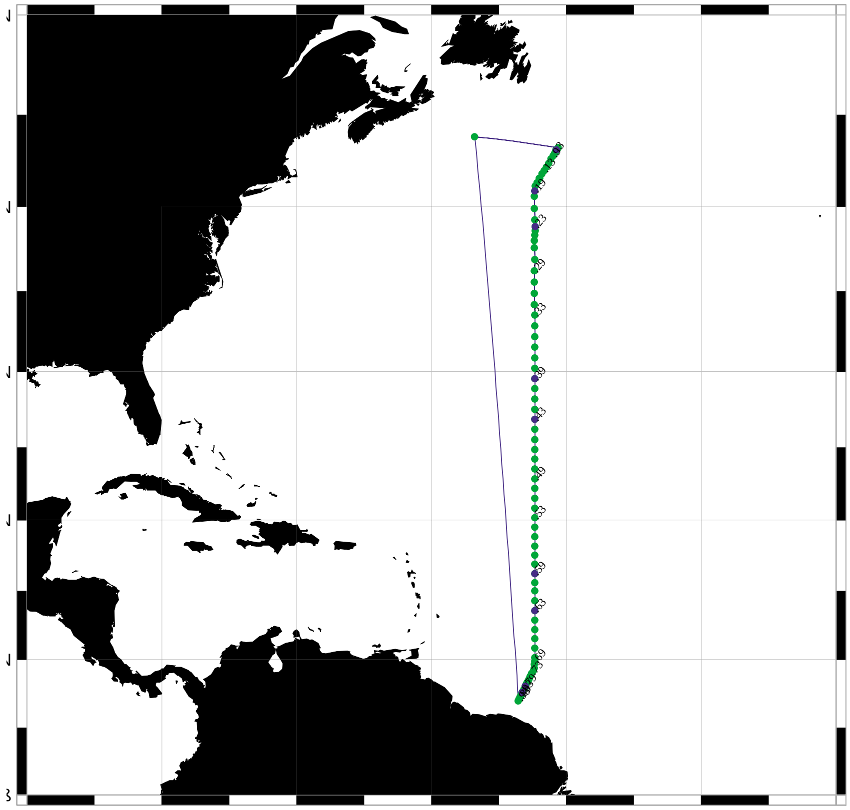
A. CRUISE REPORT: A20

(updated 3/1/2005)



A.1. HIGHLIGHTS

WHP Cruise Summary Information

WOCE section designation	**A20**
Expedition designation (EXPOCODE)	**316N151_3**
Chief Scientist / affiliation	**Robert Pickart / WHOI**
Dates	1997 JUL 17 – 1997 AUG 10
Ship	*RV KNORR*
Ports of call	Halifax to Trinidad
Station geographic boundaries	43°57.94'N 56°4.62'W 50°36.98'W 06°58.13'N
Stations	95
Floats and drifters deployed	11 ALACE floats deployed
Moorings deployed or recovered	4
Contributing Authors	R. Pickard

Chief Scientist's Contact Information

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Woods Hole Oceanographic Institution • Clark 3 MS # 21 * Woods Hole, MA 02543
UNITED STATES
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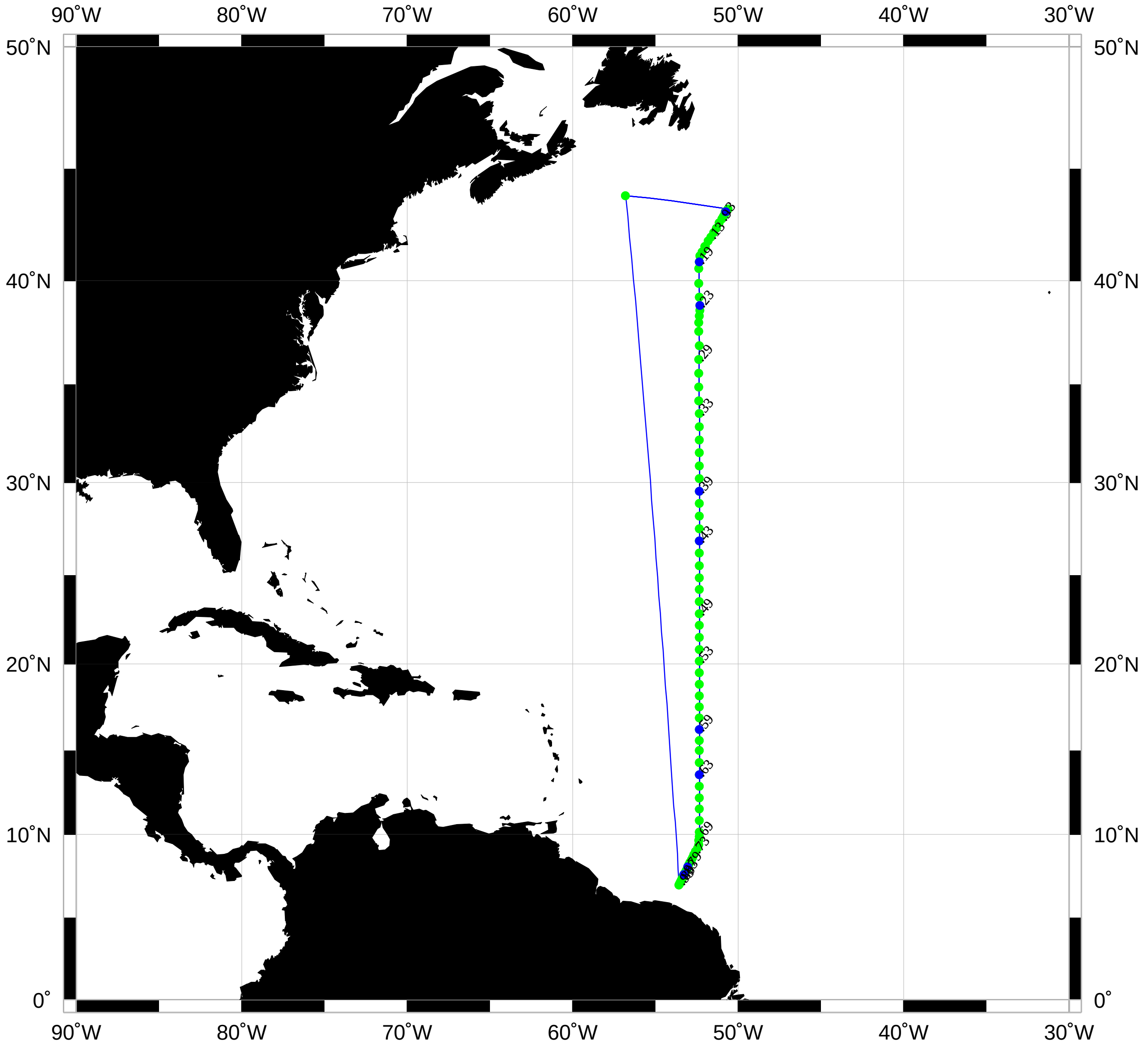
WHP CRUISE AND DATA INFORMATION

Links to text locations. Shaded items are not relevant to this cruise or were not available when this report was assembled.

Cruise Summary Information	**Hydrographic Measurements**		
Description of Scientific Program	**CTD Data**	Calibration	Processing
Geographic Boundaries	Salinity	Calibration	Processing
Cruise Track (WHPO) (PI)	Oxygen	Calibration	Processing
Description of Stations	Pressure	Calibration	Processing
Description of Parameters Sampled	Temperature	Calibration	Processing
Bottle Depth Distributions (Figure)			
	Bottle Data		
Floats and Drifters Deployed	Salinity		
Moorings Deployed or Recovered	Oxygen		
	Nutrients		
Principal Investigators for All Measurements	CFCs		
Cruise Participants	CO_2 System Parameters		
	Helium Tritium		
Problems and Goals Not Achieved	Radiocarbon		
Other Incidents of Note	Other Parameters		
Underway Data Information	**DQE Reports**		
Navigation Bathymetry	CTD		
Acoustic Doppler Current Profiler (ADCP)	S/O2/Nutrients		
Thermosalinograph and Related	Cfcs		
XBT and/or XCTD	14C		
Meteorological Observations			
Atmospheric Chemistry Data			
Acknowledgments	**Data Processing Notes**		

References: Temp/Sal Changes Nutrients

Station Locations for A20 • Pickart • *Knorr* • 1997



Produced from .sum file by WHPO-SIO

A.2. SUMMARY

From 17 July - 10 August 1997 the research vessel KNORR occupied a hydrographic section extending from the Newfoundland shelf to the Suriname shelf, nominally along 52° W. This section, known as A20, is part of the Atlantic Circulation and Climate Experiment (ACCE), and one of two North Atlantic WOCE "Meridional Long- lines". The other meridional line, at 66° W, was occupied during the subsequent leg (T. Joyce, chief scientist). Thirty-one scientists representing 10 different projects participated on the cruise (Table 1).

Due to wonderful weather and excellent cooperation among the different groups, we ended up occupying more stations than originally planned for a total of 95 (Figure 1). At both ends the resolution on the shelf break was 3 mi, increasing to 10-15 mi on the continental slope, and finally 40 mi in the interior (except for the Gulf Stream where the spacing was 15-25 mi). A typical deep water station included a NBIS Mark-III CTD with oxygen sensor, lowered ***ADCP***, and 33 10-liter Niskin bottle samples. Depending on the station up to 9 different WOCE quantities were measured: ***CFCs, Tritium/Helium, Oxygen, PCO2, TCO2, C14, Alkalinities, Nutrients, and Salts***. On selected stations (such as TTO and GEOSECS repeat stations) all of the quantities were measured; more often a subset of them was collected. Table 2 gives the position/depth of each station and indicates which tracers (including numbers of samples) were drawn. Note that Oxygen, Nutrients and Salts were collected on every station (with the exception of the shelf break crossings where limited sampling was done).

In addition to the WOCE variables, Halocarbon measurements were made nominally once per day in the upper 200 m (usually from the shallowest 10 Niskin bottles, see Table 2). Underway measurements included PCO2, Halocarbons, ***ADCP***, and thermosalinograph (which was calibrated daily using surface salinity samples). A bio-optical cast was made once per day using a self contained winch and CTD package. This was done during the CTD cast falling closest to the noon hour. ***Eleven ALACE floats*** were launched in the Sargasso Sea, corresponding to CTD sites.

A.3. BRIEF NARRATIVE

After occupying a test station in 3000 m of water near 57° W, we steamed to the 1000 m isobath along the northern dog-leg (Figure 1) and commenced dropping ***XBTs*** onto the shelf. This enabled us to identify the configuration of the Labrador Current prior to the CTD work (allowing us to optimally place the shelf break stations). This turned out to be quite useful as the Labrador Current contained an anomalous, large intrusion of warm water (Figure 2). For the shelf break work we used a 24-position 3.3-liter frame with a separate Mark-III, and collected water samples only within the core of the Labrador Current. At the 1000 m isobath we switched to the larger 36-position 10-liter package, which included the lowered ***ADCP***. Water samples were taken according to the scheme described above. The dogleg portion of the section nicely sampled the slope water, including the Labrador Current, slope water front/jet, Labrador Sea Water, and Deep Western Boundary Current (DWBC, Figure 3). It should be noted that there were ***four current meter moorings*** located along the dogleg as part of a separate experiment.

A Gulf Stream warm core ring was located near the seaward edge of the dogleg, and we seem to have crossed through the center of it. Shortly after this we encountered the Gulf Stream front. ***XBTs*** were used to identify the precise position of the north wall, and CTDs were subsequently placed in order to properly resolve the current. Interestingly the Gulf Stream was a factor of two narrower than normal at this longitude (only 80-90 km wide).

Upon reaching the Sargasso Sea we began the 40 mi spacing, which was maintained until the southern boundary. After crossing the Corner Seamounts (near 35° N) we skirted along the outer flank of the Mid-Atlantic Ridge until roughly 15° N (Figure 1). During this part of the survey we consistently steamed at 12-13 knots. This enabled us to make up time lost on the northern boundary (due to fog near the Grand Banks). Near 10° N we doglegged into the southern boundary, again sampling the boundary current system with more detailed measurements. As in the north, we changed to the small package at the 1000 m isobath (this time including the lowered ***ADCP***) and took measurements onto the shelf across the North Brazil Current system.

Our section contains some familiar and expected features, as well as some surprises and puzzles. It is the third long line occupied near this longitude, the other two being an IGY line in 1956 and a high-quality CTD section occupied in 1983 (Figure 1). A major aim of our study is to use the 1997 ACCE lines in conjunction with the past data sets to investigate ocean climate change. The A20 salinity section (Figure 4a) shows many of the major water mass/circulation features. On the northern side note the high-salinity warm core ring and Gulf Stream front. Inshore of this, within the DWBC, resides the Labrador Sea Water whose low-salinity signal extends south of the Gulf Stream and is the cause of significant freshening at mid-depths. In the bottom-most layer the Antarctic Bottom Water becomes progressively fresher toward the southern boundary. In the upper 1000 m there is a pronounced core of Antarctic Intermediate Water extending from the southern boundary.

The suite of tracers measured on the cruise will provide valuable information in elucidating the water masses as well as understanding the climate signal. The oxygen section (Figure 4b) beautifully shows both the Labrador Sea Water and Norwegian-Greenland overflow water emanating from the northern boundary. Both these features appear again on the southern boundary. Note also the low oxygen of the Antarctic Bottom Water on the southern end of the section.

One of the surprises revealed by the tracers concerns the spreading of the Norwegian-Greenland overflow water from the northern boundary. The deep oxygen core extends into the Sargasso Sea centered near 3700 m (Figure 4b), whereas the analogous CFC core (not shown) is displaced roughly 500 m deeper. This perhaps reflects the difference in source functions of the two tracers in that CFCs have only entered the system in the last 50 years. Another unexpected feature is the complexity of the Labrador Sea Water signal along the northern boundary. It appears that discrete density layers are being ventilated, possibly the result of inter-annual variability in the formation of this water mass.

At the conclusion of the cruise the majority of the water sample data were merged into standard WOCE data files, and, aside from the post-cruise laboratory calibrations, the CTD data were nearly final. The combination of the 52° W and 66° W sections, along with the other ACCE fieldwork and previous hydrography, will provide a revealing look at the present state of the North Atlantic and its long-term variability.

Figure 1: A20 Station Positions

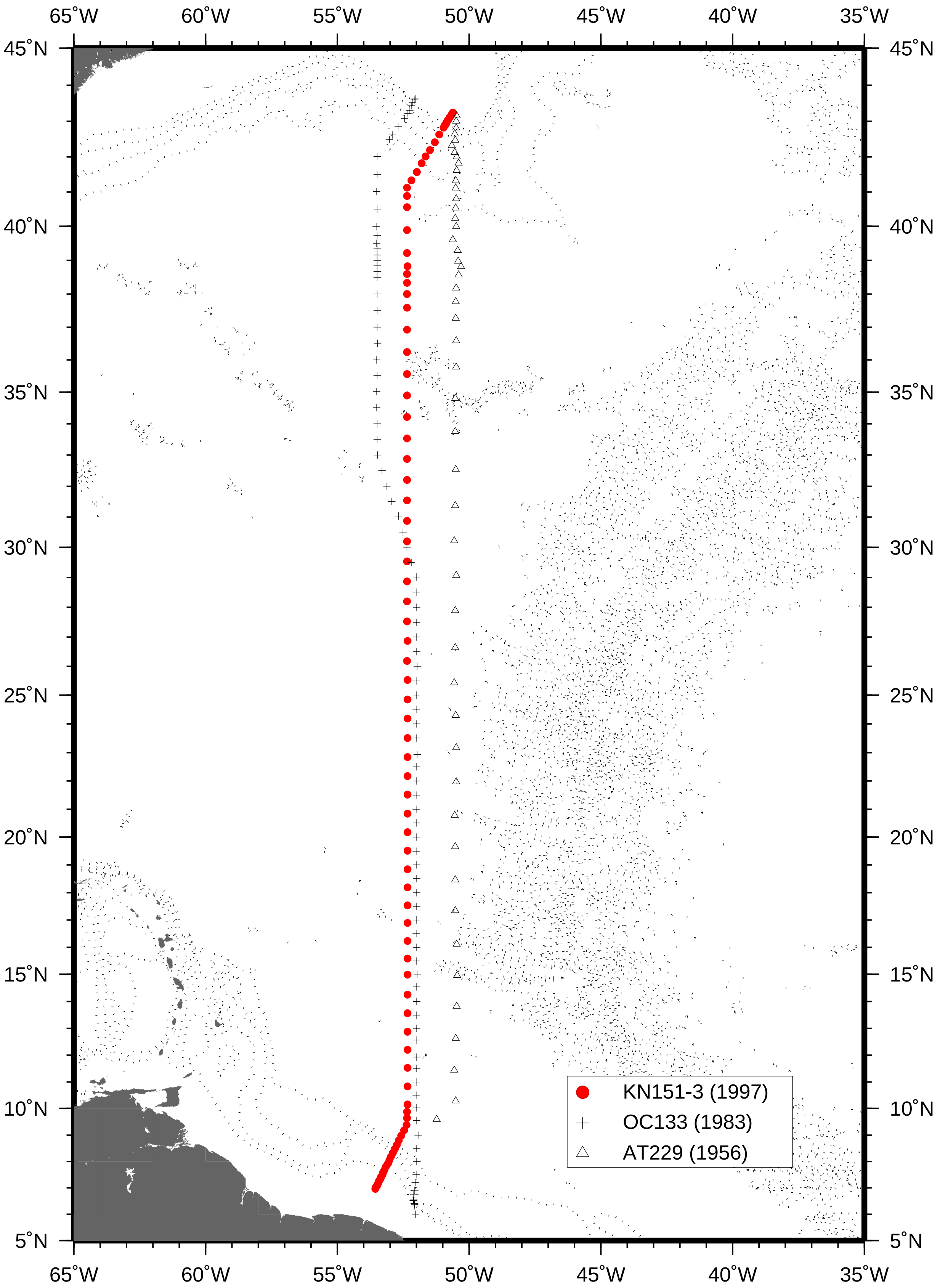


Figure 2: A20 Labrador Current   Theta (C)

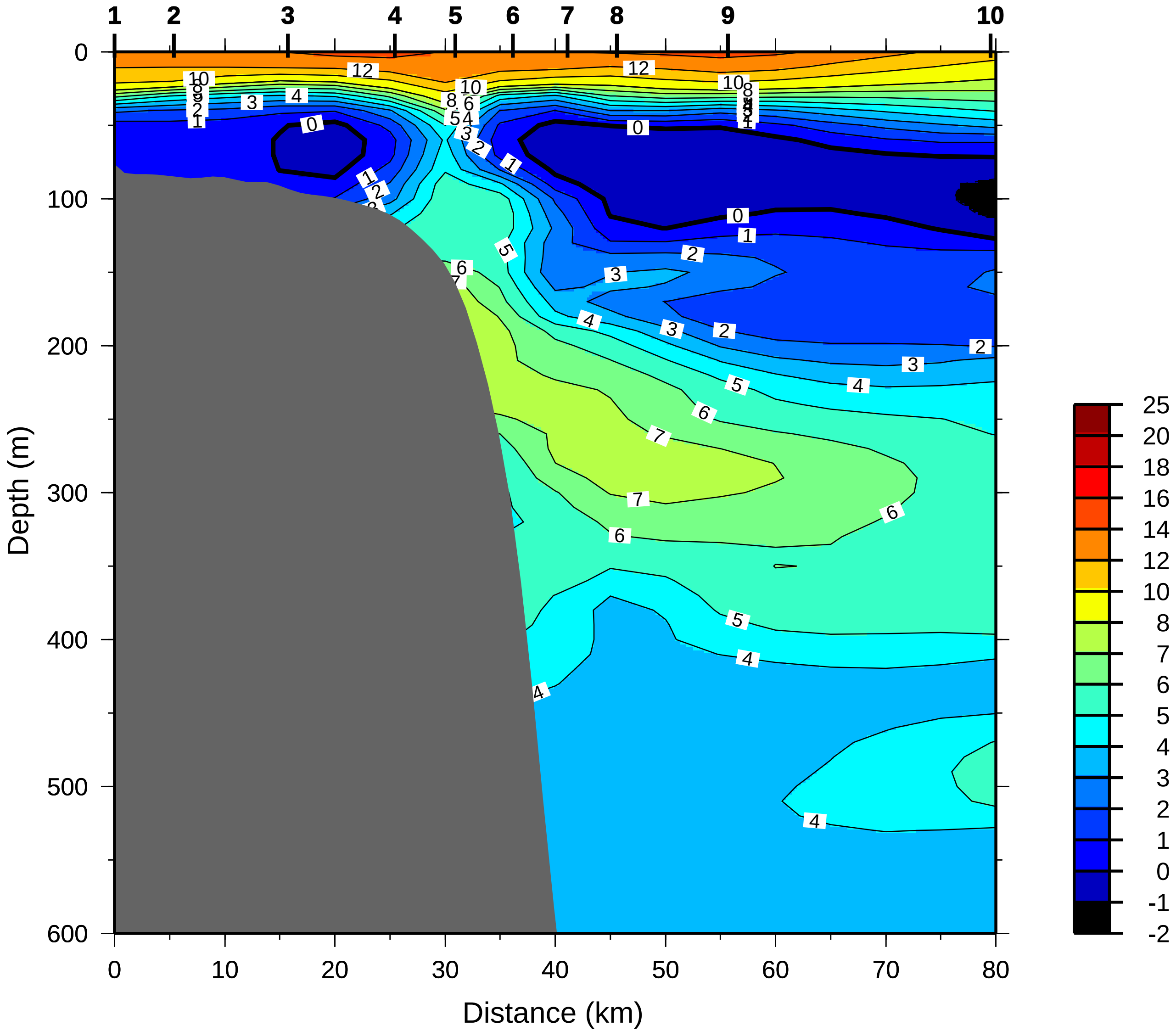


Figure 3: A20 Northern Boundary   Salinity (PSU)

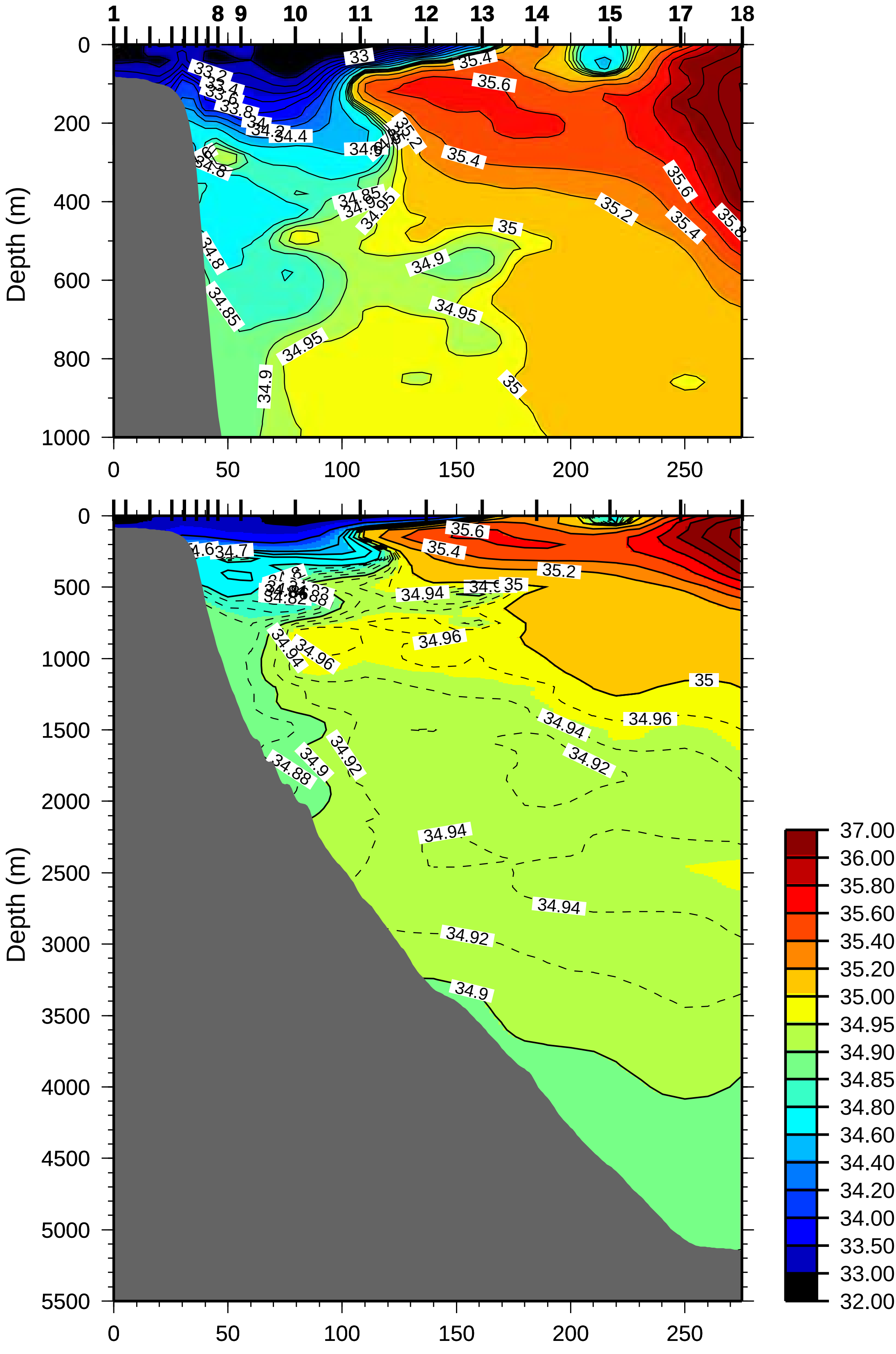


Figure 4a: A20 Salinity (PSU)

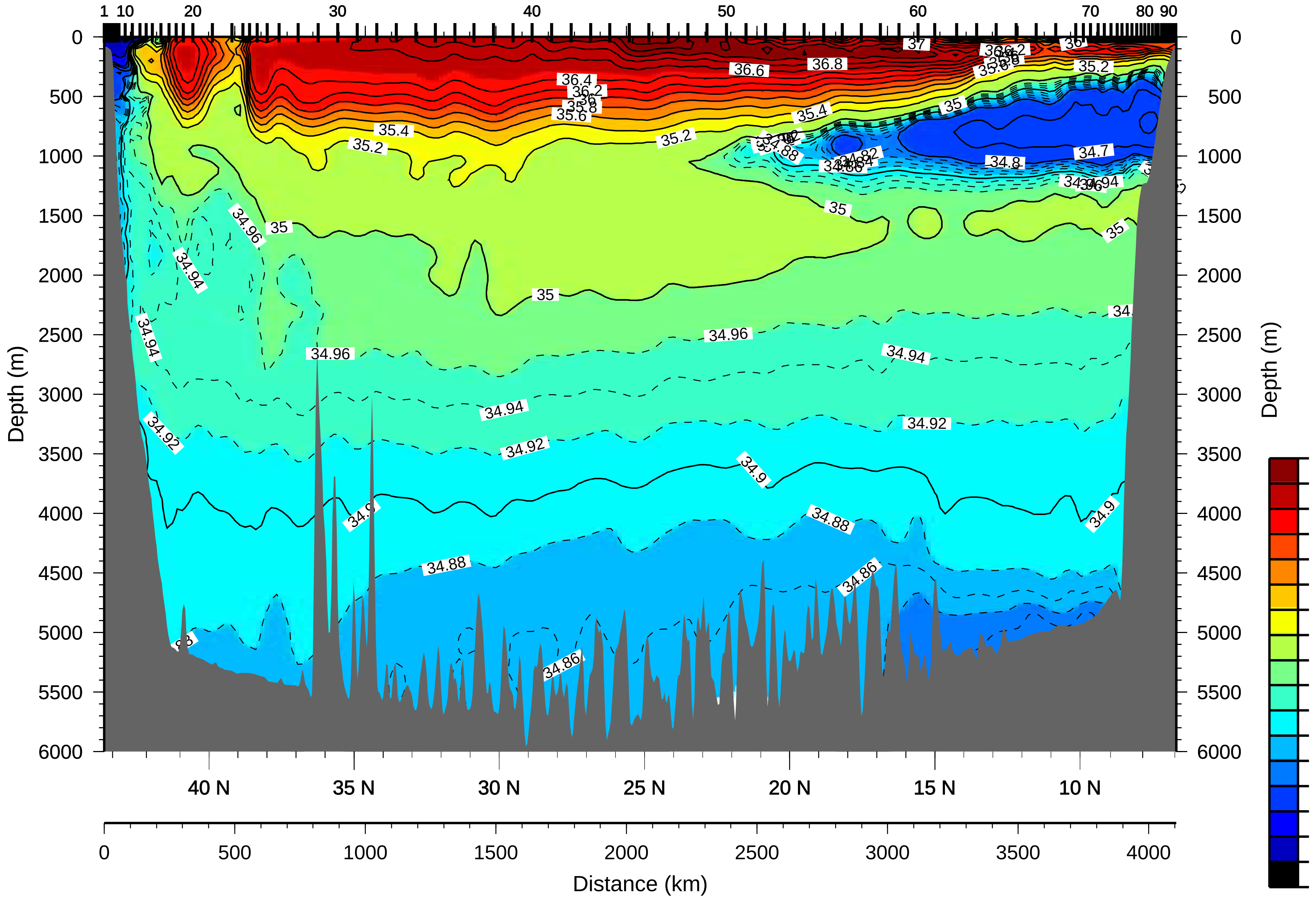
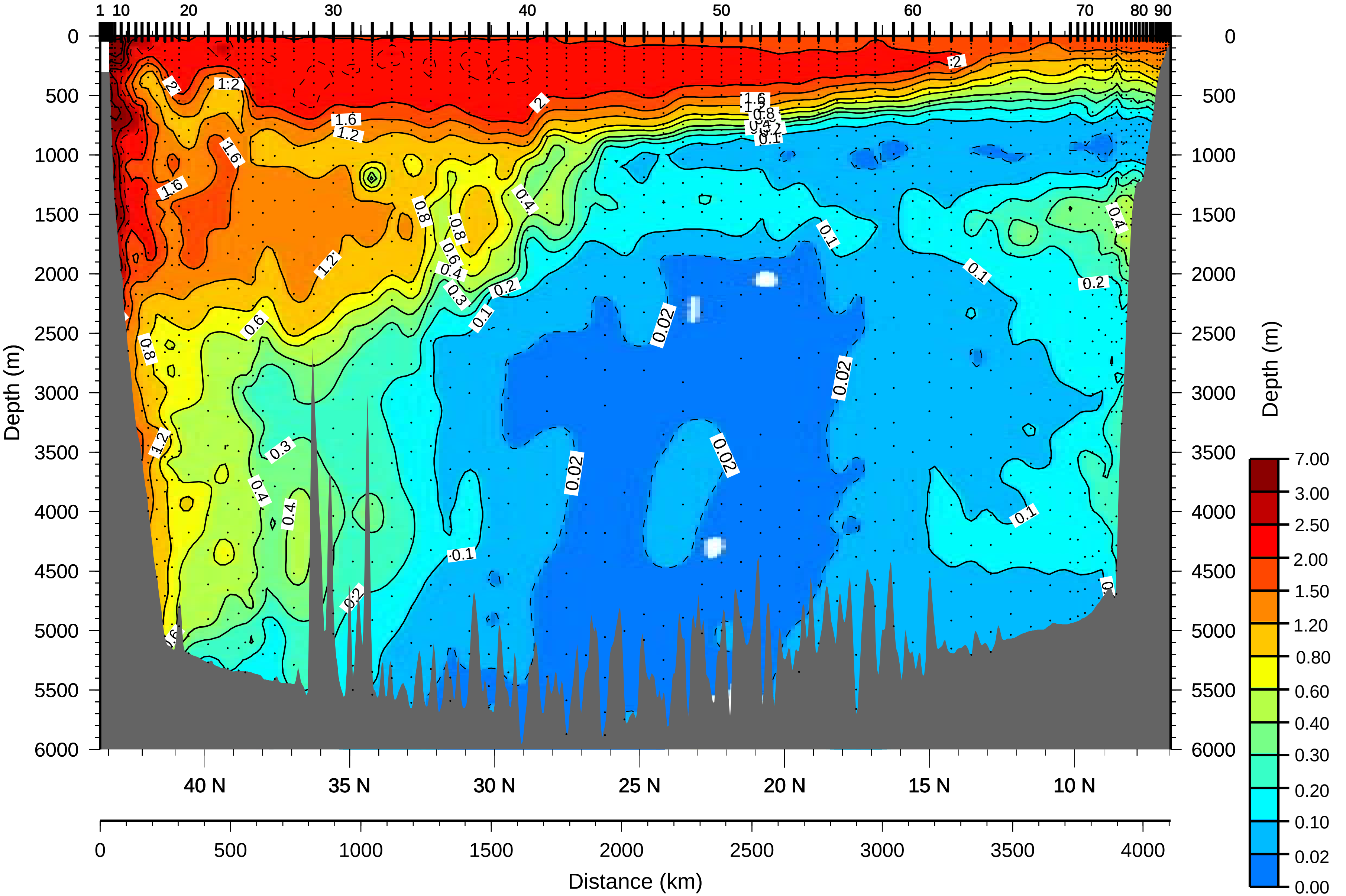


Figure 4b: A20 F-11 (pM/kg)



TEMPERATURE AND SALINITY CHANGES OVER TIME[1]

WOCE line A20 was one of two hydrographic lines were done in the western N. Atlantic along longitudes of 52 and 66° W as part of the onetime hydrographic survey of the oceans (Figure 5). The other line, at 66° W was A22. Each of these two lines approximately repeated earlier ones done during the International Geophysical Year(s) (IGY) and the mid-1980s. Because of this repeated sampling, long-term hydrographic changes in the water masses can be examined. In this report, we focus on temperature and salinity changes within the subtropical gyre mainly between latitudes of 20 & 35° N and compare our results to those presented by Bryden *et al* (1996) who examined changes along a zonal line at 24° N, most recently occupied in 1992. Since this most recent 24° N section in 1992, substantial changes have occurred in the western part of the subtropical gyre at the depths of the Labrador Sea Water (LSW). In particular, we see clear evidence for colder, fresher Labrador Sea Water throughout the gyre on our two recent sections that was not yet present in 1992 at similar longitudes along 24° N. At shallower depths inhabited by waters which are an admixture of Mediterranean (MW) and Antarctic Intermediate Waters (AAIW), our recent survey shows an increase in salinity, which can only be attributed to changes in water masses on potential temperature or neutral density surfaces. Furthermore, waters above the MW/AAIW layer and into the deeper part of the main pycnocline have continued to become saltier and warmer throughout the 40 year period spanned by our sections. These latter changes have been dominantly due to a vertical sinking of density surfaces as T/S changes in density surfaces are small, but depths of individual T/S horizons have increased with time. The net change since the IGY shows a mean temperature increase between 800 & 2500m depth at a rate of 0.57° C /century with a corresponding steric sea level rise of 1 mm/yr, and a net downward heave with small values near the top and bottom, and a maximum rate of –2.7 m/yr at 1800m depth. Changes in the deep Caribbean indicate a warming since the IGY due to temperature increases of the inflowing source waters in the subtropical gyre at 1800m depth, but no significant change in the deep salinity.

Changes at 52° W (A20)

The sections of potential temperature, salinity and neutral density at 52° W (Figure 6) are contoured with dashed contours in the upper panel for θ =1.5, 2.5 & 3.5° C, middle panel for S=34.85, 34.95 & lower panel for γn=27.9, 27.95 kg/m3. Changes with time have been estimated by vertically interpolating the bottle data from IGY and as well as the CTD data at standard levels for the two modern cruises before horizontal gridding. This procedure assures comparable errors due to curvature in the interpolation of all three data set. Horizontal gridding is onto a 0.5 degree latitude grid where longitudinal differences in the sections are ignored. Resulting differences (Figure 7a, Figure 7b) have been smoothed using a 100 km gaussian filter. We show potential temperature differences for 80s-IGY (upper), WOCE-80s (middle) and WOCE-IGY (lower). Positive (negative) differences are in red (blue) with the contour interval of 0.1 up to a maximum (minimum) of 0.5 (-0.5) (a). As above but for salinity differences with the contour interval of 0.02 up to a maximum (minimum) of 0.1 (-0.1) (b). The warming of mid-depth (1000-2500m) waters from the IGY to the 80s has disappeared at depths of 2000m (near the core of the LSW) comparing the 80s to WOCE, although recent freshening of the salinity at this depth has occurred. Net changes from IGY to WOCE still show a basin-wide increase in temperature at this depth range, however. We have averaged the properties between the latitudes of 20 & 35° N in order to reduce eddy variability and to focus on mid-latitude changes away from boundary influences. On the A20 section (52° W), this eliminates the strong latitudinal gradients associated with AAIW to the south and masks out the coldest AABW and the core of the DWBC. Mean temperature (Figure 8a) and salinity (Figure 8b) differences for the section include an error in the mean based on the observed variability and an eddy length scale

[1] Excerpt from: "WOCE/ACCE cruises in the subtropical N. Atlantic on KNORR in 1997"
Terrence M. Joyce, Robert S. Pickart and Robert C. Millard, WHOI
http://www.whoi.edu/science/PO/people/tjoyce/kn_1997/acce_web.html

of 300km. One can see large, offsetting changes in the upper 1000m in the time interval IGY-80s and 80s-WOCE, largely due to the vertical heaving of the main pycnocline. Upper ocean changes are also masked by the eddy variability. Between 1000 and 2000m temperature (but not salinity) changes have been of the same sign and appear re-enforced in the net change The spatially-averaged θ/S changes (Figure 9) are shown in the upper left panels of the figure and selectively focus on the thermocline (upper right), MW/salinity maximum (lower right) and LSW (lower left). One change not obvious from the previous figures is the salinity increase in the upper thermocline between the first two occupations and the present. Symbols denote changes for depths of 200, 500, 1000, 1500, 2000, 3000 and 4500m. At a depth of 200 (first symbol on figure) this is evident as a shift of the θ/S diagram to higher salinities while at 500m depth (second symbol), it is more clearly a change along the mean θ/S diagram. The latter type of variability characterizes much of the change throughout the thermocline between depths of 500 & 1000m.

Summary

Space does not permit a more complete presentation of the observed changes including those in the Caribbean and the effects of vertical heave and water mass changes on neutral surfaces. However, a manuscript has been prepared and submitted to Deep-Sea Research by the authors, and a more thorough account will become available (eventually). We summarize our results by combining the net changes (IGY-WOCE) for both sections into a grand average for the subtropical gyre (Figure10). Spanning a time interval of about 43 years (WOCE-IGY), we see a maximum temperature increase of 0.6° C, which is nearly 1.4° C/ century. Over the depth range where a significant temperature change has occurred, the net change from IGY to present is 0.25° C (A20) and 0.24° C (A22), which works out to an increasing temperature of 0.57° C per century over a depth interval of 1700m. The net steric sea level rise can be computed from the combined contributions due to temperature and salinity. Changes in the latter will act to reduce the net sea level increase, but the overall steric increase, accounting for changes between 800 & 2500m depth, is 4.7 & 4.3 cm for A20 & A22, respectively, which is equivalent to about 1 mm/yr. These figures for sea level and mean temperature change are only slightly greater than those estimated from Bermuda by Joyce and Robbins (1996, 0.5° C per century & 0.7-0.9 mm/yr) but apply to a thicker water column and point to a long-term increase in the stratification between mid-depths and the underlying deep waters. The mid-depth increase in temperature and salinity is dominantly due to heaving. The depth variation of the 'heave' signal (not shown) indicates a maximum negative shift of 112m at a depth of 1800m giving a downward vertical velocity of the density surface at 1800m depth of -2.7 m/yr.

Acknowledgements

We wish to acknowledge the support of an NSF grant (OCE95-29607), the assistance of J. Dunworth-Baker and R. Goldsmith in helping with some of the calculations and finally, the WHOI CTD and hydro groups and the captain & crew of the *R/V Knorr* for their assistance in obtaining this new WOCE dataset.

References

Bryden, H. L., M. J. Griffiths, A. M. Lavin, R. C. Millard, G. Parrilla & W. M. Smethie, 1996. Decadal changes in water masses characteristics at 24° N in the subtropical Atlantic Ocean. J. Climate, 9, 3162-3186.

Joyce, T. M. & P. Robbins, 1996. The long-term hydrographic record at Bermuda. J. Climate, 9, 3121-2131.

[1] Excerpt from: “WOCE/ACCE cruises in the subtropical N. Atlantic on KNORR in 1997”
Terrence M. Joyce, Robert S. Pickart and Robert C. Millard, WHOI
http://www.whoi.edu/science/PO/people/tjoyce/kn_1997/acce_web.html

Figure 5: Hydrographic Sections

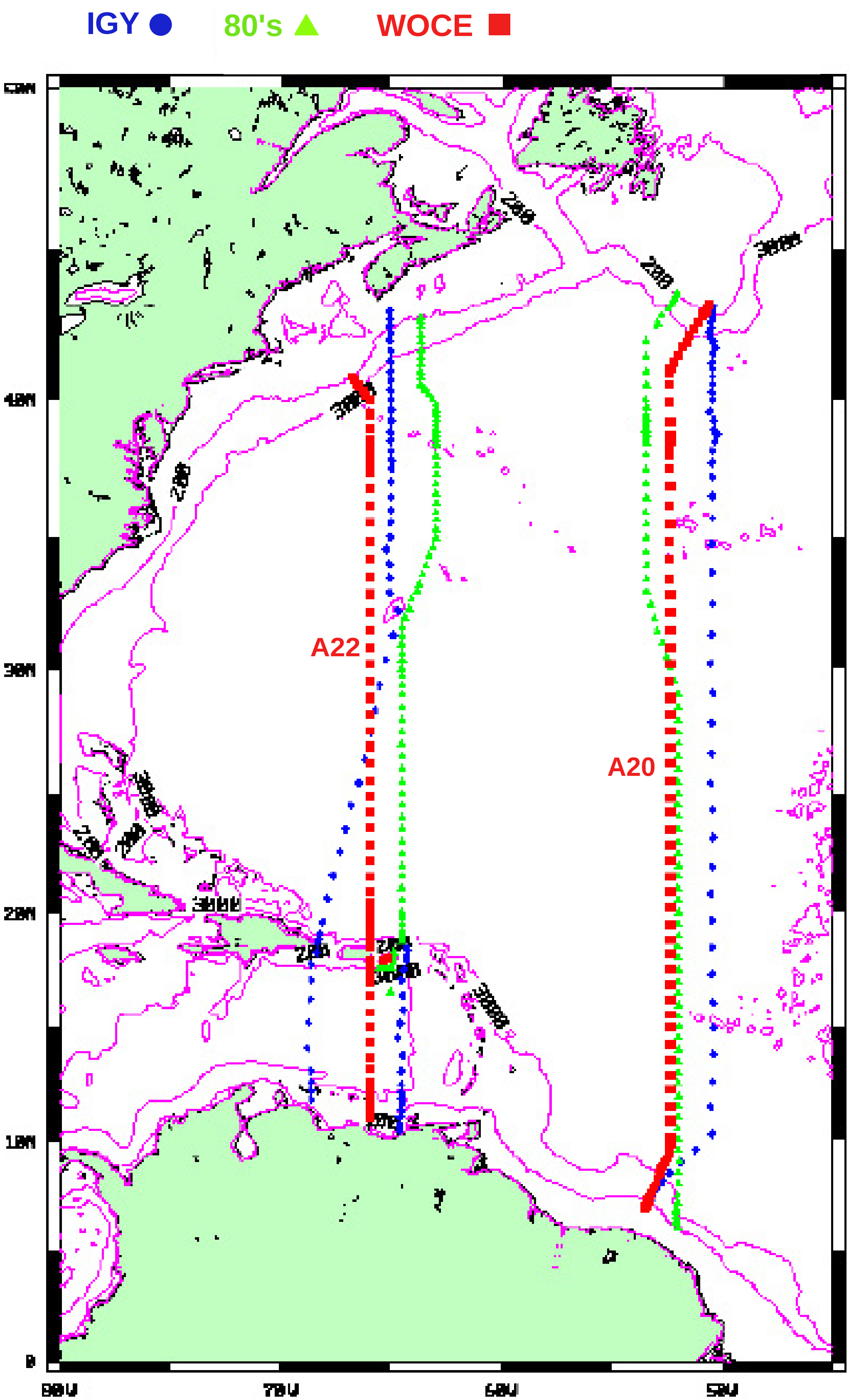


Figure 6

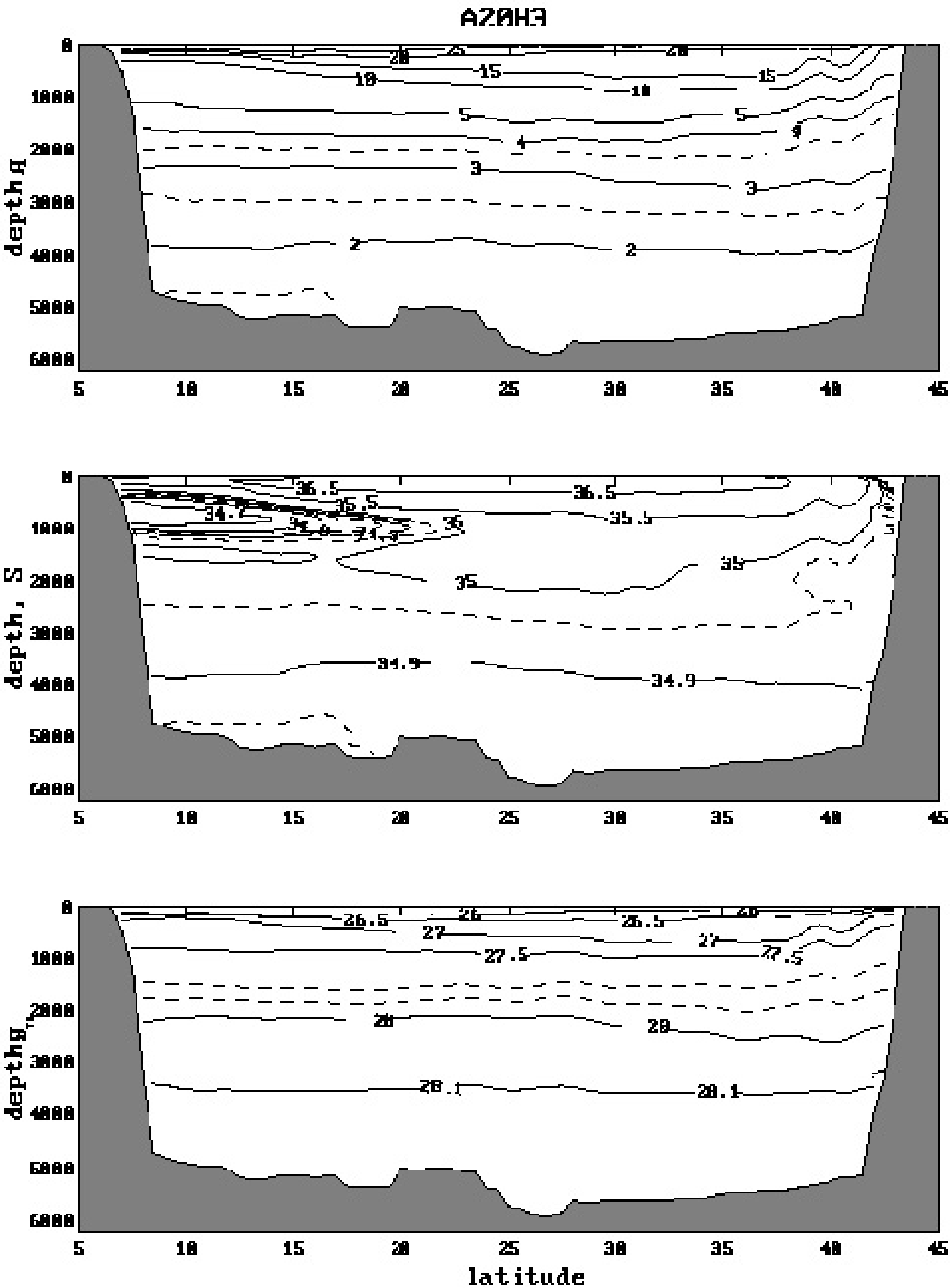


Figure 7a

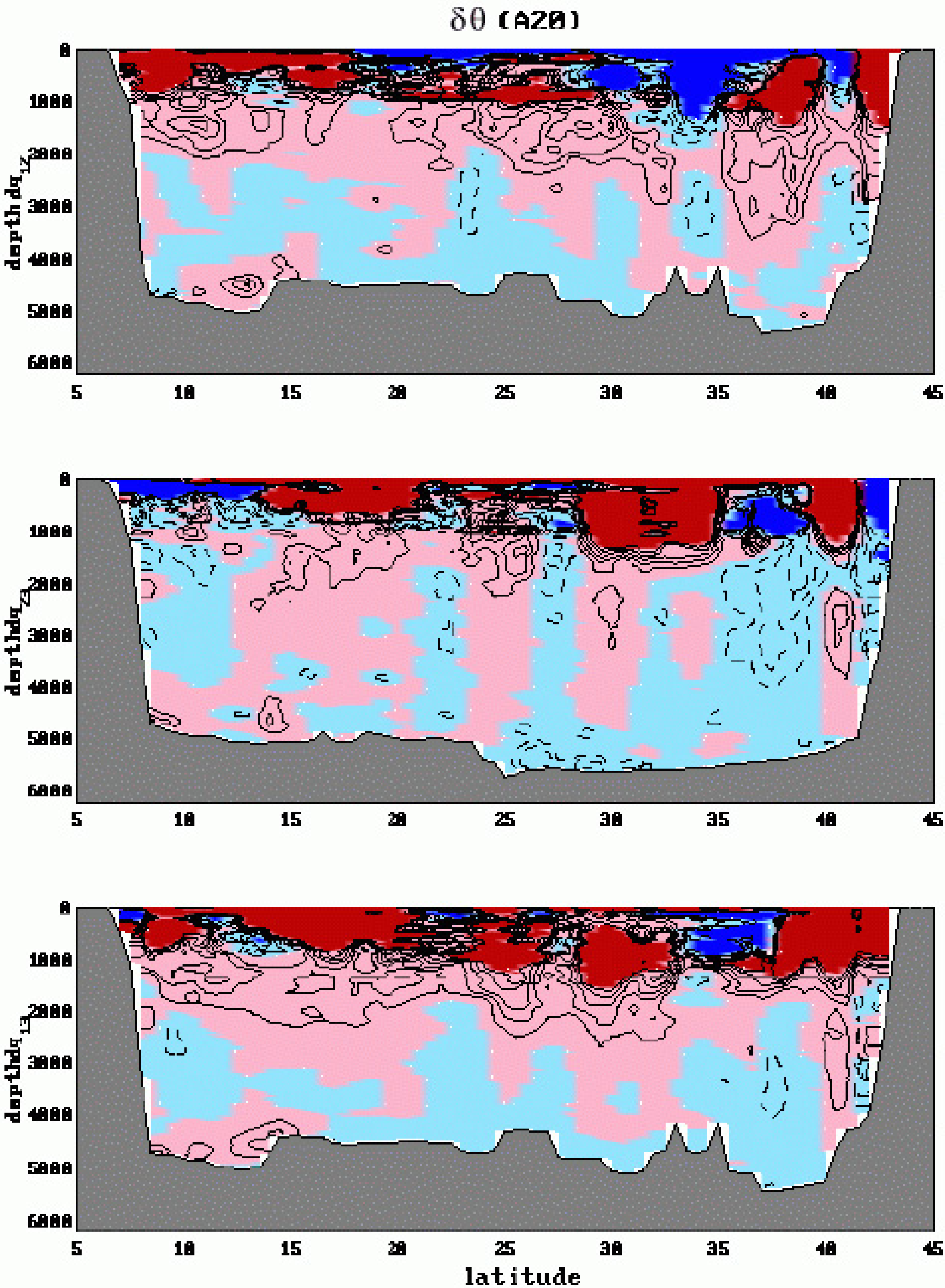
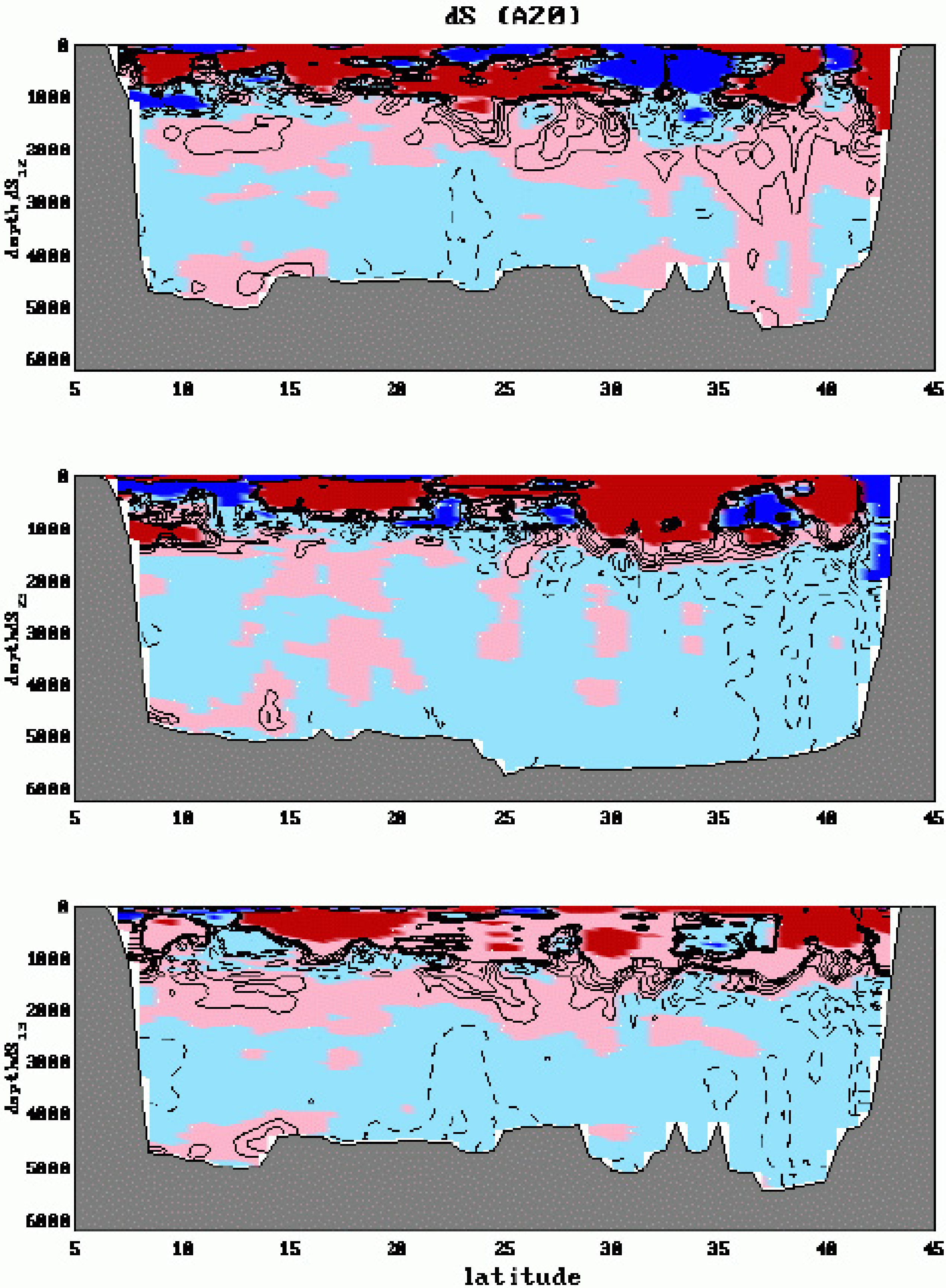

δθ (A20)
0
1000
2000
3000
4000
5000
6000
5
10
15
20
25
30
35
40
45
latitude

Figure 7b



dS (A20)
depth,dS12
depth,dS23
depth,dS13
0
1000
2000
3000
4000
5000
6000
5
10
15
20
25
30
35
40
45
latitude

Figure 8a

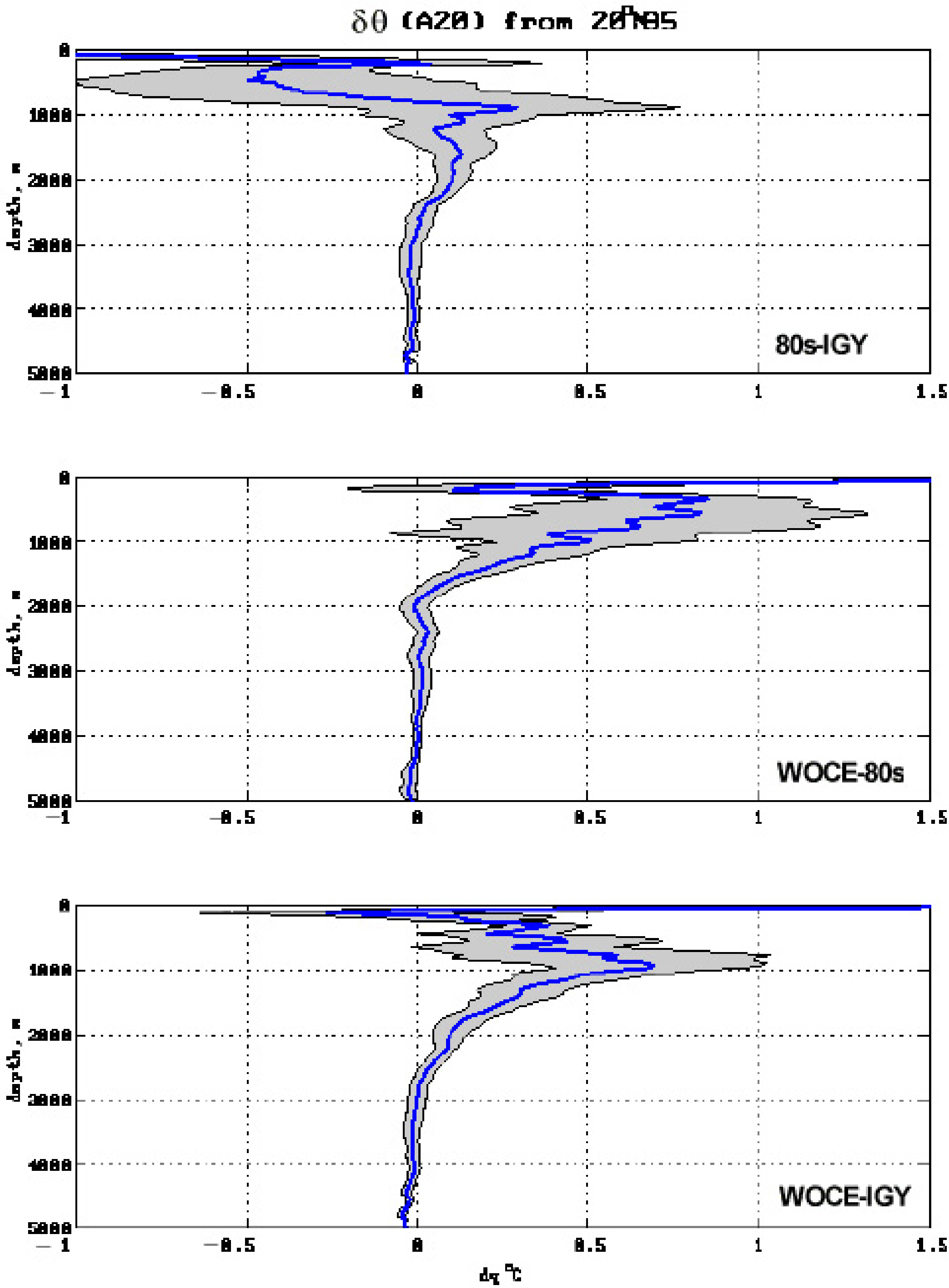
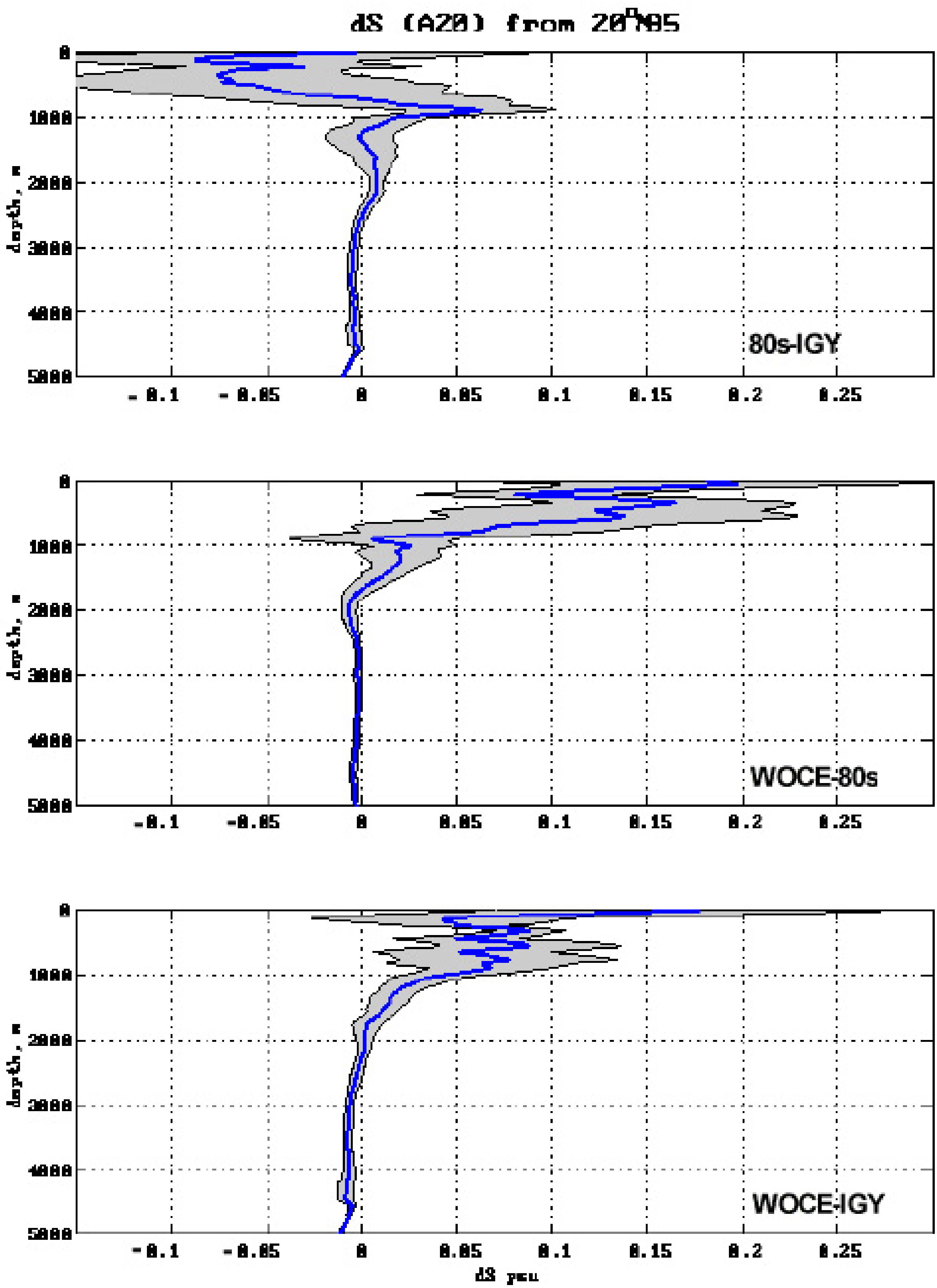

depth, m
0
1000
2000
3000
4000
5000
−1
−0.5
0
0.5
1
1.5
80s-IGY
WOCE-80s
WOCE-IGY

Figure 8b



dS (A20) from 20°W05
depth, m
0
1000
2000
3000
4000
5000
-0.1
-0.05
0
0.05
0.1
0.15
0.2
0.25
80s-IGY
WOCE-80s
WOCE-IGY
dS psu

Figure 9

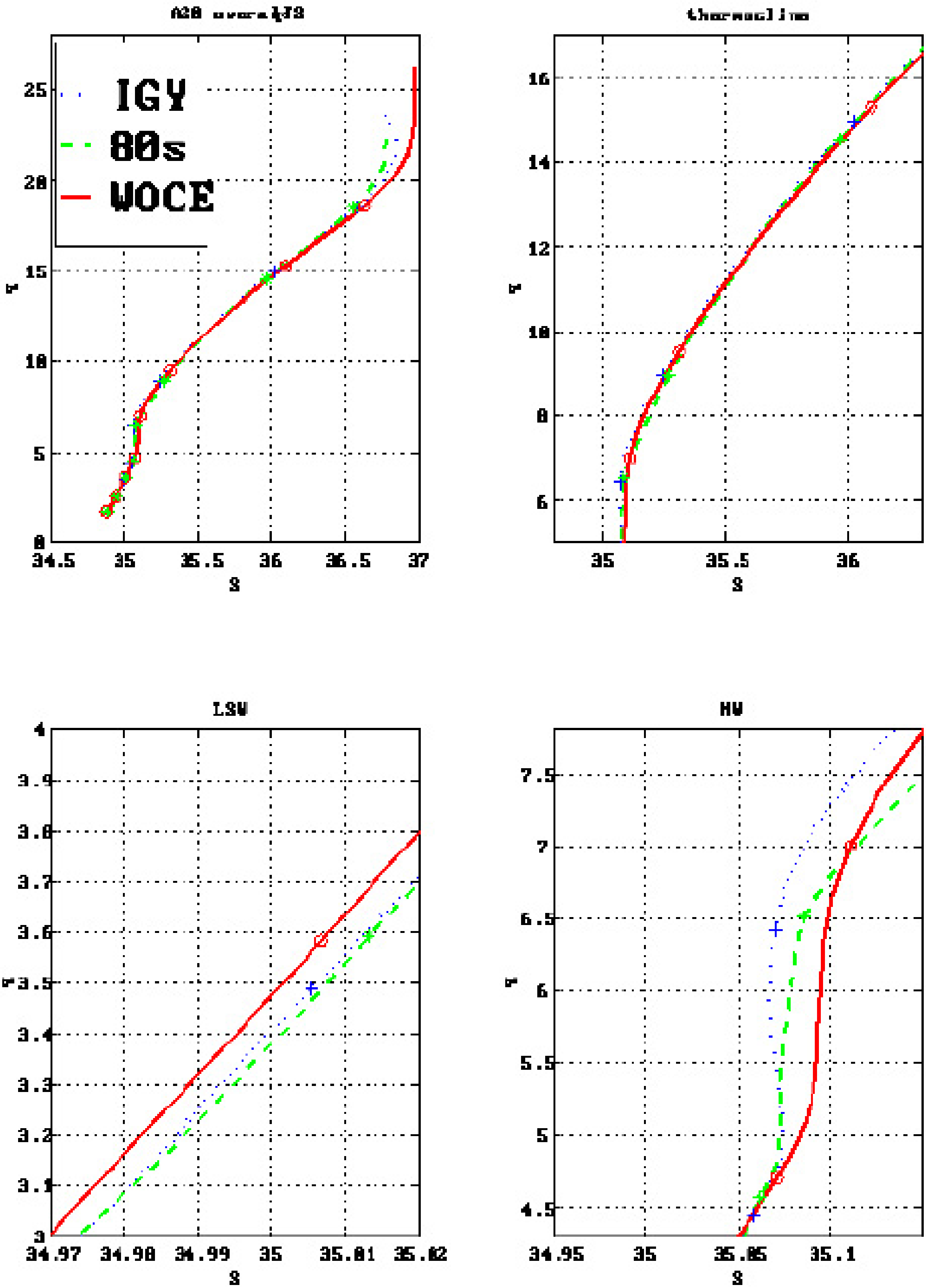
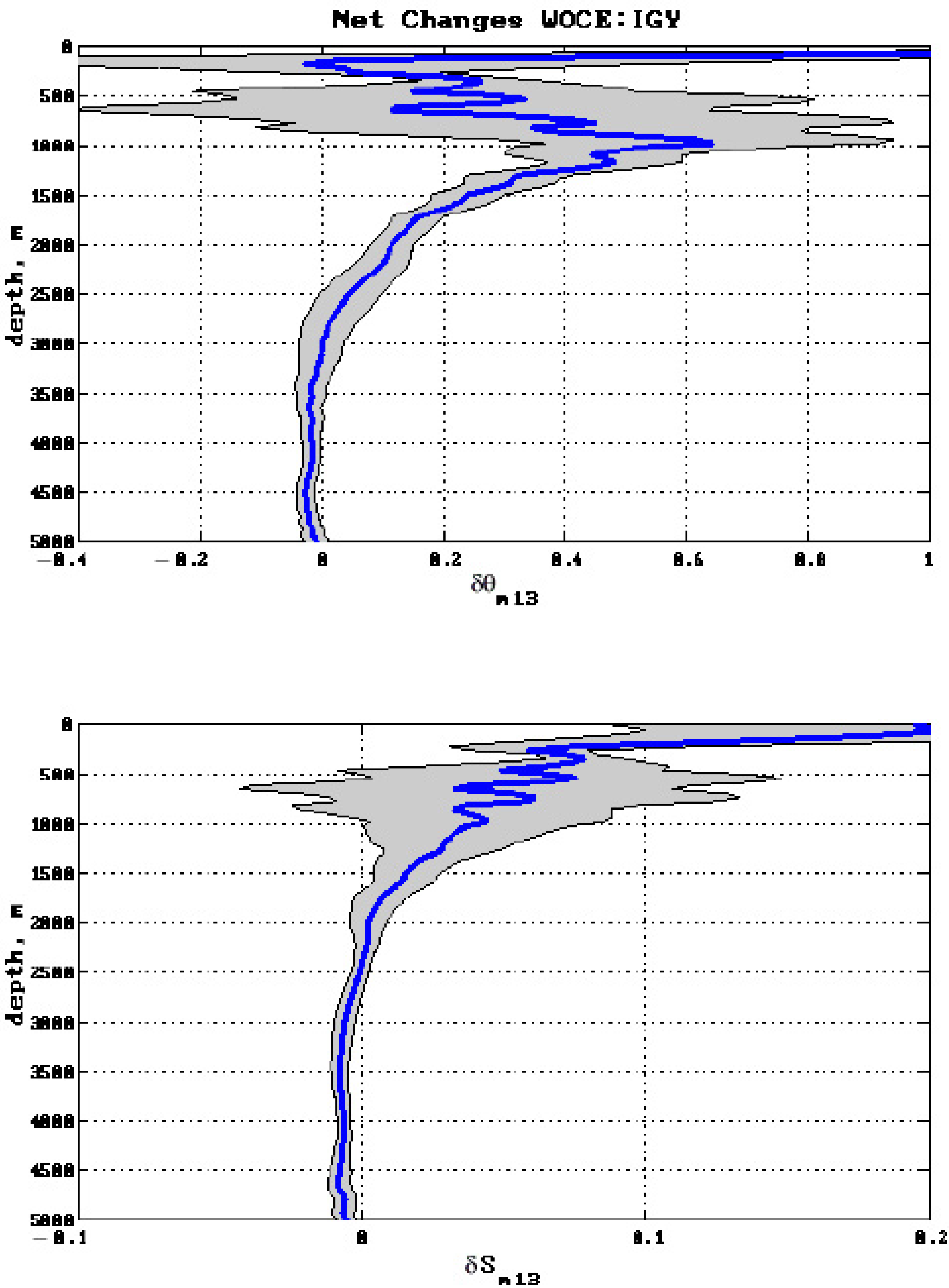


Figure 10



Net Changes WOCE:IGY
depth, m
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
−0.4
−0.2
0
0.2
0.4
0.6
0.8
1
δθ m13
depth, m
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
−0.1
0
0.1
0.2
δS m13

TABLE 1: CRUISE PARTICIPANTS

1.	Bob Pickart	WHOI	CTD (Chief Scientist)
2.	Marshall Swartz	WHOI	CTD-hardware/watchleader
3.	Daniel Torres	WHOI	CTD-LADCP
4.	Terry McKee	WHOI	CTD-Software
5.	Bob Millard	WHOI	CTD-Software
6.	George Tupper	WHOI	CTD-Hydrography
7.	Dave Wellwood	WHOI	CTD-Hydrography
8.	Shelley Ugstad	WHOI	CTD-watchleader
9.	Mindy Hall	WHOI	CTD-watchstander
10.	Avon Russell	WHOI	CTD-watchstander
11.	Brian Arbic	WHOI	CTD-watchstander
12.	Mark Davis	WHOI	CTD-watchstander
13.	Naomi Knoble	WHOI	CTD-watchstander
14.	Bill Smethie	LDEO	CFCs
15.	Eugene Gorman	LDEO	CFCs
16.	Damon Chaky	LDEO	CFCs
17.	Linda Baker	LDEO	CFCs
18.	Scott Birdwhistell	WHOI	Tritium/He
19.	Peter Landry	WHOI	Tritium/He
20.	Chris Sabine	Princeton	C14/Alkalinities
21.	Carrie Thomas	Princeton	C14/Alkalinities
22.	Rick Wilke	BNL	TCO2
23.	Ken Erikson	BNL	TCO2
24.	Angela Wilson	LDEO	PCO2
25.	Joe Jennings	OSU	Nutrients
26.	Barbara Sullivan	OSU	Nutrients
27.	Bob Moore	Dalhousie	Halocarbons
28.	Phil Morneau	Dalhousie	Halocarbons
29.	Wayne Groszko	Dalhousie	Halocarbons
30.	Carol Knudson	LDEO	Bio-optics
31.	Dana Swift	UW	PALACE floats

Table 2: Station Sampling Summary

STN	LAT (N)	LONG (W)	DEPTH*	CFC	HC	HE/TR	OXY	PCO2	TCO2	C14	ALK	NUTs	SALT	COMMENT
1	43°14.80	50°37.01	81											"Small Frame, CTD #1088"
2	43°12.23	50°38.87	85											
3	43°07.54	50°43.01	95											
4	43°03.13	50°46.95	112											
5	43°00.56	50°48.95	156											
6	42°58.09	50°50.78	306	6		5	6	6	6		6	6	6	
7	42°55.80	50°52.73	673	10		10	10	10	10	8	10	9	9	
8	42°53.65	50°54.26	948	14	10	13	18	18	18		18	18	18	"Switch to Large Frame, CTD #9"
9	42°49.03	50°58.16	1387	18			18	4			1	18	18	
10	42°38.06	51°07.30	1990	21		20	21	21	21	16	21	21	21	Subsurface Mooring Site
11	42°24.85	51°17.95	2664	20			25		1		1	25	25	
12	42°11.70	51°29.20	3257	21	10	24	30	24	30	24	30	30	30	
13	42°00.41	51°38.50	3578	22			30	1			1	30	30	
14	41°49.48	51°47.59	4007	24		24	30	22	30		30	30	30	Subsurface Mooring Site
15	41°34.38	51°59.00	4565	8			10					10	10	Missing All But the Bottom 6 Btls
16	41°34.50	51°59.15	4560	18			23		1		1	23	23	Repeat of Station 15 to 3100 db
17	41°20.22	52°10.62	5068	24	10		30	24	30		30	30	30	
18	41°07.72	52°20.85	5145	26		24	30	1			1	30	30	Begin Dogleg South
19	40°53.03	52°21.38	5031	25		24	30	20	30		30	30	30	
20	40°33.24	52°21.36	5188	20			30		1		1	30	30	
21	39°53.22	52°21.54	5269	27	10		30	1	30	26	30	30	30	
22	39°12.88	52°20.96	5321	30			30	1			1	30	30	
23	38°49.43	52°20.05	5337	30		23	30	22	30		30	30	30	North Wall of Gulf Stream
24	38°35.95	52°20.96	5344	12	11		30	15	30		1	30	30	
25	38°20.00	52°21.28	5355	30			30	24	30		30	30	30	
26	37°59.92	52°21.32	5375	29		24	30	1			1	30	30	
27	37°35.08	52°21.45	5429	18			30	22	30		30	30	30	Begin 40-Mile Spacing
28	36°55.16	52°20.95	5447	30	10	8	30				1	30	30	
29	36°14.35	52°21.13	2763	22			30	18	30		30	30	30	Seamount
30	35°33.70	52°20.89	4997	30		24	30	20	30	27	30	30	30	ALACE 013
31	34°53.33	52°21.10	5517	30			30		1		1	30	30	
32	34°12.83	52°21.10	5558	30	11		30	23	30		30	30	30	
33	33°32.33	52°21.17	5565	30		8	30	15	30		30	30	30	ALACE 020

Table 2: Station Sampling Summary

STN	LAT (N)	LONG (W)	DEPTH*	CFC	HC	HE/TR	OXY	PCO2	TCO2	C14	ALK	NUT	SALT	COMMENT
34	32°52.48	52°20.93	5632	31			33			32	1	33	33	
35	32°12.32	52°20.80	5360	33	11	23	33	20	33		33	33	33	ALACE 021
36	31°32.10	52°20.89	5498	30			33	4	33		33	33	33	
37	30°52.03	52°20.59	5165	31			33	15	1		1	33	33	ALACE 026
38	30°11.83	52°20.65	5676	32		8	32	22	32		32	32	32	
39	29°31.93	52°21.00	5380	30	11		33	21	33		33	33	33	ALACE 016
40	28°51.98	52°20.65	5639	32		25	33		1		?	33	33	
41	28°11.81	52°20.59	5478	33			33		33		33	33	33	ALACE 023
42	27°31.57	52°20.57	5899	30	11	8	33	33	33	27	33	33	33	
43	26°51.53	52°20.38	5405	33			33	1	1		1	33	33	ALACE 002
44	26°11.32	52°20.65	5909	33		23	33	?	33		33	33	33	
45	25°31.27	52°20.53	5782	29	14		33	20	33		33	33	33	ALACE 029
46	24°51.26	52°20.48	5127	33		8	33	1	1		1	33	33	
47	24°11.15	52°20.53	5450	33			33	21	33		33	33	33	ALACE 003
48	23°30.80	52°20.51	5028	29	12		33		33		33	33	33	
49	22°50.78	52°20.40	5090	33		24	33	1			1	33	33	ALACE 014
50	22°10.75	52°20.38	5016	33			33	22	33		33	33	28	
51	21°30.64	52°20.38	4907	32		16	32	24	32	27	32	32	32	
52	20°50.25	52°20.42	4391	33	13		33		1		1	33	33	ALACE 027
53	20°10.18	52°20.23	4881	33		24	33	22	33		33	33	33	
54	19°30.07	52°20.36	5363	33			33		33		33	33	33	
55	18°49.91	52°20.23	5137	31	12	4	33		1		1	33	33	
56	18°11.02	52°20.10	4851	33		8	33	24	33		33	33	33	
57	17°31.95	52°20.17	5690	33			33	11	33		33	33	33	
58	16°53.08	52°20.06	4825	33		23	33		1		1	33	33	
59	16°13.87	52°20.10	4987	31	12		33		33		33	33	33	
60	15°34.93	52°19.97	5115	17		8	33	24	33		33	33	33	
61	14°59.90	52°20.03	4521	33			33	14	33	27	33	33	33	
62	14°14.96	52°20.20	5187	33		24	33				1	33	33	
63	13°33.88	52°20.02	5231	29	12		33	24	33		33	33	33	
64	12°52.91	52°19.97	5231	33		8	33	12	33		33	33	33	
65	12°12.04	52°20.03	5068	33			33		1		1	33	33	
66	11°31.12	52°19.95	5005	31	12	23	33		33		33	33	33	

Table 2: Station Sampling Summary

STN	LAT (N)	LONG (W)	DEPTH*	CFC	HC	HE/TR	OXY	PCO2	TCO2	C14	ALK	NUT	SALT	COMMENT
67	10°50.02	52°19.85	4954	24			33	24	33		33	33	33	
68	10°09.10	52°19.72	4944	33		8	33		1	26	1	33	33	End 40-Mile Spacing
69	09°53.08	52°20.90	4921	4			33	24	33		33	33	33	
70	09°38.28	52°21.41	4892	31	12		33		33		33	33	33	
71	09°23.07	52°21.94	4836	24		24	33	13	1		1	33	33	Begin Dogleg West
72	09°11.15	52°27.80	4770	20			33		33		33	33	33	
73	08°58.50	52°33.98	4686	31			33		1		1	33	33	
74	08°47.05	52°39.86	4631	33		24	33		33		33	33	33	
75	08°38.08	52°43.90	4737	29	11		33	4	1		2	33	33	
76	08°28.87	52°49.03	3302	30	7	24	33	19	33	24	33	33	32	
77	08°19.97	52°53.27	2421	25			33	1	1		1	33	33	
78	08°10.93	52°57.47	1609	17		16	21	16	21	16	21	21	21	
79	08°03.47	53°01.25	1285	6			18		1		1	18	18	
80	07°55.93	53°04.95	1229	14			18		18		18	18	18	
81	07°49.00	53°08.57	1197	6			17		1		1	17	17	
82	07°41.57	53°12.11	999	14	12	13	18	18	18	8	18	18	18	
83	07°36.10	53°15.00	833				18		1		1	18	18	"Switch to Small Frame, CTD #1088"
84	07°30.90	53°17.18	682	11			12	4	12		12	12	12	
85	07°25.22	53°20.15	475	11			11		1		1	11	11	
86	07°22.48	53°21.40	399	10		8	10	1	1		1	10	10	
87	07°19.72	53°22.67	334		3		9	9	9		9	9	9	
88	07°17.03	53°24.00	282	7	1		7		1		1	7	7	
89	07°14.32	53°25.35	238				7		1		1	7	7	
90	07°11.60	53°26.68	208	6			6	6	6		6	6	6	
91	07°08.92	53°28.05	181				6		1		1	6	6	
92	07°06.18	53°29.30	131	11		3	7		1		1	7	7	
93	07°03.55	53°30.60	93				5		5		5	5	5	
94	07°00.82	53°32.00	85	5			5		1		1	5	5	
95	06°58.12	53°33.25	76				5		5		5	5	5	
Total				2066	238	608	2381	788	1488	288	1468	2380	2374	
Percent				15	2	4	17	6	11	2	10	17	17	

B. CTD PROCESSING and CALIBRATIONS

CTD CALIBRATIONS AND AT-SEA PROCESSING:

CTD 9 Cal files

Station 999 was a test station and was taken using CTD 9 and cal file:

kn51d999.c00 taken from cal file sent out for CTD 9: im09kn51.cal

kn51d999.c00 was updated with new conductivity terms and Pressure bias by R. Millard to kn51d999.c01

Differences in cal extensions:

	.c00	.c01
conductivity		
slope	0.972844e-03	.99569966E-3
bias	-0.416258e-01	.22897E-1
oxygen current		
slope	1.310000e-004	.0015
bias	8.540000e-001	0.0000
pcor	-1.177000e-005	.00015
tcor	-3.900000e-003	-.03
Pressure Temperature		
D1	-2.9015	-290.15

For CTD 9 im09kn51.c01 -- cal used for station 8 .c02 - was created but seemingly never used for ACQuistion.

Differences between .c002 and .c03 are:

diff im09kn51.c02 im09kn51.c03 (< = .c02 > = .c03)

Oxygen Current

SENSOR S/N ; New Sensor Installed 5 Oct 93
SENSOR S/N ; New Sensor Installed July 97
LAG ; 5.0
LAG ; 8.000000e+000

970720-MS: IM09kn51.c03 file updated from *.c01 modified by Millard.
.c01 used only for stn 008. Oxygen current and conductivity values were changed from previous version.

COMMENTS ON CAL FILES:

.c03 > 970720-MS: IM09kn51.c03 file updated from *.c01 modified by Millard. .c01 used only for stn 008. Oxygen current and conductivity values were changed from previous version.

.c04 > 970725-TKM: im09kn51.c04 file updated from *.c03 using new cals provided by Bob Millard. New conductivities from stations 14 - 18(?) and O2 cal from stations 11 - 14.

.c05 > 970728-TKM: im09kn51.c05 New pressure bias applied and new Oxygen cals provided by Bob Millard based on stations 20 - 36. Conductivity cal for stations xx - xx.

.c06 > 970801-TKM im09kn51.c06 New pressure bias applied and new Oxygen cals based on stations 24 - 41

Sta.	CTD	Cal
1-7	CTD 1088	im88kn51.cal (attached)
8	CTD 9	im09kn51.c01
9-29	CTD 9	im09kn51.c03
30-39	CTD 9	im09kn51.c04
40-53	CTD 9	im09kn51.c05
54-83	CTD 9	im09kn51.c06
83-95	CTD 1088	im88kn51.c01 (Oxygen current params zeroed)

CTD 1088 cal files:

PRESSURE

quadratic	-.131851E-09
slope	0.107562
bias	-.435024E+02
lag	0
ACQLAG	0.200

STANDARD TEMPERATURE

quadratic	0.545757E-12
slope	0.496728E-03
bias	-.164305E+01
lag	250.0

CONDUCTIVITY

slope	0.100263E-02
bias	-.108491E-01
lag	0
ACQLAG	0.100
ALPHA	-6.5E-6
BETA	1.5E-8
TO	2.8
PO	3000.0

OXYGEN CURRENT ;

A ;	9.658398926872436D-17
B ;	-1.412062274713116D-11
C ;	7.68213574439594D-07
D ;	-1.834161650101719D-02
E ;	162.4567809569779
LAG ;	7.50
PCOR ;	0.00015
TCOR ;	-0.036
C2 ;	0.75
TAU ;	0.0

OXYGEN TEMPERATURE

A ;	0
B ;	0.0
C ;	-.198691E-08
D ;	0.871938E-03
E ;	-.110374E+02
LAG ;	0

PRESSURE TEMPERATURE

A ;	0
B ;	0
C ;	0
D ;	-.255382E-02
E ;	0.107186E+03
LAG ;	0
ACQLAG ;	0.225
S1 ;	-2.6778E-06
S2 ;	-0.36463
T0 ;	1.4
D1 ;	0.218169

CHANGES TO O2 CAL FILE
CTD9
OXYGEN CURRENT ;

D ;	0.2325E-04
E ;	0.0
LAG ;	7.50
PCOR ;	0.00015
TCOR ;	-0.036
C2 ;	0.75
TAU ;	0.0

AT-SEA PROCESSING:

For CTD 9, conductivity sensor was very stable and required little adjusting. Terry McKee processed the data and Bob Millard provided calibration. Pressure bias required some adjusting at station 40 to make instrument measure 0 for on-deck pressure and to minimize the difference between on-deck pressure for the downcast and the upcast.

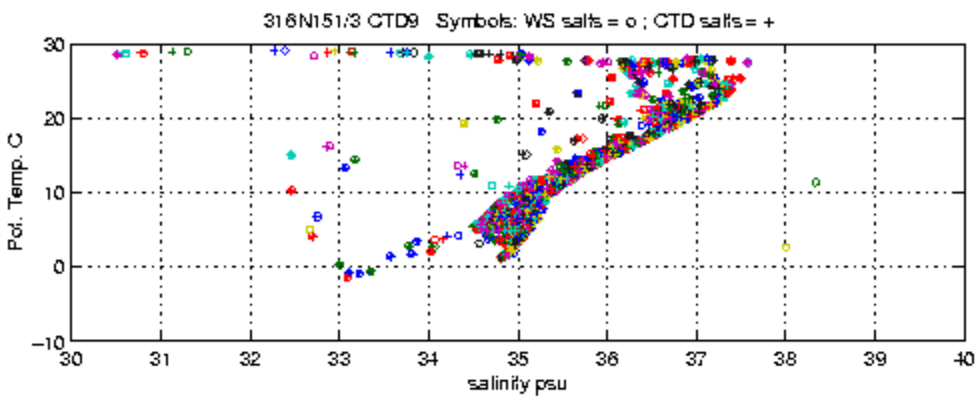
SHORE-BASED PROCESSING:

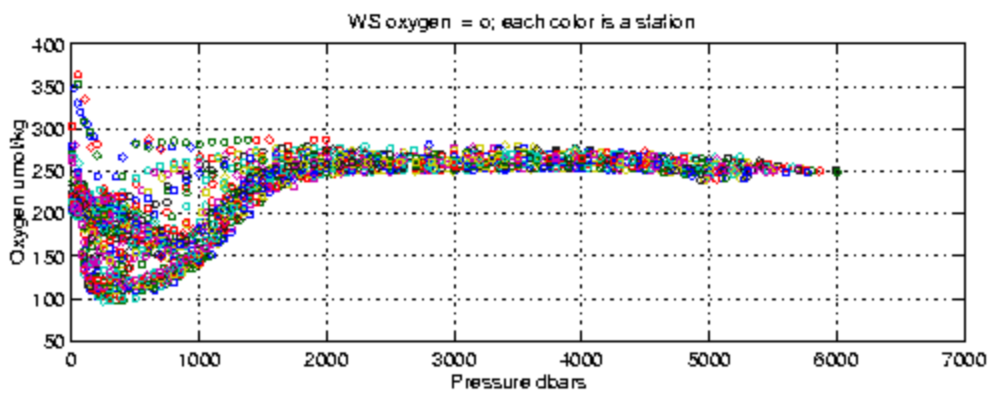
Calibrations were done by R.Millard , and processing by J.Dunworth-Baker

Extensive plotting and comparing led to converting the D1 term in pressure to -400 for CTD9

CTD9

Matlab routines were developed to better fit the data in station groups. Conductivity cals were refined. Oxygen fitting programs/routines were modified to allow for 2 different cals for each station...0-1500 dbars and 1500-bottom. The two cals were feathered together over 200 dbars. Bad surface values were smoothed or eliminated. The ctd data were extracted from the matlab workspace into the woce format, using wct_wrt2. Corrected ctdsal and ctdoxy at bottle levels were also extracted from the workspace into a sea file template, and merged into the final sea file (316N151_3.sea).



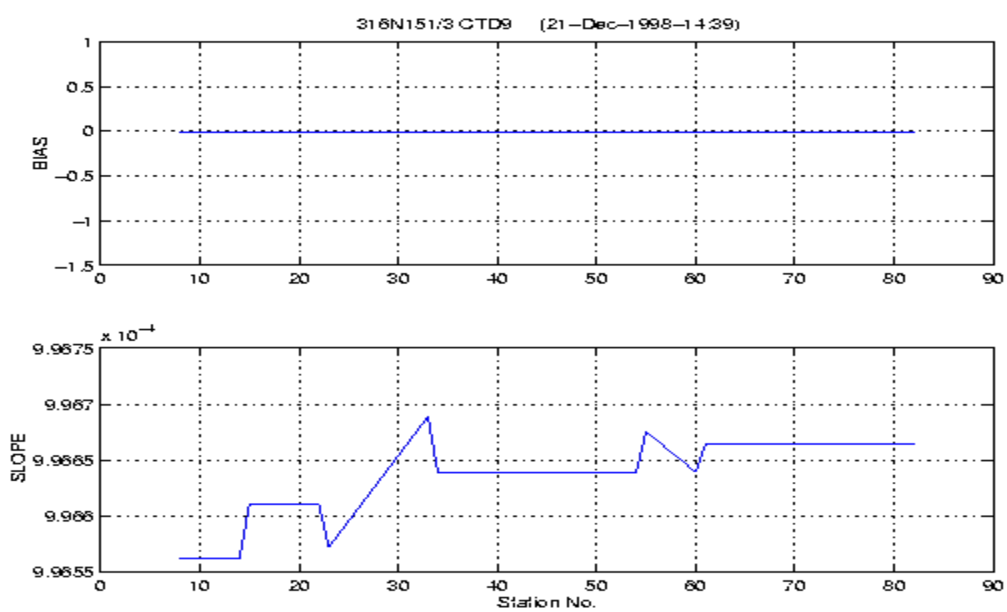


MATLAB FILE: kn151v3
CRUISE: 316N151_3
DATE: 17-Dec-1998

CTD9 sta	Conductivity slope	Calib. bias
8	0.000996561	-0.01
9	0.000996561	-0.01
10	0.000996561	-0.01
11	0.000996561	-0.01
12	0.000996561	-0.01
13	0.000996561	-0.01
14	0.000996561	-0.01
15	0.000996611	-0.01
16	0.000996611	-0.01
17	0.000996611	-0.01
18	0.000996611	-0.01
19	0.000996611	-0.01
20	0.000996611	-0.01
21	0.000996611	-0.01
22	0.000996611	-0.01
23	0.000996572	-0.01
24	0.000996584	-0.01
25	0.000996595	-0.01
26	0.000996607	-0.01
27	0.000996619	-0.01
28	0.00099663	-0.01
29	0.000996642	-0.01
30	0.000996654	-0.01
31	0.000996665	-0.01
32	0.000996677	-0.01
33	0.000996689	-0.01

CTD9 sta	Conductivity slope	Calib. bias
34	0.000996639	-0.01
35	0.000996639	-0.01
36	0.000996639	-0.01
37	0.000996639	-0.01
38	0.000996639	-0.01
39	0.000996639	-0.01
40	0.000996639	-0.01
41	0.000996639	-0.01
42	0.000996639	-0.01
43	0.000996639	-0.01
44	0.000996639	-0.01
45	0.000996639	-0.01
46	0.000996639	-0.01
47	0.000996639	-0.01
48	0.000996639	-0.01
49	0.000996639	-0.01
50	0.000996639	-0.01
51	0.000996639	-0.01
52	0.000996639	-0.01
53	0.000996639	-0.01
54	0.000996639	-0.01
55	0.000996675	-0.01
56	0.000996668	-0.01
57	0.000996661	-0.01
58	0.000996654	-0.01
59	0.000996646	-0.01

CTD9 sta	Conductivity slope	Calib. bias
60	0.000996639	-0.01
61	0.000996664	-0.01
62	0.000996664	-0.01
63	0.000996664	-0.01
64	0.000996664	-0.01
65	0.000996664	-0.01
66	0.000996664	-0.01
67	0.000996664	-0.01
68	0.000996664	-0.01
69	0.000996664	-0.01
70	0.000996664	-0.01
71	0.000996664	-0.01
72	0.000996664	-0.01
73	0.000996664	-0.01
74	0.000996664	-0.01
75	0.000996664	-0.01
76	0.000996664	-0.01
77	0.000996664	-0.01
78	0.000996664	-0.01
79	0.000996664	-0.01
80	0.000996664	-0.01
81	0.000996664	-0.01
82	0.000996664	-0.01



MATLAB FILE: kn51v5
CRUISE: 316N151_3
DATE: 21-Dec-1998

SHALLOW OXYGEN CALIBRATIONS

sta	bias	slope	pcor	tcor	wt	lag
8	0.04014	0.00139344	0.000148981	-0.03203	0.4331	3.7445
9	0.04014	0.00139344	0.000148981	-0.03203	0.4331	3.7445
10	0.04014	0.00139344	0.000148981	-0.03203	0.4331	3.7445
11	0.04014	0.00139344	0.000148981	-0.03203	0.4331	3.7445
12	0.04014	0.00139344	0.000148981	-0.03203	0.4331	3.7445
13	0.04014	0.00139344	0.000148981	-0.03203	0.4331	3.7445
14	0.04014	0.00139344	0.000148981	-0.03203	0.4331	3.7445
15	0.04014	0.00139344	0.000148981	-0.03203	0.4331	3.7445
16	0.04014	0.00139344	0.000148981	-0.03203	0.4331	3.7445
17	0.04014	0.00139344	0.000148981	-0.03203	0.4331	3.7445
18	0.04014	0.00139344	0.000148981	-0.03203	0.4331	3.7445
19	0.04014	0.00139344	0.000148981	-0.03203	0.4331	3.7445
20	0.04014	0.00139344	0.000148981	-0.03203	0.4331	3.7445
21	0.04014	0.00139344	0.000148981	-0.03203	0.4331	3.7445
22	0.04014	0.00139344	0.000148981	-0.03203	0.4331	3.7445
23	0.01354	0.00133207	0.000198752	-0.02617	0.5241	3.7445
24	0.01354	0.00133207	0.000198752	-0.02617	0.5241	3.7445
25	0.01354	0.00133207	0.000198752	-0.02617	0.5241	3.7445
26	0.01354	0.00133207	0.000198752	-0.02617	0.5241	3.7445
27	0.01354	0.00133207	0.000198752	-0.02617	0.5241	3.7445
28	0.01354	0.00133207	0.000198752	-0.02617	0.5241	3.7445
29	0.01354	0.00133207	0.000198752	-0.02617	0.5241	3.7445
30	0.01354	0.00133207	0.000198752	-0.02617	0.5241	3.7445
31	0.01354	0.00133207	0.000198752	-0.02617	0.5241	3.7445
32	0.01354	0.00133207	0.000198752	-0.02617	0.5241	3.7445
33	0.01354	0.00133207	0.000198752	-0.02617	0.5241	3.7445
34	0.01354	0.00133207	0.000198752	-0.02617	0.5241	3.7445
35	0.01354	0.00133207	0.000198752	-0.02617	0.5241	3.7445
36	0.10237	0.00127476	0.000134255	-0.02508	0.7139	3.7445
37	0.10237	0.00127476	0.000134255	-0.02508	0.7139	3.7445
38	0.10237	0.00127476	0.000134255	-0.02508	0.7139	3.7445
39	0.10237	0.00127476	0.000134255	-0.02508	0.7139	3.7445
40	0.10237	0.00127476	0.000134255	-0.02508	0.7139	3.7445
41	0.10237	0.00127476	0.000134255	-0.02508	0.7139	3.7445
42	0.10237	0.00127476	0.000134255	-0.02508	0.7139	3.7445
43	0.08834	0.00104998	0.000239343	-0.01718	0.9557	3.7445
44	0.08834	0.00104998	0.000239343	-0.01718	0.9557	3.7445
45	0.08834	0.00104998	0.000239343	-0.01718	0.9557	3.7445
46	0.08834	0.00104998	0.000239343	-0.01718	0.9557	3.7445
47	0.08834	0.00104998	0.000239343	-0.01718	0.9557	3.7445
48	0.08834	0.00104998	0.000239343	-0.01718	0.9557	3.7445
49	0.08834	0.00104998	0.000239343	-0.01718	0.9557	3.7445
50	0.07287	0.000999973	0.000270196	-0.01557	0.8203	3.7445
51	0.07287	0.000999973	0.000270196	-0.01557	0.8203	3.7445
52	0.07287	0.000999973	0.000270196	-0.01557	0.8203	3.7445
53	0.07287	0.000999973	0.000270196	-0.01557	0.8203	3.7445
54	0.07287	0.000999973	0.000270196	-0.01557	0.8203	3.7445
55	0.07287	0.000999973	0.000270196	-0.01557	0.8203	3.7445

SHALLOW OXYGEN CALIBRATIONS (continued)

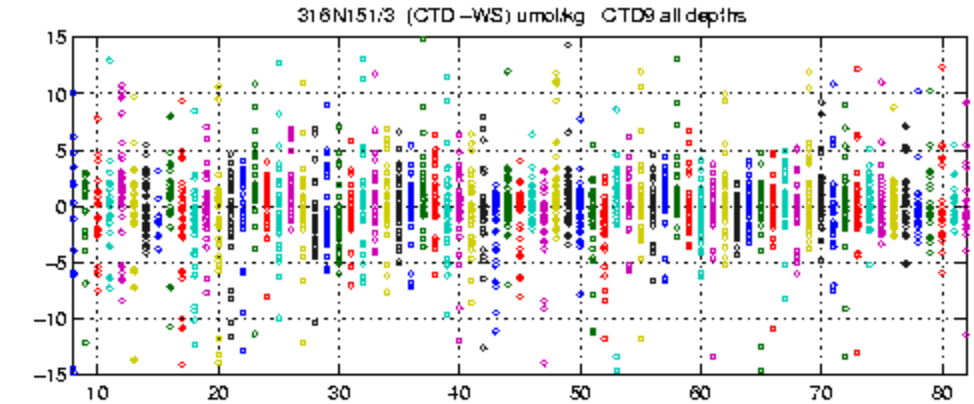
sta	bias	slope	pcor	tcor	wt	lag
56	0.07287	0.000999973	0.000270196	-0.01557	0.8203	3.7445
57	0.07287	0.000999973	0.000270196	-0.01557	0.8203	3.7445
58	0.07287	0.000999973	0.000270196	-0.01557	0.8203	3.7445
59	0.07287	0.000999973	0.000270196	-0.01557	0.8203	3.7445
60	0.09969	0.000772958	0.000351996	-0.00832	1.0417	3.7445
61	0.09969	0.000772958	0.000351996	-0.00832	1.0417	3.7445
62	0.09969	0.000772958	0.000351996	-0.00832	1.0417	3.7445
63	0.09969	0.000772958	0.000351996	-0.00832	1.0417	3.7445
64	0.09969	0.000772958	0.000351996	-0.00832	1.0417	3.7445
65	0.09969	0.000772958	0.000351996	-0.00832	1.0417	3.7445
66	0.09969	0.000772958	0.000351996	-0.00832	1.0417	3.7445
67	0.09969	0.000772958	0.000351996	-0.00832	1.0417	3.7445
68	0.0374	0.00141479	0.000130707	-0.02767	0.6427	3.7445
69	0.0374	0.00141479	0.000130707	-0.02767	0.6427	3.7445
70	0.0374	0.00141479	0.000130707	-0.02767	0.6427	3.7445
71	0.0374	0.00141479	0.000130707	-0.02767	0.6427	3.7445
72	0.0374	0.00141479	0.000130707	-0.02767	0.6427	3.7445
73	0.0374	0.00141479	0.000130707	-0.02767	0.6427	3.7445
74	0.0374	0.00141479	0.000130707	-0.02767	0.6427	3.7445
75	0.0374	0.00141479	0.000130707	-0.02767	0.6427	3.7445
76	0.0374	0.00141479	0.000130707	-0.02767	0.6427	3.7445
77	0.0374	0.00141479	0.000130707	-0.02767	0.6427	3.7445
78	0.0374	0.00141479	0.000130707	-0.02767	0.6427	3.7445
79	0.0374	0.00141479	0.000130707	-0.02767	0.6427	3.7445
80	0.0374	0.00141479	0.000130707	-0.02767	0.6427	3.7445
81	0.0374	0.00141479	0.000130707	-0.02767	0.6427	3.7445
82	0.0374	0.00141479	0.000130707	-0.02767	0.6427	3.7445

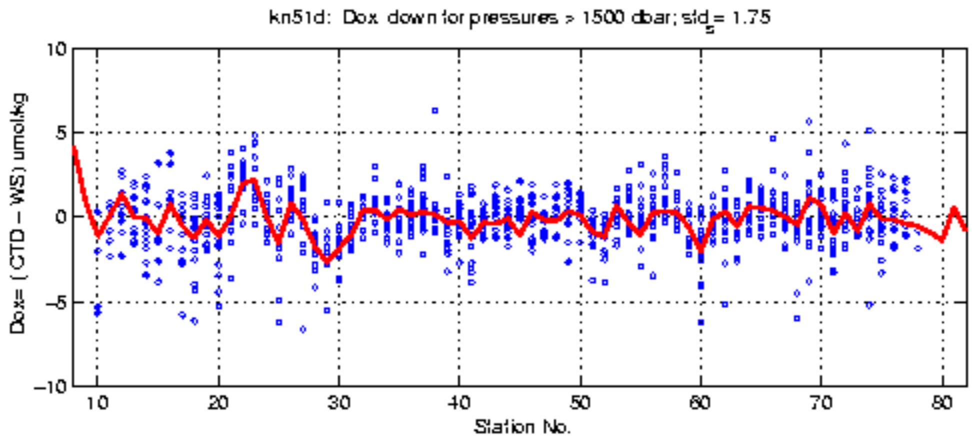
DEEP OXYGEN CALIBRATIONS

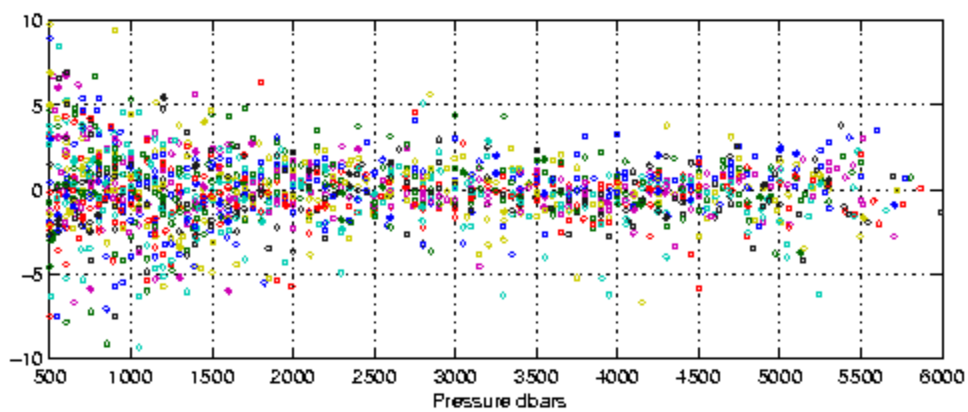
sta	bias	slope	pcor	tcor	wt	lag
8	0.85511	0.000391626	-1.51141e-005	-0.04796	-0.2813	3.7445
9	0.85511	0.000391626	-1.51141e-005	-0.04796	0.2813	3.7445
10	0.85511	0.000391626	-1.51141e-005	-0.04796	0.2813	3.7445
11	0.85511	0.000391626	-1.51141e-005	-0.04796	0.2813	3.7445
12	0.85511	0.000391626	-1.51141e-005	-0.04796	0.2813	3.7445
13	0.85511	0.000391626	-1.51141e-005	-0.04796	0.2813	3.7445
14	0.85511	0.000391626	-1.51141e-005	-0.04796	0.2813	3.7445
15	0.85511	0.000391626	-1.51141e-005	-0.04796	0.2813	3.7445
16	0.85511	0.000391626	-1.51141e-005	-0.04796	0.2813	3.7445
17	0.85511	0.000391626	-1.51141e-005	-0.04796	0.2813	3.7445
18	0.85511	0.000391626	-1.51141e-005	-0.04796	0.2813	3.7445
19	0.85511	0.000391626	-1.51141e-005	-0.04796	0.2813	3.7445
20	0.85511	0.000391626	-1.51141e-005	-0.04796	0.2813	3.7445
21	0.85511	0.000391626	-1.51141e-005	-0.04796	0.2813	3.7445
22	0.85511	0.000391626	-1.51141e-005	-0.04796	0.2813	3.7445
23	0.05047	0.00156142	0.000127505	-0.0496	0.2164	3.7445
24	0.05047	0.00156142	0.000127505	-0.0496	0.2164	3.7445
25	0.05047	0.00156142	0.000127505	-0.0496	0.2164	3.7445
26	0.05047	0.00156142	0.000127505	-0.0496	0.2164	3.7445
27	0.05047	0.00156142	0.000127505	-0.0496	0.2164	3.7445
28	0.05047	0.00156142	0.000127505	-0.0496	0.2164	3.7445
29	0.05047	0.00156142	0.000127505	-0.0496	0.2164	3.7445
30	0.05047	0.00156142	0.000127505	-0.0496	0.2164	3.7445
31	0.05047	0.00156142	0.000127505	-0.0496	0.2164	3.7445
32	0.05047	0.00156142	0.000127505	-0.0496	0.2164	3.7445
33	0.05047	0.00156142	0.000127505	-0.0496	0.2164	3.7445
34	0.05047	0.00156142	0.000127505	-0.0496	0.2164	3.7445
35	0.05047	0.00156142	0.000127505	-0.0496	0.2164	3.7445
36	0.02659	0.00158339	0.00013476	-0.05036	0.1415	3.7445
37	0.02659	0.00158339	0.00013476	-0.05036	0.1415	3.7445
38	0.02659	0.00158339	0.00013476	-0.05036	0.1415	3.7445
39	0.02659	0.00158339	0.00013476	-0.05036	0.1415	3.7445
40	0.02659	0.00158339	0.00013476	-0.05036	0.1415	3.7445
41	0.02659	0.00158339	0.00013476	-0.05036	0.1415	3.7445
42	0.02659	0.00158339	0.00013476	-0.05036	0.1415	3.7445
43	-0.05262	0.00152784	0.000173455	-0.02333	1.0655	3.7445
44	-0.05262	0.00152784	0.000173455	-0.02333	1.0655	3.7445
45	-0.05262	0.00152784	0.000173455	-0.02333	1.0655	3.7445
46	-0.05262	0.00152784	0.000173455	-0.02333	1.0655	3.7445
47	-0.05262	0.00152784	0.000173455	-0.02333	1.0655	3.7445
48	-0.05262	0.00152784	0.000173455	-0.02333	1.0655	3.7445
49	-0.05262	0.00152784	0.000173455	-0.02333	1.0655	3.7445
50	-0.00274	0.00149448	0.000153066	-0.02868	0.8203	3.7445
51	-0.00274	0.00149448	0.000153066	-0.02868	0.8203	3.7445
52	-0.00274	0.00149448	0.000153066	-0.02868	0.8203	3.7445
53	-0.00274	0.00149448	0.000153066	-0.02868	0.8203	3.7445
54	-0.00274	0.00149448	0.000153066	-0.02868	0.8203	3.7445
55	-0.00274	0.00149448	0.000153066	-0.02868	0.8203	3.7445
56	-0.00274	0.00149448	0.000153066	-0.02868	0.8203	3.7445
57	-0.00274	0.00149448	0.000153066	-0.02868	0.8203	3.7445
58	-0.00274	0.00149448	0.000153066	-0.02868	0.8203	3.7445
59	-0.00274	0.00149448	0.000153066	-0.02868	0.8203	3.7445

DEEP OXYGEN CALIBRATIONS (continued)

sta	bias	slope	pcor	tcor	wt	lag
60	0.02911	0.00149021	0.000139251	-0.03213	1.0417	3.7445
61	0.02911	0.00149021	0.000139251	-0.03213	1.0417	3.7445
62	0.02911	0.00149021	0.000139251	-0.03213	1.0417	3.7445
63	0.02911	0.00149021	0.000139251	-0.03213	1.0417	3.7445
64	0.02911	0.00149021	0.000139251	-0.03213	1.0417	3.7445
65	0.02911	0.00149021	0.000139251	-0.03213	1.0417	3.7445
66	0.02911	0.00149021	0.000139251	-0.03213	1.0417	3.7445
67	0.02911	0.00149021	0.000139251	-0.03213	1.0417	3.7445
68	0.00492	0.00149473	0.000149884	-0.03184	1.0000	3.7445
69	0.00492	0.00149473	0.000149884	-0.03184	1.0000	3.7445
70	0.00492	0.00149473	0.000149884	-0.03184	1.0000	3.7445
71	0.00492	0.00149473	0.000149884	-0.03184	1.0000	3.7445
72	0.00492	0.00149473	0.000149884	-0.03184	1.0000	3.7445
73	0.00492	0.00149473	0.000149884	-0.03184	1.0000	3.7445
74	0.00492	0.00149473	0.000149884	-0.03184	1.0000	3.7445
75	0.00492	0.00149473	0.000149884	-0.03184	1.0000	3.7445
76	0.00492	0.00149473	0.000149884	-0.03184	1.0000	3.7445
77	0.00492	0.00149473	0.000149884	-0.03184	1.0000	3.7445
78	0.00492	0.00149473	0.000149884	-0.03184	1.0000	3.7445
79	0.00492	0.00149473	0.000149884	-0.03184	1.0000	3.7445
80	0.00492	0.00149473	0.000149884	-0.03184	1.0000	3.7445
81	0.00492	0.00149473	0.000149884	-0.03184	1.0000	3.7445
82	0.00492	0.00149473	0.000149884	-0.03184	1.0000	3.7445

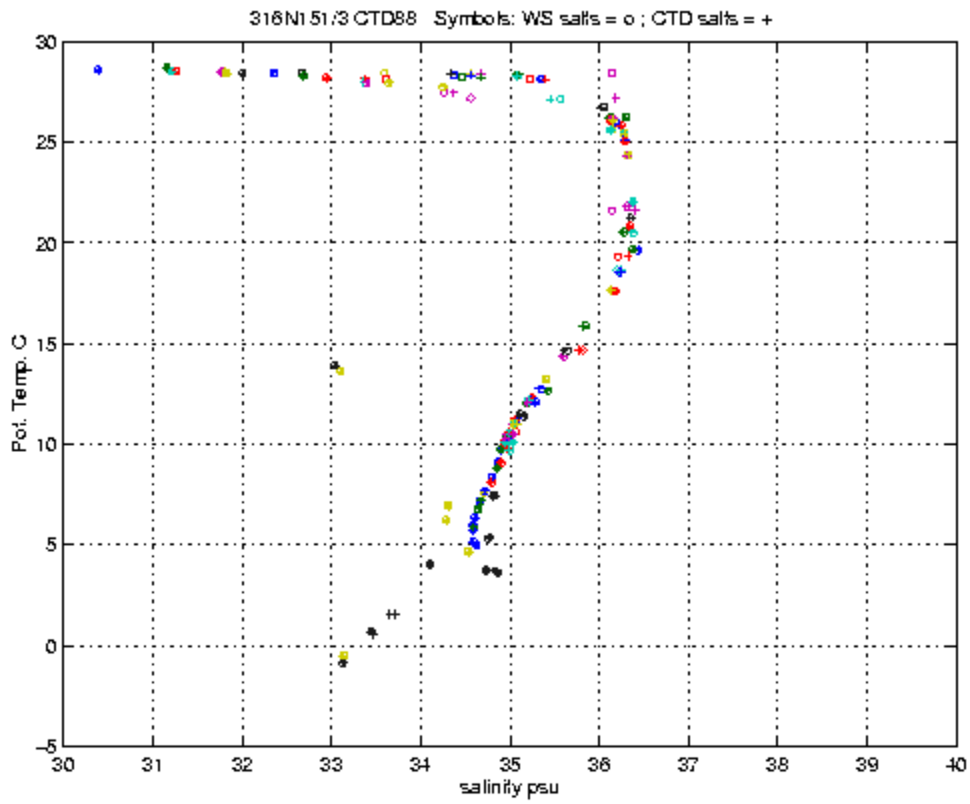

316N151/3 (CTD –WS) umol/kg CTD9 all depths

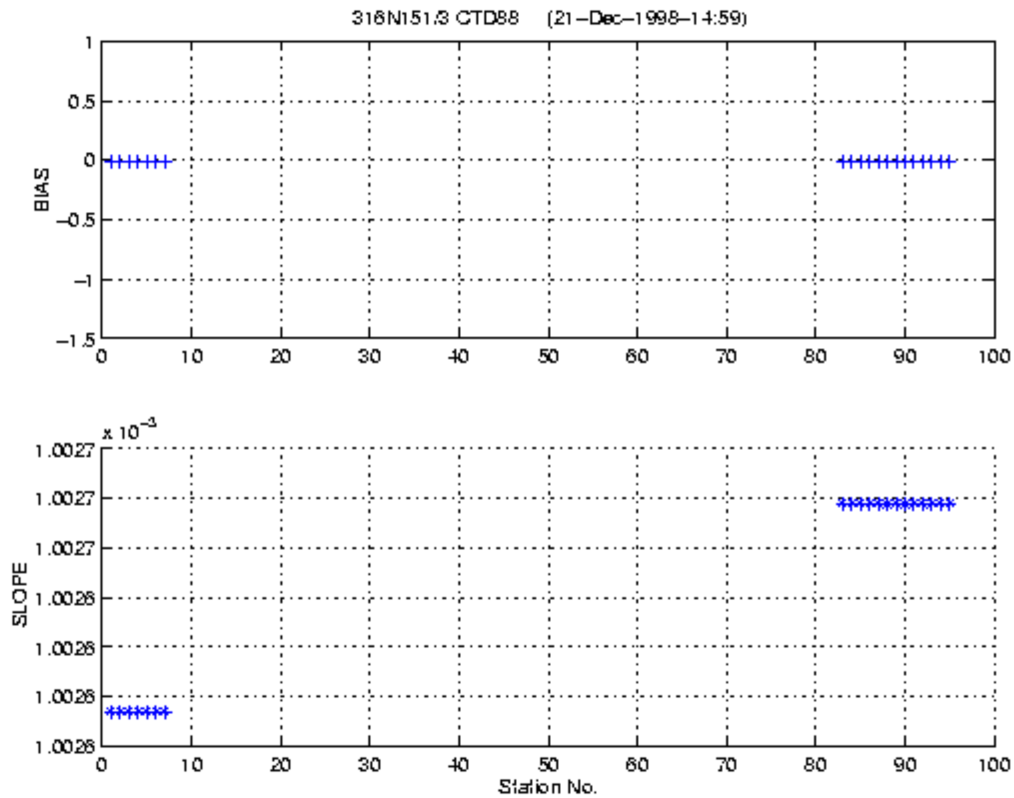

kn51d: Dox down for pressures > 1500 dbar; std$_s$= 1.75
Dox= (CTD – WS) umol/kg
Station No.


Pressure dbars

CTD88

At sea co cals were checked and considered final. The ctdoxy was deemed un-fixable. Quality flags for ctdoxy in the ctd data and in the sea file are set to 4, and the quasi-calibrated ctdoxy are reported.





MATLAB FILE: kn51v88
CRUISE: 316N151/3

Conductivity Calibrations

sta	bias	slope
1	-0.011	0.00100259
2	-0.011	0.00100259
3	-0.011	0.00100259
4	-0.011	0.00100259
5	-0.011	0.00100259
6	-0.011	0.00100259
7	-0.011	0.00100259
83	-0.011	0.00100268
84	-0.011	0.00100268
85	-0.011	0.00100268
86	-0.011	0.00100268
87	-0.011	0.00100268
88	-0.011	0.00100268
89	-0.011	0.00100268
90	-0.011	0.00100268
91	-0.011	0.00100268
92	-0.011	0.00100268
93	-0.011	0.00100268
94	-0.011	0.00100268
95	-0.011	0.00100268

C. NUTRIENT ANALYSES
(8-Jun-98)

C.1. EQUIPMENT AND TECHNIQUES

Dissolved nutrient analyses were performed by J.C. Jennings, Jr. and B. E. Sullivan from Dr. L. I Gordon's group at Oregon State University (OSU). The analyses were performed using a Technicon AutoAnalyzerII (AAII) which is the property of Scripps Institution of Oceanography's Oceanographic Data Facility (ODF). This AutoAnalyzer has been used throughout the ACCE Program. For this 52W leg, we substituted an Alpkem Model 303 autosampler for the ODF autosampler. A Keithley model 575 data acquisition system was used in parallel with analog stripchart recorders to acquire the absorbance data for this leg. The software used to process the nutrient data was developed at OSU. OSU provided all of the reagent and standard materials. The analytical methods are described in Gordon et al (1994).

Sampling Procedures:

Nutrient samples were drawn from all sampled depths on CTD/rosette casts at stations 006 to 095. High-density polyethylene (HDPE) bottles of approximately 30-mL volume were used as sample containers, and these same bottles were positioned directly in the autosampler tray. These sample bottles were routinely rinsed at least 3 times with the sample seawater before filling. Sample bottles were rinsed twice with deionized water after sample runs, and were soaked in 10% HCl every other day. The nutrient samples were drawn following those for CFCs, helium, tritium, dissolved oxygen, carbon dioxide, alkalinity and salinity. At most stations, the AAII sample run was started before sampling was completed to reduce delay and minimize possible changes in nutrient concentration due to biological processes.

C.2. CALIBRATION AND STANDARDIZATION:

Calibration standards for the nutrient analyses were prepared from high purity preweighed crystalline standard materials. The phosphate and nitrate standard materials had been compared in the OSU laboratory with NIST Standard Reference Materials and the silicofluoride with ultra high purity SiO_2 and silicon metal. The materials used were: Phosphate standard: JT Baker potassium di-hydrogen phosphate lot 39548. Nitrate standard: Mallinkrodt potassium nitrate lot VTA. Silicic acid standard: J. T. Baker sodium silicofluoride lot 21078 10A. Nitrite standard: MCB sodium nitrite lot 4205.

At the beginning of the cruise, six separate high concentration standards were prepared in deionized water; two silicic acid standards, two nitrite standards, and two mixed phosphate and nitrate standards. These duplicate standards were compared before use to ensure the accuracy of their preparation. Then more dilute mixed standards containing silicic acid, nitrate and phosphate were prepared from these high concentration standards. Similar mixed standards containing nitrate, phosphate, and silicic acid were prepared in duplicate at intervals of 7 to 10 days and kept refrigerated in HDPE bottles. For almost every station, a fresh "working standard" was prepared by adding aliquots of the high concentration mixed standard and the nitrite standard to low nutrient seawater. Working standards were not used if more than six hours had elapsed after their preparation. These working standards had nutrient concentrations similar to those found in Deep and Bottom waters.

The volumetric flasks and pipettors used to prepare standards were gravimetrically calibrated prior to the cruise. The Eppendorf Maxipettor adjustable pipettors used to prepare mixed standards typically have a standard deviation of less than 0.002 mL on repeated deliveries of 10-mL volumes. Corrections for the actual volumes of the flasks and pipettors were included in the preliminary data. The WOCE Operations Manual calls for nutrient concentrations to be reported in units of micromole/kg. Because the salinity information required to compute density is not usually available at the time of initial computation of the nutrient concentrations, our concentrations are always originally computed as micromole/L (uM). This unit conversion will be made using the corrected salinity data when it is available.

C.3. MEASUREMENT OF PRECISION AND BIAS:

C.3.1. Short Term Precision and Bias:

Throughout the cruise, replicate samples drawn in different sample bottles from the same Niskin bottle were analyzed to assess the precision of the AAII analyses. These replicate samples were analyzed both as adjacent samples (one after the other) and at both the beginning and end of sample runs to monitor deterioration in the samples or uncompensated instrumental drift

We used a randomly selected subset of these replicate samples to estimate short- term (within run) precision. The average standard deviations of 26 sets of quadruplicate determinations are listed below. The deviation of the absolute values of the sample differences gives an estimate of short-term precision while the average difference with regard to sign is an estimate of uncompensated drift or bias.

Nutrient (uM)	Avg. Std Dev. (uM)	Avg. Difference (wrt sign)
Nitrate	0.043	0.014
Nitrite	0.002	0.002
Phosphate	0.003	0.002
Silicic acid	0.102	-0.070

C.3.2. Longer Term Precision:

In an attempt to assess the longer-term, between-station precision of the nutrient data, we fitted the deep nutrient data to sigma 4 data at several adjacent stations where natural background variability appeared to be small. We believe that the magnitude of the residuals can provide an estimate of station- to-station precision. The means of the absolute values of the residuals for several multi-station curves are presented below.

Sta Groups	# point used	Mean Silicic acid Residual (uM)	Mean Phosphate Residual (uM)	Mean Nitrate Residual (uM)
33 & 34	19	0.58 (1.16%)	0.010 (0.67%)	0.091 (0.45%)
45-47	36	0.37 (0.74%)	0.004 (0.26%)	0.054 (0.27%)
54 & 55	19	0.29 (0.58%)	0.005 (0.33%)	0.070 (0.35%)

Only data from depths greater than 2700m were used. Station pairs 54&55 and 33&34 were selected because high concentration mixed standards used changed at these stations. Stations

45-47 were selected because the deep-water variability appeared to be quite small at these locations. In all cases except the silicic acid fit for stations 33&34, the mean absolute value of the residuals expressed as a percentage of the deep-water concentration is <1.0%.

C.4. NUTRIENT QUALITY CONTROL NOTES:

During the 52W cruise, only limited flagging of the nutrient data was performed, except for those few bottles that were obvious leakers and for bottles whose values are average of replicate samples. (The relatively few Niskin bottles with obvious problems were usually not sampled.)

Nitrate values at 11 stations on the final day of sampling were flagged because of recognized problems. Unusually rapid declines in the efficiency of the Cd reduction column affected the nitrate determinations at stations occupied on 8 August 1997 despite repeated replacement of the columns. Our protocol of running calibration standards at both the start and end of each set of samples allows us to minimize the effect of linear changes in system response, but if the change in column efficiency is non-linear with time, some error will be introduced. We have carefully examined the nitrate data at the affected stations. Although we can find no clear effects on the accuracy of these data, we have flagged them as questionable because of the recognized analytical problem affecting these stations. Wherever possible, we compared replicate samples analyzed at both the beginning and end of the affected sample runs. In the worst cases (stations 082, 084, and 087) the replicate samples differ by 0.6-0.8 uM over the course of the run. (This is about 2.5% of the near bottom nitrate values.) This should provide a worst case estimate of the imprecision in these stations. Nitrate values were flagged at the following stations: 082, 084-087, and 091-095.

Post-Cruise QC Summary:

All of the nutrient data has been re-examined for problems. A few typographical errors were discovered and corrected and several "questionable" values were identified and flagged. A summary of data flagging and other notes that may aid in DQE examination is given below:

STATIONS 1-5:	were CTD only, no bottle samples were drawn.
STATION 006:	Odd numbered bottles sampled
STATION 007:	Odd numbered bottles sampled. No sample from #13, ran out of water.
STATION 015:	Only deep bottles tripped. All parameters shifted slightly relative to adjacent stations. The deepest two bottles (1 and 2) have very low silicic acid and high salinity, flagged as questionable.
STATION 20:	Kink in profiles at bottles 6 & 7, with 6 low and 7 high. No problems found in our raw data.
STATION 021:	Three low silicic acid values resulted from a typo (bottles 13, 14, and 15). Edited and recalculated
STATION 022:	Many nitrite values of -0.01. There was a problem with the DIW peaks and what looks like some non-linear drift. Flagged as 3's.
STATION 028:	High nitrite at the bottom. No obvious problem found in our raw data.
STATION 038:	5648m. Low phosphate due to a typo in editing. Recalculated and edited.
STATION 39:	1879m. Bottle 14 Slight low nutrient, high oxygen kink, no obvious problem.
STATION 45:	2028m, Bottle 12 High silicic acid, flagged as questionable.
STATION 51:	3941m. Bottle 6 High oxygen, low nut kink. Also present as a 2-bottle feature at Station 52. No problem obvious in our raw data.
STATION 59:	4074m, Bottle 4 Low nutrient, high oxygen kink., No obvious problem found in our raw data. Flagged nitrate, phosphate, and silicic acid as questionable.
STATION 60:	Multiple nutrient/oxygen kinks at 4231,3251, and 2762 m. Noobvious problems found
STATIONS 67-70:	Lots of variability in nutrients and oxygen around theta range from 2.5 - 3 degrees. No obvious problems found.
STATION 75:	26m, Bottle 32. High silicic acid in original data. Based on the low salinity/high silicic acid relationship of the Amazon outflow, we think that nutrient samples for bottles 32 and 33 were reversed and the high silicic acid belongs with the low salt. Edited accordingly.
STATION 76:	Bottles 12 - 16 Low phosphate (ca 0.03M). May be a temporary baseline shift. Flagged as questionable.
STATION 77:	1485m. Phosphate shifted up with no change in nitrate or oxygen. This appeared to be a correctable baseline shift. Phosphate data for this station were edited and recalculated accordingly.Nitrate values were flagged at stations: 082, 084-087, 091-095 due to Cd column problems discussed above.

REFERENCES

Gordon, L. I., J. C. Jennings, Jr., A. A. Ross and J. M. Krest. 1994. A suggested protocol for continuous flow automated analysis of seawater nutrients (phosphate, nitrate, nitrite and silicic acid) in the WOCE Hydrographic Program and the Joint Global Ocean Fluxes Study. In WOCE Operations Manual, WOCE Report No. 68/91. Revision 1, 1994.

D. CTD Data Consistency Evaluation

(Hajrasuliha/WHPO-SIO)
2001 DEC 20

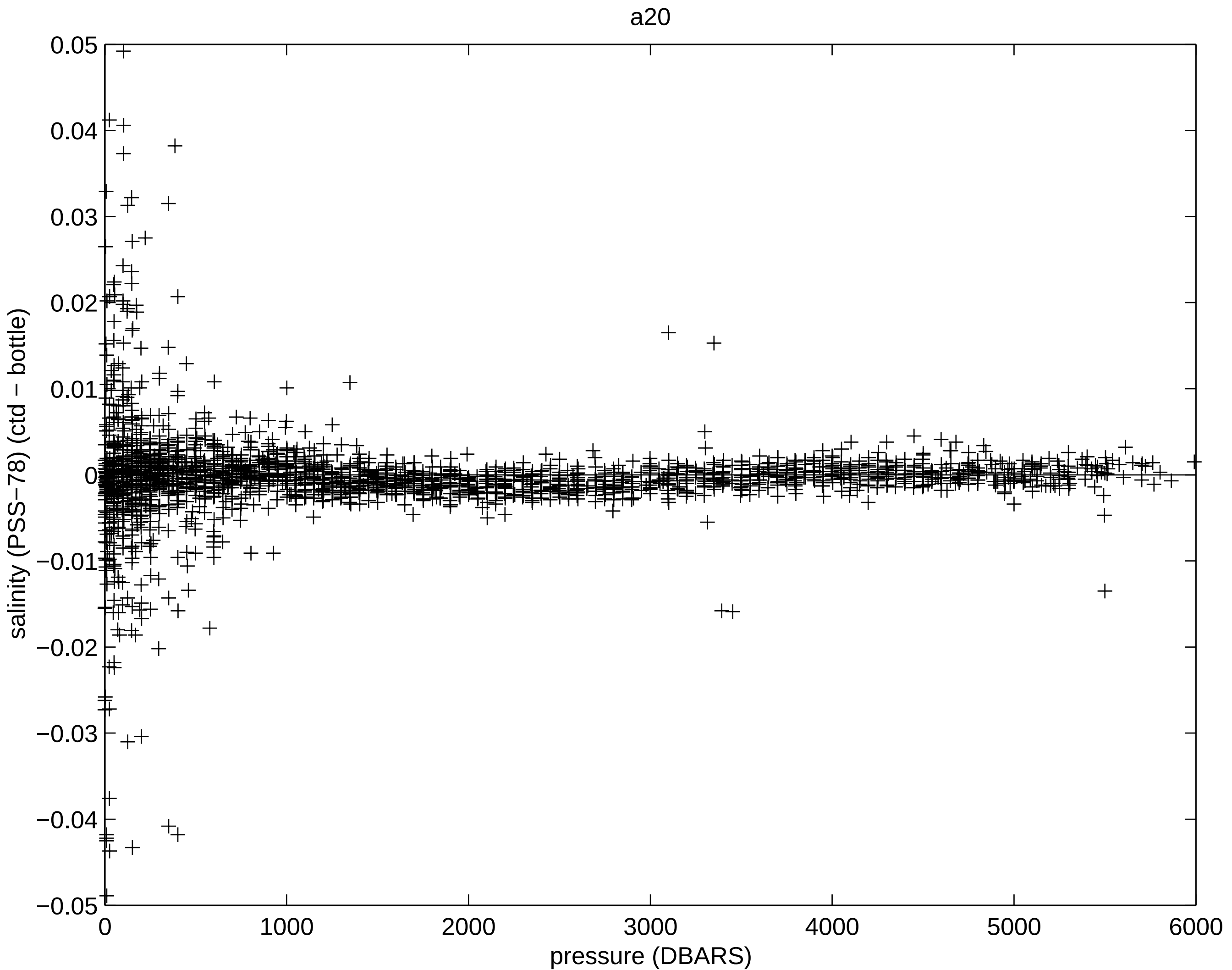
The WHP-Exchange format bottle and/or CTD data from this cruise have been examined by a computer application for contents and consistency. The parameters found for the files are listed, a check is made to see if all CTD files for this cruise contain the same CTD parameters, a check is made to see if there is a one-to-one correspondence between bottle station numbers and CTD station numbers, a check is made to see that pressures increase through each file for each station, and a check is made to locate multiple casts for the same station number in the bottle data. Results of those checks are reported in this '_check.txt' file.

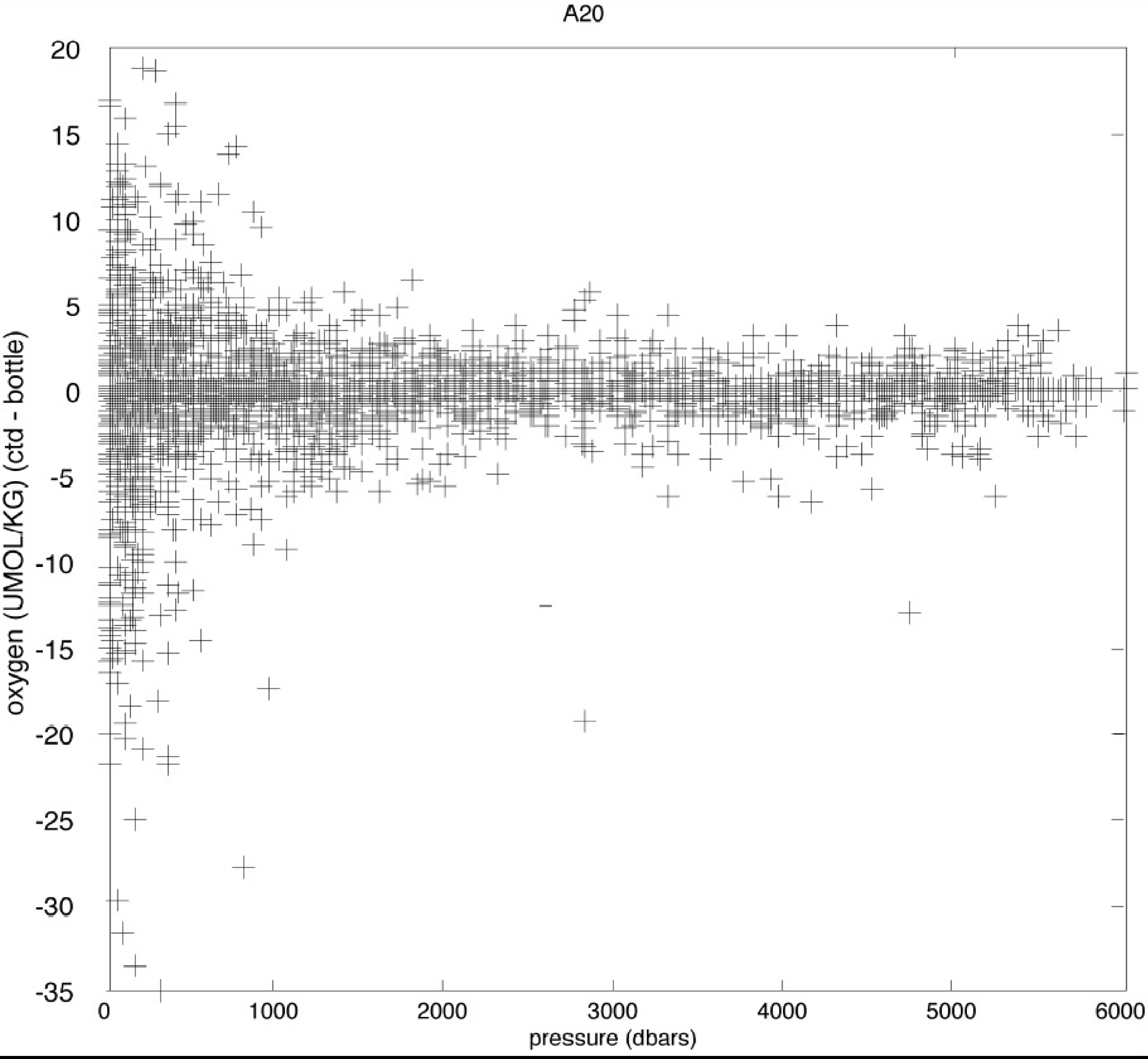
When both bottle and CTD data are available, the CTD salinity data (and, if available, CTD oxygen data) reported in the bottle data file are subtracted from the corresponding bottle data and the differences are plotted for the entire cruise. Those plots are the '_sal.ps' and '_oxy.ps' files.

Following parameters found for bottle file:

EXPOCODE	SALNTY	CFC-12
SECT_ID	SALNTY_FLAG_W	CFC-12_FLAG_W
STNNBR	CTDOXY	CFC113
CASTNO	CTDOXY_FLAG_W	CFC113_FLAG_W
SAMPNO	OXYGEN	TRITUM
BTLNBR	OXYGEN_FLAG_W	TRITUM_FLAG_W
BTLNBR_FLAG_W	SILCAT	HELIUM
DATE	SILCAT_FLAG_W	HELIUM_FLAG_W
TIME	NITRAT	DELC14
LATITUDE	NITRAT_FLAG_W	DELC14_FLAG_W
LONGITUDE	NITRIT	TCARBN
DEPTH	NITRIT_FLAG_W	TCARBN_FLAG_W
CTDPRS	PHSPHT	PCO2
CTDTMP	PHSPHT_FLAG_W	PCO2_FLAG_W
CTDSAL	CFC-11	ALKALI
CTDSAL_FLAG_W	CFC-11_FLAG_W	ALKALI_FLAG_W

- All ctd parameters match the parameters in the reference station.
- Station #1 has a CTD file, but does not exist in a20_hy1.csv .
- Station #2 has a CTD file, but does not exist in a20_hy1.csv .
- Station #3 has a CTD file, but does not exist in a20_hy1.csv .
- Station #4 has a CTD file, but does not exist in a20_hy1.csv .
- Station #5 has a CTD file, but does not exist in a20_hy1.csv .
- No bottle pressure inversions found.
- Bottle file pressures are increasing.
- No multiple casts found in bottle data.


a20
salinity (PSS−78) (ctd − bottle)
pressure (DBARS)
0.05
0.04
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
−0.04
−0.05
0
1000
2000
3000
4000
5000
6000


A20
oxygen (UMOL/KG) (ctd - bottle)
pressure (dbars)
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
0
1000
2000
3000
4000
5000
6000

E. WHPO DATA PROCESSING NOTES

Date	Contact	Data Type	Data Status Summary
11/19/97	Dunworth	Cruise Report	Submitted
	I just put the 'zipped-up' cruise report and sum file in INCOMING.		
01/11/99	Smethie	CTD/BTL	Will submit data by 8/99
03/03/99	Dunworth	CTD/BTL/SUM	Submitted for DQE
	I just put the A20 data in your anonymous ftp INCOMING. One of the zipped repeat files is the one you got from Bob Pickart, the other one I constructed from data I got from the nutrient people, the ctd people, and post cruise processing that I did to the data. Questions re: • data acquisition should be directed to Terry Mckee (TMcKee@whoi.edu), • data calibration to Bob Millard (RMillard@whoi.edu). Anything else (i.e. unit conversion, Temp conversion, formatting...) I can try to handle.		
11/10/99	Dunworth	SUM	Submitted new file with position corrections
02/25/00	Diggs	SUM	Updated file added to website
05/11/00	Pickart	CTD/BTL	Data are Public
	Line ExpoCode Parameter > A20 316N151_3 BTL > A20 316N151_3 CTD Please mark these data as public and include them on the cdrom.		
06/08/00	Bartolacci	CTD/BTL	Website Updated: online data unencrypted
07/10/00	Huynh	Cruise Report	Website Updated: new pdf, txt docs online
02/01/01	Huynh	Cruise Report	Website Updated: pdf, txt versions updated
	Incorrect DQE statement removed		
03/23/01	Dunworth	SUM	Update Needed
	One of the PI's in a20 gave me the following corrections to be made to the sum file. sta 4 BO 43 03.135 EN 43 03.176 sta 56 EN 18 10.996		
05/04/01	Kozyr	CO2	Final Data Submitted
	I have put the final CO2-related data files for the N. Atlantic Ocean WOCE Sections A20, A22, and A24 to the WHPO ftp INCOMING area. There are 4 CO2 parameters: Total CO2, Total Alkalinity, pH, and pCO2 (with pCO2 temp) with quality flags. Note, that these data are different from those you have in your data base for these cruises on WHPO web site. Please confirm the data submission.		
06/20/01	Uribe	BTL	Website Updated: Exchange file online
	Bottle file in exchange format has been linked to website.		
06/21/01	Uribe	CTD/BTL	Website Updated; new Exchange files online
	The Exchange bottle file name in directory and index file was modified to lower case. CTD Exchange files were put online.		

E. WHPO DATA PROCESSING NOTES

<table>
<tr><th>Date</th><th>Contact</th><th>Data Type</th><th>Data Status Summary</th></tr>
<tr><td>08/27/01</td><td>Swift</td><td>He/Tr</td><td>Data Request</td></tr>
<tr><td></td><td colspan="3">Birdwhistell listed as PI for missing He/Tr data but WHPO presumes this means Jenkins. WHPO records indicate he/tr data not yet submitted. Request for earliest possible submission sent to Bill Jenkins.</td></tr>
<tr><td>12/17/01</td><td>Hajrasuliha</td><td>CTD/BTL</td><td>WHPO Data Consistency Check begun</td></tr>
<tr><td></td><td colspan="3">The following are results from the examminer.pl and plotter.pl code that were run on this cruise. Not all of the errors are reported but rather a summery of what was found. For more information you can go to the cruise directory, and look at the NEW file called CruiseLine_check.txt. Two plot files are also present. _oxy.ps and _sal.ps
• The _oxy.ps and _sal.ps files created.
• CTD file is producing errors. Missing some values because examiner.pl reports use of uninitialized values for the files in ct1.zip
• No _check.txt file created for this cruise</td></tr>
<tr><td>12/20/01</td><td>Hajrasuliha</td><td>CTD</td><td>WHPO Data Consistency Check completed</td></tr>
<tr><td></td><td colspan="3">*check.txt file created for this cruise.</td></tr>
<tr><td>12/20/01</td><td>Uribe</td><td>CTD</td><td>Website Updated: Exchange File Added</td></tr>
<tr><td></td><td colspan="3">CTD has been converted to Exchange using the new code and put online.</td></tr>
<tr><td>02/06/02</td><td>Muus</td><td>CO2</td><td>Website Updated: carbon data & Exchange file</td></tr>
<tr><td></td><td colspan="3">tcarbn, alkali, pCO2, pH, QUALT2 merged into BTL, new Exchange file added. Carbon data merged with web bottle file. Exchange file version on-line. WOCE format version will be on-line after web links modified.
Notes on A20 merging Feb 6, 2002 D.Muus
1. Merged TCARBN, ALKALI, PCO2 and PH from: /usr/export/html-public/data/onetime/atlantic/a20/original/2001.05.04_A20_A22_A24_CARBON_KOZYR/a20carb.txt into A20 bottle file from web (20010328WHPOSIOKJU)
2. Used QUALT1 codes for QUALT2.
3. Unable to find CFC data from LDEO(Smethie). Table says at WHPO-SIO but not in .../onetime/atlantic/a20/original. Table says He/Tr not yet available from Jenkins(WHOI) and C-14 not yet available from Key(Princeton).
4. Sta 75 Ca 1 Sample 33 has CTDPRS -0.5db which gives wocecvt error. Changed to 0.0db.
5. Made new exchange file for Bottle data.
6. Checked new bottle file with Java Ocean Atlas.</td></tr>
<tr><td>04/01/02</td><td>Buck</td><td>DELC13</td><td>Data moved from incoming</td></tr>
<tr><td></td><td colspan="3">Moved data from
/usr/export/html-public/cgi/SUBMIT/INCOMING/20020401.103223_GERLACH_A20 to /usr/export/html-public/data/onetime/atlantic/a20/original/20020401.103223_GERLACH_A20.
Data contains a readme file from the data submission page and a txt file called 20020401.103223_GERLACH_A20_a20_desc.txt that lists the flags for the replicate value, it is a detailed listing of those stations which have c13 flags.</td></tr>
</table>

E. WHPO DATA PROCESSING NOTES

Date	Contact	Data Type	Data Status Summary
04/10/02	Lebel	CFCs	Submitted final, public CFC data
	The data disposition is: Public The file format is: Plain Text (ASCII) The archive type is: NONE - Individual File The data type(s) is: Other: updated/finalized CFC data with QUALT2 flags The file contains these water sample identifiers: Cast Number (CASTNO) Station Number (STATNO) Bottle Number (BTLNBR) Sample Number (SAMPNO) LEBEL, DEBORAH would like the following action(s) taken on the data: Merge Data Place Data Online Update Parameters Any additional notes are: This is the finalized CFC data from A20. Scale is SIO98. Includes QUALT2 flag.		
12/17/02	Anderson	CFCs	Website Updated
	Merged the CFC11 and CFC12 submitted by Lebel in April, 2002 into the online file. Put new file online, and made a new exchange file. Notes on A20 merging: Alex Kozyr sent an e-mail asking about CFCs for a20. I checked and found 20020410.102538_LEBEL_A20.a20.dat in /usr/export/html-public/data/onetime/ atlantic/a20/original/20020410.102538_LEBEL_A20. I merged the CFC11 and CFC12 from this file into the online file 20020205WHPOSIODM. There were no apparent problems. There were 4 stations whose pressures were not in descending order. I reordered those stations.		
01/09/03	Key	DELC14	Submitted
	The A20 and A22 C14 results are attached. I have QC'd the data and each file contains flag values. I just got these a couple of days ago, but they can go public as soon as NOSAMS releases the printed data report which should be very soon. It'll take me about 2 weeks to get my "final" report to you. The electronic version of the data I received from NOSAMS did not include C13, but they (Ann McNichol) should have those numbers.		

E. WHPO DATA PROCESSING NOTES

Date	Contact	Data Type	Data Status Summary
04/08/03	Anderson	CO2/C14/PHSPHT	Website Updated: data OnLine
	PHSPHT flags re e-mail from A. Kozyr. Merged DELC13 from Gerlach, DELC14 and C14ERR from Key, and TCARBN, ALKALI, PH and PCO2 from Kozyr. Put file online, made new exchange file, sent notes to Jerry. a20 merging notes: April 8, 2003 • Alex Kozyr noted that the flags for PHSPHT were 1 in the online file. He had a file with the time stamp 20000607WHPOSIODMB that had correct flags. I copied the PHSPHT flags from 20000607WHPOSIODMB into the online file. • Merged the DELC13 from file found in • ... original/20020401.071220_GERLACH_A20 • Merged DELC14 and C14ERR from file found in • ... original/20030109_A20_C14_KEY. • Data history indicated that in May of 2002 Kozyr submitted final data for TCARBN, ALKALI, PH, PCO2, and PCO2TMP. I got this data from his web site and merged it. - Sarilee Anderson		
11/10/04	Anderson	CFCs	Website Updated: NetCDF files corrected
	Keith Lindsay (see email below) noted that the NetCDF file was generated before the CFCs were merged. I regenerated the NetCDF files for the bottle data using the Apr. 9, 2003 file a20_hy1.csv, and put the file online. I emailed Keith to let him know the file had been updated. – S. Anderson "I have downloaded the NetCDF bottle data from the 1997 occupation of the a20 line. All freon_11 & freon_12 values, in all of the files, are missing values (-999). Based on the NetCDF metadata and the Data History from the web, it looks like the NetCDF files were generated before the CFCs were merged. Could this be looked into please?" – K.Lindsay, 11/10/04		
02/25/05	Kappa	Cruise Report	Updated
	• Added report on temp., sal changes over time • Added these Data Processing Notes • Updated WHPO-generated station location map and other figs. in PDF version for clarity • Added bookmarks to PDF version • Added WHPO "CTD Data Consistency Check"		