DIURNAL AND SEASONAL VARIATION IN CO_2 LEVELS IN THE SURFACE AIR OF GARHWAL HIMALAYA

S. Chandra and S.C. Joshi*

G.B. Pant Institute of Himalayan Environment and Development, Garhwal Unit, Srinagar (Garhwal) 246 174, India.

Abstract: Systematic measurements of atmospheric CO_2 in the surface air of the study site during the period from February 1996 to January 1997 showed seasonal and diurnal variability in the atmospheric CO_2 concentration, with highest values in the morning and lowest values in the afternoon. The data also showed a winter-summer oscillation in CO_2 levels with a minimum in July - August and a maximum in March. These diurnal and seasonal fluctuations may be related to the photosynthetic activity of vegetation of this region.

INTRODUCTION

Atmospheric carbon dioxide (CO_2) is an important greenhouse gas leading to global warming on the earth (Bolin *et al.*, 1986). Its relative contribution to global warming is more than 60% (Strzalka and Ketner, 1997), and its concentration is rapidly increasing due to the human activity since the industrial revolution (Houghton *et al.*, 1996), its concentration in the atmosphere is now regularly observed at a worldwide sampling network (Watkins, 1976). Measurements of CO_2 levels recorded at various places throughout the world show geographical and temporal variations of atmospheric CO_2 which vary with time and magnitude (Keeling, 1961; Pales and Keeling, 1965; Inoue and Matsueda, 1996). However, to the best of our knowledge, no systematic measurements of CO_2 levels in the surface air of the Himalayan atmosphere are available. Such measurements are particularly important to examine factors controlling atmospheric CO_2 concentrations/climate of the region and to develop strategies to adapt to a CO_2 enrich environment.

MATERIALS AND METHODS

The study was conducted at the Garhwal Unit of G.B. Pant Institute of Himalayan Environment and Development, Srinagar (altitude 550 m amsl; latitude 30°13'; longitude 78°48'; average annual temperature 21.03°C; average annual rainfall 711 mm). Measurements of the CO_2 concentration in the air 1.5 m above the surface were made at 2-hourly intervals during daytime from 0900 hr to 1800 hr (local time) throughout the year (from February 1996 to January 1997) using Binos 100 gas analyser (Rosemount GmbH & Co, Germany) in the absolute mode. The CO_2 gas analyzer was calibrated prior to use. Air from a height of 1.5 m above the ground was drawn (flow rate approximately 1.1 l/min) through non-CO_2-absorbing teflone tubing into the gas analyzer. The incoming air was passed through a column of magnesium perchlorate to absorb residual moisture since water vapour also absorbs strongly in the same wavelength. The mean daily values of CO_2 (µmol/mol) for each month were averaged to get the monthly average concentration of CO_2, and mean daily values were calculated by averaging CO_2 values obtained at 2-hourly intervals from 0900 hr to 1800 hr.

RESULTS AND DISCUSSION

Atmospheric CO_2 concentration in the surface is being monitored at several places in the world, to the best of knowledge, this is the first report from the Himalayan region. Diurnal variation in atmospheric CO_2 concentrations at 1.5 m above the ground observed at Srinagar during the period from

* Author for correspondence : joshisc@hotmail.com

February 1996 to January 1997 is shown in Figs. 1 & 2. Atmospheric CO_2 levels showed a typical diurnal pattern, with highest values in the morning hour (0900 hr) and lowest values in the afternoon hours (1700-1800 hr). However, the differences in CO_2 concentrations between minimum and maximum values significantly ($P \leq 0.05$) varied with the months. The differences were considerably large, i.e. 80 µmol/mol during July and August and 70-80 µmol/mol in November and December similar to the results of Pales and Keeling (1965) for Mauna Loa, Hawaii. While the average daytime values of CO_2 concentration varied from 298 µmol/mol to 383 µmol/mol during July and August, it ranged from 329 µmol/mol to 413 µmol/mol in the months of November and December. A difference of 70 to 140 µmol/mol between the minimum and maximum CO_2 concentrations during a day has been reported when measurements were made in rural areas (Clarke, 1969), over a field (Huber and Pommer, 1954), in tropical east African biomes (Schnell *et al.*, 1981) and in a forest (Bazzaz and Williams, 1991). These diurnal fluctuations in atmospheric CO_2 concentrations may have significant implications on the vegetation of the region as the variability of atmospheric CO_2 affects plant photosynthesis (Veste and Herppich, 1995). Many factors such as the intensity of photosynthesis, dense vegetation and the degree and speed of atmospheric mixing have been reported to influence the diurnal fluctuations in atmospheric CO_2 (Pales and Keeling, 1965; Inoue and Matsueda, 1996).

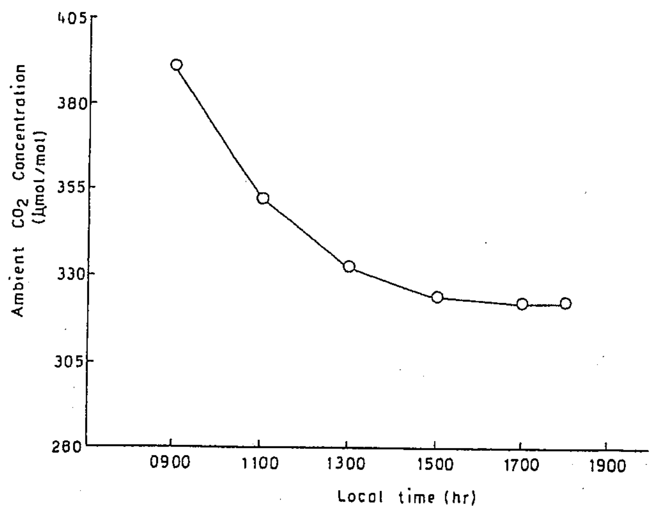

Fig. 2. The annual average diurnal course of atmospheric CO_2 concentrations at 1.5 m above the ground observed at Srinagar during the period from February 1996 to January 1997.

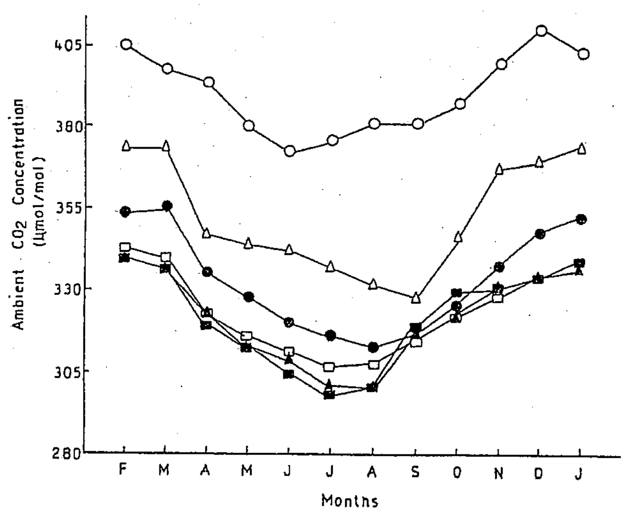

Fig. 1. Diurnal variation in atmospheric CO_2 concentrations at 1.5 m above the ground observed at Srinagar during the period from February 1996 to January 1997: O, 0900; Δ, 1100; ●, 1300; □, 1500; ▲, 1700 and ■, 1800 hr.

Long-term recordings of atmospheric CO_2 concentrations show that atmospheric CO_2 fluctuates both diurnally and seasonally (Woodwell, 1978; Keeling *et al.*, 1983; Fung *et al.*, 1987). In addition to daily changes in CO_2 levels in the surface air of the study site, seasonal changes in atmospheric CO_2 were found (Fig. 3). The concentrations of atmospheric CO_2 increased in winter and declined in summer season. Daytime averaged value of atmospheric CO_2 was more than 355 µmol/mol during winter months (November-March), while it varied from 322 µmol/mol to 340 µmol/mol during summer months (April-September). Though the tropospheric baseline levels of CO_2 are not known for the area of our study site (it needs to be mentioned here that more extensive measurements of atmospheric CO_2 over the Himalayan region are required to get precise estimates of background CO_2 concentration), the daytime CO_2 values are slightly (during winter) and considerably (during summer) lower than the mean atmospheric CO_2 which is now generally given as 360 μmol/mol (Houghton *et al.*, 1996). It has been reported that the biosphere acts as a net sink of atmospheric CO_2 during the growing season, as more CO_2 is absorbed by vegetation than is released by the respiration of soil organisms, and as a net source of atmospheric CO_2 during the winter season, when there is an excess of CO_2 released to the atmosphere over that taken up by plants (Fung *et al.*, 1987). Measurements of photosynthetic activity of plants of this region throughout the year also show seasonal variation in CO_2 uptake with maximum activity occurring during April-September and a subsequent decline thereafter with minimum during winter season (Bhadula *et al.*, 1995). This supports the view that probably the regional vegetation by serving as a source or sink regulates seasonal and diurnal CO_2 variation in the surface air of Himalayan atmosphere as the interference from industry is entirely absent in the study site. Keeling *et al.* (1996) have also demonstrated that in spite of atmospheric mixing processes, spatial variability is retained in the seasonal cycle of CO_2 that reveal regional detail in

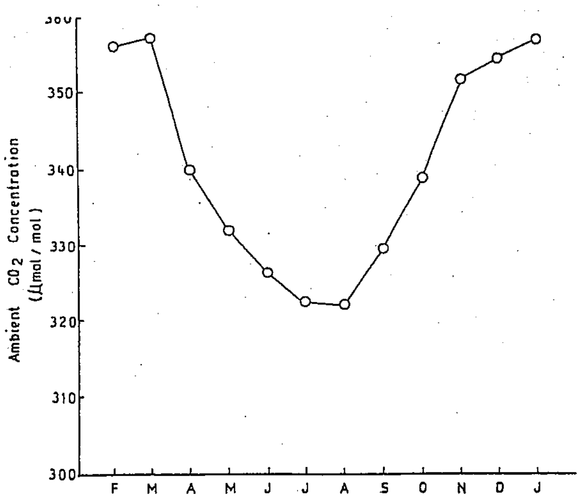

Fig. 3. Monthly average concentration of atmospheric CO_2 at Srinagar.

seasonal plant activity. If this CO_2 measurement program is continued for few more years, the data so obtained will provide a valuable insight into the factors affecting climate of the region. Therefore, continuous measurements of CO_2 and other greenhouse gases are required to gain a valuable insight into the factors affecting climate of the region.

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