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Monthly and seasonal variation on particulate matter (PM2.5) and meteorological parameters over Beijing

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ABSTRACT

The primary purpose of this study was to investigate the extent to which factors play an important role in air pollution and perceive the concept of meteorological parameters such as temperature, pressure, relative humidity, etc. This study demonstrates the monthly variation of meteorological parameters with the different conditions of weather over the year. Monthly variations of particulate matter (PM2.5) scatters were observed higher in September month and the lesser scatters were found in June. PM2.5 with blue color particles has the maximum scattering wavelength as compared with green and red color particles. The observed facts indicate that the correlations between PM2.5 scattering and temperature have very weak positive correlations. PM2.5 scattering and air pressure have very weak negative correlations with green and blue colors of particles and very weak positive correlations with red color particles. This data interpreted that the scatter of particulate matter (PM2.5) scatter is determined by the temperature and relative humidity. Correlation between PM2.5 scatter and relative humidity has strong positive correlations with different colors scatter particles and the positive with the blue color scatter particles. Although this is statistically significant strong positive correlation was found with the particulate matter (PM2.5) and relative humidity in all the months over the year. The average PM2.5 scatter in the winter season is higher than the spring and summer seasons. Cold and dry weather getting more scatters of particulate matter (PM2.5) as compared with the hot and clean weather. There are strong positive correlations between mass concentrations and the particulate matter (PM2.5) scatter which is statically significant. Cold and dry weather getting more and more pollution than other weather.

Keywords: Meteorological Parameters, Seasonal Variations, Correlations, Particulate Matter, Mass Concentrations

1. INTRODUCTION

PM2.5 stands for particulate matter (also called particle pollution) the term of a mixture of solid particles and liquid droplets found in the air is known as a particulate matter like dust, soot, smoke...etc. [13]. Fine particles with a diameter that is generally equal to or less than 2.5 micrometers. These particles come in different shapes and sizes by the formed up of hundreds of many different chemicals. Some of them are released from a source of manufacturing areas, dirt roads, crops farming, vehicles or burning fire, nuclear explosions etc. Most of the particles arises in the environment or atmosphere as a production of a complex reaction of chemical components such as carbon mono-oxide, Ozone, Chlorine, Nitric Oxide and other reactions of natural gases which pollutants are emitted from natural combustion or human activities. It may damage the materials, make acid deposition and help to increase the ozone levels. PM2.5 or pollution comes from industrial area or fire bushing regions or other pollutants reaching the atmosphere [1]. There are many sources including combustion (like industries, vehicles, fire burning, volcano eruption etc.), natural processes, and chemical changing that may happened with other gases such as carbon mono-oxide (CO), nitrogen dioxide (NO2), sulfur dioxide (SO2) and other volatile organic compounds. Generally, we found two types of particulate matter in nature such as primary particulate matter (directly released into the atmosphere by wind combustion process or human activities) and secondary particulate matter (released in the atmosphere from primary gaseous pollutants explicitly like carbon dioxide, nitrogen, oxygen, ammonia and other volatile organic compounds). These are directly formed and emitted directly from particular sources [18]. As a result, rapid progress is being made in different regions of the industrial world to develop a better understanding of the issues related to various aspects of the environment and its pollution including air pollution. During the last decade, there is a huge awareness has been conducted in the public sectors and as well as government sectors as to computes of prevention from pollution on the human life or other living beings and the whole ecosystems. Particles can have either a cooling effect on the atmosphere through a scattering of short-wave radiation like sulfate and organic carbon particles or a warming effect through absorption of shorter wave radiation like black carbon particles [2].

Diesel and petrol, atmospheric gases burning discharge particulate matter or pollution may be made up of first-class particles with a high number of ultra-fine particles and respirable particles with the large surface areas of organics can absorbed and may cause serious diseases. At the pollution level, there is not enough evidence to identifying differences in the effects of particles with different chemical compositions or emanating from various sources [6]. It should be noted, however, that the evidence for the hazardous nature of combustion-related particulate matter (from both mobile and stationary sources) is more consistent than that for PM2.5 from other sources [7]. The sizes of the particles are directly linked with their prospective reason for the significant human health problems or other well-being health problems. Small particles whose diameters less than 10 micrometer poses the greatest problems because they can directly enter into our body through respiratory system and may cause serious effects into our heart, lungs functions and some well fine particles which size very small less than 1 micron get into our brain and bloodstreams. The particulate matter pollution or air pollution may cause numerous long term and shot term impacts to the well-being and environment equally such as reduced visibility, depletion in harmful radiation, changing the climate, increase greenhouse effects etc. These particles are mainly categories according to their shape, size, wavelengths, weight, density as it is coarse particles or well fine particles. Well fine particles are generally very small in size and density highly rich in ammonium ions, halogens, oxides etc.. Coarse particles are mostly in the production of automatically occurring in environment by natural process through blowing wind or storm. Coarse particles containing mainly silicon ions, iron molecules, calcium ions, neon, carbon and other materials exists in Earth [10]. The Earth and its environment are facing a serious threat by the increasing particulate matter (PM2.5) pollution of the air, water, and soil. The vital life supports a system of the Earth. The damage to the environment is caused by using chemical fertilizers, wastes from industrial areas, uses of harmful chemical and other human activities like deforestation, improper management of garbage, industrialization etc.. We need to understand the sources of these pollutants and find ways to control PM2.5 pollution. we can prevent particulate matter pollution by the emission of air pollutants from industries, fuel burning, wood burning should be controlled by using electrostatic precipitators, over population controlled, plantation of trees, awareness programs in public, using alternate sources of energy can be protected human life and other economic well-being can be strengthened [9]. Pollution is the mixture of any substances like solid, liquid, and gases in the atmosphere on the environment [14]. There are different forms of pollutants such as water pollution, air pollution, and land pollution. Changing the form of pollution may occur negative impacts on human life, the environment, and other well-being. Water and air pollution are the two major problems of human life and other well-being.

2. DATA SET AND METHODOLOGY

Beijing is the capital city of China located in the northern part of the country. The latitude of Beijing China is 39.916668 and the longitude is 116.383331. Beijing lies on low and flat land with elevation generally between 40-60 meters above sea level. The population of Beijing city was 20,463,000(2020 census) which is the most populous capital city in the world. Beijing is a cultural, economic, business, and social life of the country, where the ancient culture and the modern civilization are well integrated.

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Figure 1: China map [source: google map]

In this work we have taken the Nephelometer data to study the monthly variation of meteorological parameters temperature, pressure, relative humidity (RH) and the particulate matter (PM2.5) scatter with three wavelengths red, green, and blue. The Nephelometer is an instrument that measures aerosol light scattering which can be determine scattering properties from the light scattered by the suspended particles and gas, the wall of the instrument, and which detect the background noise contained by the particles. The three wavelength model splits then scattered light into red (700nm), green (550nm), and blue (450) wavelength. The data is compiled from the website https://www.spartan-network.org/data. The data includes the daily PM2.5 scatter of each month from 01 May 2019 to 30 January 2020 in Beijing, China.

The correlation is one of the most common and most useful statistics. Correlation is a number which describes the linear of relationship between two variables in terms of single number. The degree of association is measured by a correlation coefficient, denoted by r. The correlation coefficient value of two variables lies between number of + 1 to – 1. If the two variables are correlated with each other can be written or expressed as + 1 or -1. If one variable increases with the increasing of other variables is the positive correlations, when one variables decreases with the decreasing other variables it is negative correlation. Complete absence of correlation is represented by zero (0) mean no correlations between two variables. Regression analysis is a statistical method that helps us to analyze, representation, validation and understand the relation between two or more than two variables. This method analyzed the relations between one independent variables with the references of more than one dependent variables.

3. RESULTS AND DISCUSSION

In this section, we have discussed the results of monthly and seasonal variation of particulate matter (PM2.5) with the meteorological parameters and correlations with different colors of scattering wavelengths.

3.1 Monthly variation on Temperature, Pressure, Relative Humidity, Scattering Particles, and Mass Concentrations

Figure 2 shows that the daily average temperature for the nine months. The horizontal line is the day, and the vertical line is the temperature (°C) of the day.

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Temperature is the measure of the average kinetic energy of the particles or materials in an object. When the temperature is increasing the motion of the particulate matter (PM2.5) is also increases. When the temperature of the particulate matter (PM2.5) increased or decreased its direct effects on the chemical and physical composition of the PM2.5. Its effects on the solubility of substances or materials, density, vapor pressure, air pressure, relative humidity, scattering of particles, etc. When temperature increases or decreases its direct affects the electrical conductivity of the materials. It also caused the thermal radiation of the particulate matter (PM2.5). Most of the days are sunny and the temperature of the weather started to increase from the mid of March. From March to August temperature of the weather increases continuously. These are the most beautiful months in Beijing after a long period of cold days. The warm sunshine provides a pleasant atmosphere in the absence of a high degree of humidity. July is the hottest month of the year with the temperature hovering in the range of maximum 39.2°C and minimum of 22.9 °C with an average temperature of 32.22 °C. After the end of August or beginning of the September, the weather temperature slowly dropped down. The weather temperature is not excessively high because of the influence of the ocean though sometimes a hot and dry wind. The weather from September to mid of November is quite interesting. End of November, the weather temperature continuously drops down, and finally, it's reached minus. December and January are the coldest months and most of the days are too much cold.

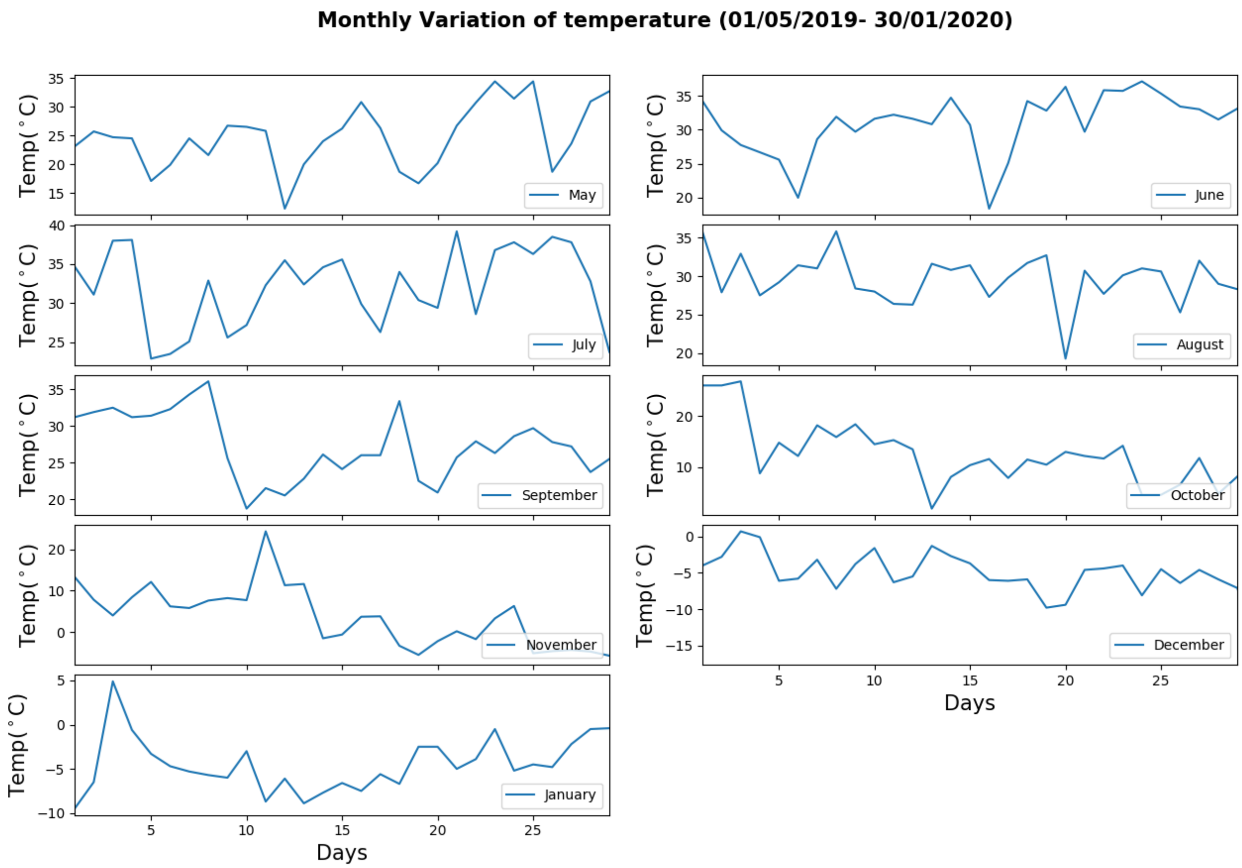

Figure 2: Monthly variation of Temperature

Figure 3 represents that the daily average pressure for the nine months. The horizontal line is the day, and the vertical line is the pressure (hPa) of the day. Atmospheric pressure is the pressure exacerbated by atmospheric liquid droplets, different gases, and dust particles in the space above the surface of earth. This pressure may occurred the variety of problems such as rotational motion of substances in space, velocity of wind speed, density of an objects by the variation of weather temperature etc.. It depends on the altitude. In Beijing, China March to July the atmospheric pressure was neither high nor very low due to the monsoon seasons held in these days. During July the lowest pressure was observed over the year. From July the average maximum pressure was increasing slightly up to November because of high temperature. After December, the average maximum pressure was decreasing due to the decreasing average temperatures so during the cold month temperature was found to be very low and then the air

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pressure is going to decreases. In January & February the sun shines almost vertically on the tropic region in the southern hemisphere, because of this there is low temperature and low pressure was measured.

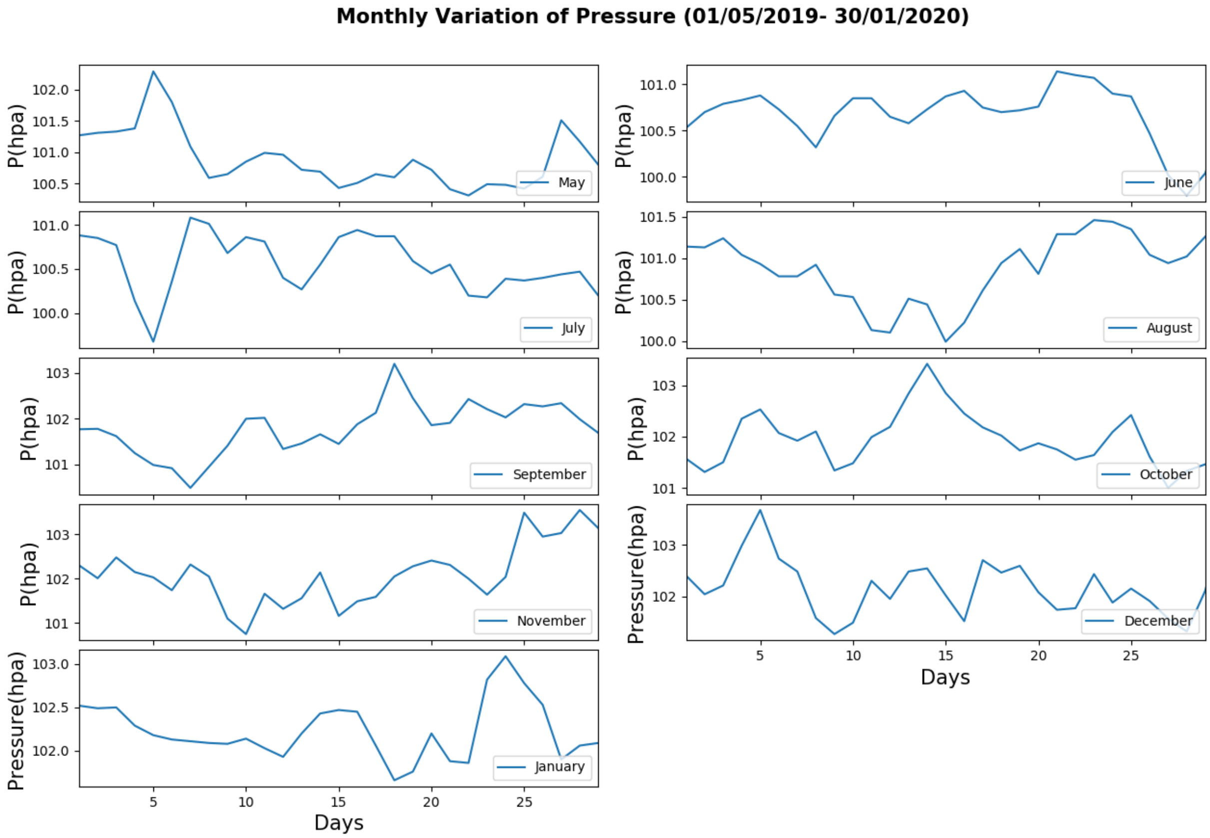

Figure 3: Monthly variation of Pressure

Figure 4 shows a daily average relative humidity (RH%) for the nine months. The horizontal line is the day, and the vertical line is the RH% (Percentage) of the day. Relative humidity is a part of the atmosphere in which the liquid droplets or vapor form of water contain in the air present. The temperature of the weather higher then that of present air can absorbed more liquid droplets (water vapor) because of more energy available in the atmosphere. So while the temperature of weather fall down at nights than that of days, it may caused by the nights also muggy. The temperature of the weather is slightly increasing after the last of February and starting of March. March to May has with middle temperature neither too cool nor too hot. These days are beautiful and pleasant in Beijing China. When the temperature of the weather is increased with the decreasing of average maximum relative humidity. July is the hottest month over the whole year in Beijing, China. Maximum and minimum relative humidity was recorded at 78% and 21% with average relative humidity at 47.03%. July was the most humid month of the year. After July and August the weather average temperature slightly decreasing day by day until September, October, and November then the average relative humidity also decreasing with the decreasing temperature. Finally, in December the weather was cold in Beijing, and in January the average maximum temperature drops down. The average relative humidity was also dropped down with maximum and minimum relative humidity in January 35% and 12% with an average relative humidity of 25.3%.

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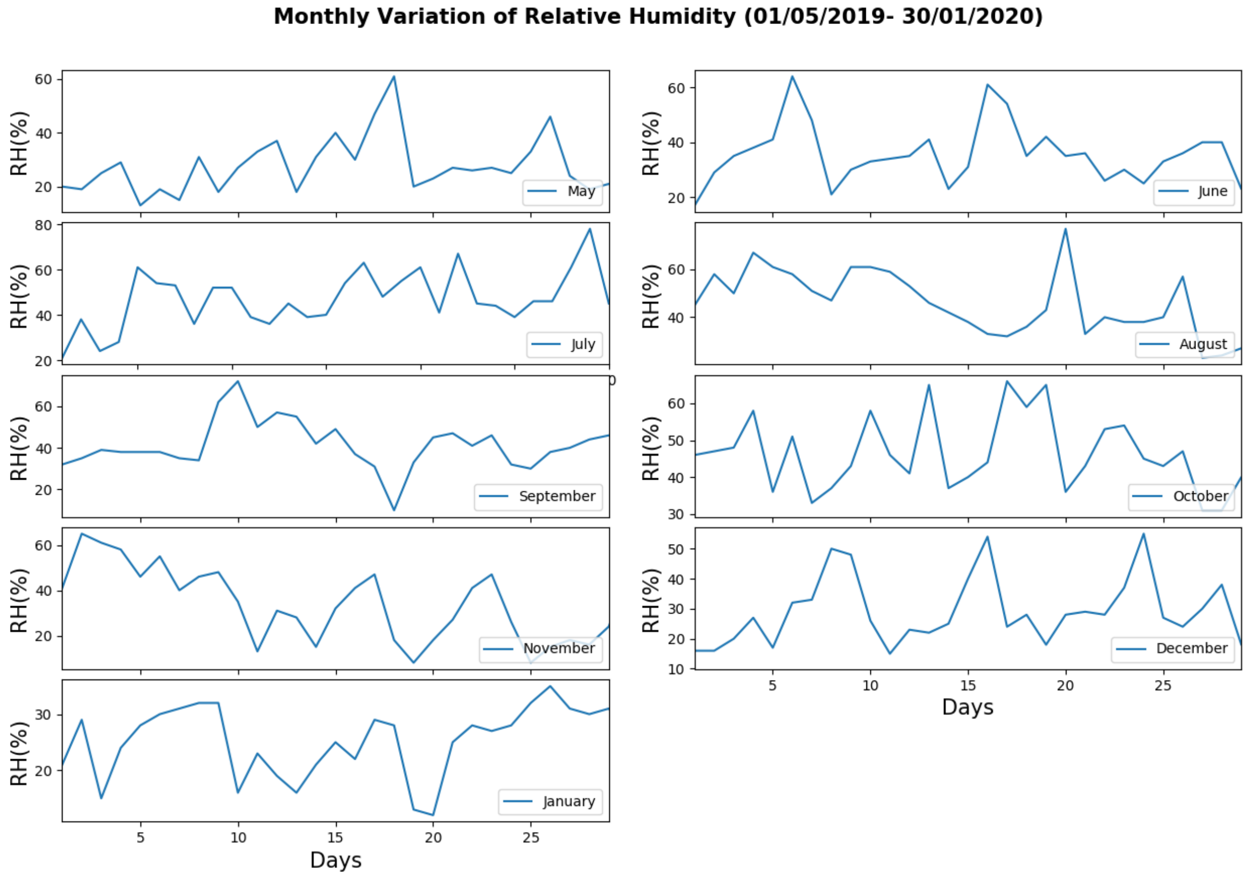

Figure 4: Monthly Variation of Relative Humidity

The light scattering method for measuring mass concentration is based on the Mie scattering theory of particles [7]. When light strikes suspended particles in the air, the light scatters. For a certain conditions scattering of suspended particles properties and light intensity of the scattered particles determine to the mass concentration of the particulate matter [10]. Light scattering of well fine particles turn on numerous components such as physical properties, composition of chemical reactions, relative humidity of air, shape and size of the particles distribution in the atmosphere.

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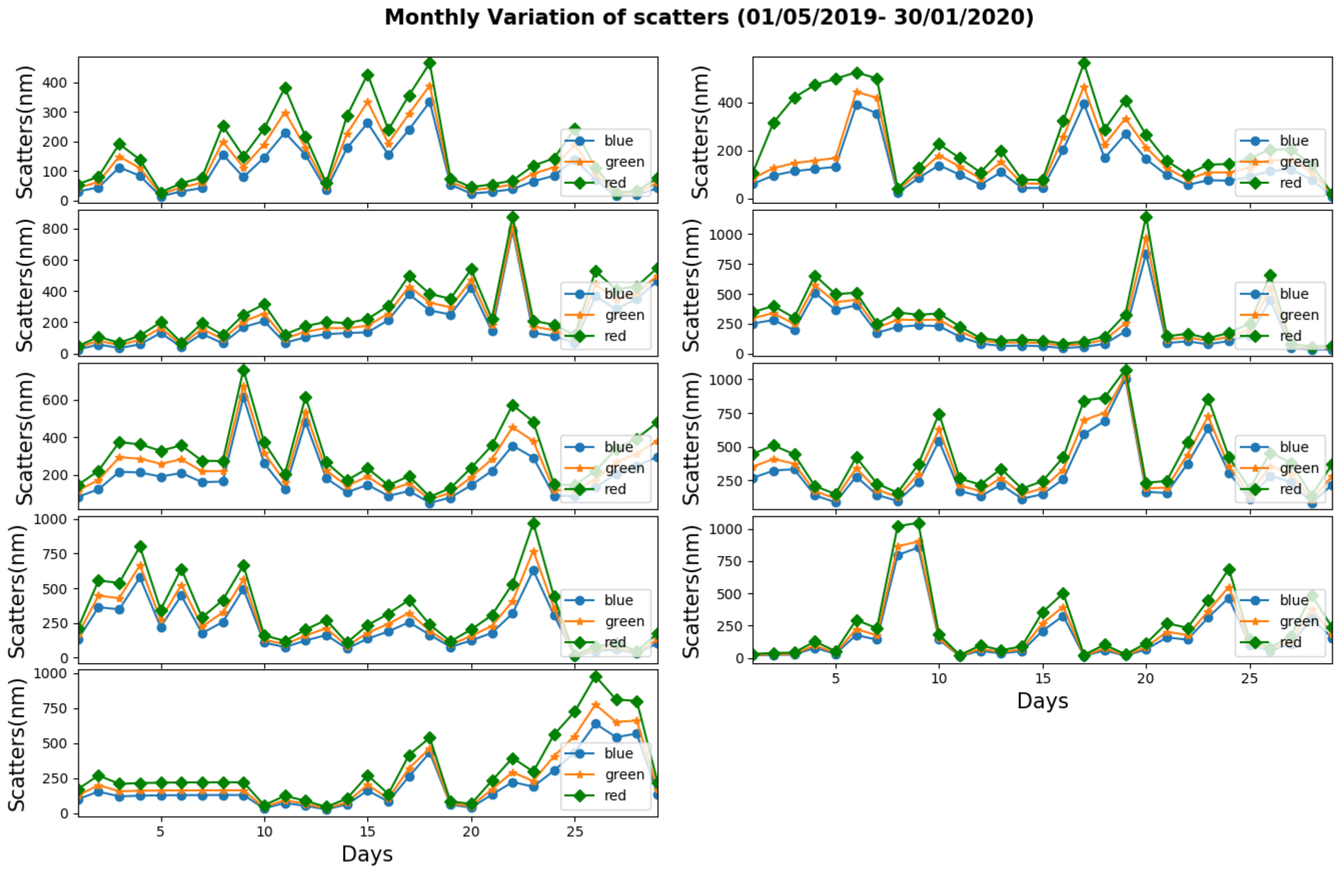

Figure 5: Monthly Variation on Scattering of Particles

Figure 5 shows that the characterization of the daily average scattering Particles Wavelength for the twelve months. The horizontal line is the day, and the vertical line is the Particles Scatter (nm) of the day. The maximum scattering particulate matter was found in September. July to September scattering of PM2.5 wavelengths was found in more than others month because these months are sunny. When the weather temperature was high then the motion of the particles strikes more. From October to February the scattering of PM2.5 was found in lesser than previous months. The minimum amount of scattering was found in March to June because the weather temperature in these months is mild and pleasant.

Figure 6 shows that the daily average mass concentrations for the twelve months. The horizontal line is the days, and the vertical line is the Particles Scatter (nm) of the days.

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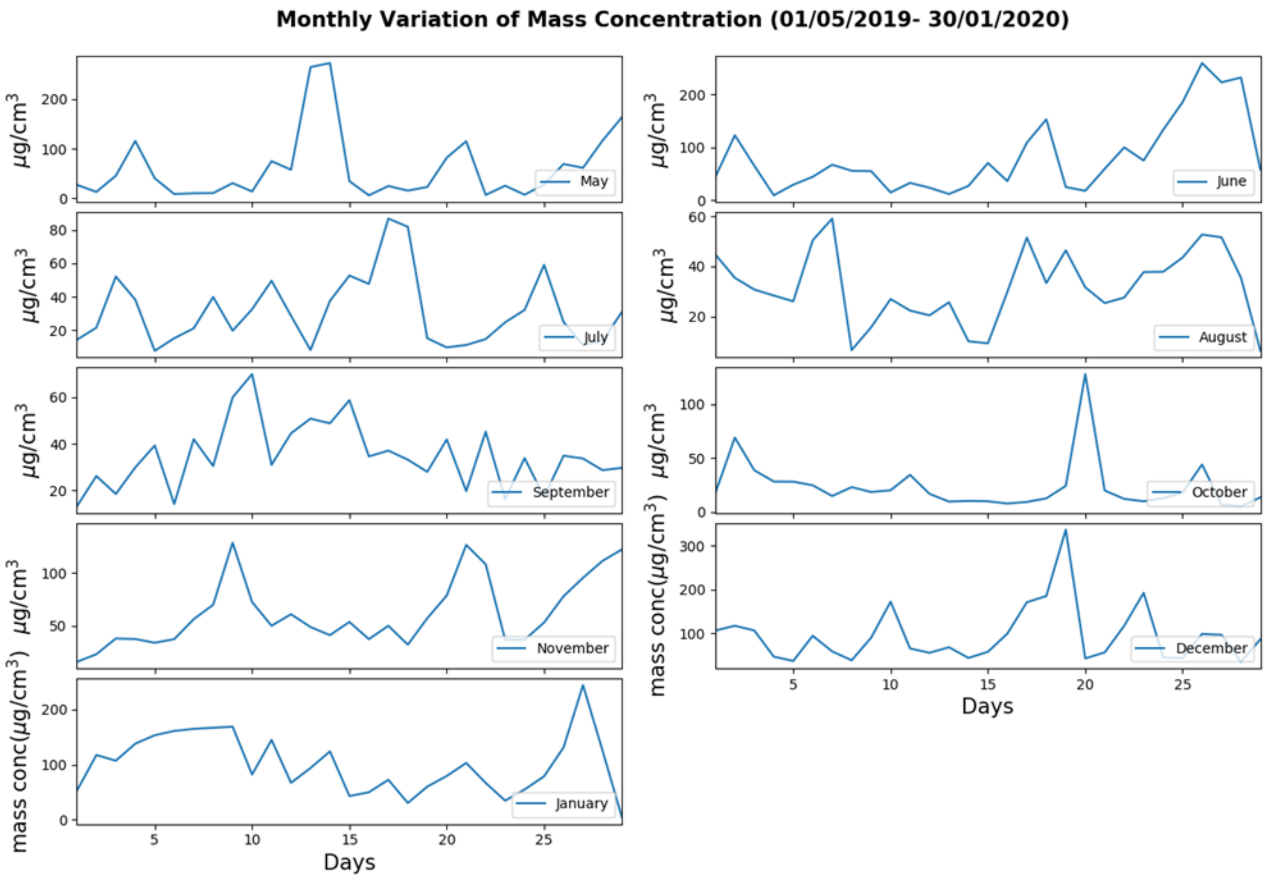

Figure 6: Monthly Variation on mass concentrations

The mass concentration of a solute is defined as the mass of the solute per unit volume of the solution. The weather temperature increases from March to August. The PM2.5 mass concentrations during these months were less amount of pollution. The average minimum pollution was found in august with 5.1μg/m^3. Generally, these months weather was rainy not dried so the pollution of these months slightly less than another month. After starting of the September or autumn season the weather temperature and pressure slightly dropped till the end of February. These days become dry, windy, and muggy then the PM2.5 pollution was found maximum in October. Cold and dry days can contain more pollution than other days.

3.2 Seasonal Variation on Temperature, Pressure, Relative Humidity, Scattering Particles, and Mass Concentrations

Figure 7 represents the daily average scattering Particles Wavelength for the twelve months. The horizontal line is the day, and the vertical line is the Particles Scatter (nm) of the day.

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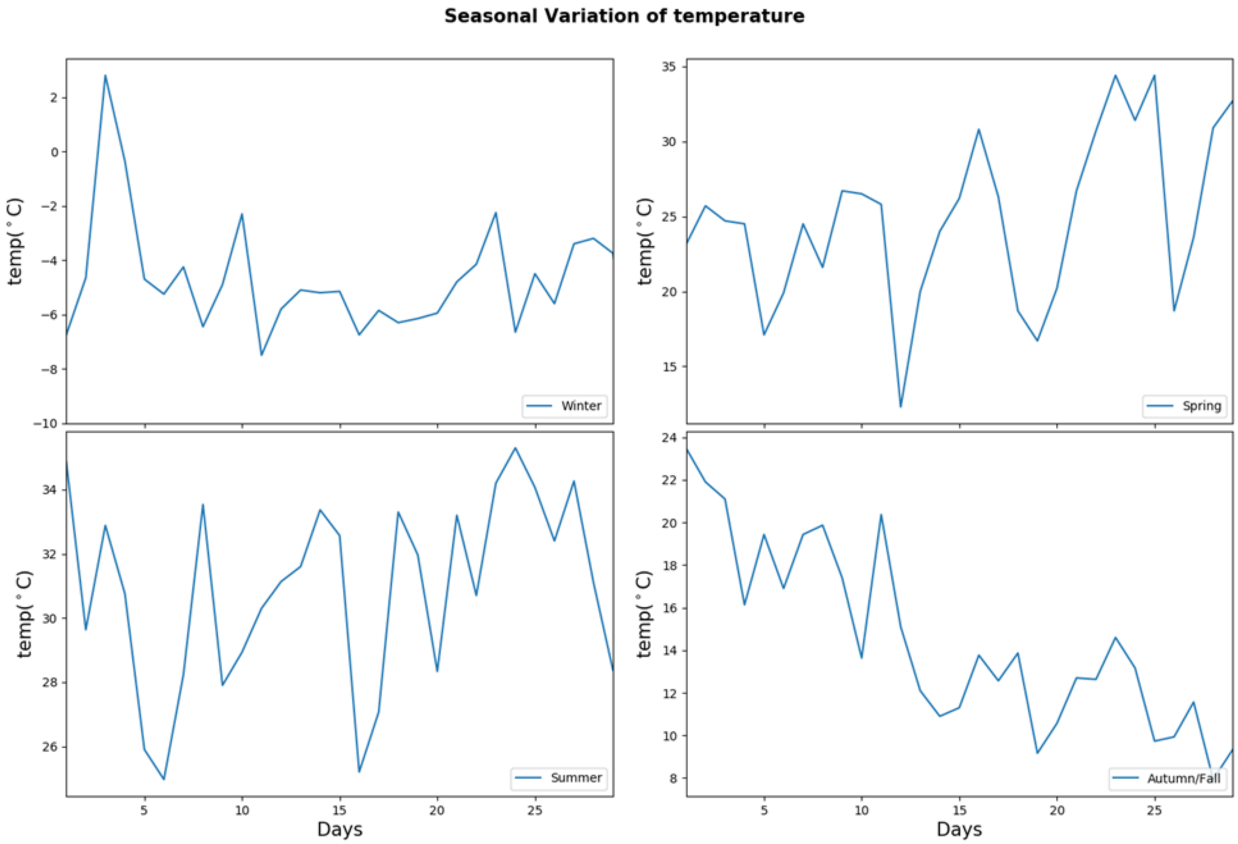

Figure 7: Seasonal Variation of Temperature

Winter is generally December, January, and February, the winter weather can start in the last of November and through early March. The highest places, mountains areas and most of the regions are freezing and much cold, where the winter is moderate with little snow. In the winter season, temperature of the weather falls around -10.7 °C. From these data, we can say that the winter is too cold in Beijing and most of the place's temperature in winter is the negative number found. The spring season in Beijing, China is starts from March to May, this season is considered as one of the beautiful seasons in the country. It is also called the king of the season. The day becomes longer, and night becomes shorter, leaves of the tree fall when new emerge, buds play their magic. During this season, the temperature is going to increases and the days become quite warmer. In summer season starts from July to August. Summer is the hottest season in Beijing, China. During these months, days are longer duration then that of nights. In this season the temperature of the sun increasing sharply at last of the June and up to the middle of the July and the temperature become decreasing last of August. The maximum highest temperature was found in this season 35.4°C. An autumn/fall season is the time of year when the leaves of the trees fall down and colors of the environment stunning or it is also called a fall season. This is one of the most wonderful times of the year. In this season days and nights are the almost same length. The average temperature of autumn/fall is 4.05°C. The starting days of autumn are very quiet and the temperature is also mild neither warm nor chill but during the end of this season, the days become cool. Pressure depends on the condition of the weather when the temperature of the weather is high then pressure becomes high. The seasonal pressure of the year is described below.

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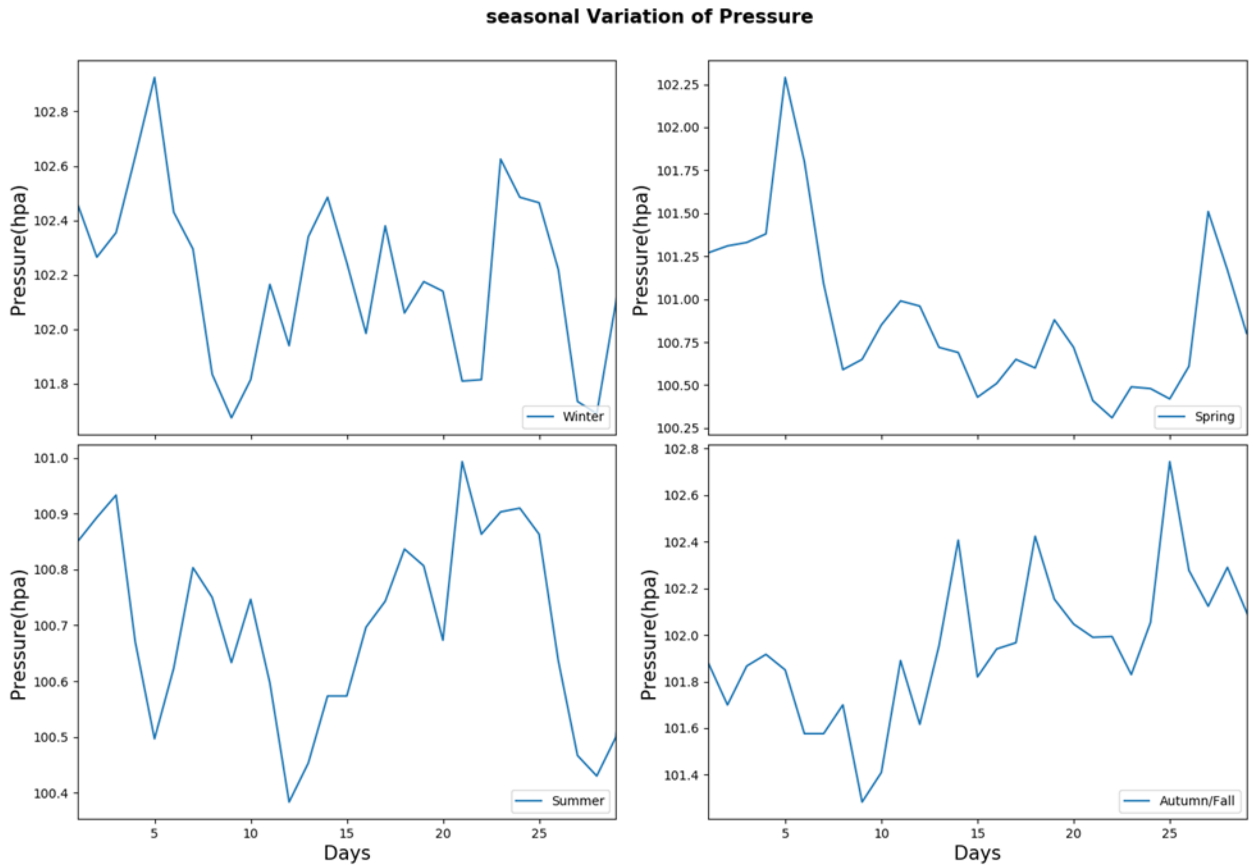

Figure 8: Seasonal Variation of Pressure

The figure 8 shows that daily average scattering Particles Wavelength for the twelve months. The horizontal line is the day, and the vertical line is the Particles Scatter (nm) of the day. During the winter season weather, the temperature drops the level of negative reading and pressure becomes quite dropped. In the winter season the days and nights in Beijing, China become cold and chill. In spring the climate starts to increase in the last of March and the pressure is also increased during the spring season. From the middle of the month, the cold winds are minimal. The pressure in this season increases with increasing the average temperature of the weather. The season of summer is characterized by continuously raising the temperatures. The pressure of this season is also going in increasing order that's affects the average seasonal pressure. In this season average temperature is 20.87 °C, this is the highest average pressure of the year or season. At the start of autumn, the weather is very mild and pleasant. Autumn throughout Beijing is delightful the average temperature slowly drops and finally the end of the season the weather is drastically changed. The air pressure is also decreasing range with the decreasing of the weather temperature.

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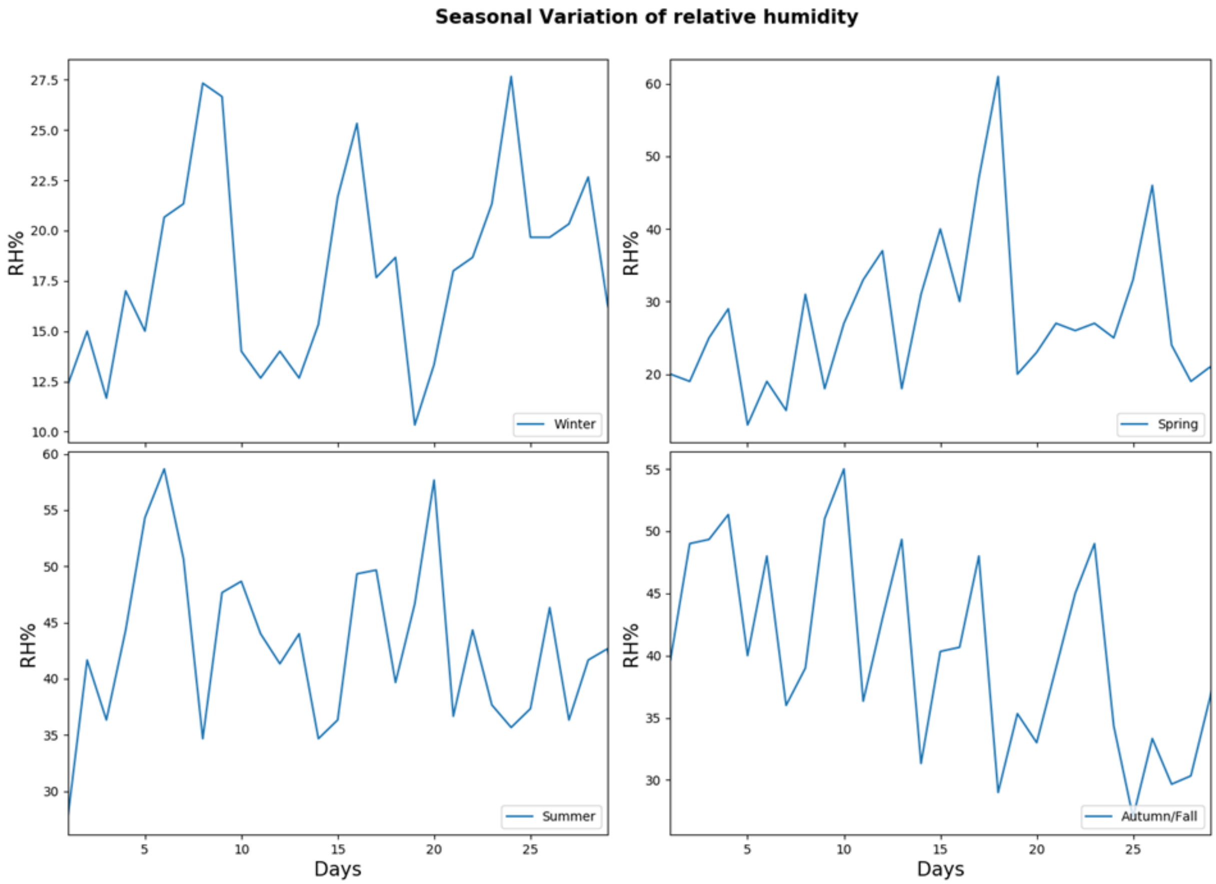

Figure 9: Seasonal Variation of Relative Humidity

Figure 9 represents the seasonal relative humidity for the four seasons. The horizontal line is the day, and the vertical line is the relative humidity (%) of the season. In winter, the weather temperature is finally negative in Beijing. When the temperature and pressure were increasing in order then the average relative humidity is going to decreasing because warm weather can be absorbing more water vapor. The average minimum relative humidity was found in spring. In summer, the temperature was hot excessively high because of the influence of the ocean though sometimes hot and dry air. In autumn, the average temperature slowly doped down, and finally the end of the season the weather is drastically changed or cold. When the temperature decreased, the relative humidity is going to the increasing range with the decrease of the weather temperature.

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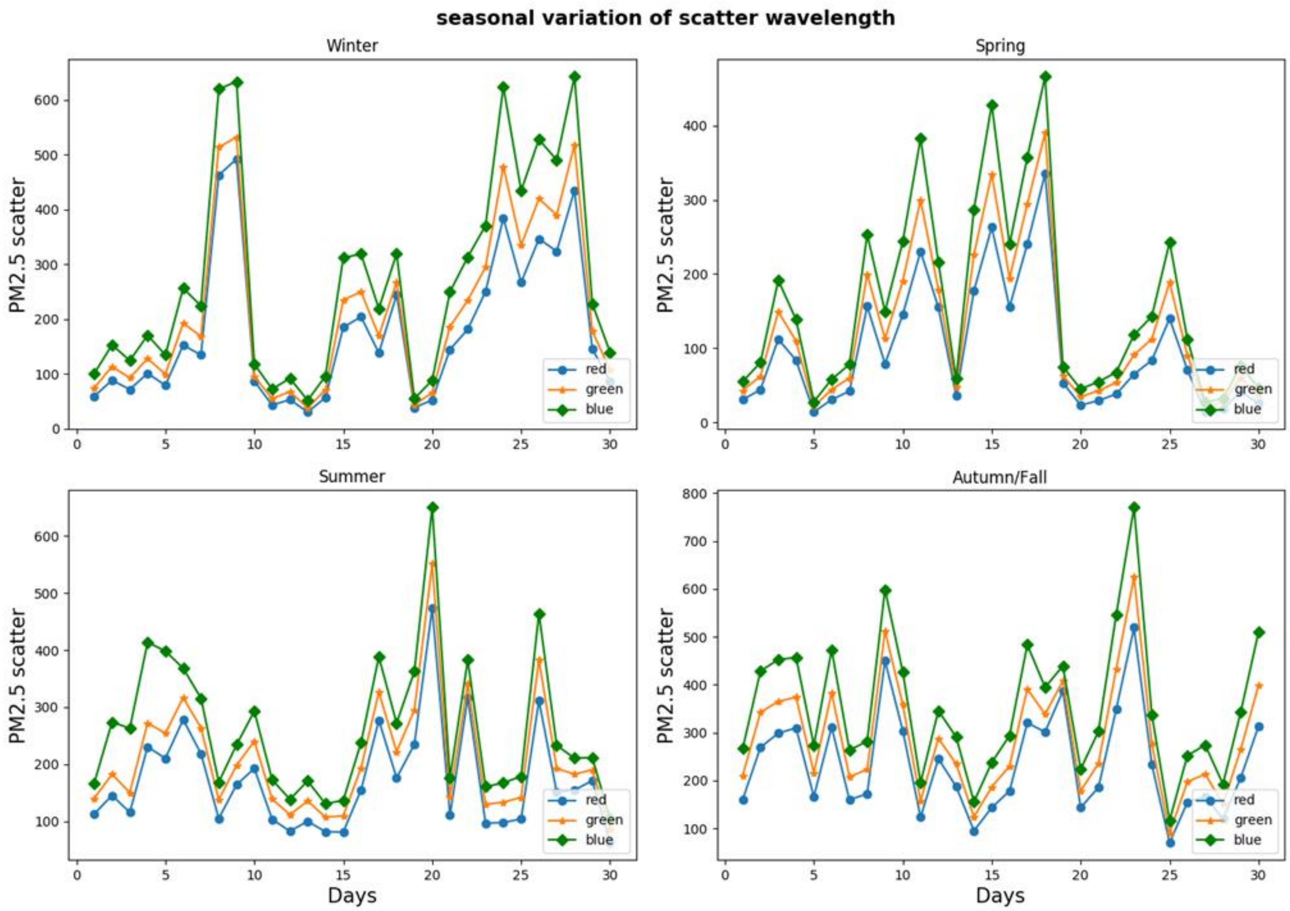

Figure 10: Seasonal Variation of Particulate Matter Scattering

The figure 10 shows that of the seasonal variation of scattering wavelengths for the four seasons. The horizontal line is the days, and the vertical line is the scatter of particles (nm) of the season. In winter, during this winter blue scatter particles were more scattered with compression of other red and green scattering. So, the blue scattering particulate matter has more wavelengths in winter. In spring, from this result, the temperature and pressure have increased the scattering of the particulate matter wavelength was decreased. During this spring season blue scatter particles were more scattered with compression of others red and green scattering. So, the blue scattering particulate matter (PM2.5) has more wavelengths in winter. In summer, the temperature of the atmosphere is increasing with the increase of pressure but the average scattering of the particulate matter (PM2.5) was decreased. In autumn, during this spring blue scatter particles were more scattered with compression of other red and green scattering. So, the blue scattering particulate matter has more wavelengths in winter.

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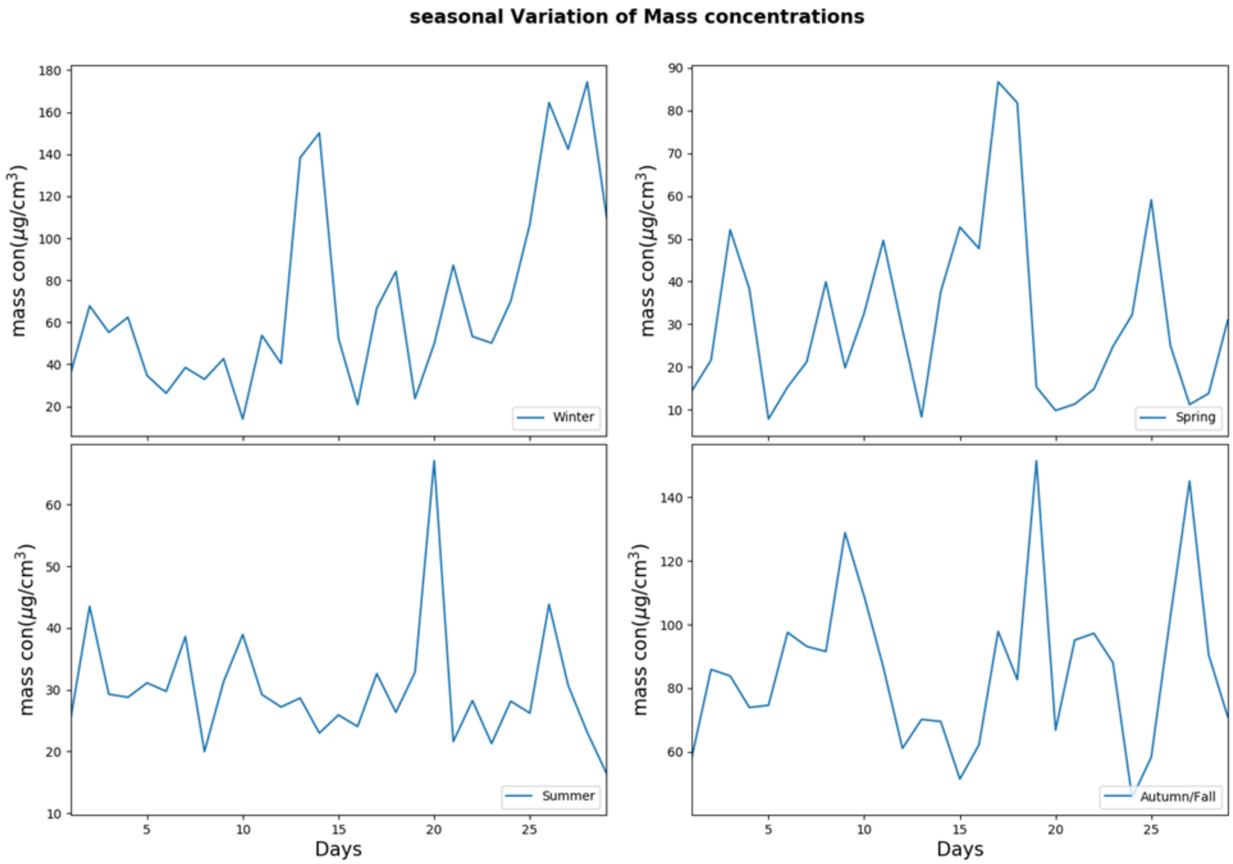

Figure 11: Seasonal Variation of Mass concentrations

Figure 11 shows that the seasonal relative humidity for the four seasons. The horizontal line shows days and the vertical line shows the mass concentration of the season. In winter, the weather temperature is finally negative in Beijing. When the temperature was dropping down then the average mass concentration is going to increase because cold weather can be absorbed the particulate matter pollution. The temperature of the weather increases from spring to summer then the mass concentration of the hot and warm weather contained less amount of PM2.5 pollution. Autumn/Fall season in China was dry and muggy and autumn the weather temperature slowly going to decreasing order than the average mass concentrations in this weather increasing in order. Autumn was the most pollutant season as compared to other seasons.

3.3 Correlation Analysis

Below table 1 shows that correlation between meteorological parameters with different colors of particulate matter (PM2.5) scatter wavelengths. Correlations between temperature and pressure with different colors of scattering wavelengths have very weak correlations which are statically not significant. This signifies that as the temperature and pressure increase the rate of PM2.5 scattering with different wavelength scatters decreases. Correlations between relative humidity and mass concentrations with different color of wavelength have strong positive correlations which are statically significant. This signifies that the relative humidity of the weather increases with the increasing rate of PM2.5 scatters with red, green, and blue wavelengths also increased. This shows that relative humidity and mass concentrations have a relation with particulate matter (PM2.5) scatter or pollution. Below table 2 represents the P-Value between meteorological parameters and particulate matter (PM2.5) scatter with three wavelengths red, green, and blue with the 0.05 (5%) level of significance. If the P-value is greater than 0.05 (5%) level of significance which is not statically significant and if P -value less than 0.05 (5%) level of significance which is statically significant. Table 3 shows the regression coefficient value (R^2) with the meteorological parameters and particulate matter (PM2.5) scatter with different wavelengths. This regression coefficient value is less than 10% which is not good for fitness and a value between 10% to 60% is the good fitness for the independent and dependent variables.

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Table 1 represents the correlation coefficient between particulate matter (PM2.5) scatter with different wavelengths and meteorological parameters such as temperature, pressure, and relative humidity.

Parameters	PM2.5 with Red	PM2.5 with Green	PM2.5 with Blue
Temperature	r = - 0.0857	r = -0.0720	r = -0.0850
Pressure	r = -0.0075	r = -0.0053	r = 0.0073
Relative Humidity	r = 0.662	r= 0.672	r = 0.655
Mass Concentrations	r = 0.503	r = 0.512	r = 0.512

Table 2 represents P-Value between meteorological parameters and particulate matter (PM2.5) scatter with three wavelengths red, green, and blue with the 0.05 (5%) level of significance.

Parameters	PM2.5 with Red	PM2.5 with Green	PM2.5 with Blue
Temperature	P = 0.155 > 0.05	P = 0.242 > 0.05	P = 0.166 > 0.05
Pressure	P = 0.889 > 0.05	P = 0.919 > 0.05	P = 0.915 > 0.05
Relative Humidity	$P = 6.87*10^{-36} < 0.05$	$P = 2.46*10^{-37} < 0.05$	$P = 5.46*10\text{-}^{35} < 0.05$
Mass Concentrations	$P = 5.76*10^{-19} < 0.05$	$P = 1.09*10^{-19} < 0.05$	$1.11*10^{-19} < 0.05$

Table 3 Regression coefficient between meteorological parameters and particulate matter (PM2.5) scatter with three wavelengths red, green, and blue

Parameters	PM2.5 with Red	PM2.5 with Green	PM2.5 with Blue
Temperature	$R^2 = 0.007$	$R^2 = 0.0049$	$R^2 = 0.0070$
Pressure	$R^2 = 7.031*10^{-5}$	$R^2 = 3.7*10^{-5}$	$R^2 = 4.1*10^{-5}$
Relative Humidity	$R^2 = 0.436$	$R^2 = 0.450$	$R^2 = 0.428$
Mass Concentrations	$R^2 = 0.252$	$R^2 = 0.261$	$R^2 = 0.260$

4. CONCLUSIONS

In this study, we explore how the annual variations in the different climate (weather) with different meteorological parameters like temperature, pressure, relative humidity (RH%), mass concentrations, and particulate matter (PM2.5) scatter with different wavelengths red, green, and blue. Based on the investigation which we have concluded as follows:

1. The finding of this study the hottest month of the year was July with a maximum temperature of 35.4 °C and January was the coldest month with a minimum temperature of -24.1° cover the year. This can be suggested that we should most care of July because the increase in temperatures during this month, combined with humidity and heat, can also increase and the cold weather also makes us uncomfortable. Atmospheric weather temperature going to decreases it may increases in the human health problems like cardiovascular diseases, asthma, hypothermia, heart diseases, problem in respiratory system etc. These changes can cause heart disease chest pain.
2. During the period of study, we found the highest pressure was recorded in March and the lowest pressure was in January due to the temperature vary with pressure when the weather temperature high then pressure also high via vice-versa. Air pressure plays a vital role in the atmosphere the change in air pressure could have a big effect on climate and weather control system or circulation and influences of temperature.
3. We found the highest percentage of relative humidity was 84% in January, it was the most humid day and the lowest was found 21% in April, it was the less humid day over the year. When the relative humidity levels are too high then we feel respiratory infections and extremely low, we lose more water vapor through respiration and the pores in our skin, this can cause chronic dry skin, a scratchy throat, and an itchy nose. The relative humidity should be between 30% to 50%. If the relative humidity is below

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30%, then atmospheric air is dry and if the relative humidity is above 50%, then atmospheric air is in uncomfortable muggy conditions.

4. The highest particulate matter (PM2.5) scatter was occurred during the winter season and PM2.5 was also higher during the spring and autumn season compared to the summer season. Lower PM2.5 scatter were occurred in the Summer season. In summer, the scattered decreases because of the airflow from the desert region. The clean airflow through the wind speed, the influence of particulate matter (PM2.5) scatter changed. This indicates that further control of PM2.5 is needed for the winter and spring season. Therefore PM2.5 Scatter pattern was found Winter > Spring > Autumn > Summer. So, the summer is the best season for visiting Beijing because this season most of the days are hot and rainy.
5. The yearly average of weather temperature and pressure with different color particulate matter (PM2.5) scatter has very weakly correlate in this study period. This concludes that when the weather temperature and pressure increase and the scattering of particulate matter (PM2.5) scatter could be decreased slowly. The influence of the temperature and pressure on the gaseous pollutant is much more effective on sunny days than other days due to the higher temperature but in the core of the particulate matter (PM2.5) scatter.
6. Relative humidity (RH%) and mass concentrations with different colors of PM2.5 scatter wavelengths have very strong correlations over the year which is statically significant. From this study, we can conclude that there is the influence of relative humidity and mass concentrations are more effective on scattering on particulate matter (PM2.5) scatters. Relative humidity and mass concentrations have greatest impacts in weather forecasting.

Conflict of interest

The authors declare that they have no conflict of interest.

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Data and materials availability

All data associated with this study are present in the paper.

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