## REVISION NOTICE TABLE

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| DATE | DESCRIPTION OF REVISION |
| 19 March 2025 | Updated channel names & formats in TOB files. G.G. |

## PROCESSING NOTES

Cruise: 2021-005

Agency: OSD

Location: West Coast Vancouver Island

Project: La Perouse / WCVI Plankton Monitoring Program

Chief Scientist: Sastri A.

Platform: John P. Tully

Date: 18 May 2021 – 30 May 2021

Processed by: Germaine Gatien

Date of Processing: 14 September 2021 – 1 October 2021

Number of original HEX files: 117 Number of processed CTD files: 116

Number of rosette files: 73 (2 for 1 cast) Number of processed CHE files: 72

Number of original TSG files: 1 Number of processed TOB files: 12 (1 per day)

# INSTRUMENT SUMMARY

CTD #0443 was mounted in a rosette and attached were 2 Wetlabs CSTAR transmissometer (1185DR & #1883DG), a SBE 43 DO sensor on the primary pump (#3791), SeaPoint Fluorometer on the secondary pump (#3950), a Biospherical QSP-400 PAR sensor (#70613) and an altimeter (#75321).

A thermosalinograph (SeaBird 45 S/N 0620) was mounted with a Wetlabs WETStar fluorometer (#1656) and flow meter.

Seasave version 7.26.7.121 was used for acquisition.

The data logging computer WP #102.

The deck unit was a Seabird model 11+ #425.

A Guildline model 8400B Autosal serial # 68572 was used to analyze salinity samples.

An IOS rosette with 24 10L bottles was used.

# SUMMARY OF QUALITY AND CONCERNS

The Daily Science Log Book and rosette log sheets were in good order with comments about problems encountered and a detailed list of equipment. There was no list of personnel, though that was available from the post-cruise report.

For bottles fired above 125db there was a wait of 60s and from 125db downwards it was 30s. This was done to allow better flushing of Niskin bottles in high vertical gradients. The fit of oxygen samples versus CTD oxygen was tighter than usual especially near the surface. This could be partly due to better flushing. The comparison of upcast bottles with recalibrated downcast SBE DO was also tighter in the top 100db than seen during 2019-005 when the same sites were occupied.

There were 2 WetLabs CStar transmissometers in use during this cruise:

Channel Transmissometer refers to sensor #1185DR (650nm - red)

Channel Transmissometer:Green refers to sensor #1883DG (530nm - green)

For comparison with other Institute of Ocean Sciences cruises, note that the transmissometer wavelength is 650nm unless otherwise stated.

Some corrections have been made to the water depth entries in the headers. Errors may come from sounder problems or typing errors. Depths may also vary significantly during a cast; where that appears to be the case the correction aimed to get the depth corresponding to the time when the CTD reached the bottom. For more detail see section 11of this report.

While CTD fluorescence data are expressed in concentration units, they do not always compare well to extracted chlorophyll samples. It is recommended that users check extracted chlorophyll values where available.

The chlorophyll CV% was higher than usual at 6.61. This was likely due to multiple and new analysts running samples and analysis spread over a longer period of time than usual, 1 month.

The SBE DO sensor has a fairly long response time so data accuracy is not as high when it is in motion as it is during stops for bottles. This will be especially true when vertical DO gradients are large. To get an estimate of the accuracy of the SBE DO data during downcasts (after recalibration) a rough comparison was made between downcast SBE DO and upcast titrated samples. Some of the difference will be due to problems with flushing of Niskin bottles and/or analysis errors and small mismatches in depth in the presence of large DO gradients, so the following statement likely underestimates SBE DO accuracy.

Downcast (CTD files) Oxygen:Dissolved:SBE data are considered, very roughly, to be:

±0.40 mL/L from 0 to 20db

±0.20 mL/L from 20db to 100db

±0.10 mL/L from 100db to 250db

±0.06 mL/L from 250db to 750db

±0.02 mL/L below 750db

The Thermosalinograph worked well with good detail in temperature, salinity and fluorescence traces and no significant spikes. The TSG salinity were recalibrated by adding 0.191psu based on comparisons with CTD data. This correction is slightly higher than for two other 2021 cruises when this TSG was used; that could be due to slight calibration drift and/or variations in sea state leading to an variations in the density of small bubbles in the loop. The TSG intake temperature may be reading high by 0.02C°, but the evidence is not sufficient to justify recalibration.

There was a separate flow meter on the TSG fluorometer. The TSG fluorescence values are remarkably close to those from the CTD. The ratio of TSG fluorescence to extracted chlorophyll samples had the usual pattern of gradually decreasing from a high of ~2.5 for CHL <1.5ug/L until it reached roughly 0.5, a level at which it stayed for CHL > 4ug/L.

# PROCESSING SUMMARY

##### Seasave

This step was completed at sea; the raw data files have extension HEX.

Two files had names with the wrong format (missing a 0); the names were fixed.

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The deployment protocol was:

* The rosette was brought to the surface. Pumps were turned ON. The rosette was brought down to 10m and kept there for 30 seconds. Once back at the surface, the data started to be archived, with the rosette at the surface for 30 seconds longer. Then the cast would start.
* For depths deeper than, and including, 125db, there was a wait for 30 seconds before closing a bottle. For depths shallower than, and including, 100db, the wait was 60 seconds before closing a bottle.

##### Preliminary Steps

The Log Book and rosette log sheets were obtained.

* Nutrients, extracted chlorophyll, dissolved oxygen, salinity and NH4 data were obtained in QF spreadsheet format from the analysts.
* The cruise summary sheet was completed.
* The histories of the pressure sensor, conductivity and dissolved oxygen sensors were checked. he temperature, conductivity and dissolved oxygen sensors had been used on 2 previous cruises since the last factory recalibrations. See section 14 for details.

Based on a log note the station name was changed in files for event #119.

Event #171 is split into 2 parts. The downcast is all in the main file, but for the bottle file it will be necessary to join 2021-005-0081 and 2021-005-0081a. The file for event 81a was removed from the processing list for downcast files.

The configuration file did not change through the cruise. All parameters were correct. One file was saved as 2021-005-ctd.xmlcon.

##### BOTTLE FILE PREPARATION

The ROS files were created using files 2021-005-ctd.xmlcon.

The ROS files were converted to IOS format.

The IOS files were put through CLEAN to create BOT files.

File 2021-005-0081.BOT was renamed as 2021-005-0081.BOTa.

File 2021-005-0081a.BOT was renamed as 2021-005-0081.BOTb.

JOIN was then run to join these two files. The output file was opened in Ultraedit and the bottle number was changed from 1 to 8 for the data from the BOTb file.

Temperature and salinity were plotted for all BOT files to check for outliers.

The files for events 29, 93, 110 and 173 were opened in CTDEDIT and channel Salinity:T0:C0 was edited lightly. The output files were copied to \*.BOT. Comments about editing applied were entered in the files.

A preliminary header check was run and no problems were found.

The BOT files were bin-averaged on bottle number.

The output was used to create file ADDSAMP.csv. First, the file was sorted on event number and Bottle Position order. Then sample numbers were added based on the rosette logs.

The ADDSAMP file was then reordered on event # & sample #.

The ADDSAMP file was used to add sample numbers to the BOT files – output \*.SAM.

The SAM files were bin-averaged on bottle # and called SAMAVG.

The addsamp.csv file was converted to CST files, which will form the framework for the bottle files.

Next, each of the analysis spreadsheets were examined to see what comments the analysts wanted included in the header file. These were used to create file 2021-005-bot-hdr.txt which will be updated as needed during processing.

Loops samples were moved from the salinity and chlorophyll CSV files to a combined loop data file for later use.

DISSOLVED OXGYEN

Dissolved oxygen data were provided in spreadsheet QF2021-005\_OXY\*.xlsx which includes flags, comments and a precision study. Draw temperatures are available. The spreadsheet page with the final data was simplified and saved as 2021-005oxy.csv. That file was converted into individual \*.OXY files.

There were some samples in the DO file that had comments starting with “ALL:” The files for salinity, NH4, Nutrients and CHL had flag 3 added, as required.

EXTRACTED CHLOROPHYLL

Extracted chlorophyll and phaeo-pigment data were obtained in file QF2021-005\_CHL QF\*.xlsx. The file included comments and flags and a precision study. A simplified version of the spreadsheet was prepared and saved as 2021-005chl.csv. Flags were added for 2 bottles with comments about leaks. The csv file was then converted to individual CHL files.

SALINITY

Salinity analysis was obtained in file QF2021-005\_SAL.xlsx which included a precision study. The analyses were carried out in a temperature-controlled lab 72 to 83 days after collection. The files were simplified and saved as 2021-005sal.csv. That file was then converted to individual SAL files.

NUTRIENTS

The nutrient data were obtained in spreadsheet QF2021-005\_NUTS\*.xlsx. This includes a precision study. The file was simplified, saved as 2021-005nuts.csv. The file was converted to individual NUT files.

AMMONIUM

NH4 data were obtained in spreadsheet 2018-39 QF NH4\*.xlsx. This includes a precision study. The file was simplified and saved as 2018-039NH4.csv. This file was converted to NH4 files.

The SAL, CHL, OXY, NUT and NH4 files were merged with CST files in 5 steps.

After the 5th step the files were put through CLEAN to reduce the headers to File and Comment sections only.

The files were then put through CLEAN to reduce the headers to File and Comment sections only.

These files are ordered on sample number, but the SAMAVG files are ordered on bottle number, so one or the other set needs to be reordered in order to merge them. The MRGCLN1 files were reordered on Bottle\_Number and saved as \*. MRGCLN1s.

The MRGCLN1s files were then merged with SAMAVG files using merge channel Bottle\_Number.

The output of the MRG files were exported to a spreadsheet and compared to the rosette log sheets to look for omissions. A few problems were found and resolved with help from analysts. This involved repeating the MERGE process.

##### Compare

Salinity

Compare was run with pressure as reference channel.

There was a lot of scatter in the results and identifying outliers was somewhat arbitrary. The differences between the two salinity channels was consistent with the results of the previous cruise during which this equipment was used, but both were lower relative to bottles than previously. Both cruises used the same sampling technique. The depths of sampling were much greater, on average, for Line P.

On initial inspection, the primary salinity appears to be low by about 0.006psu and the secondary appears to be very close to bottles. During 2021-006 an initial comparison showed the CTD to be low by about 0.0025 and the secondary high by ~0.0036psu. It is unlikely that both salinity channels should have drifted lower by 0.0035psu from the previous cruise. What factors could account for this other than calibration drift?

* Based on Alexander and Hinrichsen (1986) desorption of glass particles over 2.5-3 months would raise bottle values by about 0.003psu. But the same error would affect 2021-006.
* Evaporation of samples over 2.5 to 3 months is expected to be ~0.002psu if seals are good. This could vary from cruise to cruise. There are a number of outliers that suggest it may have been affected La Perouse more than Line P. The obvious ones were excluded from the comparison but it could suggest a more general problem.
* Flushing errors –Line P had an average pressure included in the comparison that is 2 times that of La Perouse after samples above 250db are excluded. The deeper samples are less prone to flushing errors due to lower gradients. Conditions were fairly rough for most of the 2021-005 casts with salinity sampling, but there will still be some flushing errors. Looking at data from a few deep casts from Line P and La Perouse shows that the average vertical salinity gradient is much lower below 1000m and there are fewer samples from that level from 2021-005.

Excluding cases where pressure is <250db, standard deviation in CTD salinity is >0.001 plus 1 bottle fired at the bottom of a cast and 8 outliers, the primary salinity is lower than bottles by an average of 0.0046psu and secondary high by 0.0014psu. Adding 0.003psu as the expected error from desorption would suggest the primary salinity is low by 0.0016psu and the secondary high by 0.0044psu. Making a small allowance for evaporation and incomplete flushing in the higher vertical gradients sampled in La Perouse would bring the differences close to those observed during 2021-006.

Large outliers were examined – they were all from casts well offshore where CTD data were very noisy during stops:

* Cast 94 Sample 281 at 99db – Large shed wake but wrong “sign” to explain difference. Conditions were good for flushing. There was a lot of variability during the stop so the CTD values captured in the 10s window can be seen during the stop but so can the value from the bottle sample. So this case should not be used in calibration studies but there is nothing to indicate that the sample should be flagged.
* Cast 94 Sample 280 at 124.5db – as for sample 281 – CTD for this cast very noisy during the stop; both bottle and CTD values seen in CHE file can be found during the stop. No flag justified.
* Cast 140 Sample 373 at 150.72db – very spiky CTD Sal and large shed wake – can explain difference.
* Cast 162 Sample 431 at 124.6db – very noisy CTD DO – As for cast 162 both the values in the CHE file for bottle and CTD salinity were measured by the CTD during the bottle stop. No flag justified.

So no further flagging of samples is recommended.

If we adjust the differences to account for desorption and evaporation then the primary are likely low by no more than 0.001psu and the and secondary high by ~0.005psu. While this still leaves a change of 0.002psu between the 2 cruises, the primary is within ±0.001psu for both, and the comparisons too noisy to read too much into the change. No recalibration is recommended for the primary salinity.

For full details for the COMPARE run see file 2021-005-sal-comp1.xls.

**Dissolved Oxygen**

COMPARE was run with pressure as the reference channel.

The initial fit of differences against SBE DO was quite tight except for 3 significant outliers. Those were investigated first:

* Cast #57 Sample 190– The DO sample was flagged 3 by the analyst as a possible misfire. It is clearly way out of line as are the draw temperature, nutrient and NH4 samples. All were padded and flagged 5. The bottle likely closed around 40m, though it was clearly fired at 10m. Flagged 5 for all samples with analyst’s agreement..
* Cast #65 – DO and nutrients both look slightly out of line in profile but CHL does not, so this does not look like a misfire. The oxygen difference can be explained if flushing is poor since the vertical gradient is large. No flag recommended.
* Cast #144 – The sample looks ok – this is an area of very high gradient and the CTD DO is noisy. No flag recommended.

When those outliers were removed plus 36 other minor outliers based on residuals, the fit was:

CTD DO Corrected = CTD DO \* 1.0536 - 0.0018 R2 = 0.95

This compares well with the fit found for the Line P section of cruise 2021-006:

CTD DO Corrected = CTD DO \* 1.0515 - 0.0131 R2 = 0.98

Most of the outliers were in the top 20db and all were above 200db. The fit is unusually tight near the surface which may be at least partly due to longer waits before firing bottles.

For full details for the COMPARE run see file 2021-005-dox-comp1.xls.

Fluorescence

COMPARE was run with extracted chlorophyll and CTD Fluorescence using pressure as the reference variable.

As usual, the SBE fluorescence is higher than extracted chlorophyll for low CHL and drops to about 50% of extracted chlorophyll for CHL>5ug/L.

For full details for the COMPARE run see file 2021-005-fl-chl-comp1.xls.

##### Conversion of Full Files from Raw Data

File 2021-005-ctd.xmlcon was used to convert all files.

The Tau function and the hysteresis function were selected since there was deep sampling. Depth was included in the conversion.

A few casts were examined and all expected channels are present. The descent rate was generally kept high but was often extremely noisy. The T and C pairs were reasonably close during downcasts. Upcasts are noisy. The transmissivity channels look reasonable with the “Green” transmissometer generally higher than the “Red”; the 2 profiles had similar shapes. The altimetry looked ok even though the signal was sometimes noisy at the bottom of casts. Dissolved oxygen and fluorescence traces looked normal.

##### WILDEDIT

Program WILDEDIT was run to remove spikes from the pressure, depth, conductivity & temperature only in the full cast files (\*.CNV).

Parameters used were: Pass 1 Std Dev = 2 Pass 2 Std Dev = 5 Points per block = 50

The parameter “Keep data within this distance of the mean” was set to 0 so all spikes would be removed.

##### ALIGN DO

A few casts were examined; both temperature channels were noisy during upcasts so the tests were not easy to interpret, but using +2.5s certainly improves the alignment and overall looks like a good choice for both sensors. That setting has worked well for many SBE DO sensors in recent years.

ALIGNCTD was run on all casts using +2.5s.

##### CELLTM

The noise in the upcast data makes tests for the best parameters for this routine very difficult to interpret. In the past when upcast data were not so noisy, the default setting of (α = 0.0245, β=9.5) was generally found to be the best choice. A few casts were checked for this cruise and the default setting does improve the data. CELLTM was run using (α = 0.0245, β=9.5) for both the primary and secondary conductivity.

##### DERIVE and Channel Comparisons

Program DERIVE was run on all casts to calculate primary and secondary salinity and dissolved oxygen concentration.

DERIVE was run a second time on 5 of the deeper casts to find the differences between the pairs of temperature, conductivity and salinity channels.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Cast # | Press | T1-T0 | C1-C0 | S1-S0 | Descent Rate |
| 2021-020-0037 | 320 | -0.0002 | ~ | +0.0002 | High, F.Steady |
| 2021-020-0082 | 350 | +0.0001 | +0.00017 | +0.0015 |  |
| 2021-020-0117 | 375 | +0.0004 | +0.00022 | +0.0021 | High, Noisy |
| 2021-006-0020 | 375 | +0.0004 | +0.00044 | +0.0043 | High, Noisy |
|  | 1200 | +0.0002 | +0.00042 | +0.0050 | “ |
| 2021-006-0039 | 1200 | 0 | +0.00042 | +0.0049 | High, XNoisy |
| “ | 2000 | -0.0002 | +0.00044 | +0.0055 | “ |
| “ | 3000 | -0.0003 | +0.00044 | +0.0057 | “ |
| 2020-006-0052 | 1200 | 0 | +0.00043 | +0.0057 | High, XNoisy |
| “ | 2000 | -0.0005 | +0.00042 | +0.0056 | “ |
| “ | 3000 | -0.0005 | +0.00044 | +0.0060 | “ |
| 2021-006-0077 | 1200 | -0.0005 | +0.00042 | +0.0059 | High XNoisy |
|  | 2000 | -0.0007 | +0.00044 | +0.0063 | “ |
|  | 3000 | -0.0006 | +0.00045 | +0.0062 | “ |
| 2021-005-0038 | 1000 | -0.0005 | +0.00045 | +0.0055 | High, Noisy |
| 2021-005-0089 | 1000 | -0.0002 | +0.00050 | +0.0060 | High, Moderate |
| 2021-005-0099 | 1000 | -0.0002 | +0.00050 | +0.0058 | High Noisy |
|  | 1900 | -0.0004 | +0.00050 | +0.0064 | High, V.Noisy |
| 2021-005-0140 | 1000 | -0.0002 | +0.00055 | +0.0065 | High, Noisy |
|  | 1900 | -0.0005 | +0.00055 | +0.0072 | F.High, Noisy |
| 2021-005-0167 | 1000 | -0.0002 | +0.00055 | +0.0065 | High, X.Noisy |
|  | 1700 | -0.0006 | +0.00055 | +0.0070 | High, X.Noisy |

There is little evidence of drift in temperature. Conductivity differences appear to be drifting slightly as do salinity differences, but the changes are not large.

##### Conversion to IOS Header Format

The IOSSHELL routine was used to convert SEA-Bird 911+ CNV files to IOS Headers.

CLEAN was run to add event numbers and to replace pad values in the pressure channel with interpolated values based on record number.

##### Checking Headers

* The Header Check turned up only one item of concern. The maximum value for Transmissivity:Green was 102.2%. That was in a spike with just one point >100%. This is likely in the noise level for full voltage. (Note: The value disappeared at the DELETE stage.)
* Fluorescence did not go off-scale.
* The cross-reference check and header check were run. No problems were found.
* Surface check was run and the average value was 2.95m which is reason results for the Tully in the offshore. The values were about 2.5m towards the end of the cruise in the Strait of Georgia.
* During cast #68 the CTD acquired data with a minimum pressure of 0.57db. The pumps were off at that level. There is no evidence that the CTD was out of water though transmissivity did have a spike first to low values, then high. The shallowest record found with pumps on was 1.5db and salinity was 32.15psu. There is no evidence suggesting pressure needs recalibration, but also little to say it is ok.
* Cruise tracks were plotted and added to the end of this report.

The altimeter and water depth readings from the headers of the CLN files were exported to a spreadsheet. A check value was calculated by subtracting water depth from maximum depth sampled plus altimetry header). Where that number was > 4 or <-4 plots of the altimetry were checked. Some casts didn’t get near the bottom so there are no altimetry headers and for most the check value was small.

23 casts were investigated further.

* Altimetry was plotted to make sure the header entry is reasonable. In one case it was very noisy but the estimate looks reasonable. All others looked to be within ±2m.
* The log entries for water depth were compared to the header entries and in 9 cases the log entries produced a much better result.
* For 10 casts neither the log nor the header water depth entry produced reasonable results. Either the sounder gave poor results or there was ship movement between the recoding of water depth and the bottom of the CTD cast. There were a number of casts where there was mention of drifting and/or high winds. For these 10 casts the water depth was changed to the sum of maximum depth sampled plus Altimetry Header reading.
* For 4 other casts there may have been drifting and the check value was ≤7m, so the entries were left unchanged.

Water depth was changed to the 19 affected CLN files.

11 of the changes also affect bottle files so water depth was changed in the BOT files.

##### Shift

Dissolved Oxygen

The Dissolved Oxygen voltage channel was aligned earlier. A few casts were checked to see if the alignment looked ok, and it did. No further alignment is needed for the DO concentration channel,

Conductivity

Tests were run on a few casts to assess what settings are best to align conductivity with temperature (as judged by the effect on salinity as seen in T-S space). The best settings overall were -0.8 records for both the primary and the secondary channels.

SHIFT was run twice on all SBE911 casts using -0.8 records for both conductivity channels. Salinity was recalculated for both channels.

Fluorescence

SHIFT was run on the SeaPoint fluorescence channel in all casts using the usual advance of +24 records. Plots show that the fluorescence offset is reasonably close to the temperature offset after this step.

##### DELETE

The following DELETE parameters were used:

Surface Record Removal: Last Press Min

Maximum Surface Pressure (relative): 10.00

Surface Pressure Tolerance: 1.0 Pressure filtered over 15 points

Swells deleted. Warning message if pressure difference of 2.00

Drop rates < 0.30m/s (calculated over 11 points) will be deleted.

Drop rate applies in the range: 10db to 10db less than the maximum pressure

Sample interval = 0.042 seconds. (taken from header)

COMMENTS ON WARNINGS: There was one warning.

*Event #219: Scans 9358 and 9359 have spiky pressure in opposite directions. The CLN file was edited by inserting interpolated values for pressure and depth in those 2 records based on the values for records 9357 and 9360. The SHIFT steps were then repeated on that cast.*

DELETE was rerun and no further warnings were found.

##### Other Comparisons

Experience with these sensors since last factory service –

The pressure, temperature, and conductivity sensors were used during 2 cruises since the last factory visit:

* 2021-020 – The salinity channels started out being close and gradually drifted apart. Based on information from the Line P section of cruise 2021-006 it appears that the primary salinity did not drift much. The drift in secondary salinity appears to have been fairly sudden and then settled down. Dissolved oxygen was recalibrated using slope/offset =1.0515/-0.0131 based on cruise 2021-006. This correction seemed high since it was first use since previous factory calibration. Pressure looked ok.
* 2021-006. Calibration checks were based on the Line P part of the cruise. Pressure looked ok, primary salinity was considered close to bottles and was not corrected. The secondary salinity was thought to be high by about 0.006psu and was not chosen for archiving.

The correction to dissolved oxygen was CTD DO Corrected = CTD DO \* 1.0515 - 0.0131.

Historic ranges – Profile plots were made with 3-standard deviation climatology ranges of T and S superimposed. There were some excursions. Offshore at stations LG7 and LJ7 temperatures were slightly above the climatology maximum near the bottom, 1700-1750db. At LJ03 temperature was slightly low around 40db. In the Strait of Georgia temperatures were high in near-surface waters to the north (Texada to Nanaimo) reaching to 60m at station 14 but only 20m further south. Salinity was mostly within the climatology except in waters between 20 and 60m off the west coasts. Near-shore in shallow waters values tended to be above the climatology maximum and offshore they were below the minimum. Given the varying sign of these excursions and evidence from many sources of warming in the region, these results do not suggest instrument calibration problems.

Post-Cruise Calibration – None available.

Repeat Casts – There were no repeat casts deep enough to expect a good comparison.

##### DETAILED EDITING

The primary channels were chosen for editing because the salinity was found to be more accurate in the bottle comparison and problems were noted in secondary temperature and salinity near the surface in cast #233. It is possible this also affected fluorescence since the sensor was on the secondary pump but that is not obvious in the profile plots.

All DEL files were copied to \*.EDT.

CTDEDIT was used to remove records that appear to be corrupted by shed wakes. Salinity was cleaned to remove spikes that appear to be due to small misalignment or instrumental noise. All files required some editing. Notes about editing applied were added to the files.

Fluorescence data were examined as well for cast #233 but there was no clear evidence of a problem and the profile is similar to nearby casts.

The edited files were copied to \*.EDT.

After editing, T-S plots were examined for all casts. Small unstable features remain in some casts but they were in shallow near-shore areas where such features may well be real. No further editing was done.

##### Corrections to Pressure, Salinity and Dissolved Oxygen Concentration

Pressure and salinity will not be recalibrated. The Dissolved Oxygen channel does need recalibration..

File 2021-005-recal.ccf was prepared to apply the following correction to channel Oxygen:Dissolved:

CTD DO Corrected = CTD DO \* 1.0536 - 0.0018

This correction was first applied to the SAM and MRGCLN2 files.

COMPARE was rerun for dissolved oxygen and shows that the correction was applied properly. When data are excluded based on using the same points as in the original fit the average is 0.00015mL/L, with a standard deviation of 0.025mL/L. See file 2021-005-DO-comp2.xls for details.

CALIBRATE was then run on the EDT files using the same recalibration file.

##### Final Calibration of DO

The initial recalibration of dissolved oxygen corrects for sensor calibration drift. Alignctd corrects for transit time errors. Those 2 steps may partly correct for response time errors, but to see if a further correction is needed, a comparison is made of downcast CTD data to bottle data from the same pressure. Small differences are expected due to ship drift, temporal changes, incomplete flushing of Niskin bottles and delayed response and noise in CTD data.

Downcast files were bin-averaged to 0.5m bins for the casts with DO bottle samples. Those files were then thinned and compared to the bottle values in the MRG files. COMPARE was run to study the differences between the downcast CTD DO data and the titrated samples from upcast bottles.

When outliers were removed based on high standard deviation in the CTD DO data, the CTD DO was higher than the titrated samples by an average of ~0.023mL/L. The standard deviation was 0.10mL/L. The outliers all came from the 0-200db range with most in the top 20db. It is notable that there are fewer large outliers in the top 100db than during 2019-005 which may be due to the increased wait time before firing bottles. (The 2020 spring cruise was multi-project so not comparable.)

Some of the difference will be due to problems with flushing of Niskin bottles and/or analysis errors and small mismatches in depth in the presence of large DO gradients, so the following statement likely underestimates SBE DO accuracy.

Downcast (CTD files) Oxygen:Dissolved:SBE data are considered, very roughly, to be:

±0.40 mL/L from 0 to 20db

±0.20 mL/L from 20db to 100db

±0.10 mL/L from 100db to 250db

±0.06 mL/L from 250db to 750db

±0.02 mL/L below 750db

For more detail see file 2021-005-dox-comp3.xls.

##### Fluorescence Processing

A median filter, size 11, was applied to the fluorescence channel in the COR1 files. Plots of a few casts showed that the filter was effective. (Output:\*.FIL)

##### BIN AVERAGE of CTD files

The following Bin Average values were applied to the FIL files (output AVG):

Bin channel = pressure Averaging interval = 1.000 Minimum bin value = .000

Average value will be used. Interpolated values are NOT used for empty bins.

On-screen T-S plots were examined.

Profile plots were examined. No problems were noted.

##### Final CTD File Steps (REMOVE and HEADEDIT)

For all casts REMOVE was run to remove the following channels:

Scan\_Number, Temperature:Secondary, Conductivity:Secondary, Oxygen:Voltage:SBE, Descent\_Rate, Status:Pump, Altimeter, Salinity:T1:C1 and Flag.

A second SBE DO channel (with umol/kg units) was added.

REORDER was run to get the two DO channels together.

HEADER EDIT was used to fix formats and channel names and to add the comments about processing.

The Standards Check routine was run and no problems were found.

The Header Check was run; no problems were found.

Profile and T-S plots were examined. No problems were found.

The sensor history was updated.

##### Dissolved Oxygen Study

As a final check of dissolved oxygen data, % saturation was calculated and plotted. Values at about 3m ranged between ~80% to 150%. In Haro Strait, Juan de Fuca Strait and the inshore area of the LB line values were very low. In other areas there was great variability. The casts from farthest offshore had values from 102% to 106% which is typical for this area.

These values look reasonable and do not suggest any problem with DO calibration.

##### Final Bottle Files

SORT was run to arrange casts in pressure order.

For all casts REMOVE was run to remove the following channels:

Scan\_Number, Temperature:Primary, Conductivity:Primary, Oxygen:Voltage:SBE, Descent\_Rate, Status:Pump, Altimeter, Salinity:T0:C0 and Flag.

A second SBE DO channel with mass units was added for both the CTD DO and titrated DO and REORDER was run to get the pairs of DO channels together.

EDIT HEADERS was run to fix formats and channel names and to add comments about analyses and CTD processing.

Data were exported from the CHE files to file 2021-005-bottles-final.xlsx. The entries were compared with the rosette log sheets and a few problems were found with missing flags in CHL an NH4. The analyst also found an error in one NH4 values. Those files were fixed.

Standards check and a header check were run. No problems were found.

The track plot looks ok.

Plots of each file were examined and no problems were found.

A cross-reference listing and header check were produced for the CHE files.

##### Thermosalinograph Data

An IOS TSG45 was used for this cruise and data were saved in 1 file.

The IOS SBE TSG45 files were opened in EXCEL.

The files have extensions RAW but are in csv format, so the files were opened in EXCEL and combined in a single CSV file. (In opening use DELIMITED, deselect TAB, select COMMA and OTHER (\*).

It is necessary to choose TEXT for the time on the 2nd page of the text import wizard.)

The spreadsheets were adjusted as follows:

* 2 lines of headers were added – channel names and units.
* A column with pressure was added with all values set to 4.5 (to enable derivation of salinity).
* A temperature difference column was added (Lab-Intake).
* The fluorescence channel is in volts. It was moved to column M. Then a concentration value was calculated in column F using scale 14.6 as determined in the most recent recalibration of the fluorometer. No clean water offset value was available. A study was made during cruise 2021-006 which immediately preceded this cruise to determine what offset was appropriate. The fit that produced results most like what we expect was 0.065ug/L. To check that this setting was reasonable for this cruise comparisons were made to chlorophyll and downcast CTD fluorescence from CTD casts. The TSG fluorescence was reasonably close to the downcast CTD fluorescence. It was higher than extracted chlorophyll samples when CHL was low and lower for high CHL. This is typical of this type of fluorometer. This is far from a proof but does not indicate a problem. There were few near-surface values with very low CHL for this cruise, so it is impossible to fine-tune the offset as well as for 2021-006 which had a wide range of near-surface CHL values.
* A file break column was filled with the cruise #-data/time info from the original file name.
* The TSG was running for 45 minutes at station SI. For the first minute the flow rate was 0 and for the 2nd minute it was increasing from 0 to about 1L/min. By the 2 minute mark the flow appears to have been established. The temperature, conductivity and fluorescence data were padded for the first 25 records.
* There were no other sections of flow being turned off though there were some short sections of flow rate <0.8L/min.
* Time and Date formats are a problem – when converting from RAW choose TEXT but once opened in EXCEL set Time Format to HH:MM:SS and save the file again.
* The file break column was completed so that new files would be created at the beginning of each day by assigned file names like 2021-005-20210519-000000 except for the first file which has a time later than 000000.

The file was then converted to IOS Header format with header info added. There are12 IOS files, one for each day.

CLEAN was run to reset the number of records, min and max values, set the start and end times, and latitude and longitude limits.

ADD TIME CHANNEL was used to add Julian dates – i.e. Decimal Year. A record number was also added to enable averaging (for use in comparison to CTD files). Time zero was set to 31 December 2020 0:00:00. (Note that this step leads to problems plotting until REORDER is run.)

DERIVED QUANTITIES was run twice, first to derive salinity using the lab temperature and again to derive sigma-T.

REORDER was run to move the Julian date to after the Time/Date channels and to put salinity and fluorescence after the lab temperature. Also the record # was moved to the end.

a.) Plots

A track plot was produced and added to the end of this report.

Time-series plots were produced. No problems were noted.

* Salinity has no significant spiking and spikes in fluorescence are few and possibly real.
* The loop flow rate was generally steady for hours at a time and it was mostly between 0.9 and 1.2L/min.
* The flow rate to the fluorometer was mostly in the same range except for the latter part of May 27th and most of May 28th, when there was a period of low flow rates (0.6 to 0.7) followed by a period of high rates, ~1.4L/min.

b.) Checking Time Channel

The CTD files were thinned to reduce the files to a single point from the downcast at or within 0.5db of 4.5db. These were exported to a spreadsheet which was saved as 2021-005-tsg-ctd-loop-rosette-comp.xlsx. The CTD cast at SI was run before the TSG had started and the TSG was turned off before the last 3 casts were run. So there are 112 records for comparison.

The TSG files were averaged over 24 records (2 minutes) on record number to reduce the noise and file size. Standard deviations were included. The files were joined and then the required records (times, positions, temperatures with standard dev, salinity with standard dev, fluorescence with standard dev, flow rate) were exported to a spreadsheet and that file was thinned to the closest times of CTDs and added to file 2021-005-ctd-tsg-loop-rosette-comp.xlsx.. The same file was thinned to the closest times to the 3 loop samples and added to the TSG-Loop comparison.

Comparisons were made of positions to check for good matches. The average differences were 0.0001º for latitude and longitude, but 13% of the matches had differences > 0.001º. The times were checked and the matches are good, but the TSG data were averaged over 2 minutes so if the ship is drifting matches will not be perfect. But the average and median differences were small, so the clock does appear to have worked well.

c.) Comparisons

* Comparison of T, S and Fluorescence from TSG and CTD data

The initial comparison between TSG and CTD data using all casts includes some large outliers.

|  |  |  |  |
| --- | --- | --- | --- |
| **All Casts** | **TSG (int) - CTD Temp** | **TSG Sal-CTD Sal** | **TSG FL/ CTD FL** |
| max | 0.7398 | 0.1966 | 1.93 |
| min | -0.9643 | -3.2974 | 0.37 |
| avg | 0.0375 | -0.2960 | 1.00 |
| median | 0.0257 | -0.1947 | 0.97 |
| stdev | 0.1884 | 0.4473 | 0.29 |

The comparison was then run separately using 41 casts with standard deviation in TSG temperature <0.004C° and for 44 casts with standard deviation in TSG salinity <0.0005psu.

|  |  |  |
| --- | --- | --- |
| **Offshore** | **TSG (int) – CTD Temp** | **TSG Sal-CTD Sal** |
| max | 0.0769 | -0.1455 |
| min | 0.0042 | -0.2701 |
| avg | 0.0226 | -0.1955 |
| median | 0.0195 | -0.1914 |
| stdev | 0.0123 | 0.0204 |

The temperature differences are somewhat larger than during other recent cruises. There is too much variability in the result to justify recalibration.

The salinity differences are similar to those from other recent cruises.

The TSG fluorescence is remarkably close to that from the TSG.

Heating in the loop (Lab Temperature – Intake Temperature) was plotted against intake temperature. Temperature varied little through most of the cruise, but was higher in the Strait of Georgia. Heating was about 0.5 Cº for the coldest intake water. As ambient temperatures rose there was a hint of less heating but data from the Strait of Georgia were very noisy.

* Comparisons of Loop samples and TSG data

There were 3 loop Salinity and Chlorophyll samples, all taken while underway. Salinity was lower than loops by an average of 0.20psu (range 0.195 – 0.204psu). TSG fluorescence was higher than loop samples by an average factor of 1.4, with the highest ratio for the lowest chlorophyll value, as usual.

* Comparison of 5m Rosette data with TSG data

There were no loop samples taken during rosette casts.

There were 13 5m-rosette samples taken and those were compared with TSG data. The times do not match well since the TSG data come from the beginning of casts while the 5m rosette is fired at the end. However, it is hoped the resultant errors are random. The TSG Salinity was lower than the rosette samples by a median of 0.1973psu and lower than the CTD salinity during the bottle stops by 0.1900psu.

There were 60 5m-chlorophyll rosette samples, so the time errors in the matches should be minimized in median differences. The ratio of TSG fluorescence to extracted chlorophyll from the 5m bottles shows the usual pattern of the fluorometer reading higher than the CHL for CHL<1.5l/ug and drop to 50% of CHL for CHL>4ug/L.

d.) Calibration History

The TSG and fluorometer were recalibrated shortly before cruise 2021-001.

* During 2021-001 the TSG salinity was found to be lower than CTD salinity by a median of 0.178psu, and lower than loops by 0.181psu with no significant difference between underway and stopped samples. There was no evidence of drift through the cast. The TSG intake temperature was higher than the CTD temperature by ~0.02C° offshore but if only casts with a low standard deviation in the intake temperature are included it is high by a median of 0.009C°. No recalibration was applied as the differences were reasonably small given some differences in depth and time between the 2 data sets. The TSG fluorescence values were about 32% of fluorescence from the CTD and 74% of the loop CHL samples. Loop and rosette salinity samples compared very well, while the loop chlorophyll was about 75% of that from the rosette.
* During 2021-006 the TSG salinity was recalibrated by adding 0.183psu. TSG temperature were higher than those from co-incident CTDs by about 0.01 C°. The TSG fluorescence values were about 50% higher than those from the CTD and higher than loop CHL samples by 50 to 300%. For the cases where the CHL was in the range 0.49 to 5.0ug/L, the TSG fluorescence was higher than loop samples by 8%, but the loop chlorophyll values were lower than rosette samples.

e.) Conclusions re TSG

1. The TSG clock worked well.

2. The flow rate to the TSG was mostly between 0.9 and 1.2L/min.

3. The flow rate to the fluorometer was mostly in the 0.9-1.2L/min range except for the latter part of May 27th and most of May 28th, when there was a period of low flow rates (0.6 to 0.7) followed by a period of high rates, ~1.4L/min.

4. The TSG salinity was found to be lower than CTD salinity by a median of 0.191psu using casts with the lowest standard deviations in the TSG data. Compared to loops it was low by 0.195 to 0.204psu. and compared to rosette samples it was low by 0.197psu and by 0.190psu compared to CTD salinity during bottle stops. During 2021-001 it was considered to be low by 0.180psu and for 2021-006 low by about 0.183psu. So there has been only a small change since February. Some of the difference may be due to variations in sea state introducing small bubbles to the loop. Salinity will be recalibrated by adding 0.191psu.

5. The TSG intake temperature was higher than the CTD temperature by about 0.02C°. No recalibration is justified as differences are highly variable and may be partly due to some differences in depth sampled by the 2 data sets.

6. The TSG fluorescence values are very close to those from the CTD. In comparison to rosette chlorophyll samples the TSG fluorescence shows the usual pattern of reading high for low CHL and reading about 50% of CHL when CHL>4ug/L. There are insufficient loop samples to conclude much, but the comparisons do not suggest a problem.

g.) Editing

Time-series plots were examined. No editing is required.

h.) Preparing Final Files

REMOVE was used to remove channel Pressure, Temperature:Difference , and record #.

i.) Calibrate

CALIBRATE was used to add 0.191psu to channel Salinity

HEADER EDIT was used to change the DATA DESCRIPTION to THERMOSALINOGRAPH and add the depth of sampling to the header and to change channel names to standard names and formats and to add comments.

A cross-reference list was prepared.

The TSG sensor history was updated.

As a final check plots were made of the cruise track and time-series and all looks fine.

**Deployment schemes:**

Down to 10m, 30s wait, up to surface, 30s wait, then cast began.

For depths deeper than, and including, 125 db, there was a 30 second wait before closing a bottle.

For depths shallower than, and including, 100 db, there was a 60 second wait before closing a bottle.

**Particulars:**

68. Pump turned off at surface before acquisition stopped; pumps on for final bottle-firing window.

71. Same event number used for NET and ROS events, so NET was changed to 971.

81. Fired 5m bottle while not archiving. Started second file (81a) to collect CTD data for bottle #8.

104. Cast 2n.m. from intended site – shallower than expected. Sample #303 not collected.

162. Stops at 752 and 1764db of downcast. Windy.

167. Stop at 1243db on downcast for repositioning. Big swell. Drifting north.

174. Warm layer 400-500m. California Undercurrent.

196. Stopped at 108db downcast to fix cable angle.

219. Error in station name. Fixed in processing.

223. Held at 65m to adjust wire angle.

233. Secondary salinity bad to ~16db of downcast. Secondary Temp and Fluorescence suspicious. Primary could be slightly off but not clearly bad.

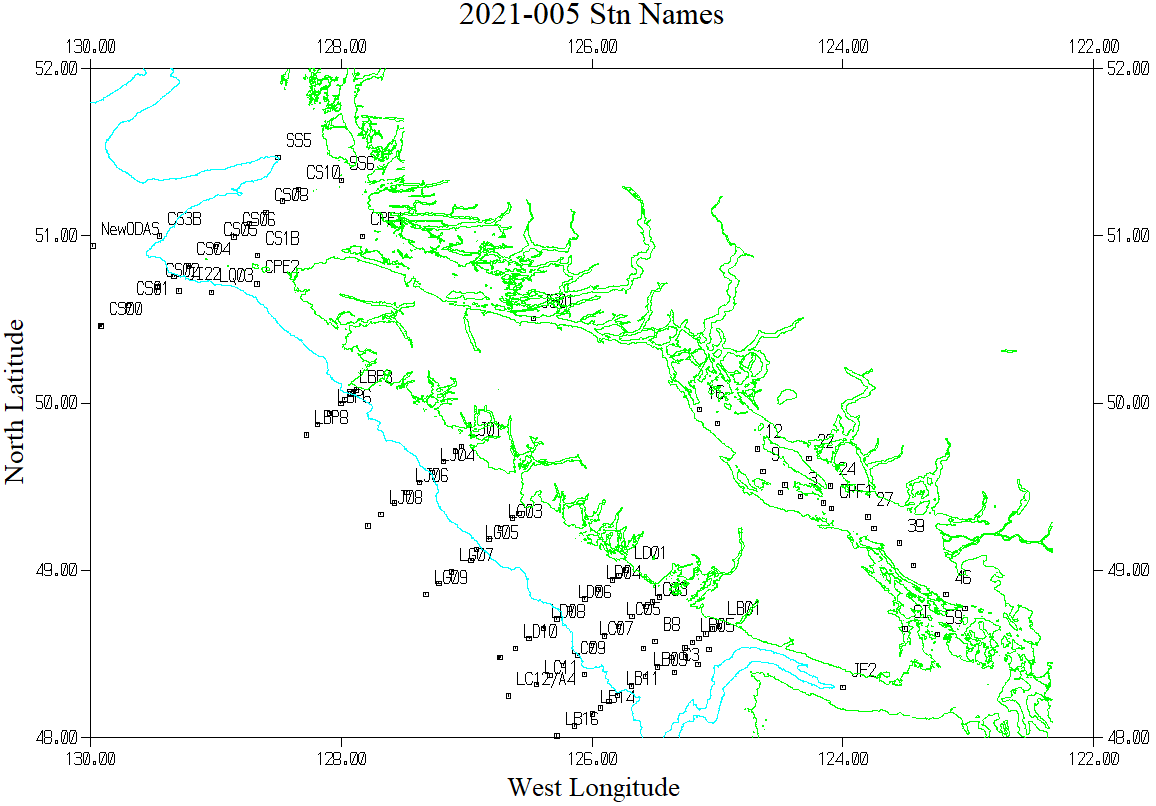
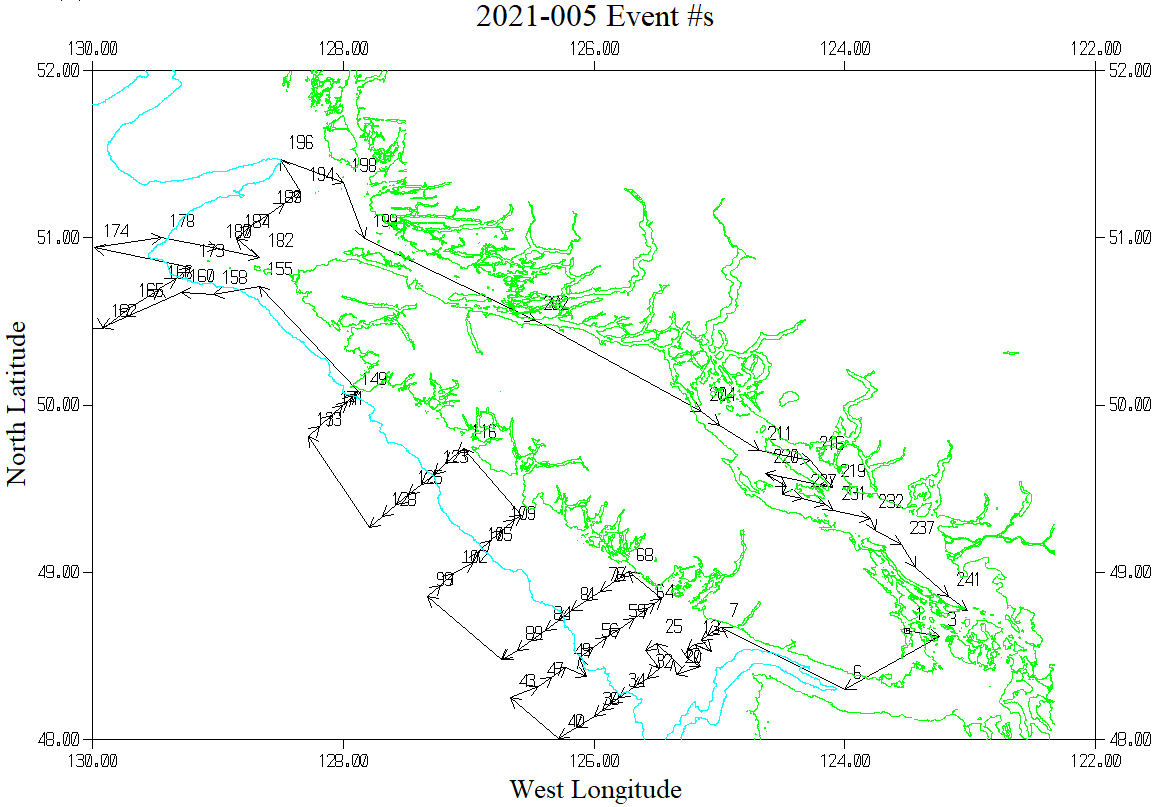
**2021-005**

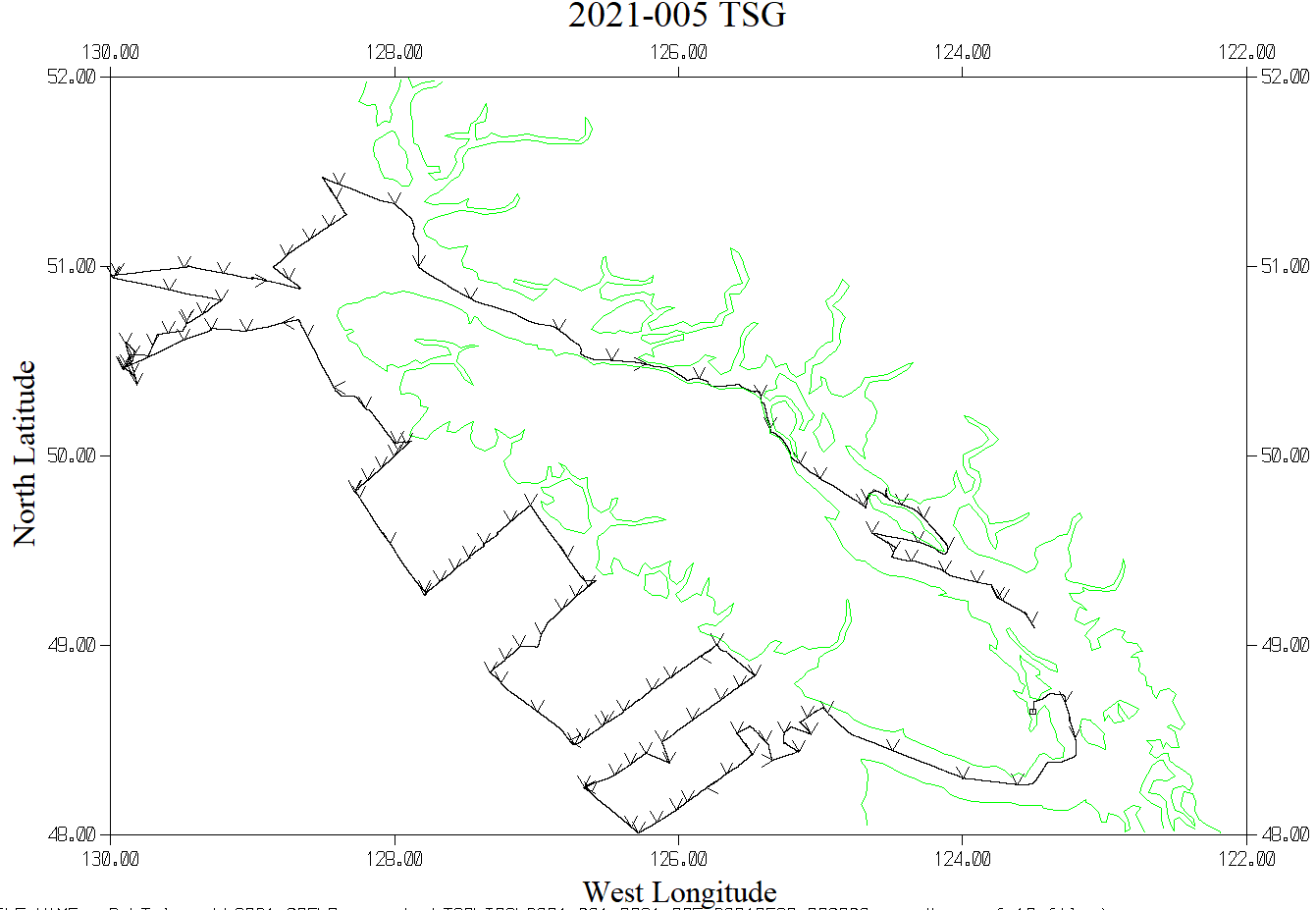
|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **CTD#** | **Make** | **Model** | | **Serial#** | | **Used with Rosette?** | | **CTD Calibration Sheet Competed?** | | |
| **1** | **SEABIRD** | **911+** | | **0443** | | **Yes** | | **Yes** | | |
| **Calibration Information - 0506** | | | | | | | | | | | |
| **Sensor** | | | | | **Pre-Cruise** | | | | **Post Cruise** | | |
| **Name** | | | **S/N** | | **Date** | | **Location** | | **Date** | **Location** | |
| **Temperature** | | | **4700** | | **12Dec2020** | | **Factory** | |  |  | |
| **Conductivity** | | | **3531** | | **06Jan2021** | | **Factory** | |  |  | |
| **Secondary Temp.** | | | **4888** | | **12Dec2020** | | **Factory** | |  |  | |
| **Secondary Cond.** | | | **4513** | | **18Dec2020** | | **Factory** | |  |  | |
| **Transmissometer** | | | **1185DR** | | **28Apr2021** | | **Factory** | |  |  | |
| **Transmissometer** | | | **1883DG** | | **28Apr2021** | | **Factory** | |  |  | |
| **SBE 43 DO sensor** | | | **3791** | | **22Dec2020** | | **Factory** | |  |  | |
| **PAR sensor** | | | **70613** | | **24Feb2021** | | **Factory** | |  |  | |
| **SeaPoint Fluor.** | | | **3950** | |  | |  | |  |  | |
| **Pressure Sensor** | | | **0443** | | **07Jan2021** | | **Factory** | |  |  | |
| **Valeport Altimeter** | | | **75321** | |  | | **Factory** | |  |  | |

**CRUISE SUMMARY – CTD**

# TSG Make/Model/Serial#: SEABIRD/45/0620

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Calibration Information** | | | | | |
| **Sensor** | | **Pre-Cruise** | | **Post Cruise** | |
| **Name** | **S/N** | **Date** | **Location** | **Date** | **Location** |
| **Temperature** | **0620** | **21Jan20** | **Factory** |  |  |
| **Conductivity** | **0620** | **21Jan20** | **Factory** |  |  |
| **Wetlabs WETStar Fluor.**  For depths deeper than, and including, 125 dbar, we would wait 30 seconds before closing a bottle. For depths shallower than, and including, 100 dbar, we would wait 60 seconds before closing a bottle. | **1656** | **12Mar2021** | **Factory** |  |  |

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