Geotraces-IOL 0903 CTD processing notes

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Foreword.

Québec-Océan has developed a procedure to process, to perform a quality control and to store into a database oceanographic data collected from a Sea-Bird CTD. This procedure should ensure both the quality and the durability of such data.

The data processing is performed through the “Sea-Bird SBE Data Processing program”. The quality control is based on the UNESCO’s algorithms and is performed through matlab toolbox developed by the Maurice-Lamontagne Institute (Fisheries and Ocean Canada).

1. DATA PREPARATION.

1.1. Check the configuration files.

For all the casts, the SBE43 oxygen date calibration “17-Apr-09p” has been replaced by “17-Apr-09”.

For all the casts, the fluorometer Seapoint date calibration “mai 2009” has been replaced by “01-May-09”.

There are 76 casts recorded by a Sea-Bird 911*plus* CTD.

There are 11 sensors (see table 1).

From the configuration files, there is a unique instrumental configuration for the 76 casts (see table 2). But the data show that the nitrate sensor has been removed from the cast 014 to 045 inclusively.

The variables “user defined”, “User Polynomial” defined into the configuration files are related to the Dr. Haardt Back Scat sensor.

The variables “user defined”, “User Polynomial 2” and “User Polynomial 3” defined into the configuration files are related to the nitrate sensor.

Table 1. List of the sensors installed on the 911*plus* CTD system during the Geotraces-IOL 0903 cruise.

Sensor	Type	Unit	Serial number	Web link	Casts
pressure	Paroscientific Digiquartz®	db	0730	http://www.paroscientific.com/overview.htm#depth	76
temperature	SBE 3plus	ITS-90 deg C	4204	http://seabird.com/products/spec_sheets/3pdata.htm	76
conductivity	SBE 4	mS/cm	2696	http://seabird.com/products/spec_sheets/4data.htm	76
oxygen	SBE 43	ml/l	0240	http://seabird.com/products/spec_sheets/43data.htm	76
fluorescence	Seapoint	µg/l	2900	http://www.seapoint.com/scf.htm	76
PAR/Irradiance	QCP-2300 Bioshérical	µEinsteins/m$^{2}\cdot$sec	4664	http://www.biospherical.com/BSI%20WWW/Products/Listing.htm	76
SPAR/Surface Irradiance	QCR-2200 Bioshérical	µEinsteins/m$^{2}\cdot$sec	20147	http://www.biospherical.com/BSI%20WWW/Products/Listing.htm	76
Transmissometer	WetLabs C-Star	%	CST-671dr	http://wetlabs.com/products/cstar/cstar.htm	76
Nitrate / salinity	MBARI-ISUS Satlantic	µMolar / PSU	132	http://www.satlantic.com/details.asp?ID=11&CategoryID=2&SubCategoryID=0	76/76
Altimeter	Benthos	m	1061	http://www.benthos.com/	76
CDOM fluorometer	Dr. Haardt Back Scat		12030	http://www.dr-haardt.de/BackScat.html	76

Table 2. Modification of the Sea-Bird CTD configuration during the cruise 0903.

Cast number	Cast list	Version
76 cast(s)	0903001 0903002 0903003 0903004 0903005 0903006 0903007 0903008 0903009 0903010 0903011 0903012 0903013 0903014 0903015 0903016 0903017 0903018 0903019 0903020 0903021 0903022 0903023 0903024 0903025 0903026 0903027 0903028 0903029 0903030 0903031 0903032 0903033 0903034 0903035 0903036 0903037 0903038 0903039 0903040 0903041 0903042 0903043 0903044 0903045 0903046 0903047 0903048 0903049 0903050 0903051 0903052 0903053 0903054 0903055 0903056 0903057 0903058 0903059 0903060 0903061 0903062 0903063 0903064 0903065 0903066 0903067 0903068 0903069 0903070 0903071 0903072 0903073 0903074 0903075 0903076	V1

1.2. Check the logbook and the rosette sheets.

Table 3. Modifications into the logbook and the rosette sheets.

Cast	File	Parameter	Original	New
002	Rosette sheet	Bottom Lon.	137°39.66	137° 59.66
007	Rosette sheet	Cast number	006	007
021	Rosette sheet	Begin Time	14:39	17:25
022	Rosette sheet	Bottom Lon.	137°27.619	137°2 1.619
038	Rosette sheet	Pa(mbar)		1017.6
038	Rosette sheet	Tair(℃)		-3.4
038	Rosette sheet	Wind		16/80
042	Rosette sheet	Bottom time		10:58
042	Rosette sheet	Bottom Lat.		72°33.3120
042	Rosette sheet	Bottom Lon.		137°5.6520
048	Rosette sheet	Start Lat.	70°	70° 34.948
048	Rosette sheet	Start Lon.	136°	13 5°38.825
048	Rosette sheet	Bottom Lon.	136°38.825	13 5°38.825
048	Rosette sheet	End Lon.	136°38.862	13 5°38.862
050	Rosette sheet	Start Lon.	136°26.834	13 5°26.834
051	Rosette sheet	Bottom Lon.	135°22.634	13 6°22.634
051	Rosette sheet	End Lon.	135°22.574	13 6°22.574
052	Rosette sheet	Bottom Lon.	135°6.775	13 6°6.775
052	Rosette sheet	End Lon.	135°6.852	13 6°6.852
053	Rosette sheet	Start Lon.	136°36.586	13 5°36.586
054	Rosette sheet	Bottom Lon.	135°21.868	13 6°21.868
054	Rosette sheet	End Lon.	135°21.892	13 6°21.892
056	Rosette sheet	End Time	03:	03:34
056	Rosette sheet	End Lat.	70°	70° 47.8668
056	Rosette sheet	End Lon.	136°	136° 6.1044
059	Rosette sheet	Start Lon.	136°57.463	13 5°57.463

059	Rosette sheet	Bottom Lon.	136°57.523	13 5°57.523
059	Rosette sheet	End Lon.	136°52.583	13 5°5 7.583
068	Rosette sheet	Bottom Lon.	136°44.957	13 5°44.957
068	Rosette sheet	End Lon.	136°44.941	13 5°44.941

1.3. Check the bottle data summary files (extension .btl).

There is no water sample from the cast 046. There is no problem between bl and btl files for the other casts.

1.4. Compare meta data from logbook, rosette sheets and converted file header.

Actually, this step is partly performed after the data processing (Sea-Bird Data conversion module). For the meta data, little differences (for instance start time difference less than 10 minutes) are not took into account (see Table 4 4). There is also sign difference as far the longitude is concerned, this difference is not considered as a mistake.

Table 4. Comparisons and modifications between the logbook, the rosette sheets and the converted files.

Cast	File	Parameter	Original	New
004	Rosette sheet	Start Lon.	137°59.016	137°5 8.969
007	Rosette sheet	Station	S1.1	S1.2
007	Rosette sheet	Bottom depth	128	189
007	Rosette sheet	Cable length	123	181
007	Rosette sheet	Begin time	11:57	13:25
007	Rosette sheet	Bottom time	12:03	13:30
007	Rosette sheet	End time	12:11	13:48
007	Rosette sheet	Start Lat.	69°40.441	69°4 9.888
007	Rosette sheet	Start Lon.	138°9.72	138° 19.628
007	Rosette sheet	Bottom Lat.	69°40.480	69°49. 9080

007	Rosette sheet	Bottom Lon.	138°9.761	138° 19.7040
007	Rosette sheet	End Lat.	69°40.522	69°4 9.8780
007	Rosette sheet	End Lon.	138°9.781	138° 20.1660
007	Rosette sheet	Comments	Water …	Mauvaise station
009	LogBook	Fond (m)	194	191
010	LogBook	Fond (m)	242	258
013	LogBook	Heure UTC	6:48	6:54
013	Rosette sheet	Begin Time	6:48	6:54
013	LogBook	Lat. (N)	69°59.688	70°1.3920
013	LogBook	Lon. (W)	138°32.870	138°32. 940
013	Rosette sheet	Start Lat.	69°59.688	70°1.3920
013	Rosette sheet	Start Lon.	138°32.870	138°32. 870
014	LogBook	Heure UTC	20:17	20:22
014	Rosette sheet	Begin Time	20:17	20:22
014	LogBook	Prof. Cast	1900	1874
014	Rosette sheet	Cable length	1900	1874
015	LogBook	Heure UTC	02:13	02:18
015	Rosette sheet	Begin Time	02:13	02:18
015	LogBook	Prof. Cast	1906	1879
015	Rosette sheet	Cable length	1906	1879
016	LogBook	Lat. (N)	71°7.154	71°7. 38
015	LogBook	Prof. Cast	1978	1949
015	Rosette sheet	Cable length	1978	1949
017	LogBook	Prof. Cast	2066	2036
017	Rosette sheet	Cable length	2066	2036
017	LogBook	Fond (m)	2015	
017	Rosette sheet	Bottom depth	2015	
018	LogBook	Lon. (W)	139°19.723	139° 20.002
018	LogBook	Prof. Cast	2077	2046
018	Rosette sheet	Cable length	2077	2046

018	LogBook	Fond (m)	2030	
018	Rosette sheet	Bottom depth	2030	
019	LogBook	Prof. Cast	2073	2043
019	Rosette sheet	Cable length	2073	2043
020	LogBook	Prof. cast (m)	2086	2045
020	Rosette sheet	Cable length	2076	2045
021	LogBook	Lon. (W)	139°15.839	139°1 7.839
021	LogBook	Heure UTC	14:39	17:25
021	Rosette sheet	Cable length	2059	2028
021	LogBook	Prof. Cast	2059	2028
022	LogBook	Lat. (N)	74°38.740	74°3 9.164
022	LogBook	Lon. (W)	137°20.890	137°2 2.952
022	Rosette sheet	Cable length	3000	3391
022	LogBook	Prof. Cast	3000	3391
022	Rosette sheet	Bottom depth	3000	
022	LogBook	Fond (m)	3000	
023	Rosette sheet	Cable length	1000	989
023	LogBook	Prof. Cast	1000	989
024	LogBook	Heure UTC	14:12	14:18
024	Rosette sheet	Begin Time	14:12	14:18
026	Rosette sheet	Start Lat.	74°34.134	74°34.1 74
026	Rosette sheet	Cable length	3000	3296
026	LogBook	Prof. Cast	3000	3296
026	Rosette sheet	Bottom depth	3000	
026	LogBook	Fond (m)	3000	
027	LogBook	Lat. (N)	74°26.464	74°2 6.503
027	LogBook	Lon. (W)	136°28.141	136°2 8.106
027	LogBook	Heure UTC	03:35	03:42
027	Rosette sheet	Begin Time	03:35	03:42
027	Rosette sheet	Bottom Time	03:42	03:44

031	Rosette sheet	Cable length	3000	3266
031	LogBook	Prof. Cast	3000	3266
031	Rosette sheet	Bottom depth	3000	
031	LogBook	Fond (m)	3000	
032	Rosette sheet	Cable length	3000	3457
032	LogBook	Prof. Cast	3000	3457
032	Rosette sheet	Bottom depth	3000	
032	LogBook	Fond (m)	3000	
034	Rosette sheet	Cable length	3000	3501
034	LogBook	Prof. Cast	3000	3501
034	Rosette sheet	Bottom depth	3000	
034	LogBook	Fond (m)	3000	
035	Rosette sheet	Station	L11	L1.1
040	Rosette sheet	Start Lon.	136°3.226	13 7°3.226
040	Rosette sheet	Bottom Lon.	136°3.33	13 7°3.33
040	Rosette sheet	End Lon.	136°3.49	13 7°3.49
040	LogBook	Lon. (W)	136°3.226	13 7°3.226
041	LogBook	Lon. (W)	136°4.136	13 7°4.136
043	LogBook	Lon. (W)	136°8.716	13 7°8.716
044	LogBook	Heure UTC	23:17	23:19
044	LogBook	Lat. (N)	72°37.316	72°37.3 69
044	LogBook	Lon. (W)	137°19.655	137°19.6 32
045	Rosette sheet	Begin time	23:51	23:52
045	LogBook	Prof. cast (m)	80	85
047	Rosette sheet	Start Lat.	70°50.098	70°50. 149
047	LogBook	Lon. (W)	136°2.844	136°2.8 94
049	Rosette sheet	Cable length	982	971
049	LogBook	Prof. Cast	982	971
054	LogBook	Fond (m)	750	765
054	LogBook	Prof. Cast (m)	765	742

054	Rosette sheet	Cable length	750	742
056	LogBook	Prof. Cast (m)	743	736
056	Rosette sheet	Cable length	743	736
057	LogBook	Lon. (W)	136°17.689	136° 16.974
057	LogBook	Heure UTC	11:33	11:38
057	Rosette sheet	Begin Time	11:33	11:38
057	LogBook	Prof. Cast (m)	614	609
057	Rosette sheet	Cable length	614	609
060	LogBook	Prof. Cast (m)	970	959
060	Rosette sheet	Cable length	970	959
061	Rosette sheet	Start Lon.	136°33.934	13 5°33.934
061	Rosette sheet	Bottom Lon.	136°34.082	13 5°34.082
061	Rosette sheet	End Lon.	136°34.135	13 5°34.135
065	LogBook	Prof. Cast (m)	585	579
065	Rosette sheet	Cable length	585	579
070	LogBook	Prof. Cast (m)	752	743
070	Rosette sheet	Cable length	752	743
073	Rosette sheet	UTC Date	01/10/01	09/10/01
073	Rosette sheet	UTC Date	01/10/01	09/10/01
073	LogBook	Prof. Cast (m)	996	983
073	Rosette sheet	Cable length	996	983
074	LogBook	Prof. Cast (m)	668	661
074	Rosette sheet	Cable length	668	661
076	LogBook	Prof. Cast (m)	688	680
076	Rosette sheet	Cable length	688	680

Moreover, some metadata are different between 2 sets of data but it is difficult to confirm the good value (see table 5).

So the final odf files have been updated with the time extracted from the log book.

Table 5. Metadata values impossible to confirm.

Cast	Parameter	File 1	Value 1	File 2	Value 2
040	Bottom	Rosette sheet	2558	LogBook	2554
041	Bottom	Rosette sheet	2560	Logbook	2554
042	Bottom	Rosette sheet	2560	Logbook	2554

1.5. Compute new calibration coefficients for SBE 43 oxygen sensor.

The Sea-Bird's application note N° 64-2 was used to compute much accurate calibrations thanks to Winkler titrations (table 6). See the report "Tests to configure SBE43 data for the cruise Geotraces-IOL 0903.pdf" to have the complete description of the analysis.

Table 6. Calibration coefficients for the sn 0240 SBE43 sensor.

	Original	Winkler derived
Soc	0.361900	0.37946
Voffset	-0.4886	-0.4886

1.6. Compute the time alignment correction for dissolved oxygen data.

The oxygen data must be corrected in time relative to the pressure because of the long time constant of the sensor and because of the water time transit through the pipe.

The data analysis shows that a correction of **5** seconds gives the best results. See the report "Tests to configure SBE43 data for the cruise Geotraces-IOL 0903.pdf" to have the complete description of the analysis.

1.7. Format bottle salinity data file for CTD comparison.

Similarly to the oxygen sensor, field titrations are used to compute accurate coefficients. See the report “Étalonnage du capteur de nitrate durant la mission Geotraces-IOL 0903” (in French only) to have the complete description of the analysis.
Although there was a unique nitrate sensor, the analysis shows that 2 sets of calibration are needed as following (see table 7).

Table 7. Calibration coefficients for the sn 132 nitrate sensor.

Casts	Coefficient	Original value	Optimized value
001 to 045	A_0	-8.2328	-13.7664
001 to 045	A_1	27.017	21.4513
046 to 076	A_0	-8.2328	15. 5198
046 to 076	A_1	27.017	28.4067

1.8. Format bottle salinity data file for CTD comparison.

229 autosal measurements have been used for the comparison with the CTD data.

2. DATA PROCESSING.

2.1. The “Data Conversion” module: raw data conversion.

This step is used from the updated SBE Data Processing 7.20 software.

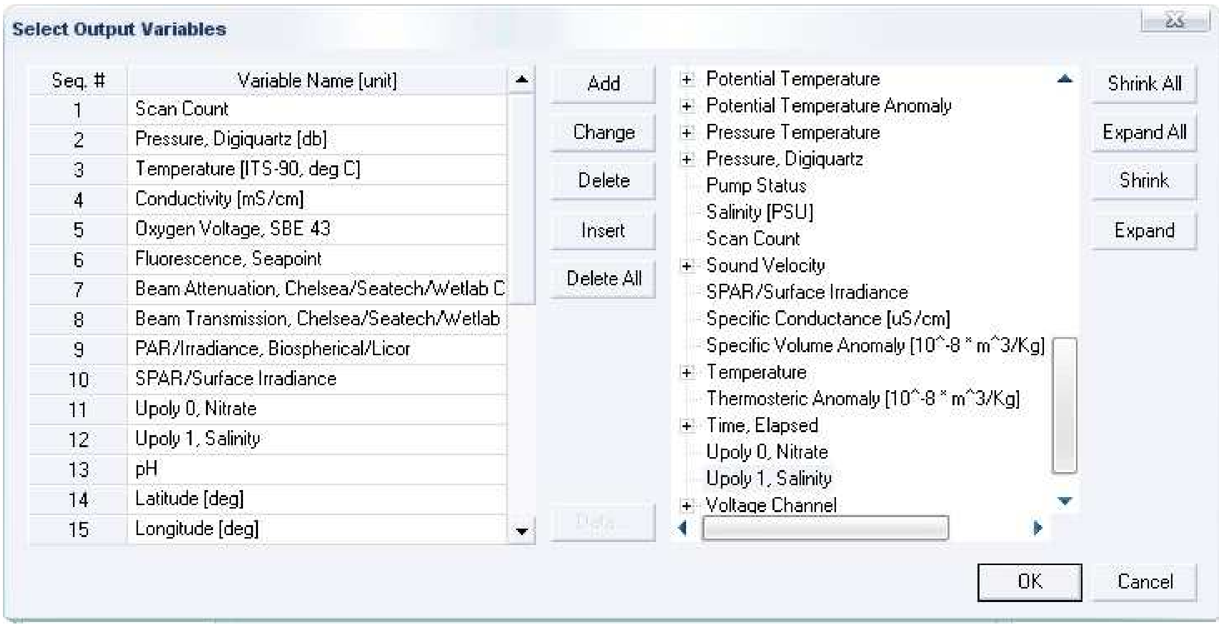

Figure 1. The “Data Conversion” module.

2.2. Data Extraction.

This step (performed through the Matlab software) is particularly useful to eliminate useless data such as those corresponding to sensor acclimatization period (“the surface soak”).

This step allows to detect miscellaneous problem:

- The cast 009 is only 10 db depth.
- The cast 013 starts at 15.5 db.
- The cast 021 starts at 17 db.
- The cast 023 starts at 33 db.
- The cast 041 is only 10 db depth.
- The cast 042 is only 10 db depth.

Also, this step is useful to detect pressure spikes (see figure 2 for an example). The original values are replaced by the Sea-Bird “bad flag” value (-9.990e-29) into the corresponding Sea-Bird converted files. Pressure spikes are usually associated by unreliable value of other parameters such as conductivity and temperature. The corresponding data into the derived ODF file is associated with a flag value equals to 5 ("the data was modified").

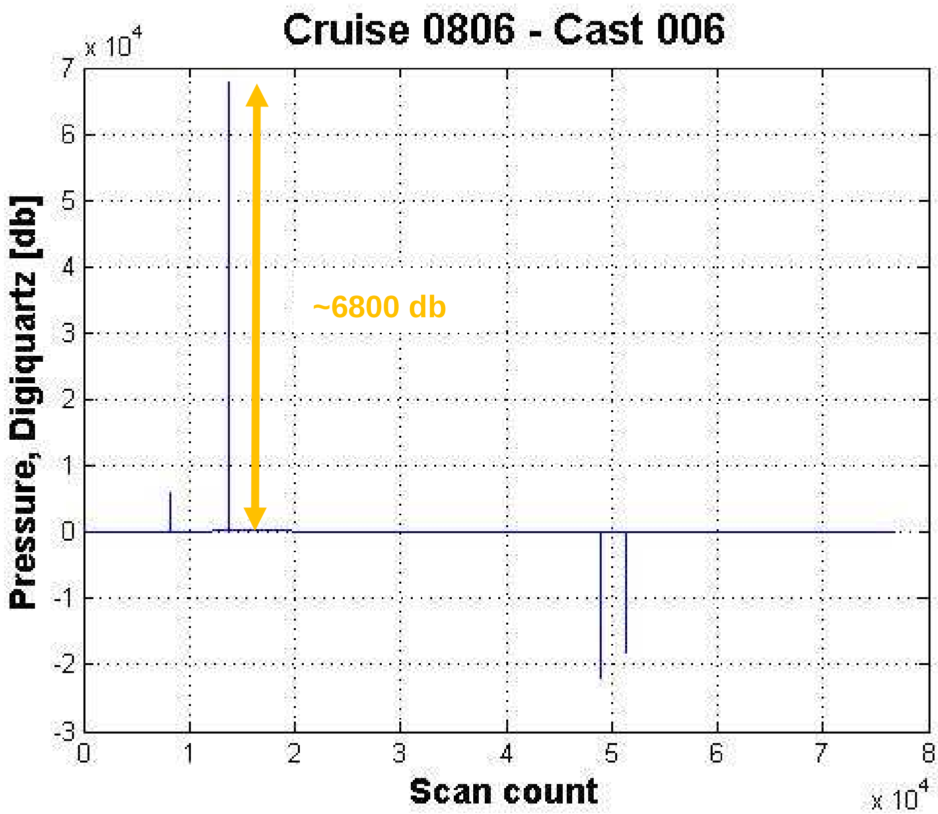

Figure 2. Example of evolution of a spiky pressure.

2.3. The "Wild Edit" module.

I have decided to put out this module from the SBE Data Processing sequence in order to keep unchanged at the most the original data. The outliers will be removed by the control quality sequence. Nevertheless, the previous step "Data Extraction" allows to detect the main pressure spikes which are often associated by temperature and conductivity spikes.

As far as the ctd 911*plus* is concerned, it is necessary to detect the temperature outliers and to cancel them because the temperature values are used into the module "Cell Thermal Mass" (see figure 3 as an example). Moreover, major temperature spikes have an impact upon derived variables using temperature such as salinity and oxygen from SBE43 (see figure 4 as an example).

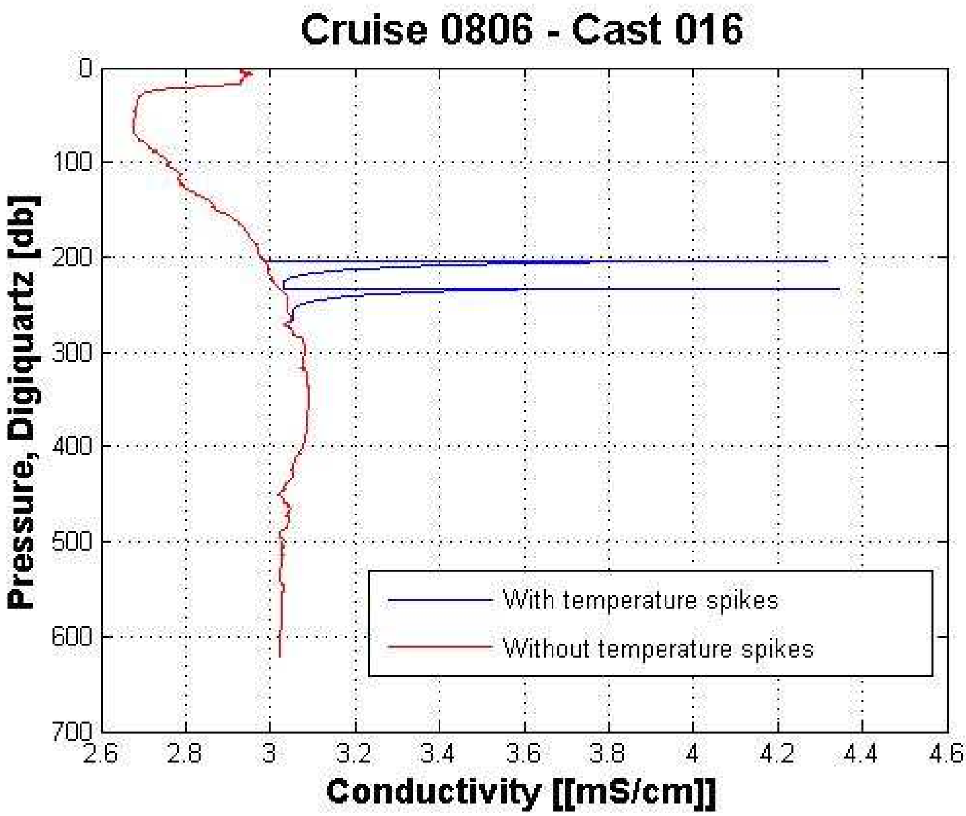

Figure 3. Example of the impact of temperature spikes upon the conductivity variable through the “Cell Thermal” module.

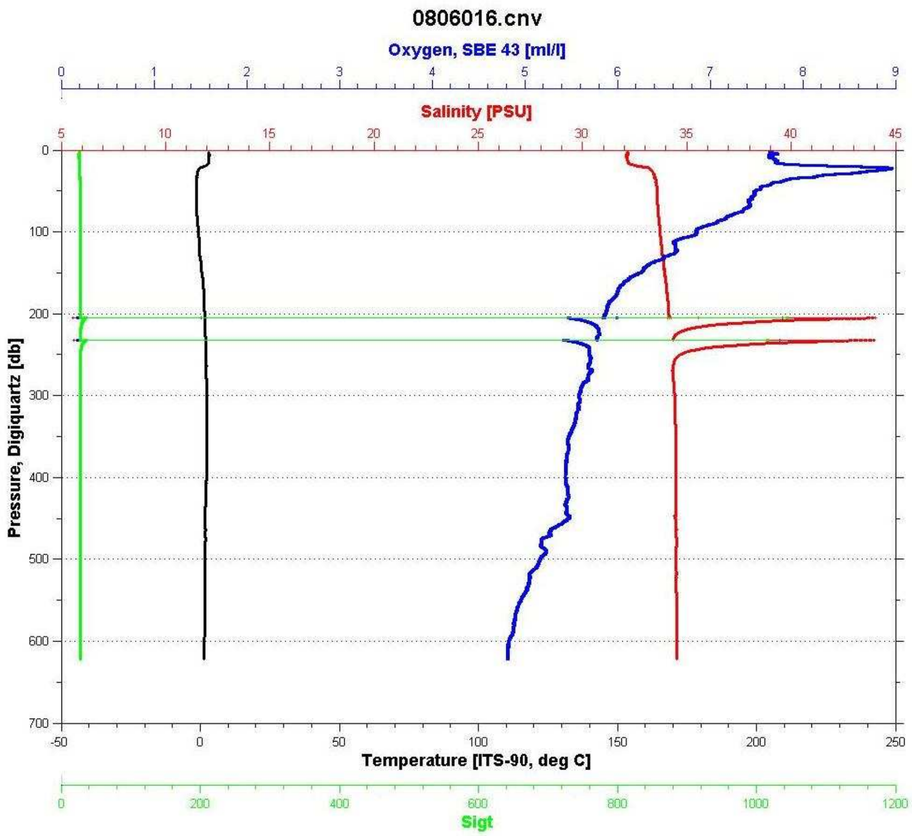

Figure 4. Example of the impact of temperature spikes upon the derived variables such as oxygen, salinity and density.

2.4. The "Filter" module.

This module allows to apply a low-pass filter in order to smooth high-frequency data. The new Sea-Bird's documentation henceforth suggests to apply this module only on the pressure data.

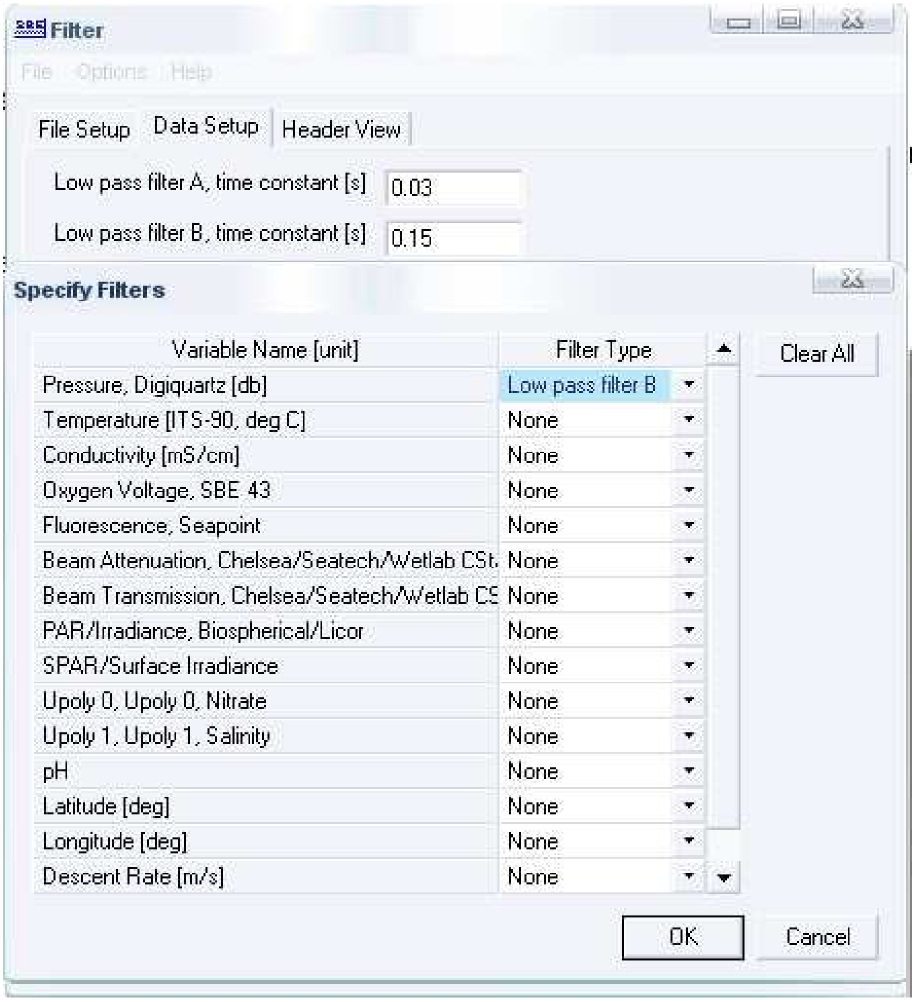

Figure 5. The “Filter” module

2.5. The “Align CTD” module.

The corrections (**5 seconds**) have been applied to align oxygen data relative to pressure. This correction allows to resolve the systematic time delay between oxygen and pressure data which is due to the long time constant of the sensor and to the time transit of the water through the pipe.

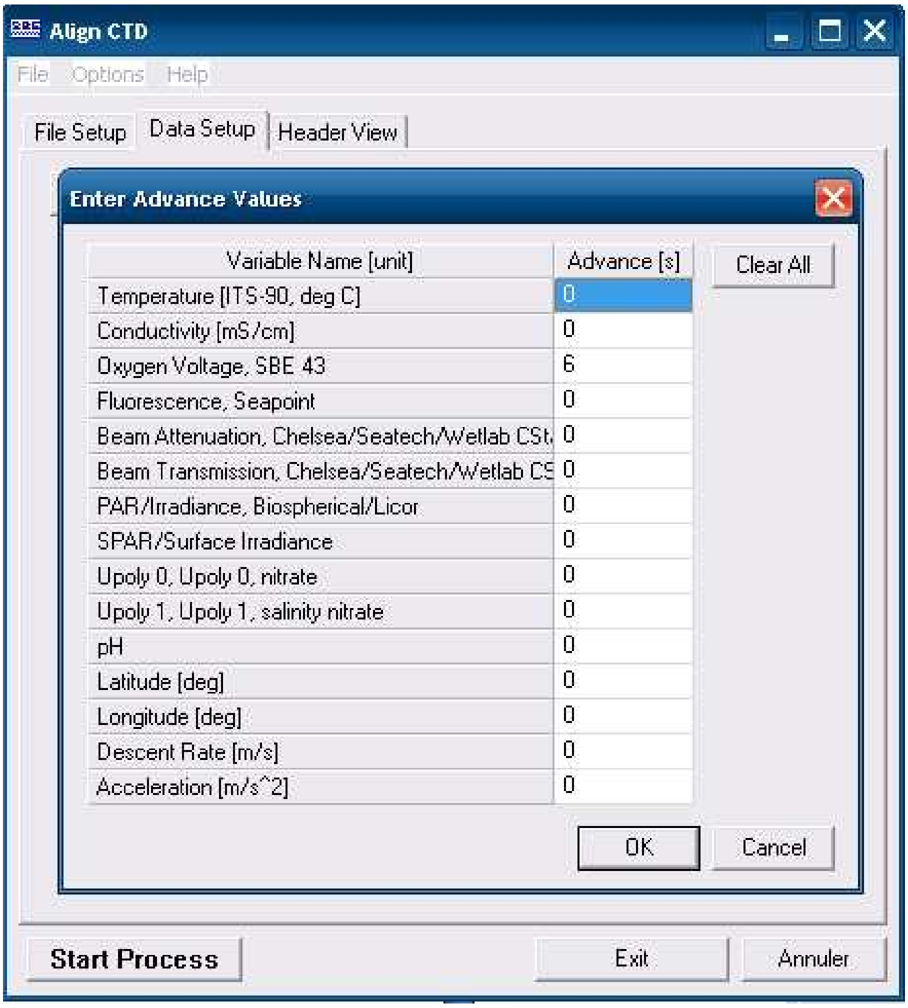

Figure 6. The Align Ctd module.

2.6. The “Cell Thermal Mass” module

This module concerns the conductivity parameter. It permits to remove conductivity cell thermal mass effects. It was set with the default value.

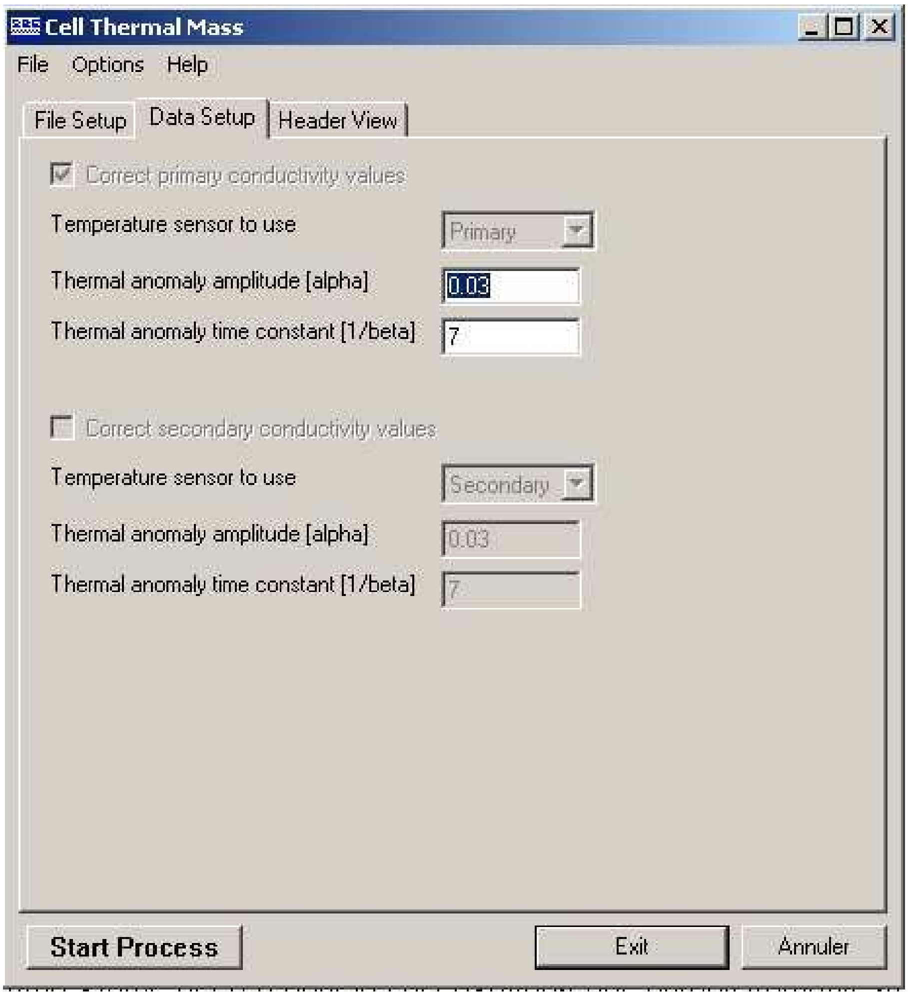

Figure 7. The “Cell Thermal Mass” module.

2.7. The “Loop Edit” module.

This module marks with the bad flag value records with pressure slowdowns or reversals.

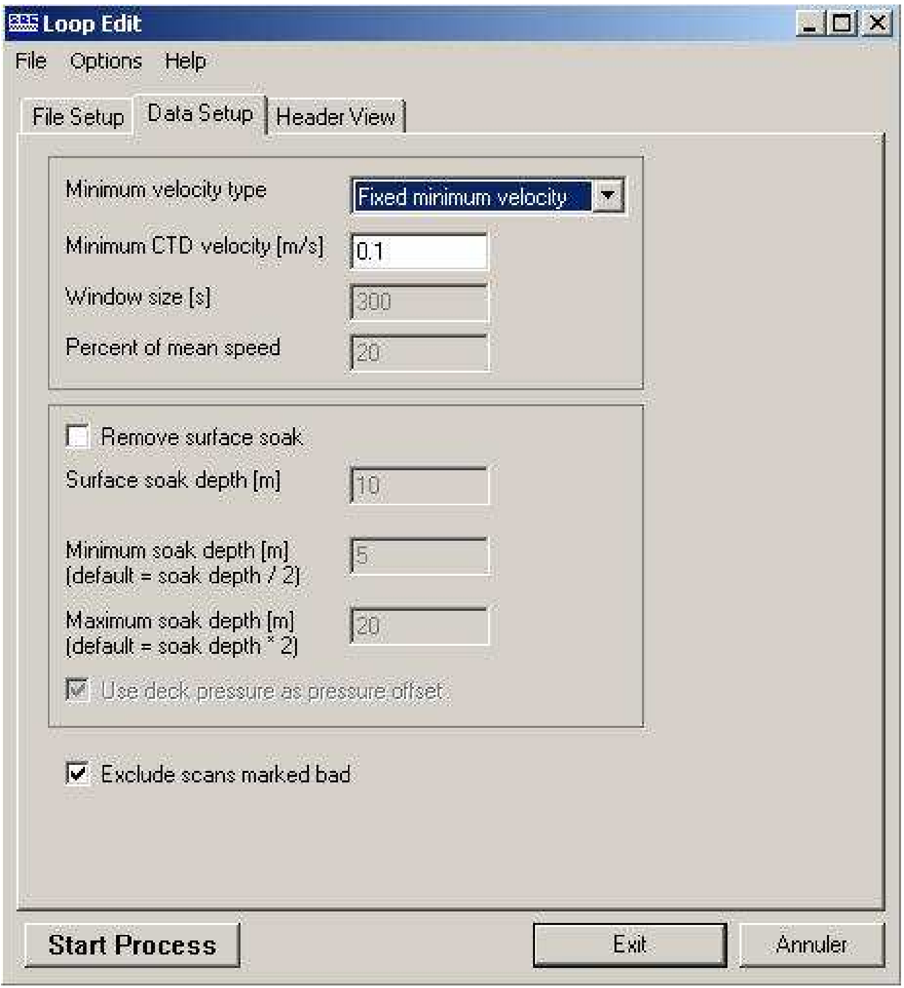

Figure 8. The "Loop Edit" module.

2.8. The "Derive" module.

This module allows to compute additional oceanographic parameters as shown in the next figure.

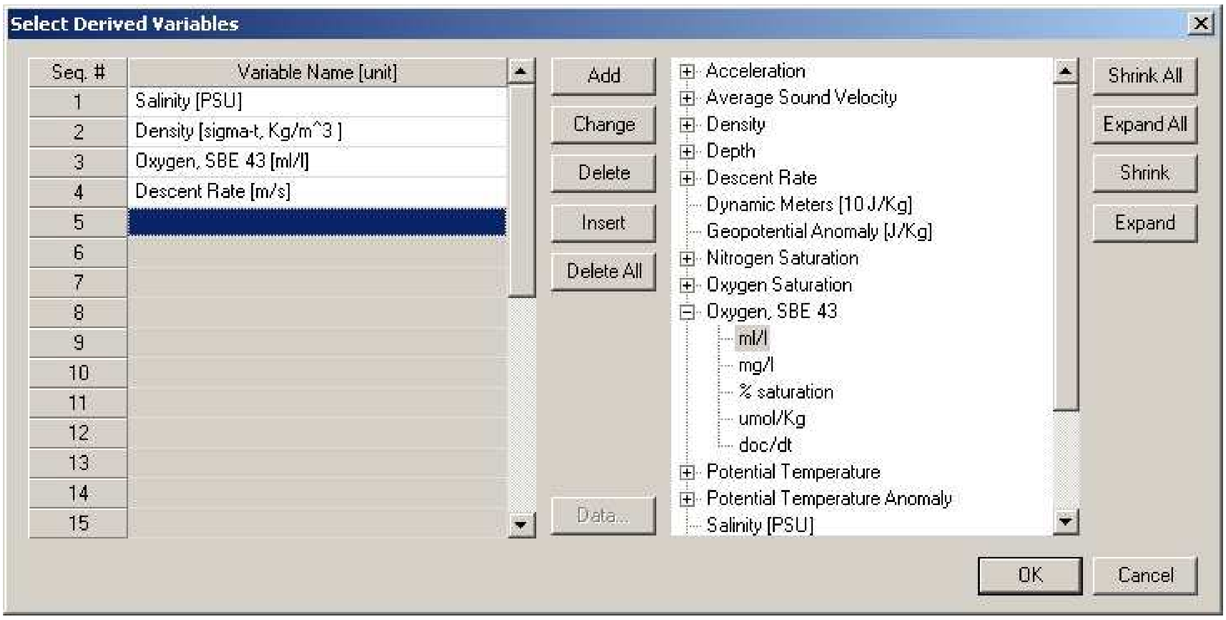

Figure 9. The “Derive” module.

2.9. The Median Filter module.

No median filter has been applied.

2.10. Detect 9plus pump problem

This step allows to detect that the pump works correctly that ensures that a best data quality for the sensors plumbed with the pump as conductivity and oxygen (see the corresponding Sea-Bird application note).

A simple matlab function has permitted to check that there is some pump problems for the following casts (see Table 8).

Table 8. Detect pump issue.

	Scan Count		Pressure [db]		
Cast	Start	End	Start	End	Direction
012	22491	22492	1.363	1.362	Upcast
049	172	774	2.693	29.354	Downcast

2.11. The “Strip” module.

This module allows to extract columns. In this part, the following variables are cancelled: the “Pump Status” and the “Descent Rate”, both from the coming from the “Data Conversion” module. This “Descent Rate” variable is henceforth useless because there is a more accurate “Descent Rate” variable calculated from the “Derive” module.

3. THE DATA QUALITY CONTROL.

3.1. Miscellaneous remarks.

- All the casts have been recorded from the deck.
- The first data corresponding to the subsurface (about the first 15 db) might be characterized by large and chaotic variations or even by large density inversions. It is well known that salinity data are much influenced as temperature by low velocities and that the best quality data are collected from a 1 m/s rosette descent rate. For some casts in subsurface, it is quite difficult to detect if salinity and temperature variations are physically valid or if the data profile is caused by a combination of a low rosette velocity (CTD acceleration from 0 to 1 m/s) and the influence of the ship hull and movement (stabilization).

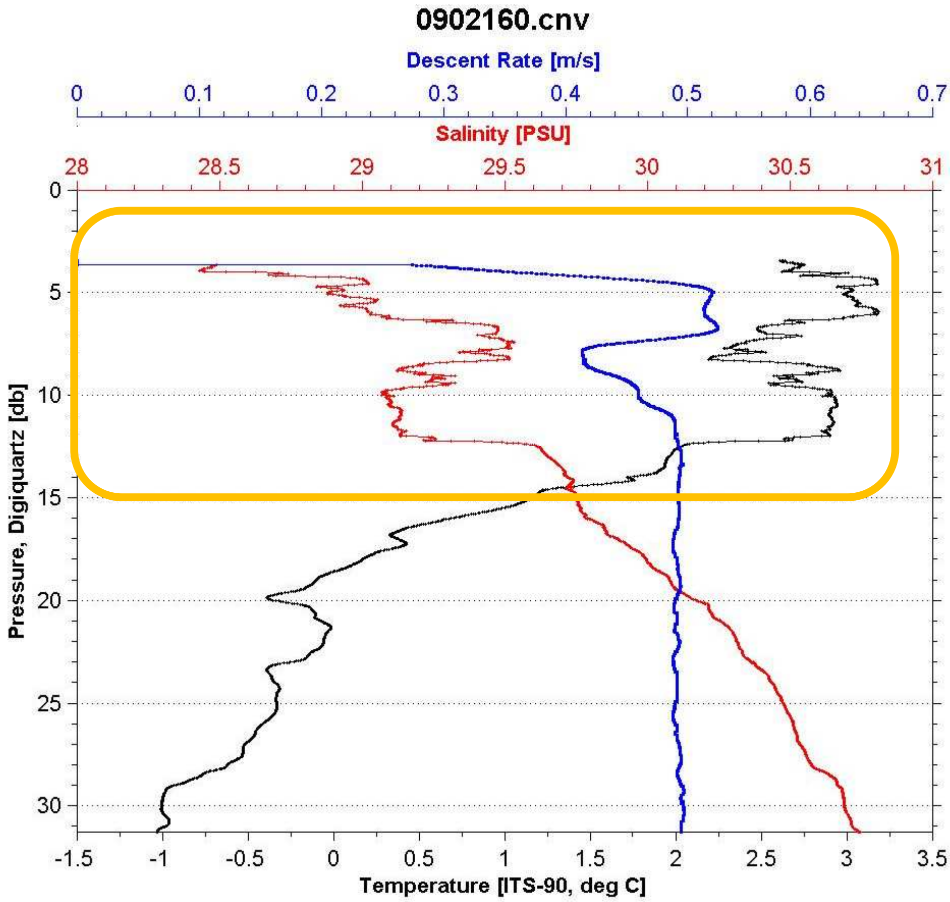

Figure 10. An example of irregular temperature and salinity variations at the surface.

- At the bottom, it is current to record noisy data and chaotic variations. These artefacts may often be linked with the rosette deceleration (see figure 13).

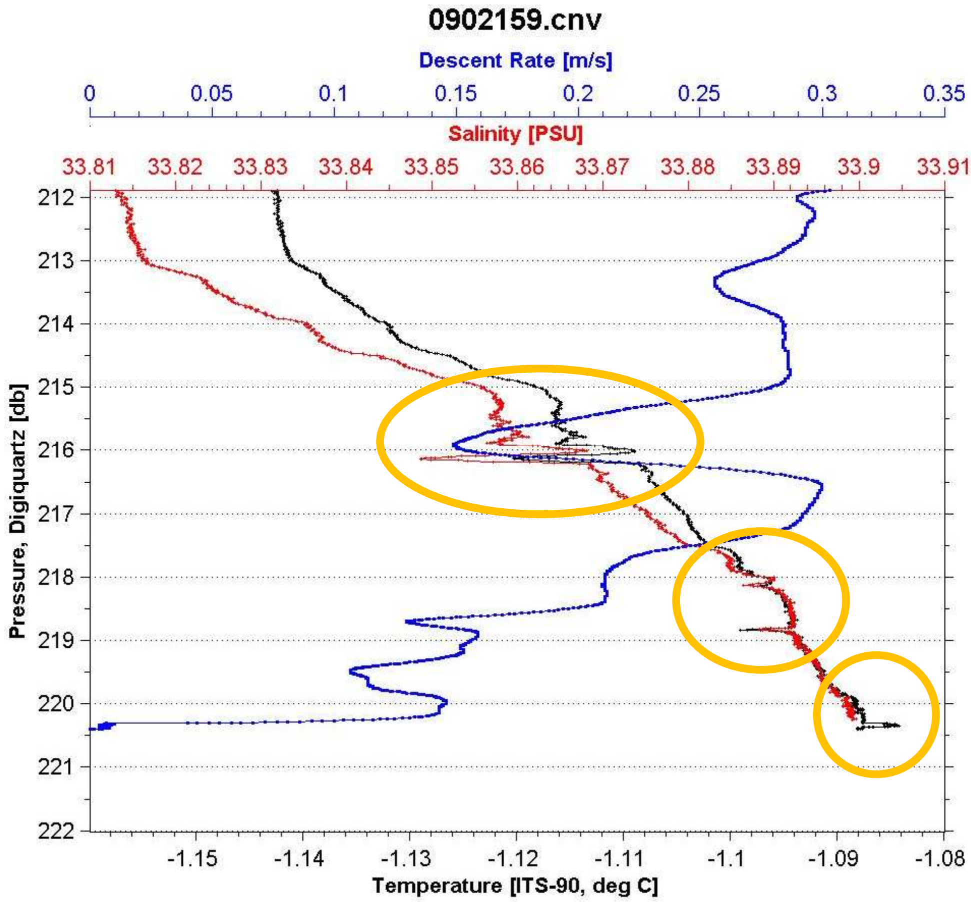

Figure 11. An example of doubfull data occuring during the rosette deceleration at the bottom.

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- For some casts, there may have some oxygen spikes coinciding with a sharp temperature gradient. Although these artefacts seem to be doubtful and may be produced by an inappropriate Sea-Bird algorithm, no data is flagged as doubtful (see annex A for more details).
- For some casts, there may have several very little oxygen spikes.

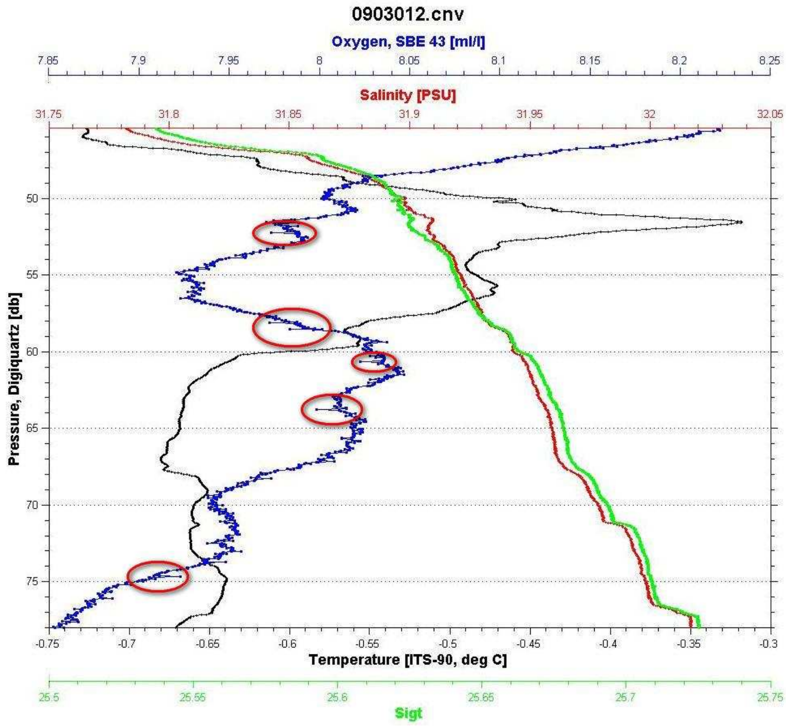


Figure 12. Example of spiky oxygen profile.

- For some casts (014 to 045), the temperature and salinity profiles are step like (figure 13). This phenomenon is restricted to pressure between 200 and 400 db. These pressures correspond to a “sharp” temperature gradient (from -1 to 0.8 ℃). The corresponding ascendant profile is much sm oother (figure 14). One must notice that the conductivity data present also a step like evolution. This evolution seems to be real (double diffusive convection). Sea-Bird has been contacted to eliminate technical issue.

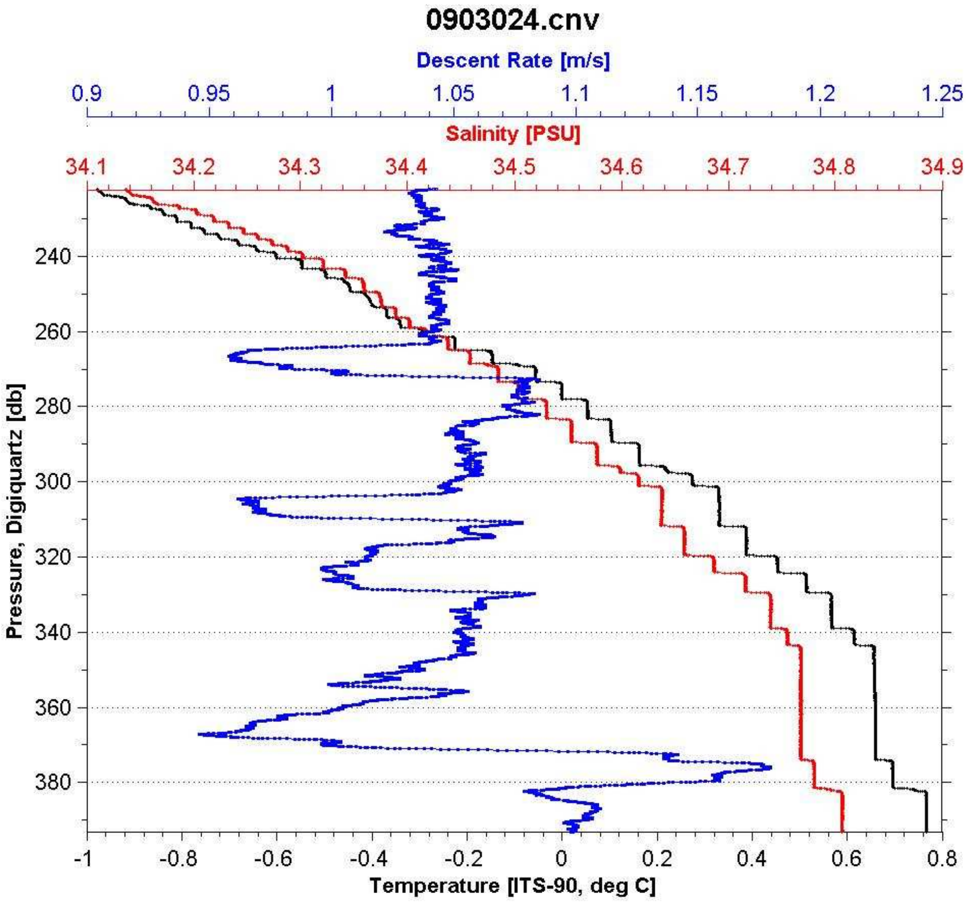


Figure 13. Example of a staircase profile evolution.

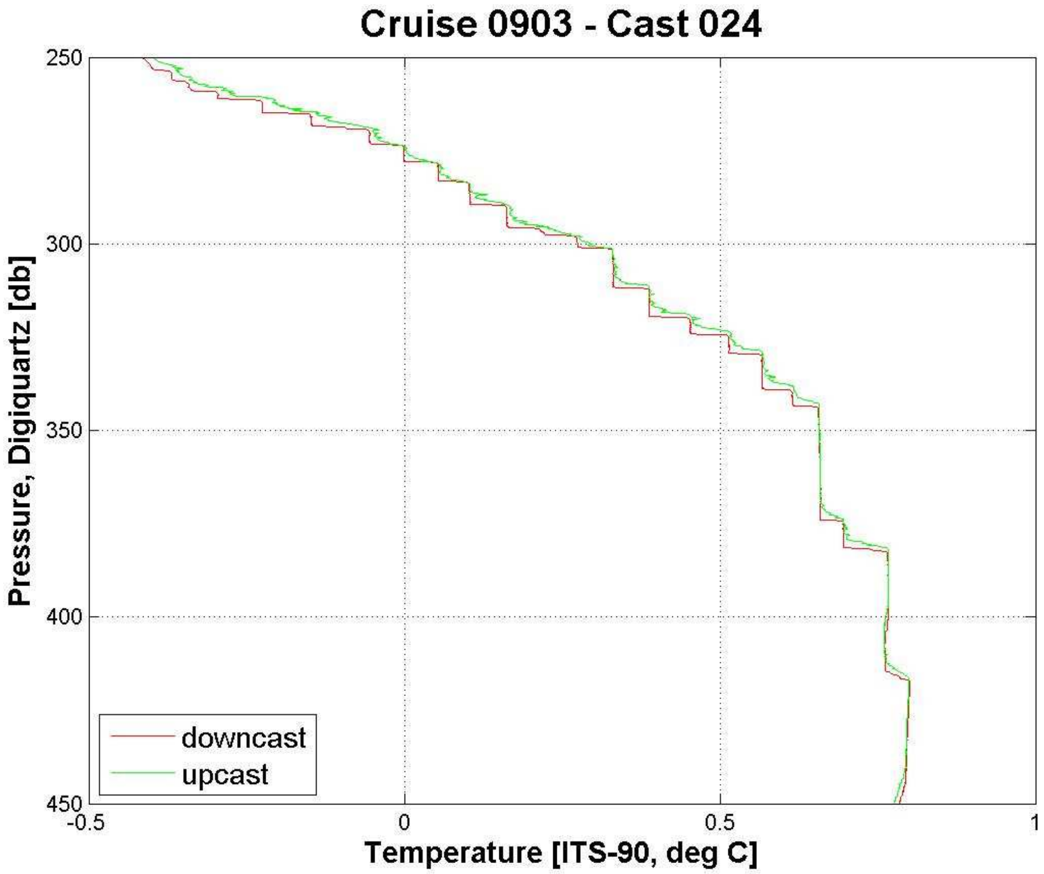


Figure 14. Example of a staircase ascendant and descendant profile evolution.

3.2. A little reminder about the used quality flag.

0 ➔ no quality control.

1 ➔ the element appears to be correct.

2 ➔ the element appears to be inconsistent with other elements (never used).

3 ➔ the element appears to be doubtful.

4 ➔ the element appears to be erroneous.

5 ➔ the value was modified.

3.3. List of the carried out tests.

Test 1.1: GTSPP Platform Identification

Test 1.2: GTSPP Impossible Date/Time

Test 1.3: GTSPP Impossible Location

Test 1.4: GTSPP Position on Land

Test 1.4: GTSPP Position on Land

Test 1.5: GTSPP Impossible Speed

Test 1.6: GTSPP Impossible Sounding

Test 5.1: GTSPP Cruise Track Visual Inspection

Test 2.0: IML Minimum Descent Rate (2) (0.10m/s)

Test 2.1: GTSPP Global Impossible Parameter Values (4)

Test 2.3: GTSPP Increasing Depth (16)

Test 2.4: GTSPP Profile Envelope (Temperature and Salinity) (32)

Test 2.6: GTSPP Freezing Point (128)

Test 2.7: GTSPP Spike in Temperature and Salinity (one point) (256)

Test 2.8: GTSPP Top and Bottom Spike in Temperature and Salinity (512)

Test 2.9: GTSPP Gradient in Temperature and Salinity (1024)

Test 2.11: IML Spike in Pressure, Temperature and Salinity (one point or more) (4096)

Test 5.2: GTSPP Profile Visual Inspection

3.4. Cruise Track Visual Inspection.

The location map is based on the geographic coordinates recorded into the logbook.

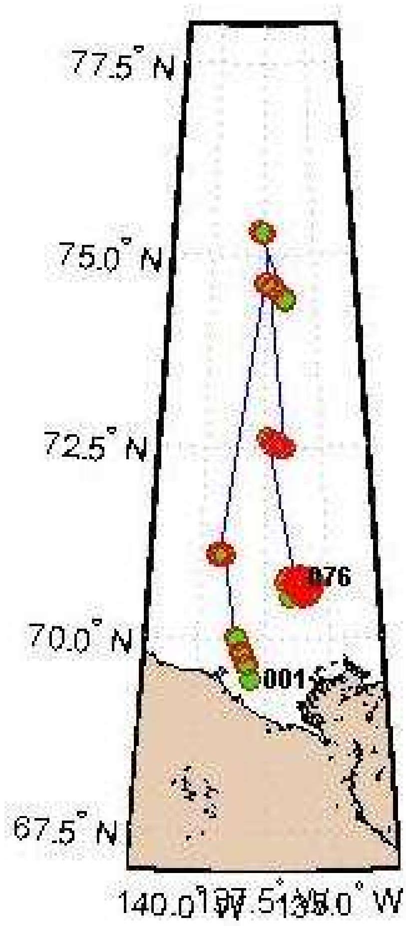


Figure 15. The 0903 location map.

- The cast **052** is **6.6** km far from the casts **051** although they had been recorded at the same station (**101**).
- The casts **14** to **21** have been the same station name (L1) although they have been distant of up 12.5 km.
- The casts **22** to **31** have been the same station (L2) name although they have been distant of up 37 km.
- The casts **35** to **45** have been the same station (L1.1) name although they have been distant of up 37 km.

3.5. Profile Visual Inspection.

*******The casts 001 to 004 have been recorded at the same station S1.**

001 ➔ The rosette drop is chaotic that leads to some doubtful data.

002 ➔ There is an oxygen artefact at 10 db coinciding with a thermocline.

003 ➔ Nothing to notice.

004 ➔ There is an oxygen artefact at 10 db coinciding with a thermocline.

*******The casts 005 to 006 have been recorded at the same station S1.1.**

005 ➔ There is an oxygen artefact at 6 db coinciding with a thermocline.

006 ➔ There is an oxygen artefact at 7 db coinciding with a thermocline.

*******The casts 007 to 009 have been recorded at the same station S1.2.**

007 ➔ Nothing to notice.

008 ➔ The end of the profile is quite noisy due to the rosette deceleration.

The rosette descent rate is quite irregular.

009 ➔ Only 10 db depth. As the upcast profile is much smoother (see the 2 figures), the traditional downcast profile is left behind.

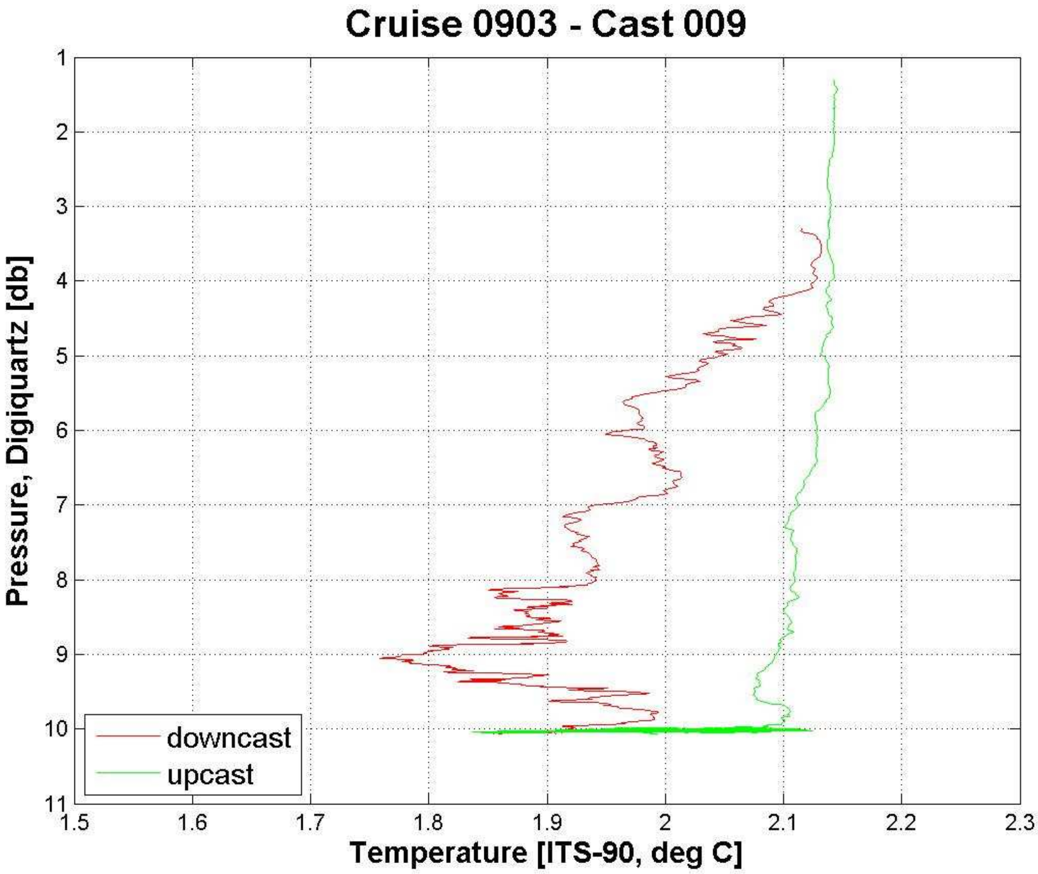


Figure 16. The ascendant and descendant temperature profiles for the cast 009.

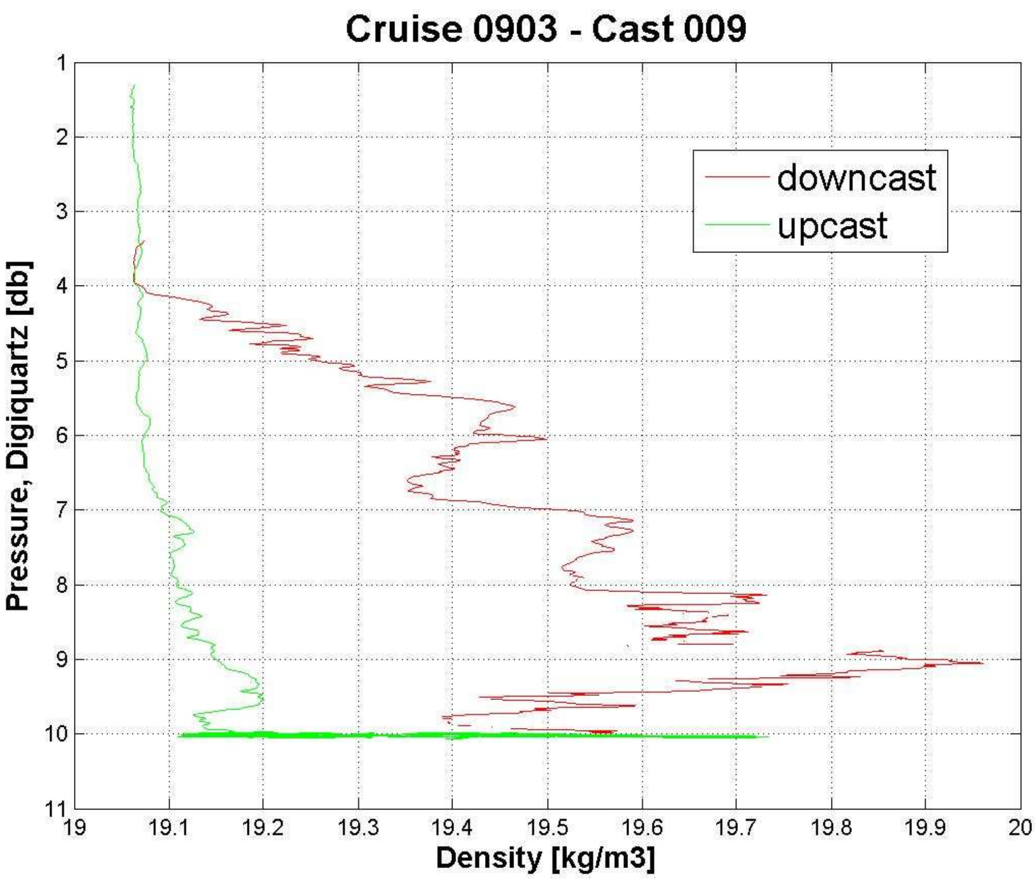


Figure 17. The ascendant and descendant density profiles for the cast 009.

*******The casts 010 to 013 have been recorded at the same station S2.**

010 ➔ The first 14 db are quite irregular.

011 ➔ Nothing to notice.

012 ➔ Nothing to notice.

013 ➔ Nothing to notice.

*******The casts 014 to 021 have been recorded at the same station L1.**

014 ➔ There is a rosette stop at 124 db leading to doubtful data. The temperature and salinity profiles are step like for some sections.

015 ➔ The rosette drop from 1726 db until the end 1910 end is very chaotic. The temperature and salinity profiles are step like between 365 db and 390 db.

016 ➔ There are several rosette stops (908, 1563 and 1578 db). The temperature and salinity profiles are step like between 230 db and 340 db.

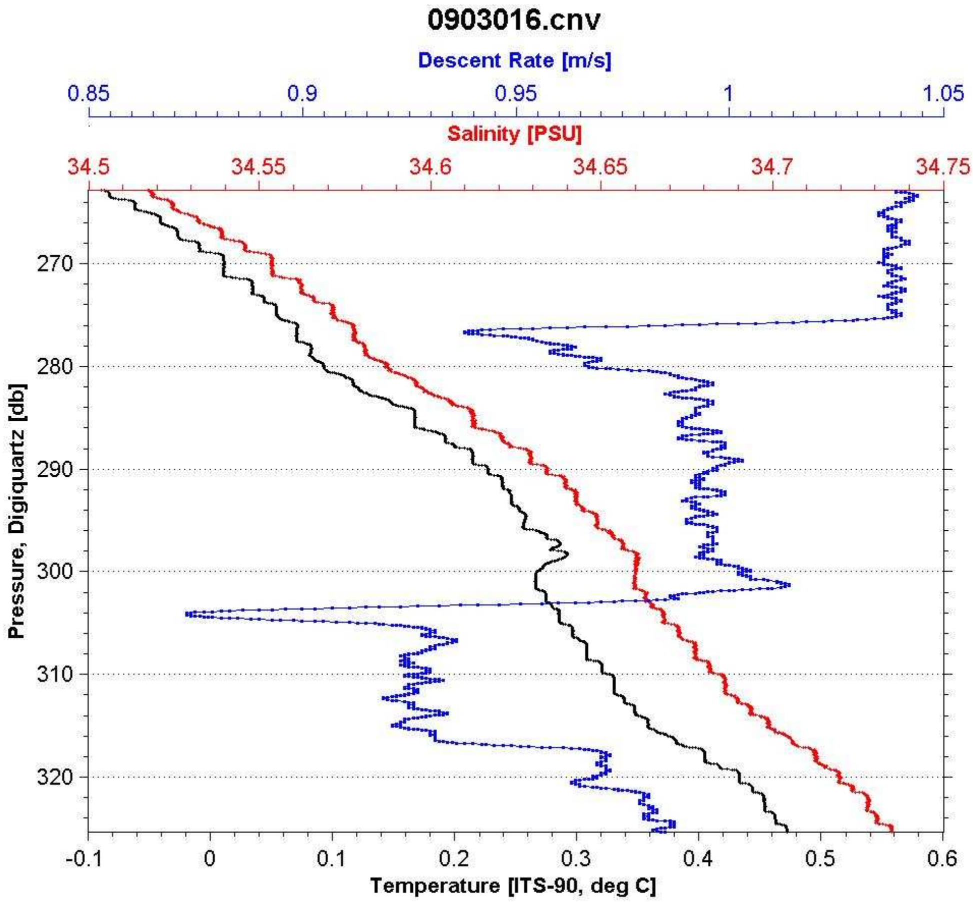


Figure 18. Evolution of the descendant temperature and salinity for the cast 016.

017➔ The temperature and salinity profiles are step like for several sections.

018➔ The temperature and salinity profiles are step like for several sections.

019 ➔ There is a density inversion at the surface which may be detected on the ascendant profile. The temperature and salinity profiles are step like for several sections.

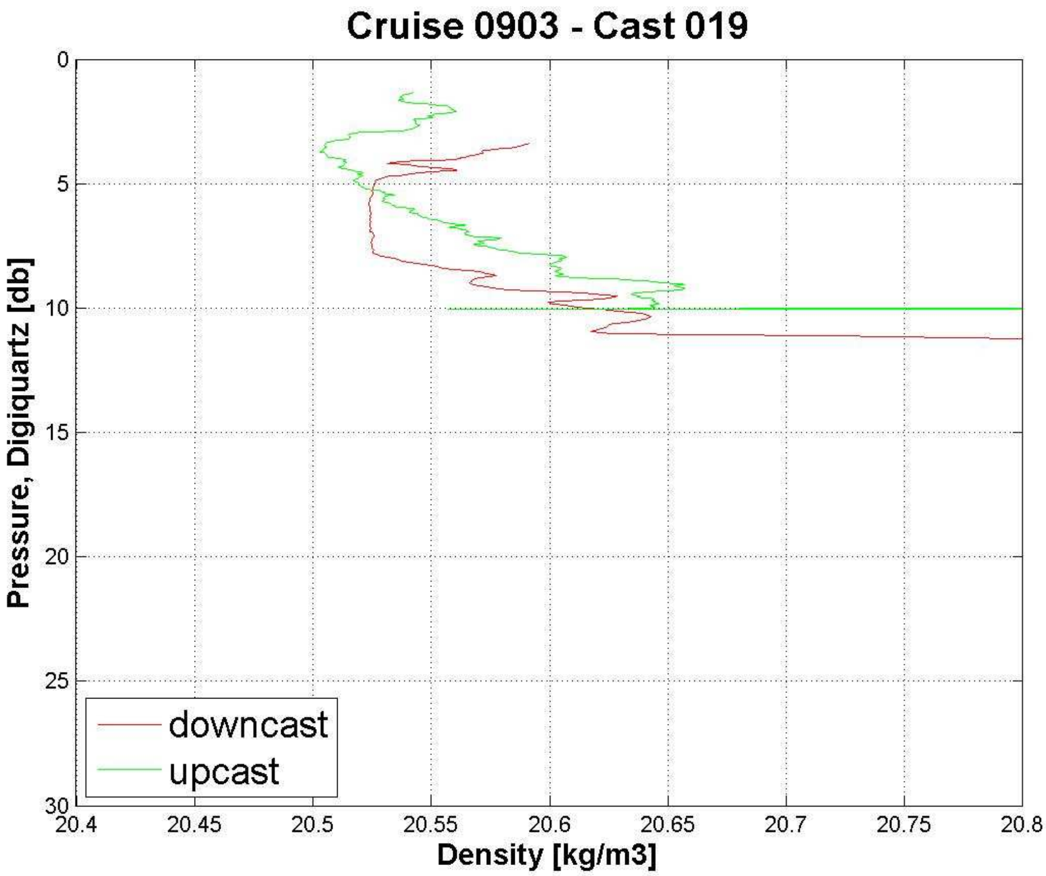


Figure 19. Evolution of the ascendant and descendant density evolution at the surface for the cast 019.

020➔ The temperature and salinity profiles are step like for several sections.

021 ➔ The cast starts at 17 db. The temperature and salinity profiles are step like for several sections.

022 ➔ The temperature and salinity profiles are step like for several sections.

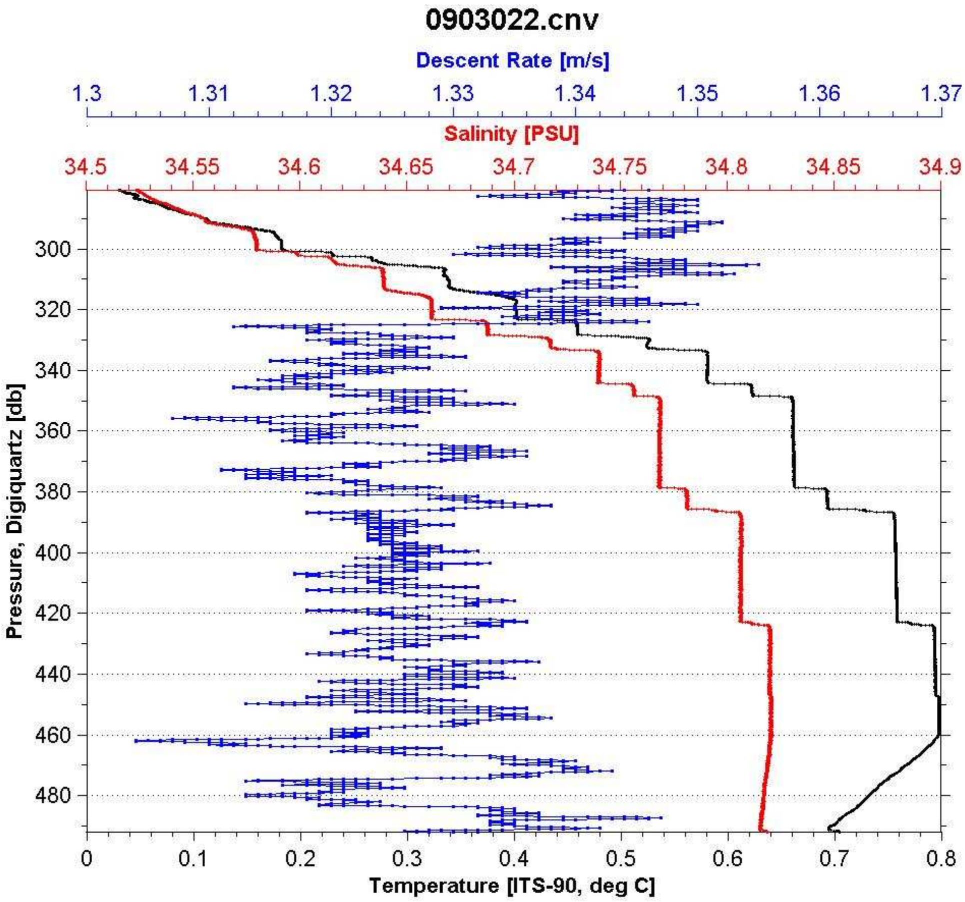


Figure 20. Evolution of the descendant temperature and salinity for the cast 022.

*******The casts 022 to 031 have been recorded at the same station L2.**

023 ➔ The cast stats at 33 db. The temperature and salinity profiles are step like for several sections.

024 ➔ The temperature and salinity profiles are step like for several sections.

025 ➔ The temperature and salinity profiles are step like for several sections.

026 ➔ There is a rosette stop at 1475 db. The temperature and salinity profiles are step like for several sections.

027 ➔ There is an oxygen artefact at 18 db coinciding with a thermocline.

028 ➔ Nothing to notice.

029 ➔ Nothing to notice.

030 ➔ Nothing to notice.

031 ➔ There is a temperature artefact at the surface which is not recorded on the ascendant profile. The temperature and salinity profiles are step like from 215 to 420 db.

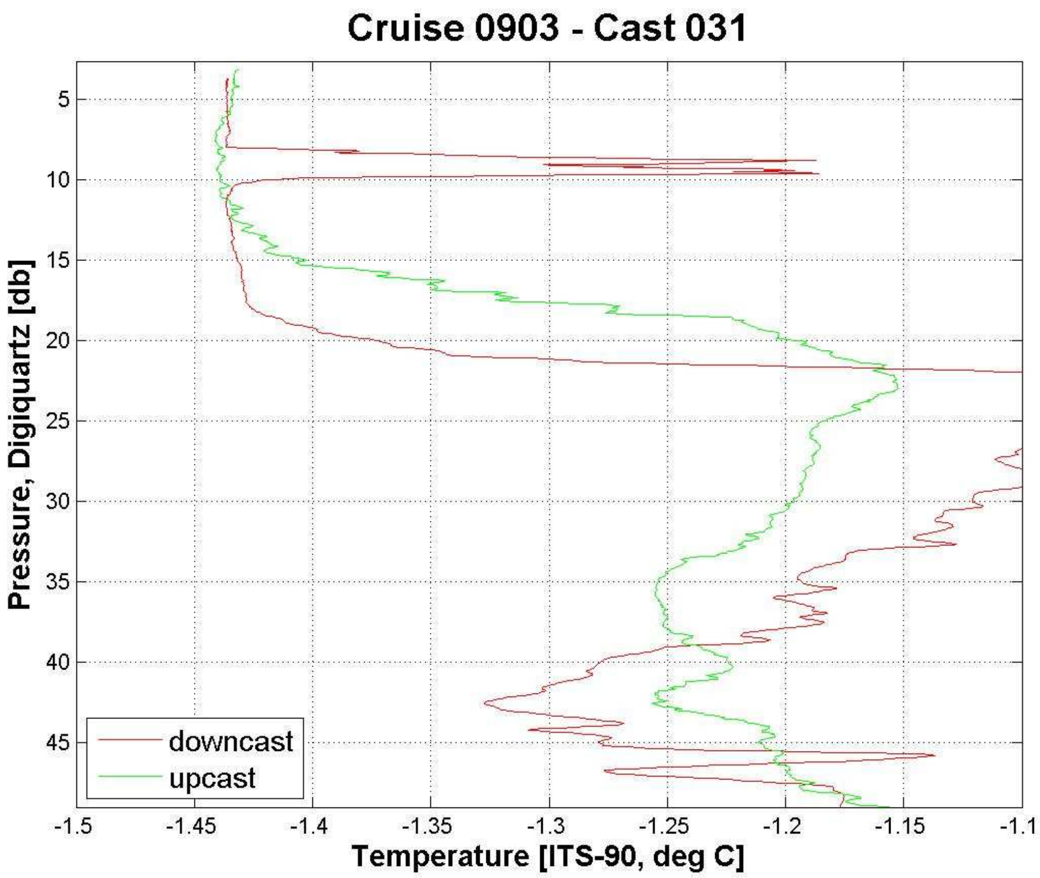


Figure 21. Evolution of the ascendant and descendant temperature evolution at the surface for the cast 031.

*******The casts 032 to 034 have been recorded at the same station L3.**

032 ➔ There is a density inversion at the surface which is not recorded on the ascendant profile. The temperature and salinity profiles are step like from 215 to 420 db.

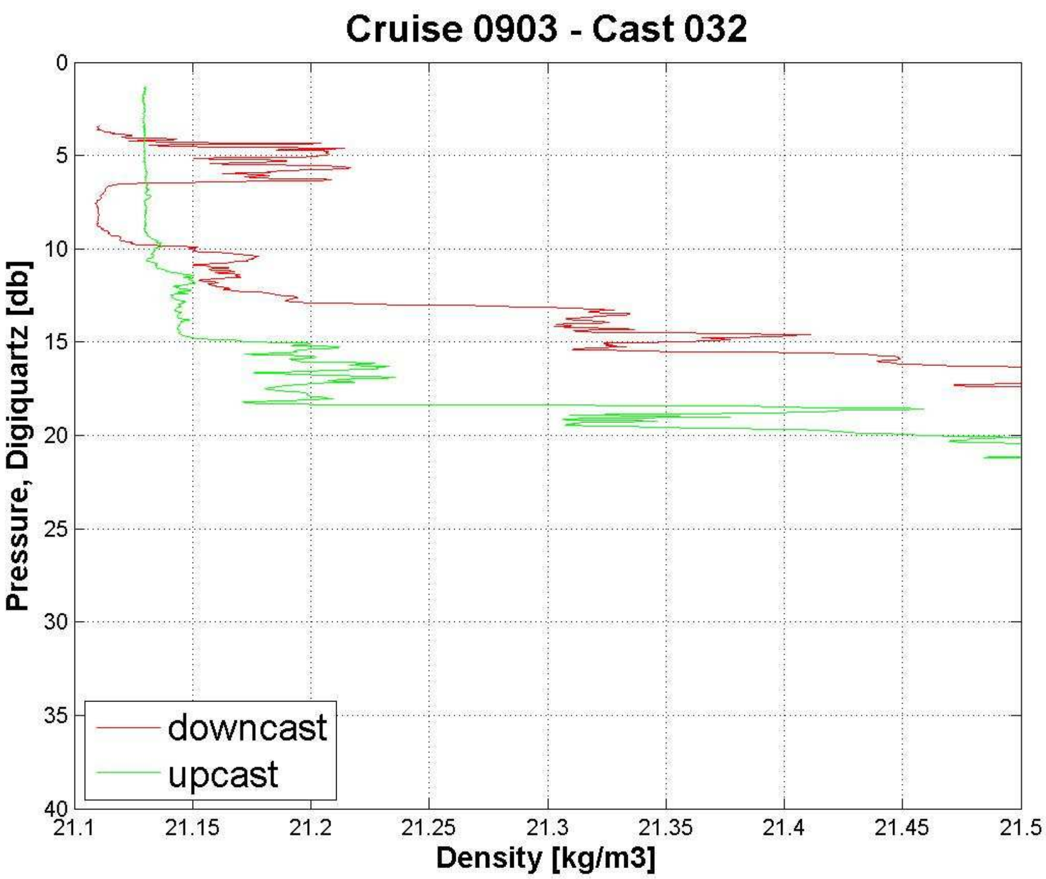


Figure 22. Evolution of the ascendant and descendant density evolution at the surface for the cast 032.

033 ➔ Nothing to notice.

034 ➔ The temperature and salinity profiles are step like from 215 to 420 db.

*******The casts 035 to 045 have been recorded at the same station L1.1.**

035 ➔ There is a density inversion at the surface which may be detected on the ascendant profile. The temperature and salinity profiles are step like from 215 to 420 db.

036 ➔ The temperature and salinity profiles are step like from 220 to 340 db. There is a gap between the oxygen profile and the other casts of the same station. The cast 036 is distant of 4.9 km from the cast 035 and 3.4 from the cast 037.

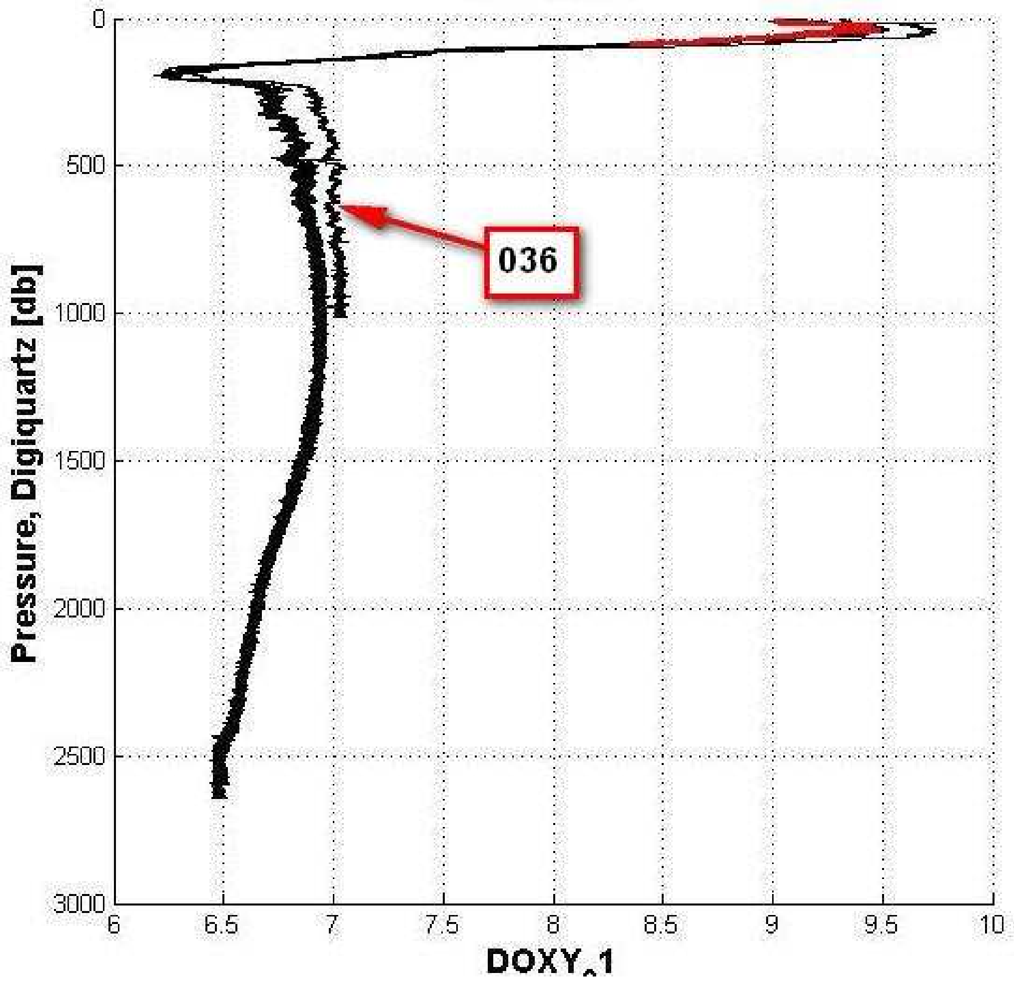


Figure 23. Evolution of the oxygen profile for the cast 036 and the profiles of the station L1.1.

037 ➔ Nothing to notice.

038 ➔ There is a density inversion at the surface which is not recorded on the ascendant profile. The temperature and salinity profiles are step like from 220 to 340 db.

039 ➔ There is an oxygen artefact at 22 db coinciding with a thermocline. The temperature and salinity profiles are step like from 220 to 390 db.

040 ➔ The first 20 db are quite irregular. The temperature and salinity profiles are step like from 220 to 390 db.

041 ➔ The cast starts at 4.5 db. The cast's depth is 10 db.

042 ➔ The cast starts at 4.2 db. The cast's depth is 10 db. The density data decrease from the surface to 10 db (the ascendant profile is quite similar).

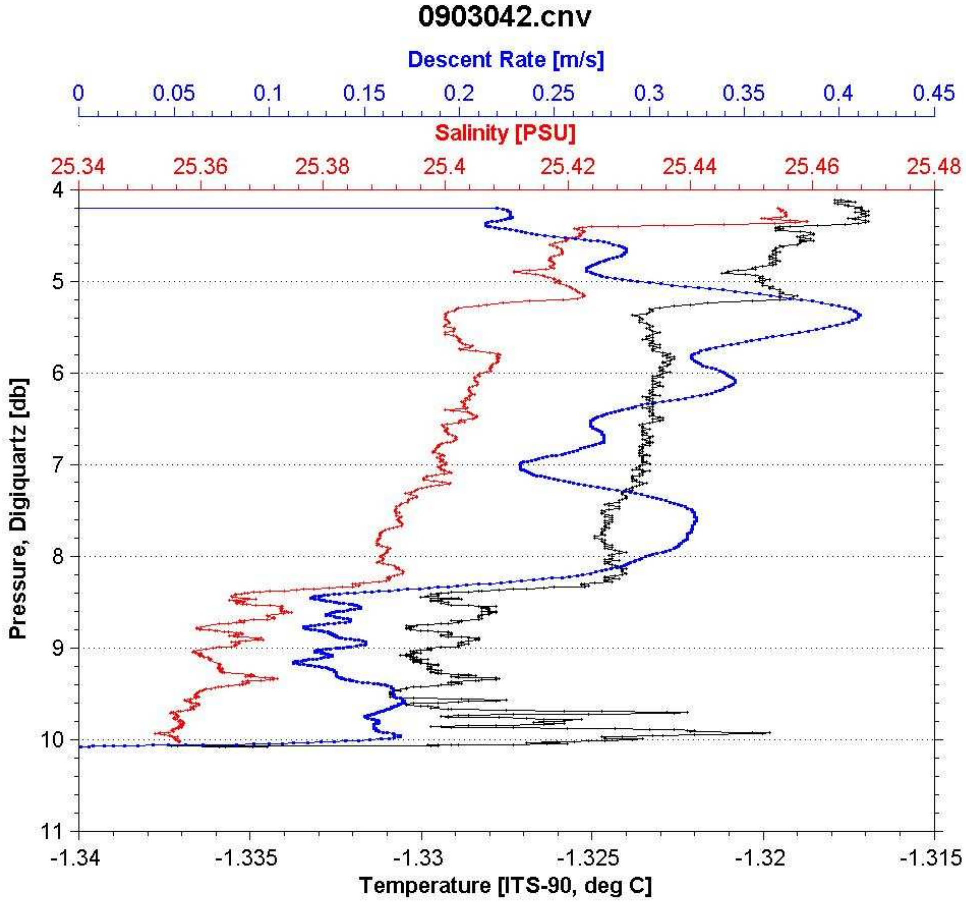


Figure 24. Evolution of the descendant temperature and salinity for the cast 042.

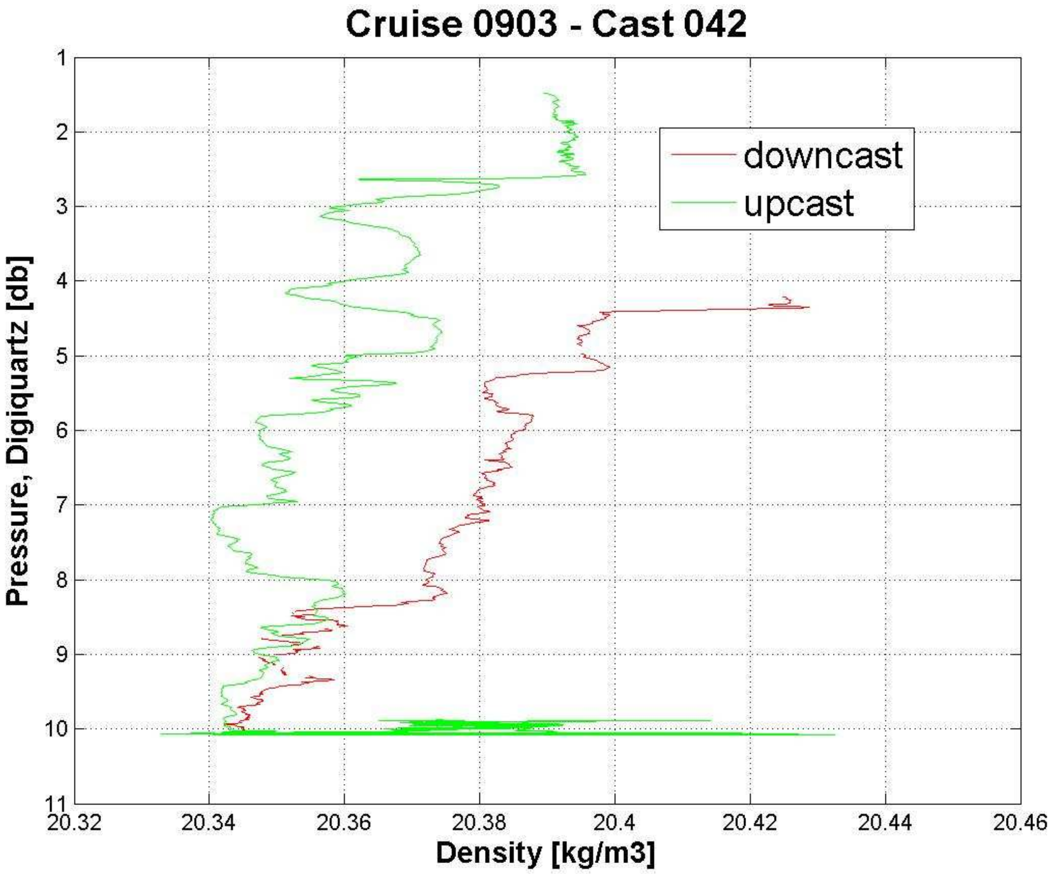


Figure 25. Evolution of the ascendant and descendant density evolution at the surface for the cast 042.

043 ➔ There is an oxygen artefact at 22 db coinciding with a thermocline. The temperature and salinity profiles are step like from 260 to 420 db.

044 ➔ There is an oxygen artefact at 20 db coinciding with a thermocline.

045 ➔ There is an oxygen artefact at 20 db coinciding with a thermocline.

046 ➔ The rosette deceleration at the bottom leads to some doubtful data. There is an oxygen artefact at 11 db coinciding with a thermocline.

047 ➔ Nothing to notice. There is an oxygen artefact at 11 db coinciding with a thermocline.

048 ➔ The rosette deceleration at the bottom leads to some doubtful data. There is an oxygen artefact at 11 db coinciding with a thermocline.

049 ➔ There are pump problems until 29 db.

050 ➔ Nothing to notice.

051 ➔ There is an oxygen artefact at 14 db coinciding with a thermocline.

052 ➔ There is an oxygen artefact at 10 db coinciding with a thermocline.

053 ➔ There is a small density inversion at the surface which is not recorded on the ascendant profile. There is an oxygen artefact at 16 db coinciding with a thermocline.

054 ➔ Nothing to notice.

055 ➔ Nothing to notice.

056 ➔ There is an oxygen artefact at 16 db coinciding with a thermocline.

057 ➔ There is an oxygen artefact at 19 db coinciding with a thermocline.

058 ➔ The irregular descent rate leads to doubtful data. The descendant profile starts at 20 db.

059 ➔ Nothing to notice.

060 ➔ There is an oxygen artefact at 14 db coinciding with a thermocline.

061 ➔ There is an oxygen artefact at 14 db coinciding with a thermocline.

062 ➔ Nothing to notice.

063 ➔ There is an oxygen artefact at 11 db coinciding with a thermocline.

064 ➔ There is an oxygen artefact at 7 and 15 db coinciding with a thermocline.

065 ➔ There is a rosette stop at 151db leading to doubtful data.

066 ➔ There is an oxygen artefact at 17 db coinciding with a thermocline.

067 ➔ Nothing to notice.

068 ➔ There is an oxygen artefact at 19 db coinciding with a thermocline.

069 ➔ There is a rosette stop between 220 and 230 db. There is an oxygen artefact at 19 db coinciding with a thermocline. There is a large density inversion at 9 db which may be detected on the ascendant profile.

070 ➔ There is an oxygen artefact at 13 db coinciding with a thermocline.

071 ➔ There is an oxygen artefact at 6 db coinciding with a thermocline.

072 ➔ There is a rosette stop at 151db leading to doubtful data. There is an oxygen artefact at 15 db coinciding with a thermocline.

073 ➔ Nothing to notice.

074 ➔ Nothing to notice.

075 ➔ The end of the profile is quite noisy due to the rosette deceleration at the bottom. There is a rosette stop at 151db leading to doubtful data. There is an oxygen artefact at

14 and 17 db coinciding with a thermocline.

076 ➔ Nothing to notice. There is an oxygen artefact at 14 db coinciding with a thermocline.

3.6. Salinity comparisons.

A first run with the downcast controlled data has shown major differences.

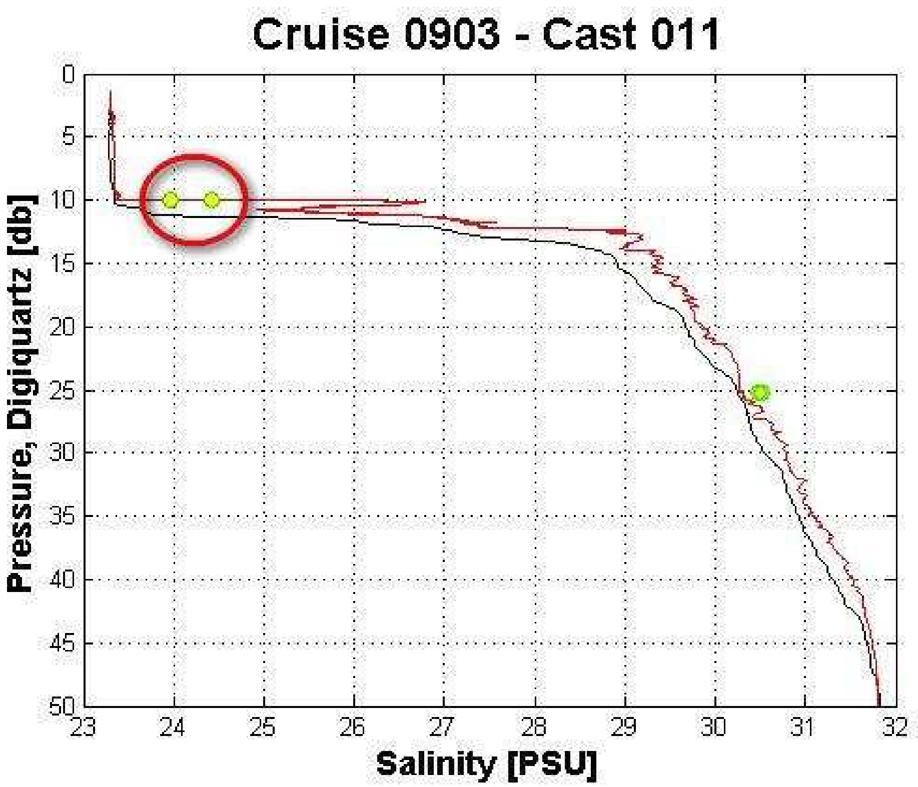


Figure 26. Comparison of the salinity difference between CTD and bottles for the cast 011.

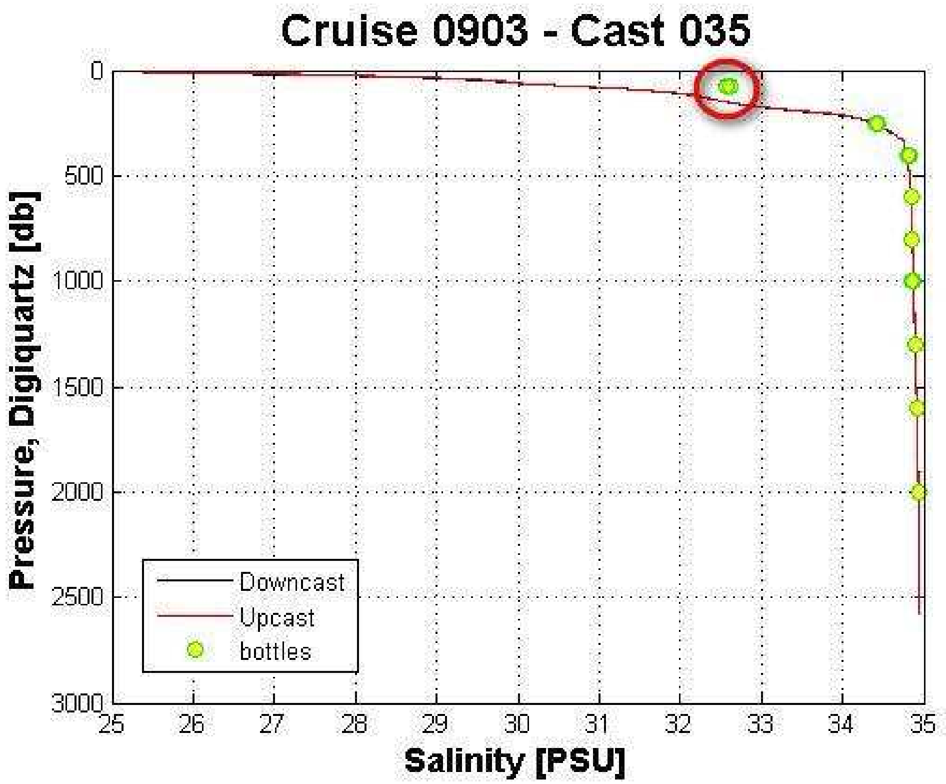


Figure 27. Comparison of the salinity difference between CTD and bottles for the cast 035.

Downcast profiles versus bottle data.

Mean(AutoSAL-CTD) = 0.032459 ±0.074637 (209 data)

Mean(AutoSAL-CTD 100db+) = 0.015721 ±0.039174 (178 data)

Mean(AutoSAL-CTD 100db-) = 0.12857 ±0.13551 (31 data)

Upcast profiles versus bottle data.

Mean(AutoSAL-CTD) = 0.017589 ±0.052134 (212 data)

Mean(AutoSAL-CTD 100db+) = 0.010935 ±0.030248 (180 data)

Mean(AutoSAL-CTD 100db-) = 0.055015 ±0.1073 (32 data)

3.7. TS diagram from controlled data.

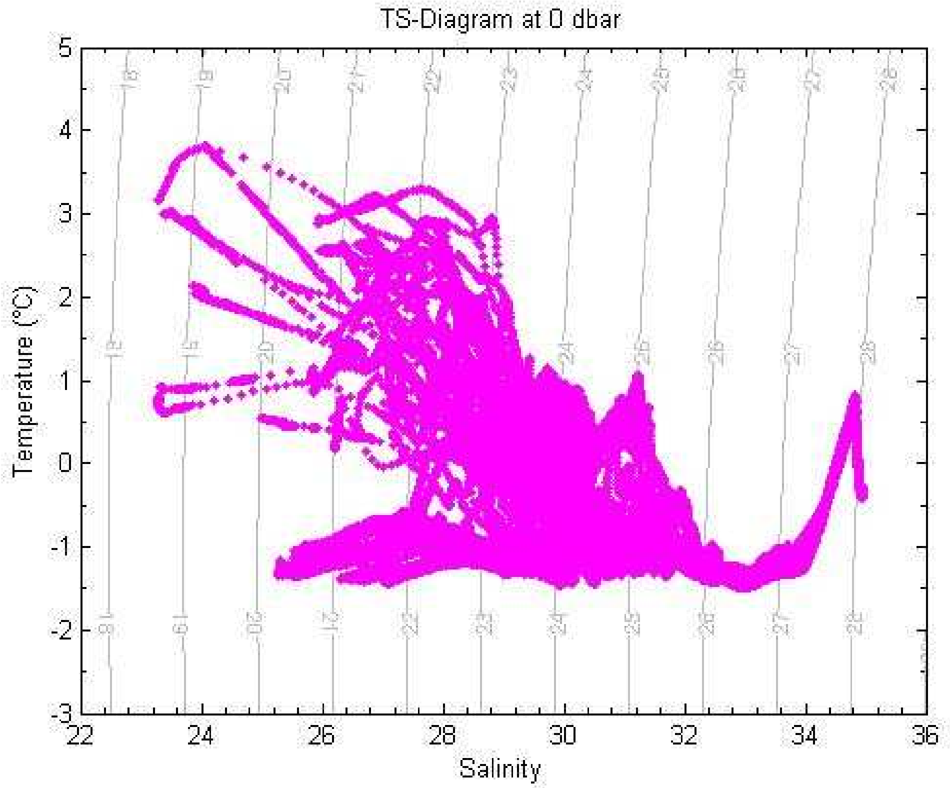


Figure 28. TS-diagram for the cruise 0903.

4. DATA AVERAGE AND INTERPOLATION.

Data are typically averaged using 1 db interval. I use the same method as Sea-Bird “Bin Average” module, that is:

pressure – 0.5 db < center pressure ≤ pressure + 0.5 db

After average step, missing data are linearly interpolated (see the table 9 at Annex B to have the complete list of interpolated data).

Remark.

When more than two successive values are missing, interpolated data are not computed.

Annex A

Dissolved oxygen profiles recorded by the Sea-Bird SBE 43 sensor may show some doubtful sections. This doubtful data could have some origins. Two are presented in this paper.

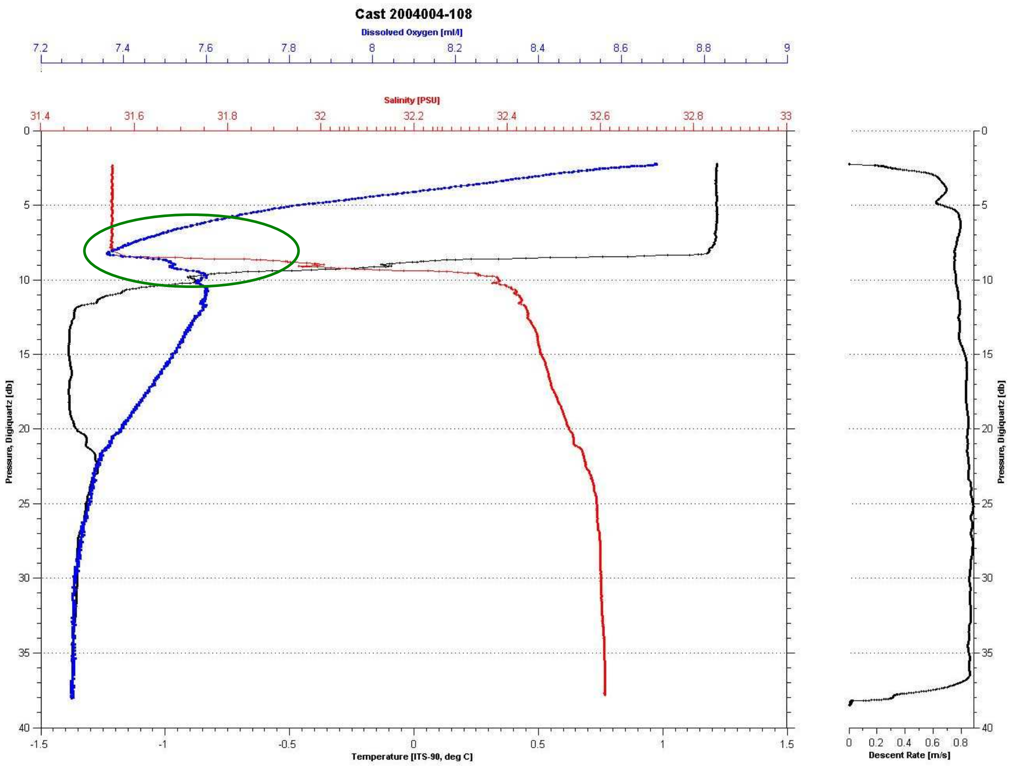
1. The oxygen data processing mainly consists in two steps.

    1) Improve sensor coefficient calibration with Winkler titrations. This step allows to calculate much accurate calibration values by fitting SBE 43 oxygen profiles with Winkler derived oxygen concentration coinciding in space and time. This step has no impact on doubtful data.

    2) Align data in time, relative to pressure.
    Dissolved oxygen data collected by the Sea-Bird 911*plus* CTD probe are characterized by a systematic delay with respect to pressure. The main causes are: 1) a time transit of the water through the pipe; according to Sea-Bird a typical plumbing delay for the SBE 43 DO sensor is about 5 seconds. 2) a long time constant of the oxygen sensor which is temperature inversely dependant; according to Sea-Bird this constant varies from approximately 2 seconds at 25 °C to up to 10 seconds at 0 °C. So the total delay sho uld vary from 7 to 12 seconds. This delay must be corrected to ensure that the temperature and the salinity used to calculate the dissolved oxygen concentration from the SBE 43 voltage come from the same parcel of water, the higher the time correction, the greater the vertical shift of the oxygen data relative to the pressure. Sea-Bird suggests testing the “ALIGN CTD” module of the “SBE Data Processing-Win 32” software with different values in order to reduce the misalignment of the dissolved oxygen data between the upcast and the downcast profiles.

So choosing a correction value is a compromise between the different casts of a leg and between the different sections of a profile. As a unique time correction is used for every cast and for all oxygen data of a cast, some misalignment issues may occur that could lead to hysteresis (hysteresis is a delay in the evolution of a physical or chemical parameter), and so to doubtful dissolved oxygen data.

2. For some oceanographic condition –cold water and sharp temperature gradient, the oxygen profile recorded by the SBE 43 sensor may be characterized by a spike coinciding with the thermocline (see the figure B1 for an example). This artefact should be taken with great care and may not reflect an actual oceanographic phenomenon. Actually this spike may be an artefact of the equation used to compute dissolved oxygen (see the equation). A term of this equation is saturation of oxygen (*Oxsol*) which is function of temperature and salinity. *Oxsol* is changing as fast as these 2 parameters are changing due to very short sensor time constant while the oxygen voltage (*V*) is changing much slower due to a high constant time which is exacerbate by cold temperature.



B 1. An example of oxygen artefact coinciding with a thermocline (the alignment correction is 10 seconds).

Where :

- — = time derivative of SBE43 output signal (volts/second).
- T = CTD temperature (°C).
- K = CTD temperature (°K).
- S = CTD salinity (psu).
- V = SBE 43 output voltage signal (volts).

- $Oxsol(T, S)$ = oxygen solubility (ml/l) from temperature and salinity values using Garcia and Gordon equation.
- S*oc*, *Voffset*, $tau(T, P)$, *A, B, C* and *E* are calibration coefficients:

  - $tau(T, P)$ = sensor time constant at temperature and pressure.
  - Soc = calibration slope.
  - Voffset = electronic offset.
  - *A*, *B* and *C* terms in a polynomial and *E* term in an exponential that compensate for changes in the sensor's sensitivity.

Annex B

Interpolated value for missing data.

Table 9. Interpolation results for missing temperature, salinity and oxygen data.

Cast	Variable	Pressure	Interpolated Value
015	salinity	1740.00	34.924
058	temperature	143.00	-1.008
058	salinity	143.00	33.938