Using Wavelet Transform on Suspended Particulate Matter (PM10) and Meteorological Time Series

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Abstract: - Malaysia has experienced several haze periods since early 1980s in which suspended particulate matter (SPM) was the major components. The temporal variations observed are the result of interactions of various meteorological variables and pollutants emissions in different time scale. In order to study the relationship between particulate matter, temperature and rainfall, non-decimated wavelet transform is applied to the time series. The low frequency components of the temperature and rainfall showed significant relationship with PM10. The finding also support the suggestion that during the dry season one of the major sources of particles are from outside the country.

Key- Words:- PM10, wavelet, rainfall, temperature, non-decimated wavelet transform, MODWT

1 Introduction

Air quality and meteorological time series can be complex in nature. Suspended particulate matter (SPM) temporal fluctuations are due to various processes of emissions, dilutions and accumulations operated in different time scales such as intraday, diurnal, several days, seasonal, annual and long terms [8]. Dilution process are affected by meteorological processes which caused the time series to become noisy and showing periodicities of different scales. Short term variations (intraday, diurnal, several days) may be due to local meteorological factors and the changes in emission rate from the sources such as road traffic. Long term changes could be due to economic and policy factors which affect the emission of pollutants in the long run, thus time series may present non stationary characteristics. Annual and inter-annual variations may be due to the weather and climate factors such as monsoon cycles in the tropical countries. In fact, the changes due to weather and meteorological factors are larger than changes due to long term changes in pollutant emissions [8]. In this paper, SPM with diameter less than 10µm (PM10) is chosen as it has gained more concern in the country recently [3].

Spectral decomposition methods like wavelet have the ability to demonstrate and analyze the variations among different scales in a time series. Wavelet transform has been used for data analysis since its application in Geophysics in early 1980s [4,5]. Non-decimated (discrete) wavelet transform (MODWT) is chosen in this study rather than continues form since it has better characteristics in the statistical point of view.

Additional knowledge gained from wavelet analysis could enhance the understanding on how meteorological factors affecting PM10 fluctuations and thus be used for general air quality management.

2 Problem Formulation

PM10 time series consists of average daily observation of PM10 concentration in microgram/m^3 (µg/m^3) recorded at Petaling Jaya Air Quality Station by Malaysian Meteorological Department from year August 2000 to December 2004. Daily average rainfall and temperature time series for the duration were also recorded for the same station. The station is located in a residential and commercial area of Petaling Jaya district which located 15 km to the south-west of Kuala Lumpur. Petaling Jaya and Kuala Lumpur are situated in highly populated Klang Valley. The Klang Valley is surrounded by hills to the north, east and south, and this impedes the horizontal transport of surface generated pollutants. Hence, meteorological variables have strong influence on the concentration and transport of PM10. These factors have resulted in the Klang Valley becoming the most polluted area in Malaysia [1].

In this paper, the relationships between PM10, rainfall and ambient temperature are investigated by applying non-decimated wavelet decomposition. MODWT is a modification of discrete wavelet transform (DWT), achieved by avoiding down sampling as in DWT. MODWT has better adapted to statistics due to its better resolution at coarser scales.

Mother wavelet is the fundamental building block functions. The different scales in a time series are estimated by translating and dilating the mother wavelet $\psi(t)$ producing $\psi_{j,k}(t)=2^{j/2}\ \psi(2^j t-k)$, where $j,k \in Z$. The dilation parameter j control the size of the wavelet, the translation parameter k shifts the wavelet along the t-axis. For the set of $\{\ \psi_{j,k}(t)\ \}_{j,k}$ the function f can be expanded as;

$$f(t) = \sum_{k=-\infty}^{\infty} c_{0k}\varphi_{0,k}(t) + \sum_{j=1}^{J}\sum_{k=-\infty}^{\infty} d_{j,k}\psi_{j,k}(t) \qquad (1)$$

where $\varphi 0$ is the scaling function. The maximum J scale is determine by the number of data. c_{0k} denote the lowest frequency smooth.

MODWT is similar to DWT except it is highly redundant non orthogonal transform [6]. MODWT is more flexible as it well adapted to sample size J while DWT needs the sample size to be a multiple of 2^J. As it avoids down sampling, direct comparison can be made between the decomposed series and the original time series. MODWT is also insensitive to the starting point of a time series. In this work Daubechies (db8) is used [2].

3 Problem Solution

MODWT decomposition is applied to PM10, temperature and rainfall time series which separated the variance in each time series into 10 consecutive series according to their time scale. The original time series are shown in Figure 1,2 and 3.

Generally, the mean and variance for PM10 are increased throughout August 2000 to December 2004 (Fig 1). Generally, PM10 concentration are higher during the month of June, July and August while the lowest concentration registered for November, December and January. This is the wet duration where the amount of rainfall recorded are highest throughout a year (Fig 3). The fluctuations in temperature and rainfall time series looked more stable for the same duration of August 2000 to December 2004 (Figure 2 and 3).

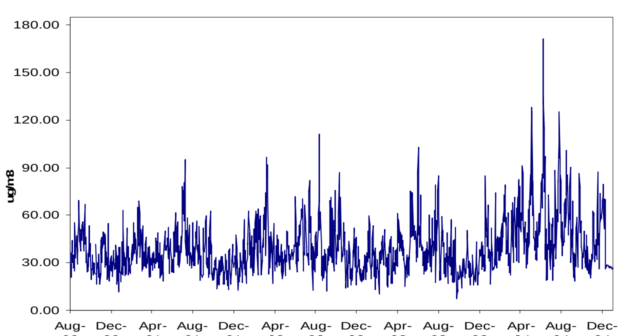

Fig 1: The original time series of PM10 during August 2000 to December 2004.

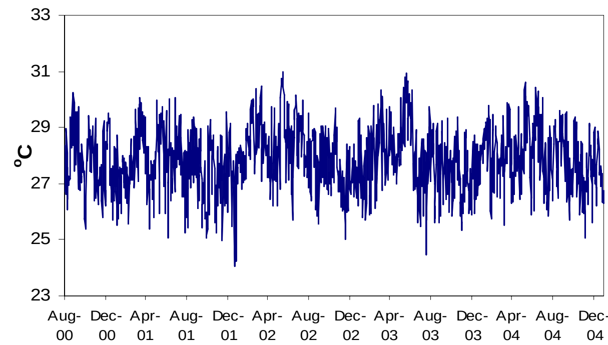

Fig 2: The original time series of ambient temperature during August 2000 to December 2004.

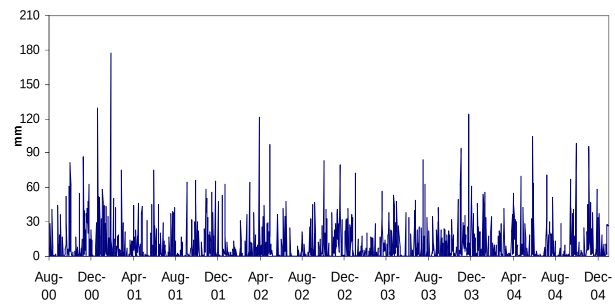

Fig 3: The original time series of rainfall during August 2000 to December 2004.

3.1 Relationship between PM10 and temperature

The significant relationship between the components of PM10 and temperature are indicated by correlation coefficients (r). The significant correlations are registered for the low-frequency spectrums (D5-D9) as showed in Table 1. The correlations are increased from D5 towards D9 with D8 (256 days) registered the highest value. The correlation between detail component D8 is depicted in Figure 4. The original time series (without decomposition) do not show the link between PM10 and temperature as the correlation coefficient is not significant. Short term temperature fluctuations (less than 30 days) has no significant influence to PM10 variations.

	Details components					
	D5	D6	D7	D8	D9	D10
Period (days)	32	64	128	256	512	>512
R	0.07	0.26	0.31	0.58	0.41	-

Table 1: Significant correlation coefficients (r) at the 0.01 level and periodicity between detail components of PM10 and temperature.

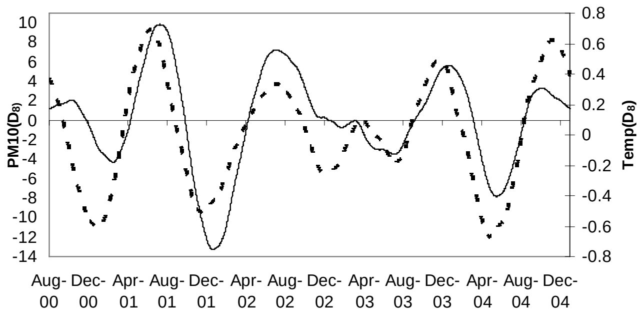

Fig 4: The detail component *D8* for PM10 (solid) and temperature (dashed) during August 2000- December 2004.

High temperature of low frequency is linked to high PM10 . This could be associated to the suggestion that forest fire is one of the major sources of particle beside road traffic [1,3]. This could suggest the influence of seasonal factors as high temperature in a long run will promote forest fire which is a major contributor to particle during the dry season. This is in agreement with other findings which suggest that during the dry season the major sources of particle is from outside the country [1,3].

3.2 Relationship between PM10 and rainfall

The negative correlation between rainfall and PM10 is an indication of the role of rainfall as wet deposition which remove particles from the atmosphere. Significant relationship between PM10 and rainfall are registered for low frequency detail components D5-D10 (Table 2). Low frequency time scales are associated with seasonal and more regional rainfall event. Since the episodes of high PM10 in this region are associated with forest fire, the long duration of rainfall event is not only has the ability to remove the particles from the atmosphere. The more regional rainfall also has the influenced on the source of particle *ie.* the forest fire. The more localized rainfall events may replenished the particle from the atmosphere, however the PM10 concentration will be in high level again in the next few days as the source of the particle is not affected by the local rainfall.

	Details components					
	D5	D6	D7	D8	D9	D10
Period (days)	32	64	128	256	512	>512
R	-0.09	-0.1	0.25	-0.41	-0.47	-0.49

Table 2: Significant correlation coefficients (r) at the 0.01 level and periodicity between detail components of PM10 and rainfall.

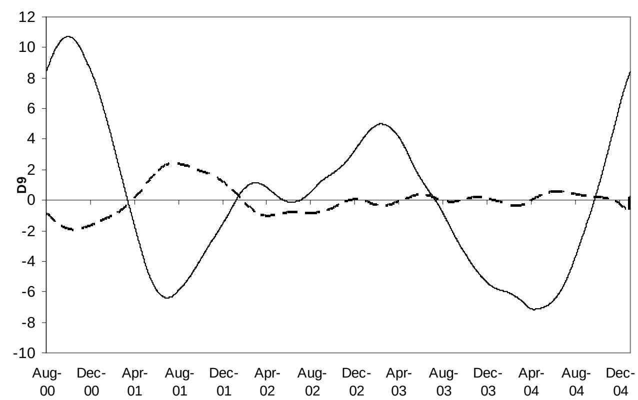

Fig 5: The detail component *D8* for PM10 (solid) and rainfall (dashed) during August 2000- December 2004.

4. Conclusions

Using non-decimated wavelet decomposition, the relationships between PM10, temperature and rainfall are examined. The correlation between PM10 and temperature is positive with the highest correlation registered for spectrum 256 days. PM10 and rainfall showed negative correlation with the highest correlation is for spectrum scale larger than 512 days followed by 512 days. Without decomposing the original time series, the correlations between PM10, temperature and rainfall remained insignificant. The significant correlation coefficients between the detail components support the other findings which suggested that forest fire outside the country as the major source of particles during dry season.

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