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# Climate Variability and Population Health in China: Updated Knowledge, Challenges and Opportunities

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## 1. Introduction

With remarkable economic growth in the past three decades, China has already overtaken the USA as the largest single emitter of carbon dioxide since 2007 (United Nation Statistics Division, 2009) and encountered many environmental challenges such as climate change, which significantly affects population health. According to the latest assessment report by the Intergovernmental Panel on Climate Change (IPCC) (Cruz et al., 2007), an evident clear warming trend has been observed in most areas of China during the last 50 years. Moreover, since the 1990s, China has experienced frequent extreme weather events, such as a 40-day episode heatwave in Shanghai in 2003, the longest heatwave being recorded for the last 50 years (Tan & Huang, 2004). The recent severe drought in Yunan Province of southwest China highlights the climate threat in China (Qiu, 2010). Under a medium-low greenhouse gases emission scenario, an annual temperature increase of 1.5°C by 2020 is projected in China (relative to the mean annual temperature of 1961–1990) and the figure will go up to 4.5°C by 2080s (Chinese Academy of Agricultural Sciences, 2009). More extreme weather events will likely occur more frequently and intensively (Cruz et al., 2007). The impacts of such climate variability should be better understood in order to develop adaptation strategies at all levels of government as well as practice guidelines for service providers to build climate change resilience for citizens.

Study of the association between climate variability and human health has been largely neglected among Chinese researchers in the past decades as argued in two recently published editorials (Kan, 2009, Wang & Chen, 2009). Given the largely affected population size, various regions with different climatic characteristics, and a diverse socio-economic status across China, it is necessary to understand and recognize the updated knowledge of health impact associated with climate variability in China, and to identify the opportunities available to meet further challenges. However, there has been no such complete picture presented in China to date. This study has systematically reviewed the research examining the association between climate variability and population health in China. The aim is to

provide evidence for policy makers and practitioners which will assist in the reduction of health risks of climate change and the development of national and regional adaptation strategies to deal with the health impacts of future climate change.

## 2. Methods

Indicators of climate variability included temperature, rainfall, relative humidity, air pressure, wind speed, hours of sunshine, evaporation and the Southern Oscillation Index (SOI, an index of El Nino/La Nina events). Extreme weather events, i.e. heatwave/extreme heat, flood, draught and typhoon, were also included. Direct and indirect impacts of climate variability on population health were reviewed, including communicable diseases and non-communicable conditions. Indoor exposures and clinical case reports and studies solely on the health impacts of air pollution were excluded.

Studies published during the last 30 years between 1<sup>st</sup> January 1980 and 31<sup>st</sup> December 2010 were included as few studies before the 1970s could be found due to the Great Cultural Revolution in China. Publications in academic journals, conference proceedings, and reports from governments and professional organizations written either in English or in Chinese were included. The key words, in both English and Chinese, included “climate or weather or temperature or rainfall or El Nino or heat wave” and “health or mortality or morbidity or death or hospital” and “China or Chinese”. In addition to PubMed, Web of Science, Scopus, and Google Scholar, major Chinese literature search engines in China were used, including the China National Science and Technology Library (NSTL), China Knowledge Resource Integrated Database (CNKI), VP info (VIP) and Wanfang Data. Although meta-analysis is not recommended for this review due to the large variance of the data sources, study designs and quality of research, the spatial and temporal distribution of the reviewed studies were described. In addition, the strength of the association between climate variability and health outcomes were qualitatively indicated based on the number of studies which show a significant relationship.

## 3. Results

In total, 270 original studies were identified with 77% of them published in Chinese journals with a majority having an English abstract. There were only 4 relevant studies published before 1990 and over 90 articles in 2009 and 2010. These studies were conducted in different regions across China with most in major cities such as Beijing and Shanghai. The health impacts include indirect impacts on communicable and non-communicable diseases and direct health impacts of extreme weather events. The strength of the association between climate variability/extreme weather events and the health outcomes is summarised in Tables 1 and 2, while the tempo-spatial distribution of the number of studies is presented in Figure 1.

### 3.1 Indirect impacts

#### 3.1.1 Communicable diseases

Communicable disease is still a major public health problem in China. In 2009, there were 5,898,415 newly notified cases of infectious diseases, which was a 9.2% increase comparing to that in 2008 (Ministry of Health in P. R. China, 2009). For some infectious diseases, climate variability such as temperature, rainfall and relative humidity could be one of the driving causes of their transmission. The studies of the association between climatic variables and infectious diseases in China mainly focused on vector-borne disease, water/food borne disease and airborne disease.

|                                       | Temperatures | rainfall | relative humidity | air pressure | wind speed | Evaporation | hours of sunshine | El Nino |
|---------------------------------------|--------------|----------|-------------------|--------------|------------|-------------|-------------------|---------|
| <b>vector-borne diseases</b>          |              |          |                   |              |            |             |                   |         |
| malaria                               | +++          | ++       |                   |              |            | +           | +                 |         |
| dengue fever                          | ++           | +        | +                 |              | +          |             |                   | +       |
| schistosomiasis                       | +++          | ++       |                   |              |            | +           |                   |         |
| typhus                                | +            | +        |                   | +            |            |             |                   |         |
| Japanese encephalitis B               | +            | +        |                   | +            |            | +           |                   |         |
| hemorrhagic fever with renal syndrome | ++           | ++       | +                 | +            | +          | +           | +                 | +       |
| <b>water/food borne diseases</b>      |              |          |                   |              |            |             |                   |         |
| bacillary dysentery                   | +++          | +        | +                 | +            | +          | +           | +                 |         |
| cholera                               | +            | +        |                   | +            |            |             | +                 |         |
| hepatitis                             | +            |          | +                 | +            |            |             |                   |         |
| typhoid                               | ++           | +        |                   | +            |            | +           | +                 |         |
| other enteric infections              | +            | +        |                   |              | +          |             |                   |         |
| <b>airborne diseases</b>              |              |          |                   |              |            |             |                   |         |
| severe acute respiratory syndrome     | +++          |          | +                 | +            | ++         |             | +                 |         |
| asthma                                | ++           |          | +                 | +            |            |             |                   |         |
| pneumonia                             | ++           |          | +                 | +            |            |             |                   |         |
| influenza                             | +            |          | +                 | +            |            |             |                   |         |
| chronic bronchitis                    | +            |          |                   | +            |            |             |                   |         |
| measles                               |              | +        |                   | +            |            | +           |                   |         |
| scarlet fever                         |              |          |                   |              | +          |             | +                 |         |
| pulmonary tuberculosis                | +            |          | +                 | +            |            |             |                   |         |
| <b>non-communicable conditions</b>    |              |          |                   |              |            |             |                   |         |
| hypertension                          | +            |          |                   | +            |            |             |                   |         |
| cancer mortality                      | +            |          |                   | +            |            |             |                   |         |
| chronic liver disease                 | +            |          |                   |              |            |             |                   |         |
| cardio cerebral vascular disease      | +++          |          |                   |              |            |             |                   |         |
| respiratory disease                   | +            |          |                   |              | +          |             |                   |         |
| <b>Total mortality</b>                | +++          |          | +                 |              |            |             |                   |         |

Table 1. Strength of the association between climate variability and health outcomes in China (Number of studies showing a significant association: + 0-5, ++ 5-10, +++ >10)

### 3.1.1.1 Vector-borne diseases

Malaria, dengue fever, schistosomiasis, Japanese encephalitis, hemorrhagic fever with renal syndrome and typhus were examined in China with regard to their associations with climatic variables.

|                                    | extreme weather events     |       |         |         |
|------------------------------------|----------------------------|-------|---------|---------|
|                                    | heatwaves/<br>extreme heat | flood | drought | typhoon |
| <b>vector-borne diseases</b>       |                            |       |         |         |
| malaria                            |                            | +     |         |         |
| schistosomiasis                    |                            | +     |         |         |
| Japanese encephalitis B            |                            | +     | +       |         |
| <b>water/food borne diseases</b>   |                            |       |         |         |
| bacillary dysentery                |                            | +     | +       |         |
| typhoid                            |                            | +     | +       |         |
| <b>airborne diseases</b>           |                            |       |         |         |
| measles                            |                            | +     |         |         |
| <b>non-communicable conditions</b> |                            |       |         |         |
| chronic liver disease              |                            |       | +       |         |
| cardio cerebral vascular disease   | +++                        |       |         |         |
| respiratory disease                | +                          |       | +       |         |
| <b>Total mortality</b>             | ++                         | +     |         | +       |

Table 2. Strength of the association between extreme weather events and selected health outcomes in China (Number of studies showing a significant association: + 0-5, ++ 5-10, +++ >10)

*Malaria* is the most studied mosquito-borne disease related to climate variability. There has been a recent come back of malaria in China and climate variability might be one of the drivers. Studies, using empirical data, showed a positive association between temperatures and incidence of malaria in different areas of China with a lagged effect ranging from one to two months (Bi et al., 2003, Hui et al., 2009, Xiao et al., 2010). Increase in rainfall could also lead to more malaria cases in southern China but may not be an influencing factor in northern region with temperate climate (Wang et al., 2009, Zhang et al., 2010). Moreover, malaria transmission can be related to other meteorological variables, such as the effect of fog with an one-year lag time and the impact of El Nino (Tian et al., 2008, Bi et al., 2005).

*Dengue Fever* is a tropical or subtropical disease occurring only in three Provinces in southern China. Minimum temperature, rainfall, and relative humidity could affect the density of *Aedes*, the vector of dengue in China. These variables therefore play a role in the transmission of dengue fever (Yi et al., 2003a, 2003b, Yu et al., 2005). An empirical model using average vapour pressure projected that the epidemic area of dengue fever in southern China may extend to northern areas due to the effect of population growth and climate change (Hales et al., 2002). If temperature increases about 1-2°C, some non-endemic tropical regions in China may suffer from dengue fever epidemics in future (Chen et al., 2002).

*Schistosomiasis* has re-emerged in southern China despite great success of the disease prevention and control programs over the last 50 years. There are more than 800,000 chronic schistosomiasis sufferers in the seven southern Provinces with about 3,000 new cases being notified each year (Ministry of Health in P. R. China, 2009). In 2009, the incidence increased nearly 20% compared with that in 2008. Since the late 1990s, there have been several studies identifying both favourable and unfavourable effects of the changing environment, including climate variability, on the transmission of schistosomiasis due to the construction of the Three Gorges Reservoir (Zheng et al., 2002, Xu et al., 1999, Xu et al., 2000). Results from other studies also indicate that increase in temperatures could lead to more schistosomiasis cases (Yang et al., 2005a, 2005b, 2006). With consideration of the biological activities of host snails, a study suggested that expansion of schistosomiasis transmission

into currently non-endemic areas in the north is possible, with an additional risk area of 783,883 km<sup>2</sup> by 2050 due to climate change (Zhou et al., 2008).

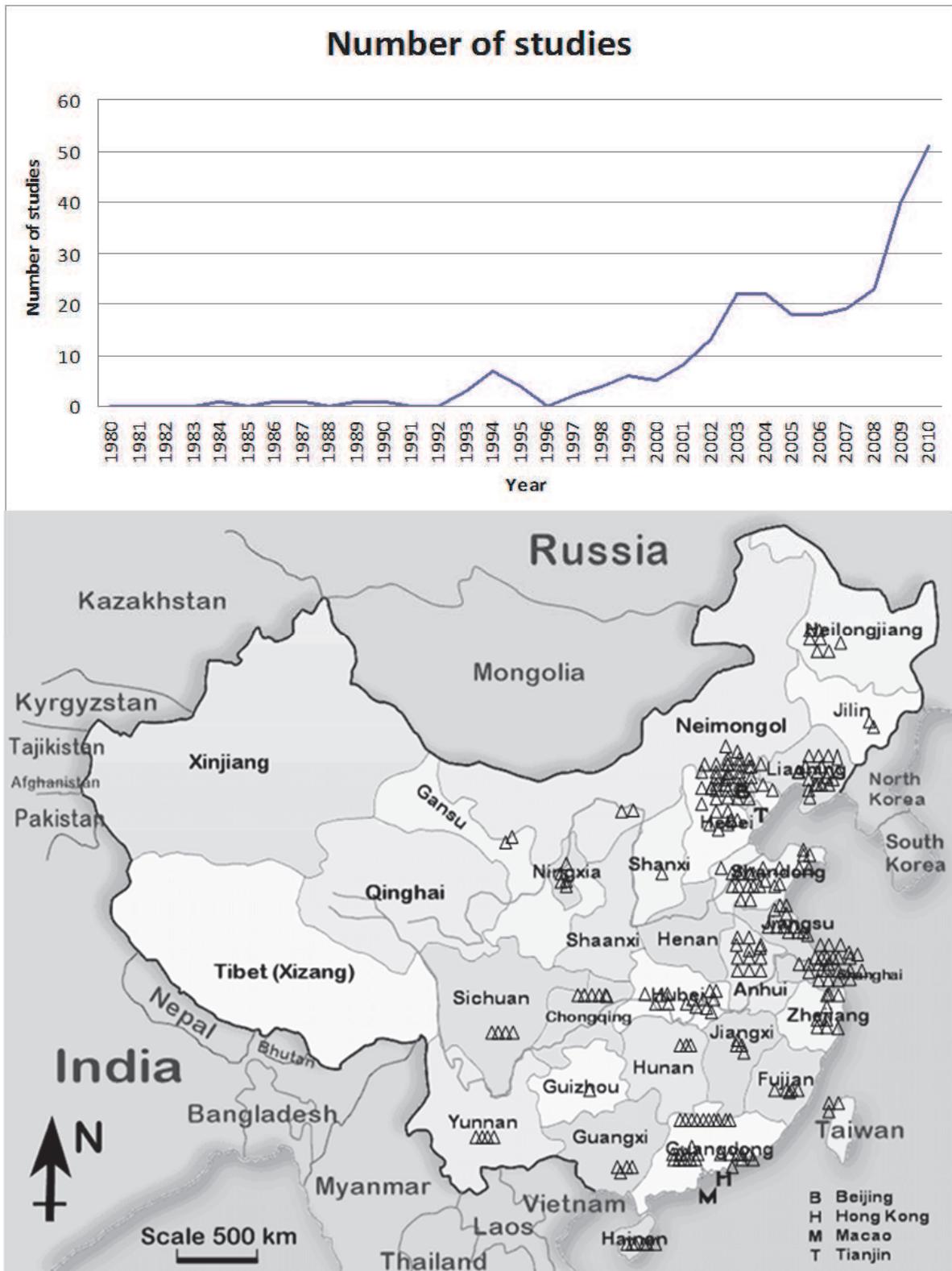


Fig. 1. Tempo-spatial distribution of the reviewed articles in this study (Each Δ represents one study)

*Japanese encephalitis* (JE) is another major mosquito-borne disease in China with 3,914 new cases notified in 2009. Evidence suggested that temperature and precipitation had a significant relationship with the transmission of JE with an one-month lag effect and a threshold of 25.2 °C for maximum temperature and 21.0 °C for minimum temperature were also detected in a northern city (Bi et al., 2007b, Liu & Du, 2008, Qu et al., 2006). Its incidence may also be negatively related to air pressure (Qu et al., 2005). In addition, mosquito density in conjunction with pig density were used to forecast JE epidemics (Hsu et al., 2008).

*Hemorrhagic fever with renal syndrome* (HFRS) is caused by Hantaviruses, with rodent as the host. Although great achievements have been made for the disease control since the 1980s, there are still around 9,000 new cases notified each year (Song, 1999). Using different models, studies suggest that the density of rodent and autumn crop production were positively associated with the incidence of HFRS while rainfall and Huai River water level were negatively associated with the incidence in low-lying epidemic areas (Bi et al., 1998, Bi et al., 2002, Hu et al., 2007). A positive relationship between HFRS and temperature, precipitation and relative humidity was also reported in northeast China (Guan et al., 2009). Recent studies in northern China indicate that rainfall, temperature and relative humidity play a significant role in HFRS transmission (Zhang et al., 2010, Lu, 2007).

*Typhus* is caused by Rickettsiae and transmitted by rodent and mite. A negative relationship between air temperature or land surface temperature and the incidence of scrub typhus was reported (Qu et al., 2004a, 2005). However, the analyses of annual dataset rather than monthly or weekly data may affect the accuracy of the study results.

### 3.1.1.2 Water/food borne diseases

Less attention has been paid to water/food borne diseases, compared with vector-borne diseases. The most common water/food borne diseases that have been studied are infectious diarrhoeal diseases, including bacillary dysentery, cholera, hepatitis, typhoid, and other enteric infections.

*Bacillary dysentery* suitable climatic conditions are high temperature and high humidity in Chengdu, southwest China, and Shaoxing, northern China (Liao et al., 2009, Tan & Chen, 2003, Lu et al., 2009, Zhou et al., 2009, Sun et al., 2008, Huang et al., 2009). Possible impact of El Nino on the transmission of bacillary dysentery in Shandong, north China, was reported (Zhang et al., 2007). In addition to weather factors, a study in Beijing also included socio-economic factors. The results indicate that less rainfall, less hours of sunshine as well as a higher number of refrigerators per 100 households were related to lower incidences of bacillary dysentery in urban areas in Beijing (Jia et al., 2009).

*Cholera* is an acute enteric infection transmitted by contaminated drinking water or food. However the number of cases in China has reduced dramatically in recent years due to effective disease prevention and control programs. The association between meteorological variables and the incidence of cholera has been reported by a very limited number of studies in China. Results from these ecological studies indicate that high temperature, high rainfall and low air pressure might increase the number of cases of cholera (Yang, 2003, Tan et al., 2003, Li et al., 2006, Tan, 2004).

*Typhoid fever and paratyphoid fever* have decreased significantly in China due to health promotion and improvement of environmental hygiene. However, there was an increase of new cases in China with 16,938 notified cases in 2009, 8% higher than that in 2008 (Ministry of Health in P. R. China, 2009). Back-Propagation Neural Network models were developed to examine the relationship between meteorological factors and Typhoid Fever or

Paratyphoid Fever (Zhang et al., 2009a, 2009b; Qu et al., 2004b). These results indicate that meteorological and geographic factors may contribute more than 80% of the transmission of typhoid fever in China.

#### *Other enteric infections*

In 2009, there were more than 650,000 new cases of 'other infectious diarrhoeal disease' notified to the Ministry of Health in China (Ministry of Health in P. R. China, 2009). A medical-meteorological forecast model of infectious diarrhoeal disease was developed to be able to provide a better service for Olympic Games 2008 in Beijing (Zhang et al., 2008). Preventive measures with consideration of climate variations were discussed in a study in Nanjing regarding intestinal communicable disease in general (Cheng et al., 1995).

#### **3.1.1.3 Airborne diseases/respiratory diseases**

Similar to water/food borne diseases, the association between climate variability and airborne diseases has not been well addressed in China. After the 2003 pandemic of severe acute respiratory syndrome (SARS), several studies raised the question that if meteorological factors could be one of the drivers of this pandemic, particularly by studies in Beijing, Guangdong Province and Hong Kong, where most of the cases came from (Yip et al., 2007, Tan et al., 2005, Chan et al., 2009, Zhang et al., 2004, Ye et al., 2003, Chen et al., 2004, Huang et al., 2004, Lin & Zheng, 2004, Tang et al., 2010, Bi et al., 2007a). Temperature, relative humidity, and wind velocity were identified as the three key meteorological determinants affecting the transmission of SARS in Guangdong (Yuan et al., 2006). A negative association between temperature and daily number of cases was reported (Lin et al., 2006, Bi et al., 2007a) and a certain range of temperature (14-28°C) was identified suitable for development and transmission of the SARS virus (Chen et al., 2004, Tan et al., 2005).

The relationship between weather variables and other respiratory diseases, including asthma, pneumonia, influenza, chronic bronchitis, measles, scarlet fever and pulmonary tuberculosis (TB), were also analysed in some areas in China. A study in a coastal city Qingdao, for instance, reported that high air pressure, low temperature, and low humidity were favourable weather conditions for asthmatic attack among children in the urban area (Liu et al., 2007). A study of pneumonia in children indicates that low air temperature could increase the epidemic of respiratory syncytial virus (RSV), one of the main factors causing pneumonia in children (Wang et al., 2005). Furthermore, a time-series analysis for hospitalised children with pneumonia 1970-1990 in Heilongjiang Province in northeast China also found the association with temperature, air pressure and humidity (Wang et al., 1994). Influenza was mainly investigated in Hong Kong and Shenzhen in southern China (Chan et al., 2009, Zhai et al., 2009b, Lin & Zheng, 2004, Zhai et al., 2009a, Fang et al., 2005, Tang et al., 2010) as well as in Beijing (Liu et al., 2002). An international study indicated that relative humidity was associated with the incidence of influenza A while mean temperature was the key climate variable associated with the incidence of influenza B in Hong Kong (Tang et al., 2010). A study of 200 older patients with chronic bronchitis suggested that decreased temperature and high air pressure were related with increased number of cases in Nanjing in southeast China (Li et al., 2008a). A study in a drought area in northeast China suggested that incidences of epidemic measles and cerebrospinal meningitis were correlated to annual mean air pressure, precipitation, and evaporation (Qu et al., 2004a). Wind speed and daily sunshine hours were reported being positively related to the incidence of scarlet fever in Beijing (Li et al., 2007). Furthermore, a significant positive relationship between temperature and pulmonary TB was reported in Nanjing, which may provide more

evidence to encourage development of national TB control programs (Liu & Sun, 2009) as TB is a major public health problem in China with more than 270,000 new cases in 2009 (Ministry of Health in P. R. China, 2009). However, more studies need to be conducted to confirm the findings.

### 3.1.2 Non-communicable conditions

The association between weather conditions and hypertension, cancer mortality, chronic liver disease, cardio-cerebral vascular disease, respiratory disease and total mortality were reported in China. Several studies used meteorological variables to develop artificial neural net models predicting incidence of hypertension, indicating that temperatures, particularly large variations between seasons, were key factors for prediction (Ma et al., 2003, Li, 2004, Zhou et al., 2008, Gu et al., 2001). One study analysed weather conditions and cancer mortality, indicating an increased mortality of lung cancer and a decreased mortality of liver cancer may be related to high temperatures (Li et al., 2005). Two studies applied Chinese traditional medicine to study the relationship between climatic factors and liver cirrhosis (Cai & Wang, 2005) and chronic virus hepatitis (Wang, 2002), suggesting that temperatures, particularly cold seasons might be a trigger of upper gastrointestinal bleeding in cirrhosis. Based on 42,005 cases from four major hospitals in Wuhan from 1994 - 1998, eight cardiovascular and respiratory diseases were analysed and four meteorological forecast models of daily hospitalisation of each disease were developed based on a set of indices in different seasons, especially the weather process of cold front (Chen et al., 2001). In addition, an association between temperature, air pressure, humidity and incidence of cardio-cerebral vascular disease including stroke was reported in various regions in northern and southern China (Liu et al., 2004, Liu et al., 2008, Han et al., 2008, Wang et al., 2001, Yu et al., 2008, Meng & Li, 2004, Lu & Li, 1997, Zhao et al., 2000, Cheng et al., 1994, Guo et al., 2000, Yang et al., 2009, Zhu & Chen, 2008a, Li et al., 2009, Zhu & Chen, 2008b, Chen et al., 1993, Zhao et al., 1998, Cheng et al., 2000, Wu & Ge, 1990). These studies have focused either on hospital visits or mortality with most of them using time-series analyses. However, one of the key limitations is that the impact of seasonality and potential long term trend were not adjusted in most of the analyses. The relationship between climate variability and total population mortality was reported in studies in southern China (Du et al., 1987, Li et al., 2009). In addition to the seasonal variations in mortality observed in Wuhan, the results indicate that the excess mortality would increase by 12% for 1°C increase in temperature and by 4% for 1% decrease in relative humidity in Chongqing, southwest China. However, they did not attempt to identify a threshold temperature of the association.

### 3.2 Direct impacts

Although China has experienced frequent and severe extreme weather events in recent years, research on the impacts of these extreme weather events on population health is very limited.

Heat-related mortality was the mostly investigated health outcome due to the impact of extreme heat (Hajat & Kosatky, 2010). The health impacts of heatwaves in Shanghai have been reported recently (Tan et al., 2006, 2007, 2010). Results from these studies indicate that high temperature is associated with increased mortality. Furthermore, air pollution and urban heat island effect could worsen the adverse health effects from exposure to extreme heat. However, a lower mortality was observed in 2003 than that in 1998 in Shanghai, which

may be due to the introduction of a heat-health warning system implemented in 2001 (Tan et al., 2004), along with the improvement in living conditions and socio-economic status (Tan et al., 2007). A V-shape association between heatwave and mortality was also reported in another coastal city, indicating 1°C degree increase in temperature may lead to relative risk of mortality increase by 3.6% but a threshold temperature was not reported (Chen et al., 2009). A U-shape relationship between temperature and mortality from coronary heart disease and cerebral infarction in elderly Chinese was reported in Taiwan (Pan et al., 1995). It was found that in the elderly, the risk of cerebral infarction at 32°C was 66% higher than that at 27-29°C while the mortality from cerebral haemorrhage decreased with increasing temperature at a rate of 3.3% /1°C. An international study indicates that among the four studied countries, the United States, Canada, China and Egypt, the greatest increase in heat-related mortality would occur in China, particularly in areas with irregular heatwaves (Kalkstein & Smoyer, 1993). Another international study conducted by researchers in Japan also reported that climate change would significantly increase excess heat stress mortality in China, if no adaptation or mitigation efforts were made (Takahashia et al., 2007).

Heat-related morbidity has not attracted sufficient attention by Chinese scholars, even though morbidity should be more sensitive as a health indicator comparing to mortality. The association between heat stress and cardiovascular disease was reviewed by a Chinese researcher but interestingly not one reference was cited from China (Cheng & Su, 2010). The characteristics of disease spectrum in internal medicine outpatients during the period of extremely high temperature and drought were investigated in Chongqing, reporting the health impacts varied by age and sex and respiratory disease was the most affected by extreme high temperature and drought (Yu et al., 2009b).

Health impacts of other extreme weather events, such as drought, flooding, and typhoon, were examined by a very limited number of studies. The interactions of drought and extreme heat on infectious diseases, including digestive infection, malaria and Japanese Encephalitis, were reported (Long et al., 2009, Qu et al., 2009, Yu et al., 2009a, Yu et al., 2004). Using a synthetic evaluation model, a significantly higher loss of life in flood season was observed than that in the no-flood season (Li et al., 2007, Tan et al., 2007). Typhoon Saomei in August 2006 hit southern China and an epidemiological study reviewing more than 3,000 residents in a village in Fujian suggested that risk factors of injuries in typhoon include wind speed and failure to take specific preventive measures (Shen et al., 2009).

## 4. Discussion

### 4.1 Increased concerns among Chinese scholars

The lack of studies on climate change and human health in China has been clearly reflected in the latest 2007 IPCC fourth assessment report. Two sections discussed the association between climate change and human health in China. One is in Chapter 8 (Confalonieri et al., 2007), a chapter reviewing the worldwide human health impacts, vulnerability and adaptation to climate change. The other is the human health section in Chapter 10 (Cruz et al., 2007), which very briefly summarised the risks to human health and adaptation in Asia. It is not surprising that, among the over 570 cited articles from both sections, only two studies were specifically about climate change and human health in China, which included a study of the health effect of heat and a study of climate variations and schistosomiasis (Yang et al., 2005, Tan et al., 2004).

Based on our review, however, a clear increase in the number of studies in this research field in China has been observed, particularly since 2000. Researchers from the China Medical University, Beijing University, Chinese Academy of Sciences, Chinese Center for Disease Control and Prevention, Fudan University, Shanghai Urban Environmental Meteorological Research Centre, Nanjing University, Chongqing Medical University, Hong Kong University, have conducted important studies that are of significance to improve the understanding of the complex relationship between climate variations and human health in Chinese settings. Based on the map in Figure 1, it is interesting to see that most of the studies were conducted in major cities along the east coast and the Yangtze River region. It could be due to the research capability of local institutions and the increased concerns about the environmental and ecological change related to the construction of the Three Gorges Reservoir region over the Yangtze River. This distribution reflects the increased concerns not only about the climate change per se but also about the ecological sustainability due to other environmental changes in China, which may have implications for other developing countries that have similar environmental issues.

A global study recently initiated by the United Nations Development Programme (UNDP), entitled “Piloting Climate Change Adaptation to Protect Human Health” will allocate more than 20 million US dollars to improve the adaptive capacity in health sectors in seven countries (UNDP, 2009). As one of the participating countries, the Chinese government has promised to make a great effort to tackle climate change. It is expected that with the implementation of this global study, a strong link between climate monitoring and the health surveillance system will be established and more quality research on climate change and human health will be published to provide evidence for policy making regarding the protection of human health from climate change.

#### **4.2 Advances and limitations in previous studies**

It is recognized that previous studies have identified some important associations between meteorological variables and human health in China. There are some advantages of these studies. For example, in addition to ecological time-series models, various statistical models were applied to quantify the association between climatic variables and diseases, such as back-propagation neural network models, Bayesian models and grey relational analysis. Results from these advanced models confirmed the impact of climate variability on diseases, particularly at a local or regional level. Several projective studies have also been conducted to predict the potential health risks due to climate change. In addition to climatic variables, modified effects with other environmental factors, such as urban heat island and air pollution, were included by some of the previous studies in examining the health impacts of heatwaves.

Some of the research gaps are summarised as follows.

- a. Health impacts of climate change have not been systematically assessed, i.e. there is not a national or state study presenting the overall distribution of the vulnerability to future climate change. Previously covered study regions and populations are limited given China has a very large population and area with distinct climatic zones. Some regions, such as Tibet and Xinjiang in western China, are obviously neglected, although residents in these regions may even be more vulnerable due to their low economic status and poor adaptation capacity. There is also a lack of studies on sub-groups who are more vulnerable to climate variations, particularly children, elderly and the people living in rural areas.

- b. Studies on the health impacts of extreme events, such as heat waves and flooding, are limited. Only association between extra mortality and heatwaves or flooding was analysed in southern China. Other adverse health outcomes, e.g. the impacts of heatwaves on mental health and renal disease, have not been examined, while some evidence indicates significant associations exist (Hansen et al., 2008a, 2008b).
- c. There is a lack of studies on risk factors for the vulnerability to climate change. Most of previous studies focused on health impact assessment with few of them exploring the risk factors associated with these extra health burdens. However, this information would be of great value to develop effective intervention programs with focuses on vulnerable groups.
- d. Although a survey of coastal residents in China, Japan and Korea in 2006 indicates global warming was perceived as one of the higher environmental risks (Zhai & Suzuki, 2009), there is an obvious lack of studies on risk perceptions among individuals and stakeholders, a lack of investigating any adaptation barriers as well as cost-benefit analysis of potential intervention programs. However, results from these studies would be very useful to build resilience to climate change in local communities.
- e. There is a lack of solid evidence to form a base for decision making, given the limitations in quality of previous studies in China. Few studies can be transferred into policy and public health practices, such as direct evidence (e.g. threshold temperature identification) for developing early warning and emergency response systems to adapt to future climate change.

#### **4.3 Challenges for conducting research in this field**

Possible barriers and challenges in conducting quality studies in this research field in China and other developing countries may include the following issues.

- a. Data quality issues: Reliable and complete data, either from surveillance systems or project based, are the key to conduct research on climate change and human health. Similar to other developing countries, data quality could be a problem for Chinese researchers. Although Chinese government established an infectious disease notification system in the 1950s and after the pandemic of SARS in 2003, the infectious disease notification system has been improved dramatically to ensure accurate and quick reporting of new cases to the Ministry of Health, data quality is still not comparable to those from developed countries that may have over 100 years established disease surveillance systems. Moreover, data of non-communicable disease have not been routinely collected in most regions of China. However, by acknowledging the challenges, it should not be an excuse for not doing any research in China and other developing countries.
- b. Issues on data availability and sharing: In addition to a short period of reliable data availability, most health surveillance data and environmental data are not open to the public and not free available to researchers. Problems also lie in the management and exchange/sharing data between relevant departments, such as meteorological bureau and public health departments. This reflects little collaboration between health departments and other relevant environmental departments, which is essential for research on climate change as this is not a task that one single department can fulfil.
- c. Research capacity: There is a lack of experienced scholars with advanced knowledge and skills in this field in developing countries. As an emerging research field, research on climate change and human health requires the latest, advanced and cross-

- disciplinary knowledge and analytic skills to address this global exposure with various local impacts. Therefore, it is agreed that developing countries, including China, do need support from colleagues in developed countries to build research capacity in effective collaboration.
- d. Knowledge transfer between languages: English is one of the big obstacles for Chinese researchers to access up-to-date literature and communicate with colleagues from other countries. Some excellent literature review of overseas studies have been written and published in Chinese (Li et al., 2008b, Qin & Zhang, 2009, Tan & Huang, 2004, Tan & Zheng, 2005) but only a very small proportion of the Chinese studies have been published in international journals and most Chinese journals cannot be accessed by overseas scholars. One of the aims of this review is to summarise the results from studies published mostly in Chinese to provide more evidence for developing a global adaptation strategy.
  - e. Research funding and government support: Although there are more climate-health studies being published in recent years, compared with the funding for conducting research on meteorological modelling and the impact of climate change on agriculture, ecology and nature protection, the research funding for examining health impacts of climate change is significantly less. At the time of writing this review, by searching “climate change” in the National Nature Science Foundation of China, the main research funding source for Chinese scholars, among the 202 supported climate change projects between 2008 and 2010 only one project is related to human health, which is to study the interactive impacts of air pollution and climate change on short-term mortality in major cities (Pan, 2009).

#### 4.4 Opportunities and recommendations

China issued its first National Environment and Health Action Plan (2007-2015) in 2007, aiming to develop an efficient system for environmental health by 2015 (Ministry of Health in P. R. China, 2007). The plan addresses some of the important issues regarding environment and health, such as the need to develop relevant laws and regulations, to establish nationwide surveillance networks and early warning systems and to share information among different government agencies and stakeholders. This plan also recognizes the importance of a supportive coordination mechanism by placing environment and health “in the list of government priorities”, which is a great positive change of the Chinese government’s attitude to environment and health. Research on climate change and health is mentioned in one paragraph of this strategic plan and is identified as one of the research priorities to provide technical support capacity on environment and health (Ministry of Health in P. R. China, 2007).

It is no doubt that more systematic research should and will be conducted in China to have a better understanding of the relationship between climate change and human health and to better adapt to future inevitable climate change. The causes of vulnerability to climate change in the Asia Pacific region, e.g. destructive growth, poverty, political rigidity, dependency and isolation, were summarised in a paper in the late 1990s, indicating that climate change would bring an extra health burden to the currently over-loaded health system in these regions (Woodward et al., 1998). In China, the largest country in Asia with a very high population density and relatively low socio-economic status, environmental health risks have not had a high priority in public health practice. More research is necessary to provide robust evidence to policy makers to address this global exposure with various local impacts.

Potential research directions for further studies in China, perhaps for other similar developing countries as well, may include:

- a. Improving early warning systems for infectious diseases by integrating meteorological variables, with consideration of different categories and subcategories of infectious disease in regions with various geographic and climatic characteristics;
- b. Examining health impacts of climate variability on more health outcomes that have local importance, particularly non-communicable diseases;
- c. Identifying risk factors among vulnerable subgroups and regions with higher risks that would be most vulnerable to climate change in the future;
- d. Modelling future health burden of disease that can be attributable to climate change or can be avoidable by effective interventions;
- e. Developing intervention studies and programs with a focus of local communities with high risks and conducting cost-effective analysis of any mitigation programs, which would be more appealing to policy makers;
- f. Formulating research on disaster preparation in terms of public health response systems; and
- g. Integrating multi-disciplinary research on climate change adaptation to increase resilience of local communities, which should be systematically conducted as early as possible to deal with future climate change.

It is acknowledged that government support and international collaboration would be crucial to the success of research in this field. Support from government at all levels is extremely important in terms of providing research funding and opportunities for capacity of research building in Chinese institutions. In addition, collaborations with colleagues in developed countries would be significantly helpful in transferring knowledge and skills and sharing information, particularly that young researchers should be encouraged to communicate at an international platform. It is expected that Chinese scholars can recognize these risks/opportunities and are willing to devote themselves in such a challenging and rewarding research area for the health benefit of ourselves, our next generations and our planet.

## 5. Conclusion

This systematic review has identified the current research status about climate variability and population health in China, suggesting that climate variability could play a role in some of the major public health problems in China. Recommendations for further studies have been provided not only for Chinese scholars but also for researchers in other developing countries. It is expected that in order to reduce the health risks of future climate change, further research should be conducted with sufficient support from governments to fill up the identified research gaps so as to assist in evidence-based policy-making process in public health within a changing climate.

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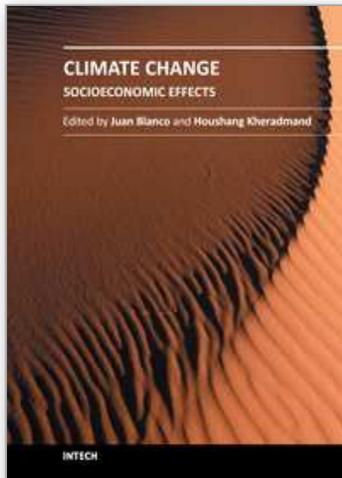
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