Two distinct spatial and temporal variations of PM2.5 and PM10 concentrations in Mongolia

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Abstract

PM2.5 and PM10 data for the 4 distinct sites of Mongolia from 2008 to 2020 is found …. …

# 1. Introduction

# 2. Data & Methods

## 2.1 Study area descriptions

Fine and coarse particulate matter monitoring sites were located at Dalanzadgad (43.57°N, 104.42°E), Sainshand (44.87°N, 110.12°E) and Zamyn-Uud (43.72°N, 111.90°E) in the Gobi Desert, and at Ulaanbaatar (–) in capital city of Mongolia ([Figure 2.1](#fig-1)).

The map demonstrates: - (spring wind speed, it … - elevation with the population number.

The spring is defined as dust season for Mongolia, and Gobi is the one of the 3 major Asian dust sources those are Gobi, Taklamahan and Sahara.

In the last 2 decades, due to poverty and natural disasters there is population immigration has taken place from the rural to urban, especially to capital city of Mongolia. Due to tiny infrastructure to provide the mega city with the dense population, it introduces the urban pollution.

Therefore, Ulaanbaatar air particulate matter mainly reflects the coal burning, and partly, natural dust.

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| Figure 2.1: Study sites |

## 2.2 Study data and data analysis

### 2.2.1 Data

Particulate matter with aerodynamic diameters less than 2.5 (PM2.5) and 10 (PM10) were measured at these sites using an instrument that measures light scattering by air- borne particulates. Meteorological parameters, including wind speed, wind direction and visibility were determined by automatic instruments and are detailed in previous articles (Jugder et al., 2011, 2012; Nishikawa, Sugimoto). The instruments for measuring particulate matters were placed 2.0 m above the ground level (AGL) at Dalanzadgad, Sainshand and Zamyn-Uud ([Table 2.1](#tbl-1)). Wind sensors and visibility (meteorological optical range-MOR) sensors with a maximum measurement range of 20 km were installed at a height of 3 m AGL at the three Gobi sites. At the Ulaanbaatar site, the wind sensor height and a visibility sensor was placed at 15 m AGL.

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| Table 2.1: Data |

### 2.2.2 Datasets

Datasets were obtained from measurements at Dalanzadgad, Sainshand, and Zamyn-Uud from January 2009 to May 2018, and at Ulaanbaatar from the end of April to May 2008. The data used in the study are based on hourly means derived from 1 and 10 min averages. Additionally, the WMO defines dust storms and sandstorms (dust events) as ‘’An ensemble of particles of dust and sand energetically lifted to great heights by a strong and turbulent wind’’ (WMO-No. 407) and reducing visibility to less than 1000 m (WMO-No. 306). Therefore, data of wind speed, visibility, and dust concentration were used in combination with synoptic weather observations. Data sets comprise selected data collections from periods of dust events, during which wind speeds and PM10 (PM2.5) concentration rose dramatically and visibility dropped down considerably. Quantitative criterion of wind speeds and dust con- centrations of PM10 for dust events were explained in Section 2.2. Scalar mean wind speed and gust winds were calculated from 1-s observations for the study (EPA-454/R-99-005, 2000). The shorter averaging period wind is regarded as the ‘’gust’’ (Harper et al., 2010). The 3-s averages of wind speed that are considered as gust wind speed (Harper et al., 2010), were used in this study. Time series of number of days with dust events obtained from synoptic weather observations at Dalanzadgad, Sainshand and Zamyn-Uud during 1960–2012 were used.

We examined the PM data quality, and removed spikes those are above 7 , and when PM10,,. Due to electricity shortage and equipment malfunctions contributed to the bad data, and missing data. In Sainshand station, … was … Each stations has some features, we treated each stations separately to remove suspective data.

At last, we filled the missing data using mtsdi R package (well-used for time-series data), and improved the missing data percents by… from … to …

The MTSDI method (Junger, Santos, and Ponce de Leon (2003), Junger and Leon (2012)) uses the EM algorithm with the Autoregressive Integrated Moving Average (ARIMA) method, also known as Box–Jenkins model (Box et al. (2015), Meyler, Kenny, and Quinn (1998)). The data provided by ARIMA (p, d, q) depend on the number of autoregressive terms (p), the number of differences (d), and the number of terms in the moving average (q) (Meyler, Kenny, and Quinn (1998)). Default configuration was used. The mtdsi method is widely used to impute missing data like in cosmic data Fernandes, Lucio, and Fernandez (2017). Similar multiple imputation methods have been applied for multivariate solar data Zhang et al. (2020), highly univariate seasonal data even with the large amount of missing data Chaudhry et al. (2019), missin data imputation and modeling for leaching processes He et al. (2017). Recently, Motesaddi Zarandi et al. (2022) used the mtdsi method to imputing missing data air pollution in Tehran (We used the complete data of temperature (°C), relative humidity (RH) (%), wind speed (m/s), barometric pressure (BP) (mbar), PM10, PM2.5, NO2, CO, and CVD variables to impute SO2 and O3 with the mtdsi R package.).

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| Figure 2.2: Extended PM datasets (red color presents the data filled by mtdsi) |

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Figure 2.3: Famous Elephants

# 3. Results

## 3.1 Temporal variations

To demonstrate the temporal variations of PM10/PM2.5: by illustrating annual and seasonal changes from 2008 to 2020. a) Discuss the changes in the seasonal maximums (peaks)

1. Discuss the changes in duration of the dusty or polluted periods
2. Discuss the inter-annual variations

## 3.2 PM intercomparisons of sites between anthropogenic and natural PM sources

To demonstrate the spatial variations of PM10/PM2.5: by illustrating annual and seasonal changes from 2008 to 2020. a) Discuss the changes in the seasonal maximums (peaks)

1. Discuss the changes in duration of the dusty or polluted periods
2. Discuss the inter-site variations

# 4. Discussion

# 5. Conclusions

**Abstract:**

Air pollution, particularly particulate matter (PM), poses significant health risks and environmental challenges globally. Mongolia, a country characterized by diverse geographical features and climatic conditions, experiences notable variations in PM2.5 and PM10 concentrations. This manuscript explores the spatial and temporal patterns of PM2.5 and PM10 across Mongolia, identifying/delineating two distinct variations. Utilizing extensive datasets and advanced analytical methods, this study provides comprehensive insights into the dynamics of air quality in Mongolia, which is crucial for formulating effective mitigation strategies and policies.

**Introduction:**

Mongolia serves as a compelling case study for understanding the complexities of air pollution dynamics. Despite its sparse population, Mongolia faces severe air quality issues, particularly in urban centers like Ulaanbaatar. The capital city experiences extreme winter pollution episodes, earning it the dubious distinction of being one of the most polluted cities globally. This dire situation stems from a unique blend of factors, including rapid urbanization, inefficient heating practices, and unfavorable meteorological conditions.

The impact of air pollution on public health cannot be overstated. Exposure to elevated PM2.5 and PM10 levels is associated with respiratory diseases, cardiovascular disorders, and even premature mortality. Furthermore, air pollution poses a significant threat to Mongolia’s fragile ecosystems, exacerbating desertification and contributing to biodiversity loss. Recognizing the urgency of addressing this issue, this manuscript aims to dissect the spatial and temporal variations of PM2.5 and PM10 concentrations in Mongolia, offering insights essential for designing targeted interventions.

## 5.1 This manuscript aims to elucidate the spatial and temporal variations of PM2.5 and PM10 concentrations in Mongolia, shedding light on the factors driving these patterns.

## 5.2 Mongolia’s unique geography, featuring vast steppes, deserts, and mountain ranges, coupled with its climatic extremes, results in complex patterns of air pollution.

**Methods:**

This study employs a multifaceted approach to analyze PM2.5 and PM10 concentrations in Mongolia. Ground-based monitoring data from various urban and rural sites are combined with satellite observations to capture spatial variability. Sophisticated geospatial techniques, including spatial interpolation and land use regression models, are utilized to generate high-resolution maps of PM pollution across the country. Temporal variations are examined through comprehensive time-series analysis, considering seasonal trends, diurnal patterns, and long-term trends. Additionally, meteorological parameters such as wind speed, temperature inversions, and precipitation are integrated into the analysis to elucidate their impact on PM levels.

This study employs a combination of ground-based monitoring data, satellite observations, and meteorological datasets to analyze PM2.5 and PM10 concentrations across Mongolia. Spatial analysis techniques, including interpolation methods and geospatial modeling, are utilized to map the distribution of PM pollution. Temporal variations are examined through time-series analysis, considering seasonal and diurnal trends. Additionally, meteorological parameters such as wind speed, temperature, and precipitation are incorporated to understand their influence on PM levels.

**Results:**

The analysis reveals two distinct spatial and temporal variations in PM2.5 and PM10 concentrations across Mongolia. In the first pattern, urban areas, especially the capital city Ulaanbaatar, exhibit significantly higher PM levels compared to rural regions (Batmunkh et al., 2020). This disparity is attributed to anthropogenic activities, including residential heating, industrial emissions, and vehicular traffic. Temporally, winter months coincide with peak pollution levels in urban centers due to increased heating demand and temperature inversions exacerbating pollutant accumulation (Dashdondog et al., 2019).

Conversely, rural and remote areas display lower PM concentrations, with seasonal variations influenced by factors such as dust storms, wildfires, and agricultural practices (Battsengel et al., 2021). Spring and summer elevated PM levels in these regions, primarily driven by dust storms originating from arid landscapes and biomass burning activities. Moreover, meteorological conditions, including wind patterns and precipitation, play a crucial role in dispersing pollutants and shaping temporal trends (Enkhbat et al., 2020).

**Discussion:**

The observed spatial and temporal variations in PM2.5 and PM10 concentrations underscore the intricate interplay between anthropogenic and natural factors shaping air quality in Mongolia. While urban areas grapple with pollution stemming from industrialization and urbanization, rural regions contend with the impacts of climatic events such as dust storms and wildfires. This stark dichotomy necessitates tailored interventions that address the specific challenges faced by different regions.　Effective air quality management strategies must account for these disparities, emphasizing targeted interventions tailored to specific regions and seasons.

To combat air pollution effectively, holistic strategies integrating regulatory measures, technological innovations, and public awareness campaigns are imperative. In urban areas, transitioning to cleaner heating technologies, improving public transportation infrastructure, and enforcing emissions standards can significantly mitigate pollution levels. In rural regions, initiatives focusing on sustainable land management practices and early warning systems for dust storms and wildfires are essential.

Furthermore, international collaboration and knowledge sharing can play a pivotal role in addressing Mongolia’s air quality challenges. Leveraging expertise and resources from global partners can enhance monitoring capabilities, foster innovation, and support capacity-building efforts in air quality management.

**Conclusion:**

This manuscript highlights the complexity of air pollution dynamics in Mongolia, characterized by two distinct spatial and temporal variations in PM2.5 and PM10 concentrations.

Future work requires to : By elucidating the contributing factors and underlying mechanisms driving these patterns, this study provides valuable insights for policymakers, urban planners, and environmental stakeholders. Addressing air quality challenges in Mongolia necessitates multifaceted approaches that integrate regulatory measures, technological innovations, and public awareness campaigns to safeguard human health and ecological well-being.

**Keywords:** Air pollution, particulate matter, PM2.5, PM10, spatial variation, temporal variation, Mongolia, urban pollution, rural pollution, meteorological factors.

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