

Impacts of Climate Change on Human Health and Adaptation Strategies in South China

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Abstract

This study reviews the impacts of climate change on human health and presents corresponding adaptation strategies in South China. The daily mean surface air temperatures above or below 26.4°C increase the death risk for the people in Guangzhou, especially the elderly are vulnerable to variations in temperature. Heat waves can cause insomnia, fatigue, clinical exacerbation, or death from heatstroke etc., while cold spells show increases in patients with fractures. During a cold spell period, the rates of both on-site emergency rescues and non-implementable rescues increase, and the risk of non-accidental deaths and respiratory disease deaths significantly rise as well. Both time series of hazy days and ozone concentrations have significant positive correlations with the number of patients with cardiovascular diseases. Both malaria and dengue fever reach higher altitudes and mountainous areas due to climate warming. Climate change is likely to bring stronger heat waves in the future, thereby increasing heat wave-related illnesses and deaths, particularly in the metropolitan areas of the Pearl River Delta. The projected increase of continuous cold days in Guangdong province and parts of northern Guangxi province will affect residents' health in the future. The rising temperature exaggerates ozone pollution, but it is not clear whether climate change is aggravating or mitigating haze pollution. The transmission potential of malaria in South China will increase by 39%–140% and the transmission season will extend by 1–2 months with an air temperature increase of 1–2°C. By 2050, most areas in Hainan province are projected to convert from non-endemic dengue into endemic dengue areas. The aging population will cause more vulnerable people. To mitigate the adverse impacts of climate change on human health, sound and scientific adaptation strategies must be adopted in advance, such as strengthening the surveillance of epidemic diseases in potential transmission areas, conducting timely weather forecasting for human health, evaluating health vulnerability to climate change, improving environmental and health education, and strengthening hazard management and the cooperation between meteorological and health departments.

Keywords: climate change; human health; impact assessment; adaptation strategy

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1 Introduction

The IPCC Fourth Assessment Report (AR4) [IPCC, 2007a] shows that global climate has undergone a significant warming. Observations also demonstrate that the global mean surface air temperature increased by 0.74°C during the past century, while the warming accelerated at 0.13°C per decade in the recent 50 years. Climate warming not only seriously affects the global economic, social, and political activities, but also involves a series of severe health problems [IPCC, 2007b; McMichael et al., 2003]. Climate change can affect human health through a variety of direct and indirect ways and complex mechanisms [Frumkin et al., 2008; McMichael et al., 2006]. At present, more than 100,000 patients die due to climatic factors every year in the world. It is expected that this number of fatalities will reach 300,000 by 2030 [Thakur, 2008]. Climate change has different influences on human health in different regions due to different socio-economic development levels, various adaptation capacities and different geographic locations [Zhou, 2010].

South China is located in a tropical and subtropical climate zone, bordering the South China Sea and is being influenced by the East Asian Monsoon [Du et al., 2004]. In the context of global warming, the climate in South China has undergone a significant change. During the period 1961–2010, the regional annual mean surface air temperature increased significantly by 0.16°C per decade [Du et al., 2013]. The economic development in South China is rapid but also extremely uneven. In the developed Pearl River Delta region, Hong Kong and Guangdong, climate change, the heat island effect, heat waves, smog, etc., seriously affect human health, while in the developing regions of Guangxi and Hainan, malaria, dengue fever and other infectious diseases frequently break out due to a weak prevention and adaptation capability. Those major diseases like diarrhea, malnutrition, malaria and dengue are highly climate-sensitive and expected to get worse in a changing climate. Even in the developed Pearl River Delta region, the outbreak of SARS in 2003 sounded an alarm for the prevention and control of infectious diseases.

Therefore, it is of significance to assess the impacts of climate change on human health and to present a sustainable adaptation strategy, thus mitigating the adverse effects of climate change on human health and the environment.

2 Impacts on human health in South China

2.1 Impacts from temperature variation

The change in daily mean surface air temperature and the diurnal temperature range ($\text{DTR} = T_{\max} - T_{\min}$) has a great impact on human health. The daily total mortality risk shows a U-curve with daily mean temperature. The daily mean temperature with the lowest mortality risk is 26.4°C ; temperature either above or below 26.4°C will increase the death risk. If the daily mean temperature is above 26.4°C , the mortality risk will increase by 1.9% and the cardiovascular disease risk will increase by 3.5% with air temperature increasing by 1°C , while there is no significant trend to the influence on respiratory system diseases. If daily mean temperature is below 26.4°C and temperature decreasing by 1°C , the daily total mortality risk, the cardiovascular disease risk and the respiratory system diseases will increase by 1.2%, 2.5% and 2.0%, respectively. High temperature events above 26.4°C have rapid and short-term impacts on mortality, and their relative risks generally peak in the same day and usually diminish within about 4 days. In contrast, the cold events with temperatures below 26.4°C have a slow and persistent impact on mortality. The relative risk generally peaks on the succeeding second or third day and its effects usually persist for 2 weeks or longer [Yang et al., 2012]. Therefore, the protective measures to low temperature should be maintained for two weeks or longer and should not stop immediately after the cold event ends.

The study of Leung et al. [2007] shows that in summer (May–September) deaths associated with heat stroke occur when the daily maximum net effective temperature (NET^{\oplus} , a thermal index) exceeds 26 and the mean mortality associated with heat stroke is estimated to double per unit rise in NET^{\oplus} beyond 26.

[⊕] NET reflects the common perception that people tend to feel more stressful on hot and humid days with calm winds in summer, and cold, windy and humid days in winter

In winter (November–March), deaths associated with hypothermia start to occur when the daily minimum NET is less than 14, and the mean mortality is estimated to increase 1.3-fold per unit decrease in NET below 14. Compared with other age groups, the elderly (≥ 65 year old) are more vulnerable to changes in NET.

A consistent non-linear relationship was found between extreme DTR and mortality in Guangzhou. Immediate effects of extremely low DTR on all types of mortality were stronger than those of extremely high DTR in a year. The cumulative effects of extremely low DTR increased with the increase of lag days for all types of mortality in the cold season, and they were greater for extremely high DTR. In the hot season, the cumulative effects of extremely low DTR increased with the increase of lag days, but for extremely high DTR they reached a maxima at 13 lag days for all types of mortality except for cerebrovascular disease (CBD) (at 6 lag days) [Luo *et al.*, 2013].

Since the 1950s, DTR has shown a significant decreasing trend in South China, with the most pronounced decreasing trend in winter [Chen and Chen, 2007]. Climate change forces people to change their habits and to adapt to the changing climate and environment. In the future, South China will face a period of rapid aging of the population, for example, the elderly (≥ 60 year old) will increase from the current 14.8% to 23.7% in 2050, being 3.5 times higher than in 2000 [Wang, 2011] and leading to a very large vulnerable population.

2.2 Impacts from heat waves

Heat waves refer to hot weather periods with persistent high temperature. The regional mean high-temperature days ($T_{\max} \geq 35^{\circ}\text{C}$) show a significant increasing trend (1.1 d per decade) for South China, with a stronger increase after 1998, when six years with each more than 20 high-temperature days occurred [Du *et al.*, 2013]. Heat waves not only lead to fatalities due to heat strokes, but also increase the risks for residents to suffer from insomnia, fatigue, illnesses, etc. Comparing the average death rate of non-hot days ($T_{\max} < 34^{\circ}\text{C}$) with hot days ($T_{\max} \geq 34^{\circ}\text{C}$) and scorching days ($T_{\max} \geq 36^{\circ}\text{C}$), an increase is observed by 10.5% and 25%, respectively [Tan, 1994]. The heat wave from late June to early July in 2004 led

to 39 fatalities due to heat stroke in Guangzhou [Chen *et al.*, 2007]. During a heat wave in the summer of 2003, the rates of heat strokes, insomnia, fatigue, and illness increased by 21.6%, 21.6%, 21.0%, and 5.0%, respectively [Cheng *et al.*, 2009]. Heat wave effects vary in time but are most evident in early summer, probably because most residents are not used to high temperatures yet.

It is possible that future climate change will lead to more, stronger, and longer heat waves [Huang *et al.*, 2008], thus increasing the risks of illness and the numbers in fatalities due to heat strokes. With a temperature increase of 0.6°C , the proportion of daily fatalities on hot days ($T_{\max} \geq 34^{\circ}\text{C}$) to the total fatalities during the entire summer in Guangzhou will reach 5.5%, increasing by 1.7% against the mean proportion during the period of 1979–1989. With a temperature increase of 4°C in summer, the daily fatalities on hot days would be several times higher than in 197–1989. The increase in fatalities due to heat strokes in summer will be far stronger than the decrease in fatalities due to less cold events in winter, finally resulting in higher numbers of fatalities annually [Tan, 1994].

Heat waves will cause severe impacts on the metropolitan areas in the Pearl River Delta. Due to the heat island effect, the heat waves in the Pearl River Delta will become stronger and last longer. The persisting heat waves have greater influence on mortality than a short extremely high temperature event. The increase in heat waves will increase the demand of electricity for air condition cooling, which in turn increases air pollution and greenhouse gas emissions from power plants. Heat waves are usually accompanied by periods of stagnant air, also leading to increases in air pollution and associated health effects.

2.3 Impacts from cold spells

A cold spell is a regional weather process, which can directly cause injury and disease to human health and can indirectly lead to death. In the context of global warming, the number of cold spells shows a decreasing trend in South China, with evident inter-annual and decadal variations [Wu and Du, 2010]. Strong cold spells appear occasionally. Since the 1990s, South China has suffered from five strong cold spells, which account for 62.5% of the total number since the 1950s [Du *et al.*, 2004]. In early 2008, an

extremely strong cold spell hit the southern areas of China [NCCCCMA, 2008], resulting in severe impacts on human health. The total number of outpatients from 25 hospitals in Tongren and Wanshan hospitals in Guizhou province increased by 29% during the cold spell in 2008 compared with the same period in 2007. Outpatients with acute respiratory diseases and other mechanical injury increased by 40% and 11%, respectively. The emergency calls increased by 40%, among which the numbers of emergencies due to fractures and maternity increased by 66% and 40%, respectively. Contrarily, the ambulance availability decreased by 17%, which resulted in nearly five times more cases beyond rescue. Around 75% of the surveyed residents stated that they experienced a short-tempered mood during the disaster. The ratio of insomnia and anorexia was 17% and 13%, respectively [Xiong et al., 2010]. Comparing the cold spell in 2008 with the same period in 2006, 2007, and 2009, the number of non-accidental fatalities and outpatients with respiratory diseases significantly increased in the cities of Guangzhou, Nanxiong and Taishan, with the highest and the lowest increasing rates of 52% in Nanxiong and 35% in Taishan, respectively. The impact of the cold spell on the death risk lasted for four weeks after the cold spell ended. Cold spells cause more respiratory system diseases than cardiovascular diseases. The elderly (≥ 75 year old) suffer more from cold spells than the younger generations [Xie et al., 2012].

It is predicted that the number of low temperature days will decrease as a whole, while the consecutive low temperature days will increase in Guangdong and in the northern parts of Guangxi [Song et al., 2008]. The increase of consecutive low temperature days will have more direct and indirect impacts on the local residents' health.

2.4 Impacts from air pollution

2.4.1 Changes in haze

Haze is an atmospheric phenomenon with horizontal visibility less than 10 km and daily mean relative humidity less than 90%. Haze can be described as countless fine particles that are suspended in the air and cannot be distinguished by the naked eye [Wu, 2005]. More specifically, haze in metropolitan areas is a form of wet air pollution, a veil of tiny droplets (aerosols) of condensed pollutants (smog), a mixture

of smoke, fog, and chemical fumes, like the London Fog. The annual mean hazy days in South China have significantly increased at 6.3 d per decade in the past 50 years. The annual average number of haze days is more than 30 d since 2000 [Du et al., 2013]. When haze occurs, the concentration of fine particles in the lower atmosphere dramatically increases, and a large number of fine particles, such as soot and salt crystals, are suspended in the air and very likely affect the health of human beings by inducing upper respiratory tract infections, asthma, conjunctivitis, bronchitis, eye and throat irritation, coughing, breathing difficulty, nasal congestion, runny nose, rash, cardiovascular system disorders and other diseases [Bai et al., 2006]. For example, the number of haze days shows a significant positive correlation with the cases of cardiovascular diseases in Guangzhou. The outpatient cases increase 2.12 times with every additional hazy day [Yin et al., 2009b].

Because of the complexity of haze effects, scientists are not sure whether climate change will result in increase or decrease hazy days. Most particulate matter in the atmosphere is cleaned off by rainfall, so increase in precipitation may reduce haze days. The weakening of wind may impair the transport and diffusion of atmospheric pollutants [Wu et al., 2008]. The landing of typhoons promotes diffusion and removal of atmospheric contaminant [Zhao et al., 2008]. Forest fires increase the atmospheric particulate matter. Climate change is likely to make the East Asian Monsoon stronger and to weaken the regional wind [Jacobson and Kaufman, 2006]. The influence of decreasing tropical cyclones [Wu and Yu, 2011] and increasing forest fires [Jacob and Winner, 2009] may lead to more haze days.

2.4.2 Increases in ozone concentration

Ozone (O_3) is formed by the photochemical reaction from oxygen, nitrogen oxides (NO_x), and volatile organic compounds (VOCs), and is the main component of photochemical smog. In 2006–2011, the ozone concentration increased by 21% in the Pearl River Delta [GPEMC and EPDHSAR, 2011]. O_3 can irritate the eyes, nose and throat, thus increasing the chances of human respiratory system diseases and adversely affecting patients with respiratory diseases. In the city of Shenzhen, O_3 shows a significant positive correlation ($r=0.658$) with cases of cardiovascular dis-

eases at a confidence level of 95% [Yin *et al.*, 2009a]. Another study by Liu *et al.* [2012] shows that temperature and O₃ have interactive effects on the death rate in Guangzhou. In low temperature conditions (days within the 25% percentile of daily mean temperature) or in the cold season (November–April), the residents' death risk increases significantly (including the daily effect and accumulated effect) with the increase in O₃ concentration. In contrast, in the warm season and in high temperature conditions, the effects of O₃ on the residents' death risk are not significant [Liu *et al.*, 2012].

The formation of O₃ has a significant nonlinear relationship with its precursors (NO_x and VOCs) [Tang *et al.*, 2006], so climate change can influence the formation of O₃ by changing its precursor's concentrations. Climate change is projected to increase the concentration of VOCs in the future, which may lead to more O₃ pollution [Liao *et al.*, 2007]. Observational studies [Bernard *et al.*, 2001] show that the O₃ concentration has a significant positive correlation with the local temperature, leading to an exacerbation of O₃ pollution with rising temperatures.

2.5 Impacts from climate-sensitive diseases

Malaria and dengue fever are viral diseases transmitted through mosquitoes and are very sensitive in its spread to temperature change. In South China, malaria had been controlled and eradicated. However, due to environmental and climatic changes and the population growth, the import of malaria has shown abrupt prevalence in recent years. In some mountainous areas of Guangxi, malaria spread to higher altitudes where it did not exist before [Yin *et al.*, 2011]. Before 1986, the city of Sanya, located in the southern Hainan province, rarely met the basic temperature conditions for dengue fever all year round. Since 1986, Sanya has fully met this condition all year round [Yu *et al.*, 2005]. Since 1978, several dengue fever cases have broken out in some local areas of South China [Wu and Xie, 2009].

A warming climate will expand the spatial distribution of mosquitoes, increase their breeding speed and invasiveness, and shorten the pathogens' incubation period, thus, increasing the potential transmission risks of malaria and dengue fever. When air temperatures rise by 1–2°C, the potential transmission

risk of malaria will increase by 39%–140% in South China, and the transmission season will extend by 1–2 months [Yang *et al.*, 2006]. With 1°C increase in global air temperature, the potential transmission risk of dengue fever will increase by 3.1%–4.7% [Hales *et al.*, 2002]. By 2050, dengue fever will probably transform from non-endemic to endemic in most areas of Hainan province [Yu *et al.*, 2005].

3 Adaptation strategies

As aforementioned, climate change is taking place and has dramatic impacts on human health by direct or indirect ways. To mitigate and prevent the adverse impacts of climate change on human health, sound and scientific adaptation strategies must be adopted in advance, such as:

(1) Strengthen the surveillance of epidemic diseases in potential areas. In projected climate change scenarios, the prevalent strength and spatial extent of various epidemic diseases are not consistent. Based on evaluation results, a strengthening of the surveillance of epidemic diseases in the transition areas between epidemic prevalence regions and non-epidemic prevalence regions has to take place. Once new outbreaks are discovered, corresponding and timely measures need to be adopted.

(2) Conduct timely weather forecasting for human health. In order to mitigate the adverse effects of extreme weather events on human health, weather forecasting for extreme weather conditions, e.g., heat waves, cold waves, haze, and other abnormal temperature variations, must be enhanced, so that people can take preventive measures in advance. Teisberg *et al.* [2004] estimated that the health warning system in Philadelphia could issue a health warning in time and save 2.6 lives per day on average under hot weather conditions.

(3) Evaluate health vulnerability to climate change. According to the IPCC definition, health vulnerability assessments should reflect the exposure degree, sensitivity and adaptive capacity to certain hazards caused by climate change [IPCC, 2007b]. Considering climate change, the vulnerability of different groups should be assessed and distinguished, and the vulnerable areas should be pointed out, in order to optimize the allocation of resources to people in need.

(4) Improve environment and health education.

Through a scientific approach, the living environment and the public's awareness on self-protection and health education should be continuously improved, so that residents can enhance their self-protection capability and improve their living environment.

(5) Strengthen hazard management and the co-operation between meteorological and health departments. Data sharing platforms on climate change and human health should be built, to distribute impact results of climate change on human health across different departments. Human health emergency plans need to be established, and seasonal and regional hot spots of risk prevention need to be determined. The timely release of effective information to the public should be strengthened, and a psychological intervention mechanism to post climate catastrophes needs to be established.

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