REVISION NOTICE TABLE

DATE	DESCRIPTION OF REVISION
3 Feb 2020	Added DMSP-D&DMSP-T–values padded due to problem in blank G.G.
23 Jan 2019	Silicate and Phosphate data corrected in file 2014-18-surface.loop.
1 April 2015	Correction to header comment about salinity bottles in CHE files. G.G.
19 Nov. 2014	Note added to Summary section on factory post-cruise calibrations. GG

PROCESSING NOTES

Cruise: 2014-018
Agency: OSD
Location: North-East Pacific
Project: Line P
Party Chief: Robert M.
Platform: John P. Tully
Date: 8 June 2014 – 24 June 2014

Processed by: Germaine Gatien
Date of Processing: 18 July 2014 – 30 October 2014

Number of original HEX files:	50	Number of CTD files: 49 (2 files joined)
Number of bottle files:	49	Number of bottle casts processed: 49
Number of original TSG files:	7	Number of processed TSG files: 7

INSTRUMENT SUMMARY

SeaBird Model SBE 911+ CTD (#0585) was used for this cruise. It was mounted in a rosette and attached were a Wetlabs CSTAR transmissometer (#1396DR), an SBE 43 DO sensor (#1119) on the primary pump, a SeaPoint Fluorometer (#3642) with a 3X cable on the secondary pump, a Biospherical QSP-200 PAR sensor (#4601) and an altimeter.

A thermosalinograph (Seacat 21 S/N 3363) was mounted with a Wetlabs/Wetstar fluorometer (WS3S-713P), remote temperature sensor and a flow meter.

The data logging computer was #3. Seasave version V7 22.4 was used for acquisition.
The deck unit was a Seabird model 11, serial number 0471.
All casts were run with the LARS mid-ship station.
The salinometer used at IOS was a Guildline model 8400B Autosal, serial # 68572.
An IOS rosette with 24 10L bottles was used.

SUMMARY OF QUALITY AND CONCERNS

The Daily Science Log Book and rosette sampling log sheets were generally in good order, though there were no entries for the TSG. Sometimes TSG data does not get downloaded with the CTD data and it is a good idea to make it clear that the system was used. The Chief Scientist provided sampling notes that were very helpful.

There was one case of a cast being interrupted by a computer crash. It was restarted with a new event number. It is recommended that any Niskin bottles that had already been fired during the acquisition of the 1st file be fired again at the beginning of the 2nd file. This makes the combining of the files easier and so helps avoid errors.

The descent rate of the CTD was very noisy between stations P14 and P20 (events # 39 - 53). This led to much loss of data due to shed wakes and high deceleration rates are associated with salinity values that appear to be too high. A graphical editor was used to remove obviously bad data, but when there are complete reversals of the CTD it is harder to distinguish good from bad, so the quality of the data is somewhat lower than usual.

The recalibration of CTD salinity was based on observations over 6 cruises that used this equipment between March and June 2014. The difference between the two salinity channels was large even on the first cruise using this equipment following factory servicing of all sensors. The difference appears to be increasing slowly. All bottle comparisons except that from 2014-21 have had complications that limit confidence in the results. The primary salinity is believed to be close to bottles based on 2014-21 results, but the secondary salinity has been found to be less noisy, so was chosen for archiving. For this cruise the secondary salinity was recalibrated by subtracting 0.0053 to make it match the primary salinity. The sensors have been sent to the factory and all the cruises can be revisited if evidence arises that the salinity has not been recalibrated appropriately.
NOTE: 19 November 2019: Post-cruise factory calibration shows that the secondary salinity was high by about 0.005 by mid-August. Based on observations during a series of cruises, it appears that the calibration applied to these data in July was appropriate, though there remains some doubt about when drift occurred. G. Gatien

The Oxygen:Dissolved:SBE data are considered, very roughly, to be:

±0.8mL/L from 0db to 50db
±0.6mL/L from 50db to 100db
±0.2mL/L from 100db to 250db
±0.15mL/L from 250db to 800db
±0.04mL/L below 800db

The Chief Scientist reported many problems with the TSG system including computer issues, inadequate flow to the fluorometer and difficulties accessing valves and the debubbler safely.

The TSG salinity was extremely noisy with one-sided spikes towards low values, presumably due to air bubbles. There are large sections with extremely large spikes, with changes as high as 12 salinity units below adjacent readings. Even the quieter sections have frequent spikes on the order of size 0.5. This was disappointing since during its previous use in 2014-21 the salinity data had very few spikes. There were sudden improvements in the noise level that were probably due to cleaning of the filter or adjustment of valves as attempts were made to improve the quality of TSG data. The flow rate was very steady throughout the cruise. In many sections editing to remove spikes is not practical, but isolated single-point spikes in salinity were removed, as were temperature, salinity and fluorescence from a short section with zero flow in the first file. The TSG salinity data is given with only 2 decimal places to draw users' attention to the low quality of the data.

PROCESSING SUMMARY

1. Seasave

This step was completed at sea; the raw data files have extension HEX.
An initial cast was sent from sea for initial processing. The only problem noted was a difference of 0.005 in salinity between the two channels as was noted on other cruises using these sensors.

2. Preliminary Steps

The Log Book and rosette log sheets as well as various analysis logs were obtained.

There was only a single version of the configuration file.
Extracted chlorophyll, DMS, nutrients, dissolved oxygen and salinity data were obtained in spreadsheet format from the analysts.
The cruise summary sheet was completed.
The history of the pressure sensor, conductivity and DO sensors were obtained.

The calibration constants were checked for all instruments. The only errors found were a missing calibration date and a format error in another date. Those were fixed and the file was saved as 2014-18-ctd.xmlcon.

The PAR sensor was not always mounted. Cast lists of PAR and NO PAR were prepared based on log notes.

3. BOTTLE FILE PREPARATION

The ROS files were converted using file 2014-18-ctd.xmlcon with Tau and Hysteresis corrections selected. Those files were put through CLEAN to add event numbers (*.BOT).

Temperature and salinity were plotted for all BOT files. There were a few small spikes in primary salinity not seen in the secondary, but they were near the surface and could be real, so they were not removed.

Header Check was run on the BOT files and no problems were found.

The BOT files were then averaged to enable an ADDSAMP file to be prepared. First, the file was sorted on event number and Bottle Position order. Then sample numbers were added based on the rosette logs.

Cast #1 was interrupted during the upcast, so the BOT files for #1 and #2 needed to be combined. The bottle positions are correct in both files, but the bottle firing number has to be adjusted in the second file. It is easier if the bottles fired during the 1st part are fired again at the beginning of the 2nd file. File 2014-18-0001.bot and 2014-18-0002.bot were renamed 2014-18-0001.bota and 2014-18-0001.botb. The bottle numbers were adjusted in the 2nd file and then JOIN was used to create a new file, 2014-18-0001.bot.

Sort was used to ensure that the ADDSAMP file was in sample number order.
SAM files were created using the Add Sample Number routine and those files were then bin-averaged.
Bin-average was then run using bottle numbers for bins to produce SAMAVG files.
The addsamp.csv file was ordered on sample number and converted to CST files. The CST files will form the framework for the bottle files.

Next, each of the analysis spreadsheets were examined to see what comments the analyst wanted included in the header file. These were used to create file 2014-18-bot-hdr.txt.

<u>EXTRACTED CHLOROPHYLL</u>
Extracted chlorophyll and phaeo-pigment data were obtained in file QF2014-18CHL.xls. A simplified version of the spreadsheet was saved as 2014-18chl.csv which was then converted to individual CHL files. Loop data were added to file 2014-18-loop.csv.

<u>DISSOLVED OXGYEN</u>
Dissolved oxygen data were provided in spreadsheet QF2014-18oxy.xls which includes flags, comments and a precision study. Draw temperatures are available. The spreadsheet page with the final data was

simplified by removing a few unnecessary columns and the file was then saved as 2014-18oxy.csv. That file was converted into individual *.OXY files.

SALINITY

Salinity analysis was provided in spreadsheet QF2014-18SAL.xls. The file was simplified, loop samples were removed and the file was saved as 2014-18sal.csv. That file was converted to individual SAL files. The salinity data were analyzed 23 to 39 days after collection. Loop samples were saved to 2014-18-loop.csv.

NUTRIENTS

The nutrient data were obtained in spreadsheet QF2014-18nuts.xls which included a report on precision. The file was simplified, reordered on sample numbers and the file was saved as 2014-18nuts.csv. The file was converted to individual NUT files. The loop data were copied to file 2014-18-loop.csv.

DMS

DMS data were obtained in file DMS summary (2014-18).xls. (There was a separate report on analysis techniques and problems.) The file was simplified and saved as 2014-18DMS.csv and converted to individual DMS files.

The SAL, CHL, OXY, NUT and DMS 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 merged 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. The output files were named MRGCLN1s. Those files were then merged with SAMAVG files choosing the Bottle_Number from the SAMAVG files.

The MRG files were exported to a spreadsheet and compared to the rosette sheets. A few inconsistencies were noted:

- Cast #1 – Niskin #24 was not sampled and was given no sample number, so this line was removed from the SAMAVG file.
- Cast #38 – Niskin 19 was closed by mistake at the surface, it has no sample number assigned and is not needed, so that line was removed from the SAMAVG file and the final MERGE and CLEAN steps were repeated.
- Cast #68 – Niskin 1 was closed by mistake; a sample number was assigned but no samples were taken and this line is not needed according to notes from the chief scientist, so it was removed from the SAMAVG file and then final MERGE and CLEAN steps were repeated.
- Casts 64, 65 and 68 – CHL data are missing. These got lost between the RAW page and the final page. The analyst corrected this error and the merge process was rerun for files 64-68.
- Cast 72 – The log sheet shows duplicates or triplicates for all frozen nutrients, but the only nutrients in the QF spreadsheet is for the ones shown as triplicates. It is assumed that the extra samples were gathered for some other purpose since they are clearly not in the spreadsheet.
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An initial header check did not turn up any problems.

4. COMPARE

Hysteresis Check

Before doing the full COMPARE runs, tests were run to check whether the hysteresis parameters for the dissolved oxygen sensor needed fine-tuning. COMPARE was run on dissolved oxygen with pressure as the reference channel. An initial examination suggested that there might be a problem with hysteresis, but there is a complication due to analysis problems. There are some clear outliers but some appear to be due to a different problem that was first noted during cruise 2014-06 and was also seen during 2014-21. The analyst notes include the following explanation:

> *(Some) casts suffered what was determined to be a communication problem between software and titrant Dosimat. Titrant dosage was much too high for the majority of the samples in both casts as if the titration ran on before the software could catch up. The problem seems somewhat random and is mitigated by either re-initializing the system for a new cast or by rebooting either the notebook or the Dosimat.*
> *There was no evidence that the CTD DO was bad and all other casts during the cruise behaved as expected relative to the CTD DO sensor. Values are not recoverable and are therefore padded and flagged with a 5. This is a new problem that was introduced with the implementation of a Windows 7 notebook and new serial to USB converter required for compatibility with the latest hardware upgrades in Windows 7 machines.*

It will be difficult to tease apart what outliers are due to hysteresis and which are due to bad bottle values. The apparent hysteresis looks much worse than we usually see making this even more difficult. However, the pattern does look like hysteresis. Tests were run by varying the value of E and converting 2 deep casts. E values of 0.030, 0.031 or 0.032 look appropriate depending on what points are compared. The value of 0.031 was used to convert all the cast with DO calibration sampling. The results show a great improvement, but there is a lot of scatter with some values too high and others too low. There is a slight suggestion that there might be some samples affected by the analysis problem mentioned above, most particularly those from cast #45, while cast #72 looked fine.

The data for all files were reconverted using an updated version of configuration file 2014-18-ctd.xmlcon, with E=0.031 for the DO calibration. Then the steps described in the previous section were repeated.

Dissolved Oxygen

COMPARE was run using the newly converted files.
There are only 2 significant outliers and 1 was already flagged 4 and the other is right at the surface where such differences are not unusual. When those outliers are excluded along with some others based on residuals, the fit is:

DOX_BOT = 1.0417 * DOX_CTD +0.0289 with R^2 =0.97

A variety of fits were tried, including fixing the offset at 0 and removing all DO values <1 and the results were either unsatisfactory to the eye or made little difference to the fit.
A last check was made for signs of hysteresis and the results look fine.

There was only 1 bottle that looks like a significant outlier in the comparison. Sample #436 had already been flagged 4 by the analyst. As the bottle value was higher than the CTD DO by about 0.2mL/L the analyst changed the flag to 5 and replaced the value by a pad value.

For more details see 2014-18-dox-comp1.xls.

Salinity

Compare was run with pressure as reference channel. Salinity samples were analyzed within 23 to 39 days of collection.

There is a lot of scatter in the comparison. This could be due to inefficient flushing or evaporation of samples since the analysis was somewhat delayed. A plot of differences against file pair number does suggest that there is some time dependence. That might suggest evaporation since the early samples waited a week longer for analysis than the later ones, but the scatter is too large to say that is the case and the difference in waits for analysis is not so large that we would expect a significant difference from one cast to another. The randomness of outliers is consistent with evaporation.

When data from above 500db are excluded as well as 1 flagged value, the primary salinity channel is found to be lower than bottles by an average of 0.0012 and the secondary salinity is higher by an average of 0.0041. The range of (primary salinity – bottle) in the fit was from -0.0046 to +0.0011 and for secondary salinity the range was +0.0012 to +0.0064. The standard deviations in the 2 fits are 0.0012 and 0.0011. No data were included that had a standard deviation in the salinity during the 10s window that was >0.0008.

This contrasts with the results of 2014-21 when all data were analyzed within 3 to 14 days. When data were selected from below 500db and with standard deviation in the CTD salinity <0.0008, the range of (primary salinity – bottle) was from -0.0015 to +0.0024 with an average difference of -0.0003 and a standard deviation of 0.0007. So there was less scatter for the earlier cruise and the CTD was relatively higher compared to bottles than for this cruise. The 2014-21 secondary salinity was high by an average of ~0.0052 and standard deviation of 0.0008. Both the scatter and the average differences suggest that there was more evaporation of samples from 2014-18.

Another explanation for the change between 2014-21 and 2014-18 is calibration drift. The following table shows differences from all the cruises using this equipment between March and July 2014. Since there is usually some gradient in differences in the top 500m and we only have data from above that level for the first 4 cruises, the estimate was made by looking at plots around 300-400db.

Cruise	CTD Sal1 – CTD Sal0 at 350db	Sal 0 – Sal Bottle
2014-03	0.0042	n/a
2014-06	0.0043	-0.0035
2014-27	0.0048	-0.004
2014-15	0.0050	-0.0032
2014-21	0.0055	-0.0003
2014-18	0.0053	-0.0012

There was no drift obvious in the difference through the latter 2 cruises which were long. The estimates for the differences between channels are very rough for the last two cruises due to very noisy descent rates. The results of COMPARE, which include deeper sampling, show the difference between the 2 CTD salinity channels to be 0.0052 for 2014-21 and 0.0053 for 2014-18.

There may be a very slow drift towards very slightly larger differences, but it is not enough to explain the differences in the comparison with bottles between 2014-21 and 2014-18.

There were 24 bottles fired at 2000m during one cast. It is interesting to compare the variation in the bottles as a measure of evaporation. The range of bottle values was 0.0052. This is a little higher than the expected analysis accuracy of ±0.002. There are 3 outliers towards higher bottle values and 1 towards lower values. The pressure range during the stop was 1db, and the maximum and minimum bottle values came from consecutive bottle firings. Any error in salinity due to evaporation was likely no more than 0.001.

The precision study from analysis of replicates, after removing Chauvenet outliers, was Sp=0.0006 for this cruise, while the 2014-21 result was Sp=0.0002. This is consistent with more evaporation (which would be fairly random) for this cruise than for 2014-21.

There is one other possible explanation and that is flushing of Niskin bottles. It is not likely to be a major factor in the open ocean with very noisy descent rates, but there could be some detectable effect close to the surface.

So it seems best to use the results of 2014-21 to recalibrate this cruise. If we make the assumption that the primary salinity has not drifted significantly, then the secondary has probably drifted upwards by about 0.001 between April 2014 and July 2014. So since secondary salinity was chosen for the first 4 cruises, recalibration of that channel will be achieved by subtracting the difference between the secondary and primary salinity. For this cruise the secondary can be recalibrated by subtracting 0.0053.

For full details for the COMPARE run see file 2014-18-sal-comp1.xls.

Outliers were examined and none suggest a need to change flags. Most are right at the surface where the distance between the CTD and the Niskin bottle may be significant or are associated with high standard deviation in the CTD salinity.

Fluorescence

COMPARE was run to see how the SeaPoint fluorescence channel compared with extracted chlorophyll. The fit of SeaPoint Fluorescence / extracted CHL vs CHL has the usual general pattern of high ratios for CHL<1 and ratios dropping gradually to lower values. However, the drop-off in the ratio is steeper than usual and it settles to a value of about 1 which is higher than during the previous cruise, 2014-21 when it was about 0.5.

There are many cases of fluorescence values being much higher than chlorophyll; that would not be surprising for low CHL, but for many the CHL is >1ug/L. This was not noticed during 2014-21. This is a new fluorometer and we want to understand its behaviour.

There is no notable difference between the standard deviation in the fluorescence data during bottle stops. The range of CHL is similar for the 2 cruises though there are more very low values during this cruise. Incomplete flushing of Niskin bottles could explain some of these high ratios, in particular those where bottles were sampled below the maximum in high vertical gradients. While flushing is not usually a big problem in offshore waters, the ascent rate was quieter than usual.

One question is why was this not seen during 2014-21, or was it just not so obvious? There were cases of a fairly high ratio, but not as high as many of the 2014-18 cases. There may have been differences in the efficiency of bottle flushing, depth of the CHL maximum and types of phytoplankton sampled.

The upcast and downcast fluorescence traces are similar with the usual vertical offset due to the CTD carrying deeper water with it on the way up. When stopped for a bottle, the fluorescence generally reaches the downcast value. So there is no evidence that the fluorometer is not working properly.

For more detail see file 2014-18-fl-chl-comp.xlsx.

Plots of Titrated DO and CTD DO against CTD salinity were examined. No further problems were detected.

5. Conversion of Full Files from Raw Data

All files were converted using con file 2014-18-ctd.xmlcon with hysteresis and Tau corrections chosen. A few casts were examined and all expected channels are present.

The two temperature conductivity channels are fairly close to each other during the downcasts; there is clear evidence of shed wake corruption. Upcast data are much noisier with sometimes one channel higher, sometimes the other. We expect the upcast data to have lower temperature and conductivity than the downcast when we match depths due to the rosette dragging deeper water with it. But cast #60 examined had a section where the reverse was true despite the usual profile of temperature decreasing with depth; perhaps this is caused by an internal wave. There were sections with a step structure on the downcast. The conductivity channels have a similar character except that the differences are larger than we usually see; however, other recent uses of this particular equipment have had similar differences.

The fluorescence, transmissivity, dissolved oxygen and PAR data look normal. The altimetry is sometimes very noisy but it looks like a reasonable reading can be found by plotting if the header algorithm fails to do so.

6. WILDEDIT

Program WILDEDIT was run to remove spikes from the pressure, conductivity & temperature only.
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.

7. ALIGN DO

Tests were run on 4 casts with only a few stops during the upcast, but the results are not easy to interpret because of noisy upcast temperature data and much shed wake corruption of all channels. However, the +4s setting looks reasonable and is certainly an improvement over no adjustment. This setting was used on other recent uses of this equipment.
ALIGNCTD was used to advance the DO Voltage by 4s relative to the pressure.

8. CELLTM

The upcast data are noisy so the usual tests for CELLTM settings were very hard to interpret. Tests were run on 4 casts with few bottles fired to see if the settings used for cruise 2014-21 which immediately preceded this cruise were appropriate. The choice of ($\alpha = 0.03$, β=9) and ($\alpha = 0.03$, β=7) definitely improved the correspondence of the upcast and downcast on a T-S surface.
CELLTM was run using ($\alpha = 0.03$, β=9) for the primary conductivity and ($\alpha = 0.03$, β=7) for the secondary conductivity.

9. DERIVE

Program DERIVE was run twice:

on all casts to calculate primary and secondary salinity and dissolved oxygen concentration.

on a few casts to calculate the differences between primary and secondary channels for temperature, conductivity and salinity. These were placed in a test directory and will not be archived.

10. Test Plots and Channel Check

A sample of casts was plotted to check for agreement between the pairs of T and C sensors. The differences were very noisy. The results from a few casts from previous cruises that used the same sensors are included to check for calibration drift. Only shallow sampling was done during 2014-06 and 2014-27.

Cast #	Press	T1-T0	C1-C0	S1-S0	Descent Rate
2014-06-0053	350	~0	0.00044	0.0044	V.Steady

2014-27-0073	335	+0.0002	0.00045	0.0045	V. steady
2014-21-0036	350	-0.001 XN	0.0004	0.005	High, X Noisy
“	1000	~0	0.00043	0.005	“
“	1950	+0.0001	0.00045	0.005	“
2014-21-0128	350	-0.0002	0.00045	0.0055	High, X Noisy
“	1000	-0.0002	0.00045	Too noisy	“
“	1950	-0.0001	0.00047	0.006	“
2014-18-0029	350	~0 XN	0.00032 VN	0.0048 VN	High, Mod
	1000	~0.0002 VN	0.00034	0.0051	High, VNoisy
	1950	0.0003	0.00046	0.0052 XN	“
2014-18-0042	350	0.0002	0.00041	~0.005 VN	High, XNoisy
	1000	0.00004 VN	0.00041	~0.005 XN	“
	1950	0.0002	0.00044	0.0053	“
2014-18-0045	350	0.0003	0.00043	0.0048	High, XNoisy
	1000	~0N	0.00042 N	0.0053	“
	1950	0.0003	0.00044	0.0052 N	“
	3500	0.0002	0.00045	0.0052	“
2014-18-0068	350	0.0003	0.00042	0.0047	High, Noisy
	1000	0.0001	0.00045	0.0053	“
	1950	0.0002 VN	0.00045	0.0054	“

There is no obvious drift in temperature or conductivity differences, but there is a slight increase in differences between the 2 salinity channels.

11. Conversion to IOS Headers

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.

12. Checking Headers

The header check was run. No problems were found though there is at least one cast (#39) with a very high descent rate. A plot was made of that cast and there were just a few incidences of high values and the resultant high deceleration rates. There could be a problem with salinity data if such high deceleration rates are common.

The surface check gave an average value of 2.8db. The corresponding salinity values mostly look reasonable but a few cases with very low values were investigated. One was in Haro Strait and is reasonable for that area and the other reflected a spike with most of the file containing data well within the local climatology.

The cross-reference check was compared with the log book and the only discrepancy was one latitude entry, but it looks like the log is wrong, since the start position differs from the bottom and end readings. No change was made to the header.

The altimeter, maximum pressure and water depth were exported from the headers of the CLN and MRG files to spreadsheets.

Plots were made to examine the altimetry at the bottom and all header entries look reasonable except for cast #74 which had an entry based on only spikes; that cast did not get close to the bottom so the entry was removed from the header. There were 2 cases where the CTD did get close to the bottom, but there was only near-surface sampling. In those cases the altimetry header was removed from the MRG files since it suggests that the bottle sampling is near the bottom.

There were some discrepancies in water depths between log entries and header entries in both the CLN and MRG files. Where the differences were only a few metres they were left unchanged, but larger differences were investigated by examining the maximum pressure and altimetry trace and looking at the historic value for the station. Generally, the header entries look fine, but in 3 cases the log looks more reasonable, so the header was changed and depth was added to one file where there was no entry.

The cruise track was plotted and added to the end of this report. No problems were found.

13. Shift

Fluorescence

Normally a shift of +24 records is used to align SeaPoint fluorescence with temperature. Tests were run to see if that setting improves the alignment and it does.
SHIFT was run on all casts to advance the SeaPoint fluorescence by +24 records.

Conductivity

Tests were run on a few casts using a variety of settings to see which shift produces reasonably stable T-S plots. Because the data are heavily corrupted by shed wakes it is difficult to judge what is noise that alignment SHOULD remove and what is not. Tests were run on 3 casts with a variety of settings. The best results were with a setting of -0.5records for the primary, which is the same as used for 2014-21. For the secondary settings of +1.3 records looks best for some features and +1.5 records for others, so +1.4 was chosen. For 2014-21 the setting used was +1.3 records.
Two runs of SHIFT were used to apply advance the primary by -0.5 records and the secondary by +1.4 records.

Dissolved Oxygen

The Dissolved Oxygen voltage channel was aligned earlier. A few casts were checked to see if further alignment is needed for the DO concentration channel. The alignment looks as good as we are likely to achieve.

14. 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: None

15. Other Comparisons

Previous experience with these sensors – All sensors were recalibrated in late December 2013 or January 2014 and were used for 5 other cruises before this one in near-shore waters.

1. Salinity:

The difference between the sensor pairs was 0.004 during the first use after the factory visit and it has grown slowly since then. From the earlier cruises it appeared that the secondary salinity was closer to the bottles and the primary salinity appears to be low. However, the sampling was shallow and conditions were such that poor flushing of Niskin bottles is suspected to have led to bottle contents coming from lower in the water column than the level of the CTD sensors. For 2014-21 which immediately preceded this cruise the primary salinity was found to be very close to the bottles and the secondary high by ~0.0052. Analysis was done very promptly and incomplete flushing of bottles was not thought to be a major problem for 2014-21so the results of the bottle comparisons are likely more trustworthy than earlier ones.

2. Dissolved Oxygen

The earlier cruises included 2 with too few bottles to enable a reasonable comparison and many bottles close to the bottom which are not reliable. Of the 3 that did provide enough bottles 2 produced results that were very unusual with large offsets in the fit of differences against CTD DO, but fairly low slopes. This may be related to fairly shallow sampling, and the very quiet conditions under which the samples were gathered may reduce the efficiency with which the Niskin bottles were flushed. Cruise 2014-21 was an off-shore cruise with some deep sampling and the fit has a small offset and larger slope. The fits for the 3 cruises before this one were:

DOX_BOT = 1.0286 * DOX_CTD + 0.0772 (2014-06)
DOX_BOT = 1.0325 * DOX_CTD + 0.1019 (2014-15)
DOX_BOT = 1.0400 * DOX_CTD - 0.0259 (2014-21)

3. Pressure

The factory calibration has been found satisfactory for the 5 previous cruises.

<u>Historic ranges</u> – Profile plots were made with 3-standard deviation climatology ranges of T and S superimposed. These are not appropriate for the casts closest to shore. The only excursions were some low temperatures at P16 around 175-300db and low salinity at the surface in Haro Strait and at P15 around 150-250db. P16 is an area of great variability and where the temperature is below the climatology minimum the salinity is also close to the minimum. This suggests an intrusion of fresh, cooler water from the Gulf of Alaska. On T-S plots these features are stable. Given the outliers are not systematic, these are not consdiered indicative of calibration problems.

<u>Repeat Casts</u> –

There were some repeat casts. At P26 three deep casts (separated by up to 19 hours) were compared and the variability in the temperature was ~1500db was 0.002C° and salinity varied by ~0.0005. This is good repeatability

<u>Post-Cruise Calibration</u>

There were no post-cruise calibrations available.

16. DETAILED EDITING

The first issue is to decide which sensor pair to edit. There is not a lot of difference, but the primary data are slightly noisier and the secondary have been selected for the 5 previous cruises using these sensors. So the secondary pair was chosen for editing.

CTDEDIT was used to remove spikes that appear to be due to instrumental problems and likely to affect the bin-averaged values and records corrupted by shed wakes including some surface records. Editing was heaviest for events 39 to 53 (P14 to first cast at P20) during which the descent rate was extremely noisy.

As noted on other recent Tully cruises, there were some odd excursions in salinity that do not appear to be related to shed wake corruption or stray spikes. These unstable features look like they are caused by misalignment of temperature and conductivity, possibly related to high deceleration rates of the CTD.

This was not as serious a problem as seen during 2014-01 when the descent rate was extraordinarily noisy. The maximum descent rates were not nearly as high as during the winter cruise. Where it is clear that the temperature points are ok, only salinity points were removed.

A problem was encountered during editing of a few files, so frequent saves were done.
All ED1, ED2 and ED5 files were copied to EDT.

T-S plots were examined and a little more editing was applied to 2 casts.

17. Initial Recalibration

The pressure does not need recalibration.

The secondary salinity will be recalibrated by subtracting 0.0053 to make it match the primary salinity as discussed in section 4.

Sal1 Corrected = Sal1 - 0.0053

Based on the bottle comparison described in section 4 the dissolved oxygen channel was recalibrated using the fit:

DOX_BOT = 1.0417 * DOX_CTD +0.0289

File 2014-18-recal1.ccf was prepared to apply the corrections to dissolved oxygen and secondary salinity. CALIBRATE was run on the MRGCLN2, SAM and EDT files using that file.

COMPARE was rerun to check that the corrections were done correctly and they were. The average difference after removing a few outliers shows the CTD DO to be low by an average of 0.003, but the standard deviation is 0.03mL/L. The fit looks best at higher CTD DO values, with slightly high values at the low end of the DO range. However, the scatter suggests this is as good a fit as we can achieve. The salinity difference between primary and secondary salinity was ~0.0003 after recalibration. (See files 2014-18-dox-comp2.xls and 2014-18-sal-comp2.xlsx.)

18. Final Calibration of DO

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

COMPARE was run again. When the differences were plotted against DO concentration, the fit had a lot of scatter but looked reasonable. When a few outliers were removed the SBE DO was high by an average of 0.0002L/L but the standard deviation of 0.08mL/L. SBE values were a little high at the high end of the DO range and a little low at the low end. When points from below 1300db are displayed in red it is clear that deep CTD DO values are mostly a little lower while above that they are mostly a little high. This makes sense if there is any incomplete flushing of Niskin bottles, the effect would be in the opposite direction above and below the DO minimum which is around 800-1000db. Near the DO minimum the DO gradients are very low so flushing is not critical, and below 3000db it is fairly low as well. Low values between 1300 and 3000db is not a sign of hysteresis, but a measure of errors due to flushing. Given the uncertainty in whether errors are due to calibration drift or incomplete flushing and the large scatter in the comparisons, no further recalibration is justified.

A plot of differences against pressure was used to make a final study of outliers and to make a rough estimate of the accuracy of downcast CTD dissolved oxygen.

19. **Special Fluorometer Processing**

A median filter, fixed size=11, was applied to reduce spikiness in the fluorescence channel. A few casts were examined before and after this step and showed that the filter was effective.

20. **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.
After averaging, page plots were examined on screen and no further editing was considered appropriate.

21. **Final CTD File Steps (REMOVE and HEADEDIT)**

Cast lists of events with and without PAR sensor were prepared.

REMOVE was run on all casts with a PAR sensor mounted to remove the following channels:

    Scan_Number, Temperature:Primary, Salinity:T0:C0, Conductivity:Primary, Conductivity:Secondary, Oxygen:Voltage:SBE, Fluorescence:URU:Seapoint, Altimeter, Status:Pump, Descent_Rate and Flag

REMOVE was run on all casts with no PAR sensor mounted to remove the following channels:

    Scan_Number, Temperature:Primary, Salinity:T0:C0, Conductivity:Primary, Conductivity:Secondary, Oxygen:Voltage:SBE, Fluorescence:URU:Seapoint, Altimeter, PAR, Status:Pump, Descent_Rate and Flag

Profile and T-S plots were produced at this point to check for errors. No problems were found.

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, to add “Mid-ship” to the instrument location section and to add the following comments:

Data Processing Notes:

Transmissivity, Fluorescence and PAR data are nominal and unedited except that some records were removed in editing temperature and salinity.

For details on how the transmissivity calibration parameters were calculated see the document in folder "\cruise_data\documents\transmissivity".

Dissolved oxygen was calibrated using the method described in SeaBird Application Note #64-2, June 2012 revision, except that a small offset in the fit was allowed.

The Oxygen:Dissolved:SBE data are considered, very roughly, to be:
±0.8mL/L from 0db to 50db
±0.6mL/L from 50db to 100db
±0.2mL/L from 100db to 250db
±0.15mL/L from 250db to 800db
±0.04mL/L below 800db

The secondary CTD salinity channel was recalibrated to make it match the primary salinity which appears to have the more accurate values.

For details on the processing see the report: 2014-18_Processing_Report.doc.

The cross-reference list was produced and no problems were found.
The Standards Check routine was run and no problems were found.
The Header Check was run and no problems were found.
The final files were named CTD.

Profile plots were made and look ok.
The track plot looks ok.
The sensor history files were updated.

22. Dissolved Oxygen Study

As a final check of dissolved oxygen data, % saturation was calculated and plotted. The near-surface values were ~90% in Juan de Fuca Straits and varied from 120% to 140% at stations P1 to P5 with the highest values at P4. From P5 to P26 surface saturation values were between 104% and 107%. These look like reasonable values for June.

24. Final Bottle Files

The MRGCOR1 files were put through SORT to order on increasing pressure.

REMOVE was run on all casts with a PAR sensor mounted to remove the following channels:
Scan_Number, Temperature:Primary, Salinity:T0:C0, Conductivity:Primary, Conductivity:Secondary, Oxygen:Voltage:SBE, Fluorescence:URU:Seapoint, Altimeter, Status:Pump, Descent_Rate and Flag
REMOVE was run on all casts with no PAR sensor mounted to remove the following channels:
Scan_Number, Temperature:Primary, Salinity:T0:C0, Conductivity:Primary, Conductivity:Secondary, Oxygen:Voltage:SBE, Fluorescence:URU:Seapoint, Altimeter, PAR, Status:Pump, Descent_Rate and Flag

A second SBE DO channel was added with different units and REORDER to get the 2 SBE DO channels together.

HEADER EDIT was run to fix formats and units, fix a few headers, change the channel name Bottle_Number to Bottle:Firing_Sequence and the name Bottle:Position to Bottle_Number and to add a comment about quality flags and analysis methods and a few notes about the CTD data.

For a final check the CHE bottle data were exported to a spreadsheet and compared with the rosette log sheets. No further problems were found.

A header check was run and no errors were found.

Plots were made of CTD Salinity versus SBE Dissolved Oxygen and bottle DO and no further outliers were identified.

Standards check was run on all files and no problems were found.
A cross-reference list turned up no errors.

The track plot was produced on screen and no errors were found.

25. Thermosalinograph Data

There were loop nutrients, extracted chlorophyll and salinity samples taken, some while stopped and some while underway.

a.) Checking calibrations

The configuration files for the 7 casts are identical. One file was renamed as 2014-18-tsg.xmlcon. No errors were found in the calibration parameters.

b.) Conversion of Files

The 7 files were converted to CNV files using configuration file 2014-18-tsg.con. They were then converted to IOS HEADER format.
CLEAN was run to add End times and Longitude and Latitude minima and maxima to the headers.
ADD TIME CHANNEL was used to add Time and Date channels.

Time-series plots were produced. The flow rate was about 0.9 and very steady throughout. The traces look good except for the salinity which is very noisy with one-sided spikes of size 0.5 to 5 salinity units. Filtering salinity will not be useful. There are some sudden improvements in the spikes that do not coincide with file changes. The smallest spikes are always present but vary from occurring every few minutes to every few hours. In some parts of the record editing should be practical, in others there is both too much noise, and while you can pick out a basic signal from the noise, the salinity looks lower than in the sections with few spikes.

The track plot looks fine. The plot was added to the end of this report.

c.) 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 4db and exported to a spreadsheet which was saved as 2014-18-ctd-tsg-comp.xls. There were 49 casts which overlapped with TSG files but for 2 of them there was no good data from ~4db. There were no CTD casts that overlapped with the last 2 TSG files from the homeward journey.

The first 5 TSG files were opened in EXCEL, median and standard deviations (over 5 records) were calculated for intake temperature, salinity and fluorescence and the files were reduced to the times of CTD files and loop samples. The median difference between intake temperature and lab temperature during a quiet section of the first file was 0.22C°.

To check for problems in the TSG clock or bad matches of TSG and CTD data, the differences between latitudes and longitudes were found. The differences in latitude and longitude were all≤0.00035°. This shows both the times and positions are reliable for both systems.

The loop samples were combined in file 2014-18-loop-tsg-rosette-comp.xlsx. Then 5m rosette salinity and CHL bottle data were added from 5 casts which occurred at the same time as loop sampling; there was 5m CHL sampling from 2 bottles at some casts.

The two spreadsheets will be used in step (d) to compare temperature, salinity and fluorescence.

d.) Comparison of T, S and Fl from Loop & Rosette Samples and TSG and CTD data

- <u>T1 vs T2</u> The intake temperature worked throughout the cruise. The differences between the intake and lab temperatures during CTD casts ranged from 0.12 and 0.28C°, with a median value of 0.21C°. As usual, the heating in the loop increases as the intake temperature decreases.
- <u>TSG vs CTD</u> The spreadsheet comparing CTD and TSG files was then examined to find the differences between the salinity, fluorescence and temperature channels for the CTD and the TSG.
  1. *Intake Temperature* The intake temperature is higher than the CTD temperature by an average of 0.029 but the median difference is only 0.006C°. A plot of differences versus the standard deviation in the TSG intake temperature makes it clear that there were large outliers when TSG variability was high. The median value suggests that the TSG intake temperature is as close to the CTD as we can possibly expect. When only casts with well-mixed surface waters are included, the median difference is only 0.003C°.
  2. *LAB TEMP* The lab temperature was higher than the CTD temperature by from 0.15 C° to 0.83 C° and a median of 0.22C°. The results were the same when using only the well-mixed casts.
  3. *SALINITY* The TSG salinity data are lower than the CTD salinity by from 0.02 to 0.68 and a median of 0.014. Using the median of the well-mixed casts, the CTD is low by 0.09. A plot of these differences versus standard deviation in the TSG salinity does not have the pattern found in temperature differences – there are outliers even when it is low. The noise in the TSG salinity is very high with almost all spikes towards low salinity values. For these data the minimum difference is probably a better measure of calibration errors than the median or average.
  4. *FLUORESCENCE* The TSG fluorescence was 1.13 times higher, on average, than the CTD fluorescence with a range of 0.8 to 2.6 and a median ratio of 1.0. The ratio is close to 1 for all readings >5ug/L. There are a number of cases of the TSG reading significantly higher than the CTD (ratio 1.5 to 2.5) at low fluorescence levels, but no cases of the CTD being much higher than the TSG. The correspondence is as good as we can expect. The well-mixed casts have a higher median ratio but those casts were well offshore where CHL is low.

  (See 2014-18-ctd-tsg-comp.xls.)
- <u>Loop Bottle - TSG Comparisons</u>

  The TSG salinity was found to be lower than the loop samples by from 0.02 to -3.7. When 3 obvious outliers are excluded, the median difference was ~0.03. Two of those outliers come from Juan de Fuca Strait. The TSG salinity does not show a lot of variability and the loop salinity at JF1 and JF3 looks about what is expected at 5m based on rosette samples from two casts at station JF2. The noise in the salinity trace looks one-sided and may be due to bubbles, making the TSG look lower than it really is. The traces started to look better on June 18th and it is noticeable that the differences are also notably lower from that time onwards. There are still one-sided spikes in the salinity, but not as many large ones.

  The TSG fluorescence is higher than the loop extracted chlorophyll by a median factor of ~2.6, or ~2.2 if one outlier is excluded. As is usually the case, the TSG fluorescence reads too high at low CHL values. For CHL>5 the ratio of TSG / loop was 0.47, 0.77, 0.37 and 0.98, with the 0.98 ratio coming from the highest CHL value.

  An attempt to compare differences while stopped with those while moving failed because there was only one point of comparison for salinity while stopped and the effect of variable CHL drowned out any useful signal from the fluorescence comparison.

  (See 2014-185-loop-tsg-rosette-comp.xlsx.)
- <u>Surface rosette vs TSG (salinity and chlorophyll)</u>

  There are 4 cases where we have both rosette CHL loop CHL samples, and in 3 cases there were 2 rosette bottles from a single cast. The two values are close, with the loop CHL being a little lower, on average.

There are only 2 rosette salinity samples to match loop salinity samples. In one case the loop is lower by 0.022 and in the other it is higher by 0.006.

- Calibration History
  The TSG temperature and conductivity were recalibrated in December 2013 and this appears to be the second use since then. During 2014-21 the TSG salinity was found to be lower than loop samples and CTD salinity by ~0.03 but the difference varied with flow rate which was highly variable. No recalibration was applied due to the variability in the comparisons and the fact that such a large drift in calibration on its first use seemed unlikely.
  The fluorometer was used during 2013-18 and 2014-21. The TSG fluorometer was about 1.1 to 1.2 times the SeaBird fluorometer on the CTD when the flow rate was >1 during the first of those cruises and very close to the CTD fluorometer on the second. During 2014-21 the TSG fluorometer was ~79% of the loop CHL and 65% of the rosette CHL samples.

Conclusions

1. The TSG clock worked well.
2. The TSG flow rate was very steady at about 0.9 with just a short drop-out during the first file.
3. The temperature in the loop increases by about 0.22Cº between the intake and lab based on comparisons during stops for CTD casts. The heating in the loop varies according to intake temperature.
4. The TSG intake temperature appears to be higher than the CTD temperature by ~0.006Cº when outliers are excluded, but there is a lot of variability in that comparison. Using only the casts with well-mixed surface waters the median difference is only ~0.003Cº No recalibration is not justified.
5. The TSG Salinity is lower than the CTD salinity by a median of ~0.014 or ~0.09 using the well-mixed casts only. The TSG salinity is lower than loop samples by a median value of 0.03 when 3 outliers are excluded. The one-sided noise in the TSG salinity means that it will look low even if the calibration is perfect. No recalibration is justified.
6. The TSG fluorescence is very close to the CTD fluorescence. It is higher than the loop samples and rosette CHL samples when CHL is low, but for higher CHL it was lower than loop values, but was very close for the case with the highest CHL value.
7. The flow rate was very steady, yet the salinity noise was highly variable, so variability in the flow rate is not the primary problem with the TSG system. Bubbles appear to be the issue. The signal improved towards the end of the cruise though there were still some large spikes and many small ones. This is notably different from the performance on the previous cruise, 2014-21, when the signal looked good.

f.) Editing

The ATC files were copied to *.EDT.
Each file was opened in CTDEDIT and the following editing was applied:

File #1 – Data were removed where flow was zero.
File #2 – 1 salinity point was removed.
Files #3-7 –Some isolated single-point spikes in salinity were removed.

g.) Recalibration

The salinity was found to be lower than loop and CTD salinity, but the comparison more likely is due to noise in the TSG salinity with many spikes to low values, rather than calibration drift.
No recalibration was applied.

h.) Preparing Final Files

REMOVE was used to remove the following channels from all casts: Scan Number, Temperature:Difference, Conductivity:Primary, Flag and Position:New channels.
The flow channel was not removed since it may be useful for further studies of optimal flow rate.

HEADER EDIT was used to add a comment, change the DATA TYPE to THERMOSALINOGRAPH and add the depth of sampling to the header and to change channel names to standard names and formats. The salinity format was changed from F9.4 to F9.2 to draw attention to the reduced quality of the data due to the very noisy signal.
Those files were saved as TOB files.
The TSG sensor history was updated.

As a final check plots were made of the cruise track and it looks fine.
The cruise plot was added to the end of this report.

26. Producing final files
A cross-reference listing was produced for CTD and CHE files.
The sensor history was updated.

27. Loop File
An initial surface & loop file was prepared with rosette samples and all loop samples.
The CHE files were put through DERIVE to calculate sigma-t. They were then exported to a spreadsheet and sorted on pressure. (2014-18-loop-che.csv) The loop sample data prepared for the TSG processing were added to the file and lined up appropriately with the CHE data. The data were then ordered on time. The sampling method column was added entered ROS or UWS for rosette data and true loop data, respectively.
Comments were added as required; for each flag other than 6, the files were checked for the relevant comment and those were entered in the 2014-18-loop-che.csv file.
A 6-line header was added and the original header was removed.
The file break column was filled with value 1 so all data will be in a single file when converted.
The file was then saved as 2014-18-surface-6linehdr.csv.

CONVERT was run to get an IOS Header file, followed by CLEAN to get start and stop times and positions.

Header Edit was used to add general comments from the CHE files. Comments were added concerning flags on samples from Niskin bottles. The flags from the loop samples were entered automatically in the conversion process.
The final file was named 2014-18-surface.loop. A track plot looks reasonable and a plot of temperature and salinity versus longitude looks reasonable.

<u>Particulars</u>
PAR ON: 1-13, 19-20, 36-38, 41-43, 56-72, 80-81.
PAR OFF: 16-18, 21-35, 39, 45-53, 74-78, 83.

1. Split cast logged as 1 and 2. Combined.
3. Logged as 3. Should have been named 4. Fixed.
13. Bottle 9 tripped early.
28. Thousands of Velellas, water surface looks green and sunfish; big diff between salinities in top 100m
29. Few velellas
34. Lots of velella in water

38. Niskin 19 fired in error – no sampling.
43. Syringes had been on.

Institute of Ocean Sciences
CRUISE SUMMARY
CTDs

CTD#	Make	Model	Serial#	Used with Rosette?	CTD Calibration Sheet Competed?
1	SEABIRD	911+	0585	Yes	Yes

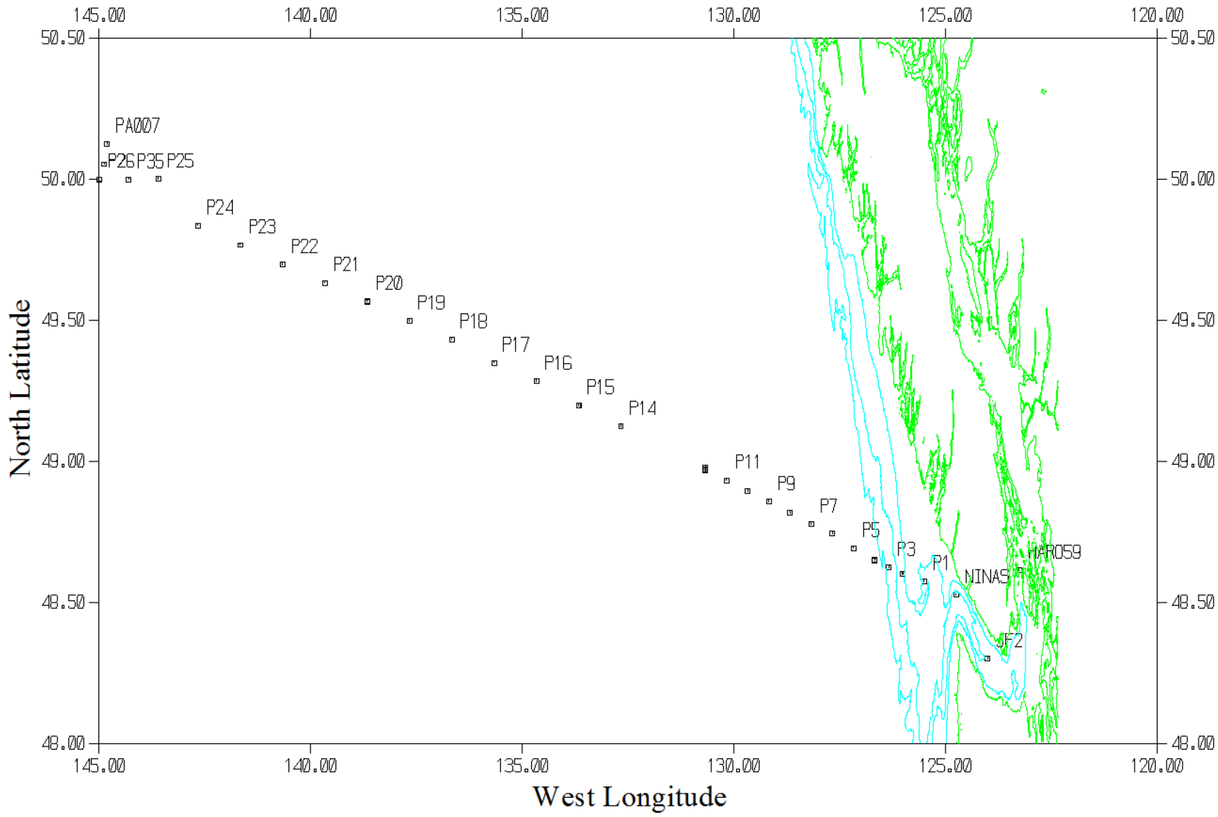
Calibration Information					
Sensor		Pre-Cruise		Post Cruise	
Name	S/N	Date	Location	Date	Location
Temperature	4054	31Dec2013	Factory		
Conductivity	1766	1Jan2014	Factory		
Secondary Temp.	4700	4Jan2014	Factory		
Secondary Cond.	3321	3Jan2014	Factory		
Transmissometer	1396DR	5Feb2014	IOS		
SBE 43 DO sensor	1119	21Jan2014	Factory		
PAR	4615	16Mar2011	IOS		
SeaPoint Fluor	3642	Jan. 2014			
Pressure Sensor	77511	30Dec2013	Factory		
Altimeter	1204	n/a			

TSG

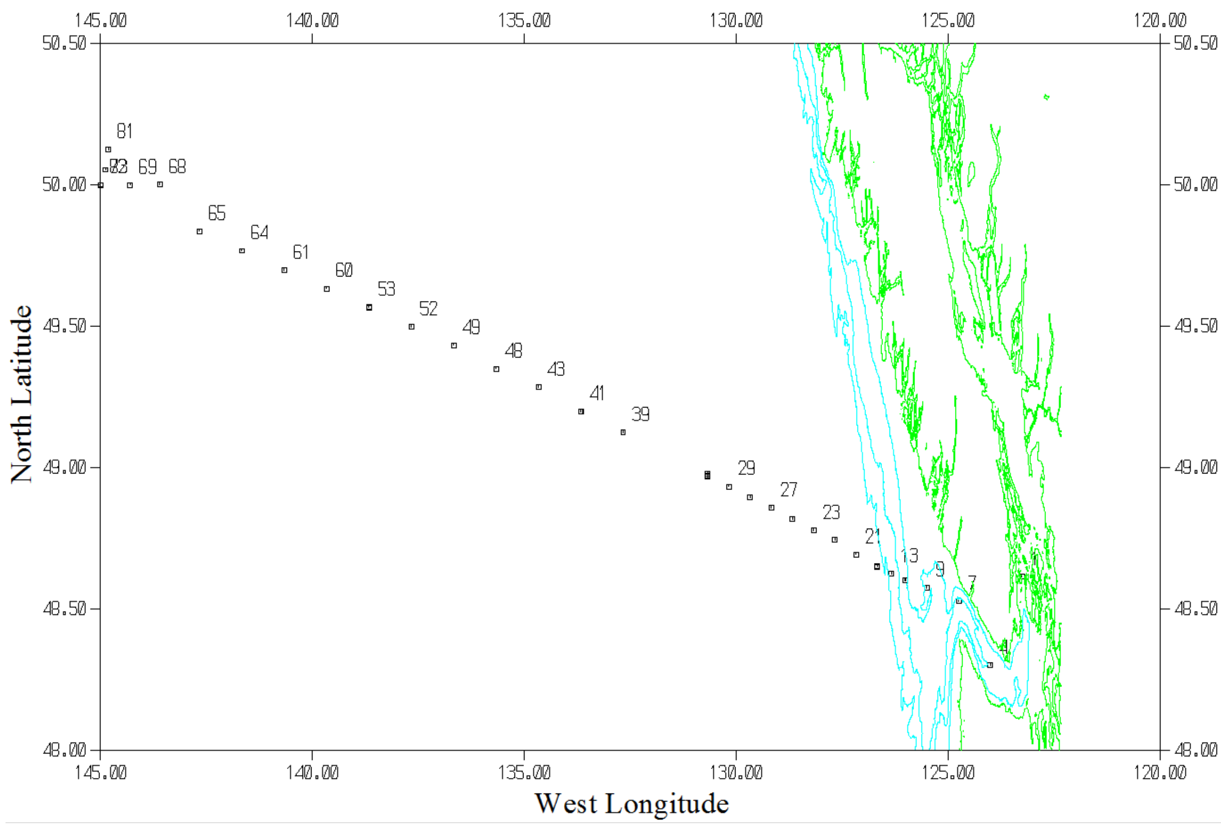
Make/Model/Serial#: SEABIRD/21/2487 Cruise ID#: 2014-21

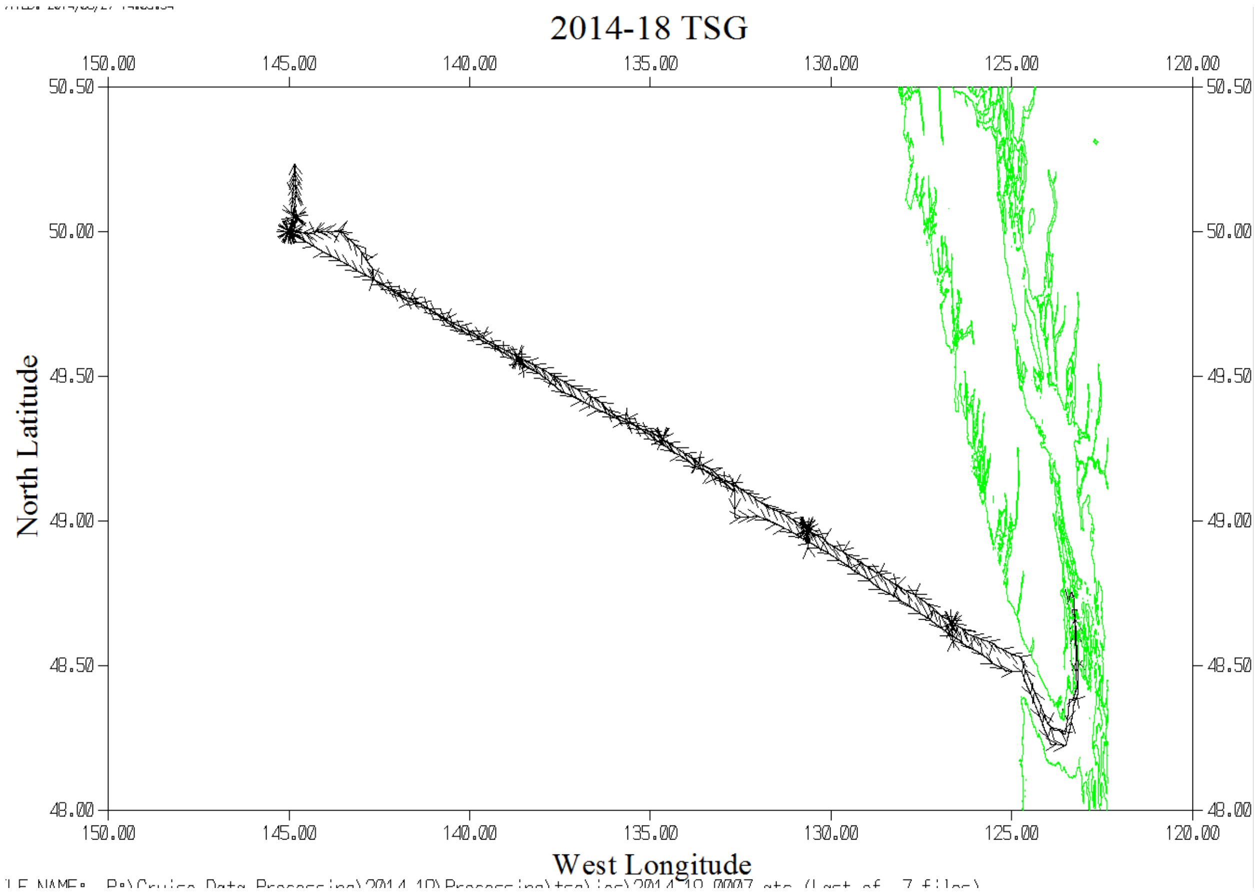
Calibration Information					
Sensor		Pre-Cruise		Post Cruise	
Name	S/N	Date	Location	Date	Location
Temperature	3363	28Mar13	Factory		
Conductivity	3363	28Mar13	“		
Wetlab/Wetstar FL	WS3S-713P	Aug12	IOS		
Temperature:Secondary	0603	7Mar12	“		
Flow meter	?	n/a			

2014-18 Stn Names



2014-18 Event #s




2014-18 TSG
150.00
145.00
140.00
135.00
130.00
125.00
120.00
50.50
50.00
49.50
49.00
48.50
48.00
North Latitude
West Longitude