Assessment Of Surface Ozone Levels in A Semi-Urban Site and Its Predictions Using Neural Network.

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Abstract

Ozone (O_3) is one of the important trace gases because of its role as both an oxidant and a greenhouse gas. Around 90% of the ozone lies in the stratosphere and the remaining lies in the Earth's surface (troposphere).Elevated levels of surface ozone can be phytotoxic and cytotoxic as well. This steady intends to access the amount of surface ozone concentration at a site in Suchindrum (8° 9′ 18″ N, 77° 27′ 54″ E) of southern Tamilnadu during March 2011-Febraury 2012 for a period of 12 months. The surface ozone variation marked a clear diurnal cycle with maximum values around 1430 hrs and minimum around 0530 hrs. The maximum value of surface ozone recorded was 56 ppb during April 2011 and minimum of 13 ppb during November 2011.Seasonal pattern of surface ozone showed maximum values during summer and minimum during NE Monsoon. Also a simple Neural Network model was proposed to predict the peak surface ozone concentration (1430 hrs) depending upon the various input parameters like temperature, relative humidity, Nitrogen dioxide and build-up ozone concentration and all corresponding to the morning hours. The network yields good predictions and it showed a correlation of r = 0.80 between observed and predicted surface ozone levels.

Key-words: Surface ozone, cytotoxic, diurnal cycle, seasonal pattern, greenhouse gas, neural network

Introduction

The World Health Organisation (WHO) reports that 25% of all preventable diseases are due to a poor physical environment. Industrialization, population growth and rapid developments in technology have all resulted in enormous human impact on the environment [1]. Surface ozone (O_3) is an important well known secondary pollutant and also a greenhouse gas contributing to the climate change. Even though it is a trace constituent, ozone plays an important role in the atmospheric environment through radiative and chemical process [2]. O_3, being a greenhouse gas, the increase in its tropospheric concentration contribute significantly to local and global warming effects. Ozone is the primary constituent of photo-oxidative smog and is Considered as an indicator of the overall burden of the atmospheric pollutants [3]. Elevated levels of surface ozone can cause potential damage to human respiratory system and can affect the cilia membrane of the lungs. Also it can cause damages to vegetation and materials as well.

It is now clearly established that ozone, at the ambient concentrations can cause a range of ill effects including visible leaf injury, growth and yield reductions, and altered sensitivity to biotic and abiotic stresses [4]. It is evident that the amount of stratospheric ozone is decreasing while the amount of tropospheric ozone is increasing. Atmospheric CO_2 concentrations are currently rising at approximately 0.5% per year and surface ozone (ground-level O3) values are increasing at a rate of 0.32% per year [5]. So increasing levels of surface ozone is really a potential threat to the planet earth. In order to provide adequate early warnings, it is important to have accurate and reliable forecasts of future high ozone levels [6]. There are many different numerical methods for forecasting and analysing ozone levels and the widely used technique is using neural networks. Neural networks have been found to outperform other statistical techniques [7]. In this study, a simple neural network model has been proposed to predict the peak time surface ozone concentration with some of the important input parameters at Suchindrum during the period of March 2011-Febraury 2012.

Photo Chemistry of Surface Ozone

Surface ozone is not emitted directly into the atmosphere. It is produced as the result of photochemical reactions between oxides of nitrogen (NO_x) and Volatile organic compounds (VOCs) in the presence of sunlight. During daylight hours nitrogen dioxide (NO_2) is photolytically converted to nitric oxide (NO) leading to the formation of ozone.

$$NO_2 + h\nu\ (\lambda <= 430nm) \rightarrow NO + O \qquad (1)$$

$$O + O_2 \rightarrow O_3 \qquad (2)$$

Therefore, surface ozone control is generally achieved by reducing the anthropogenic emissions of both NO_x and VOCs into the atmosphere [8].

Methods

Surface ozone measurements were carried out by using a portable sensitive gaseous monitor Aeroqual S300 coupled with ozone sensor. Its ultra low concentration ozone sensor head measures the ozone concentration from 0.000 to 0.150 ppm with an accuracy of ± 0.001 ppm (from 0 to 0.100 ppm). The measurement unit being either ppm or μg/m^3. The operating temperature range is from - 5°C to 50°C, relative humidity limits are 5% and 95%. The ozone sensor was calibrated against a certified UV photometer. Eight readings were taken per day starting from 0530 h to 0230 h.

Fig.1. Aeroqual S300 monitor with various sensors

Study Area

Surface ozone measurements were carried out in Suchindrum (8° 918″ N, 77° 27′54″ E) in Kanyakumari district for a period of one year from March 2011- February 2012.Suchindrum is one of the tourist spots and traffic prones of the district.

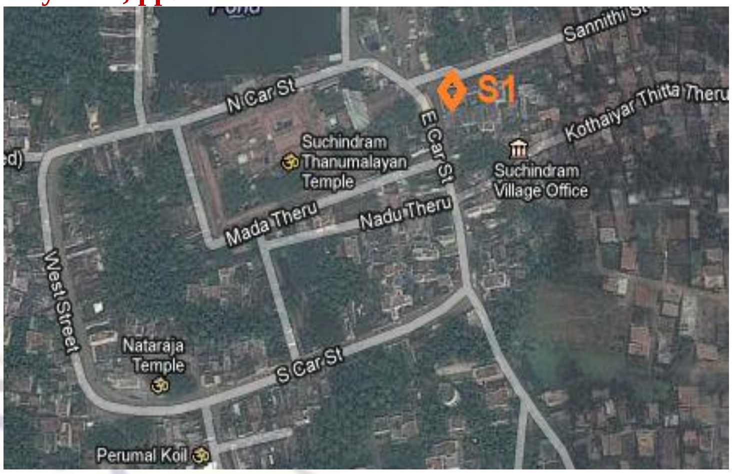

Fig.2. Study Area, Suchindrum

Results and Discussion

1. Variation of Surface ozone

Surface ozone variations showed a clear global diurnal pattern for both the sites. The ozone concentration gradually increased after sunrise because the photochemical reactions are dominant only in the presence of sunlight. The maximum value of surface ozone was recorded around 1430 h and this is due to the high intensity of solar flux during afternoon hours. This indicates that the photochemical production of surface ozone is strongly related to the surface temperature. During the late evening hours, a decreasing trend was observed in the surface ozone levels. Also this low concentration of ozone during night and early morning time could be a result of its deposition and surface chemical reactions [9]. The morning (0530h) lowest values are the result of night time ozone destruction process including loss due to atmospheric chemistry and dry deposition on the earth.

The high values of surface ozone were recorded during the months of summer (March – May).During the summer, high insulation, high temperature; high stability and low mid-day humidity produce photochemical smog [10]. The lower values were recorded during north east monsoon (October to December). Table 1. gives the seasonal average values of surface ozone concentration and Fig.3 shows its seasonal variation.

Table 1. Seasonal Average of Surface Ozone

Season/Time	5:30	8:30	11:30	14:30	17:30	20:30	23:30	2:30
SUMMER	19.04	26.29	42.43	50.83	44.96	37.87	31.94	24.40
SWM	16.99	22.26	35.98	45.68	40.59	34.21	27.52	21.85
NEM	15.26	19.18	31.29	40.63	34.90	27.62	22.54	18.21
WINTER	19.03	23.39	36.95	46.08	41.53	33.60	27.03	22.35

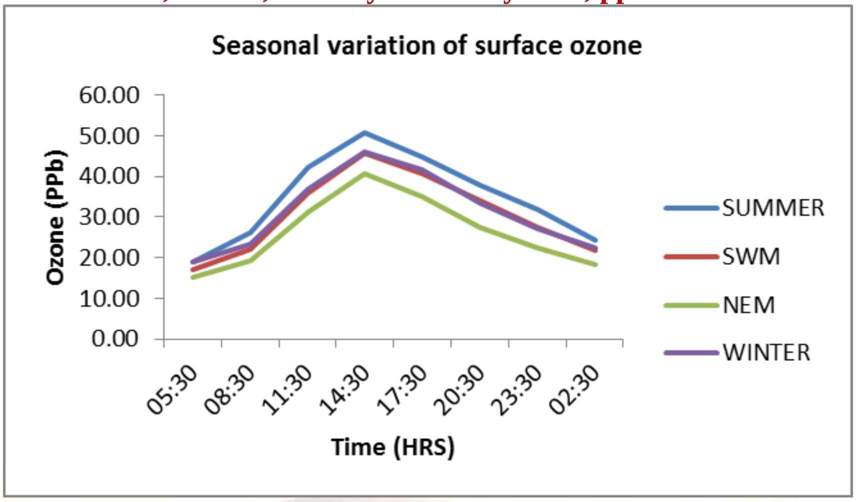

Fig.3. Seasonal variation of Surface ozone during Mar 2011-Feb 2012.

The overall diurnal average values of surface ozone concentration with various meteorological parameters for the entire study period are shown in table 2 and figure 4 presents it graphically.

Table 2. Diurnal Average of Surface Ozone

Parameters/time	**5:30**	**8:30**	**11:30**	**14:30**	**17:30**	**20:30**	**23:30**	**2:30**
Temperature	25.36	27.21	29.69	30.12	29.02	27.79	27.18	26.21
Ozone	17.41	22.69	36.58	45.77	40.41	33.37	27.30	21.66
RH	85.20	76.77	66.49	64.98	70.28	77.01	81.07	82.75
NO2	4.88	5.31	4.02	1.69	3.85	5.19	6.44	5.12

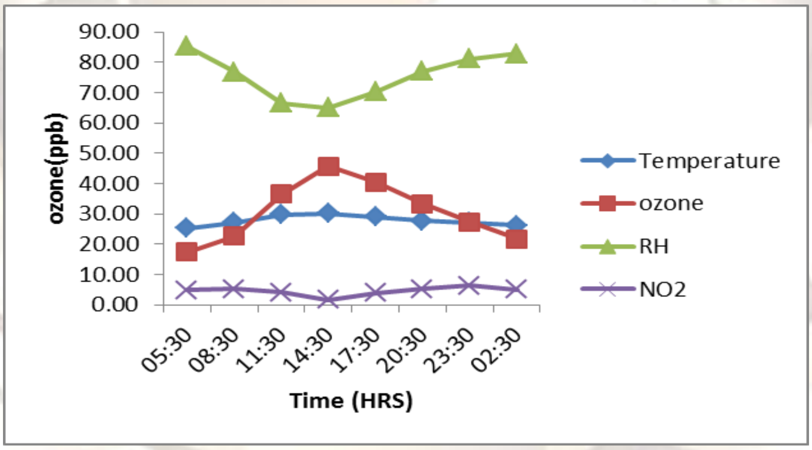

Fig.4. Diurnal variation of Surface ozone with met. Parameters during Mar 2011-Feb 2012.

2. Network model

Surface ozone concentration reaches a peak value around 1430 hrs due to the availability dominant solar flux during afternoon hours. The peak value determines whether the particular day is ozone high day or not. So it is very important to forecast the peak hour ozone concentration. In this model, the maximum ozone or peak ozone is forecasted by using the input parameters like temperature (T), relative humidity (RH), NO_2 and surface ozone (O_3) itself. These inputs are the data corresponding to the morning hours. They are the readings recorded at 0830 hrs and totally the data contain 109 sample points.

The data set is randomly divided into three sets namely training, validation, testing. Training set is the largest set (70%) and the remaining sets are assigned to contain 15 % of the samples. The training set is a set of samples used to adjust or train the weights in the neural network to produce desired outcome. The validation set is used to find the best network configuration and testing set is to evaluate the fully trained networks. Eventhough there are many computational functions, the most used function in air quality modelling is the sigmoid function [10]. The Log Sigmoid function is given as f(x) = 1/(1+e-x). The model is developed using feed-forward back propogation multilayer perceptron using three neurons in the hidden layer. The model is carried out in matlab using Levenberg Marquadrt algorithm. The model is presented in the Figure 5.

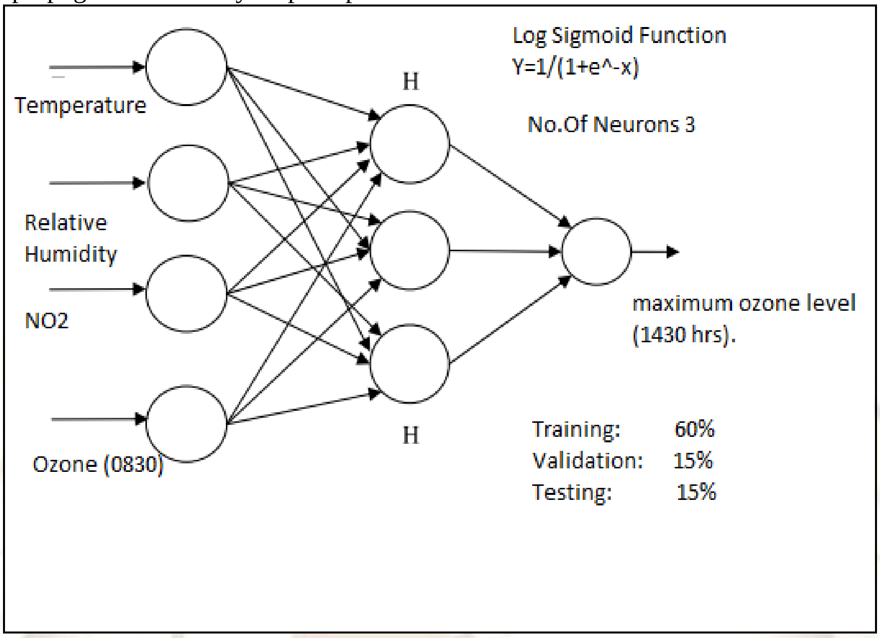

Fig.5. Neural Network Model

Model Results

The neural network model is trained using all the input parameters.The model gives an R^2 of 0.85727 for all the data points with MSE of 6.476. Figure 6 shows the scatter plot between the observed and predicted parameters.

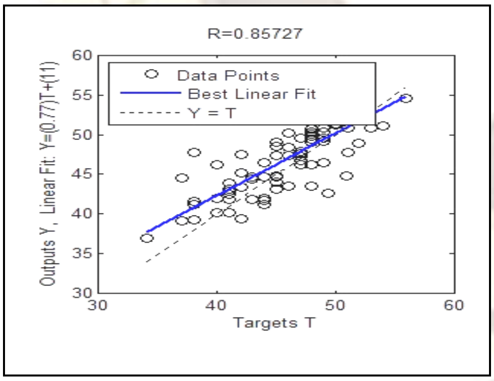

Fig 6.Scatter plot between observed and predicted ozone levels.

The correlation between the predicted and the observed surface ozone concentration lies around 0.8 and the Figure 7 depicts the observed and predicted levels.

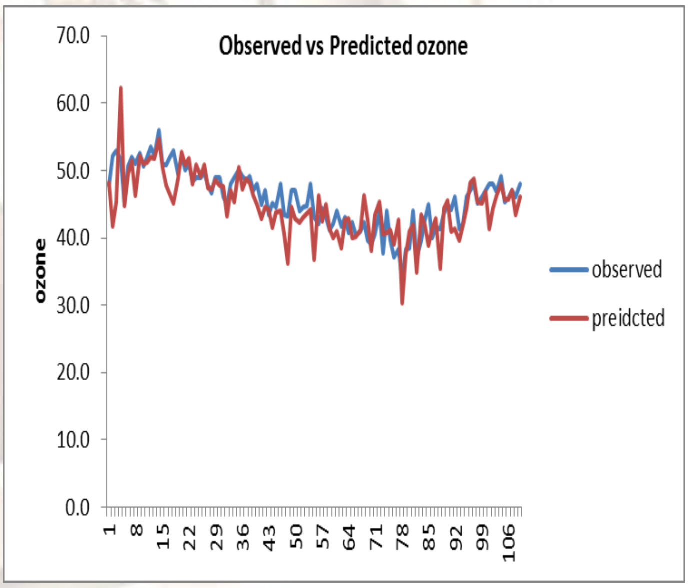

Fig.7 Observed vs predicted surface ozone levels

Conclusion

Surface ozone measurements were made for a period of one year and the data was analysed with various meteorological parameters. It showed a well diurnal pattern. The seasonal variation of surface ozone showed maximum in summer and minimum in NE Monsoon. The data points varied between 13 ppb and 56 ppb. A simple neural network model was designed to predict the peak hour ozone concentration and it yielded good correlation between observed and predicted ozone levels. Even though the ozone levels are within the permissible air quality standards of 60 ppb, continuous monitoring is essential.

References

[1] Rasa Girgzdiene, Aloyzas Girgzdys, The Troposphere Ozone – an Indicator of the Environmental Sustainability, Journal of Environmental research, engineering and management, Vol.26,No.4,2003,pp.45-50.
[2] A.L. Londhe, D. J. Surface ozone variability in the urban and nearby rural locations of tropical India. CURRENT SCIENCE, VOL. 95, NO. 12.2008.
[3] Elampari K, Chithambarathanu T, Krishna Sharma R, Examining the variations of ground level ozone and nitrogen dioxide in a rural area influenced by brick kiln industries, Indian journal of Science and technology,Vol.3,No.8,2010.
[4] Grunhage L, Jager HJ, Influence of the atmospheric conductivity on the ozone exposure of plants under ambient conditions, Environmental pollution, Vol.85, No.2, 1994, pp.125-129.
[5] Akram Ali, Factors Affecting on Response of Broad Bean and Corn to Air Quality and Soil CO_2 Flux rates in Egypt, Journal of water, air and soil pollution,Vol.195,No.1-4,2008,pp.311-323.
[6] Dominik Wieland and Franz Otawa,Local Maximum ozone concentration prediction using neural networks,AAAI Technical Report ,1999 WS 99-07.
[7] Arigiriou.A, Use of neural networks for tropospheric ozone time series approximation and forecasting,a review.,Atmos.Chem.Phys-Discuss. 7, 2007, pp.5739-5767.
[8] Lin Tang, Regional and local surface ozone variations in relation to meteorological conditions in Sweden, Ph.D.,Thesis, Department of Earth Sciences, University of Gothenburg, Sweden, 2009.
[9] S. Renuka GS, Satsangi and Taneja A, Concentrations of surface O_3, NO_2 and CO during winter seasons at a semi-arid region Agra, India, Indian Journal of Radio & Space Physics, vol.37, 2008,pp. 121-130.
[10] Seinfeld.J.H., Pandis,S.N.,From Air pollution to climate change, Atmospheric chemistry and Physics,1998,J.wiley,Newyork.