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UNDERWAY pCO_2 MEASUREMENTS IN SURFACE WATERS DURING THE OCEAN MARGINS PROGRAM CRUISES IN THE NORTH WESTERN ATLANTIC OCEAN

by

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3 May 2001

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1. INTRODUCTION

This report is the final technical report for the grant DE-FG02-95ER62065, and describes the methods employed and the data obtained during the Ocean Margins Program expeditions for the measurement of pCO_2 in surface waters and in the overlying atmosphere in 1993, 1994, and 1996. This is a companion report to Chipman and Takahashi (1995), in which the results obtained under the grant DE-FG02-92ER61451, the predecessor of the present grant, have been summarized.

The dates and number of measurements made during this project are summarized in Table 1. The operational procedures of the underway pCO_2 measurement system are described in the "pCO_2 Equilibrator Users Manual" prepared by the LDEO CO_2 Group (1999). The methods for measurements and calibrations are described in section 3 of this report. The ships' tracks are shown in Figure 1.

Table 1 - Surface Observations listed by ship, date, and number of observations.

Ship (LDEO Leg)	**Dates mm/dd/yy**	**Julian Dates**	**pCO_2 in Seawater**
R/V Gyre & Columbus Iselin (9)	05/11/93-05/16/93	131-136	1,350
R/V Oceanus (8)	04/18/94-05/01/94	108-121	3.064
R/V Oceanus (1)	02/01/96-02/16/96	032-047	3,628
R/V Endeavor (2)	03/01/96-03/21/96	061-081	4,093
R/V Oceanus (3)	05/06/96-05/17/96	127-138	2,906
R/V S. Johnson (4)	06/22/96-06/30/96	174-182	2,073
R/V S. Johnson (5)	07/11/96-07/13/96	192-194	448
R/V S. Johnson (6)	07/19/96-07/27/96	201-209	2,169
R/V Oceanus (7)	10/07/96-10/17/96	281-291	2,624
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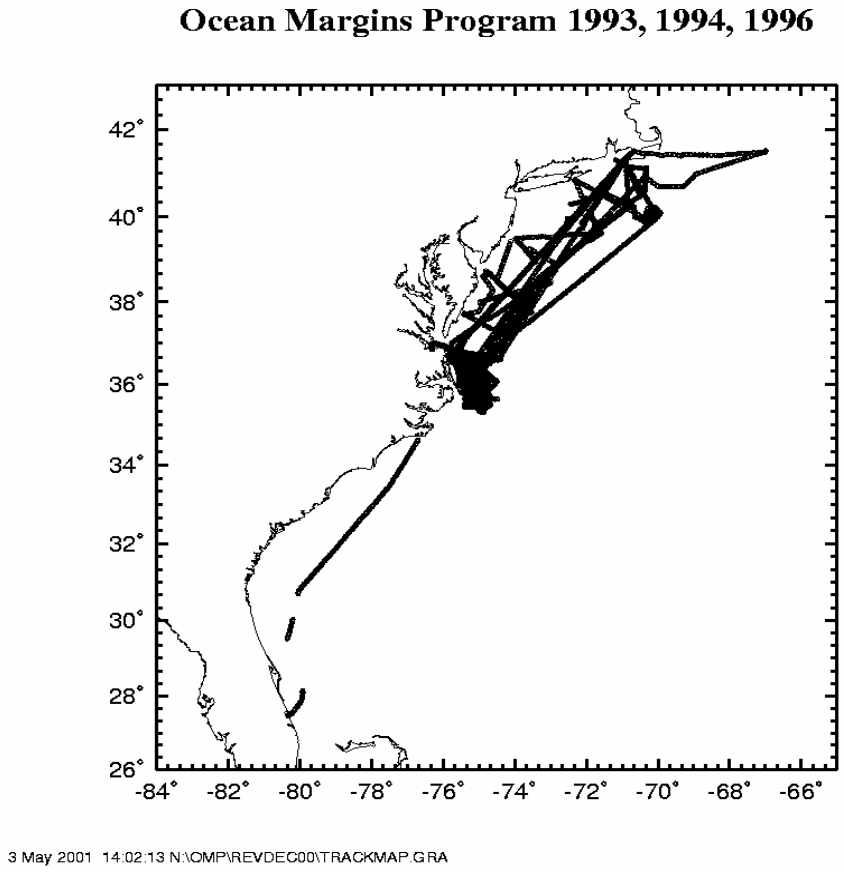
Total		**99 days**	**22,355**

Figure 1 - Map of station locations.



2. SAMPLE DATA LISTING.

We have submitted to the Carbon Dioxide Information and Analysis Center (CDIAC), Oak Ridge National Laboratory, an electronic data listing for the 22,355 measurements for surface water pCO_2 , and other associated data of time, date, position, sea surface temperature, and sea-air pCO_2 difference. CDIAC will be responsible for archiving and distributing these data. A letter of acknowledgement from Alex Kozry of CDIAC is attached as Appendix 1 at the end of this report. In this section we have reproduced as examples the first 20 and last 10 records from each of the 9 legs

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Source File = OMP_SFCR LDEO Leg No: 1 Ship: R/V Oceanus Page 1

pCO2 of air calculated from the GlobalView CO2 Database VCO2 of dry air
assuming 100% relative humidity at the sea/air interface.

Seawater pCO2 is reported at Sea Surface Temperature.

Only the first 20 and last 10 records of each leg are printed.

Sta No.	Date MM/DD/YYYY	Julian Date	Lat DD-MM.mm	Long DDD-MM.mm	Sea Surface Temp Deg C	Sal PSS	Seawater pCO2 uatm	Atmosphere VCO2 ppm	pCO2 uatm	Delta pCO2 sw-air uatm
1	2/ 1/1996	32.6989	41-10.98N	71- 5.46W	3.43	31.983	386.1	364.5	361.4	24.7
2	2/ 1/1996	32.7012	41-10.38N	71- 6.06W	3.38	31.996	379.1	364.5	361.4	17.7
3	2/ 1/1996	32.7035	41- 9.72N	71- 6.78W	3.37	31.982	374.0	364.5	361.4	12.6
4	2/ 1/1996	32.7058	41- 9.36N	71- 7.26W	3.43	31.956	368.7	364.5	361.4	7.4
5	2/ 1/1996	32.7081	41- 8.82N	71- 7.86W	3.42	31.950	374.8	364.5	361.4	13.4
6	2/ 1/1996	32.7105	41- 8.16N	71- 8.58W	3.39	31.957	383.0	364.5	361.4	21.6
7	2/ 1/1996	32.7128	41- 7.74N	71- 9.06W	3.43	31.981	385.1	364.5	361.4	23.8
8	2/ 1/1996	32.7151	41- 7.20N	71- 9.66W	3.44	31.984	387.8	364.5	361.4	26.4
9	2/ 1/1996	32.7238	41- 5.16N	71-11.88W	3.52	31.979	384.7	364.5	361.4	23.4
10	2/ 1/1996	32.7261	41- 4.56N	71-12.54W	3.52	31.979	391.3	364.5	361.4	30.0
11	2/ 1/1996	32.7284	41- 4.08N	71-13.08W	3.57	31.980	393.1	364.5	361.3	31.8
12	2/ 1/1996	32.7307	41- 3.54N	71-13.68W	3.61	31.974	392.2	364.5	361.3	30.9
13	2/ 1/1996	32.7330	41- 3.00N	71-14.28W	3.64	31.978	394.3	364.5	361.3	33.0
14	2/ 1/1996	32.7353	41- 2.46N	71-14.88W	3.69	31.969	396.6	364.5	361.3	35.3
15	2/ 1/1996	32.7377	41- 1.98N	71-15.42W	3.70	31.987	397.1	364.5	361.3	35.8
16	2/ 1/1996	32.7400	41- 1.32N	71-16.14W	3.75	31.989	398.5	364.5	361.3	37.2
17	2/ 1/1996	32.7487	40-59.22N	71-18.48W	3.87	32.018	388.4	364.5	362.2	26.2
18	2/ 1/1996	32.7510	40-58.86N	71-18.90W	3.93	32.020	388.3	364.5	362.2	26.1
19	2/ 1/1996	32.7533	40-58.26N	71-19.56W	3.98	32.025	388.5	364.5	362.2	26.3
20	2/ 1/1996	32.7556	40-57.60N	71-20.28W	4.00	32.031	388.1	364.5	362.2	25.9
3619	2/16/1996	47.7781	40-58.02N	70-42.78W	2.15	31.854	329.1	364.9	362.3	-33.3
3620	2/16/1996	47.7805	40-58.68N	70-43.32W	2.06	31.842	322.1	364.9	362.3	-40.3
3621	2/16/1996	47.7915	41- 2.04N	70-45.78W	1.81	31.829	306.8	364.9	362.1	-55.3
3622	2/16/1996	47.7938	41- 2.64N	70-46.26W	1.90	31.871	304.2	364.9	362.1	-57.8
3623	2/16/1996	47.7961	41- 3.36N	70-46.74W	2.05	31.884	304.3	364.9	362.0	-57.7
3624	2/16/1996	47.7984	41- 4.02N	70-47.28W	2.15	31.888	312.6	364.9	362.0	-49.4
3625	2/16/1996	47.8008	41- 4.74N	70-47.82W	2.09	31.898	318.6	364.9	362.0	-43.4
3626	2/16/1996	47.8030	41- 5.46N	70-48.30W	2.00	31.903	317.8	364.9	362.0	-44.2
3627	2/16/1996	47.8054	41- 6.06N	70-48.78W	2.00	31.915	314.0	364.9	362.0	-48.1
3628	2/16/1996	47.8077	41- 6.84N	70-49.32W	2.06	31.914	311.7	364.9	362.0	-50.3

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Source File = OMP_SFCR LDEO Leg No: 2 Ship: R/V Endeavor Page 2

pCO2 of air calculated from the GlobalView CO2 Database VCO2 of dry air
assuming 100% relative humidity at the sea/air interface.

Seawater pCO2 is reported at Sea Surface Temperature.

Only the first 20 and last 10 records of each leg are printed.

Sta No.	Date MM/DD/YYYY	Julian Date	Lat DD-MM.mm	Long DDD-MM.mm	Sea Surface Temp Deg C	Sal PSS	Seawater pCO2 uatm	Atmosphere VCO2 ppm	pCO2 uatm	Delta pCO2 sw-air uatm
10	3/ 1/1996	61.8019	41-18.84N	71-10.92W	1.60		500.8	365.4	363.3	137.5
11	3/ 1/1996	61.8043	41-18.42N	71-10.26W	1.57		484.7	365.4	363.3	121.4
12	3/ 1/1996	61.8067	41-18.06N	71- 9.54W	1.52		453.2	365.4	363.3	89.9
13	3/ 1/1996	61.8092	41-17.76N	71- 8.88W	1.49		455.8	365.4	363.3	92.5
14	3/ 1/1996	61.8115	41-17.40N	71- 8.22W	1.50		472.0	365.4	363.3	108.7
15	3/ 1/1996	61.8138	41-17.10N	71- 7.62W	1.48		469.1	365.4	363.3	105.8
16	3/ 1/1996	61.8161	41-16.74N	71- 6.96W	1.46		478.4	365.4	363.3	115.1
17	3/ 1/1996	61.8184	41-16.44N	71- 6.30W	1.39		490.1	365.4	363.3	126.8
23	3/ 1/1996	61.8305	41-14.52N	71- 2.52W	1.63		466.4	365.4	363.3	103.2
24	3/ 1/1996	61.8329	41-14.16N	71- 1.80W	1.70		465.5	365.4	363.3	102.2
25	3/ 1/1996	61.8353	41-13.80N	71- 1.08W	1.71		483.1	365.4	363.3	119.9
26	3/ 1/1996	61.8378	41-13.44N	71- 0.36W	1.79		469.0	365.4	363.3	105.8
27	3/ 1/1996	61.8402	41-13.08N	70-59.64W	1.75		464.0	365.4	363.3	100.7
28	3/ 1/1996	61.8426	41-12.72N	70-58.92W	1.80		483.0	365.4	363.3	119.8
29	3/ 1/1996	61.8451	41-12.36N	70-58.26W	1.80		448.1	365.4	363.3	84.8
30	3/ 1/1996	61.8475	41-12.00N	70-57.54W	1.79		431.5	365.4	363.3	68.2
36	3/ 1/1996	61.8589	41-10.32N	70-54.24W	1.90		513.6	365.4	363.2	150.4
37	3/ 1/1996	61.8614	41- 9.96N	70-53.58W	1.93		476.0	365.4	363.2	112.8
38	3/ 1/1996	61.8638	41- 9.60N	70-52.92W	1.91		453.6	365.4	363.2	90.4
39	3/ 1/1996	61.8662	41- 9.42N	70-52.08W	1.95		439.3	365.4	363.2	76.1
6717	3/21/1996	81.1283	40- 4.20N	72-15.00W	5.08		271.9	366.3	364.1	-92.2
6718	3/21/1996	81.1306	40- 4.68N	72-14.58W	5.11		274.2	366.3	364.1	-89.9
6724	3/21/1996	81.1424	40- 7.20N	72-12.60W	5.24		281.0	366.3	364.1	-83.1
6725	3/21/1996	81.1448	40- 7.68N	72-12.12W	5.22		283.0	366.3	364.1	-81.1
6726	3/21/1996	81.1472	40- 8.22N	72-11.70W	5.26		283.1	366.3	364.1	-81.0
6727	3/21/1996	81.1496	40- 8.70N	72-11.28W	5.25		283.2	366.3	364.1	-80.9
6728	3/21/1996	81.1521	40- 9.24N	72-10.86W	5.21		283.0	366.3	364.1	-81.1
6729	3/21/1996	81.1545	40- 9.78N	72-10.44W	5.14		282.6	366.3	364.1	-81.5
6730	3/21/1996	81.1569	40-10.26N	72- 9.96W	4.96		281.5	366.3	364.1	-82.6
6731	3/21/1996	81.1594	40-10.74N	72- 9.54W	4.62		281.8	366.3	364.1	-82.3

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pCO2 of air calculated from the GlobalView CO2 Database VCO2 of dry air
assuming 100% relative humidity at the sea/air interface.

Seawater pCO2 is reported at Sea Surface Temperature.

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Sta No.	Date MM/DD/YYYY	Julian Date	Lat DD-MM.mm	Long DDD-MM.mm	Sea Surface Temp Deg C	Sal PSS	Seawater pCO2 uatm	Atmosphere VCO2 ppm	pCO2 uatm	Delta pCO2 sw-air uatm
1	5/ 6/1996	127.5780	41-21.84N	70-53.58W	8.77		373.6	366.5	363.9	9.7
2	5/ 6/1996	127.5803	41-21.42N	70-54.12W	8.74		368.6	366.5	363.9	4.7
3	5/ 6/1996	127.5826	41-20.94N	70-54.72W	8.81		366.2	366.5	363.9	2.3
4	5/ 6/1996	127.5849	41-20.40N	70-55.32W	8.91		367.8	366.5	363.8	3.9
5	5/ 6/1996	127.5872	41-19.86N	70-55.92W	8.98		368.4	366.5	363.8	4.6
6	5/ 6/1996	127.5895	41-19.38N	70-56.52W	8.93		367.4	366.5	363.8	3.6
7	5/ 6/1996	127.5919	41-18.78N	70-57.12W	8.95		366.3	366.5	363.8	2.5
8	5/ 6/1996	127.5942	41-18.24N	70-57.72W	8.88		366.4	366.5	363.8	2.5
9	5/ 6/1996	127.6052	41-15.78N	71- 0.66W	9.04		372.9	366.5	363.8	9.1
10	5/ 6/1996	127.6075	41-15.30N	71- 1.32W	9.14		373.2	366.5	363.8	9.4
11	5/ 6/1996	127.6098	41-14.70N	71- 1.86W	9.16		372.8	366.5	363.8	9.1
12	5/ 6/1996	127.6121	41-14.28N	71- 2.58W	9.23		372.8	366.5	363.7	9.1
13	5/ 6/1996	127.6145	41-13.68N	71- 3.18W	9.22		373.0	366.5	363.8	9.3
14	5/ 6/1996	127.6168	41-13.14N	71- 3.78W	9.18		372.9	366.5	363.8	9.2
15	5/ 6/1996	127.6191	41-12.66N	71- 4.38W	9.13		370.0	366.5	363.8	6.3
16	5/ 6/1996	127.6214	41-11.94N	71- 4.86W	9.34		371.8	366.5	363.7	8.1
17	5/ 6/1996	127.6324	41- 9.12N	71- 7.14W	9.11		360.8	366.5	363.8	-3.0
18	5/ 6/1996	127.6348	41- 8.46N	71- 7.50W	9.14		359.2	366.5	363.8	-4.5
19	5/ 6/1996	127.6371	41- 7.86N	71- 7.98W	8.99		358.0	366.5	363.8	-5.9
20	5/ 6/1996	127.6394	41- 7.20N	71- 8.34W	8.93		356.4	366.5	363.8	-7.5
2897	5/17/1996	138.6480	41-20.46N	70-53.46W	9.92	31.465	383.6	366.2	363.3	20.3
2898	5/17/1996	138.6503	41-21.06N	70-52.98W	9.88	31.463	382.7	366.2	363.3	19.4
2899	5/17/1996	138.6614	41-24.06N	70-50.52W	9.80	31.529	393.9	366.2	363.4	30.5
2900	5/17/1996	138.6636	41-24.60N	70-49.74W	9.75	31.509	395.1	366.2	363.4	31.7
2901	5/17/1996	138.6660	41-25.02N	70-48.90W	9.76	31.362	395.3	366.2	363.4	31.9
2902	5/17/1996	138.6683	41-25.50N	70-48.06W	10.36	31.362	397.8	366.2	363.2	34.6
2903	5/17/1996	138.6706	41-25.92N	70-47.22W	10.29	31.270	407.3	366.2	363.2	44.1
2904	5/17/1996	138.6729	41-26.34N	70-46.44W	10.47	31.212	413.5	366.2	363.2	50.3
2905	5/17/1996	138.6752	41-26.76N	70-45.78W	10.47	31.057	419.0	366.2	363.2	55.9
2906	5/17/1996	138.6775	41-27.24N	70-44.94W	10.54	31.066	422.1	366.2	363.1	59.0

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pCO2 of air calculated from the GlobalView CO2 Database VCO2 of dry air
assuming 100% relative humidity at the sea/air interface.

Seawater pCO2 is reported at Sea Surface Temperature.

Only the first 20 and last 10 records of each leg are printed.

Sta No.	Date MM/DD/YYYY	Julian Date	Lat DD-MM.mm	Long DDD-MM.mm	Sea Surface Temp Deg C	Sal PSS	Seawater pCO2 uatm	Atmosphere VCO2 ppm	pCO2 uatm	Delta pCO2 sw-air uatm
1	6/22/1996	174.5614	41-22.68N	70-51.66W	16.54	31.328	481.9	364.6	359.4	122.4
2	6/22/1996	174.5637	41-22.20N	70-52.20W	16.49	31.328	479.2	364.6	359.5	119.7
3	6/22/1996	174.5660	41-21.78N	70-52.68W	15.84	31.318	473.5	364.6	359.7	113.8
4	6/22/1996	174.5683	41-21.30N	70-53.16W	15.75	31.329	470.1	364.6	359.8	110.4
5	6/22/1996	174.5706	41-20.82N	70-53.64W	15.68	31.331	466.6	364.6	359.8	106.8
6	6/22/1996	174.5730	41-20.34N	70-54.18W	15.51	31.356	460.7	364.6	359.9	100.8
7	6/22/1996	174.5753	41-19.92N	70-54.66W	15.50	31.347	456.0	364.6	359.9	96.1
8	6/22/1996	174.5776	41-19.44N	70-55.14W	15.74	31.350	449.8	364.6	359.8	90.1
9	6/22/1996	174.5886	41-17.28N	70-57.60W	15.62	31.311	425.9	364.6	359.8	66.1
10	6/22/1996	174.5909	41-16.80N	70-58.08W	15.64	31.308	425.9	364.6	359.8	66.1
11	6/22/1996	174.5933	41-16.44N	70-58.56W	15.65	31.293	426.0	364.6	359.8	66.2
12	6/22/1996	174.5956	41-15.90N	70-59.04W	15.55	31.278	427.0	364.6	359.8	67.2
13	6/22/1996	174.5979	41-15.48N	70-59.58W	15.34	31.294	426.5	364.6	359.9	66.6
14	6/22/1996	174.6002	41-15.06N	71- 0.06W	15.26	31.302	426.8	364.6	359.9	66.9
15	6/22/1996	174.6025	41-14.64N	71- 0.48W	15.31	31.322	427.5	364.6	359.9	67.6
16	6/22/1996	174.6049	41-14.16N	71- 1.02W	15.29	31.319	428.1	364.6	359.9	68.2
17	6/22/1996	174.6159	41-12.06N	71- 3.30W	15.06	31.501	455.0	364.6	360.0	95.0
18	6/22/1996	174.6182	41-11.64N	71- 3.84W	15.05	31.492	432.1	364.6	360.0	72.1
19	6/22/1996	174.6205	41-11.16N	71- 4.32W	15.12	31.494	417.1	364.6	360.0	57.1
20	6/22/1996	174.6228	41-10.68N	71- 4.80W	15.10	31.517	408.2	364.6	360.0	48.2
2065	6/30/1996	182.4061	41-16.14N	70-57.84W	17.04	28.910	431.2	364.0	358.7	72.5
2066	6/30/1996	182.4084	41-16.68N	70-57.36W	17.03	28.786	433.0	364.0	358.7	74.3
2067	6/30/1996	182.4195	41-19.14N	70-55.32W	17.39	29.251	442.9	364.0	358.5	84.4
2068	6/30/1996	182.4218	41-19.68N	70-54.90W	17.45	28.947	443.9	364.0	358.5	85.4
2069	6/30/1996	182.4241	41-20.22N	70-54.48W	17.44	29.012	444.0	364.0	358.5	85.5
2070	6/30/1996	182.4264	41-20.76N	70-54.00W	17.42	28.748	444.3	364.0	358.5	85.8
2071	6/30/1996	182.4288	41-21.36N	70-53.52W	17.38	28.212	444.7	364.0	358.5	86.2
2072	6/30/1996	182.4311	41-21.90N	70-53.10W	17.26	29.708	444.3	364.0	358.6	85.8
2073	6/30/1996	182.4334	41-22.50N	70-52.50W	16.93	31.070	442.9	364.0	358.7	84.2
2074	6/30/1996	182.4357	41-22.98N	70-51.78W	16.86	30.734	439.1	364.0	358.7	80.4

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Source File = OMP_SFCR LDEO Leg No: 5 Ship: R/V Seward Johnson Page 5

pCO2 of air calculated from the GlobalView CO2 Database VCO2 of dry air
assuming 100% relative humidity at the sea/air interface.

Seawater pCO2 is reported at Sea Surface Temperature.

Only the first 20 and last 10 records of each leg are printed.

Sta No.	Date MM/DD/YYYY	Julian Date	Lat DD-MM.mm	Long DDD-MM.mm	Sea Surface Temp Deg C	Sal PSS	Seawater pCO2 uatm	Atmosphere VCO2 ppm	Atmosphere pCO2 uatm	Delta pCO2 sw-air uatm
6	7/11/1996	193.1047	27-32.16N	80-21.36W	22.30		525.0	363.4	355.7	169.3
7	7/11/1996	193.1070	27-32.16N	80-21.30W	22.32		522.1	363.4	355.7	166.5
8	7/11/1996	193.1181	27-32.10N	80-21.24W	22.46		522.8	363.4	355.6	167.2
9	7/11/1996	193.1204	27-32.10N	80-21.30W	22.49		525.2	363.4	355.6	169.6
10	7/11/1996	193.1227	27-32.16N	80-21.30W	22.50		526.4	363.4	355.6	170.8
11	7/11/1996	193.1250	27-32.10N	80-21.30W	22.48		527.6	363.4	355.6	172.0
12	7/11/1996	193.1274	27-32.10N	80-21.30W	22.47		528.7	363.4	355.6	173.1
13	7/11/1996	193.1297	27-32.10N	80-21.24W	22.48		529.4	363.4	355.6	173.9
14	7/11/1996	193.1320	27-32.10N	80-21.24W	22.46		530.1	363.4	355.6	174.5
15	7/11/1996	193.1343	27-32.10N	80-21.30W	22.45		530.7	363.4	355.6	175.1
16	7/11/1996	193.1454	27-32.10N	80-21.30W	22.42		532.8	363.4	355.6	177.2
17	7/11/1996	193.1477	27-32.10N	80-21.24W	22.42		532.8	363.4	355.6	177.2
18	7/11/1996	193.1500	27-32.10N	80-21.24W	22.42		533.2	363.4	355.6	177.6
19	7/11/1996	193.1523	27-32.10N	80-21.24W	22.41		533.6	363.4	355.6	178.0
20	7/11/1996	193.1546	27-32.10N	80-21.30W	22.44		534.0	363.4	355.6	178.4
21	7/11/1996	193.1569	27-32.10N	80-21.30W	22.51		534.2	363.4	355.6	178.6
22	7/11/1996	193.1592	27-32.10N	80-21.30W	22.52		534.6	363.4	355.6	179.0
23	7/11/1996	193.1615	27-32.10N	80-21.30W	22.57		534.7	363.4	355.5	179.1
24	7/11/1996	193.5724	27-27.60N	80-19.38W	23.18		546.8	363.4	355.2	191.7
25	7/11/1996	193.5747	27-27.60N	80-19.38W	23.21		546.2	363.4	355.2	191.1
448	7/13/1996	195.7444	34-32.82N	76-44.94W	25.63		445.3	363.0	353.0	92.3
449	7/13/1996	195.7467	34-33.06N	76-44.70W	25.63		446.5	363.0	353.0	93.5
450	7/13/1996	195.7577	34-34.92N	76-43.44W	25.75		452.1	363.0	352.9	99.2
451	7/13/1996	195.7600	34-35.34N	76-43.20W	25.78		453.3	363.0	352.9	100.4
452	7/13/1996	195.7623	34-35.70N	76-42.90W	25.86		455.3	363.0	352.8	102.5
453	7/13/1996	195.7647	34-36.06N	76-42.66W	25.94		457.1	363.0	352.8	104.3
454	7/13/1996	195.7669	34-36.42N	76-42.36W	25.95		458.4	363.0	352.8	105.6
455	7/13/1996	195.7693	34-36.78N	76-42.12W	26.00		459.5	363.0	352.7	106.8
456	7/13/1996	195.7715	34-37.20N	76-41.88W	26.02		460.4	363.0	352.7	107.7
457	7/13/1996	195.7739	34-37.50N	76-41.52W	26.06		462.1	363.0	352.7	109.4

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Source File = OMP_SFCR LDEO Leg No: 6 Ship: R/V Seward Johnson Page 6

pCO2 of air calculated from the GlobalView CO2 Database VCO2 of dry air
assuming 100% relative humidity at the sea/air interface.

Seawater pCO2 is reported at Sea Surface Temperature.

Only the first 20 and last 10 records of each leg are printed.

Sta No.	Date MM/DD/YYYY	Julian Date	Lat DD-MM.mm	Long DDD-MM.mm	Sea Surface Temp Deg C	Sal PSS	Seawater pCO2 uatm	Atmosphere VCO2 ppm	Atmosphere pCO2 uatm	Delta pCO2 sw-air uatm
1	7/19/1996	201.6051	35-30.12N	75-23.64W	24.65		421.0	362.9	352.2	68.8
2	7/19/1996	201.6074	35-30.18N	75-23.64W	24.67		393.3	362.9	352.2	41.0
3	7/19/1996	201.6097	35-30.06N	75-23.88W	24.68		382.3	362.9	352.2	30.1
4	7/19/1996	201.6120	35-30.06N	75-24.12W	24.61		377.2	362.9	352.2	24.9
5	7/19/1996	201.6143	35-30.06N	75-24.12W	24.60		373.6	362.9	352.2	21.4
6	7/19/1996	201.6166	35-30.12N	75-24.06W	24.52		373.4	362.9	352.2	21.2
7	7/19/1996	201.6190	35-30.12N	75-24.00W	24.60		373.5	362.9	352.2	21.3
8	7/19/1996	201.6213	35-30.12N	75-23.88W	24.62		371.9	362.9	352.2	19.6
9	7/19/1996	201.6323	35-30.12N	75-24.30W	24.44		366.5	362.9	352.2	14.3
10	7/19/1996	201.6346	35-30.12N	75-24.18W	24.44		364.0	362.9	352.2	11.7
11	7/19/1996	201.6369	35-30.00N	75-24.18W	24.48		363.2	362.9	352.2	10.9
12	7/19/1996	201.6392	35-30.06N	75-24.12W	24.48		363.4	362.9	352.2	11.1
13	7/19/1996	201.6416	35-30.06N	75-24.12W	24.46		362.3	362.9	352.2	10.0
14	7/19/1996	201.6439	35-30.18N	75-24.12W	24.48		361.5	362.9	352.2	9.2
15	7/19/1996	201.6462	35-30.18N	75-24.06W	24.48		361.1	362.9	352.2	8.9
16	7/19/1996	201.6485	35-30.12N	75-24.00W	24.52		360.8	362.9	352.2	8.6
17	7/19/1996	201.6595	35-29.82N	75-24.12W	24.39		365.7	362.9	352.2	13.5
18	7/19/1996	201.6618	35-29.70N	75-24.24W	24.34		367.7	362.9	352.2	15.5
19	7/19/1996	201.6642	35-29.70N	75-24.30W	24.31		370.0	362.9	352.2	17.7
20	7/19/1996	201.6664	35-29.64N	75-24.36W	24.28		371.3	362.9	352.2	19.0
2215	7/27/1996	209.1330	36-41.64N	75-17.94W	23.66		395.7	362.0	352.4	43.3
2216	7/27/1996	209.1353	36-41.94N	75-18.72W	23.65		393.3	362.0	352.4	40.9
2217	7/27/1996	209.1463	36-43.32N	75-22.14W	23.66		376.7	362.0	352.4	24.3
2218	7/27/1996	209.1487	36-43.56N	75-22.92W	23.68		377.5	362.0	352.4	25.1
2219	7/27/1996	209.1509	36-43.80N	75-23.64W	23.69		410.6	362.0	352.4	58.2
2220	7/27/1996	209.1533	36-44.04N	75-24.42W	23.68		424.5	362.0	352.4	72.1
2221	7/27/1996	209.1555	36-44.28N	75-25.14W	23.67		430.6	362.0	352.4	78.2
2222	7/27/1996	209.1579	36-44.46N	75-25.92W	23.68		433.8	362.0	352.4	81.4
2223	7/27/1996	209.1602	36-44.70N	75-26.58W	23.65		436.1	362.0	352.4	83.8
2224	7/27/1996	209.1625	36-44.88N	75-27.36W	23.63		442.7	362.0	352.4	90.3

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Source File = OMP_SFCR LDEO Leg No: 7 Ship: R/V Oceanus Page 7

pCO2 of air calculated from the GlobalView CO2 Database VCO2 of dry air
assuming 100% relative humidity at the sea/air interface.

Seawater pCO2 is reported at Sea Surface Temperature.

Only the first 20 and last 10 records of each leg are printed.

Sta No.	Date MM/DD/YYYY	Julian Date	Lat DD-MM.mm	Long DDD-MM.mm	Sea Surface Temp Deg C	Sal PSS	Seawater pCO2 uatm	Atmosphere VCO2 ppm	Atmosphere pCO2 uatm	Delta pCO2 sw-air uatm
1	10/ 7/1996	281.5683	41-19.86N	70-53.40W	15.67	31.013	448.4	359.2	354.5	93.9
2	10/ 7/1996	281.5706	41-19.14N	70-53.34W	15.68	31.009	405.4	359.2	354.5	50.9
3	10/ 7/1996	281.5729	41-18.42N	70-53.34W	15.70	31.011	383.8	359.2	354.5	29.3
4	10/ 7/1996	281.5753	41-17.76N	70-53.40W	15.64	31.005	376.3	359.2	354.5	21.7
5	10/ 7/1996	281.5776	41-16.98N	70-53.40W	15.50	30.999	378.0	359.2	354.6	23.4
6	10/ 7/1996	281.5799	41-16.20N	70-53.40W	15.47	30.968	370.8	359.2	354.6	16.2
7	10/ 7/1996	281.5822	41-15.54N	70-53.34W	15.47	30.955	363.0	359.2	354.6	8.4
8	10/ 7/1996	281.5845	41-14.70N	70-53.28W	15.47	30.960	362.0	359.2	354.6	7.4
9	10/ 7/1996	281.5955	41-11.34N	70-52.38W	15.37	31.003	367.3	359.2	354.6	12.7
10	10/ 7/1996	281.5978	41-10.68N	70-52.02W	15.27	31.015	382.0	359.2	354.7	27.3
11	10/ 7/1996	281.6002	41- 9.96N	70-51.66W	15.26	31.059	397.2	359.2	354.7	42.5
12	10/ 7/1996	281.6025	41- 9.24N	70-51.36W	15.10	31.055	404.7	359.2	354.7	50.0
13	10/ 7/1996	281.6048	41- 8.52N	70-50.88W	15.11	31.074	421.8	359.2	354.7	67.0
14	10/ 7/1996	281.6071	41- 7.86N	70-50.58W	14.95	31.184	431.5	359.2	354.8	76.7
15	10/ 7/1996	281.6094	41- 7.26N	70-50.22W	14.76	31.186	435.1	359.2	354.9	80.2
16	10/ 7/1996	281.6117	41- 6.54N	70-49.86W	14.77	31.189	432.1	359.2	354.9	77.3
17	10/ 7/1996	281.6228	41- 3.18N	70-48.06W	14.31	31.301	425.3	359.2	355.0	70.2
18	10/ 7/1996	281.6251	41- 2.64N	70-47.82W	14.20	31.337	426.9	359.2	355.1	71.8
19	10/ 7/1996	281.6274	41- 1.92N	70-47.46W	14.14	31.343	432.1	359.2	355.1	77.0
20	10/ 7/1996	281.6297	41- 1.26N	70-47.10W	14.06	31.341	430.0	359.2	355.1	74.8
2615	10/17/1996	291.4066	41-10.80N	70-53.04W	14.96	30.950	380.7	360.1	355.7	25.0
2616	10/17/1996	291.4089	41-11.34N	70-53.10W	14.96	30.947	382.3	360.1	355.7	26.6
2617	10/17/1996	291.4200	41-13.98N	70-53.10W	14.94	30.902	397.1	360.1	355.7	41.4
2618	10/17/1996	291.4223	41-14.70N	70-53.16W	14.97	30.920	398.1	360.1	355.7	42.4
2619	10/17/1996	291.4246	41-15.36N	70-53.16W	15.01	30.890	396.9	360.1	355.7	41.2
2620	10/17/1996	291.4269	41-16.02N	70-53.10W	14.94	30.931	394.1	360.1	355.7	38.5
2621	10/17/1996	291.4293	41-16.80N	70-53.10W	15.06	30.927	395.7	360.1	355.6	40.1
2622	10/17/1996	291.4315	41-17.40N	70-53.10W	15.08	30.902	395.7	360.1	355.6	40.1
2623	10/17/1996	291.4339	41-18.06N	70-53.10W	15.01	30.916	393.1	360.1	355.7	37.5
2624	10/17/1996	291.4362	41-18.78N	70-53.10W	15.01	30.935	394.8	360.1	355.7	39.1

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Source File = OMP_SFCR LDEO Leg No: 8 Ship: R/V Oceanus Page 8

pCO2 of air calculated from the GlobalView CO2 Database VCO2 of dry air
assuming 100% relative humidity at the sea/air interface.

Seawater pCO2 is reported at Sea Surface Temperature.

Only the first 20 and last 10 records of each leg are printed.

Sta No.	Date MM/DD/YYYY	Julian Date	Lat DD-MM.mm	Long DDD-MM.mm	Sea Surface Temp Deg C	Sal PSS	Seawater pCO2 uatm	Atmosphere VCO2 ppm	pCO2 uatm	Delta pCO2 sw-air uatm
1	4/18/1994	108.9391	41- 6.78N	70-21.12W	6.38	32.053	309.8	363.9	361.9	-52.1
2	4/18/1994	108.9414	41- 6.48N	70-21.06W	6.40	31.941	309.5	363.9	361.9	-52.4
3	4/18/1994	108.9437	41- 5.70N	70-21.06W	6.40	32.040	309.0	363.9	361.9	-52.9
4	4/18/1994	108.9460	41- 4.80N	70-21.06W	6.45	32.031	309.7	363.9	361.9	-52.2
5	4/18/1994	108.9483	41- 4.38N	70-21.06W	6.44	32.023	309.2	363.9	361.9	-52.7
6	4/18/1994	108.9506	41- 3.48N	70-21.00W	6.43	32.044	309.2	363.9	361.9	-52.7
7	4/18/1994	108.9603	41- 0.48N	70-21.06W	6.26	32.133	301.0	363.9	362.0	-61.0
8	4/18/1994	108.9626	40-59.58N	70-21.06W	6.10	32.269	300.4	363.9	360.9	-60.5
9	4/18/1994	108.9649	40-59.22N	70-21.06W	5.97	32.210	300.4	363.9	360.9	-60.5
10	4/18/1994	108.9672	40-58.32N	70-21.06W	5.92	32.211	303.6	363.9	360.9	-57.3
11	4/18/1994	108.9695	40-57.48N	70-21.12W	5.74	32.276	304.7	363.9	360.9	-56.2
12	4/18/1994	108.9718	40-57.24N	70-21.06W	5.58	32.189	304.8	363.9	360.9	-56.1
13	4/18/1994	108.9816	40-56.94N	70-20.94W	5.67	32.224	307.3	363.9	360.9	-53.6
14	4/18/1994	108.9839	40-56.94N	70-20.88W	5.67	32.341	306.6	363.9	360.9	-54.3
15	4/18/1994	108.9862	40-56.94N	70-21.00W	5.67	32.210	306.3	363.9	360.9	-54.6
16	4/18/1994	108.9885	40-57.00N	70-20.94W	5.66	32.222	307.0	363.9	360.9	-53.9
17	4/18/1994	108.9907	40-57.00N	70-20.88W	5.66	32.229	307.2	363.9	360.9	-53.7
18	4/18/1994	108.9930	40-57.00N	70-20.88W	5.67	32.232	307.1	363.9	360.9	-53.8
19	4/19/1994	109.0028	40-57.00N	70-20.94W	5.64	32.225	306.5	363.9	360.9	-54.4
20	4/19/1994	109.0051	40-57.06N	70-20.88W	5.61	32.229	306.3	363.9	360.9	-54.6
3055	5/ 1/1994	121.5124	41-28.80N	70-32.04W	9.03	31.319	390.6	364.0	361.4	29.3
3056	5/ 1/1994	121.5148	41-29.04N	70-33.06W	8.93	31.327	390.5	364.0	361.4	29.1
3057	5/ 1/1994	121.5171	41-29.22N	70-34.14W	8.88	31.346	389.9	364.0	361.4	28.5
3058	5/ 1/1994	121.5194	41-29.34N	70-34.68W	8.80	31.389	390.3	364.0	361.4	28.9
3059	5/ 1/1994	121.5292	41-30.12N	70-38.64W	9.40	31.179	399.9	364.0	361.3	38.7
3060	5/ 1/1994	121.5315	41-30.30N	70-39.84W	9.68	31.136	404.7	364.0	361.2	43.5
3061	5/ 1/1994	121.5338	41-30.72N	70-40.26W	10.04	31.001	411.9	364.0	361.1	50.8
3062	5/ 1/1994	121.5361	41-31.02N	70-40.26W	9.88	30.986	404.3	364.0	361.1	43.2
3063	5/ 1/1994	121.5384	41-31.38N	70-40.32W	9.60	31.060	400.0	364.0	361.2	38.8
3064	5/ 1/1994	121.5407	41-31.44N	70-40.32W	9.95	30.915	405.1	364.0	361.1	44.0

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Source File = OMP_SFCR LDEO Leg No: 9 Ship: R/V Gyre & Columbus Iselin Page 9

pCO2 of air calculated from the GlobalView CO2 Database VCO2 of dry air
assuming 100% relative humidity at the sea/air interface.

Seawater pCO2 is reported at Sea Surface Temperature.

Only the first 20 and last 10 records of each leg are printed.

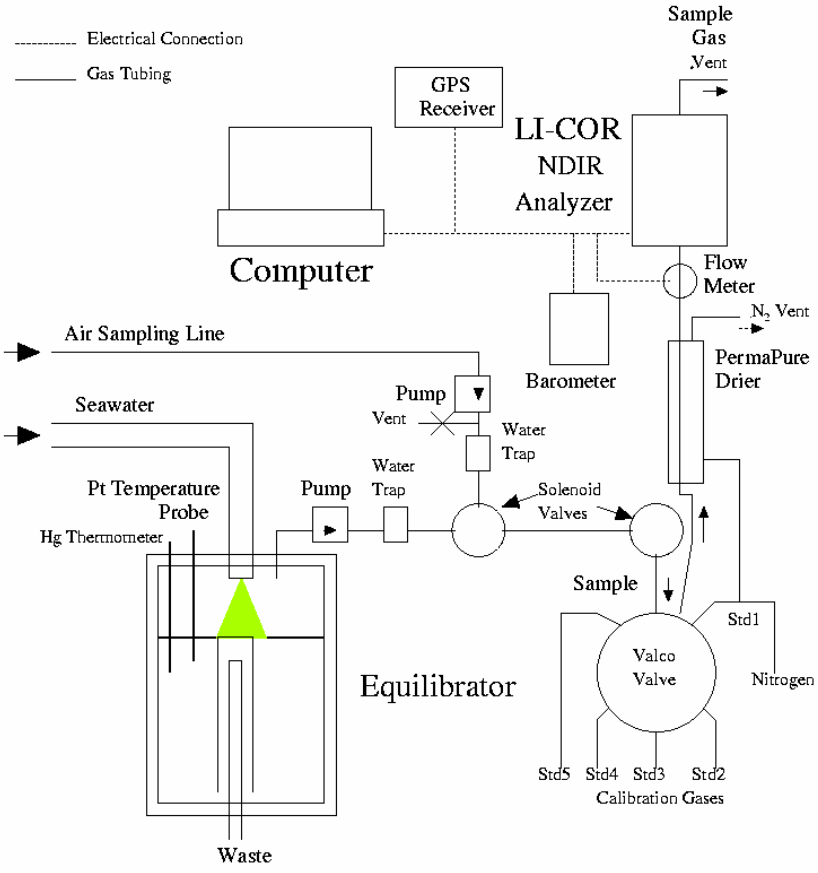
Sta No.	Date MM/DD/YYYY	Julian Date	Lat DD-MM.mm	Long DDD-MM.mm	Sea Surface Temp Deg C	Sal PSS	Seawater pCO2 uatm	Atmosphere VCO2 ppm	Atmosphere pCO2 uatm	Delta pCO2 sw-air uatm
1	5/11/1993	131.4670	35-33.48N	75-21.90W	18.06		359.6	361.4	353.6	6.0
2	5/11/1993	131.4693	35-33.00N	75-22.20W	17.87		354.3	361.4	353.6	0.8
3	5/11/1993	131.4716	35-32.52N	75-22.50W	17.62		352.9	361.4	353.6	-0.7
4	5/11/1993	131.4739	35-32.04N	75-22.80W	16.96		351.0	361.4	353.6	-2.6
5	5/11/1993	131.4762	35-31.56N	75-23.16W	16.68		345.9	361.4	353.6	-7.7
6	5/11/1993	131.4785	35-31.08N	75-23.46W	16.70		340.6	361.4	353.6	-13.0
7	5/11/1993	131.4808	35-30.60N	75-23.76W	16.75		334.7	361.4	353.6	-18.9
8	5/11/1993	131.4831	35-30.24N	75-23.94W	16.77		331.6	361.4	353.6	-22.0
10	5/11/1993	131.4926	35-30.06N	75-24.12W	16.58		339.8	361.4	353.6	-13.8
11	5/11/1993	131.4949	35-30.00N	75-24.12W	16.38		346.9	361.4	353.6	-6.7
12	5/11/1993	131.4972	35-30.00N	75-24.12W	16.41		352.2	361.4	353.6	-1.4
13	5/11/1993	131.4995	35-30.00N	75-24.12W	16.43		355.8	361.4	353.6	2.2
14	5/11/1993	131.5018	35-30.00N	75-24.12W	16.46		359.0	361.4	353.6	5.4
15	5/11/1993	131.5041	35-30.00N	75-24.12W	16.51		360.2	361.4	353.6	6.6
16	5/11/1993	131.5064	35-30.00N	75-24.12W	16.46		361.0	361.4	353.6	7.4
17	5/11/1993	131.5087	35-30.00N	75-24.12W	16.48		360.7	361.4	353.6	7.1
19	5/11/1993	131.5182	35-30.00N	75-24.06W	16.48		357.9	361.4	353.6	4.4
20	5/11/1993	131.5205	35-30.00N	75-24.06W	16.48		360.7	361.4	353.6	7.1
21	5/11/1993	131.5229	35-30.06N	75-24.06W	16.52		364.1	361.4	353.6	10.5
22	5/11/1993	131.5252	35-30.06N	75-24.06W	16.46		367.5	361.4	353.6	14.0
1531	5/16/1993	136.3976	36-54.06N	75-52.38W	17.21		183.1	360.9	355.0	-172
1532	5/16/1993	136.3999	36-54.36N	75-52.92W	17.51		166.4	360.9	355.0	-189
1534	5/16/1993	136.4095	36-55.68N	75-55.20W	17.82		123.7	360.9	355.0	-231
1535	5/16/1993	136.4118	36-55.98N	75-55.74W	17.85		118.2	360.9	355.0	-237
1536	5/16/1993	136.4141	36-56.16N	75-56.16W	17.95		113.9	360.9	355.0	-241
1537	5/16/1993	136.4164	36-56.28N	75-56.52W	18.10		110.2	360.9	355.0	-245
1538	5/16/1993	136.4187	36-56.46N	75-57.12W	18.20		106.9	360.9	355.0	-248
1539	5/16/1993	136.4210	36-56.64N	75-57.78W	18.24		104.5	360.9	355.0	-250
1540	5/16/1993	136.4233	36-56.76N	75-58.44W	18.26		103.0	360.9	355.0	-252
1541	5/16/1993	136.4257	36-56.88N	75-59.04W	18.31		102.1	360.9	355.0	-253

3. MEASUREMENTS OF pCO_2 IN SURFACE WATERS

3-a) The LDEO Underway System for Surface Water pCO_2 Measurements:

The system for underway measurements of pCO_2 in surface waters consists of a) a water-air equilibrator, b) a non-dispersive infra-red CO_2 gas analyzer and c) a data logging system. The measurement system is schematically shown in Fig. 1, and is similar with the one described in Bates et al. (1998). Each of these units and the data reduction procedures used will be described below.

Figure 2 - The underway pCO_2 system used for the measurements of pCO_2 in surface waters during the Ocean Margins Program.



3-b) Water-air Equilibrator:

The equilibrator has a total volume of about 30 liters and is equipped with a specially designed drain which maintains automatically the level of water in the equilibrator at a constant level at about half the height of the equilibrator leaving about 15 liters of headspace. Seawater

from the ship's uncontaminated water line is continuously pumped into the equilibrator at a rate of about 10 liters/min, giving a mean residence time of water in the equilibrator of about 1.5 minutes. The headspace above the water serves as an equilibration chamber. A carrier gas (commonly marine air) is drawn into the chamber by a diaphragm pump, and exchanges CO_2 with a continuous flow of seawater sprayed into the chamber through a shower head. Because of large gas-water contact areas created by fine water droplets as well as gas bubbles in the pool of water, CO_2 equilibration between the carrier gas and seawater is achieved rapidly with a e-folding time of 2 to 3 minutes. Under normal operating conditions, the carrier gas in the equilibration chamber is pumped into the infra-red gas analyzer at a rate of about 50 ml/min. At this rate, the residence time of the carrier gas in the equilibration chamber is about 300 minutes, that is about 100 times as long as the equilibration time. Therefore, the carrier gas in the head space is always in equilibrium with water. The over all response time of the equilibrator system has been estimated to be of an order of several minutes. The large volume of water in the equilibrator is chosen in order to have a large thermal inertia of the equilibrator, so that the effects of room temperature changes on the equilibration temperature may be minimized. The temperature of water in the equilibrator is monitored continuously using a Guildline platinum resistance thermometer (readable to 0.05 ^oC) and recorded on the data logging computer. A calibrated mercury thermometer is also inserted in the equilibrator for testing the performance of the platinum thermometer.

At the gas intake end of the equilibrator, a flow indicator based on U-tube manometer is attached. This gives a visual confirmation for the fact that marine air is taken into the equilibration chamber at a desired flow rate. Since we operate the system with the equilibration chamber at the same pressure as the ambient room pressure, the total pressure, at which the gas was equilibrated, is measured using a precision electronic barometer (Setra Model 270, Acton, MA) outside the equilibrator. This equilibration pressure is also logged on the computer.

The temperature and salinity of seawater at the in-situ conditions were measured using a SeaBird Model SBE-21 thermosalinograph aboard Oceanus, Endeavor, and Seward Johnson. The precision of the reported temperature data has been estimated to be about 0.005 ^oC.

3-c) Infra-red CO_2 Gas Analyzer:

The equilibrated gas was passed through a water trap (to collect aerosols and condensates), mass flow controller and a reverse flow naphion dryer (PermaPure flushed with pure nitrogen gas) to remove water vapor (to a level of -20^oC), and was introduced into the IR sample cell at a rate of about 50 ml/min for CO_2 determinations. A LI-COR infra-red gas analyzer (Model 6251, Lincoln, NB) was used. After about 3 minutes of purging period, the gas flow was stopped and readings were recorded on the computer. Although an electronic circuit was provided by the manufacturer in order to linearize the CO_2 response, it exhibited a few inflexions that deviated from linearity by a few ppm. Therefore, we chose not to use the outputs from the linearization circuit supplied by the manufacturer. Instead, we used five standard gas mixtures (one pure nitrogen and four CO_2-air mixtures) during the expeditions, and established response curves using the raw output from the analyzer. The CO_2 concentrations in the gas mixtures were calibrated using the SIO standards determined by C. D. Keeling's group using the manometric method. The concentrations of CO_2 in the standard gas mixtures are summarized in Table 2.

Table 2 - Concentrations of CO_2 in the CO_2-air gas mixtures using during the OMP Expeditions, 1993-1996. The values are in ppm mole fraction of CO_2 in dry air, and have a precision of about $\pm$ 0.1 ppm. Std. 1 is pure nitrogen gas and has a CO_2 concentration of 0.00 ppm.

Ship/Cruise (LDEO #)	Dates	CO_2 concentrations (ppm)			
		Std. 2	Std 3	Std 4	Std5
R/V Gyre & Columbus Iselin (9)	05/11/93-05/16/93				
R/V Oceanus (8)	04/18/94-05/01/94	157.29	346.74	855.52	471.60
R/V Oceanus (1)	02/01/96-02/16/96	236.29	364.25	105.20	493.72
R/V Endeavor (2)	03/01/96-03/21/96	233.84	366.52	109.95	495.18
R/V Oceanus (3)	05/06/96-05/17/96	236.29	364.25	105.20	493.72
R/V S. Johnson (4)	06/22/96-06/30/96	236.29	364.25	105.20	493.72
R/V S. Johnson (5)	07/11/96-07/13/96	236.29	364.25	105.20	493.72
R/V S. Johnson (6)	07/19/96-07/27/96	236.29	364.25	105.20	493.72
R/V Oceanus (7)	10/07/96-10/17/96	236.29	364.25	105.20	493.72

During normal operations, each of the standard gas mixtures was passed through the analyzer for 70 to 90 seconds at a rate of about 60 ml/min. This replaced the IR analyzer cell completely with the new gas. The flow was stopped for 5 seconds and then a millivolt reading from the analyzer was taken and recorded. Samples of equilibrated air and marine air were pumped through the analyzer for 180 seconds (3 minutes) at a rate of about 50 ml/min to purge the previous sample in the IR cell. The flow was stopped for 5 seconds and a reading for the analyzer output was recorded. This procedure was intended to eliminate errors due to fluctuations of the dynamic pressure within the IR cell by irregular gas flow rates. The slow flow rates used for samples were required for the removal of water vapor using the PermaPure membrane dryer. Between two sets of calibration runs using the five standard gases, 6 to 20 samples were analyzed depending upon the stability of the IR analyzer.

3-d) Data Logging System:

The following values were recorded on a laptop computer. The sample locations were derived from a GPS positioning unit that is a part of our surface water pCO_2 system. The CO_2 readings for samples were recorded once every 3 minutes (180 seconds), and those for the standard gas mixtures once every 1.5 minutes.

Date,
Time (GMT),
Latitude,
Longitude,
Sample ID (standard gas cylinder numbers, seawater CO_2, atmospheric CO_2)
Barometric pressure in the laboratory (to 0.1 mb)
IR cell temperature,
Gas flow rate in the IR cell (to 0.1 ml/min),
Temperature of equilibration (to 0.01 ^oC),
Analyzer output (millivolts to 0.1 mv)
CO_2 concentration in dry gas sample (preliminary based on the last response curve), and
pCO_2 (preliminary value based on the last response curve).

3-e) Data Reduction Procedures:

The concentration of CO_2 in the sample was computed in the following way based on the millivolt reading and time of the reading. The millivolt reading taken for each of the five standard gases at the time of sample measurement was computed by linearly interpolating as a function of time using the readings taken before and after the respective standard gases were analyzed. This yields millivolt reading for each of the five standard gases at the time when the sample was analyzed. These five values were fit to a quadratic equation . This serves as the response curve. The CO_2 concentration in the sample was computed using the response curve that was established at the time of each sample analysis. The method described above yields atmospheric CO_2 values that are consistent with those reported for the South Pole and the Cape Grim by the Climate Monitoring and Diagnostics Laboratory/NOAA in Boulder, CO.

The partial pressure of CO_2 in seawater, $(pCO_2)sw$, at the temperature of equilibration, Teq, in the unit of microatmospheres (μatm) was computed using the concentration of CO_2 in dried equilibrated air $(VCO_2)eq$ in the following expression:

$$(pCO_2)sw \text{ @ } Teq = (Vco_2)eq \times (Pb - Pw), \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

$(Vco_2)eq$ = the mole fraction concentration (ppm) of CO_2 in the dried equilibrated carrier gas;
Pb = the barometric pressure (that is equal to the total pressure of equilibration) in atmospheres; and
Pw = the equilibrium water vapor pressure in atmospheres at Teq (^oC) and salinity.

The water vapor pressure was computed using the following formulation;

$$Pw\ (atm) = (1/760)x(1 - 5.368x10^{-4}x\ Sal) \\ x\ EXP\{[0.0039476 - (1/TK)]/1.8752x10^{-4}\},\ .....\ [2]$$

where Sal is salinity on the Practical Salinity Scale measured using the ship's thermosalinograph, and TK is the temperature of equilibration in ^{o}K.

The $(pCO_2)sw$ at the in-situ temperature, was computed using a constant value of 0.0423 % per ^{o}C for the effect of temperature (Takahashi et al., 1993):

$$(pCO_2)sw\ @\ T\ in\text{-}situ\ = (pCO_2)sw\ @\ Teq\ x\ EXP[0.0423\ x\ (Tin\text{-}situ - Teq)].\ \ldots[3]$$

The value for Tin-situ is taken to be the seawater temperature measured by the ship's thermosalinograph at the time of pCO_2 measurements. Teq is generally warmer than Tin-situ by 0.5 ~ 0.8 ^{o}C. Hence the temperature correction is normally less than 3% of pCO_2 values.

The over all precision of the reported $pCO_2)sw$ values has been estimated to be about $\pm$1.5 μatm.

4. MEASUREMENTS OF pCO_2 IN THE ATMOSPHERE AND SEA-AIR pCO_2 DIFFERENCE

4-a) Measurements:

The air measurement system is shown schematically in Fig. 1. Uncontaminated marine air samples were collected about 10 m above the sea surface using a DEKORON tubing (1/4" i.d., Calco Inc., PA), a thin-wall aluminum tubing protected by plastic outside casing. The intake was located at the middle of the foremast about 10 m above the sea surface. A KNF Neuberger air pump that was located near the IR analyzer was used to pump air through the tubing and into the IR analyzer. Even when air samples were not analyzed, the pump was on all the time to keep the air flowing through the sampling line. For the analysis, the air sample was passed through a water trap and a drying column to remove water vapor (the same PermaPure column as used for the equilibrated gas) and introduced into the IR cell for CO_2 analysis at a rate of about 50 ml/min. After 3 minutes of purging the cell, the flow was stopped for 5 seconds and the IR millivolt output reading was recorded.

4-b) Data Processing:

The partial pressure of CO_2 in the air, (pCO_2)air, was computed in the unit of microatmospheres (μatm) in the same way as that for seawater using Eq. [4] below:

$$(pCO_2)air = (Vco_2)air \times (Pb - Pw), \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [4]$$

(Vco_2)air = the mole fraction concentration (ppm) of CO_2 in the dried air sample;
Pb = the barometric pressure at sea surface in atmospheres; and
Pw = the equilibrium water vapor pressure in atmospheres at T in-situ (^oC) and salinity given by Eq. [2].

The precision of the atmospheric pCO_2 values have been estimated to be about ± 1 μatm.

4-c) Results:

The results of our measurements were used for internal quality control purposes only, and are not reported here. Due to the small size of the ships involved in this program, we were unable to eliminate stack-gas contamination of our intake. Furthermore, being down wind from the northeastern United States and the large industrial and vehicle CO_2 emissions seems to have contributed to excessive local variations we could not eliminate.

4-d) Sea-air pCO_2 difference:

Since the atmospheric CO_2 concentrations measured aboard the ships during the project are not representative values for the marine air over our study areas as discussed above, we have used the weekly zonal mean concentrations of atmospheric CO_2 in marine boundary layer reported in the GLOBALVIEW-CO2 (2000). The pCO_2 in marine air has been computed using Eq. [4], in which the following were used: (1) climatological mean barometric pressure from Atlas of Surface Marine data (1994), (2) the observed SST, (3) the observed salinity when available, or an estimated salinity of 35.0. The sea-air pCO_2 difference, delta pCO_2 sw-air, reported in the data table has been computed by subtracting the atmospheric pCO_2 thus computed from the seawater pCO_2 obtained using Eq. [3].

5. SALINITY MEASUREMENTS:

The salinity data reported here were obtained from the shipboard analytical system. Each of the five ships has a slightly different system, maintained in five different ways. Since we have not been able to verify the quality of these data, we report them as they were provided to us aboard the ship.

6. REFERENCES CITED

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APPENDIX I.

Email Letter of Acknowledgement for CDIAC submittal:

Subject: Re: OMP Data Revision & Methods
Date: Fri, 4 May 2001 11:22:02 -0400 (EDT)
From: Alexander Kozyr 1000 ms6335 40390 <ako@akosun.sdi.utk.edu>
To: suth@ldeo.columbia.edu

Dear Stew,
Thank you for the data. I received the revised omp_pco2.rev1.txt file for Ocean
Margins Program data. It consists of 9 legs (total 22, 355 records). I am planning to perform the CDIAC QA-QC procedure and put this file along with the
methods information on CDIAC web site for public use.
Regards,
Alex.
****

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Ocean CO2 WWW Page: http://cdiac.esd.ornl.gov/oceans/home.html
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