m) = 18.5
--> UNCheck box Use deck pressure as pressure offset
--> Check box Exclude scans marked bad
*In FILE SETUP

-- Append added = L7m4m18p5mndp

THIS GIVES files called: BStrait22nnnnA00B15AdvOx2CTM L7m4m18p5mndp.cnv

=== 8) Sixth step of SBEDataProcessing. Derive the parameters you want.

This step takes the raw data and calculates derived parameters, such as salinity, density, oxygen values, etc.

IN SBEDATA PROCESSING, RUN: DERIVE

(PSA file for this = DeriveCTDBStrait2022_CTDforprocess.psa)

Inputs are: BStrait22nnnnA00B15AdvOx2CTML7m4m18p5mndp.cnv

-- CHECK box on match instrument to configuration file (Prior notes says to check this box, however, in 2016 this crashed if the box was checked, so instead uncheck the box, **BUT MUST MAKE SURE IS USING A CURRENT CALIBRATION FILE**). If ever change sensors during cruise, will have to do something different here. Check these files to make sure the .con files are consistent.

** FOR 2022 - FINAL, use the combined post/pre XML file

*In DATA SETUP

--> Select derived variables... add:

-- Salinity (psu)

-- Salinity,2 (psu)

-- Salinity difference

-- Sigma theta (kg/m3)

-- Sigma theta,2 (kg/m3)

-- Sigma theta difference

-- Oxygen, SBE 43 (ml/l)

-- Oxygen, SBE 43 (saturation)

-- Oxygen, SBE 43, 2 (ml/l)

-- Oxygen, SBE 43, 2 (saturation)

*In FILE SETUP

-- Append added = D

THIS GIVES files called: BStrait22nnnnA00B15AdvOx2CTM L7m4m18p5mndp D.cnv

Could stop here, and use these files, but to be more useful want to have Bin averages and despike, and the combination of the two of those processes. So, first look at the despiking options. SBEDataProcessing includes a file called "Wild Edit", but the manual describes that as "not the faint of heart" and says much trial and error is necessary to get good results. Thus, instead use something more automatic, Window Filter.

=== 9) Twelfth step of SBEDataProcessing. Use Window Filter to despike.

This is an attempt at automatic despiking. If just try so smooth over a spike, you will flatten it, but the bad data will still remain. Here we make one basic attempt, as outlined in the manual. This takes a window of data points, and for each window, replaces the central (?) point with the median of all the points. In some way thus, this is smoothing over the data points, but one that neglects extreme values. Their example suggests 17 points, and we have used that. Sampling rate is 24Hz. Drop rate is ~ 1m/s. So this is roughly equivalent to smoothing at 0.7 sec, or 70cm.

IN SBEDATA PROCESSING, RUN: WINDOW FILTER

(PSA file for this = W_FilterCTDBStrait2022_CTDforprocess_MF17.psa)

Inputs are: BStrait22nnnnA00B15AdvOx2CTM L7m4m18p5mndp D.cnv

*In DATA SETUP

--> Select Exclude scans marked bad

--> Specify Window Filters:

Type: Median Parameters: 17

For variables: Temp1, Temp2, Cond1, Cond2, Oxraw1, Oxraw2, Fluorescence, Upoly (Turbidity/Transmissivity), Latitude, Longitude, Salinity1, Salinity2, Density1, Density2, Ox1ml/l, Ox1%, Ox2ml/l, Ox2%,Upoly2(rawSUNA)

-- Append added = MF17

THIS GIVES files called: BStrait22nnnnA00B15AdvOx2CTM L7m4m18p5mndpDMF17.cnv

Feb2024

=== 9.5) SUNA postprocessing. During profiling, the SUNA returns a voltage to Seasave which can be plotted at a nominal calibration. Final corrected SUNA data are however obtained directly from the SUNA instrument, where data are stored internally at higher resolution allowing for postprocessing. The steps of that post processing are given briefly here, with full details below. Data processing has been checked against bottle samples, with the final agreement of SUNA data to the bottle samples being ~0.6uM, somewhat better than the manufacturer's specifications of 2uM.

SUNA processing summary:

** Very important to ensure SUNA clock is correct to NMEA time

Pre deployment,

- run SUNA reference update
- run test runs of DI water, standard solution (ours made up at UW to 20uM), and DI water again

Post-deployment

- run test runs of DI water, standard solution (ours made up at UW to 20uM), and DI water again
- run SUNA reference update

Use matlab routines to create from the final CTD data a file of temperature and salinity data on timestamps matching the SUNA data that was recorded internally on the SUNA

Run the Seabird UCI program to correct SUNA data for temperature and salinity, using both the pre-deployment reference update and the post-deployment reference update. The resultant timeseries will differ by a constant.

Linearly interpolate (by record number) between the pre and the post cal. (Test against bottle data show this product has an RMS error to the bottle data of 1.1uM)

Calculate offsets of these data to the pre and post DI water and standard runs.

Linearly interpolate that error (by record number) to obtain final data set. (Test against bottle data show this product has an RMS error to the bottle data of 0.6uM.

Use matlab routine to update .cnv files with corrected SUNA data.

=== 10) Seventh step of SBEDataProcessing. Bin average all the data.

All data files prior to this have been the 24Hz data up and down casts. Here we separate out the downcasts only, exclude the data marked bad by loop edit, and create 1m bin averages. We chose here to create a surface sample, however often the number of scans in that sample is small and in any case surface stirring by the ship must also be considered.

IN SBEDATA PROCESSING, RUN: BIN AVERAGE

(PSA file for this = BinAvgBStrait2022_CTDforprocess.psa)

Inputs are: BStrait22nnnnA00B15AdvOx2CTM L7m4m18p5mndp.cnv &

BStrait22nnnnA00B15AdvOx2CTM L7m4m18p5mndpDMF17.cnv

*In DATA SETUP

-- Bin type = Pressure

-- Bin size = 1

--> Select Exclude scans marked bad

→ Select include number of scans per bin

-- Scans to skip over = 0

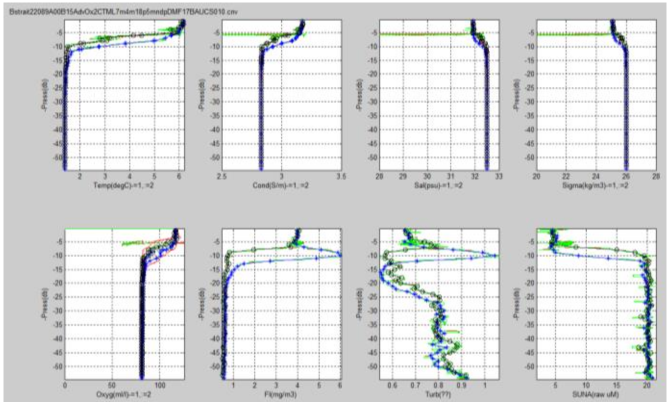
-- Cast to process = **Downcast**

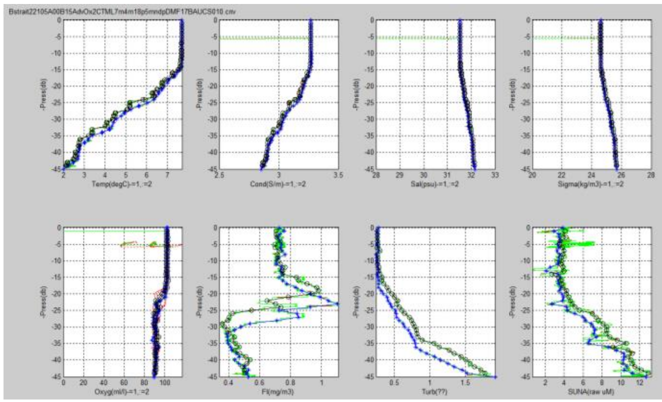
-> Include surface bin 0,1,0
*In FILE SETUP
-- Append added = BADCS010
THIS GIVES files called: ~~BStrait22nnnnA00B15AdvOx2CTM L7m4m18p5mndpDBADCS010.cnv &~~
BStrait22nnnnA00B15AdvOx2CTM L7m4m18p5mndp DMF17BADCS010.cnv

==== 11) Eighth step ... do Bin average up also.
THIS GIVES files called: ~~BStrait22nnnnA00B15AdvOx2CTM L7m4m18p5mndpDBADCS010.cnv &~~
BStrait22nnnnA00B15AdvOx2CTM L7m4m18p5mndp DMF17BADCS010.cnv
In 2022 this marks the end of the CTD pre processing.

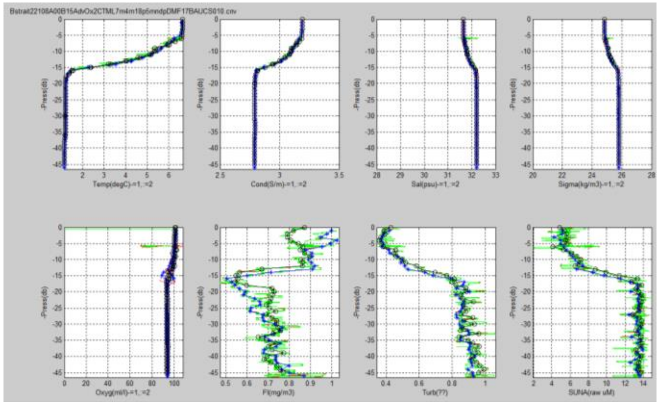
Consider if differences between up and down cast are meaningful, or represent entrainment.

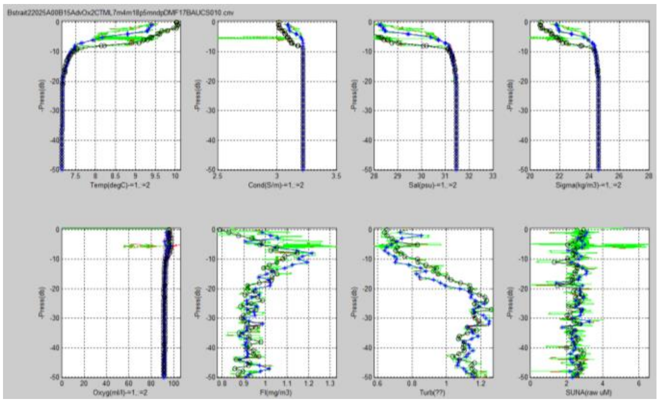
Plots of example casts with Red=orig; green=final processed, blue*= Bin av downcast, blacko = Bin av upcast





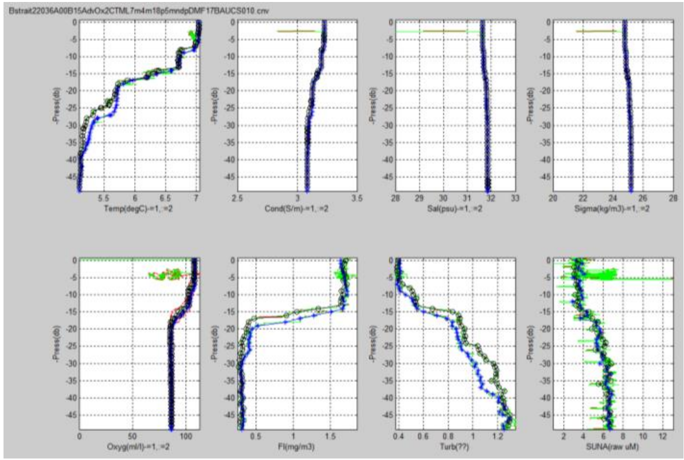
Almost always it looks like water is being swept up with the rosette, though there are exceptions of e.g., no offset, 108, Which was a slower raise or TS in up being less (#25-27)



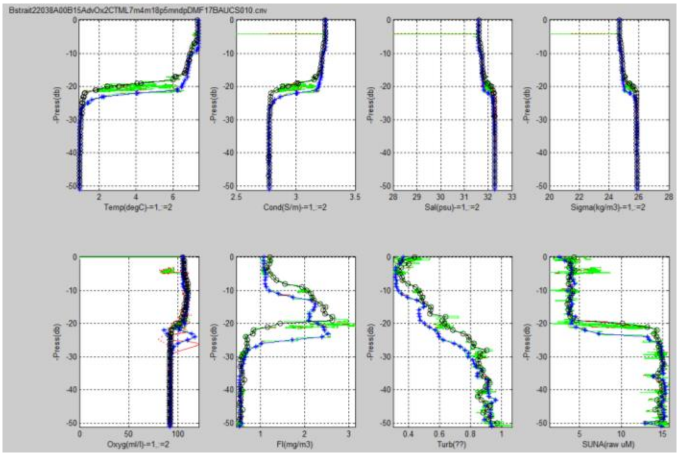


..these are around BS18-19 and probably represent drifting into different water.

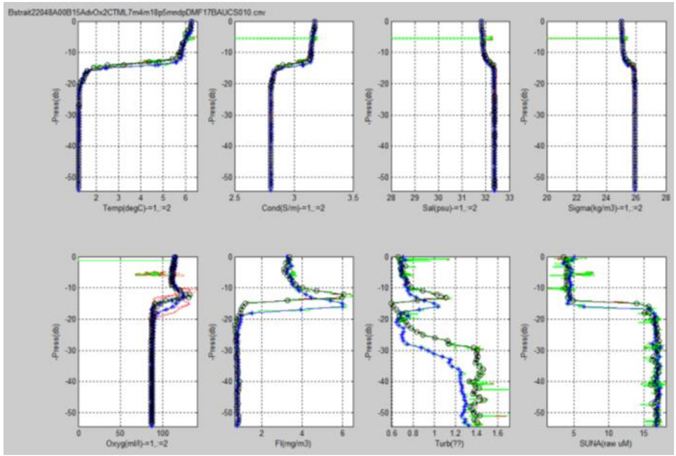
But an offset is not consistent over the depth of the cast, e.g. (see temperature),



That said, it is often about 2m, and sometimes in TS, ...



but also sometimes only in the Fl, Turb, with T ad S matching well.

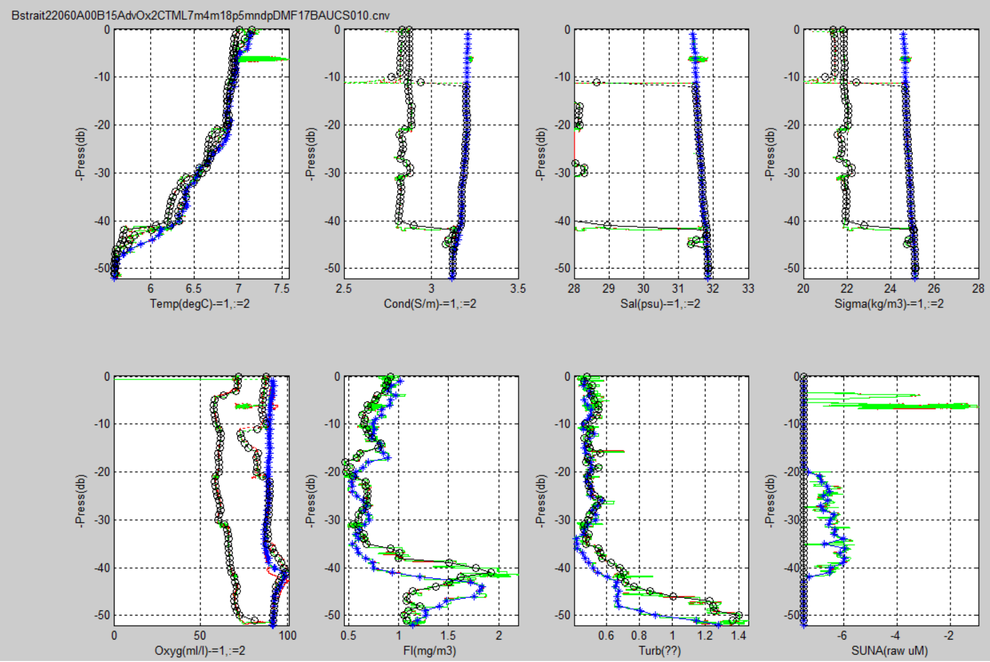


Conclude

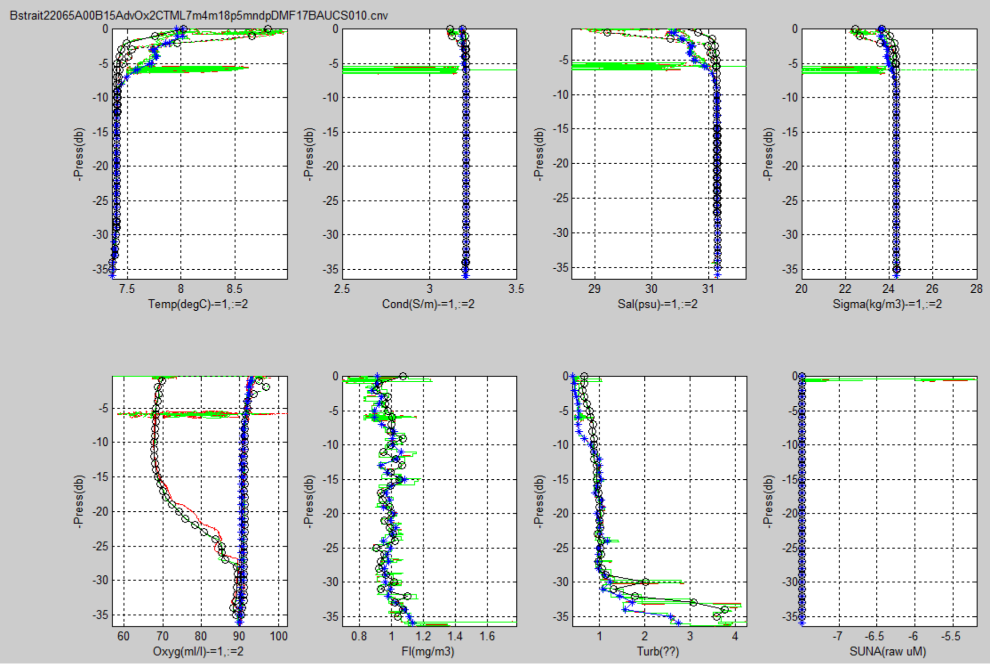
- location of features in vertical probably only good to 2m, with entrainment possibly being an issue, although drifting into different waters certainly is occurring.
- offset in Fl and Turb between down and up cast may reflect lag in sampling time and could be adjusted in software, though not done here.

Now problem casts - 60 and 65

#60 - down cast ok ... both S and Ox systems go bad on up cast, SUNA data here bad also Al20, has 6 bottles. BUT temperature track well, so can likely use down cast



#65 - down cast ok ... Ox 1 bad on upcast, but Ox2 ok. SUNA data here bad also AL22.5, but has no bottles.



<u>**Now Bottle processing**</u>   ** will need special treatment of cast 60.

- during cast, **seasave** writes **.bl** file, which has bottle fire scan number, and that plus 36 (1.5s)
- **dataconversion**, creates a **.ros** file from .bl .. (option of how long for averaging bottle (2s)

  This is extracted lines from .cnv for 2s after bottle files

  Run this on .rw1 as it has all the converted data in it.
- **bottle summary**, ..takes the .ros file and makes a **.btl** using 49 scans per bottle

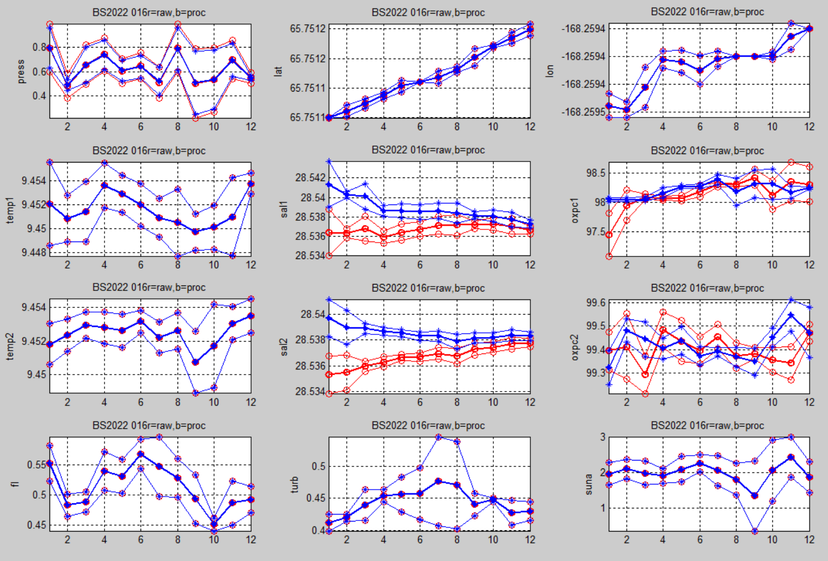
  Options: Select all averaged variables

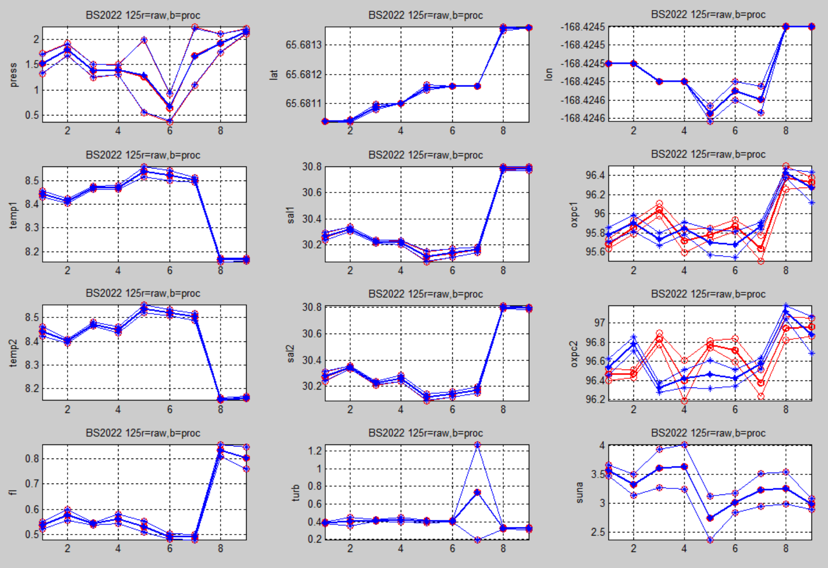
  Apply Tau correction

So one could use:

- the bottle summary (Advantage: Standard. Disadvantage: Does not include correction)
- extract the same data from the final calibrated data

Compare the 2s average (with standard deviation) for the preprocessed and postprocessed. Find no significant difference. Salinities usually within 0.005psu (cast 98 0.02psu) and Ox within 2%, usually closer., e.g.,





Thus, we opt to extract bottle data from the final calibrated data in matlab, allowing us to easily combined the bottle information with the nutrient (and where taken, salinity) sample data into one ascii file.

SUMMARY OF 2022 CTD SUNA processing - 25th Feb 2024

AT SEA Suna 1916

- deployed on profiling SBE 9-11 CTD
- using a custom battery set up, modelled on that used by Seth Danielson,
    - power up voltage from SBE9 switches on power to SUNA from independent battery
    - prevents large current draw required for SUNA overpowering CTD
- preliminary data are recorded in Seasave .. however
    - this uses just a nominal calibration and a linear fit to voltage
    - has some data dropouts, possibly due to water in the connector?
- raw data are recorded at full resolution on the SUNA itself
    - **** VERY IMPORTANT to ensure SUNA is on NMEA TIME ****

- pre and post cruise, run SUNA checks including:
    - **updating the reference spectra using DI water ** VERY IMPORTANT****
    - **running a standard solution (made at UW to ~20uM concentration ** VERY IMPORTANT ****

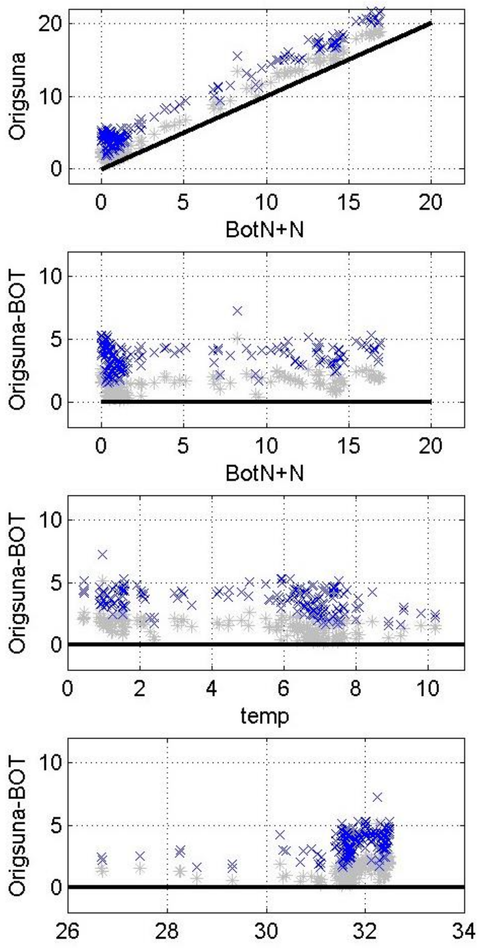
- water samples taken at standard depths, during cruise and analysed for standard nutrients
    - SUNA is recording Nitrate+Nitrite. *** See Nitrite Note below

PROCESSING

- comparison of the CTD SUNA to bottles shows
    - significant differences CTD SUNA ~ 4uM too high
    - strong correlation to bottle data.
    - difference changing in time
    - no clear relationship of difference to T, S or P

- raw SUNA data (i.e. that stored on the SUNA) is
    - very similar to the CTD SUNA in value
    - starts before the CTD SUNA
      (SUNA powers on while CTD waking up)
    - stops after CTD SUNA
      (CTD recording stopped before power off)
    - has the zeros every 30 frames
    - these zeros appear as noise in CTD SUNA
    - shows clocks are well aligned.

(See example figures in 2023 cruise report).



- SUNA requires TS correction, so use CTD data to make that file
    - want TS interpolated to all times the SUNA is on
    - note there is dubious TS data before the pumps come on, but that will be removed later
- To run correction in UCI needs:
    - raw SUNA data
    - TS file
    - package file (an instrument specific file, only changing when the instrument is repaired)
    - REFERENCE FILE - we have two … before (here G) and after (here H) cruise.
        (Note H file is from April 2023, so several months after the cruise, but the instrument was only in transit/storage during this time).
    - RUN TS correction in UCI for both reference files.

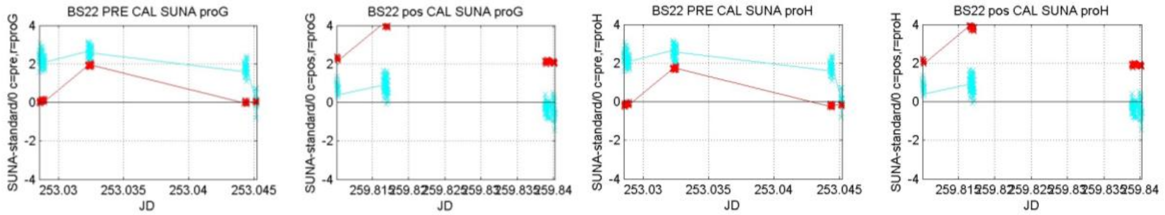
Learn:

- for FRESHWATER (the standards we run), this correction is NOT a function of temperature
    (i.e. don't have to be concerned about measuring temperature of standard)
- for rest, can make a very LARGE difference (about 5uM)
- this introduces noise, related to sharp TS gradients.
    Possibly this is due to minor timing mismatches?
    Assume we can smooth this out later.

NOW compare corrected data to standards (0 and 20uM) and to the bottles:

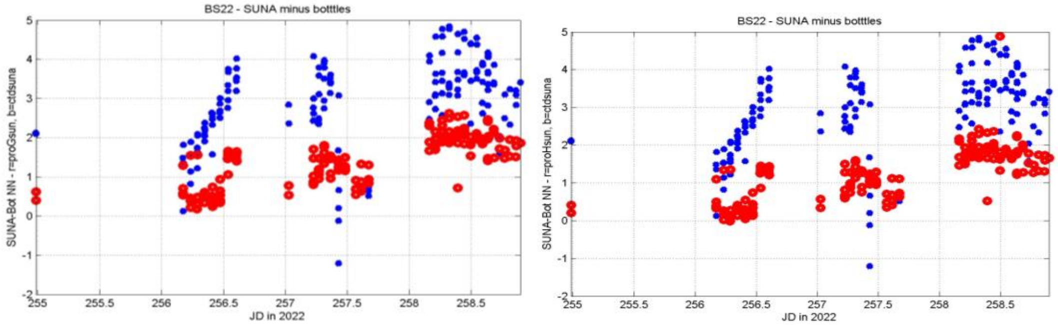
- run with pre cruise calibration (here I) and post cruise (J)
- find these differ only by a constant!
- TS correction has made BIG difference, in unexpected ways.

Standards (showing difference between standard (0 or 20uM) and the SUNA reading):



- light blue, pre TS; Red, with TS correction; Left to Right (G Pre, G post, H Pre, H post)

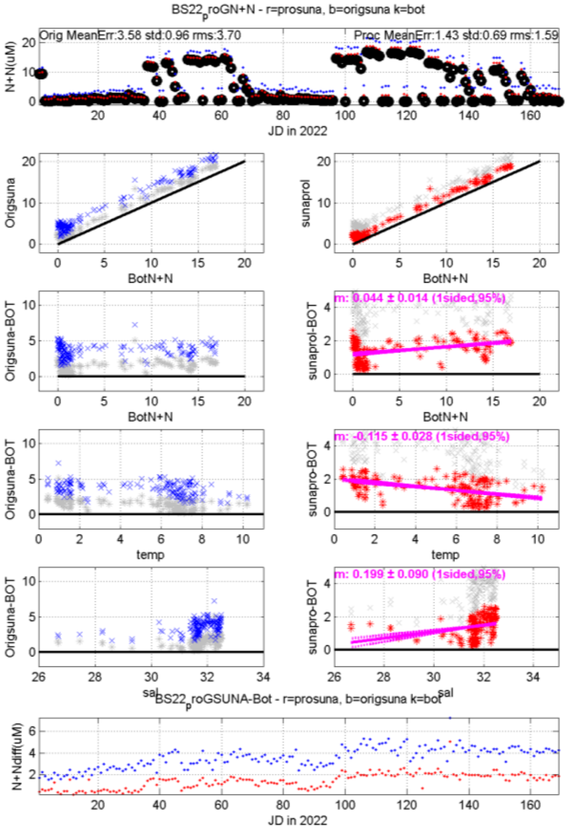
Bottles: (Showing SUNA value – bottle value)

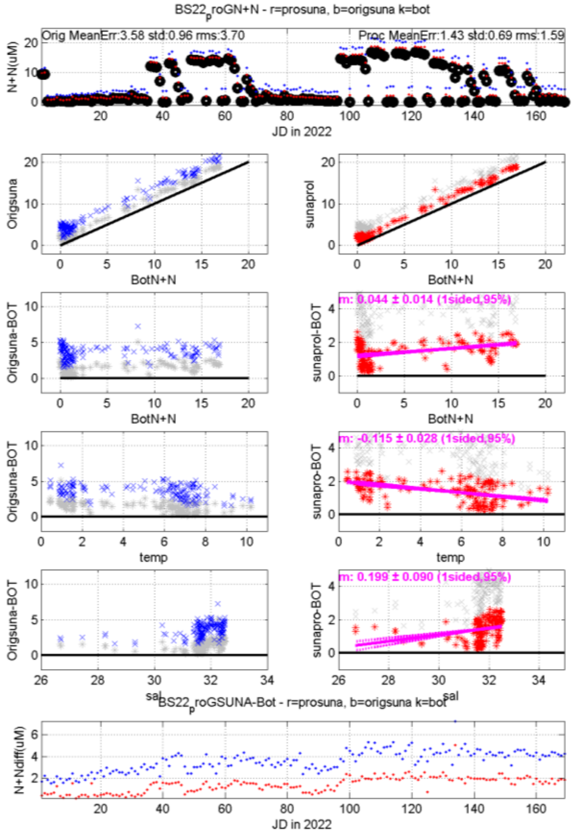


- blue, pre TS; Red, with TS correction; left G, right H.

And comparison of the SUNA-bottle values versus various parameters:

- blue, pre TS correction, Red, with TS correction; left G, right H





Although here the difference between pre and post calibrations are small, in other cases (2023) this was not so, so we follow the method developed there, and linearly interpolate in time between pre (G) and post (H), interpolating by record number.

- Finally compute remaining error to cals and bottles, as MEAN, STD and RMS

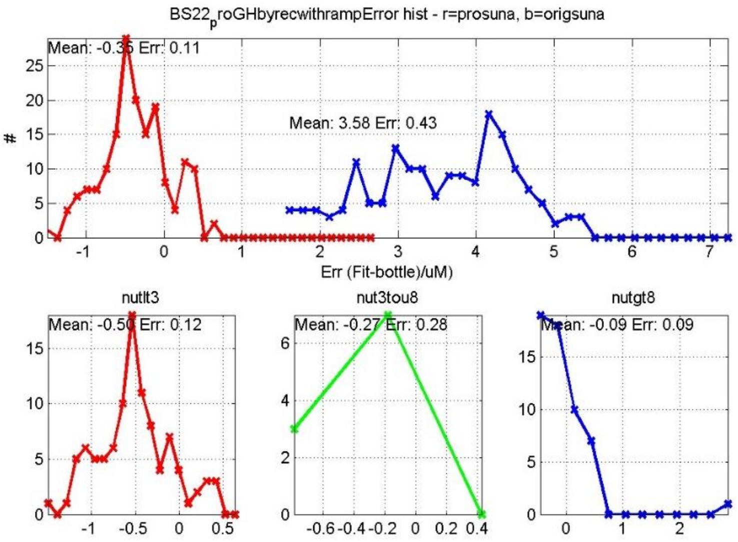
What	Err to precal	Err to bottles	Err to postcal
Orig	2.06 (std 0.73) rms 2.19	3.58 (std 0.96) rms3.70	0.26 (std 0.70)rms 0.75
proG	0.64 (std 0.87) rms 1.08	1.43 (std 0.69) rms 1.59	2.84 (std 0.93) rms 2.98
proH	0.43 (std 0.87) rms 0.97	1.23 (std 0.69) rms 1.41	2.63 (std 0.93) rms 2.79
proGHbyrec	0.64 (std 0.87) rms 1.08	1.33 (std 0.66) rms 1.48	2.63 (std 0.93) rms 2.79
proGHbyJD	0.64 (std 0.87) rms 1.08	1.29 (std 0.67) rms 1.46	2.63 (std 0.93) rms 2.79
proGHbyrecwitconstoffset	-1.00 (std 0.87) rms 1.32	-0.31 (std 0.66) rms 0.72	1.00 (std 0.93) rms 1.36
proGHbyJDwithconstoffset	-1.00 (std 0.87) rms 1.32	-0.34 (std 0.67) rms 0.75	1.00 (std 0.93) rms 1.36
proGHbyrecwithramp	-0.02 (std 0.87) rms 0.67	-0.34 (std 0.49) rms 0.60	0.00 (std 0.93) rms 0.93
proGHbyJDwithramp	-0.01 (std 0.87) rms 0.87	-0.68 (std 0.52) rms 0.85	0.00 (std 0.93) rms 0.93

So the important lines are now in YELLOW:

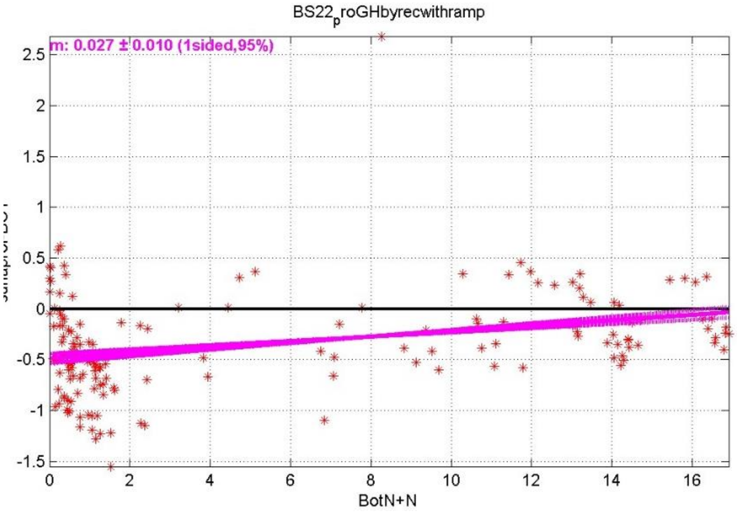
Doing the SEABIRD ONLY .. proGHbyrec …gets us to RMS errors of about 1.5uM

Using our standard pre and post allows us to take out a background trend and bring RMS error down to about 0.6uM (proGHbyrecwithramp, yellow and green).

Using this preferred fit gives the following error characteristics



Conclude:
- without correction, SUNA data are ~4uM too high.
- using just reference updates, and interpolating by record number between pre and post reference updates, rms error to bottles is ~1.5uM, but is 1.1 – 2.8uM to pre and post cruise distilled water and standards.
- linearly interpolating between these standards, allows us to create a final data set with rms errors to bottles of 0.6uM and to pre and post cruise distilled water and standards of 0.7-0.9uM.
- although a significant fit to nitrate value remains (bottom plot), since the correction from such a fit would be 0.5uM or less, we choose not to further correct the data.



- Conclude with all these corrections, final error rms is about 0.6uM.

Note could have got same numeric result just by using the pre and post standard runs, but have the satisfaction of knowing how good the reference updates were (and how much we are correcting beyond that with the standard).

From here
- read in .cnv files, correct SUNA and write back out
- replot .. find
  - less noisy
  - some data below zero – obviously not negative, just within errors.

*** Nitrite Note:
Although the SUNA is advertised as a Nitrate sensor, due to overlapping of the absorption spectra of nitrate and nitrite, it is expected that the presence of nitrite in the water will affect the absorption and the SUNA will interpret that as additional nitrate.
Through the processing above thus, the SUNA was compared to the nitrate+nitrite of the bottle data. However, SUNA runs sampling a pure 20uM nitrite solution registered SUNA values of 8uM. Thus, we might conclude the SUNA is actually measuring nitrate + (8/20)*nitrite. = nitrate + 0.4*nitrite.
If this is the case, our comparison to bottle samples is slightly erroneous, specifically by 0.6*nitrite.
Fortunately, the nitrite values of our bottle samples are low, viz 0.14uM maximum, 0.07uM mean.
Thus the error we are making is only maximum 0.08uM, average 0.04uM, i.e., much smaller than the final uncertainties in the data.

BERING STRAIT 2022 CTD OPERATION NOTES from end of cruise

0. Coming onto station
    - pre fill Event Log (Excel file)
    - In Seasave
        - Real time data, Start, Begin archiving data immediately
        - Select Output Data File Name: Bstrait21nnn.hex, *** NOTE NAME 17, not 2017
        - Start
    - fill in header
        - Ship: Norseman 2, Station name (e.g., BS24), Operator
        - then WAIT
    - **Driver to Deck:** "**clean wetlabs sensor**"
    - **Deck to Driver:** "**sensor cleaned**"
    - **Driver to Deck:** "**Are all bottles primed?**"
    - **Deck to Driver:** "**Bottles are primed**"

1. On station confirmed from bridge "**on station**",
    - **Driver to deck**, "**Ready to Deploy**"
    CTD in the water (**Deck to Driver**: "**CTD in water and at 5m**") (**Driver: double click radio**)
    - Power on CTD Deck Unit, check get readout of "10" (0110)
    - OK on SeaSave header, wait until SeaSave gray windows close
    - Real-time Control, Pump on (to turn pump on manually)
    - Fill out rest of Event log (Excel file) for deployment (including time).
    - Driver to deck, "**Please note wave height(m), clear or fog,and depth lose sight of ctd"**
    - WAIT until –"11", "Pump on", Data ok (incl S and position), check #'s agree
    - check target depth ~ water depth under keel
    - **Driver to Deck**: "**return to surface and go down to xxx meters**" (GET SURFACE WIRE OUT)
    - **Deck to Driver**: "**Going down**"
    - Check lower speed (want 30/40 m/min) on winch readout

3. CTD lowers
    - watch pressure ... *(resist temptation to analyze the cast on the way down) .. focus only on the pressure*
    - **Driver to Deck**: "**3 2 1 stop**" for target depth
    - **Deck to Driver**: "**CTD stopped**" (GET BOTTOM WIRE OUT)
    - wait ~2sec
    - **Driver to Deck**: "**Come to surface/ come up 10m**" AND CHECK CTD COMES UP

4. CTD comes up Fire bottle OR ** COMPARE SENSOR PAIRS - decide if data good enough to leave
    When at surface (**Deck to Driver: "At surface"**) (**Driver: double click radio**)
    - real time control – Pump off
    - real time data – STOP
    - Power off CTD Deck Unit
    - **Driver to deck**: "**Recover CTD and proceed to next station/stay on station for pumping**"
    - OR IF may have to recast .. add "**We have CTD issues, do not leave after this cast"**
    - fill in Event Log for up cast (including time), while
    - **Deck to Driver** "**CTD recovered SUNA off, bottle issues**, **wave height, fog, depth seeing ctd**."
    THEN
    - screen dump to paint (Alt-print screen, Cntrl V, save as BStrait21nnn.png); F12 (save as);
    - QUIT paint.
    - Copy the 4 files (.hex, .hdr, .xmlcon, .png) to USB Backup file directory

(Start event log for next cast)

**CHANGE SUNA BATTERY AT 500min (about 50 casts)

<u>Deck responsibilities every cast:</u>

- checking sensor cleaned and bottles correctly primed, including
  caps correctly position, spigots out and vent plugs tight.
- checking depth of surface soak
- watch wire (out aft is ok, under ship is not, far to side near ship not)
- keep winch operator focused
- count CTD as it goes down, listen for 3 2 1 stop and make sure winch stops

- At Bottom, make sure winch comes UP (e.g., watch wheel)
- Watch for tape on way up,

- Observe and report surface issues (e.g., broke surface, ask for repeat soak if out of water for more than 4 sec)
- report - clarity of water (max range at which you can see CTD in m)
  - fog
  - wave height if exciting
- report bottle issues once CTD is on deck.
- report if jelly fish remains on salinity cells

- make sure secure on deck.
- every 50 casts, check all CTD bolts

- do water sampling as required

BERING STRAIT 2022 CTD LINES

Due to the exceptionally bad weather and the highly unusual need for days of searching for the moorings, only 4 CTD lines (one split below into two) were run on the cruise.

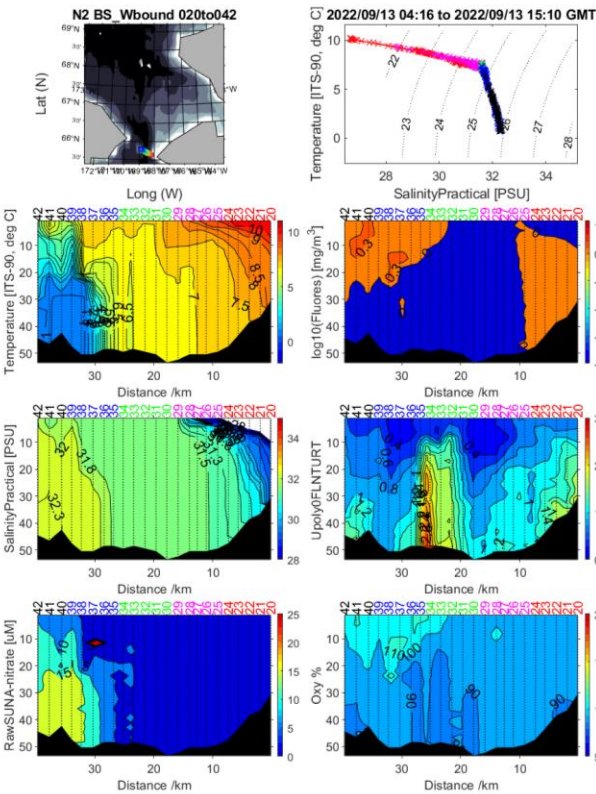
Preliminary sections were plotted using code from An Nguyen from the preliminary processed data, which uses pre-cruise calibrations, and the quality control procedures outlined above to give 1m bin averages for plotting.

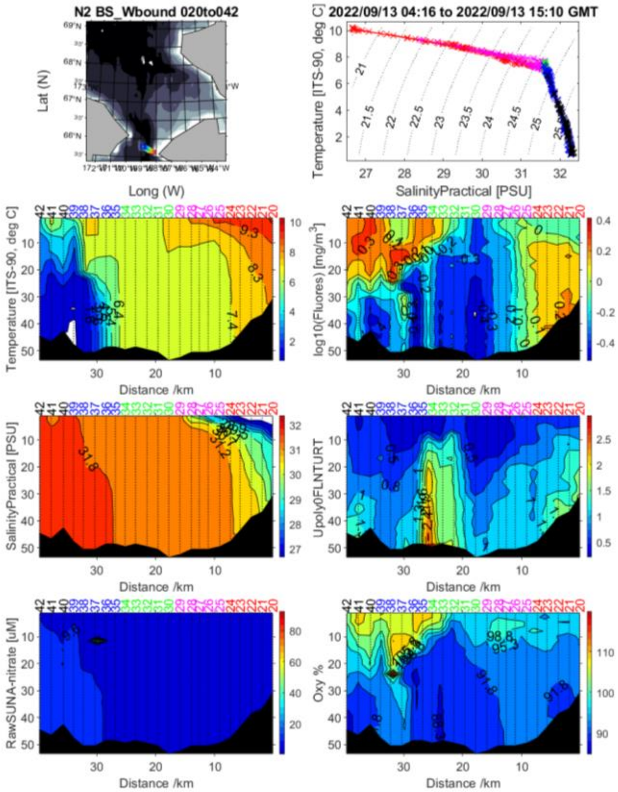
The plots below give all sections on the same scales (left) and on a scale for that section (right), presented in order of data acquisition. Note that:
- this uses the S1 and Ox1 data,
- typically stops 2 to 3+ m above the bottom.
- the SUNA data are the simplistic calibration used to allow visualization on seasave, and thus values here are only qualitative.

One repeat section (BS) was run on the cruise (see naming below), however the eastern end of the second running was not completed due to bad weather.

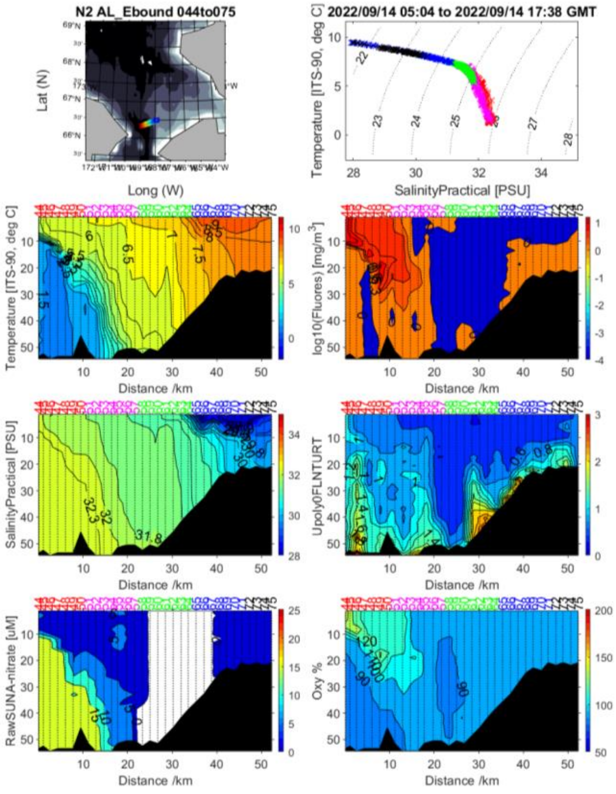
For full positions and times see event log and data file headers.

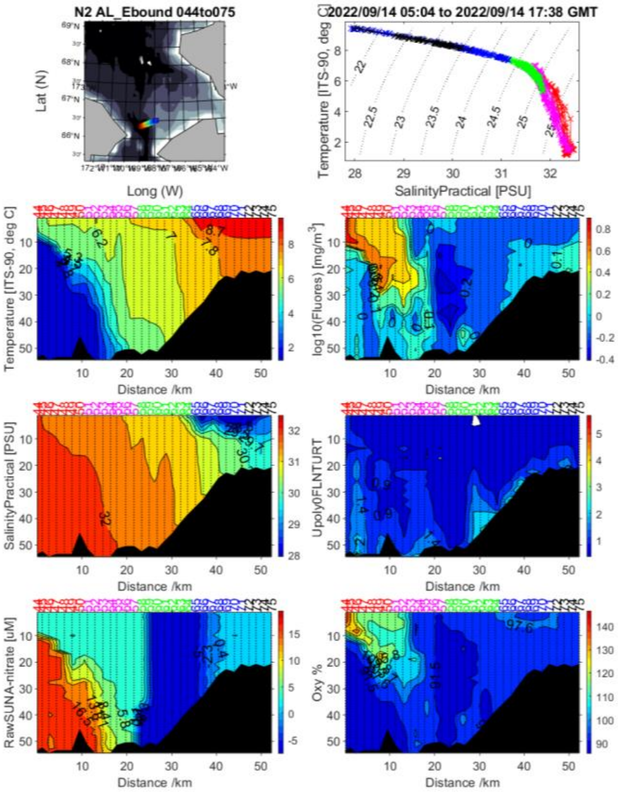
1) Bering Strait line (BS) – first running, Westward



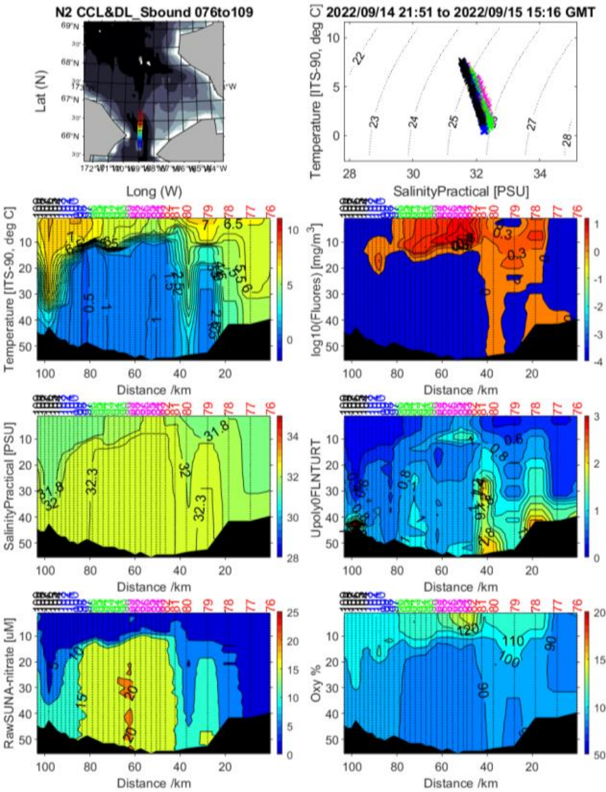


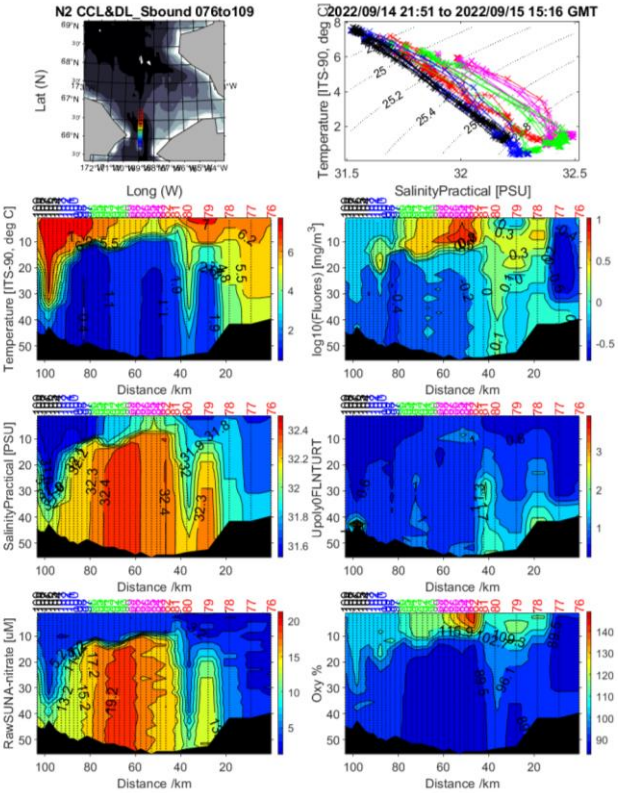
2) A3 line (AL) - first running, Northeastward



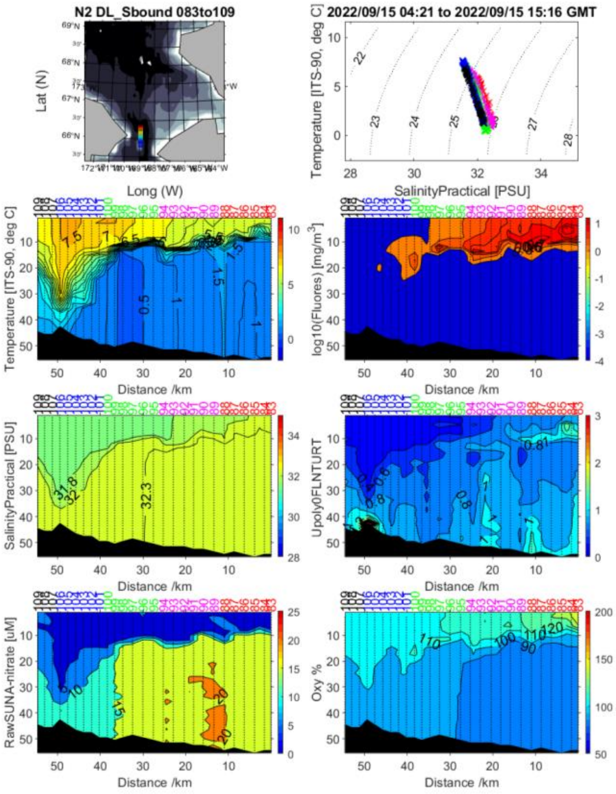


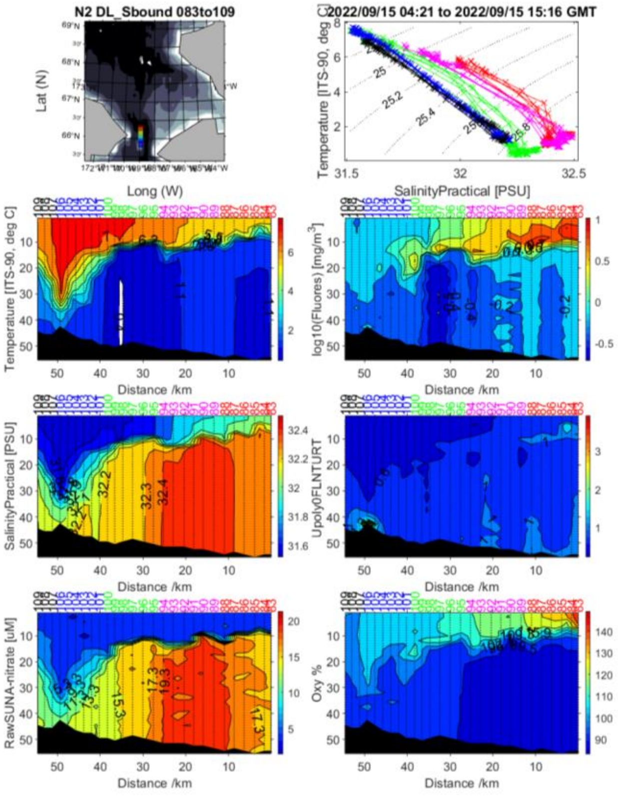
3) Chukchi Central line South part (CCL-S) combined with DL Line (DL) - Southward



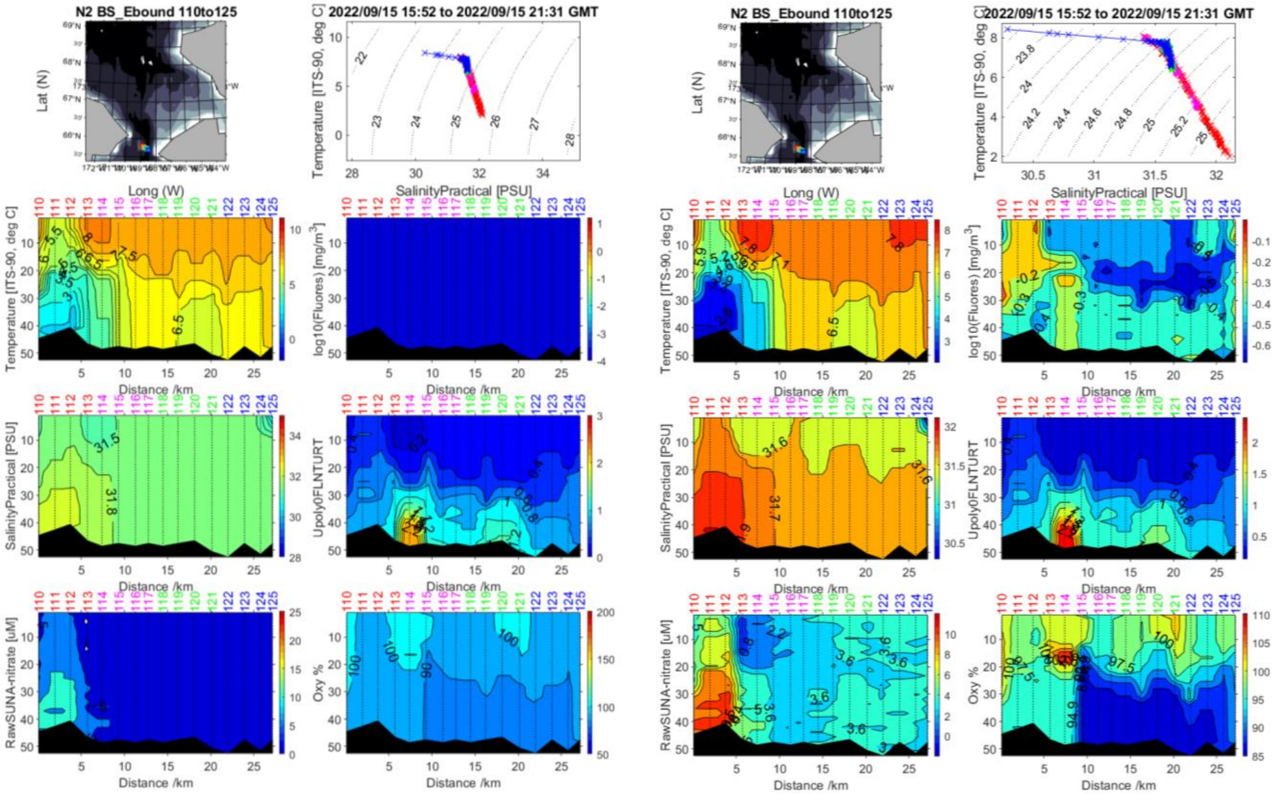


4) Diomede Islands line (DLS) - first running, Southward

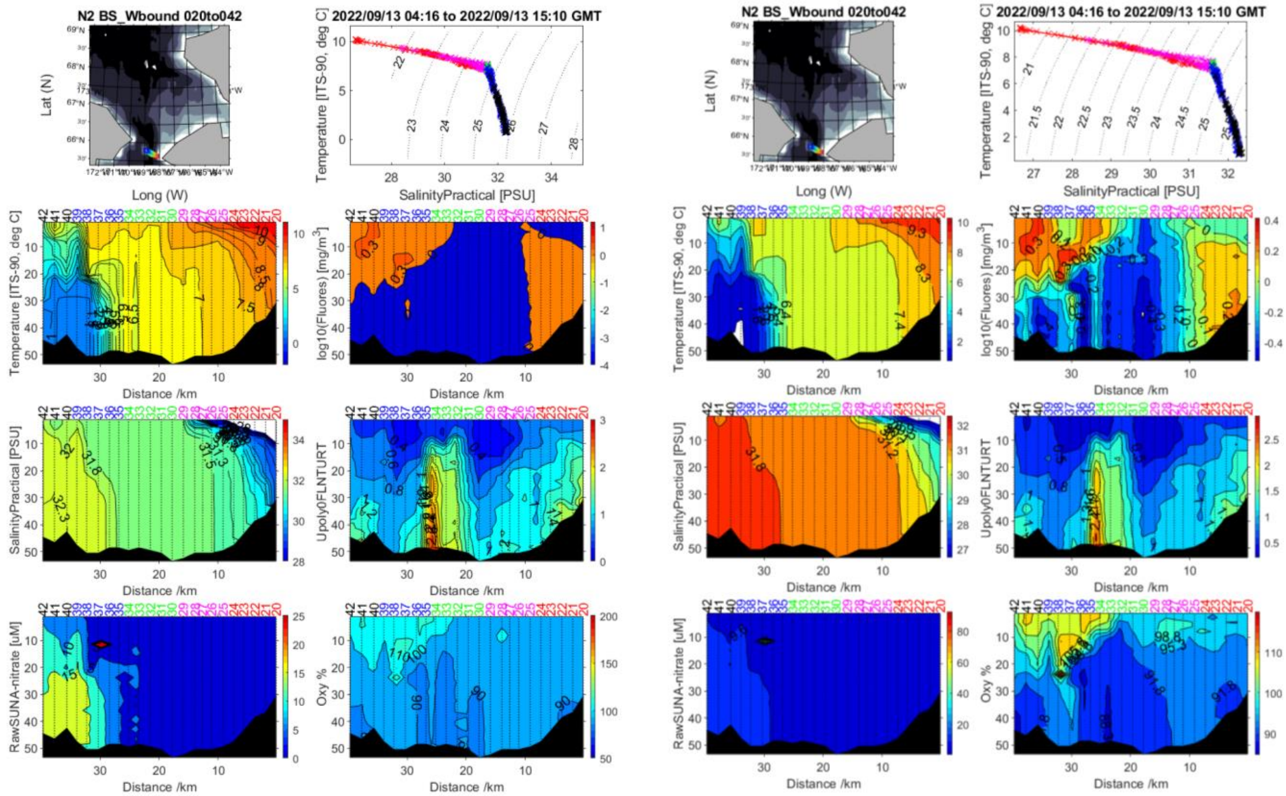




5) Bering Strait (BS) - repeat, Southeastward (not complete)

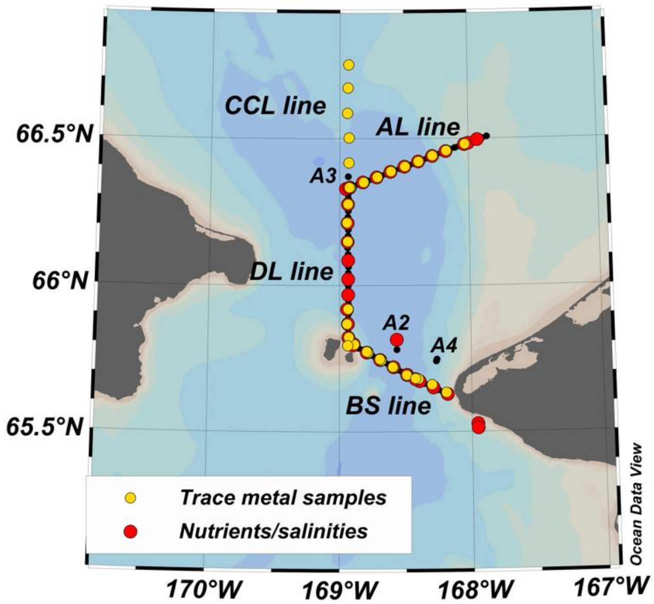


REPEAT OF 1) Bering Strait line (BS) – first running, Westward TO ALOW EASIER COMPARISON
NOTE DIFFERENT X SCALES AND EXTENTS



BERING STRAIT 2022 TRACE METAL AND NUTRIENT PUMPING REPORT (Laramie Jensen)

Summary: In 2022, 35 stations were sampled for trace metals and nutrients (marked purple on the main map above, yellow dots on the map below) using the pumping system used in 2021. Samples were collected at the surface (5m) and lower layer (variable depending on bottom depth). A total of 74 trace metal samples and 74 nutrient samples were taken, including two sets of duplicates. Samples were returned to UW for processing post cruise.



Background: The objective of this sampling is to take high quality/high resolution trace metal (iron, zinc, nickel, copper, cadmium, manganese, lead) and macronutrient (nitrate, phosphate, silicate) samples alongside the CTD and mooring temperature and salinity sampling. Trace metals (found in small or trace concentrations, ~10^{-9}mol/L) may be useful in deciphering water mass circulation or provenance. Many, like iron, are biologically important for phytoplankton in the surface waters. Importantly, the Bering and Chukchi shelves provide a large source of these trace metals to the Western Arctic Ocean.

Moreover, the inventory of these trace metals appears to increase moving from the North Pacific/Bering Sea through the Bering Strait and onto the Chukchi Shelf. Sources for these metals are primarily sediment resuspension (export of organic matter to the sediments release trace metals through diagenesis or non-reductive dissolution) or riverine input. Freshwater intrusions (salinity <30psu) were observed throughout the CTD transects, especially along the Alaskan coast at Stations LIS1-3. Rivers may act as a source or diluent for metals and nutrients. Variations in temperature and salinity indicate the presence of multiple water masses observed along the CTD lines sampled.

The major objective of this high-resolution sampling is to assess if or to what extent trace metals and nutrients vary across these different water masses feeding into the Bering Strait. Trace metals could be used to trace water mass movement further north where currents are complicated by bathymetric features and become more difficult to track.

Pump sampling of trace metals: Sampling was done using a trace metal clean PTFE double diaphragm pump (Wilden, see picture below) with a max flow capacity at 56 liters/minute at 125 psi air supply. Tubing both in and out of the water was Grainger 1/2in OD (polyethylene) connected to the pump with PVDF 1/2in compression fittings (all acid cleaned prior to the cruise). Tubing was cut to ~70m and marked with tape up to 60m from the surface and attached to 3/8in Nylon line. An 8lb kettleball weight was attached directly to the Nylon rope and a RBR Concerto^3 CTD was lashed to the rope with Dynacon line (see figure). Thus, the tubing sat approximately 1m above the kettleball weight.

Air was supplied by the ship service air connection on the starboard side and pressure was ultimately controlled using an air regulator (see picture) before entering the pump. Pumping at max capacity, pump was cleared in 60-70 seconds, estimated by introducing a bubble before each cast to mark "new water" being sampled. Thus, before each surface and deep sample the pump was flushed for at least 80 seconds at max capacity/speed.

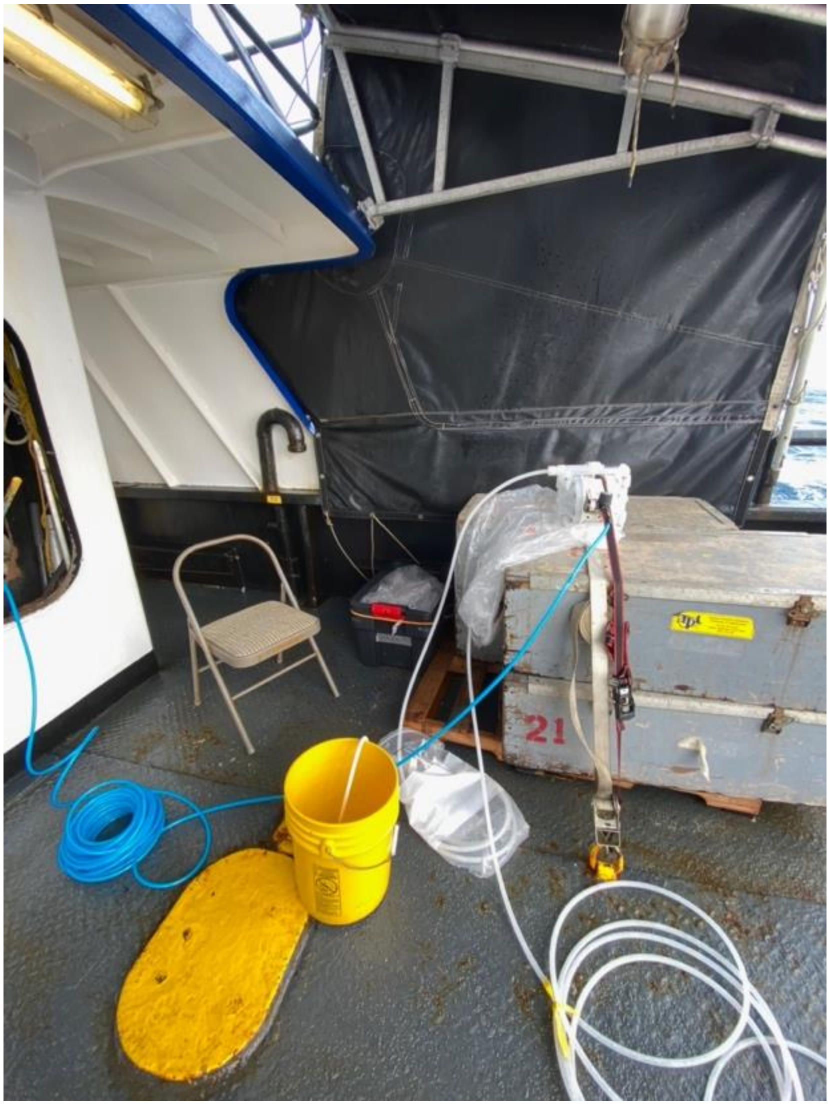
To combat issues in 2021 with filter back pressure, a few modifications were made/standardized this year. For example, larger capacity Acropaks were used (Acropak-1500 0.2 μm filter) instead of the Acropak-200 used in 2021. These filters did not clog (although two were used over the total filtering time to assuage sample contamination) and thus there was very little pressure on the pump and tubing. Additionally, acid clean

Masterflex L/S 24 tubing was used rather than the C-flex tubing last year that has a thinner outer diameter and thus "wears out" more easily in response to any back pressure. Both the filtered and unfiltered flow were attached to the main Grainger tubing via a plastic wye split and the Masterflex tubing connection was reinforced by zipties. Flow between the filtered and unfiltered tubing was controlled by plastic snap clamps. After flushing the system, flow was reduced to ~60 psi via the regulator to comply with the pressure ratings on the filter and alleviate back pressure.

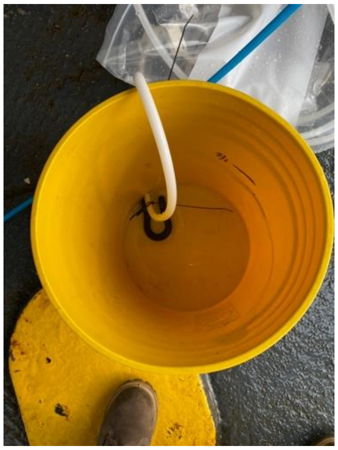
Filtered samples (trace metals and nutrients) were filtered directly into 250 mL (TMs) and 60 mL (nuts) Nalgene bottles (pre-cleaned) following 2-3 10% volume rinses as water budget allowed. Samples were bagged in two poly bags. Nutrient samples were placed in -20°C freezer inside another poly bag within 4 hours of sampling. Trace metal samples were double bagged in poly bags in increments of 12. Nutrient samples remained frozen until they could be analyzed in the Marine Chemistry Lab at the University of Washington. Trace metal samples were all acidified to pH 1.8 using 500 μL of Optima HCl (12M) under a Class 100 laminar flow hood (OSB 443) on 9/18/22. Note that volume was estimated for incomplete samples (clearly less than 250 mL volume) and acidification volume was adjusted accordingly (i.e., if only 50 mL of seawater was collected, 100 μL of Optima HCl was used).

Issues encountered during sampling:

- **Back pressure on filters**: As described above, the maximum pressure output of 125 psi from the Whilden pump was too strong for the Acropak capsule filters.
    - **Solution(s) at sea:** Reduced pressure to ~80 psi when actively sampling. Also, only slightly closed the unfiltered tubing so that some pressure was relieved that way. Tubing was reinforced with zipties rather than plastic hose clamps. Larger capacity filters were used this year (1500cm^2 vs 200cm^2) and this was a successful solution for backpressure due to clogging. Stronger tubing (Masterflex L/S 24) were also used to great effect.
- **End of tubing staying clean:** The ship's crew did an excellent job of making sure the end of the tubing attached to the Nylon rope did not hit the side of the ship upon recovery. However, this meant that when recovering the weight/CTD/end of the tubing one must lean out over the side of the ship and not use the ship railing as a counterbalance.
    - **In the future:** Results from 2021 suggest very minimal contamination of samples, so end of tubing is likely not a major contamination source if it stays clean during sampling effort. Will continue to monitor.
- **Hauling in the apparatus:** One 8lb weight plus the 1.5 kg (3.3 lbs) RBR CTD was about at the limit for one person to haul in comfortably and repeatedly. However, sometimes the weight was not enough to get the tubing down to desired depth.
    - **In the future:** Reconsider using a block and A-frame for tubing sampling. This may not be possible for quick deployment/recovery purposes. Crew suggested using Tenex line around the tubing rather than taping rope
- **Trace metal cleanliness:** Ideally, sampling would be done in a clean, positive pressure environment. Occasionally, filter apparatus and sample bottles were exposed to seaspray, water on the deck, surfaces inside the ship, or ungloved hands.
    - **Solutions at sea:** Using plastic bags and gloves as much as possible to protect samples from potential contamination.



View of trace metal pump sampling on deck



View of coiled rope and tubing with tape markings (left) and mini RBR CTD (red, white, black). Bucket used to collect waste flow during flushing with shackle attached to restrict the “bouncing” of the white C-flex tubing that occurs due to the pump pressure.

Close-up of pump with air regulator and air hose (blue) sitting on the mooring release pallets. It was necessary to use a ratchet strap to stabilize the pump so it did not move during sampling. Plastic bags were used as an extra precaution against contamination.

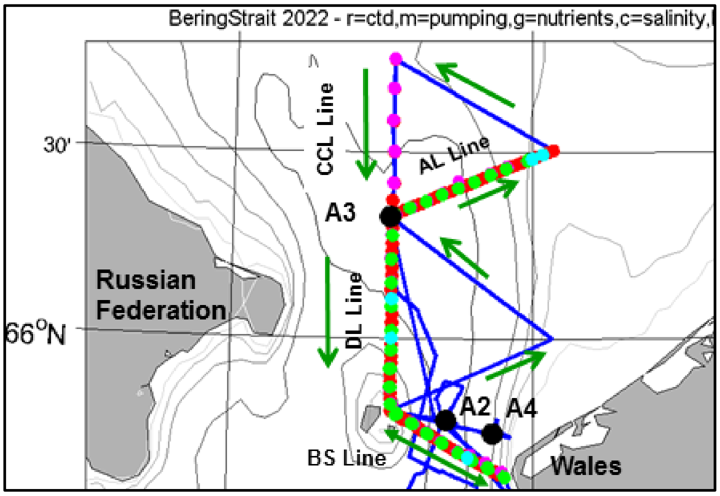
Clogged/used Acropak 200 (0.2um) filter. Top is the barbed connection that would be attached to the white C-flex tubing. To the right is the air valve that was opened during flushing to prevent bubbles from clogging the filter. Note that the folded Supor filter inside the capsule is dark green/brown after sampling due to clogging from plankton and sediment in the water.

Further details and table of nutrient samples is given below, in the nutrient sampling report.

BERING STRAIT 2022 CTD WATER SAMPLING REPORT (Jensen, Woodgate, Peralta-Ferriz, Jensen)

Water sampling (nutrients and salinity samples): *Woodgate & Peralta Ferriz*

With the new NSF grant this year, water sampling from the rosette became part of our at-sea work until 2026. Sampling is for:
(a) nutrients (to check the new SUNA nitrate sensor on the CTD package, and for non-nitrate nutrients); and
(b) salinity, to check bottle firing protocols were resulting in water in the bottle from the correct depth.



Water was taken from the rosette on **4 hydrographic lines, viz.** both runnings of the BS line, and on the AL and DI lines**.**

A total of 39 casts were sampled - 34 just for nutrients (green) , 4 just for salinity (cyan), and 1 for both salinity and nutrients (last cast of the cruise). (Main cruise map repeated here for ease of access.) Almost always nutrient sampling stations were coincident with pumped trace metal sampling stations (exceptions - CCL, pumping only; 3 stations in the middle of the DL line, nutrient only). This allows also for comparison between “pumped” nutrients and “bottle” nutrients.

A total of 169 nutrient samples were taken, including 6 duplicates (D or UF in table below), 4 of which were unfiltered (UF in table below). (Cast 88 (DL17) and Cast 109(DL1) have unfiltered duplicates taken from surface and bottom bottles . Cast 109 also has filtered duplicates taken from surface and bottom bottles

A total of 20 salinity samples were taken with no duplicates.

A 12-position rosette fitted with 11 x 1.5L Niskin bottles (position 6 remained open to accommodate the SUNA sensor) was deployed from the aft deck .

Bottles were tripped on the upcast, with **protocol of waiting 10s at the desired depth to allow for bottle flushing.** The salinity test (described below) shows this to give a good sample of the water at the firing depth. Upon recovery of the CTD, bottles were checked for signs of leaking from the bottom and by opening the spigot without loosening the gas valve to ensure that the bottle was airtight. Any leaks were noted in the paper logs (now scanned) and that bottle was not sampled. Generally two bottles were fired at each required depth (other than the surface) to give redundancy in case of leaks. This gave a non-leaking bottle to sample from in all but two cases (cast82 (AL12.5) at 30m and cast 100 (DL10) at 30m - no samples were taken from these depths). Measures to fix leaks (generally tightening of the lanyards, or twisting the cap so as to twist the internal rubber) were usually successful (see: issues encountered below). As the rosette has not been used for several years, many problems were encountered with leaking bottles and stiff spigots. Much of this related to o-rings needing servicing. **Action item: Overhaul rosette before 2023 cruise. Acquire complete o-ring spares kit.**

Nutrients: For the first running of each line, nutrient samples were taken at standard 10m levels, and bottom of the cast (targeted as 2m above the seafloor, though past experience shows 3 or 4m above bottom was more common. (This year no altimeter as on the rosette, so maximum target depth was determined from the ship’s echo sounder. Past experience has shown this to be accurate.) Since the bottom layer is typically well mixed, if this sampling regime meant less than 7m between the two lowest depths, the shallower depth was skipped. (Thus for bottom depth of 54m, bottles were at 54, 40, 30, 20, 10, surface.) This resulted in a maximum of 6 depths per cast. For the second running of the BS line, sample were taken only at bottom and surface, unless the system was clearly three layer, in which case a bottle was fired in the middle layer also. In the last cast of the cruise, only a surface sample was taken, as it was not a station planned for sampling, but it became clear before recovery that the weather was too poor to continue working. For the mooring calibration casts at A2 and A3, which carry SUNA sensors, bottles were fired 1m above and 1m below the expected instrument depth.

To match protocols used by others (Mordy, Danielson, Torres-Valdes), nutrient samples were filtered on sampling. Filtering is designed to remove microbes to prevent nutrients being consumed between sampling and processing. It also removes phytoplankton that otherwise might decompose while in the sample bottle. Recommended were **Whatman GF/F filter or Whatman nylon 0.45um filters**. (Finer filters, 0.2um, are generally not used, and indeed the smaller pore size may cause leakage from larger organisms crushed against the filter during sampling.) Another recommended filter was **Corning part #431220 0.45um surfactant free, cellulose acetate membrane** ($167 for 50). Although we ordered the latter in July for delivery same month, without notice the delivery date was moved to May 2023. We thus obtained two further recommendations:
Sterlitech, cellulose acetate syringe filters 0.45um, 25mm, 100 pack for $80,
https://www.sterlitech.com/cellulose-acetate-syringe-filters-sterlitech-0-45-micron-25mm-100-pk.html, and
FisherSci, https://www.fishersci.com/shop/products/choice-cellulose-acetate-ca-syringe-filters ($90 for 100).
We obtained 200 of each, and tests at UW showed both had no silicate contamination and were suitable for use. (Another recommendation, not acted on, was also from Fisher, 724-2045, Nalgene syringe filter, sfca membrane 0.45um, 25mm.) For the 2022 cruise we used the Sterlitech filters, using 71 for the entire cruise. (We found 1 filter could be used for 2 or 3 samples and still give reasonable flow rate.)

Sampling protocol was as follows: A 60 CC plastic syringe was rinsed with water from the desired bottle three times and fitted with an syringe filter (luer lock). The 60 mL HDPE sample bottle ad cap was then rinsed three times with filtered water (~5-10 mL) and filled to approximately 45 mL. Pressure was applied to the filter by hand. (Use of a caulking gun was found to break the syringes too easily.) Powder free vinyl gloves (not neoprene, not colored nitrile) were worn for sampling. Immediately upon collection, samples were logged and double bagged in sets of 5 and put into a -22degC freezer upright. After they were frozen, samples were combined into larger bags and stored in the same freezer. Samples were transported in a cooler with icepacks back to Seattle as hold luggage on the day the ship docked and transferred to UW freezers that evening. Samples will be analyzed by the UW Marine Chemistry Laboratory, for nitrate, nitrite, ammonia, silicate and phosphate.

To investigate the effect of filtering, some unfiltered samples were taken during the cruise in regions of high productivity in surface and bottom waters (cast 88, DL17; and cast 109, DL1). Normal duplicates were also taken at cast 109 from surface and bottom bottles.

The trace metal pumping also collected nutrients, using a 0.2um capsule filter. Tests at sea at the end of the cruise showed the niskin bottles did have enough head to give flow though this filter, however, since the flushing volume is greater and harder to keep track of, and water is limited, we propose to continue with the syringe technique.

Note that due to some confusion in the many freezers in UW Oceanography, some samples became partially thawed while in Seattle. Full notes on this exist and will be added to this report once nutrient analysis is complete.

Issues encountered:

Test casts: (Note, no samples were taken from leaking bottles)

Cast 005: leaky o-ring on bottle #7, which was switched out with bottle #6 that was not being used.

Cast 006: had three leaky bottles and subsequently modifications were made on all bottles. Nipple/spigot o-rings were replaced on bottles 1, 5, 6, 7, 12 and the internal rubber holding the top and bottom stoppers were twisted on nearly every Niskin to ensure a better fit during firing.

Cast 009: 9, 11, 12, bottle leaking, and 5 a little

Cast 010: 5,12,2 leaking; adding extra twists

Cast 011: 4,11,12 leaking (put in extra twists)

Cast 012: 5, 9, 11 12 and maybe 10 are leaking

Cast 013: Zipties added to top of bottles 5,11,12 before cast

Subsequent cast issues during sampling:

Cast 035: nutrient sample bottle # was very faint (it was 2075).

Cast 057: Bottle #3 was leaky, no samples taken from it

Cast 063: Bottle #9 was leaky, samples collected from #8 instead

Cast 066: Bottle #5 was leaky, no samples taken

Cast 071: salinity cast. Bottle #3 spigot was pushed. Bottle #7 was leaky, one twist added.

Cast 082: Bottles #5, 7, 8, and 9 were leaking from the top

Cast 100: Bottles #5, 7, 8, 12 were leaking. Twists were added and surface sample from #12 was still taken.

Cast 103: Bottle #3 leaky from top.

Notes on partial thawing:

Unfortunately, a subset of nutrient samples (both Jensen and Woodgate&Peralta Ferriz) were thawed for up to 76 hours in a 4°C environment soon after arrival in Seattle, due to a confusion as to freezer temperatures. This partial thawing occurred from Friday afternoon (7th October 2022) to early Monday morning (10th October 2022). Some of these samples were still cold to the touch with ice crystals visible, but most were completely thawed.

Affected samples were in bags 1, 3, 4, 6, and 7, noted in the Freezer bag # column of the tables below.

Jensen was able to refreeze all samples later in a -20°C freezer upright. All were completely refrozen by the evening of 10th October 2022.

This partial thawing did not affect all samples. In particular, 62 samples were not moved between the freezers and thus remained completely frozen. These samples were in bags 2 and 5 and are highlighted in red in the tables below.

Discussion with various nutrient chemists suggests this should not have compromised the quality of the nutrient data. However, comparison between affected and unaffected samples is obviously in order. Fortunately, some of the cruise duplicates were split from their double during this process, allowing some assessment of the impact of this partial refreezing (although it will be impossible to separate that effect from differences due to sampling).

April 2023 Note: An analysis of duplicates and casts (details below) suggest that indeed this partial melting did not result any significant error increase in the data.

LIST OF **APL** NUTRIENT SAMPLES. Red highlight indicates no partial thaw. * has duplicate, UF unfiltered duplicate

Station	Latitude(degN)	Longitude(degW)	Cast	Niskin #	Target depth (db)	Sample #	Freezer bag #
A3	66.32885	168.951983	18	11	45	3315	1
A3	66.32885	168.951983	18	1	47	3316	1
BS22	65.6307833	168.186533	20	1	30	3318	1
BS22	65.6307833	168.186533	20	3	20	3319	1
BS22	65.6307833	168.186533	20	5	10	3320	1
BS22	65.6307833	168.186533	20	9	0	3321	1
BS20.5	65.651	168.288683	23	10	0	3313	4
BS20.5	65.651	168.288683	23	5	20	3314	4
BS20.5	65.651	168.288683	23	8	10	3322	4
BS20.5	65.651	168.288683	23	1	43	3326	4
BS20.5	65.651	168.288683	23	3	30	3327	4
BS19	65.6726667	168.3934	26	5	30	2103	4
BS19	65.6726667	168.3934	26	12	0	2104	4
BS19	65.6726667	168.3934	26	3	40	3323	4
BS19	65.6726667	168.3934	26	11	10	3324	4
BS19	65.6726667	168.3934	26	9	20	3325	4
BS19	65.6726667	168.3934	26	1	50	3328	4
BS17.5	65.6942333	168.486933	29	5	30	2092	1
BS17.5	65.6942333	168.486933	29	8	20	2093	1
BS17.5	65.6942333	168.486933	29	3	40	2094	1
BS17.5	65.6942333	168.486933	29	10	10	2100	1
BS17.5	65.6942333	168.486933	29	1	52	2101	1
BS17.5	65.6942333	168.486933	29	12	0	2102	1
BS16	65.72085	168.5899	32	3	40	2076	1
BS16	65.72085	168.5899	32	1	49	2077	4
BS16	65.72085	168.5899	32	7	20	2078	4
BS16	65.72085	168.5899	32	5	30	2079	4
BS16	65.72085	168.5899	32	12	0	2090	4
BS16	65.72085	168.5899	32	9	10	2091	4
BS14.5	65.7455	168.691383	35	3	40	2075	1
BS14.5	65.7455	168.691383	35	8	20	2095	1
BS14.5	65.7455	168.691383	35	12	0	2096	1
BS14.5	65.7455	168.691383	35	10	10	2097	1
BS14.5	65.7455	168.691383	35	5	30	2098	1
BS14.5	65.7455	168.691383	35	1	49	2099	1
BS13	65.77115	168.792783	38	12	0	2080	2
BS13	65.77115	168.792783	38	10	10	2081	2
BS13	65.77115	168.792783	38	3	40	2082	2
BS13	65.77115	168.792783	38	8	20	2083	3

BS13	65.77115	168.792783	38	5	30	2084	2
BS13	65.77115	168.792783	38	1	50	2089	2
BS11.5	65.79935	168.891667	41	5	20	2073	2
BS11.5	65.79935	168.891667	41	3	30	2074	2
BS11.5	65.79935	168.891667	41	1	45	2085	2
BS11.5	65.79935	168.891667	41	8	10	2086	2
BS11.5	65.79935	168.891667	41	10	0	2088	2
A2	65.7816	168.5644	43	11	48	2087	4
A2	65.7816	168.5644	43	1	50	3265	3
AL12.5	66.3333333	168.9215	45	3	40	2071	4
AL12.5	66.3333333	168.9215	45	7	30	2072	4
AL12.5	66.3333333	168.9215	45	10	10	2175	4
AL12.5	66.3333333	168.9215	45	12	0	2176	4
AL12.5	66.3333333	168.9215	45	8	20	3266	4
AL12.5	66.3333333	168.9215	45	1	54	3267	3
AL14	66.3515	168.8215	48	10	10	2169	4
AL14	66.3515	168.8215	48	8	20	3268	3
AL14	66.3515	168.8215	48	12	0	3269	4
AL14	66.3515	168.8215	48	7	30	3270	4
AL14	66.3515	168.8215	48	3	40	3271	4
AL14	66.3515	168.8215	48	1	54	3272	4
AL15.5	66.3683667	168.713333	51	5	30	2065	3
AL15.5	66.3683667	168.713333	51	8	20	2066	3
AL15.5	66.3683667	168.713333	51	10	10	2067	3
AL15.5	66.3683667	168.713333	51	12	0	2068	3
AL15.5	66.3683667	168.713333	51	2	50	2069	3
AL15.5	66.3683667	168.713333	51	3	40	2070	3
AL17	66.3744	168.6033	54	10	10	2165	1
AL17	66.3744	168.6033	54	12	0	2166	1
AL17	66.3744	168.6033	54	3	40	2167	1
AL17	66.3744	168.6033	54	5	30	2168	4
AL17	66.3744	168.6033	54	8	20	2173	1
AL17	66.3744	168.6033	54	1	54	2174	1
AL18.5	66.4040833	168.498117	57	10	10	2157	5
AL18.5	66.4040833	168.498117	57	2	51	2158	5
AL18.5	66.4040833	168.498117	57	8	20	2159	5
AL18.5	66.4040833	168.498117	57	12	0	2170	5
AL18.5	66.4040833	168.498117	57	4	40	2171	5
AL18.5	66.4040833	168.498117	57	5	30	2172	4
AL20	66.4214167	168.388917	60	10	10	2156	2
AL20	66.4214167	168.388917	60	12	0	2160	2

AL20	66.4214167	168.388917	60	5	30	2161	2
AL20	66.4214167	168.388917	60	3	40	2162	2
AL20	66.4214167	168.388917	60	1	51	2163	2

JENSEN NUTRIENT SAMPLES. Position, cast, and depth as per trace metal samples. Red highlight indicates no partial thaw

Station name	Latitude (degN)	Latitude (degW)	Cast	Target depth (db)	Sample #	Freezer bag #
BS22 surf	65.63345	168.189867	1	5	1413	7
BS22 bot	65.63345	168.189867	1	25	1412	7
BS20.5 surf	65.6605	168.299	2	5	1411	7
BS20.5 bot	65.6605	168.299	2	35	1410	7
BS19 surf	65.67985	168.400833	3	5	1409	7
BS19 bot	65.67985	168.400833	3	45	1418	7
BS17.5 surf	65.6943333	168.485983	4	5	1417	7
BS17.5 bot	65.6943333	168.485983	4	40	1416	7
BS16 surf	65.7201333	168.587783	5	5	1415	7
BS16 bot	65.7368	168.587783	5	40	1414	7
BS14.5 surf	64.7437833	168.684167	6	5	1428	7
BS14.5 bot	64.7437833	168.684167	6	45	1427	7
BS13 surf	65.7437833	168.684167	7	5	1425	7
BS13 bot	65.7437833	168.684167	7	40	1426	7
BS11.5 surf	65.7983333	168.887333	8	5	1424	7
BS11.5 bot	65.7983333	168.887333	8	40	1448	7
AL12.5 surf	66.3329667	168.914667	9	5	1447	7
AL12.5 bot	66.3329667	168.914667	9	40	1446	7
AL14 surf	66.3509333	168.814417	10	5	1444	7
AL14 surf	66.3509333	168.814417	10	5	1445	7
AL14 surf	66.3509333	168.814417	10	40	1442	7
AL14 surf	66.3509333	168.814417	10	40	1443	7
AL15.5 surf	66.3687	168.707617	11	5	1441	7
AL15.5 surf	66.3687	168.707617	11	45	1440	7
AL17 surf	66.3880833	168.603	12	5	1439	6
AL17 bot	66.3880833	168.603	12	45	1438	7
AL18.5 surf	66.4045667	168.49355	13	5	1436	6
AL18.5 surf	66.4045667	168.49355	13	45	1437	6
AL20 surf	66.4214167	168.388917	14	5	1435	6
AL20 surf	66.4214167	168.388917	14	45	1434	6
AL21.5 surf	66.4411667	168.280333	15	5	1433	6
AL21.5 surf	66.4411667	168.280333	15	35	1432	6
AL23 surf	66.4581167	168.173417	16	5	1431	6
AL23 surf	66.4581167	168.173417	16	30	1430	6

AL25 surf	66.48035	168.028083	17	5	1429	6
AL25 bot	66.48035	168.028083	17	20	1423	6
CCL8.5 surf	66.7505667	168.93045	18	5	1422	6
CCL8.5 bot	66.7505667	168.93045	18	35	1421	6
CCL8 surf	66.6716833	168.93605	19	5	1420	6
CCL8 bot	66.6716833	168.93605	19	35	1419	6
CCL7 surf	66.58585	168.93915	20	5	2054	6
CCL7 bot	66.58585	168.93915	20	40	2053	6
CCL6 surf	66.50195	168.928417	21	5	2052	6
CCL6 bot	66.50195	168.928417	21	40	2051	6
CCL5 surf	66.4172667	168.928433	22	5	2050	6
CCL5 bot	66.4172667	168.928433	22	45	2049	6
AL12.5 surf rpt	66.3337333	168.923667	23	5	1472	6
AL12.5 bot rpt	66.3337333	168.923667	23	40	1471	6
DL18.5 surf	66.2770167	168.934783	24	5	1470	6
DL18.5 surf	66.2770167	168.934783	24	45	1469	6
DL17 surf	66.2135	168.9418	25	5	2063	6
DL17 bot	66.2135	168.9418	25	45?	2062	6
DL15.5 surf	66.15105	168.937217	26	5	2064	6
DL15.5 surf	66.15105	168.937217	26	45	2061	6
DL7 surf	65.9190167	168.9345	27	5	2060	6
DL7 bot	65.9190167	168.9345	27	45	2059	6
DL4 surf	65.8690167	168.935533	28	5	2058	6
DL4 bot	65.8690167	168.935533	28	40	2057	6
DL1 surf	65.8233167	168.929067	29	5	2055	5
DL1 surf	65.8233167	168.929067	29	5	2056	5
DL1 bot	65.8233167	168.929067	29	43	1467	5
DL1 bot	65.8233167	168.929067	29	43	1468	5
BS11.5 rpt surf	65.7944833	168.937067	30	5	1466	3
BS11.5 rpt bot	65.7944833	168.937067	30	40	1465	3
BS13 rpt surf	65.7737333	168.793383	31	5	1464	3
BS13 rpt bot	65.7737333	168.793383	31	45	1453	3
BS14.5 rpt surf	65.7477833	168.694083	32	5	1452	6
BS14.5 rpt bot	65.7477833	168.694083	32	45	1451	6
BS16 rpt surf	65.7212667	168.594217	33	5	1450	6
BS16 rpt bot	65.7212667	168.594217	33	45	1449	6
BS17.5 rpt surf	65.6935833	168.4888	34	5	1463	5
BS17.5 rpt bot	65.6935833	168.4888	34	45	1462	5
BS18.5 surf	65.682	168.422433	35	5	1461	5
BS18.5 bot	65.682	168.422433	35	45	1460	5

Salinity sampling: It is customary on CTD bottle sampling, to close bottles on the upcast, after a usually fairly short wait to allow the CTD to equilibrate. How long a wait seems to vary by science party, and indeed GEOTRACES protocols are to fire bottles on the fly without stopping. A recent study [*Paver et al.*, 2020] suggests that, due to insufficient bottle flushing, this can result in the water in the bottle being at least in part from a different depth to the depth of bottle firing. Swift [2010], in GO-SHIP protocols discuss this (long standing) issue and conclude waiting 2 ship rolls is sufficient. However, Paver *et al.,* [2020] challenge this, citing examples from the 2002 SBI cruise, where bottles fired just above steep salinity gradients had salinities greater than the salinity at the firing depth. Paver *et al.,* [2020] uses at sea tests to recommend that, in addition to bottles being rigged so the caps do not obstruct the bottle entrances, one should wait at least 3 ship rolls before closing bottles. Their tests are, however, not entirely conclusive, as they fire bottles on, rather than above, the salinity gradient, and are thus there is an inherent bias between the depth of the bottle and the depth of the CTD mounted below it. However, the issue was brought up as a concern during proposal review and was worthy of testing.

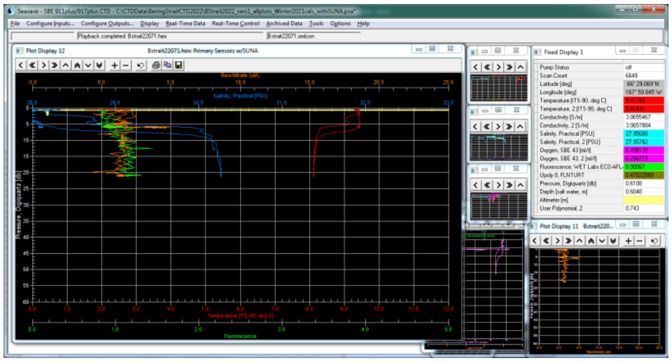
Our standard bottle firing protocol was to wait 10s before firing bottles. Other plans (e.g., wait till the upcast salinity matches the downcast) were too subjective to be useful. To test our standard plan, we chose stations where there was a strong salinity step between the lower and the upper layer, effectively the worst case scenario. At these stations, we fired a series of bottles at the next usual sampling depth above the salinity step. These bottles were fired after a total of 10s, 20s, 30s, and 1minute, and sampled for salinity. (As usual, two or more bottles were fired at each time interval, but only one was sampled.) Samples (~250mL, unfiltered) were collected in glass salinity bottles, after 3 rinses of bottle and cap, and were taken as hold luggage to UW after the cruise for analysis at the UW Marine Chemistry Lab. Preliminary results are given below.

LIST OF SALINITY SAMPLES

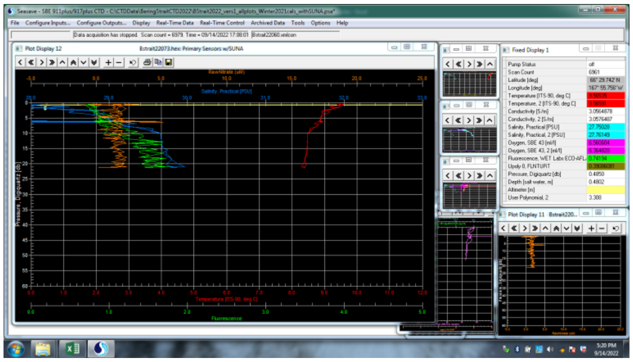
Station	Cast	Latitude (degN)	Longitude (degW)	Bottle #	Target Depth (db)	Sample #
AL 25.5	71	66.4834	168.0012	2	0	217
AL 25.5	71	66.4834	168.0012	4	0	218
AL 25.5	71	66.4834	168.0012	5	0	219
AL 25.5	71	66.4834	168.0012	9	0	220
AL 26.5	73	66.4951	167.9295	1	0	221
AL 26.5	73	66.4951	167.9295	3	0	222
AL 26.5	73	66.4951	167.9295	5	0	223
AL 26.5	73	66.4951	167.9295	8	0	224
DL14.5	93	66.1063	168.9334	1	0	226
DL14.5	93	66.1063	168.9334	3	0	225
DL14.5	93	66.1063	168.9334	5	0	227
DL14.5	93	66.1063	168.9334	8	0	228
DL12	98	66.0000	168.9327	1	10	234
DL12	98	66.0000	168.9327	3	10	231
DL12	98	66.0000	168.9327	5	10	233
DL12	98	66.0000	168.9327	8	10	232
BS18.5	125	65.6853	168.4264	1	0	229
BS18.5	125	65.6853	168.4264	3	0	230
BS18.5	125	65.6853	168.4264	7	0	235
BS18.5	125	65.6853	168.4264	9	0	236

Five casts were sampled in this manner. The SeaSave diagram for each cast gives a (rather messy) idea of the stratification:

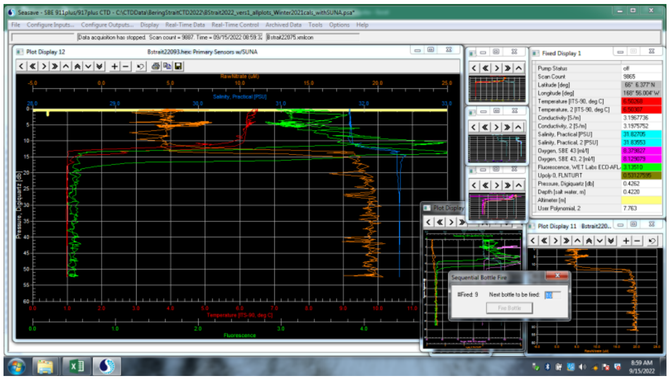
Cast 71



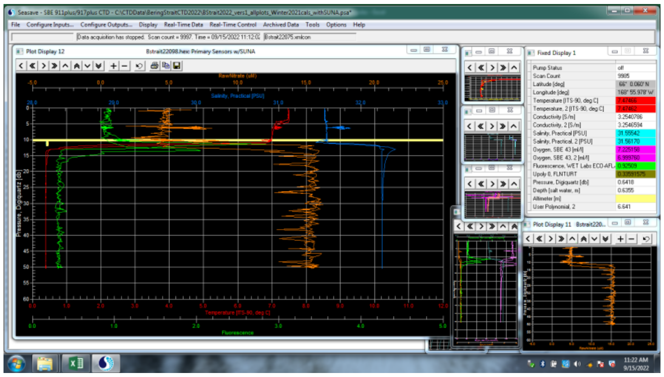
Cast 73



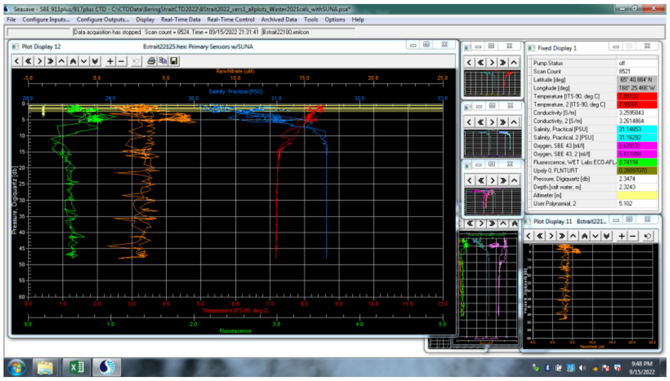
Cast 93



Cast 98



Cast 125

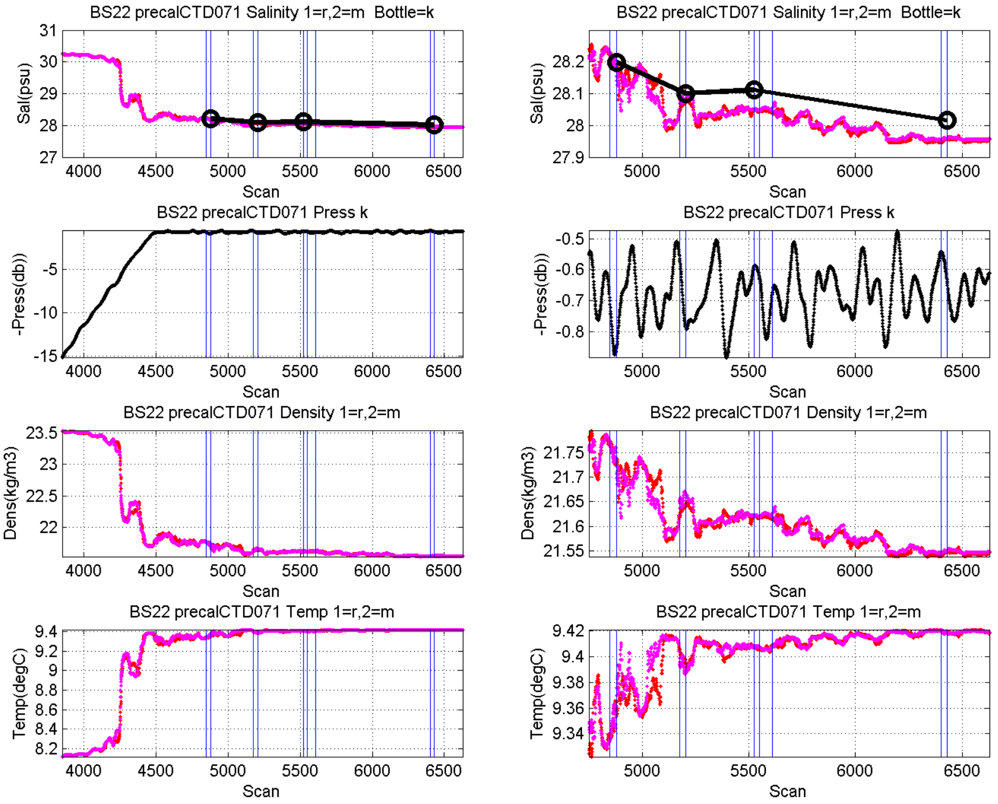


(This was the final cast of the cruise, and thus although not our ideal experimental set up, was taken as it was the last opportunity.)

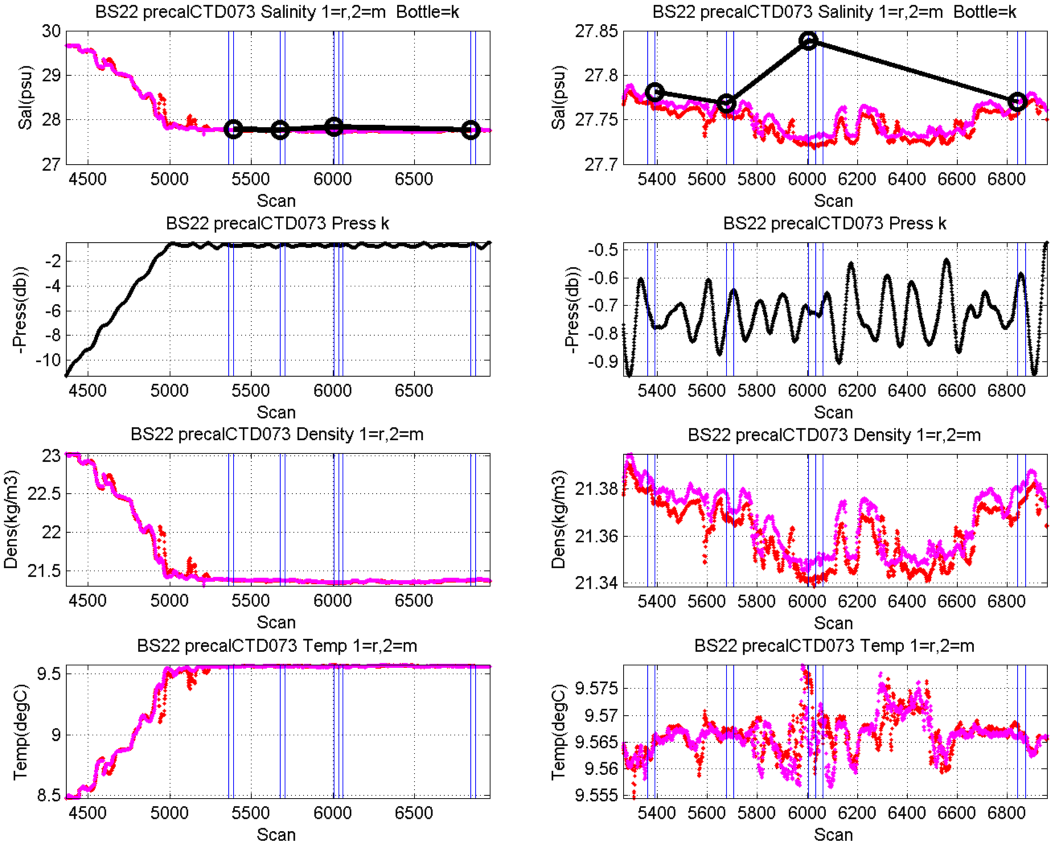
The following plots, are timeseries per cast (large scale left, zoomed scales right), showing sample salinities (black circles) and CTD data (lines). Note these are using the CTD precalibration and there is an obvious offset between the two salinity sensors. **Nonetheless, it is clear the 10s wait is sufficient to obtain a flushed bottle with this system. Cast 125 is particularly informative. The CTD drifts into saltier water during the wait between bottles, but the bottle salinities capture this transition extremely well.**

Note one sample, cast 73, 30s sample, lies outside the range of the others, suggesting perhaps a leaking bottle or some other sampling issue.

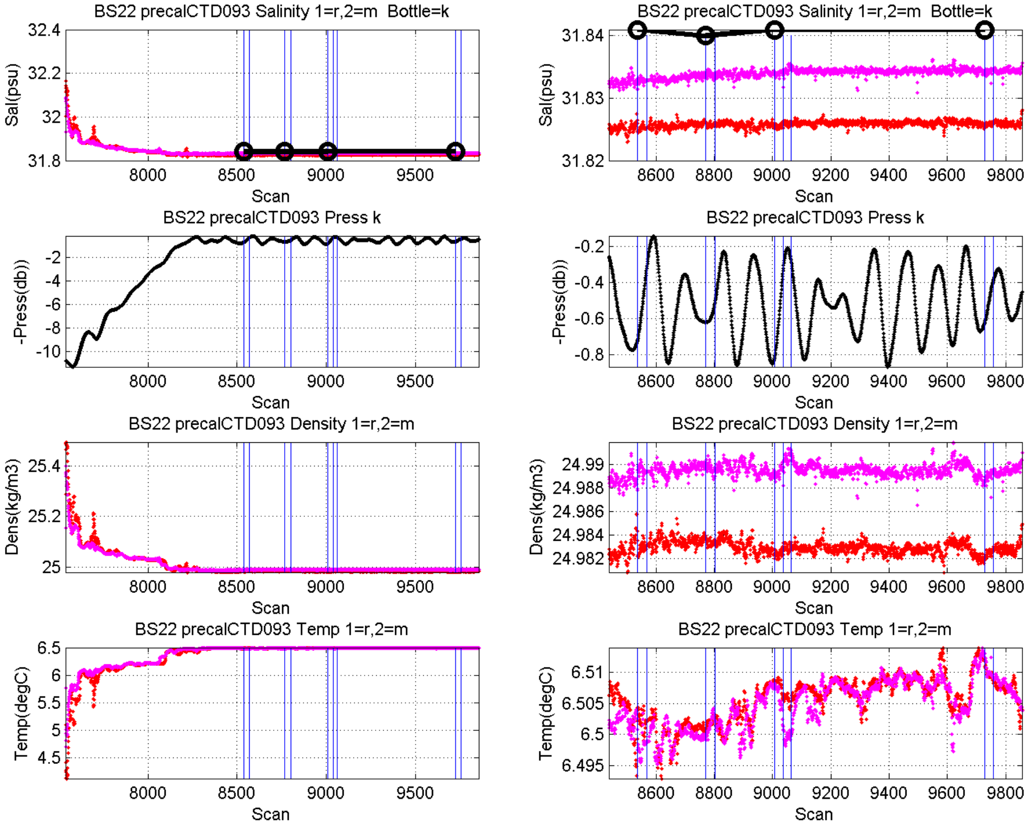
Cast 71: Here you might believe in an offset .. but it doesn't get better .. in fact it gets worse with time



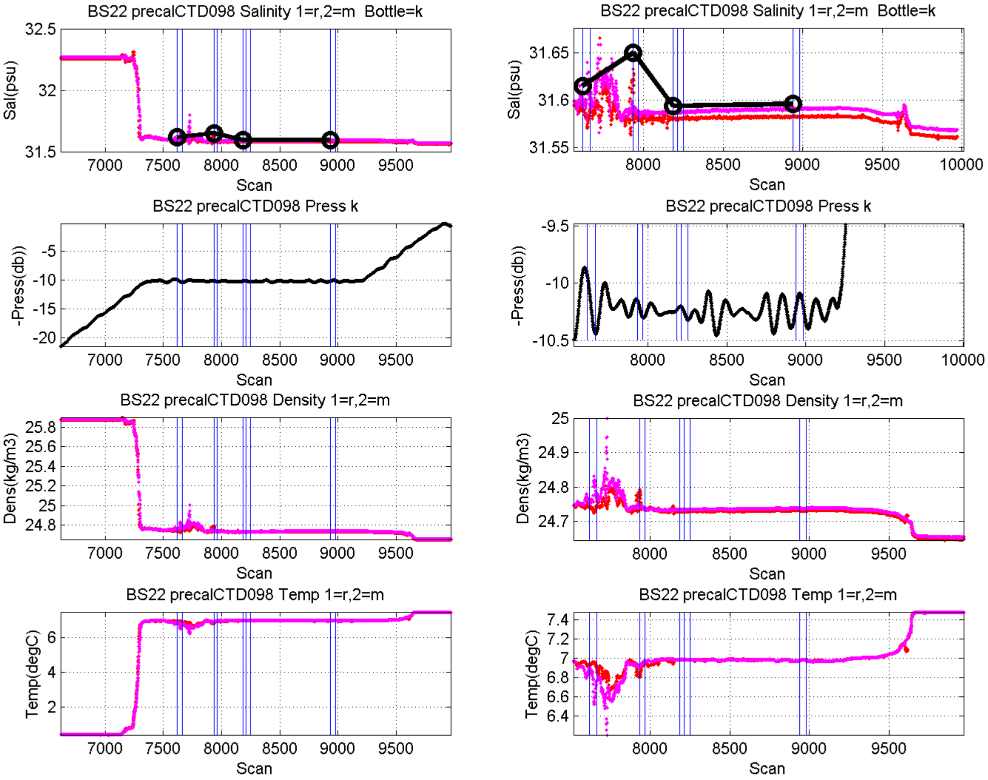
Cast 73: The 30s bottle seems erroneous … BUT diff otherwise are always small



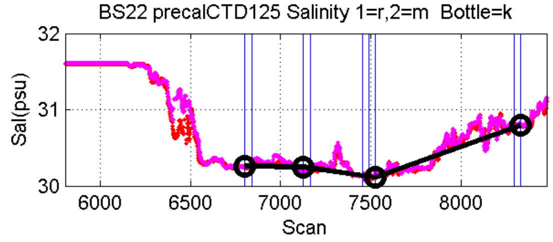
Cast 93: Note discrepancy between sensors. Bottles are close, though the density step is small and ill defined

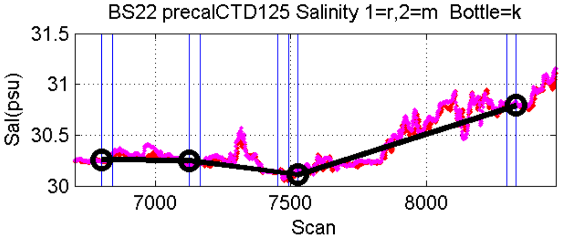


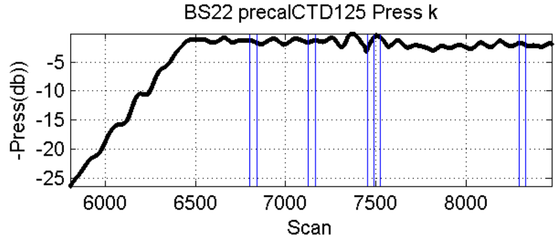
Cast 98: When zoom, see the same resolution as the 1-2 difference. Note noise in both the CTD the bottles

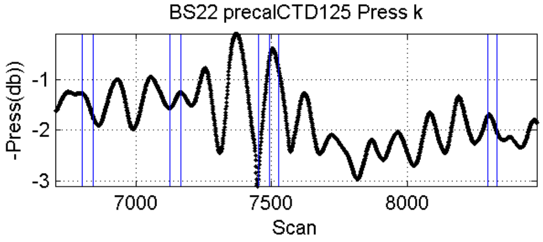


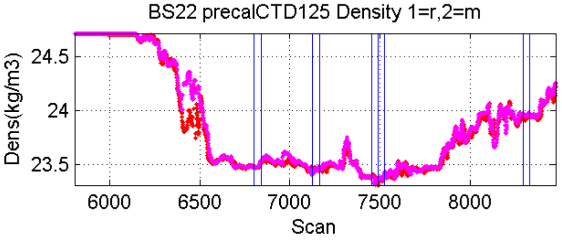
Cast 125: Again close, but note here how the ship drifts back into much saltier water as you wait. So waiting long not a good idea. But this cast shows the bottles are flushing well, as they track this salinity change.

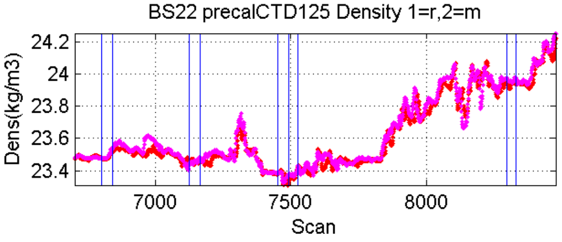

BS22 precalCTD125 Salinity 1=r,2=m Bottle=k

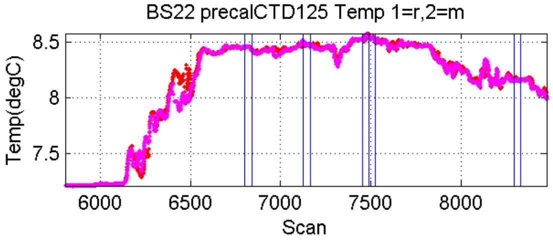

BS22 precalCTD125 Salinity 1=r,2=m Bottle=k

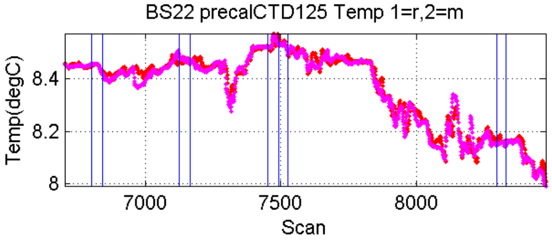

BS22 precalCTD125 Press k

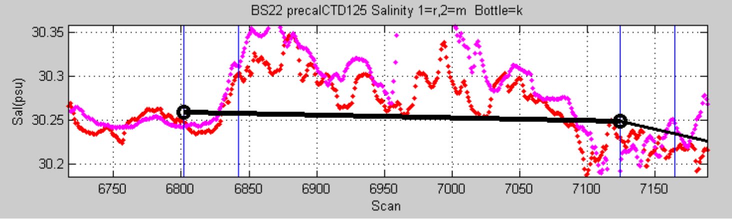

BS22 precalCTD125 Press k


BS22 precalCTD125 Density 1=r,2=m


BS22 precalCTD125 Density 1=r,2=m


BS22 precalCTD125 Temp 1=r,2=m


BS22 precalCTD125 Temp 1=r,2=m


BS22 precalCTD125 Salinity 1=r,2=m Bottle=k

Zoom in on first

CONCLUDE:

- waiting too long is a problem in an area with this variability - can drift out of your water mass
- one bottle anomalously off - **Action item: investigate**
- Cast 125 shows this is flushing well as Bottle tracks salinity changes. Sampling is 24Hz, so 500 samples is ~ 20s.
- ship is rolling at about 2 complete roles in 10s ... amplitude about 0.4m
- difference usually ~0.01psu which is comparable with difference between sensors.

Cast	**DS to lower layer**	**DZ to lower layer**	**Roll Amp (peak to peak)**	**DS to Sal1 at 10s**	**20s**	**30s**	**60s**
71	2psu	5m	0.3m	0psu	0psu	0.05	0.05
73	1.5psu	Grad	0.2m	0.01psu	0psu	0.12!!	0psu
93	0.1psu	Grad	0.6m	<0.01psu	<0.01psu	<0.01psu	<0.01psu
98	0.7psu	2m	0.3m	0	0.05	<0.01psu	<0.01psu
125	1.1psu	8m	1m	0	0	0	0

So 10s pause gives good flushing ... and might even be too long. **Action item: Test that next year.**

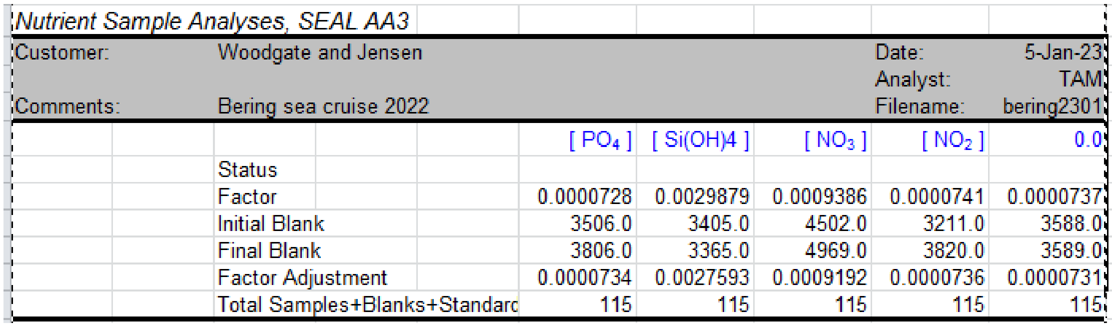
Apr2023: Update on Nutrient Analysis. Samples were analyzed for nutrients (Phosphate (PO4), Silicate (SO4), Nitrate (NO3), Nitrite (NO2) and ammonia (NH4)) in early Jan 2023 (5th-9th) by the UW Marine Chemistry Lab https://www.ocean.washington.edu/story/Marine_Chemistry_Laboratory ,using a Seal Analytical AA3, following protocols of the WOCE Hydrographic Program, UNESCO, 1994, Protocols for the joint global ocean flux study (JGOFS) core measurements. Vol. 29.

Minimum Detection Limits are:

0.03uM(PO4), 0.45uM(SO4), 0.18uM(NO3), 0.01uM(NO2), 0.09uM(NH4)

Analysis summaries are below. Data are combined into one file including post-cruise processed data from the CTD cast, averaged over the 2s immediately after the bottle fired. On cast 60, CTD sensors returned bad data and so data from the downcast is instead extracted for the bottle firing depths. The surface bottle was taken at 0.5db, however, the downcast started only a 1db, so data from those depths is used instead.

2301

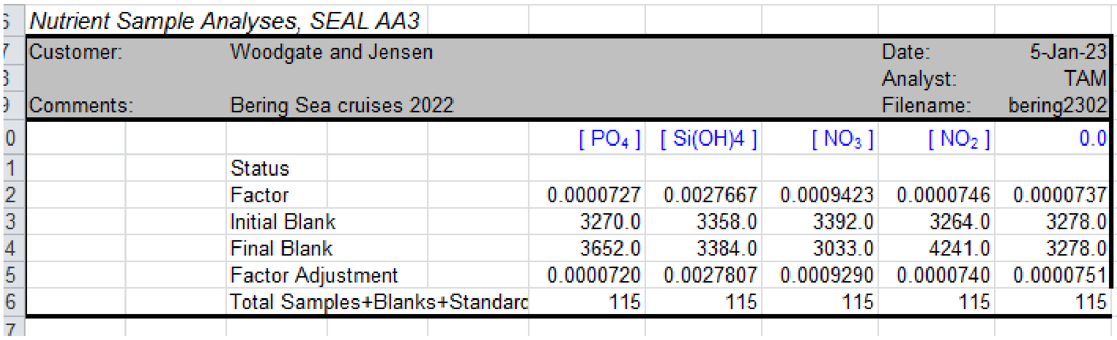


Nutrient Sample Analyses, SEAL AA3

Customer:	Woodgate and Jensen	Date:	5-Jan-23
		Analyst:	TAM
Comments:	Bering sea cruise 2022	Filename:	bering2301

	[PO_4]	[Si(OH)4]	[NO_3]	[NO_2]	0.0
Status					
Factor	0.0000728	0.0029879	0.0009386	0.0000741	0.0000737
Initial Blank	3506.0	3405.0	4502.0	3211.0	3588.0
Final Blank	3806.0	3365.0	4969.0	3820.0	3589.0
Factor Adjustment	0.0000734	0.0027593	0.0009192	0.0000736	0.0000731
Total Samples+Blanks+Standarc	115	115	115	115	115

2302

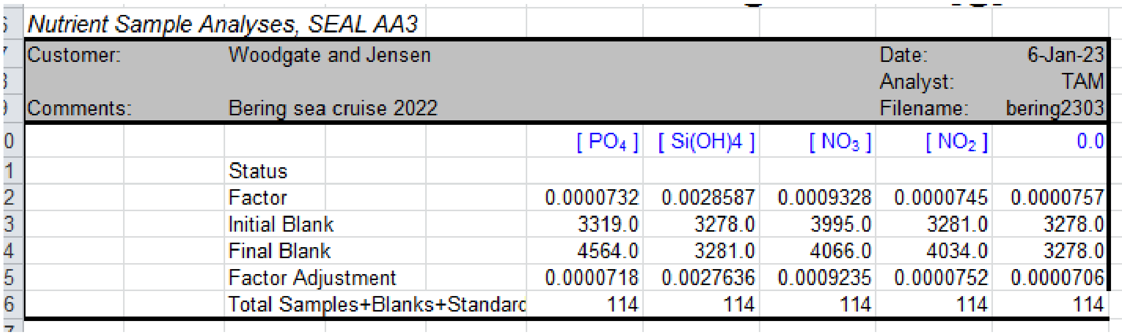


Nutrient Sample Analyses, SEAL AA3

Customer:	Woodgate and Jensen	Date:	5-Jan-23
		Analyst:	TAM
Comments:	Bering Sea cruises 2022	Filename:	bering2302

	[PO_4]	[Si(OH)4]	[NO_3]	[NO_2]	0.0
Status					
Factor	0.0000727	0.0027667	0.0009423	0.0000746	0.0000737
Initial Blank	3270.0	3358.0	3392.0	3264.0	3278.0
Final Blank	3652.0	3384.0	3033.0	4241.0	3278.0
Factor Adjustment	0.0000720	0.0027807	0.0009290	0.0000740	0.0000751
Total Samples+Blanks+Standarc	115	115	115	115	115

2303

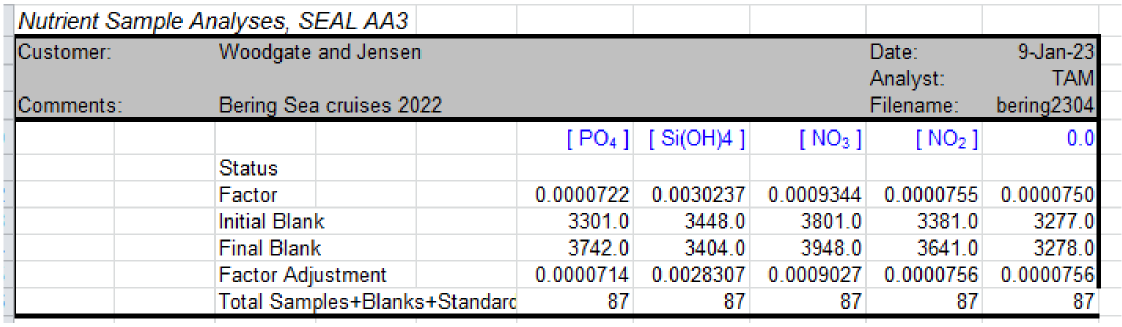


Nutrient Sample Analyses, SEAL AA3

Customer:	Woodgate and Jensen	Date:	6-Jan-23
		Analyst:	TAM
Comments:	Bering sea cruise 2022	Filename:	bering2303

	[PO_4]	[Si(OH)4]	[NO_3]	[NO_2]	0.0
Status					
Factor	0.0000732	0.0028587	0.0009328	0.0000745	0.0000757
Initial Blank	3319.0	3278.0	3995.0	3281.0	3278.0
Final Blank	4564.0	3281.0	4066.0	4034.0	3278.0
Factor Adjustment	0.0000718	0.0027636	0.0009235	0.0000752	0.0000706
Total Samples+Blanks+Standarc	114	114	114	114	114

2304



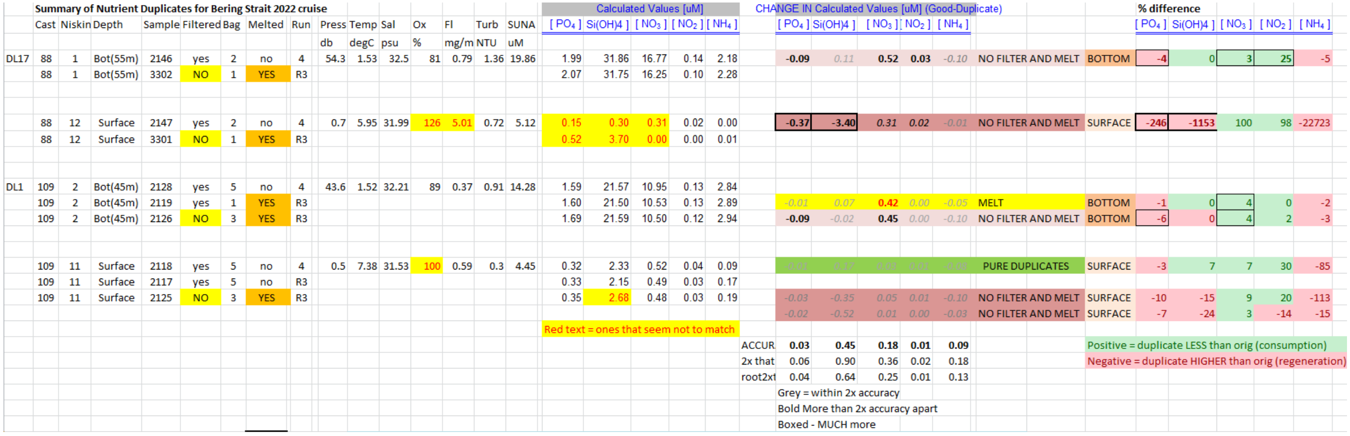
Nutrient Sample Analyses, SEAL AA3

Customer:	Woodgate and Jensen	Date:	9-Jan-23
		Analyst:	TAM
Comments:	Bering Sea cruises 2022	Filename:	bering2304

	[PO_4]	[Si(OH)4]	[NO_3]	[NO_2]	0.0
Status					
Factor	0.0000722	0.0030237	0.0009344	0.0000755	0.0000750
Initial Blank	3301.0	3448.0	3801.0	3381.0	3277.0
Final Blank	3742.0	3404.0	3948.0	3641.0	3278.0
Factor Adjustment	0.0000714	0.0028307	0.0009027	0.0000756	0.0000756
Total Samples+Blanks+Standarc	87	87	87	87	87

Results from Duplicates:

Summary of results from duplicates is given here.



	Summary of Nutrient Duplicates for Bering Strait 2022 cruise															Calculated Values [uM]					CHANGE IN Calculated Values [uM] (Good-Duplicate)								% difference				
	Cast	Niskin	Depth	Sample	Filtered	Bag	Melted	Run	Press	Temp	Sal	Ox	Fl	Turb	SUNA	[PO_4]	Si(OH)4]	[NO_3]	[NO_2]	[NH_4]		[PO_4]	Si(OH)4]	[NO_3]	[NO_2]	[NH_4]			[PO_4]	Si(OH)4]	[NO_3]	[NO_2]	[NH_4]
									db	degC	psu	%	mg/m	NTU	uM																		
DL17	88	1	Bot(55m)	2146	yes	2	no	4	54.3	1.53	32.5	81	0.79	1.36	19.86	1.99	31.86	16.77	0.14	2.18		**-0.09**	0.11	**0.52**	**0.03**	-0.10	NO FILTER AND MELT	BOTTOM	-4	0	3	25	-5
	88	1	Bot(55m)	3302	NO	1	YES	R3								2.07	31.75	16.25	0.10	2.28													
	88	12	Surface	2147	yes	2	no	4	0.7	5.95	31.99	126	5.01	0.72	5.12	0.15	0.30	0.31	0.02	0.00		**-0.37**	**-3.40**	0.31	0.02	-0.01	NO FILTER AND MELT	SURFACE	-246	-1153	100	98	-22723
	88	12	Surface	3301	NO	1	YES	R3								0.52	3.70	0.00	0.00	0.01													
DL1	109	2	Bot(45m)	2128	yes	5	no	4	43.6	1.52	32.21	89	0.37	0.91	14.28	1.59	21.57	10.95	0.13	2.84													
	109	2	Bot(45m)	2119	yes	1	YES	R3								1.60	21.50	10.53	0.13	2.89		-0.01	0.07	**0.42**	0.00	-0.05	MELT	BOTTOM	-1	0	4	0	-2
	109	2	Bot(45m)	2126	NO	3	YES	R3								1.69	21.59	10.50	0.12	2.94		**-0.09**	-0.02	**0.45**	0.00	-0.10	NO FILTER AND MELT	BOTTOM	-6	0	4	2	-3
	109	11	Surface	2118	yes	5	no	4	0.5	7.38	31.53	100	0.59	0.3	4.45	0.32	2.33	0.52	0.04	0.09		-0.01	0.17	0.03	0.01	-0.08	PURE DUPLICATES	SURFACE	-3	7	7	30	-85
	109	11	Surface	2117	yes	5	no	R3								0.33	2.15	0.49	0.03	0.17													
	109	11	Surface	2125	NO	3	YES	R3								0.35	2.68	0.48	0.03	0.19		-0.03	-0.35	0.05	0.01	-0.10	NO FILTER AND MELT	SURFACE	-10	-15	9	20	-113
																						-0.02	-0.52	0.01	0.00	-0.03	NO FILTER AND MELT	SURFACE	-7	-24	3	-14	-15
																Red text = ones that seem not to match																	
																					ACCUR	**0.03**	**0.45**	**0.18**	**0.01**	**0.09**		Positive = duplicate LESS than orig (consumption)					
																					2x that	0.06	0.90	0.36	0.02	0.18		Negative = duplicate HIGHER than orig (regeneration)					
																					root2xt	0.04	0.64	0.25	0.01	0.13							
																						Grey = within 2x accuracy											
																						Bold More than 2x accuracy apart											
																						Boxed - MUCH more											

We consider situations where the difference between duplicates is greater than twice the analytic detection limit.
Note all of our unfiltered duplicates also underwent partial melting in early October.

Conclude:
1) Pure duplicates (1sample only, no melt and all filtered, and low nuts) agree within accuracies. However, they are from low productivity/nutrient surface waters, and thus result might underestimate impact in higher nutrient/productivity waters.

2) Pure Melt (1 sample only, filtered, moderate nutrients, low chl and ox) reduced nitrate by 0.4uM

3) 1 sample only comparing melt on filtered/non filtered. Both reduce nitrate by 0.4uM. Unfiltered increases PO4 by 0.1uM

4) 2 samples comparing filtered no melt to no filtered and melt, no difference BUT this is in low nutrient waters and so likely underestimate of effects

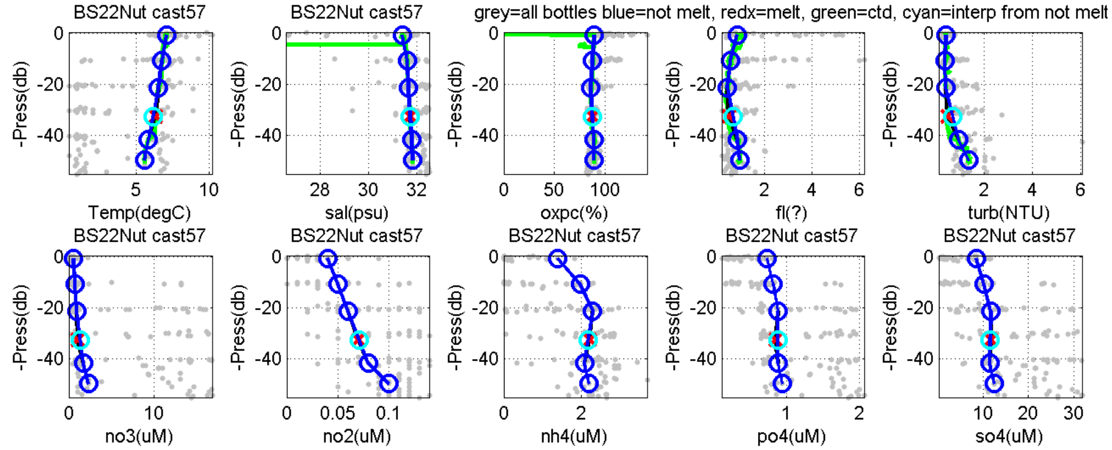
5) 2 samples of no filter and melt - one in high prod (hi ox and fl, low nuts), one in low prod (low Ox, and mednut). Both show drawn down of No3 (0.5uM No3, 0.02No2, modest increase in NH4 below detection, or drawn down to zero NO3, No2)
Low productivity waters show small increase in P (as per other), 0.1uM.
High productivity water has LARGE increases in P (0.4uM) and Si(3.4uM).
But we don't know if that is melt or filtering.

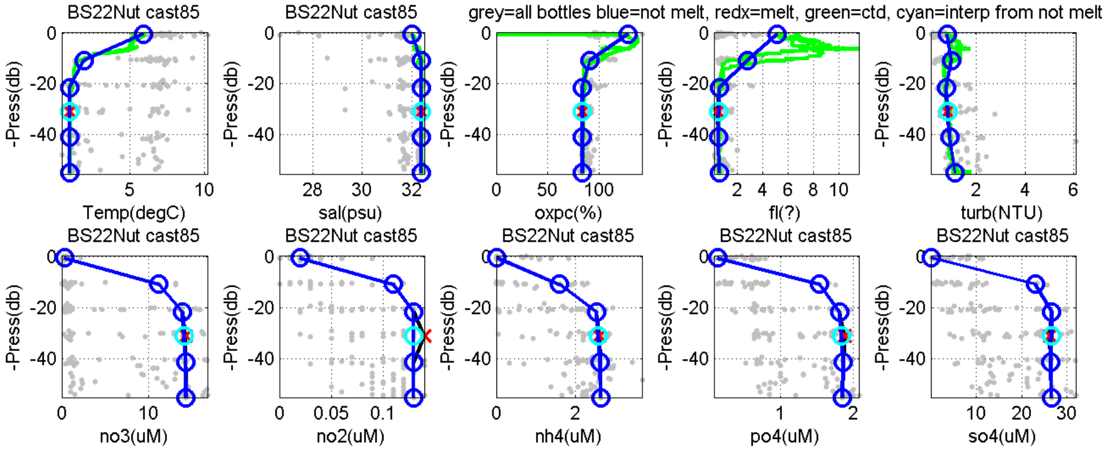
SUMMARY FROM DUPLICATES
1) Filtering appears advantageous in moderate/high nutrient content waters, yielding smaller change in the melt situation, although we only have one relevant comparison here.

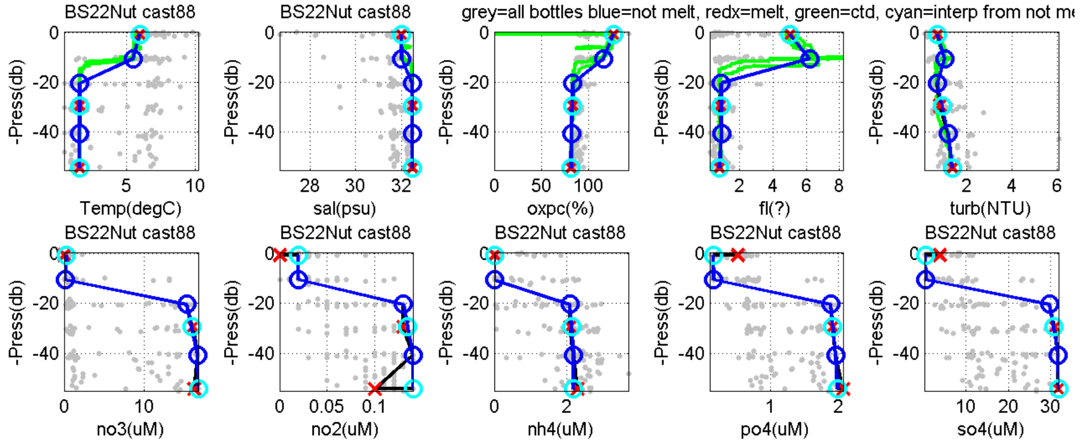
2) Most of our samples are filtered. We only have 1 sample to assess the effect of melt on unfiltered samples. However, we assume it must be less than the effect on unfiltered samples, which is:
.. in Low nut/low prod waters … likely no change …
.. in med nitrate, but low fl .. likely melted NO3 is ~ 0.4-0.5uM too low. and Ph might be ~0.1uM too high
.. in high prod, NO3 could be wrongly taken to zero, Ph could be 0.4 too high, and Si could be 3.4 too high. …

CONCLUSIONS FROM CASTS

A further check is possible. We can compare consistency of samples within mixed layers of a cast, where we expect little change in nutrients. The random nature of the selection of the samples that were melted mean that some casts contain all melted samples (16 casts), some contain all non-melted samples (4 casts), and some contain a mix of melted and non melted (7 casts). (A total of 35 casts were sampled - of which 2 were calibration casts, and 6 took only 2 or 3 samples). All non-melt casts confirmed the 2 layer system we expect in the region. Of the 7 casts of mixed melt/non melt samples, 3 (cast 57, 85, and 88) had both melt and non-melt samples within a layer we expected to be homogenous. For these, we linearly interpolated the non-melt data to the depth of the melted data, and quantified the differences. In all cases, these differences were less than twice the accuracy of the nutrient analysis. We conclude thus, that the partially melted samples are still within the accuracy of the nutrient analysis.

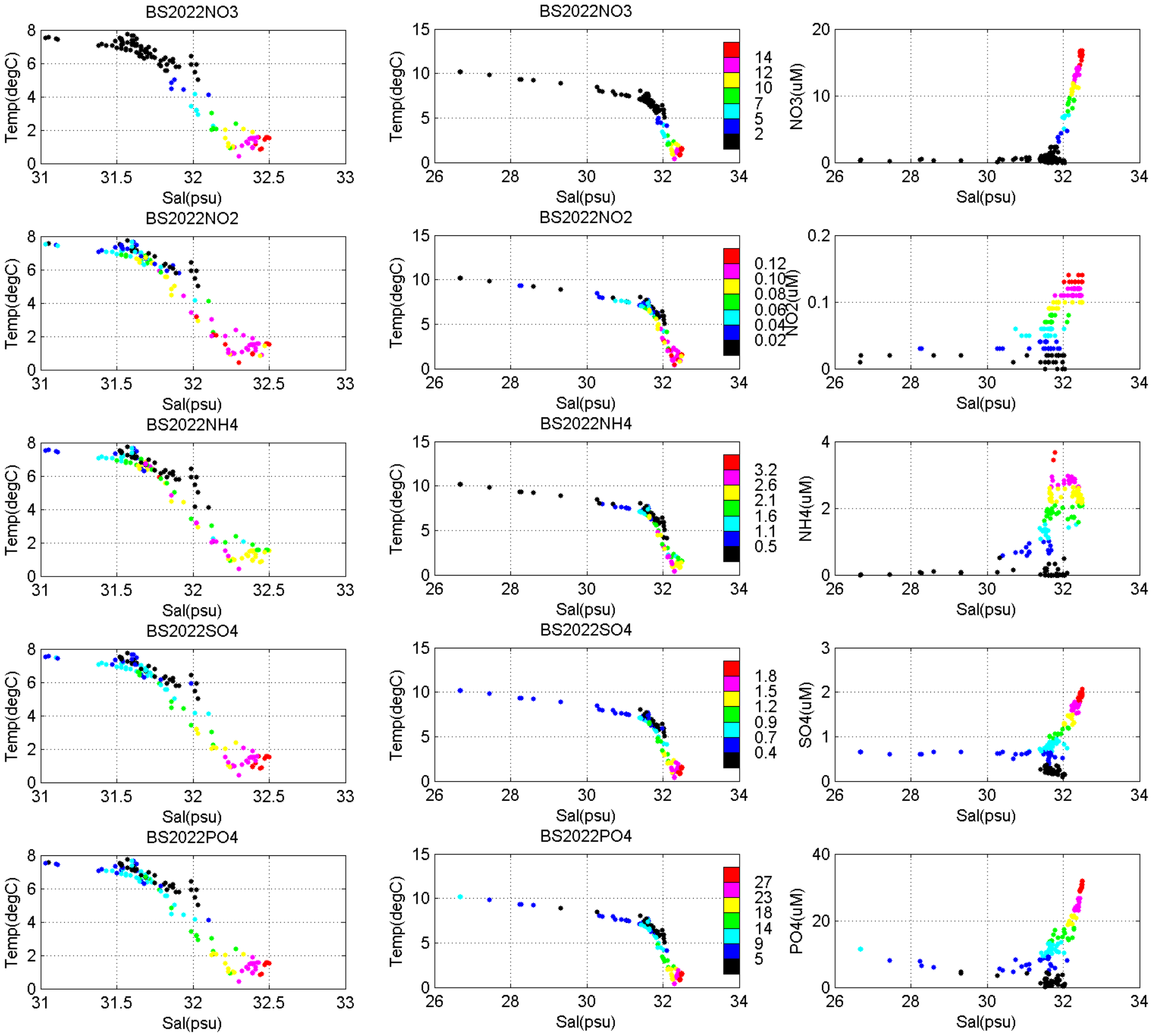




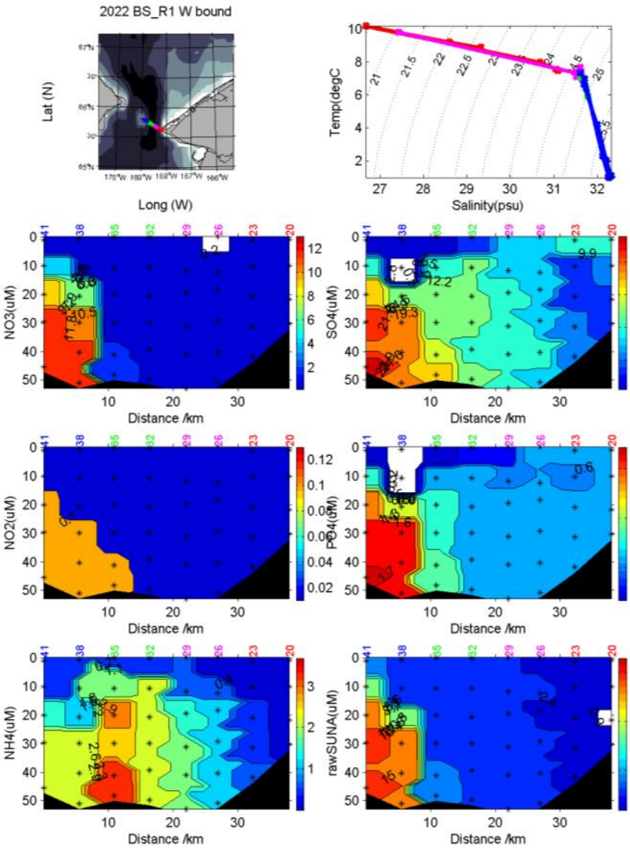


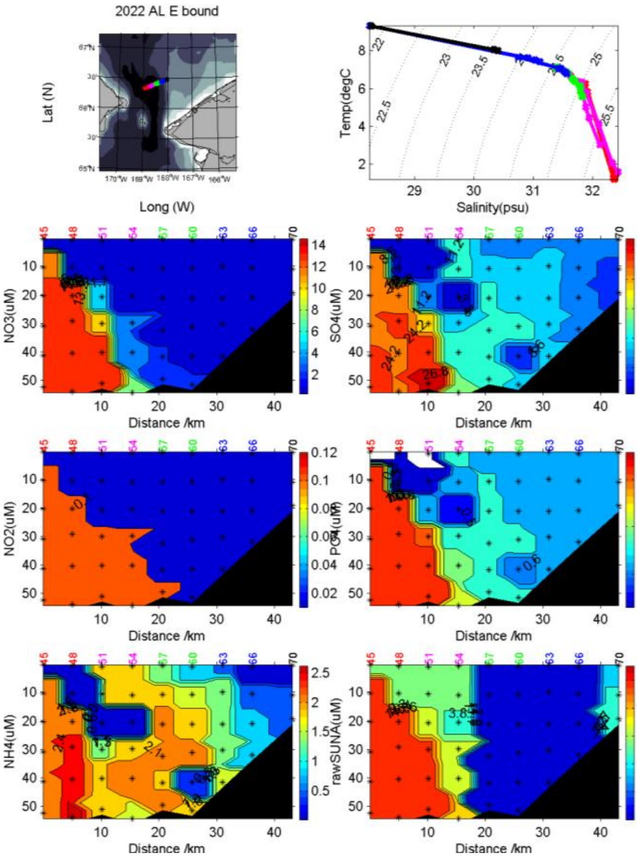
Finally, we present some summary plots, either for the whole cruise, or by section.

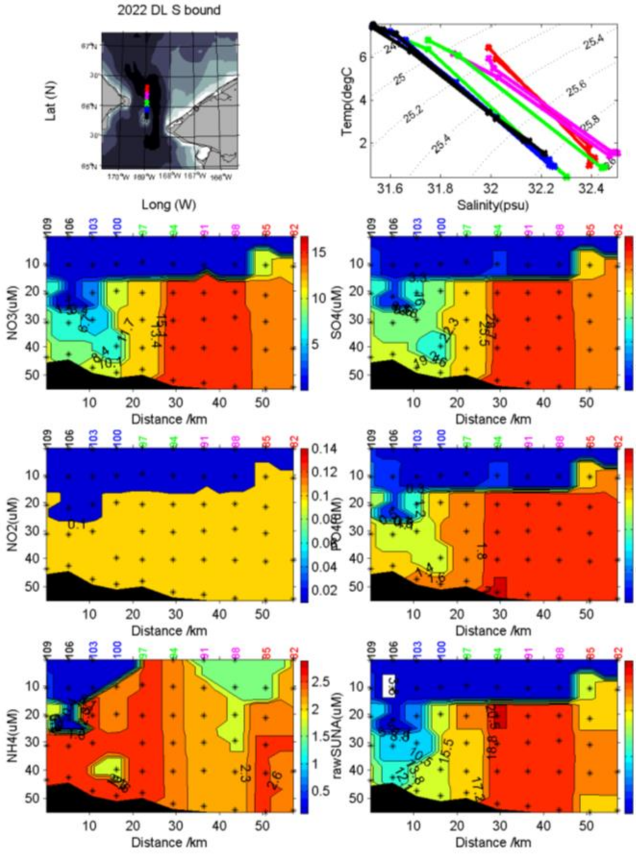
BS2022 Nutrients in TS Space

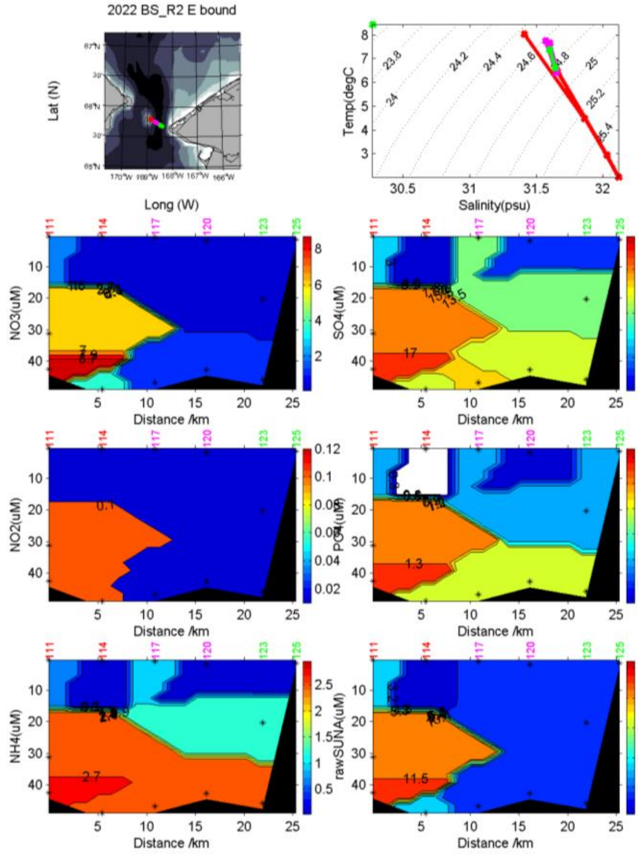


BS2022 Nutrients in Sections (own scales)

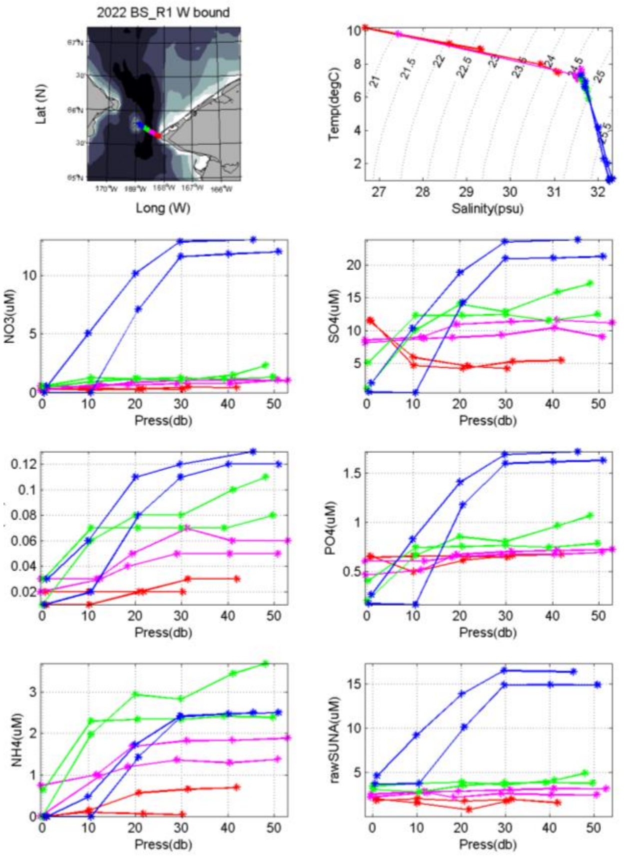

2022 BS_R1 W bound

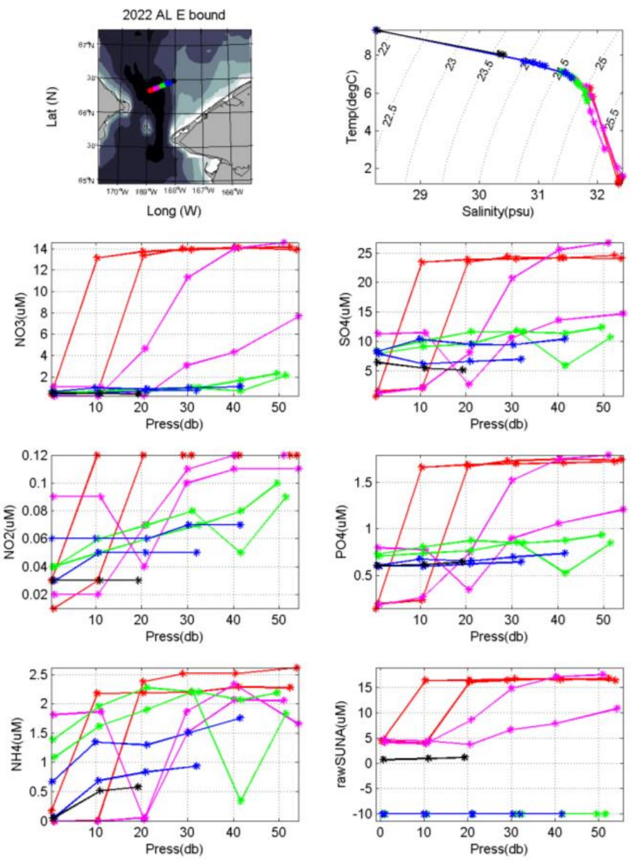

2022 AL E bound

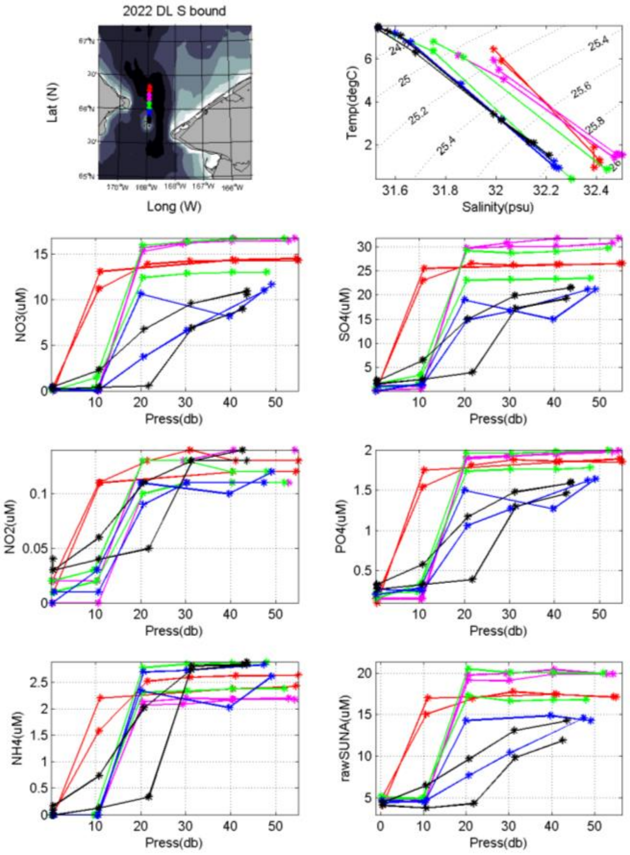

2022 DL S bound

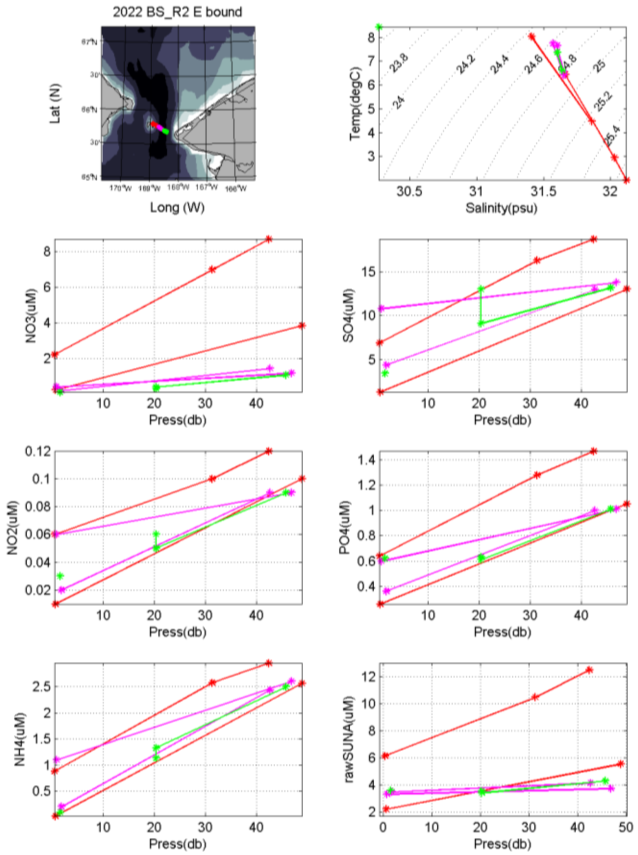

2022 BS_R2 E bound

BS2022 Nutrients by section, versus depth

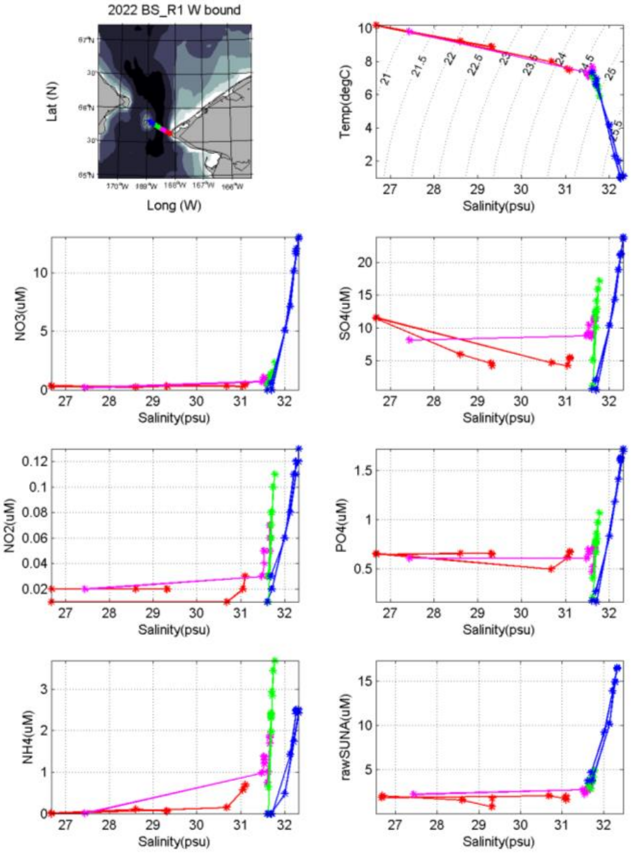




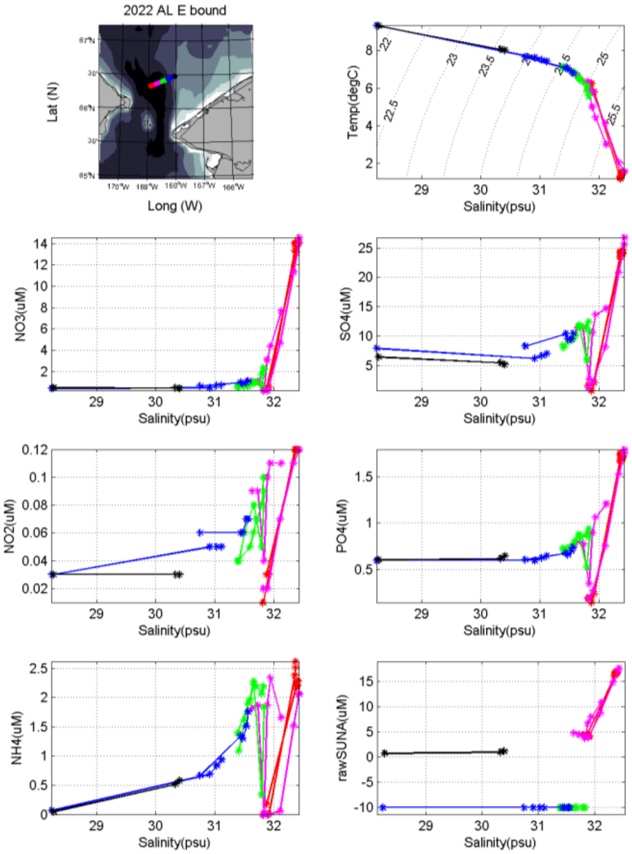




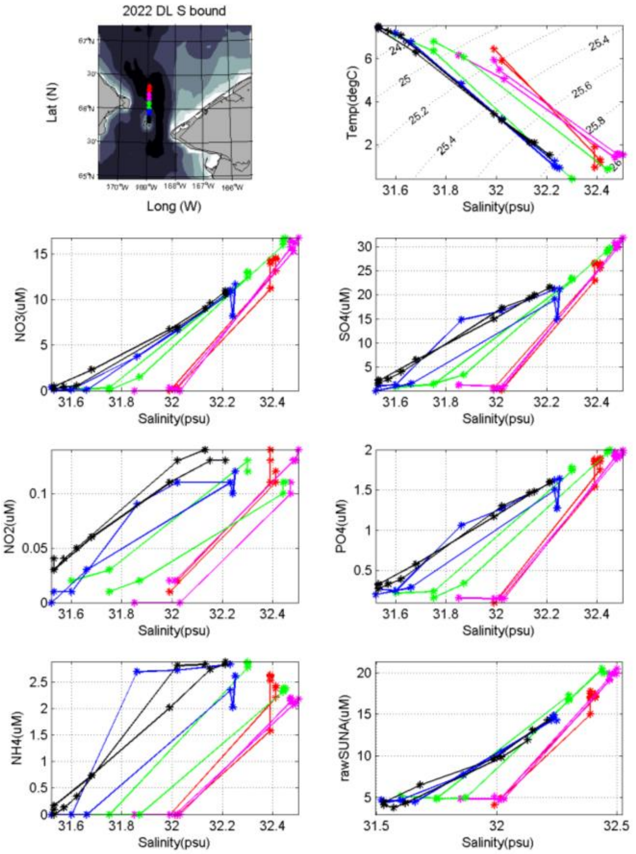
BS2022 Nutrients by section, versus salinity



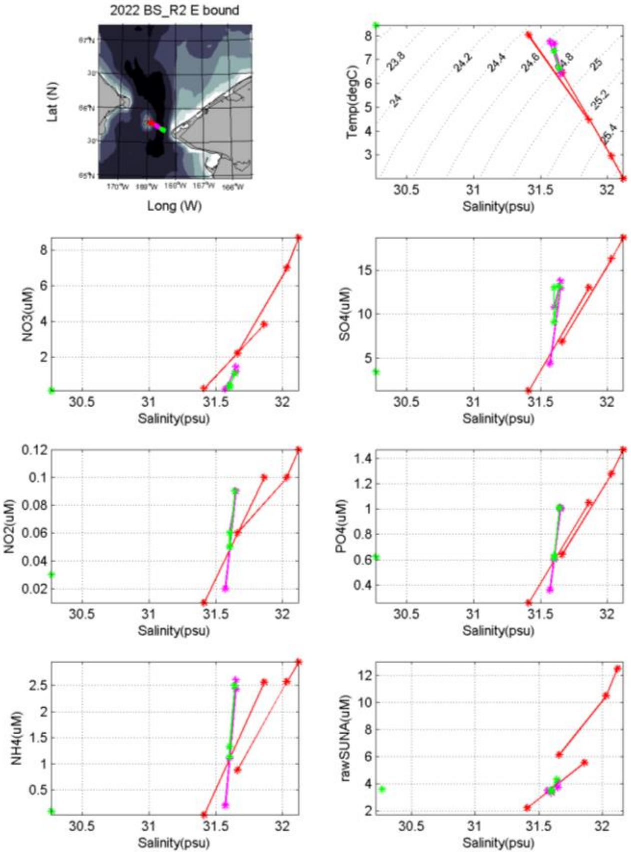
2022 BS_R1 W bound



2022 AL E bound



2022 DL S bound



2022 BS_R2 E bound

BERING STRAIT 2022 UNDERWAY DATA REPORT – Woodgate (UW)

Underway CTD, ADCP and some meteorological data were collected during the cruise using the Norseman II's ship-based systems. These systems are set up by the Norseman II crew at the start of the cruise. **Action item: Pre-cruise, develop checksheets for the setup of these instruments to ensure settings are as desired. Check the setups as soon as the ship leaves port.**

ADCP: This year, as last year, we collected data from the Norseman II's Teledyne RD Instruments 300kHz Workhorse Mariner ADCP (SN 19355), which is equipped with high accuracy bottom tracking. The ADCP is mounted 3m below the water line. This system was operational for the cruise, running with 1m bins and bottom track. The following file types are available for processing (file information copied from http://po.msrc.sunysb.edu/SBI/Healy_ADCPs.htm)

*.ENR – raw binary ADCP data which contains every ping
*.ENS – Binary ADCP data after the data has been preliminarily screened for backscatter and correlation
*.ENX - Binary ADCP data after screening and rotation to earth coordinates
*.STA - Binary ADCP ensemble data that has been averaged into short term averages
*.LTA - Binary ADCP ensemble data that has been averaged into long term averages
*.N1R - Raw NMEA ASCII data from the primary navigation source
*.N2R - Raw NMEA ASCII data from the secondary navigation source, if available, and which should include Ashtech heading data
*.NMS - Binary screened and averaged navigation data
*.VMO - This ASCII file is a copy of the *.ini options file that was used during the data collection
*.LOG - ASCII file containing a log of any errors the ADCP detected during the session

Preliminary data plots will be added to this report once available. Bottom track data was logging during this deployment. **Action item: Ensure that bottom tracking is turned on. Process ADCP data.** Note also that since heading information is given by the ship's GPS position, it is not necessary to correct for magnetic declination. **Action item: Check prior data for magnetic declination issue.**

MET DATA: The Norseman2 had South Central Radar install a new Meteorological sensor package in 2021, as the previous sensors failed. The new version is an Airmar 220WX instrument Weather caster 153 (https://www.airmar.com/weather-description.html?id=153, https://www.airmar.com/uploads/InstallGuide/17-461-01.pdf) running WeatherCaster 3 software. Trouble shooting of these sensors (and comparison to ERA, JRA and NCEP data) concluded that the unit was reading:
- too high for wind speed (by about 2m/s on average, i.e., about 4 knots)
- too low for temperature (by about 2degC on average)
- too low for pressure (by ~ 2hPa).

These differences are all greater than the stated accuracy of the sensor https://www.airmar.com/weather-description.html?id=153 (0.5m/s for speed; 1.1degC for temperature, 0.5hPa for pressure).

Note the instrument calculates true wind direction and speed (and this is not reproducible exactly from relative wind and ship heading. In 2021, a compass calibration was performed off Nome in less than ideal conditions, and this may have contributed to the errors in the 2021 data. For 2022, a better calibration was performed pre cruise, in suitable conditions. It is possible thus that the 2022 data are of higher quality in 2021 but this should be confirmed with comparison to the model wind products: Note that the temperature and wind chill temperature reported remain identical, which is clearly erroneous. **Action item: Repeat comparison to ERA, JRA and NCEP wind data.**

As can be seen in the plots below, winds were high for much of the cruise, and exceptionally so at the end of the cruise (although by that point we had already left the strait). Unusually, winds (especially the strong winds at the start of the cruise) were frequently from the north, and thus should be taken into account when considering the hydrographic sections. **Action item: Add wind direction to the CTD sections. .**

UNDERWAY TEMPERATURE AND CONDUCTIVITY DATA: The Norseman II used an Seabird SBE21 temperature conductivity sensor mounted 3.4m below the water line (slightly to port of the ship's ADCP, in the center of the ship) to collect underway data throughout the cruise, also logging position information and depth. A separate temperature sensor (SBE38) is placed closer to the intake to measure the temperature (recorded as temperature 2) before it is warmed by the ship. **Action item: Ensure depth is always logged in this file.** An hourly watch was kept on these data to ensure no loss of data. **Action item: Continue hourly monitoring of underway data while at sea. Check the temperature and salinity data to the CTD casts.**

The calibration file used was the December 2016 calibration. **Action item: Ensure the most recent calibration is used in the field.** Data were logged every 3 seconds.

Preliminary plots of the underway temperature and salinity data are given below.

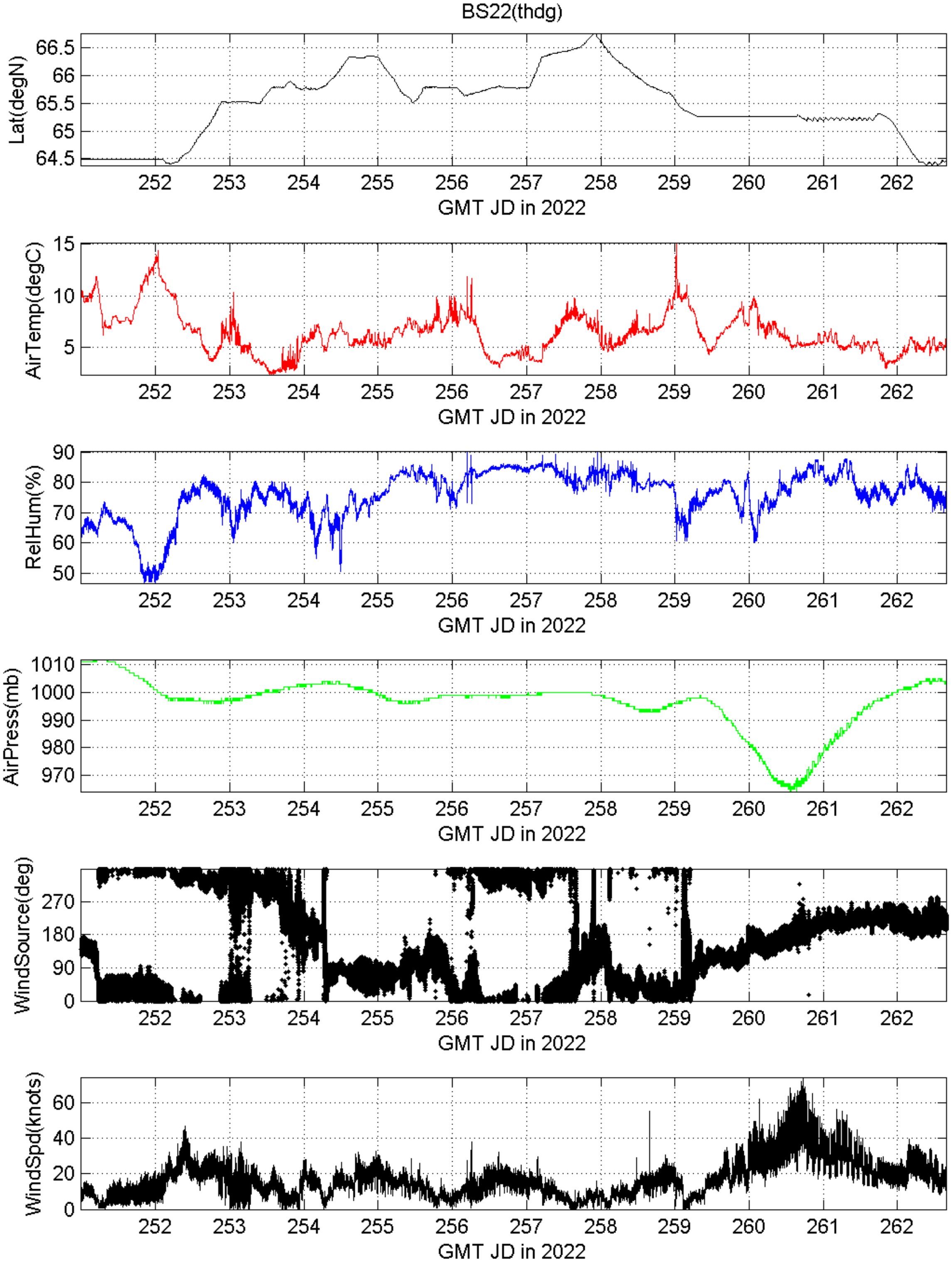
Note the NMEA data string logged by the underway temperature and salinity SB21 shows the same GPS roll over error that was present in 2021. This means that the raw data dates start from 24th Jan 2003, rather than 9th Sept 2022. It is only the date that is in error. The time is correct. The date is corrected in post processing. **Action item: Correct this problem with the GPS**

It is very important to remember when interpreting these data, that they are taken over the many days of the cruise, and the oceanographic conditions change significantly during this time, as is evidenced by the plots of the various crossings of the Bering Strait also shown below. **Action item: Examine surface salinities and temperatures, especially in conjunction with prior data.**

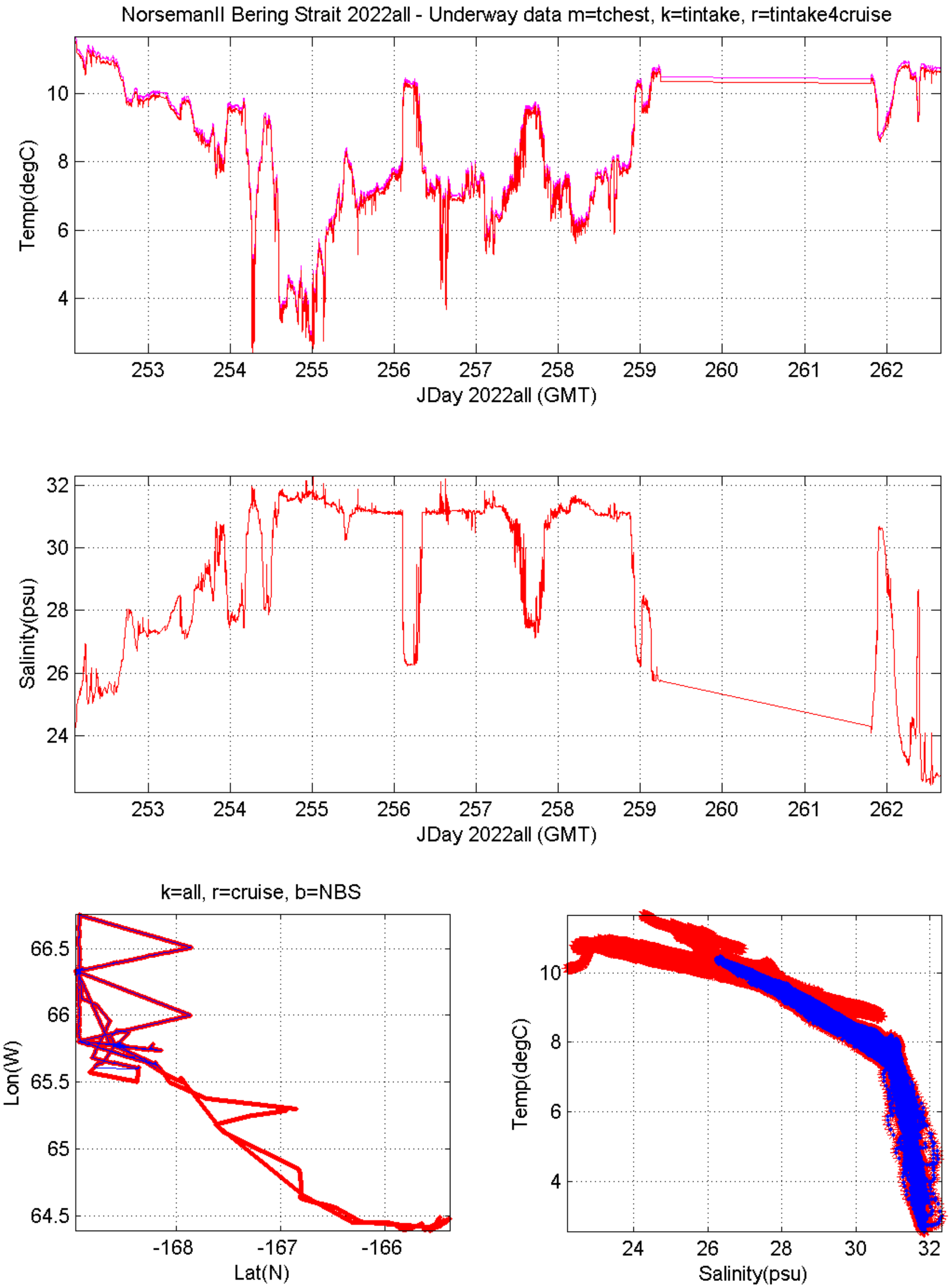
For dates and times, see cruise schedule at start of report.

BERING STRAIT 2022 METEOROLOGICAL DATA PLOTS

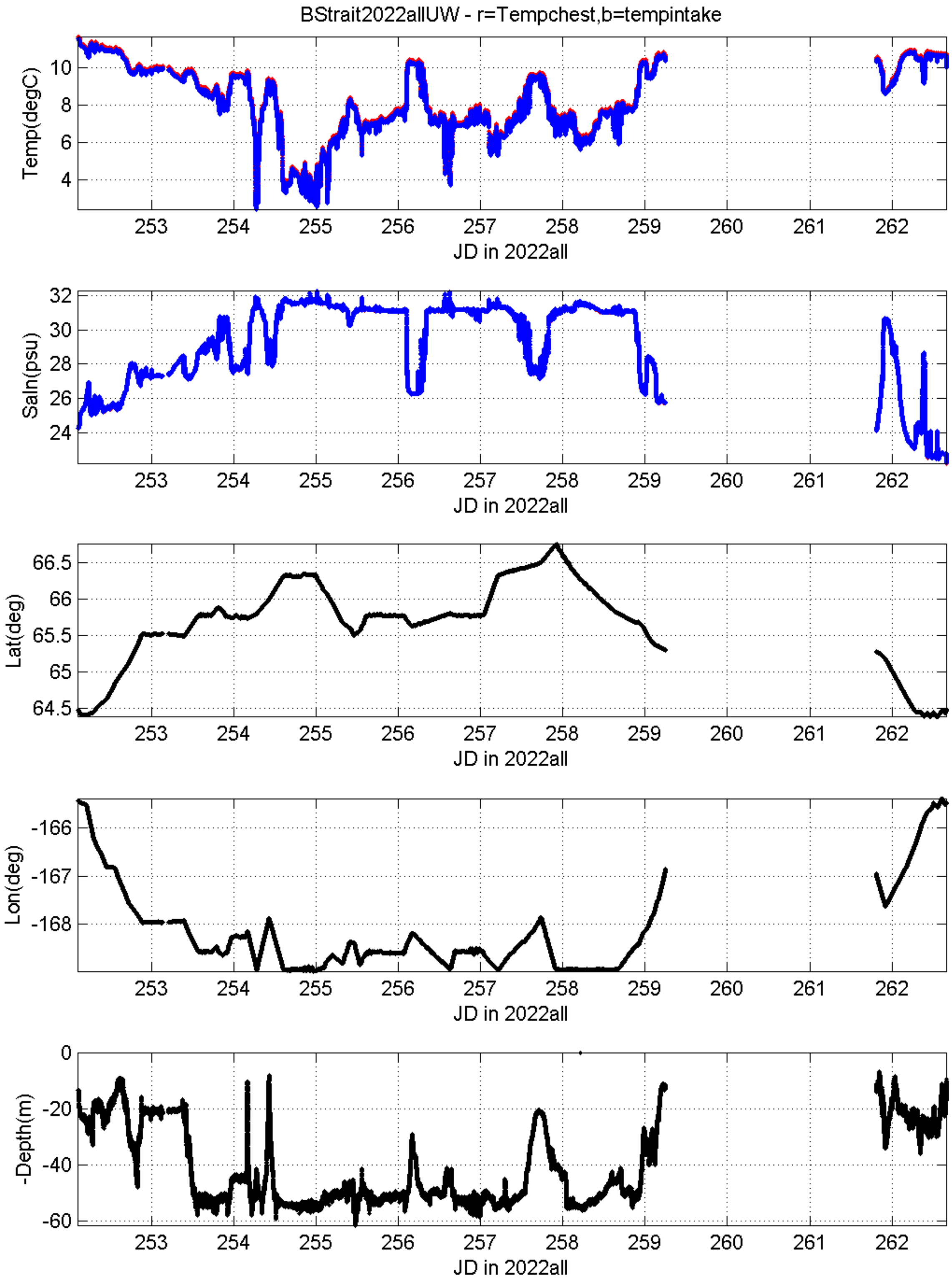
Stated accuracy of the sensor https://www.airmar.com/weather-description.html?id=153 (0.5m/s for speed; 1.1degC for temperature, 0.5hPa for pressure), but 2021 analysis suggests these accuries are over optimistic. Note the instrument calculates true wind direction and speed (and this is not reproducible exactly from relative wind and ship heading



BERING STRAIT 2022 UNDERWAY TEMPERATURE SALINITY DATA

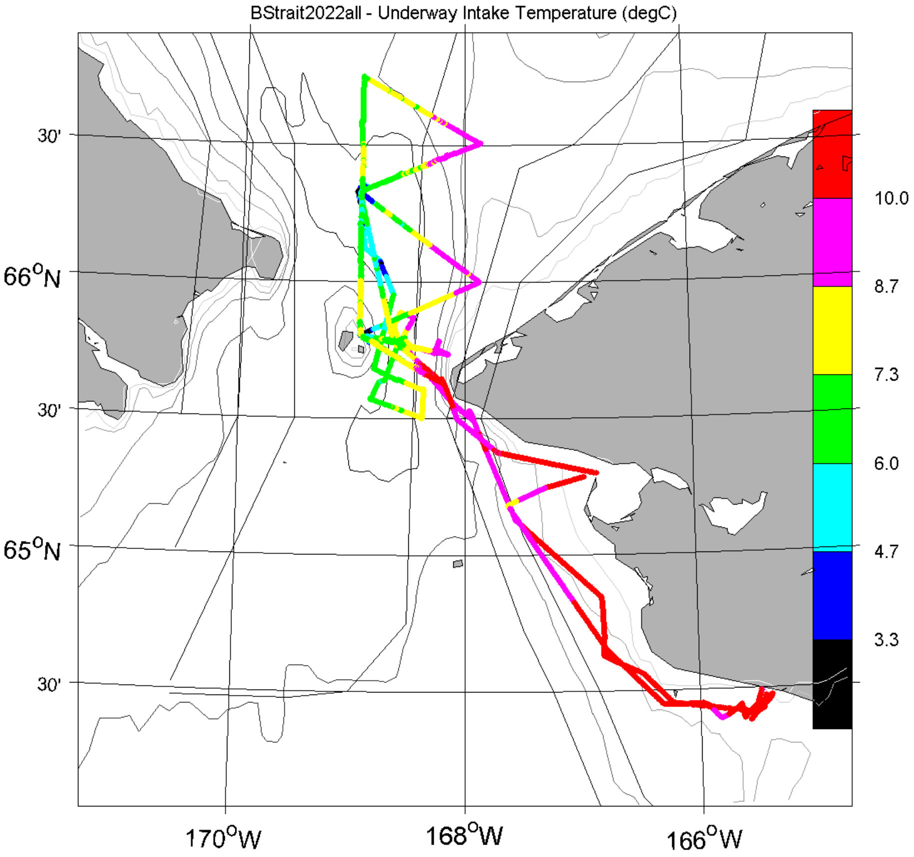


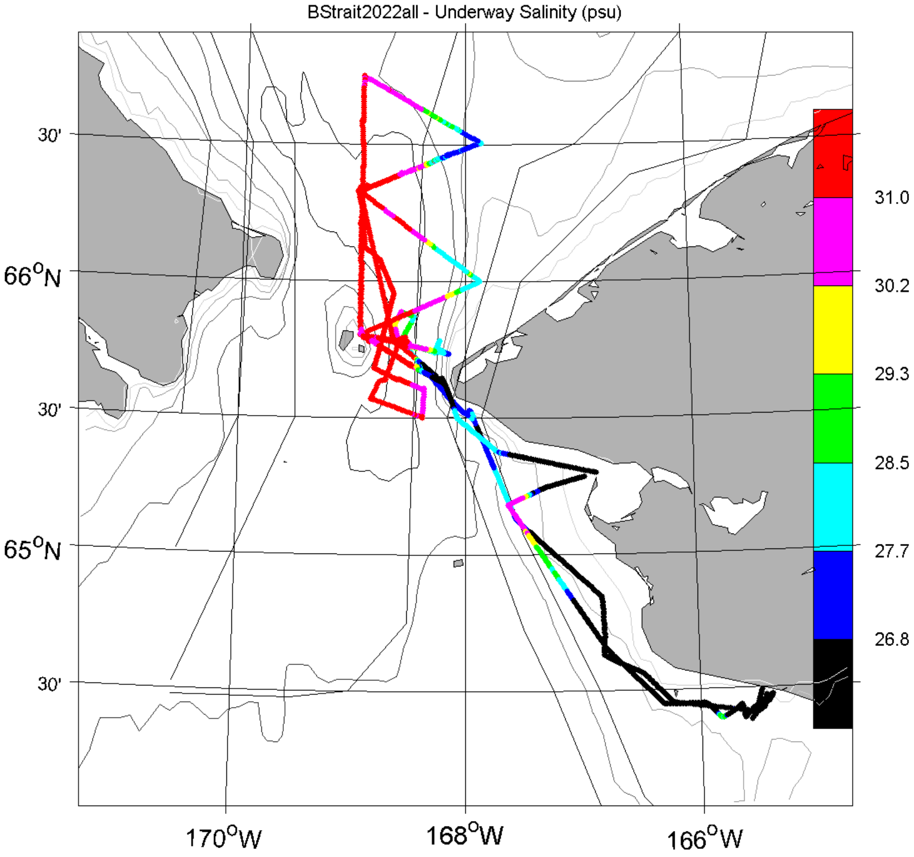
BERING STRAIT 2022 UNDERWAY TEMPERATURE SALINITY DATA (continued)



BERING STRAIT 2022 UNDERWAY TEMPERATURE SALINITY DATA (continued)

(Note multiple runnings of the Bering Strait (and other) lines are masked in these plots.)

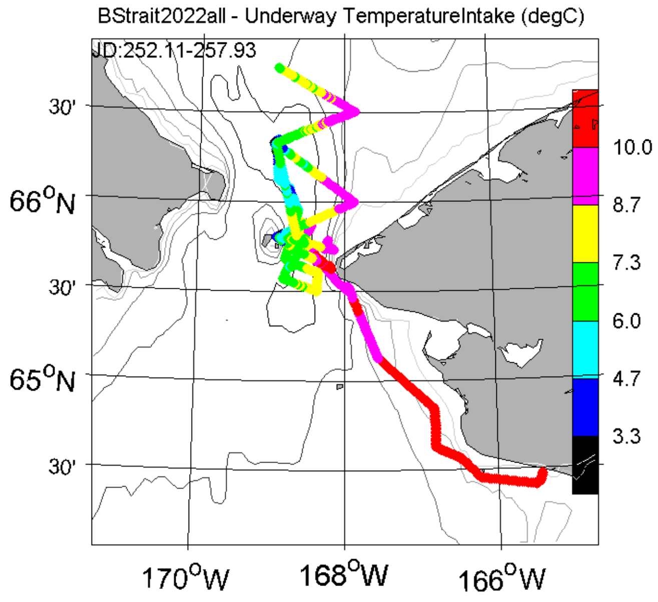


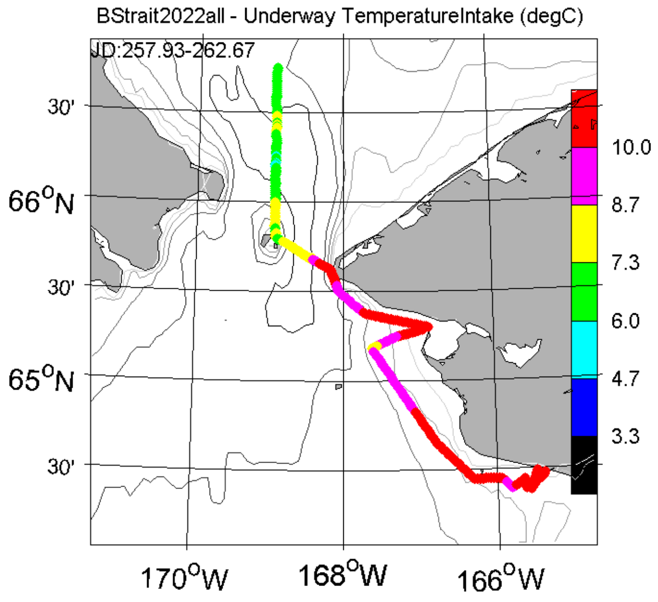


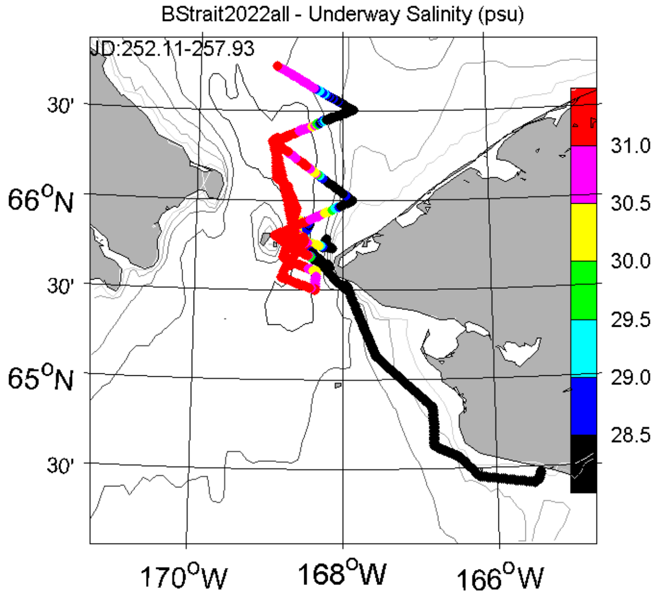
BERING STRAIT 2022 UNDERWAY TEMPERATURE SALINITY DATA (continued)

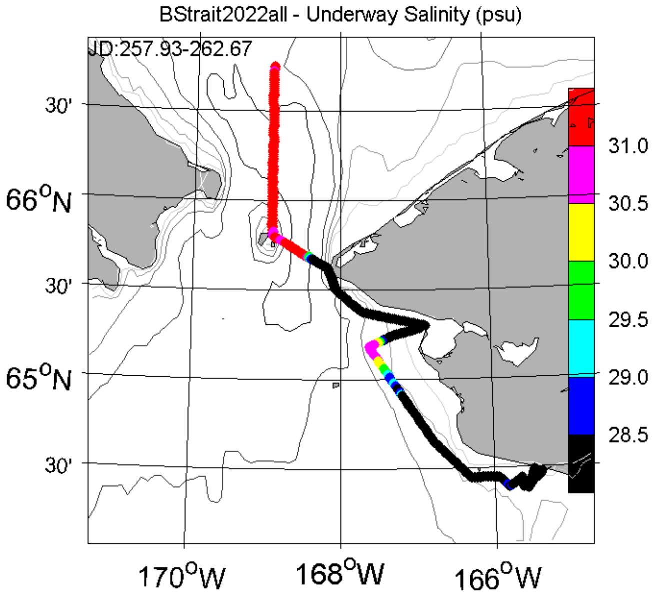
First Half

Second half





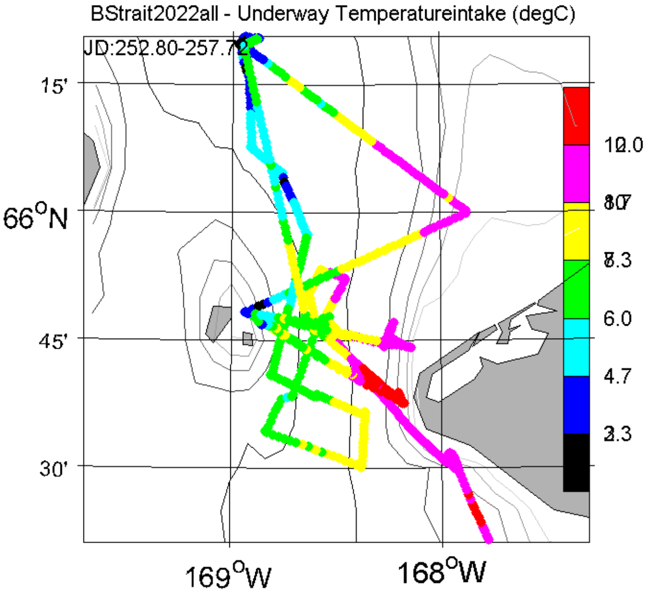


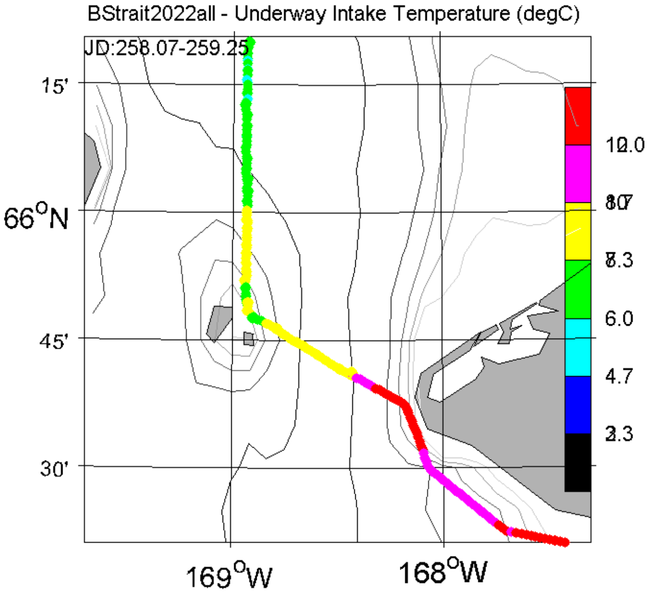


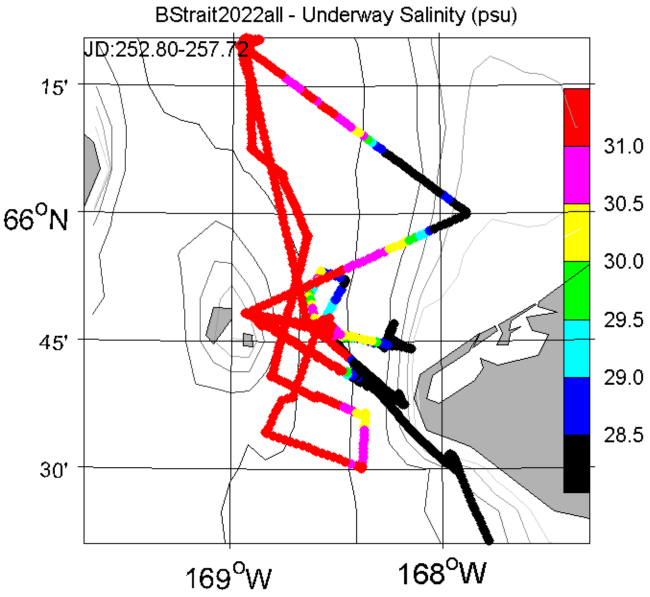
BERING STRAIT 2022 UNDERWAY TEMPERATURE SALINITY DATA (continued)

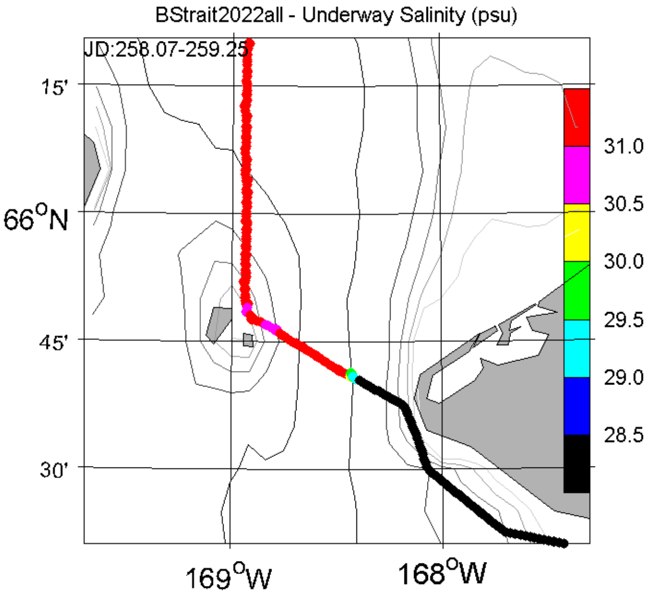
Focus on the strait only

First Half **Second half**









BERING STRAIT 2022 MARINE MAMMAL REPORT – Marie Zahn, UW

Acoustic recorders: A marine mammal acoustic recorder (SoundTrap Ocean Instruments Inc., NZ) was recovered from the A4-21 mooring and a new one was deployed on the A4-22 mooring. These recorders will be used to identify the acoustic presence of cetaceans and pinnipeds in the Bering Strait.

Marine mammal survey: Outside of mooring and CTD operations during the cruise, a marine mammal survey was conducted from the bridge of the R/V Norseman II. Surveys occurred while the vessel was in transit at a speed of at least 5 knots and weather conditions were suitable (daylight with good visibility and Beaufort sea state less than 6). In general, sustained efforts to retrieve the A2 mooring and severe weather near the end of the cruise limited opportunities for marine mammal surveys. Hurricane force winds and dangerous ocean conditions required ending the cruise short by two days as we waited out the storm in Port Clarence. Being limited on time, we did not transit to northern sampling stations where more marine mammal sightings were expected. On the previous cruise aboard the Norseman II, there were sightings of many humpback whales near Point Hope. Overall, sightings for the 2022 Bering Strait cruise were minimal compared to previous years (e.g., last one conducted in 2017).

For 2022, visual sightings included cetaceans and a phocid in the Bering Strait and lower Chukchi Sea (Table 1, Figure 1). Species included gray whales (*Eschrichtius robustus*), harbor porpoise (*Phocoena phocoena*), an unidentified seal, and a minke whale (*Balaenoptera acutorostrata*). The unidentified seal was likely a ringed (*Pusa hispida*) or spotted (*Phoca largha*) seal. Despite the minimal survey effort attained this season, these visual sightings may help corroborate acoustic detections from the hydrophone fixed to the A3 mooring. Sightings recorded this year are consistent with those from 2017 where harbor porpoise were found in the Bering Strait and gray whales were observed near the 67º N latitude line.

Table 1: Total counts from marine mammal survey in 2022 Bering Strait cruise.

Species	**# animals**	**# sightings**
Harbor porpoise	9-12	4
Gray whale	6-8	1
Unidentified phocid	1	1
Minke whale	1	1
Total	**17-22**	**7**

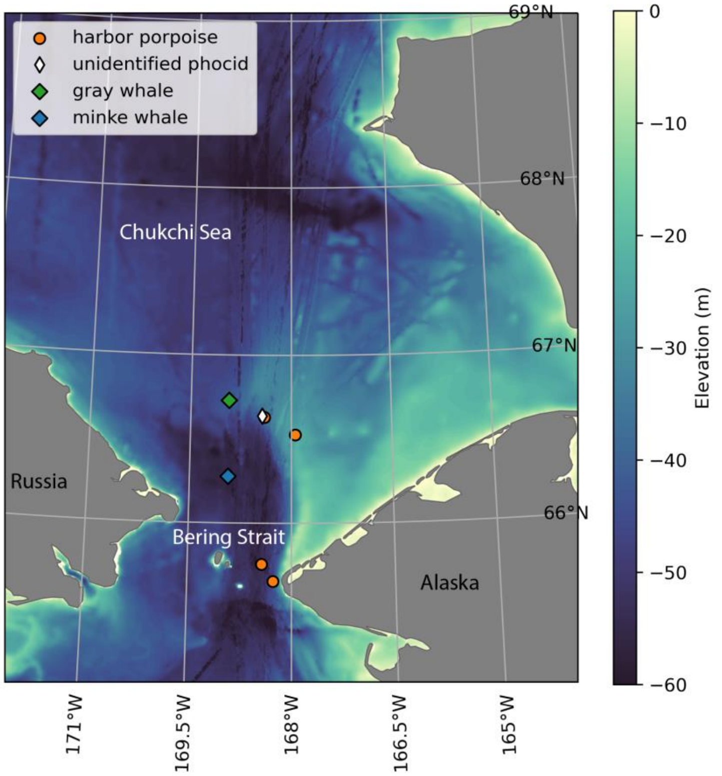


Figure:. Locations of cetacean and pinniped sightings during marine mammal surveys for the 2022 Bering Strait cruise.

BERING STRAIT 2022 TARGET CTD POSITIONS

```
%==========================================================
% Stations for BStrait Mooring Cruise 2022 NorsemanII
%==========================================================
% Vers: 5th August 2022
%
% US-Russian convention line is at 168deg 58.7'W.
% All stations in this file are in US waters.
% (Let me know if any points are too close to border for you.)
%
% Time estimates are based on the 2013 NorsemanII cruise.
%==========================================================
% INCLUDING NEW LINES FROM 2017 CRUISE, viz
% - higher res DL north
% - higher res A3L
% - higher res SBS
% - LIS redone to avoid cable at LIS9
%==========================================================
% *****   MOORING POSITIONS *****
%==========================================================
% In likely order of servicing, i.e.,
% - recoveries from east to west in strait, then northern site;
% - deployments northern site, the west to east in strait.
% == 3 moorings to recover
% == 3 moorings to deploy
%-----------------------------------------
% RECOVERIES of moorings deployed in 2021
%-----------------------------------------
%NAME       Lat(N)        Long (W)      Water   Top
%           deg min       deg min       depth   Float
% A3-21    66  19.636     168  56.993    59m     8m
% A2-21    65  46.849     168  34.089    57m    16m
% A4-21    65  44.737     168  15.767    50m    16m
%--------------------------------
% DEPLOYMENTS for this 2022 cruise
%--------------------------------
% Target same as 2012 positions.
%NAME      Lat(N)       Long (W)      Water
%          deg min      deg min       depth
% A3-22   66  19.61     168  57.05     58m
% A2-22   65  46.86     168  34.07     56m
% A4-22   65  44.75     168  15.77     49m
%
%----------------------
% INTERMOORING DISTANCES
%----------------------
% A2 - A4 ~ 8nm
%-----------
% To A3 from
```

```
%------------
%   A2  - 34nm
%   A4  - 39nm
%-------------
% To Nome from
%-------------
%   A4 - 120nm
%   CS1 - 200-220nm
%========================================================
%
%========================================================
% *****   HISTORIC CTD SECTIONS *****
%========================================================
% There are 14 historic CTD lines here.
% These are the same positions as suggested in 2017, with
% the addition of 3 lines run in 2017 and the moving of
% one line (a change also made on the 2017 cruise).
% We may not have time for all of these, in which case
% we will do a subset.  But I've included
% them all, so you have the positions in advance.
% If operations/science dictate, then there
% might be different lines proposed while at sea.
%
% Some lines are given here at a high resolution and low
% resolution.  Time permitting we will run lines at high
% resolution.
%
% Naming is based on historic data.
% "+net" also refers to historic operations and
% is not relevant for this cruise.
% "no bottles" refers to historic operations and
% is not relevant for this cruise.
%
% On this cruise we will take CTD bottles
% a) for nutrients on lines BS, DI and AL lines only, and only on the
% first running.  These stations are marked *NUT22

% b) for salinity on approx 6 stations, to be decided in real time
% c) for delta O18, to be decided in real time

% Additionally, at ~32 stations on the BS, AL, CS and LIS lines,
% after some casts, we will take trace metal samples using the
% hand lowered pumped system. These stations are marked *PUMP22

% Known Hazards are indicated.
%
% Stay a safe distance (300m?) from all deployed
% moorings.
%
% Except for around moorings or for mooring work,
```

```
% within 200m is ok for positions.
%
%
%==============================================================
% BS = Bering Strait Line (US portion)
%==============================================================
% - 15 stations
% - station spacing generally ~ 2nm
% Distances: - BS11-BS22 21.7nm
%           - BS22-BS24  3.1nm
% Total length 24.8nm
%--
% Time from NorsemanII, 6 hrs running W, 5 hrs running E
% Time from Khromov 10.5hrs
%-------------------------------------------------
% Lat (N) Long (W)   Lat (N)    Long (W)    Name
%                deg min    deg   min
%-------------------------------------------------
% LOW RESOLUTION VERSION
%-------------------------------------------------
  65.805  168.933   65  48.31   168  55.96  % BS11
  65.788  168.860   65  47.26   168  51.62  % BS12
  65.772  168.794   65  46.33   168  47.64  % BS13
  65.755  168.721   65  45.28   168  43.29  % BS14
  65.739  168.663   65  44.35   168  39.80  % BS15
  65.722  168.591   65  43.29   168  35.46  % BS16 + net
  65.704  168.521   65  42.23   168  31.28  % BS17
  65.695  168.486   65  41.70   168  29.16  % BS17S
  65.686  168.449   65  41.18   168  26.94  % BS18
  65.672  168.391   65  40.35   168  23.44  % BS19
  65.655  168.318   65  39.29   168  19.09  % BS20
  65.642  168.250   65  38.53   168  14.97  % BS21
  65.625  168.177   65  37.48   168  10.63  % BS22 + net
  65.599  168.161   65  35.96   168   9.66  % BS23
  65.582  168.117   65  34.91   168   7.00  % BS24
%-------------------------------------------------
% HIGH RESOLUTION VERSION (with nutrient sampling plan)
%-------------------------------------------------
%65.805        168.933       65      48.31   168     55.96   %       BS11
65.797  168.897         65      47.79   168     53.79   %       BS11.5 *NUT22 *PUMP22
65.788  168.86  65      47.26   168     51.62   %       BS12
65.780  168.827         65      46.8    168     49.63   %       BS12.5
65.772  168.794         65      46.33   168     47.64   %       BS13      *NUT22 *PUMP22
65.764  168.758         65      45.81   168     45.47   %       BS13.5
65.755  168.721         65      45.28   168     43.29   %       BS14
65.747  168.692         65      44.82   168     41.55   %       BS14.5 *NUT22 *PUMP22
65.739  168.663         65      44.35   168     39.8    %       BS15
65.731  168.627         65      43.82   168     37.63   %       BS15.5
65.722  168.591         65      43.29   168     35.46   %       BS16      *NUT22 *PUMP22
65.713  168.556         65      42.76   168     33.37   %       BS16.5
```

```
65.704  168.521         65      42.23   168     31.28   %       BS17
65.695  168.486         65      41.7    168     29.16   %       BS17.5 *NUT22 *PUMP22
65.686  168.449         65      41.18   168     26.94   %       BS18
65.679  168.42  65      40.77   168     25.19   %       BS18.5
65.672  168.391         65      40.35   168     23.44   %       BS19      *NUT22 *PUMP22
65.664  168.355         65      39.82   168     21.27   %       BS19.5
65.655  168.318         65      39.29   168     19.09   %       BS20
65.649  168.284         65      38.91   168     17.03   %       BS20.5 *NUT22 *PUMP22
65.642  168.25  65      38.53   168     14.97   %       BS21
65.634  168.214         65      38.01   168     12.8    %       BS21.5
65.625  168.177         65      37.48   168     10.63   %       BS22      *NUT22 *PUMP22
65.599  168.161         65      35.96   168     9.66    %       BS23
65.582  168.117         65      34.91   168     7       %       BS24
%
%
%=================================================================
% DL = Diomede Line (US only, 1nm east of border)
%=================================================================
% This line is to map eddying area north of the Diomedes
% - 19 stations
% - station spacing ~ 1nm in South,
%               ~ 2.5nm in north
% Distance: - DL1 to DL19  28.7nm
%--
% Time from NorsemanII - 5.5 hrs running N; 9hrs running S
% Time from Khromov to DL19 ~10hrs
%-------------------------------------------------
%    Lat (N)     Long (W)     Name
%    deg min      deg   min
%-------------------------------------------------
% LOW RESOLUTION VERSION
%-------------------------------------------------
0 0  65   49.28   168   56.2  % DL1  *NUT22
0 0  65   50.26   168   56.2  % DL2
0 0  65   51.23   168   56.2  % DL3
0 0  65   52.21   168   56.2  % DL4  *NUT22 + net
0 0  65   53.18   168   56.2  % DL5 - no bottles
0 0  65   54.15   168   56.2  % DL6
0 0  65   55.13   168   56.2  % DL7  *NUT22 - no bottles
0 0  65   56.10   168   56.2  % DL8
0 0  65   57.08   168   56.2  % DL9 - no bottles
0 0  65   58.05   168   56.2  % DL10 *NUT22
0 0  65   59.03   168   56.2  % DL11- no bottles
0 0  66    0.00   168   56.2  % DL12
%-----
0 0  66    2.55   168   56.2  % DL13- no bottles
0 0  66    5.10   168   56.2  % DL14
0 0  66    7.65   168   56.2  % DL15- no bottles
0 0  66   10.19   168   56.2  % DL16
0 0  66   12.74   168   56.2  % DL17- no bottles
```

```
0 0  66   15.29    168   56.2  % DL18
0 0  66   17.84    168   56.2  % DL19- no bottles
%-------------------------------------------------
% HIGH RESOLUTION VERSION (with nutrient sampling plan)
%-------------------------------------------------
0 0  65   49.28    168   56.2  % DL1  *NUT22
0 0  65   50.26    168   56.2  % DL2
0 0  65   51.23    168   56.2  % DL3
0 0  65   52.21    168   56.2  % DL4  *NUT22 + net
0 0  65   53.18    168   56.2  % DL5 - no bottles
0 0  65   54.15    168   56.2  % DL6
0 0  65   55.13    168   56.2  % DL7  *NUT22 - no bottles
0 0  65   56.10    168   56.2  % DL8
0 0  65   57.08    168   56.2  % DL9 - no bottles
0 0  65   58.05    168   56.2  % DL10 *NUT22
0 0  65   59.03    168   56.2  % DL11- no bottles
0 0  66    0.00    168   56.2  % DL12
%--
0 0  66    1.28    168   56.2  % DL12.5  *NUT22
0 0  66    2.55    168   56.2  % DL13
0 0  66    3.83    168   56.2  % DL13.5
0 0  66    5.10    168   56.2  % DL14    *NUT22
0 0  66    6.38    168   56.2  % DL14.5
0 0  66    7.65    168   56.2  % DL15
0 0  66    8.92    168   56.2  % DL15.5  *NUT22
0 0  66   10.19    168   56.2  % DL16
0 0  66   11.47    168   56.2  % DL16.5
0 0  66   12.74    168   56.2  % DL17    *NUT22
0 0  66   14.02    168   56.2  % DL17.5
0 0  66   15.29    168   56.2  % DL18
0 0  66   16.57    168   56.2  % DL18.5  *NUT22
0 0  66   17.84    168   56.2  % DL19
0 0  66   18.73    168   56.2  % DL19.5
% Ending at A3
 0 0  66  19.61    168   57.05  % A3mooring  *NUT22
% *** Adjust this first position to be safe distance (300m?) from A3 mooring
%
%
%==============================================================
% DL A and B lines (Diomede A and B lines)
%==============================================================
% These lines, with DL, form a grid to map
% eddying N of the Diomedes.
% - each line 12 stations
% - station spacing ~ 1nm
% Distances: - each line ~ 11nm
%--
% Estimate for NorsmanII for each line ~3.5hrs
% Time from Khromov for each line ~5hrs
%----------------------------------------
```

```
%    Lat (N)      Long (W)     Name
%    deg min       deg   min
% Northbound leg
0 0   65   49.30    168   52.2  % DLa 1
0 0   65   50.27    168   52.2  % DLa 2
0 0   65   51.25    168   52.2  % DLa 3
0 0   65   52.22    168   52.2  % DLa 4
0 0   65   53.19    168   52.2  % DLa 5
0 0   65   54.16    168   52.2  % DLa 6
0 0   65   55.14    168   52.2  % DLa 7
0 0   65   56.11    168   52.2  % DLa 8
0 0   65   57.08    168   52.2  % DLa 9
0 0   65   58.05    168   52.2  % DLa 10
0 0   65   59.03    168   52.2  % DLa 11
0 0   66    0.00   168   52.2  % DLa 12
% Southbound leg
0 0   66    0.00   168   48.2  % DLb 12
0 0   65   59.03    168   48.2  % DLb 11
0 0   65   58.05    168   48.2  % DLb 10
0 0   65   57.08    168   48.2  % DLb 9
0 0   65   56.11    168   48.2  % DLb 8
0 0   65   55.14    168   48.2  % DLb 7
0 0   65   54.16    168   48.2  % DLb 6
0 0   65   53.19    168   48.2  % DLb 5
0 0   65   52.22    168   48.2  % DLb 4
0 0   65   51.25    168   48.2  % DLb 3
0 0   65   50.27    168   48.2  % DLb 2
0 0   65   49.30    168   48.2  % DLb 1
%
%
%===============================================================
% AL = A3 Line (US portion)
%===============================================================
% Hazards on this line:
% == First station on this line is at mooring A3-17, so exact
% position needs to be altered to be a safe distance (300m?)
% from mooring A3-17 site.
%----------------------------------------------------
% - 13 stations including cast at A3mooring site
% - station spacing ~ 1.9nm
% Distance: - A3 to AL24 = 22.2nm
% --
% Time from NorsemanII ~5.5hrs
% Time from Khromov ~9hrs
%----------------------------------------------------
% Lat (N) Long (W)   Lat (N)     Long (W)     Name
%                  deg min      deg   min
%-------------------------------------------------
% LOW RESOLUTION VERSION
%-------------------------------------------------
```

```
  66.327  168.951   66  19.61   168   57.05  % A3-17
% *** Adjust this first position to be safe distance (300m?) from A3-17
  66.340  168.895   66  20.39   168   53.71  % AL13
  66.352  168.823   66  21.09   168   49.40  % AL14
  66.363  168.752   66  21.80   168   45.09  % AL15
  66.375  168.680   66  22.51   168   40.78  % AL16
  66.387  168.608   66  23.21   168   36.47  % AL17 + net
  66.399  168.536   66  23.92   168   32.16  % AL18
  66.410  168.464   66  24.63   168   27.84  % AL19
  66.422  168.392   66  25.33   168   23.53  % AL20
  66.434  168.320   66  26.04   168   19.22  % AL21
  66.446  168.249   66  26.75   168   14.91  % AL22 + net
  66.458  168.177   66  27.45   168   10.60  % AL23
  66.469  168.105   66  28.16   168    6.29  % AL24
%-------------------------------------------------
% HIGH RESOLUTION VERSION (with nutrient sampling plan)
%-------------------------------------------------
  66.3270  168.9510   66   19.6100  168   57.0500   % A3 mooring
% *** Adjust this first position to be safe distance (300) from A3 mooring
  66.3335  168.9230   66   20.0000  168   55.3800   % new AL12.5  *NUT22 *PUMP22
  66.3400  168.8950   66   20.3900  168   53.7100   % AL13
  66.3460  168.8590   66   20.7400  168   51.5550   % new AL13.5
  66.3520  168.8230   66   21.0900  168   49.4000   % AL14        *NUT22 *PUMP22
  66.3575  168.7875   66   21.4450  168   47.2450   % new AL14.5
  66.3630  168.7520   66   21.8000  168   45.0900   % AL15
  66.3690  168.7160   66   22.1550  168   42.9350   % new AL15.5  *NUT22 *PUMP22
  66.3750  168.6800   66   22.5100  168   40.7800   % AL16
  66.3810  168.6440   66   22.8600  168   38.6250   % new AL16.5
  66.3870  168.6080   66   23.2100  168   36.4700   % AL17        *NUT22 *PUMP22
  66.3940  168.5657   66   23.6400  168   33.9400   % new AL17.5  % AND MOVED OFF Q CABLE
  66.3990  168.5360   66   23.9200  168   32.1600   % AL18
  66.4045  168.5000   66   24.2750  168   30.0000   % new AL18.5  *NUT22 *PUMP22
  66.4100  168.4640   66   24.6300  168   27.8400   % AL19
  66.4160  168.4280   66   24.9800  168   25.6850   % new AL19.5
  66.4220  168.3920   66   25.3300  168   23.5300   % AL20        *NUT22 *PUMP22
  66.4280  168.3560   66   25.6850  168   21.3750   % new AL20.5
  66.4340  168.3200   66   26.0400  168   19.2200   % AL21
  66.4400  168.2845   66   26.3950  168   17.0650   % new AL21.5  *NUT22 *PUMP22
  66.4460  168.2490   66   26.7500  168   14.9100   % AL22
  66.4520  168.2130   66   27.1000  168   12.7550   % new AL22.5
  66.4580  168.1770   66   27.4500  168   10.6000   % AL23        *NUT22 *PUMP22
  66.4635  168.1410   66   27.8050  168    8.4450  % new AL23.5
  66.4690  168.1050   66   28.1600  168    6.2900  % AL24
  66.4745  168.0690   66   28.5150  168    4.1350  % new AL24.5
  66.4800  168.0330   66   28.8700  168    1.9800  % AL25        *NUT22 *PUMP22
  66.4855  167.9970   66   29.2250  167   59.8200   % new AL25.5
  66.4910  167.9610   66   29.5800  167   57.6650   % AL26
  66.4965  167.9250   66   29.9350  167   55.5100   % new AL26.5
  66.5020  167.8890   66   30.2900  167   53.3550   % AL27
  66.5075  167.8530   66   30.6450  167   51.2000   % new AL27.5
```

```
%
%
%=====================================================================
% AS = from AL to CS Line
%=====================================================================
% Across-topography line linking Al line with CS
% - 20 stations (counting first of CS line)
% - station spacing
%       AS1-7 at ~ 4nm spacing.
%       AS7-14 at 2nm spacing,
%       A14 to end 4nm
% Distances: - AS1 to CS10 64.7nm
%--
% Time from Khromov (12casts, odds+2&18) ~11hrs
% Estimate for NorsmanII 20 casts ~ 12hrs
% Estimate for Khromov 20 casts ~ 14hrs
%---------------------------------------------
%    Lat (N)       Long (W)      Name
%    deg min        deg   min
0 0   66   41.47    167   38.86   % AS 1
0 0   66   45.01    167   43.78   % AS 2-no bottles
0 0   66   48.55    167   48.70   % AS 3
0 0   66   52.09    167   53.62   % AS 4-no bottles
0 0   66   55.63    167   58.55   % AS 5
0 0   66   59.17    168    3.47   % AS 6-no bottles
0 0   67    2.71    168    8.39   % AS 7
%                  (2nm spacing over slope)
0 0   67    4.48    168   10.85   % AS 8-no bottles
0 0   67    6.25    168   13.31   % AS 9
0 0   67    8.02    168   15.77   % AS 10-no bottles
0 0   67    9.78    168   18.23   % AS 11
0 0   67   11.55    168   20.69   % AS 12-no bottles
0 0   67   13.32    168   23.15   % AS 13
0 0   67   16.86    168   28.07   % AS 14
%                  (back to 4nm spacing)
0 0   67   20.40    168   32.99   % AS 15-no bottles
0 0   67   23.94    168   37.92   % AS 16
0 0   67   27.48    168   42.84   % AS 17-no bottles
0 0   67   31.02    168   47.76   % AS 18
0 0   67   34.56    168   52.68   % AS 19-no bottles
0 0   67   38.10    168   56.00   % CS10US
%
%
%=====================================================================
% SAS = S extension of AS line
%=====================================================================
% Adding another 8 stations at 4nm spacing south
% from AS1 to the coast.
%--
% Estimate for NorsemanII 8 casts ~ 4hrs
```

```
% Not run yet
%------------------------------------------
%    Lat (N)       Long (W)      Name
%    deg min       deg   min
0 0   66   37.91    167   34.00   % SAS 1
0 0   66   34.35    167   29.14   % SAS 2
0 0   66   30.79    167   24.29   % SAS 3
0 0   66   27.23    167   19.43   % SAS 4
0 0   66   23.68    167   14.57   % SAS 5
0 0   66   20.12    167    9.72   % SAS 6
0 0   66   16.56    167    4.86   % SAS 7
0 0   66   13.00    167    0.00   % SAS 8
%
%
%=============================================================
% CS = Cape Serdtse Kamen to Point Hope Line (US portion)
%=============================================================
% Hazards on this line:
% == Final station CS19 is shallow.  Check on
% modern charts to see if deep enough for NorsemanII.
% (this station was too shallow for the Khromov, but
% was ok for the NorsemanII in 2013).
% == NOAA mooring at:
%         67 54.712N, 168 11.628W
%---------------------------------------------------------
% - 16 or 17 stations
% - station spacing ~ 5nm in the central Chukchi,
%                ~ 2.2nm near the coast
% Distances: - CS10US to CS18 60.8nm
%          - CS18 to CS19    2.2nm
%--
% Time from NorsemanII (toCS19) ~ 10.5 hrs
% Time from Khromov (toCS18) ~12hrs
%---------------------------------------------------------
%    Lat (N)    Long (W)      Name
%    deg min    deg   min
%-----------------------------------------------
% LOW RESOLUTION VERSION
%-----------------------------------------------
0 0   67   38.1   168   56.0    % CS10US + net
0 0   67   41.7   168   48.1    % CS10.5  - no bottles
0 0   67   45.3   168   39.9    % CS11
0 0   67   48.9   168   29.4    % CS11.5  - no bottles
0 0   67   52.5   168   18.8    % CS12 + net
0 0   67   55.9   168    9.1    % CS12.5  - no bottles
0 0   67   59.3   167   59.4    % CS13
0 0   68    2.7   167   49.7    % CS13.5  - no bottles
0 0   68    6.1   167   39.9    % CS14 + net
0 0   68    9.1   167   30.7    % CS14.5  - no bottles
0 0   68   12.1   167   21.4    % CS15
```

```
0 0   68   13.6   167   16.8    % CS15.5  - no bottles
0 0   68   15.0   167   12.2    % CS16
0 0   68   16.6   167    7.6    % CS16.5  - no bottles
0 0   68   18.0   167    2.9    % CS17 + net
0 0   68   18.9   166   57.6    % CS18
0 0   68   19.9   166   52.3    % CS19 *** SHALLOW **
%              CS19 too shallow for Khromov.
%-------------------------------------------------
% HIGH RESOLUTION VERSION (with nutrient sampling plan)
%-------------------------------------------------
% - 27 stations
% - station spacing ~ 2.5nm in the central Chukch (0.25 stations)
%                ~ 2.2nm near the coast
% Distances: - CS10US to CS18 60.8nm
%          - CS18 to CS19    2.2nm
% Time from NorsemanII (toCS19) ~ 11hrs
%---------------------------------------------------------
%    Lat (N)    Long (W)      Name
%    deg min     deg   min
0 0   67   38.1   168   56.0    % CS10US + net *PUMP22
0 0   67   39.9   168   52.0  % new CS10.25
0 0   67   41.7   168   48.1    % CS10.5  - no bottles
0 0   67   43.5   168   44.0  % new CS10.75
0 0   67   45.3   168   39.9    % CS11        *PUMP22
0 0   67   47.1   168   34.6  % new CS11.25
0 0   67   48.9   168   29.4    % CS11.5  - no bottles
0 0   67   50.7   168   24.1  % new CS11.75
0 0   67   52.5   168   18.8    % CS12 + net   *PUMP22
0 0   67   54.2   168   13.9  % new CS12.25
0 0   67   55.9   168    9.1    % CS12.5  - no bottles
0 0   67   57.6   168    4.2  % new CS12.75
0 0   67   59.3   167   59.4    % CS13        *PUMP22
0 0   68    1.0   167   54.5  % new CS13.25
0 0   68    2.7   167   49.7    % CS13.5  - no bottles
0 0   68    4.4   167   44.8  % new CS13.75
0 0   68    6.1   167   39.9    % CS14 + net   *PUMP22
0 0   68    7.6   167   35.3  % new CS14.25
0 0   68    9.1   167   30.7    % CS14.5  - no bottles
0 0   68   10.6   167   26.0  % new CS14.75
0 0   68   12.1   167   21.4    % CS15        *PUMP22
0 0   68   13.6   167   16.8    % CS15.5  - no bottles
0 0   68   15.0   167   12.2    % CS16        *PUMP22
0 0   68   16.6   167    7.6    % CS16.5  - no bottles
0 0   68   18.0   167    2.9    % CS17 + net   *PUMP22
0 0   68   18.9   166   57.6    % CS18
0 0   68   19.9   166   52.3    % CS19 *** SHALLOW ** %
%
%
%==================================================================
% LIS = Cape Lisburne Line (redone to avoid Qcable at Lis9)
```

```
%=================================================================
% - 18 stations (including first of CCL line)
% - station spacing ~ 2nm near coast,
%           ~ 3nm and ~ 5nm away from coast
% Distances: - LIS1 to CCL22 57.2nm
%--
% Time from NorsemanII, ~ 10hrs
% Time from Khromov ~11hrs
% (Times different now added stations)
%------------------------------
%    Lat (N)      Long (W)     Name
%    deg min       deg   min
  0   0        68   54.40   166   19.80  % LIS 1 + net *PUMP22
  0   0        68   54.80   166   25.15  % LIS 2       *PUMP22
  0   0        68   55.20   166   30.51  % LIS 3       *PUMP22
  0   0        68   55.80   166   38.54  % LIS 4
  0   0        68   56.40   166   46.57  % LIS 5
  0   0        68   57.00   166   54.60  % LIS 6 + net
  0   0        68   57.60   167    1.95  % LIS 6.5 - no bottles *PUMP22
  0   0        68   58.20   167    9.30  % LIS 7
  0   0        68   58.80   167   16.65  % LIS 7.5 - no bottles
  0   0        68   59.40   167   24.00  % LIS 8       *PUMP22
  0   0        69   00.20   167   33.8   % NEW ** LIS 8.5
%DO NOT DO LIS 9
% 69   0.60   167   38.70  % LIS 9  ** on Q cable - do not do
%DO NOT DO LIS 9
  0   0        69    1.00   167   43.60  % NEW ** LIS 9.5
  0   0        69    1.80   167   53.40  % LIS 10 + net
  0   0        69    1.35   168    7.95  % LIS 11      *PUMP22
  0   0        69    0.90   168   22.50  % LIS 12
  0   0        69    0.45   168   37.05  % LIS 13      *PUMP22
  0   0        69    0.23   168   46.62  % LIS 14n + net
  0   0        69    0.00   168   56.00  % CCL22n % was 56.2  *PUMP22
%
%
%=================================================================
% CCL = Chukchi Convention Line
%=================================================================
% Hazards on this line:
% == First station on this line is the same as last station
% included in the LIS line above.  It does not need to be
% repeated.
% == Last station on this line is at mooring A3-14, so exact
% position needs to be altered to be a safe distance (300m?)
% from mooring A3-14 site.
% == There are 2 JAMSTEC moorings ~ 3nm east of station
% CCL16 on this line.  Those positions are:
% SCH13  68 2.002N   168 50.028W
% SCH13w 68 3.006N   168 50.003W
%--------------------------------------
```

```
% Line running from northern most point
% due south, ~ 1nm US side of conventionline
% - 20 stations (counting arriving at A3-14)
% - station spacing ~ 10nm until CCL8,
%     then reducing to ~5nm and ~2.5nm
% Distances: - CCL22 to A3-13 ~ 161nm
%--
% Time from NorsemanII, 21.5hrs
% Time from Khromov ~26hrs
%---------------------------------------
% MAIN LINE STARTS IN N WITH THESE
%---------------------------------------
%     Lat (N)       Long (W)     Name
%     deg   min      deg   min
0 0   69    0.0    168  56.0  % CCL22
0 0   68   50.0    168  56.0  % CCL21
0 0   68   40.0    168  56.0  % CCL20
0 0   68   30.0    168  56.0  % CCL19
0 0   68   20.0    168  56.0  % CCL18 + Net
0 0   68   10.0    168  56.0  % CCL17
0 0   68   00.0    168  56.0  % CCL16
0 0   67   50.0    168  56.0  % CCL15
0 0   67   38.1    168  56.0  % CCL14 (same as CS10US) + Net + Prod
%------------------------------------------------
% THEN EITHER - LOW RESOLUTION VERSION
%------------------------------------------------
0 0   67   30.0    168  56.0  % CCL13
0 0   67   20.0    168  56.0  % CCL12
0 0   67   10.0    168  56.0  % CCL11
0 0   67   00.0    168  56.0  % CCL10 + Net
0 0   66   50.0    168  56.0  % CCL9
0 0   66   40.0    168  56.0  % CCL8
%       - spacing now 5nm
0 0   66   35.0    168  56.0  % CCL7
0 0   66   30.0    168  56.0  % CCL6
0 0   66   25.0    168  56.0  % CCL5
%       - spacing now 2.5nm
0 0   66   22.3    168  56.0  % CCL4
0 0   66   19.61    168  57.05  % A3-17
% *** Adjust this position to be safe distance (300m?) from A3-17
%------------------------------------------------
%  - OR HIGH RESOLUTION VERSION
% (halves from 8.5 to 13.5 are new)                    73nm ..
%------------------------------------------------
0 0   67   35.0    168  56.0  % CCL13.5
0 0   67   30.0    168  56.0  % CCL13
0 0   67   25.0    168  56.0  % CCL12.5
0 0   67   20.0    168  56.0  % CCL12
0 0   67   15.0    168  56.0  % CCL11.5
0 0   67   10.0    168  56.0  % CCL11
```

```
0 0   67   05.0    168  56.0   % CCL10.5
0 0   67   00.0    168  56.0   % CCL10 + Net
0 0   66   55.0    168  56.0   % CCL9.5
0 0   66   50.0    168  56.0   % CCL9
0 0   66   45.0    168  56.0   % CCL8.5
0 0   66   40.0    168  56.0   % CCL8
%         - spacing now 5nm
0 0   66   35.0    168  56.0   % CCL7
0 0   66   30.0    168  56.0   % CCL6
0 0   66   25.0    168  56.0   % CCL5
%         - spacing now 2.5nm
0 0   66   22.3    168  56.0   % CCL4
0 0   66   19.61    168  57.05  % A3-17
% *** Adjust this position to be safe distance (300m?) from A3-17
%
%
%=================================================================
% MBSn = Mid Bering Strait line
%=================================================================
% Just north of the Bering Strait line
% - 14 stations
% - station spacing 1.7nm, less near coast
% Distance: - 21.0nm total
%--
% Time from Helix (8casts only) ~2.5hrs
% - Estimate NorsemanII (8 casts only) ~ 4hrs
% - Estimate NorsemanII (14 casts)  ~ 6hrs
% - Estimate Khromov (8casts only)~5.5hrs
% - Estimate Khromov (14casts) ~7hrs
%------------------------------------
%     Lat (N)       Long (W)     Name
%     deg   min      deg   min
0 0   65   52.1    168  56.0   % MBSn1 % was 57.0
0 0   65   52.0    168  52.5   % MBSn1.5
0 0   65   51.9    168  49.1   % MBSn2
0 0   65   51.8    168  45.0   % MBSn2.5
0 0   65   51.7    168  40.9   % MBSn3
0 0   65   51.6    168  36.4   % MBSn3.5
0 0   65   51.5    168  31.9   % MBSn4 % was 51.6
0 0   65   51.4    168  27.5   % MBSn4.5
0 0   65   51.3    168  23.0   % MBSn5 % was 51.4
0 0   65   51.2    168  18.5   % MBSn5.5
0 0   65   51.1    168  13.9   % MBSn6
0 0   65   51.1    168  10.4   % MBSn6.5
0 0   65   51.0    168   6.9   % MBSn7
0 0   65   50.9    168   5.0   % MBSn8
%
%
%=================================================================
% NBS - North Bering Strait line
```

```
%=============================================================
% Hazards on this line:
% == Section crosses shallow waters.
% Beware of shallows from NBS9 and eastwards.
% (Helix diverted N to avoid shallows between
% stations NBS10 and NBS11)
% == Consider terminating line at NBS9
%-----------------------------------------
% Another cross strait line, run previously
% at lower resolution (i.e. without the 0.5 stations).
% - stations 9 (NBS1-9) to 16 (NBS1-9 with 0.5s)
%    to 21 (full section, including shallows).
% - station spacing (with 0.5s) ~ 1.7nm
% Distance: - NBS1-9  25.8nm
%          - NBS1-14 44.1nm
%--
% Time from Helix to NBS9, 9 casts ~5.5hrs
% - Estimate for NorsemanII to NBS9, 9 casts, 6hrs
% - Estimate for NorsemanII to NBS9, 16 casts, 7.5hrs
% - Estimate Khromov to NBS9, 9 casts ~6.5hrs
% - Estimate Khromo to NBS9, 16 casts ~8hrs
% Time from Helix to NBS14, 14 casts ~8.5hrs
% - Estimate for NorsemanII to NBS14, 14 casts, 9hrs
% - Esimate for NorsemanII to NSB14, 21 casts, 10.5hrs
% - Estimate Khromov to NBS14, 14 casts ~10hrs
% - Estimate Khromov to NBS14, 21 casts ~13hrs
%-----------------------------------------
%     Lat (N)       Long (W)     Name
%     deg   min      deg   min
0 0    66     0.0     168  56.0   % NBS1 % was 58.1
0 0    66     0.0     168  53.0   % NBS1.5
0 0    66     0.0     168  49.9   % NBS2
0 0    66     0.0     168  45.8   % NBS2.5
0 0    66     0.0     168  41.6   % NBS3
0 0    66     0.0     168  37.4   % NBS3.5
0 0    66     0.0     168  33.2   % NBS4
0 0    66     0.0     168  29.1   % NBS4.5
0 0    66     0.0     168  25.0   % NBS5
0 0    66     0.0     168  20.7   % NBS5.5
0 0    66     0.0     168  16.4   % NBS6
0 0    66     0.0     168  12.4   % NBS6.5
0 0    66     0.0     168   8.4   % NBS7
0 0    66     0.0     168   4.2   % NBS7.5
0 0    66     0.0     168   0.0   % NBS8 - 34m water
0 0    66     0.0     167  55.1   % NBS9 - 20m water
%  (consider terminating line here)
0 0    66     0.0     167  52.0   % NBS10 - 12m water
% (Helix diverted N to avoid shallows between these stations)
0 0    66     0.0     167  40.1   % NBS11 - 15m water
0 0    66     0.0     167  29.1   % NBS12 - 18m water
```

```
0 0    66     0.0     167  18.1   % NBS13 - 13m water
0 0    66     0.0     167  10.2   % NBS14 - 10m water
%
%
%=================================================================
% North North Bering Strait Line (NNBS)
%=================================================================
% A section across the ACC and main flow between
% the A3L line and the NBS line.
% With the 0.5s, at 1.76nm spacing
% 22.8nm length
%----------------------------------
% Run for the first time in 2015 - check water depths on
% the eastern (NNBS7.5) end)
% Dovetails with DL line.  NNBS1 is the same as DL16
% Now has one extra shallower station in the east NNBS8

 66.170 168.937   66   10.19 168   56.20  %NNBS1
 66.170 168.865   66   10.19 168   51.88  %NNBS1.5
 66.170 168.793   66   10.19 168   47.55  %NNBS2
 66.170 168.721   66   10.19 168   43.23  %NNBS2.5
 66.170 168.648   66   10.19 168   38.91  %NNBS3
 66.170 168.576   66   10.19 168   34.58  %NNBS3.5
 66.170 168.504   66   10.19 168   30.26  %NNBS4
 66.170 168.432   66   10.19 168   25.94  %NNBS4.5
 66.170 168.360   66   10.19 168   21.62  %NNBS5
 66.170 168.288   66   10.19 168   17.29  %NNBS5.5
 66.170 168.216   66   10.19 168   12.97  %NNBS6
 66.170 168.144   66   10.19 168    8.65  %NNBS6.5
 66.170 168.072   66   10.19 168    4.32  %NNBS7
 66.170 168.000   66   10.19 168    0.00  %NNBS7.5
 66.170 168.000   66   10.19 167   55.70  %NNBS8   *** NEW
%
%
%=================================================================
% NPH - North Point Hope Line
%=================================================================
%  Crossing from Point Hope to the ENE roughly.
% - 11 stations,
%    from 1-5 and 1.25nm spacing
%    for the rest of the line at 2.5nm
% - Distance 21nm
% - new in 2016
%   - ** CHECK DEPTH OF SHALLOWEST  NPH1
%
% Run from east (NPH1) to west (NPH11)
% - estimate 3hrs 15min
%---------------------------------------------
%    Lat (N)     Long (W)     Name
%    deg min     deg min
```

```
0 0   68  22.40    167  07.93   % NPH1
0 0   68  22.64    167  11.31   % NPH2
0 0   68  22.87    167  14.68   % NPH3
0 0   68  23.11    167  18.06   % NPH4
0 0   68  23.35    167  21.44   % NPH5
0 0   68  23.83    167  28.19   % NPH6
0 0   68  24.30    167  34.95   % NPH7
0 0   68  24.77    167  41.71   % NPH8
0 0   68  25.25    167  48.46   % NPH9
0 0   68  25.73    167  55.22   % NPH10
0 0   68  26.20    168  01.97   % NPH11
%-- with extension to the west (20nm, 8 stations, 4hrs)
0 0   68  26.68    168  08.72   % NPH11.5
0 0   68  27.15    168  15.47   % NPH12
0 0   68  27.63    168  22.23   % NPH12.5
0 0   68  28.10    168  28.98   % NPH13
0 0   68  28.58    168  35.74   % NPH13.5
0 0   68  29.05    168  42.49   % NPH14
0 0   68  29.53    168  49.25   % NPH14.5
0 0   68  30.00    168  56.00   % CCL19
%
%
%=================================================================
% CD- Cape Dyer
%=================================================================
%  Crossing east west, midway between Point Hope
% and Cape Lisburne (near Cape Dyer) and trying
% to avoid some topographic irregularites just
% N of the line on the charts.
% - originally 14 stations, 2nm spacing
% - Distance 26nm
% - new in 2016
%   - ** CHECK DEPTH OF SHALLOWEST  CD1
%---------------------------------------------
% extended to the west, by angling to meet CCL20
% at the Convention line.
% - Total distance 54nm, 27 stations
%    Lat (N)     Long (W)     Name
%    deg min     deg min
%---------------------------------------------
% STARTING FROM WEST EXTENSION
%---------------------------------------------
0 0   68  40.00    168  56.0   % CCL20
%**NEW
0 0   68  39.79    168  50.6   % CD27
0 0   68  39.57    168  45.3   % CD26
0 0   68  39.36    168  39.9   % CD25
0 0   68  39.14    168  34.6   % CD24
0 0   68  38.93    168  29.2   % CD23
0 0   68  38.71    168  23.9   % CD22
```

```
0 0   68  38.50    168  18.5   % CD21
0 0   68  38.29    168  13.1   % CD20
0 0   68  38.07    168   7.8   % CD19
0 0   68  37.86    168   2.4   % CD18
0 0   68  37.64    167  57.1   % CD17
0 0   68  37.43    167  51.7   % CD16
0 0   68  37.21    167  46.4   % CD15
%----------------------------------------
%*END OF NEW, carry on with orig stations
0 0   68  37.00    167  41.0   % CD14
0 0   68  37.00    167  35.5   % CD13
0 0   68  37.00    167  29.9   % CD12
0 0   68  37.00    167  24.4   % CD11
0 0   68  37.00    167  18.8   % CD10
0 0   68  37.00    167  13.3   % CD9
0 0   68  37.00    167   7.8   % CD8
0 0   68  37.00    167   2.2   % CD7
0 0   68  37.00    166  56.7   % CD6
0 0   68  37.00    166  51.2   % CD5
0 0   68  37.00    166  45.6   % CD4
0 0   68  37.00    166  40.1   % CD3
0 0   68  37.00    166  34.5   % CD2
0 0   68  37.00    166  29.0   % CD1
%
%
%=================================================================
%  NCD - North Cape Dyer Line
%=================================================================
%  2nm near the coast NCD1-16
%  2.5nm on out to CCL21 (which is NCD 26)
%--------------------------------------------------
% Length to CCL21 is 55.4nm
%-------------------------------------------------------------
% Lat(N)   Lon  (W)    Lat (N)       Lon (W)      NAME
% decdeg  decdeg    deg      min     deg   min
 68.753 166.422     68   45.20     166   25.30  %NCD1
 68.757 166.513     68   45.39     166   30.78  %NCD2
 68.760 166.604     68   45.59     166   36.26  %NCD3
 68.763 166.696     68   45.78     166   41.74  %NCD4
 68.766 166.787     68   45.97     166   47.22  %NCD5
 68.769 166.878     68   46.17     166   52.70  %NCD6
 68.773 166.970     68   46.36     166   58.18  %NCD7
 68.776 167.061     68   46.55     167    3.66  %NCD8
 68.779 167.152     68   46.75     167    9.14  %NCD9
 68.782 167.244     68   46.94     167   14.62  %NCD10
 68.786 167.335     68   47.13     167   20.10  %NCD11
 68.789 167.426     68   47.33     167   25.58  %NCD12
 68.792 167.518     68   47.52     167   31.06  %NCD13
 68.795 167.609     68   47.71     167   36.54  %NCD14
 68.798 167.700     68   47.91     167   42.02  %NCD15
```

```
 68.802 167.792     68   48.10    167   47.50  %NCD16  2nm up to here, 2.5nm after
 68.805 167.906     68   48.29    167   54.35 %NCD17
 68.808 168.020     68   48.48    168    1.20 %NCD18
 68.811 168.134     68   48.67    168    8.05 %NCD19
 68.814 168.248     68   48.86    168   14.90 %NCD20
 68.817 168.363     68   49.05    168   21.75 %NCD21
 68.821 168.477     68   49.24    168   28.60 %NCD22
 68.824 168.591     68   49.43    168   35.45 %NCD23
 68.827 168.705     68   49.62    168   42.30 %NCD24
 68.830 168.819     68   49.81    168   49.15 %NCD25
 68.833 168.933     68   50.00    168   56.00 %NCD26
%
%
%===============================================================
% - South Bering Strait section  (NOW REPLACED BY SBSnn)
%===============================================================
% First ran in 2014 and 2015 and then only partly
% Run in full in 2017
% To catch ACC before it enters the strait
%  - 22.5nm long
%  - 21 stations including halves
%-------------------------------------------------------------
% Lat(N)   Lon  (W)        Lat (N)       Lon (W)      NAME
% decdeg  decdeg       deg      min     deg   min
 65.5818  168.1167       65        34.91    168        7.00     % SBS1 = BS24
 65.5736  168.1571       65        34.42    168        9.43     %  SBS1.5
 65.5655  168.1975       65        33.93    168       11.85     % SBS2
 65.5573  168.2379       65        33.44    168       14.28     %  SBS2.5
 65.5491  168.2784       65        32.95    168       16.70     % SBS3
 65.5409  168.3188       65        32.45    168       19.13     %  SBS3.5
 65.5327  168.3592       65        31.96    168       21.55     % SBS4
 65.5245  168.3997       65        31.47    168       23.98     %  SBS4.5
 65.5163  168.4401       65        30.98    168       26.40     % SBS5
 65.5081  168.4805       65        30.49    168       28.83     %  SBS5.5
 65.5000  168.5209       65        30.00    168       31.26     % SBS6
 65.4918  168.5614       65        29.51    168       33.68     %  SBS6.5
 65.4836  168.6018       65        29.02    168       36.11     % SBS7
 65.4754  168.6422       65        28.52    168       38.53     %  SBS7.5
 65.4672  168.6826       65        28.03    168       40.96     % SBS8
 65.4590  168.7231       65        27.54    168       43.38     %  SBS8.5
 65.4508  168.7635       65        27.05    168       45.81     % SBS9
 65.4426  168.8039       65        26.56    168       48.24     %  SBS9.5
 65.4345  168.8444       65        26.07    168       50.66     % SBS10
 65.4263  168.8848       65        25.58    168       53.09     %  SBS10.5
 65.4181  168.9252       65        25.09    168       55.51     % SBS11
%
%
%===============================================================
% - South Bering Strait section  redone - SBSnn
%===============================================================
```

```
% First ran in 2014 and 2015 and then only partly
% Run in full in 2017
% Re aligned in 2019 to start from BS22
% 2019 stations slightly off this (SBSn)
% To catch ACC before it enters the strait
%  - 22.5nm long
%  - 21 stations including halves
%--------------------------------------------------------------
% Lat(N)   Lon  (W)    Lat (N)       Lon (W)      NAME
% decdeg  decdeg    deg      min     deg   min
 65.625 168.177     65   37.48     168   10.63 % SBSnn1 = BS22
 65.614 168.215     65   36.86     168   12.87 % SBSnn1.5
 65.604 168.252     65   36.24     168   15.12 % SBSnn2
 65.594 168.289     65   35.62     168   17.36 % SBSnn2.5
 65.583 168.327     65   35.00     168   19.61 % SBSnn3
 65.573 168.364     65   34.38     168   21.85 % SBSnn3.5
 65.563 168.402     65   33.76     168   24.09 % SBSnn4
 65.552 168.439     65   33.14     168   26.34 % SBSnn4.5
 65.542 168.476     65   32.52     168   28.58 % SBSnn5
 65.532 168.514     65   31.90     168   30.83 % SBSnn5.5
 65.521 168.551     65   31.29     168   33.07 % SBSnn6
 65.511 168.589     65   30.67     168   35.31 % SBSnn6.5
 65.501 168.626     65   30.05     168   37.56 % SBSnn7
 65.490 168.663     65   29.43     168   39.80 % SBSnn7.5
 65.480 168.701     65   28.81     168   42.05 % SBSnn8
 65.470 168.738     65   28.19     168   44.29 % SBSnn8.5
 65.459 168.776     65   27.57     168   46.53 % SBSnn9
 65.449 168.813     65   26.95     168   48.78 % SBSnn9.5
 65.439 168.850     65   26.33     168   51.02 % SBSnn10
 65.428 168.888     65   25.71     168   53.27 % SBSnn10.5
 65.418 168.925     65   25.09     168   55.51 % SBSnn11
%
```

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% Bering Strait 2022 NORSEMAN2 log CTD																									
%example from 2013																									
%Date	Time	1	**Cast NO**	Down(1),Up(2)	Depth (m)	Lat (deg)	Lat (min)	Lon (deg)	Lon(min)	%	StationID	**#Nuts**	**#Salts**						Windspeed	Winddir	Operator				Comments
20130704	0627	1	**1**	1	52.5	65	21.690	167	53.450	%	testcast								14.4	182	ACPF				Test cast en route to BS line
20130704	0635	1	**1**	2	52.5	65	21.000	167	53.650	%									5.7	51	ACPF				1, 5 ans 6 are leaking
20130704	0713	1	**2**	1	42.2	65	25.100	167	59.270	%	testcast2								15.6	197	ACPF				This is to test bottles - All bottles OK
20130704	0721	1	**2**	2	42.2	65	25.175	167	59.260	%											ACPF				
%Date	**Time**	**1**	**Cast NO**	**Down(1),Up(2)**	**Depth (m)**	**Lat (deg)**	**Lat (min)**	**Lon (deg)**	**Lon(min)**	**%**	**StationID**								**Windspeed**	**Winddir**	**Operator**	**Wave H**	**Fog**	**Distanc**	**Comments**
%Please fill in all data for every event (CTD/net tow)										%									knots			**(m)**	**0 = clear;**	**(m)**	
%There should be one line for the beginning of the event and one line for the end										%															
%Date is GMT and has the format yyyymmdd										%															
%Time is GMT and has the format hhmm										%															
%Ty=Type: 1=CTD | 2=Net tow | 4=prod cast x | 5=LaramieTM | 6=CTD w Nuts | 7=CTD w Sal | 8=CTD w Sal and Nut										%															
%#,Number is consecutive for that event type										%															
%In/out (I/O): 1=In / 2=Out										%															
%Dep=waterdepth(m) from Furuno readout by CTD which is depth below keel, keel is 3m (10ft)																									
%LatD and LatM are Latitude Degrees and Minute and are positive N										%															
%LonD and LonM are Longitude Degrees and Min and are positive W										%															
%St is the name of the station (Line ID then station number)										%															
% SS = CTD operator estimate of sea state (Beaufort Scale)																									
%WSp=wind speed in m/s; WD=Wind direction from bridge																									
%Op=CTD operator																									
% when 3 lines for NET, dep indicates wire out for net																									
% Altimeter = 0 if complete rubbish, 0.5 if some good readings, 1 if good both up and down																									
%Fill in any comments if needed.										%									KNOTS						
20140630	2035	1	**1**	1	17.3	64	43.774	166	41.009	%	dry test								3.4	217	atn				dry test to learn CTD driving
20140630	2045	1	**1**	2	17.1	64	44.855	166	43.033	%	dry test								4.6	214	atn			NEXT YEAR: m VISIBLE	
20140703	642	1	**20**	1	51.8	65	41.144	168	26.929	%	0.1								16.6	187	atn				
20140703	645	1	**20**	2	52.5	65	41.235	168	26.937	%	BS18								16.8	184	atn				BStrait14020.hdr file: put Station=BS20 by mistake, should be Station=BS18 as shown here in StationID
%%%%%%%%%% STARTING HERE FOR 2022						**AND GET A WIRE TO CLEAN PUMPS WHEN NEEDED**										**Changeat**	**Wire Out**								
SET LAPTOP TIME TO GMT																									
%Date	**Time**	**Type**	**Cast NO**	**Down(1),Up(2)**	**Depth (m)**	**Lat (deg)**	**Lat (min)**	**Lon (deg)**	**Lon(min)**	**%**	**StationID**	**#Nuts**	**#Salts**	**SUNA bat s**	**Min SUNA on**	**Total tim**	**Surf**	**Bot**	**Windspeed**	**Winddir**	**Operator**	**Wave H (r**	**Clear(0) o**	**Water c**	**Comments**
20220909	813	1	**1**	1	19	64	30	166	22.22	%	Dry test			21						30.8	ACPF				Dry test with new termination -- OK!!
20220909	813	1	**1**	2	19	64	30	166	22.22	%	Dry test			21	10	10				30.8	ACPF				Dry test with new termination -- OK!!
20220909	1605	1	2	1	0	65	2.6	167	20	%	Dry test			21							ACPF				Dry test with new term after dried. -- OK. Comp Interf. ***Transmit*** **light ON after initially** ***Receive*** **ON**
20220909	1605	1	2	2	0	65	2.6	167	20	%	Dry test			21	5	15					ACPF				Dry test with new term after dried. -- OK. Comp Interf. ***Transmit*** **light ON after initially** ***Receive*** **ON**
20220909	1640	1	**3**	1	0	65	4	167	25	%	Dry test			21							ACPF				Dry test again - same as above. Transmit light switches to ON when comms achieved
20220909	1640	1	**3**	2	0	65	4	167	25	%	Dry test			21	5	20					ACPF				Dry test again - same as above. Transmit light switches to ON when comms achieved
20220909	1652	1	**4**	1	0	65	5	167	27	%	Drytest w Bottles			21							ACPF				Drytest with bottle firing test -- OK
20220909	1652	1	**4**	2	0	65	5	167	27	%	Drytest w Bottles			21	2	22					ACPF				Drytest with bottle firing test -- OK
20220909	2135	1	**5**	1	21.2	65	31.61	167	57.3	%	Test w Bottles			21				375	15	358	ACPF	1	0	2.5	Test with bottle firings and sampling test
20220909	2146	1	**5**	2	21.2	65	31	167	57.34	%	Test w Bottles			21	11	33		375	15	358	ACPF	1	0	2.5	Did not fire bottle 12 (intentionally - kinda)
20220910	12	1	**6**	1	21.5	65	30.734	167	57.183	%	Test cast bottles integrity			21			358		13.1	341.1	KC	1	0	3	Testing bottles after redoing o rings, no samples taken
20220910	17	1	**6**	2	20.7	65	30.714	167	57.027	%	Test cast bottles integrity			21	5	38	358		13.1	341.1	KC	1	0	3	8 and 12 are leaking, possibly 5
20220910	41	1	**7**	1	0	65	31.594	167	57.362	%	Deck test SUNA w DI Water			21							KC				Testing SUNA with DI water
20220910	41	1	**7**	2	0	65	31.594	167	57.362	%	Deck test SUNA w DI Water			21	0.5	38.5					KC				Value = 4uM
20220910	47	1	**8**	1	0	65	31.58	167	57.343	%	Deck test SUNA w 19.98uM Nitrate			21							KC				Testing SUNA with 19.98uM Nitrate
20220910	47	1	**8**	2	0	65	31.58	167	57.343	%	Deck test SUNA w 19.98uM Nitrate			21	0.5	39					KC				Value = 24 uM
20220910	127	1	**9**	1	20.7	65	31.241	167	56.586	%	Test cast with bottles firing			21			358	377	13.4	286	RJD	1	0	4	9, 11, 12, bottle leaking, and 5 a little
20220910	131	1	**9**	2	20.7	65	31.235	167	56.648	%	Test cast with bottles firing			21	5	44	358	377			RJD	1	0	4	Added extra twist to bottles 9, 11, 12
20220910	151	1	**10**	1	20.6	65	31.105	167	56.574	%	Test cast with bottles firing			21							MZ	1	0	3	5,12,2 leaking; adding extra twists
20220910	155	1	**10**	2	20.6	65	31.003	167	56.544	%	Test cast with bottles firing			21	4	48	358	377	17	330	MZ	1	0	3	
20220910	209	1	**11**	1	21.4	65	31.273	167	57.001	%	Test cast with bottles firing			21			358	380	14	282	JG	1	0	3	4,11,12 leaking (put in extra twists)
20220910	213	1	**11**	2	21.4	65	31.252	167	56.95	%	Test cast with bottles firing			21	4	52						1	0	3	
20220910	228	1	**12**	1	21.1	65	31.164	167	56.818	%	Test cast with bottles firing			21			358	379	3.4	15	MZ	0.5	0	3	5, 9, 11 12 and maybe 10 are leaking
20220910	233	1	**12**	2	21.1	65	31.164	167	56.818	%	Test cast with bottles firing			21	5	57						0.5	0	3	
20220910	405	1	**13**	1	21.5	65	31.547	167	57.504	%	Cast to 12 meters with bottles firing			21								1	0	3	Zipties added to top of bottles 5,11,12 before cast. A
20220910	409	1	**13**	2	21.5	65	31.542	167	57.476	%	Cast to 12 meters with bottles firing			21	4	61	358	370	22.9	356	MZ	1	0	3	After cast: all good apart from 12; Going to shorten black rubber band in middle for bottle 12 and try again
20220910	431	1	**14**	1	21.2	65	31.484	167	57.257	%	Cast to 12 meters with bottles firing			21								1	0	3	12 didn't leak! None leaked (yay!)
20220910	434	1	**14**	2	21.2	65	31.472	167	57.221	%	Cast to 12 meters with bottles firing			21	3	64	358	371	15.4	333	MZ	1	0	3	
20220910	2321	1	**15**	1	45.7	65	44.52	168	16.004	%	A4-21 pre-recovery			21								1	0	2.5	A4-21 pre-recovery cast
20220910	2330	1	**15**	2	45	65	44.96	168	15.56	%	A4-21 pre-recovery			21	11	75	358	410	11	208	ACPF	1	0	2.5	
20220911	326	1	**16**	1	45.3	65	44.894	168	15.667	%	A4-22 post-deployment cast			21								0.5	0	1.5	No leaking bottles
20220911	331	1	**16**	2	45.7	65	45.12	168	15.542	%	A4-22 post-deployment cast			21	5	80	357	407	12.1	190	MZ	0.5	0	1.5	
20220911	1603	1	**17**	1	54.3	66	19.565	168	56.367	%	A3-21 pre-recovery			21								0.5	0	1.5	This cast was 2km away from A3-21 site - so, it is **not good** for validation.
20220911	1614	1	**17**	2	54.4	66	19.773	168	57.004	%	A3-21 pre-recovery			21	11	91	358	414	14	55.6	MZ	0.5	0	1.5	
20220911	2331	6	**18**	1	54.6	66	19.731	168	57.119	%	A3-22 post-deployment			21			358	417	24	68.5	MZ	1	0	3	Fired bottles 1-6 for nutrients (waited 10 sec before firing) at 47 m;
20220911	2338	6	**18**	2	54.4	66	19.89	168	57.653	%	A3-22 post-deployment	2		21	7	98	358	417	24	68.5	MZ	1	0	3	fired 7-12 at 45 m (did not wait 10 sec); fired NUTS to get above and below SUNA
20220912	431	1	**19**	1	52.6	65	46.893	168	33.89	%	A2-21 pre-recovery (via dragging)			21			358	412	9.3	155.5	KC	0.5	0	3	
20220912	437	1	**19**	2	53.7	65	47.054	168	33.789	%	A2-21 pre-recovery (via dragging)			21	6	104	358	412	8.8	151.1	KC	0.5	0	3	
20220913	404	6	**20**	1	30	65	37.66	168	10.94	%	BS22			21			358		12	20		0.5	0	1	**START OF BS LINE (westward). CTD and Nuts + Laramie's TM sampling**
20220913	411	6	**20**	2	31	65	37.847	168	11.192	%	BS22	4		21	7	111									Bottle 8 leaked (top didn't seal properly)
20220913	416	5	**1**	1	32.5	65	38.007	168	11.392	%	BS22-Laramie														
20220913	435	5	**1**	2		65	38.606	168	11.992	%	BS22-Laramie														
20220913	455	1	**21**	1	37.2	65	38.09	168	13.016	%	BS21.5			21			358	399	9.7	53	ACPF	0.5	0	2.5	BS21.5 CTD only
20220913	500	1	**21**	2	37.2	65	38.26	168	13.18	%	BS21.5			21	5	116					ACPF				
20220913	511	1	**22**	1	40.6	65	38.58	168	15.14	%	BS21			21							ACPF				CTD only
20220913	516	1	**22**	2	40.9	65	38.76	168	15.26	%	BS21			21	5	121	358	405	12.9	45	ACPF	0.5	0	1.5	
20220913	530	6	**23**	1	44.5	65	39.06	168	17.321	%	BS20.5			21							ACPF				CTD and NUTS + Laramie's TM sampling
20220913	537	6	**23**	2	45	65	39.35	168	17.59	%	BS20.5	5		21	7	128	358		10	38	ACPF	0.5	0	2	
20220913	542	5	**2**	1	45.9	65	39.63	168	17.94	%	BS20.5														
20220913	552	5	**2**	2	47	65	40.062	168	18.327	%	BS20.5														
20220913	616	1	**24**	1	47	65	39.437	168	19.258	%	BS20			21							ACPF				CTD only.

20220913	621	1	**24**	2	47	65	39.581	168	19.352	%	BS20			21	5	133	358		12	40	ACPF	0.5	0	2	
20220913	634	1	**25**	1	48.7	65	39.878	168	21.388	%	BS19.5			21							ACPF				CTD only
20220913	638	1	**25**	2	49	65	40.071	168	21.467	%	BS19.5			21	4	137	358	413	12.4	28	ACPF	0.5	0	2	
20220913	651	6	**26**	1	50	65	40.36	168	23.604	**%**	BS19			21							ACPF				BS19 and NUTS + Laramies TM sampling
20220913	658	6	**26**	2	50.6	65	40.605	168	23.896	%	BS19	6		21	7	144	358		7	20	ACPF	0.5	0	2	CTD hooked a bit earlier - bottle 12 (surface sample) might've closed partly on air
20220913	702	5	**3**	1	51	65	40.791	168	24.05	%	BS19														
20220913	711	5	**3**	2	51.4	65	41.28	168	24.321	%	BS19														
20220913	730	1	**27**	1	50.7	65	40.806	168	25.253	%	BS18.5			21							ACPF				CTD only
20220913	735	1	**27**	2	51.1	65	40.99	168	25.41	%	BS18.5			21	5	149	358	420	10	358	ACPF	0.5	0	1	
20220913	754	1	**28**	1	51.5	65	41.199	168	26.88	**%**	BS18			21							ACPF				CTD only
20220913	759	1	**28**	2	51.4	65	41.318	168	26.907	%	BS18			21	5	154	358	412	11	27	ACPF	0.5	0	2	
20220913	814	6	**29**	1	51.9	65	41.654	168	29.216	%	BS17.5			21							ACPF				BS17.5 and NUTS + Laramie's TM sampling
20220913	822	6	**29**	2	51.9	65	41.631	168	29.199	%	BS17.5	6		21	8	162	358		7	8	ACPF	0.5	0	2	Shark checking out the CTD
20220913	828	5	**4**	1	51.6	65	41.66	168	29.159	%	BS17.5														
20220913	840	5	**4**	2	51.6	65	41.812	168	29.118	%	BS17.5														
20220913	859	1	**30**	1	52.4	65	42.177	168	31.294	**%**	BS17			21			358	420	13	350	JG	1	0	2	CTD only
20220913	904	1	**30**	2	52.4	65	42.171	168	31.288	%	BS17			21	5	167			13	350	JG	1	0	2	
20220913	920	1	**31**	1	50.2	65	42.735	168	33.367	%	BS16.5			21			358	420	7.5	346	JG	1	0	4	CTD only
20220913	925	1	**31**	2	50.2	65	42.724	168	33.264	%	BS16.5			21	5	172			7.5	346	JG	1	0	4	
20220913	942	6	**32**	1	49.6	65	43.259	168	35.394	%	BS16			21			358	420	13	346	JG	1	0	3	
20220913	950	6	**32**	2	49.8	65	43.208	168	35.267	%	BS16	6		21	8	175			13	346	JG	1	0	3	
20220913	953	5	**5**	1	49.8	65	43.208	168	35.267	**%**	BS16										JG				
20220913	1010	5	**5**	2	49.8	65	43.208	168	35.267	%	BS16										JG				
20220913	1028	1	**33**	1	49.6	65	43.796	168	37.605	%	BS15.5			21			358	414	8.5	340	JG	1	1	4	JG forgot PNGs for 30-32
20220913	1033	1	**33**	2	49.7	65	43.768	168	37.574	%	BS15.5			21	5	180			8.5	340	JG	1	1	4	
20220913	1051	1	**34**	1	49.7	65	44.269	168	39.67	%	BS15			21			359	419	10	341	JG	1	1	3	
20220913	1056	1	**34**	2	49.3	65	44.226	168	39.529	%	BS15			21	5	185	359	419	10	341	JG	1	1	3	
20220913	1112	6	**35**	1	49.9	65	44.73	168	41.483	**%**	BS14.5			21			358	419	8.4	341	JG	1	1	3	
20220913	1120	6	**35**	2	49.5	65	44.642	168	41.179	%	BS14.5	6		21	8	188	358	419	8.4	341	JG	1	1	3	
20220913	1122	5	**6**	1	49.5	65	44.627	168	41.05	%	BS14.5										JG				
20220913	1135	5	**6**	2	49.5	65	44.641	168	40.963	%	BS14.5										JG				
20220913	1151	1	**36**	1	50.5	65	45.22	168	43.3	%	BS14			21			358	414	15.7	325	JG	1	1	4	
20220913	1158	1	**36**	2	50.6	65	45.126	168	43.226	%	BS14			21	7	195	358	414	15.7	325	JG	1	1	4	
20220913	1219	1	**37**	1	50.7	65	45.738	168	45.335	%	BS13.5			21			359	415	14	334	JG	1	1	4	Big Nitrate spike >25 microM on downcast, disappeared on upcast. Possible jellyfish ?
20220913	1225	1	**37**	2	50.8	65	45.668	168	45.248	%	BS13.5			21	6	201	359	415	14	334	JG	1	1	4	
20220913	1245	6	**38**	1	50.2	65	46.269	168	47.567	%	BS13			21			359	415	12.8	332.9	JG	1	1	4	
20220913	1254	6	**38**	2	50.5	65	46.228	168	47.09	%	BS13	6		21	9	210	359	415	12.8	332.9	JG	1	1	4	
20220913	1257	5	**7**	1	50.5	65	46.233	168	46.902	%	BS13										JG				
20220913	1308	5	**7**	2	50.5	65	46.284	168	46.74	%	BS13										JG				
20220913	1325	1	**39**	1	48.3	65	46.747	168	49.477	%	BS12.5			21			359	413	13.5	344.5	JG	1	1	4	
20220913	1330	1	**39**	2	50	65	46.736	168	49.176	%	BS12.5			21	5	215	359	413	13.5	344.5	JG	1	1	4	
20220913	1349	1	**40**	1	43.7	65	47.171	168	51.472	%	BS12			21			358	414	15.9	331.1	JG	1	1	3	
20220913	1355	1	**40**	2	44.4	65	46.974	168	51.341	%	BS12			21	6	221	358	414	15.9	331.1	JG	1	1	3	
20220913	1423	6	**41**	1	46.8	65	47.961	168	53.5	%	BS11.5			21			358	415	15.6	353	MZ	1	1	3	
20220913	1432	6	**41**	2	46.2	65	47.9	168	53.242	%	BS11.5	5		21	9	230	358	415	15.6	353	MZ	1	1	3	
20220913	1440	5	**8**	1	46.2	65	47.9	168	53.24	%	BS11.5										MZ				
20220913	1446	5	**8**	2	46.2	65	47.92	168	53.253	%	BS11.5										MZ				
20220913	1504	1	**42**	1	45.1	65	48.307	168	55.921	%	BS11			21			358	407	15.7	318	MZ	1	1	2	
20220913	1510	1	**42**	2	44.9	65	48.253	168	55.75	%	BS11			21	6	236	358	407	15.7	318	MZ	1	1	2	
20220914	32	6	**43**	1	52.6	65	46.896	168	33.864	%	A2-22 Post-deployment			5		NEW	359	418	12.4	333.6	KC	1	1	3	5 bottles at 50, 6 bottles at 48 (targeting 49), SUNA battery changed (now number 5);
20220914	40	6	**43**	2	53.4	65	46.892	168	33.503	%	A2-22 Post-deployment	2		5	8	8	359	418	6.6	325.8	KC	1	1	3	
20220914	504	1	**44**	1	54.4	66	19.704	168	56.441	**%**	A3			5			356		9	329	ACPF	0.5	1	3	**Start of AL line (Eastward)**
20220914	509	1	**44**	2	54.4	66	19.752	168	56.3	%	A3			5	5	13	356		9	329	ACPF	0.5	1	3	
20220914	518	6	**45**	1	54.6	66	20.003	168	55.294	%	AL12.5			5			356		4	350	ACPF	0.5	1	3	AL12.5 with NUTS and Laramie's TM sampling
20220914	527	6	**45**	2	54.4	66	19.962	168	55.066	%	AL12.5	6		5	9	22	356		4	350	ACPF	0.5	1	3	
20220914	530	5	**9**	1	54.4	66		168		%	AL12.5										ACPF				
20220914	539	5	**9**	2	54.4	66	19.978	168	54.88	%	AL12.5										ACPF				
20220914	549	1	**46**	1	54.6	66	20.345	168	53.491	**%**	AL13			5			356		355	6	ACPF	0.5	1	2	
20220914	554	1	**46**	2	54.4	66	20.325	168	53.314	%	AL13			5	5	27	356		355	6	ACPF	0.5	1	2	
20220914	605	1	**47**	1	53.1	66	20.721	168	51.376	%	AL13.5			5			356	420	7	7	ACPF	0.5	1	2	
20220914	609	1	**47**	2	53.1	66	20.705	168	51.204	%	AL13.5			5	4	31	356	420	7	7	ACPF	0.5	1	2	
20220914	621	6	**48**	1	53.9	66	21.073	168	49.21	%	AL14			5			356		9	20	ACPF	0.5	1	1.5	AL14 CTD w NUTS and Laramie's TM sampling
20220914	628	6	**48**	2	53.7	66	21.061	168	48.905	%	AL14	6		5	7	38	356		9	20	ACPF	0.5	1	1.5	
20220914	632	5	**10**	1	53.7	66	21.056	168	48.865	%	AL14										ACPF				
20220914	642	5	**10**	2	53.7	66	21.11	168	48.67	%	AL14										ACPF				
20220914	652	1	**49**	1	53.9	66	21.417	168	47.059	%	AL14.5			5			356	418	9.2	39	ACPF	0.5	1	2	
20220914	657	1	**49**	2	54	66	21.387	168	46.9	%	AL14.5			5	5	43	356	418	9.2	39	ACPF	0.5	1	2	
20220914	708	1	**50**	1	46.2	66	21.748	168	44.92	%	AL15			5			357	410	7.1	30	JG	0.5	1	2	
20220914	713	1	**50**	2	46.3	66	21.728	168	44.751	%	AL15			5	5	48	357	410	7.1	30	JG	0.5	1	2	
20220914	723	6	**51**	1	51.4	66	22.102	168	42.8	**%**	AL15.5			5			357	415	6.2	33	JG	0.5	1	2	AL15.5 CTD w NUTS and Laramie and Range
20220914	731	6	**51**	2	52.5	66	22.112	168	42.521	%	AL15.5	6		5	8	56	357	415	6.2	33	JG	0.5	1	2	JG missed png for cast #51
20220914	734	5	**11**	1		66	22.122	168	42.457	%	AL15.5										JG				
20220914	743	5	**11**	2		66	22.176	168	42.452	%	AL15.5										JG				
20220914	800	1	**52**	1	55.6	66	22.454	168	40.656	%	AL16			5			358	416	7.5	25.3	JG	0.5	1	2	
20220914	805	1	**52**	2	55.6	66	22.464	168	40.55	%	AL16			5	5	61	358	416	7.5	25.3	JG	0.5	1	2	Slight offset between S1/S2 more than prior casts
20220914	817	1	**53**	1	55	66	22.851	168	38.519	**%**	AL16.5			5			357	415	10.1	36	JG	0.5	1	4	Lots of Jellyfish
20220914	822	1	**53**	2	55.5	66	22.887	168	38.404	%	AL16.5			5	5	66	357	415	10.1	36	JG	0.5	1	4	
20220914	836	6	**54**	1	53.9	66	23.205	168	36.36	%	AL17			5			357	415	10.4	27.9	JG	0.5	1	4	Nuts + Pumping. Cast Header might have wrong station information. AL17 is correct
20220914	845	6	**54**	2	53.8	66	23.256	168	36.198	%	AL17	6		5	9	75	357	415	10.4	27.9	JG	0.5	1	4	
20220914	847	5	**12**	1		66	23.285	168	36.18	%	AL17										JG				
20220914	858	5	**12**	2		66	23.352	168	36.264	%	AL17										JG				
20220914	932	1	**55**	1	53.1	66	23.542	168	34.69	%	AL17.5			5			358	415	7.7	31	KC	0.5	0	4	
20220914	937	1	**55**	2	53.2	66	23.553	168	34.695	%	Al17.5			5	5	80	358	415	7.5	29	KC	0.5	0	4	
20220914	951	1	**56**	1	51.6	66	23.897	168	32.094	**%**	AL18			5			358	413	8.2	37	KC	0.5	0	5	Cast started with fast winch speed going down, slowed for second half

20220914	957	1	**56**	2	51.6	66	23.88	168	32.226	%	AL18			5	6	86	358	413	5.8	28	KC	0.5	0	5	SUNA ok
20220914	1010	6	**57**	1	52.1	66	24.245	168	29.887	%	AL18.5			5			357	412	6.6	39	KC	0.5	0	5	40m bottles fired after 5 (not10)s; Nutrients very different on up and down. Even after waiting 20sec
20220914	1020	6	**57**	2	51.9	66	24.267	168	29.651	%	AL18.5	6		5	10	96	357	412	8.5	33	KC	0.5	0	5	SUNA ok on downcast, reading low on upcast
20220914	1022	5	**13**	1	52.1	66	24.274	168	29.613	%	AL18.5										KC				Tube popped off, needed repair
20220914	1036	5	**13**	2	51.9	66	25.343	168	29.658	%	AL18.5										KC				
20220914	1045	1	**58**	1	52.2	66	24.572	168	27.742	**%**	AL19			5			358	415	7.5	29	KC	0.5	0	5	Range on mooring here.
20220914	1052	1	**58**	2	52.2	66	24.556	168	27.538	%	AL19			5	7	103	358	415	5.7	27	KC	0.5	0	5	SUNA went to -7.5 below 35m, but came back on the up cast???
20220914	1109	1	**59**	1	51.3	66	24.92	168	25.623	%	AL19.5			5			357	412	6	33	KC	0.5	0	5	
20220914	1116	1	**59**	2	51.3	66	24.902	168	25.485	%	AL19.5			5	7	110	357	412	7.3	21	KC	0.5	0	5	SUNA Bad. Down cast low, and then to -7.5. Upcast -7.52 for the whole upcast
20220914	1130	6	**60**	1	51.1	66	25.286	168	23.398	%	AL20			5			358	413	6.7	33	KC	0.5	0	4	SUNA No data both down and upcast, but we continued in order to get samples for LJ cast.
20220914	1139	6	**60**	2	51.2	66	25.287	168	23.327	%	AL20	6		5	9	119	358	413	7.1	38	KC	0.5	0	4	One salinity channel bad, ?jellyfish (many in water). Rinsed CTD. Delay to diagnose SUNA issues.
20220914	1141	5	**14**	1	51.1	66	25.285	168	23.335	**%**	AL20										KC				
20220914	1151	5	**14**	2	51.1	66	25.308	168	23.419	%	AL20										KC				
20220914	1251	1	**61**	1	49.7	66	25.634	168	21.308	%	AL20.5			5			358	410	7	11	KC	0.5	0	5	
20220914	1257	1	**61**	2	49.6	66	25.617	168	21.326	%	AL20.5			5	6	125	358	410	5.9	39	KC	0.5	0	5	SUNA no data
20220914	1310	1	**62**	1	46.3	66	26.009	168	19.15	%	AL21			5			357	407	4	28	ACPF				
20220914	1316	1	**62**	2	46.4	66	25.995	168	19.192	%	AL21			5	6	131	357	407	4	28	ACPF				SUNA not sending data still, but we have confirmed it stores data internally OK
20220914	1331	6	**63**	1	42.1	66	26.383	168	16.923	**%**	AL21.5			5					5	40	ACPF	0.5	0	4	
20220914	1339	6	**63**	2	41.8	66	26.47	168	16.82	%	AL21.5	5		5	8	139			5	40	ACPF	0.5	0	4	SUNA no data
20220914	1342	5	**15**	1	41.9	66	26.47	168	16.82	%	AL21.5										ACPF				
20220914	1348	5	**15**	2	41.9	66	26.62	168	16.802	%	AL21.5										ACPF				
20220914	1400	1	**64**	1	39.6	66	26.765	168	15.032	%	AL22			5			357	398	3	22.1	MZ	0.5	0	3	
20220914	1406	1	**64**	2	39.5	66	26.85	168	15.045	%	AL22			5	6	145	357	398	3	22.1	MZ	0.5	0	3	SUNA no data
20220914	1418	1	**65**	1	36.2	66	27.05	168	12.765	**%**	AL22.5			5			357	395	0.4	33.1	MZ	1	0	3	Oxygen 1 sensor profile off - something likely got stuck in sensor
20220914	1423	1	**65**	2	36.2	66	27.139	168	12.667	%	AL22.5			5	5	150	357	395	0.4	33.1	MZ	1	0	3	SUNA no data
20220914	1435	6	**66**	1	32.3	66	27.356	168	10.54	%	AL23			5			357	391	2.4	1.2	MZ	0	0	3	Did not wait 10 seconds before bottom (31m) and 20m bottles; nitrate sensor values erroneous
20220914	1442	6	**66**	2	32.3	66	27.466	168	10.428	%	AL23	4		5	7	157	357	391	2.8	2.2	MZ	0	0	3	SUNA starting to give data again
20220914	1443	5	**16**	1	30.8	66	27.487	168	10.405	**%**	AL23										MZ				
20220914	1451	5	**16**	2	30.8	66	27.676	168	10.062	%	AL23										MZ				
20220914	1514	1	**67**	1	28.1	66	27.782	168	8.516	%	AL23.5			5			357	386	1.9	175.1	MZ	0	0	3	
20220914	1518	1	**67**	2	28.1	66	27.839	168	8.445	%	AL23.5			5	4	161	357	386	1.9	175.1	MZ	0	0	3	SUNA data appears ok again
20220914	1532	1	**68**	1	25.9	66	28.107	168	6.314	%	AL24			5			357	384	1.4	50.2	MZ	0.25	0	3	SUNA values look a little more valid this cast (over 0)
20220914	1536	1	**68**	2	25.9	66	28.14	168	6.241	%	AL24			5	4	165	357	384	1.4	50.2	MZ	0.25	0	3	
20220914	1546	1	**69**	1	23.8	66	28.395	168	4.204	%	AL24.5			5			357	381	4	75.4	MZ	0.25	0	4	
20220914	1550	1	**69**	2	23.8	66	28.413	168	4.102	%	AL24.5			5	4	169	357	381	4	75.4	MZ	0.25	0	4	
20220914	1601	6	**70**	1	22.2	66	28.722	168	1.947	%	AL25			5			357	380	0.2	231.1	MZ	0.25	0	3	CTD touched bottom (cable briefly slack) - no signs on salinity profile. No issues when CTD recovered
20220914	1608	6	**70**	2	22.2	66	28.859	168	1.44	%	AL25	3		5	7	176	357	380	0.2	231.1	MZ	0.25	0	3	
20220914	9999	5	**17**	1	22	66	28.821	168	1.685	%	AL25										MZ				
20220914	9999	5	**17**	2	22	66	28.886	168	1.239	%	AL25										MZ				
20220914	1629	7	**71**	1	21.4	66	29.003	168	0.069	**%**	AL25.5			5			357	380	8.1	77.8	MZ	0.25	0	3	Sampled salinity
20220914	1634	7	**71**	2	21.4	66	29.07	167	59.834	%	AL25.5		4	5	5	181	357	380	8.1	77.8	MZ	0.25	0	3	
20220914	1649	1	**72**	1	21.1	66	29.403	167	57.826	**%**	AL26			5			357	380	5.8	45.5	MZ	0.25	0	3	No png screenshot saved for this cast (need to make it later)
20220914	1653	1	**72**	2	21.1	66	29.416	167	57.656	%	AL26			5	4	185	357	380	5.8	45.5	MZ	0.25	0	3	
20220914	1703	7	**73**	1	21	66	29.706	167	55.772	**%**	AL26.5			5			357	379	3.5	50.2	MZ	0.25	0	3	Sampled salinity
20220914	1709	7	**73**	2	21	66	29.748	167	55.739	%	AL26.5		4	5	6	191	357	379	3.5	50.2	MZ	0.25	0	3	
20220914	1722	1	**74**	1	21.4	66	30.054	167	53.552	**%**	AL27			5			357	379	2.1	64.1	MZ	0	0	3	
20220914	1725	1	**74**	2	21.4	66	30.071	167	53.516	%	AL27			5	3	194	357	379	2.1	64.1	MZ	0	0	3	
20220914	1734	1	**75**	1	21.6	66	30.357	167	51.417	**%**	AL27.5			5			357	379	6.4	104.5	MZ	0.25	0	3	
20220914	1738	1	**75**	2	21.6	66	30.374	167	51.39	%	AL27.5			5	4	198	357	379	6.4	104.5	MZ	0.25	0	3	
20220914	2151	1	**76**	1	40.9	66	45.015	168	55.837	%	CCL8.5			5				379	6.7	85	RW	1.5	0.5	4	
20220914	2155	1	**76**	2	40.8	66	45.015	168	55.826	%	CCL8.5			5	4	202		379	7.5	85	RW	1.5	0.5	4	
20220914	2156	5	**18**	1	40.9	66	45.034	168	55.827	**%**	CCL8.5										RW				
20220914	2205	5	**18**	2	41.1	66	45.048	168	55.791	%	CCL8.5										RW				
20220914	2258	1	**77**	1	41.9	66	40.224	168	56.014	%	CCL8			5			358	400	4.4	225	RW	0.25	1	5	
20220914	2303	1	**77**	2	41.5	66	40.265	168	56.136	%	CCL8			5	5	207	358	400	4.1	133	RW	0.25	1	5	
20220914	2304	5	**19**	1	41.5	66	40.301	168	56.163	%	CCL8										RW				
20220914	2311	5	**19**	2	41.5	66	40.369	168	56.178	%	CCL8										RW				
20220915	4	1	**78**	1	44.2	66	35.016	168	56.061	**%**	CCL7			21		NEW	358		6.7	138	RJD	1	0	4	Changed out Suna at14th Sept 2021 23:35; battery pack taken out has voltage of 12.51V (was 12.8 when put i
20220915	10	1	**78**	2	44	66	35.093	168	56.265	%	CCL7			21	6	6	358		7.8	140	RJD	1	0	4	
20220915	11	5	**20**	1	44.1	66	35.151	168	56.349	%	CCL7										RJD				
20220915	20	5	**20**	2	44.1	66	35.154	168	56.401	%	CCL7										RJD				
20220915	112	1	**79**	1	55.2	66	30.016	168	55.767	**%**	CCL6			21			358	414	5.2	150	RJD	0.5	0	3	Presents of Anadear water
20220915	117	1	**79**	2	55.1	66	30.016	168	55.707	%	CCL6			21	5	11	358	414	4	154	RJD	0.5	0	3	
20220915	118	5	**21**	1	55.1	66	30.117	168	55.705	%	CCL6										RJD				
20220915	128	5	**21**	2	55.4	66	30.208	168	55.736	%	CCL6										RJD				
20220915	227	1	**80**	1	53.4	66	24.986	168	55.53	**%**	CCL5			21			357	414	3.2	41.4	KC	0.5	1	3	
20220915	232	1	**80**	2	53.5	66	25.009	168	55.682	%	CCL5			21	5	16	357	414	1.6	60.8	KC	0.5	1	3	
20220915	234	5	**22**	1	53.8	66	25.036	168	55.706	%	CCL5										KC				
20220915	243	5	**22**	2	54.2	66	25.102	168	55.907	%	CCL5										KC				
20220915	318	1	**81**	1	53.9	66	22.259	168	56.08	**%**	CCL4			21			358	415	3.2	33.4	KC	0.5	1	3	
20220915	323	1	**81**	2	53.9	66	22.253	168	56.135	%	CCL4			21	5	21	358	415	4.9	66.7	KC	0.5	1	3	
20220915	346	6	**82**	1	54.5	66	19.988	168	55.432	%	AL12.5			21			357	415	13.4	49.5	KC	0.5	1	2	Bottles 5, 7, 8, 9 all leaked. Lost data from depths: 30 & 20m
20220915	355	6	**82**	2	54.4	66	20.006	168	55.394	%	AL12.5	4		21	9	30	357		10.7	50.7	KC	0.5	1	2	
20220915	356	5	**23**	1	54.4	66	20.024	168	55.42	%	AL12.5										KC				
20220915	406	5	**23**	2	54.5	66	20.043	168	55.456	%	AL12.5										KC				
20220915	421	1	**83**	1	55	66	18.698	168	56.176	**%**	DL19.5			21			357	417	9.1	61.4	KC	0.5	0	1	
20220915	426	1	**83**	2	54.8	66	18.703	168	56.103	%	DL19.5			21	5	35	357	417	9.8	59.1	KC	0.5	0	1	
20220915	437	1	**84**	1	55.1	66	17.829	168	56.123	%	DL19			21			358	419	9.8	54.8	KC	0.5	0	1	
20220915	443	1	**84**	2	54.8	66	17.803	168	56.055	%	DL19			21	6	41	358	419	9.1	54.2	KC	0.5	0	1	
20220915	457	6	**85**	1	55.1	66	16.583	168	56.142	**%**	DL18.5			21			358	418	9.1	57.5	KC	0.5	0	1	No leaking bottles, twists fixed the issue
20220915	506	6	**85**	2	55.1	66	16.603	168	56.084	%	DL18.5	6		21	9	50	358	418	9.2	47.8	KC	0.5	0	1	
20220915	507	5	**24**	1	55.1	66	16.621	168	56.087	**%**	DL18.5										KC				
20220915	518	5	**24**	2	55.3	66	16.677	168	56.158	%	DL18.5										KC				
20220915	532	1	**86**	1	55.8	66	15.272	168	56.12	**%**	DL18			21			358	416	11.2	44.5	KC	0.5	0	1	Chl max at surface, matched with SUN nitrate min

20220915	538	1	**86**	2	55.7	66	15.287	168	56.025	%	DL18			21	6	56	358	416	11.2	38	KC	0.5	0	1	
20220915	554	1	**87**	1	54.9	66	13.995	168	56.221	%	DL17.5			21			357	415	5.9	59	KC	0.5	0	1	
20220915	600	1	**87**	2	55	66	14.046	168	56.135	%	DL17.5			21	6	62	357	415	7.3	69	KC	0.5	0	1	
20220915	616	6	**88**	1	55.3	66	12.752	168	56.324	**%**	DL17			21					7	40	ACPF	0.5	1	1	Took filtered AND unfiltered NUT samples at surface and bottom depths.
20220915	623	6	**88**	2	55.4	66	12.81	168	56.508	%	DL17	8		21	7	69			7	40	ACPF	0.5	1	1	
20220915	624	5	**25**	1	55.4	66	12.81	168	56.508	**%**	DL17														
20220915	633	5	**25**	2	55.4	66	12.846	168	56.637	**%**	DL17														
20220915	651	1	**89**	1	54.4	66	11.46	168	56.086	**%**	DL16.5			21					10	53	ACPF	0	1	1	
20220915	657	1	**89**	2	54.5	66	11.497	168	55.938	%	DL16.5			21	6	75			10	54	ACPF	0	1	1	
20220915	717	1	**90**	1	53.8	66	10.146	168	56.17	%	DL16			21			358		10	54	ACPF	0	1	1	
20220915	721	1	**90**	2	53.5	66	10.124	168	56.105	%	DL16			21	4	79	358		10	54	ACPF	0	1	1	
20220915	737	6	**91**	1	52.9	66	8.913	168	56.28	**%**	DL15.5			21			358		8	52	ACPF	0	1	1	Bottle 5 came up empty (leaking as system was being recover. Twisted the inner tube one more loop to tighter
20220915	745	6	**91**	2	53.2	66	8.984	168	56.248	%	DL15.5	6		21	8	87	358		8	52	ACPF	0	1	1	
20220915	747	5	**26**	1	53.2	66	8.984	168	56.248	**%**	DL15.5														
20220915	756	5	**26**	2	53.7	66	9.063	168	56.233	**%**	DL15.5														
20220915	829	1	**92**	1	53.2	66	7.731	168	56.418	%	DL15			21			358	414	10	26.8	JG	0	1	3	
20220915	836	1	**92**	2	53.3	66	7.738	168	56.501	%	DL15			21	7	94	358	414	10	26.8	JG	0	1	3	
20220915	852	7	**93**	1	53.2	66	6.364	168	56.181	**%**	DL14.5			21			358	415	9	61	JG	0	1	3	Salinity sample at surface. Possible wrong station header on CTD profile
20220915	859	7	**93**	2	53.3	66	6.378	168	56.004	%	DL14.5		4	21	7	101	358	415	9	61	JG	0	1	3	
20220915	917	6	**94**	1	53.2	66	5.104	168	56.117	**%**	DL14			21			358	413	8.5	51.3	JG	0	0	3	Nutrients cast NO Laramie
20220915	926	6	**94**	2	53.6	66	5.133	168	56.222	%	DL14	6		21	9	110	358	413	8.5	51.3	JG	0	0	3	
20220915	945	1	**95**	1	52.6	66	3.849	168	55.959	%	DL13.5			21			358	411	7	32.9	JG	0	0	4	
20220915	951	1	**95**	2	52.9	66	3.929	168	55.762	%	DL13.5				6	116	358	411	7	32.9	JG	0	0	4	
20220915	1008	1	**96**	1	51.5	66	2.542	168	56.042	**%**	DL13			21			357	411	10.4	28.2	JG	0	0	5	missed screenshot
20220915	1015	1	**96**	2	51.3	66	2.576	168	55.787	%	DL13			21	7	123	357	411	10.4	28.2	JG	0	0	5	
20220915	1032	6	**97**	1	50.9	66	1.251	168	56.079	**%**	DL12.5			21				409	11	30.2	JG	0	0	5	
20220915	1040	6	**97**	2	50.9	66	1.298	168	55.813	%	DL12.5	6		21	8	131		409	11	30.2	JG	0	0	5	Nutrients cast NO Laramie
20220915	1104	7	**98**	1	51.1	66	0.01	168	56.068	%	DL12			21			358		13	20	ACPF	0	0	3	Salinity samples taken. Changed orings on bottle 5
20220915	1112	7	**98**	2	51.3	66	0.06	168	55.966	%	DL12		4	21	8	139	358		13	20	ACPF	0	0	3	
20220915	1126	1	**99**	1	50.9	65	58.99	168	56.05	**%**	DL11			21			358		12	47	ACPF	0	0	4	Small spikes on T and S…
20220915	1132	1	**99**	2	50.7	65	59.063	168	55.798	%	DL11			21	6	145	358		12	47	ACPF	0	0	4	
20220915	1147	6	**100**	1	50.6	65	58.063	168	56.059	**%**	DL10			21			358		12.4	58	ACPF	0.5	0	5	Tightened bottle 7 innertube
20220915	1156	6	**100**	2	50.4	65	58.178	168	55.86	%	DL10	5		21	9	154	358		12.4	58	ACPF	0.5	0	5	Leaked bottles: 5, 7, 8 and 12.
20220915	1214	1	**101**	1	49.7	65	57.06	168	56.01	%	DL9			21			358		13	67	ACPF	0.5	0	4	
20220915	1218	1	**101**	2	49.7	65	57.09	168	56	%	DL9			21	4	158	358		13	67	ACPF	0.5	0	4	
20220915	1231	1	**102**	1	48.4	65	56.104	168	56.027	**%**	DL8			21			358	408	12	81	ACPF	0.5	0	4	
20220915	1236	1	**102**	2	48.4	65	56.13	168	55.983	%	DL8			21	5	163	358	408	12	81	ACPF	0.5	0	4	
20220915	1258	6	**103**	1	47.5	65	55.104	168	56.55	**%**	DL7			21			358		16	72	ACPF	0.5	0	4	
20220915	1305	6	**103**	2	47.5	65	55.139	168	56.055	%	DL7	5		21	7	170	358		16	72	ACPF	0.5	0	4	
20220915	1307	5	**27**	1	47.5	65	55.141	168	56.07	**%**	DL7														
20220915	1316	5	**27**	2	47.4	65	55.228	168	56.15	%	DL7														
20220915	1330	1	**104**	1	47.2	65	54.121	168	56.156	**%**	DL6			21			358	406	16.8	69.2	JG	0.5	0	4	
20220915	1335	1	**104**	2	47.1	65	54.121	168	56.166	%	DL6			21	5	175	358	406	16.8	69.2	JG	0.5	0	4	
20220915	1347	1	**105**	1	45.9	65	53.134	168	56.094	**%**	DL5			21			358	405	17.2	51.8	JG	0.5	0	4	
20220915	1352	1	**105**	2	46	65	53.092	168	56.091	%	DL5			21	5	180	358	405	17.2	51.8	JG	0.5	0	4	
20220915	1405	6	**106**	1	44.5	65	52.141	168	56.132	%	DL4			21			358	407	16	25.4	MZ	0.5	0	6	
20220915	1413	6	**106**	2	44.5	65	52.116	168	56.464	%	DL4	5		21	8	188	358	407	16	25.4	MZ	0.5	0	6	
20220915	1416	5	**28**	1	43.1	65	52.108	168	56.534	**%**	DL4										MZ				
20220915	1423	5	**28**	2	43	65	52.086	168	56.573	%	DL4										MZ				
20220915	1436	1	**107**	1	46.3	65	51.2	168	56.151	**%**	DL3			21			358	406	16.4	27.5	MZ	0.25	0	5	
20220915	1440	1	**107**	2	46.3	65	51.147	168	56.211	%	DL3			21	4	192	358	406	16.4	27.5	MZ	0.25	0	5	
20220915	1452	1	**108**	1	46.1	65	50.23	168	55.991	%	DL2			21			358	407	15.8	31.1	MZ	0.25	0	4	
20220915	1458	1	**108**	2	45.9	65	50.155	168	56.048	%	DL2			21	6	198	358	407	15.8	31.1	MZ	0.25	0	4	
20220915	1509	6	**109**	1	45.6	65	49.337	168	55.96	**%**	DL1			21			358	408	16.6	24.3	MZ	0.25	0	4	Took nutrient duplicates and unfiltered sample for surface and bottom bottles
20220915	1516	6	**109**	2	45.6	65	49.385	168	55.791	%	DL1	9		21	7	205	358	408	16.6	24.3	MZ	0.25	0	4	
20220915	1518	5	**29**	1	45.5	65	49.399	168	55.744	**%**	DL1										MZ				
20220915	1528	5	**29**	2	45.5	65	49.452	168	55.526	**%**	DL1										MZ				
20220915	1552	1	**110**	1	45	65	48.377	168	55.941	%	BS11			21			358	xxx	12	32	ACPF	0.25	1	5	
20220915	1558	1	**110**	2	45	65	48.43	168	55.821	%	BS11			21	6	211	358	xxx	12	32	ACPF	0.25	1	5	
20220915	1618	6	**111**	1	45.5	65	47.726	168	53.958	**%**	bs11.5			21			xxx	xxx			rw	0.25	0	5	
20220915	1626	6	**111**	2	45	65	47.669	168	54.224	%	bs11.5	3		21	8	219	xxx	xxx	15.4	25	rw	0.25	0	5	For last line, take nutrients in to and bottom. plus middle layer if different
20220915	1628	5	**30**	1	45.5	65		168		**%**	BS11.5										MZ				Need to get LAT LONG exact from position log
20220915	1635	5	**30**	2	45.5	65		168		%	BS11.5										MZ				
20220915	1649	1	**112**	1	42.3	65	47.337	168	51.697	%	bs12			21			xxx	xxx	15.6	24	rw	0.5	0	4	
20220915	1655	1	**112**	2	42.2	65	47.353	168	51.855	%	bs12			21	6	225	358	xxx	14	21	rw	0.5	0	4	
20220915	1708	1	**113**	1	47.8	65	46.823	168	49.508	**%**	BS12.5			21			358	404	13.8	20	RJD	0.5	0	4	
20220915	1713	1	**113**	2	48.3	65	46.888	168	49.419	%	BS12.5			21	5	230			14.1	1	RJD	0.5	0	4	
20220915	1724	6	**114**	1	50	65	46.308	168	47.64	**%**	BS13			21			358		14.4	28	RJD	0.5	0	5	Nutrient samples top and bottom
20220915	1731	6	**114**	2	49.1	65	46.413	168	47.611	%	BS13	2		21	7	237					RJD				
20220915	1732	5	**31**	1	49.6	65	46.424	168	47.603	**%**	BS13										RJD				
20220915	1740	5	**31**	2	49.9	65	46.48	168	47.661	**%**	BS13										RJD				
20220915	1754	1	**115**	1	50.6	65	45.727	168	45.575	**%**	BS13.5			21	5	242	358		14	42	RJD	0.5	0	4	
20220915	1759	1	**115**	2	50.6	65	45.775	168	45.508	%	BS13.5			21							RJD				
20220915	1811	1	**116**	1	50.7	65	45.157	168	43.405	**%**	BS14			21	4	246	358		12.9	39	RJD	0.5	0	4	
20220915	1815	1	**116**	2	50.2	65	45.186	168	43.362	%	BS14			21							RJD				
20220915	1825	6	**117**	1	49.7	65	44.794	168	41.614	%	BS14.5			21	5	251	358		18.6	42	RJD	0.5	0	4	Nutrient samples top and bottom
20220915	1830	6	**117**	2	49.6	65	44.801	168	41.628	%	BS14.5	2		21							RJD				Long minutes taken from png
20220915	1831	5	**32**	1	49.5	65	44.867	168	41.645	**%**	BS14.5										RJD				
20220915	1840	5	**32**	2	50	65	44.891	168	41.671	**%**	BS14.5										RJD				
20220915	1854	1	**118**	1	49.7	65	44.349	168	39.701	**%**	BS15			21			358		17.4	50	RJD	0.5	0	4	
20220915	1858	1	**118**	2	49.3	65	44.368	168	39.699	%	BS15			21	4	255					RJD				
20220915	1910	1	**119**	1	49.4	65	43.853	168	37.787	%	BS15.5			21			358		18	47	RJD	0.5	0	4	
20220915	1914	1	**119**	2	49.4	65	43.872	168	37.744	%	BS15.5			21	4	259					RJD				
20220915	1927	6	**120**	1	49.3	65	43.292	168	35.686	**%**	BS16			21			358		17.1	38	RJD	0.5	0	4	Nutrient samples top and bottom

20220915	1931	6	**120**	2	49.7	65	43.267	168	35.665	%	BS16	2		21	4	263					RJD				
20220915	1933	5	**33**	1	49.7	65	43.276	168	35.653	**%**	BS16										RJD				
20220915	1941	5	**33**	2	49.8	65	43.42	168	35.856	%	BS16										RJD				
20220915	2001	1	**121**	1	49.9	65	42.735	168	33.453	%	BS16.5			21			358	410	11.5	31.4	MZ	1	0	5	
20220915	2005	1	**121**	2	49.9	65	42.681	168	33.44	%	BS16.5			21	4	267	358	410	11.5	31.4	MZ	1	0	5	
20220915	2018	1	**122**	1	52.8	65	42.225	168	31.388	**%**	BS17			21			358	414	13.7	32.9	MZ	1	0	5	
20220915	1823	1	**122**	2	52.8	65	42.188	168	31.332	%	BS17			21	5	272	358	414	13.7	32.9	MZ	1	0	5	
20220915	2036	6	**123**	1	51.9	65	41.672	168	29.244	**%**	BS17.5			21			358	417	19.2	42.3	MZ	1	0	5	Nutrient samples top and bottom
20220915	2041	6	**123**	2	51.9	65	41.619	168	29.317	%	BS17.5	3		21	5	277	358	417	19.2	42.3	MZ	1	0	5	
20220915	2044	5	**34**	1	51.4	65	41.615	168	29.328	%	BS17.5										MZ				
20220915	2052	5	**34**	2	51.9	65	41.689	168	29.496	%	BS17.5										MZ				
20220915	2106	1	**124**	1	51.9	65	41.199	168	26.99	**%**	BS18			21			358	414	18.1	47.4	MZ	1.5	0	5	
20220915	2111	1	**124**	2	51.9	65	41.182	168	27.052	%	BS18			21	5	282	358	414	18.1	47.4	MZ	1.5	0	5	
20220915	2126	8	**125**	1	50.8	65	40.789	168	25.434	**%**	BS18.5			21			358		24.5	33	rw		0		Nutrient AND salt samples
20220915	2131	8	**125**	2	51.1	65	40.881	168	25.434	%	BS18.5	1	4	21	5	287	358		24.5	33	rw		0		Battery at 12.5V
20220915	2136	5	**35**	1	51.3	65	40.92	168	25.346	**%**	bs18.5 (just off)														
20220915	2147	5	**35**	1	51.3	-999	-999	-999	-999	%	bs18.5 (just off)														
	% Concluded CTDing here due to seastate, southward wind meeting the ACC making significant waves and unsafe conditions for further work.																								
	~~%~~											169	20												
	%											**#Nuts**	**#Salts**												
# Casts type	1	86	**no samples**																						
# Casts type	5	35	**pumping**																						
# Casts type	6	34	**with nutrients**																						
# Casts type	7	4	**with salinity**																						
# Casts type	8	1	**with nutrients and salinity**																						
SUM of sampled		39																							