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Ten Years Seasonal and Spatial Particulate Matter (PM_{10}) Concentration at Selected Region in Klang Valley, Malaysia

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Abstract

The aim of this study is to determine both temporal and spatial particulate matter (PM_{10}) concentration distribution at selected region in Klang Valley, Malaysia for ten years' dataset according to monsoon seasons. Air quality data used in this study provided by Malaysia Department of Environment (DOE). A total of 14,608 daily mean of PM_{10} and meteorological parameters (humidity, temperature and wind direction) data from 2006 to 2015 at eight Continuous Air Quality Monitoring (CAQM) stations in Klang Valley are used in this study. Statistical Package for the Social Sciences (SPSS) and ArcGIS 10.4 software are used in this study to apply the descriptive statistical and spatial trend of this PM_{10} concentration. The result showed that increasing of PM_{10} concentration are being observed in Southwest monsoon and decreasing during Northeast monsoon. The Ordinary Kriging distribution map shows that the station located at urban and industrial area will have higher PM_{10} concentration as compared to the station that is located in the rural area. The spatial interpolation method, Ordinary Kriging was used to interpolate the PM_{10} concentration outside the station's range.

Keywords: Air Pollution; Kriging; Meteorological; Particulate Matter; Seasonal Monsoon.

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1. Introduction

Air is never "perfectly clean", meaning that there are gases or aerosols which are emitted naturally or anthropogenically, creating a high enough concentration to cause damage to human health, plants, animals, air quality, atmospheric visibility, structures and works of art either directly or indirectly [1]. Air pollution is defining as the presence of one or more air contaminants in the atmosphere at certain concentration and duration which can cause irritation or to be harmful to human health, animal life or vegetation [2]. In Malaysia, the Air Pollution Index (API) is calculated by taking into consideration the concentration of air pollutants namely suspended particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3) and Sulphur dioxide (SO_2). Among of these pollutants, the particulate matter (PM) is the major cause of the cardio-respiratory mortality and morbidity among children and elderly. Several studies have been reported the effects of air pollution to human health such as lung cancer, cardiovascular diseases, respiratory infections, degenerative brain diseases and high morbidity risk [3]. Air pollution is the fourth leading fatal risk for human health globally, and in the estimates, more than 5 million pre-mature deaths are linked with this air pollution [3]. Particulate matter (PM) is a major important pollutant in ambient air especially in city and industrial area become an environmental issue in the Southeast Asia country region especially Indonesia, Malaysia, Singapore and Brunei. It contains of metals, acids, organic chemicals and soil or dust particles. PM present in different shapes and densities in the air can be divided into coarse particles and fine particles depending on their size. These particle measurements are usually based on their aerodynamic diameter. Particulate matter with a diameter of less than 10μm are known as PM_{10} while particulate matter of less than 2.5μm in diameter are known as $PM_{2.5}$. Under normal conditions, these particles are usually derived from natural and anthropogenic (man-made) sources such as sea spray, soil, road dust, emission from motor vehicles, industrial processes and biomass burning [4]. Klang Valley region which are known as the most densely populated area in Malaysia experienced high concentration of PM_{10} due to industrial activity, local biomass burning and emission from motor vehicles during the non-haze periods. However, during the haze incidents higher PM_{10} concentration was be recorded due to transboundary haze from Sumatra, Indonesia and Indochina in which the burning of peat soil and plant waste were release large quantities of smoke that containing high quantity of particles into the atmosphere. The concentration of PM_{10} in Malaysia is also influenced by meteorological conditions such as temperature, humidity, wind speed and wind direction [5]. A higher concentration of particulate matter was recorded during the southwest monsoon, especially during the El Nino/Southern Oscillation (ENSO) events [6]. A large quantity of particulate matter will bring by this southwest wind which comes from Sumatra to Klang Valley between July and September. Another factor such as local wind direction for example sea and land winds and the movement of wind within the valley will enhance the particulate matter to accumulated in the valley area. However, the concentration of particulate matter is recorded lower during the rainy seasons (northeast monsoon season) due to all particle will be wash away by the water. Activities on weekdays and weekends also will affect the number of particulate matter in the area. This is because, more activities are recorded during weekdays such as industrial processes and heavy traffic will increase the particulate matter level. From the meteorological perspectives, different area will give different meteorological conditions, therefore different variation of pollution will be observed. In recent years, the applications of GIS become wider. GIS application is frequently involving spatial-temporal interpolation of an input data set. The example application GIS in transport issues included infrastructure planning, design and management, transportation safety analysis, travel demand analysis, traffic monitoring and control, public transit planning and operations, environmental impact assessments, hazard mitigation and intelligent transportation systems [7]. There is also an increasing demand for visualization of spatial data to identify the areas of greatest potential threat such as in air and water pollution. Different spatial interpolation techniques which are Inverse Distance Weight (IDW), Splines, Trend Surfaces Model, Kriging and Cokriging model was applied for Particulate matter (PM_{10}), Nitrogen Dioxide (NO_2) and Sulphur Dioxide (SO_2) [8]. From the study, the author found that Kriging method should be used for analyzing air pollution in Egypt as the Root Mean Square Error (RMSE) values obtain was lower as compared with other methods. Kriging is a well-known spatial interpolation technique in geostatistics developed by Krige in 1951. This method is based on the spatial autocorrelation and provides an unbiased approximation of unknown locations by reducing the estimated variance [9]. In Malaysia, it is limited to visualizing PM_{10} distribution spatially rather than based on monitoring stations because these air pollution monitoring stations only measured the pollutants within three kilometers radius. Therefore, by using the interpolation methods in Geographic Information System (GIS), it will provide additional information about the level of pollutants that are outside the range. In other words, the values of random fields at unobserved locations will be predicted by considering the sample data from neighboring locations given a neighborhood based on the spatial autocorrelation-variogram. This study aims to combine both the temporal and spatial effect in determining the particulate matter concentration at selected region in Klang Valley, Malaysia in monsoon seasons. The analysed pollutant is PM_{10}, by using data from a ten years' period to observe the pollutant concentration distribution in the seasonal monsoon trend. The statistical software use is SPSS to conduct a descriptive analysis on PM_{10} concentration distribution, while Kriging interpolation technique in ArcGis is used to visualize the PM_{10} concentration distribution map for these area.

2. Material and Methods

2.1. Study area

The area of study is selected region in Klang Valley, located in Selangor and Kuala Lumpur. This geographical area defined by the Straits of Malacca to the west and Titiwangsa Mountains to the north and east with 6.9 million people in Klang Valley for year 2013. The Klang valley is a major economic region in Malaysia with extensive physical development of the infrastructure, urbanisation and industrialisation which have considerably deteriorated the air quality. There is no official designation of the boundaries to make up Klang Valley, but it is often assumed to comprise several districts including Gombak, Hulu Langat, Klang, Kuala Lumpur, Kuala Selangor, Petaling and Putrajaya. Al the locations background is referred as residential area, while only Petaling Jaya station is located in industrial area. The movement of air and pollutant levels in the study area is affected by Klang Valley topography. This condition contributes a stagnant condition where all the pollutants are trapped down to the valley area [10]. In this study, the PM_{10} concentration and meteorological parameters from eight continuous air quality monitoring stations were obtained by Malaysian Department of Environment (DOE). The geographical locations of the stations are depicted in Figure 1 and their coordinates tabulated in Table 1.

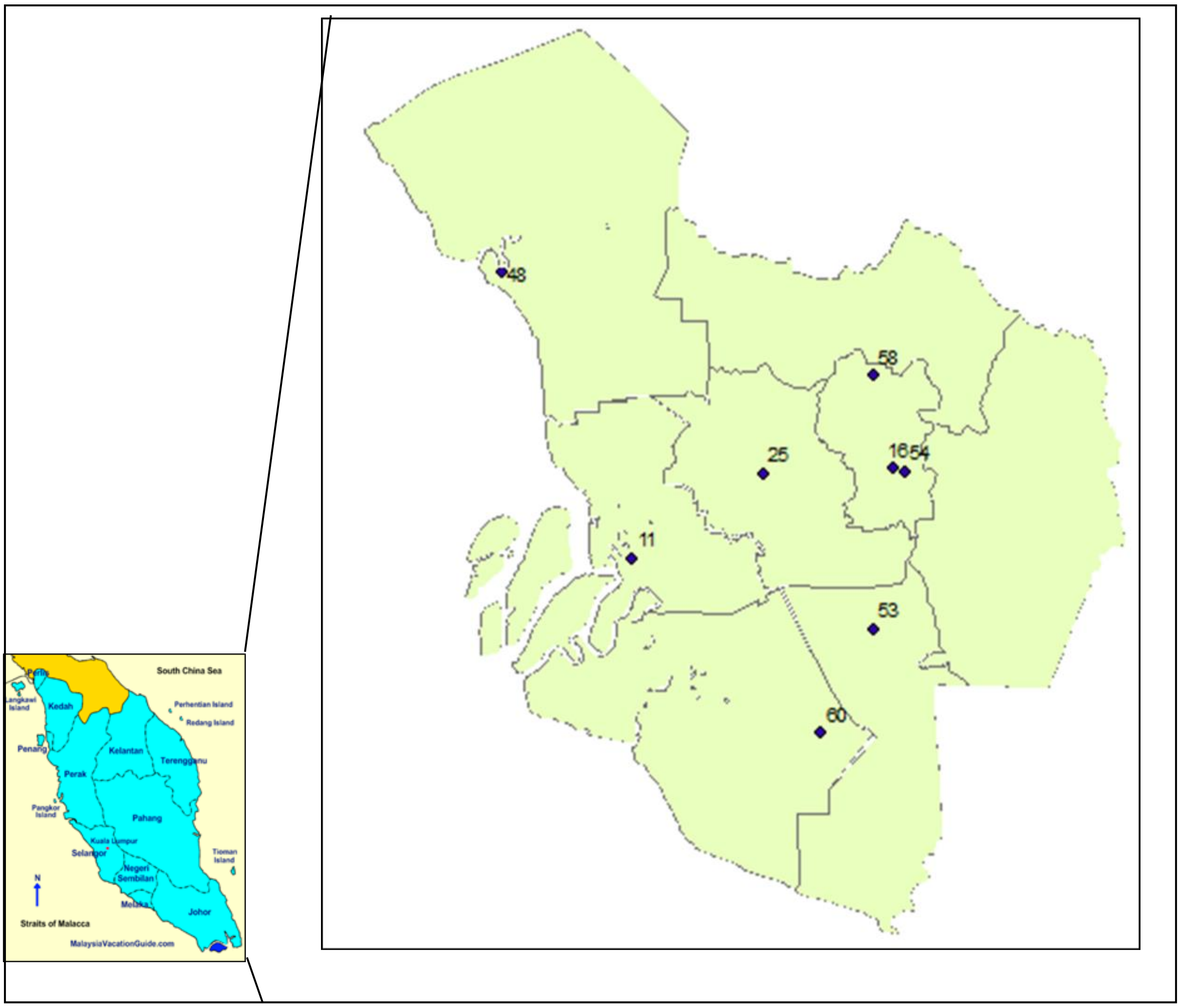

Figure 1: Location of Eight Continuous Air Quality Monitoring Stations (CAQMS) at Selected Regions in Klang Valley

Table 1: Location of Eight Continuous Air Quality Monitoring (CAQM) stations within Klang Valley, Malaysia

Station ID	Air Monitoring Station	Coordinate Latitude (N)	Longitude (E)	Background
CA011	SM(P) Raja Zarina, Klang	N03° 00.620	E101° 24.484	Residential
CA016	Sek. Keb Seri Petaling, Petaling Jaya	N03° 06.612	E101° 42.274	Industrial
CA025	Sek. Keb TTDI, Shah Alam	N03° 06.287	E101° 33.368	Residential
CA048	SM Sains Kuala Selangor	N 03° 19.592	E101° 15.532	Residential
CA053	Sek. Keb Presint 8(2)	N 02° 55.915	E101° 40.909	Residential
CA054	SM Keb. Seri Permaisuri, Cheras	N 03° 06.376	E 101°43.072	Residential
CA058	Sek. Keb. Batu Muda	N03°12.748	E101°40.929	Residential
CA060	Kolej Mara Banting	N02° 49.001	E101° 37.381	Residential

2.2. Data Acquisition

The daily recorded of PM_{10} and meteorological data (humidity, temperature and wind direction) from year 2006 to 2015 at eight CAQM stations in Klang Valley region were obtained from Malaysia Department of Environment (DOE). All the ten years' data then has been separated into four different monsoon seasons. Four seasons within one year had been recognizes based on the direction and speed of the airstreams that cross the Peninsular Malaysia, in which the time commencement and the duration of which vary slightly with altitude from year to year [11]. The four seasons are described in Table 2.

Table 2: Descriptive summary of seasonal wind patterns in Malaysia

Season	Date	Characteristics
Spring intermonsoon (SI)	15 March to 14 May	Light variable winds when an equatorial through lies over Malaysia.
Southwest monsoon (SW)	15 May to 14 September	South-westerly winds below $8ms^{-1}$. Sabah and Sarawak may experience winds of $10ms^{-1}$ when typhoons develop over the west Pacific and move westwards across the Philippines.
Autumn intermonsoon (AU)	15 September to 31 October	Light variable winds when equatorial through lies over Malaysia
Northeast monsoon (NE)	1 November to 14 March	Easterly to North-easterly winds 5 to $10ms^{-1}$. East coast states of Peninsular Malaysia may experience winds of 15ms-1 during cold surges from the north.

2.3. Statistical Methods

In order to obtain a better continuous air quality monitoring data, all the missing values was undergoing data treatment technique. From overall observation, approximately less than five percent (<5%) of missing data was treated by using mean substitution technique in which it replaces missing data with the value of mean available neighbouring data. Mean substitution method is better and more accurate way rather than eliminating the missing value with list wise and pairwise deletion method. The descriptive statistic for all the parameters were being analysed by using Statistical Package for the Social Sciences (SPSS) software.

2.4. Interpolation Methods

The PM_{10} daily data were clustered into four seasonal monsoon values to give an overview of seasonal PM_{10} concentration levels in Klang Valley. An Ordinary Kriging (OK) technique was used to obtain seasonal PM_{10} interpolation map. These maps were used to compared with ground measurement data. ArcGIS 10.4 software was used to interpolate the PM_{10} data in which Klang valley districts and air quality monitoring stations were digitized as a vector base map. Then, Kriging interpolation methods was used to generate spatial PM_{10} concentration distribution in the study area. Kriging includes many different types of algorithms and it can be classified into simple kriging (SK), ordinary kriging (OK) and universal kriging (UK). Among them, the most frequently used is the ordinary kriging (OK). The OK predicts the result in the form of linear combination of measured values, whose the weight *i* depends on the λ model to be measured locations, the spatial relationship among the measured values around the estimated location, and the distance to the predicted location.

3. Results and Discussion

3.1. Descriptive statistic of PM_{10} for ten years' dataset (2006-2015)

The descriptive statistic of PM_{10} in these ten years, 2006 to 2015 at eight continuous air quality monitoring (CAQM) stations at selected region in Klang Valley, Malaysia were summarized in Table 2. The result was reported according to the seasonal monsoon namely Spring Intermonsoon (SI), Southwest Monsoon (SW), Autumn Intermonsoon (AI) and Northeast Monsoon (NE). From the result, CA11 shows highest mean of PM_{10} concentration for the whole seasons (66.06-82.00µgm^{-3}) followed by CA60 (54.85-76.15µgm^{-3}), and the lowest average concentration was recorded at station CA53 (42.19-62.98 µgm^{-3}). The same result was found by Awang and his colleagues (2000) where higher PM_{10} concentrations have been reported at the urban and traffic stations compared with those of rural stations. CA11 located in Klang station, near to the industrial and port area are the main factors that contribute to the deterioration of PM_{10}. In addition, the maximum reading of PM_{10} concentration also recorded at CA11 for most of seasons (363-595µgm^{-3}) as compared with other stations. This maximum value can have reached up to 595µgm^{-3} during SW monsoon due to haze episodes. The concentration of PM_{10} in Klang Valley during the summer monsoon dry season is particularly high due to the contribution of smoke from biomass burning from regional sources [12].

3.2. Seasonal pattern of PM_{10} and meteorological parameters

Seasonal PM_{10} and meteorological parameters are interpolated by using Ordinary Kriging method. Figure 2 show the average of seasonal PM_{10} and Figure 3 shows the seasonal meteorological parameters (humidity, temperature and wind direction), at eight stations in selected region in Klang Valley for ten years' dataset. Each stations were marked as Klang (CA11), Petaling Jaya (CA16), Shah Alam (CA25), Kuala Selangor (CA48), Putrajaya (CA53), Cheras (CA54), Batu Caves (CA58) and Banting (CA60). From Figure 2, it can be seen that high concentration of PM_{10} increases when high temperature was recorded especially during Southwest monsoon. Temperature varies are indirectly proportional to the humidity, as an increasing in temperature will create a decreasing in humidity. A negative correlation between annual cycle of the PM_{10} and annual cycle of rainfall was being discovered, and the result is consistent with several previous study [12]. The Southwest monsoon recorded the highest PM_{10} concentration (54.97-82.00µgm^{-3}), followed by both intermonson (51.15-80.47µgm^{-3}), and show a reduction in Northeast monsoon (42.19-66.24µgm^{-3}). Three severe haze episodes had been analysed and concluded that maximum PM_{10} was coincided with south-westerly winds [13]. The highest concentration of coarse particulate matter in a single site in Kuala Lumpur was seen during dry periods and lowest in the wet periods [14]. The seasonal variations, El Nino modulation may enhance the effects of haze and the pollutants concentration in the region during the southwest monsoon dry season. Klang station which located in west area experienced higher PM_{10} concentration distribution as compared to the eastern and northern part in Klang valley. This is because the Klang monitoring station is located closer to the industrial sources and port areas. Port Klang is the 12th largest port in the world and it is one of the busiest port that handling all the import and export activities. In addition, this port also has trade links with more than 120 countries and dealings with over 500 ports around the world, possibly contributing to the high particles in this area.

Table 3: Descriptive statistic of seasonal PM_{10} for ten years' dataset (2006-2015)

Season	CAQM ID	Min	Max	Median	Mean	Std Dev
SI	CA11	21	363	62	66.06	23.58
	CA16	23	256	52	53.39	16.34
	CA25	22	234	52	55.59	18.02
	CA48	17	160	44	47.14	16.44
	CA53	15	232	44	45.86	16.20
	CA54	23	192	50	52.31	14.76
	CA58	23	212	48	51.15	17.69
	CA60	26	296	56	61.16	24.82
SW	CA11	23	595	72	82.00	43.30
	CA16	21	372	56	61.87	29.62
	CA25	21	421	60	66.37	31.30
	CA48	14	383	58	66.93	35.45
	CA53	16	348	49	54.97	28.68
	CA54	24	322	55	61.87	28.12
	CA58	16	350	56	65.34	34.78
	CA60	24	415	60	69.89	38.30
AI	CA11	25	388	68	80.47	50.11
	CA16	23	390	56	68.28	45.95
	CA25	18	426	54	70.29	52.46
	CA48	16	314	49	63.86	46.82
	CA53	17	377	47	62.98	50.19
	CA54	21	320	54	67.58	42.27
	CA58	20	416	50	69.15	56.32
	CA60	27	386	58	76.15	56.60
NE	CA11	26	466	62	66.24	29.14
	CA16	15	322	45	47.25	19.14
	CA25	22	282	50	52.11	18.94
	CA48	16	310	42	46.11	21.85
	CA53	14	314	39	42.19	18.22
	CA54	21	244	47	49.26	15.71
	CA58	17	304	40	44.30	19.89
	CA60	25	438	49	54.85	28.37

3.3 Kriging interpolation of PM_{10} and meteorological parameters

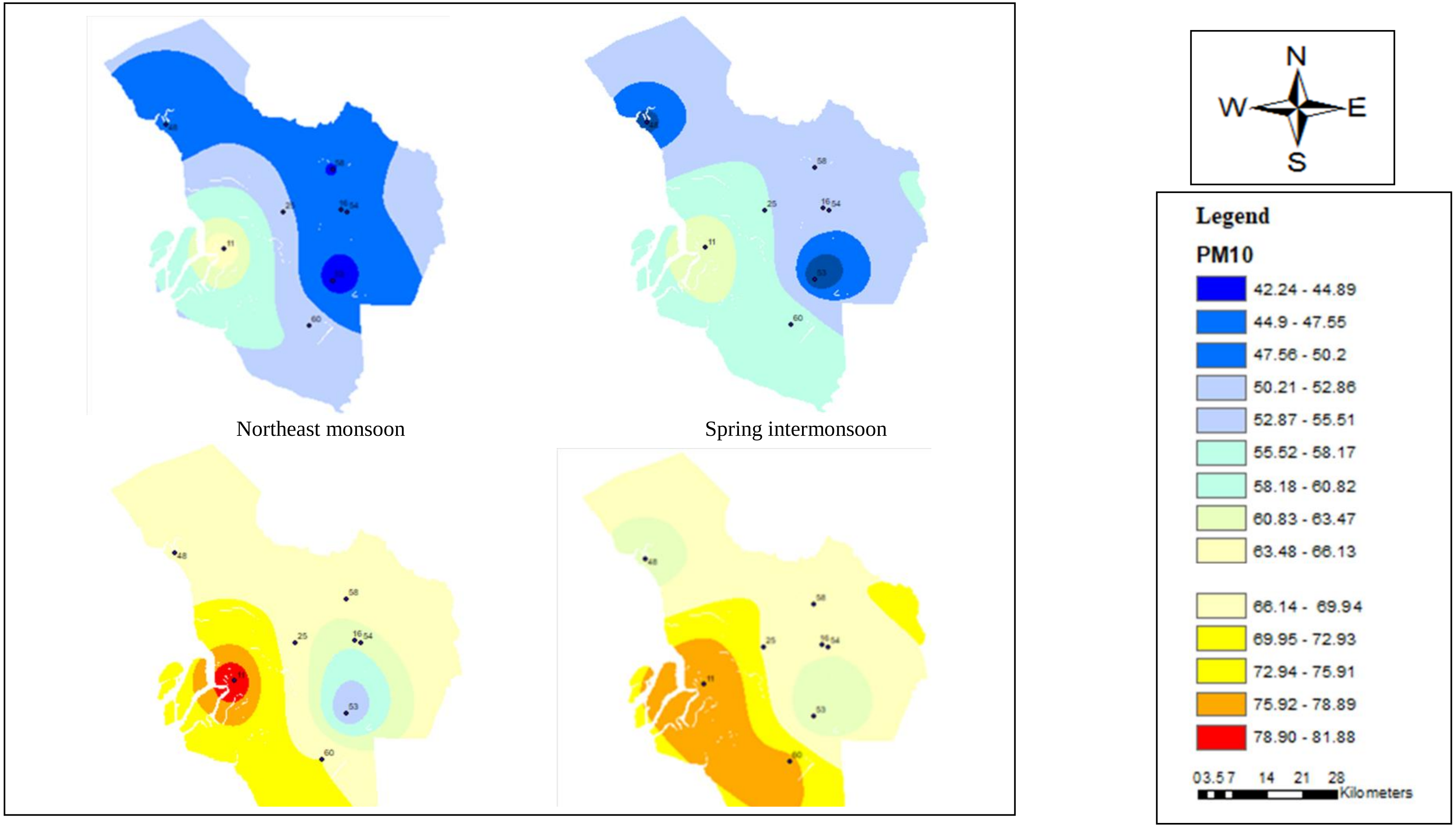

Figure 2: Kriging Interpolation for PM_{10} at Four Different Monsoon Seasons in Klang Valley, Malaysia

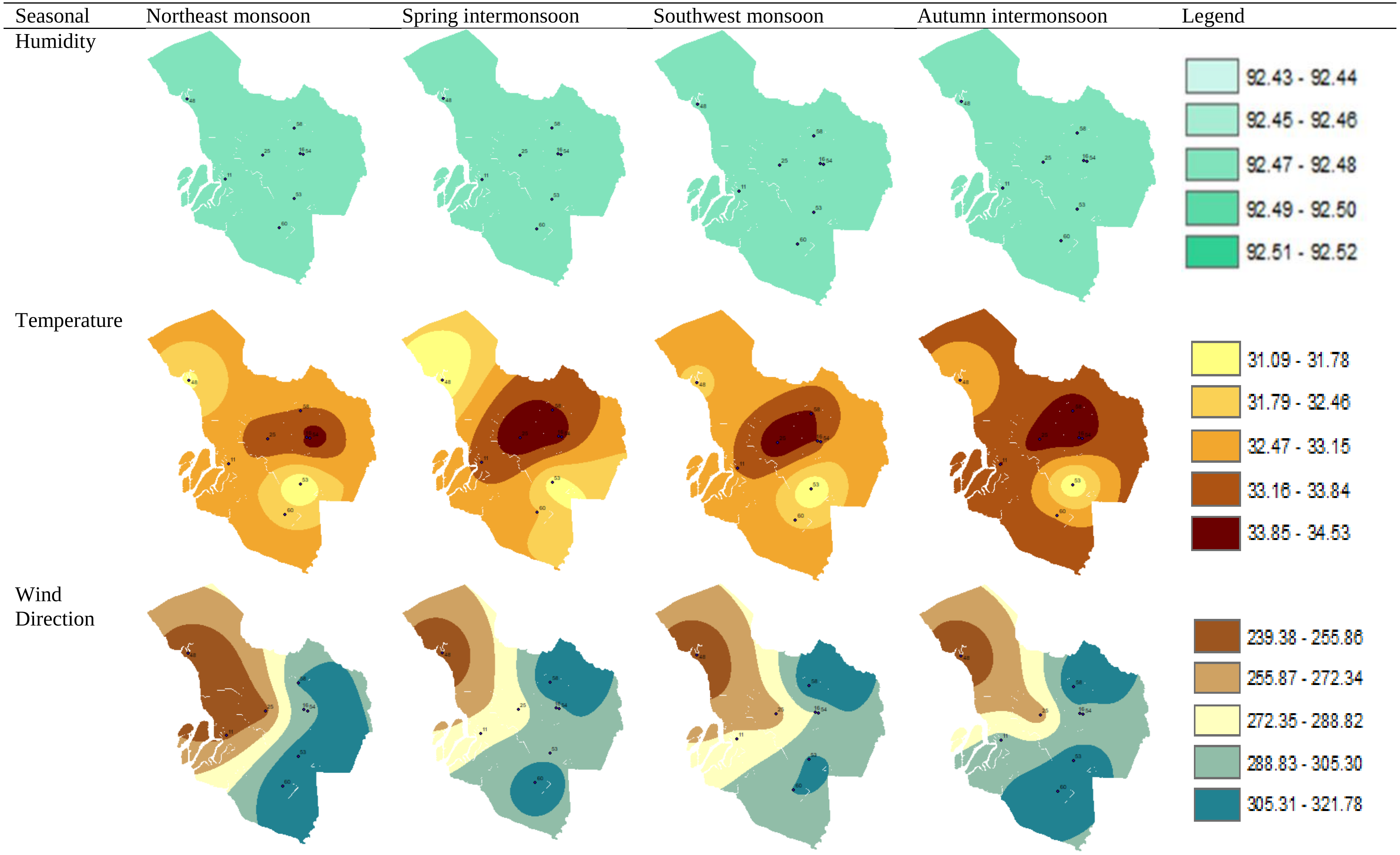

Figure 3: Kriging Interpolation for Humidity, Temperature and Wind Direction at Four Different Monsoon Seasons in Klang Valley, Malaysia

4. Conclusion

The study concluded that particulate matter (PM_{10}) concentration at selected region in Klang Valley, Malaysia are seasonally varied and this distribution can be influenced by primary emissions, ambient natural environment and meteorological conditions for that area. The closer CAQM station to the industrial area will give a higher concentration of particulate matter as compared to the rural area. The Kriging interpolation methods in this study help to creating interpolated surfaces in which the area are out the radius to visualizing the variability in PM_{10} which help the decision maker to take effective and precise decisions for targeting the air pollution control and measure.

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