Variations of Atmospheric Carbon Dioxide Concentration and Greenhouse Effect at Syowa Station (69°00′S, 39°35′E), Antarctica

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Received October 20, 1990; revised December 8, 1990

ABSTRACT

On the basis of the analysis of atmospheric carbon dioxide concentration variations and the annual mean air temperature at Syowa Station, Antarctica in the period of 1984–1988, the following results are easily obtained:

(1) The annual mean values of the atmospheric carbon dioxide concentration are gradually increased and equal to 342.59, 343.80, 345.15, 346.83 and 348.82 ppmv for 1984, 1985, 1986, 1987 and 1988, respectively. Its annual increase rates are 1.21, 1.35, 1.68 and 1.99 ppmv / yr. For 1984–1985, 1985–1986, 1986–1987 and 1987–1988, respectively and are raised year by year.

The seasonal variations are observed and the maximum concentration is in spring and the minimum one is in late–summer or early–autumn.

(2)The increasing tendency of the concentration of the atmospheric carbon dioxide is consistent with that of the air temperature.

I. INTRODUCTION

Now the climatic variation and climatic anomaly is an important topic in the researches of the earth change (Qu Shaohou, 1989). Scientists and governments of many countries have paid attentions to the greenhouse effect of the global scale induced by emissions of greenhouse gases i.e., carbon dioxide, methane, nitrous oxide and chlorofluorocarbon etc.. The increase of atmospheric carbon dioxide concentration is associated with exploiting burning of fossil fuels.

Since 1958 monthly average carbon dioxide concentration observed continuously at Mauna Loa, Hawaii shows that it has increased by 40 ppmv over the past 30 years(Keeling et al. ,1989), the increasing yearly rate was about 0.4% and for various years it is obviously different.

At Pre–Industrial Revolution the atmospheric carbon dioxide concentration of 280+10ppmv was almost maintained (Houghton et al., 1990). For the past 100 years from 1985 the air temperature increasing had reached to 0.3–0.6°C by greenhouse effect.

According to present emmission of greenhouse gases, the increasing rate of temperature in the next century will be about 0.3°C per decade (with uncertainty range of 0.2°C to 0.5°C per decade), and the global mean temperature will raise about 1°C by the year of 2025 and 3°C by the end of next century. If it is so, global mean sea surface will be risen about 6 cm per decade at the next century (with uncertainty range of 3–10 cm per decade) mainly due to thermal expansion of the oceans and melting of some land ice.

The predicted rise is about 20 cm for the global mean sea level by the year of 2030, and

65 cm by the end of next century.

Now there are approximately 40 ground stations around the world including Antarctica and Arctica to monitor the variations of atmospheric carbon dioxide (Pearman et al., 1980). Aircraft measurements of atmospheric carbon dioxide concentration over Japan, initiated January 1979, had been continued to May 1985 by Tohoky University et al. (Tanaka et al.,1987). The results show that the average rate of annual increase of atmospheric carbon dioxide concentration was about 1.3 ppmv / yr.

In the period of March 1979–June 1985, the measurements of atmospheric carbon dioxide concentration at Mt. Cimone (2165 m m.s.l.), Italy, had been carried out by Italian Air Meteorological Service (Ciattaglia et al., 1987). The average rate of annual increase during the period was about 1.7 ppmv / yr.

Systematic measurements of the atmospheric carbon dioxide concentration are currently made at several places in the Antarctic region, either by continuous sampling with an analyzer in situ or by discrete flask sampling with subsequent laboratory analysis (Keeling et al., 1976; Beardsmore et al., 1984; Komhyr et al., 1985).

Syowa Station (69°00'S, 39°35'E) used a flask sampling technique firstly in January 1983 and then operated the continuous measurement system since February 1984. Based on the analysis of observational data of atmospheric dioxide carbon concentration at the station in the period of 1984–1988, this paper gives the annual mean concentration, the interannual variations, the annual increase rates and the seasonal variations of atmospheric carbon dioxide. Besides, it also describes the correlation relation between the concentration of atmospheric carbon dioxide and the mean annual air temperature.

II. SYOWA STATION (SAMPLING SITE) AND MONITORING INSTRUMENT

Syowa Station (69°00'S, 39°35'E) is located in East Ongul Island of Lutzow –Holm Bay (see Fig.1). Being separated from continent by the Ongul Strait which is about 4km wide, the Ongul Island is about 11 km^2 in area and 29 m above the sea level. The Ongul Strait is usually frozen throughout the year but since 1980 open water has been occasionally observed in summer to autumn. The surface of the island is composed of naked rocks with some lichen growth in summer and covered with snow and ice in other seasons. Since the station is isolated from vegetated lands and industrial regions it is an excellent site monitoring the variations of atmospheric carbon dioxide concentration.

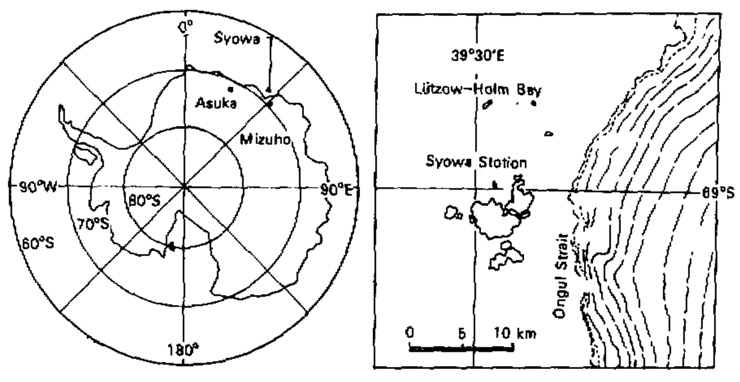

Fig.1. Location of Syowa Station and its surrounding area.

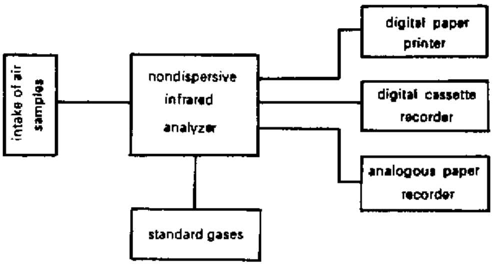

Fig.2. Block diagram of the measuring atmospheric CO_2 concentration system at Syowa Station.

Syowa Station was established in January 1957 for International Geophysics Year. Since 1957 the scientific research and observation in various fields including atmospheric physics, atmospheric chemistry, upper atmospheric physics, meteorology, satellite meteorology, earth sciences, environment sciences, biology, medicine, marine sciences and glaciology etc. have been carried out. Up–to–date morden technology has been introduced to the station, such as soun ding rocket launching pad, an automatic meteorological observation system, a computer system for data retrieval and processing, satellite data reception systems, and other research laboratories have been built.

The climate in the island is comparatively moderate. The annual mean temperature is −10.5°C (1957–1984) and it was increased for recent years. Its monthly mean value can be down to −20°C in August (winter) and up to −1°C in January (summer). The highest temperature is 10.0°C (21 January, 1977) and the lowest one is −45.2°C (4 September, 1982). The wind speed is about 6 m/s. The directions of prevailing wind are mostly north–northeasterly, north–easterly and easterly. The occurrence of calm condition is about 14% per year.

It is well known that following two methods uaually are used to measure the atmospheric carbon dioxide concentration.

(1)The discrete flask sampling measurement system.

(2)The continuous sampling measurement system.

The monitoring of atmospheric carbon dioxide concentration was initiated at Syowa Station by using a flask sampling technique in January 1983 and then operated with a continuous measurement system since February 1984.

The continuous measurement system (see Fig.2) consists of nondispersive infrared analyzer, gas handling system and data acquisition system (Tanaka et al., 1984), and it was installed in an air–conditioned laboratory.

The intake of air samples was mounted atop of a 8 m high mast being standed (19 m above sea level) at the coast line of the land about 30 m away from the laboratory and it facing to the sea, has a sector angle about 250°. Air samples were pumped in the analyzer through an annealed copper tube from the intake. A flow of air sample or standard gas of 350 ml/min is passed the analyzer. The number of air samples analyzed is about 70,000 each year. The output signals of the analyzer were recorded digitally on printing paper or analogously printed on the recorder. A digital cassette recorder was also added to this data acquisition system in January 1986 to simplify the data analysis.

To maintain the consistency of measurements for a long time, standard gases used were classified into 3 categories: primary, secondary and working ones. The purity of carbon dioxide was higher than 99.995%. The carbon dioxide concentrations of the working standard gases used in this measurement were compared with secondary and standard gases before and after their use in order to meet the precision of +0.01ppmv. The secondary and working gases were calibrated by the primary gas every one or two months to minimize a possible initial drift of the carbon dioxide concentration. Details of the measurement system have been described in the paper of Tanaka et al. (1984).

III. RESULTS AND DISCUSSIONS

The values of atmospheric carbon dioxide concentration variations and the corresponding air temperature at Syowa Station are illustrated in Table 1 for the period of 1984–1988. Besides, Table 1 also lists the annual increase rates, the monthly mean maximum value and the minimum value etc. for the atmospheric carbon dioxide concentration.

Table 1. Variations of Atmospheric Carbon Dioxide Concentration and Annual Mean Air Temperature at Syowa Station

Date (yr.)	1984	1985	1986	1987	1988
Annual mean value (ppmv)	342.59	343.80	345.15	346.83	348.82
Annual increase rate (ppmv / yr.)		1.21	1.35	1.68	1.99
Monthly mean maximum value (ppmv)	343.43	344.73	346.17	348.16	349.78
Appearance month of maximum value	Oct.	Oct.	Oct.	Nov.	Oct.
Monthly mean minimum value (ppmv)	341.62	342.62	344.28	345.50	347.63
Appearance month of minimum value	Mar.	Feb.	Feb.	Mar.	Feb.
Annual mean air temperature (℃)	−10.3	−10.1	−10.0	−9.9	

The eliminats the effects of local contimination and human activities on the variations of atmospheric carbon dioxide concentration and to select an optimum location for the intake of air samples and the optimum sampling time, an objective statistical selection scheme was tentatively used in this study.

(1) The Time Variation of Atmospheric Carbon Dioxide Concentration.

Up to now the variations of the concentration show that: (A) a regular diurnal variation has not been observed; (B) irregular variations were observed with extremely small amplitudes of 0.2 ppmv in most cases.

The results of the continuous sampling measurement in the period of 1984–1988 are given in Fig.3. From Fig.3 it is seen that the seasonal variations are obvious and the maximum concentration is in spring and the minimum one is in late–summer or early–autumn. For 1984 the maximum concentration with 343.43 ppmv appeared in October and the minimum one with 341.62 ppmv in March, and its peak–to–peak amplitude was 1.81 ppmv; for 1985 the maximum concentration with 344.73 ppmv is in October and the minimum one with 342.62 ppmv in February, and its peak–to–peak amplitude was 2.11 ppmv; for 1986 the maximum concentration with 346.17 ppmv is in October and the minimum one with 344.28 ppmv in February and its peak–to–peak amplitude was 1.89 ppmv; for 1987 the maximum concentration with 348.16 ppmv is in November and the minimum one with 345.50 ppmv in March and its peak–to–peak amplitude was 2.66 ppmv; for 1988 the maximum concentration with 349.78 ppmv is in October and the minimum one with 347.63 ppmv in February and its peak–to–peak amplitude was 2.15 ppmv. It is noteworthy that the season of appearance of the maximum carbon dioxide concentration is consistent with that of "Ozone Hole" occurrence over the antarctic continent.

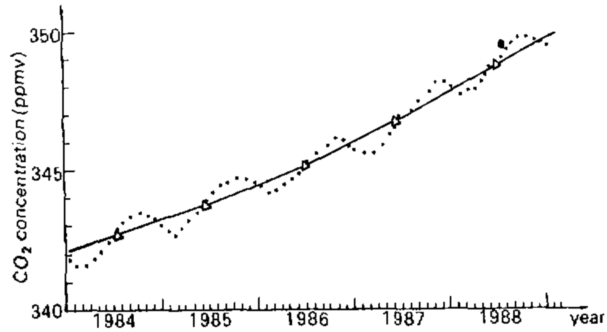

Fig.3. Seasonal variations of atmospheric CO_2 concentration at Syowa station.

Fig.3 also shows that the values of atmospheric carbon dioxide concentration gradually increase and are equal to 342.59, 343.80, 345.15, 346.83 and 348.82 ppmv for 1984, 1985, 1986, 1987 and 1988, respectively. Its increase rates of year to year are 1.21, 1.35, 1.68 and 1.99 ppmv / yr for 1984–1985, 1985–1986, 1986–1987 and 1987–1988 respectively, presenting increasing trend. The annual mean concentrations and the increase rates of gradual rise mentioned above must be noted.

The annual increase rate of gradual rise in this region comparing with developed regions (e.g., Japan and Europe) is worrying: before 1986 it was lower than Japanese stations' (In the period of 1979–1985 the annual average increase rate was about 1.3 ppmv / yr) and Italian stations' (It was about 1.7 ppmv / yr). But after 1986 it was higher than those at Japan and Italy stations.

(2)The Correlation Relation between the Annual Mean Concentration of Atmospheric Carbon Dioxide and the Annual Mean Air Temperature at Syowa Station.

From Fig.4 it is seen that the increased tendency of annual mean concentration of atmospheric carbon dioxide is consistent with that of the annual mean air temperature. They have an obviously positive correlation. It seems that the antarctic region also has greenhouse effect.

IV. CONCLUSIONS

On the basis of the variations of atmospheric carbon dioxide obtained at Syowa Station

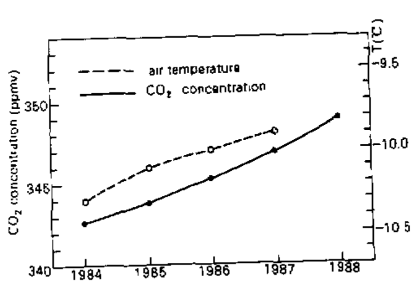

Fig.4. Variations of the annual mean atmospheric CO_2 concentration and the annual mean air temperature at Syowa Station.

by using nondispersive infraved analyzer in the period of 1984–1988 we may gain following conclusions.

(1) A regular diurnal variation has not been observed and irregular variations were observed with extremely small amplitudes of 0.2 ppmv in most cases. Seasonal variations are detected and the maximum of monthly average appears in spring (see Table 1). It is consistent with the occurrence of "Ozone Hole" above the antarctic continent. The minimum concentration appears in late–summer or early–autumn(see Table 1).The annual average variations of atmospheric carbon dioxide concentration at this station gradually increase and its annual increase rate is yearly raised(They are about 1.21, 1.35, 1.68 and 1.99 ppmv / yr for 1984–1985, 1985–1986, 1986–1987 and 1987–1988 respectively).

(2)The increasing tendency of annual average concentration of atmospheric carbon dioxide is consistent with that of the annual mean air temperature. They have an obviously positive correlation.

The only clean antarctic region has been already influenced by the greenhouse effect induced by emissions of greenhouse gases. It results in the increase of air temperature,the decrease of sea ice and land ice and the increase of open water. The functions of the cold source (Qu Shaohou 1990) will be weakened. This has feedback effects to warming climate: Therefore,it is an important tast of atmospheric physicists, atmospheric chemists, meteorologists and glaciologists to study and observe the variations of atmospheric carbon dioxide concentration, "Ozone Holl" and the air–ice exchange at antarctic region.

This research was supported by the office of National Committee for Antarctic Research of China. Authors are grateful to the office of National Comittee for Antarctic Research of China for his helps. Authors wish to express their thanks to the National Institute of Polar Research of Japan for the permission of using their data, and to the staffs of the 24th,25th,26th,27th and 28th Japanese Antarctic Research Expeditions for their cooperation in this measurement. Thanks are also due to Prof. Gao Dengyi for his helps and discussions.

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