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U.S. GLOBEC Georges Bank Long-Term Moored Program: Part 2 – Yearly Data Summary and Report

by

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Technical Report

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Approved for Distribution

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Introduction:

This report is a continuation of the WHOI Technical Report “U.S. GLOBEC Georges Bank Long-Term Moored Program: Part 1 - Mooring Configuration,” and refers to plots, tables and discussion contained in that report. Part 1 summarizes the buoys, sensors, moorings (chain and elastic tethers) and guard buoys used in the Long-term moored program. A short, final summary of the results presented in this sections in year by year format is found in “U.S. GLOBEC Georges Bank Long-Term Moored Program: Part 3 – Data Summary.”

IV. OBSERVATIONAL RESULTS

The Long-Term moorings were deployed on Georges Bank from the fall of 1994 through the summer of 1999. The Southern Flank site (40º 58’ N x 67º 19’ W in 76 m of water – see Fig. 1) was occupied all years, the Crest (41º 24’ N x 67º 32.5’ W in 43 m of water – see Fig. 1) just the first and the Northeast Peak (41º 44’ N x 66º 32’ W in 76 m of water – see Fig. 1) the second, fourth and fifth years. The sensors and the depths at which they were deployed are listed in Tables 6, 7 and 8 below. The times of each deployment are listed in Tables 9, 0 and 11 below. The data returned from those deployments is summarized in the bar graphs in Figures 14 and 15 below. Not all depths were occupied by all sensors at all times. The data returned for each deployment for each mooring for each year is discussed in detail below and summarized in the last Technical Report – Part 3.

The data from each mooring for each calendar year is presented below with plots of (1) meteorology, (2) water temperature and salinity, (3) bio-optical properties and (5) ADCP results at each deployment site. These detailed plots are discussed in more detail and descriptive results form each year presented. Then to summarize the data from the whole experiment, the same data is presented from all 5 years on a single graph and the results again summarized and compared. Tables 12 and 13 summarize the various events noted in the data and the yearly descriptions of the properties on Georges Bank. .

Table 6. Southern Flank Science Mooring Sensor Serial Number and Location

Depth	Sensor	Sensor	SF1	SF2	SF3	SF4	SF5a	SF5b	SF6a	SF6b	SF7	SF8a	SF8b	SF8c	SF9	SFaa	SFab	SFb
-3 m	Air Temperature	WHOI/Rotronics	1	1	17457	17457	35851	35851	35851	35851	16302	16302	16302	35851	16302	35851	35851	17457
	Relative Humidity	Rotronics			17457	17457	35851	35851	35851	35851	16302	16302	16302	35851	16302	35851	35851	17457
	Wind Speed & Dir	RMYoung			5103	5103	5103	5103	5103	5103	5103	5103	5103	5103	23908	5103	5103	5103
	PAR	LiCor	4949	4949	5018	5018	5018	5018	5018	5018	4949	5018	5018	5018	4949	5018	5018	4949
	SWR	Eppley 8-48			28771	28300	28771	28771	28771	27953	28300	25418	25418	25418	28300	25418	25418	28300
	LWR	Eppley PIR			28379	27953	28379	28379	27953	27953	19999	27953	27953	27953	28379	27953	27953	28379
1 m	Temperature	SBE-3	485	1627	1632	1632	1617	1632	1632	1632	2176	1632	1632	2176	1624	2176	2176	2176
	Conductivity	SBE-4													1340			
3 m	ADCP	RDInstruments			1271	57	125	125	125	125	130	125	125	125	130	705	705	894
5 m	Temperature	SBE-3	1630	1630	1630	478	1624	1624	1624	2429	2173	2177	2177	2177	1628	477	477	477
	Conductivity	SBE-4	1379	1379	1379	1379	1365	1365	1365	1890	1342	1333	1333	1333	1342	1333	1333	1333
10 m	Bio-Optical Package	Luigi #	2	1	1	1	1	1	3	1	5	2	2	2	4	1	1	1
	Temperature	SBE-3	1622	1623	485	2173	484	484	1629	484	478	482	482	482	478	484	484	484
	Conductivity	SBE-4	1340	1333	59	1711	68	68	1625	68	1379	1365	1365	1365	56	59	59	59
	Transmissometer	SeaTech	621	620	620	620	620	620	617	620	626	621	621	621	628	620	620	620
	Fluorometer	SeaTech	296	295	295	295	295	295	290	295	305	296	296	296	306	296	296	296
	PAR	LiCor	1660	1659	1794	1795	1794	1659	1661	1659	1972	1971	1971	1971	1659	1972	1972	1792
	OBS	SeaPoint		102	102	102	102	102		102	102	1222	1222	1222		1222	1222	31912
15 m	Temperature	SBE-3	1628	1628	1628	1628	1623	1623	481	2430		2178	2178	2178		481	481	481
	Conductivity	SBE-4	1343	1343	1343	1343	1343	1343	1343	1890		1368	1368	1368		1370	1370	1370
20 m	Temperature	SBE-16	1629	1629	1736	1736	1818	1818	1818	2359	1820	1861	1861	1861	1736	2006	2006	2006
	Conductivity	SeaCat	1365	1365	1736	1736	1818	1818	1818	2359	1820	1861	1861	1861	1736	2006	2006	2006
25 m	Temperature	SBE-3	1615	1615	1615	485	1621	1621	1321	2432		2429	2429	2429		482	482	482
	Conductivity	SBE-4	1366	1366	1366	59	1341	1341	1341	1713		1370	1370	1370		1327	1327	1377
30 m	Temperature	SBE-16	1632	1632	1735	1735	1819	1819	1819	2360	1735	2360	2360	2360	1820	1861	1861	1861
	Conductivity	SeaCat	1367	1367	1735	1735	1819	1819	1819	2360	1735	2360	2360	2360	1820	1861	1861	1861
35 m	Temperature	SBE-3	1631	1631	1631	1632	493		493	2431		2430	2430	2430		2178	2178	2178
	Conductivity	SBE-4	1377	1377	1377	1377	1340		1340	1367		1711	1711	1711		1625	1625	1625
40 m	Bio-Optical Package	Luigi #	1	2	2	2	2	2	5	2	4	3A	3A	3A	5	4	4	4
	Temperature	SBE-3	1623	1622	478	2176	481	481	1628	2178	477	484	484	484	493	478	478	478

	Conductivity	SBE-4	1333	1340	56	1713	59	59	1596	59	1377	1367	1367	1367	68	56	56	56
	Transmissometer	SeaTech	620	621	621	621	621	621	626	621	628	143	143	143pr	626	628	628	628
	Fluorometer	SeaTech	295	296	296	296	296	296	305	296	306	143pr	143pr	290	305	306	306	306
	PAR	LiCor	1659	1660	1660	1971	1971	1971	1972	1971	1792	1661	1661	1661	1660	1659	1659	1659
45 m	Temperature	SBE-3	1624	1624	1624	1624	478	178	478	2177		2431	2431	2431		1629	1629	1629
	Conductivity	SBE-4	1342	1342	1342	1342	1333	1333	1333	1365		1713	1713	1713		1713	1713	1713
50 m	Temperature	SBE-3	1613	494	484	484	490	490	490	1624	2064	2432	2432	2432	2173	2177	2177	2177
	Conductivity	SBE-4	1369	56	1341	1370	1342	1342	1342	1711	1342	1890	1890	1819	1343	1711	1711	1711
72 m	Temperature	SBE-16/SBE-37			1803	1818	1736	1736	1736	1861	2006	2006	2006	2006	716	716	716	716
	Conductivity	SeaCat/MicroCat			1803	1818	1736	1736	1736	1861	2006	2006	2006	2006	716	716	716	716

Table 7: Bottom Pressure, Guard and Crest Mooring Sensor Serial Numbers and Location

Southern Flank Bottom Pressure																		
Depth	**Sensor**	**Sensor**				**BP4**					**BP7**	**BP8**			**BP9**	**Bpa**		**BPb**
76 m	Temperature	SBE-26									49	49			49	49		49
	Pressure	SeaGauge				53084					49	49			49	49		49
	Conductivity	SBE-4									1164	1596			1596	1596		1596
Southern Flank Guard Mooring																		
Depth	**Sensor**	**Sensor**		**SG2**														
1 m	Temperature	PMEL		3239														
10 m	Temperature	PMEL		3241														
20 m	Temperature	PMEL		3248														
50 m	Temperature	PMEL		3249														
Crest Mooring																		
Depth	**Sensor**	**Sensor**	**CR1**	**CR2**														
-3 m	Air Temperature	WHOI	2	2														
	PAR	LiCor	0	0														
1 m	Temperature	SBE-3	1627	493														
	Conductivity	SBE-4	1368	1370														
10 m	Bio-Optical Package	Luigi #		3														
	Temperature	SBE-3		1617														

	Conductivity	SBE-4		1341
	Transmissometer	SeaTech		617
	Fluorometer	SeaTech		290
	PAR	LiCor		1661

Table 8. Northeast Peak Science Mooring Sensor Serial Numbers and Location

Depth	Sensor	Sensor	NP3	NP4	NP5a	NP5b	NP6	NP9	Npa	NPb
-3 m	Air Temperature	WHOI	2	2	2		2	1	1	1
	PAR	LiCor	1793	1958	4948	4948	4948	4975	4975	4975
1 m	Temperature	SBE-3	1627	1629	2080	2080	2064	2488	2488	2488
	Conductivity	SBE-4		41367	1379	1379	1379	1365	1365	1365
3 m	ADCP	RDInstruments	1272		130	130	130	125	130	130
5 m	Temperature	SBE-3	493					2064	2064	2173
	Conductivity	SBE-4	68					1367	1367	1367
10 m	Bio-Pptical Package	Luigi #	3	5	4	4	4			
10 m	Temperature	SBE-3	494	1621	482	482	482	490	490	490
	Conductivity	SBE-4	70	1340	56	56	56	2182	2182	2182
	Transmissometer	SeaTech	617	626	628	628	628	621	621	621
	Fluorometer	SeaTech	290	305	306	306	306	296	296	296
	PAR	LiCor	1793	1972	1792	1792	1792	1793	1793	1793
	OBS	SeaPoint						1222	1222	1222
15 m	Temperature	SBE-3	481					2431	2431	2431
	Conductivity	SBE-4	1365					1890	1890	1890
20 m	Temperature	SBE-16	1819	1820	1820	1820	1820	2360	2359	2359
	Conductivity	SeaCat	1819	1820	1820	1820	1820	2360	2359	2359
25 m	Temperature	SBE-3	1629							
	Conductivity	SBE-4	1367							
30 m	Temperature	SBE-16	1818	1819	2006	2006	2006	2359	2360	2360
	Conductivity	SeaCat	1818	1819	2006	2006	2006	2359	2360	2360
35 m	Temperature	SBE-3	1617							
	Conductivity	SBE-4	1595							
40 m	Bio-Pptical Package	Luigi #	4	4				3A	3A	3A

	Temperature	SBE-3			490	490	2173	2173	2173						1632	1632		1632
	Conductivity	SBE-4			58	58	1370	1370	1370						2186	2186		2186
	Transmissometer	SeaTech			628	628									143pr	143pr		143pr
	Fluorometer	SeaTech			306	306									290	290		290
	PAR	LiCor			1792	1792									1661	1661		1661
45 m	Temperature	SBE-3			482													
	Conductivity	SBE-4			1625													
50 m	Temperature	SBE-3			1623	2006	2176	2176	2176						2432	2432		2432
	Conductivity	SBE-4			1368	2006	1377	1377	1377						1379	1379		1379
72 m	Temperature	SBE-37			1820		1735	1735	1735						715	715		715
	Conductivity	MicroCat			1820		1735	1735	1735						715	715		715

Table 9. ADCP Record Summary

GLOBEC Workhorse Downward Looking ADCP Records																
Deploy	ADCP File	File Size	Mag. Var. Applied	ADCP Start Date	ADCP Start Time	Start Date On Bottom	Start Time On Bottom	1st Term On Bottom	End Date On Bottom	End Time On Bottom	Last Term On Bottom	ADCP End Date	ADCP End Time	Number Ensembles Recorded	DT (Hrs)	ADCP Serial Number
Southern Flank																
SF4	GLOB4000	6,001,332	0.00	06-Apr-96	11:44:27	06-Apr-96	14:44:27	4	07-Sep-96	13:44:27	3,697	07-Sep-96	18:44:27	3,704		57
SF5a	SFLA5000	4,274,436	-17.49	26-Oct-96	11:38:45	26-Oct-96	19:38:45	17	19-Dec-96	18:08:45	2,606	23-Dec-96	11:38:45	2,792	0.50	125
SF5b	SFL5B000	4,635,044	-17.29	07-Feb-97	16:15:00	14-Feb-97	16:45:05	338	11-Apr-97	12:15:05	3,017	11-Apr-97	17:45:00	3,028	0.50	125
SF6a	SFL5C000	3,440,148	-17.29	13-Apr-97	19:00:00	15-Apr-97	2:30:00	64	22-May-97	3:00:00	1,841	30-May-97	13:30:00	2,246	1.00	125
SF6b	SFL6B000	9,390,180	-17.29	18-Jun-97	13:20:53	21-Jun-97	15:50:54	150	23-Oct-97	13:20:54	6,103	24-Oct-97	10:50:53	6,140	0.50	125
SF7	GLOB7000	6,143,180	0.00	22-Oct-97	14:32:46	23-Oct-97	14:32:47	25	07-Apr-98	13:32:47	4,008	07-Apr-98	20:32:46	4,015	1.00	130
SF8a	GLOB8002	859,356	0.00	07-Apr-98	11:29:03	07-Apr-98	20:29:01	10	18-Apr-98	11:29:04	265	30-Apr-98	15:29:03	557	1.00	125
SF8b	GLOB8000	1,481,252	0.00	05-May-98	14:30:00	06-May-98	9:30:00	20	11-Jun-98	22:30:00	897	14-Jun-98	14:30:00	964	1.00	125
SF8c	GLOB8000	3,716,716	0.00	28-Jun-98	18:30:00	02-Jul-98	12:30:00	91	05-Oct-98	12:30:00	2,371	07-Oct-98	20:30:00	2,427	1.00	125
SF9	GLOB9001	5,742,844	0.00	05-Oct-98	16:30:00	07-Oct-98	18:30:00	51	10-Mar-99	13:30:00	3,742	11-Mar-99	0:30:00	3,753	1.00	130
SFaa	GLOBA000	2,060,298	0.00	10-Mar-99	15:45:00	10-Mar-99	21:15:00	6	03-Apr-99	1:15:00	1,118	05-Apr-99	20:15:00	1,252	0.50	705
SFab	GLOBA002	4,413,902	0.00	12-May-99	16:45:00	13-May-99	10:45:00	37	07-Jul-99	10:15:00	2,676	07-Jul-99	16:15:00	2,688	0.50	705
SFb	SFLAB000	5,793,371	0.00	09-Jul-99	14:07:30	09-Jul-99	21:27:30	31	17-Aug-99	11:37:30	3,735	17-Aug-99	17:37:30	3,759	0.25	894
Northeast Peak																
NEP5a	NEPK5000	4,196,508	-17.49	27-Oct-96	11:44:38	27-Oct-96	21:14:39	20	19-Dec-96	12:14:39	2,546	23-Dec-96	13:44:38	2,741	0.50	130
NEP5b	GLO5B000	1,294,836	-17.27	07-Feb-97	15:56:47	17-Feb-97	0:56:47	226	10-Mar-97	14:56:47	774	14-Mar-95	15:56:47	842	1.00	130
NEP6	GLOB6000	3,825,204	-17.29	12-Apr-97	11:18:57	12-Apr-97	14:18:58	4	29-Jun-97	8:18:57	1,870	25-Jul-97	12:18:57	2,498	1.00	130

NEP9	GNPE9000	4,330,972	0.00	13-Nov-98	21:30:00	29-Nov-98	20:30:00	144	11-Mar-99	16:30:00	2,828	11-Mar-99	12:30:00	2,829	1.00	125
NEPa	GNEPa000	8,652,156	0.00	12-Mar-99	2:45:00	12-Mar-99	14:45:00	25	07-Jul-99	16:15:00	5,650	07-Jul-99	22:45:00	5,657	0.50	130
NEPb	NEPKB000	5,475,444	0.00	08-Jul-99	21:07:30	08-Jul-99	20:22:30	23	14-Aug-99	14:07:30	3,550	14-Aug-99	21:07:30	3,578	0.25	130

Table 10 – Southern Flank Mooring Deployment and Recovery Times and Cruises

Mooring	Name	Deployment	Cruise	Start	End	Recovery	Cruise	Comments
Southern Flank - Nominal Position 40 Deg 58 Min North x 67 Deg 19 Min West in 76 m water								
	SF1	1307 27 Oct 1994	EN256	1800 27 Oct 1994	1500 04 Mar 1994	10-Mar-94	SJ9503	recovered adrift
	SF2	1315 26 Apr 1995	SJ9506	1400 26 Apr 1995	1300 30 Oct 1995	1312 3 Oct 1995	EN274	
	SF3	1700 31 Oct 1995	AL9513	1800 31 Oct 1995	2000 07 Mar 1996	1542 01 April 1996	OC276	cut loose
	SF4	1445 6 Apr 1996	OC276	1600 06 Apr 1996	1300 07 Sep 1996	1435 7 Sep 1996	EN288	
	SF5a	1939 26 Oct 1996	OC291	2000 26 Oct 1996	1700 19 Dec 1996	19-Dec-96	OC294	
	SF5b	1625 14 Feb 1997	OC298	1800 14 Feb 1997	1100 11 Apr 1997	1215 11 Apr 1997	KN149	
	SF6a	0214 15 Apr 1997	KN149	0300 15 Apr 1997	0300 22 May 1997	10-May-97	AL97??	cut loose
	SF6b	1550 21 Jun 1997	OC3??	1700 21 Jun 1997	1400 23 Oct 1997	1700 23 Oct 1997	EN308	
	SF7	1418 23 Oct 1997	EN308	1500 23 Oct 1997	1300 07 Apr 1998	1050 07 Apr 1998	OC321	
	SF8a	1608 07 Apr 1998	OC321	2100 07 Apr 1998	1100 18 Apr 1998			
	SF8b	0942 06 May 1998	ISABELS	1000 06 May 1998	2200 11 Jun 1998			
	SF8c	1300 02 Jul 1998	MARYK	1300 02 Jul 1998	1200 05 Oct 1998	1355 05 Oct 1998	OC331	
	SF9	1412 07 Oct 1998	OC331	1900 07 Oct 1998	1300 10 Mar 1999	1416 10 Mar 1999	OC338	
	SFaa	2121 10 Mar 1999	OC338	2200 10 Mar 1999	0100 03 Apr 1999			
	SFab	1042 13 May 1999	HARMONY	1100 13 May 1999	1000 07 Jul 1999	1036 07 Jul 1999	OC344	
	SFb	2021 09 Jul 1999	OC344	2300 09 Jul 1999	1100 17 Aug 1999	1205 17 Aug 1999	OC346	
S Flank Guard - Nominal Position 40 Deg 58 Min North x 67 Deg 19 Min West in 76 m water								
	SG2	1355 01 Apr 1995	SJ9504	1412 01 Apr 1995	0045 09 Sep 1006	1614 3 Oct 1995	EN274	buoy sunk Sept

Table 11. Crest, Northeast Peak & Bottom Pressure Mooring Deployment and Recovery Times & Cruises

Mooring	Name	Deployment	Cruise	Start	End	Recovery	Cruise	Comments
Crest - Nominal Position 41 Deg 24.5 Min North x 67 Deg 32.5 Min West in 42 m water								
	CR1	1048 28 Oct 1994	EN256	1800 28 Oct 1994	1300 21 Jan 1995	0757 29 Mar 1995	SJ3504	
	CR2	2326 01 Apr 1995	SJ9504	0400 02 Apr 1995	1700 30 Sep 1995	1310 30 Sep 1995	EN274	
Northeast Peak - Nominal Position 41 Deg 44 Min North x 66 Deg 32 Min West in 76 m water								
	NP3	2039 01 Nov 1995	AL9513	2100 01 Nov 1995	0600 30 Mar 1996	1217 31 Mar 1996	OC276	
	NP4	1420 07 Nov 1995	OC276	1600 07 Apr 1996	0100 18 Apr 1996	1415 08 Set 1996	EN288	
	NP5a	1450 28 Oct 1996	OC291	Data GOES only	13-Dec-96	19-Dec-96	OC294	recovered bottom
	NP5b	0024 17 Feb 1997	OC298	0200 17 Feb 1997	1400 10 Mar 1997	10-Mar-97	OC299	cut loose
	NP6	1427 12 Apr 1997	KN149	1500 12 Apr 1997	0900 29 Jun 1997			cut loose
	NP9	2027 19 Nov 1998	OC333	2100 19 Nov 1998	1600 11 Mar 1999	1756 11 Mar 1999	OC338	
	NPa	1430 12 Mar 1999	OC338	1600 12 Mar 1999	1600 07 Jul 1999	1836 07 Jul 1999	OC344	
	NPb	2010 08 Jul 1999	OC344	2100 08 Jul 1999	1400 14 Aug 1999	1440 14 Aug 1999	OC346	
Bottom Pressure - Nominal Position 40 Deg 58 Min North x 67 Deg 19 Min West in 76 m water								
	BP4	1816 06 Apr 1996	OC276	1821 06 Apr 1996	27-Jul-96	07-Sep-96	EN288	becomes bad at end
	BP7	1630 23 Oct 1997	EN308	1645 23 Oct 1997	1655 07 Apr 1998	1300 07 Apr 1998	OC321	
	BP8	1515 09 Apr 1998	OC321	1530 09 Apr 1998	1300 05 Oct 1998	1328 05 Oct 1998	OC331	
	BP9	1608 07 Oct 1998	OC331	2030 07 Oct 1998	1100 10 Mar 1999	1125 10 Mar 1999	OC338	
	BPa	1521 12 Mar 1999	OC338	2030 12 Mar 1999	1445 07 Jul 1999	1013 07 Jul 1999	OC344	
	BPb	2037 09 Jul 1999	OC344	0045 10 July 1999	1945 12 Aug 1999	2010 12 Aug 1999	OC346	

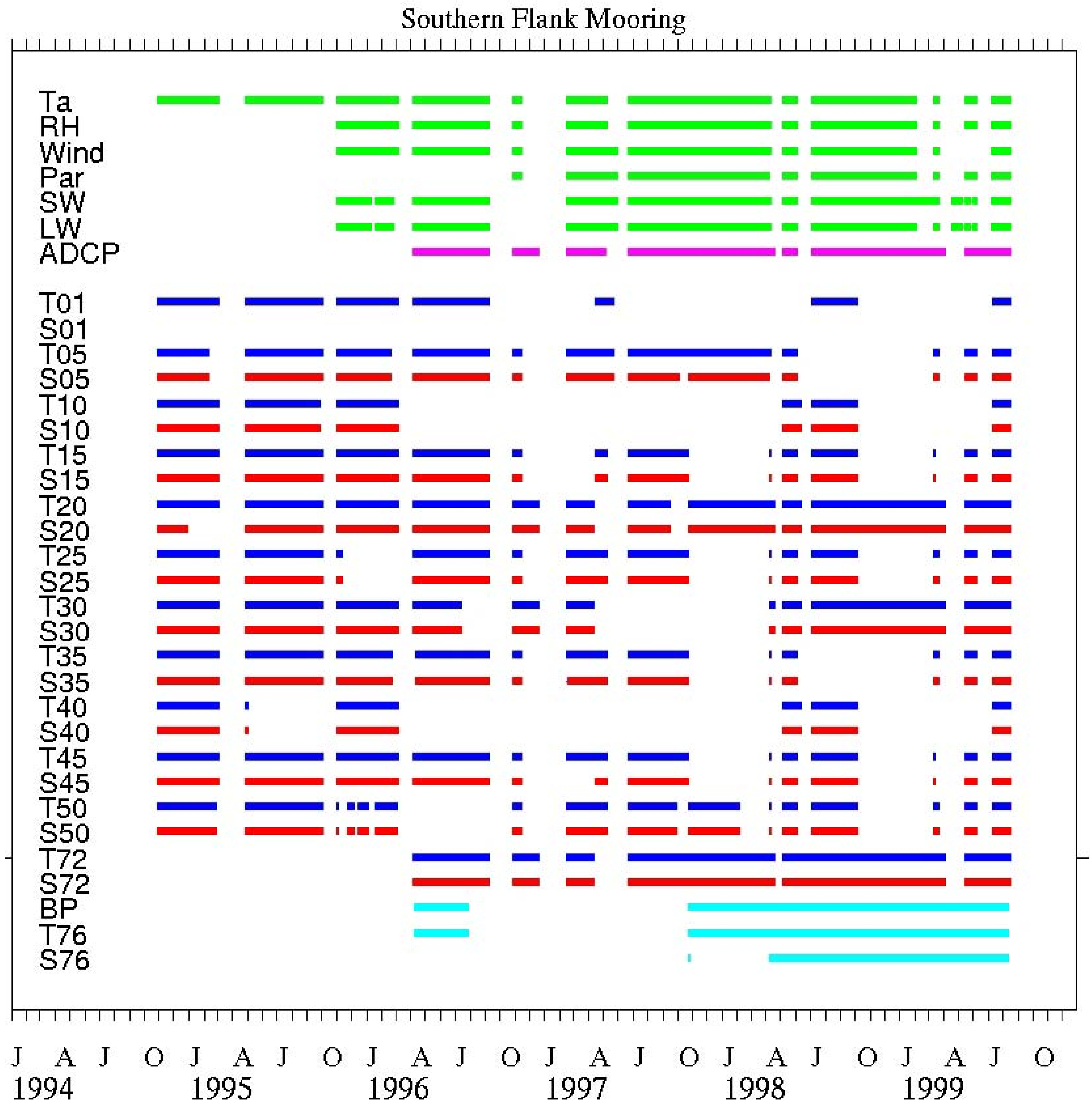

Figure 14. The data return for each sensor at each depth versus time for the Southern Flank Site. Not all sensors were deployed at each depth for the duration of GLOBEC.

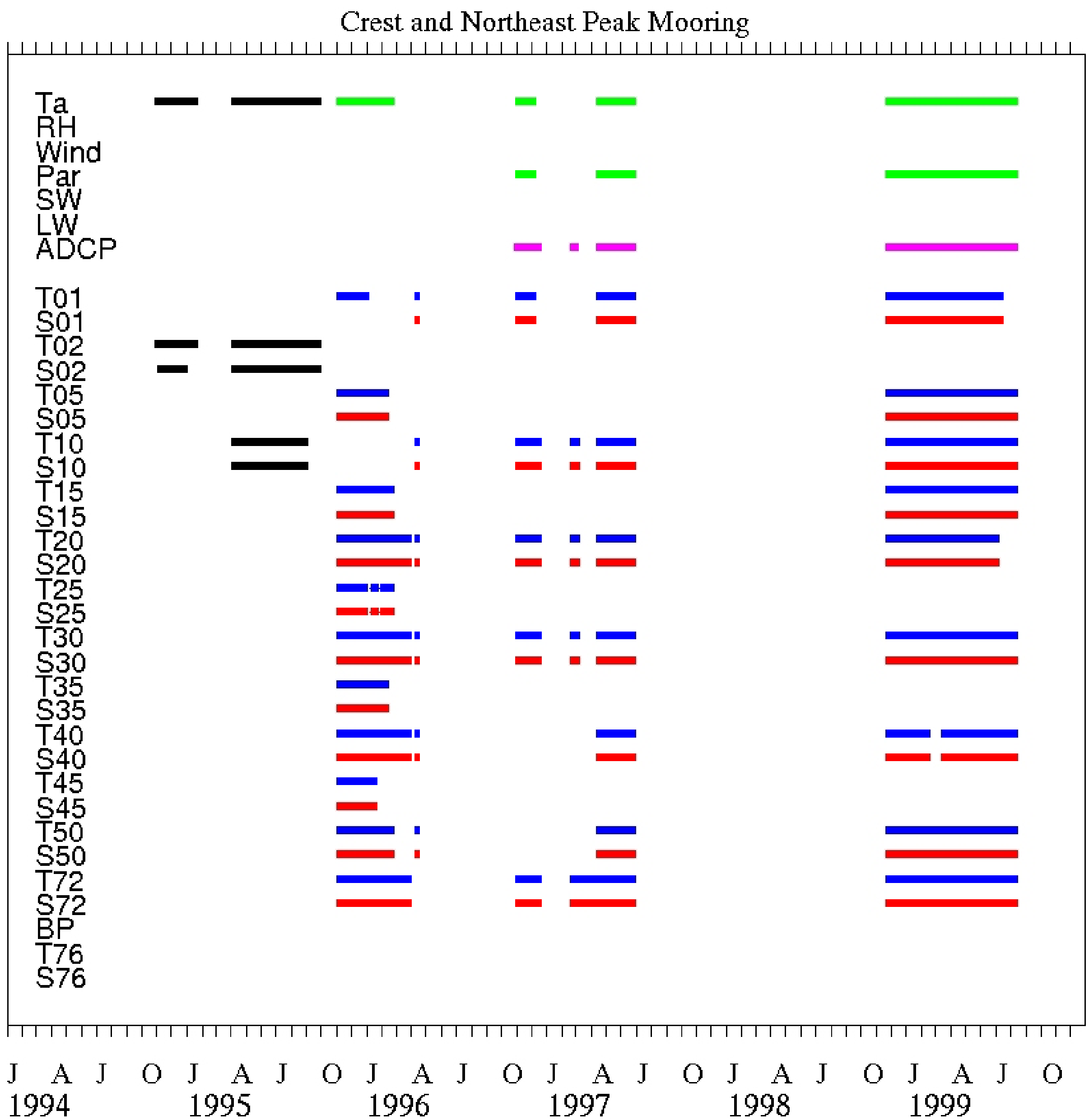

Figure 15. The data return for each sensor at each depth versus time for the Crest (black lins to the left in 1994 and 1995) and Northeast Peak (red and blue lines in 1995 through 1999) Sites. Not all sensors were deployed at each depth for the duration of GLOBEC.

A. YEARLY DETAILED DISCUSSION

The moored water temperature and salinity data presented here illustrate the temporal variability at each site and the effort required to obtain the records needed to present a realistic picture of the local conditions and add another data point for long-term climate studies. Figures 16 to 18 show the data from the Crest, Figures 19 through 40 from the Southern Flank, and Figures 41 to 59 from the North East Peak. All plots have the same vertical scale and a full year time axis. The meteorology data is presented first, with the sea surface temperature (taken at 1

m) superimposed on the air temperature. Next the temperature and salinity are presented. The temperature data at all measurement depths are plotted superimposed on the same scale in the top panel of each figure. The salinity data are plotted similarly in the lower panel and separate by depth region by the colors shown in the legend with each plot. The bio-optical data is presented next, in rough edit form. Finally, the ADCP data is summarized. Since thetides dominate, the data is plotted in the top to panels as depth averaged, low passed with a stick diagram on the top panel, then the two components in the next. These plots are rotated to along and cross bank orientation. The next two panels are the depth dependent low passed currents plotted in contour form for the Eastgoing and Northgoing components. The bottom panel is the uncalibrated amplitude of the backscattered signal which gives an indication of the number of scatters in the water column.

Crest 1994:

a. **Meteorology:** The crest site had only a air temperature and sea surface temperature (at 2 m depth on the buoy) sensors, so is presented below with the T/S data in Fig. 16.

b. Water Temperature and Salinity: The temperature records show the fall and winter cooling of the water. The air temperature has more variability, but is generally cooler than the water. The two major cooling events are seen in the minimum temperatures in the air temperature of zero deg C or below. These occur about 22 November at the end of the year. The sea surface temperature drops about 2 ºC in the first event and about 1 ºC in the second. The first is associated with a 16 m/s Northerly wind event, and the second with a 14-15 m/s wind event.

b. Bio-optical: No bio-optical in 1994

c. ADCP: No currents were measured at the Crest site.

2. Crest 1995:

a. **Meteorology:** The crest site had only a air and sea surface temperature sensors, so is presented with the T/S data in Figure 17.

b. **Water Temperature and Salinity:** The temperature records show the continued winter cooling until a failure in the load cell, used in engineering studies of the compliant elastic mooring technology(see Paul, et al., 1998), flooded and prematurely discharged the data system battery. The minimum estimated temperature on the crest in winter 1995 was about 5 ºC. The water started warming in April, and the 10 m depth bio-optical package temperature (Fig 16) was nearly identical to the 2 m temperature until the bio-optical record stopped. The salinities show a similar well mixed nature, with a tendency for the salinity at 2 m to be less at some times than at 10 m. In general, (as compared with the southern flank mooring directly off bank to the SSE) there was little observed stratification at the Crest mooring site during the year.

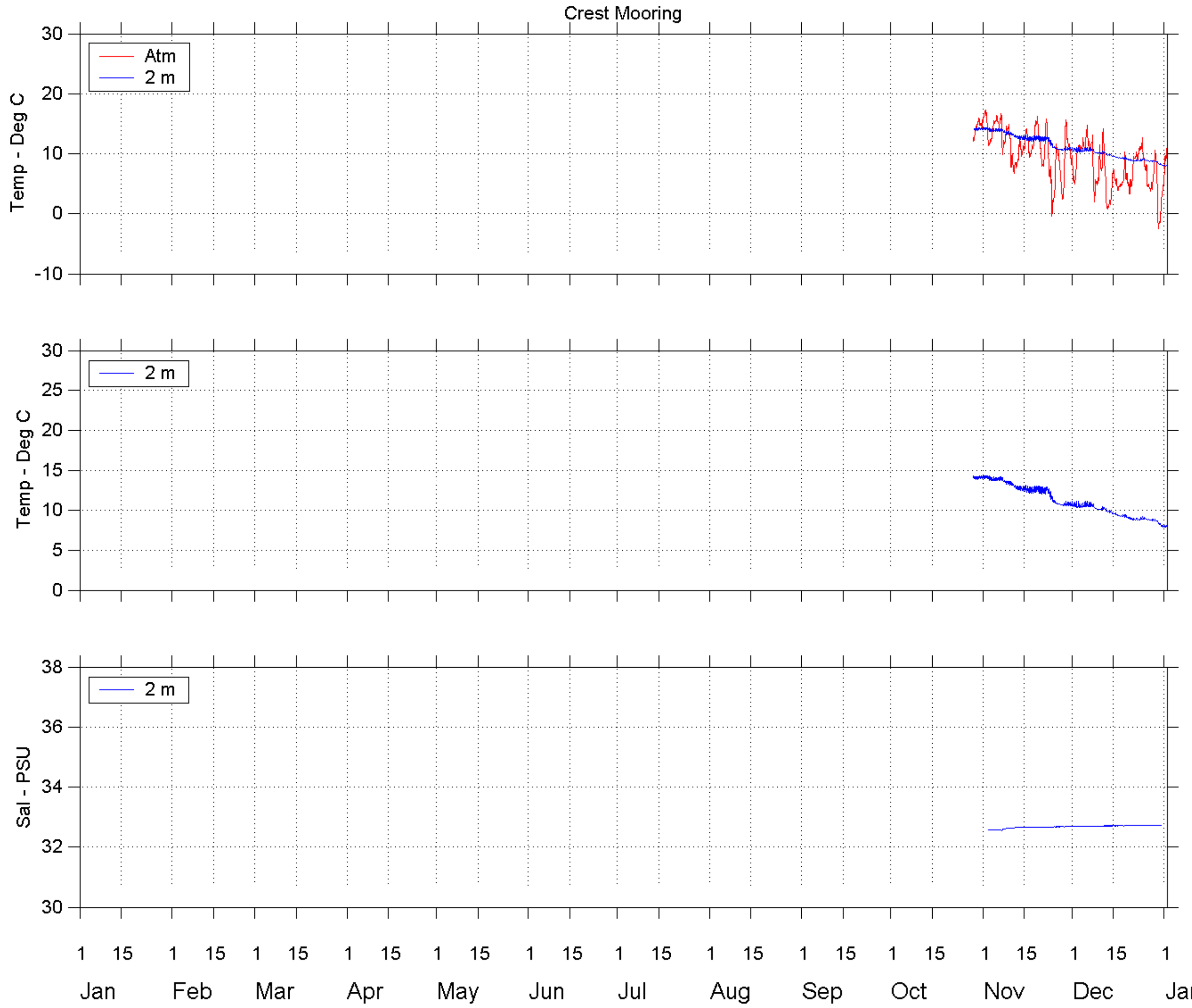

Figure 16. Crest moored temperature and salinity data from 1994. The mooring was first deployed at the end of October 1994.

The maximum temperature of 17.5 ºC occurred mid-September when the fall cooling started. The salinity was fairly constant at the end of 1994, starting out at 32.5 and ending up at 32.7 PSU. During the summer and fall of 1995, the salinity decreased to a minimum of 32.3 PSU at the time of the maximum temperatures. Then the salinity increase with decreasing temperatures as the fall cooling continued. There were no major events seen in the temperature or salinity during the second deployment.

c. **Bio-optical:** A bio-optical package was moored at 10 m (Fig. 8) to monitor the bio-optical properties on the crest. It was only in for one deployment, and then moved to the Northeast Peak. The transmissometer record appears to decline at a steady rate starting mid-record. This may be due to biofouling, but a similar drift is not seen in the fluorometer. I would be interesting if there were an increase in non-fluorescent particulate matter on the bank in the summer. The fluorometer shows a strong peak in the first week of April (immediately after deployment). The fluorometer record shows strong tidal variability as compared to the temperature and salinity records. The early

April fluorometer peak is associated with a drop in transmissometer as would be expected in a bloom with increasing scattering. There is a second broad peak in the fluorometer that is not associated with as strong a drop in transmission as the first peak.

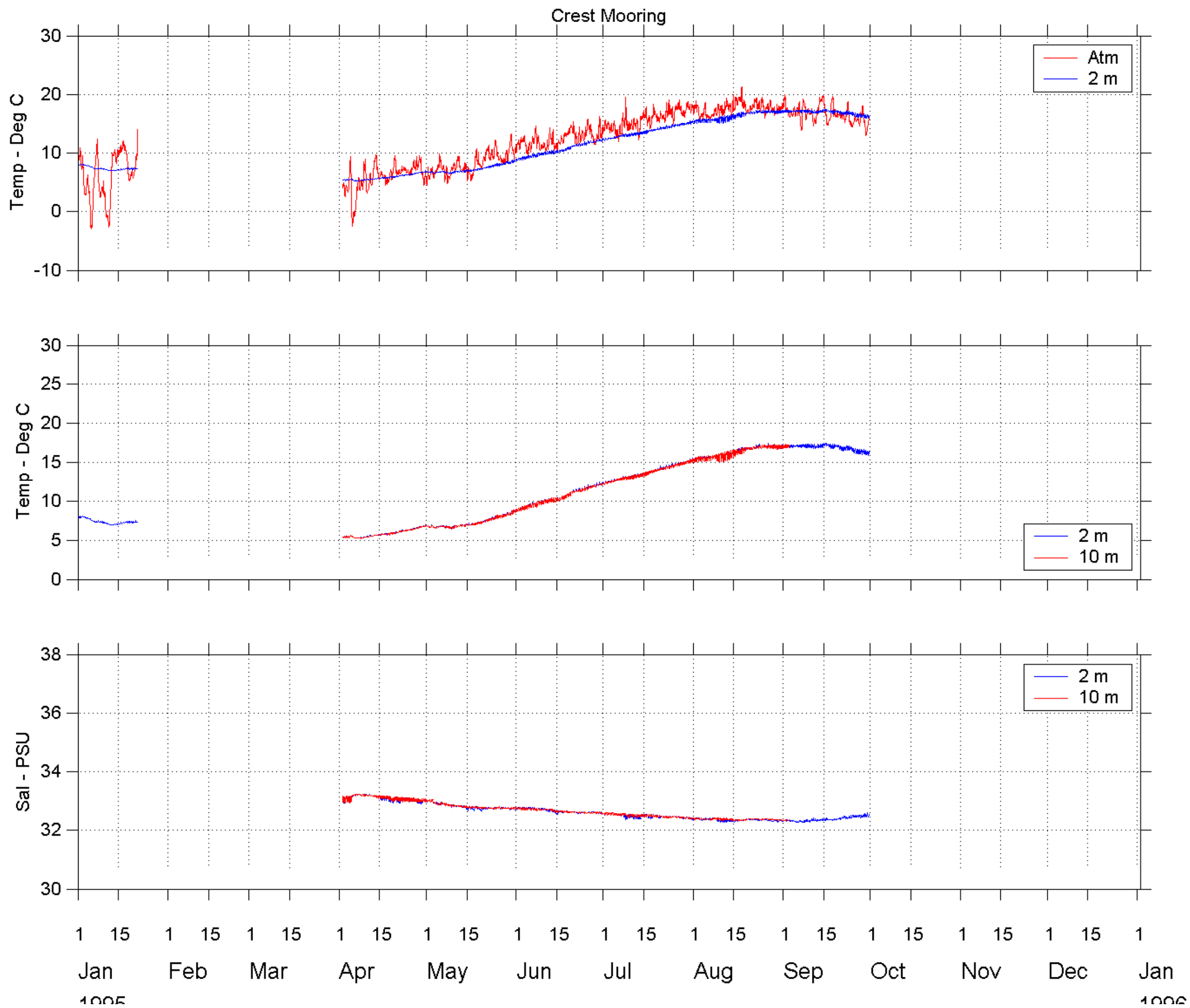

Figure 17. Crest moored temperature and salinity data from 1995. All temperature (top) and all salinity (bottom) records are plotted on the same axis. The mooring was recovered in late Sept 1995 and redeployed at the Northeast Peak for the duration of the field effort.

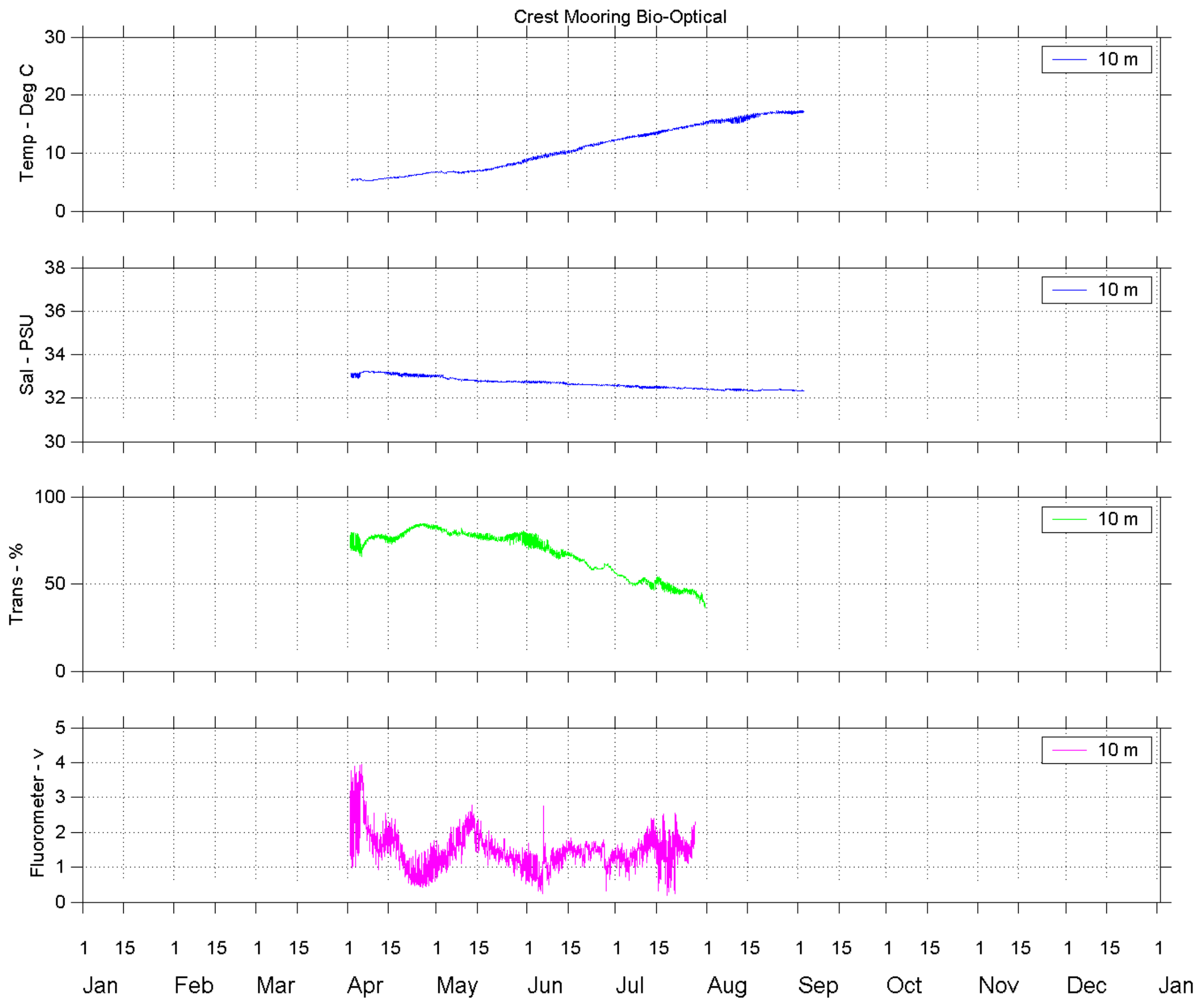

Figure 18. Crest Bio-Optical Data from 1995.

d. **ADCP:** No currents were measured at the Crest site.

3. SOUTHERN FLANK 1994

The temperature and conductivity data from all instruments were checked with pre-deployment and post-deployment calibrations. All sensors were calibrated once per year during the fall turnaround at Sea Bird, and the sensor drift, stability and operation evaluated. Corrections were then made to the observations and a preliminary data set prepared. A series of 1-hour yo-yo *in situ* CTD comparison profiles were made at the start and end of each deployment, and these results were also used to check sensor drift. The temperature sensors typically drifted only a couple of millidegrees C per year. The conductivity sensors used ---------------Tributyltin poison cylinders to reduce biofouling drift. These sensors, particularly the shallower ones, did drift a few hundredths of a PSU during the summer months. A linear drift was applied to correct for this change, and to bring the data into agreement with the CTD data. Most of the data displayed here have had this first order quality assurance and validation effort applied.

a. Meteorology: The mooring was first deployed in October 1994 in the middle of a warm core ring intrusion. The mooring remained in place until March 1995. The full meteorology suite was deployed on the stratification moorings (see Alessei et al, 2001), so was not available at the Southern Flank site until fall 1995. Also, the PAR sensor deployed in 1995-95 had gain problems that rendered the data unreliable. Therefore the air temperature and sea surface temperature are plotted (Fig. 19) to show the fall cooling. As expected the air temperature shows greater variations and is generally cooler than the surface water temperature (measured about 1 m below the sea surface).

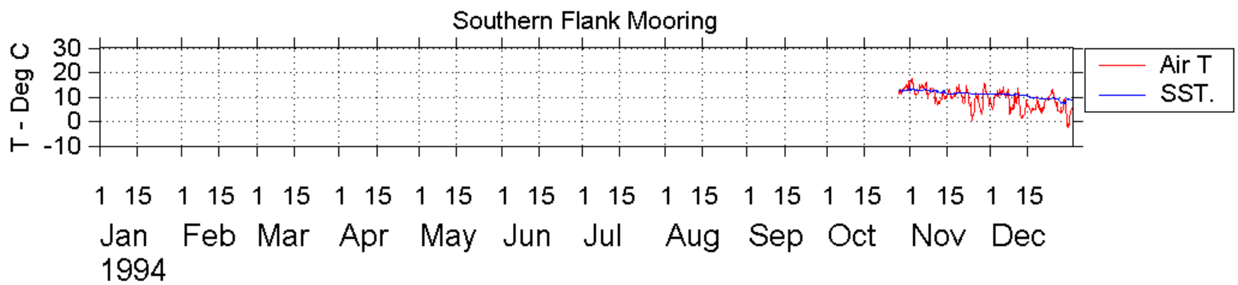

Figure 19. Southern flank mooring meteorology data from 1994.

b. Water Temperature and Salinity: The temperature and salinity records from 1994 (Fig. 20) show warm-core ring effects in the bottom waters (below 30 m) until about mid-November. Warm (19 º C from 13º C), salty (35.5 PSU from 32.8 PSU) water was being advected back and forth by the tidal currents (which sweep out a 10-km ellipse at this site). There are two main intrusion groups of pulses seen, when first deployed the last few days of October and the end of the first week of Nov. Between these two groups of pulses, warm core ring effects are seen, but not as strong. Then they "fade out" over the second week of November when the water column becomes well mixed with temperatures of 12 º C and salinities of 32.8 PSU. The temperature then continues to cool to about 8.8 ºC at the end of the year. During the same time the salinity (which starts out constant at about 32.8), rises about 0.2 PSU by the end of the year.

About 15 November 1994, the temperature drops about 1.5 º C at the same time as the salinity rises 0.2 PSU. No strong local wind event was associated with this cooling (advective) event. The largest event during winter occurred near the end of 1994 (24 to 28 December) when a large mass of cooler, fresher Scotian Shelf water was seen in the upper 30 m of the water column with "compensating" warmer, saltier water at the bottom. The surface temperatures dropped from about 9.5 º C to about 7.3 º C then returned to about 9 ºC. The surface salinities dropped from 33.0 PSU to about 31.75 PSU, then back to 32.8 PSU. The deeper temperature and salinity response lags slightly. After the major surface temperature and salinity event, the bottom temperatures rose from 9.0 to 10.2 º C and the bottom salinity rises from 33.0 to 33.3 PSU then slowly decays with tidal fluctuaqtions over the next vew days. This temperature and salinity change produced the greatest stratification observed in 1994. The water properties end up the year with temperature of 8.8 º C and salinities of 32.8 º C. The crossover event cooled the water column about 0.7 º C and freshened it about 0.2 PSU.

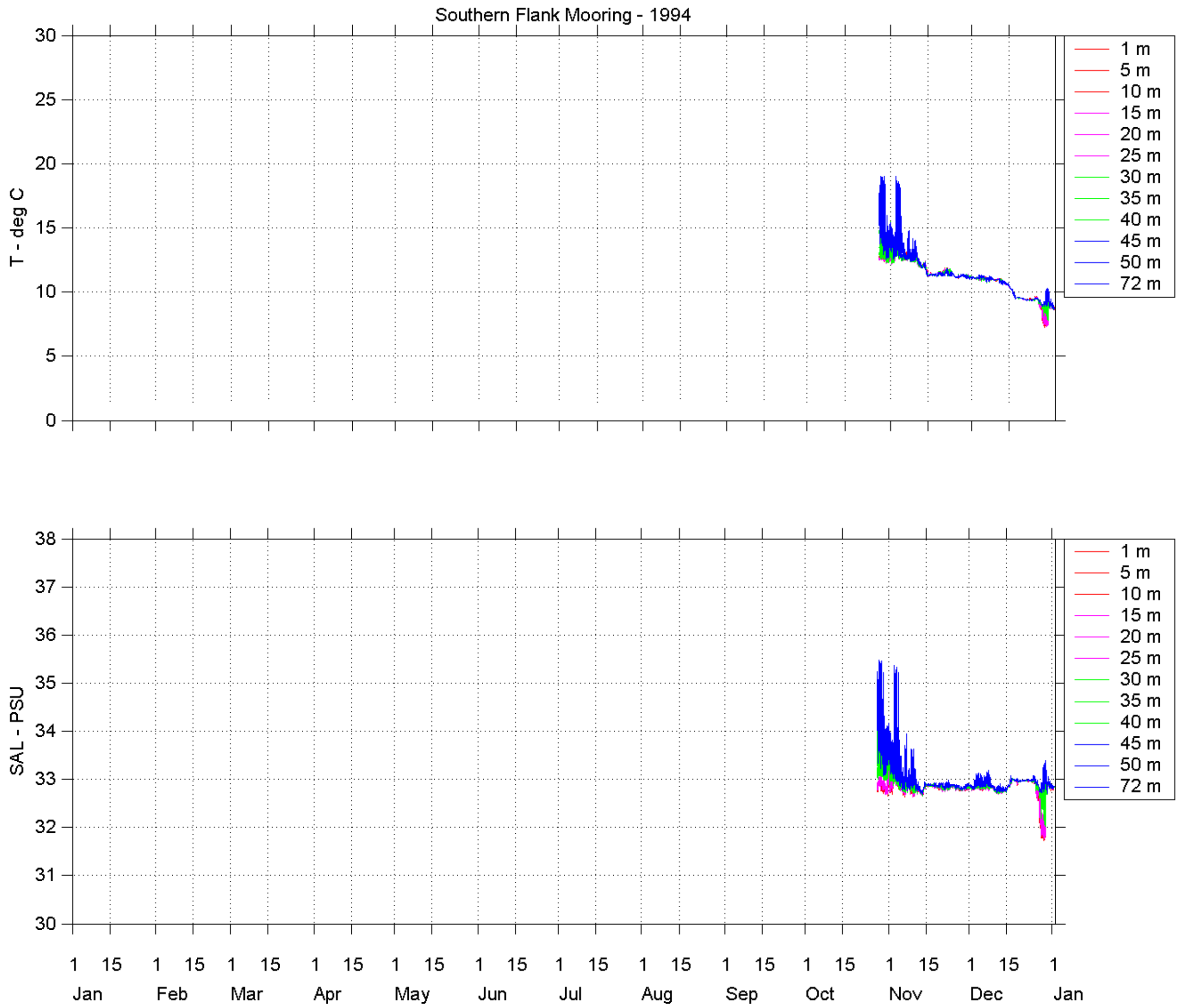

Fig 20. Southern flank moored temperature and salinity data from 1994. All temperature (top) and all salinity (bottom) records are plotted on the same axis. The mooring was first deployed in October 1994 for the start of the moored program.

c. **Bio-Optical:** The bio-optical packages at 10 and 40 meters were deployed throughout the Southern Flank deployment. The temperature and salinity observations (Fig. 21) are also plotted with the TS in Fig. 20. The PAR (photosynthetically active radiation) also had some overflow problems, but are plotted anyway. The fluorometer and transmissometer data are plotted without editing out spikes in transmissometer when it is blocked (by fish or seaweed), or when the fluorometer or transmissometer are affected by biofouling. It is left to the reader to determine when the data are unreliable.

The fluorometer and transmissometer show strong effects of the warm core ring intrusion at the start of the deployment. The 40 m transmissometer shows high transmission (low particulate concentration) and the fluorometer shows unusually steady and low chlorophyll-a concentrations. The 10 m transmissometer shows a lower reading during the warm core ring event and the fluorometer shows an unusually high reading. The implication is that the warm core ring water is low in biological activity, while the concentration in the upper part is higher because of the compression of the shelf water on Georges Bank by the warm core ring intrusion – both horizontally, crowding the biological activity up onto the bank, and vertically, into the upper part of the water column.

The 10 m fluorometer shows a small increase in reading during the Scotian Shelf crossover event at the end of the year, possibly indicating higher biologically productive water being brought onto the Bank. The 40 m fluorometer shows a slight decrease during the lower water mass reaction to the crossover. The implication is that there was some offshore (warmer and saltier) water that came up onto the shelf at the bottom during the transition of the cooler, fresher crossover water at the top of the water column.

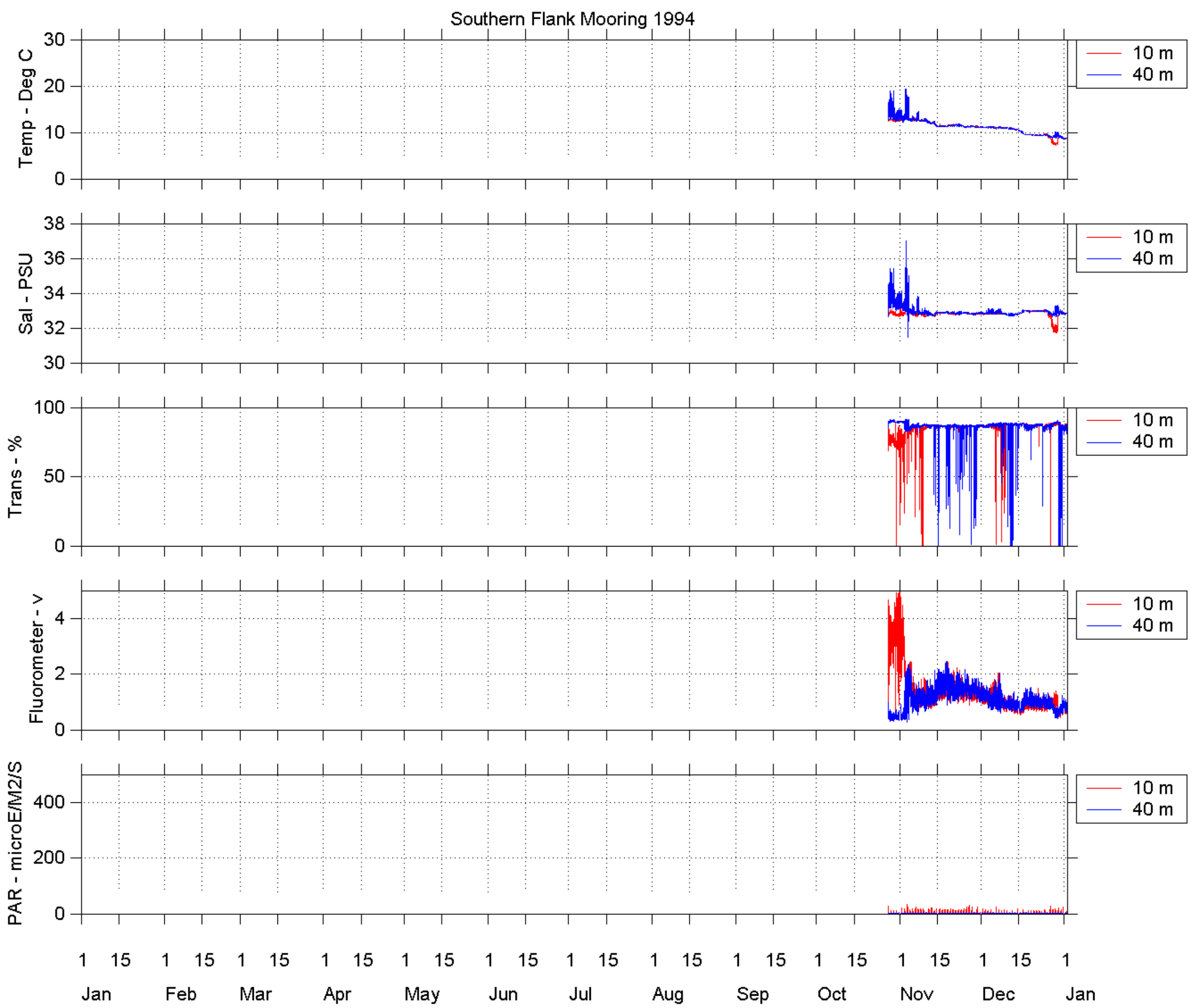

Figure 21 Southern flank moored bio-optical data from 1994

d. ADCP: No ADCP data were obtained from the Southern Flank in 1994.

4. SOUTHERN FLANK 1995

The continuation of the first deployment, the turnaround and the second deployment, and finally the start of the third deployment are seen in the 1995 record. The mooring was cut loose in March 1995 by fishing activity, recovered, repaired and redeployed in April. Also, some temperature sensors were deployed on a Guard mooring in early April, before the main mooring was repaired and deployed. The mooring was recovered in early October, and all sensors cleaned, calibrated and redeployed at the end of October. The sensors serial numbers and depths, deployment and recovery times and cruises are listed in Tables 2, 3, 5, and 6, and a time line of the data returned shown in Figs. 14.

a. **Meteorology:** The first and second deployments had the major meteorological sensors on the stratification mooring. The end of the year has the full suite of sensors, with the exception of the PAR sensor that was unreliable, so not displayed (Fig. 22). The air temperature and sea surface temperature appear as expected, following each other with the air temperature showing more fluctuations and leading the water temperature in the annual cycle. The warm core ring effects in the surface waters can be seen in the last half of September, when the surface waters warm above the air temperatures during the fall cooling.

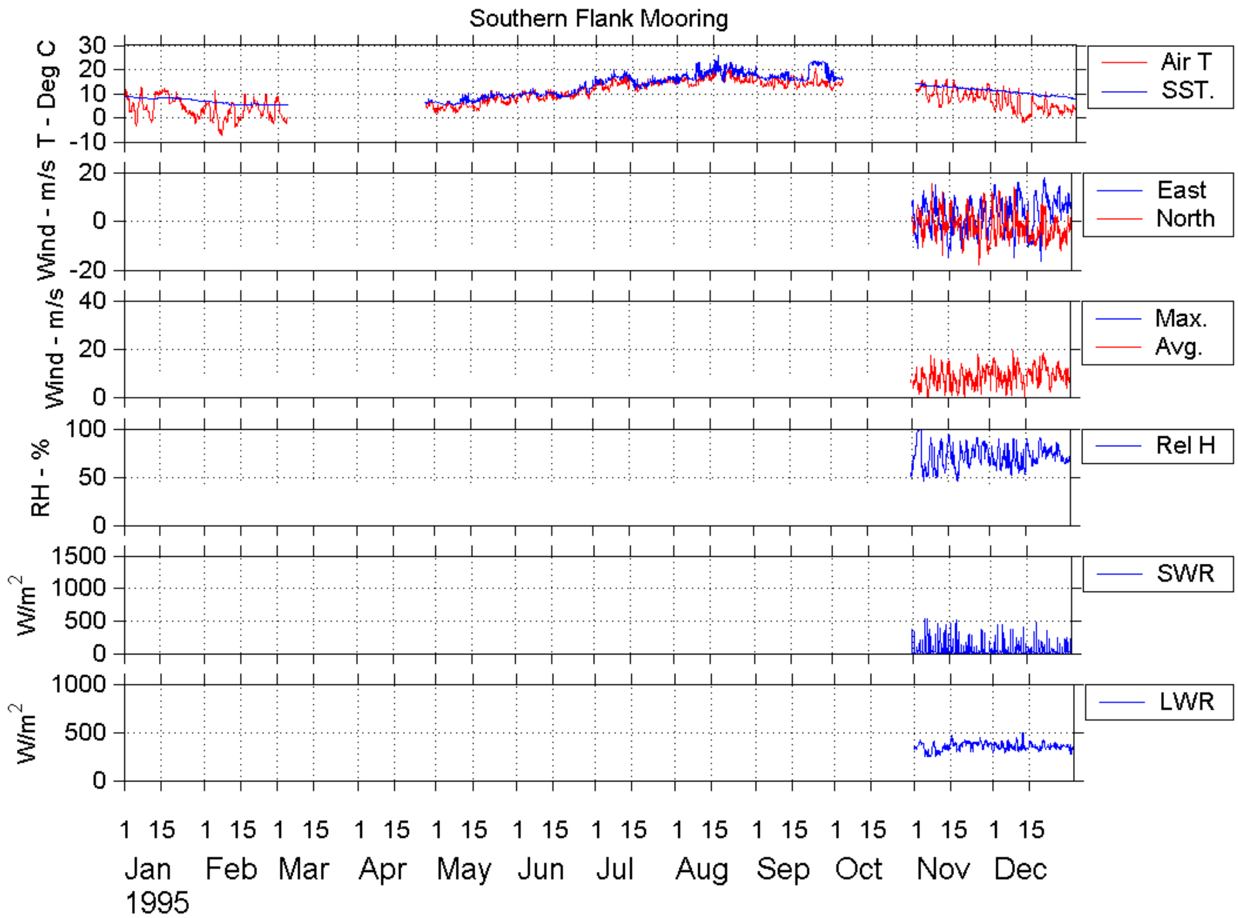

Figure 22. Southern flank moored meteorology from 1995.

b. **Water Temperature and Salinity:** The second year (1995) shows the summer heating and the fall cooling and mixing. Again warm-core ring effects are seen, peaking around 15 May. During the summer, warm saltier water is seen indicating some ring effects. The large late September event affects the entire water column, which becomes warm and salty, with salinities above 35 PSU. Note that the warm-core ring effects do not seem to influence the longer-term trends in temperature and salinity. The gaps in the time series are due to routine servicing and repair/replacement of moorings damaged by fishing activities. The mooring is recovered and refurbished during the one-month fall gap.

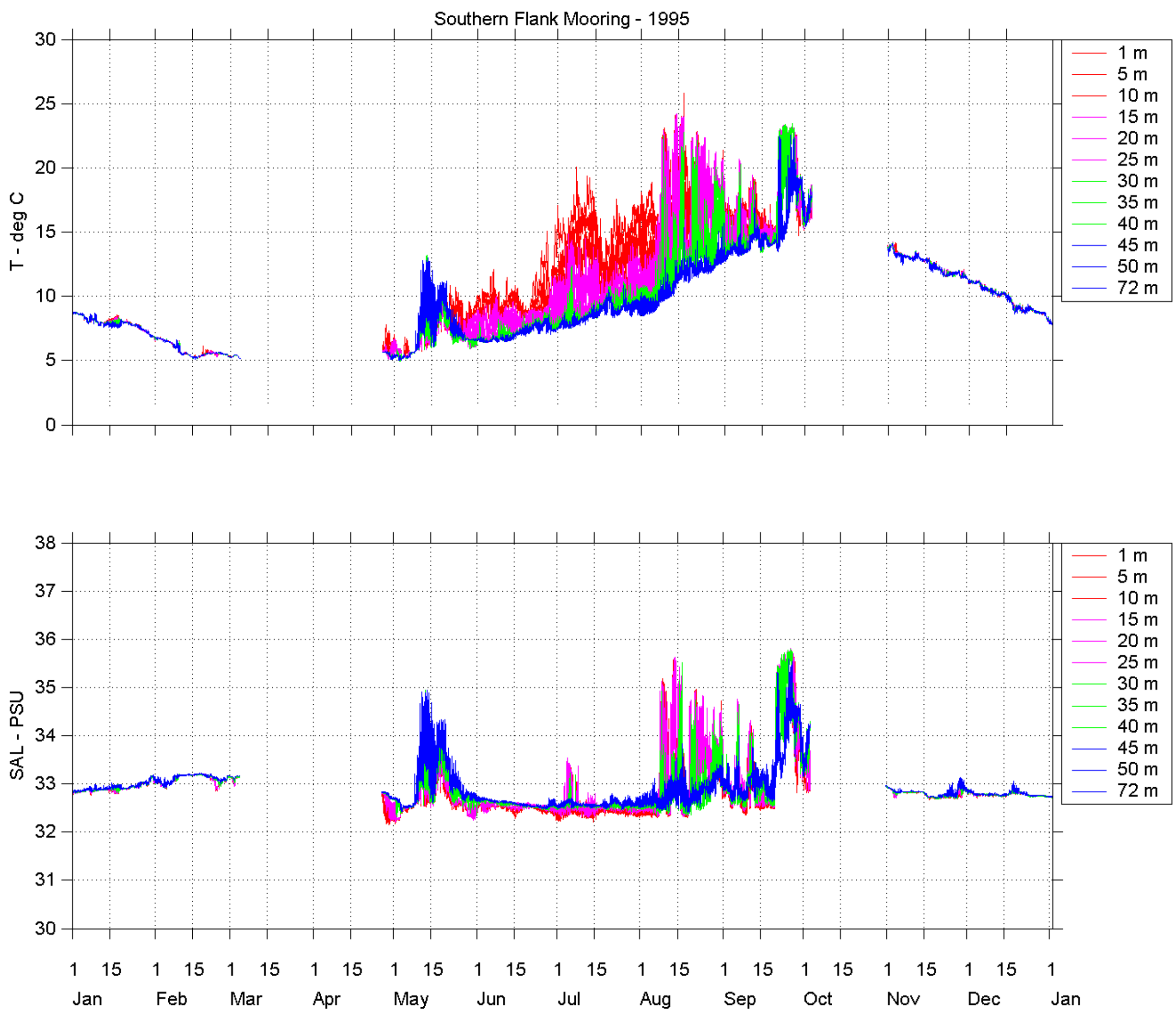

Fig 23. Southern flank moored temperature and salinity data from 1995. All temperature (top) and all salinity (bottom) records are plotted on the same axis.

The water starts out fairly well mixed top to bottom at 8.8 º C and 32.8 PSU (Fig. 23). The water temperature continues to cool to a minimum of around 5 º C. The cooling is not uniform, showing a stop in cooling and slight stratification mid January 1995. The salinity shows a rather steady increase to 33.2 by early March when the mooring was cut adrift. There is a slight hint of crossover waters on 22 February when the surface waters freshen to 32.86 PSU. The Southern Flank mooring missed the large crossover event seen in the stratification mooring in March (when the Southern Flank mooring was being serviced). At the end of April when the mooring is redeployed, the upper 30 meters of the water column has warmed and stratification had already started. The water has warmed to 8 º C. The upper water column has also freshened to 32.2 PSU. However, the water column again becomes well mixed by the end of the first week in May with temperatures of 5.6 º C and salinities of 32.5. Note that there is about a 0.5 PSU drop in salinity while the mooring was being serviced.

During 8 to 23 May 1995 there are two strong warm core ring intrusion events (or one that returns) that affects the entire water column. The bottom water temperatures rise from about 5.6 º C to a maximum of 13 º C. The salinity appears well mixed at 32.5 PSU and rises to a maximum of 34.95 PSU. The signal (as in the fall of 1994) shows strong tidal advective effects in its variations. A week after the first peak values, a second peak, not as strong, is observed with temperatures rising to 11.1 º C and salinities rising to 34.3 PSU. During both of the warm core ring events, the whole water becomes warmer indicating that the warm core ring has moved fully onto the Bank to the position of the mooring. Unlike the events of the fall 1995 where the effects were send only in the bottom of the water column.

After the warm core ring event has passed, the salinity returns to its previous values, but the temperatures show the seasonal warming in the upper part of the water column. The top 20 to 30 meters is warmer, with temperatures around 10 º C. The salinities do show some fresher water in the upper 20 to 30 meters of the water column. During most of the summer and fall there is fresher water in the top 20 m of the water column by about 0.1 to 0.2 PSU below the deeper waters.

The surface waters (above 30 m) show typical summer warming to a maximum of 26 ºC mid-August. After that time the fall cooling of surface waters reduces the temperature to about 15 º C mid September, when the water column becomes nearly mixed.

There is warm core ring effects in the upper half of the water column about 5 July, when the salinity rises to 33.5 PSU then returns to slightly below 32.5 PSU. The accompanying temperature signal is obscured by the seasonal surface warming where the temperature reaches a maximum of 20 º C, but there is a general surface water warming that starts the end of June and continues to mid-July that is probably associated with this warm core ring event. The penetration of the thermal effects to 40 m can be seen in the temperature record (Fig. 23.)

During 8 August into early September more warm core ring effects are seen mainly in the upper half of the water column, but with effects that extent throughout the water column. These effects show strong tidal advective variability again and slowly decrease in occurrence into September. The temperatures peak during this time at about 25 to 26 º C and salinities increase to 35.5 PSU. This event is not a sudden onset and departure, but more of a continued presence just offshore that is advected by tidal currents past the mooring. During this event, the bottom waters show a greater variability in salinity than normal, with salinities rising to above 33.3 PSU at the end of August. The deeper temperatures show a sudden increase in value starting about the first of August and continue to warm at a more rapid rate than previously until mid-September when the water column is about 15 º C and 33 PSU.

About 20 September a final warm core ring event is seen with peaks in temperature of 23.5 º C and salinities of 35.8 PSU. These effects are seen fairly uniformly throughout the water column. This event is about over by the end of September, when the mooring was recovered and the water column is nearly mixed vertically with temperatures around 17 º C and salinities around 33.6 PSU, so the water column has become warmer and saltier than it was mid-September before the event when it was nearly homogeneous.

When the mooring is redeployed at the end of October, the water column is well mixed and decreases in temperature from 14.0 ºC to 7.0 ºC by the end of they year. The salinity remains fairly constant at 32.8 PSU with fluctuations from a minimum of 32.7 PSU to a maximum of 33.1 PSU. These salinity fluctuations are not well correlated with larger temperature fluctuations. The end of November salinity pulses is associated with a small warming in temperature. The salinity pulse in mid-December is preceded by a drop in temperature that is not correlated with a local wind event.

c. Bio-Optical:

The bio-optical data set (Fig. 24) shows strong biofouling effects in the transmissometer and fluorometer in August that effectively ends the observations. The winter shows variations in the fluorometer, but the general peaks are not correlated with any of the temperature or salinity. The peak in the 40 m fluorometer about 15 Feb is associated with a relatively flat signal in temperature and salinity with higher salinity (33.2 PSU) and lower temperatures (5.1 ºC).

During the summer there is a peak in the fluorometer record during the second week in June that is accompanied by a decrease in transmission. This is a normal signature of a productivity event. The major signal in the fluorometer is the strong (saturated to full scale) event that starts in the later part of June and runs into early August. This signal is not accompanied by a strong decrease in transmission and may not be entirely due to increased primary productivity. Finally, just after deployment there is a rise in the fluorometer readings at 10 and 40 m that is not associated with a temperature or salinity event, but is seen in the lowered transmissometer and probably indicates a fall productivity event.

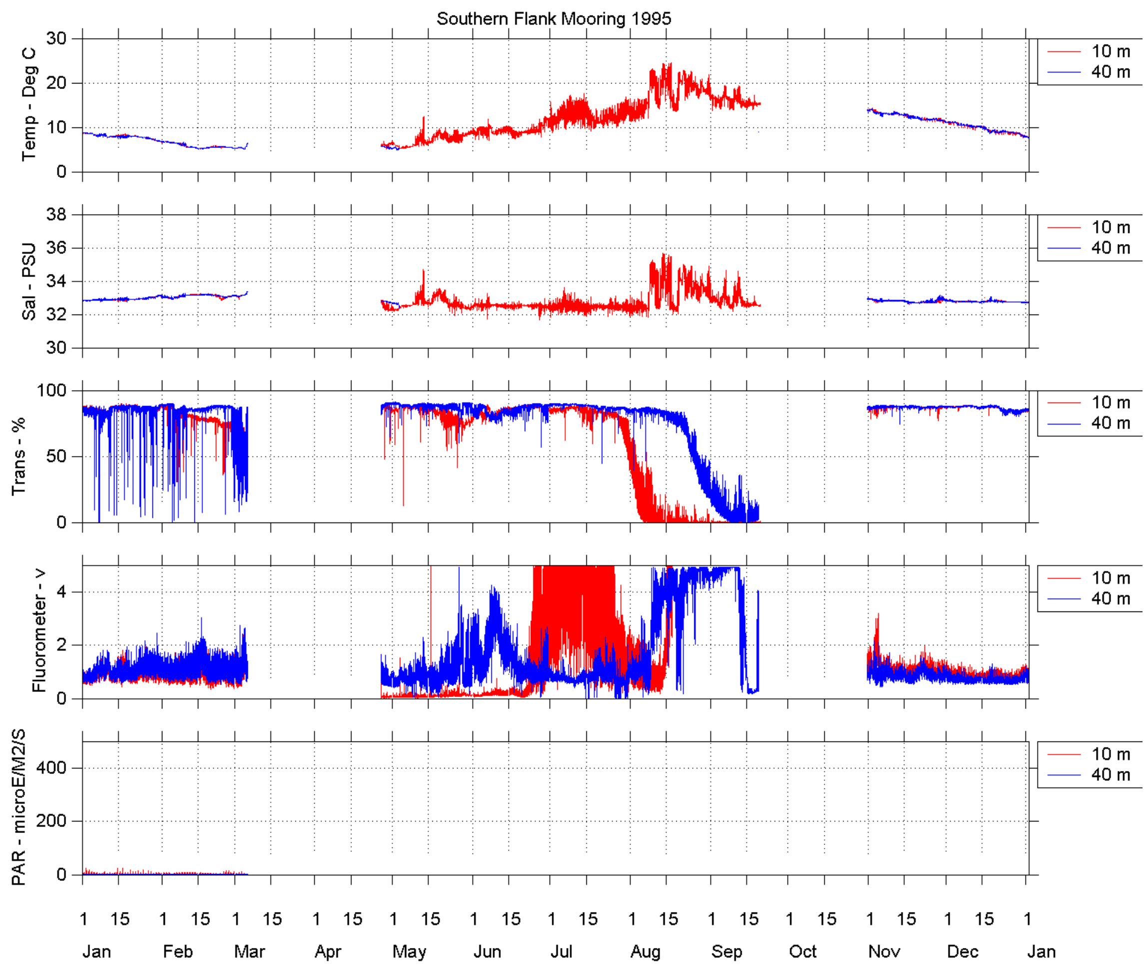

Figure 24. Southern flank moored bio-optical data from 1995.

d. ADCP: No ADCP No ADCP data were obtained from the Southern Flank in 1995.

5. SOUTHERN FLANK 1996

a. **Meteorology:** The atmosphere was still there

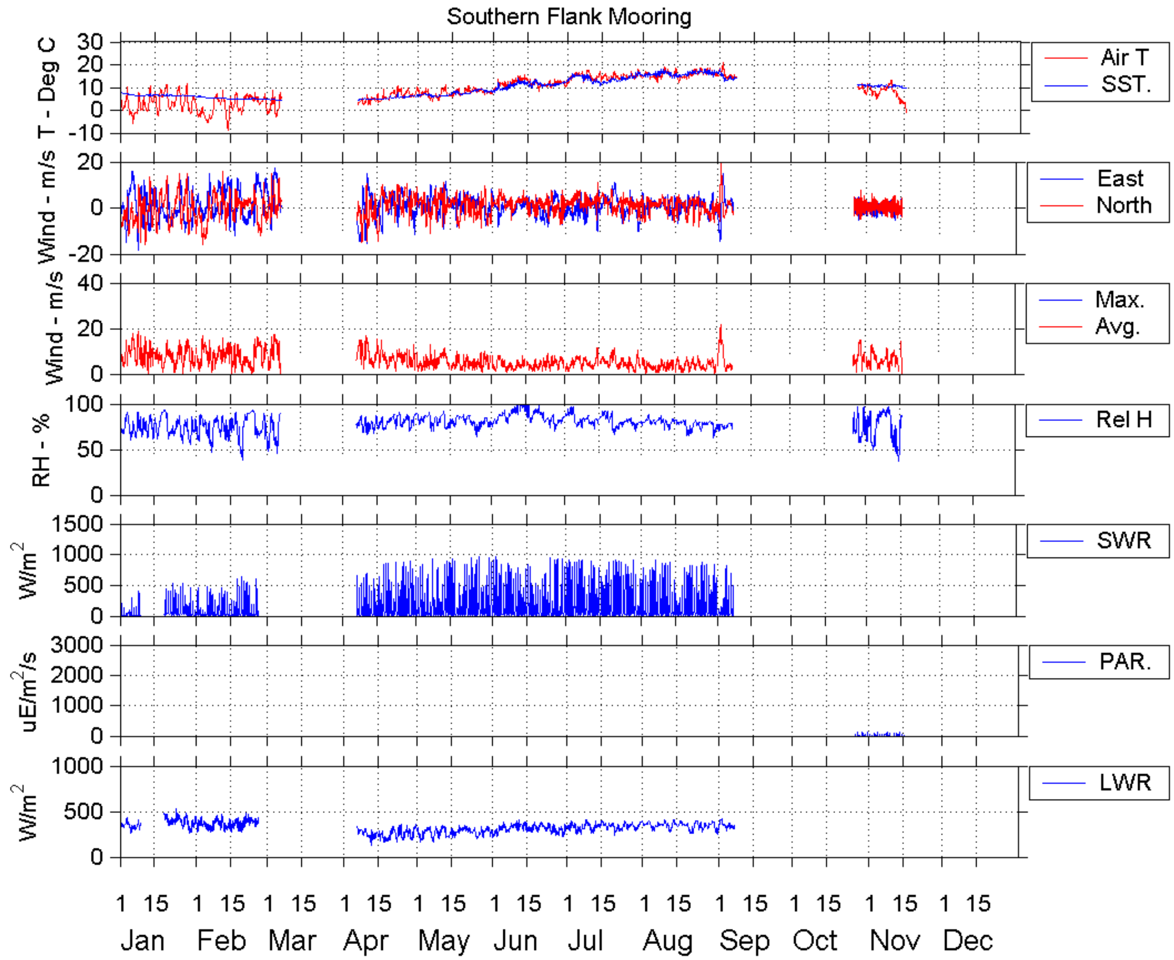

Figure 25. Southern flank moored meteorology from 1996.

b. Water Temperature and Salinity: The third year (1996) temperature and salinity records (Fig. 26) show the spring-summer warming (stratification) and initial fall-mixing without any obvious warm-core ring effects – a marked difference from the 1994 and 1995 southern flank records. The water cools rapidly until mid-January when it levels off at about 6.5 ºC until mid-February. It then decreases to a mid-March minimum of abou4 4.5 ºC, which is about 0.6 ºC cooler than observed in 1995. For about a week mid-January, there is a warmer saltier event where the temperature increases about 0.5 ºC in spikes associated with tidal advection. The salinity increases from the first of the year to a maximum of 33.0 PSU at the onset of the 1-week event. The salinity signal associated with this event increases the salinity by another 0.4 PSU with tidal variations. Although the water column is fairly well mixed, the signature of this event is stronger at the bottom of the water column, and the density is dominated by salinity. There is little stratification associated with this event.

About 1 Feb there is another warmer saltier event for a couple of days. This signature is markedly different, with the warmer (0.7 ºC) and saltier (0.25 PSU) spikes occurring in the bottom of the water column, and cooler (0.3 ºC) and fresher (0.1 PSU) spikes seen in the upper 25 m of the water column.

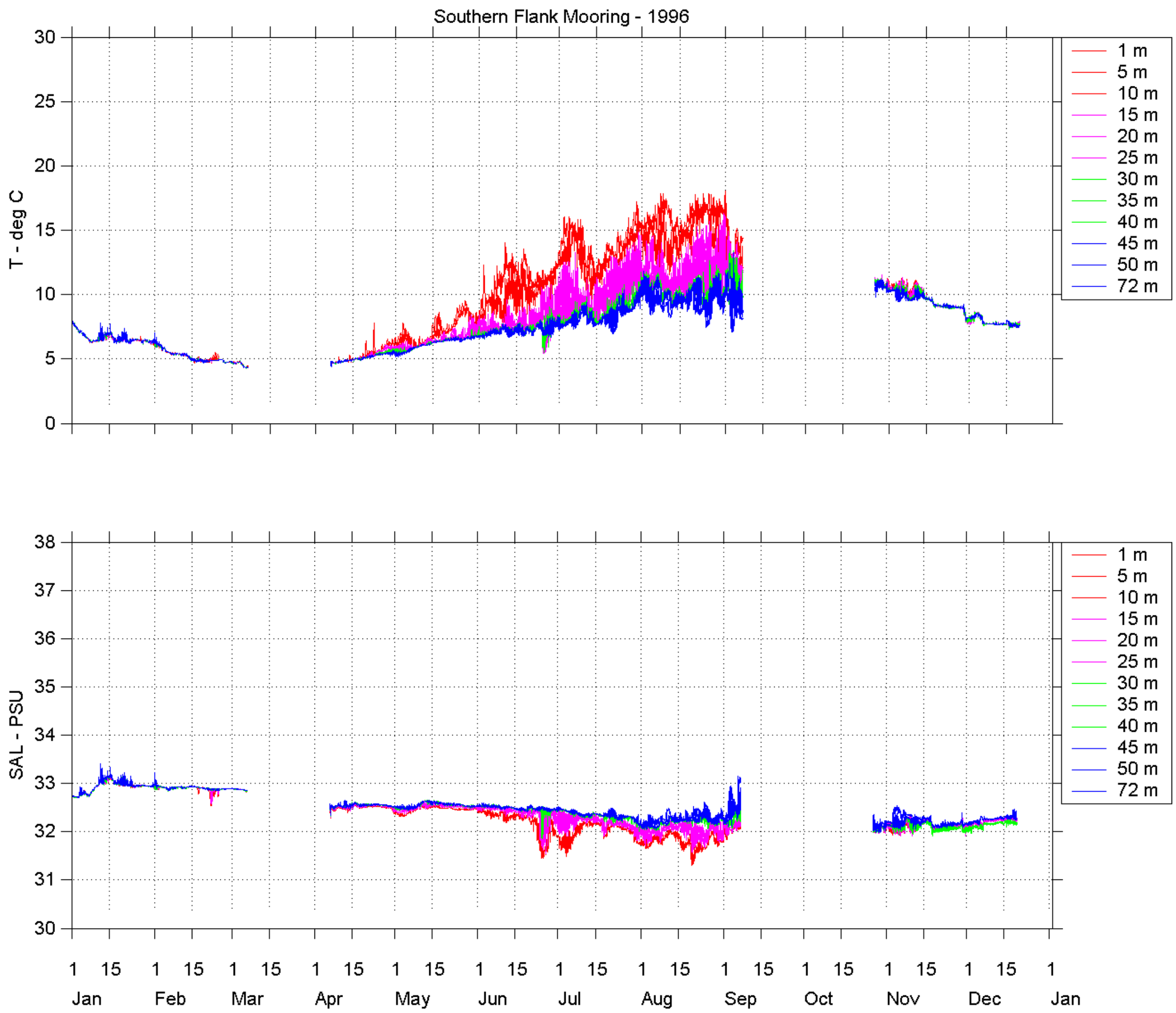

Fig 26. Southern flank moored temperature and salinity data from 1996. All temperature (top) and all salinity (bottom) records are plotted on the same axis.

Starting about 21 February for about a week, there is warmer (0.6 ºC) and fresher (0.4 PSU) event is seen in the upper water column. There are no observed effects in the lower water column. This produces a definite stratification in the water column, which again varies with tidal advection of water.

The salinity record increases at the start of the year to a maximum of 33.2 PSU in most of the water column with a maximum of 33.4 PSU at the bottom. Then after mid-January, the salinity freshens and reaches a minimum toward the end of November of 32.1 PSU. Note that this is a steady drop of over 1 PSU during the spring, summer and fall, and is seen as a major change in the 5-year summary plot in Fig. 63.

As in 1995, there is a tendency for the surface waters above 30 m to have lower salinity, by 0.1 to 1 PSU. The associated temperature is not cold, but may represent warmer Scotial shelf water, or other Gulf of Maine water that bring its freshness and warmth during the summer.

The surface warming and the onset of stratification start toward the end of April into May. This is accompanied by some surface freshening. Then the stratification decreases with a decrease in surface temperature and the salinity, especially in the deep waters, increases. Then mid-May the spring warming really starts. The surface warming (to 25 m) continues until late August with maximum temperatures of 18.0 ºC at the end of August. The deeper (below 40 m) temperatures also increase slowly during this time to around 10 ºC. The stratification reaches its maximum in early July and again in late August.

The major weather event of the year is hurricane Edouard that moved almost directly over the Southern Flank mooring on 2 September 1996 (see Williams et al., 2001 for further discussion). The hurricane was moving quickly and decaying rapidly. However, the winds did reach a maximum of 22 m/s measured at the buoy (which is not that different from severe winter storms observed at the site). From before the hurricane to after, the surface waters cooled from 18 to 14 ºC and the bottom waters cooled from 10 to 8 ºC. At the same time the surface salinities increases from 32.3 to 33 PSU and the bottom asininities increased from 31.8 to 32.1 PSU, indicating some on-bank mixing of cooler saltier slope water. The on-Bank and off-bank velocity in the top and bottom of the water column can be seen in the ADCP record (Fig. 28). Again the velocity signature is not that different from other storm events.

When the mooring was redeployed in late October, the water column is reasonably well mixed with temperatures of 11 ºC and salinities of 32.1 PSU. The water column continues to cool to about 7.5 ºC at the end of the year. The salinities increase slightly during this fall cooling period from about 32.1 to 32.2 PSU. The cooling and salting of the water column was not smooth but occurred in jumps. The first half of November there was some surface warming and freshening that caused some stratification.

The water column became relatively well mixed in mid-November with temperatures dropping to 9 ºC and remaining there until near the end of November when it drops again to about 8 ºC with some thermal stratification in the surface waters. Then in early Dec, the water cools jumps a bit cooler and ends up the year at about 7.5 ºC. With the drop in temperature in mid-November the salinity decreases to 32.0 then increases to 32.2 at the end of the year. These signals do have strong tidal variability due to the horizontal advection of waters as is seen at most times on the southern flank of Georges Bank.

c. **Bio-Optical:** The bio-optical packages at 10 and 40 m temperatures are shown in Fig 26 as well as Fig 27 and discussed there. It is interesting that there are large seasonal changes that become visible in the fluorometer and transmissometer records here. In January, the 10 and 40 m transmissometer and fluorometer records appear the same and fairly constant. Then toward the end of January, the 40 m fluorometer starts increasing until it saturates (full scale) at the start of March. The 10 m fluorometer starts increasing early February and reaches a relative peak at the end of the first week on March. When redeployed in early April, both fluorometers read high (near full scale), then drop off significantly by 15 March. The transmissometers show a decrease in transmission consistent with a spring bloom and more scatters in the water column. The mid-April to mid-May fluorometer readings are again low, then from the later part of May through the later part of May there is again a strong fluorometer signal, with associated transmissometer decrease. This is especially strong in the third week of May at 10 m when the fluorometer saturates and the transmissometer drops to below 50% transmission. Finally there is another peak centered on the third week of July in the 40 m fluorometer. After that it is not clear if the fluorometer is fouling or there is another peak in mid-Aug. Finally the transmissometer shows a fall bloom during the second week of November.

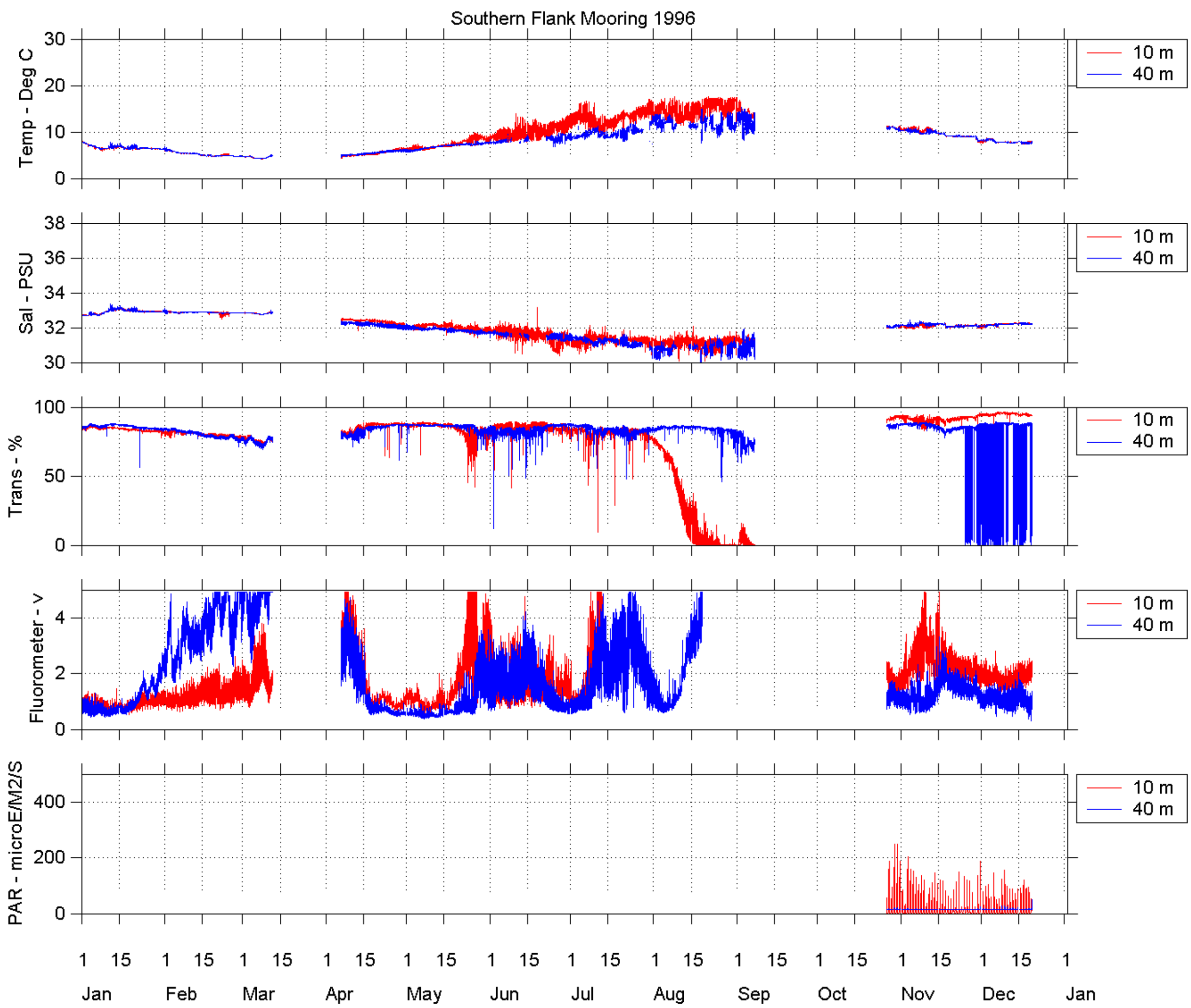

Figure 27. Southern flank moored bio-optical data from 1996.

d. ADCP: The ADCP was mounted on the mooring line below the buoy and looking down. The ADCP is a Workhorse 300 kHz unit and so the backscattered signal strength is an indication of the number of the larger scatterers (several cm in size) rather than the small phytoplankton. The measured profiles of currents extend from about 8 m to 65 m depth in 76 meters of water. The bottom three panels show the eastgoing, the northgoing and the average of the four beams of acoustical backscattering (uncorrected for spreading loss). All the data sets shown are low-passed to show subtidal variability. The tides dominate the current record, so were removed to allow the lower frequency currents to be more easily seen and studied. The top panel stick plot has coordinates of Eastgoing and

Northgoing velocities, as the third and forth panel. The second panel shows the two velocity components rotated into along-Bank (aligned about 60 ºTrue) and on-Bank (aligned about 300 ºTrue).

The cross-bank component has a positive mean, or on-bank flow during the summer. The along bank flow is increasingly negative as the summer progresses showing the down bank (toward the New England shelf and New York Bight) flow. By the end of the year, this had nearly return to zero, with strong weather forced variations that are correlated with the winds

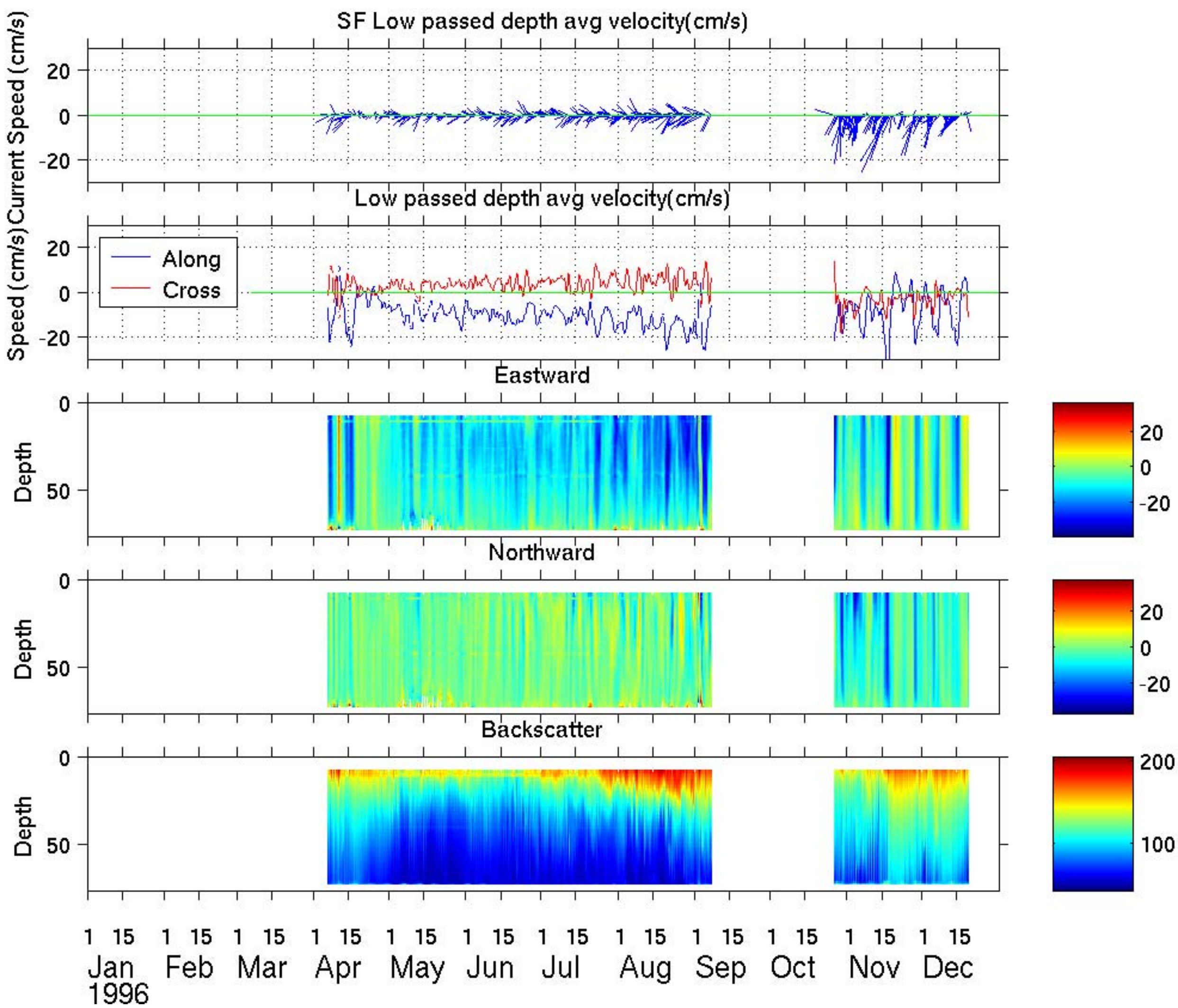

Figure 28: Southern flank moored ADCP data from 1996.

There are several strong wind events to note. About 15 April, there is a strong down bank flow pulse following another just at the time of deployment. Between these the flow reverses, moving toward the Northeast Peak. This is not really strongly correlated with the wind, but there is some storm activity at that time. The main storm event is Hurricane Edouard. A strong flow along the Bank to the ENE precedes the hurricane, then there is a strong off bank then on bank flow and a strong down bank flow to the

WSW (Fig. 28). This flow pattern is not long lasting, and so doesn't have as much effect as some of the longer duration winter storm events.

At the end of the year, there are four main down bank pulses (negative blue curve in Fig. 28). These are correlated with strong winds at deployment time, 16 and 28 November, and 7 and 15 Dec.

The acoustical backscattering signal is not well correlated with the fluorometer as the acoustics show low scattering during June when the fluorometer is showing the high summer pulse. However, the chlorophyll-a is not associated with the larger scatterers that the acoustics signal sees, so that is not to surprising.

6. SOUTHERN FLANK 1997

a. Meteorology: We finally got the PAR going fine, and it looks like SW radiation. One can see the summer higher incoming radiation and winter lower quite nicely. The negative spikes in the long wave radiation are due to radio telemetry intereference with the sensitive pyrometer. – over to you Bob.

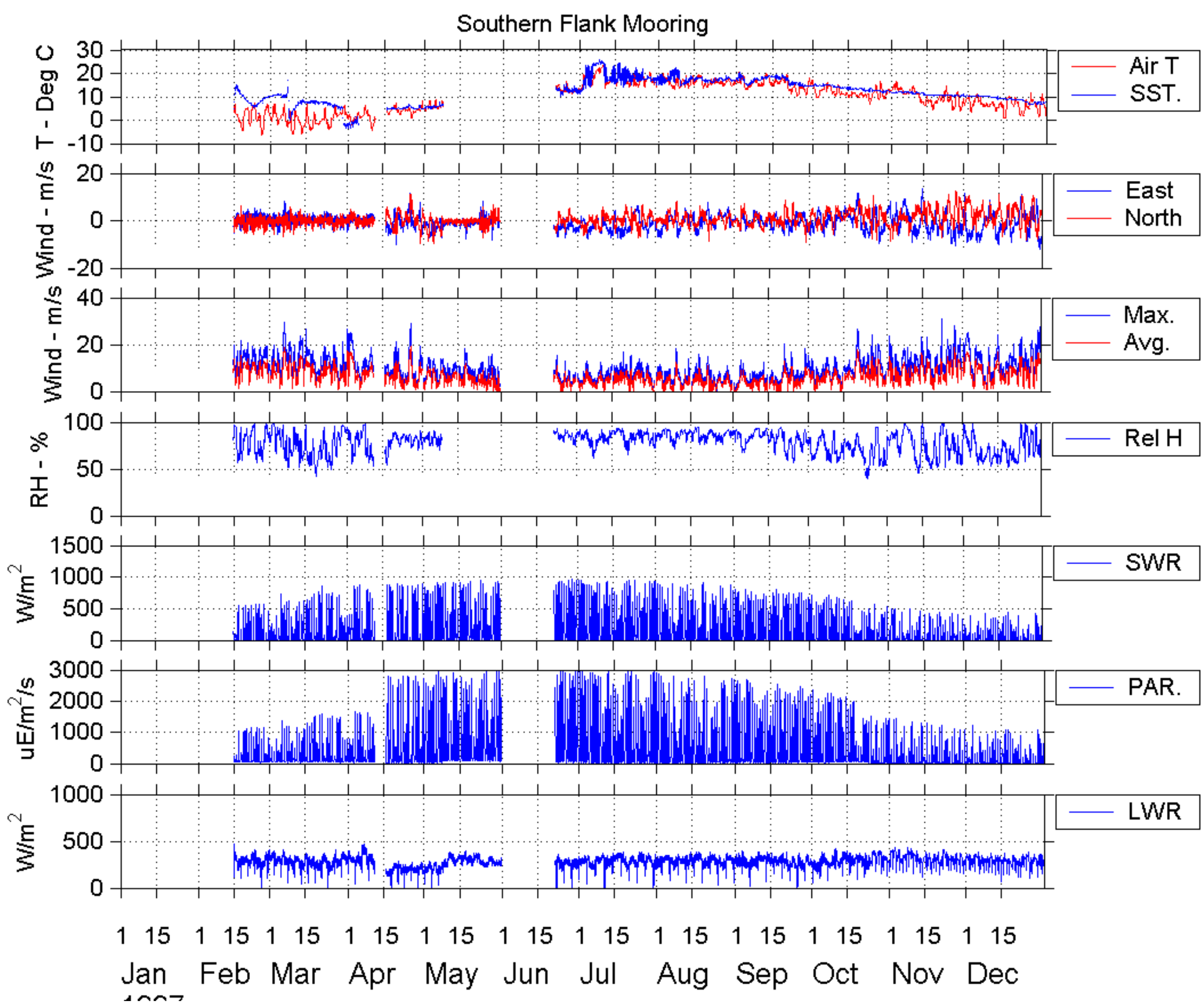

Figure 29. Southern flank moored meteorology data from 1997.

b. **Water Temperature and Salinity:** The temperature and salinity time series (Fig. 30) shows yet another picture of properties on the southern flank of Georges Bank which is very different from 1994, 95 and 96. The most dominant signal during GLOBEC is the warm core filament that moves up onto the shelf, crossing over the mooring and giving the warmest and saltiest waters encountered at the southern flank mooring site. These effects extend throughout the water column.

There, with relatively smooth cooling throughout the winter and only a hint of Scotian Shelf water in late February (fresh, but warmer water). The water column is relatively well mixed and reaches a minimum temperature of 4.0 ºC and salinities of 32.2 PSU. The salinity is fairly constant, without the advective signatures seen in 1995 and 1996. The onset of stratification occurs with the warming of surface waters and the salting of deper waters associated with warm core ring effects. The bottom temperature also rises with this intrusion.

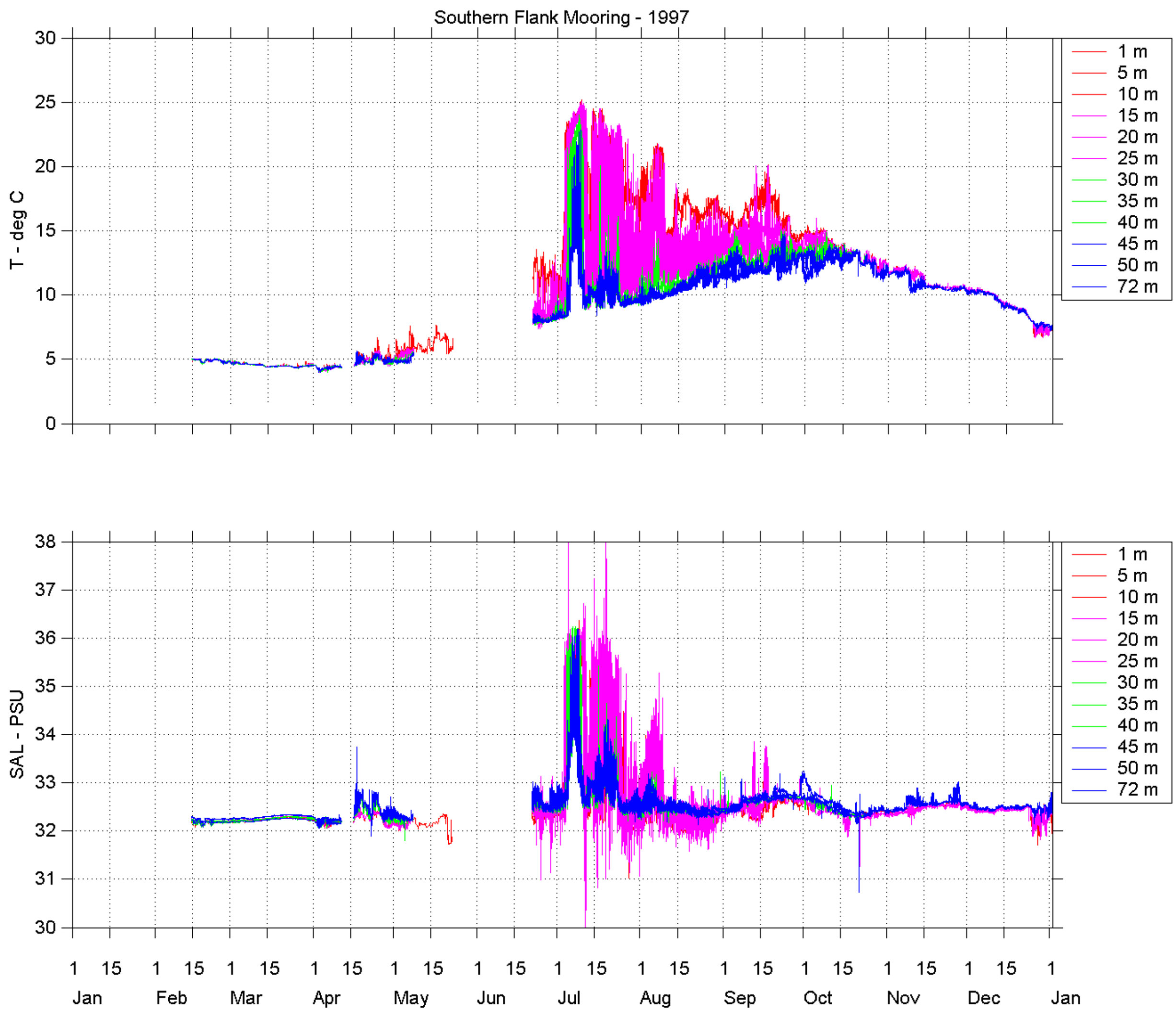

Fig 30. Southern flank moored temperature and salinity data from 1997. All temperature (top) and all salinity (bottom) records are plotted on the same axis.

The largest event seen for about a week centered around 8 July when a warm core filament (with temperatures to 25 $^{\circ}$C and salinities to above 36 PSU) from an extreme northward loop of the Gulf Stream moves onto the southern flank of Georges Bank. Although the main event is about a week in duration, lasting raised temperatures and salinities are seen into the second week of August. Satellite imagery shows that this filament on the surface extends up onto the bank to about the 60-m isobath. At the SF mooring (on the 76 m isobath), the warm core filament extends to the bottom, with bottom salinities exceeding 36 PSU. There are strong tidal advective variations in this structure. Although the first main pulse is centered on the end of the first week of July, during the third week (centered on 18 July) there is a second intrusion with elevated bottom temperatures and salinities and a third pulse in the first week of August. After these pulses, the salinity appears fairly well mixed by the end of August, but has a two month long slowly decaying sinusoidal oscillation of about 0.4 PSU amplitude in September.

The surface waters are cooling off from the mid-July peak to mid-September, when there is another surface warming not associated with a salinity signal where the surface waters warm to 20 ºC, then start cooling and mixing until the second week of November when the water column becomes well mixed. The water column continues to cool until the end of the year when the temperature is about 7.5 ºC.

The salinity increases with the warm core ring and remains about 0.5 PSU higher after then even then decreases back toward 32.5 PSU by the end of the year. There is a cool (6.7 ºC) and fresh (31.8 PSU) Scotian Shelf crossover event in the upper 20 meters of the water column during the last week of the year.

c. **Bio-Optical:** The bio-optical data (Fig. 31) clearly shows the warm core ring crossover. The transmissometer and fluorometer show no peaks during the winter. The 40 m transmissometer shows some fouling effects with floating material that block then unblock the light path. With the filament crossover, both transmissometers go to a higher reading and the fluorometers to a lower reading. Upon deployment in April, the fluorometers read high then drop. Both fluorometers show the peak centered on the third week of July and the end of the first week of Aug. The 10 m fluorometer increases to full scale, due to biofouling or signal. We suspect biofouling as the transmissometer also drops to zero. The 40 m PAR sensor also shows this. It starts out low, then when the ring filament arrives with clear water, the PAR show higher signals due to clearer ring water allowing deeper light penetration, then drops as the filament moves on. Then it fails, so no farther signals can be studied. The 10 m PAR shows the seasonal increase and decrease in incoming radiation as seen on the buoy with the incoming PAR and the short wave radiation sensors. For the third deployment in late October, both fluorometers start out mid-range and decrease steadily to the end of the year. The accompanying transmission records rise over the same time, indicating a decreasing number of primary production organisms in the water column.

d. **ADCP:** The ADCP records shown include a stick diagram of the sub-tidal depth-averaged velocity in East and North reference frame. The second panel is the along-Bank and on-Bank depth averaged components rotated to Bank coordinates. The bottom three panels are the eastgoing, northgoing and the 4-beam average of acoustic backscattering all low-passed to sub-tidal.

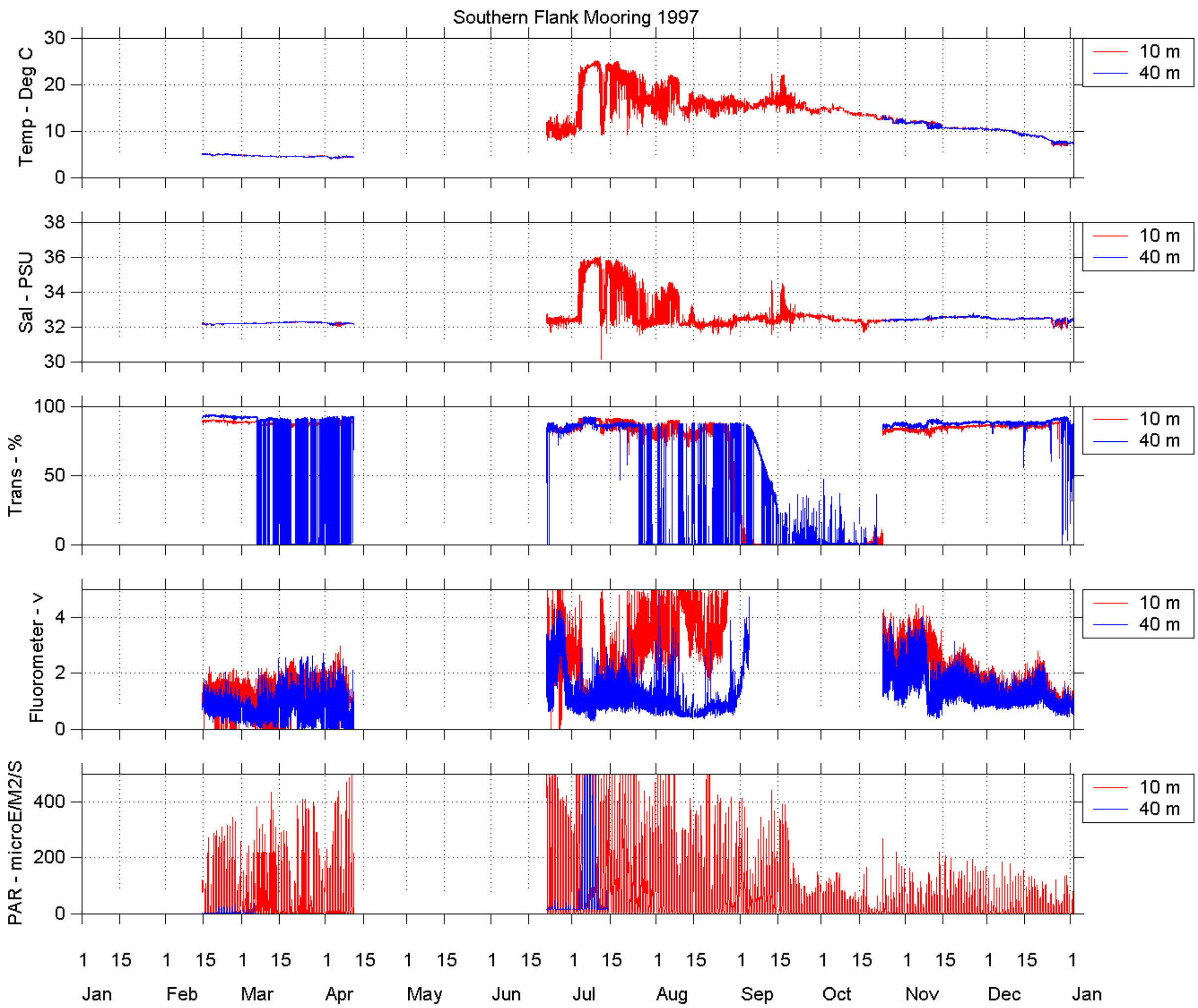

Figure 31. Southern flank moored bio-optical data from 1997.

The second panel shows the along-bank transport (blue line) and its variation with time. During the winter into spring, the along-Bank variations are closely related to winds. The peaks in down (negative) Bank flow on 2 and 22 April are associated with 18 and 20 m/s wind events. The positive along-Bank flow peaks observed in Feb and March are related to the low wind periods.

The general down bank flow toward the New England shelf starts in April with the onset of stratification and continues into late October when the stratification disappears. The strong down-Bank pulse is associated with a strong (18 m/s) wind event. These strong events extend to full water column depth, as can be seen in the third and fourth panels showing velocity profiles, although there is a tendency for the less strong fluctuations to be concentrated in the upper water column, with smaller variations in deeper waters.

The acoustic backscattering does not show the strong seasonal variations as seen in 1996. While there are some strong backscattering peaks the duration and depth extent aren't as great seen in 1996. Also, these events are not correlated with the fluorometer record (Fig. 31).

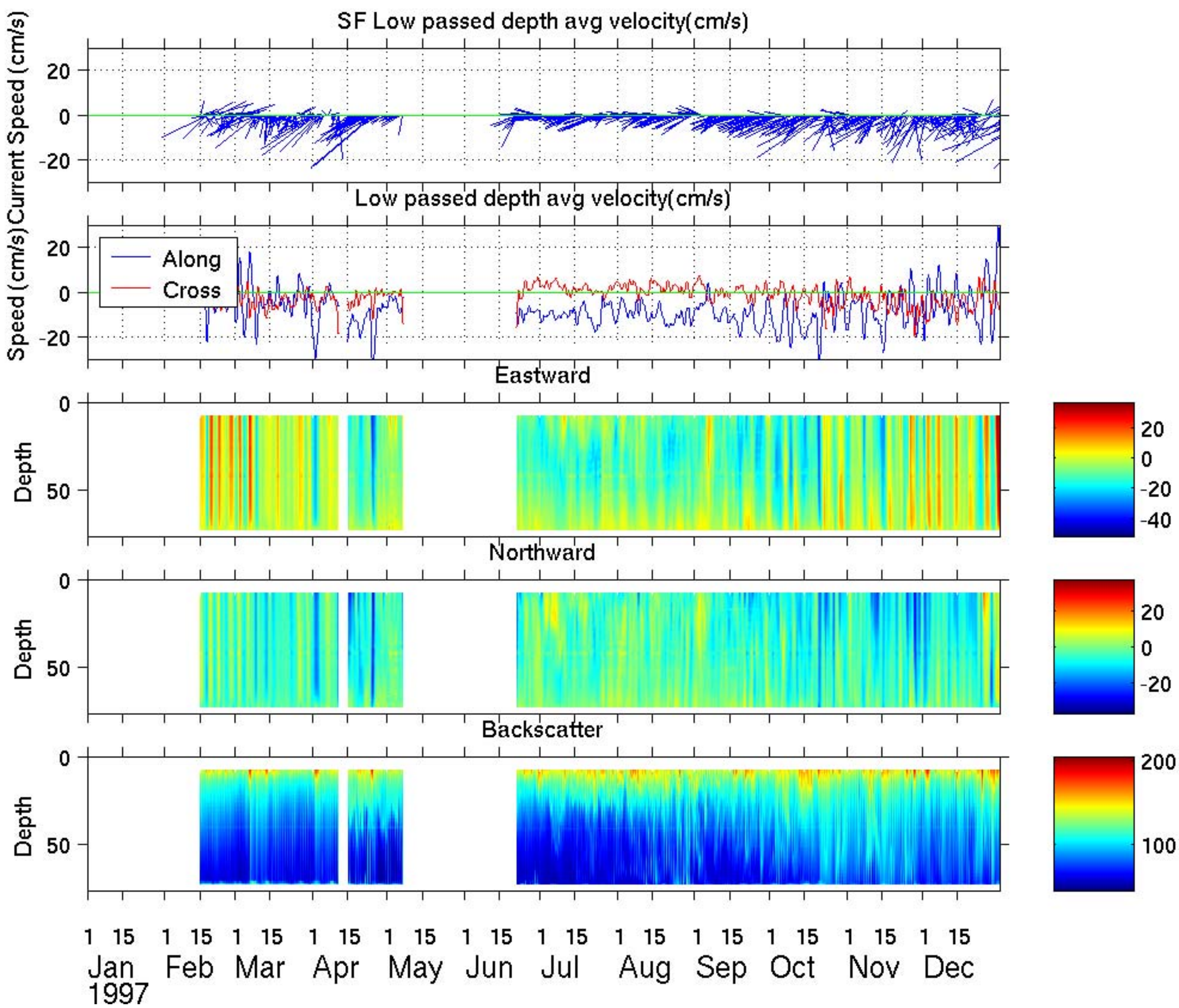

Figure 32. Southern flank moored ADCP from 1997.

7. SOUTHERN FLANK 1998

a. Meteorology: The weather

What about a table of the number of storms in a year? (I don't see any as large as 20 m/s and only 1 that got to just to 19 m/s in 1998 (Bob's NDBC data set). Therefore, 1998 was the 2nd calmest year (after 1994) of the GLOBEC field years, while 1999 (or 97?) was the stormiest.

Number of Storms in the year with winds greater than given wind speed.

Wind speed	1994	1995	1996	1997	1998	1999

>22 m/s	0 (0)	0	1*	0	0	2 (1)
>21 m/s	0 (0)	2	1	0	0	3 (2)
>20 m/s	0 (0)	2	2	5	0	3 (2)
>19 m/s	2 (0)	5	3	5	1	5 (2)
>18 m/s	3 (0)	8	3	10	5	6 (3)
>17 m/s	5 (1)	12	9	15	6	10 (5)
>16 m/s	7 (2)	18	18	19	12	17 (8)

The numbers in parentheses in the first and last years are the number of storms which occurred when the moorings were deployed.

* Huricane Edouard

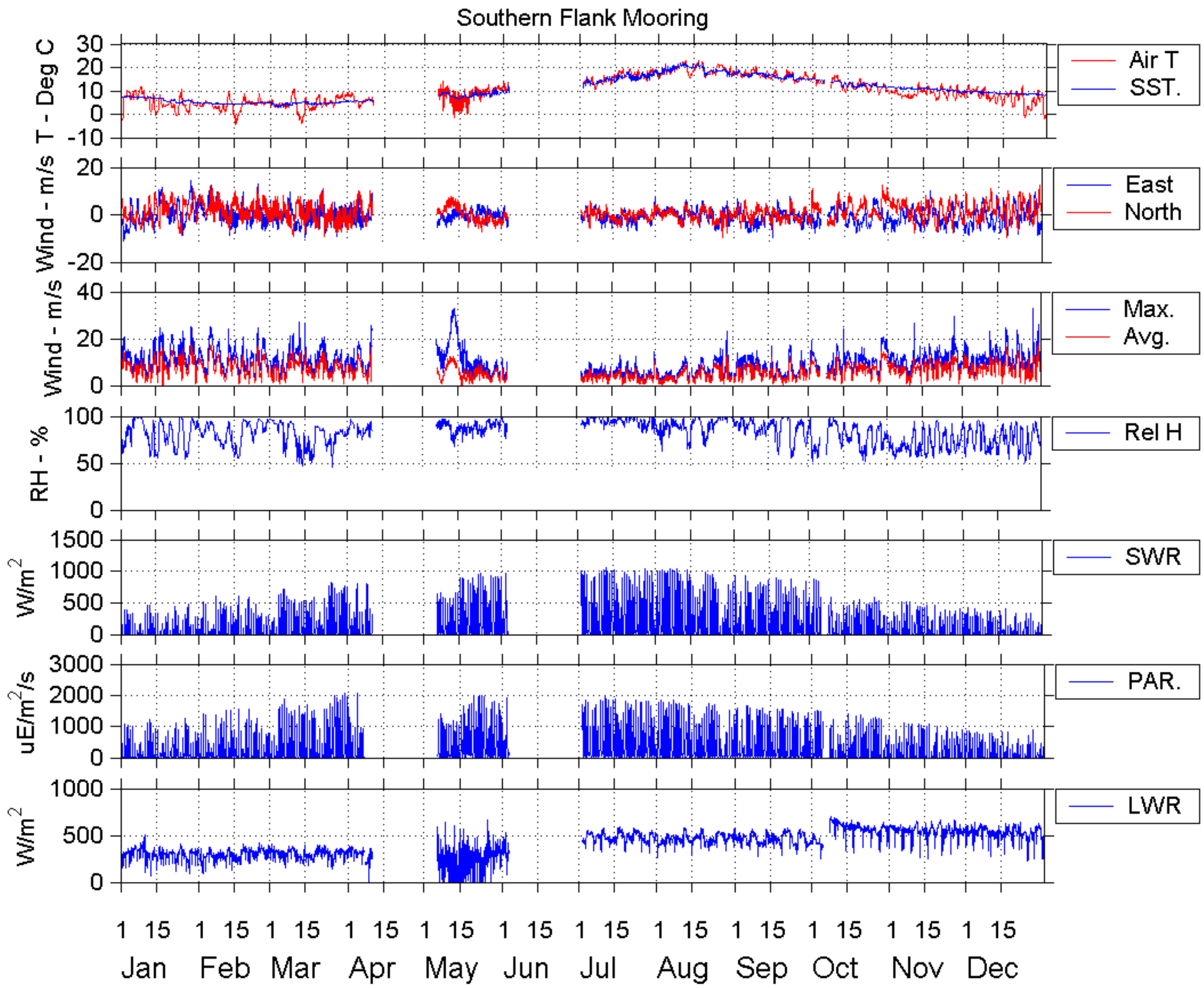

Figure 33. Southern flank moored meteorology data from 1998.

b. Water Temperature and Salinity: The fifth year (1998) temperature and salinity records (Fig 34) show a year without warm core ring effects, but with several cool fresh crossover events. The normal winter cooling reaches a minimum of 4.0 ºC (note that crossover intrusion water temperatures are below 4 ºC). The salinity has a steady freshening trend over the whole year, starting out at about 32.4 PSU and ending up at 32.0 PSU.

There is a cool, fresh crossover event for about 10 days during the third week of January, where waters in the upper 20 m of the water column cool to 4.8 ºC and salinities drop to about 31.8 PSU. In the first week of March another 10 day long crossover event is observed with temperatures down to 3 ºC and salinities as fresh as 31.5 PSU. There appear to be no long lasting effects of these crossover events.

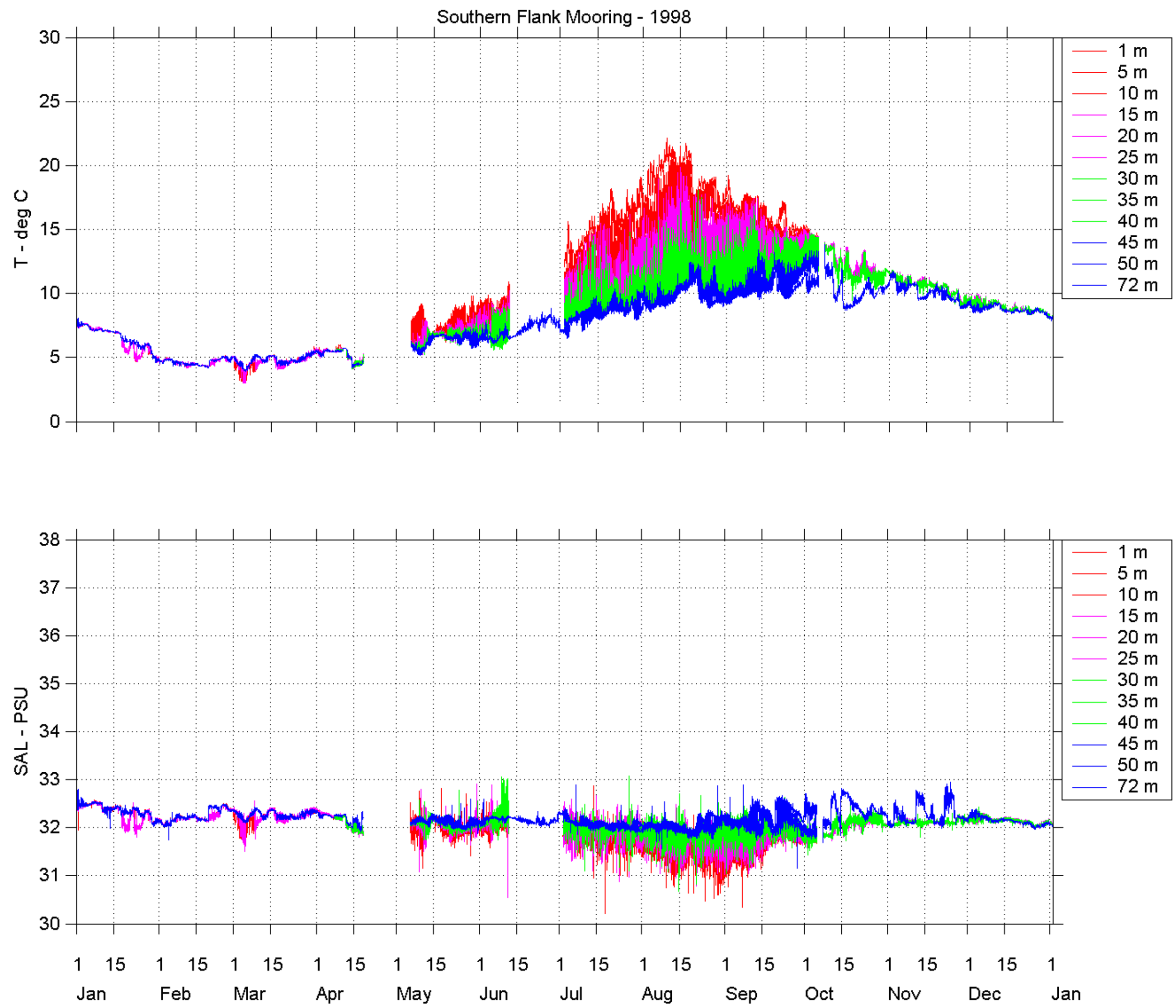

Fig 34. Southern flank moored temperature and salinity data from 1998. . All temperature (top) and all salinity (bottom) records are plotted on the same axis.

This appears to be a "normal" year of summer heating and fall cooling. The stratification starts toward the end of April with surface warming and freshening. However by mid-May the water column is well mixed again in both temperature and salinity, and then the surface warming is quite smooth (compared with other years) and reaches a maximum temperature of 22 ºC mid-August. The water column then cools to a year-end low of 8 ºC. The water column does not become well mixed until mid-December, retaining some warmer and fresher surface waters. It first becomes well mixed about 1 Nov, then the surface restratifies with warmer, fresher water until mid-December.

The salinity starts the year at about 32.5 PSU and ends at about 32.0 PSU, canceling out the slight salting observed in 1997. The salinity records show fresher waters in the upper 30 meters during the summer, with suface salinities falling as low as 30.4 at the end of August. This is more obvious, and stronger than previously observed. While not having the large salinity changes observed with the warm core ring, the temperature and salinity had more variability during the year than in other years (exclusive of the warm core ring effects). The stratification was strongest in 1997 of any GLOBEC field year with the least dense surface waters.

c. Bio-Optical: The bio-optical results (Fig. 35) are a bit obscured by "noise" in the transmissometer due to something (small fish or seaweed) floppying back and forth blocking the path as well as some biofouling. There aren't any reall T-S events to try and correlate with the bio-optical signals. There appears to be a peak in the fluorometer readings in the 10 and 40 m sensors in mid-July, then three peaks `around 18 October, 1 and 25 November. The 10-meter fluorometer goes offscale around 20 October with an accompanying dip in transmissometer indication high levels of primary productivity.

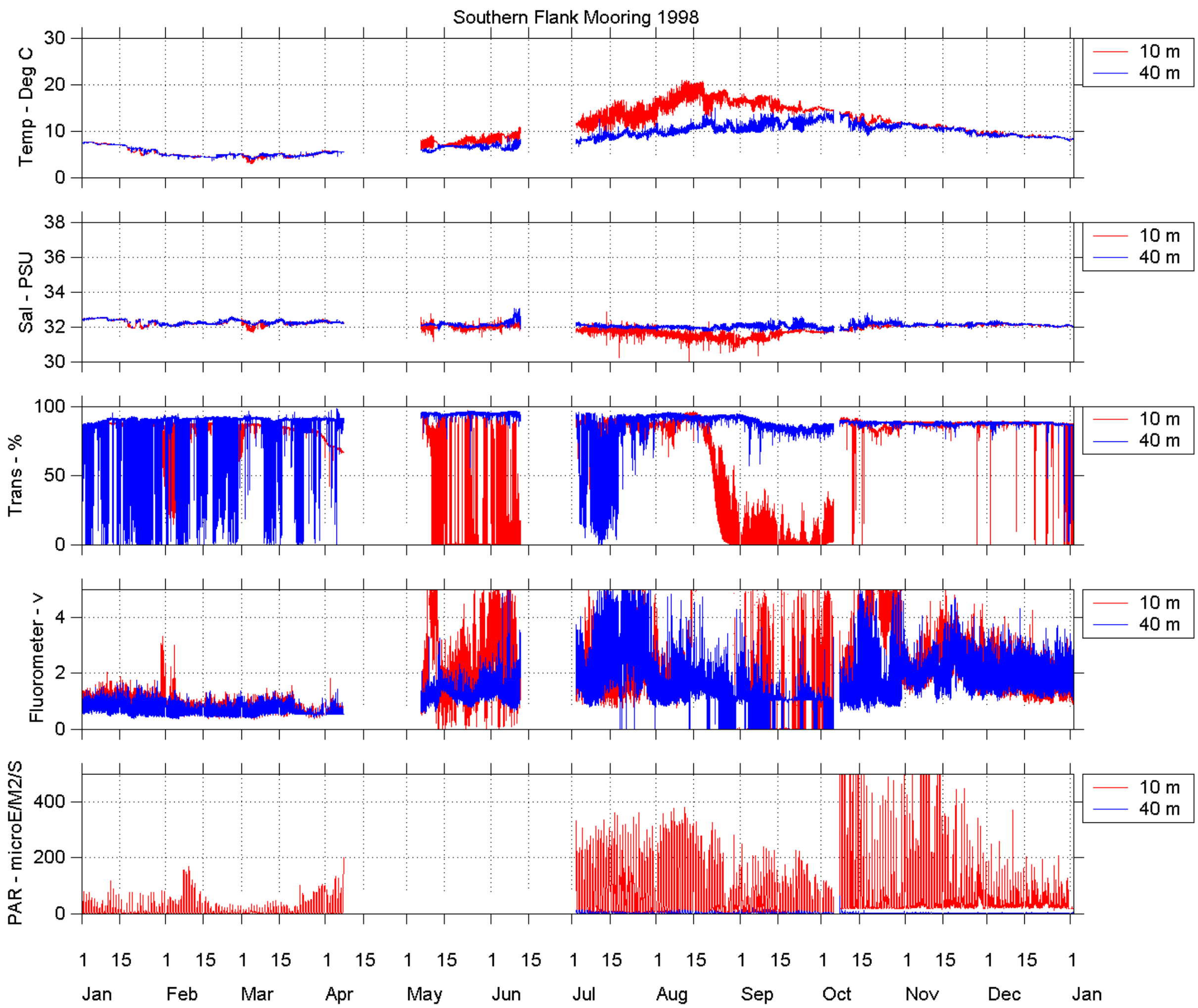

Figure 35. Southern flank moored bio-optical data from 1998.

d. ADCP: The ADCP (Fig. 36) shows the depth integrated along- and cross-bank velocities in panel 2. The variations in 1998 were stronger, and more numerous than in 1997 look particularly in the blue (down Bank) component. The general down bank flow toward the New England shelf extends over more of the year than in previous years. Also, note in the Eastgoing and Northgoing components (relative to true) in panels 3 and 4, that there is more vertical structure in the velocities, with some higher velocities being seen at the bottom.

Also this year, there is stronger backscattering than in 1997, and there is more of a seasonal signal. The scattering is high mid-February, low 1 March, then two broad high peaks early July and mid-August, low mid-September to mid-October, then high 1 December. The two high peaks in deeper waters extend from mid-January to mid-February and from mid-November to mid-December.

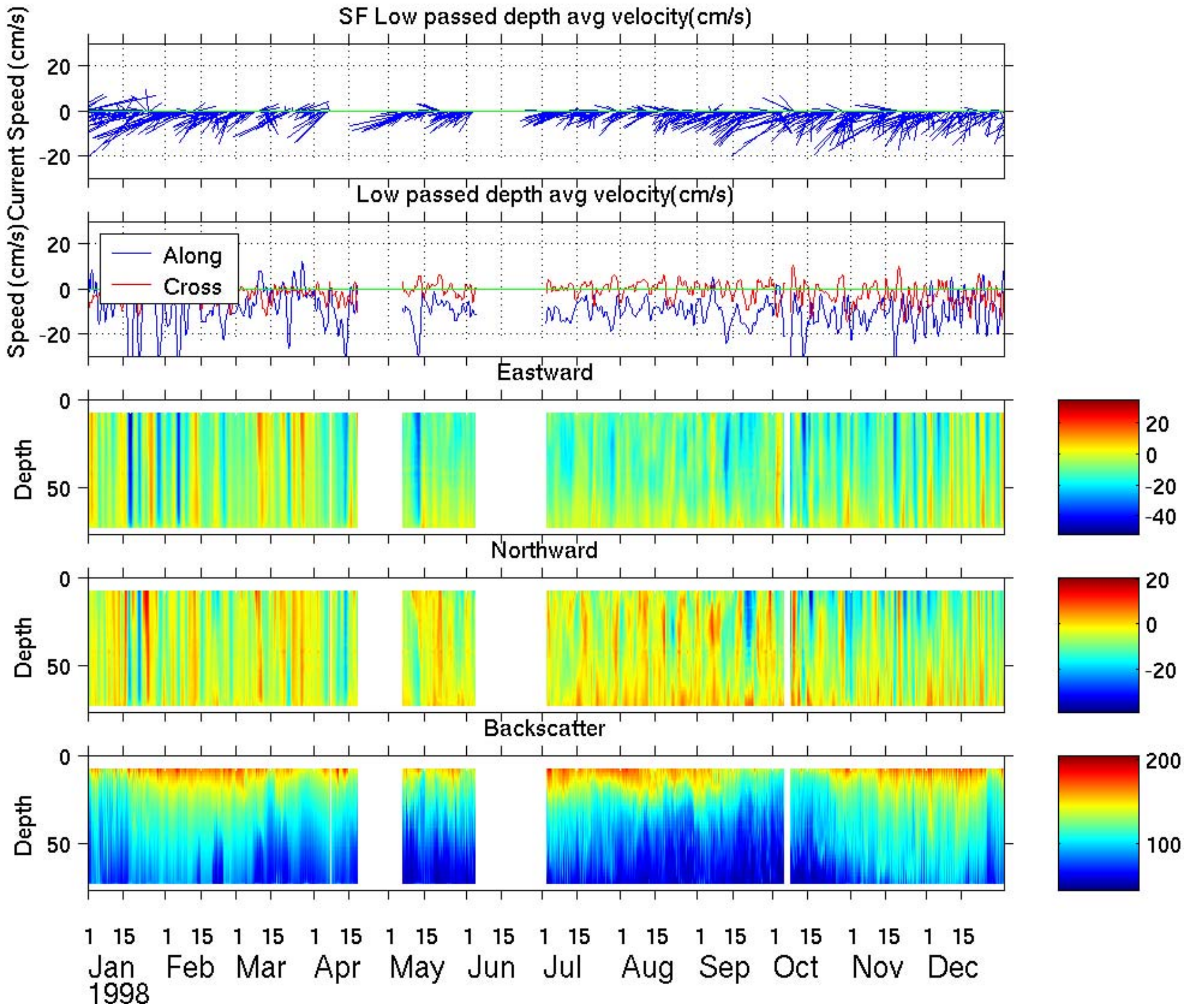

Figure 36. Southern flank moored ADCP data from 1998.

8. SOUTHERN FLANK 1999

a. Meteorology: This is the final shot at things

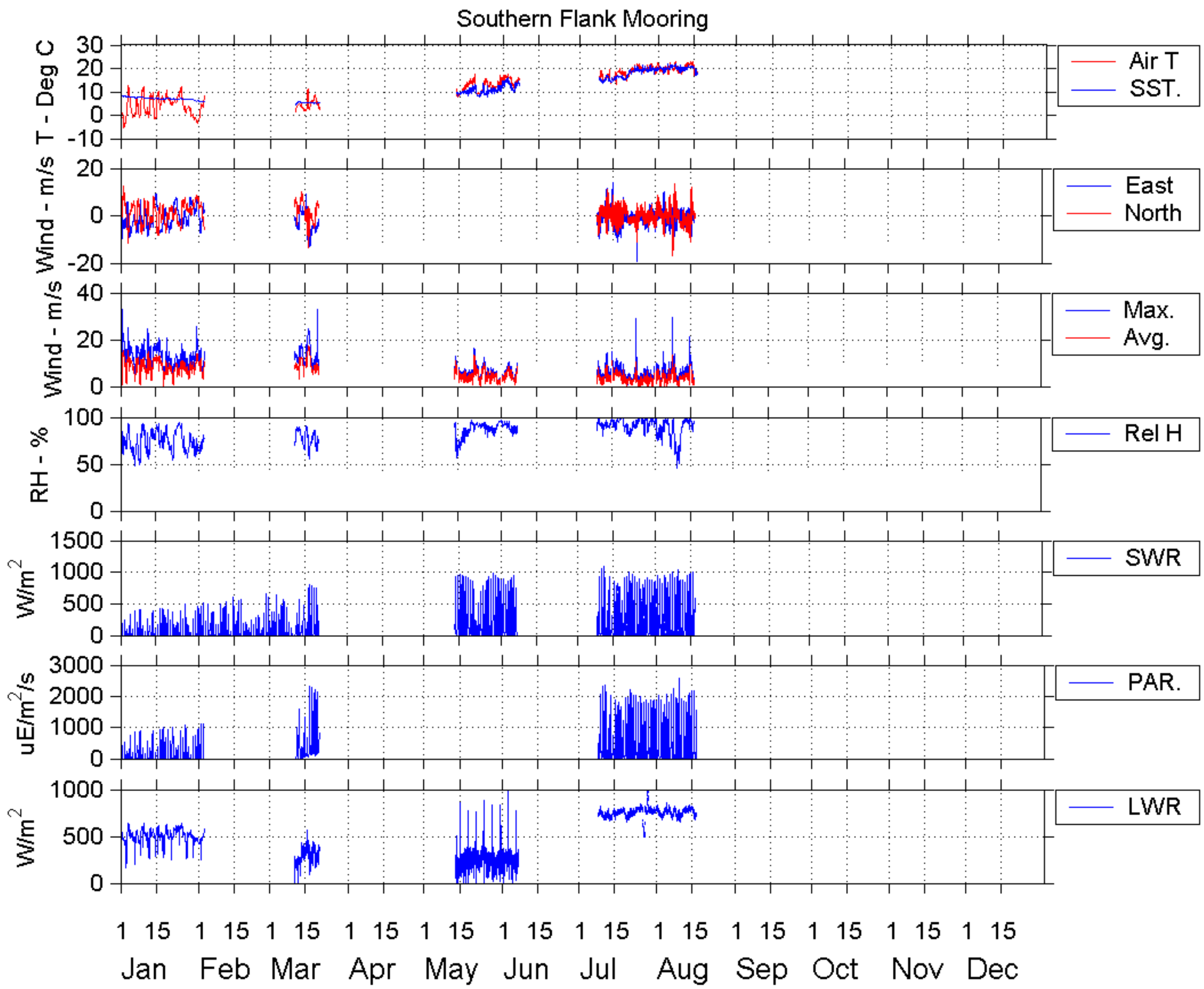

Figure 37. Southern flank moored meteorology data from 1999.

b. Water Temperature and Salinity: In the final year (1999) the instrumentation was recovered in August for the final time, ending the field effort. The winter cooling continues until the end of March with water temperatures of 4.6 ºC ad salinities of 32.5 PSU, having increased to over 33.5 PSU during intrusive events. Over the winter (1 January to 15 March) the salinity increases by almost 1 PSU before it drops back to 32.5 by the end of March. Warmer, saltier bottom intrusions are seen during the winter. About 20 January, temperatures rise from 7 to 8 ºC and salinities from 32.1 to 32.7. The surface waters are not as strongly affected as these deeper waters. The bottom intrusions continue in mid-February with temperatures rising from 6 to above 9 ºC and salinities increasing from 32.5 to 33.7 PSU. By mid-March these intrusions are finished and the temperature is 5.5 ºC and salinities back down to 32.6 PSU in the whole water column.

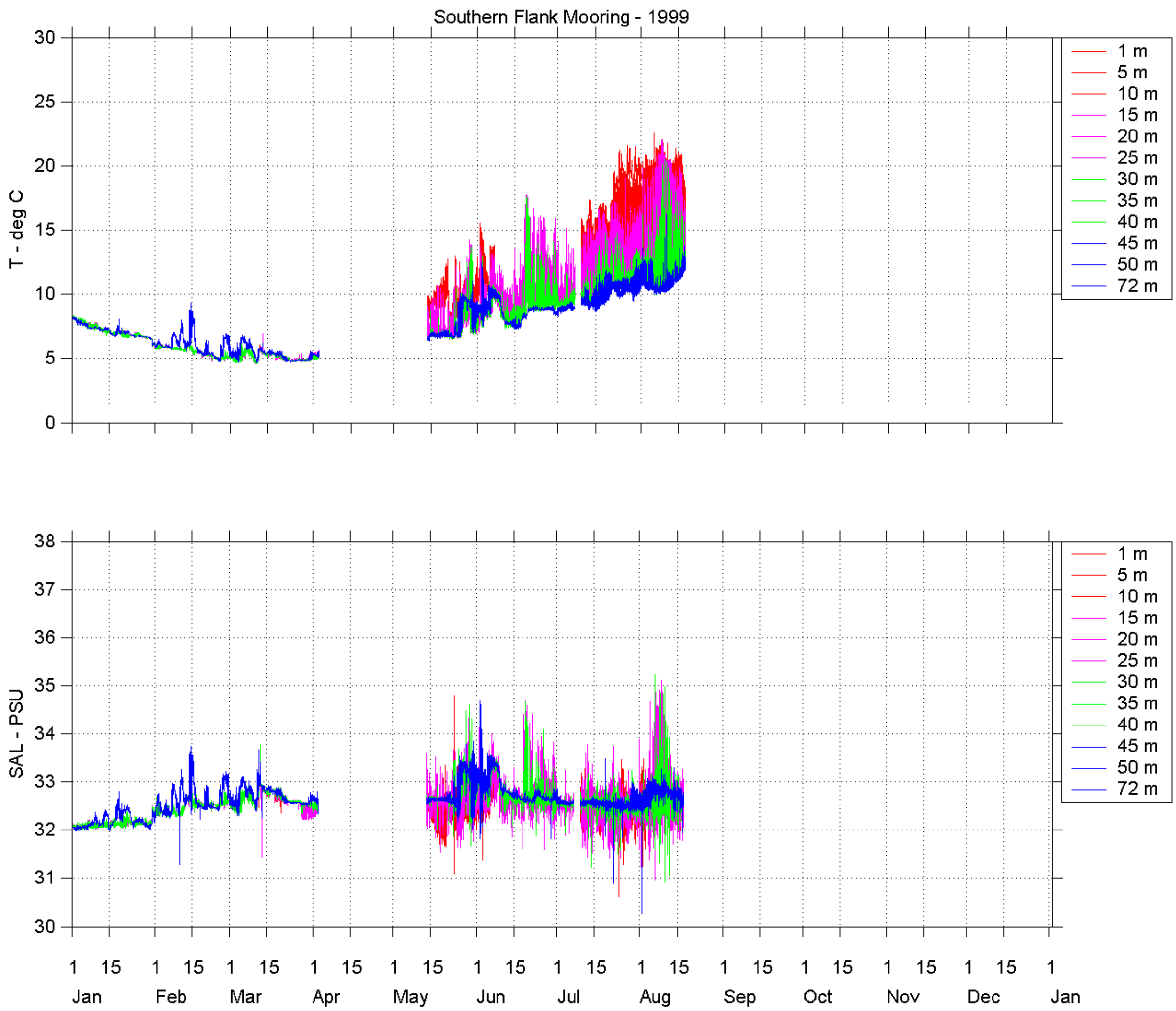

Fig 38. Southern flank moored temperature and salinity data from 1999. All temperature (top) and all salinity (bottom) records are plotted on the same axis. The moorings were recovered and the moored field effort ended in Aug 1999.

Stratification in the surface waters begins in May, with some warmer, saltier intrusions in bottom waters in late May and early June with surface temperatures above 10 ºC and salinities up to 34.5 PSU. Then the salinities decrease back toward 32.5 PSU by early July. The temperature shows the seasonal warming (with some warm core ring intrusions) until mid-August when cooling begins just before final mooring recovery. About 20 June there is a strong surface intrusion of warm (nearly 19 ºC) water and salty (above 34.5 PSU) water in the surface 30 meters of the water column with no effects seen in deep waters. Another warm core ring intrusion is seen in surface waters in early August with temperatures rising to 22 ºC and salinities in the upper 30 meters rising to 25 PSU. By mid-August these salinities are back down to about 32.6 as temperatures start to cool. There is a general 0.66 PSU increase in salinity during the year that is not seen in the Northeast Peak mooring (Fig. 57).

c. **Bio-Optical:** The bio-optical instrumentation (cables) was having some problems during the last year that lost some data (Fig. 39). The fluorometer, transmissometer and PAR all show problems at some time. The mid-June 40 m fluorometer peak is lined up nicely between the two warm core ring intrusion events (see Fig. 38). There is an indication of high productivity in Feb, but is affected by biofouling? Also, in early August in surface waters there is an indication of low particulates (high transmissometer) that may be related to warm core ring water, while there is indication of higher fluorometer readings under this event, perhaps due to additional sunlight penetration.

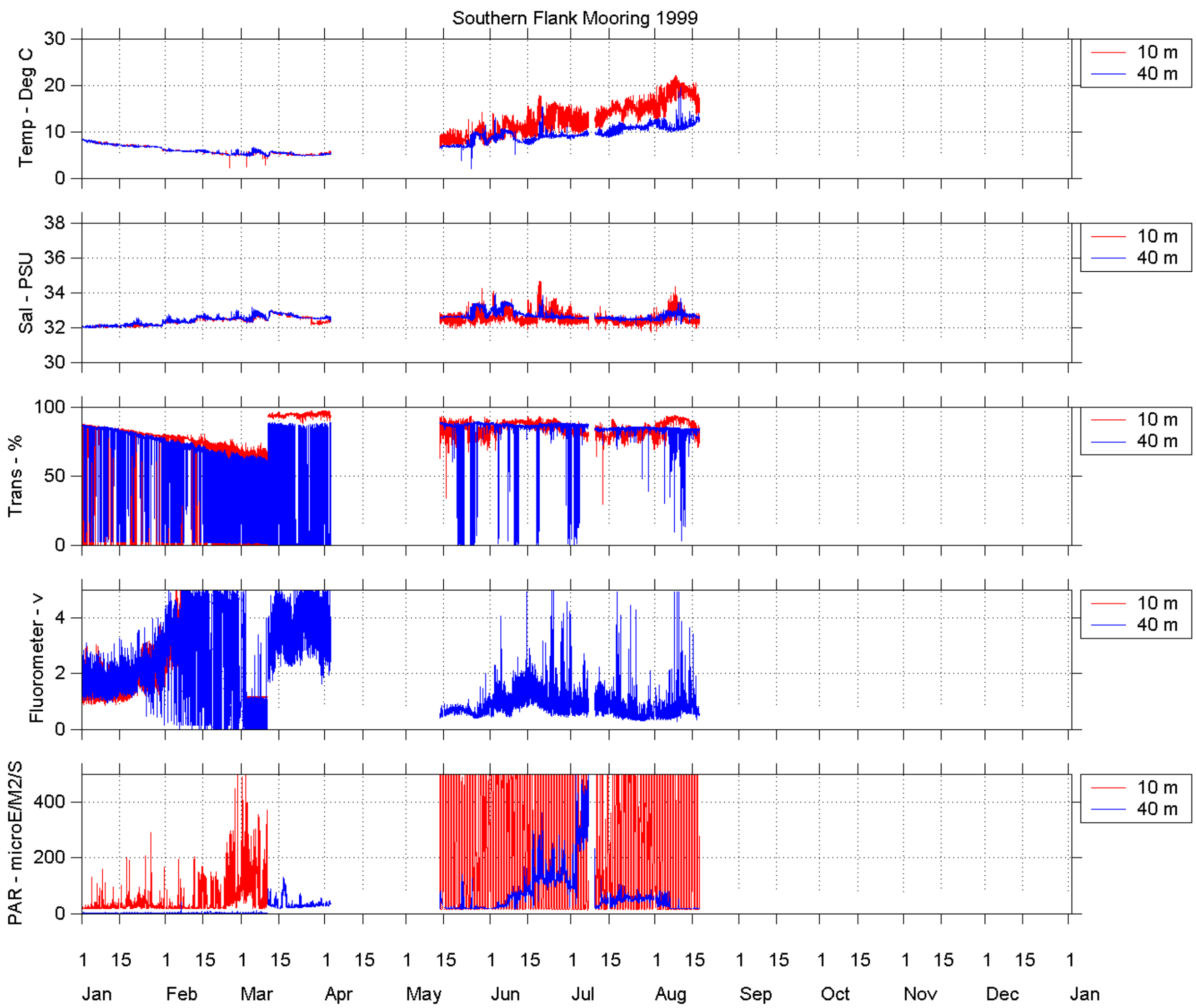

Figure 39. Southern flank moored bio-optical data from 1999.

d. **ADCP:** The final year's ADCP data (Fig. 40) shows the some effects of the strong wind events. The two strong along bank flow periods (mid-January and mid-March) are associated with low wind periods. The high wind events early February, late-February and mid-March are seen as the negative along Bank flows. The negative along bank peak in the second week of June aligns with a weak wind event. The seasonal negative along bank flow is not as pronounced as in earlier years.

It is interesting to note that because the scales of the components have changed, you can see the side lobe reflection from the instrumentation on the mooring in the Northgoing component. This scattering from stationary objects biases the velocities toward lower values and shows up as the horizontal bars of low velocity.

The amplitude of the backscattered signal also shows the yearly variations in scatters. The biggest peak is seen in mid-May to mid-June with lowest values end of Jan, end of March and early July.

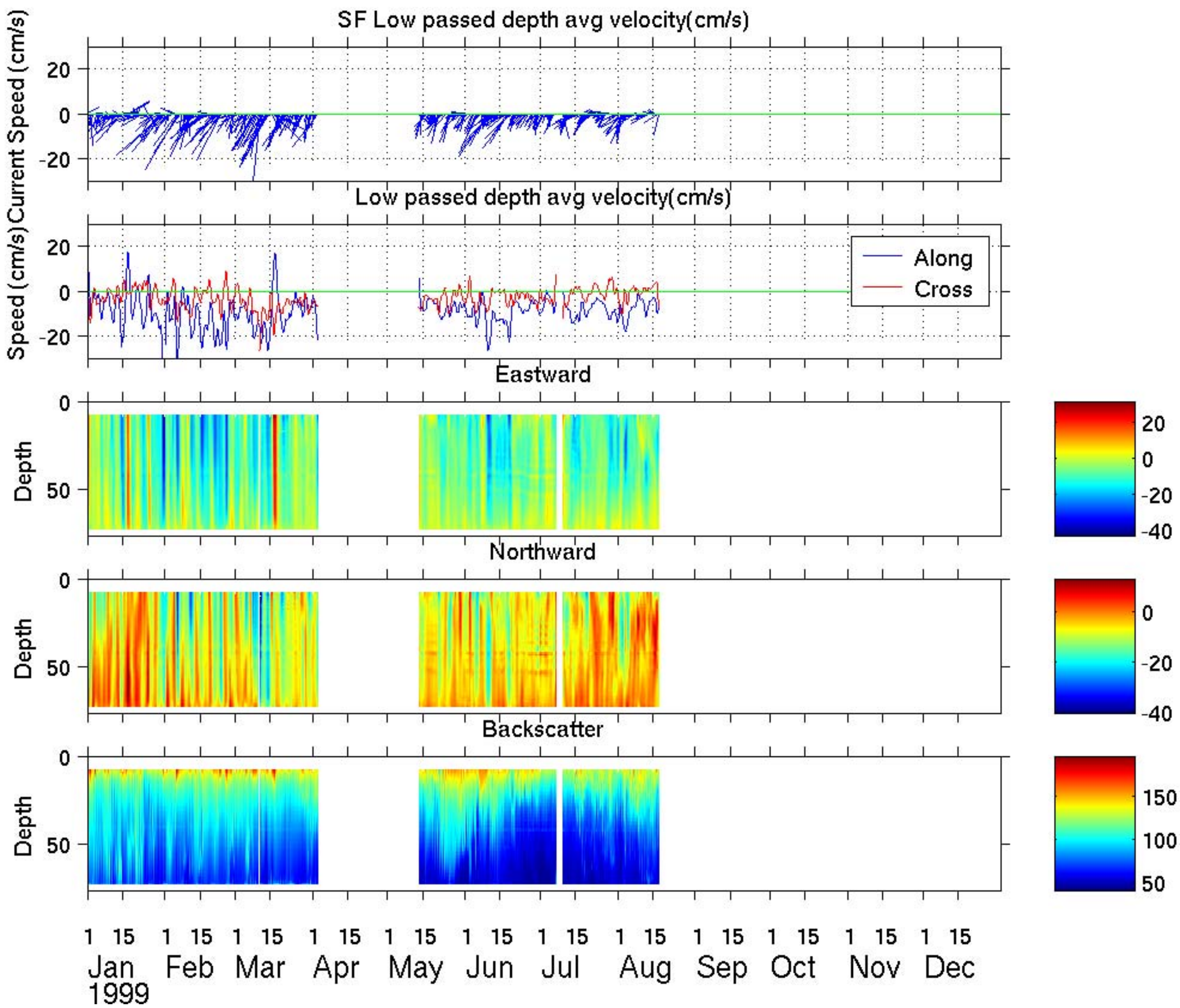

Figure 40. Southern flank moored ADCP data from 1999.

9. NORTHEAST PEAK 1995

The Northeast Peak mooring was first deployed in November 1995. It was deployed at 76 m depth, the same as the Southern Flank mooring. As the mean flow rotates around Georges Bank in a clockwise sense, the Northeast Peak mooring is “upstream” of the Southern Flank mooring.

The Northeast Peak mooring is also in the spawning region for the Cod and Haddock to observe the water properties there.

a. Meteorology: data in file SF rather than NEP
{note that the archived data is not the northeast peak, but southern flank, so this blank plot is a placeholder}.

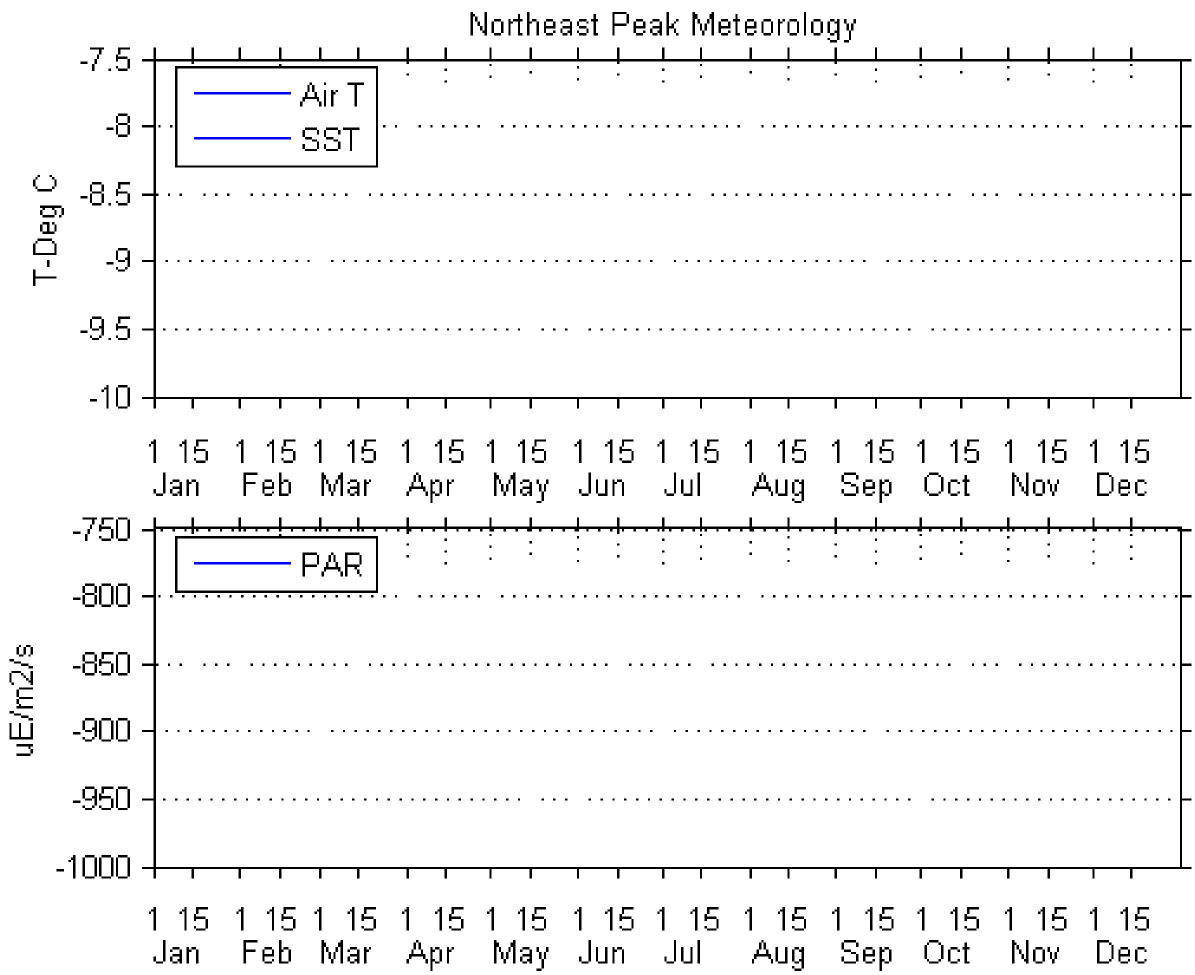

Figure 41. Northeast Peak moored meteorology data from 1995.

b. Water Temperature and Salinity: For the later part of 1995 after deployment, the water column was ell mixed in temperature and salinity, with the temperature decreasing from 13 to 7.2 ºC, while the salinity increased from 32.6 to 33 PSU. The variability in both the temperature and salinity records are less than observed at the Southern Flank site. The Northeast Peak site ended the year slightly warmer (7.2 rather than 7.0 ºC, but the salinity was slightly higher (33.0 rather than 32.8). The rise in salinity seen at the Northeast Peak in later December is reflected in an increase in salinity in the Southern Flank record in mid-January 1996 (Fig. 26).

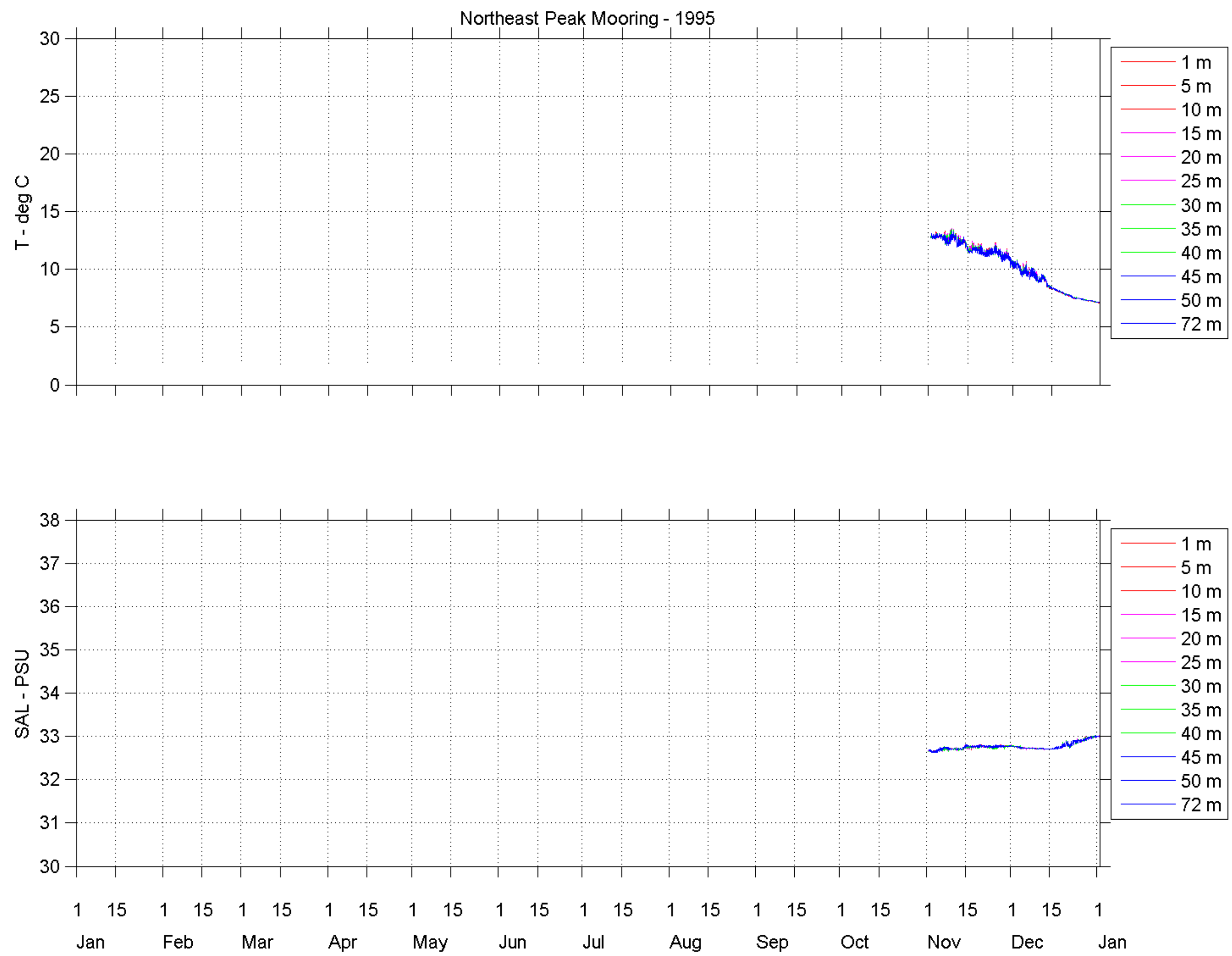

Figure 42. Northeast Peak moored temperature and salinity data from 1995. All temperature (top) and all salinity (bottom) records are plotted on the same axis. The mooring was first deployed at the end of October 1995.

c. Bio-Optical:

Figure 43. *Northeast Peak moored bio-optical data from 1995.*

d. ADCP: No ADCP data was collected in 1995.

10. NORTHEAST PEAK 1996

a. Meteorology: looks ok

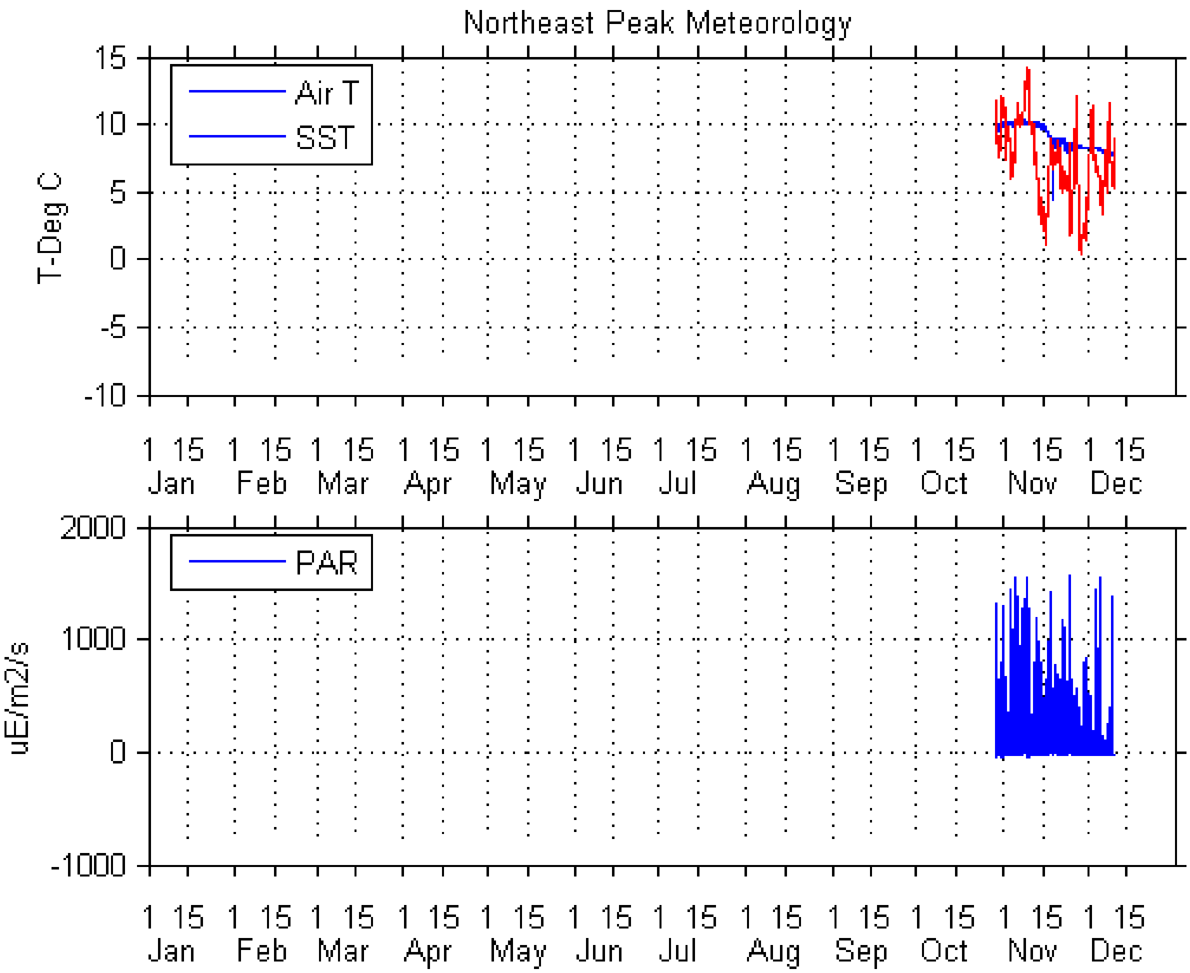

Figure 44. Northeast Peak moored meteorology data from 1996.

b. Water Temperature and Salinity: The water column is well mixed during the times the mooring was on site. There is a large gap from mid-April to late October when the mooring was cut loose and drifted up near Halifax, was recovered, repaired and redeployed. There is a small cool, fresh crossover event seen at the end of the first week in February, but it is not as large as others seen later. The water column is observed to freshen from 33.0 and in later November getting lower than 32 PSU before ending the year about 32.2 PSU. This same significant salinity drop is observed at the Southern Flank site (Fig. 26), and shows similar values (freshening from 33 PSU to 32 PSU). There is the hint of some cool, fresh water spikes seen in the surface in late Nov and around 8 Dec. The temperature ends up at 7.5 deg C - about the same level as when the year started (7.2 deg C) and reached a minimum of 3.9 deg C in early March. The variability in the temperature and salinity records during the winter are greater than observed at the Southern Flank site, which is different than seen in the previous fall.

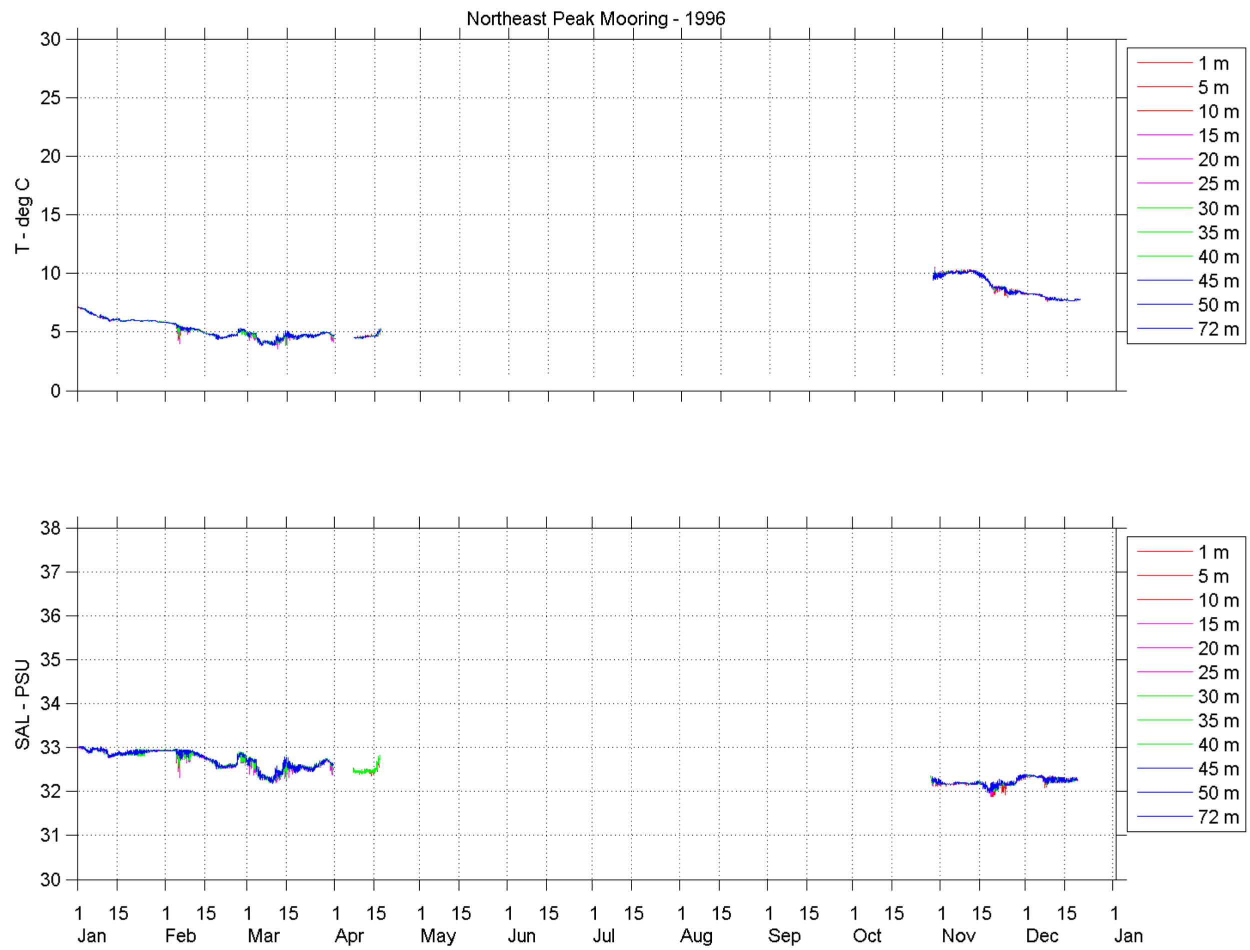

Figure 45. Northeast Peak moored temperature and salinity data from 1996. All temperature (top) and all salinity (bottom) records are plotted on the same axis.

c. Bio-Optical:

Figure 46. *Northeast Peak moored bio-optical data from 1996.*

d. ADCP:

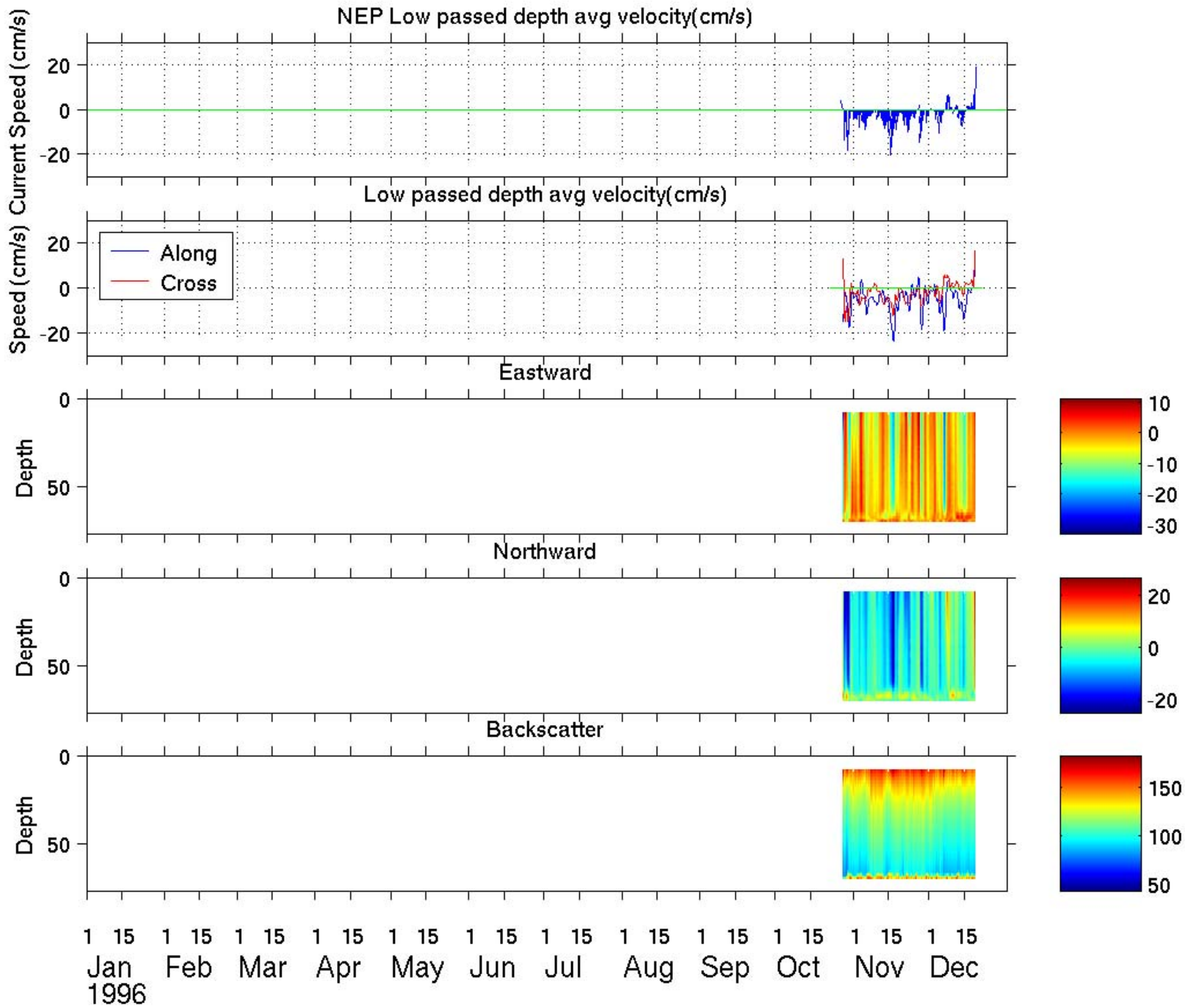

Figure 47. Northeast Peak moored ADCP data from 1996.

11. NORTHEAST PEAK 1997.

The mooring was cut loose in July, and was not redployed during the next field year, but was deployed for the last year of the observational program (Nov 1998 to Aug 1999) at the same time as the Crossover Process study was being conducted and was part of that moored array.

a. Meteorology: looks ok

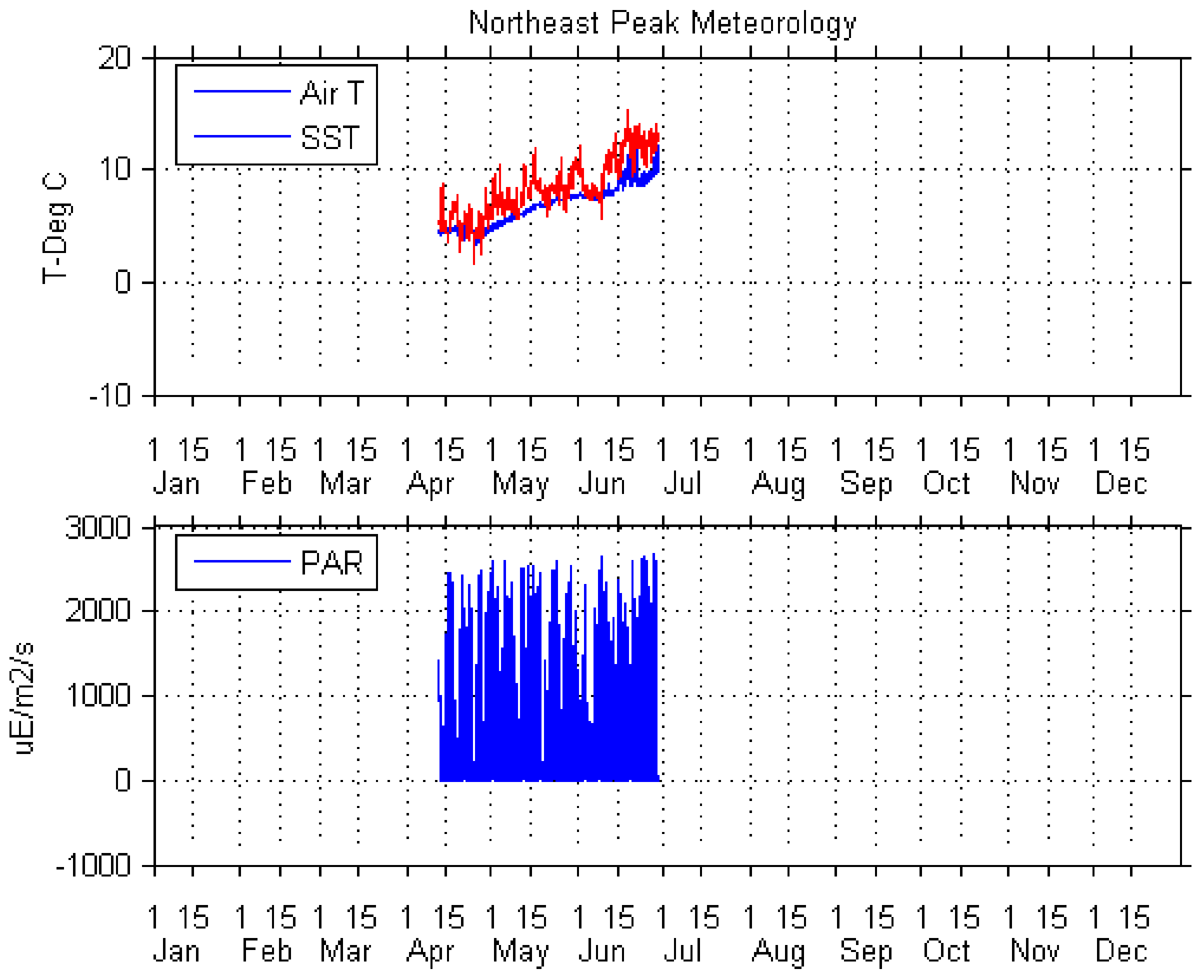

Figure 48. Northeast Peak moored meteorology data from 1997.

b. Water Temperature and Salinity: The data was lost from the winter when the buoy quit and was recovered in Dec and redeployed on a Broadscale survey cruise in mid February. The temperatures start off around 5 deg C and cool to about 4 deg C at the end of April. Then rise until July when the mooring was again cut loose and recovered. The temperatures show some surface warming and stratification starting in early June. The salinity remains fairly constant throught the record starting and ending about 32.2 PSU. The "big" event seen during the deployment is the fresh surface water in later April (with no real accompanying temperature signal). The surface water reaches about 31.5 PSU in salinity. When the surface warming occurs there is some surface salinity variability also observed.

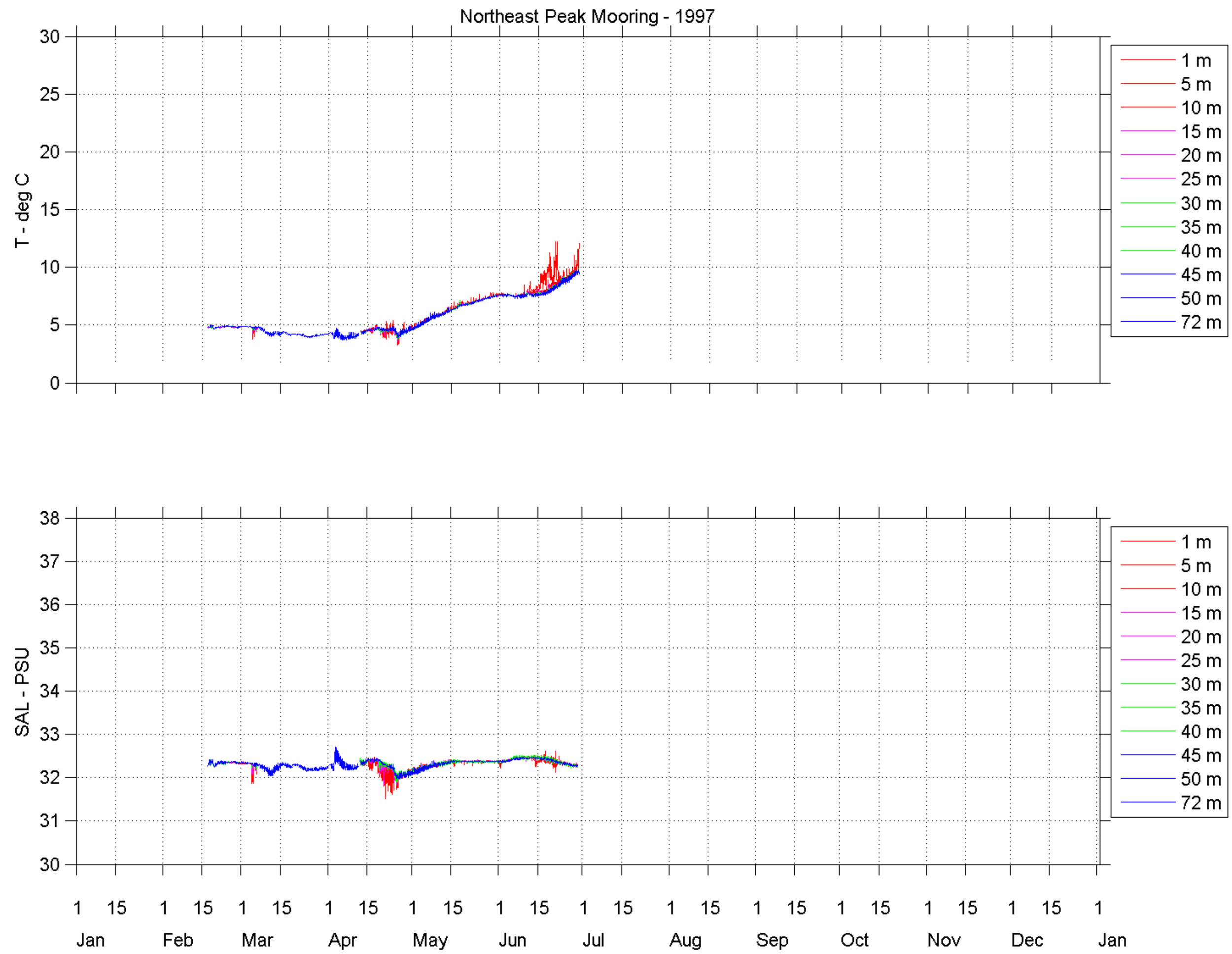

Figure 49. Northeast Peak moored temperature and salinity data from 1997. All temperature (top) and all salinity (bottom) records are plotted on the same axis.

c. Bio-Optical:

Figure 50. *Northeast Peak moored bio-optical data from 1997.*

d. ADCP:

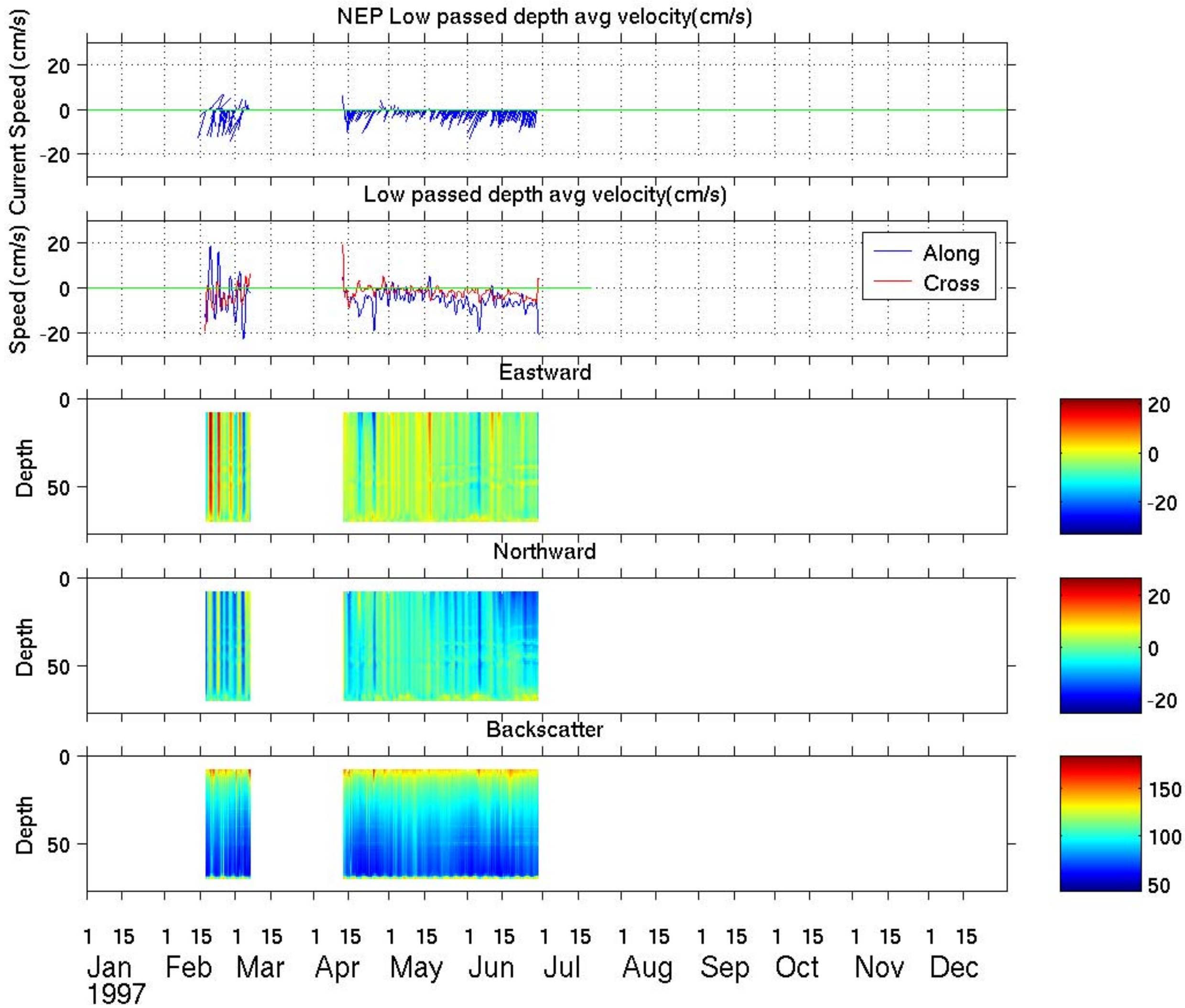

Figure 51. Northeast Peak moored ADCP data from 1997.

12. NORTHEAST PEAK 1998

a. Meteorology: ok

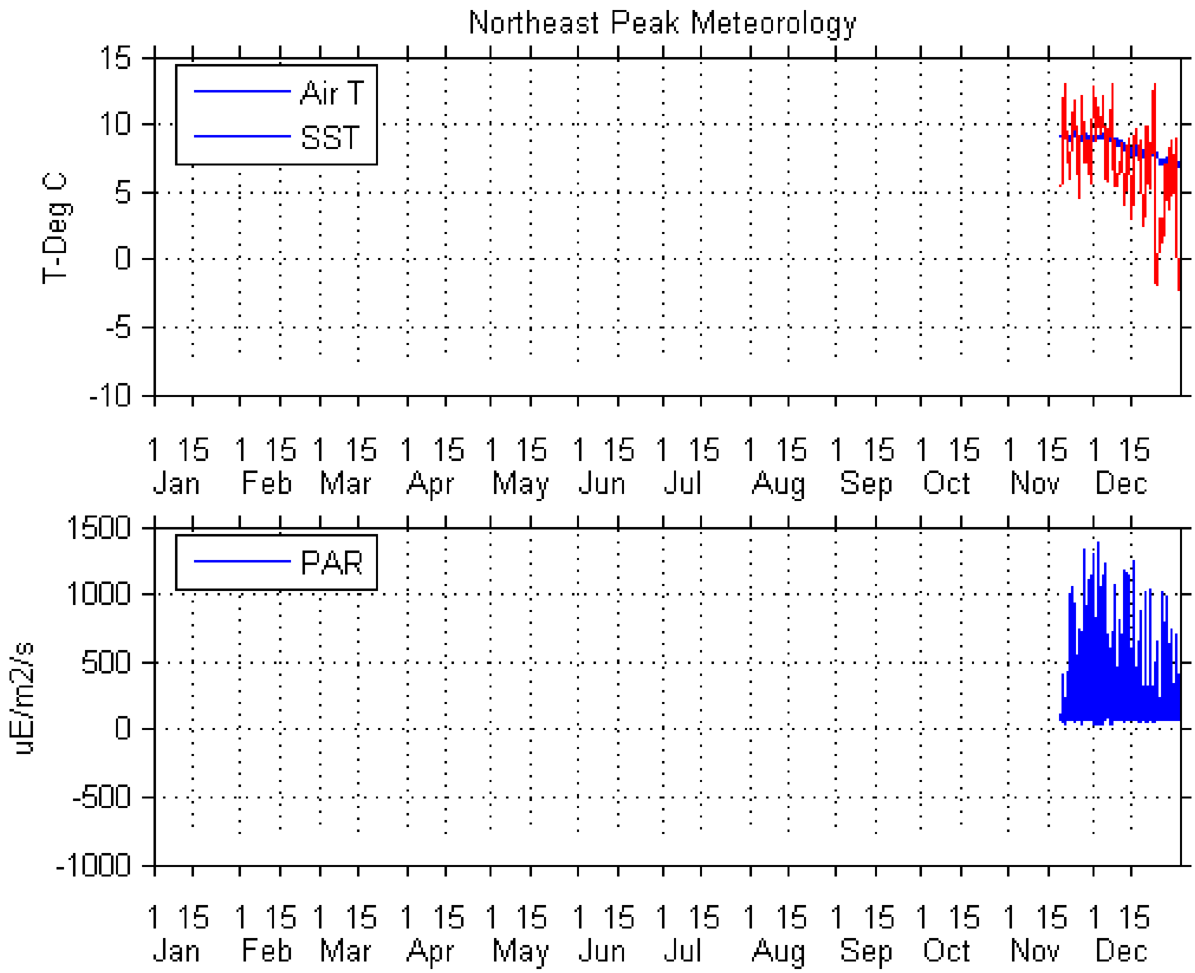

Figure 52. Northeast Peak moored meteorology data from 1998.

b. Water Temperature and Salinity: The water column is well mixed in temperature and salinity again, and the temperature decreaswes from 9.2 deg C to 7.0 deg C with little structure or variability. The salinity starts out at 32.2, decrease to 32.0 and then back to 32.2 PSU, showing no trend. No crossover events were observed at the end of 1998.

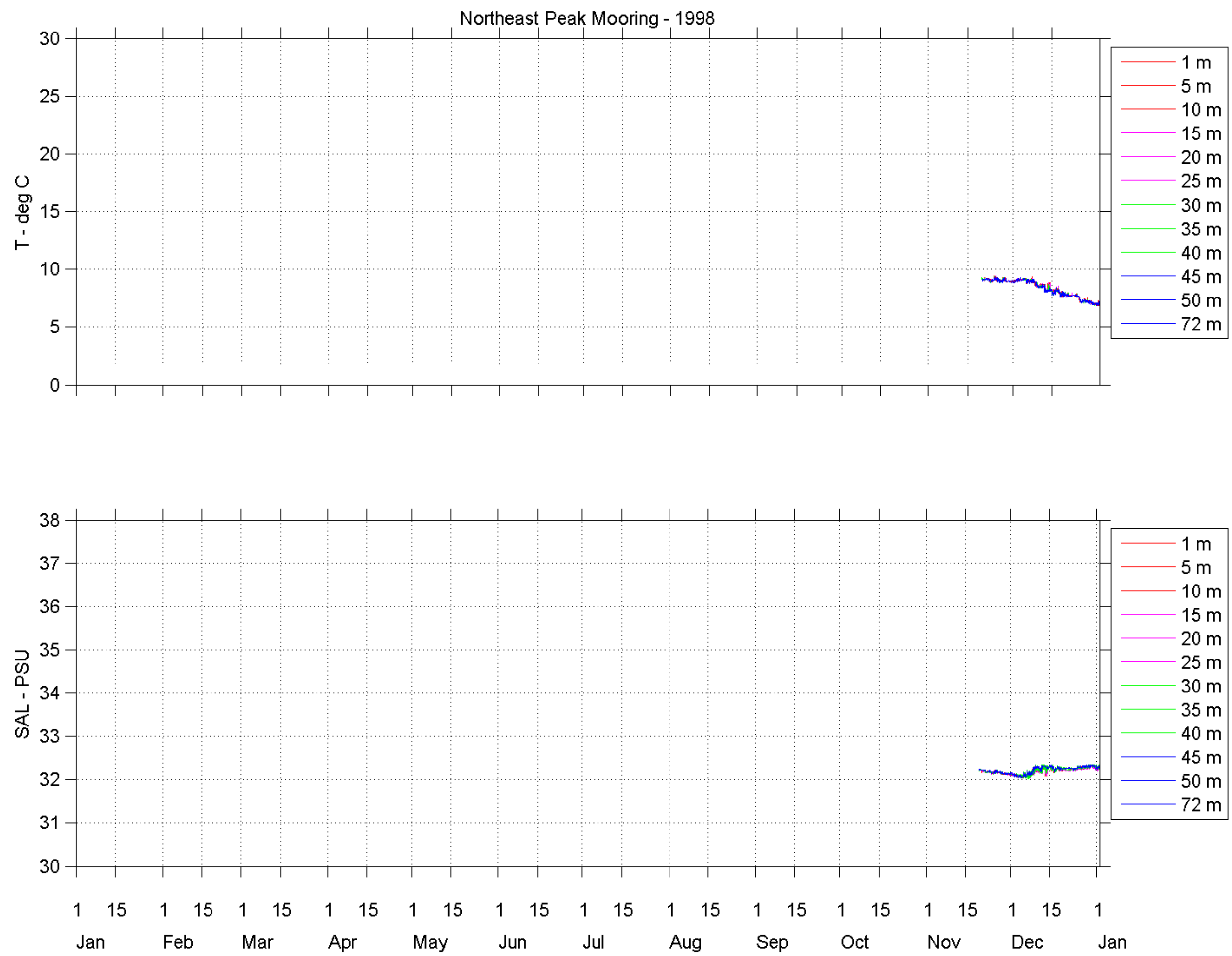

Figure 53. Northeast Peak moored temperature and salinity data from 1998. All temperature (top) and all salinity (bottom) records are plotted on the same axis.

c. Bio-Optical:

Figure 54. *Northeast Peak moored bio-optical data from 1998.*

d. ADCP:

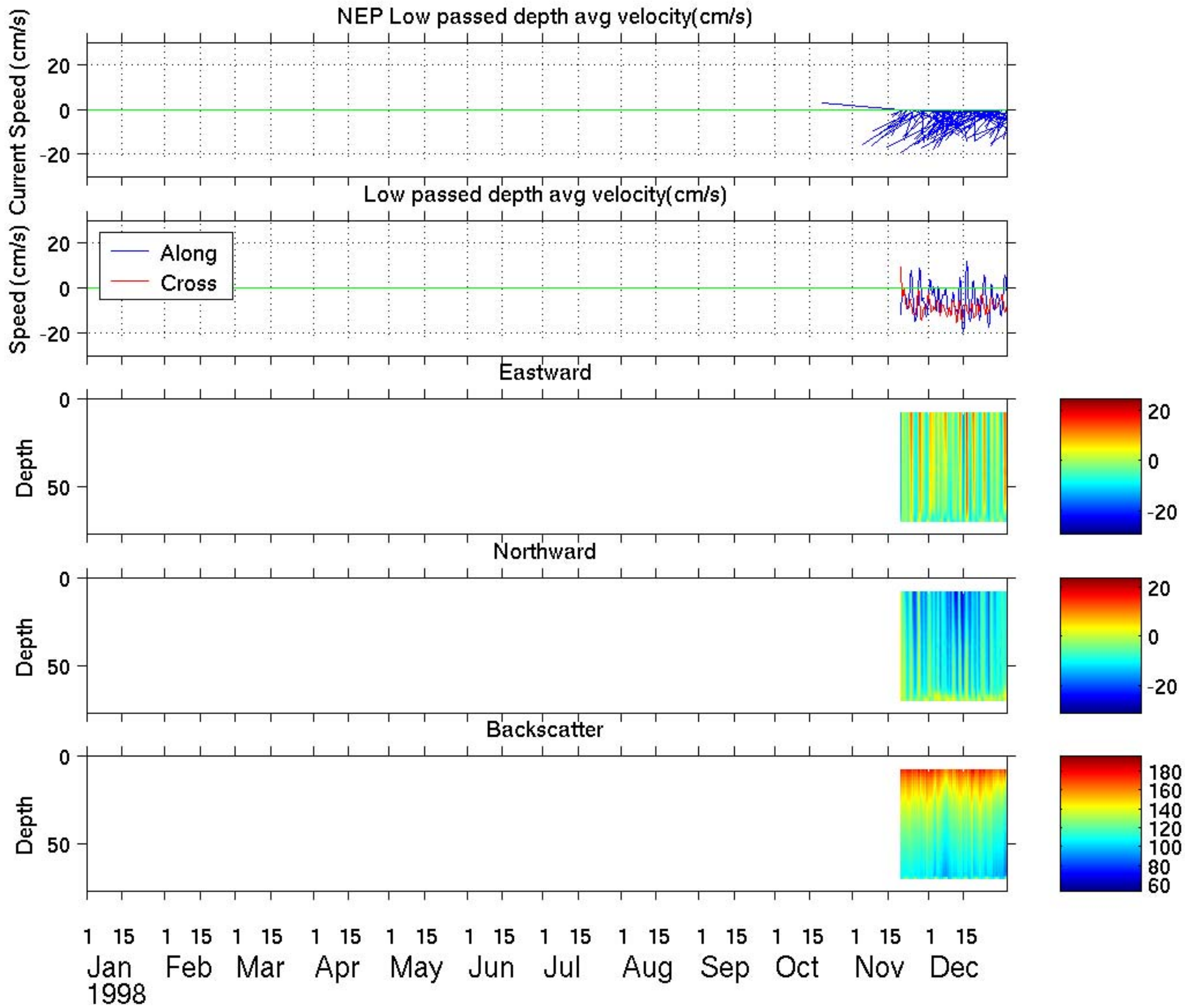

Figure 55. Northeast Peak moored ADCP data from 1998.

13. NORTHEAST PEAK 1999

a. Meteorology: ok

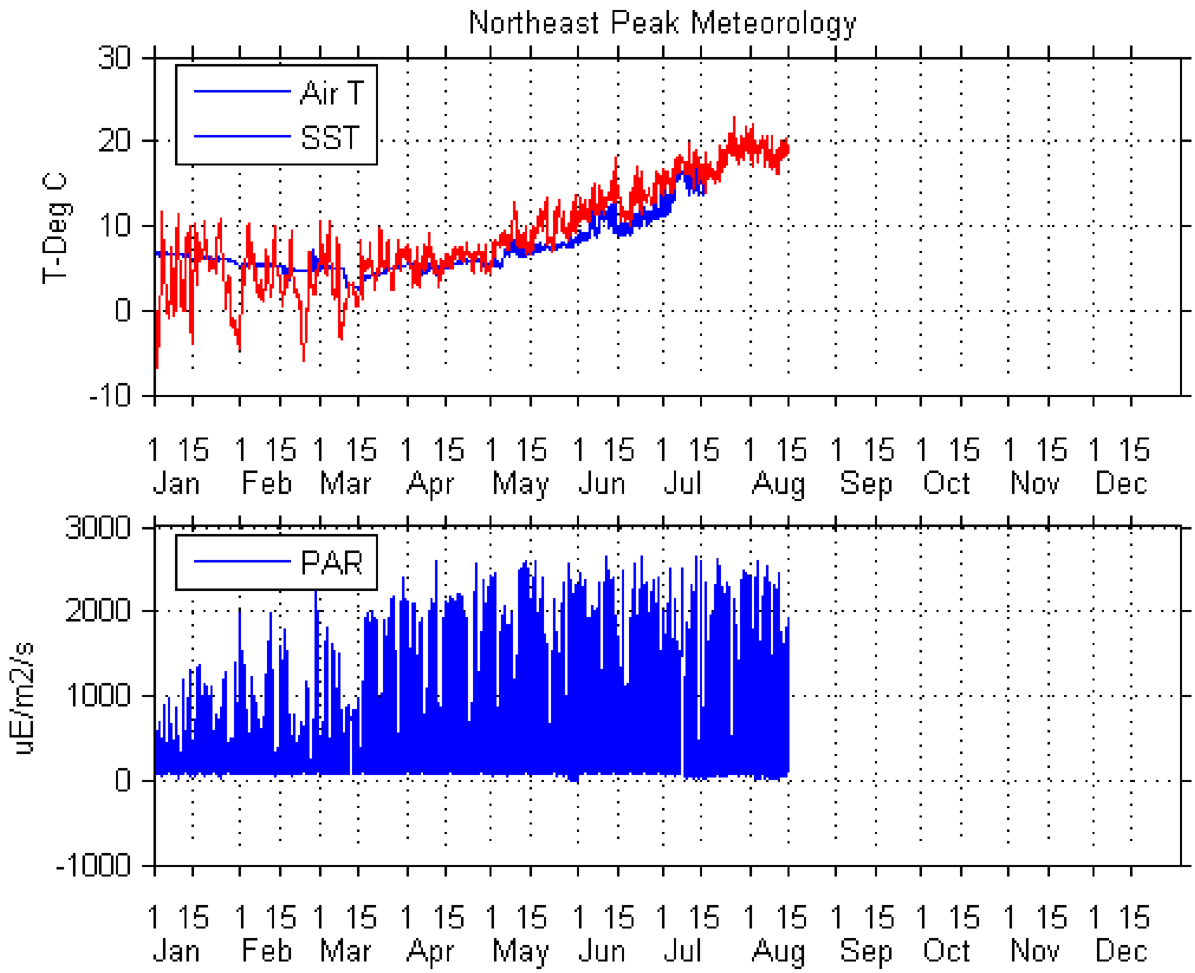

Figure 56. Northeast Peak moored meteorology data from 1999.

c. **Water Temperature and Salinity:** The mooring was deployed from fall 98 through August and the end of the field program. 1999 showed more variability than previous years. The temperature started off at 7.2 deg C and cooled to about 3.8 degrees, with cooler periods down to 2.5 deg C associated with crossover events. The temperature and salinity show stratification in the upper 20 m of the water column with temperatures rising to 18 deg C and salinities freshing to 32 PSU. There is no sign of and recovery from the 1 PSU freshening of the water seen at the Northeast Peak site that was seen at the end of the Southern Flank record, and probably due to temporary effects of the warm core rings seen there.

About 16 Feb there is a cool, fresh crossover event where the temperature drops from 5 deg C to 3.2 deg C in the upper 15 meters of the water column, and the salinity shows an accompanying drop from 32.7 to 31.6 PSU. This event last fro about 5 days and has strong tidal variability, indicating horizontal structure advected back and forth by the tidal currents. Another cool fresh crossover event is observed to start about 9 March with temperatures well mixed at about 5 deg C and salinities well mixed at about 32.8 PSU and rising. The temperatures drop to 2.5 deg C and salinities to 31.5 PSU, again with tidal variability. This event ends about 16 March with the water column becoming well mixed vertically with temperature of 3.8 deg C (the coldest send not in an event) and salinities of 32.15 PSU.

Additional fresh crossover events that are not so cool are seen during 6 to 13 April when the salinities drop to 31.8 with accompanying temperatures dropping to 4 deg C. Between 25 April and 12 May another crossover event is seen with temperature only dropping to 4.5 deg C, but salinities dropping to 31.6. The temperature signature of this event is different. While the surface temperatures drop at first, before the middle of the event, the become warmer than deeper waters.

Another very different signature event is seen with warm, salty waters seen in deeper waters. The temperature rises suddenlyu from 5 deg C to 8.6 deg C then the envelope decreases over the next week, with strong tidal oscillations. The salinities rise from 32.5 to 33.8 PSU. A similar event, but smaller in amplitude was observed in 1997 (Fig. 49) where the salinity increased by about 0.5 PSU, but the temperature showed little change.

During July when the surface warming is strongest, the surface waters also freshen,a nd reach a minimum of 32 PSU around the first of August with the freshening extending down to mid-water depths. This is similar to the freshening of surface waters seen regularly, but particularly in later years at the Southern Flank site.

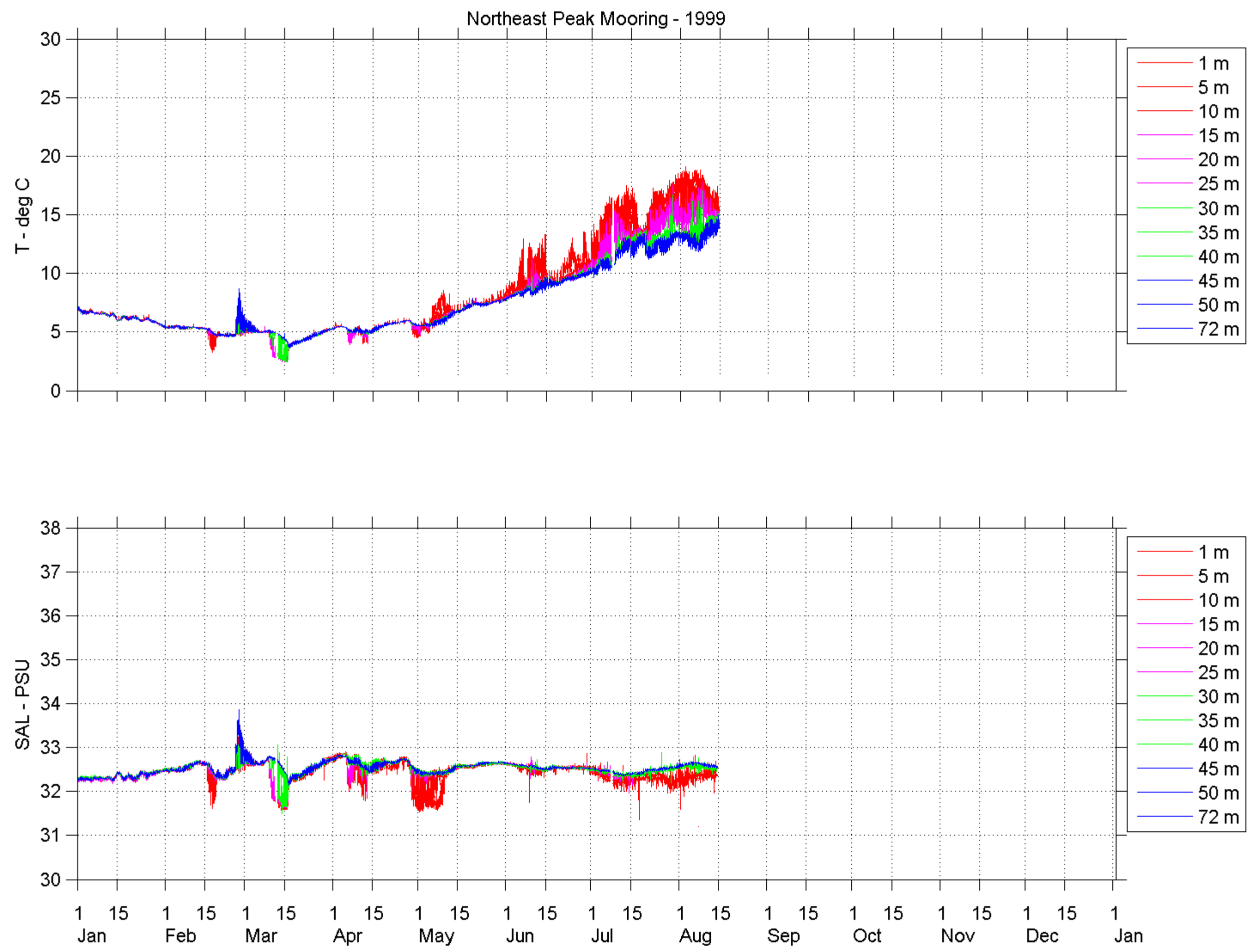

Figure 57. Northeast Peak moored temperature and salinity data from 1999. All temperature (top) and all salinity (bottom) records are plotted on the same axis. The moorings were recovered and the moored field effort ended in Aug 1999.

c. Bio-Optical:

Figure 58. *Northeast Peak moored bio-optical data from 1999.*

d. ADCP:

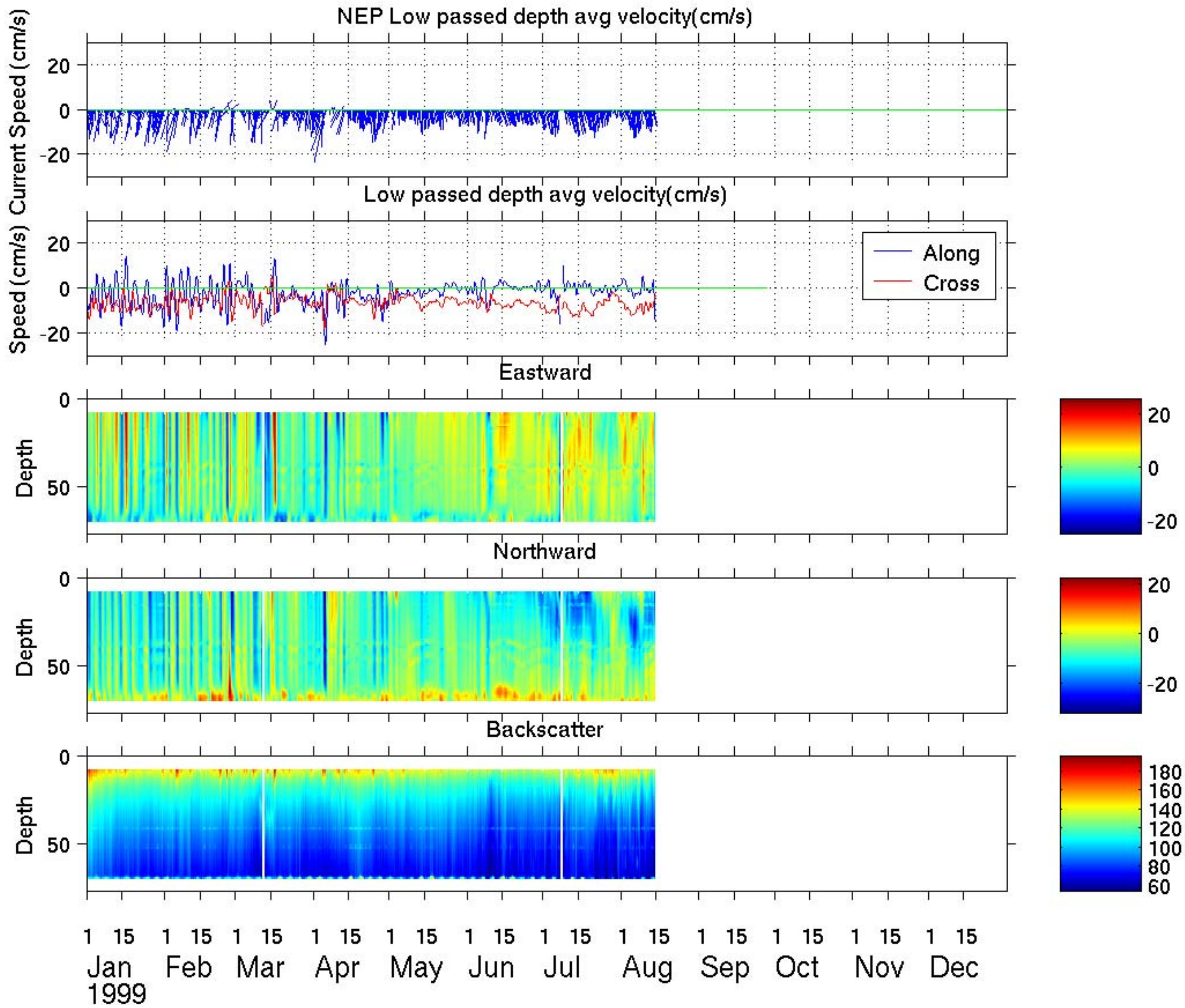

Figure 59. Northeast Peak moored ADCP data from 1999.