

Diurnal and Monthly Variations in Atmospheric CO₂ Level in Qena, Upper Egypt

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Abstract The diurnal and monthly variations of carbon dioxide (CO₂) concentrations levels have been studied in Qena, Upper Egypt during the period Jan.2013-Dec.2014. The variations in CO₂ are characterized by highest values in winter months (405 ppm) and lowest values in summer months (397 ppm) reflecting fluctuations in motor traffic and humans activities. A weekly cycle with highest values of CO₂ during the weekdays and lowest ones during weekends has been identified. The hourly CO₂ concentrations showed two peaks – one corresponding to the morning traffic peak; and another corresponding to evening traffic peak. The lower values of CO₂ levels were considerably between 12:00 to 4:00 pm. The effect of meteorological variables such ambient air temperature, relative humidity and wind speed on the CO₂ level is examined. The results show that the wind speed and the ambient air temperature have negative correlations on the CO₂ levels with coefficient -0.38 and - 0.5, respectively. On the other hand, the relative humidity has a positive effect with a correlation coefficient equals 0.51. A data set of PM₁₀, O₃ and NO₂ corresponding to the same period was used to examine its relation with CO₂. The analysis shows that the relationships between CO₂ levels and O₃, NO₂ and PM₁₀ are not good where coefficient of determination, R², equals 0.017, 0.061 and 0.015, respectively. This finding may be attributed to the low values of CO₂ autocorrelation, may be portions of CO₂ have been transported to the sampling site.

Keywords Carbon dioxide, Qena, Regression analysis, Autocorrelation

1. Introduction

The study of atmospheric CO₂ emissions is important for its potential effects on climate. The atmospheric CO₂ concentrations are increasing due to human and automobile activities such as burning of fossil fuels [1] Human and automobile activities produce more than 80% of the CO₂ in an urban environment [2]. Despite its relatively low concentration in the atmosphere, the CO₂ is a greenhouse gas and plays a vital role in regulating the earth's surface temperature through the greenhouse effect. Moreover, CO₂ is site and time dependent [3] and it is related to weather conditions.

In the last few years, much attention has been focused on the increase of the CO₂ concentrations [for example 4-11] These studies focused on the role of sources of atmospheric CO₂ and the partition of the anthropogenic CO₂ into various components. Also, these studies were interested in the diurnal and seasonal variations of CO₂ and its relation with metrological factors and human activities. Most of these studies reported that the CO₂ concentrations in winter are greater than the summer ones and are correlated with traffic

density. Also, its weekly trend had the lowest values during the weekends when the traffic density reduced. The daily trend had a peak in the early morning when traffic was highest and the atmosphere was more stable.

Most of the previous studies for the CO₂ levels in the atmosphere were conducted in city centre. The present work was undertaken outside the city (in a desert area) to increase our understanding. The present study is concerned with the following:

1. Diurnal and monthly variations in atmospheric CO₂ concentration levels.
2. Analysis of the main factors affecting CO₂ concentration.
3. Relation the CO₂ concentrations to other pollutants such as PM₁₀, NO₂ and O₃.
4. Analysis of the autocorrelation functions of the hourly CO₂ values to investigate the proportion of the transported of CO₂ into the measured values.

2. Data Collection

Hourly atmospheric CO₂, PM₁₀ and NO₂ concentrations as well as air temperature, wind speed, and wind direction measurements have been monitored at the South Valley University (SVU)-meteorological research station, during the period Jan. 2013 to December 2014. The station is located about 6 km northeast of Qena city in a desert area.

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Also, the station is located about 0.5 km from the University Campus and 1 km from red sea road (Qena – El Hurghada high way). Little vegetation is found around the station.

Qena City (26°17' N, 32°43' E, 97 m asl) is located in Upper Egypt, about 600 Km south of Cairo and 60 Km north of Luxor (Figure 1). It is located mainly within the narrow Nile valley which separates Egypt in two unequal desert parts, the western and the eastern deserts.

The climate of Qena is very hot and dry in summer and cold in winter. In summer, the average daily maximum temperature $T = 40^{\circ}\text{C}$ and the average daily minimum relative humidity $\text{RH} = 17\%$, while in winter the average daily maximum temperature $T = 25^{\circ}\text{C}$ and average daily minimum $\text{RH} = 26\%$. It rarely rains. Also, it receives large quantity of solar radiation, especially in summer [12]. The prevailing wind directions are North, North East and East. Also, Qena city is characterized by low traffic density and no industrial activities.

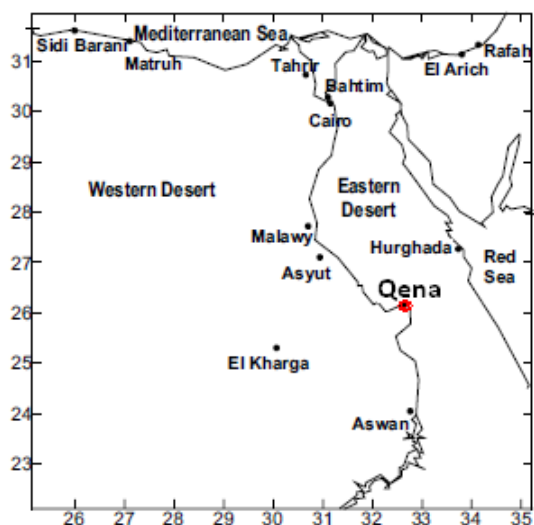


Figure 1. The studied area, Qena, Egypt

3. Results and Discussions

3.1. Diurnal Variations of CO₂ Concentrations

Figure 2 provides the diurnal variations of CO₂ concentrations at the study site. In the diurnal cycle, the CO₂ concentration shows two peaks – one corresponding to the morning traffic peak between 6:00 am and 8:00 am; and another corresponding to the evening traffic peak between 6:00 pm and 8:00 pm. The CO₂ levels are considerably lower between 12:00 and 4:00 pm for all the study period because of low traffic densities (and consequently low emission rates) and favourable dispersion conditions (increase in the mixing height).

During nighttime, i.e. after 10:00 pm, the CO₂ concentrations significantly decrease because of low traffic density and human activities (low emission rate). However, noticeable increases in CO₂ concentrations are observed after 1:00 am. The probable reason for this may be that the

emissions of CO₂ are under inversion conditions. Further, it was found that the nighttime CO₂ concentrations were, approximately, equal to the morning peak CO₂ concentrations. Figure 2, also, shows mean maximum CO₂ concentration during the studied period to be 406.5 ± 7.2 ppmv while the minimum one 397.5 ± 5.2 ppmv. Many previous studies have also reported a similar trend for carbon dioxide concentration [for example 13 - 15].

Also, the atmospheric CO₂ measurements in Qena reveal a significant weekly cycle with highest levels during the work-week (Saturday–Thursday) and lowest levels during the weekend (Friday). The recorded data show a peak at 10.00 am in weekend morning (Friday). The mean atmospheric CO₂ concentration during the week is 403 ppmv compared to 400 ppmv during the weekend. This is probably because the weekdays traffic at the study site is significantly higher compared to weekends (Friday) traffic.

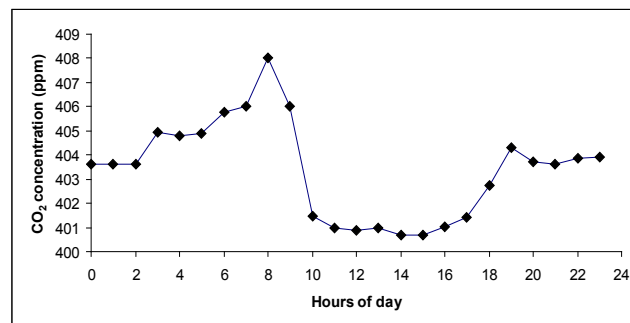


Figure 2. Diurnal variations of CO₂ concentrations at the study site

3.2. Monthly Variations of CO₂ Concentrations

The monthly variations of CO₂, Figure 3, are characterized by highest value (405 ppm) in the cold months (November - February) and lowest value (397 ppm) in summer months (May - August). Some of the previous studies report the similar findings. For example, Gratan and, Varone [4] report that the winter carbon dioxide concentration in Rome was 18% greater than the summer one. The difference between winter and summer CO₂ concentrations, in our location, may be attributed to the following facts:

1. The human activities in the winter months are grater than in the summer months where these activities are associated with the study in the South Valley University. The study- period extends from October to June, while the summer holiday extends from June to October.
2. The mixing high, as shown in Figure 4, in summer months is greater than during winter. The mixing height is calculated from radiosonde data [16].
3. During summer, the atmosphere in Qena is highly unstable (turbulent) because of increased solar radiation [17], wind speed and frequent changes in wind directions. This also results in an increase in mixing height and so enhances the dispersion of CO₂ emissions.

3.3. Impact of Meteorological Factor on CO₂ Concentrations

Meteorological parameters are having great importance in transportation, dispersion and natural cleansing of the air pollutants in the atmosphere. Thus, meteorological information is very essential in locating the industry and planning the control measures for air pollution. Based on this principle the present study has been conducted for studying the effects of meteorological variables on carbon dioxide levels. The meteorological variables are air temperature, relative humidity and wind speed.

3.3.1. Effect of Air Temperature and Relative Humidity

Figure 5 shows a negative relationship between the ambient temperature and the CO₂ concentration where the correlation coefficient (R) is -0.5. The increasing ambient temperature, in summer, is associated with a decrease in the human's activities and reducing of fuels consumption. Also, during the hot summer days, the air near the surface can be much warmer than the air above. Sometimes large volumes of this warm air rise to great heights. This results in vigorous mixing. On the other hand the relative humidity has a positive relationship with carbon dioxide concentration as shown in Figure 6. The positive correlation R is 0.51. This positive correlation may be due to the

formation of inversion layer because an increase in humidity reduces the amount of solar radiation reaching the earth's surface. The heat from the solar radiation is absorbed by the air, resulting in minimizing atmospheric temperature nearer to the surface of the earth. The air layer nearer to the surface of the earth becomes colder than the upper layers, thus reducing the up going air currents and leading to the increase in CO₂ and other pollutants concentrations.

3.3.2. Effect of Wind Speed

The Surface wind plays an important role in the transport and dispersion of pollutants. Figure 7 shows the relationship between the wind speed and CO₂ concentration during the study period. It is obvious that the relation is negative with correlation R equals -0.38. The figure shows that the maximum CO₂ concentration has occurred at calms. The effect of wind can be explained as follows: increasing of wind will increase the rate of transport of air pollutants. Also, a further increase in wind may be affecting the mixing height through the fractional force of air movement over the ground, which supports the creation of mechanical turbulence. Consequently, increasing wind speed leads to decreasing CO₂ concentrations and vice versa.

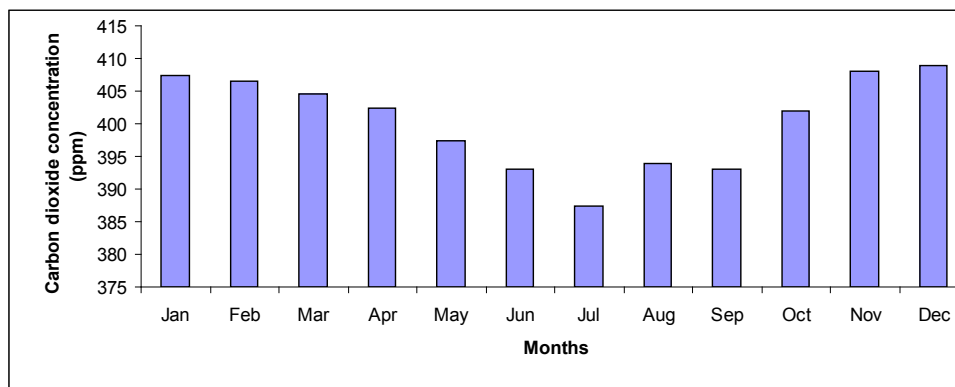


Figure 3. Mean monthly atmospheric CO₂ concentrations at study site during the period Jan.2013-Dec.2014

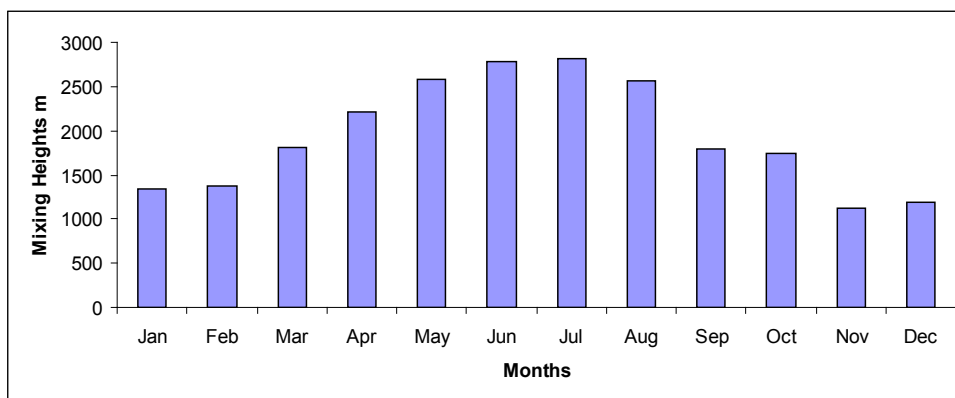


Figure 4. Mean monthly mixing height at study site during the period Jan.2013-Dec.2014

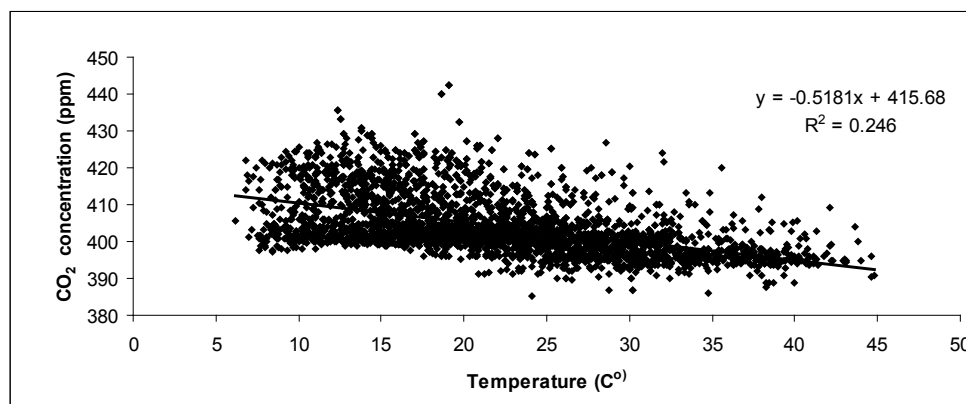


Figure 5. The relationship between hourly values of CO₂ and air temperature at study site during the period Jan.2013-Dec.2014

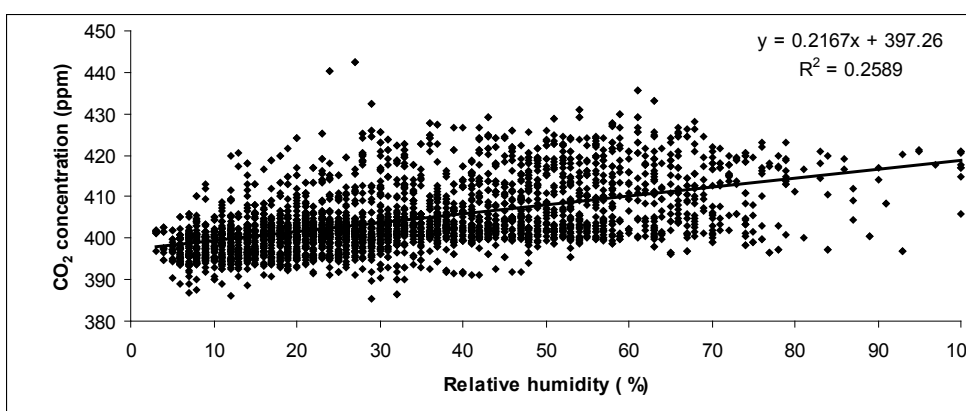


Figure 6. The relationship between hourly values of CO₂ and relative humidity at study site during the period (Jan.2013-Dec.2014)

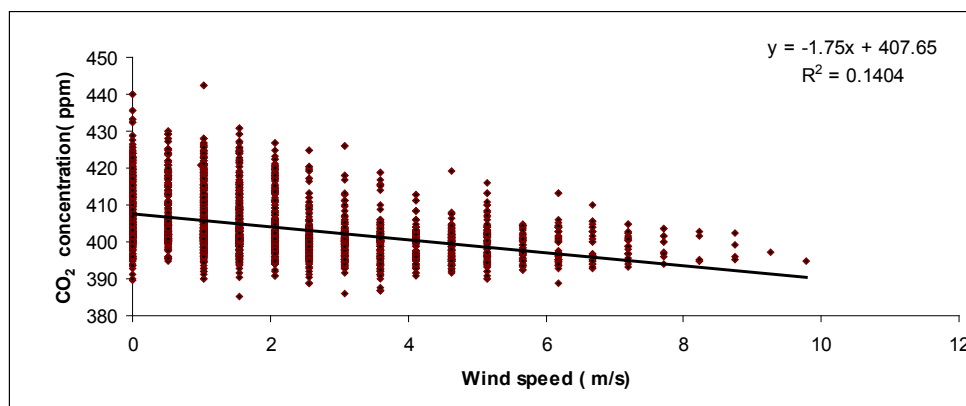


Figure 7. The relationship between hourly values of CO₂ and wind speed at study site during the period Jan.2013-Dec.2014

3.4. Analysis of Autocorrelation Function

Figure 8 illustrates the autocorrelation function for hourly CO₂ values in Qena during winter and summer seasons in the period Jan. 2013 to December 2014. The following can be deduced:

- There is no complete periodicity in the autocorrelation function within 24 hours, where the autocorrelation function decreased after 24 hour becomes 0.331 and 0.371 in winter and summer, respectively
- This result leads us to suggest that there may be

portions of CO₂ to have been transported to the sampling site. The transported CO₂ may be from Qena city centre. For more understanding this point, air mass trajectory analysis of CO₂ should be undertaken.

3.5. Relation between CO₂ and Other Pollutants

Air pollution is made up of a mixture of gases and particles that have been released into the atmosphere by man-made processes. Such emissions are typically from the combustion of fossil fuels such as coal, oil, petrol or diesel. The available measured gases data in study site during the

same period, Jan.2013 - Dec.2014, are NO_2 and O_3 . Particulate matter with diameter less or equals to $10\mu\text{m}$ was measured as well. The present section studies the relation between the hourly CO_2 concentration and hourly concentrations of NO_2 , O_3 and PM_{10} . Figures 9(a-b-c) show the relationships of hourly concentrations of CO_2 to those of PM_{10} , NO_2 and O_3 . The following findings are deduced:

Atmospheric CO_2 concentrations correlate quite well with PM_{10} concentrations. The regression analysis showed positive relationship between CO_2 and PM_{10} which is characterized by a regression slope of 0.033 and intercept of

401.9 with correlation coefficient R equals 0.38. This may be due to human activities.

The regression analysis between CO_2 and O_3 , as shown in Figure 9b, shows a negative relation with slope of 0.21 and intercept of 411.2 and weakly correlation coefficient of -0.13. The weakly and negative correlation between CO_2 and O_3 may be due to the ozone gas as secondary pollutant.

Figure 9c shows that the CO_2 concentration is positively correlated with NO_2 concentration with slope 0.30 and intercepts equals 403.7. The positively correlation coefficient is 0.25.

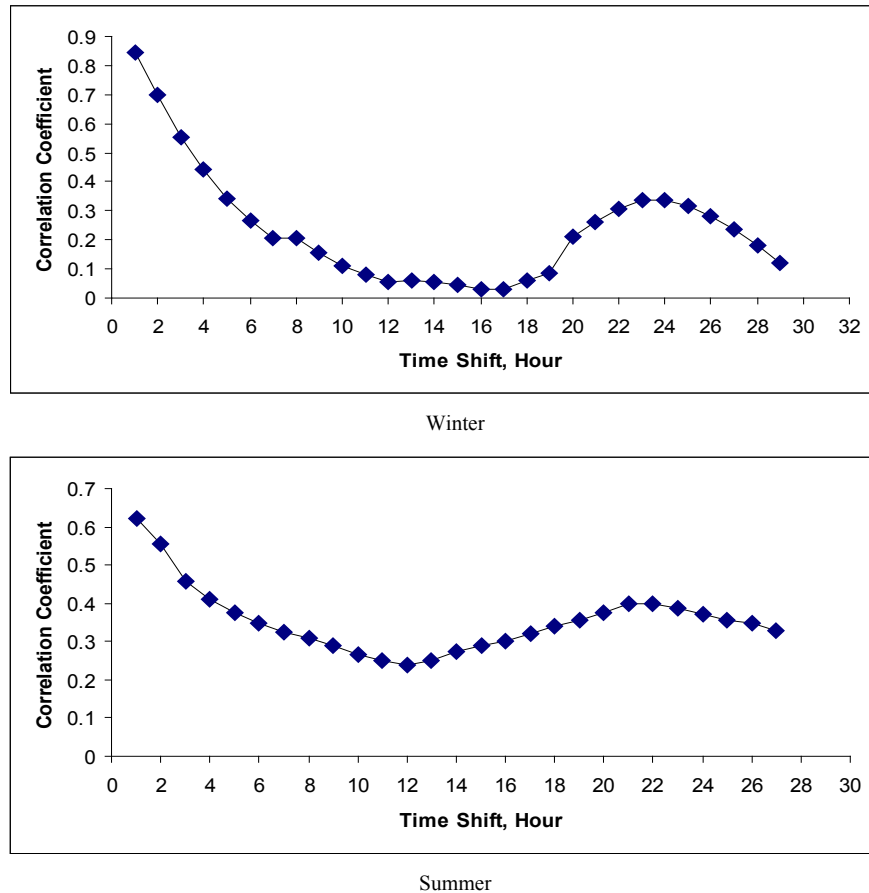


Figure 8. Autocorrelation function of CO_2 in Qena during summer and winter seasons of the period Jan.2013-Dec 2014

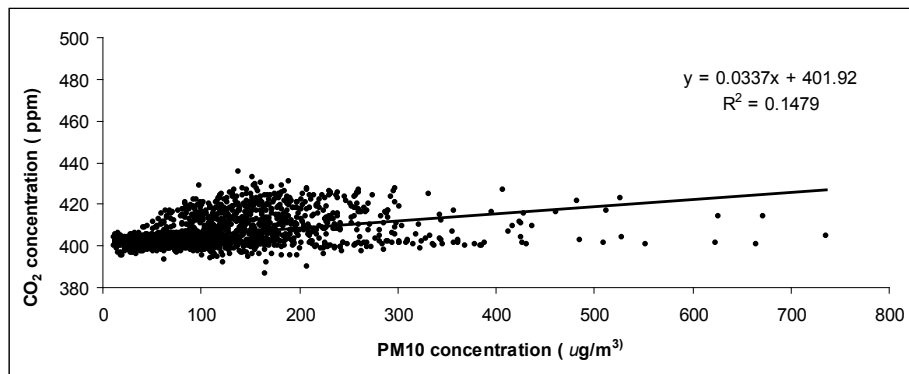


Figure 9a. The relation between CO_2 and PM_{10} hourly concentration

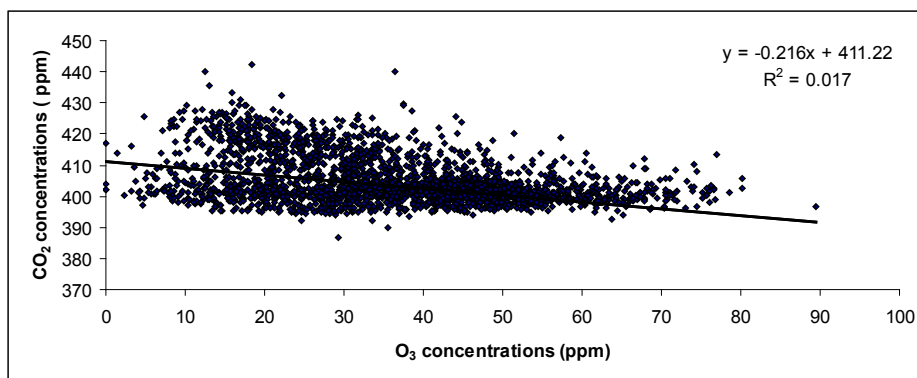


Figure 9b. The relation between CO₂ and O₃ hourly concentration

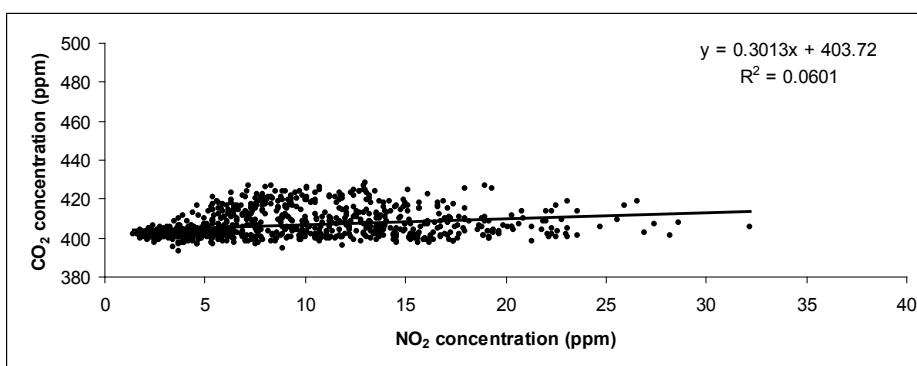


Figure 9c. The relation between CO₂ and NO₂ hourly concentration

4. Conclusions

From January 2013 to December 2014, the atmospheric CO₂ concentration was measured above the ground on the campus of SVU meteorological research station, which is located outside Qena city, Upper Egypt (26°17' N, 32°43' E, 97 m asl). During the same period, both of meteorological factors and concentrations of atmospheric PM₁₀, O₃ and NO₂ were also measured. The analysis of these data leads to the following:

1. During the diurnal variation, the maximum CO₂ concentration occurred in the morning (6-8 am) and the broad minimum in the daytime (12-4 pm).
2. The monthly variations of CO₂ is characterized by February) and lowest value (397 ppm) in summer months (May - August).
3. The atmospheric CO₂ measurements in Qena reveal a significant weekly cycle with highest levels during the work-week (Saturday–Thursday) and lowest levels during the weekend (Friday).
4. The atmospheric CO₂ has a negative relation with both ambient temperature and wind speed while it has a positive relation with relative humidity.
5. The relations between other measured pollutants such as PM₁₀, O₃ and NO₂ with CO₂ were examined. The examination showed that the relationships were not good, may be a portion is transferred from other location.

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