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Association between dengue fever incidence and meteorological factors in Guangzhou, China, 2005–2014

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ABSTRACT

This study aims to (1) investigate the associations between climatic factors and dengue; and (2) identify the susceptible subgroups. De-identified daily dengue cases in Guangzhou for 2005–2014 were obtained from the Chinese Center for Disease Control and Prevention. Weather data were downloaded from the China Meteorological Data Sharing Service System. Distributed lag non-linear models (DLNM) were used to graphically demonstrate the three-dimensional temperature-dengue association. Generalised estimating equation models (GEE) with piecewise linear spline functions were used to quantify the temperature-dengue associations. Threshold values were estimated using a broken-stick model. Middle-aged and older people, people undertaking household duties, retirees, and those unemployed were at high risk of dengue. Reversed U-shaped non-linear associations were found between ambient temperature, relative humidity, extreme wind velocity, and dengue. The optimal maximum temperature (T_{max}) range for dengue transmission in Guangzhou was 21.6–32.9 °C, and 11.2–23.7 °C for minimum temperature (T_{min}). A 1 °C increase of T_{max} and T_{min} within these ranges was associated with 11.9% and 9.9% increase in dengue at lag0, respectively. Although lag effects of temperature were observed for up to 141 days for T_{max} and 150 days for T_{min}, the maximum lag effects were observed at 32 days and 39 days respectively. Average relative humidity was negatively associated with dengue when it exceeded 78.9%. Maximum wind velocity (& $2gt;10.7 m/s) inhibited dengue transmission. Climatic factors had significant impacts on dengue in Guangzhou. Lag effects of temperature on dengue lasted the local whole epidemic season. To reduce the likely increasing dengue burden, more efforts are needed to strengthen the capacity building of public health systems.

1. Introduction

Dengue fever is an *Aedes* mosquitoes-borne acute viral infectious disease with clinical manifestations ranging from influenza-like symptoms to potentially life-threatening dengue shock syndrome (World Health Organization, 2009). During the past five decades, global dengue incidence has increased about 30-fold with an estimate of 50–100 million new infections per year at present, making it a major public health problem for over 100 countries in tropical and subtropical regions where almost half of the world's population live (Word Health Organization, 2012; Bhatt et al., 2013). Dengue fever has been ranked as the most important mosquito-borne neglected disease by the World Health Organization (WHO) (Word Health Organization, 2012). It exerts a huge burden on public health systems and economies especially in densely populated Asia-Pacific low-middle income countries (Gubler, 2002; Word Health Organization, 2012; Bhatt et al., 2013). To curb dengue incidence, WHO has formulated a global strategy with aims to reduce dengue morbidity and mortality by 25% and 50% respectively by 2020 (Word Health Organization, 2012).

Dengue fever in mainland China is a growing public health concern

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in subtropical southern coastal areas since its emergence in Guangdong Province in 1978 (Wu et al., 2010; Jin et al., 2015). More recently, an increased frequency of imported cases has triggered indigenous epidemics. Geographic expansion of the disease has occurred in previously unaffected northern areas, the farthest being Xuchang City (latitude 34°2′N and longitude 113°51′E) in Henan Province (Wu et al., 2010), possibly due to climate change, accelerated urbanization, rapid population growth, ineffective mosquito control, increased human travel and international trading (Wu et al., 2010; Jin et al., 2015). The majority of dengue cases in China are reported in Guangdong Province, where annual local dengue transmission occurs (Li et al., 2012; Luo et al., 2012). In 2013 and 2014, Guangzhou (capital of Guangdong Province) was continuously struck by unprecedented dengue outbreaks (Jin et al., 2015; Sang et al., 2015), which seriously affected local economic productivity and resulted in about 50,000 cases with 6 deaths (China Ministry of Health, 2016). Hence, urgent actions are needed against dengue emergence (Jin et al., 2015).

Dengue fever is primarily transmitted through the bite of dengue virus (DENV 1–4) infected *Aedes aegypti* and *Aedes albopictus* mosquitoes (World Health Organization, 2009). In Guangdong Province, *Aedes albopictus* is the dominant vector (Wu et al., 2010; Luo et al., 2012). All four serotypes of dengue viruses have been identified in Guangzhou, with the DENV-1 being most prevalent at about 70% of all cases in 1978–2009 (Luo et al., 2012).

Dengue fever is a climate sensitive disease. Climatic factors can influence dengue ecology both directly and indirectly by affecting mosquito growth dynamics, virus replication, and mosquito-human interactions (Morin et al., 2013). Evidence has shown that climate-dengue associations are site-specific and may vary within-country/region or even within-province (Nitatpattana et al., 2007; Chen et al., 2010; Morin et al., 2013; Vu et al., 2014), largely depending on the combined effects of local climate context and socioeconomic situation. In this study, we aimed to investigate the climate-dengue associations in Guangzhou City, Guangdong Province, China. Results of this study may be useful for better understanding local dengue ecology, provide implications for dengue early warning and timely control, and predict likely potential impact of climate change on dengue occurrence.

2. Materials and methods

2.1. Study area

Located along the south-east coast of mainland China and with a subtropical climate (Fig. 1), Guangdong Province has the highest dengue incidence rate in China, which is about 8 times the national average level (0.569 per 100,000 vs. 0.068 per 100,000 people) (Li et al., 2012). Guangzhou (latitude 23°8′N and longitude 131°17′E), situated in the Pearl River Delta, is the capital of Guangdong and the largest metropolis in southern China, with a population of 13,080,500 and a population density of 1759 people/km^2 in 2014 (Guangzhou Municipal Statistic Bureau, 2015). Guangzhou serves as an important regional center of transportation, logistics, commerce, trading, and industrial manufacturing. There is a large amount of population mobility (floating population) from inland provinces (about 3 million in 2014) (Guangzhou Municipal Statistic Bureau, 2015), as well as Africa and Southeast Asia, since the implementation of an open-door policy and economic reform in China in 1978. Influenced by the East Asian monsoon, Guangzhou has a humid subtropical climate and a lengthy monsoon season (April–September) with an annual mean temperature of 22.6 °C and a mean relative humidity of 68%, which is favourable for *Aedes* mosquitoes to breed (Luo et al., 2012).

2.2. Data collection

Dengue fever is a notifiable B-category infectious disease in China. According to the Law for the Prevention and Treatment of Infectious

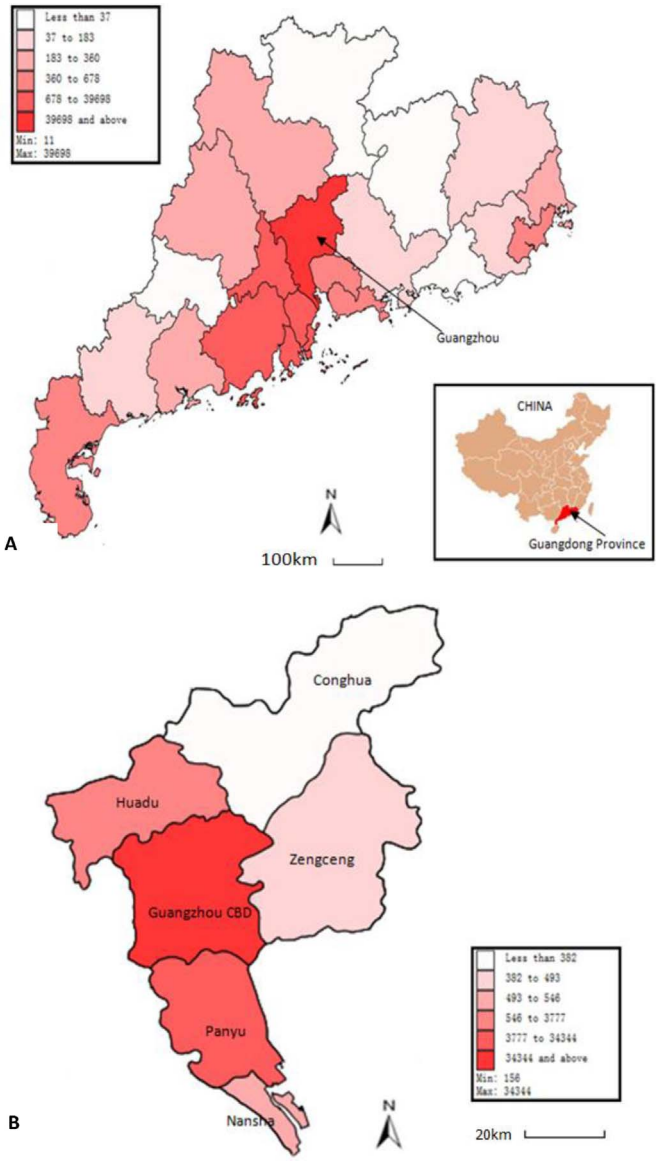

Fig. 1. Geographic distribution of dengue fever (total cases) in Guangzhou City and Guangdong Province, China, 2005–2014. *A*: spatial distribution of dengue in Guangdong Province; *B*: spatial distribution of dengue in Guangzhou.

Diseases, all dengue cases should be reported online within 24 h after diagnosis. All dengue fever cases were diagnosed according to the unified national dengue diagnostic criteria (China Ministry of Health, 2001), which can be divided into clinically diagnosed and laboratory confirmed cases. Both types of dengue cases were included in this study. De-identified daily dengue fever data for the period of 2005–2014 in Guangdong Province were obtained from the Chinese Center for Disease Control and Prevention, who extracted those data from the China Information System for Disease Control and Prevention. The variables included in the dengue dataset mainly comprised age, gender, occupation, dates (disease onset, diagnosis, and reporting), case category, and site of onset.

Daily meteorological data for Guangzhou (observation site code: 59287), including maximum (T_{max}) and minimum temperatures (T_{min}), rainfall, average relative humidity, sunshine duration, and maximum wind velocity for the study period were downloaded from the China Meteorological Data Sharing Service System (China Meteorological Administration, 2016). Relevant national dengue epidemic information was obtained from the monthly notifiable infectious diseases overview reports available on the website of the National