OBSERVATION AND INVESTIGATION OF VARIABILITIES OF BASELINE CO_2 CONCENTRATION OVER WALIGUAN MOUNTAIN IN QINGHAI PROVINCE OF CHINA *

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ABSTRACT

In-situ measurement of atmospheric CO_2 was made at the top of the Waliguan Mountain (36°17′N, 100°54′E, 3816 m asl), where the air is not directly affected by the local anthropogenic and natural sources, by using a nondispersive infrared (NDIR) analyzer and following the procedures proposed by WMO. The CO_2 in the flask samples collected on the mountain was also analyzed in a laboratory. The measurements uncover the daily, monthly and seasonal variabilities and the baseline level of the CO_2 in the air over the "clean" area of Chinese hinterland. Results suggest that the CO_2 concentration over the East Asia continent has evident periodical variation, similar to that of global distribution. In 1992, an annual mean baseline CO_2 concentration of 356.4 ppm over the continent was obtained. The annual mean value was 357.2 ppm for 1993. Some relationships between the CO_2 concentration at Waliguan and the weather conditions, especially, wind speed and direction are found through the observation.

Key words: background observation, baseline concentration of CO_2, variability of concentration, greenhouse gases

I. INTRODUCTION

Measurements over the past decades have shown that the concentrations of the greenhouse gases have been increasing due to anthropogenic emissions. The concentration of atmospheric CO_2, one of the most important greenhouse gases, was stable at about 280 ppm for hundred thousands of years in the pre-industrial period (Barnola et al. 1987). But it has been increasing since the industrial revolution. Now, its annual mean concentration has reached 356 ppm and the increasing rate has been quickened, although the increasing rate has retarded at present. The climate change induced by the increasing of CO_2 concentration and its impacts on the ecosystem and environment have drawn extensive attention. To make an accurate assessment of the impacts of increasing CO_2 on global climate and to avoid the uncertainty of the prediction due to the lack of field data, the long-term and precise measurement of baseline concentration of atmospheric CO_2 at the sites where no strong local sources and sinks exist, has become one of the important tasks for the scientists from many countries and organizations. Since 1958, atmospheric CO_2 has been observed in some countries (Keeling et al. 1976). In order to

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investigate the impacts of human activities on the climate, WMO, supported by UNEP, founded the GAW / BAPMoN network[1]. The monitoring has provided very valuable data for revealing the impacts of human activities on the global climate.

It is well known that the terrestrial ecosystem, like the ocean, also plays an important role in adjusting atmospheric CO_2. But all of the WMO's operating stations, at which atmospheric CO_2 is being monitored, are located either on islands or in the coast areas. This causes the shortage of data of the baseline CO_2 in the atmosphere over hinterlands of the continents. In order to obtain the atmospheric CO_2 data over the hinterland of East Asia, we have made in-situ measurement of CO_2 at the top of the Waliguan Mountain (36°17′N, 100°54′E, 3816 m asl) in Qinghai Province, China. Moreover, flask air samples have also been collected at the Waliguan Mountain and later analyzed in a laboratory. In this paper, we present and discuss the variabilities of the baseline CO_2 over the continental hinterland.

II. SITE AND METHODOLOGY

In order to provide representative CO_2 data, it is necessary to prevent the site from being affected by local sources and sinks. According to the GAW / BAPMoN station criteria of WMO (WMO 1978), a suitable location for CO_2 measuring was found at the Waliguan Mountain in the Qinghai–Xizang Plateau.

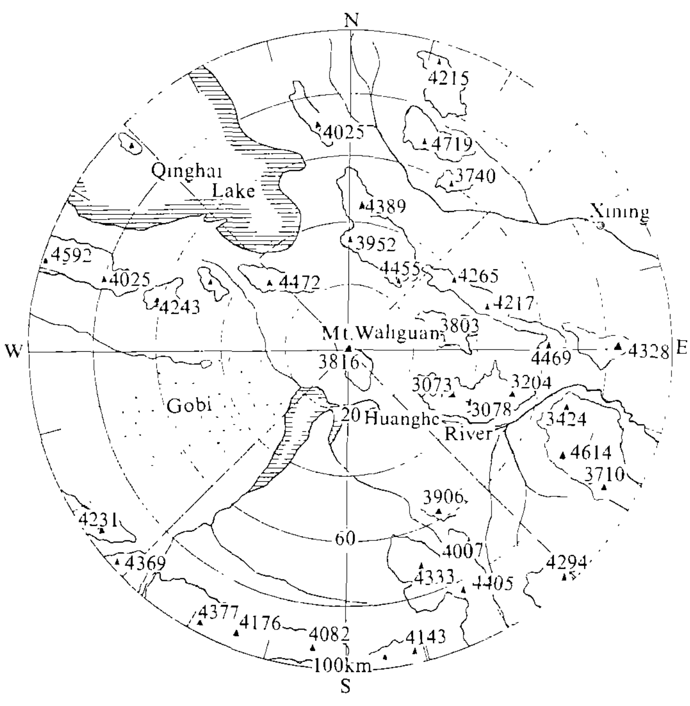

Fig. 1. Geographical distribution of the area 100 km around the Waliguan Mountain. Heights (m asl) of the mountains in the area are shown on the map.

[1] To reinforce the monitoring of air constituents, WMO merged the original BAPMoN and GO_3OS into the Global Atmospheric Watch (GAW) network in 1989.

Figure 1 shows the location and surroundings of the site. The Waliguan Mountain is an isolated mountain, having a northeast–southwest stretch. The atmospheric CO_2 measurement is made at the highest top of the Waliguan Mountain (Fig.2). The large area around the site is covered by thin short grasses of arid and semiarid waste grasslands, and is sparsely populated, so the site is hardly influenced by the local anthropogenic and natural sources and sinks.

In–situ measurement has been made by using a NDIR CO_2 analyzer (Ultramat–3, Siemens). After some improvements, the system is able to measure CO_2 with the precision better than 0.1 ppm (Wen et al. 1993). Air was collected at 300 ml / min through a stainless steel tube (inner diameter is 3 mm) and then into a cryotrap (−70—−75℃) before entering the analyzer to remove the water vapor, which otherwise would interfer the measurement. The inlet was 15 m above the ground and equipped with freeze– and dust–proof devices. CO_2 was measured continuously except some interruptions due to equipment and power problems. To ensure the high quality of the data, the system was calibrated regularly. Working reference gases—— W_1, W_2 (CO_2 in air) were compared every ten days with the secondary standards—— H, M, L (CO_2 in air) from NBS and NOAA / USA. The system was checked and its drift was corrected once everyday by using W_1 and W_2 (in the last ten minutes of each hour, the drift correction was carried out by using W_1 and W_2). The calibration of analyzer by using W_1 and W_2 should be done repeatedly, until the standard deviations (SDs) of the concentration values are sequentially below about 0.06 ppm for the last three cycles. The sampling interval was 5 seconds. All data were copied on the disk.

Besides the in–situ measurement, flask sampling was also made as another important quality control measure. Two pairs of parallel flask samples were collected every week at the site and analyzed in CMDL / NOAA. More than 100 pairs of samples were taken and analyzed in 1992. Comparison of the annual and monthly mean data shows very little differences between in–situ measurement and flask sampling. This suggests that our in–situ data are internationally comparable.

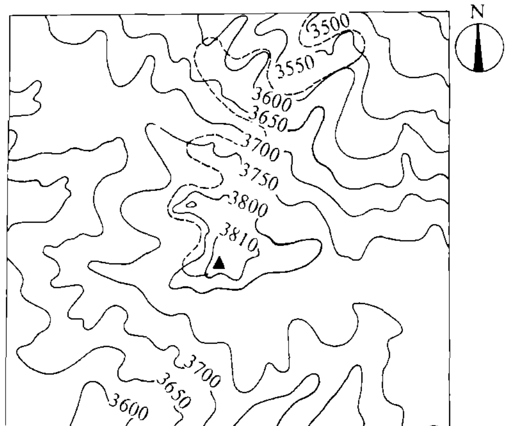

Fig. 2. The topography of the CO_2 sampling site. The figures represent altitudes (the sea level elevation, m) of the different levels of the mountains, ▲ sampling site.

Wind speed and direction at 10 m above the ground were measured simultaneously while measuring CO_2 to investigate the relationship between CO_2 concentration and wind speed and direction.

To obtain the baseline concentration of atmospheric CO_2, raw data should be filtered. The reasonable selection of CO_2 raw data should be made. The data influenced by air mass, local emission, power supply and analyzer system failures etc., should be removed. The SD of CO_2 hourly mean values below 0.3 ppm is acceptable, below 0.1 ppm is better and the data with SD above 0.3 ppm should be removed. More than 60% of the data were left after the selection.

III. RESULTS AND DISCUSSIONS

1. *Variabilities of CO_2 Concentration*

(1) *Annual mean concentration*

Table 1 lists the monthly mean concentrations of the baseline CO_2 at the Waliguan Mountain.

Table 1. The CO_2 Monthly Mean Concentration (ppm) at the Waliguan Mountain

Month	1990	1991	1992	1993
January	—	—	356.78	359.12
February	—	—	358.64	358.57
March	—	—	359.88	359.35
April	—	—	360.82	360.66
May	—	360.56	360.84	360.03
June	—	—	355.57	358.70
July	—	347.38	352.25	352.06
August	348.29	350.29	352.18	351.50
September	—	352.12	352.71	355.43
October	—	354.74	354.82	—
November	—	354.79	355.90	356.44
December	—	355.67	356.25	357.20
Annual mean	—	—	356.4	~ 357.19

The mean from May 1991 to April 1992 was 355.8 ppm. The annual mean baseline CO_2 at the Waliguan Mountain in 1992 was 356.4 ppm. It was about 357.2 ppm in 1993. The data in Table 1 do not allow us to give a credible annual increase rate of the atmospheric CO_2 at the Waliguan Mountain.

(2) *Seasonal variation*

The seasonal variation of atmospheric CO_2 over the continent is caused mainly by the periodicity of the terrestrial vegetation growth. The seasonal oscillation in the Southern Hemisphere (1—2 ppm) is much smaller than in the Northern Hemisphere due to the difference of the plant quantity and the differences of the anthropogenic emissions between the two hemispheres. Figure 3 shows the variation of the mean baseline concentration of atmospheric CO_2 at the Waliguan Mountain in 1992. The daily mean CO_2 concentration indicates a larger seasonal variation. The concentration of CO_2 decreases quickly in April— May, to a minimum in late summer and rises quickly from September to December, then rises slowly to a maximum in spring. A maximum value appears in later April and earlier May and a minimum in August. The difference between maximum and minimum is about 10—12 ppm. The seasonal trend of the atmospheric CO_2 over the Asia Continent is very clear. In Fig.3, the seasonal variations of the CO_2 concentration measured in 1992 at Barrow and Mauna Lao Observatory (NOAA / USA 1992) are also shown along with that at the Waliguan Mountain for comparison. There are big latitude differences among these observatories. We can see from Fig.3 that the higher the latitude of the observatory is, the larger the oscillation of the CO_2 concentration. The pattern of the seasonal variation of the CO_2 at the Waliguan Mountain coincides basically with global distributions of CO_2.

(3) *Diurnal variation*

Diurnal variation of atmospheric CO_2 at the Waliguan Mountain and its seasonal dependence have been found. The variations in the summer are much more significant than in the winter (see Fig.4). Photosynthesis and respiration of terrestrial vegetation and the activities of soil

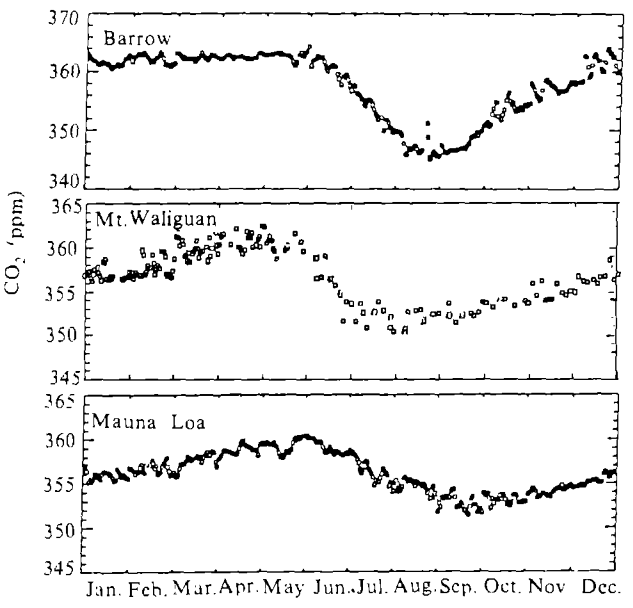

Fig. 3. Variation of the baseline CO_2 concentration at the Waliguan Mountain (a) and comparison with other baseline observatories (b) in 1992.

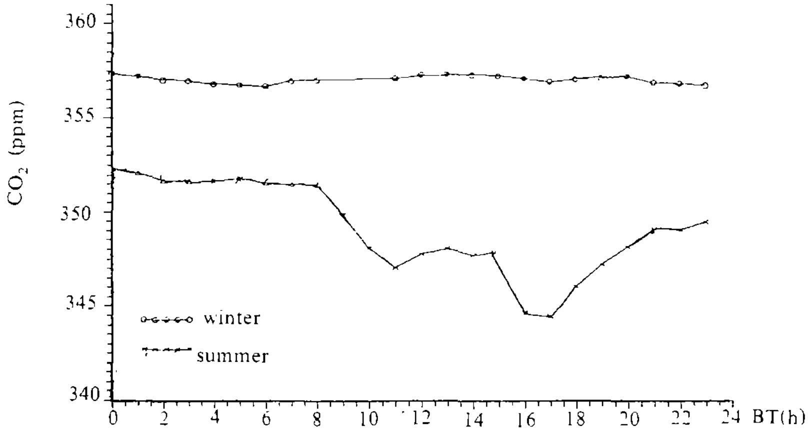

Fig. 4. Diurnal variations of CO_2 at the Waliguan Mountain in the winter and summer from 1991 to 1992.

microbes may be causes of this kind of variation. In the summer (June—August), the plants assimilate a large amount of atmospheric CO_2 through photosynthesis during daytime and give out CO_2 through respiration during nighttime; therefore, CO_2 concentration reaches its lowest and highest points in the later afternoon and after midnight, respectively. The difference between the hourly mean concentrations of the two points can be as large as 5 ppm. But in the winter, the biological activities are significantly decreased, effects of the plants and microbes on atmospheric CO_2 are so small that the diurnal variation is very unapparent. Only a fluctuation of about 1 ppm could been found. In the spring and fall, atmospheric CO_2 shows a transitory variability. Similar phenomena were also observed at Mauna Lao, Hawaii (Keeling et al. 1976) and at the Cimone Mountain, Italy (Ciattaglia 1983).

2. *Relationship between Atmospheric CO_2 and Meteorological Conditions*

The inhomogeneous air masses and nonuniform distribution of small local sources around the Waliguan Mountain have led to the relationship between the CO_2 concentration at the Waliguan Mountain and synoptic systems, wind speed and direction. There are 4—5 day cycles in the daily mean CO_2 concentration distribution at the Waliguan Mountain (Fig.5). It tallies basically with the changes of the local synoptic systems and air masses. According to our statistics, whenever a front passes the observatory or the observatory is controlled by the col–field or the southeast air current in the rear of a high pressure system, atmospheric CO_2 fluctuates obviously. A difference of 1 ppm could be observed in the cases.

To illustrate the relationship between atmospheric CO_2 and wind, the mean CO_2 concentration has been calculated according to the wind speeds and directions. Winds have been classified into 16 directions and 5 speed levels. Table 2 lists the results. When the wind comes from the sector between NNE (22.5°) and SSE (157.5°), the mean CO_2 concentration increases with the increasing of wind speed. The increase could be 0.5 ppm when the wind speed was larger than 4 m / s. We attribute this to the anthropogenic emissions in that sector; since the living area of the observatory in the ESE direction is very close to the observing site; its effect on the CO_2 concentration was relatively significant if the air was blowing from the ESE direction, even if the wind speed was not high. When the wind speed was high enough (> 4 m / s), the influences of farther

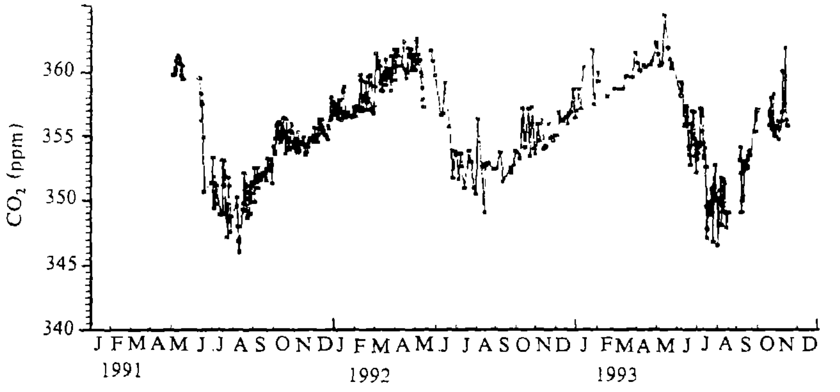

Fig. 5. Variation of the daily mean CO_2 concentration at the Waliguan Mountain. Periodical fluctuation can be identified.

Table 2. Hourly Mean CO_2 Values Related to Wind Direction and Speed at the Waliguan Mountain from October 1991 to May 1992

Wind direction	Wind speed (m / s)				
	<2	2—3	3—4	4—5	>5
NNE	356.5	356.25	356.82	357.2	357.73
NE	356.27	356.28	357.05	357.26	358.77
ENE	356.78	357.47	357.63	358.31	358.8
E	356.9	356.77	356.8	357.32	358.08
ESE	357.1	357.27	357.72	357.25	357.95
SE	356.02	356.45	358.23	358.67	358.48
SSE	356.59	356.38	356.82	357.11	358.03
S	355.96	355.87	356.33	356.91	357.32
SSW	356.31	355.86	356.08	356.24	356.64
SW	355.96	355.95	355.73	355.66	356.27
WSW	356.72	355.87	355.56	355.58	355.8
W	356.31	355.95	355.6	355.76	355.76
WNW	356.33	355.81	355.8	355.62	355.96
NW	356.87	355.91	355.73	355.77	356.34
NNW	356.35	356.2	355.96	356.02	356.55
N	355.23	356.32	356.38	356.33	357.48

local sources became evident due to the upslope wind.

IV. CONCLUSIONS

Atmospheric CO_2 at the Waliguan Mountain, Qinghai Province has been measured. Data from May 1991 to the end of 1993 have been analyzed. Significant seasonal and diurnal variations of atmospheric CO_2 are found. The maximum of the monthly mean concentration appears in April or May and the minimum in August. The seasonal oscillation of hourly mean values is about 10 to 12 ppm. The diurnal variation of the hourly mean of the CO_2 concentration in the hinterland is much larger in the summer than in the winter. The maximum is reached at about 0100 or 0200 BT (Beijing time) and the minimum in the later afternoon. In the summer, the daily fluctuation is about 5 ppm, but in the winter only about 0.5—1 ppm. These conform to the other studies. Such short−term variation of the continental CO_2 is caused by terrestrial biological activities. Relationship between the CO_2 concentration at the Waliguan Mountain and synoptic systems, wind speed and direction is observed. When the wind comes from the sector between NNE (22.5°) and SSE (157.5°), the small local sources may slightly influence the CO_2 concentration. But in most cases, the data can well represent the global baseline.

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