MASTER

INTERIM REPORT

TO THE DEPARTMENT OF ENERGY

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CARBON DIOXIDE IN ARCTIC AND SUBARCTIC REGIONS

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This is our first interim report to the Department of Energy under this contract number (80EV10429). We reported last year through the Office of Naval Research (Code 461). We had had a long standing Arctic research contract program with ONR and through that agency last year we received phase-in funds from the Department of Energy.

We have completed our investigation of sea surface water PCO_2 between Greenland and Franz Joseph's Land. This was conducted in conjunction with the Swedish sponsored arctic expedition YMER-80 during the summer of 1980.

A copy of the cruise report is attached.

As a result of that cruise we:

- (1) confirmed our earlier observations of extensive low partial pressures of CO_2 (ca. 180-220 ppm) in surface waters in that region (Kelley 1973).
- (2) showed that the very low partial pressures extend farther north (ca. 82°N) and to the west (ca. 5°W) (see map in cruise report and cruise track data.
- (3) obtained estimates as to how deep these very low partial pressures (ca. 20 m) and the equilibrium depth (ca. 130 m) penetrate (see cruise report).
- (4) confirmed a new simple empirical method for the determination of PCO_2 in sea water (Technical paper in preparation).
- (5) obtained an estimate for the invasion rate of CO_2 across cold Arctic surface waters ($0.078 \text{ m moles atm}^{-1} \text{ cm}^{-2} \text{ min}^{-1}$).
- (6) have estimated the Barents-Kara-Laptev Norwegian Seas area as enormously strong sinks, absorbing ca. $2 \times 10^{15} \text{ g CO}_2$ during the summer months alone.
- (7) can now estimate that the Arctic is an annual set sink of $1 \times 10^{15} \text{ g CO}_2$ per year and that a large portion of its annual variations are naturally occurring. (Technical paper in preparation).

At the present time we are engaged in repairing our old equipment, obtaining and calibrating our new equipment, and preparing for two more field events before the end of our first fiscal year of support under this contract. One field trip is to observe tundra and taiga surface CO₂ emissions during spring breakup to confirm our earlier evidence of substantial release of gases from those soils during that period of time, e.g. Coyne and Kelley 1971 and 1973, Gosink and Kelley 1978 and Gosink and Kelley 1979. The second field trip is to be into the north Bering Sea edge during spring thaw.

REFERENCES

1. Coyne, P.I. and J. J. Kelley, 1971. Release of carbon dioxide from frozen soil to the arctic atmosphere. *Nature*, 234, 407-408.
2. Coyne, P. I. and J. J. Kelley, 1974. Variations of carbon dioxide across an arctic snowpack during spring. *J. Geophys. Res.*, 79, 799-802.
3. Gosink, T. A. and J. J. Kelley, 1978. Annual report to the Office of Naval Research, Code 461. From the Inst. of Mar. Sci. Univ. of Alaska, Fairbanks.
4. Gosink, T. A. and J. J. Kelley, 1979. Carbon monoxide evolution from Arctic surface during spring thaw. *J. Geophys. Res.*, 84, 7041.
5. Kelley, J. J., 1973. Carbon dioxide in surface waters of the North Atlantic Ocean, the Barents and Kara Seas. *Limnol. and Oceanog.*, 15 80-87.

CRUISE REPORT, YMER-80 LEG I & II, July-September 1980

Nitrous oxide data are presented in tabular form
Reduced, corrected cruise data for PCO_2 , temperature and salinity
are presented in graph form.

Activities

Nitrous oxide determination of surface waters at 15 stations on 3 transects were completed during Leg I. A few comparison measurements were also made during Leg II.

Partial pressures of carbon dioxide in the air and in surface waters were measured over the entire area covered by Leg II.

Partial pressures of CO_2 in surface waters for Leg I, were calculated from pH data from that period, and verified during Leg II.

Routine observations of the in situ pH temperature, and salinity of surface waters were recorded during both Leg I and Leg II.

Methods

pH and temperature measurements were made with a Corning Model 135 pH meter with a combination reference electrode. NBS standardized buffer solutions (4.01, 7.00, 9.12) were used for instrument calibration.

Salinity measurements were made with #4403 Electromark Digital Analyzer. Standardized sea water was used for calibration.

Nitrous oxide measurements were made on a Perkin Elmer Model 3920 gas chromatograph with electron capture device (ECD), using standardized ECD methods with a 2 m. Porapak Q column. A 1 ppm Matheson calibrated gas standard was utilized. Samples were collected using the vacuum expansion methods of Herr and Barger (1978).

Carbon dioxide measurements were made with a Perkin Elmer Model 3920 flame ionization detector (F 10) after methanization of the carbon dioxide. A 4' carbosieve B column with appropriate valving was used for restoring the CO₂. A Keeling international carbon dioxide standard (287 ppm) was used for calibration. Sample collection was achieved with a continuous countercurrent equilibrator as described by Gosink and Kelley (1978).

Results

The entire area covered by both legs I and II are markedly undersaturated with CO₂ in the water. Less so than any open waters of the Barents and Kara Seas, but still more than any open ocean areas at lower latitude. The undersaturation extends to a depth of about 75 meters, varies from 50 to 100 m and occasionally goes to a depth as great as 200 m. The only exception was the region in the vicinity of Nord, Greenland, 80°N 2.5°E.

Atmospheric carbon dioxide also decreased as one proceeded north, particularly in the vicinity of Greenland, and when the wind originated from maritime areas.

Late season carbon dioxide concentrations in the sea water seem to be essentially the same as the early season.

pH data are presented in only the broadest outlines. In general, the higher the pH the lower the PCO₂. The pH varied around 8.17±.03 for most of the cruise rising to 8.37±.02 during the deepest penetrations of the ice pack. There was a period between 27 and 31 July, during the trip from heavy ice NW of Franz Joséfs Land to about 50% open water southwest of Franz Josefs Land when the pH steadily rose from 8.2 to 8.5.

Unfortunately there was some reference electrode problems at that time, but two replacement electrodes provided similar high values. This high pH would agree with the extremely low partial pressures of CO_2 reported by Kelley over a decade ago for the Barents and Kara Seas.

Surface (1-20 m) nitrous oxide measurements for 35 observations is 16.8 ± 4.2 nmoles $\text{N}_2\text{O}/\text{L}$. The range was from 7.4 to 22.4 nmoles $\text{N}_2\text{O}/\text{L}$. Average temperature and salinity were -1.5°C and 31%. Intermediate depth waters ranged from 13-30 nmoles $\text{N}_2\text{O}/\text{L}$ and deep waters between 12 and 16 nmoles $\text{N}_2\text{O}/\text{L}$. Two stations near 79.3°N 36°E had unusually high values, up to ca. 50+nmoles $\text{N}_2\text{O}/\text{L}$.

Discussion

The normal range of partial pressure differences between the atmosphere and ocean CO_2 is on the order of ± 30 ppm, usually on the negative side. Kelley has already reported exceptionally low (-90 to -190 ppm) for the entire Barents and Kara Seas surface. Confirmation of these values was successfully achieved during Leg II. The probable cause of the extremely low PCO_2 values is cooling of warmer N. Atlantic waters rather than biological activity. A 10°C temperature drop in a body of water lowers its PCO_2 by about 140 ppm. If the water was already normally (biologically caused) low by 20-40 ppm, the net result would be to produce the extreme (-160 ppm) lows observed.

The arctic seas appear to be a major sink for atmospheric carbon dioxide during the brief summer period. As a preliminary estimate 0.3×10^{16} g of CO_2 may be absorbed in the region alone, and may represent the apparent missing sink for CO_2 .

Nitrous oxide concentrations are about normal for surface and deeper waters. The principal difference is again due to temperature differences. These polar ocean surface waters are not highly saturated with N_2O as at lower latitude (110-180%) but almost exactly saturated ($\pm 30\%$) with respect to air at 330 ppb. Nitrous oxide is a ubiquitously produced trace gas which influences stratospheric chemistry.

YMER-80 LEG I NITROUS OXIDE DATA

Date	Lat. (°N)	Long. (°E)	Depth (m)	nmoles N ₂ O/l	
13 July	81.0	23.0	0	7.4	
			15	20.3	
			22	21.1	
14 July	81.4	23.0	35	15.4	
			55	16.0	
			250	13.9	
			500	14.2	
			000	18.9	
			1500	14.4	
			2000	15.8	
			2500	15.8	
17 July	82.2	25.0	3230	15.0	
			all surface	16.3	
			samples	14.5	
			taken	13.3	
			from	14.3	
			around	15.2	
			melting	14.3	
			sea ice	13.4	
22 July	81.5	49.9		15.2	
				13.8	
				14.8	
			10	13.7	
			20	12.8	
			40	14	
29 July	80	38	50	13.4	
			75	13.5	
			100	13.3	
			all	20.7	29.4
			surface	21.4	30.2
			samples	17.9	32.4
			taken	18.4	31.4
			from	17.9	31.7
			around	21.8	31.4
			melting	19.9	27.9
			sea	17.9	26
			ice	17.7	28.5
				16.9	25.5

YMER-80 LEG I NITROUS OXIDE DATA

Date	Lat. ($^{\circ}$ N)	Long. ($^{\circ}$ E)	Depth (m)	nmoles $\text{N}_2\text{O}/\ell$
3 August	79.5	40	10	22.4
			20	22.2
			40	17.5
			50	22.2
			100	18.0
			125	20.0
			150	20.9
			200	19.6
3 August	79.7	44	275	21.2
			10	21.3
			20	18.2
			30	19.4
			40	18.8
			50	16.7
			75	16
			100	16
3 August	79.7	46	150	17
			10	19.4
			20	19.3
			30	17.6
			40	17.1
			50	20
			75	15.6
			100	18.3
4 August	75.5	22	125	18.5
			150	19.7
			200	17.5
			250	17.9
			10	22.4
			20	22.1
4 August	75.5	22	30	20.3
			40	22.9
			50	26.2
			65	23.6

YMER-80 LEG I NITROUS OXIDE DATA

Date	Lat. (°N)	Long. (°E)	Depth (m)	nmoles N ₂ O/l
4 August	75	20	10	16.1
			20	-
			30	19.7
			40	20.0
			50	19.3
			75	22.9
			100	24.0
			125	23.5
			150	21.0
			170	22.6
5 August	74	23	10	14.3
			20	16.7
			30	16.1
			40	17.8
			50	18.5
			75	17.8
			100	20.2
			150	19.9
			190	20.9
5 August	73	20	250	19.3
			440	20.0
			10	13.9
			20	18.0
			30	18.2
			40	14.2
			50	21.1
			150	15.9
			200	22.1
			300	21.7
			400	21.4

REFERENCES

GOSINK, T. and KELLEY, J.J. 1978 . ANNUAL REPORT TO THE OFFICE OF NAVAL RESEARCH CODE 461. INSTITUTE OF MARINE SCIENCE, UNIVERSITY OF ALASKA, FAIRBANKS, AK.

HERR, F. and BARGER W. 1978. "Molecular Hydrogen in the near surface atmosphere and dissolved in waters of the tropical north Atlantic." Journal of Geophysical Research 83:6199-6205.

KELLEY, J.J. 1970. "Carbon dioxide in the surface water of the north Atlantic and the Barents and Kara Sea." Limnology and Oceanography. 15:80-87.

	Date																					
Depth	7/27	8/4	8/5	8/5	8/13	8/14	8/14	8/16	8/17	8/17	8/19	8/23	8/27	9/2	9/5	9/6	9/7	9/11	9/13	9/15	9/18	9/22
Surface Bucket					235			198	187		200		N.E. Greenland "Brown Water" 320 255						"Brown water" (195)	215		267
7 m Pump Sink		270	280	265	225	210	196	199	200	200		218	260	280	258	310	288	223	214	215	219	270
10 m					223												281					
15 m								229	233		208				271							272
20 m		280	280	280		239												262	224	229	237	
25 m								267		230			299	295	289							
30 m					220	249	212															271
40 m	(280)	280				282		311		270							290		258	278	271	
50 m			310	340	250		260		260		287	315	360	295	303	320		291				
75 m		310				277		321		285						334	310	320	289	297	301	333
100 m	(350)				(380)			353							319							
150 m							296		306		340					360	334	324	323		302	342
> 200 m		350				305			305									320 at 400 m				

--- Equilibrium Depth - estimated ca. 130 m

.... Strong ΔPCO_2 depth (270 ppm) estimated ca. 20 m