CONVEX MOORED INSTRUMENTS DATA REPORT

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I. INTRODUCTION.

As part of the CONVEX field program, UNH's Ocean Process Analysis Laboratory (OPAL) deployed a cluster of moored buoys in Wilkinson Basin in the western Gulf of Maine between late fall of 1997 and early winter of 1997-1998 (Figure 1, Table 1). The main instrument buoy (A) was equipped with meteorological sensors, an array of eight water temperature and conductivity sensor pairs, and an upward-looking/downward-looking pair of ADCPs. (See Figure 2 and Tables 2a-d). Two 10-sensor temperature chains (B and C) with a pressure sensor on their subsurface buoys were deployed nearby mooring A. Two of the "guard" buoys (D, E) were equipped with fixed-depth water temperature/conductivity sensor pairs. The third guard buoy was not instrumented.

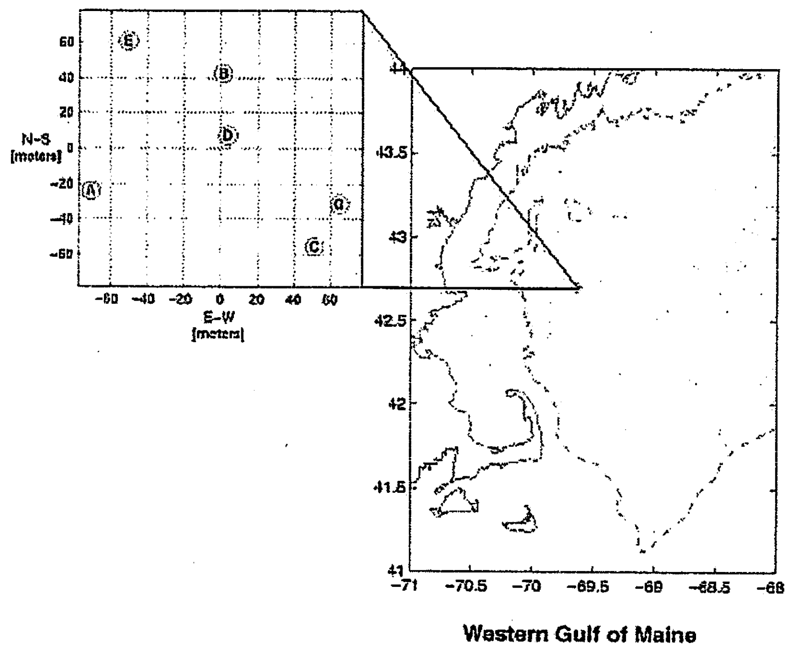

Figure 1: Location map of the moored CONVEX array in Wilkinson Basin between October 1997 and May 1998.

The inset shows the relative locations of the moorings. The main array A is at 42° 42.102' N and 69° 38.130' W.

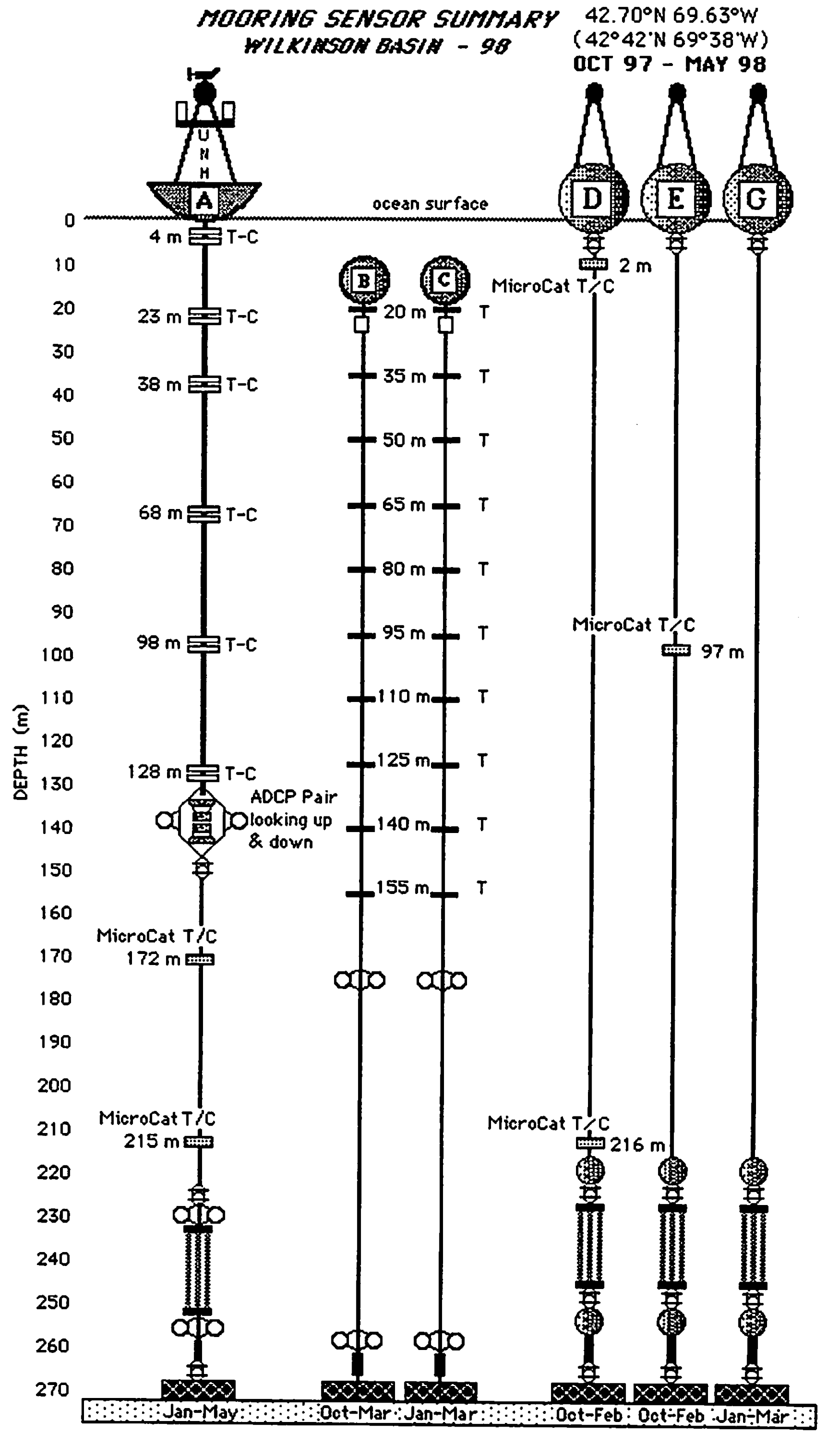

Figure 2: CONVEX Wilkinson Basin Mooring Schematics.

Table 1. Buoy Locations

ID	Type	N. Latitude	W. Longitude
A	Met/ADCP/T/C	42 ° 42.102'	69 ° 38.140'
B	T-Chain	42 ° 42.138'	69 ° 38.080'
C	T-Chain	42 ° 42.085'	69 ° 38.040'
D	Guard T/C	42 ° 42.199'	69 ° 38.080'
E	Guard T/C	42 ° 42.148'	69 ° 38.120'
G	Guard T/C	42 ° 42.098'	69 ° 38.027'

Table 2a. Buoy A instrumentation for measuring two-minute samples from 10 January 1998 through 17 March 1998.

Depth [meters]	Sensor Description	Variable
-2	Epply Model PIR Infrared Pyrgeometer	Long-Wave Radiation
-2	Epply Model PSP Spectral Pyranometer	Short-Wave Radiation
-2	Young Model 05103 Wind Monitor	Wind Speed and Direction
-2	Rotronic Model MP010A Humidity Temperature Meteorological Probe	Air Temperature Relative Humidity
6	Seabird SBE 3S Oceanographic Thermometer	Temperature and Conductivity
25	Seabird SBE 3S Oceanographic Thermometer	Temperature and Conductivity
39	Seabird SBE 3S Oceanographic Thermometer	Temperature and Conductivity
70	Seabird SBE 3S Oceanographic Thermometer	Temperature and Conductivity
99	Seabird SBE 3S Oceanographic Thermometer	Temperature and Conductivity
129	Seabird SBE 3S Oceanographic Thermometer	Temperature and Conductivity
133	Rotronic Model MP010A Humidity Temperature Meteorological Probe	Current Profiles
136	Rotronic Model MP010A Humidity Temperature Meteorological Probe	Current Profiles
172	SeaBird MicroCat SBE 37-SM Conductivity and Temperature Recorder	Temperature and Conductivity
216	SeaBird MicroCat SBE 37-SM Conductivity and Temperature Recorder	Temperature and Conductivity

Table 2b. The Buoy B temperatures were measured with an Aanderaa temperature chain. A pressure sensor at the top of the array allowed us to estimate the actual mean depths of the sensors. The mean and standard deviation of each of the 15-minute series from 3 October 1997 through 17 March 1998 are listed. (See Fig. 3.)

Sensor	Depth [m]	Sensor Description	Variable	Mean	Std. Dev.
	17	TR-7 Silicon Piezoresistive Bridge	Pressure	27.593	1.012
1	17	Model 2862 Thermistor	Temperature	7.798	2.940
2	32	Model 2862 Thermistor	Temperature	7.695	2.493
3	47	Model 2862 Thermistor	Temperature	7.481	1.936
4	62	Model 2862 Thermistor	Temperature	7.360	1.549
5	77	Model 2862 Thermistor	Temperature	7.287	1.321
6	92	Model 2862 Thermistor	Temperature	7.301	1.154
7	107	Model 2862 Thermistor	Temperature	7.348	0.988
8	122	Model 2862 Thermistor	Temperature	7.498	0.781
9	137	Model 2862 Thermistor	Temperature	7.543	0.562
10	152	Model 2862 Thermistor	Temperature	7.456	0.375

Table 2c. The Buoy C temperatures were measured with an Aanderaa temperature chain. The mean and standard deviation of each of the five-minute series from 10 January 1998 through 17 March 1998 are listed. (See Fig. 4.)

Sensor	Depth [m]	Sensor Description	Variable	Mean	Std. Dev.
	21	TR-7 Silicon Piezoresistive Bridge	Pressure	32.157	1.038
1	21	Model 2862 Thermistor	Temperature	5.116	0.834
2	36	Model 2862 Thermistor	Temperature	5.368	0.669
3	51	Model 2862 Thermistor	Temperature	5.629	0.555
4	66	Model 2862 Thermistor	Temperature	5.847	0.484
5	81	Model 2862 Thermistor	Temperature	6.094	0.450
6	96	Model 2862 Thermistor	Temperature	6.339	0.485
7	111	Model 2862 Thermistor	Temperature	6.734	0.642
8	126	Model 2862 Thermistor	Temperature	7.226	0.656
9	141	Model 2862 Thermistor	Temperature	7.500	0.530
10	156	Model 2862 Thermistor	Temperature	7.576	0.375

Table 2d. Sea Bird instrumentation for measuring 2-minute samples of temperature and conductivity. The mean and standard deviations of Buoy D and E temperature and salinity between 3 October 1997 and 5 December 1997; and Buoy A between 10 January 1998 and 3 May 1998 are listed.

Buoy ID	Depth [m]	Measurement Description	Variable	Mean	Std. Dev.
D	22	SeaBird Microcat SBE 37-SM	Temperature Salinity Conductivity	10.800 32.610 3.645	1.898 0.215 0.153
E	97	SeaBird Microcat SBE 37-SM	Temperature Salinity Conductivity	7.827 33.093 3.433	0.983 0.266 0.104
D	215	SeaBird Microcat SBE 37-SM	Temperature Salinity Conductivity	7.397 34.143 3.496	0.033 0.070 0.009
A	172	SeaBird Microcat SBE 37-SM	Temperature Salinity Conductivity	7.367 33.474 3.430	0.268 0.183 0.390
A	216	SeaBird Microcat SBE 37-SM	Temperature Salinity Conductivity	7.402 33.387 3.427	0.062 0.124 0.012

II. TEMPERATURE CHAIN CALIBRATIONS.

The calibrations of the Buoy B temperature chain (T-chain B) were conducted in a 2m diameter x 2m deep cylindrical concrete tank, beginning on 25 September 1700 UTC and ending at 2000 UTC the same day. The tank temperature was increased in steps of about 2 degrees from about 8 dC to 16 dC. The "steady" segments of the original one-minute T-chain B thermistor series at each step were fit to the corresponding one-minute MicroCat 209 reference temperature time series. We assumed a linear relation between the MicroCat 209 reference temperature T_{true} and the n^{th} thermistor temperature T(n) according to:

$$T_{true} = a(n) + b(n) * T(n) \quad (1)$$

The offset (a) and slope (b) of the linear correction relationship, as well as the misfit standard deviation (sigma) for each T-Chain B thermistor (Table 3a) was determined using the REGRESS routine in the Ocean Analysis Software Package (OASP, Irish and Brown, 1986). The typical misfit standard deviation (*i.e.* precision uncertainty) of a calibrated T-Chain B temperature was +/- 0.015 dC.

Table 3a. T-Chain B Thermistor Calibration Coefficients and Misfits.

Sensor ID n	Regression Coefficient a(n)	Regression Coefficient b(n)	Misfit Standard Deviation sigma(n)
1	0.1580	0.9782	0.0160
2	0.0222	1.0001	0.0163
3	0.0532	1.0000	0.0166
4	0.0601	0.9934	0.0139
5	0.0594	0.9969	0.0157
6	0.1487	0.9869	0.0168
7	0.1683	0.9907	0.0172
8	0.0709	0.9969	0.0163
9	-0.2600	1.0323	0.0226
10	0.1098	0.9957	0.0164

The calibrations of the 10 thermistors on the Buoy C temperature chain (T-Chain C) were also conducted in the 2m diameter x 2m deep cylindrical concrete tank, beginning on 7 January 1998 at 2200 UTC and ending on 8 January 1998 1239 UTC. Linearly increasing segements (beginning on 08 January 98 0315 UTC and continuing for 541 minutes) from each of the original five-minute T-chain C thermistor time series were linearly interpolated to the one-minute sample interval of the MicroCat 251 reference temperature time series. For this calibration run, temperatures ranged from approximately 2 dC to approximately 6.5 dC. In determining the corrections, we assumed a linear relation between the MicroCat reference temperature T_{true} and the n^{th} thermistor temperature according to Equation (1) (see Table 3b). The typical precision uncertainty of a calibrated T-Chain C temperature record was +/- 0.008 dC.

Table 3b. T-Chain C Thermistor Calibration Coefficients and Misfits.

Sensor ID n	Regression Coefficient a(n)	Regression Coefficient b(n)	Misfit Standard Deviation sigma(n)
1	0.0003	1.001	0.0077
2	0.0096	0.9998	0.0083
3	0.0662	0.9957	0.0105
4	0.0055	0.9994	0.0080
5	-0.0300	1.0000	0.0079
6	-0.0290	0.9980	0.0076
7	-0.0160	1.0008	0.0082
8	-0.0374	0.9997	0.0086
9	-0.0237	1.0021	0.0088
10	-0.0194	1.0061	0.0089

III. DATA PROCESSING.

T-Chain Corrections.

The measured temperatures (based on the factory calibrations) on both T-chain B and T-chain C were corrected according to the Tables 3a and 3b calibration relationships. The 15-minute T-chain B time series are presented in Figure 3. A comparison of the 5-minute T-chain C time series and the corresponding segment of the T-chain B time series is shown in Figures 4a and 4b.

The instantaneous depths of the T-chain water temperature measurements (see Figure 4) varied from their nominal depths, due to the effects of current drag and tidal sea level change. The pressure measurement at the top of the thermistor chain (nominal depth of 20m) was used to estimate the instantaneous depth $z_i(t)$ of the i^{th} sensor of each T-chain using the following procedure.

1. Determine the instantaneous depth of the pressure sensor at the top of the array, $z_p(t)$ according to the hydrostatic relation - correcting for atmospheric pressure patmos.

$$z_p = (p_m(t) - p_{atmos})/(roe * g) \qquad (2)$$

where $p_m(t)$ is measured pressure, p_{atmos} is atmospheric pressure, roe is water density, and g is gravitational acceleration.

2. Determine the depth of the i^{th} T-chain temperature sensor according to

$$z_i(t) = z_p(t) + \text{delta-}z_i \tag{3}$$

where delta-z_i is the depth of the i^{th} temperature sensor relative to the pressure sensor.

The depth-time contour plot of these depth-correlated T-chain temperature measurements is presented in Figure 4. These depth-corrected 10-temperature time series $T_i(z_i(t),t)$ have also been used (via linear interpolation) to create constant-depth temperature time series from 20m to 155m in 15m increments.

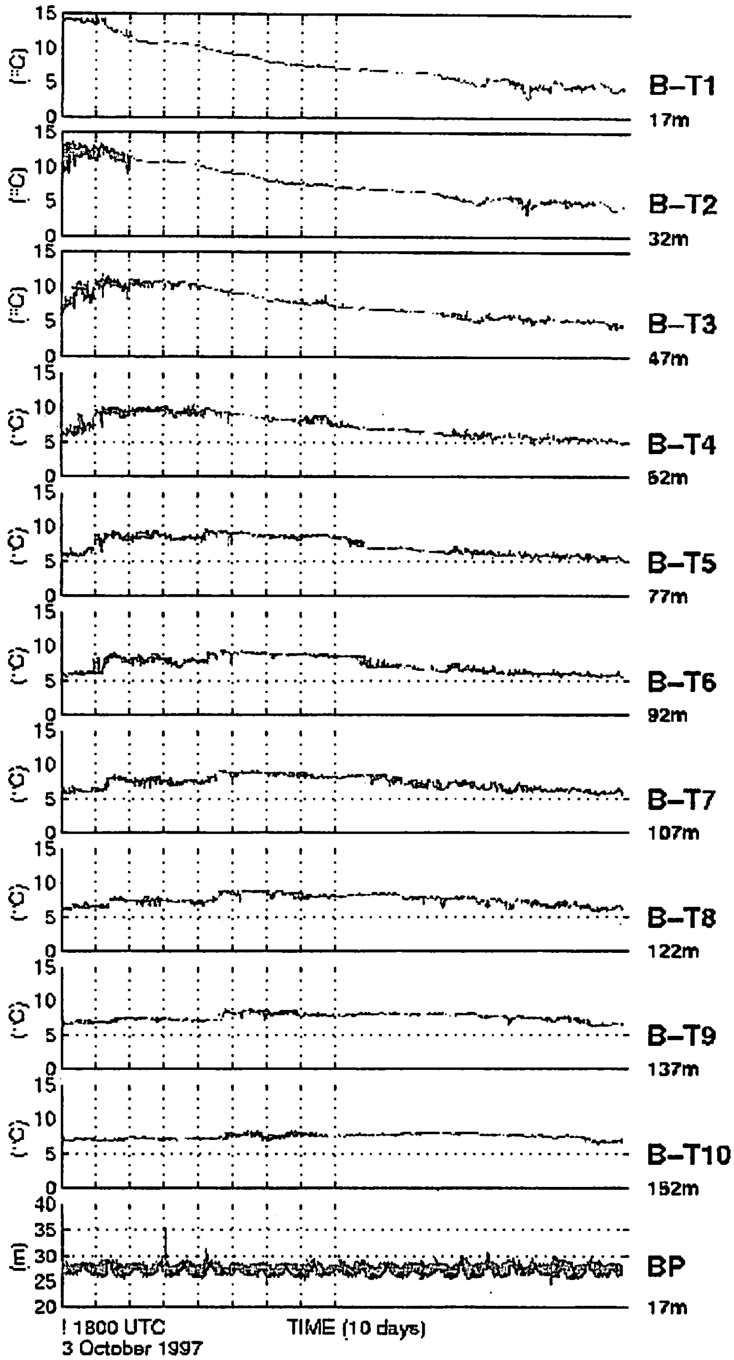

Figure 3: T-Chain B 15-Minute Temperature Series at Indicated Depths (nominal).
Pressure record from the top of the T-chain appears at the bottom.
(Click on image to see full-size version.)

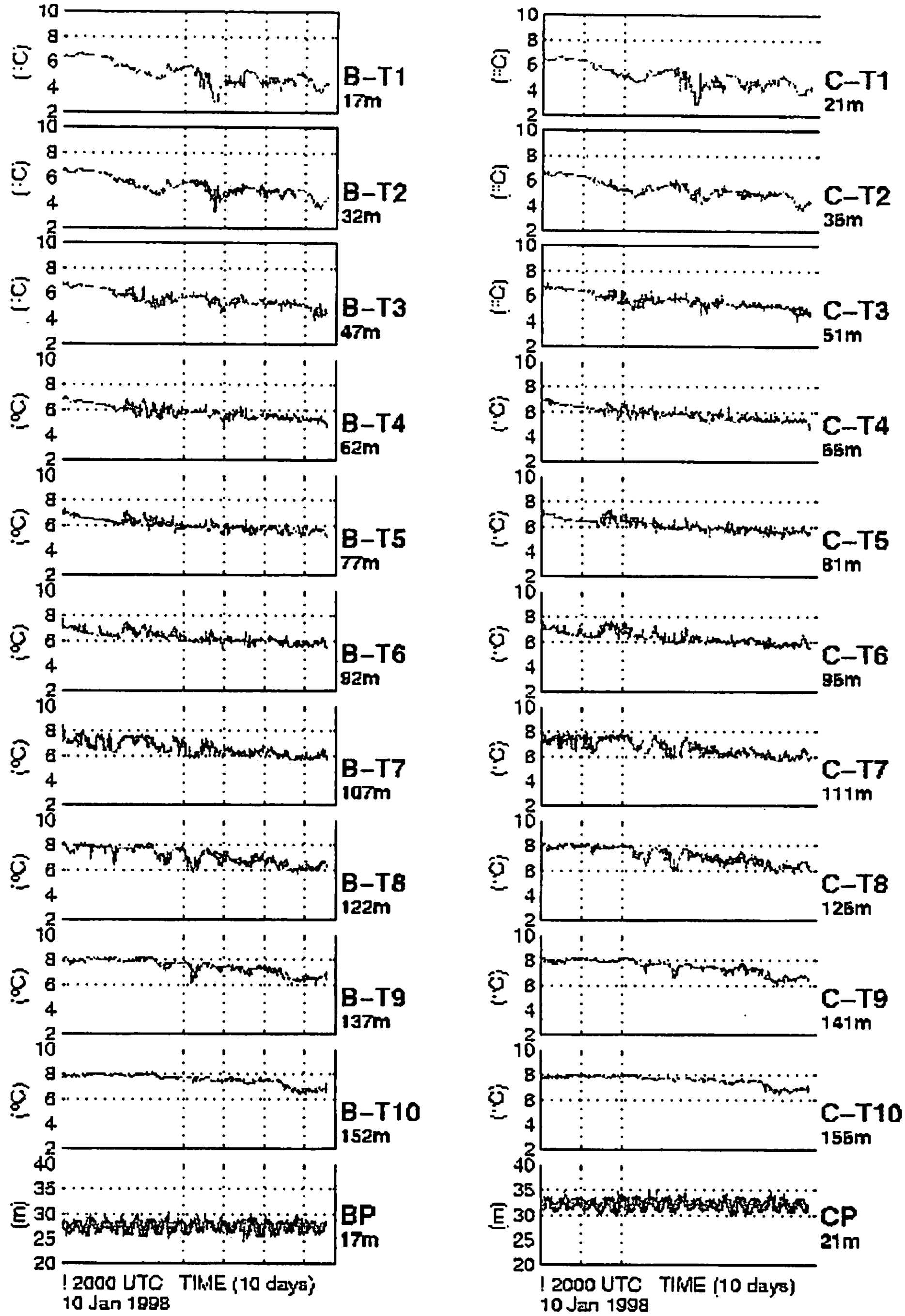

Figure 4: T-chain C 5-minute temperatures (right) and T-chain B 15-minute temperatures (left) for the 2000 UTC 10 January to 1400 UTC 17 March 1998.

Pressure records are presented along with mean depths of the measurements.

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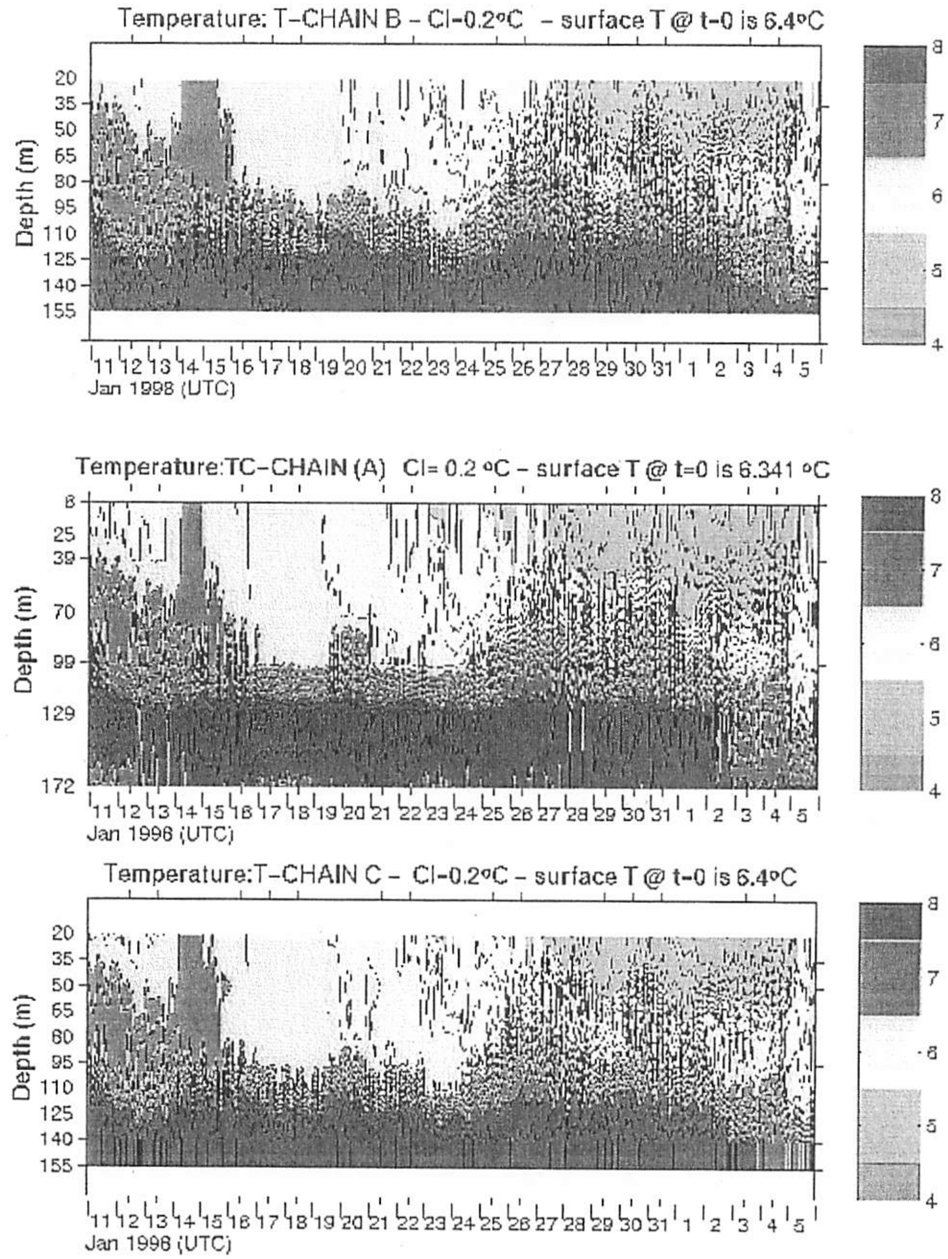

Figure 5: Depth-time Contour Plot of (upper) T-chain B and (lower) T-chain C Temperatures. The TC-chain temperatures appear in the middle panel, beginning on 11 January 1998 0000 UTC and ending on 06 February 1998, 0000 UTC. Hourly temperature is contoured at an interval of 0.2 dC. (Click on image to see full-size version.)

Temperature-Conductivity Chain Corrections.

The Buoy A SeaBird temperature/conductivity sensors and MicroCats were mounted on a taut mooring wire and thus were constrained to be at constant depths (except for tide-induced water depth changes of around 2m). Thus no depth-correction was necessary. Unfortunately, the Buoy A temperature and salinity time series at 6m, 70m and 129m ended before the others (see Figure 6 and Table 4). To permit a more comprehensive analysis, we augmented these short series with "patches" generated by temperature and salinity correlations.

To estimate the missing part of the Buoy A 6m temperature and salinity series, we linearly regressed the overlapping parts of the 6m and 25m records and used the fits to predict the missing end sections.

The missing portion of the Buoy A 70m salinity time series was estimated by taking vertical distance-weighted averages of the measured salinity records at 39m and 99m respectively.

The missing portion of the Buoy A 129m salinity time series was estimated by taking vertical distance-weighted averages of the measured MicroCat salinities at the 99m and the 172m salinities (see Figure 6) respectively.

The missing portions of the 70m and 90m temperature series from Buoy A were replaced by the appropriate sections of the linearly interpolated, depth-corrected, temperatures from the T-chain C.

Figure 6 illustrates the results before and after the augmentation procedure. The temperature and salinity time series were used with the International Equation of State of Seawater (Pond and Pickard, 1983) to compute the Brunt-Vaisala frequency (BVF, i.e. water column stability).

Temperature and salinity records from the guard buoys D and E are presented in Figure 7. The 97m MicroCat temperature record, which was corrupted by instrument failure, was repaired by a depth-weighted interpolation of the T-chain 92m and 107m records. This replacement temperature was used with the measured conductivity to produce what appears to be an unusually noisy salinity record. Time-depth contour plots of the Buoy A Brunt-Vaisala frequency, temperature, and salinity series are presented in Figure 8.

Table 4: The start time/date of the temperature and salinity patches to the Buoy A time series.

Depth [meters]	**Start Time [UTC]**	**Start Date [UTC]**
6	1014	29 Jan 1998
70	1310	22 Jan 1998
129	218	27 Jan 1998

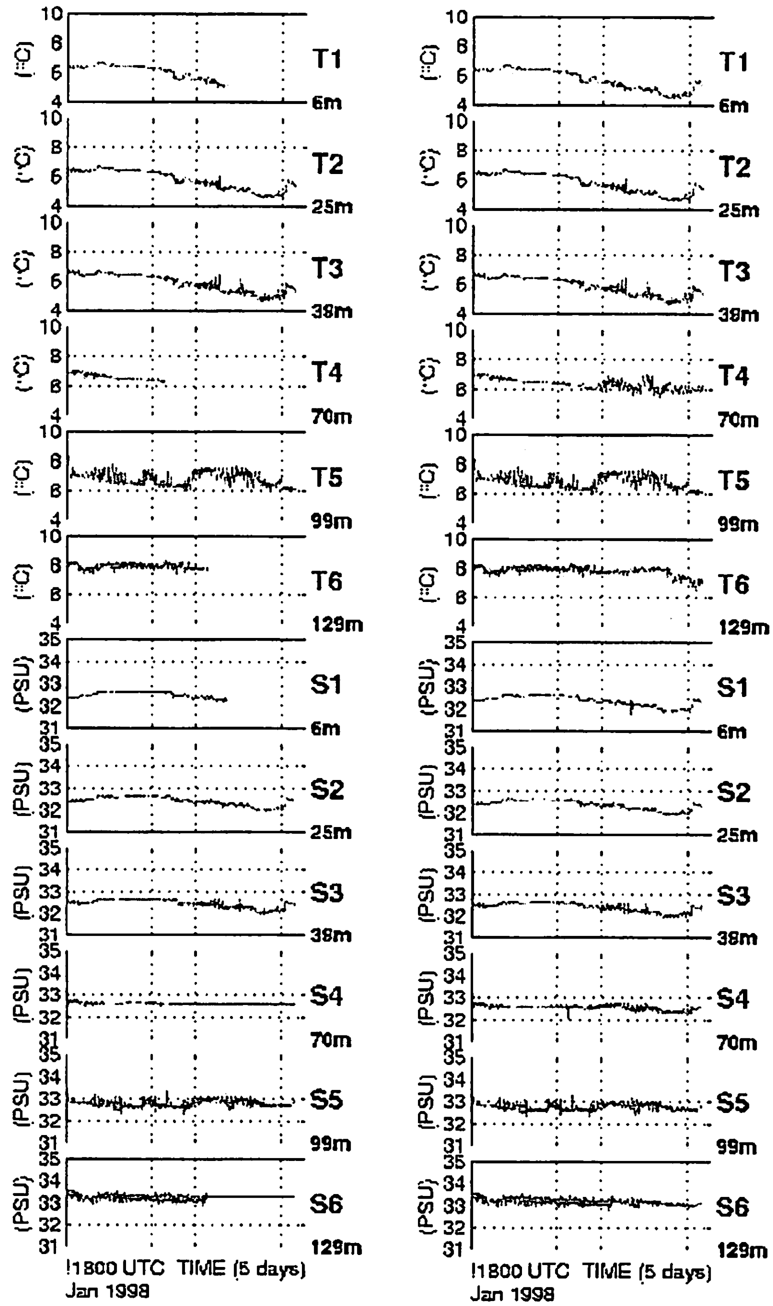

Figure 6: Buoy A 2-Minute Temperature and Salinity Series: (left) Measured and (right) Augmented (see text).

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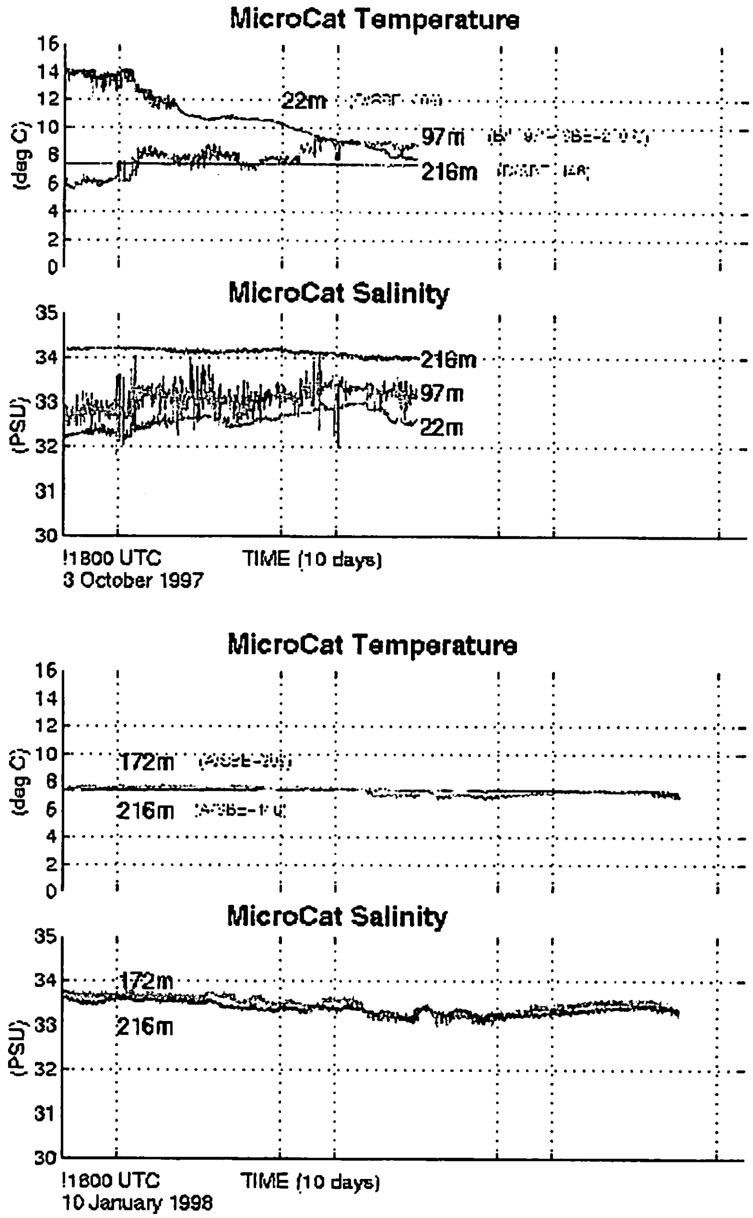

Figure 7: MicroCat 2-Minute Temperature/Salinity Series.

Upper panels -- Guard Buoy D 22m and 216m series ended at 1400 UTC on December 7, 1997 when the buoy was cut loose by fishing activity and recovered. The Guard Buoy E 97m MicroCat record was ended by similar means in late February 1998.

Lower panels -- The Buoy A 172m and 216m records started on 10 January and ended at 1515 UTC 3 May 1998.

(Click on image to see full-size version.)

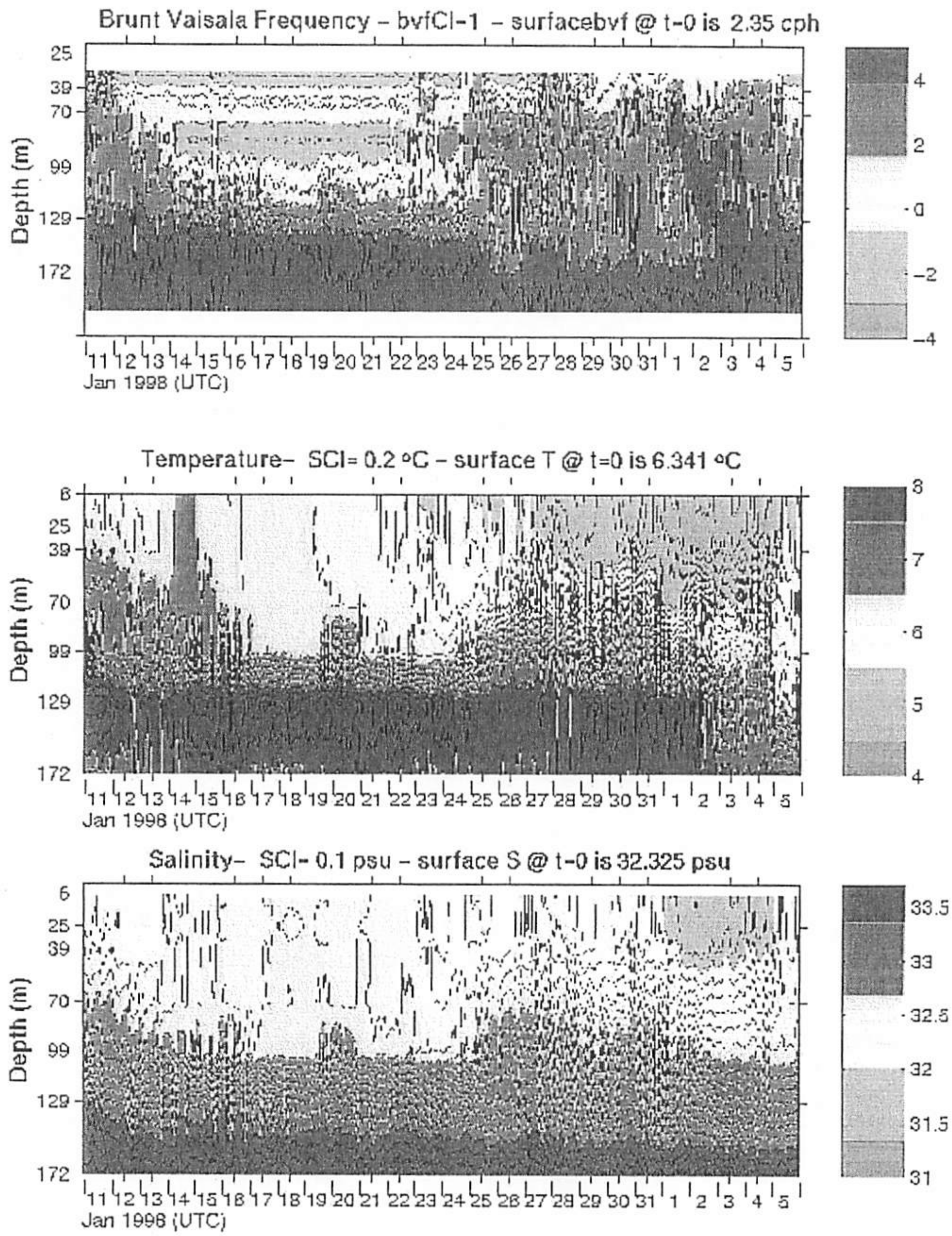

Figure 8: Depth-Time Contour Plot of Buoy A Brunt-Vaisala Frequency (BVF) (top), Temperature (T) (middle) and Salinity (S) (lower).

Beginning on 11 January 1998 0000 UTC and ending on 6 February 1998 0000 UTC. These hourly series are presented. BVF, T, and S contour intervals are 1cph, 0.2 dC and 0.1 psu respectively. (Click on image to see full-size version.)

Doppler Currents.

A pair of RD Instrument 4-Beam Sentinel Broadband Workhorse Acoustic Doppler Current Profilers (ADCP) were deployed in an upward-downward looking configuration on mooring A, at depths of 133m and 136m respectively, in 270 meters of water. Ensembles of 180-pings-per-10-minutes were obtained in 15 eight-meter bins centered at depths between 15 and 127 meters (inclusive) (ADCP-up) and 15 eight-meter bins centered at depths between 142 and 254 meters (inclusive) (ADCP-down). These were obtained for the period beginning 11 January and ending on 25 April 1998 or ADCP-up and ending on 6 May 1998 for ADCP-down. A selected set of the horizontal currents are presented in Figure 9. (See Table 5 for statistics of the 11 January 1998 0000 UTC through 25 April 1998 0000 UTC currents.)

Table 5. Selected ADCP 10-Minute Horizontal Current Statistics for 0000 UTC 12 January - 25 April 1998.

Bin Depth [meters]	Mean u [cm/s]	Mean v [cm/s]	Maj Axis Amp [cm/s]	Maj Axis Dir [deg T]	Min Axis Amp [cm/s]	Min Axis Dir [deg T]
19	-62.9	-21.8	157.0	144.1	109.2	234.1
35	-57.4	-19.3	149.7	145.3	90.3	235.2
51	-45.9	-18.6	141.2	147.4	78.2	237.4
67	-39.1	-20.4	138.1	147.5	74.8	237.5
83	-36.3	-18.4	138.4	148.1	73.3	238.1
99	-35.1	-17.7	136.5	147.6	73.3	237.6
115	-33.1	-17.0	132.7	145.1	70.4	235.1
123	-31.5	-15.9	128.4	145.1	69.0	235.1
146	-19.5	-17.5	109.0	143.2	69.3	233.2
162	-11.0	-12.9	103.2	157.3	71.9	247.3
178	-5.5	-3.1	105.4	167.5	70.7	257.5
194	-0.3	7.1	112.8	169.3	64.2	259.3
206	1.2	11.5	118.7	168.5	60.0	258.5
210	-1.9	13.0	121.0	168.0	57.9	258.0
226	-6.6	12.0	122.7	168.9	58.3	258.9

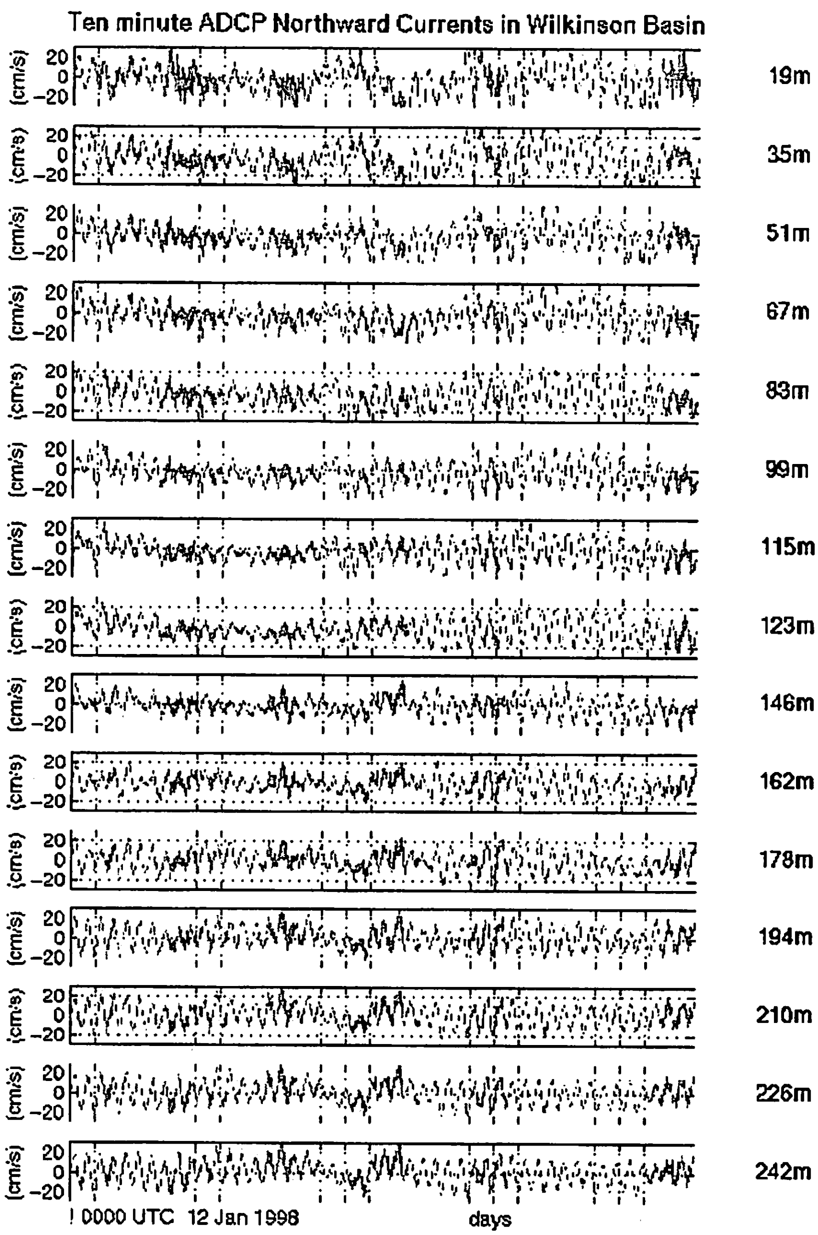

Figure 9. Representative set of ADCP northward currents between 0000 UTC 12 January and 6 February 1998.
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IV. ACKNOWLEDGMENTS.

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V. REFERENCES.

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