Environmental Pollution xxx (2017) 1–9

Contents lists available at ScienceDirect

Environmental Pollution

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

Impact of climate change on heat-related mortality in Jiangsu Province, China☆

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ARTICLE INFO

Article history:
Received 25 October 2016
Received in revised form
17 January 2017
Accepted 4 February 2017
Available online xxx

Keywords:
Heat
Mortality
Projection
Climate change

ABSTRACT

A warming climate is anticipated to increase the future heat-related total mortality in urban areas. However, little evidence has been reported for cause-specific mortality or nonurban areas. Here we assessed the impact of climate change on heat-related total and cause-specific mortality in both urban and rural counties of Jiangsu Province, China, in the next five decades. To address the potential uncertainty in projecting future heat-related mortality, we applied localized urban- and nonurban-specific exposure response functions, six population projections including a no population change scenario and five Shared Socioeconomic Pathways (SSPs), and 42 temperature projections from 21 global-scale general circulation models and two Representative Concentration Pathways (RCPs). Results showed that projected warmer temperatures in 2016–2040 and 2041–2065 will lead to higher heat-related mortality for total non-accidental, cardiovascular, respiratory, stroke, ischemic heart disease (IHD), and chronic obstructive pulmonary disease (COPD) causes occurring annually during May to September in Jiangsu Province, China. Nonurban residents in Jiangsu will suffer from more excess heat-related cause-specific mortality in 2016–2065 than urban residents. Variations across climate models and RCPs dominated the uncertainty of heat-related mortality estimation whereas population size change only had limited influence. Our findings suggest that targeted climate change mitigation and adaptation measures should be taken in both urban and nonurban areas of Jiangsu Province. Specific public health interventions should be focused on the leading causes of death (stroke, IHD, and COPD), whose health burden will be amplified by a warming climate.

1. Introduction

Heat exposure has been associated with increases in both total non-accidental mortality and cause-specific mortality from cardiovascular and respiratory diseases (Basu, 2009; Bobb et al., 2014; Curriero et al., 2002; Hajat and Kosatky, 2010; Yang et al., 2013). A warming climate is projected to increase future heat-related total non-accidental mortality across developed countries (Ballester et al., 2011; Guo et al., 2016; Huang et al., 2011; Kingsley et al., 2016; Li et al., 2013; Petkova et al., 2013; Vardoulakis et al., 2014). However, few studies have estimated the impact of climate change on heat-related specific causes of death, such as cardiovascular mortality and respiratory mortality (Li et al., 2015). Anticipating changes in future cause-specific mortality is crucial to understanding and reducing future population vulnerability to climate change. In addition, many of these studies have focused on

☆ This paper has been recommended for acceptance by David Carpenter.

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http://dx.doi.org/10.1016/j.envpol.2017.02.011
0269-7491/

urban areas due to the urban heat island effect and high density of susceptible population (Huang et al., 2011; Li et al., 2013). However, there is emerging evidence supporting high risk of heat-related health impacts in nonurban areas (Bennett et al., 2014; Chen et al., 2016; Madrigano et al., 2015; Sarofim et al., 2016; Sheridan and Dolney, 2003). Less is known about how total and cause-specific mortality will change in response to changes in projected heat exposure in nonurban areas. Moreover, limited studies have specifically assessed climate change impacts on heat-related mortality in developing countries such as China where socioeconomic and demographic conditions differ from those in developed counties. To date in China, only limited evidence of climate change impacts on heat-related mortality were found in Beijing, China, leading to considerable uncertainty as to whether the single city result can be applied to larger regions of China (Li et al., 2015).

Projecting heat-related mortality under a changing climate requires information on the exposure response function (ERF) for temperature-related mortality, projected changes in temperature, baseline rates of cause-specific mortality, and the size of the exposed population (Huang et al., 2011), all of which contribute uncertainties. The choice of ERF contributes a large part of the variations in estimating future temperature-related mortality (Benmarhnia et al., 2014; Wu et al., 2014). As the ERF of heat-related mortality can vary substantially within countries (Bennett et al., 2014; Ma et al., 2015), a region-specific ERF instead of a single ERF covering different regions or countries is critically important in evaluating the impact of climate change on regional heat-related mortality. Another source of uncertainty lies in the projected temperature, based on both scenarios of future 'forcing' associated with greenhouse gas concentrations and from climate model response to those greenhouse gas concentrations. The latter varies due to different model formulations, representation of processes and initial states (Flato et al., 2013), so a multi-model ensemble approach is required to address this uncertainty (Li et al., 2013). In addition, population growth would also affect the impact of climate change on heat-related health effects by increasing exposed population, which has not been well considered in many previous studies (Jones et al., 2015).

In this study, we aimed to assess the impact of climate change on heat-related total and cause-specific mortality in both urban and rural counties of Jiangsu Province, China. We applied urban-specific and nonurban-specific ERFs for heat-related total, cardiovascular (including more specific causes of stroke and ischemic heart disease (IHD)), and respiratory (including chronic obstructive pulmonary disease (COPD)) mortality from our previous analysis (Chen et al., 2016) to multiple climate and population projections to estimate the climate change-induced heat-related health burdens in 104 counties of Jiangsu Province, China.

2. Methods

This study was conducted in 104 counties of Jiangsu Province, China with a total population of 78.2 million people in 2010. Jiangsu Province is located along the eastern coast of China and is the most densely populated province in China. Situated in the transition belt from a subtropical to temperate zone, Jiangsu Province has a typical monsoonal climate with an average daily mean temperature of 15.7 °C and four distinct seasons. Jiangsu Province is one of the most developed regions in China and had the second largest Gross Domestic Product (GDP) among Chinese provinces in 2015.

2.1. Temperature projections

Daily maximum and minimum temperatures for the historical period 1980–2005 and the future period 2011–2070 under two Representative Concentration Pathway (RCP) climate scenarios were obtained from the NASA Earth Exchange (NEX) Global Daily Downscaled Projections (GDDP) dataset. The NEX-GDDP dataset includes downscaled daily climate projections at a high spatial resolution of 0.25° × 0.25° from 21 global-scale general circulation models (GCMs) conducted under the Coupled Model Intercomparison Project Phase 5 (CMIP5) (Thrasher et al., 2012). Detailed information about the 21 models can be found in Supplementary Table A1. These GCM runs were developed for the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5) (Flato et al., 2013). The NEX-GDDP dataset consists of CMIP5 GCM outputs bias corrected against the Global Meteorological Forcing Dataset (GMFD) (Sheffield et al., 2006), a historical reanalysis dataset based on meteorological station data, using the Bias-Correction Spatial Disaggregation method. This quantile-mapping approach corrects biases between the GCMs and GMFD data over the historical period (1980–2005) for each quantile individually, allowing for non-constant bias across the temperature domain. All 21 CMIP5 GCMs available through NEX under RCP4.5 and RCP8.5 were used in this study, resulting in 42 temperature projections. RCP8.5 is a high-emission business-as-usual scenario in absence of climate mitigation policies, resulting in the highest radiative forcing among the total set of RCPs (Riahi et al., 2011). RCP4.5 is a medium-low climate mitigation scenario that stabilizes radiative forcing at 4.5 W per square meter (W/m^2) in the year 2100 without ever exceeding that value (Thomson et al., 2011). Thus, using RCP4.5 and RCP8.5 can provide a range of possible future climate conditions in this study.

The daily temperature projections in the geographic region (116.875°E-121.125°E, 30.875°N-35.125°N) that covers 104 counties of Jiangsu Province (see Supplementary Fig. A1) were selected in this study. Daily average temperature projections were computed as the average of daily minimum temperature and maximum temperature for each grid cell. County-level daily average temperature projections were calculated by taking the area-weighted mean daily average temperature of each grid cell that fell fully or partially within a certain county boundary in Jiangsu Province. The weights that represented the approximate fraction of each cell covered by the county polygon were normalized so that they added up to one. In order to keep consistent with the 25-year baseline period from 1981 to 2005, two 25-year future periods from 2016 to 2040 and 2041–2065 were used in this analysis.

2.2. Population projections

To isolate the climate-only effect on heat-related mortality, a no population change scenario was first used in this study by assuming the future population is the same as the baseline population in Jiangsu, China. County-level population data based on the 2010 Population Census of China was used as the baseline population. To account for the future demographic changes, population projections at 0.125° × 0.125° resolution under five shared socioeconomic pathways (SSPs) in Jiangsu Province from 2010 to 2060 were applied (Jones and O'Neill, 2016). The SSPs describe a set of plausible alternative futures of societal development without considering the effects of climate change and new climate policies over the 21st century (O'Neill et al., 2014). In SSP population projections, the assumptions of Chinese population changes are low fertility, low mortality, medium migration, and high education for SSP1; medium fertility, medium mortality, medium migration, and medium education for SSP2; high fertility, high mortality, low migration, and low education for SSP3; high fertility, high mortality, medium migration, and polarized education for SSP4; low fertility, low mortality, high migration, and high education for SSP5 (KC and Lutz, 2017).