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Letter

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Mass human migration and Beijing's urban heat island during the Chinese New Year holiday

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Abstract Population movements around the Chinese New Year (CNY), which are much larger in recent years than before, are the largest annual human migration in the world. However, it is still largely unknown how or to what extent such mass human migration affects urban climate. Here, we investigate the role of mass human migration in influencing Beijing's urban heat island (UHI) during the CNY holiday for the period of 2004–2013. We find that the UHI effects expressed as daily mean (ΔT_{mean}), maximum (ΔT_{max}), and minimum (ΔT_{min}) temperature differences between urban and rural areas show a weakening trend during the CNY week relative to the background period (4 weeks including 2–3 weeks before and 2–3 weeks after the CNY week). In particular, large reductions occurred during the CNY week for the period of 2009–2013, when nearly half of population left the city before the CNY holiday. ΔT_{mean}, ΔT_{max}, and ΔT_{min} averaged over the period of 2009–2013 during the CNY week were 0.64, 0.45, and 0.83 °C lower than during the background period, representing relative reductions of 35 %, 66 %, and 27 %, respectively. Our findings highlight the important role of modern mass human migration for urban climate based on a case study in Beijing.

Keywords Urban heat island · Chinese New Year holiday · Mass human migration · Surface air temperature · Beijing City

Urban areas cover a very small fraction of the global land surface, yet house more than half of the human population [1]. The urban heat island (UHI), a phenomenon in which urban areas are significantly warmer than surrounding rural areas, represents one of the most evident human impacts on the earth system [2]. Temperature increases within cities, which are comparable with or even higher than the predicted global mean temperature rise for the next several decades, bring profound impacts on the lives of urban dwellers [3].

The Chinese New Year (CNY, also called Spring Festival or Lunar New Year) is the most important festival in China. People in big cities usually go back to their hometowns for family reunion or other purposes before the CNY holiday and return after the CNY holiday. The population movements around the CNY are the largest annual human migration in the world. During the Spring Festival transport season, it is estimated that the numbers of passenger flow nationwide had increased from about 0.8 billion in 1989 to 1.9 billion in 2004, and they had continued to increase to 2.4–3.4 billion during the period

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of 2009–2013. However, so far it is still largely unknown how or to what extent such mass human migration modulates the UHI.

Beijing, the capital of China, is one of the ten largest cities in the world [1]. The population of Beijing had experienced a remarkably rapid growth during the period of 2004–2013 (Fig. 1a). In 2004, 14.9 million people lived in Beijing, and the numbers reached up to 18.6 million and 21.1 million in 2009 and 2013, respectively. The percentage of floating population rapidly increased from 22 % in 2004 to 33 % and 38 % in 2009 and 2013, respectively (Fig. 1a). The floating people and some of people with Beijing *hukou* usually leave the city and go back their hometowns for family reunions or other purposes before the CNY holiday. It has been estimated that nearly half of Beijing's population leave the city during the CNY holiday in recent several years (http://news.xinhuanet.com/local/2013-02/18/c_124355887.htm). The mean UHI intensity in Beijing has been shown to reach several degrees during the past decades, with a larger magnitude in nighttime minimum temperature than in daytime maximum temperature [4, 5]. Here, we investigate the role of mass human migration in influencing Beijing's UHI during the CNY holiday for the period of 2004–2013.

Daily maximum (T_{max}) and minimum (T_{min}) surface air temperature data were obtained from the China Meteorological Administration. The daily mean temperature (T_{mean}) is computed by averaging T_{max} and T_{min}. The UHI effect is expressed as the temperature difference between urban and rural areas.

$$\Delta T = T_{urban} - T_{rural}. \quad (1)$$

For urban areas, we use Beijing and Fengtai stations (Fig. 1e), which are both located in the most populous areas of Beijing [6]. For rural areas, we use Miyun and Huairou stations (Fig. 1e), which are both located in plain areas of Beijing with low population density [4, 6]. Since the people movements during recent years are much larger than before, we focus our study on the period of 2004–2013. All four stations do not have any relocations during our study period [7, 8].

The CNY day is set according to the lunar calendar; therefore, the date changes from year to year. The CNY holiday officially lasts for 7 days, and the CNY week is defined as 7 days from the CNY day to 6 days after the CNY day in this study. The CNY week is denoted as week +1, and 1 week before and 1 week after the CNY week as week −1 and week +2, and so on. In total, our analysis includes 7 weeks (the CNY week, 3 weeks before, and 3 weeks after the CNY week) for each year. We define 4 weeks including weeks −3 to −2 and weeks +3 to +4 as the background period. The inclusion of both 2–3 weeks before and 2–3 weeks after the CNY week should largely remove the possible effects of seasonal transition from winter to spring.

ΔT_{mean}, ΔT_{max}, and ΔT_{min} during the CNY week show a weakening trend relative to those during the background period for 2004–2013 (Fig.1b–d). Large decreases in ΔT_{mean}, ΔT_{max}, and ΔT_{min} occurred during the CNY week relative to those during the background period for 2009–2013, while changes in all three variables were small and insignificant for 2004–2008. For each year of 2009–2013, ΔT_{mean}, ΔT_{max}, and ΔT_{min} during the CNY week were all lower than those during the background period except for ΔT_{max} in 2012.

We further examine weekly means of ΔT_{mean}, ΔT_{max}, and ΔT_{min} during weeks −3 to +4 averaged over the period of 2009–2013 (Fig. 1f–h). In the CNY week, ΔT_{mean}, ΔT_{max}, and ΔT_{min} were 1.21, 0.23, and 2.19 °C, respectively. And, they were all lower than those during any one of non-holiday weeks. ΔT_{mean}, ΔT_{max}, and ΔT_{min} averaged for 2009–2013 during the CNY week were 0.64, 0.45, and 0.83 °C lower than those during the background period, respectively (Table 1). These changes are all significant at the 95 % confidence level by Student's t test. Regarding the relative changes, the reductions of ΔT_{mean}, ΔT_{max}, and ΔT_{min} during the CNY week reached 35 %, 66 %, and 27 % of those during the background period, respectively. We also examine the difference in ΔDTR (diurnal temperature range difference between urban and rural areas) between the CNY week and the background period averaged over the period of 2009–2013, and find that the ΔDTR difference was insignificant and was much smaller than those for ΔT_{mean}, ΔT_{max}, and ΔT_{min}, regarding the relative changes (Table 1).

Our results show that the UHI effects expressed as temperature differences between urban and rural areas during the CNY week show a weakening trend relative to those during the background period for the period of 2004–2013, particularly with large reductions occurring during 2009–2013. The mass human migration can largely reduce human activities such as anthropogenic heat emitted by buildings, factories, and vehicles during the CNY holiday, thus significantly weakening Beijing's UHI during 2009–2013. The complicated mechanisms involved need to be further clarified by using model simulations in the future. We find that significant reductions in the UHI effects during the CNY week occurred over the period of 2009–2013, while only small changes were detected for 2004–2008. This difference may be largely explained by much more population movements during the CNY week over the period of 2009–2013 than before. Some non-human migration factors may also play a role. These issues warrant further investigation.

The important impacts of mass human migration on the UHI during the CNY holiday exist not only in Beijing, but