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Research Article

Wavelet & Correlation Analysis of Air Pollution Parameters Using Haar Wavelet (Level 3)

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Abstract

This paper deals with the wavelet and correlation analysis of air pollution parameters in Delhi, India. Hourly average value of air pollution parameters Carbon Monoxide (CO), Nitrogen Oxide (NO), Nitrogen Dioxide (NO_2), Ozone (O_3), Particulate Matters ($PM_{2.5}$) and Sulphur Dioxide (SO_2) have been studied. Discrete wavelet using Haar wavelet at level 3 and Continuous wavelet of air pollution parameters have been discussed. Discrete wavelet decomposition of each parameter presented in five parts namely s, a_3, d_1, d_2, d_3. The first part "s" represents the signal or raw data and the second part "a_3" corresponds to the amplitude of the signal. The next three parts d_1, d_2, d_3 represent details of the signal or raw data at three different levels. 1D continuous wavelet decomposition of each parameter has four parts; first part on top represents the analyzed signal or raw data, second part contains the scalogram value. The third part shows the daily variation of coefficients. The fourth part depicts the local maximums of related parameters. It has been observed that all the pollutants have positive correlation with all the other pollutants except with O_3. Ozone has negative correlation with all the pollutant parameters.

***Keywords**: Wavelets, Correlation, Air Pollution, Air pollutant, Discrete Wavelet, Continuous wavelet*

1. Introduction

Wavelet analysis is a tool for analyzing localized variations in power by decomposing a trace into time frequency space to determine both the dominant modes of variability and how those modes vary in time. This method is appropriate for analysis of non-stationary traces, i.e. where the variance does not remain constant with increasing length of the data set. The problem of air pollution is increasing tremendously day by day in all the metropolitan cities by exponential increase in vehicles, emission form industries and unplanned urbanization. Therefore evaluation of a suitable method for predicting and monitoring the pollution is very important. The wavelet method is based on the property that wavelet transforms of the self-affine traces have self-affine properties. Kurnaz (2004)discussed model based predictions about climate change and the application of de-trended fluctuation analysis to monthly average of the maximum daily temperatures to resolve different climates. Rangarajan et. al. (2004) studied the fractal and multi-fractal analysis of Indian climate dynamics. Nature provides different forms of data which can be converted to climatic data but wavelet based multi-fractal formalism will be used for better understanding the climatic changes. The combined behavior of pressure, temperature, and relative humidity, which defines the refractivity, is very critical for radar coverage of an area adjacent to the earth as studied by Ochotta and Gebhart (2006) . Wavelet based analysis of meteorological parameters like temperature, relative humidity and total rainfall was performed in terms of decomposition, approximation, compression and de-noising of the original signals as studied by Vincent et. al. (2006). Application capability of the wavelet transform depends on the selection of the wavelet functions from which a basis function can be constructed for signal decomposition. The application of wavelet transform in reflection of seismic data analysis is discussed by Xiao-Gui Miao and Wooil M. Moon (1999). Non-decimated Wavelet Transform is applied to study the relationship between suspended particulate matter. The low frequency components of the air pollutant time series showed significant relationship with PM_{10} while the high frequency spectrums showed no significant relationship with PM_{10}. The turbulent interactions among vertical wind velocity and temperature time-series measured in the Amazonian forest, is studied by Maurıcio Jose and etal **(2006)**. The approach is based on the estimation of the correlation coefficient between the different scales in turbulent fields and Cross Wavelet Power (XWP) discussed by Shahruddin et. al. (2008). Zhang Xiang et al

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(1998) analysed the non-stationary, shock signals using Wavelet Analysis Method (WAM). The gear testing signal has been analysed by WAM and the results of WAM are compared with that of Fourier spectrum. This paper is based on the analysis of wavelet decomposition of Indian air pollution parameters using Haar wavelet at level 3

2. Statistical Analysis

The hourly average value of last 3 years of air pollutant parameters CO, NO, NO_2, O_3, $PM_{2.5}$ and SO_2 observed by Central Pollution Control Board (CPCB) at different locations of Delhi have been considered for study. The average value of CO, NO, NO_2, O_3, $PM_{2.5}$ and SO_2 are respectively 2560.11, 62.10, 106.68, 38.15, 120.64 and 17.36 throughout the period. Observation shows a much decrease in O_3 and SO_2 parameter and high increase in CO, NO_2 and $PM_{2.5}$ from their prescribed standard. While NO shows a slightly increase and decrease behaviour. The cross-correlation coefficient (r), is a measure of the strength of the linear relationship between two variables and values ranging between -1 and +1 is defined as,

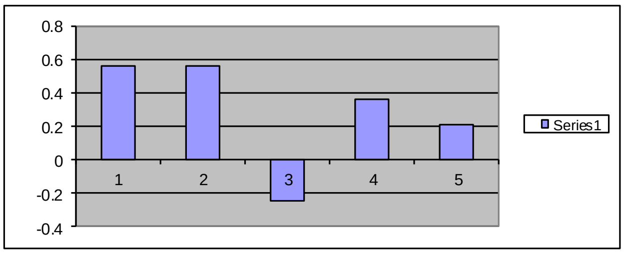
$$r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2 \sum_{i=1}^{n}(Y_i - \bar{Y})^2}}$$

The correlation coefficients between each pair of air pollutant parameters are given in Table-1.

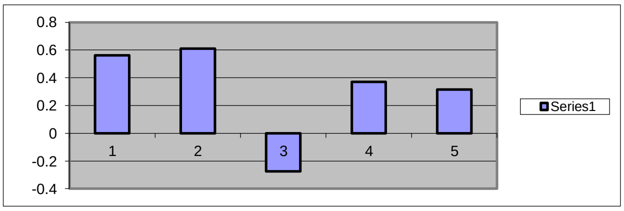
Table 1 Correlation coefficient between Air pollution parameters

Parameters	Correlation coefficient (r)
CO – NO	0.562928
CO – NO_2	0.559122
CO – O_3	-0.25261
CO – $PM_{2.5}$	0.358108
CO – SO_2	0.205627
NO – NO_2	0.609197
NO – O_3	-0.27433
NO – $PM_{2.5}$	0.371519
NO – SO_2	0.315875
NO_2 – O_3	-0.23562
NO_2 – $PM_{2.5}$	0.268646
NO_2 – SO_2	0.236677
O_3 – $PM_{2.5}$	-0.21666
O_3 – SO_2	-0.13401
$PM_{2.5}$ – SO_2	0.31365359

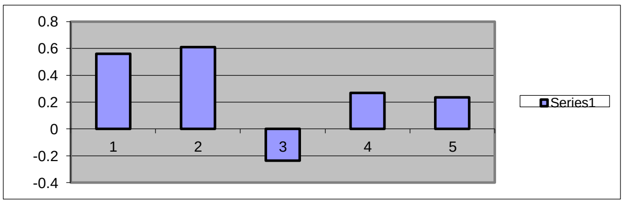
The variation of parameters with other pollutant parameters are shown in the Figure 1. The figure 1(a) shows the variation of CO with NO, NO_2, O_3 , $PM_{2.5}$ and SO_2. O_3 shows negative correlation with all other parameters. Carbon monoxide is strongly positive related with nitrogen oxide and nitrogen dioxide. All other parameters except ozone are positively related with each other. The positive value of the correlation coefficient r indicates that as one value increases other tend to increase and the negative value of the correlation coefficient r indicates that as one value increases other tend to decrease. It has been observed that all the pollutants have positive correlation with all the other pollutants except with O3. Ozone has negative correlation with all the air pollutant parameters



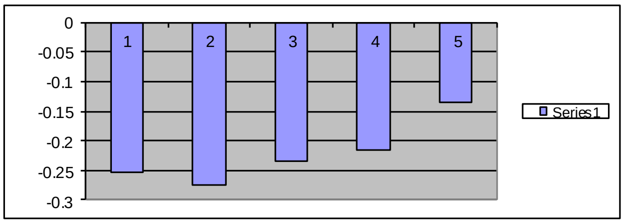
1(a)



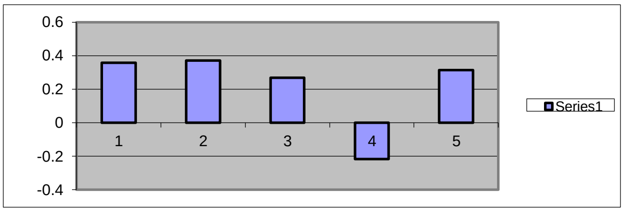
1(b)



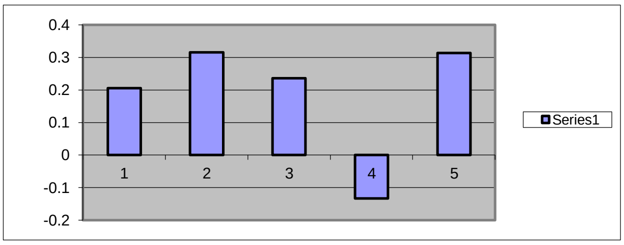
1(c)



1(d)



1(e)



1(f)

Fig. 1 Analysis of cross correlation between each parameters CO, NO, NO_2, O_3, $PM_{2.5}$ and SO_2 with (a) CO (b) NO (c) NO_2 (d) O_3 (e) PM2.5 (f) SO_2 respectively .

3. Air Pollution Data through Discrete Wavelet

Discrete wavelet analysis of one dimensional discrete Haar wavelet analysis of air pollution parameters such as CO, NO, NO_2, O_3 $PM_{2.5}$ and SO_2 for ITO-Crossing, Delhi, India have been studied. The discrete wavelet analysis of air pollution parameters are performed in terms of decomposition, approximation, compression and de-noising of the original signal. The decomposition analysis of CO, NO, NO_2, O_3 $PM_{2.5}$ and SO_2 for ITO-Crossing have been performed using discrete wavelets.

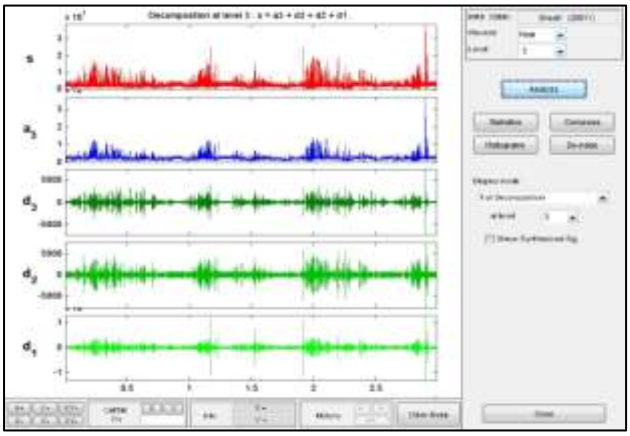


Fig. 2 a I.D. wavelet (ITO, Delhi, haar; level: 3) CO.

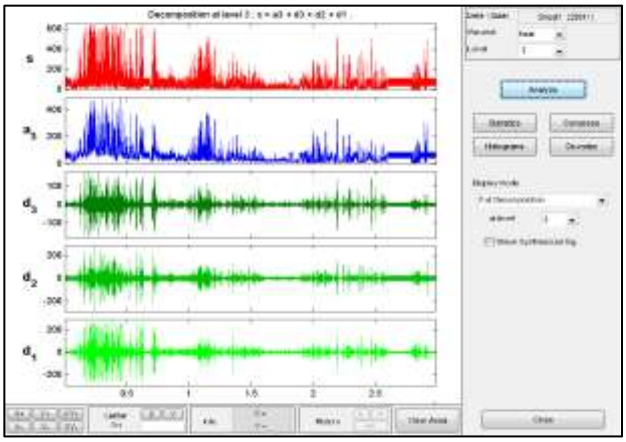


Fig. 2 b I.D. wavelet (ITO, Delhi, haar; level: 3) NO.

Figures 2(a)-(f) shows 1D Discrete wavelet decomposition of CO, NO, NO_2, O_3 $PM_{2.5}$ and SO_2 for ITO-Crossing using Haar wavelet (level 3) for Delhi station respectively. In these figures, the x-axis shows the number of days of the entire data period used in this study and each of these figures have five parts namely s, a_3, d_1, d_2, d_3. The first part "s" represents the signal or raw data and the second part "a_3" corresponds to the amplitude of the signal. The next three parts d_1, d_2, d_3 represent details of the signal or raw data at three different levels. The next three parts d_1, d_2, d_3 represent details of the signal or raw data at three different levels.

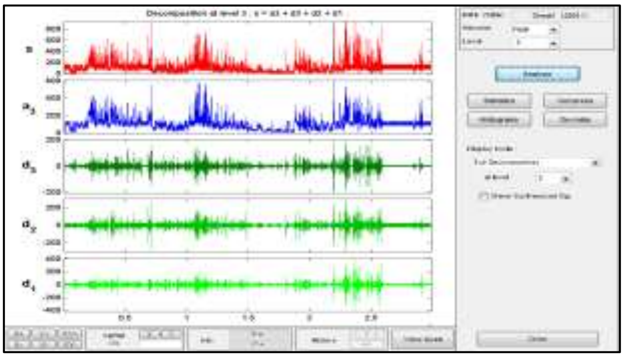


Fig. 2c I.D. wavelet (ITO, Delhi, haar; level: 3) NO_2

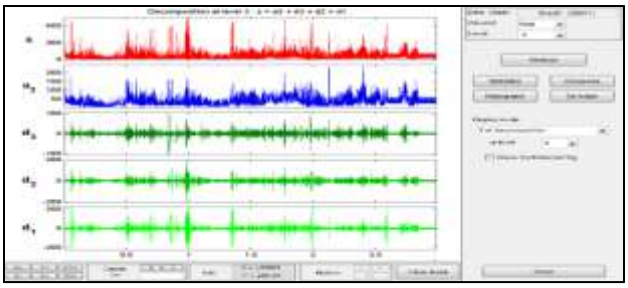


Fig. 2d I.D.wavelet (ITO,Delhi, haar; level: 3) O_3

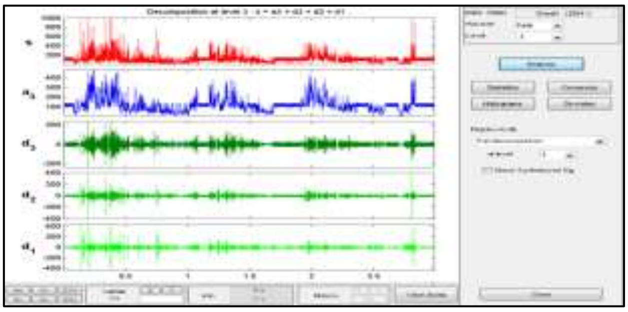


Fig. 2 I.D. wavelet (ITO,Delhi, haar; level: 3) $PM_{2.5}$

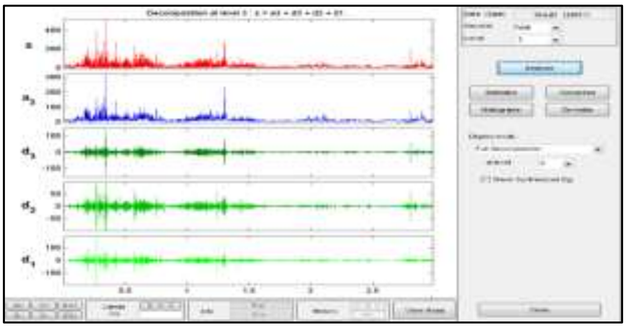


Fig. 2f I.D wavelet (ITO, Delhi, haar; level: 3) SO_2

4. Air Pollution Data through Continuous Wavelet

1-dimensional continuous wavelet analysis of hourly average values of parameters CO, NO, NO_2, O_3 $PM_{2.5}$ and SO_2 have been analyzed and shown in Figures 3 (a) - (f) using continuous wavelet decomposition. Each of these figures have four parts. The first part on top of the figure represents the signal or raw data. The second part shows scalogram. The scale of colors changes from minimum (dark colors) to maximum (light colors). The vertical axis shows the frequency values while the horizontal axis represents the number of days. The third part shows the daily variation of coefficients. The last part of the figure explains the local maximums of related parameters.

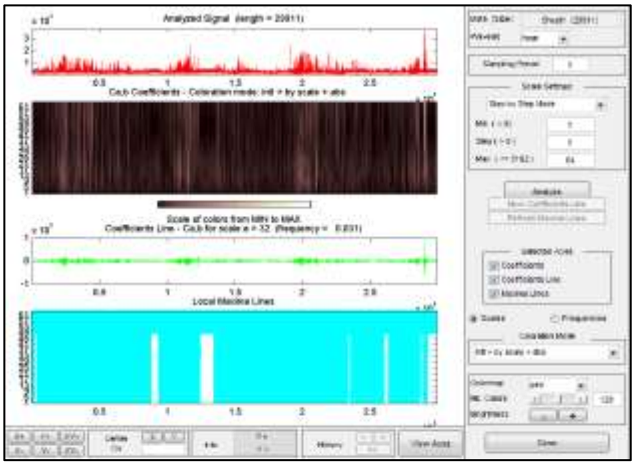


Fig. 3a I.D. continuous wavelet of CO ITO-crossing

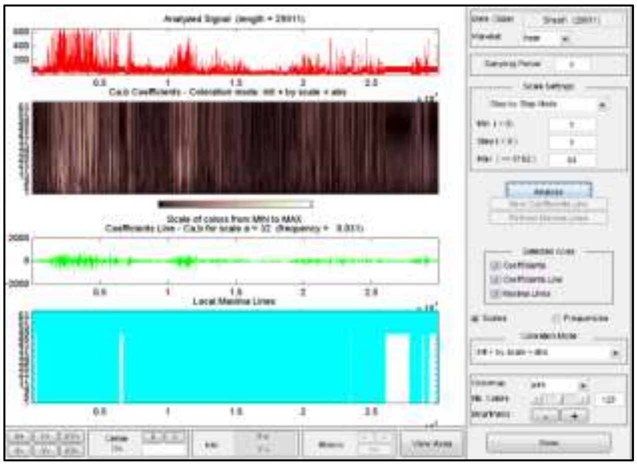


Fig. 3b I.D. continuous wavelet of NO for ITO-crossing, Delhi

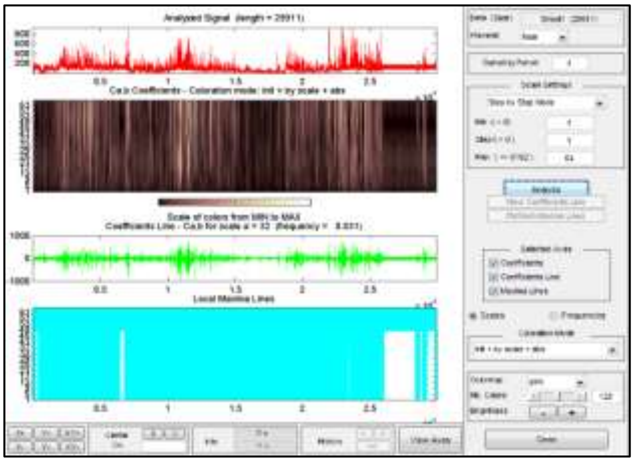


Fig. 3c I.D. continuous wavelet of NO_2 for ITO-crossing,

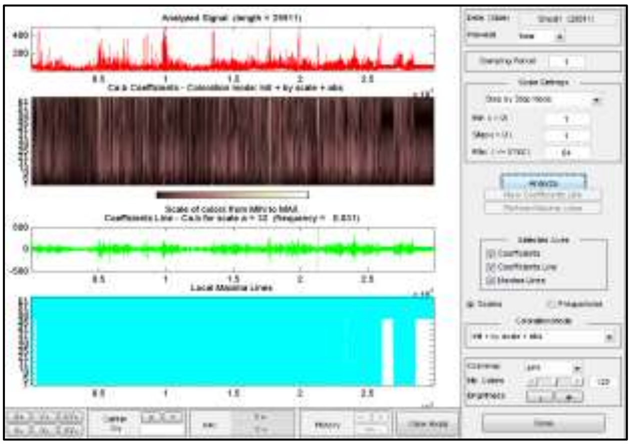


Fig. 3d I.D. continuous wavelet of O_3 for ITO-crossing

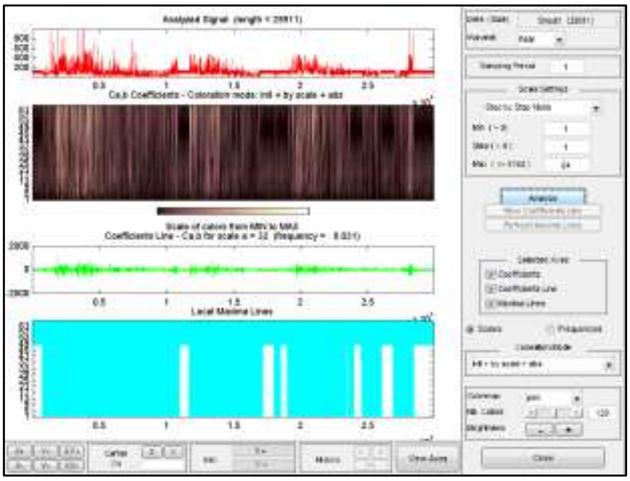


Fig. 3e I.D. continuous wavelet of $PM_{2.5}$ for ITO-crossing,

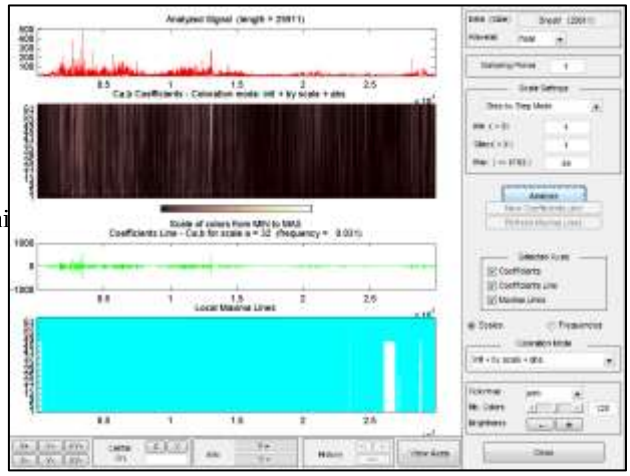


Fig. 3f I.D. continuous wavelet of SO_2 for ITO-crossing

Conclusion

It has been observed that all the pollutants have positive correlation with all the other pollutants except with O_3. Ozone has negative correlation with all the pollutant parameters. The same results have been confirmed with the help of Discrete and Continuous wavelet analysis.

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