REVISION NOTICE TABLE

DATE	DESCRIPTION OF REVISION
8 January 2010	Corrections to Dissolved Oxygen data in CHE files and 2009-03-oxygen-duplicates.xls. See end of report, after Particulars Section, for details.
2 July 2010	Correction to Instrument Serial # for CHE files from #46 to 60
16 July 2010	PAR added to CHE file for cast #37 and CTD files for #37, 42 & 44
2 September 2010	Transmissivity was corrected. See end of report for details.
8 July 2013	Corrections to Nitrate and Phosphate data; see headers for details.
16 October 2013	Pad values entered for some obviously bad data and comments adjusted for CHE files - events #27, 31, 34 and 38.

PROCESSING NOTES

Cruise: 2009-03
Agency: OSD
Location: North-East Pacific
Project: Line P
Party Chief: Robert M.
Platform: John P. Tully
Date: January 27, 2009 – February 10, 2009

Processed by: Germaine Gatien
Date of Processing: 8 February 2009 – 3 July 2009

Number of original CTD casts:	44	Number of CTD casts processed: 42 (1 aborted/1 upcast only)
Number of bottle casts:	41	Number of bottle casts processed: 41
Number of original TSG files:	2	Number of TSG files processed: 2

INSTRUMENT SUMMARY

Two SeaBird Model SBE 911+ CTDs (#0443 and 0550) were used during this cruise. Both were mounted in rosettes and attached were a Wetlabs CSTAR transmissometer (#1005DR), an SBE 43 DO sensor (#0997/#1119), a Seapoint Fluorometer (#2228/#2356) with a 10X cable (DO and FL both on the primary pump), a Biospherical QSP-400 PAR sensor (#4615) and an altimeter (#1252). The deck unit was a model 911+ (#0424) and the logging computer was an HP Compaq. Seasave v7 was used.

A thermosalinograph (SeaBird 21 S/N 2487) was mounted with a Wetlab/Wetstar fluorometer (WS3S-713P) and a flow meter; temperature sensor #2416 was mounted at the intake but not hooked up.

SUMMARY OF QUALITY AND CONCERNS

The CTD and rosette logs were generally in good order, but it appears that the equipment list for the 2nd CTD has serious errors in it. Notes from the chief scientist were very helpful.

There were two serious equipment problems involving CTD #0443. For casts #15 through 38, the primary temperature and conductivity were bad below 1400db and the dissolved oxygen data were very noisy. (Cast #15 was the first cast that got as deep as 1400db.) That problem cleared up when two cables were replaced. The CTD was changed before cast #46 because of a failure in the primary conductivity during casts #44 and poor performance for casts #42 and #44. The secondary channels look fine.

While the dissolved oxygen data from casts #15 – 38 is noisy below 1400db and the calibration is not as reliable there, it was decided to archive the data, but it should be kept in mind that the errors are larger than usual at those depths. For casts #42 and 44 the dissolved oxygen data were removed.

Sea-Bird have a new algorithm for dissolved oxygen with several parameters that need fine-tuning for each instrument to produce the best data. This requires bottle samples from deep casts. When a new sensor is bought it would be useful if it be deployed on a cruise with at least one cast that goes below the DO minimum, with lots of DO bottle samples from all depths. Line P is perfect for this, but unfortunately this cruise was pressed for time and no DO sampling was done while one of the sensors was in use and the other SBE DO sensor was not performing well for all but one of the deep casts. Fine-tuning of the parameters for the other sensors could not be done, so nominal values were used.

The results of the dissolved oxygen titrations were sent as ADD files with an error in formatting that was difficult to fix; it required that the flag channel be removed and added again. Formatting errors are common in ADD files; this issue could be addressed by sending the data in spreadsheet format (with flag and comment columns), thus leaving the preparation of ADD files as part of the processing job. The spreadsheet would be archived so information about the details such as flask numbers would be available there.

The bottle Dissolved Oxygen values did not agree with the values on the rosette sheets because a correction had been applied. This correction was not noted in the headers of the ADD files, nor was there a prominent note about it anywhere. The answer was buried in a 3rd hand e-mail, but could easily have been missed. This break in the "chain of evidence" for data handling threatens data quality for dissolved oxygen. Given the numerous analysts involved, it is critical to have some sort of report among the cruise documents to explain if corrections are applied. The notes on the rosette sheet are usually very helpful.

The dissolved oxygen data in the CTD files for casts #1 to 44 (sensor #0997) were recalibrated in two steps. The first correction was applied to data from above 1400db and to all of cast #40. The second was applied to data below 1400db from casts #15-38. Data below 1400db are considered less reliable both because the second correction is a rough estimate and because it was impossible to fine-tune the configuration parameters to get the best possible deep data, so there may be some hysteresis. The DO data should be considered:

- ±0.4ml/l from 0- 200db
- ±0.1ml/l below 200- 500db
- ±0.04ml/l from 500-1500db
- ±0.1ml/l below 1500db

The Tau correction in the derivation of dissolved oxygen concentration is known to exaggerate residual noise in deep water. It is possible that deep data could be improved by processing it without that correction, but that would affect data in regions of large oxygen gradients where the Tau correction improves the response. Since there are clearly problems with the deep data due to temperature signal problems, it is thought best to do the correction that best suits shallower DO data.

There were no bottle samples available to recalibrate the dissolved oxygen sensor used for casts #46 to 60. Recalibration was based only on an inter-comparison of repeat casts at station P26, one with sensor #0997 and two with sensor #1119. The casts were separated in time by 4 to 6 hours. Temporal variations were found to be very large between 100 and 700db during repeat casts using a single sensor, so the inter-comparison of sensors was limited to the mixed layer from 0 to 100db and below 700db. This limits the range included in the fit to high and low values. The comparisons in areas of low DO gradients suggests that it performed well. A rough estimate suggests that the data is likely to be within ±0.4ml/l in the top 200db and ±0.1ml/l below that.

The data in file 2009-03-0044.ctd were collected during the upcast, so the quality is considered lower than for other casts.

There was good agreement between the loop salinity and extracted chlorophyll and corresponding surface CTD rosette samples. There has been some concern that freshwater was getting into the loop; while that may have occurred in the past, it clearly did not do so during this cruise.
There are 2 thermosalinograph files. Data acquisition did not begin until the ship was near station P20 of the outward journey. The intake thermistor was not hooked up. Recalibration of temperature by subtracting 0.22C° was based on comparison with CTD data and past experience of ship heating. Salinity was increased by 0.025psu based on post-cruise calibration. Note is made that loop/TSG and CTD/TSG comparisons suggest that the recalibrated salinity may be too low (by ~0.05), but there is too much uncertainty in those studies to justify further recalibration.

PROCESSING SUMMARY

1. **Seasave**

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

2. **Preliminary Steps**

The Log Book and rosette log sheets were obtained as well as a summary from the Chief Scientist of problems and points of interest with reference to processing. A number of problems were noted including header errors.

Extracted chlorophyll, nutrients and DMS data were obtained in spreadsheet format.
There were a variety of spreadsheet files with salinity data.
The titrated dissolved oxygen files were provided in individual ADD files with a flag channel but the format was wrong and numbers were entered in the flag channel. The values differ slightly from those on the rosette sheets.
The cruise summary sheet was completed.
The histories of the conductivity, DO and pressure sensors were obtained.

There were two instrument configurations used during the cruise. The log book and configuration file disagree about which sensors were mounted on CTD #0550. The configuration file will be taken as correct, since that fits the Chief Scientist's memory and Hugh Maclean confirms that the log book must be wrong. Another problem is that the first cast using #0550 was not set to capture NMEA data. So 3 different configuration files are needed as follows:
2009-03-ctd1.con – for CTD #0443: casts #1-44
2009-03-ctd2.con – for CTD #0550 (except cast #46): casts #48-60
2009-03-ctd3.con – file CTD #0550: cast #46

The calibration constants were checked for all instruments. There were a number of problems:

- The calibration information for dissolved oxygen sensor #0997 was not on file. When it was found, it was in the old style without the Murphy-Larson parameters which are called for by the new algorithm for DO concentration. When the new-style calibration sheet was obtained for #0997 from Sea-Bird, it was discovered that there are now 3 more parameters and new software! It is recommended that users establish the ideal values for E, H1 & H3 for each instrument. They are stable, so only need establishing once.
- The configuration for DO #0119 also lacked the Murphy-Larson parameters, so they were added. There was one error in the Owens-Millard parameters for #1119 which was fixed. This is the first use in deep waters since the new algorithm was made available, so we have to do tests for E, H1

and H3. Testing the difference from bottles will not be possible since there were none taken for the casts using this sensor.

- The transmissivity date and parameters are wrong in 2009-03-ctd1.con, so checks were made to see if the serial number might be wrong. The only transmissivity calibrations for that date had different values and no calibration could be found with those values. It will be assumed that this really is 1005DR since it is attached to the rosette itself, so not likely to have been changed when the CTD was changed.
- The pressure offset for CTD #0443 has been drifting, and for other recent cruises a setting of +6.7db has been used, so that was entered for this cruise too. The offset for CTD #0550 was set to +0.5db which was what was last used a year ago.
- A Surface PAR is included in the configuration file, but is not mentioned in the log book and a few casts tested had no signal in that channel, so it will not be converted.

The DO parameters for the configuration files will have to be fine-tuned at the DERIVE stage when dissolved oxygen is calculated. For now, the above CON files will be used to convert the full files. Rosette files will be converted after a decision is made on the DO parameters.

3. Conversion of Raw Data

Data were converted using the configuration files 2009-03-ctd1.con, 2009-03-ctd2.con and 2009-03-ctd3.con for files 1-44, 48-60 and 46, respectively.

A few casts were examined and all expected channels are present.

- The descent rate is extremely noisy for many casts.
- The two temperature channels are in reasonable agreement on the downcast. The upcast data are much noisier so there are significant differences. Spikes in the primary temperature are unusually large during the upcast for both CTDs. Could this be caused by having both dissolved oxygen and fluorescence connected to the primary pump affecting its efficiency? Conductivity is similar.
- The fluorescence looks a little spiky but ok.
- Dissolved oxygen voltage looks odd at depth for one cast, ok for another.
- PAR looks strange for cast #60, but according to the chief scientist it was not mounted for that cast. There are zero values throughout the downcast, just some small but non-zero values near the surface on the upcast. The channel will be removed from this cast later.
- Transmissivity traces contain many spikes but the worst seem to be in the upcast. The values in deep water are high, as expected, and there is no obvious hysteresis.
- The altimetry looks useful for some casts, but others look extremely noisy; all casts will have to be checked carefully to ensure header entries are reasonable.

Rosette files were converted using a start time of -5s and duration of 10s and bottom depths were corrected in 2 casts. The rosette files were then converted to IOS SHELL files. The event numbers were present so CLEAN was not run, but the IOS files were renamed as *.BOT. (NOTE: Late in the processing it was discovered that PAR had not been converted for the bottle files of casts 1-44, so the process was rerun with PAR selected just for those casts that actually had a PAR mounted (#1-8, 30-31, 33-34, 42 and 44). For that reason PAR will need to be removed only from bottle files #46-60 at the end of processing.)

All BOT files were plotted. There were no outliers that required editing, but the primary salinity looks very bad for casts 40 and 44.

At this stage tests were run to determine the optimal parameters E, H1 and H3 for running the new algorithm for reducing hysteresis in the calculation of DO concentration. Once determined, these are expected to be stable, but the tests have not been done for these two sensors, #0997 and #1119. Line P would normally be a good opportunity for determining these parameters because it has deep sampling where hysteresis is a problem. However, a quick check showed that the noise in the primary temperature data at depth has also made the dissolved oxygen data extremely noisy for sensor #0997. The vertical offsets in both temperature and dissolved oxygen traces are roughly the same, suggesting hysteresis is not a major problem using the nominal parameters. But the primary temperature of the downcast is offset by about 70db from the upcast below 800db. It looks much better above that. The secondary temperature has lots of evidence of shed wake corruption, but the upcast is much closer to the downcast than it is for the primary sensor. It looks like the primary pump was not working properly at least at great depth. So testing of the dissolved oxygen sensor #0997 is pointless since deep data are needed to do it.

The nominal values from the factory will be used.

For CTD #0550, there are no bottle DO data to enable the tests to be run, so nominal values will be used. One deep cast was studied in detail and it looks like the algorithm has worked quite well. The upcast and downcast traces are offset by about 0.06ml/l at 1800db. Some of that will be real due to internal waves since the temperature is also offset a little. It looks as though aligning the DO data will account for ~0.04ml/l based on the offset between the arrival of shed wake corruption in the temperature trace and in the oxygen trace.

4. WILDEDIT

Program WILDEDIT was run to remove spikes from the pressure, conductivity and temperature channels only. Parameters used were: Pass 1 Std Dev = 2 Pass 2 Std Dev = 5 Points per block = 50
At this point corrections were made to the CNV headers based on the chief scientist's notes.

5. CELLTM

The data are generally too noisy for the CELLTM tests to be clear.

- For CTD 0443 the choices made the last time these sensors were used were ($\alpha = 0.03$, $\beta=7$) for the primary and (0.02, 7) for the secondary. A test was run on the secondary salinity for 1 cast and the previous choice does look best. It is not likely that the primary will be used. So CELLTM was run for casts 1-44 using those values.
- For CTD 0550 the data were far too noisy for a judgment and the sensors have not been used recently or with the same configuration, so that is not very helpful. So CELLTM was run for casts #46-60 using the standard value from the literature ($\alpha = 0.0245$, $\beta=9.5$) for both sensors.

6. 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.

7. 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 are noisy so these are very rough averages. The first three are from CTD #0443 and the last two are from CTD #0550.

Cast #	Press	T1-T0	C1-C0	S1-S0	Descent Rate
9	1200	+0.0003	+0.0006	+0.0067	High, moderate
22	1200	-0.0002	+0.0007	+0.0086	High, X noisy
35	1200 3500	~0 -0.011	+0.0007 +0.00005	+0.009 -0.012	High, X noisy
48	1200	+0.0014	+0.0003	+0.0022	High, X Noisy

	2500	+0.0016	+0.0003	+0.002	
54	1200	+0.0015	+0.0003	+0.0018	High, X Noisy

The most striking observation is that for CTD #0443, the differences change suddenly at about 1400db. This is due to bad primary data. The primary temperature, conductivity and dissolved oxygen are all affected. This could be a problem with the temperature sensor or the pump. The only pumped channel that is not temperature-dependent is the fluorescence which has no signal at that depth. But one indication that the problem is a pump rather than the sensor, is that the differences gradually get smaller between 1400db and the bottom as the temperature gradients gets smaller. If the pump is not operating, or working poorly, this would not have such a great effect at the bottom. The temperature trace has the look of unpumped data, wandering back and forth in a meandering fashion. On the way down the temperature is too high, while on the way up it is too low, also evidence of pump problems. The 1200db differences are small and don't vary a lot. There is no significant pressure dependence above 1400db.

For CTD #0550, there may be a problem with the secondary sensors. The differences overall are small and show no depth or time-dependence, but there are some spikes in the differences that coincide with excursions in the primary traces. These don't seem to be related to shed wake corruption. The excursions look systematic, but the noisy descent rate does make this a difficult judgment.

8. 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 using linear interpolation based on scan number.

9. Checking Headers

The header check was run. The only problem found was that the latitude and longitude were missing from the headers of cast #46. Those were added.
The cross-reference check was compared with the log book, making random checks of times and positions and checking all station names. One station name error was found and corrected.

Cast #29 was aborted and the file contains only a little data from 10db. This cast will not be processed further. Cast #30 is the 2nd attempt.

The cruise track was plotted and added to the end of this report. No problems were found.
The surface values program was run. The average surface pressure is 2.2db for CTD #0443 and 2.8db for CTD #0550. Conditions were often bad during the time the second CTD was used, so it is not surprising that it was not operated as close to the surface. These values look reasonable.

10. BOTTLE FILE PREPARATION

The BOT files were averaged to enable an addsamp file to be created. This file was edited to add sample numbers taken from the rosette sheets. A problem was found for cast #42 – there is a sample number for a bottle that did not fire. And for cast #48 there are two samples with #491 – the second was named #7491 for clarity, but there was no IOS sampling for that one. After those corrections were made to the addsamp.csv file, it was converted to CST files to be used as a framework for the bottle files. The file for cast #48 was rearranged in sample order. It was also used to add sample numbers to the BOT files. The SAM files were then bin-averaged.

SALINITY

File "2009-03 line p.xls" contained all the Autosal data. There were 4 files with Portasal data. Files "2009-09-sal.txt" and "2009-03-casts 24-25-sal.txt" contain the same data, samples analyzed on a

Portasal at sea. There was no standard water available for those analyses. Files “2009-03-PortaSAL1 MR.txt” and “2009-03 line p Portasal.xls” contain the same data, the Portasal analyses done at IOS.

The Autosal data were delivered in spreadsheet format and included duplicates and loop samples in file 2009-03 line p.xls. The duplicates were copied to a separate spreadsheet, 2009-03-salinity-duplicates.xls. The duplicate entries in the spreadsheet were then replaced by average values and flag “f” was entered for those values. The spreadsheet was then simplified, unneeded columns removed, event numbers added and headers changed to standard format. Loop data were copied to file 2009-03-loop-sal.xls and then removed from the main spreadsheet which was saved as 2009-03-sala.csv. A few comments were entered but they just referred to the order of analysis for duplicates, since most were run sequentially, but some were run in 2 sessions. A few errors were found in the data:

- Sample #16/17 – The rosette sheet and autosal analysis logsheet indicate there were duplicates from sample #16, but in the data spreadsheet there are two entries for #17 and no indication that any were duplicates. The values and the order on the Autosal logsheet show that the first “17” should have been a “16” in the spreadsheet. This was changed in 2008-03-sala.csv.
- Sample #353 – there are two values listed for sample #353 but there was no duplicate sampling indicated on the rosette sheet for that one. However, #352 is missing from the spreadsheet. The first value is higher, so is presumed to be the deeper sample, #352.
- Three samples in the spreadsheet are labelled Thorium 1 Drum, Thorium 2 Drum and Thorium 3 Drum and had values 34.5769, 34.5784 and 34.5766. They were removed from the simplified spreadsheet.
- Sample #370, 418 – there are two entries for this but no indication in the rosette log of duplicates being taken. The extra samples were intended to be run on the Portasal, but went astray.

The Portasal data analyzed at IOS were saved as “2009-03-Portasal-ios.csv” and that done at sea as “2009-03-Portasal-sea.csv”. For each set the data needed to be averaged. In the case of the samples run at IOS, the analyst generally entered 2 values even when there were more than 2, rejecting outliers. When 3 are entered, it is assumed all 3 should go into the average. For sample #280 only 1 value was entered, though there are 2 on the analysis sheet; the value in the file will be used. For sample 351 there were 4 values, but the analysis sheet makes it clear the second pair is from a duplicate so the sample number was changed to 9351 for the 2nd pair. Three other duplicate samples were renamed from 879, 897, 959 to format 9279, 9197, 9059; the leading “9” indicates duplicate and the number that follows is the number of the other sample. The values were averaged as detailed above and just the averages were saved – other data were removed from the file. The duplicate for sample #197 was entered on the logsheet as having readings 34.6273 and 34.6773; the analyst noted that he entered both as 34.6273 in the file.

The Portasal data analyzed on board the Tully were harder to deal with. There were many readings and in all but one case the values increase with no sign that they are becoming stable. For a first study of the data all values were included in the average and the individual values were arranged in other columns in the same line; they were all then compared to the CTD data to see if a pattern emerged. On average the Portasal data were much higher than both CTD salinity channels (by ~0.08) with the differences steadily growing through the session. Given there were many bottles from a single level, this is clearly a measure that the analyses are not trustworthy. They were only intended to give researchers information at sea. These data should not be archived. (See 2009-03-Portasal-study.xls.)

The study of duplicates is complex as there are 10 duplicates pairs from the Autosal and 4 duplicate pairs from the Portasal. There are also multiple bottles fired at a single depth for both salinometers and there are 108 cases of 1 sample from a bottle being analyzed on the Autosal and another on the Portasal. Of those, 4 pairs are themselves duplicates, so they were examined separately to see if anything could be learned. Each of these studies is on a separate worksheet of file 2009-03-salinity-duplicates.xls.

Duplicate Studies from a single salinometer

(i) There were 10 pairs of duplicates that were analyzed on the Autosal. Using all Sp=0.0012 where Sp is defined as:

Sp = Square Root (sum of squares of differences / 2*number of pairs)

When 2 outliers (differences >0.007) were removed Sp=0.0008. For comparison, during 2007-26 the results were Sp=0.0017 using 7 pairs, and 0.0005 when one pair was excluded as an outlier. A "c" flag was attached to the two outliers. Two of the duplicate samples were analyzed at different times; while they differ by more than the average, they are not among the 2 major outliers. The average difference of all the data is ~0.0013. (See Worksheet 1 of 2009-03-salinity-duplicates.xls.)

(ii) There were only 4 duplicate samples analyzed on the Portasal and the differences are scattered from 0.0001 to 0.0093. If all pairs are included Sp=0.0033 and if one is excluded Sp=0.0006. This compares with values from 2008-27 of Sp=0.0012 for all data and Sp=0.0005 when 1 outlier was excluded. While this doesn't seem bad the scatter in differences is not encouraging. The average difference is ~0.002 but the standard deviation is ~0.005. (See worksheet 2 of 2009-03-salinity-duplicates.xls)

(iii) Next to be examined were 108 cases for which there was a sample analyzed on each of the Autosal and the Portasal at IOS. When all were included the Sp value was 0.0099 and when 2 outliers were excluded it was 0.003. Removing 2 values that had been flagged did not affect Sp much. The average indicates that the Portasal is higher than the Autosal by 0.0033 with a standard deviation of 0.0026. A closer look was taken at 4 bottles for which there were 2 samples each run on each salinometer. Among the 8 duplicates, 4 had flags because of large differences between the duplicates including sample #351 with both Autosal and Portasal sets flagged. Only sample #59 had no flags and that showed the Portasal to be higher than the Autosal by 0.004. (See worksheet 3 of 2009-03-salinity-duplicates.xls)

(iv) Next, Autosal samples that were drawn from different bottles fired at the same depth were examined. This is the only one of these studies that involved both CTDs, though this should not affect the results. There were a few outliers, including sample #197 which differed from #196 by 0.055. The other 4 cases with 2 bottles each at 2500db differed by 0.0001, 0.004 and 0.0036. Looking then at cases with many more bottles fired at a single depth, the standard deviations (range) were generally low if a few outliers were excluded. Particularly striking were 4 bottles at 10db during cast #49 which varied from 32.5739 to 32.5747, an excellent result. At 2000db during cast #46 the values for the 11 bottles ranged from 34.5815 to 34.5863 with no clear pattern and no obvious outliers. This might suggest that the Autosal salinity is good to ±0.0025; the variation in the CTD data through that period was only 0.0004. (See worksheet 4 of 2009-03-salinity-duplicates.xls)

(v) Finally, Portasal samples were examined in the same way as for (iv). There were only 4 cases to examine and they are the same samples as had duplicates. Sample #197 stands out as very different from #196. The others are within 0.001 of each other. (See worksheet 5 of 2009-03-salinity-duplicates.xls)

Conclusions

On average the study suggests the Autosal performed well enough; this is especially clear from the good repeatability at 5m and reasonably good repeatability for other multiple bottles at a single depth. However, the duplicate study shows that there is a lot of variability. If the Autosal performed well, why don't the duplicates agree better? Looking at the duplicates run on both salinometers shows a lot of variability. Sample #59 shows small differences and does not stand out in any of the comparisons. All the others stand out in one or more of them, with sample #196/197 the most striking. The data were examined closely to see if there was a possibility that sample #s got confused, but there is no evidence of that. The average descent rate was relatively high for the casts with higher differences, so maybe it has something to do with the rough weather. Is it possible that the contents of the Niskin bottles never equilibrated and were stratified? If so, this does not show up in the CTD salinity standard deviation. Another possibility is that the gathering of samples was compromised by the conditions. Another possibility is that the problem is somehow related to CTD #0443. The repeatability looks very good from CTD #0550, but not so good for the few tests of that for CTD#0443, the CTD that was in use for all the duplicate samples taken. This is probably just another suggestion that sea conditions affected the results as it is hard to imagine how changing the CTD could affect these results.

DISSOLVED OXGYEN

Dissolved oxygen files (*.add) were provided. There were many problems:

- The flag channel had the wrong format and flag " 1" was entered for every sample.
- When the rosette sheets are compared with the ADD files there are small differences in all values; an e-mail note was found that mentions that Bernard Minkley applied a correction because the "new program determines the endpoint .002 too soon". I can see no indication of this in the headers. If corrections are applied I recommend a header comment to explain what was done and why. Alternately, a README.DOC file could be left with the raw oxygen files with any information that should be incorporated in the header comments added at the end of processing. The following note was added to the headers of the ADD files:

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All Dissolved Oxygen data were recalculated after the addition of 0.002 to channel Thiosulfate_titer. This was to correct an error found in the oxygen program that detects the end point too soon.

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- For event #1/2 there were duplicates at 125db. There is a note in the header "SAMPLE 9005(DUPLICATE AT 125M) OXYGEN OF .190 TOO LOW, DATA REMOVED." The data were still in the file and it is seems premature to say which of the duplicates is wrong given there is hypoxia in this area. The CTD data from that level have very low DO. So the 2 values were averaged and the original values entered in the headers. A decision can be made later as to which value is better. For now flags "fd" will be entered.
- The sample numbers were incorrect for most of the entries for cast #38.
- For casts #27 and 40 there are no duplicates in the ADD files, but the rosette sheets have two values that were reasonably close and the values were in the OXY files. Estimates were made for the correction to the second samples for #212 and #412 duplicates based on the correction to the first values since they are close. The averages were entered, but the original values were entered in a comment in the header, together with an explanation of how the corrections were done.

File 2009-03-0001.ADD was renamed as 2009-03-0002.ADD since the rosette file for that cast is -0002.

There were duplicates included in the ADD files. The data were copied to file 2009-03-oxygen-duplicates.xls. The original values were replaced with averages and "f" entered in the flag channel except in the case where the analyst mentioned one value was bad. In one other case a "c" flag was applied and a note added giving the original values because they differed by more than 10%. When all data were included Sp=0.047 and without the value rejected by the analyst, it was 0.011. Rejecting the one with 10% differences gives Sp=0.010. This compares well with other cruises (Sp=0.075 for all data and 0.022 excluding a few outliers for 2008-10; Sp=0.085 for all and 0.037 excluding 1 outlier for 2008-27); however, the number of duplicates is lower for this cruise.

There was also 1 pair of bottles fired at a single level during 6 casts. Those were also entered in the duplicate study file. The differences are very large for one of these pairs (not clear which is wrong), but the others are very close, with Sp=0.007.

NUTRIENTS
The nutrient data were obtained in spreadsheet QF2009-03nuts.xls which was simplified and saved as 2009-03nuts.csv. Extraneous columns were removed, header names were changed to standard format and "-99" was entered for blank values. Data were sorted on sample number. File 2009-03-nuts.csv was then converted to individual NUT files.

EXTRACTED CHLOROPHYLL
Extracted chlorophyll data were obtained in file QF2009-03 CHL.xls which included a report on precision. The file was edited to remove extraneous lines and columns, header names were changed to standard format, the file was sorted on sample number, and saved as 2009-03-chl.csv. The analyst noted a mis-trip for Niskin #7, cast #31. The nutrients are also a little off, but there is no salinity or DO sample and the CTD gradients are not huge, so the flag will be left as "c". The simplified spreadsheet file was converted to individual CHL files. There were loop samples which were saved separately as 2009-03 loop-CHL.csv; that included rosette data taken at the same time as the loops.

DMS
DMS data were obtained in file DMS 2009-03 summary.xls. It was saved as 2009-03-dms.csv and edited. All entries "<" were replaced with "0"; a note in the header will explain that the minimum detectable level is 0.1. Where there were duplicates they were averaged to get a single value for each bottle and an f flag was added. Headers were changed to standard format and unnecessary columns were removed. The file was then converted to individual DMS files.

The SAL, CHL, ADD, NUT and DMS files were merged with CST files in five steps. (Output: MRG1, MRG2, MRG3, MRG4 and MRG5), MRG5 was put through CLEAN to reduce the headers to File and Comment sections only. That file was then merged with SAMAVG files (Output:MRG).

The MRGCLN2 files were examined to see if the comments on mis-fires in the nutrient data apply to all channels. For cast #38, sample 219, a flag was added to the salinity channel and all the "c" flags were changed to "d" since it is clear there was a mis-fire.

Data were exported to a spreadsheet 2009-03-che-bottles.xls and compared to the rosette sheets to ensure all expected data are present. A number of problems were found and fixed. CLEAN was rerun and a data exported again and found ok.

11) Compare

Salinity
Compare was run using only the Autosal data since they look reliable and there are Autosal samples for all the data.

The comparison of Autosal bottles with CTD turned up two severe outliers for both channels of CTD #0443.

- Sample #247 from 19db of cast #33 was higher than the CTD by >2 despite a low standard deviation in the CTD salinity. No such sample exists according to the rosette sheet and salinity analysis worksheet. But sample #347 is missing, and the value of this sample would make sense for #347 which was deeper. So the value was moved to sample #347, cast #38. Sample #247 was the only salinity sample from cast #33, so when that was found to be an error the sal file was deleted. A comment was put in the header of cast #38, and flag "c" attached to warn users, but it does look fine.

- Sample #363 from cast #38 is lower than the CTD by 0.5. The CTD salinity is a little noisy, but does not look noisy enough to cause such a large error. The dissolved oxygen samples look like #363 and #364 could have been reversed, but doing that makes one salinity match worse and does not improve the other much. It is more likely that #363 closed above 150m. The nutrients suggest that it closed at about 125m. The salinity sample #363 will be flagged "d" as a severe outlier.

Outliers with differences >0.05 were examined and most had noisy CTD data as judged by the standard deviation in the COMPARE file. The following should be flagged:

- Sample #9 from 24db of cast #2 – The bottle salinity is a little high and the dissolved oxygen a little low, so you might imagine the bottle had closed prematurely. But a look at the temperature profile shows a lot of structure. Assuming the bottle is wrong seems dangerous here. There could be a CTD problem, but more likely this is a "noisy area" and both are giving reasonable representations of it, just slightly different.
- Sample #196 from cast 27 – it looks as though this bottle closed well above 2500db. Other samples also look out of line. Flag "d".

A few other outliers with differences >0.025 were investigated and most were from the noisy section of cast #2, and one other had a fairly high standard deviation in the CTD data. Sample #13 from the bottom of cast #4 was plotted and while the temperature and salinity had settled down just at the time of bottle firing, they were very noisy just before that and primary and secondary differed greatly. So the bottle is probably fine, just captured a different moment in this noisy time.

Plots were prepared for each T/C pair.

- For CTD #0443 the primary salinity looks bad for cast #40 which was expected. We know it was also bad for casts #42 and #44 but there are no bottles for those casts. For the earlier casts the CTD salinity is low by an average of 0.0040 when data above 200db and differences >0.01 are excluded, but the standard deviation in the differences is quite high at 0.0025.
- For CTD #0443 the secondary salinity is high by an average of about 0.0059 with a standard deviation in the differences of 0.0016 using the same criteria as for the primary. The fit is flatter against pressure and time than the primary, but that may be partly due to having more deep data in the fit. The secondary salinity looks ok for casts 40-44.
- For CTD #0550 the primary salinity is low by about 0.004 when only data from below 900db are included and differences >0.01 are excluded. The standard deviation in the points included in the fit is about 0.0014. The average would be closer to the bottles if the 500db bottles were included in the fit, but they look out of line for both the primary and secondary comparisons. The local salinity gradient was high and the cast at which all of them were collected was one for which the CTD was likely bouncing around and thus more sensitive to the local gradient. It is difficult to judge either time or pressure-dependence because of the way the deep casts are clustered.
- For CTD #0550 the secondary looks low by about 0.0009 using the same criteria as for the primary. The standard deviation in that data was 0.0011. There is little time dependence. Depth dependence is harder to judge because bottles came from just 4 depths. The bottles from 500db do not look much like those from 1000 and 2000db, but there was a fairly significant gradient at the station from which they all came and it was a very rough cast. A plot of standard deviation in Sal1 vs pressure confirms this as it shows the quietest section is at 2000db and the noisiest is 500db. If recalibration is done, no more than 0.001 should be added, but it is probably best to do nothing at this point since salinity is quite close to bottles and both CTD data and the sea state are probably having some effect on this comparison, it is just not clear what. The plot of standard deviations vs pressure shows very little scatter at 2000db, where the CTD is found to be low by an average of 0.001.

Studies were then made of the stability of the CTD when multiple bottles were fired at the same depth.

Cast	Pressure	# of bottles	Average difference CTD-BOT	Std Dev. in Pressure	Standard Deviation in bottle samples	Std. Dev. In CTD SAL1
46	2000	10	-0.0004	0.96	0.0015	0.0009
46	500	12	+0.0012	1.30	0.0019	0.0005
49	1000	12	-0.0007*	2.20	0.0006*	0.0005
54	2000	10	-0.0017	1.81	0.0009	0.0002
49	10	4	-0.0015	0.15	0.0004	0.0000

* excluding 1 outlier; with all included the average difference is -0.0016.

It is interesting that for the 500db bottles while the CTD salinity standard deviation is relatively high for the 10s of data for each bottle, the standard deviation among the 10 averaged CTD salinity values is not high. This suggests small-scale noise that is consistent from one firing to the next. They all were fired in less than 1 minute. When 3 bottles are excluded the average difference is reduced to +0.0007.
(See 2009-03-sal-comp1.xls.)

Dissolved Oxygen –

NOTE: Comparisons were run early in the processing, at which time it was assumed that the deepest data from CTD #0443 could not be used. It was later realized that the errors in the deepest bottles were pressure-dependent, and that a multi-step approach to recalibration could rescue the deep data, so all but the first run of COMPARE were rerun. See section 17 for details.

COMPARE was run for DO sensor #0997; unfortunately, there was no DO sampling for the other sensor. From the plot of differences against pressure it is very clear that something is wrong below 1400db. This fits with the problems noted in the primary temperature and conductivity for CTD #0443. There were two major outliers but both had already been flagged "d" based on the salinity comparison and comments from the nutrients analyst. Other outliers were examined to see if flags are appropriate:

- Cast #2, Sample 9, 24db – This bottle looks like it could have closed below 24db – Salinity and CHL are both a little out of line as well. However, the local gradients are high, so this is not clear. The bottle stands out slightly in a DO vs Sal plot. However, there is a very high gradient in this area, and the standard deviation in the CTD data is very high. This bottle should not be flagged.
- Cast #18, Sample 135, 175db – Minor outlier, no evidence of misfire – very noisy cast.
- Cast #18, Sample 143, 11db – as above
- Cast #35, Sample 285, 597db – Very noisy CTD data
- Cast #40, Sample 408, 248db – This is a moderate outlier. The primary salinity is very bad for this cast and failed totally soon after this. The temperature differences are ok, so this is not a temperature-induced error. The CTD data are not especially noisy. The bottle is a mild outlier in a plot of DO vs CTD secondary salinity, but not against primary salinity, which probably does suggest a pump problem. So the bottle is probably fine, but not the CTD data.
- Cast #40, Sample 416, 24db – Again the CTD is probably the source of disagreement.

A few other outliers were excluded based on residuals and the fit was:

CTD_BOT = 1.0396 DOX_CTD + 0.0146

The deep data for cast #40 seem ok. A fit was done for cast #40 excluding the two outliers noted above and it looked very close to the one above even when deep data are included. The deepest bottle is a minor outlier. (See 2009-03-dox-comp1.xls.)

The problem seen in the primary salinity for cast #40 looks like a conductivity cell failure. The problems seen earlier seem more like a pump problem, and cleared up after replacement of a y cable and pump cable. However, there is a possibility that the bad primary temperature data account for the bad DO data rather than the pump problem. To test whether better dissolved oxygen could be obtained by choosing secondary temperature, the data from cast #35 were taken at the CELLTM stage and put through STRIP to remove the primary temperature and conductivity. Then DERIVE was run to calculate dissolved oxygen again. This did not improve the DO data.

Plots were made of CTD Dissolved Oxygen and Titrated Dissolved Oxygen versus salinity. The only outliers were from bottles that had already been noted above.

Fluorescence

COMPARE was run using the CTD CHL and the Titrated Chlorophyll from bottles. Plots were prepared of titrated CHLa versus CTD CHL. When extracted CHL is plotted against CTD fluorescence the results look odd. There were two different fluorometers, and there are some questions about how well the primary pump was working for the first one. We usually expect to see a fairly good fit for CHL<1 and the ratio is close to that for the lowest values, but for bottle CHL values from 0.35 to 0.45 there are many points with fluorescence much higher than CHL which is odd. Plotting the ratio of CTD to Bottle CHL against event numbers (and excluding cases with extracted CHL<0.2 where the ratio is unreliable) shows a steady rise. The ratio is generally <1 up to cast #8, ranging from 0.5 to 2 for casts #13 to #23. The next section shows a lot of samples clumped with fluorescence 2 to 2.5 times the extracted CHL for casts 31 to 42. Finally for the other fluorometer used for casts 52 to 60, the fluorescence is about 3 times the CHL. We do often see the ratio vary with distance from shore, so overall this looks ok, though with the group from 31 to 44, the ratio appears to be going down as the ship moved offshore. Nonetheless, the overall pattern suggests that this is not due to a pump problem. That does not mean there was no such problem, but it won't account for the geographic pattern.

A comparison with the data from the winter Line P cruise of 2008 shows the median extracted chlorophyll value the same as for 2009, but the maximum is much higher and the average a little higher. So there is a greater range of values and the standard deviation is twice what it was in 2008.
The large range of values all occur early in the cruise. Later the range is remarkably small. (See 2009-03-chl-fluor-comp.xls.)

13. Shift

Fluorescence

The usual method to find what shift is needed for the fluorescence is to examine upcast and downcast profiles to determine the vertical offset of the temperature and fluorescence traces. The differences between these two offsets are treated as a measure of how much the fluorescence needs to be shifted. The "excess" offset for the fluorescence was divided by the averaged descent/ascent rate and divided by 2(since the shift will be applied to both up and downcast) to find the shift (in seconds) to remove that offset. This is always rough estimate as the upcast data are usually noisy, but for this cruise it was extraordinarily difficult to find sections of data useful for the tests. The usual shift of +24 records (1s) was found to improve the alignment, but whether it is the best choice is impossible to say. This is the shift that has been used in most other cruises, so it was applied to these data. (Output: SHFFL)

Conductivity

Since the primary sensors are certainly not going to be used for CTD #0443 no tests of alignment were done to the primary conductivity. Tests were run on the primary for CTD #0550 and the best choice was found to be leaving it unchanged. Applying shifts of -0.2s and +0.2s both made the data noisier. So SHIFT will not be applied to primary conductivity for any casts.

Tests were run on the secondary conductivity for 2 casts for each CTD using a variety of shifts and T-S plots were prepared to compare the results. A setting of -0.6s worked best for casts 1 - 44 and -0.3s worked best overall for casts 44-60. SHIFT was run using those settings. (Output: *.SHFC1).

Dissolved Oxygen
Tests were run on a few casts for each sensor to determine the best SHIFT value to apply to the Dissolved Oxygen channel. This was judged by how the vertical offset between downcast and upcast traces compares with that of the temperature. Because there is an offset in values between upcast and downcast due to the time response, alignment will not produce traces that overlie each other exactly. Distinctive features aid this judgment. A values of +70 seemed best for sensor #0997, but for sensor #1119 the descent rate was extremely noisy for all cast and there were many bottle stops, so none of the casts was very useful for testing. A setting of +70 looked reasonable, but it is impossible to say that it is the best choice.
SHIFT was run using +70 records for all casts.

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: The only warning was for cast #2 which contained only upcast data and will not be processed further. Cast #1 has the downcast data for that deployment.

Cast #44 is also an upcast only file, but in this case there was no downcast data available. So Cast #44 was put through REVERSE and then through DELETE. A comment was then put in the header to warn users that the quality will not be as high as for other casts.

15. Pre-edit steps

The equipment problems were reviewed to determine which sensors should be chosen for archiving, and whether DO data should be removed in editing.

- For CTD #0443, from cast #15 onwards there are problems with the primary data being spiky and drifting away from the secondary values. In some cases trouble starts near the bottom, so that the downcasts are mostly usable, but for cast #35 the primary data from 1400db downwards look unreliable during both downcast and upcast. This includes the dissolved oxygen. The spikiness is reduced during bottle stops. This fits the idea that the problem is due to a pump problem. However, the problems seen during casts 40, 42 and 44 look like a cell failure as the primary salinity values are consistently wrong, while temperature is still spiky, but not completely unrealistic. It is clear that the primary data should not be selected for casts #1-44. The other question is whether we should edit the dissolved oxygen channel. It appears from the bottle comparison that data above 1400db have the sort of fit we have come to expect from this type of sensor. However, we have no history of this sensor being used since its last recalibration. If it has not been used at all we might expect a smaller slope to the fit, unless time on the shelf leads to drift. After editing, the downcast data can be thinned and compared to the upcast. It looks like we have a reasonable means of recalibrating the deep data as described in section 11, but that should be reviewed when we compare the downcast data to the bottles.

- For CTD #0550 it is not clear which sensors to use. The bottle comparisons are limited to multiple bottles at a few depths during just a few casts. Based on those the secondary salinity is very close to the bottles, and closer than the primary salinity. The history of the sensors indicates that the secondary was low by about 0.006, but there are grave doubts about how the salinometer was working at that time. The secondary salinity is a little spikier though the differences are not great. The COMPARE results were odd with larger differences at great depth and at the surface than at 500db; the pressure shows there was considerable CTD movement during the 500db stop and standard deviations in the CTD data were very high at 500db, though why that should have a systematic effect is not clear. Even more puzzling is that when only the bottles from 2000db are included the differences for each pair are larger for cast #48 than for cast #54, yet the standard deviations are similar for the two. Calibrations could be drifting, but we don't expect exactly the same in both pairs. Also the differences at the surface are the larger at the surface than at depth for both sensor pairs. The secondary sensors were selected for editing and archiving. No recalibration should be done at this stage, but when the sensors are next at the factory, this can be reviewed.

The altimeter readings from the headers of the CLN and BOT files were exported to spreadsheets and all casts were checked. Plots were made and the log book was checked. The algorithm worked well where the CTD got close to the bottom, but it recorded erroneous low values for many casts when it did not get close to the bottom according to the log. The altimetry headers were removed from the SAM and/or DEL files for casts #7, 14, 21, 42, 44, 46, 50, 54, 55, 57, 58 and 59 because the algorithm didn't work well. For some it worked well for the full file and not for the bottle file and vice versa.

16. DETAILED EDITING

The secondary temperature and salinity channels were selected for editing.
Graphical editing was done using program CTDEDIT. On-screen plots of descent rate and pump status were also used. All casts required at least a little editing. The descent rate was extremely noisy from cast #21 to the end of the cruise, so those data files needed the heaviest editing to remove many records corrupted by shed wakes.

17. Initial Recalibration

CTD #0443:
The SAM files were recalibrated using file 2009-03-recal1.ccf to subtract 0.006 from the salinity and to apply the following DO correction to files 1-44:

$$DOX\_BOT = 1.0396\ DOX\_CTD + 0.0146$$

This applies a correction to the deep DO data where it is not appropriate, but there is no simple way to avoid this. COMPARE was rerun and showed that the correction had been applied properly. (See 2009-03-dox-comp2.xls.)

At this point a fit was done using just the recalibrated deep bottles from casts #15 to 38 (there are no deep data before cast #15). If we exclude cast #40 and one other outlier a reasonable fit is found for differences versus pressure below 1400db:

$$DOX\_BOT = 0.00007 * Pressure + 0.0495$$

That is convenient because there is an equation for having a pressure-dependent correction that can be divided into two ranges. So we can leave the data above 1400db uncorrected and apply the above correction below 1400db. The SAMCOR1 files from the first run were copied to *.SAMCOR1b and the recalibration was run on just casts 15-38 using file 2009-03-recal1b.ccf applying the above correction

restricted to the pressures >1400db. No correction was applied above that. The output files were SAMCOR1b, so we have a complete set of files with 1 or 2 corrections as appropriate. COMPARE was then rerun and the output showed a satisfactory correction at all depths.
The 2 calibrations were then applied to the EDT files for casts 1-44, with output COR1 and COR2. (See 2009-03-dox-comp2b.xls.)

CTD #0550
Recalibration of CTD #0550 is more difficult. The salinity data appear to be close to bottles, though sampling was limited to a few depths; they will not be recalibrated. There are no bottles for calibration of the dissolved oxygen. There were some repeat casts at P26 using both CTDs, so we can do a comparison of the DO in those. Fortunately, the problems below 1400db do not appear to have affected cast #40 though the bottom bottle is a mild outlier.

The downcast files were thinned so they could be examined in COMPARE. First casts #46 and 48 at P26 using sensor 1119 were compared to see how large temporal changes are in this area. In the top 100db the differences were <0.04ml/l. They then increased to a maximum of 0.65ml/l at 150db and then came down to <0.03 from 500db downwards. In most cases the differences had the same sign, but there are a few levels at which the opposite was seen. The same comparison was done for casts #46 and 49 and again the top 100db have differences <0.042ml/l. At 150db they are 0.87ml/l. By 600db the differences are quite steady at <0.02ml/l, but there are no data to compare below 1000db for cast #49.

Looking then at the differences between casts #40 and 46 with two different DO sensors, the DO is low for #1119 by an average of 0.17ml/l in the top 75db. These data come from a well-mixed layer and the differences seen above were <0.04ml/l, so we can assume that #0997 is low by at least 0.1ml/l at the surface. The differences then grow to about 0.34 at 150db; given the changes noted for #1119, these differences could be entirely temporal. From 700db down it looks like #1119 is low by 0.04, but at least 0.01 of that could be temporal, so it is probably low by at least 0.03ml/l. Given surface values of ~7ml/l, that would imply a minimum correction of:

DOX(corrected) = 1.01 * DOX +0.03

When a fit is done of differences against DOX and data are excluded for below 1500db and for 100db<Pressure<700, the fit found is:

DOX(corrected) = 1.019 * DOX +0.044

When the same steps are applied to compare casts #40 and #48, the result is:

DOX(corrected) = 1.017 * DOX +0.039

Given that these corrections include some temporal effects, they are remarkably close, though of course the high gradient zones are not being considered. The size of the correction is about what is expected from a sensor that has not been used much. So applying a correction is reasonable, but note must be made in the headers that this is very rough. If the sensor is used on a subsequent cruise and has a smaller correction this should be revisited. Note should be made in the header that the recalibration is based on a rough estimate.

File 2009-03-recal2.ccf was prepared to apply the following correction to casts #46-60:

DOX(corrected) = 1.018 * DOX +0.04

Salinity was not recalibrated for those casts.
This was applied to the SAM files to create SAMCOR1b and to the EDT files to create COR1b

Note: The Tau correction was applied in the derivation of dissolved oxygen concentration. This is intended to improve response at levels of high DO gradient, but is known to amplify residual noise especially at depth. That clearly happened with many of the deep casts. It is a trade-off between shallow and deep data. For this data set, given the problems with the deep data due to temperature noise, it is probably best to use the Tau correction, but the data could be re-derived without it if desired. However, that would change DO values, so bottle comparisons would have to be redone to enable recalibration of the data.

18. Final Calibration of DO

The first recalibration of dissolved oxygen corrects for calibration drift. Shift corrects for transit time errors. Those 2 steps may partly correct for response time errors, but a further correction can be applied to further correct for response time by comparing downcast CTD data to bottle data from the same pressure. For this particular cruise there are other concerns about how the pump performed and any errors due to that may show up here too.

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. When extreme outliers are excluded, the differences range from -0.3 to +0.4ml/l, with an average difference of +0.06. When more points are removed based on residuals the following fit is found:

DOX(corrected) = DOX +3E-5 * Pressure - 0.07

This is the sort of fit we expect, confirming that any pump problems have not had serious effect on the DO data above 1400db. (See 2009-03-dox-comp3.xls.)

The thinned files were recalibrated using file 2009-03-recal3.ccf to apply the above equation and the comparison was rerun. That showed that the results were good. (See 2009-03-comp4.xls.)
Recalibration using file 2009-03-recal3.ccf was applied to the downcast files only. It was also applied to the later casts with the different DO sensor, since they were recalibrated by inter-comparison with the earlier casts. (Output:COR2)

19. Special Fluorometer Processing

An examination of the fluorescence channel shows a dark value of ~0.11mg/m^3 for sensor #2228 up to cast #22 when it goes up to ~0.17 mg/m^3 and stays at that level until it was replaced after cast #44. The CTD was then changed and for fluorometer #2356 the dark value was~0.06 mg/m^3.

The COR2 files were clipped to 150db and processed separately for A. Peña. The clipped files were bin-averaged (0.25db bins), put through REMOVE and HEADEDIT and named as *.FCTD1 and saved. A second set, *.FCTD2, were created by filtering before bin-averaging. The SAMCOR1 files for casts 1-44 and SAMCOR2 files for casts 46-60 were put through REMOVE and named *.BOF and saved. A readme.doc file was prepared with some notes on the preparation of those files.

A median filter, fixed size=11, was applied to the fluorescence channel in the COR2 files to reduce spikiness. One cast was 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. There were some slightly unstable features near the surface, but with noisy salinity this is hard to avoid without removing data that may be useful. No further editing was applied.

21. Other Comparisons

<u>Previous experience with these sensors</u> –

1. Salinity:
- The T and C sensors for CTD #-443 were used for 2008-61, when the salinity data were found to be low by 0.01 and 0.0025 respectively, but the salinity analysis was not trusted.
- The primary conductivity sensor used on CTD #0550 has not been used on any other cruises since it was last recalibrated. The secondary conductivity sensor was used with a variety of temperature sensors for 4 other cruises, when it was generally found to be low by 0.005 to 0.007, but there were doubts about those comparisons. None of the conductivity sensors on #0550 had been used since 2007.

2. Dissolved Oxygen – Neither sensor has been used since last calibrated.
3. Pressure – The sensor on CTD #0443 is older and prone to drift, but the change is steady; an offset of +6.7db has been used since late August 2008. The sensor on CTD #0550 was recalibrated in August 2007 and an offset of +0.5db has been used for the two cruises processed since then.

Historic ranges – Profile plots were made with historic ranges of T and S superimposed. Salinity was slightly below the historic minimum just below the mixed layer for a few casts, but these did not look like significant excursions.

Repeat Casts – There were a number of repeat casts. Just below the mixed layer there is a lot of variability at P4 and P12, with some cases of instability, though those are small in extent (<1m). At depth the variability is small. Examining 2 deep casts at each of stations P12 and P26, along lines of constant σ_t, temperature and salinity varied by ~0.002C^o and ~0.001 salinity units at ~1500db.

22. FINAL CTD files steps (REMOVE and HEADEDIT)

The following channels were removed from all casts except #6: Scan_Number, Temperature:Primary, Salinity:T0:C0, Conductivity:Primary, Conductivity:Secondary, Oxygen:Voltage:SBE, Altimeter, Status:Pump, Descent_Rate and Flag.
The PAR channel was removed from casts #9-27, 32, 35-38, 40 and 46-60 because the instrument was not mounted on the CTD for those casts.
The Dissolved Oxygen Channel was removed from casts #42 and 44.

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

HEADER EDIT was used to fix formats and channel names and to add the following comments to casts 1-44:

Transmissivity and fluorescence are nominal and unedited except that some records were removed in editing temperature and salinity.

The dissolved oxygen data for this CTD were recalibrated in three steps. The first correction was applied to data from above 1400db and to all of cast #40. The second was applied to data below 1400db from casts #15-38. The final correction was applied to all data. See 2009-03-proc.doc for details.

Dissolved Oxygen data below 1400db are very noisy and are considered less reliable because of the noisy signal, the limitations in the calibration, and because it was impossible to fine-tune the configuration parameters to get the best possible deep data, so there may be some hysteresis.

The DO data should be considered:
- *±0.4ml/l from 0- 200db*
- *±0.1ml/l below 200- 500db*

- *±0.04ml/l from 500-1500db*
- *±0.2ml/l below 1500db*

For casts #42 and 44, the above note was adapted to indicate that the DO data were bad, and were removed due to equipment problems.

HEADER EDIT was used to fix formats and channel names and to add the following comments to casts 46-60:

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

There were no bottles samples available to recalibrate the dissolved oxygen sensor used for this cast. Recalibration was based only on an inter-comparison of repeat casts at station P26, one with sensor #0997 and two with sensor #1119. The casts were separated in time by 4 to 6 hours. Temporal variations were found to be very large between 100 and 700db during repeat casts using a single sensor, so the inter-comparison of sensors was limited to the mixed layer from 0 to 100db and below 700db. This limits the range included in the fit to high and low values. A final calibration applied was based on studies of sensor #0997. For details see file 2009-03-proc.doc.

The comparisons in areas of low DO gradients suggests that it performed well. A rough estimate suggests that the data is likely to be within ±0.4ml/l in the top 200db and ±0.2ml/l below that.

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

Profile plots were made and no problems were found.
The track plot looks ok.
As a final check of dissolved oxygen data, % saturation was calculated and plotted. The near-surface values for Saanich Inlet was ~80%. For all offshore casts it was ~100%.

23. Final Bottle Files

The MRGCOR1b files were put through SORT to order on increasing pressure. REMOVE was run to remove Scan_Number, Temperature:Primary, Salinity:T0:C0, Conductivity:Primary, Conductivity:Secondary, Oxygen:Voltage:SBE, Status:Pump, Descent_Rate, Altimeter and Flag.
The PAR channel was removed from casts 46-60.
The Dissolved Oxygen Channel was removed from casts #42 and 44.
A second SBE DO channel was added with different units.

HEADER EDIT was run to fix formats and units and to add a comment about quality flags and analysis methods. A note was also added about limitations in the SBE DO data.

Standards check was run on all files and HEADEDIT adjusted until all format problems were resolved.
A cross-reference list was produced and turned up no errors.

24. Thermosalinograph Data

The TSG data were provided in 2 hex files. There were positions but the data were not logged until about P20. The intake thermistor was not connected.

a.) Checking calibrations

The calibrations used at sea were out of date. A new con file was prepared with the current parameters and saved as 2009-03-tsg.con. The chief scientist reports that the intake thermistor was not connected.

b.) The files were converted to CNV files using 2009-03-tsg.con and 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 run to add time and date channels.
The secondary temperature data confirms that the sensor was not operating correctly, so that data will not be processed further.
Time-series plots were produced and the only significant spike seen is near the end of the record when the flow rate was low.
The track plot was produced and looks fine; it was added to the end of this report. The track does not start until part-way to Station Papa because the TSG had not been set to log data.

c.) Checking Time Channel

The CTD data, after editing and metre-averaging, were thinned to reduce the files to a single point at or within .3db of 4db and exported to a spreadsheet which was saved as 2009-03-ctd-tsg-comp.xls. The TSG files were opened in EXCEL, median and standard deviations (over 2minutes) were calculated for temperature and salinity, and the file was then reduced to the times when CTDs were run. Those files were added to the CTD data in file 2009-03-ctd-tsg-comp.xls. The positions were compared and were close, with average differences for latitude <0.0001 and for longitude of ~0.00013º. There was one cast with a difference of 0.0014 in longitude. A small mismatch in clocks may account for this as the ship does appear to have been drifting significantly through the cast. But overall the clock does appear to be working well.
This spreadsheet will also be used in step (e) to compare temperature, salinity and fluorescence.

d.) Comparison of T, S and Fl from TSG and CTD data

- T1 vs T2 The intake thermistor was not connected.
- TSG vs CTD The spreadsheets comparing CTD and TSG files were then examined to find the differences between the salinity, fluorescence and temperature channels for the CTD and the TSG. There were 16 casts that could be used.

  The TSG lab temperature is found to be higher than the CTD by 0.226 Cº with all values between 0.21 Cº and 0.25 Cº and a median value of 0.22 Cº.

  The TSG salinity is low by an average of 0.086 and a median of 0.075. If 4 outliers are excluded based on standard deviations in the TSG salinity, the salinity is low by 0.073.

  The ratio of TSG fluorescence to CTD fluorescence ranges from 1.5 to 3.7 with an average of 2.2 and a median of 1.7. When plotted against time the ratio appears to be related to sunlight, with the 7 casts between 17:00 and 1:00UTC (roughly 7am to 5pm local time) having an average ratio of 2.8. Those outside that time span have an average of 1.6. The TSG fluorescence shows very little variation compared to the CTD fluorescence. There are 2 early readings from the TSG at about 2.9, but all other points in this comparison are in the range 1.8 – 2.3ug/l. The CTD fluorescence varies from about 0.7 to 1.3ug/l. Looking at the full TSG file confirms that fluorescence was very flat for most of the record, but salinity and temperature also look quiet. The higher ratios of TSG to CTD FL are associated with lower CTD fluorescence. (See 2009-03-ctd-tsg-comp.xls.)

- Loop Bottle Comparisons There were 12 loop bottles, but the exact time is unknown for 1 of them and there are no TSG data available to match 8 of them. The results of chlorophyll and salinity analysis were combined in a single file 2009-03-TSG-loop-comp.xls. First a few checks were made of the 5 rosette bottle samples that coincide with loops and the agreement was excellent. The Loop salinity was higher than the rosette bottle salinity by an average of 0.0015 and the Loop CHL was about 1.04 times the rosette bottle CHL.

  There are 4 loop samples that coincide with TSG data. For those the salinity is higher than the loop by an average of 0.002, but if one point is excluded it is lower by 0.08. The TSG fluorescence is higher than the loop CHL by an average of 3.7 (ratio range: 2.4 to 4.9.) There are only two rosette bottle salinity samples that match TSG readings and those indicate that the salinity is low by 0.071 and 0.079. Variability in the TSG salinity during that period was low. (See 2009-03-TSG-loop-comp.xls.)

- Calibration History

The TSG primary temperature and conductivity were recalibrated in December 2007. They have been used on 4 other cruises that had calibration sampling.

1. During 2008-01 there was no intake thermistor and the lab temperature was estimated to be high by 0.19C°. The salinity data were thought to be low by 0.055.
2. During 2008-32 the lab temperature was believed to be high by 0.228 C° and the salinity data were bad.
3. During 2008-26 the lab temperature was considered high by 0.15 and salinity low by 0.125.
4. During 2008-27 the lab temperature was considered high by 0.17 and the salinity low by 0.17.
5. During 2008-10 the comparison was considered poor, but temperature was high by 0.2 and salinity low by 0.23.

A post-cruise calibration indicates that the temperature had drifted by +0.0004C° per year and the salinity by -0.0017 PSU/month (so by ~-0.025 by the end of this cruise). This confirms that the results for the last few cruises were out of line which could be because of freshwater getting into loop and/or poor salinometer performance.

Conclusions

The lab temperature is higher than that of the CTD by an average of 0.225C° and the median is 0.22C°. The temperature difference is affected by heating in the loop and drift in calibration. The temperature sensor drift based on the post-cruise calibration on March 17, 2009 was ~+0.0004°, so we assume the temperature difference is almost entirely due to ship heating. Heating by about 0.22C° is typical for the Tully in winter.

For salinity the TSG is higher than the loop salinity by ~0.002 using 4 samples, but if one is rejected it is found to be low by 0.08. Comparison with CTD salinity shows the TSG to be low by a median value of ~0.075, and by an average of 0.073 if 4 outliers are excluded based on standard deviations in the TSG salinity. While these two comparisons seem to support each other, there is little loop data and only 16 casts with a TSG/CTD comparison, so this should not be over-interpreted. These differences are much smaller than have been seen from other recent uses, confirming that some problems have been resolved. The post cruise calibration shows that salinity had drifted lower by about 0.025, which is less than the loop and CTD comparisons indicate. What would account for both loop samples and CTD being higher than the TSG by more than the drift would explain? If there were freshwater getting into the system the loop sample should be low as well. The study of duplicates in section 10 does suggest that there may still be problems with the salinometer or sampling. Whatever the cause, it seems best to recalibrate salinity based on the post-cruise calibration, and then say that there is some evidence that the salinity in the loop may be low by ~0.05.

The TSG fluorescence ranges from 3.7 to 4.1 times the loop samples and from 1.5 to 3.7 times the downcast CTD fluorescence. There is little variation in the TSG fluorescence and the ratio between the two is generally at ~1.6, but goes higher during daylight hours when the 4m CTD fluorescence is lower.

The correspondence between the salinity and chlorophyll samples from the loop and the rosette bottles is excellent.

f.) Editing
The time-series plots were examined and editing was applied as follows:
File 1: A few spikes in salinity were cleaned where temperature and fluorescence were fairly smooth.
File 2: As for file 1, plus a second run to remove records 11060-11075 because the flow was turned off for a short time.

g.) Recalibration
As the intake temperature is unavailable, a new channel will be derived. First ADD CHANNEL was used to add channel TEMPERATURE:LAB. That was then put through CALIBRATE using file 2009-03-recal1.ccf to set Temperature:LAB equal to Temperature:Primary. Then file 2009-03-recal2.ccf was used to recalibrate Temperature:Primary by subtracting 0.22 C° and Salinity:T0:C0 by adding 0.025 for all files.

Thus we have:

- Temperature:Lab as the uncorrected temperature recorded in the lab.
- Temperature:Primary as the lab temperature adjusted to remove the effects of ship heating; this is a proxy for the intake temperature.

h.) Preparing Final Files
REMOVE was used to remove the following channels: Record #, Scan Number, Temperature:Intake, Temperature:Difference, Conductivity:Primary, Uploy0 and Flag from all files.
HEADER EDIT was used to add a comment, change the DATA TYPE to THERMOSALINOGRAPH and add the depth of sampling to the header. The comment includes notes to indicate that the Temperature:Primary was recalibrated to correct for heating in the loop based on the historic observations and comparison with CTD data and that salinity may be low by ~0.05.

The TSG sensor history was updated.
As a final check plots were made of the cruise track and data; no problems were noted.

25. Producing final files

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

The loop file was not yet available, so the following steps will be done later:
The final loop file 2009-03 loop.xls was prepared by the chief scientist including data from the final CTD files and salinity and chlorophyll samples from the loop or from 5m bottles. That spreadsheet was simplified, date calculated in DD/MM/YYYY format, header names and formats were adjusted and unneeded channels were removed and saved as a CSV file. It was converted to IOS format, put through

CLEAN and HEADEDIT to get start and stop times and positions, and to add general comments and specific comments for flagged values. The final file was named 2009-03-surface.loop.

Particulars:
Remote TSG temperature not hooked up.
TSG not set to record data until P20.
1-17 – Time is wrong
1-2. Upcast has different name for first cast in Saanich Inlet
30. According to log cast was aborted due to error beep from carousel, but there is data to ~170db.
32. No rosette sheet – 1 bottle closed at 30db and 2 at 5db. All have sample numbers.
43/44. No downcast – 44 is the upcast for what should have been 43.
Casts with PAR: 1-4, 6-8, 30-31, 33-34, 42, 44.
38-44. Problems with CTD primary salinity and oxygen
46. CTD changed
54. Calibration cast. Problem with Niskin #5 from this point on. No samples taken from it.

REVISION: January 8, 2010: A number of changes were made to the Oxygen:Dissolved channel:

- **Final dissolved oxygen values do not match those output by AutoOxy (.oxy files) and those on rosette logs, due to a software error which resulted in the incorrect endpoint being used to calculate DO. Actual endpoints were determined by manual inspection of titration curve data and corrected DO values calculated**
- **Addition of a value previously missing (sample #418)**
- **Replacement of average of duplicates for sample #5 with a single value and removal of “fd” flags**
- **Removal of “c” flag from sample #62**

REVISION: Sept. 2, 2010
Transmissometer #1005DR was calibrated in March 2008, and drifted significantly but steadily until July 2009; then a sudden shift occurred, so that maximum values between September 2009 and July 2010 were very low, ~25%/m. In August 2010 a study was made of transmissivity that led to a decision to apply post-processing corrections to all cruises between March 2008 and June 2010.

Transmissivity data from this cruise were corrected by multiplying the original values by correction factor 1.177. This was based on assumptions that deep offshore transmissivity from a June 2009 cruise should be about 62%/m and that drift was linear with time between March 2008 and July 2009. The corrections produced reasonable results for all cruises in that period.

For details on how the correction factor was derived see:
OSD_Data_Archive:\Cruise_Data\DOCUMENTS\Transmissometer 1005DR Corrections.doc

These data should be considered estimates.
Revisions done by: Germaine Gatien

Institute of Ocean Sciences
CRUISE SUMMARY
CTD

CTD#	Make	Model	Serial#	Used with Rosette?	CTD Calibration Sheet Competed?
1	SEABIRD	911+	0443	Yes	Yes
2	SEABIRD	911+	0550	Yes	Yes

Calibration Information CTD #1

Sensor		Pre-Cruise		Post Cruise	
Name	**S/N**	**Date**	**Location**	**Date**	**Location**
Temperature	**2038**	**6May08**	**Factory**		
			“		
Conductivity	**1729**	**13June08**	**“**		
Secondary Temp.	**2449**	**06May08**	**“**		
Secondary Cond.	**2424**	**07May08**	**“**		
Transmissometer	**1005DR**	**5Mar08**	**IOS**		
SBE 43 DO sensor	**997**		**Factory**		
PAR	**4615**	**15Dec2000**	**IOS**		
Fluorometer	**2228**	**?**	**IOS**		
Pressure Sensor	**63507**	**25/Oct/2004**	**Factory**		
Altimeter	**1252**	**?**	**?**		

Calibration Information CTD #2					
Sensor		**Pre-Cruise**		**Post Cruise**	
Name	**S/N**	**Date**	**Location**	**Date**	**Location**
Temperature	**4883**	**22Dec07**	**Factory** “		
Conductivity	**1763**	**11Oct07**	“		
Secondary Temp.	**2095**	**16Oct07**	“		
Secondary Cond.	**2754**	**25Apr07**	“		
Transmissometer	**1005DR**	**5Mar08**	**IOS**		
SBE 43 DO sensor	**1119**	**12Feb2008**	**Factory**		
PAR	**4615**	**15Dec2000**	**IOS**		
Fluorometer	**2356**	**?**	**IOS**		
Pressure Sensor	**75636**	**20/Aug/2007**	**Factory**		
Altimeter	**1252**	**?**	**?**		

TSG

Make/Model/Serial#: __SEABIRD/21/2487__ **Cruise ID#:** __2009-03__

Calibration Information					
Sensor		**Pre-Cruise**		**Post Cruise**	
Name	**S/N**	**Date**	**Location**	**Date**	**Location**
Temperature	**2487**	**01/12/07**	**Factory**		
Conductivity	**2487**	**01/12/07**	“		
Wetlab/Wetstar FL	**WS3S-713P**	**8/01/01**	“		
Temperature 2	**2416**	**22/Dec/06**			
Flow Meter	**?**	**?**			

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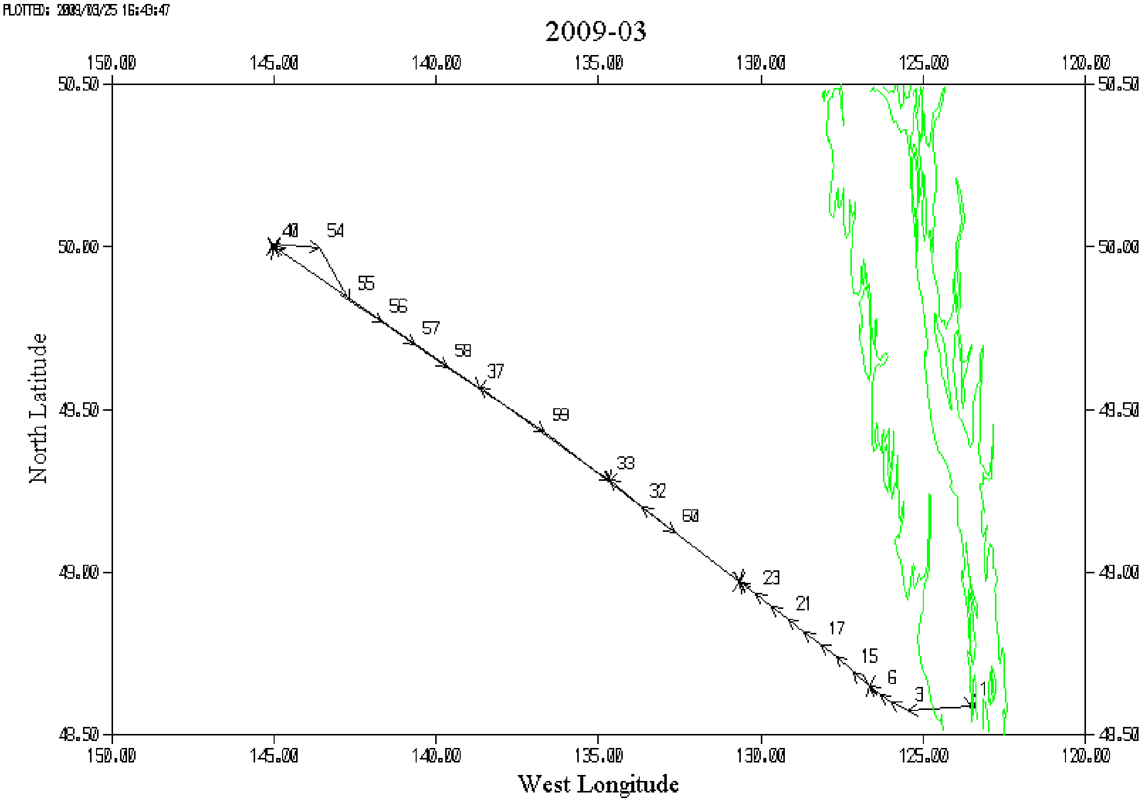

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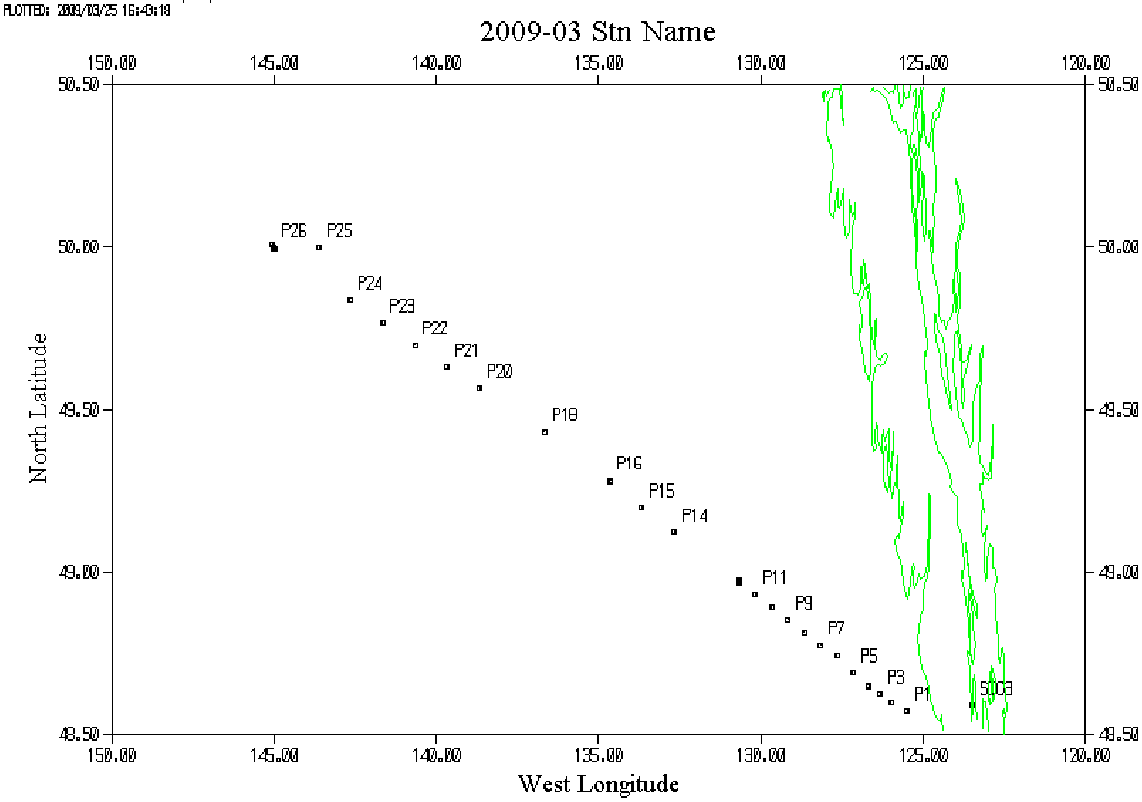

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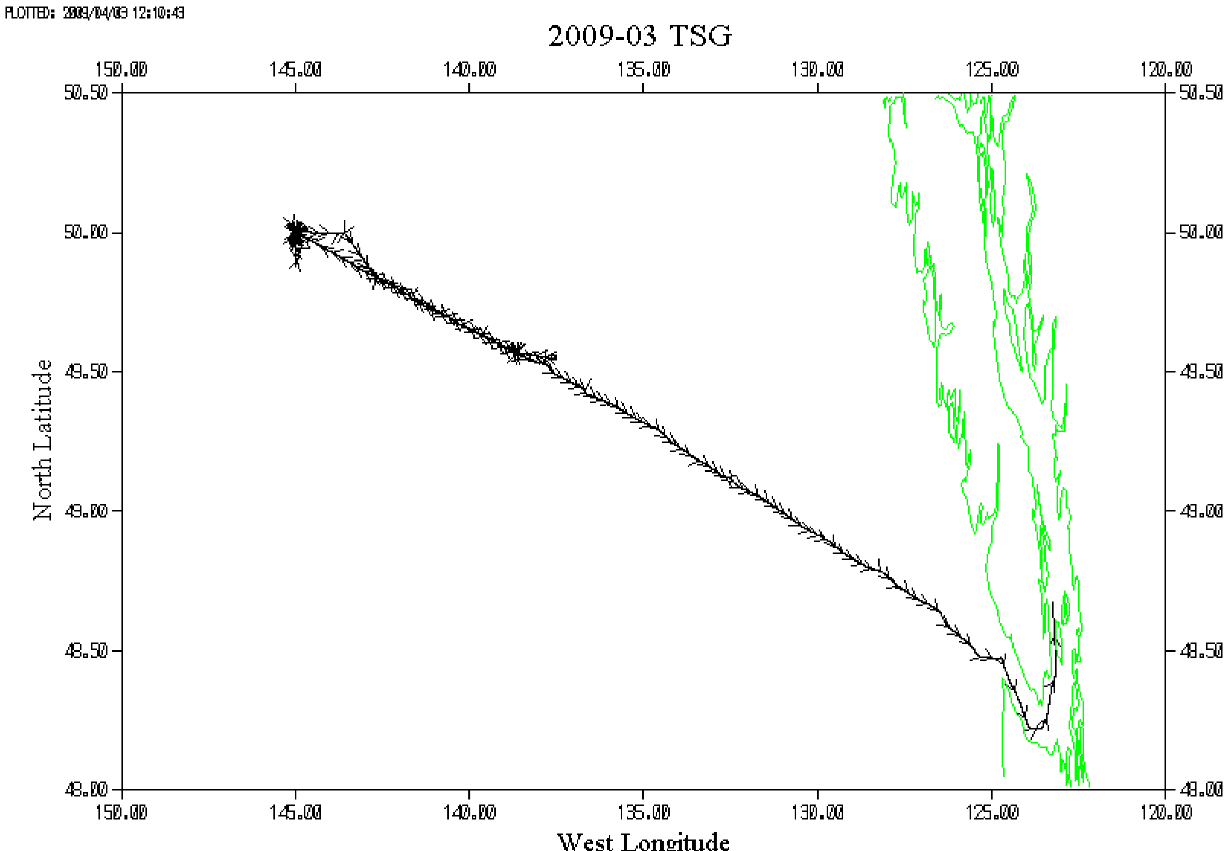

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