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Assessment of Ground-Level Ozone and Its Variability with Meteorological Parameters at Karaikal, India

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Abstract:

Ozone (O_3), an allotrope of oxygen is one of the most powerful oxidants which occur naturally in trace amounts in the Earth's atmosphere. Availability of ground level O_3, temperature and wind speed data for a period from October 2013 to September 2014 at Karaikal, Union Territory of Puducherry, a coastal region along south east India has been utilized to assess the variability of ground level O_3 against the other three parameters. Temporal variation of O_3 with temperature, wind speed clearly indicates the dependence of O_3 on the above said two parameters. The results reveals a strong dependence of O_3 on temperature (r^2=0.8722) and hence in Ozone levels in ambient air. Correlation between O_3 and wind speed shows not much significance (r^2=0.1816). Seasonal variation of O_3 reveals that Ozone levels are maximum during the summer and pre-monsoon period while minimum Ozone levels occurs during the North-east monsoon and winter seasons. It is observed from the results that not a single Ozone data exceeds the standard value and lies well within the limit of WHO recommendation (50 ppb).

Keywords: Correlation, Seasonal Variation, Temporal Variation, Ozone

1.0 Introduction:

Ozone, although found as a rare element in the atmosphere averaging just about 3 molecules for every 10 million air molecules still plays a very crucial and pivotal role in the atmosphere. Despite the stratospheric ozone depletion (Varotsos et al., 1993, 1994; Varotsos et al., 2004), the abundance of tropospheric O3 is increasing at many sites over the globe and is expected to rise significantly throughout the twenty-first century (Cartalis et al., 1994; IPCC, 2001). It is this Ozone level present in the troposphere that comes into direct contact with life-forms and exhibits its destructive side. Several studies have documented the harmful impact of tropospheric Ozone on crop production, forest growth, and human health (Lippman, 1989; Embersion et al., 2001). Tropospheric Ozone is a key component of photochemical reactions among NOx and VOCs in the presence of heat and sunlight (Derwent et al., 2003; Crutzen, 1974).

The influence of weather on Ozone formation has been examined a good deal through several research studies over the past 20 years. It has been observed that the formation of Ozone is strongly depend on meteorological conditions. Ozone levels tend to be higher under hot, sunny conditions which favour the photochemical Ozone production. Conversely, wet and rainy weather with high relative humidity is typically associated with low Ozone levels provided by wet Ozone deposition on the water droplets (Tarasova et al., 2003).Temperature is one of the most important meteorological parameters that controls, influences the speed and amount of photochemical production of Ozone. A large number of observations have depicted that lower (higher) wind speeds increases (lowers) the Ozone concentration levels as it favours the accumulation (dispersion) of Ozone molecules (Elminir, 2005).

Karaikal, a part of the union territory of Puducherry is a coastal region located along the south eastern side of the Indian Peninsula. Availability of tropospheric Ozone, temperature and wind speed data for a period from October 2013 to September 2014 has prompted us to make an attempt to analyse the near-surface Ozone concentration in this region and also to investigate the impact of meteorological parameters like temperature and wind speed over the tropospheric Ozone concentration levels in ambient air.

2.0 Measurement Site and Methodology:

Karaikal (10.9327 °N, 79.8319 °E), is situated in the eastern coast of India Figure 1. The climate at the measurement site during May is the representative for summer season (March-May). The climate at the study site during May is very hot due to intense solar radiation. The daytime temperature reaches about 40°C and nighttime above 30°C. The study area receives heavy rainfall only during northeast monsoon (Singh et al., 1999; Debaje et al., 2003). The month January is the representative for the winter season. Fair weather prevails with wind speed in the order of 3-4 m/s with northeasterly direction, and clear sky and moderate relative humidity exists during the winter season (January-February). The month July is the representative for the pre-monsoon season. Partly cloudy sky and hot weather with no rain characterizing the pre-monsoon season (June-September)(Debaje et al., 2011).

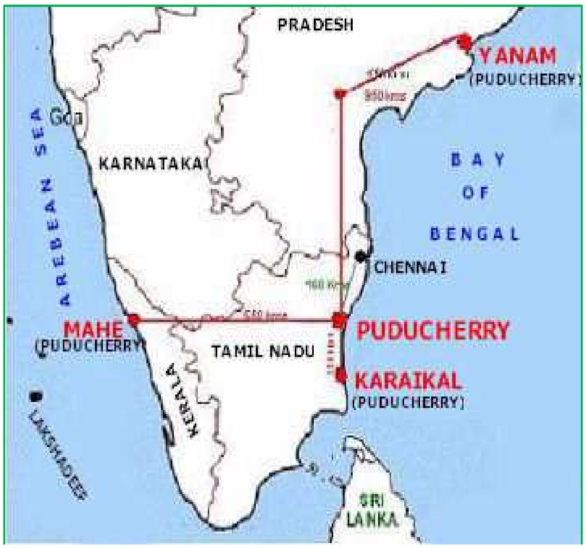

Fig.1: Location Map of Karaikal, India

The O_3 was continuously monitored from October 2013 to September 2014 at a major traffic thoroughfare in the karaikal region. The gaseous measurements were taken by using a portable sensitive gaseous monitor Aeroqual S500. This instrument is the advanced version of the S200 series utilized by (Weisinger et al., 2009) and (Elampari et al., 2011) for their studies.The measurement units being either in ppm or µg/m^3.The range of Ozone measurement is 0.0-0.150ppm. The sensor can detect Ozone values upto a lowest value of 0.001ppm with a resolution of 0.001ppm. This portable sensitive gaseous monitor performs best with an operation range of -5-40ºC for temperature and 5-95% for humidity.The Aeroqual S500 gaseous monitor utilized for this study is shown in Figure 2. Surface Ozone was measured from 7.30 hrs to 19.30 hrs. The 12hrs data were averaged to obtain the daily averaged value. The meteorological parameters were obtained from IMD and weather underground Inc.

Fig.2: Aeroqual S500 gaseous monitor

3.0 Results and Discussions:

3.1 Day to Day Variations:

12 hrs ground level Ozone concentration averages (7.30 hrs to 19.30 hrs, Indian Standard Time, IST) measured from October 2013 to September 2014 are presented in Figure 3. The level of ozone concentration at the surface can be estimated by the result of source and sink mechanism, which predominately rely on the meteorological conditions of the environment. Karaikal, being a coastal region favors the trapping of pollutants. Furthermore, Karaikal has various unregulated sources of particulates and gases in the form of high number of vehicles, dusty roads and small industries. However the measurements obtained from this study indicates that the concentration of pollutants is well below the WHO guideline value. The observations reveal that the daily averaged Ozone concentrations are well within the WHO guideline value of 50 ppb (Elampari et al., 2011). It can be noted that not a single data exceeds this standard limit. Based on the EPA classification, 12-hr Ozone concentration measured during the study period clearly indicates that the Ozone concentration level remains good (0-50 ppb) and there is no health impact expected when the concentration level in this range.

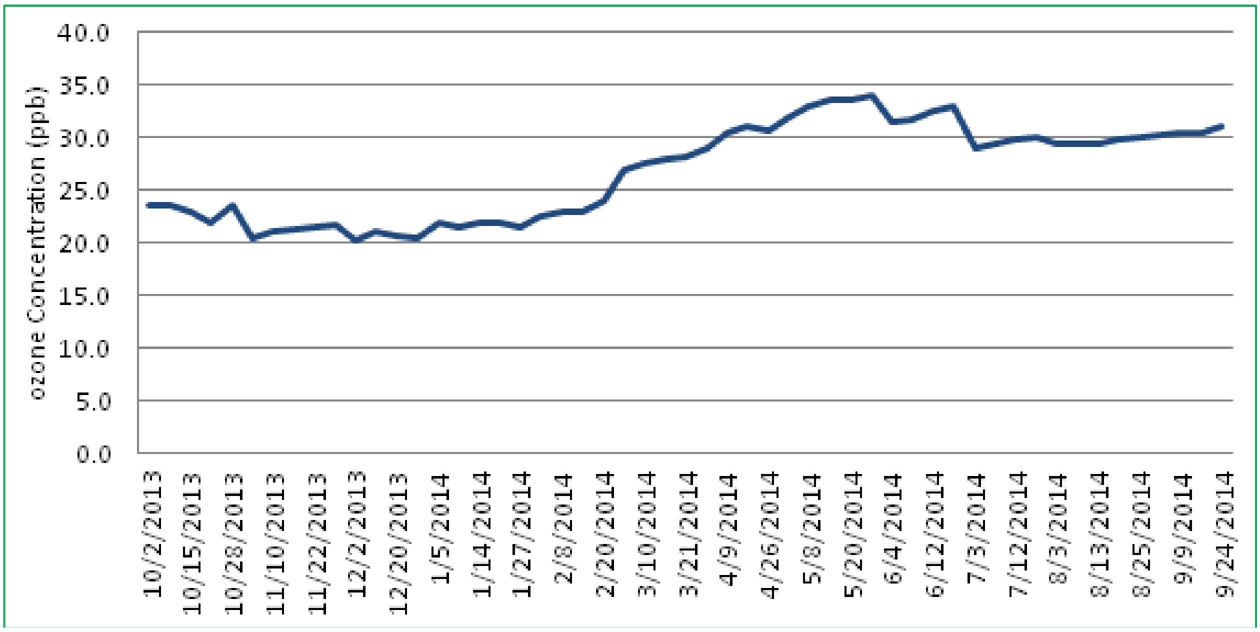

Fig.3: Diurnal Variations in Ozone

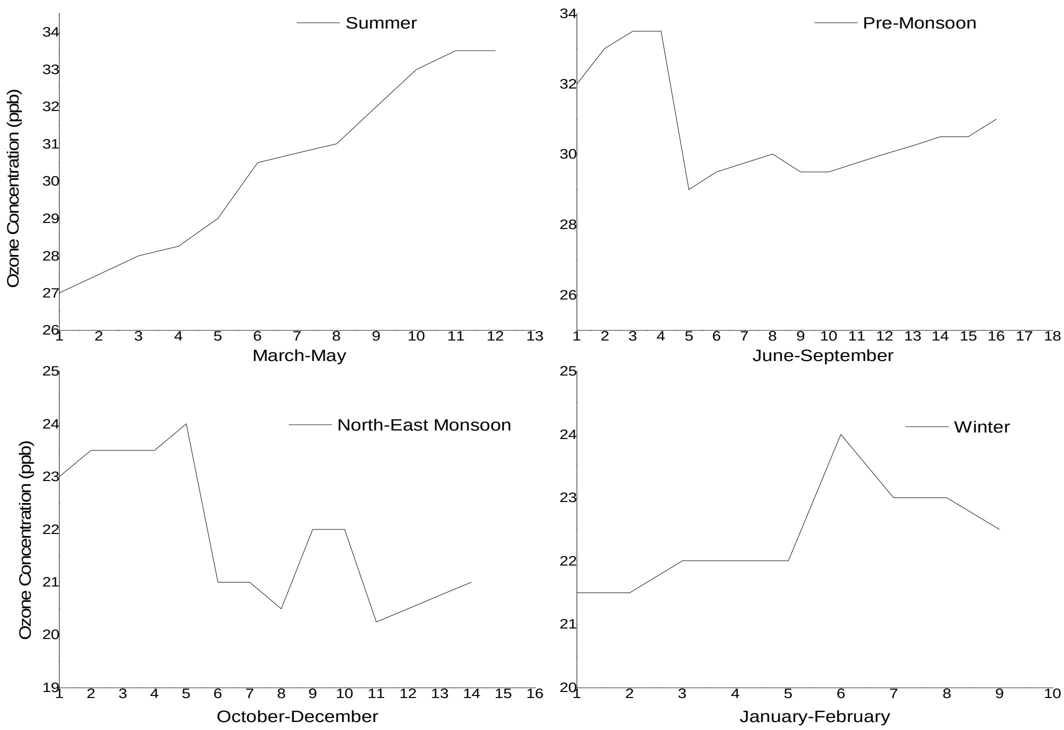

Fig.4: Seasonal Variations of Ozone

3.2 Seasonal Variations of Ozone:

On the basis of the amount and frequency of rainfall received by the study area, a year is generally classified into four seasons: Summer (March-May), Pre-Monsoon (June-September), North-East Monsoon (October-December) and winter (January-February). Seasonal variations in the amplitude of the diurnal ozone cycle are shown in Figure 4. It is observed that the ground level ozone concentrations are higher (lower) in Summer and Pre-Monsoon (North-east and winter) respectively.

The shape and amplitude of ozone cycles are strongly influenced by meteorological conditions and prevailing levels of precursors (Singh et al., 1997). Seasonal characteristics of ozone reveal that the concentration levels are found to be similar to some extent during the North-East Monsoon and Winter period. During the Summer and Pre-Monsoon period, the levels differ remarkably. This may be attributed to the fact that both during the summer and pre-monsoon period, favorable temperature and abundance of solar radiation aids to power the photochemical reaction. The temperature is high and solar radiation is more during the summer and pre-monsoon period as compared with the other two seasons. Thus high temperatures, more intense solar radiation and longer day lengths enhance the photochemistry, resulting in high concentration of O_3 during summer (Pudasainee et al., 2006). As the study area experiences North-East monsoon, the lower ozone concentration levels seen in north-east monsoon and winter seasons can be attributed to the rainfall effect. Rainfall cleanses the atmosphere, which is clearly reflected by the reduction in ozone concentration during both these seasons.

3.3 Dependence of Ozone on Meteorological Parameters:

3.3.1 Ozone Variation with Temperature:

Temperature and long term warming have a serious impact on atmospheric pollution, resulting in higher ozone concentrations, as heat accelerates the chemical reactions in the atmosphere (Clark and Karl, 1982; Walcek and Yuan, 1999). Higher ozone concentration values are mainly caused by solar radiation and pollutants. Air temperature acts as a proxy parameter, representing the diurnal variation of solar radiation.

The dependence of tropospheric ozone concentration levels with temperature is clearly exhibited in the monthly averaged time series dataset as shown in Figure 5. It can be examined that the peak tropospheric ozone concentration is obtained during the period from April to June when the temperature value is also at the peak. This period provides a favorable condition for the ozone production as this is the time with the greatest amount of daylight, when solar radiation is most direct (the sun is at a small zenith angle) and air temperatures become quite high (greater than 25°C) and photochemical production of ozone occurs at peak rates (Decker et al..,1976).On the contrary it is been observed that during the period from November to January, the tropospheric ozone concentration is found to be low owing to lower temperature values. This is the period where the winds are strong as the region under study experiences the north east monsoon; there is a possibility of dispersing the ozone by the winds outside the study region. Statically, ozone exhibits a strong dependence on temperature (r^2=0.8722) as shown in Figure 6.

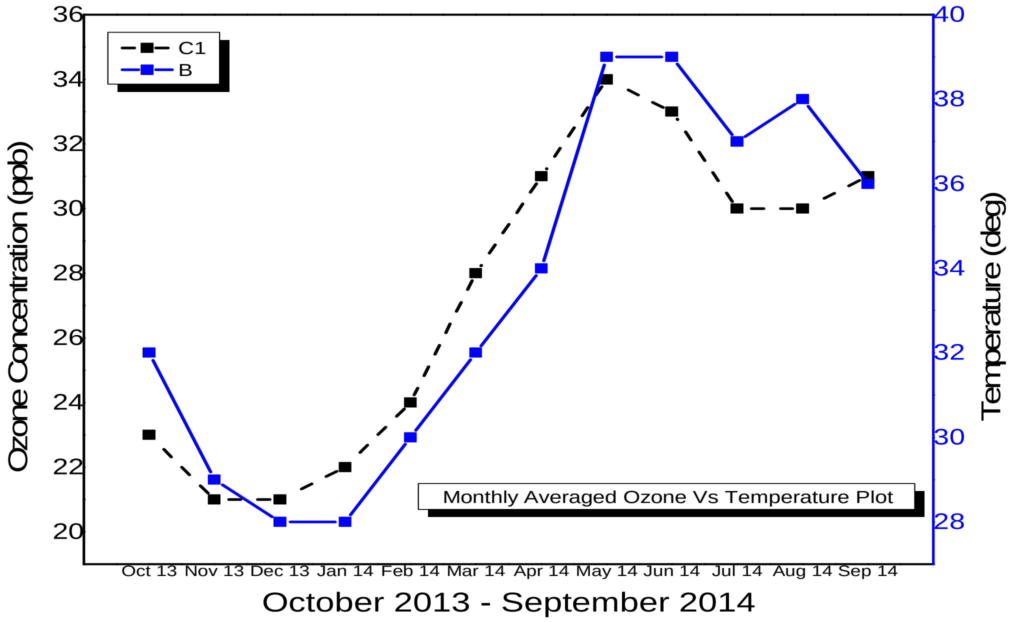

Fig.5: Variation of Ozone with Temperature

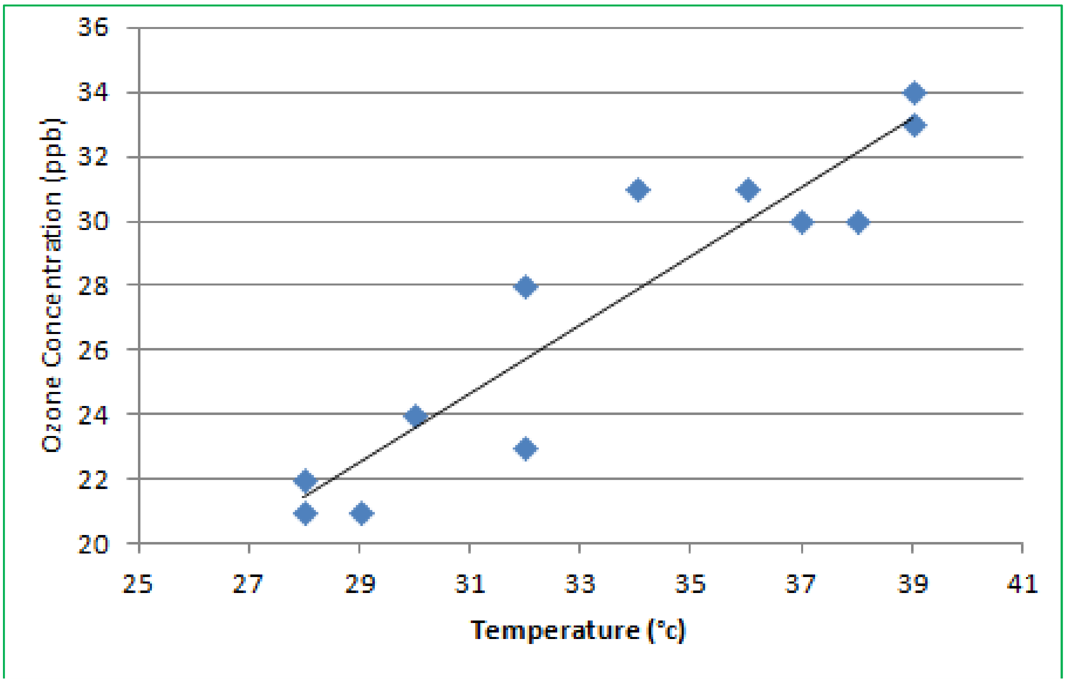

Fig.6: Scatter plot between Ozone and Temperature

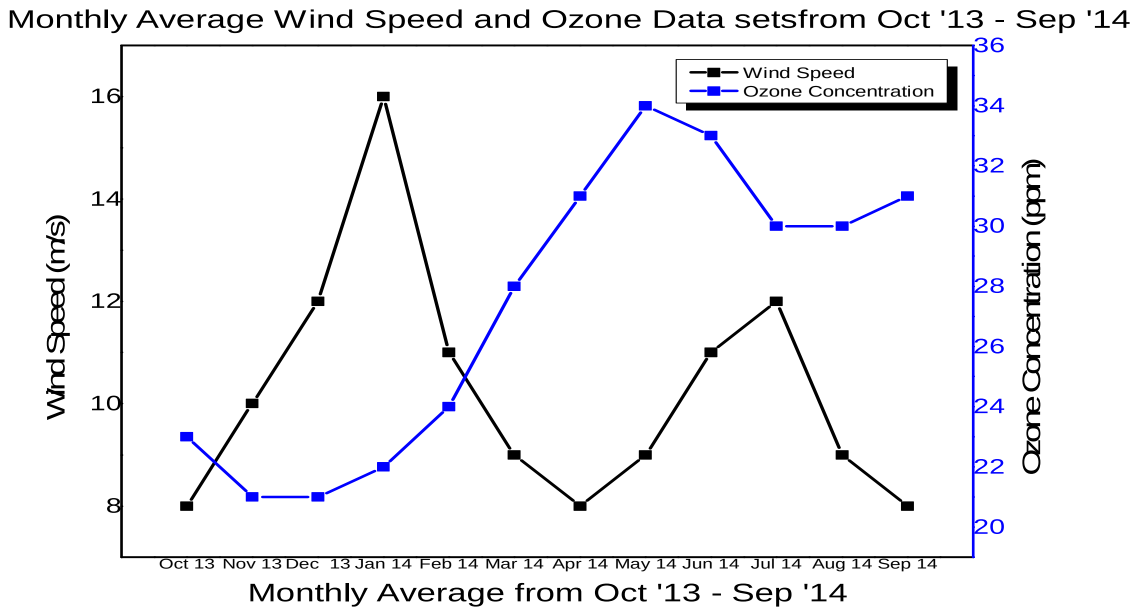

Fig.7: Variation of Ozone with Wind Speed

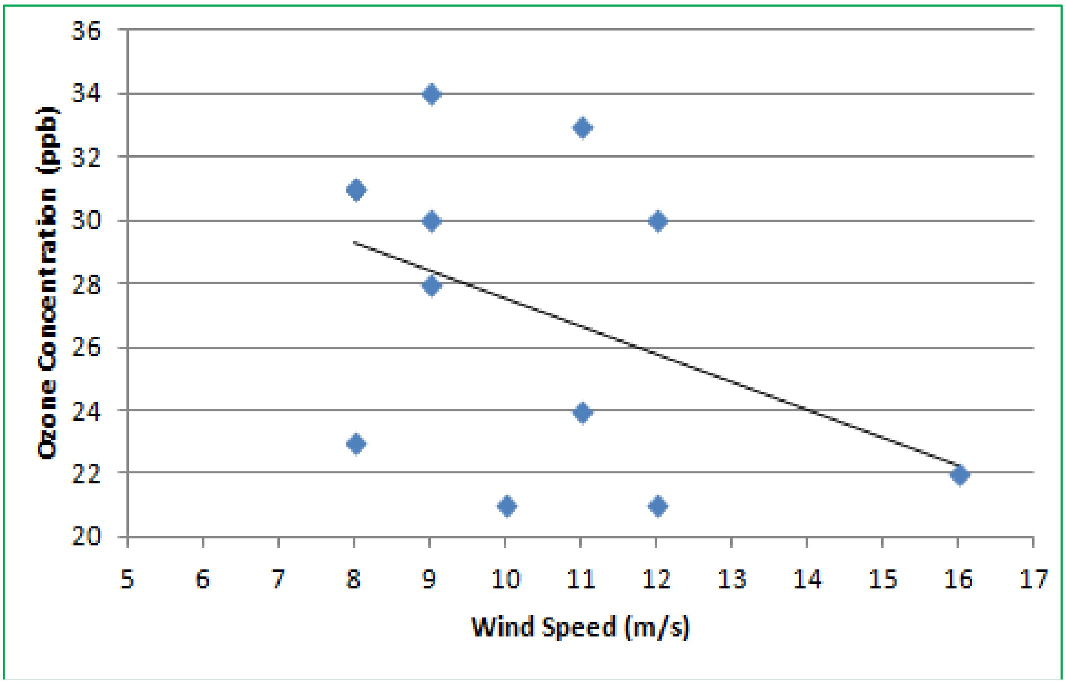

Fig.8: Scatter plot between Ozone and Wind Speed

3.2.2 Ozone Variation with Wind Speed:

Wind Speed just like other meteorological parameters also influences the tropospheric concentration levels in a region. On windy days, the wind can disperse the ozone, causing levels to drop. Ozone pollution can be especially bad during summer heat waves when the air does not mix very well and air pollution doesn't disperse. Low wind speeds are necessary for the accumulation of precursors of ozone formation (VOCs &NOx) and the subsequent formation of ozone. Higher wind speeds tend to dilute or disperse emissions. However, they can still transport ozone from other locations. Variation of Ozone with Wind Speed is as shown in the Figure 7.

It can be examined that the peak tropospheric ozone concentration is obtained during the period from April to June when the wind speed value is at a minimum. This is because during this phase the temperature is high and cloud free conditions prevail. So, this period provides a favourable condition for the ozone production as this is the time with the higher amount of daylight, when solar radiation is most direct (the sun is at a small zenith angle) and air temperatures become quite high (most of the time greater than 28°C) and photochemical production of ozone occurs at peak rates (Decker *et al.,* 1976). On the contrary it is been observed that during the period from November to January, the tropospheric ozone concentration is found to be low owing to higher wind speed values. This is the period where the winds are strong as the region under study experiences the north east monsoon; there is a possibility of dispersing the ozone by the winds outside the study region. Monthly data's sometimes show that even when the winds are strong the ozone concentration to be high. This is because there is also some possibility for the strong winds to carry emissions from other regions. The statistical results obtained reveals (r^2=0.1816) that wind speed plays no much role in the ozone formation in the study area as it exhibits a negative correlation as shown in Figure 8.

4.0 Conclusion:

The Ozone cycles in the study area are strongly influenced by meteorological conditions. Ambient temperature, Wind speed along with solar radiation together can contribute to about 93% of the observed ground level ozone concentration. Seasonal characteristics reveal that formation of ozone is high during the summer and pre-monsoon period as compared with north-east and winter period which is due to the favorable ambient temperature and solar radiation. Statistical results show the strong dependence of Ozone on ambient temperature while wind speed shows no much significance.

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