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Spectral Analysis of Ground Level Ozone Using Discrete Wavelet Transforms

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Abstract- Ozone is a gas which reacts with other gases, surfaces and biological materials, these reactions can damage living cells, so that, it can be harmful for human beings. The ozone levels tend to be lower in urban polluted areas than rural areas. This is because ozone disappears when it reacts with other pollutants, such as nitric oxide (NO), etc. Prolonged exposure to low-level ozone concentrations is as harmful to human health as exposure to higher levels for shorter durations (Ozone fluctuation). Wavelet transforms provide excellent analysis of non-stationary time series and extracts important information.Daubechies4 wavelet is orthogonal and compactly supportive and therefore, it is useful for multi resolution analysis of Ozone data. Wavelet analysis of Ozone enables the development of effective risk reduction strategies based on qualitative and quantitative knowledge.

Keywords- *Ozone; Wavelet; Daubechies wavelet; Wavelet transforms*

I. INTRODUCTION

The ozone (triatomic oxygen, or O_3) molecule consists of three oxygen atoms that are bound together and it is a powerful oxidizing agent. Ozone (O_3) is a gas that can form and react under the action of light and that is present in two layers of the atmosphere. High up in the atmosphere, ozone forms a layer that shields the Earth from ultraviolet rays, However, at ground level, ozone is considered a major air pollutant. Our focus is on Ground-level ozone that is, is formed from other pollutants and can react with other substances, in both cases under the action of light. It can react with gases (such as nitric oxide or NO), and with surfaces (such as dust particles) [1]. Ozone can also react with biological materials, such as leaves and cell membranes. These reactions can damage living cells, such as those present in the linings of the human lungs. Tailpipe emissions from automobile traffic are the main contributors to ozone pollution. Ozone pollution is created when certain chemicals in auto emissions interact with heat and sunlight. Emissions from certain manufacturing operations also contribute to ozone pollution.

In continental areas far removed from direct anthropogenic effects, ozone concentrations are generally 20-40 ppb. In rural areas downwind of urban centres, ozone concentrations are higher, typically 50-80 ppb, but occasionally 100-200 ppb. In urban and suburban areas, ozone concentrations can be high (well over 100 ppb), but peak for at most a few hours before deposition and reaction with NO emissions cause ozone concentrations to decline [2]. Ozone concentrations vary in complex ways due to its photochemical formation, its rapid destruction by NO, and the effects of differing volatile organic compound (VOC)/ nitrogen oxides (NOX) ratios in air. A high ratio of NOX emissions to VOC emissions usually causes peak ozone concentrations to be higher and minimum concentrations to be lower, comparedto background conditions. Peak ozone concentrations are usually highest downwind from urban centres. Light winds carry ozone from urban centres, and photochemical reactions create ozone from urban emissions of VOC and NOX Also, away from sources of NOX emissions, less NO is available to destroy ozone. Due to the time needed for transport, these peak ozone concentrations in downwind areas tend to occur later in the day compared to peak ozone concentrations in urban areas. Due to the lack of ozone-destroying NO, ozone in rural areas tends to persist at night, rather than declining to the low concentrations (<30 ppb) typical in urban areas and areas downwind of major urban areas, that have plenty of fresh NO emissions. Ratios of peak ozone to average ozone concentrations are typical highest in urban areas and lowest in remote areas. Within the round-based inversions that usually persist through the night, ozone concentrations can be very low. In urban areas, emissions of NO near the ground commonly reduce ozone below 30 ppb. In rural areas, however, NO emissions are less prevalent and night time ozone may persist well above 30 ppb. Temporal Variations in Ozone Concentrations Ambient ozone concentrations tend to vary temporally in phase with human activity patterns, magnifying the resulting adverse health and welfare effects. Concentrations are often low in busy urban centres and higher in suburban and adjacent rural areas, particularly on sunny days in summer. However, ozone can be transported through air over long distances and across borders.

Ground level ozone is known to cause adverse health effects. Short-term exposure to ozone peaks can temporarily affect the lungs, the respiratory tract, and the eyes. It can also increase the susceptibility to inhaled allergens. Long-term exposure to relatively low concentrations of ozone can reduce lung function. Human population studies at ozone levels currently observed in Europe have reached inconsistent conclusions regarding effects of ozone on the frequency of asthma. They have provided little evidence of long-term effects on lung cancer or mortality. However, results suggest that long-term ozone exposure may affect lung function growth in children. Ozone appears to have effects on health independently of other pollutants, particularly in the case of short-term exposure to concentration peaks which occur especially in the summer. The presence of other air pollutants, especially particulate matter, can enhance or otherwise influence the effects of ozone, and vice versa. Individuals in a population respond differently to ozone exposure, depending on how old they are, if they are asthmatic, how much air they breathe in, and for how long they have been exposed to ozone. The reasons for this difference in responsiveness remain largely unexplained but appear to be partly linked to genetic differences. No exposure threshold has been identified because different individuals respond very differently to ozone exposure. Outdoor ozone levels vary across city areas and times of the day, with peaks in the afternoon. Ozone concentrations indoors are generally 50% lower than those outdoors. Indoor ources of ozone include photocopiers and electrostatic air cleaners [3].

The study of ground level ozone and its fluctuations is very important because health perspectives of human beings. Thus, the study of turbulence in ground level ozone has attracted intense interest of Scientists and Doctors. The Fourier and Fast Fourier Transform (FFT) is a useful tool to study the spectrum of stationary time series. Wavelet extracts both time evolution and frequency composition of a signal, while Fourier sine's extracts only frequency information from a time signal, thus losing time information. The wavelet is a new analytical tool for turbulent or chaotic data to the Science community. It allows detection and characterization of short-lived structures non-stationary signal. [4, 5].

II. THEORETICAL BACKGROUND

Wavelet represents an efficient computational algorithm under the interest of a broad community. Wavelet is a special kind of the functions which exhibits oscillatory behaviour for a short time interval and then dies out. In wavelet we use a single function and its dilation and translation to generate a set of orthonormal basis functions to represent a signal [6, 7]. Number of such functions is infinite and we choose one that suits to our application. The range of interval over which scaling function and wavelet function are defined is known as support of wavelet. Beyond this interval (support) the functions should be identically zero. There is an interesting relation between length of support and number of coefficients in the refinement relation. For orthogonal wavelet system, the length of support is always less than no. of coefficients in the refinement relation. It is also very helpful to require that the mother function have a certain number of zero moments, according to:

$$\int_{-\infty}^{\infty} \psi(\mathrm{t})\mathrm{dt} = 0$$

The mother function can be used to generate a whole family of wavelets by translating and scaling the mother wavelet.

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right) = T_b D_a \psi$$

Here b is the translation parameter and a is the dilation or scaling parameter. Provided that $\psi(\mathrm{t})$ is real-valued, this collection of wavelets can be used as an orthonormal basis. A critical sampling of the continuous wavelet transform is

$$W_{a,b} = \int f(t)\frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right)dt$$

is obtained via $a = 2^{-j}$, where j and k are integers representing the set of discrete translations and discrete dilations. Upon this substitution, we can write discrete wavelet transform as;

$$W_{j,k} = \int f(t) 2^{j/2}\psi(2^j t - k)\,dt$$

Wavelet coefficients for every (a, b) combination whereas in discrete wavelet transform, we find wavelet coefficients only at very few points by the dots and the wavelets that follow these values are given by;

$$\psi_{j,k}(t) = 2^{j/2}\psi(2^j t - k)$$

These wavelet coefficient for all j and k produce an orthonormal basis. We call $\psi_{0,0}(t) = \psi(t)$ as mother wavelet. Other wavelets are produced by translation and dilation of mothere wavelet. The wavelet transform of a signal captures the localized time frequency information of the signal. Suppose we are given a signal or sequences of data $S = \{S_n\}_{n\in\mathbb{Z}}$ sampled at regular time interval □t □ □ □ S is split into a "blurred" version a1 at the coarser interval □t □ □ 2□ □ and "detail" d1 at scale t□□ □ □. This process is repeated and gives a sequence S_n , a_1, a_2, a_3, a_4,…..of more and more blurred versions together with the details d_1, d_2, d_3, d_4, …….removed at every scale ($\Delta t = 2^m\tau$ in a_m and d_m). Here a_ms and d_ms are approximation and details of original signal. After N iteration the original signal S can be reconstructed as

$$S = a_N + d_1 + d_2 + d_3 + \cdots \ldots . . d_N$$

III. METHODOLOGY

The primary and most important work in the spectral analysis of any signal using wavelet transforms is the selection of suitable wavelet according to the signal. Suitable wavelet is selected on the basis of compatibility with signal characteristics. Accurate wavelet selection retains the original signal and also enhances the frequency spectrum of denoised signal. Wavelet extracts both time evolution and frequency composition of a signal [8].

A multiresolution analysis for $L^2(\mathbb{R})$ introduced by Mallat [9] consists of a Sequence V_j, $j\epsilon\mathbb{Z}$ of closed subspaces of $L^2(\mathbb{R})$. Let f (x) be a function in $L^2(\mathbb{R})$. We can write f □ □x□ □ inV_{j+1} space, i.e.,

$$f(x) = \sum c_{j+1,k}\, \phi_{j+1,k}(x)$$

Since

$$V_{j+1} = V_j \oplus W_j$$

where

$$V_{j+1} = span\ \overline{\left(\phi_{j+1,k}(x)\right)}$$

$$V_j = span\ \overline{\left(\phi_{j,k}(x)\right)}$$

$$W_j = span\ \overline{\left(\psi_{j,k}(x)\right)}$$

Therefore

$$f(x) = \sum_k c_{j,k}\,\phi_{j,k}(x) + \sum_{j_0}^{j}\sum_k d_{j,k}\,\psi_{j,k}(x)$$

where

$$c_{j,k} = \langle f, \quad \phi_{j,k}\rangle$$

$$= \int f(x)\,\phi_{j,k}(x)\,dx, \quad \forall\, k \in \mathbb{Z}$$

and

$$d_{j,k} = \langle f, \quad \psi_{j,k}\rangle$$

$$= \int f(x)\,\psi_{j,k}(x)\,dx$$

are collectively known as approximation and detailed coefficients. Thus given signal takes place a new version such as [10]

$$f(1) = a_1 + d_1$$

$$f(2) = a_2 + d_2 + d_1$$

$$f(3) = a_3 + d_{3+}d_2 + d_1$$

$$f(4) = a_4 + d_4 + d_{3+}d_2 + d_1$$

$$f(5) = a_5 + d_5 + d_4 + d_{3+}d_2 + d_1$$

$$f(6) = a_6 + d_6 + d_5 + d_4 + d_{3+}d_2 + d_1$$

$$f(7) = a_7 + d_7 + d_6 + d_5 + d_4 + d_{3+}d_2 + d_1$$

$$f(8) = a_8 + d_8 + d_7 + d_6 + d_5 + d_4 + d_{3+}d_2 + d_1$$

Here a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8 are approximations of signal and d_1, d_2, d_3, d_4, d_5, d_6, d_7, d_8 are details of signal at various scale or time frames. A signal f can be decomposed as in simplest form;

$$f = A + D$$

where A and D are called Approximation and Details of the given signal f. Approximation is average of the signal and hence represents low frequency components, while Detail is the difference of the signal and hence represents high frequency components. Detail plays very important role and provides hidden information of any signal. The wavelet is a new analytical tool for chaotic data to the physics community. It allows detection and characterization of short-lived structures in data.

IV. STUDY AREA AND RESULTS

Our study area is Anand Vihar, Delhi and we have used data (online) observed by DPCC Anand Vihar. We have taken average quantity of Ozone for a day from 01-07-2016 to 13-03-2017.

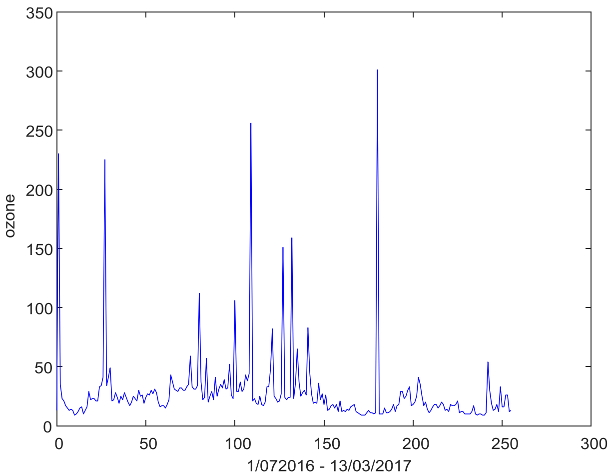

Figure 1: Average Ozone (in ppb)

In order to perform a more detailed investigation, we decompose the time series of Ozone at different scale by using discrete wavelet transform (Daubechies 4 level 8 [11]). The original time series of Ozone is shown in figure (1). A full decomposition of Ozone time series is shown in figure (2). In decomposition figures a1, a2, a3, a4, a5, a6, a7 and a8 are approximations and d1, d2, d3, d4, d5, d6, d7, and d8 are details of the of CO time series at different time modes. Original time series is the average value of Ozone, taken as one day interval. Approximation a8 represents the behaviour of the signal S at level 8. While details d1 exhibits per day variation, d2 shows 2-days variation and d3 is 4-days variation in the value of CO also d4, d5, d6, d7 and d8 are variation in the value of Ozone in 8, 16, 32, 64, and 128 days mode, respectively. A peak in a detail shows rapid fall or rise in the value of Ozone in that time mode. The measurement of Ozone depends on anthropogenic driving forces.

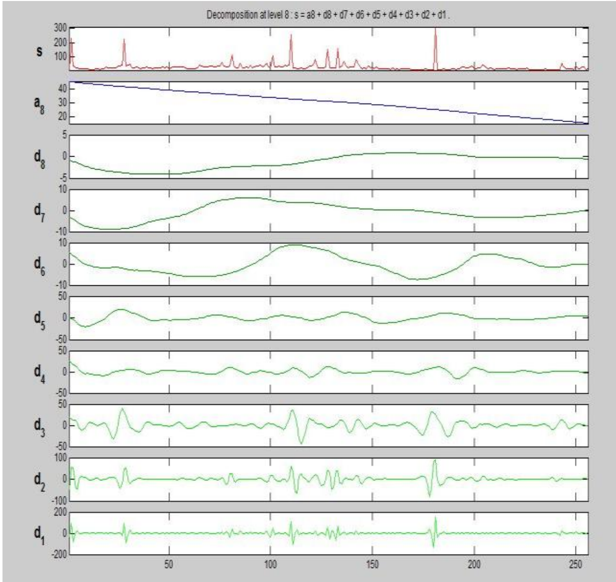

Figure 2: Wavelet decomposition of time series of Ozone

Fluctuation in quantity of Ozone over time may be as a result of effluent load. In data analysis, the low-frequency content of the signal is an important part, because it gives the identity of the signal. Trend is the slowest part of the signal means lowest frequency part of the signal. In wavelet analysis terms, this corresponds to the greatest scale value. As the scale increases, the resolution decreases, producing a better estimate of the unknown trend. A trend of the Ozone signal exhibits in figure 3.

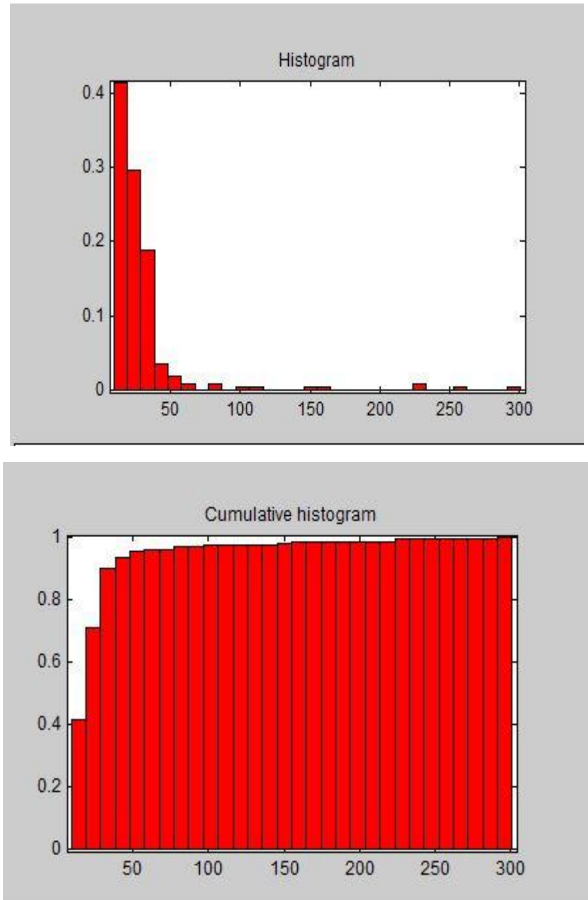

Figure 3: Histogram and cumulative histogram

Histograms depict the trends of average value of Ozone for Approximation a8. A cumulative histogram is a mapping that counts the cumulative number of observations in all of the bins up to the specified bin. The histogram provides important information about the shape of a distribution. A variance in the value of Ozone during time interval (01-07-2016 to 13-03-2017) in individual sampling spot is clearly depicts in approximation a8 of the decomposition. It is clear that fluctuations in Ozone level are high in July, October and January. The trend of the signal depicts that number of fluctuation in quantity of ozone is high in October –November 2016.

CONCLUSION

The wavelet method allows the decomposition of signal according to different frequency levels which characterize the intensity of natural and man-made disturbances. A histogram is a graphical representation showing a visual impression of the distribution of data. According to the behaviour studied, it is possible to conjecture that the difference between all-time series can be directly associated with the large number of anthropogenic activity. Taking into account these results we have shown, the wavelet analytical approach provides a simple and accurate framework for modelling the statistical behaviour of Ozone variation. Our purpose of study is to support air quality management and to make information available to public.

References

[1] T. Islam, R. McConnell, W.J. Gauderman, E. Avol, J.M. Peters, and F.D. Gilliland, "Ozone, oxidant defense genes, and risk of asthma during adolsense", American journal of respiratory and critical care medicine, Vol. 177(4), pp. 388-395, 2008.

[2] W.Chameides, P. S. Kasibhatla, J. Yienger, and H. Levy, "Growth of continental scale metro-agro-plexes, regional ozone pollution and world food production", Science, Vol. 264, pp. 74– 77, 1994.

[3] A.J. COHEN, "Outdoor air pollution and lung cancer", Environmental health perspectives, Vol. 108, pp. 743–750, 2000.

[4] C. K. Chui, An introduction to wavelets, Academic Press, New York, (1992).

[5] J. P. Antoine, "Wavelet analysis: A new tool in Physics", Wavelets in Physics, Van Der Berg, J. C., ed., 2004, 9-21.

[6] B. B. S. Kumar and P. S. Satyanarayana, ''Image Analysis Using Biorthogonal Wavelet'', International Journal of Innovative Research And Development, Vol. 2 (6), pp. 543-565. 2013.

[7] S. Kumar, A. Kumar. R. Kumar, J. K. Pathak amd M. Alam, "Spectral Analysis of Biochemical Oxygen Demand in River Water: An Analytical Approach of Discrete Wavelet Transform", American Journal of Mathematics and Statistics, Vol. 4(2), pp. 107-112, 2014.

[8] A. Grossmann, J. Morlet and T. Paul, ''Transforms associated to square integrable group representation'', J. Math. Phys., Vol. 26, pp. 2473-2579, 1985.

[9] S. G. Mallat, A wavelet tour of Signal Processing, Academic Press, New York, 1998.

[10] A. Kumar, S. Kumar and J. K. Pathak, "Spectral Analysis of River Ramganga Hydraulics using Discrete wavelet transform", Proceedings of International Conference of Advance Research and Innovation, pp. 370-373, 2015.

[11] Daubechies, I. (1992). Ten lectures on wavelets, *CBS-NSF, Regional Conference in Applied Mathematics*, SIAM Philadelphia 61, 278-285.