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# Spectral Analysis of Ground Level Nitrogen Dioxide and Sulphur Dioxide

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***Abstract.*** Nitrogen dioxide ($NO_2$) and sulphur dioxide ($SO_2$) are two major ground level atmospheric air pollutants. The higher level of $NO_2$ and $SO_2$ causes to change the composition of environment and impose adverse effect on human health. Our study area is Budh Bazar, Moradabad and we have taken value of $NO_2$ and $SO_2$ from 01-09-2015 to 31-08-2017. The wavelet transform approach provides simple and accurate framework for investigating the behaviour of non-stationary signal or function. Skewness, Kurtosis and Correlation provide detailed information regarding asymmetry, extremities and linear relation between two continuous functions or data set.

***Keywords:*** Nitrogen dioxide; Sulphur dioxide, Wavelet; Skewness; Kurtosis; Correlation

## 1. Introduction

Air is the mixture of gases that makes atmosphere of earth. Nitrogen, Oxygen and Argon are three main elements of the air. In urban atmosphere, the nitrogen dioxide and sulphur dioxide are two major pollutants.

### 1.1. Nitrogen dioxide

Nitrogen dioxide is reddish brown and a highly reactive gas and formed when nitric oxide combines with the oxygen in the atmosphere. The concentration of $NO_2$ in urban areas is much greater than rural areas and varies with distance from source. Some $NO_2$ is formed naturally in the atmosphere by lighting and some by soil, water and plants. Natural sources produce 62% of the total $NO_2$. The main anthropogenic sources of $NO_2$ are combustion of oil, coal and gas used in cars, trucks and industries. Home heaters and gas stoves can produce $NO_2$ inside home. The anthropogenic sources produce 38% of the total $NO_2$ [1, 2].

The main health effect of $NO_2$ is on respiratory system. High levels of $NO_2$ can cause damage to the human respiratory tract. $NO_2$ can cause a wide range of environmental changes including visibility impairment and eutrophication. In urban areas $NO_2$ forms secondary particles that cause haze and reduce the visibility. Due to $NO_2$ summer smog looks brownish in colour.

### 1.2. Sulphur dioxide

Sulphur dioxide is a colourless, inflammable, water soluble poisonous gas or liquid, which is emitted by combustion of sulphur on air. Volcanic activities release large quantity of $SO_2$ in air. This SO2 is main contributory factor to the acid rain. $SO_2$ is a waste gas produced by burning of coal, oil and natural gas on the air [3, 4].

$SO_2$ can impose adverse effect on human health and plant life. $SO_2$ irritates the skin and mucous membrane of eyes, nose, throat and lungs. High concentration of $SO_2$ can cause inflammation and irritation of respiratory systems and affect lung function and aggravates existing heart disease in sensitive people. In the atmosphere $SO_2$ reacts with humidity and produces sulphurous and sulphuric aerosols that are later part of acid rain. $SO_2$ and other sulphur oxides react with other compounds in atmosphere and form fine particles that are responsible to reduce visibility (haze).

### 1.3. Wavelet transforms

Wavelet transforms is a new technique in the emerging field of data analysis for Physicists, Engineers and Environmentalists [5, 6]. For a signal, the Fourier analysis extracts only frequency information and time information are lost, while wavelet analysis of a signal extracts frequency and time information simultaneously. The wavelet is a hierarchy of local fits and retains time-frequency localization, while Fourier or polynomials have global fits. Wavelet transform is a compromise between digital data at sampled times and data through a Fourier analysis in frequency space.

## 2. Basics of Spectral Analysis

The basics of spectral analysis are as following:

### 2.1. Wavelet Analysis

A wavelet is a wave like oscillation localized in the sense that it grows from zero reaches maximum and decreases back to zero. Thus it has a location where it maximizes, a characteristic time period and a scale where it amplifies and declines. There is a relation between length of support and wavelet coefficients in wavelet refinement relation [6, 7]. A mother function is used to generate a whole family of wavelets using dilation and translation.

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

where $a$ is the dialation or scaling parameter, $b$ is the translation parameter and ψ(t) is real valued. The collection of wavelets is used as orthonormal basis. The continuous wavelet transform of a function $f$ is defined as:

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

By taking $a = 2^{-j}$ and $b/a = k$ with $j, k \in \mathbb{Z}$, that is, the integers representing the set of discrete dilation and discrete translation, the discrete wavelet transform is defined as:

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

and discrete wavelets are defined as:

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

The $\psi_{0,0}(t) = \psi(t)$ is called mother wavelet. Other wavelets are produced by dilation and translation of mother wavelet. The wavelet transforms of a signal captures the localized time frequency information of as signal.

**2.2. Haar wavelet**

Haar wavelet is not continuous and hence not differentiable. This is applied to analyse signals having sudden transitions. It conserves the energy in the compactness of a signal. It is widely used to analyse local aspects of a signal due to its simplicity, low computational requirements and high computational efficiency. It shows orthogonal, bi-orthogonal and compact support. Haar wavelet is constructed from the MRA generated by scaling function $\phi(x)=\chi_{[-1,0]}(x)$. Since,

$$\frac{1}{2}\phi\left(\frac{x}{2}\right) = \frac{1}{2}\phi(x)\frac{1}{2}\phi(x+1)$$

and $$\psi(x) = \phi(2x+1) - \phi(2x) = \chi_{\left[-1,-\frac{1}{2}\right]} - \chi_{\left[-\frac{1}{2},0\right]}$$

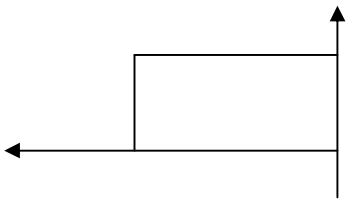

**Figure 1(a): Scaling function of Haar**

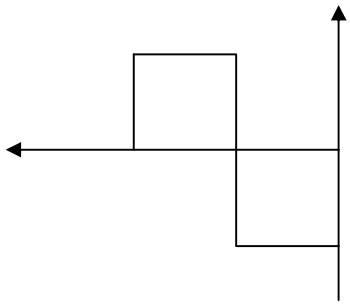

**Figure 1(b): Wavelet function of Haar**

**2.3. Multiresolution analysis**

A multiresolution analysis is introduced by Mallat [8, 9] and developed by other researchers [10, 11] consists of a sequence $V_j$, $j\epsilon\mathbb{Z}$ of closed subspaces of $L^2(\mathbb{R})$. We can express a function $f(x)$ in $V_{j+1}$ spaces as following:

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

Since

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

where

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

and

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

Therefore,

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

where

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

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 a given signal takes place a new version such as

$$s = a_1 + d_1$$

Here $a_1$ is approximation and $d_1$ is detail of signal at various scale or time frames.
Therefore, a signal $s$ can be expressed as:-

$$s = \sum_{k} a_{1,k}\, \phi_{1,k}(x) + \sum_{k} d_{1,k}\, \psi_{1,k}(x)$$

**2.4. Statistical analysis**

Skewness is the measurement of asymmetry of a signal. If skewness of any data set (signal) is zero, it means that the distribution of data is perfectly symmetric. If the skewness is negative, the distribution is skewed to the left, while if skewness is positive the distribution is skewed to the right. Kurtosis is measurement of extremities (tails) and therefore, provides an indication of presence of outliers [12]. Correlation is measurement of degree of linear relation between two continuous variables or functions [13]. A positive correlation between two functions means that they are related such that if value of one variable increases, the value of other variable also increases.

**3. Study area and methodology**

Moradabad is a metropolitan area of Uttar Pradesh state in Northern India and is situated at the banks of Ramganga River. It is known as "Brass city (Peetal Nagri)" for its famous brass handicrafts industry. The latitudinal extent of city is 28°20'N to 29°15' N and longitudinal extent is 78°4' E to79°E. We have selected Budh Bazar (dense and main market of the city) as our study area and taken quantity of $NO_2$ and $SO_2$ from 01-09-2015 to 31-08-2017.

In fig. 2a, the quantitative behaviour of $NO_2$ of Budh Bazar, Moradabad for given time period is shown. For detailed analysis, we decompose the signal using Haar wavelet transforms at level 1. The $a_1$ represents average behavior of signal (Fig. 2b), while $d_1$ represents behaviour of differences (or changes) in signal and shown in fig. 2c.

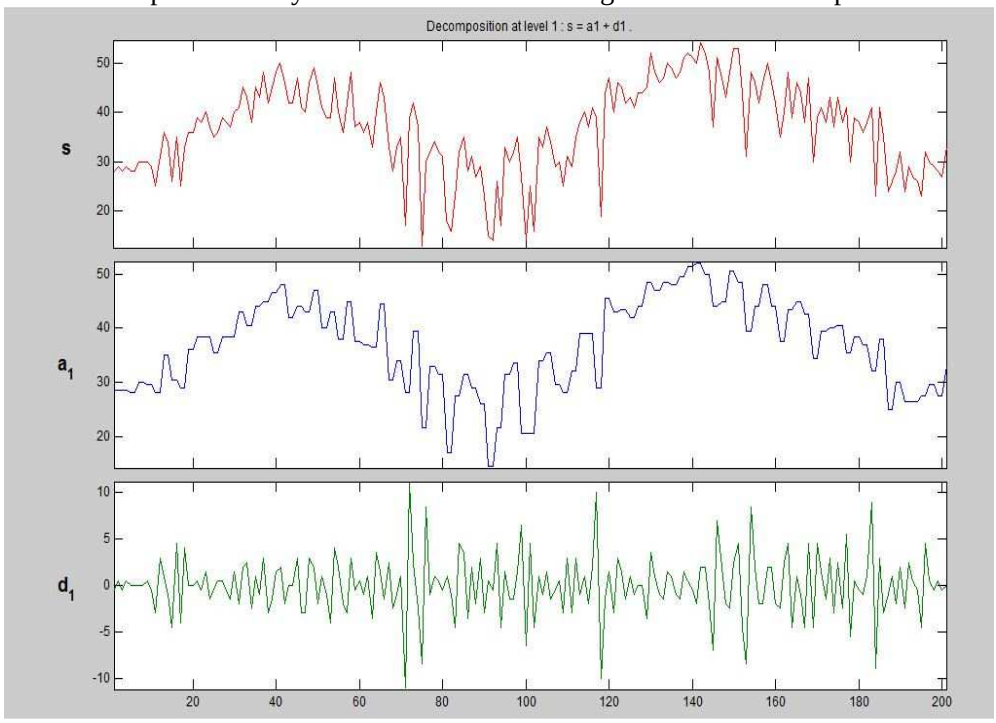


**Figure 2:** NO2 in ppb and its wavelet decomposition

In fig. 3a, the quantitative behaviour of $SO_2$ of Budh Bazar, Moradabad for given time period is shown. Its 1-level decomposition by Haar wavelet is shown in fig. 3b & 3c.

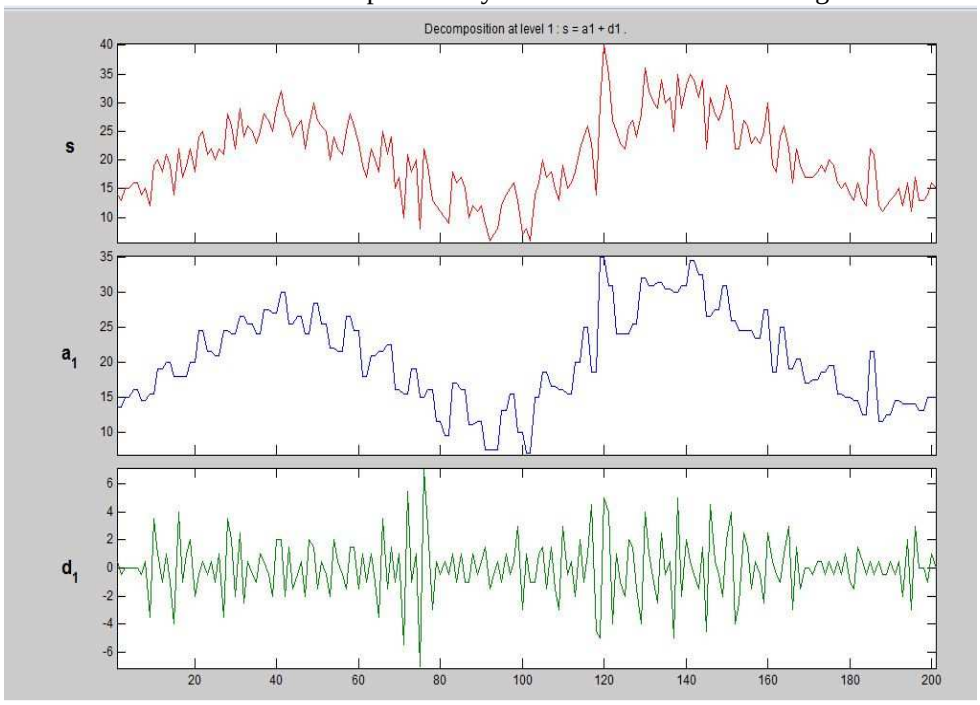


**Figure 3:** SO2 in ppb and its wavelet decomposition

The approximation is the average of any signal and therefore represents low frequency components, while detail is the difference of any signal and therefore represents high frequency components. We find-out skewness, kurtosis and correlation coefficients of $NO_2$ and $SO_2$ for given time interval.

**4. Results and discussion**

In present study it is obvious that concentration of $NO_2$ and $SO_2$ are fluctuating from time to time and season to season. Higher value of $NO_2$ and $SO_2$ is the indication of high pollution making it unsuitable for human beings and plants. Observations indicate that the value of $NO_2$ is minimum in month of July, August and September and maximum in month of November, December and January in both years at Budh Bazar, Moradabad. Higher value of $NO_2$ and $SO_2$ in winter months is because of smog. The $NO_2$ and $SO_2$ are near to earth surface due to smog and thus the concentration is increased. Maximum concentration of $NO_2$ is 50 in Jan. 2016 and 54 in Jan 2017 and $SO_2$ is 32 in Jan 2016 and 40 in Nov. 2016. In present investigation strong positive correlation of $SO_2$ has been recorded with $NO_2$. Both of these variables show positive relationship with various chemical parameters. Wavelet transforms of the time series of $NO_2$ and $SO_2$ are performed for more detailed investigation. For this purpose we used Haar Wavelet. The trend represents the slowest part of the signal and corresponds to the greatest scale value in wavelet analysis terminology. When the scale increases, the resolution decreases which provides a better estimate of the unknown trend. The decompositions of time series of $NO_2$ and $SO_2$ are shown in Figure 2 and 3 respectively. Approximation possesses low frequency information. The calculated value of skewness, kurtosis and correlation coefficients are as following:-

| S. No. | Spot | Skewness | Kurtosis |
|---|---|---|---|
| 1 | $NO_2$ | -0.410112349 | -0.253605146 |
| 2 | $SO_2$ | -0.202034781 | -0.485122179 |
| 3 | Correlation coefficient =0.845965535 | | |

The behaviour of skewness parameter tells about the intermittency phenomenon. Negative value of skewness indicates that data are skewed left. Skewed left means that left tail is long relative to the right tail. The skewness to be non-zero is heuristically connected to the vortex folding and stretching process which drains energy from large to small scale, and hence plays an important role in intermittency. Correlation describes the degree of linear relationship between two functions (or signals). The value of correlation coefficient for $NO_2$ and $SO_2$ is 0.845965535. A positive value means that are linearly related and high value means that $NO_2$ and $SO_2$ in the atmosphere are strongly correlated.

**5. Conclusion**

Increasing trend of $NO_2$ and $SO_2$ towards upstream are observed. The trend become more sharp and clear after applying the wavelet transforms. The increasing trend of the parameters towards upstream is mainly due to the large quantity of effluent discharges from vehicles and industry. Negative value of skewness and kurtosis parameters provides evidence in the favour of this increment. Strong positive correlation of $NO_2$ and $SO_2$ has been recorded. By virtue of these results, we can say that wavelet transforms technique

Spectral Analysis of Ground Level Nitrogen Dioxide and Sulphur Dioxide provides a simple and accurate framework to investigate the behaviour of $NO_2$ and $SO_2$ as atmospheric air pollutants.

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