## REVISION NOTICE TABLE

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| DATE | DESCRIPTION OF REVISION |
| 18 March 2025 | Updated channel names & formats in TSG and Loop files. GG & SH |

## PROCESSING NOTES

Cruise: 2023-066 Agency: OSD

Location: North-East Pacific Project: Line P / Strait of Georgia

Chief Scientist: Robert M. Platform: John P. Tully

Date: 30 April 2023 – 16 May 2023

Processed by: Germaine Gatien Date of Processing: 25 August 2023 – 8 November 2023

Number of original HEX files: 78 Number of processed CTD files: 75

Number of rosette casts: 59 Number of processed CHE files: 58

Number of original TSG csv files: 1 Number of processed TOB files: 11

# INSTRUMENT SUMMARY

Two CTDs were used for this cruise:

* CTD #1515 was mounted in a rosette and attached were 2 Wetlabs CSTAR transmissometer (1185DR & #1883DG), a SBE 43 DO sensor on the primary pump (#1119), SeaPoint Fluorometer on the secondary pump (#3685 for casts 1-41 and #3640 for casts #44-58), a Biospherical QSP-400 PAR sensor (#70613) and an altimeter (#76341).
* CTD #0550 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 (#3640), a Biospherical QSP-400 PAR sensor (#70613) and an altimeter (#76341).

A thermosalinograph (SeaBird 45 S/N 0789) was mounted with a Wetlabs WETStar fluorometer (#1656) and flow meter; sampling interval was 10s.

Seasave version 7.26.7.121 was used for acquisition. The data logging computer WP #102. The deck unit was a Seabird model 11+ #424. An IOS rosette with 24 10L bottles was used.

# SUMMARY OF QUALITY AND CONCERNS

This cruise was plagued by problems at sea and this made data processing complex.

The Daily Science Log Book was in excellent order with comments about problems encountered and a detailed list of equipment. The sampling logs were in good order. Sampling notes provided by the Chief Scientist were a big help in processing data.

The standard deployment procedure for this cruise as follows:

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 all rosette casts on Line P:

Niskin bottles closed from 0 to 400 db (both included) had a wait time of 60 seconds for Line P stations and 30s for the Strait of Georgia.

 All Niskin bottles deeper than 400 db had a wait time of 30 seconds.

For Events #1-39 the configuration file was set to average 24 records in acquisition. This limits quality as fine-tuning of settings for alignment can’t be checked and bad records that would normally be removed may be included in the average. Filtering of fluorescence was not applied to those files.

The CTD data were affected by frequent pressure spikes, seen in data from both CTDs and mostly below 1000db. Editing was applied to remove records that were clearly corrupted. A second round of editing was needed to remove bad data from the Oxygen:Dissolved:SBE channel in 8 casts, since the pressure spikes were spread by the window used in converting that channel.

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.

The configuration for the dissolved oxygen sensor on CTD #0550 was found to need a change to parameter E to adjust the correction for hysteresis. This choice was based on a study of 3 very deep casts with dissolved oxygen sampling plus an initial study of some fairly deep casts from the cruise that followed. There was one cast (#86) where there was no obvious hysteresis, but it was later found that there were some shifts in deep downcast values for that cast, associated with pressure spikes. So the new hysteresis factor is likely appropriate for the cruise as a whole. In the absence of a clear explanation the same hysteresis factor was used for all casts using sensor #3971. The setting has no significant effect on data above 1000db.

No recalibration was necessary for salinity for either CTD, but pressure and dissolved oxygen channels were adjusted for both.

Transmissivity values in deep water at Line P were higher than noted in other cruises over the past few years. The sensors had been recalibrated very recently. However, in the past some values from recently calibrated sensors were still lower than found during this cruise.

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 for this cruise are considered, very roughly, to be:

For Events #1-58 (DO sensor #1119)

 ±0.40 mL/L from 0-300db except in areas of very large DO gradients

 ±0.07 mL/L from 300db-600db

 ±0.03 mL/L below 600db

For Events 60-108 (DO sensor #3640) in the offshore region

 ±0.20 mL/L from 0-500db except in areas of very large DO gradients

 ±0.03 mL/L from 500db to 3000db

 ±0.10 mL/L below 3000db

For Events 109-153 (DO sensor #3640) in the inshore region

 ±0.50 mL/L from 0-50db except in areas of very large DO gradients

 ±0.40 mL/L from 50db-200db

 ±0.10 mL/L below 200m

Assessment of the thermosalinograph data was limited by problems with CTD data, including pressure spikes and equipment changes, as well problems in the TSG itself and the wide variety of environments sampled. There were 400 records with columns misaligned; some were edited before it was realized that there so many and that they were well-separated, so the others were removed. There were also 10 records with the wrong date when the time was 1s before midnight; those were fixed. The intake temperature data look bad throughout the cruise. Intake temperatures had a number of sudden shifts to higher or lower values. While the higher values are closer to CTD values, they are not close enough to be considered reliable, so the channel was removed from all files. A proxy for intake temperature was created by recalibrating the lab temperature using a value estimated by comparisons to CTD data.

Editing was applied to remove obviously bad TSG salinity data including an initial bad section and single-point large spikes towards low values. It looks like salinity drifted slowly downwards for up to 30 minutes, then a spike appears and values return to values similar to those before the drift. In one notable case salinity increased by ~0.03psu (32.33 to 32.36psu) in 30s while the ship was stopped at P26. Salinity is believed to be reading low overall, but estimates based on a variety of comparisons were so scattered that no suitable amount was found for recalibration purposes. Salinity is reported with only 3 decimal places to indicate less confidence than usual in values.

TSG fluorescence was about 80% of CTD fluorescence in the offshore and about 92% close to shore.

Loop chlorophyll and nutrient samples compared well with 5m samples from Niskin bottles. Salinity from the loop was higher than the Niskin samples by about 0.002psu.

# PROCESSING SUMMARY

##### Seasave

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

The chief scientist provided a summary of sampling protocols and problems.

The standard deployment procedure for this cruise as follows:

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 all rosette casts:

Niskin bottles closed from 0 to 400 db (both included) had a wait time of 60 seconds.

 All Niskin bottles deeper than 400 db had a wait time of 30 seconds.

##### Preliminary Steps

The Log Book and rosette log sheets were obtained as well as sampling notes from the Chief Scientist.

* Corrections were made to station names, file names & depths in hex & hdr files based on the sampling notes.
* Nutrients, extracted chlorophyll, dissolved oxygen, salinity and DMS/DMSP data were obtained in QF spreadsheet format from the analysts.
* The cruise summary sheet was completed.
* The history of use of the pressure sensor, conductivity and dissolved oxygen sensors was found.

The configuration files were checked. There were 5 different configurations used during the cruise. The different versions and associated casts are:

2023-066-ctd1.xmlcon Casts 1 to 39 Deck unit set to average data over 1s.

2023-066-ctd2.xmlcon Cast 41 only Average set to 1; fluor gain cable changed to 10X

2023-066-ctd3.xmlcon Casts 44 to 58 Fluorometer changed to #3640; gain 10X

2023-066-ctd4.xmlcon Casts 60 to 144 CTD changed to #0550; fluor gain 10X

2023-066-ctd5.xmlcon Casts 145 to 153 Fluorometer gain cable changed to 3X

Usually conversion is done using files like the 5 above, in case any errors crept in during a cruise, but given the frequent changes, conversion was instead run by using the XMLCON file that matches the hex file name. A few checks show very little likelihood of unintended changes to configuration files during the cruise.

When the comparison was run between CTD DO and titrated DO from bottles, it became obvious that there was some hysteresis in the dissolved oxygen data for sensor #3791 on CTD #0550. SeaBird recommend running checks during the first cruise with deep sampling after sensor recalibration; improvements can be made by fine-tuning factor E in the configuration. Tests were run on cast #60 using a variety of E values in the configuration to see which provided the correspondence between DO values above and below the oxygen minimum zone that best matched the differences between bottle values in those zones. There is no perfect fit, but overall it was determined that E should be changed from the default 0 036 to 0.033. For details on the tests run, see 2023-066\_hysteresis\_study.xlsx.

Further tests were run on a few casts from cruise 2023-019 which used the same sensor and the results look good using E=0.033, though sampling was not as deep so the tests were limited.

See 2023-019\_Hysteresis\_Tests.xlsx for details.

The configuration files were changed for CTD #0550 and conversion was re run for bottle files using 2023-066-ctd4.xmlcon for casts 60 to 144 and 2023-066-ctd5.xmlcon for casts 145 to 153.

No change was needed for the earlier casts as there was no deep DO sampling so no hysteresis checks could be made; such errors in DO are likely insignificant above 2000db.

There remains some doubt about cast #86 which did not show hysteresis. It is not expected for this setting to change mid-cruise. Unfortunately, there was no deep DO sampling between casts #68 and #86 or after #86. The difference may be related to the spikes noted in deep casts. A few casts from the cruise that followed were tested to see which factor works best, but the deepest DO sampling was at 2000db for one cast, and 1900db and 1600db for 2 others. The most useful comparison comes from 2000m down. Comparisons were made and in most cases using 0.033 did bring the fits above and below the minimum into better correspondence.

##### BOTTLE FILE PREPARATION

The ROS files were created using configuration files with matching names for casts 1-58.

ROS files were created using 2023-066-ctd4.xmlcon for casts #60 to 144.

ROS files were created using 2023-066-ctd5.xmlcon for casts #145 to 153.

The file for cast #101 was removed since it was a test with no bottles fired.

The split files were examined:

* Cast #69 looked ok and was renamed 67 to match the downcast.
* Cast #87 was missing Niskin #1. This was because the bottle was fired so quickly after starting the file the window around firing time used in conversion looked for files before the 1st record. A smaller window was selected (8s instead of 10s) and a proper file was produced. It was renamed as 86.
* Cast #91 had out of order sampling making it harder to judge, but it looks ok. It was renamed #90.

For casts 1 to 41, the window chosen collected only 11 records since the files were already averaged over 1s. For casts after #41the BOT files had the usual 241 records. This should not have a significant effect on the quality of the bottle files except that it will be impossible to remove spikes before averaging.

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

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

As expected there are none up to event #41 due to the averaging.

CTDEDIT was used clean salinity in casts: 49, 52, 53, 54, 71, 84, 85. Most editing was very light except for a large section of the stop at 400db during cast #52 where primary salinity was offset.

The output ED1 files were copied to \*.BOT.

A preliminary header check was run; 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.

A few problems were found:

* Event #1 has 17 bottles indicated on the Sampling Log but only 15 in the BL file and in the ROS file.
* Sample #396 is missing from the sampling logs and is assumed to not have been used at sea.
* Event #58 had a bottle fired for bulk water only. Sample #404 was used for that sample but used again on the next CTD cast. A pad value was put in for sample #, but that record is not needed for Event 58, so it was removed later.
* Event 86/87 – The first bottle was fired very quickly after starting the file, so was missed in the initial conversion; a smaller window (8s) was selected for that cast to enable conversion.

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 2023-066-bot-hdr.txt which will be updated as needed during processing.

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

DISSOLVED OXGYEN

Dissolved oxygen data were provided in spreadsheet QF2023-066\_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 2023-066oxy.csv. That file was converted into individual \*.OXY files.

EXTRACTED CHLOROPHYLL

Extracted chlorophyll and phaeo-pigment data were obtained in file QF2023-066\_CHL QF\*.xlsx. The file included comments and flags and a precision study. A simplified version of the spreadsheet was prepared and saved as 2023-066chl.csv. The csv file was then converted to individual CHL files.

SALINITY

Salinity analysis was obtained in file QF2023-066\_SAL.xlsx which included a precision study. The analyses were carried out in a temperature-controlled lab 18 to 34 days after collection. The files were simplified and saved as 2023-066sal.csv. That file was then converted to individual SAL files.

NUTRIENTS

The nutrient data were obtained in spreadsheet QF2023-066\_NUTS\*.xlsx. This includes a precision study. The file was simplified, saved as 2023-066nuts.csv. The file was converted to individual NUT files.

An error was found on the Loops page; sample # was changed from 5186 to 33.

DMS

DMS data were obtained in spreadsheet DMS Summary (2023-066).xls which includes duplicate analysis. Details on analysis are in file 2023-066 DMS report\*.doc. Only 2 figures are considered significant. Event #s were added to the file.

DMSP

DMSP-D and DMSP-T data were obtained in file DMSP 2023-066 Summary\*.xls. Details on analysis are in file 2023-066 DMS report\*.doc. The data were converted into DMSP files. Only 2 figures are considered significant. Event #s were added to the file.

The SAL, CHL, OXY, NUT, DMS and DMSP files were merged with CST files in 6 steps.

After the 6th 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. CTD salinity was checked and there are values <25psu, so silicate correction is needed.

Some issues investigated including items from the Sampling Notes:

* Event 58 – Only bulk sampling from 2000db bottle, and sample # used again on next cast, so that record was removed from the SAMAVG file and Merge was rerun.

##### Compare

Salinity

Compare was run with pressure as reference channel.

Fits were divided into 2 groups since there were 2 CTDs.

* CTD #1515 – Casts 1-58

The data in the ROS files for casts 1-39 were averaged over 24 records so the usual cleaning of spikes could not be done, but they do not look out of line with other casts.

There were no significant outliers, though 2 points from casts #46 and 52 at 3000db look a little out of line. Excluding those makes little difference to the result and there is too much scatter to justify their removal. The primary salinity was low by 0.0018psu and the secondary was low by 0.0023psu; standard deviation was 0.0013 for both channels. Pressure dependence looks low, but excluding a few outliers could change that picture.

* CTD #0550 – Casts 60-158 – (Casts 60-96 Line P; 101-114 Scott & QCS; 117-153 SoG)

For this CTD there were more outliers:

Sample 417 – event 60 – from 400m – significantly out of line in profile and in COMPARE. Difference of 0.29psu. The only other sample from that Niskin is DO which was flagged due to an analysis issue, but it does not look much out of line. So this is likely a case of sampling from the wrong Niskin. The value was padded.

Samples 781-784– event #131 – outliers were all in shallow water <20db and they come from the Strait of Georgia where flushing of Niskin bottles tends to be worse than in open waters and vertical gradients large. There is likely nothing wrong with the sampling or analysis and no change was made.

The primary salinity was high by 0.0011psu and the secondary was low by 0.0001psu with standard deviations of 0.0020 and 0.0016psu, respectively. The differences between primary and secondary salinity may be increasing slightly with time.

From the offshore section (casts 60-96) the primary salinity was found to be high by 0.0008psu and the secondary low by 0.0001psu with standard deviations of 0.0013 and 0.0016, respectively. There was slightly more pressure dependence in the secondary, but if 2 more bottles above 500db were excluded the average was only slightly larger at -0.0002psu. The offshore results are close to those using the nearshore and Strait of Georgia when outliers were excluded.

A plot of differences versus time is reflective of the change in CTD and different areas sampled. It is difficult to assess time-dependence due to variations in depths of sampling in different areas and overall small differences. For the offshore portion using CTD #0550 there appears to be some drift lower in the secondary salinity. Cast #86 seems out of line in the primary comparison; the secondary has more variability in general but it doesn’t look out of line. It was the last deep cast with salinity sampling and has generally lower salinity than the other casts in the comparison and a little higher gradient in deep water. The descent rate was similar to cast #60 so efficiency of flushing doesn’t appear to account for the difference directly, but if vertical gradients are higher, then the effect of incomplete flushing would be greater. In any case, the differences are small.

When the dissolved oxygen comparison was done cast #58 was also an outlier that showed up most clearly in the hysteresis study.

Analysis was done within a month so we do not expect much evaporation and flushing was likely good for the offshore section.

For casts 1-58 both salinity channels appear to be low by about 0.002psu which is likely to be partly due to evaporation, desorption and incomplete flushing. Recalibration is not justified.

For casts 60-153 the primary salinity is higher than bottles by about 0.001psu and secondary salinity appears to be very close to bottles. There were shorter waits before firing bottles in the inshore area, so flushing may be poorer there, but very few bottles from that section were included in the comparison. No recalibration is justified given small differences and significant variability among casts.

For full details for the COMPARE run see file 2023-066-sal-comp1.xls.

Dissolved Oxygen

COMPARE was run with pressure as the reference channel. COMPARE was run twice –

File 2023-066-dox-comp1.xls contains the comparison for #1515 and a first run for #0550. Because it indicated that the hysteresis factor in the configuration file needed adjustment, a second run was made after the files were reconverted.

File 2023-066-dox-comp1H.xls contains a comparison after updating factor E in the DO configuration.

***CTD #1515 – Casts 1-58***

Large outliers were all to the low side, mostly between 60db and 80db. While large gradients often lead to poor fits the effect is usually opposite to what is seen here. If flushing is poor then the slow response of the CTD keeps it closer to the bottle values. If flushing is good though, the CTD could read lower than the bottle samples. The 2 outliers from cast #52 are extremely odd and the data from that cast may not be reliable due to pressure spikes.

The fit found when a few outliers were excluded based on residuals was:

 CTD DO Corrected = CTD DO \* 1.0232 + 0.0157

Outliers were examined:

* Cast #7 – Sample #46 - 80db – Very high variability in CTD DO (4.05 to 4.25) during bottle stop. CTD may never have reached ambient values. No evidence of problem with the sample.
* Cast #17 – Samples #95 and #96 – 76db – Bottle values 5.88 and 5.72mL/L. The CTD data overlap but examination of the full file shows rapid rise in DO at beginning of the bottle stop, but steady values when the bottles closed. The first sample is an outlier in COMPARE while the second is just slightly out of line in the opposite direction. While flushing might be incomplete, that would lead to outliers in the opposite direction. The downcast shows a local reversal at the level of these bottles, so the first sample may be measuring a feature missed by the sensor due to slow response. No flag is justified.
* Cast #23 – Sample #144 – 76db. The CTD data was affected by a shed wake. Sample likely ok.
* Cast #52 – Samples #306 and 307 -300db and 400db – CTD DO values bad (offset from downcast) – padded in bottle file. Downcast is ok. Samples likely fine.
* Cast #52 – Sample #313 -100db. Bottle=5.52; CTD data varies from 5 to 5.3mL/L. At 5.3 the difference would be slightly lower than expected but not something that would be flagged. Flushing was likely good here, so the problem is probably that the CTD could not keep up with the rapid ambient changes. Sample likely fine.

***CTD #0550 – Casts 60-158*** – (Casts 60-96 Line P; 101-114 Scott & QCS; 117-153 SoG)

Line P (casts 60-86)

There were 3 casts with dissolved oxygen sampling using CTD 0550 in the Line P section. The fit immediately suggested there was hysteresis. However, when they were examined separately only the first 2 casts (#60 & #68) had that appearance while cast #86 had no significant hysteresis. Seabird do recommend doing checks for hysteresis after recalibration of DO sensors but say there should be no further need for such checks until the next recalibration. So having a dramatic change mid-cruise is mysterious. The fact that cast #86 also stood out as different in the salinity comparison may offer a clue that there was some difference in flow to the primary system. Faster flow might be expected to bring the CTD salinity into slightly poorer agreement with bottles and reduce hysteresis slightly, but such differences seem unlikely to have a large effect.

Tests were done to determine whether varying parameter E in the DO configuration file would reduce the hysteresis and a value of 0.033 was found to improve the results for cast #60 and for some casts from cruise 2023-019.

The casts all had problems with pressure spikes. So the first check was to see how well upcasts compared with downcasts. There did not seem to be any obvious source of trouble there, though cast #58 showed more of a shift at the bottom than usual, probably because there was a longer wait at the bottom than usual.

It is clear that for most casts adjusting the E parameter is justified. This will have a significant affect only below about 2000db.

COMPARE was rerun using the files with the hysteresis correction. This showed significant improvement for casts #60 and #68 but cast #86 looked worse, with values significantly low below 2000m. So either 60 and 68 OR 86 are out of line. Since #86 stood out somewhat in the salinity comparison as well, it is likely the “odd” cast and this is not likely due to a shift in hysteresis. The salinity differences were not as significant, and above 2000m the dissolved oxygen differences are not large.

At a later stage in processing a detailed examination of file #86 was found to have a small drop followed by a larger increase in value at depth, ~0.05mL/L. The shifts were associated with a pressure spike.

When outliers were removed where pressure<15db and for cast #86 for pressure>2000db followed by exclusions based on residuals the fit was:

 CTD DO Corrected = CTD DO \* 1.0115 -0.0094

Scott/QCS (casts 90-101) – No DO sampling.

SoG (casts 117-149)

The initial fit for casts from the Strait of Georgia had many outliers in the top 10m. This is likely due to incomplete flushing in the presence of high gradients. The waits before firing bottles were 30s, so it is likely that the fit in deeper water is also somewhat affected by incomplete flushing. When outliers were excluded based on pressure <10db and a few outliers based on residuals, the fit was:

 CTD DO Corrected = CTD DO \* 1.0092

If the offset was forced to match that from the offshore, the fit was

 CTD DO Corrected = CTD DO \* 1.0122 -0.0094

The latter is fit is remarkably close to the offshore fit, suggesting that flushing was fairly good for this section.

For full details for the COMPARE run see file 2023-066-dox-comp1H.xls.

Fluorescence

COMPARE was run with extracted chlorophyll and CTD Fluorescence using pressure as the reference variable. The data from cast #41 are bad; this was noted at sea and the fluorometer was replaced after that. The CTD was changed after cast #60 but the same fluorometer was used.

The comparison of CTD fluorescence and extracted CHL were run in 3 groups:

* Casts 3-36 – Fluorometer 3685

The CTD fluorescence was ~65% of the CHL.

 Casts #26 to #36 had fluorescence reading lower than expected compared to CHL. Even at the surface the fluorescence is much lower than CHL than is expected when CHL<1. The fluorometer failed at event #41giving very high values. The fluorescence channel should be removed from casts 26-41.

* Casts 44-153 – Fluorometer 3640 all casts

CTD Fluorescence was about 71% of CHL. At very low CHL fluorescence was high by up to a factor of 3.5 times CHL, but for CHL >1ug/L the ratio of FL/CHL ranged from 0.2 to 2. While the comparison is very noisy the ratio does gradually fall off as CHL rises as we usually see from this type of fluorometer.

* Casts 118-153 – Fluorometer 3640 Strait of Georgia only

When only Strait of Georgia casts were included there is a similar relationship with CTD fluorescence being about 70% of CHL. It is slightly higher than CHL at low CHL and slightly lower at high CHL.

For full details for the COMPARE run see file 2023-066-fl-chl-comp1.xls.

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

Hex files were converted using the configuration files of the same names.

Many of the casts have spikes in pressure, mostly in deep water. The problems started at cast #34 and continued through the cruise in both sensors. With one exception casts shallower than 600db had no spikes.

##### 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.

The pressure spikes were removed from all casts except for #34 and 39 which had a few small spikes left.

A second run of WILDEDIT removed remaining spikes from those 2 casts when settings used were:

Parameters used were: Pass 1 Std Dev = 2 Pass 2 Std Dev = 2 Points per block = 15

This second run was only applied to pressure.

Cast #46 was edited using a text editor to change oxygen voltage from 4.7088 to 0.8549 at scan 78345.

##### ALIGN DO

ALIGNCTD was run on all casts to advance the oxygen voltage by +2.5s, a setting which has worked well in the past for this type of sensor. The results were examined during step #9 and found to be good.

Note that the same setting was used for the early casts that were averaged over 24 scans since the alignment is based on time, not # of records.

##### 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. Because configuration files are selected to match file names, the XMLCON files were copied to this folder to enable the DERIVE step to work.

##### DERIVE and Channel Comparisons

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

Plots were examined and checks made:

* to see if more work is needed on spike removal. There are a few spikes in temperature and conductivity, but very few and they are not large, so will be easily handled at the CTDEDIT stage.
* to see if the alignment of dissolved oxygen looks good and it does.
* to see if CELLTM worked properly and it did.
* to see if dissolved oxygen is spiky and it sometimes is.

Further investigation was made into DO data to see if a return should be made to WILDEDIT to remove spikes. First, it was determined that only the 2 very large spikes were found in the raw voltage, one of which was at the bottom of a cast. Where the DO concentration has smaller spikes, the voltage is noisy, so

what appear to be spikes are just “exaggerated” noise, most obvious in the OMZ where average variations are extremely small.

WILDEDIT could help with the largest spikes but not the small-scale noise. One of the large spikes was at the bottom of a cast, so will get removed in normal processing. The other spike is a 1-point spike in voltage most easily handled with a text editor. The file from cast #46 (after WILDEDIT was run) was edited to replace the off-scale value with the value of the previous record. ALIGNCTD, CELLTM and DERIVE were rerun on that file and the plots look good with just a small spike at the bottom that will likely disappear after DELETE is run.

It is possible that a filter might be appropriate, but it is also possible that the dissolved oxygen sensor is responding appropriately with better response time than noticed in the past. The noise is 2-sided and bin-averaging will remove that.

DERIVE was run a second time on some of the deeper casts, 2 from CTD #1515 and 3 from CTD #0550, to find the differences between the pairs of temperature, conductivity and salinity channels. Two casts from 2023-019 are included to help judge if there is temporal drift.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Cast # | Press | T1-T0  | C1-C0 | S1-S0 | Descent Rate |
| 2023-066-0046 | 1000 | -0.0002 | -0.00007 | -0.0008 | High, Noisy |
|  | 2000 | -0.0003 | -0.00009 | -0.0008 | “ |
|  | 2500 | -0.0003 | -0.00009 | -0.0007 | High, Noisy |
| 2023-066-0052 | 1000 | -0.0002 | -0.00004 | -0.0003 | “ |
|  | 2000 | -0.0005 | -0.00006 | -0.0003 | “ |
|  | 2500 | -0.0007 | -0.00007 | -0.0002 | “ |
|  | 3000 | -0.0008 | -0.00006 | -0.0001 | “ |
|  | 3500 | -0.0008 | -0.00008 | 0 | “ |
| 2023-066-0060 | 1000 | +0.0007 | -0.00005 | -0.0013 | High, XNoisy |
|  | 2000 | +0.0005 | -0.00002 | -0.0008 | “ |
|  | 2500 | +0.0003 | +0.00001 | -0.0003 | “ |
|  | 3000 | 0 | +0.00002 | +0.0002 | “ |
|  | 3500 | +0.0001 | +0.00003 | +0.0002 | “ |
| 2023-066-0079 | 1000 | -0.0002 | -0.00023 | -0.0026 | High, Noisy |
|  | 2000 | -0.0005 | -0.00020 | -0.0020 | “ |
|  | 2500 | -0.0004 | -0.00019 | -0.0019 | “ |
|  | 3000 | -0.0003 | -0.00019 | -0.0020 | “ |
|  | 3500 | -0.0001 | -0.00017 | -0.0021 | “ |
| 2023-066-0086 | 1000 | +0.0003 | -0.00025 | -0.0032 | High, XNoisy |
|  | 2000 | -0.0002 | -0.00023 | -0.0026 | “ |
|  | 2500 | -0.0004 | -0.00022 | -0.0023 | “ |
|  | 3000 | -0.0002 | -0.00021 | -0.0024 | “ |
|  | 3500 | -0.0001 | -0.00020 | -0.0024 | “ |
|  | 4000 | +0.0001 | -0.00020 | -0.0025 | “ |
| 2023-019-0092 | 2000 | +0.0004 | -0.00012 | -0.0024 |  |
| 2023-019-0108 | 2000 | -0.0002 | -0.00018 | -0.0020 |  |

For CTD #1515 all differences were very small.

For CTD #0550 there appears to shifts in conductivity differences after cast #60 and #79. Rough estimates were made for a few other casts and suggest that differences mostly occurred between #68 and #75. While #86 may be slightly out of line, the variations are small in conductivity and salinity. Temperature variations are very small and have no obvious trend.

A return was made to the comparison of CTD salinity with bottles, focusing on the offshore casts and bottles from below 400db. Comparing the 2 plots below it looks like file pair #18 (cast #86) is somewhat out of line for both channel pairs, but overall the differences between the primary salinity and bottles appears to vary less than for the secondary, suggesting that the drift in differences is due to drift in primary conductivity. However, the differences are small, and the secondary has slightly more pressure dependence than the primary, so which sensor pair is a better choice is not obvious.

##### Conversion to IOS Header Format

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

Casts #68 and 69 were joined by naming 68 as \*.iosa and 69 as \*.iosb. Join was run to produce \*.ios.

A plot shows a good join with noise that Delete will remove, but no significant offset.

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 cross-reference check and header check were run. Fluorescence had a very high value during cast #1, but plots show that it did not go off-scale.
* Surface check was run and the average surface value was 2.0db. For CTD #1515 it was 2.5db and for CTD #0550 it was 2.0db. These are slightly lower than usually seen from a Tully cruise in the offshore area. Plots were examined to see what the minimum values were at the end of casts. For CTD 1515 the lowest values seen in 2 casts was about -0.4db but there was no indication that the CTD ever came out of water, so it is likely the surface was <-0.4db. For #0550 it was about -0.8db and that is clearly very close to the surface. So adding 0.5db to the first CTD and 0.08db to the second looks reasonable. Pressure need not be recalibrated at this stage since there were no low values in the downcasts, so no good data will be removed by DELETE
* 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 > 5m checks were made to see if the log entry differed from the header entry and whether the altimetry signal at the bottom provided a good header value. The altimetry was often very noisy but the algorithm worked well at picking out reasonable values. There were 13 casts that were examined to see if the water depth entries were reasonable.

* In 4 cases where log entries differed from header entries, the header value was changed since the log values produced better results: 106, 114, 124, 144.
* In 3 cases the altimetry was very noisy and the check value small, so no change was made.
* In 5 casts the sum of maximum depth sampled plus altimetry header value was entered for water depth since the value in the header looked wrong: casts #39, 52, 60, 75, 79, 86. Those problems all occurred in very deep casts, but seem random with no obvious suggestion of sounder calibration problems. There could be drift between top and bottom of the cast, or random noise in the sounder data. Where differences are fairly large, the depth when at the bottom seems most important to record.

These changes were made to the CLN files and to affected SAMAVG files. MERGE and CLEAN were rerun for the bottle files.

From this point onwards files #69, 87 and 91 were not processed since they contain only upcast data. (The upcast data files were renamed and processed for bottle files.)

##### Shift

Fluorescence

SHIFT was run on the SeaPoint fluorescence channel for casts 41-153 using the usual advance of +24 records. Plots show that the fluorescence offset is reasonably close to the temperature offset after this step.

For casts 1-39 a setting of +1 record was used given that the data were averaged over 24 units in acquisition. Plots show this was effective.

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 selection of casts to find the alignment shift best for the 2 conductivity sensors as judged by noise in T-S space. This was done in 3 groups:

* Casts #1-39: Tests were run to see if there is any point in trying to align conductivity for casts that have been averaged over 24 scans. Any differences found were inconsistent in whether they improved T-S stability or made it look worse. This step was skipped for those casts.
* Casts #41-59: The best choice was -0.55 records for the primary and -0.45 records for the secondary channel.
* Casts #60-153: The best choice was -0.7 records for the primary and -0.5 records for the secondary channel.

Salinity was recalculated for both channels for casts 41-153.

##### DELETE

For casts 1-39, DELETE was run on the SHFFL files.

The following DELETE parameters were used for casts 1-39:

Surface Record Removal: Last Press Min

Maximum Surface Pressure (relative): 10.00

Surface Pressure Tolerance: 1.0 Pressure filtered over 3 points

Swells deleted. Warning message if pressure difference of 3.00

Drop rates < 0.30m/s (calculated over 3 points) will be deleted.

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

Sample interval = 1 seconds. (taken from header)

COMMENTS ON WARNINGS: The only warnings concerned pressure differences >2m. All were handled well by Delete.

For casts 41-153, DELETE was run on the SHFFL files.

The following DELETE parameters were used for casts 1-39:

Surface Record Removal: Last Press Min

Maximum Surface Pressure (relative): 10.00

Surface Pressure Tolerance: 1.0 Pressure filtered over 9 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 = 042 seconds. (taken from header)

COMMENTS ON WARNINGS: The only warnings concerned pressure differences >2m. All were handled well by Delete.

##### Other Comparisons

Experience with these sensors since last factory service –

The pressure, temperature, conductivity and dissolved oxygen sensors have not been used between the last factory service and this cruise.

Historic ranges – Profile plots were made with 3-standard deviation climatology ranges of T and S superimposed. Temperature was slightly low around 300db for P15; similar results were seen from an Argo simulation of Line P from May. The only other outliers were some high values near the surface and low values at depth in the central and northern part of the Strait of Georgia. High surface values are common in this area and the low deep values were also found from other cruises in spring 2023 in the Strait of Georgia using different instruments; this is presumed to be a real variation, not an issue of calibration drift.

Salinity was within the climatology everywhere except for a few cases of low values near the surface, which is common.

Post-Cruise Calibration – None available.

Repeat Casts –No suitable casts were found to do a deep comparison.

##### DETAILED EDITING

The choice of which channel pair to edit (and hence archive) was clear for CTD #1515 as the secondary had more unstable features than the primary. For CTD #0550 the primary was slightly better than the secondary though the differences were slight.

So the primary channels were selected for editing for all casts.

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 except for casts #6, 7, 13, 135, 150.

Notes about editing applied were added to the files.

After editing, T-S plots were examined for all casts and further editing was found necessary for casts #79 and 142 but was done with a text editor.

A second round of editing was applied to 8 casts (39, 58, 60, 62, 68, 79, 82, 86) to clean small DO spikes or remove areas of bad DO data. It is unusual to have spikes in dissolved oxygen but there were many pressure spikes in these deep water.

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

File 2023-066-recal-sil.ccf was prepared to correct channel Silicate since some salinity values were <25psu. This will only be run on bottle files. See section 22.

Salinity does not require recalibration.

Dissolved oxygen and pressure do need recalibration.

For the CTD files 2023-066-recal1.ccf was prepared to apply corrections to both CTDs:

For events #1-58:

* Add 0.5 to Pressure and Depth,
* CTD DO Corrected = CTD DO \* 1.0227 + 0.0113

For events #60-153:

* Add 0.8 to Pressure and Depth,
* CTD DO Corrected = CTD DO \* 1.0115 -0.0094

There was a delay in chlorophyll data processing, so in order to prepare CTD files calibration steps were run on bottles before chlorophyll data were available. Comparisons were then run on dissolved oxygen and salinity data.

CALIBRATE was run on the SAM files to create SAMCOR1 files.

CALIBRATE was run on the MRGCLN2 files to create MRGCOR1 files in order to run the post-correction COMPARE step.

Since extracted CHL was not available at this point, the CALIBRATE steps will be repeated later on the MRGCLN2 files. See section 22.

COMPARE was rerun to check whether the DO corrections were applied correctly and an error was found in the DO offset; this was fixed and calibration rerun.

See file 2023-066-dox-comp2.xls.

CALIBRATE was then run on the EDT files.

##### 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.

The results were examined in 3 groups. Outliers were removed based on residuals. The average differences between Downcast CTD DO and Titrated Bottles were:

DO #1119 – Events 3-52 0.037mL/L (Std Dev 0.047)

DO #3640 – Offshore – Events 60-86 0.020mL/L (Std Dev 0.057)

DO #3640 – Inshore – Events 117-149 0.067mL/L (Std Dev 0.146)

The recalibration worked as well as can be expected for this complex cruise. We expect the recalibrated CTD data to look a little higher than bottles due to incomplete flushing of Niskin bottles and slow response time in CTD data. Based on differences versus pressure, rough estimates were made of SBE DO accuracy.

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

For Events #1-58 (DO sensor #1119)

 ±0.40 mL/L from 0-300db except in areas of very large DO gradients

 ±0.07 mL/L from 300db-600db

 ±0.025 mL/L below 600db

For Events 60-108 (DO sensor #3640) in the offshore region

 ±0.20 mL/L from 0-500db except in areas of very large DO gradients

 ±0.025 mL/L from 500db to 3000db

 ±0.10 mL/L below 3000db

For Events 109-153 (DO sensor #3640) in the inshore region

 ±0.50 mL/L from 0-50db except in areas of very large DO gradients

 ±0.40 mL/L from 50db-200db

 ±0.10 mL/L below 200m

For details see files 2023-066-comp3-CTD1515.xls and 2023-066-comp3-CTD0550.xls

##### Fluorescence Processing

The following step was NOT applied to casts #1-39 since they were averaged in acquisition.

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 and no significant differences were found from climatology.

Profiles showed some problems in fluorescence.

For events #26-39 fluorescence is very spiky even in deep water. The fluorometer was changed after cast #41.

The comparison with chlorophyll samples confirm that these data are not reliable and fluorescence should be removed.

##### 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.

The chief scientist provided a list of casts with no PAR mounted. Cast #49 was on the list but should be 46 and 47. According to the log it was off for 46 and 47 and the plot shows that is true. There is no mention of it being put back on, but the signal is normal for cast #49. The depths confirm that PAR would normally be off for 46 and not for 49.

PAR was removed for casts # 39, 46, 47, 52, 53, 54, 55, 60, 62, 68, 75, 79, 86.

Channel Fluorescence was removed from events 26-39.

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 comments about processing. Separate header files were created so the CTD # in the headers could be corrected for casts 1-58.

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

The Header Check was run and turned up a problem with 2 records with spiky DO in cast #58. The full cast was examined and it is full of bad data in this section, so removing records from averaged files is justified. The 2 records were replaced with pad values in the REO file, which was then put through CLEAN to update the channel limits.

No further problems were found.

Profile and T-S plots were examined. Very bad transmissivity data below 100m were found in cast #86, so CLEAN was used to pad those values below that level in the REO file. Header Edit was then run on that file.

The transmissivity values below 4000db at P20, P24 and P26 were 70.6 %/m, 71.2 %/m and 71.3 %/m for Red and 95.7%/m, 95.2 %/m, 99.7 %/m for Green. The values are much higher than seen in 2022 when Red was ~59%/m and Green was ~96%/m. Both transmissometers had been recalibrated in March 2023 while those in use in 2022 had been calibrated 16 months before the cruise, so the results of this cruise are likely more reliable. But lower values were noted in most cruises in the past, with ~67.5% during 2015-001 being the highest values found at P26 in a brief search of the archive. (A year later at P26 transmissivity was down to 61%; it had not been recalibrated in about 2 years.) It is possible that the results are due to improved recalibration methods, different mounting or better cleaning of the sensor between casts; frequent recalibration is definitely a good idea.

##### Dissolved Oxygen Study

As a final check of dissolved oxygen data, % saturation was calculated and plotted. Values at 2 to 3m ranged between ~85% in Juan de Fuca Strait and near the Gulf Islands to 170% in central Strait of Georgia. Values in casts beyond the shelf break varied from 103% -108%, with most between 103% and 105%. These values are in a typical range for the offshore.

##### Final Bottle Files

CALIBRATE was run on the MRGCLN2 files using file 2023-066-recal-SIL.ccf to correct silicate where salinity is <25psu. (output: MRGCORSIL)

CALIBRATE was run a second time using file 2023-066-recal1.ccf to correct Pressure, Depth and Oxygen:Dissolved:SBE.

SORT was run to arrange casts in pressure order.

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.

Fluorescence:URU:SBE was removed from casts #26 - 41

PAR was also removed for casts # 38,49,57,67,75,77,80,92,93.

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.

Cast #96 was removed as it is not needed; bottles closed but only for travel.

Data were exported from the CHE files to file 2023-066-bottles-final.xlsx. The entries were compared with the rosette log sheets. One problem was found in CHL samples for event 131.

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, 2023-066.txt.

The file was opened in EXCEL.

In opening DELIMITED was selected, TAB deselected, COMMA and Space selected.

Formatting problems included having Time columns with no colons, many NAN entries.

There were many NULL entries in date and time.

The file was opened in Ultraedit to fix time and date formats and saved as a csv file.

The NAN entries were replaced with pad values.

Data acquisition started on May 1st but flow was not turned on until May 3rd. The lab temperature did not equilibrate until shortly after the flow was turned on, so data up to 15:14:19 on May 3rd were removed. That included a few initial records with low flow rates.

After that date there were many corrupted records. No time and intake temperature data are no available for those records and the columns don’t line up properly. It is easy enough to pad the intake temperature, but it is not practical to interpolate the time since over 400 records are affected. Fortunately, < 0.5% of the records were removed, and they always occur only one at a time, so removing them does not lead to significant loss of data. (Some of the corrupted records were recovered by interpolation of time before it was recognized that the size of the job was so extensive.)

Headers were added with 2 lines with variable names and units.

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 factory recalibration of the fluorometer. The clean water offset value was 0.081. For previous uses of this equipment it was sometimes found necessary to adjust the offset to obtain reasonable values, but during 2022-001 and 2022-008 no change was needed. Negative fluorescence values were found with the minimum voltage being 0.072, so the offset needs adjustment. Quick checks of a selection of casts shows that a smaller offset generally gives fluorescence values closer to the CTD though there is some variability.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Event # | CTD Fluorescence | TSG Fl using offset 0.081 | TSG FL using offset 0.069 | Extracted CHL from Niskin Bottles |
| 28 | ~4.0 | 0.47\* | 0.64\* | 0.58 |
| 44  | 0.44 | 0.13 | 0.31 | 0.23 |
| 52  | 0.45 | 0.26 | 0.45 | n/a |
| 60 | 0.17 | -0.015 | 0.16 | 0.28 |
| 62 | 0.50 | 0.23 | 0.41 | 0.30 |
| 71 | 0.34 | 0.45 | 0.63 | 0.35 |
| 85 | 1.36 | 0.82 | 0.99 | n/a |
| 101 | 0.37 | 0.35 | 0.5 | n/a |
| 108 | 1.64 | 1.05 | 1.23 | n/a |
| 109 | 14.5 | 15.04 | 15.21 | n/a |

\*Comparisons with the first fluorometer (#3685) were less reliable because the data were averaged in acquisition and could not be edited. There was a lot of variability in the near-surface values.

Extracted CHL from rosette surface sampling was not available when this study was originally done. They were later added, where available, and show that the TSG fluorescence is mostly lower than CHL when offset 0.081 was used and mostly higher when 0.069 was used. We generally expect fluorometers to read higher than CHL when CHL values are <1ug/L, so the smaller offset is likely more appropriate.

The files were then converted to IOS Header format with header info added. There are 11 IOS files, each covering all or part of 1 day.

Files lists were prepared for all casts, and for 3 groups of 4, 3, 4 days to enable plotting full files.

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

Track Plots turned up 10 errors in positions. These were found to be records that got corrupted in the original data file when times ending 1 second before midnight were recorded as being on the next day at 1 minute before midnight. The 10 records were found, the date corrected to one day earlier and moved to the appropriate place in the edited file. CONVERT and CLEAN steps were rerun.

Another problem was noted at this point. Sometimes the lab temperature is higher than the intake temperature, as expected, but at other times the reverse is true. There is no noticeable shift in lab temperatures when this happens but intake temperatures clearly rose. A quick check against CTD temperature at P11, shortly after the first instance of odd differences, confirms that the intake temperature looks too high. This will be investigated further later.

ADD TIME CHANNEL was used to add Julian dates (Offset from Time Zero – i.e. Day of Year). A record number was also added to enable averaging (for use in comparison to CTD files). Time zero was set to 31 December 2022 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 and turned up some problems;

* Salinity looks bad for the first few hours. It gradually dropped from a reasonable value to about 24psu and then gradually rose to ~32psu. There was no CTD cast during that period but casts before and after have salinity ~32.3psu. The flow rate has a large spike just as the salinity approaches normal values. The salinity data should be removed from the initial section on May 3rd. After that point there are slow drops in salinity values, for up to 30 minutes, followed by sudden returns to the sort of values seen before the drops. The drops are mostly small, <0.1psu, but they do suggest that there were bubbles building up in the TSG intake and suddenly bursting. Editing was kept to a minimum, removing the most significant drops.
* Salinity has some well separated large 1-sided spikes, and smaller but more frequent ones on May 4th. Editing may be possible.
* Salinity rose abruptly by about 0.03psu on May 9th just before 14:00.
* The sharp rises in temperature are often when the ship was stopped but not always. The slow drops are seen in both underway and stopped data.
* There are a few spikes in flow rate, some associated with salinity spikes.
* Intake temperature has fine-scale noise that is not usual for this instrument. That noise disappears at the same time as temperature rose abruptly on May 4th shortly before 10:00. After the rise the shape of the variability looks like the lab temperature, but it is higher than the lab temperature.
* Intake temperature dropped on May 8th around 02:00, rose on May 9th ~05:00, fell on May 11th ~20:00, rose on May 11th before 23:00. There is no obvious connection to the ship stopping or changing direction.
* Lab temperature has no obvious noise. The plots have a similar shape to intake temperature except that there are no abrupt changes.

A plot of all differences (Lab Temp – Intake Temp) through the whole record suggests that there will be no easy correction possible for the TSG intake temperature.

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 2023-066-tsg-ctd-loop-rosette-comp.xlsx. data were removed from the list for times when the TSG was not recording or the flow in the loop was off. This left 33 points of comparison.

The TSG files were averaged over 6 records (1 minute) on record number to reduce the noise and file size. Standard deviations were included. Then 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 2023-066-tsg-ctd-loop-rosette-comp.xlsx..

The same file was thinned to the closest times to loop files (after removing loops that were taken when TSG was not recording) and added to the TSG-Loop comparison. There were 16 loop samples that overlapped with TSG records.

A comparison was made of positions for the CTD and TSG data to check for good matches. The differences in positions are expected to be small despite the averaging because the ship was stopped at these times. The median differences were 0.0000º for latitude and 0.0002º for longitude. The largest differences were 0.0018 during a Test cast and the log shows there was above-average drift during that cast.

c.) Comparisons

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

The initial comparison between TSG and CTD data using all casts was:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|   | TSG Intake -CTD Temp | TSG Lab-CTD Temp | TSG Sal – CTD Sal | TSG FL / CTD FL |
| Average | 0.6119 | 0.5997 | -0.0633 | 0.8522 |
| Median | 0.7976 | 0.5278 | -0.0348 | 0.7879 |
| Std Dev | 0.3481 | 0.2192 | 0.0980 | 0.3733 |
| Max | 0.9974 | 1.2987 | 0.1108 | 2.3436 |
| Min | 0.0565 | 0.3851 | -0.3808 | 0.0522 |

This comparison includes only data from the fluorometer used after cast #39 (FL #3640).

When the data were restricted to casts that had a standard deviation in TSG salinity <0.001psu. (casts #41-108) the following differences were found:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|   | TSG Intake -CTD Temp | TSG Lab-CTD Temp | TSG Sal – CTD Sal | TSG FL / CTD FL |
| Average | 0.6842 | 0.5400 | -0.0317 | 0.7827 |
| Median | 0.8390 | 0.5281 | -0.0260 | 0.7726 |
| Std Dev | 0.3131 | 0.0605 | 0.0255 | 0.2387 |
| Max | 0.9974 | 0.6808 | -0.0039 | 1.3595 |
| Min | 0.0683 | 0.4389 | -0.1098 | 0.0522 |

While restricting the choice to these offshore casts led to much lower standard deviations in lab temperature and salinity, it did not improve that of the intake temperature. This is further confirmation of odd behaviour in the intake temperature sensor.

Reducing the comparison to casts with CTD #0550 reduced the salinity difference somewhat, but this may be more due to lower salinity gradients than calibration of sensors.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|   | TSG Intake -CTD Temp | TSG Lab-CTD Temp | TSG Sal – CTD Sal | TSG FL / CTD FL |
| Average | 0.5578 | 0.5527 | -0.0187 | 0.8750 |
| Median | 0.6114 | 0.5329 | -0.0142 | 0.8295 |
| Std Dev | 0.3368 | 0.0718 | 0.0151 | 0.1827 |
| Max | 0.9788 | 0.6808 | -0.0039 | 1.3595 |
| Min | 0.0683 | 0.4389 | -0.0591 | 0.6933 |
|  |  |  |  |

It is harder to judge fluorescence from the offshore since most values are low; the TSG fluorescence appears to have values about 77% of CTD fluorescence, but the standard deviation is very high.

When casts 82-114 were compared, despite high standard deviation in the TSG data, the comparison looks much closer with TSG values about 92% of CTD fluorescence.

* Comparisons of Loop samples and TSG data

Salinity

There were 20 loop samples but 3 were taken before the TSG flow was started, so 17 points of comparison remain. TSG data were averaged over 1 minute and values extracted to match the times of loop samples. When all casts were included the TSG salinity was lower than loop samples by a median of ~0.01psu. Removing those with standard deviation over 1 minute of >0.001psu made no differences to the median. There were only 2 loops corresponding to the time when CTD #1 was used and data were not averaged in acquisition; the TSG was low by 0.082psu and 0.046psu for those 2. When only loops from CTD #2 are included the median differences are much lower, with the TSG reading lower by a median of 0.0073psu. This corresponds to the change in CTDs, but that might be irrelevant since temporal matches are less critical well offshore. Timing of matches is subject to errors due to the water travel time in the loop (with mixing en route) and times entered in the log for loop samples being inexact. This is particularly true for the samples taken during rosette casts as the time recorded is the end of the cast, not the time of the 5m rosette firing. The influence of bubbles is also variable.

CTD #2 casts taken while the ship was stopped had TSG salinity reading low by a median of 0.0033psu while underway TSG values were low by a median of ~0.0082psu. There were only 2 “stopped” cases so this is not strong evidence, but it may indicate bubbles were less of a problem when stopped.

Chlorophyll

There were 6 loop CHL samples at times when TSG data were available. The TSG Fluorescence was higher than the loop CHL by a median of 0.30ug/L but the standard deviation was 0.33ug/L. There was only 1 case where the TSG value was lower than the loop sample. Fluorometers tend to read high for low CHL and all the CHL values were <0.6ug/L.

* Comparison of Loops and 5m Niskin Samples

Loop samples were taken at the end of 7 rosette casts; 5m data from the rosettes were compared with loop salinity, nutrients and chlorophyll samples.

* 1. Loop salinity was higher than Niskin salinity by a median of 0.002psu (std dev 0.0012psu). This may be due to a small difference in depth of samples.
	2. The loop and Niskin CHL samples are within ±0.02ug/L with the exception of one cast for which the loop was lower than the Niskin by 0.05ug/L. The median has the loop reading slightly lower than the Niskin.
	3. Loop nutrients were in good agreement (loops = Niskin samples or higher by ~1%) except for cast #28 when the loop values were 20-30% lower than Niskin samples.

d.) Calibration History

The TSG was serviced and recalibrated shortly in early 2022.

* During 2022-0001 – Salinity was close to CTD in open ocean; larger differences in inlets. No recal applied. Problem with intake thermistor that cleared up suddenly with temperature dropping by 1C° in 5s and 1.9C° in 25s. . TSG fluorescence was higher than Extracted CHL by up to a factor of 3 for the samples with CHL < 1ug/L and dropped sharply for CHL>0.5ug/L. There were only 2 samples with CHL>5ug/L and TSG fluorescence was about 30% of CHL for those.
* During 2022-0008 – Salinity was recalibrated by adding 0.2psu. There were problems with the intake thermistor that suddenly resolved. The data were bad for part of the cruise and noisy after that, but values looked reasonable, though slightly higher than CTD temperatures. The lab temperature looked ok. TSG fluorescence was about 60% of CTD fluorescence, hither than loop CHL when CHL<0.5ug/L and lower for CHL> 05ug/L.

e.) Conclusions re TSG

1. The TSG clock worked well and position information was available.

2. Both flow rates were mostly in a good range, with just a few spikes.

3. There are too many variables to expect good results from the comparisons: CTD data was averaged in acquisition up to cast #39, there were frequent spikes in CTD from casts #36-91, The CTD was changed at cast #60, near-surface gradients were variable, few rosette/loop comparisons were available especially for CTD 550.

4. The intake thermistor produced no useful data. It swung between being lower than the lab temperature and being higher, but at no point was it close enough to the CTD temperature to justify archiving it.

5. The differences between the lab temperature and the CTD are fairly consistent through the record and subtracting 0.53C° should provide a reasonable proxy for intake temperature.

6. The TSG salinity is lower than that from the CTD but the differences varied greatly, with most between 0psu and 0.066psu. The best estimate likely comes from the offshore casts when CTD #0550 was in use when TSG salinity was lower than the CTD by 0.014psu but the standard deviation was 0.015psu. Comparisons with loops also varied greatly, with the offshore casts using CTD #0550 showing the TSG salinity to be lower than loops by 0.007psu but the standard deviation was 0.056psu. Comparisons were also varied between rosette samples closed at about the same time as the loop sample; the two in the offshore from CTD #0550 showed TSG salinity being lower by 0.005psu and higher by 0.0016psu. The varying results are likely due to some sections with bubbles in the TSG which lowers salinity, and others with few bubbles. For the latter no correction is likely needed and for those with bubbles the effect is highly variable. So the TSG salinity is likely low, on average, but no recalibration is justified given so much variability.

7. TSG Fluorescence was higher than loop chlorophyll, but that is expected as the loops all had low CHL. The TSG fluorescence was ~80% of that from the CTD fluorometer in the offshore and ~92% in the Strait of Georgia where CHL was higher. The loop and Niskin CHL samples are within ±0.02ug/L with the exception of one cast for which the loop was lower than the Niskin by 0.05ug/L. The median has the loop reading slightly lower than the Niskin. Nutrients from loops are a little higher than those from Niskin bottles; there are few points of comparison as 1 of the 5 available comparisons was clearly an outlier. In any case, the differences are <1%.

f.) Editing

Some editing was applied to

CTDEDIT was used to remove bad salinity data from the initial section on May 3rd and single-point spikes in all files. Conductivity and Sigma-t were removed from the same records later using Ultraedit.

There are many cases of salinity suddenly rising; in one notable case salinity increased by ~0.03psu (32.33 to 32.36psu) in 30s while the ship was stopped at P26. The CTD salinity shortly before this rise was about 32.36psu. This further suggests that the low values are due to bubbles that build up then suddenly break.

g.) ADD CHANNEL and CALIBRATE

ADD Channel was used to add channel Temperature:Primary which will serve as a proxy for intake temperature and was initially set to equal Temperature:Lab.

CALIBRATE was run using file 2023-066-tsg-recal.ccf to subtract 0.53C from Temperature:Primary.

h) Preparing Final Files

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.

The TSG sensor history was updated.

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

A cross-reference list was prepared:



##### Loop File

File 2023-066-loops.csv was prepared with times for each loop sample plus results from analyses; the end time of casts were used when loops were during CTD casts.

Positions were added based on concurrent CHE files where available and log entries for the rest.

The sampling method column was added and filled with ROS.

Derived Quantities was run to derive Sigma-T for the CHE files.

CLIP was run to remove all data below 7m.

Data were then exported to spreadsheet 2023-066-loop-che-data.csv

This gives start times, but we really want time of the last bottle closed.

The \*.IOS files corresponding to bottle files were put through ADD TIME CHANNEL so an END TIME is added to the header. That was exported to a spreadsheet with event #s and END TIMEs only. Those data fit into 2023-066-loop-che-data.csv.

A few alterations were made in the order of columns and then a 6-line header was inserted.

The date/time column was saved with Dates only displayed.

That file was saved as 2023-066-surface-6linehdr.csv. clip

The file break column was filled with value 1 so all data to ensure only a single file is created in conversion.

CONVERT was run to produce an IOS Header file.

CLEAN was run to get start and stop times and to add flag 0 to empty flag cells.

A comment file was prepared which was essentially the same as the one used in preparing CHE files, but including a description of the loop system and comments on the CTD data processing.

Header Edit was used to correct channel names and formats and to add comments. The final file was renamed as 2023-066-loop.txt. The track plots look reasonable and plots of temperature and salinity versus event numbers, latitude and longitude look reasonable.

Marie Robert adjusted comments and added sample numbers to the final loop file.

P**articulars - Notes from Daily Science Log and Sampling Notes**

PAR off: 39, 46, 52 to 55, 60 to 68/69, 75, 79, 86/87.

Casts with no Niskin closed:47, 96 (closed but no CHE file needed), many after 117.

Casts run out of order: 19, 41, 49, 58, 71, 91.

Split casts: 68/79 & 86/87

Deployment schemes:

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 ALL rosette casts:

Niskin bottles closed from 0 to 400 db (both included) had a wait time of 60 seconds.

 All Niskin bottles deeper than 400 db had a wait time of 30 seconds.

TSG notes

Water not turned on until ~P6.

Recording stopped on May13.

CTD notes

1. Only 15 Niskins closed; probably interference with the UHF radios.

1-39 Deck unit set to average 24 values.

26-39. Bad CTD Fluorescence data.

36-91 – Lot of spikes in data in all sensors and pressure.

47. Lost connection to CTD at 375db – no upcast and no Niskin closed.

58. Niskin at 2000 for bulk water – sample #404 was used again another cast; not needed for this cast.

60. Full Sal and Oxy sampling since new CTD in use.

69. Upcast of P20 deep – called 0068-1 – raw files renamed 0069. Whole upcast in 69.

86/87. Depth should be 4224 not 4364 – fixed in raw files

86/87. Due to many “scan length errors” started new file for upcast.

90/91 – Due to many “scan length errors” started new file for upcast.

96. Niskins closed at depth but not sampled.

101. Test cast to check bottles, but can be processed. No bottle file prepared.

120-131 – file names missing a 0.

109 – wrong station name should be CPE1. Fixed in raw files.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **CTD#** | **Make** | **Model** | **Serial#** | **Used with Rosette?** | **CTD Calibration Sheet Competed?** |
| **1** | **SEABIRD** | **911+** | **1515** | **Yes** | **Yes** |
| **2** | **SEABIRD** | **911+** | **0550** | **Yes** | **Yes** |
| **Calibration Information - 1515** |
| **Sensor** | **Pre-Cruise** | **Post Cruise** |
| **Name** | **S/N** | **Date** | **Location** | **Date** | **Location** |
| **Temperature** | **6754** | **24Jan2023** | **Factory** |  |  |
| **Conductivity** | **6141** | **24Jan2023** | **Factory** |  |  |
| **Secondary Temp.** | **6736** | **3Feb2023** | **Factory** |  |  |
| **Secondary Cond.** | **6146** | **24Jan2023** | **Factory** |  |  |
| **Transmissometer** | **1185DR** | **23Mar2023** | **Factory** |  |  |
| **Transmissometer** | **1883DG** | **23Mar2023** | **Factory** |  |  |
| **SBE 43 DO sensor** | **1119** | **10Feb2023** | **Factory** |  |  |
| **PAR sensor** | **70613** | **24Feb2021** | **Factory** |  |  |
| **SeaPoint Fluor.** | **3685** |  |  |  |  |
| **SeaPoint Fluor.** | **3640** |  |  |  |  |
| **Pressure Sensor** | **1515** | **17-Jan-2023** | **Factory** |  |  |
| **Valeport Altimeter** | **?** |  | **Factory** |  |  |
| **Calibration Information - 0550** |
| **Sensor** | **Pre-Cruise** | **Post Cruise** |
| **Name** | **S/N** | **Date** | **Location** | **Date** | **Location** |
| **Temperature** | **2663** | **15Feb2023** | **Factory** |  |  |
| **Conductivity** | **2280** | **14Feb2023** | **Factory** |  |  |
| **Secondary Temp.** | **2106** | **3Feb2023** | **Factory** |  |  |
| **Secondary Cond.** | **2754** | **24Jan2023** | **Factory** |  |  |
| **Transmissometer** | **1185DR** | **23Mar2023** | **Factory** |  |  |
| **Transmissometer** | **1883DG** | **23Mar2023** | **Factory** |  |  |
| **SBE 43 DO sensor** | **3791** | **10Feb2023** | **Factory** |  |  |
| **PAR sensor** | **70613** | **24Feb2021** | **Factory** |  |  |
| **SeaPoint Fluor.** | **3640** |  |  |  |  |
| **Pressure Sensor** | **0550** | **20Feb2023** | **Factory** |  |  |
| **Valeport Altimeter** | **37171** |  | **Factory** |  |  |

# TSG Make/Model/Serial#: SEABIRD/45/0789

|  |
| --- |
| **Calibration Information** |
| **Sensor** | **Pre-Cruise** | **Post Cruise** |
| **Name** | **S/N** | **Date** | **Location** | **Date** | **Location** |
| **Temperature** | **45-0789** | **1Feb22** | **Factory** |  |  |
| **Conductivity** | **45-0789** | **1Feb22** | **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** |  |  |

 



Station Names from section in Strait of Georgia

