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Modeling and projection of dengue fever cases in Guangzhou based on variation of weather factors

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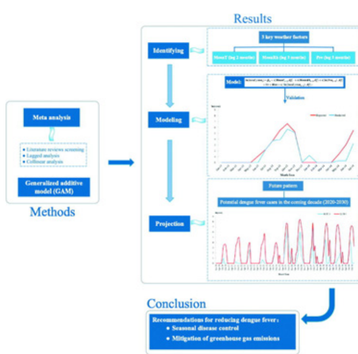
HIGHLIGHTS

- Three weather factors affecting dengue fever are determined using meta-analysis.
- A dengue model covered a long period is developed only from climate perspective.
- Modeling is validated against newly reported dengue.
- Projected dengue cases based on climate model data show a clear seasonality.
- Seasonal disease control and emission mitigation may help reduce dengue incidence.

GRAPHICAL ABSTRACT



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ABSTRACT

Dengue fever is one of the most serious vector-borne infectious diseases, especially in Guangzhou, China. Dengue viruses and their vectors *Aedes albopictus* are sensitive to climate change primarily in relation to weather factors. Previous research has mainly focused on identifying the relationship between climate factors and dengue cases, or developing dengue case models with some non-climate factors. However, there has been little research addressing the modeling and projection of dengue cases only from the perspective of climate change. This study considered this topic using long time series data (1998–2014). First, sensitive weather factors were identified through meta-analysis that included literature review screening, lagged analysis, and collinear analysis. Then, key factors that included monthly average temperature at a lag of two months, and monthly average relative humidity and monthly average precipitation at lags of three months were determined. Second, time series Poisson analysis was used with the generalized additive model approach to develop a dengue model based on key weather factors for January 1998 to December 2012. Data from January 2013 to July 2014 were used to validate that the model was reliable and reasonable. Finally, future weather data (January 2020 to December 2070) were input into the model to project the occurrence of dengue cases under different climate scenarios (RCP 2.6 and RCP 8.5). Longer time series analysis and scientifically selected weather variables were used to develop a dengue model to ensure reliability. The projections suggested that seasonal disease control (especially in summer and fall) and mitigation of greenhouse gas emissions could help reduce the incidence of dengue fever. The results of this study hope to provide a scientifically theoretical basis for the prevention and control of dengue fever in Guangzhou.

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1. Introduction

Dengue fever is one of the most important arboviral diseases transmitted to humans by mosquitoes, especially in tropical and subtropical regions. According to the World Health Organization (WHO, 2010), there were only nine countries affected by this disease in the 1970s. However, with the gradual expansion of its areas of prevalence during the latter 25 years of the 20th century, this disease is now present in over 100 countries and affects 50–100 million people annually (Azil et al., 2011; Gubler, 2002). In mainland China, dengue fever has occurred frequently since the 1980s, primarily affecting southern provinces such as Fujian, Guangdong, Hainan, and Guangxi. Dengue fever is able to cause serious morbidity and mortality, placing heavy burdens on both families and health care systems (Gubler, 2012).

Climate change impacts on the transmission of infectious disease in terms of three essential aspects: pathogens, hosts (or vectors), and transmission (Wu et al., 2016). The impact of climate change on dengue fever is not different in this respect. Climate change can affect the development, survival, and reproduction of dengue pathogens. Dengue viruses are sensitive to climate condition and changes in temperature as well as humidity can affect their replication and extrinsic incubation period (Thai and Anders, 2011; Wu et al., 2016). Climate conditions and weather factors can also affect the vectors of dengue. The mosquito *Aedes albopictus* is distributed widely in southern China, and it is considered the primary dengue vector in some parts of China (Fan et al., 1989; Gratz, 2004). The larvae development of these mosquitoes can be influenced considerably by both temperature and precipitation (Hoshen and Morse, 2004). For example, increased precipitation is able to provide additional breeding places, suitably high temperatures help extend the life cycle of the mosquitoes, and increased humidity is considered an important factor in the environmental conditions suitable for dengue vectors (Descloux et al., 2012; Tun-Lin et al., 2000). In addition, the transmission of dengue fever is also influenced by climate factors. For example, temperature and precipitation affect the longevity and biting behaviors of the female adult mosquitoes (Patz et al., 1998; Yang et al., 2009). Several studies have addressed the establishment of early warning systems of dengue fever based on weather factors (Eastin et al., 2014; Gharbi et al., 2011; Hii et al., 2012). They found different lagged relationships between the occurrence of dengue cases and weather factors such as temperature, humidity, and rainfall. Based on this, some early warning models were developed to predict the occurrence of dengue fever; however, the vectors used in these studies were *Aedes aegypti*, which are different to the vectors in Guangzhou. Additionally, a few studies have investigated the projection of potential dengue fever epidemics using vectorial capacity based on climate model data (Liu-Helmersson et al., 2016). Although the above-mentioned studies suggest that climate factors play an important role in dengue fever incidence, some studies have found socioeconomic and environmental factors also affect transmission of dengue fever. For example, a study in Colombia showed that key socioeconomic factors affecting incidence of dengue fever included population density and socioeconomic stratum; and environmental factors included plant nurseries, sewage system and tire shops (Delmelle et al., 2016).

Since 1978, dengue fever has occurred frequently in Guangzhou, the capital city of Guangdong Province in China. From 1998 to 2014, there were 40,837 dengue cases reported in Chinese Center for Disease Control and Prevention. Research on dengue fever in terms of climate change has become an active area of work. On the one hand, some studies have investigated the impact of weather factors on dengue fever in Guangzhou. For example, one study showed that minimum temperature and minimum humidity were both positively associated with the incidence of dengue fever at a lag of one month, whereas wind velocity was negatively associated with dengue fever over the same period (Lu et al., 2009). Other studies have identified correlations between climate factors and total dengue cases (Lu et al., 2009; Wang et al., 2014). On the other hand, a few studies have modeled the occurrence of dengue fever based on climate variation. One study modeled dengue fever cases, and the model was validated against data from a dengue outbreak in 2013–2014 based on imported cases and weather variables (S. Sang et al., 2015). Another study developed a dengue case model based on weather factors and mosquito density in 2005–2012, and the model was used to predict cases in 2013–2015 (Xu et al., 2016). However, until now, there has been little research addressing modeled dengue cases only from the perspective of climate change, and projected the future incidence in long-time scale.

This study used times series Poisson analysis with the generalized additive model (GAM) approach to model the occurrence of dengue cases based on weather factors over a long period (1998–2014). Based on a climate model, the future long-term (2020–2070) incidence of dengue fever was projected, so as to provide a theoretical basis for scientific guidance on its prevention.

2. Method

2.1. Study setting and data

2.1.1. Study setting

Guangzhou, the capital city of Guangdong Province in southern China, is located at 22°26′–23°56′N, 112°57′–114°3′E (Fig. 1), and its population was 8.42 million in 2014 (2014 National Census). Guangzhou has a subtropical monsoon climate that is characterized as warm and rainy with adequate sunshine and heat. Annually, the hottest month is July, with an average temperature of 28.7 °C. The rainy season is from April to June and hot weather extends from July to September. Obviously, Guangzhou provides suitable climatic conditions for dengue vectors and a large number of dengue fever cases are reported annually (Luo et al., 2012). Therefore Guangzhou was chosen as the study area based on its representativeness in China in terms of dengue fever and climate change.

2.1.2. Data

Dengue cases Details of dengue fever cases in Guangzhou from January 1998 to July 2014 were obtained from the Public Health Science Data Center. Data aggregation is at the county level in space, and at the month level in time. The dengue data used in our study is the total dengue cases of all counties within the Guangzhou City.

Weather data Monthly weather data from January 1998 to July 2014 were retrieved from the China Meteorological Data Sharing Service System. In this study, the weather factors considered included monthly average temperature (MeanT), maximum temperature (MaxT), minimum temperature (MinT), monthly average cumulative precipitation (Pre), monthly average wind speed (MeanWind), monthly average relative humidity (MeanRh) and minimum relative humidity (MinRh), monthly average vapor pressure (MeanP), monthly average sunshine hours (SunHour), average water vapor pressure (WaterVapor), and evaporation (Eva). There are two meteorological stations in Guangzhou city (Fig. 1), and the weather data used was obtained from meteorological station A, which is most close to the urban area of the Guangzhou city (S.W. Sang et al., 2015).

Climate model data To predict the number of dengue fever cases that might occur in the future, long-term weather data derived from climate prediction models were used. The model employed in this study was the Beijing Normal University Earth System Model (BNU-ESM) developed at the Beijing Normal University (Ji et al., 2014). The derivation was performed under four greenhouse gas emission pathways (RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5). The four RCP scenarios describe the possible range of radiative forcing of greenhouse gases in 2100 (i.e., +2.6, +4.5, +6.0, +8.5 W m^{-2}, respectively) (Weyant, 2009).

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