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The 1982–1983 El Niño: a 6 billion ton CO_2 release

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ABSTRACT

The atmospheric CO_2 concentration at Amsterdam Island showed important variations of the increase rate during the 1982–1983 El Niño. After elimination of the weak local and regional interferences, the main feature of the CO_2 record is a slower than normal increase rate at the beginning and at the end of this El Niño, i.e., from April to December 1982, and from July 1983 to April 1984, and higher than usual from December 1982 to July 1983. In the whole, the CO_2 increase curve is shifted upwards by 1 ppm, which corresponds to a supplementary input into the atmosphere of about 6 billion tons of CO_2.

1. Introduction

The study of different factors able to modify the long-term trend of atmospheric CO_2 is fundamental in order to account for past depletions during ice ages, as well as for the increase observed since the last century, in connection with human activities, and finally to forecast possible future levels of CO_2. Changes in the increase rate of the atmospheric CO_2 concentration have already been observed and very generally related to changes in the sea surface temperature (SST) of the Pacific Ocean (Newell et al., 1978; Bacastow, 1979; Machta et al., 1977). More particularly, Komhyr et al. (1985) found that El Niño Southern Oscillation events of 1972, 1976 and 1982–1983 were associated with slower than normal atmospheric CO_2 increase during the first year, followed by very rapid CO_2 increase in the following year.

In a previous paper, Ascensio-Parvy et al. (1984) observed similar results at Amsterdam Island from data obtained in 1980–1983. An additional year of measurements gives a much better idea of the relationship between the 1982–1983 SST anomaly and variations of the atmospheric CO_2 increase rate.

2. Site and methods

The station located at Amsterdam Island, 37°47′S, 77°31′E, is included in the Background Atmospheric Pollution Monitoring (BAPMON) network of the World Meteorological Organization (WMO). Since October 1980, atmospheric CO_2 has been continuously measured. The measurement techniques have already been described by Gaudry et al. (1983), but some important details are summarized here. The station is located on the edge of a 55 m high cliff, the sampling point being at an elevation of 9 m from the soil. The air is dried by means of a -55°C cooling trap and CO_2 continuously determined by a non-dispersive infrared device.

The carrier gas effect has been determined by two scales of standard gases: one with standards in N_2, and one in synthetic air. The CO_2 in N_2 concentrations were provided by the CO_2 Central Laboratory of the World Meteorological Organisation (Scripps Institution of Oceanography, SIO), and sent to Amsterdam Island. The

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CO_2 in air standards were composed of a set of 14 concentrations produced by a French manufacturer through an accurate gravimetric method (accuracy: 0.25 ppm). A first subset of 4 concentrations, ranging from 332.7 to 354.1 ppm were determined by the SIO. Although the adjusted 1985 SIO Mole Fraction Scale and the French Mole Fraction Scales agree within 0.25 ppm, we only used the adjusted 1985 SIO scale, and recalculated the 10 concentrations of the second subset. This last one was sent to Amsterdam Island. Due to such an indirect determination of the carrier gas effect, an accumulation of several uncertainties occurs, leading to a global uncertainty for the results of about 0.25 ppm, at a 64% confidence level. However, it is worthy to note that the reproducibility of the analytical system is better than 0.1 ppm.

Several selection criteria have been retained to obtain data in strict background conditions: only wind direction between 300° and 040° with velocities greater than 5 ms^{-1}, and wind direction between 260° and 300° with velocities greater than 8 ms^{-1} per second have been taken into account. Since Amsterdam Island is also included in the parallel network coordinated by the National Oceanic and Atmospheric Administration/Global Monitoring for Climatic Change (NOAA/GMCC), an intercomparison was needed and has recently been achieved between continuous measurements and flask data. The main result is that by considering only the period when an electrical portable sampler, pressurizing the air in the flasks, has been used at the station and by selecting only background conditions, the long-term intercomparability, determined by Gaudry et al. (1986), defined by (NOAA minus CFR) differences, is close to −0.02 ppm with a standard deviation of 0.35 ppm.

3. CO_2 long-term trend and discussion

The monthly mean values of CO_2, calculated from selected data, according to the method described above, are shown in Table 1 and Fig 1. This figure shows that the increase rate of CO_2 varied during the period under study, and more particularly in 1982–83. Beside local causes of variations, which are supposed to be eliminated by our data selection, two possible regional

Table 1. *Monthly mean CO_2 concentrations at Amsterdam Island for wind blowing from the sea, without correction*

Month		CO_2 concentration (ppm)
October	1980	338
November	1980	338
December	1980	338.3
January	1981	338.4
February	1981	338.5
March	1981	338.4
April	1981	338.3
May	1981	338.4
June	1981	338.2
July	1981	338.4
August	1981	338.9
September	1981	338.8
October	1981	338.8
November	1981	338.9
December	1981	339.1
January	1982	339.2
February	1982	339.4
March	1982	339.4
April	1982	339.2
May	1982	339
June	1982	339.2
July	1982	339.4
August	1982	340
September	1982	340
October	1982	339.8
November	1982	339.7
December	1982	339.7
January	1983	339.9
February	1983	340.3
March	1983	340.3
April	1983	340.6
May	1983	340.8
June	1983	341.2
July	1983	341.7
August	1983	342
September	1983	341.9
October	1983	341.8
November	1983	341.8
December	1983	342.3
January	1984	341.9
February	1984	341.6
March	1984	341.7
April	1984	341.6
May	1984	341.6
June	1984	341.9
July	1984	342.4
August	1984	343
September	1984	343.1
October	1984	342.8

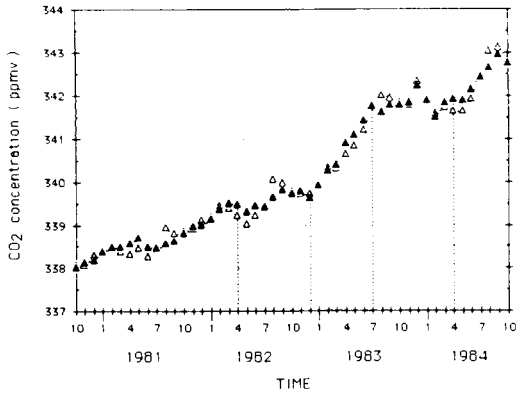

Fig. 1. Monthly mean CO_2 concentrations at Amsterdam Island: A (△), for wind blowing from the sea, without correction; B (▲), same results after correction of the seasonal effect. Vertical dashed lines correspond to reference dates (see text).

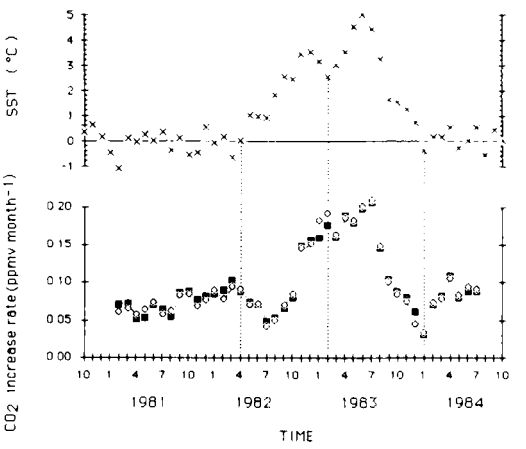

Fig. 2. El Niño 1982–1983 and atmospheric CO_2 at Amsterdam Island: A (×), sea surface temperature (SST) anomaly deduced from NOAA's climate diagnostics bulletin (area: 0°–10°S, 80°–90°W); B (○), CO_2 monthly increase rate derived from an 11-month running mean calculated after correction of the seasonal effect; C (■), same results by using only CO_2 concentrations corresponding to ^{222}Rn concentrations < 1 pCi m^{-3}. Vertical dashed lines correspond to reference dates (see text).

causes of variations have to be considered. Monfray et al. (1987) pointed out that, in the latitudinal band of Amsterdam Island, both pCO_2 in superficial sea water and the sea-air transfer piston velocity which is driven by the wind velocity, vary with the season. In the same way, the anthropogenic source of CO_2 and the continental biomass activity are also seasonally variable. Moreover, the contribution of continental sources and sinks to CO_2 concentrations measured at Amsterdam Island is dependant on the advection of continental air masses towards this station, which is also seasonally dependant (Polian et al., 1986). Finally, all of these effects result in a seasonal variation of the CO_2 atmospheric concentration with a maximum in August, a minimum in April–June, and a peak-to-peak amplitude of 0.7 ppm. The monthly mean values of CO_2, corrected for this seasonal variation, are also shown in the same Fig. 1.

It is clear that the CO_2 increase rate was very small (and sometimes even negative) from April to December 1982, and from July 1983 to April 1984, and higher than usual from December 1982 to July 1983. Fig. 2 shows that the period from April 1982 to January 1984 was characterized by a strong SST anomaly (El Niño) reaching up to +5°C (NOAA's Climate Diagnostics Bulletin) for the most affected area in the vicinity of the Peruvian coast (0°–10°S, 80°–90°W). A correlation can be seen between this SST anomaly and the monthly CO_2 increase rate, derived from an 11-month running mean (5 months preceding and following the considered month) of the CO_2 concentrations.

The slower than normal atmospheric CO_2 increases observed during the first period of the 1982–83 El Niño could be attributed to a reduction of the flux to the atmosphere from the entire equatorial oceanic region. In effect, in lack of upwelling, the carbon content of the superficial water should be lower than usual, as actually observed by Feely and collaborators (1986, private communication). However, changes in the SST were associated with drastic changes in the climate of very large areas as mentioned by Rasmusson and Wallace (1983). Such a climatic effect, and its consequences for the continental biomass, can combine with air–sea exchange modifications to account for the rapid CO_2 increases observed in 1982–1983.

The rapid advection of air masses from South Africa to Amsterdam Island are well-displayed by their high concentrations of ^{222}Rn. This natural radioactive gas is injected into the atmosphere almost only from the continent soil.

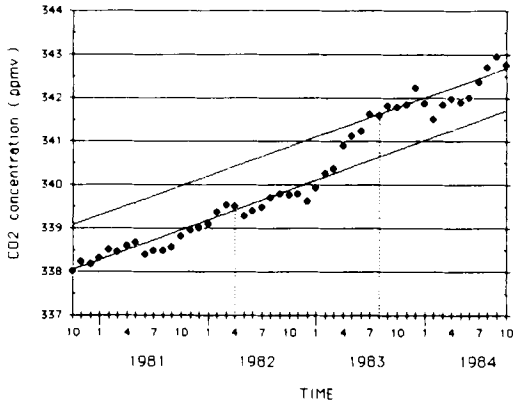

Fig. 3. Monthly mean CO_2 concentrations after correction of the seasonal effect and for ^{222}Rn concentrations <1 pCi m^{-3}. Both straight lines were drawn with the same slope. They happen to differ by 1 ppm. Dashed lines correspond to reference dates (see text).

Polian et al. (1986) have shown the existence, particularly in winter, of sharp peaks in ^{222}Rn due to the drawing in of continental air from South Africa towards Subantarctic areas. It was pointed out by Gaudry et al. (1983) that these rapid long-range transports of continental air frequently corresponded at Amsterdam Island to maxima of CO_2 concentrations about 0.5 to 1.3 ppm higher than typical values.

Following the 1982–1983 El Niño, we observed at Amsterdam Island ^{222}Rn average concentrations a little higher than usually, and more especially, very important peaks of ^{222}Rn during the winter 1983 (May–August). They indicate that the advections of air from South Africa were unusually intense at this time. The CO_2 mean concentration measured at Amsterdam Island was slightly increased by these rapid invasions of continental air. Therefore, it has been necessary to correct our results, by considering only those CO_2 values which corresponded to low ^{222}Rn concentrations: practically less than 1 pCi m^{-3}. These CO_2 values, which represent only 70% of all preceding results, are shown in the same Fig. 2. It is clear that the two curves, B (whole data) and C (CO_2 data when ^{222}Rn is less than 1 pCi m^{-3}), are practically superposed during the whole period under study, except in January and February 1983. For both these months, a small difference appears which could be attributed to a small but significant influence of South-Africa.

4. Conclusion

In conclusion, we can observe in Fig. 3 that, after subtracting out the local variations, the average seasonal cycle, and regional variations correlated with the radon concentration, the CO_2 concentration increased from October 1980 to April 1982 at a mean rate of 0.8 ppm per year. This figure shows that the CO_2 increase rate was again very similar since August 1983. Therefore, despite slower than normal CO_2 increases at the beginning and the end of the 1982–1983 El Niño, this event resulted in the whole in a 1 ppm upward shift of the CO_2 increase curve.

This shift was seen in the record at Amsterdam Island, even with only a short record, because of the near absence of local or regional influences on the interannual trend in atmospheric CO_2. Even these small effects were to a considerable degree eliminated from the record by correlation with radon as a measure of the continental influence, so as to reveal a time series roughly representative of the atmosphere over much of the southern hemisphere. Both the hemispheres having been influenced by the El Niño events and its climatic consequences, it is reasonable to assume that such a 1 ppm shift affected the whole troposphere. In contrast, owing to the long time necessary for troposphere-to-stratosphere exchanges, the air mass to consider is therefore only 4.10^{18} Kg. This, corresponding to a global effect of the 1982–19083 El Niño, could therefore have been a rapid supplementary injection into the atmosphere of about 6 billion tons of CO_2, i.e. 1.6 billion tons of Carbon. Note that this amount of Carbon is only 30% of the annual input due to industrial activities. Moreover, whether or not this supplementary input was injected into the atmosphere from continental biomass, the $\partial^{13}C$ of which is about $-25‰$, the 1 ppm shift mentioned above should correspond to a mean $\partial^{13}C$ of about $-0.05‰$. Such an order of magnitude has been determined, in both the hemispheres, by Heimann, Keeling and Mook at the 1985 Kandersteg Symposium (private communication).

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