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J. M Ascencio-Parvy, A. Gaudry, G. Lambert

GEOPHYSICAL RESEARCH LETTERS, VOL. 11, NO. 12, PAGES 1215-1217, DECEMBER 1984

YEAR-TO-YEAR CO_2 VARIATIONS AT AMSTERDAM ISLAND IN 1980-83

J.M. Ascencio-Parvy[+], A. Gaudry[1] and G. Lambert[2]

Centre des Faibles Radioactivités, Laboratoire mixte CNRS-CEA, BP 1,
91190 - Gif-sur-Yvette, France

Abstract. The atmospheric CO_2 concentrations at Amsterdam Island (37°41'S; 77°47'E) from October 1980 to November 1983 showed an increase rate of 0.11 ppm/month for a 3-year average with considerable variability within each year: 0.06-0.14 ppm/month in 1981, 0.04-0.12 in 1982 and 0.13-0.25 in 1983. The natural evasion of oceanic CO^2 following the 1982/1983 El Nino event could account for a part of the anomalous change.

Introduction

The long-term evolution of the atmospheric concentration of CO_2 has been modelled by considering the exchanges between three main reservoirs of carbon: oceans, continental biomass and atmosphere. Those exchanges should explain seasonal effects as well as irregular variations. The aim of the present paper is to analyse changes of the CO_2 increase rate observed at Amsterdam Island in 1981-1983.

Experimental results

Since April 1980, CO_2 has been continuously monitored at Amsterdam Island (37° 41' S, 77° 47' E). Except in Summer (December to February) this island is within the wind regime of the westerlies, so that the monthly mean concentrations can be considered as representative of the background subantarctic atmosphere (Gaudry et al, 1983). The air was collected on top of a 8m-high aluminium tower set up at several tens of meters from a cliff, generally directly exposed to winds blowing from the sea. Despite its geographical isolation and scarce vegetation, the site might still be affected by local CO_2 contamination. Thus, very strict selective criteria were imposed to define a marine sector: wind direction between 300° and 020° and velocities greater than 4m per second.

The CO_2 concentration was measured using a non-dispersive infrared gas analyser (Hartmann-Braun/Uras 2T). The standardization was previously performed by using CO_2 in N_2 standard gases provided by the Scripps Institution of Oceanography (SIO) and expressed in the 1974 WMO/N_2 scale. Recently, CO_2 in air standard gases produced by "L'Air Liquide" and certified by the SIO in the 1981 WMO Mole Fraction Scale, enabled us to determine all our data in this scale.

The CO_2 monthly mean values obtained from hourly data, either with or without selection are shown in Table 1. The CO_2 concentration in the marine sector increased between October 1980 and November 1983 from 337.55 to 341.61 ppm (341.74 ppm in September 1983) corresponding to an average increase rate of 0.11 ppm/month. No clear seasonal effect appears, in contrast with the results at Mauna Loa and South Pole (Keeling et al, 1976a, 1976b). The increase rate was not constant though, as shown in Figure 1.

The changes of the yearly mean value of the monthly increase rate were determined by calculating linear regressions for 11-month periods (5

Paper Number 4L6298
0094-8276/004L-6021 03.00

TABLE 1. Monthly mean CO_2 concentration at Amsterdam Island (1981 WMO Mole Fraction Scale); A-all data; B-data by marine sector; C-Difference with the preceding month (marine sector).

Year	Month	A	B	C
1980	10	337.98	337.55	
	11	337.92	337.55	0.00
	12	338.22	337.72	+0.17
1981	01	338.21	338.12	+0.40
	02	338.54	338.27	+0.15
	03	338.20	338.23	-0.04
	04	338.13	338.09	-0.14
	05	338.10	338.33	+0.24
	06	338.15	338.03	-0.30
	07	338.37	338.17	+0.14
	08	338.73	338.74	+0.57
	09	338.60	338.43	-0.31
	10	338.67	338.64	+0.21
	11	338.90	338.81	+0.17
	12	339.01	338.89	+0.08
1982	01	339.35	339.28	+0.39
	02	339.78	339.52	+0.24
	03	339.40	339.31	-0.21
	04	339.24	339.00	-0.31
	05	339.23	338.86	-0.14
	06	339.28	338.97	+0.11
	07	339.50	339.05	+0.08
	08	340.06	339.81	+0.76
	09	340.06	339.70	-0.11
	10	339.92	339.48	-0.22
	11	339.89	339.51	+0.03
	12	339.98	339.54	+0.03
1983	01	340.19	339.82	+0.28
	02	340.35	340.12	+0.37
	03	340.67	340.21	+0.02
	04	340.76	340.50	+0.29
	05	340.73	340.53	+0.03
	06	341.11	341.04	+0.51
	07	341.70	341.65	+0.61
	08	341.87	341.72	+0.07
	09	341.91	341.74	+0.02
	10	341.90	341.61	-0.13
	11	341.91	341.61	0.00

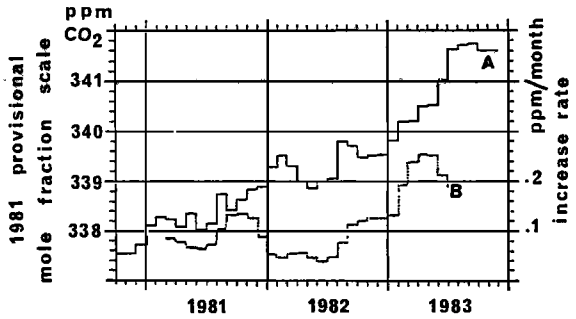

Figure 1. A-Atmospheric CO_2, Amsterdam Island; B- Monthly increase rate over an 11 month-period.

months preceding and following the considered month) from March 1981 to June 1983. Such a simple calculation was possible because of the lack of seasonal variation, in contrast with the situation in most of other WMO background stations. The results are shown in Figure 1-B. These variations are characterized by three periods. The first one, from March 1981 to December 1981, corresponds to an irregular increase rate between 0.06 and 0.13 ppm per month, averaging 0.09 ppm per month. A second period, from January to August 1982 shows a much lower CO_2 increase rate, within 0.04 and 0.08, averaging 0.05 ppm per month. The last period, up to the end of the curve B displays an anomalously high CO_2 increase rate, between 0.12 and 0.25 ppm per month.

Discussion

Such changes in the increase rate of the CO_2 concentration have been already observed in the past and very generally related to changes in the sea surface temperature (SST) of the Pacific Ocean (Newell et al, 1978; Bacastow, 1979; Wong et al, 1981; Schnell et al, 1983). More recently, Gammon et al, (1983), found that El Nino Southern Oscillation events of 1972, 1976 and 1982 were able to induce slower than normal atmospheric CO_2 increases during the first year, followed by very rapid CO_2 increases in the following year. That is precisely what we observe here.

Gill and Rasmusson (1983) described a SST anomaly in the Pacific Ocean, off the Peruvian coast,beginning in March 1982, but showing a first important peak only in December 1982, perfectly correlated to the resumption of the CO_2 increase, also observed in Table 1. In the same way the high monthly CO_2 increase rates measured in June and July 1983 in our data follow immediatly the highest peak of the SST anomaly observed in June 1983, in Gill and Rasmusson (1983).

The first idea is therefore to attribute fast atmospheric increases of CO_2 directly to a stronger outgassing from anomalously warm surface waters. MacIntyre (1978) showed that, assuming an equilibrium of CO_2 between the whole atmosphere and subtropical surface-ocean waters, as well as a constant alkalinity, the variation of the atmospheric CO_2 (dp) was related to a SST variation (dT) by dp/dT=1.54 ppm/°C for a 100m-deep mixed-layer. Bacastow (1979) confirmed such an order of magnitude (dp/dT=1/0.93=1.08 ppm/°C, for a 75m-deep mixed layer, by considering a negligible time lag for attaining the thermodynamical equilibrium and for a mean "Revelle factor" of 10. In fact, it is more realistic to take here a "Revelle factor" of 9 for warm waters (Broecker et al, 1979). Moreover, the depth of sea water containing the same amount of total CO_2 as the atmosphere was 84 m in 1983, instead of 76 in 1966 as in Bacastow's paper. These corrections lead to a figure of about 1.4 ppm/°C. However, it was pointed out by Machta (1973) and Zimen et al, (1977) that the oceanic surface layer exchanging Carbon with the atmosphere could be thicker than the wind-mixed layer. Therefore, there is a large uncertainty on the value of the coefficient dp/dT.

An average SST anomaly during the 1982-1983 El Nino event can be calculated from the NOAA SST anomaly maps outlined by Arkin et al (1983).

TABLE 2. Atmospheric CO_2 ascribed to the 1982-1983 El Nino. (1)-Area (million km^2) showing a temperature elevation; (2)-Mean SST anomaly (°C) (3)- CO_2 increase (ppm) for dp/dT = 1.08 ppm/°C (4)-CO_2 increase (ppm) for dp/dT = 1.4 ppm/°C; (5)-CO_2 increase (ppm) for dp/dT = 1.54 ppm/°C.

Southern Hemisphere					Date	Both Hemispheres				
(1)	(2)	(3)	(4)	(5)		(1)	(2)	(3)	(4)	(5)
14.8	1.04	.16	.20	.23	June/Aug 1982	21.2	1.03	.065	.08	.09
20	1.57	.32	.42	.45	Sept/Nov 1982	32.5	1.51	.14	.18	.20
24.8	1.35	.35	.45	.50	Dec 82/Feb 83	35.7	1.36	.14	.18	.20
13.9	1.30	.19	.25	.27	March/May 1983	19.5	1.32	.08	.10	.11
11.4	1.73	.21	.27	.30	June/Aug 1983	16.8	1.64	.08	.10	.11
9.8	1.07	.10	.13	.14	Sept/Nov 1983	9.9	1.07	.035	.045	.05

Table 2 shows the increases of the CO_2 atmospheric concentration calculated from quarterly values of the SST anomaly area. The three different figures 1.08, 1.4 and 1.54 ppm/°C were used with both the following hypotheses: either the Southern Hemisphere was considered separately, or the calculations were conducted for the whole atmosphere and oceans. In this last case, the atmospheric CO_2 increases are smaller than 0.2 ppm and therefore the SST anomaly influence could account for a maximum of 1/3 of the CO_2 increases actually observed. This conclusion is not so clear when the Southern Hemisphere is considered separately. In effect, the order of magnitude of the CO_2 amount possibly injected into the atmosphere varyied from figures comparable to the preceding case (0.13 to 0.30 ppm) in June/August 1982 and from March to November 1983, to values significantly higher (0.32 to 0.50 ppm) from September 1982 to February 1983. It is also worth while to remember that our study did not take account of possible changes in the total Carbon of the superficial waters. Finally, a modelling of the changes in the atmospheric CO_2, directly related to the occurence of a strong El Nino, will only be possible in the future from very accurate measurements of the physical and chemical properties of the superficial sea water in the involved region. Moreover, it is also necessary to consider the possible existence of other sources and sinks of CO_2, indirectly related to El Nino.

The global CO_2 increase, generally observed, of the order of 0.11 ppm/month, is essentially attributed to anthropogenic injections. There is no reason to assume that the input in 1983 was significantly different than in 1981 and 1982. The sources and sinks, above mentioned, could be rather a small change in the growing rate of the vegetation, possibly related to meteorological anomalies, generated in turn by the El Nino event. Rasmusson and Wallace (1983) described some meteorological anomalies, such as droughts in South Africa, Australian and Indonesian regions, during each El Nino event, and particularly from December 1982 to February 1983. Such meteorological effects may affect the CO_2 cycle in the Southern Hemisphere.

Acknowledgements. This programme has been supported by the Administration of the Territoire des Terres Australes et Antarctiques Françaises, the Commission des Communautés Européennes, and the Programme Interdisciplinaire de la Recherche en Matière d'Environnement du CNRS. We thank the referee for his useful discussions and constructive remarks. We thank B. Ardouin, A. Jegou and the staff in charge of the experiment at Amsterdam Island for their technical assistance.

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+ J.M. Ascencio-Parvy: Accidentally deceased
1 A. Gaudry: also ORSTOM/TAAF
2 G. Lambert: also Université de Picardie.

(Received July 20, 1984;
revised September 11, 1984;
accepted September 20, 1984.)