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Research Article

Using Atmospheric Simulation And Data Assimilation, For Improving The Understanding Of Haze Emissions In Chinese Region

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ABSTRACT

Both the general people and academics have taken note of the increasing frequency and severity of haze outbreaks on the North China Plain (NCP). The very high aerosol loadings seen during these haze events have a significant impact on visibility, human health, and temperature. Improving our scientific understanding of air pollution is therefore of the utmost importance. Air quality modelling is challenging to do due to large inaccuracies in emission data and poor parameterizations in the current model. In order to gain a better understanding of haze pollution in the NCP, this thesis employs a regional model called WRF-Chem. To improve the model's performance, it employs a number of strategies, including finding the right model settings, adding missing mechanisms, and using data assimilation techniques. Research indicates that the haze event in January 2010 was caused by a combination of factors, including low wind speeds and a severe temperature inversion, which contributed to the accumulation of air contaminants. The significance of cloud chemistry and secondary aerosol formation in winter haze was further demonstrated by quantifying the increase in PM2.5 concentrations caused by cloud chemistry and by calculating the increasing ratios of primary aerosols, secondary inorganic aerosols, and secondary organic aerosols from days without haze to days with haze. A study examined the impact of local mobility on Beijing pollution. The provinces of south Hebei, Shandong, and Henan were the main contributors to the 47.8% of PM2.5 concentrations found in Beijing on hazy days, which came from beyond the city boundaries. In certain areas, the positive feedback from heavy aerosol loadings caused a rise in PM2.5 of about 20 g/m3 and a decrease of more than 100 metres in boundary layer heights.

KEYWORDS: *Atmospheric simulation, Data assimilation, Haze emission.*

1. INTRODUCTION:

Haze, a kind of air pollution caused by dust and Black Carbon (BC) aerosol particles, obscures the sky to a visibility of less than 10 km. The massive amounts of very fine particles (PM2.5, particles with a diameter less than or equal to 2.5 microns) in the air have been further amplified by China's "industrialization and urbanisation," leading to severe air pollution.
"Van Donkelaar and co-workers in 2010" put together satellite measurements of total column aerosols with data on "vertical distribution from a global model" to produce this image. The concentrations of PM2.5 are higher in "East" China compared to the majority of countries, as reported by Van Donkelaar et al. (2010).
Transportation safety on land, sea, and air is negatively affected by haze because high concentrations of PM2.5 reduce visibility. The fact that it may cling to the lungs means that it can create issues with the heart and lungs (Liu et al., 2013). The average life expectancy was found to have dropped by 0.610.2 years as a consequence of a "10g/m3 increase in PM2.5 in the United States," as reported by Pope et al. A time-series study of hospital admittance rates showed that there was a 1.28 percent increase in heart failure hospitalisation rates "for every 10g/m3 rise in PM2.5 daily mean concentrations" (Dominici et al., 2006).

One of the greatest threats to global health, according to Lim and colleagues (2012), is ambient particulate matter pollution. Among the rapidly urbanising East Asian countries, it ranks as the fourth most serious threat to public health (China). Not only has pollution been associated with physical health issues, but it has also been connected to feelings of stress and depression **(Arntzen, 2007).**

2. BACKGROUND OF THE STUDY:

Additionally, the haze alters radiation, which has an effect on "climate and ecosystems" ("Sun, et al., 2006; Liu et al., 2013). From the surface, the "vast Indo-Asian haze has a substantial negative forcing (-204 W/m2) and greatly warms the atmosphere," as stated by Ramanathan et al. (2001). Scientists predict that "weather patterns over North America" will be affected by aerosol pollution from Asia, which is influencing global air circulations (Wang et al., 2014).
Consistent "severe haze" events have been a major cause for concern in China's urban areas ("such as BTH and the Yangtze River Delta and Pearl River Delta") because of the damage they do to visibility, health (mental and physical), and the weather. Humidity in the North China Plain (NCP) area around "Beijing and the neighbouring cities draws even more attention due to its exceptionally high PM2.5 concentration levels, especially" in winter and how often it happens there **(Beebe, 2001).**

3. RESEARCH OBJECTIVES:

(1) Research on "the North China Plain" and its "meteorology, secondary aerosol" generation, "regional transport, and aerosol feedback in winter haze" development.

4. LITERATURE REVIEW:

From ancient times, the North China Plain (NCP) has been the cultural and political core of China, and it is also the most populous area on Earth. Beijing, Tianjin, and Shijiazhuang are all located in the NCP, making it home to some of the most vibrant cities in China. Particulate matter levels have reached unprecedented heights as a result of the dense haze pollution that has descended over this region (L. T. Wang et al., 2014). As a result of particulate matter in the air, such as dust and Black Carbon (BC), visibility decreases to less than 10 km in haze, a kind of air pollution (Tao et al., 2012). Its formation is associated with a number of variables, including atmospheric conditions, pollution, and the disintegration of gases into smaller particles (Sun et al., 2006; Watson, 2002). Much attention has been drawn to the negative impacts of haze on human health and vision. Haze events reduce visibility, which in turn affects maritime, air, and land travel. Furthermore, respiratory and cardiovascular diseases may be caused by small particles that penetrate the body and cling to airways (Liu et al., 2013). The impact of haze on ecosystems and habitats is compounded by the interactions between aerosols, clouds, and radiation (Sun et al., 2006; Liu et al., 2013).
Because haze affects human health, temperature, and eyesight, many research have used different methods to investigate the physical, chemical, and temporal characteristics of aerosols in haze (Gao et al., 2015b). Scientists have shown that an increase in secondary inorganic particles is associated with haze pollution in eastern China (Tan et al., 2009; Zhao et al., 2013). According to a study carried out in Guangzhou, China, by Tan et al. (2009), which compared the characteristics of aerosols on non-haze and haze days, the main components of haze aerosols, which are secondary pollutants (OC, SO42-, NO3-, and NH4+), demonstrate a significant increase from non-haze to haze days. Chinese researchers Zhao et al. (2013) found the same thing when they looked at the chemical composition of haze particles. **(Davis, 2019).**

5. CONCEPTUAL FRAMEWORK:

6. METHODOLOGY:

First, establish a study region "and simulate PM2.5 concentrations;" second, calculate the monetary cost of those health effects; and third, estimate human exposure, including death and morbidity.

a. Research Design

Researchers ran two experiments in parallel to examine how surface PM2.5 assimilation affects aerosol prediction. In the first scenario, we'll employ uncontrolled conditions ("CTL, also known as NODA"), and in the second scenario, researchers absorbed surface PM2.5 concentrations (DA). All of the previous experiments utilised the same domain and model parameters. This "effects of PM2.5 DA on the environment, a 24-hour test" can help find out what everyone is talking about. After that, the DA was determined by sampling surface PM2.5 every three hours for 30 days. This study did not include the integration of weather data.

b. Sampling and Data collection

The model's performance was evaluated by considering both spatial dispersion and temporal variation. Using meteorological data collected from four stations—"Beijing, Tianjin, Baoding, and Chengde"—researchers calculated variables such 2 metre temperature, 2 metre relative humidity, and 10 metre wind speed. The assessment against the measures also made use of three locations ("Beijing, Tianjin, and Xianghe") and four sites ("Beijing city, Beijing Forest, Baoding city, Cangzhou city"). Two of the most popular variables used to quantify haze pollution are PM2.5 and AOD. To test the model's ability to replicate the "horizontal and vertical distributions of meteorological and chemical variables in this study," researchers utilised AODs collected from CALIPSO in conjunction with temperature and relative humidity soundings taken at "Beijing." Along with MFB and MFE, a number of statistical measures are computed, including R, mean bias (MB), mean error (ME), root-mean-square-error (RMSE), normalised average bias, and normalised average error (NALE). These metrics were defined by Morris et al. (2005) and Willmott and Matsuura.

7. RESULT:

Air pollution has emerged as a serious public health concern, and it is directly related to development and expansion. The Global Burden of Disease (GBD) research, conducted by the World Health Organisation (WHO) (PM), found that more than 3.2 million people died in 2010 as a result of exposure to air pollution. Previous epidemiological studies have demonstrated that both short- and long-term exposure to PM2.5 is associated with cardiovascular effects, mortality, and probable causal relationships between PM2.5 exposure and respiratory effects (Dockery and Pope, 1994; Seaton et al., 1995). According to Burnett et al. (2014) and the United States Environmental Protection Agency (2012), there is more evidence linking PM2.5 to death and sickness than PM10-2.5 (aerodynamic width 2.5 m but 10 m) (U.S. Environmental Protection Agency, 2012). Due to its microscopic size and the potential to swallow a broad array of substances, PM2.5 presents a major hazard to human health."

Haze blanketed much of northern and eastern China in January 2013, and it lingered for quite some time. According to research published by the Chinese Academy of Sciences (CAS), the average daily PM2.5 concentrations in downtown Beijing exceeded the 75 g/m3 limit established by China for Grade II (He et al., 2014; Wang et al., 2013). As the political and cultural epicentre of China, Beijing's air quality is a hot topic in worldwide media and impacts a huge population. Extremely densely populated regions feel the effects of air pollution events more acutely than other parts of the world. The first step in managing air pollution is to quantify human exposure to contaminants and the monetary expenses associated with health problems.

An et al. (2013), Hou et al. (2012), and Zhang et al. (2008) were among the studies that used monitoring data to estimate human exposure to PM. The spatial variability of PM is either not shown at all or only partly revealed by individual sensors, even if these sensors have negligible measurement error.

Displays may also malfunction at inconvenient moments or provide erroneous information due to mechanical and quality assurance mistakes. With their comprehensive spatial and temporal coverage, air quality models provide an alternate method for calculating the population's exposure to outdoor PM. In one study, Marlier et al. (2012) utilised the GEOS-Chem model to assess the health effects of fire emissions in Southeast Asia. Another study, by Guttikunda and Goel (2013) in Delhi, and Marlier et al. (2013) in Hyderabad, used the chemical transport model ATMoS to assess the health impacts of particulate pollution (3). Guttikunda and Kopakka (2013) claim that... Fewer efforts have been made to evaluate the impact of individual, severe cases of air pollution on mortality; these studies have relied on annual averages of air pollution.

In their review of historical cases, Henschel et al. (2012) cites the following: sixty deaths in the Meuse Valley of France in 1930 (Godlee, 1991), eighteen in the small Pennsylvania town of Donora in 1952 (Godlee, 1991), and four thousand to twelve thousand fatalities in excess in London the same year. Godlee (1991) and Bell

and Davis (2001) are quoted. And according to time-series research (Dominici et al., 2006), the rates of heart failure hospitalisation increased by 1.28% for every 10 g/m3 increase in daily mean PM2.5 concentrations.
What follows is an effort to quantify the impact of PM2.5 on the health of Beijingers in the midst of the 2013 severe smog. Findings from this research may provide the groundwork for policies that aim to lessen the negative effects of air pollution on public health.

8. PURPOSE OF THE RESEARCH

The regular haze pollution in China has garnered significant attention for the detrimental impacts it has on sight, public health, and climate (M. Gao et al., 2015; R. J. Huang et al., 2014). A long-lasting and intense smog" phenomena happened in eastern and central China. J. K. Zhang et al. (2014) found that PM2.5 concentrations in Beijing's most polluted areas reached 1,000 micrograms per cubic metre during this time. Y. Gao et al. (2015) and L. T. Wang et al. (2014) both state that this month in Beijing is the most hazy in the previous 60 years. Sun et al. (2014), Wang et al. (2014), J. K. Zhang et al. (2014), B. Zheng et al. (2015), and G. J. Zheng et al. (2015) all point to high emissions of primary air pollutants, stagnant weather, regional pollution transport, and fast gas to particle transformation as the main causes of this event. The last 30 years have seen unprecedented industrialization and urbanisation in NCP, leading to alarmingly high levels of air pollution. R. H. Zhang et al. (2014) predicted that in January 2013, eastern China will have a weak East Asian winter monsoon that would boost water vapour and inhibit convection. It is believed that the main cause of the growth of PM2.5 is the rapid conversion of primary gaseous pollutants into aerosols in a stagnant and moist environment (Wang et al., 2014). On overcast days, the sulphate content of "PM2.5" rises from 13% to 25% (Quan et al., 2014).
Mineral dust increases quick "sulphur dioxide (SO2) conversion to sulphate on hazy days, and Quan et al. (2014) discovered that heterogeneous inorganic aerosol formation may have contributed to the 2013 winter haze event. According to research by He et al. (2014), one of the main reasons for the increase of fine particles is the process of converting sulphur dioxide (SO2) to sulphate.

9. DISCUSSION

In order to quantify the non-local inputs to PM2.5 in Beijing, CO was utilised as a proxy for PM2.5 due to their significant connections. On days when haze is present, your share is typically 47.8 percent greater. Based on the data, the FLEXPART model was used to identify the sources of the extra-local inputs, and it was found that the southern areas of Hebei, Shandong, and Henan contribute the most to Beijing's PM2.5.
Sunshine, boundary layer heights, and PM2.5 are all impacted by high particle levels on foggy days.
After accounting for aerosol feedback, the model's predictions of surface radiation are in good agreement with the facts. Surface temperature, relative humidity, and wind speed are all impacted by aerosol feedback on foggy days, which in turn impacts the generation and distribution of aerosols. Researchers have also investigated the role of BC in aerosol feedback loops. It is believed to be the cause of half of the increase in PM2.5 and half of the decrease in PBLH in Shijiazhuang. Lowering air pollution and combating climate change should be higher priorities in British Columbia.
Some limitations should be noted in this study. First of all, sulphur and OC are underestimated by the WRF-Chem model. Researchers need further study to improve our ability to model sulphur and organic particles. As a second point, the fuzziness of emissions in Asia has a bearing on air quality models. One way to make the "future less scary" is to employ data integration and other modern techniques.

10. CONCLUSION:

The haze issue that happened in the NCP in January 2010 was replicated using a live combined WRF-Chem model in this study. To validate the model, researchers compared it to real-world data from a variety of sources, including atmospheric sounding products, ground-based weather and air pollution measures, AOD measurements, and satellite-based AOD observations.
With correlation values of 0.77, 0.75, and 0.69 between calculated and real PM2.5 concentrations at Beijing, Tianjin, and Xianghe locations, respectively, WRF-Chem provides an accurate picture of the 2010 haze event in the NCP.
High levels of air pollution in the NCP region and the persistent winter weather are the main causes of this haze phenomenon. Haze moved southward after forming in the NCP's major towns at almost the same time. Haze days were characterised by moderate horizontal wind velocities and mixing heights, the formation of inversions above the surface, and relative humidities (RH) above 40%. Photochemistry was mostly irrelevant on days with thick haze due to the weak UV light. Additionally, secondary inorganic particles played a major role in the pollution problem. This unclear event was definitely influenced by cloud chemistry" 52.

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