DIURNAL AND SEASONAL VARIATION OF MEASURED ATMOSPHERIC CO_2 AT DEHRADUN DURING 2009

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ABSTRACT:

Atmospheric carbon dioxide (CO_2) is the major greenhouse gas. We analysed the diurnal trend and seasonal variations of atmospheric Carbon Dioxide (CO_2) measured at Dehradun during 2009. The measurements are taken from the Vaisala CO_2 probe installed at the top of the IIRS building. A distinct diurnal cycle with seasonal variations is present in these measurements. Diurnal cycle exhibits a half sinusoidal variation with decreasing phase during sunrise to afternoon and increasing phase during afternoon to sunset. CO_2 mostly remains constant with higher values during the night. The largest negative anomaly with respect to the annual mean varies between +/-20 ppmv with positive anomaly during the night time and negative anomaly during the day time. The cause of such variation could be attributed to the local ecosystem activity. During the day time the sinking of CO_2 through the photosynthesis dominates its release through autotrophic and heterotrophic respiration. On the other hand, photosynthesis has been ceased during the night time and respiration only controls the night variation of CO_2..There exists significant change on the diurnal cycle of CO_2 in different seasons during the year. The maximum rapid decrease in CO_2 concentration in early morning hours is due to photosynthetic activity during the monsoon periods (maximum in August -8ppm). During monsoon period rapid night time increase of CO_2 is observed due to the enhancement of respiration. An inverse relationship exist between model simulated net ecosystem productivity and CO_2 deviations on monthly basis. This diurnal and seasonal variations in situ CO_2 are in confirmation with model simulated results.

1. INTRODUCTION

Carbon dioxide (CO_2) in the atmosphere is of vital importance because of its influence on green house (GH) effect and climate change. CO_2 being the GHG, the increase in concentration directly influence the global temperature of atmosphere. Since pre-industrial time it has been increased continuously, and during the past three decade the growth rate has been accelerated which has influenced largely the recent time global warming. During 1995 - 2005 decade, the growth rate of CO_2 in the atmosphere was 1.9 parts per million by volume (ppmv) yr^{-1} increasing the radiative forcing by 20%. This is the largest change observed for any decade in at last 200 years (IPCC, 2001). In recent decade, it is increasing by 2.14 ppmv yr^{-1} and at present it is 393ppmv (Nayak and Dadhwal et al. 2011).

Most sources of CO_2 emission are natural, that include volcanic eruption, the combustion of organic matter and the respiration process of living aerobic organisms. The man made sources of CO_2 include the burning of fossil fuels for heating, power generation and transport and industrial processes. It was reported that the important reason for increase in CO_2 is a result of human activities that have occurred over the last 150 years, including the burning of fossil fuels and deforestation.

CO_2 exchange between atmosphere and land surface is an important issue to understand the future climate scenario. For quantitative understanding of regional CO_2 transport and its variations with regional environmental boundary condition different spatial and temporal scales have to be analysed through field measurements. The distributed dense networks of observations would be useful to represent the CO_2 changes due to geographic and local environmental conditions. Recently several observational networks have been established across the globe under different national and international efforts. In India a few observation sites are operationalized and a few are planned. Mmeasurement and analysis of near surface CO_2 has been reported by Bhattacharya et al (2009) using flask sample at Cape Rama (Goa) and at high altitude on commercial aircraft by Schuck et al., (2010).

In this paper we have analyzed the diurnal and seasonal variations of CO_2 at Dehradun station of India. Vaisala CO2 CARBOCAP, GMP343 sensor is used to measure CO_2 averaged over 15 minutes. The diurnal trends of CO_2 have been analyzed with reference to local ecosystem activities. Significant changes on the diurnal cycle of CO_2 in different seasons also studied. In order to examine the causes of such variation, we have compared the CO2 data with the local ecosystem CO_2 exchanges in the form of net ecosystem productivity (NEP) and soil-respiration simulated from a terrestrial ecosystem model.

2. MATERIAL AND METHODS

2.1 Measurements

The measurement site used for the present study of CO_2 is Indian Dehradun station (30.1ºN, 77.4ºE). The site is surrounded by the vegetation and forest. The measurements are taken from the Vaisala CO_2 probe installed at the top of the IIRS building, approximately 30m above the ground in order to capture the diurnal and seasonal variability of CO_2. The Vaisala CARBOCAP GMP343 is the most reliable instrument for such studies. It is an accurate and rugged probe type instrument which provides an acceptable compromise between size, response time accuracy and stability (Table 1: Key specifications of GMP343). The measurement is based on the advanced CARBOCAP Single – Beam –Wavelength NDIR technology. Rigby, (2008) reported the reliable results of continuous measurement of CO_2 using GMP343 at Central London.

While climatic and background CO2 increase measurements are carried out with very high precision, away from anthropogenic source-led noise, need exists for additional land use and other factor controlled CO_2 variation at a number of sites. Availability of small rugged infra-red sensors has opened up such studies. This is in contrast to eddy-covariance CO_2 measurements from fast sensors that are used to derive fluxes, these sensors are slow response sensors, e.g., LiCOR (Li-820, Li840), Vaisala (GMP 343). Recently such sensors have been used to characterize CO_2 over urban area (Central London, by Rigby et al., 2008), soil CO_2 fluxes/respiration, sea-air exchange.

2.2 Working principle

The detail schematic of the sensor is shown in figure 1 The infra-red sensor of GMP343 is based on the proprietary Vaisala CARBOCAP sensing technology. The pulsed light from a miniature filament lamp is reflected and re-focused back to an IR detector which is behind a silicon based Fabry-Perot Interferometer (FPI). The tiny FPI is tuned electrically so that the measured wavelength is changed between the absorption band of the CO_2 gas and a referenced band.

Noise at 350 ppm	3 ppm
Short-term stability (up to 6 h) at 350 ppm	1 ppm
Long-term stability	<_2% of reading year_1
Response time	75

Table.1Vaisala CARBOCAP GMP343 key performance statistics (Vaisala, 2005).

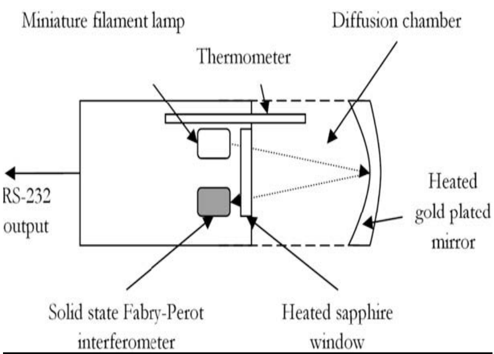

Figure.1 Vaisala CARBOCAP schematic.

3. RESULTS

3.1 Observation Results:

Hourly deviations of the observed CO_2 are calculated throughout the period. The CO_2 deviations are calculated by the subtraction of annual mean value from hourly values. A distinct diurnal cycle with seasonal variations of CO_2 is observed during the study period. The diurnal cycle of CO_2 can be explained through the interaction of number of process (Reid and Steyn, 1997). Diurnal cycle exhibits a half sinusoidal variation with decreasing phase during sunrise to afternoon and increasing phase during afternoon to sunset. CO_2 mostly remains constant with higher values during the night. The largest negative anomaly with respect to the annual mean varies between +/-20 ppmv with positive anomaly during the night time and negative anomaly during the day time. Further the amplitudes of diurnal cycles are different in different months with maximum dip during afternoon hours. The cause of such variation could be attributed to the local ecosystem activity. During the day time the sinking of CO_2 through the photosynthesis dominates its release through autotrophic and heterotrophic respiration.

To understand the maximum dip in CO_2 during afternoon hours, we have analyzed CO_2 deviations in between 12-16 hours LT (Figure 3). The minimum value (-26ppm) is observed during September. This minimum value starts decreasing with the arrival of summer monsoon. This is because of the enhanced vegetation activity during monsoon and post monsoon months.

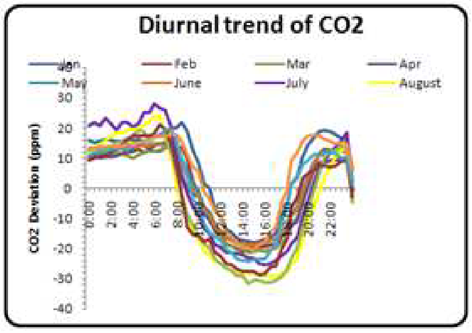

Figure 2: Observed diurnal variability of atmospheric surface layer CO_2 (deviations) at Dehradun during 2009

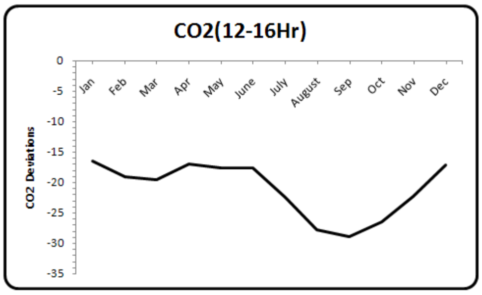

Figure 3: Observed atmospheric CO_2 deviations during 12-16 hours LT at Dehradun during 2009.

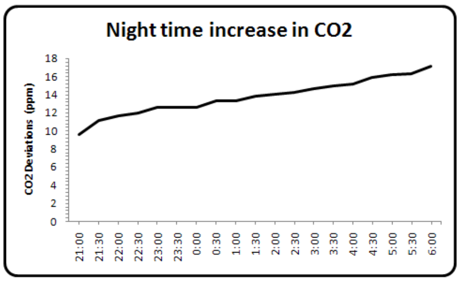

Figure.4 CO_2 variations observed between 04-07 hr LT during different months in 2009.

The rapid decrease in CO_2 in early morning throughout the year (Figure 2) is again the function of photosynthesis activity. To analyse this feature we studied the CO_2 behaviour in between 07-10 hours LT (Figure 4). The maximum decrease in CO_2 is observed during monsoon period, with the minimum value during July (-8 ppm). During rest of the months the decline of CO_2 lies around -2ppm. The rapid decrease in CO_2 is primarily due to thickening of planetary boundary layer and secondarily due to enhancement of vegetation-photosynthetic activity. During monsoon months the vegetation is maximum, thus photosynthesis is also maximum which lead to increase the uptake of CO_2 by vegetation.

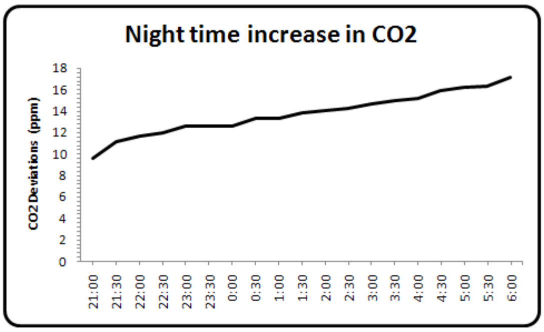

Figure.5 Night time increase in observed atmospheric CO_2 during 21 to 06 hours LT .

It is observed that CO_2 remains constant with the higher values during the night (Figure 3). The night time increase in CO_2 at Dehradun is analyzed by taking observation from 21:00 to 06:00 hous LT (Figure.5). A linear increasing trend in CO_2 is observed from 21 to 06 hours LT throughout the year. At 21 hour the value is 10 ppmv while it reached to 18 ppmv around 06 hour.

3.2 Model Results:

The Net Ecosystem Productivity (NEP) is the estimates of net carbon exchange between the vegetation-soil system and the atmosphere. It could play an important role in the control of atmospheric CO_2. It is the difference between Net Primary Productivity (NPP) and soil-respiration and could be simulated by terrestrial ecosystem model. Recently Carnegie–Ames–Stanford Approach (CASA) is implemented for the simulation of NPP, NEP, soil respiration and etc. over India at 2 min spatial resolution. The model was forced by the time varying climatological parameters and satellite measured vegetation greenness index (Nayak *et al*. 2009, 2011). The simulated results at Dehradun for the year 2009 are further used for the interpretation of CO_2 observed variations.

The variation of monthly night time increase in in situ CO_2 along with the simulated soil respiration is shown in Figure 6.

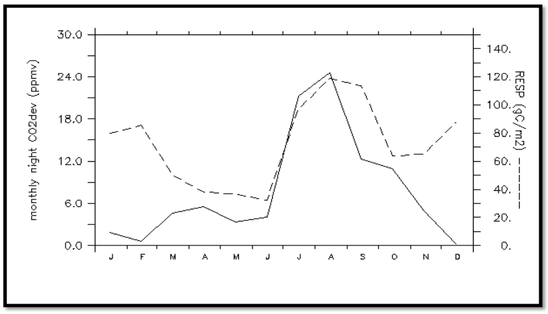

Figure 6: Comparison between night time CO_2 and simulated soil-respiration during different months in 2009.

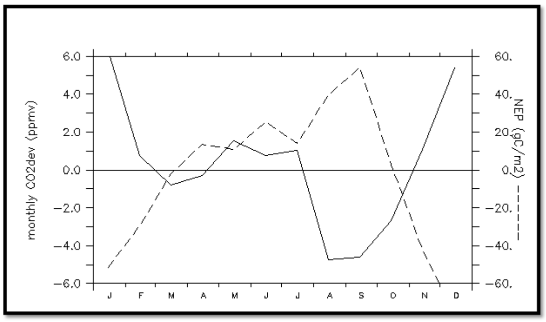

Figure 7: Comparison between monthly observed CO_2 and simulated net ecosystem productivity during 2009.

The night absolute deviations show that CO_2 start increasing with the arrival of summer monsoon (June) with the peak during August (27ppm) and then start declining. The soil respiration has one to one correspondence with the monthly night time increase in CO_2 especially during monsoon months. It starts increasing from June and reaches the peak in August. Observations show that the night time increase in CO_2 during monsoon period is mainly governed by the increase in soil respiration process. Because the photosynthetic activity stops at night.

The monthly CO2 deviations are also compared with the simulated NEP (Figure 7). An inverse relationship exists between the two parameters throughout the year. During winter months (Nov-Dec-Jan-Feb) the negative NEP enhanced the atmospheric CO_2, while in monsoon the large positive NEP governs the rapid decrease in the CO_2.

4. CONCLUDING REMARKS

Results presented here show the distinct diurnal cycle and seasonal cycle of near-surface CO_2 at Dehradun at a mixed urban-vegetation site.. The observed variations in CO_2 are controlled by the day time photosynthesis and the night time respiration process at diurnal scale. The onset and withdrawal of summer monsoon also directly and indirectly influenced the CO_2 concentration. The intra-seasonal CO_2 patterns were also compared with the CASA model simulated NEP and soil respiration process. Soil respiration and CO_2 trend perfectly correlated with each other especially during monsoon months. While the NEP and monthly CO_2 deviation shows an inverse relationship with each other. The over all results highlight the control of that observed CO_2 variations by the terrestrial ecosystem C cycle processes.

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