Temporal and spatial PM$_{10}$ concentration distribution using an inverse distance weighted method in Klang Valley, Malaysia

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Abstract. PM$_{10}$ is one of the air contaminants that can be harmful to human health. Meteorological factors and changes of monsoon season may affect the distribution of these particles. The objective of this study is to determine the temporal and spatial particulate matter (PM$_{10}$) concentration distribution in Klang Valley, Malaysia by using the Inverse Distance Weighted (IDW) method at different monsoon season and meteorological conditions. PM$_{10}$ and meteorological data were obtained from the Malaysian Department of Environment (DOE). Particles distribution data were added to the geographic database on a seasonal basis. Temporal and spatial patterns of PM$_{10}$ concentration distribution were determined by using ArcGIS 9.3. The higher PM$_{10}$ concentrations are observed during Southwest monsoon season. The values are lower during the Northeast monsoon season. Different monsoon seasons show different meteorological conditions that effect PM$_{10}$ distribution.

1. Introduction
Increasing of industrial development, vehicle emission and urbanization transformation has contributed to high amounts of atmospheric pollutants. Atmospheric pollution is the presence of one or more contaminants in the air that can cause harmful to human health, animal life and vegetation. Particulate matter with an aerodynamic diameter of less than 10nm (PM$_{10}$) was identified as an atmospheric pollutant in major cities in Southeast Asia, especially in Klang Valley, Malaysia [1-3]. Distribution of air pollutants in Malaysia is strongly influenced by the monsoon seasons and meteorological conditions such as temperature, humidity and wind speed. Several studies are carried out on the effects of meteorological conditions on the trends, variations and characteristics of particles in Turkey, [4] and in Malaysia, [1,5,6]. A strong correlation found between air pollutants in Erzurum city with temperature, meanwhile precipitation and humidity are weakly correlated with SO$_2$ and total suspended particles (TSP) [4]. Surface wind speeds recorded during the southwest monsoon at all stations in Klang valley were weak [7].

Geographic information system (GIS) is a fundamental and applicable computer – based tools for capturing, transforming, managing, analyzing and presenting the spatial distributed phenomena related to the earth [8]. GIS has been used frequently in studies to analyze the various issues related to health and air pollution. In health applications, high levels of lead exposure in children have been identified [9], localities for management of primary health care in England has defined [10], rates and distribution of child abuse had mapped and analyzed in order to allocate special services [11]. Spatial analysis of fixed monitoring sites in Beijing, China is studied and has found significant urban environmental impacts on air pollution [12]. Beijing, as the capital of China has encountered large population growth and problems in traffic congestion and is considered one of the most severely

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An inverse distance weighted interpolation is used to analyze spatial patterns of air pollutants (TSM, CO, NO\textsubscript{2} and SO\textsubscript{2}) and to model air monitoring stations in Tehran [13]. A Voronoi diagram of air pollution was produced to illustrate the spatial dispersion of the station and their influenced area [13]. Several technique of interpolation in spatial analysis can be used to interpolate the variation of air pollutants. The techniques are inverse distance weighted (IDW), kriging and natural neighbourhood. IDW is a method of interpolation that use a simple algorithm based on distance to estimates unknown value at a point by averaging the value of sample data points in the neighbourhood of known value. The closer a point is to the center of location being estimated, the more influence or weight it has in the averaging process.

Currently there are many studies done in Malaysia that involved ground measurement [14], laboratory experiment [5,15] and statistical analysis [7,16]. However, there is limited study in air pollution distribution mapping. Therefore, a study of the sources, distribution and modeling of particulate matter over a given area is important to manage and mitigate of the associated air pollution impacts. In this study, the temporal and spatial patterns of PM\textsubscript{10} distribution concentration in Klang Valley, Malaysia will be determine by using Inverse Distance Weighted in different monsoon season and meteorological conditions.

2. Data and methodology

2.1. Data acquisition
In this research, seven continuous air quality monitoring stations managed by a private company, Alam Sekitar Sdn. Bhd. (ASMA) for Malaysian Department of Environment (DOE) was selected [17]. The geographical locations of the stations are shown in Fig. 1. Mean seasonally recorded PM\textsubscript{10} and meteorological data (temperature, humidity and wind speed) from March 2004 to February 2007 are used in this study are shown in table 1. These parameters were recorded at the same locations as PM\textsubscript{10} concentration monitoring stations.

Table 1. Mean seasonally PM\textsubscript{10} and meteorological data at seven air quality monitoring stations in Klang Valley from March 2004-February 2007.

| Stations     | SI  | SW  | Al  | NE  | SI  | SW  | Al  | NE  |
|--------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Gombak       | 50.00 | 53.00 | 47.50 | 36.67 | 57.45 | 78.08 | 77.85 |
| Klang        | 62.17 | 64.92 | 58.83 | 52.92 | 73.05 | 74.27 | 76.53 |
| P.Jaya       | 55.83 | 59.33 | 56.00 | 54.83 | 71.25 | 72.94 | 74.14 |
| H.Langat     | 43.50 | 48.75 | 51.00 | 40.92 | 79.50 | 79.50 | 81.22 |
| S.Alam       | 56.50 | 58.42 | 55.33 | 47.83 | 74.86 | 75.59 | 77.47 |
| K.Selangor   | 54.67 | 58.50 | 59.33 | 49.00 | 73.74 | 62.52 | 76.06 |
| Cheras       | 53.67 | 56.92 | 52.33 | 42.58 | 74.86 | 77.73 | 79.34 |

| Stations     | SI  | SW  | Al  | NE  | SI  | SW  | Al  | NE  |
|--------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Gombak       | 27.17 | 26.48 | 27.17 | 26.48 | 2.71 | 2.57 | 2.76 | 2.83 |
| Klang        | 28.92 | 28.74 | 28.92 | 28.74 | 4.90 | 5.12 | 5.11 | 4.48 |
| P.Jaya       | 27.33 | 27.73 | 27.33 | 27.73 | 3.47 | 3.53 | 3.52 | 3.25 |
| H.Langat     | 27.02 | 26.84 | 27.02 | 26.84 | 3.32 | 3.33 | 3.63 | 3.21 |
| S.Alam       | 28.38 | 28.38 | 28.38 | 28.38 | 5.14 | 4.47 | 5.77 | 5.03 |
| K.Selangor   | 28.73 | 28.57 | 28.73 | 28.57 | 4.91 | 5.22 | 5.31 | 5.25 |
| Cheras       | 27.65 | 27.50 | 27.65 | 27.50 | 3.82 | 4.33 | 4.17 | 3.69 |
2.2. Pre-processing data
There is a very small percentage of missing data (<5%) in the data set from the overall observation. A nearest neighbourhood method was applied for the treatment of missing data through the use of R software. This analysis finds the distance for each point and the closest point to it. It is the simplest scheme where the endpoints and the gaps are used as estimates for all the missing values [18].

2.3. Temporal and spatial PM$_{10}$ data
Geographic data (digital map showing districts) were stored in raster format in the geographic database. The dataset covers the entire district’s particles distribution data as geographic layers including information such as PM$_{10}$, temperature, humidity and wind speed in different seasons. These data were used for interpolation by Inverse Distance Weight (IDW) method. This method of interpolation considers weighted moving average and gradual change of the trend surface. In this method, weight from a linear function of distance between sets of points and the predicted points are computed and the size of the starting radius is specified which defines the starting search area for interpolation points around grid point. The interpolation of spatial data represented into map which contain additional information of legend and north arrow.

3. Results and discussion

3.1 Interpolation by Inverse Distance Weight (IDW)
The seasonal variations of Klang valley are related to the monsoon. These monsoon dates are change slightly every year. In this analysis, we define the spring inter-monsoon period (SI) from March to April, Southwest monsoon (SW) from May to August, autumn inter-monsoon period (AI) from September to October and Northeast monsoon (NE) from November to February. Interpolation of PM$_{10}$ was performed using Inverse Distance Weight (IDW) and results were shown in figure 2. There are remarkable seasonal variations in mean PM$_{10}$ concentrations with highest particulate matter was observed during the SW monsoon which coincides with the regional biomass burning period which starts around May and last until September.
Figure 2. Mapping of mean seasonally PM$_{10}$ concentration distribution and meteorological conditions in Klang valley area from March 2004-February 2007. SI represent for spring inter-monsoon, SW for Southwest monsoon, AI for autumn inter-monsoon and NE is for Northeast monsoon.

During SW monsoon, Klang station recorded highest mean PM10 concentration (65.92μg m$^{-3}$) meanwhile Hulu Langat station show the lower concentration (48.75μg m$^{-3}$). At least 50% of the summer days at all stations in Klang Valley recorded PM10 concentration greater than 50μg m$^{-3}$ [7]. During the NE monsoon season, the PM10 concentration range (36.67μg m$^{-3}$-52.92 μg m$^{-3}$) is lower if compared to the SW monsoon range (48.75μg m$^{-3}$-65.92μg m$^{-3}$) and both inter-monsoon periods.
This is mainly due to strengthening of northerly winds, drastic drop in temperature and increase in surface pressure which leads to strong surges of cold air from the north.

From figure 2, higher PM$_{10}$ concentration distribution is observed when lower of humidity. Kuala Selangor station recorded the lowest humidity range (62.52%-76.06%) as compared with other station in most monsoon seasons; meanwhile Hulu Langat gave the highest humidity range (79.50%-81.22%). Humidity varies inversely proportional with temperature. Therefore, higher distribution also observed when temperature is high. Temperature is high during late of SI and beginning of SW monsoon especially at Kuala Selangor (28.79°C) and Klang station (28.92°C). Therefore, both stations showed higher PM$_{10}$ concentration distribution for most seasons (49.00μg m$^{-3}$-65.92μg m$^{-3}$), while Hulu Langat and Gombak stations which located in rural area recorded higher humidity gave the lower distribution (36.67μg m$^{-3}$-53.00μg m$^{-3}$). Higher distribution of PM$_{10}$ also observed when the speed of wind is higher. There is a strong wind blow in Kuala Selangor and Klang station during autumn inter-monsoon (5.1km/h-5.3km/h) and southwest monsoon (5.12km/h-5.22km/h), due to specific topographic condition of the areas. Kuala Selangor, which located near the coastal area facing the Malacca strait, is much dominated by localized land sea breezes of wind circulation.

4. Conclusion
This paper analyzed and visualized temporal and spatial PM$_{10}$ concentration distribution Klang valley during monsoon seasons. From the result, PM$_{10}$ concentration distribution can be observed higher during southwest monsoon, followed by both inter-monsoon and lower in northeast inter-monsoon. In meteorological conditions, higher in temperature and wind speed, and lower in humidity also the factors that contribute to higher PM$_{10}$ concentration distribution in Klang Valley.

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