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Assessment for the impact of dust events on measles incidence in western China

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HIGHLIGHTS

- Spatiotemporal distribution of dust event is consistent with that of measles.
- The incidences of measles declined on the moving path of dust storms.
- Cases of measles were positively correlated with coarse particles concentrations.
- There were certain excess measles during the dust storm period.

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ABSTRACT

Dust events affect human health in both drylands and downwind environments. In this study, we used county-level data during the period of 1965–2005 to assess the impact of dust events on measles incidence in Gansu province in Western China. We used Fast Fourier Transform (FFT) to set up the cyclical regression model; in particular, we set the model to downwind direction for the typical cities in the Hexi Corridor as well as the capital city Lanzhou. The results showed that Spring measles incidence was the highest in the Hexi Corridor, where dust events occur the most frequently over Gansu province. Measles incidence declined on the pathway of dust storms from west to east due to the weakening of both intensity and duration in dust storms. Measles incidence was positively correlated with monthly wind speed and negatively correlated with rainfall amount, relative humidity, and air pressure. Measles incidence was significantly ($p \leq 0.01$) positively correlated with daily coarse particles, e.g., TSP and PM_{10}. According to the cyclical regression model, average monthly excess measles that is related to dust events was 39.1 (ranging from 17.3 to 87.6), 149.9 (ranging from 7.1 to 413.4), and 31.3 (ranging from 20.6 to 63.5) in Zhangye, Lanzhou, and Jiuquan, respectively.

1. Introduction

From the perspective of climatology, many scholars have studied the contribution of dust storms to heavy PM (particulate matter) pollution (Liu et al., 2004; Yang et al., 2004; Wang et al., 2006; Rodríguez et al., 2001; Byeong et al., 2004). From the perspective of epidemiology and environmental toxicology, several scholars have linked the size and physical and chemical characteristics of different types of PM to human health (Perez et al., 2008; Berico et al., 1997; BéruBé et al., 1999). Scholars have rarely combined both climatological and epidemiological approaches to analyze the impact of dust storms on human health, especially for infectious diseases.

Several previous studies have confirmed that inter-continent-transported dust (e.g., Asian and African dusts) could bring airborne bacteria to distant regions (Echigo et al., 2005; Perfumo and Marchant, 2010; Maki et al., 2008; Hua et al., 2007; Lee et al., 2009). Such long-distance transport of dust could spread pathogens and cause adverse health effects of allergens that are carried in the dust (Kellogg and Griffin, 2006). One previous study by Hara and Zhang (2012) also confirmed that bacterial abundance during the dust period closely depended on concentrations of coarse particles, and total bacterial cell concentration in dusty air was one to two orders higher than that in non-dusty air. Jeon et al. (2011), who works for the Republic of Korea, suggested that culturable bacterial concentration in dusty air was approximately 10^3 CFU m^{-3}, while it was approximately 10^2 CFU m^{-3} in non-dusty

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air. Bacteria in the air are carried upwards by air currents and can remain in the atmosphere until they are removed by precipitation or directly deposited onto surfaces (Burrows et al., 2009).

Some studies have linked dust storms to respiratory diseases in Europe (Reyes et al., 2014; Mallone et al., 2011), Japan (Kanatani et al., 2010) and China (Chien et al., 2012; Meng et al., 2007; Ye, 2008). Similar findings were also reported by Huang and Wang (2001) and Chen (2007) in the Hexi Corridor, which is located upwind of Lanzhou in Gansu province in Western China. However, few studies have linked dust storms to infectious diseases. Some recent studies showed that infectious diseases were possibly associated with desert dust (Ferrari et al., 2008; Mueller and Gessner, 2010). Lien et al. (2013) found that conjunctivitis clinic visits increased during dust storm periods. Meningococcal meningitis is a serious health problem in West Africa (Thomson et al., 2009), and the incidence of epidemics appears to be related to the timing and severity of Saharan dust intrusions (the Harmattan). Agier et al. (2013) found that dust damages the pharyngeal mucosa and thereby results in easy bacterial invasion. One study in Niger of sub-Saharan Africa showed measles outbreaks occurred in dry seasons and disappeared at the onset of rainy seasons (Ferrari et al., 2008). Earle et al. (1935) found that the most severe measles epidemic in the United States occurred in Kansas in 1935 during the Dust Bowl period.

In China, measles has become a notable disease since 1989. And measles outbreaks are one of the major public health problems every year in Western china. In Western China, measles season, whether epidemic or not, coincides with the spring (from March to May) dust that is directed by the dry dust-laden wind from Northwest China. The overall goal of our work is to use statistical methods to assess the possible effect of dust events on the occurrence and transmission of measles in the Hexi corridor and its downwind city Lanzhou in Gansu province in Western China using a robust historical dataset, including weather data, dust events data, and epidemiologic data.

2. Materials and methods

2.1. Study area

The entire Gansu province is located in a down-wind dominant region of Asian dust. Local air temperature fluctuates sharply in summer (from June to August) and winter (from December to February); precipitation is often unpredictable and unevenly distributed throughout the year. Dust storms sweep through Gansu province most frequently in spring.

The Hexi Corridor is one of the most important dust source areas in Northern China and is also a main dust-channel towards the east and south directions. The narrow tube effect caused by strong cold northern air makes the Hexi Corridor the largest source area of dust storms in Northern China (Wang et al., 2003; Qiu et al., 2001). During dust storms, the content of PM_{10} in this area is often more than 300 μg/m^3, which is more than twice of the national standard and three to five times higher than that when there is no dust storm.

The capital city of Gansu province Lanzhou (36°03′ N, 103°53′ E) is the geographical center of China (Fig. 1). It is located in the transport pathway of Asian dust storms and is severely affected by dust intrusions from upwind regions, with large quantities of incoming particles especially in spring (from March to May) (Wang et al., 1999; Liu et al., 2004).

2.2. Data collection and software

The number of daily cases of measles between Jan. 1st, 2004 and Dec. 31st, 2005, and the number of monthly cases of measles between Jan. 1965 and Dec. 2005 on a geographically county level were collected from Gansu Centers for Disease Control and Prevention (CDC). No specifics of age range or sex were recorded in the dataset.

The dust events dataset during the study period mentioned above was obtained from Gansu Meteorological Bureau, including the beginning and ending time, duration, type (such as sand, floating dust, or dust storm), horizontal visibility, and meteorological data (i.e., daily minimum, maximum, and mean temperatures; daily average wind speed; daily humidity; and daily rainfall).

Daily concentrations of TSP, PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ between Jan. 1st, 2005 and Dec. 31st, 2007, in Lanzhou city were measured with an Environmental Dust Monitor (EDM) (LN5, Munro Environmental, a division of The Munro Group, Britain). The EDM is a direct-reading real-time monitor incorporating a light scattering laser photometer and can simultaneously measure concentrations of four different sizes of particles. The time resolution of the measurements was five minutes. Statistical analysis was conducted in R 3.1.2 (http://cran.r-project.org/bin/windows/base/).

2.3. Statistical analysis

Statistical methods were used to analyze the spatiotemporal correlations between incidence of measles and dust events in the study area. Pearson correlation coefficient was calculated for the correlations between incidence of measles and each of the weather variables as well as each of the particle concentrations.

In addition, "Fast Fourier Transform (FFT)" was used to identify significant cyclical components during the study period. A total of 492 (from January 1965 through December 2005), 360 (from January 1976 through December 2005), and 372 (from January 1975 through December 2005) months were included in the analysis for Lanzhou, Jiuquan, and Zhangye, respectively. Statistical stationarity was required for further modelling in each time series. Therefore, the variance was stabilized by log transformation and the linear trend was removed by linear regression and subtraction. Poisson regression was used in this study, and for the independent regression the number of monthly cases of measles was the dependent variable. Three terms were included in the core model: linear time trend, year, and trigonometric term to control for seasonality (sin (2πkt/12) and cos (2πkt/12), where k = 1, 2, 3, 4, and 6 represents a cycle of 12, 6, 4, 4, and 2 months, respectively). Then, a least-squares approach was used to fit a sine and cosine curve described by Eq. [1] (Robert, 1963).

$$\widehat{\mathrm{Y}} = a + bt + \sum a_i \cos\theta + \sum b_i \sin\theta \quad [1]$$

where $\widehat{\mathrm{Y}}$ is the expected measles, θ is a linear function of t, a and b are intercept and slope, respectively, a_i and b_i are the amplitudes of the periodic variation of a linear term, t is the index for month of reported measles. Parameters were estimated by least-squares method.

In the model, months were omitted when observed cases of measles exceeded the simulation values. 90% CI were calculated based on the standard deviation of the residuals as described in Formula [2]:

$$\widehat{\mathrm{Y}}_{\mathrm{t}} \pm 1.64 - \sqrt{\frac{\sum (Y_O - Y_E)^2}{\mathrm{n} - dof}} \quad [2]$$

where $\widehat{\mathrm{Y}}_{\mathrm{t}}$ is the expected case of measles in a given month t, Y_O is the observed case of measles during the study period, Y_E is the expected mortality in the same month as Y_O, n is the number of