Environmental Research xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Local pollutants go global: The impacts of intercontinental air pollution from China on air quality and morbidity in California

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ARTICLE INFO

Keywords:
Transboundary air pollution
Particulate matter
Morbidity
Air quality

ABSTRACT

China is among the greatest emitters of air pollution in the world and one concern is the effects of intercontinental air pollution traveling across the Pacific Ocean from China to the U.S. We exploit a natural experiment by observing the effects of changes in intercontinental air pollution associated with Chinese New Year, a 7-day national holiday, and sandstorms from China on air quality and morbidity in California. The timing of these events are unlikely correlated to other factors affecting air quality and health in California. Chinese New Year follows the Lunar New Year which varies each traditional calendar year while sandstorms are a naturally occurring phenomenon. We examine effects on morbidity using restricted emergency department and inpatient hospitalization data for the universe of patients with respiratory and heart disease between 2005 and 2012 in California. This is the first study to use patient-level data to examine the effects of trans-Pacific air pollution from China on morbidity in the U.S. We show that heavy sandstorms are associated with a modest increase in acute respiratory disease per capita, representing 0.5–4.6% of average weekly hospitalizations. However, we find no significant effect on morbidity in California from Chinese New Year. Results suggest that policymakers could prepare for changes in air quality following major sandstorms in China.

1. Introduction

China is among the greatest emitters of air pollution in the world, and numerous studies in the atmospheric science literature have examined the environmental impacts of intercontinental air pollution traveling from East Asia to the west coast of North America (Jaffe et al., 2003; Timonen et al., 2013; Jacob et al., 1999; Hadley et al., 2007; Ewing et al., 2010; Liu et al., 2003; McKendry et al., 2001; Yienger et al., 2000; Lin et al., 2014; Yu et al., 2012). The west coast of the U.S. is particularly vulnerable since winds prevail from the Pacific Ocean, while winds on the east coast generally come from the Gulf of Mexico. Current air quality regulations by the U.S. Environmental Protection Agency (EPA) focus solely on domestic pollution sources, though foreign pollution emissions could negate domestic emissions reductions. For example, in April 2013, a large sandstorm in the Gobi Desert, which borders southern Mongolia and northern China, led to bad haze in Owens Valley, California a few days later.[1] Residents in Owens Valley originally thought the pollution was from a nearby fire. Aside from anecdotal evidence, a study by Jacob et al. (1999) found that trans-Pacific ozone could potentially offset reductions in domestic anthropogenic reductions of ozone. Ewing et al. (2010) found that 29% of lead, an indicator of industrial pollution, in San Francisco derived from Asia. Other studies have found episodes of trans-Pacific particulate matter (PM) from East Asia contribute to background and urban levels of PM in the U.S. (Jaffe et al., 2003; Timonen et al., 2013; Ngo et al., 2018).

Transboundary air pollution is transported across the Pacific Ocean through different export mechanisms, where the most common are 1) convection, 2) lifting ahead of cold fronts resulting from extratropical cyclones, and 3) orographic lifting, which is movement of an air mass to higher elevations as it rises over terrain (Liu et al. (2003); Liang et al. (2004)). Previous work shows that the export of pollutants from East Asia are mostly transported at higher altitudes, reach the surface and affect human beings under specific conditions in North America (e.g. Liang et al. (2004), Jacob et al. (1999), McKendry et al. (2001)). Import mechanisms include the westerly flow from the Pacific Ocean (Hadley et al. (2007); Liang et al. (2004)). Additionally, the mechanisms for trans-Pacific transport peak during spring, which coincides with when sandstorms are most likely to occur (Jaffe et al. (2003)). The amount of time needed for the transport of intercontinental air pollution across the

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[1] Source: http://www.dailymail.co.uk/news/article-2302322/Sandstorm-China-ends-California-west-coast-wakeshazy-skies-clouded-sand-Gobi-Desert-6000-miles-away.html.

https://doi.org/10.1016/j.envres.2018.04.027
Received 13 February 2018; Received in revised form 16 April 2018; Accepted 24 April 2018
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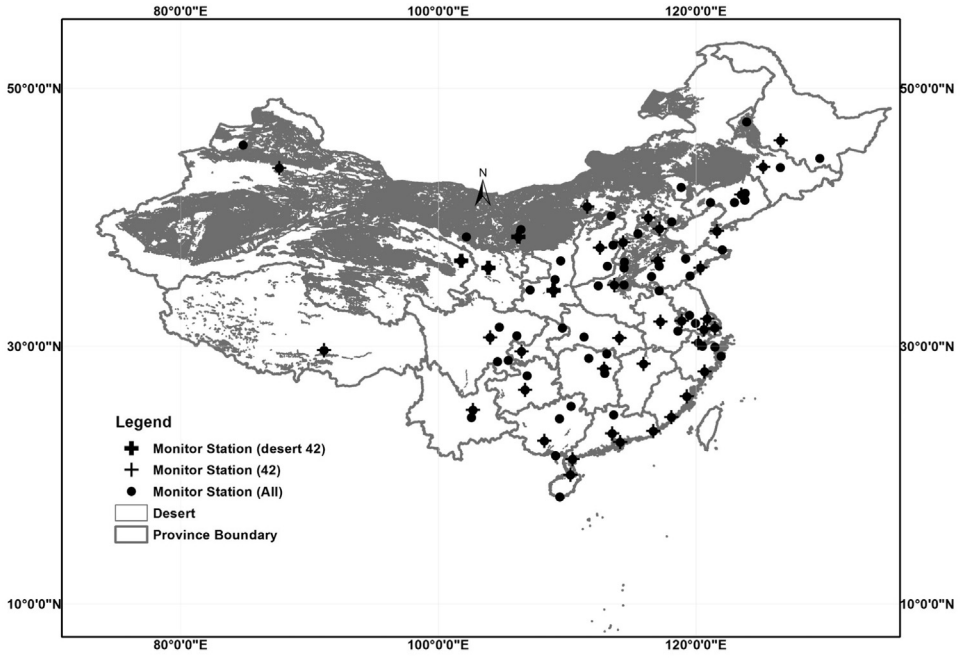

Fig. 1. This figure shows province boundaries and the 42 cities that have monitored PM_{10} in China since 2000 represented by the cross symbol (+). The circles represent the original 42 cities and those that have been added over time, and the bold cross symbol represents the four cities near the Gobi Desert (the shaded region in northern China), which are part of the original 42 cities we use in our study. The four cities near the Gobi Desert are Lanzhou, Xian, Xining, and Yinchuan.

Pacific Ocean varies by pollutant, but for PM, previous work suggests it can take between a few days and 2 weeks.

Intercontinental air pollution also raises possible concerns about public health in the U.S. While there is a large literature on the relationship between air pollution and morbidity, most studies focus on impacts from domestic sources (e.g., Schlenker and Walker, 2016, Moretti and Neidell, 2011, Beatty and Shimshack, 2011, Ngo, 2017). A handful of studies have examined the health impacts of intercontinental air pollution from dust emissions or biomass burning, but they typically use coarse health data (e.g., Zhang et al., 2017, Tobias et al., 2011, Zauli Sajani et al., 2011, Liu et al., 2009, Saikawa et al., 2009, Anenberg et al., 2009), while a closely related literature has focused on *intra*continental air pollution (Almond et al., 2009; Baek et al., 2015; Jia and Ku, 2015). Yet, to our knowledge, no study to date has observed the health impacts of intercontinental, much less trans-Pacific, air pollution using detailed patient-level hospitalization data (HTAP, 2010).

In this study, we use a natural experiment exploiting variation in the timing of two major events that affect local pollution in China and, consequently, trans-Pacific air pollution traveling to the U.S. These events are sandstorms, a common, naturally occurring source of air pollution, and Chinese New Year, a 7-day national holiday in China when anthropogenic air pollution levels from industrial and vehicle emissions are lower. Our study builds upon previous work that has examined this relationship using a combination of techniques, including chemical transport models, flight experiments, in situ observations, calculations of back trajectories, satellite data, and, to a limited degree, statistical analyses. However, these studies typically focus on a narrow time period and specific episodes of trans-Pacific air pollution since it is difficult to predict when an episode will occur due to the complex meteorological mechanisms involved. By using a natural experiment, we examine a longer time period spanning more than a decade between 2000 and 2012 and observe the impacts of a broader range of events. This approach also potentially allows policymakers to prepare for changes in air quality in the U.S. from foreign emissions following these major events in China.

The timing of sandstorms and Chinese New Year could be considered plausibly exogenous to factors affecting air quality and health in the U.S. Sandstorms are driven by local meteorological phenomena, while the timing of Chinese New Year is according to the lunar calendar which varies every traditional calendar year. As a result, the timing of these events circumvent possible endogeneity problems common in observational studies of air pollution and health. For example, a regression of health or pollution in the U.S. on air quality in China could suffer from omitted variable bias if economic factors are unaccounted for since previous work shows trade between these countries could influence pollution and health in the U.S. and China (Lin et al., 2014; Zhang et al., 2017).

We focus on several outcomes of interest. First, we assess whether these events influence air quality in China, which could consequently affect the transport of intercontinental air pollution. Then we examine their impacts on PM_{10} (PM with an aerodynamic diameter $< 10\,\mu m$), and $PM_{2.5}$ (PM with an aerodynamic diameter $< 2.5\,\mu m$), both of which are regulated by the U.S. EPA, in California between 2000 and 2012. Finally, we observe the effects of these events on morbidity in California, specifically heart and respiratory disease, using restricted patient-level hospitalization data on emergency department (ED) and patient discharge (PD) visits between 2005 and 2012. We focus on California since it is home to a large population of 38 million people. This is the first study to use patient-level data to examine the relationship between foreign pollution emissions from China and morbidity in the U.S and has important implications for current U.S. EPA regulations and foreign emissions.

2. Methods and data

2.1. Air quality, Chinese New Year, and sandstorm data in China

Since 2000, China's Ministry of Environmental Protection (MEP) has regularly monitored daily PM_{10}, nitrogen dioxide, and sulfur dioxide in 42 major cities in China, which expanded to 120 cities by 2012. For consistency, we focus on pollution measurements at the original 42 cities which are marked by the non-bold crosses in Fig. 1. Each pollutant's daily average concentration is converted into a pollutant-specific daily Air Pollution Index (API) (Table 1), and the largest API among the three pollutants is chosen as that day's primary pollutant. The concentration of the primary pollutant can be derived from the daily

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