Fast Urbanization Causes Overestimate on Global Warming Trends

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Abstract

Fast urbanization may caused overestimation on global warming tendency, whereas the contribution of urbanization on global warming tendency has not been evaluated accurately. Compared with current methods, we hold the opinion that comparing the temperature records of relocated new meteorological stations with old ones is a better way to evaluate the urbanization contribution. So we searched literature about relocation stations on *Web of Science* and *China National Knowledge Infrastructure*, and studies contained temperature record of paired relocated old and new meteorological stations were selected. Consequently, we collected temperature records on 57 paired stations and found that the temperature of old stations was higher than new ones by 0.66℃ (-0.90 to 1.63℃). The urbanization process could contribute more than 60% to the temperature increasing tendency; there are strong coincidences between the periods of temperature increasing and regional fast urbanization over the worldwide. In conclusion, the assessment of global warming by IPCC could be revised based on paired urban and rural temperature data sets of global relocated meteorological stations in the next report.

Introduction

Global warming tendency seems undeniable, whereas there is still a debate on whether the global warming tendency is overestimated due to urbanization. Based on analyses of long time series meteorological data sets, the average global surface temperature increasing rate is 0.12ºC per decade from 1951 to 2012 (*1*), and observed global mean temperature for the decade 2006-2015 was 0.87ºC higher than the average over the 1850-1900 period (*2*). Global warming affects the Earth of all ecosystems, and its known and potential consequences exist in all organisms. Estimate global warming tendency accurately is crucial for climate change studies (e.g., ecological dynamic and species response predict) and policy-making. The IPCC report(*1*) stated that the meteorological bias caused by urbanization has overestimated the global warming rate, but not exceed 10% of the whole rate. And some scholars also consider that the contribution from urbanization bias to the tendency of global warming was negligible (*3*). On the opposite, some scholars believe that the effect of the meteorological temperature increasing caused by urbanization process (i.e., the urban heat island effect (*4*)) on the global warming tendency was quite underestimated (*5*).

Assessing the impact of urbanization on global warming is difficult. There are three main ways to estimate the effect of urbanization bias on global warming: 1) Comparing the temperature change tendency in city meteorological stations with those in surrounding rural areas; 2) Comparing the observations with re-analysis model data; 3) Eliminating the observation errors in city stations by homogeneous processing based on the data set observed in rural stations in the same region. There are uncertainties in all of these three ways. For instance, how to choose the paired meteorological stations in rural areas with those in cities (*5*)? And the re-analysis data are also affected by weather conditions such as cloud and wind (*6*). Better way is therefore needed to assess the impact of urbanization on global warming.

We hold the opinion that an optimal way is comparing the temperature records of relocated new meteorological stations with old ones during the same time period. Relocated new stations are geographic closed and elevational similar with old ones, and the main difference between them is the degree of urbanization. In this study, we tried to collect paired temperature datasets of relocated old and new stations, and evaluate the bias caused by urban heat effect on global temperature increasing tendency.

Results

Based on the surface temperature records of paired relocated old and new meteorological stations, we found that urbanization contributes more than half to the temperature increasing tendency. We found 57 relocated meteorological stations which have synchronous one-year observation data both by new and old stations after relocation. And all of those datasets were from China. The period of relocation was from 2000 to 2013. The average geographic distance between old and new stations was 8.31km (n=51, sd=6.86), and altitude difference was 45.5m (n=46, sd=48.04). We analyzed the data sets, and the results showed that based on minimum temperature (TMIN), the average annual TMIN in old stations (urban) was higher than that in new ones (rural areas) by 0.80ºC (n=52, sd=0.67, t-test, p=0.001). For the average annual temperature (TAVG) and maximum temperature (TMAX), the old stations was annually higher than new ones by 0.66ºC (n=57, sd=0.45, t-test, p=0.001) and 0.53ºC (n=52, sd=0.45, t-test, p=0.001), respectively. The temperature increasing tendency is most obvious based on the comparison of TMIN between old and new stations, while TMAX has a weaker increasing tendency.

We also explored the relationship between urbanization process and temperature increasing tendency. The temporal evolution of population density is the most direct reflection of the process of urbanization in China (*7*). Based on accurate urban area and population information on 44 of the 57 towns, we found there was strong correlation between the temperature increasing range and population density (r=0.96, p=0.01, adjusted r^2=0.89; Fig. 1). There is a great diverge in the synchronous observation data between new and old stations. The 44 meteorological stations used in this study were dispersive located in the central, northeast, northwest, southeast and south of China. Old meteorological stations experienced faster temperature increasing in the towns contain higher population density and in the southeast of China, where urbanization process was heavier (*5*).

Discussion

In our study, the final available datasets are all from China, and there are few study on relocated meteorological stations in developed countries where urbanization was finished before early 19 century, resulted in less concern on global scale. However, obvious urbanization warming tendency could be proved over the worldwide. According to IPCC (*1*), the daily average temperature increasing rate of China is 0.17ºC per decade in the near half century, higher than that of global (0.12ºC per decade). In other studies, the urbanization has been proved to contribute 27~ 55% to the temperature increasing tendency(*5,8-9*). From 1980s to 2010, the temperature increased not higher than 1.04ºC in China (*10*), and

based on our results, the urbanization contributes not less than 63.5% to the temperature increasing tendency, with a rate of 0.22ºC per decade (0.66ºC/30a). The overestimation on temperature increasing tendency caused by urbanization has also been found in western America (*11*), North America (*12*), South America(*13*), Europe (*8*), Korea (*14*), and South Africa (*15*). So the overestimation on global warming tendency caused by fast urbanization could be a global scale phenomenon. And the interference caused by urbanization is hard to exclude even by the popular homogenization methods (*16*), and could be only accurately estimated by comparing the synchronous observed data sets between relocated old and new stations.

There are coincidences between the periods of temperature increasing and regional fast urbanization process. The fast economic development and urbanization processes bring heavy interference to meteorological stations. Our results indicate that the warming tendency in the near 30 years in China was affected by the unprecedented urbanization process, which causes the inconsistent of the temperature change tendency between China and worldwide. China experienced a rapid economic growth and consequently a dramatic increase in the population and areas of its cities since 1980s. With the fast urbanization in China, many meteorological stations were moved away from old to new places due to gradually surrounded by the urban. Most of the meteorological stations were built up after 1950, and at the building time the stations were located in rural areas where unbiased observation data could be obtained (Fig. 2-a). After the reform and opening policies in 1980s, the meteorological stations “entered cities” and were relocated continually (Fig. 2-b,c; *17*). Before 1980s, the temperature increasing rate in China was lower than global average level, while was faster than that of worldwide after 1980s (*18*). The East Asian region including China shows a faster warming tendency in the near half a century (*18*), whereas European region experienced that from the end of 19th to the beginning of 20th century (*8, 19*). In Europe, the earlier urbanization process erases the heat island effect on temperature increasing tendency over the 20th, because the urbanization have not changed over this time. For instance, based on Dienst et al. (*20*), the temperature increasing tendency would display a rise in TAVG trend by 0.03ºC per decade in Northern Europe, if the 20th century is regarded exclusively. In developed areas, the heat accumulation and release process repeated several times with stations relocation; while in developing countries, the heat accumulation is on going with the urban process.

The IPCC reports have not emphasize the effect of fast urban urbanization on temperature recording, the global warming tendency could be over estimated. The temperature observational bias caused by the urban heat island effect contributes to much of the global warming overestimation. Contrast to the IPCC’s conclusion that urbanization contributes not more than 10%, our results revealed that the urbanization contributed more than 60% to the temperature increasing tendency. Whether the global warming tendency is as severe as the IPCC (*1-2*) report is doubtful. At regional scale, the conclusion that urbanization contributes much to temperature increasing is derived from research analyses that based on strict selected city-rural paired data sets (*21*). Whereas the urbanization biases are few corrected at global scale and should be considered carefully to estimate the global warming tendency accurately.

Materials And Methods

We searched literature about meteorological relocation stations all over the world. In the Web of Science, we used the key words “(meteorological station* OR temperature record) AND (relocat* OR relocalization OR reposition* OR resituated) ” in the Topic Search, and found 4 related papers. In China National Knowledge Infrastructure and Baidu Scholar, we used the same search form and found 87 related papers. We screen out the papers which contained paired temperature record, and found 57 relocated meteorological stations which have synchronous one-year observation data both by new and old stations after relocation in China. So we only analyses the urbanization warming tendency in China. We analyzed the difference of minimum temperature (TMIN), maximum temperature (TMAX) and average annual temperature (TAVG) between old and new stations by t-test. All of the 57 paired stations contain records of TAVG (n=57), and 52 of them contain records of TMIN and TMAX (n=52). What’s more, we looked for information about the population and urban area of the towns where the 57 stations were located, and accurate information on 44 of the 57 towns was gained. We calculated the population density of the 44 towns through divided population by area, and consequently grouped these 44 towns into five classes based on population density. The population density of the five classes were more than 10 thousands, between 5 to10 thousands, between 1 to 5 thousands, between 0.1 to 1 thousand, and less than 0.1 thousand, respectively. Within each class, we calculated the averaged value of population density and temperature increasing tendency of TAVG. We then analyzed the correlation between temperature increasing tendency and population density of the five classes by Pearson correlation test. All the data used in this research can be found on *Dryad* (https://doi.org/10.5061/dryad.573n5tb4r).

Declarations

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Conflicts of interest/Competing interests

The authors have no relevant financial or non-financial interests to disclose.

Ethics approval

Not applicable. There are no ethical issues involved in this work.

Consent to participate

All authors are aware that this article has been completed and agree to be list as authors in this manuscript.

Consent for publication

All authors have agreed to publish this manuscript on *Climatic Change*.

Availability of data and material

Data used in this research are transparency and available available on *Dryad* (https://doi.org/10.5061/dryad.573n5tb4r).

Code availability

Not applicable.

Authors' contributions

N. Li, G.P. Ren and W. Xiao conceived and designed research. N. Li and R. Gu collected the data. N. Li, F.T. Li and Y. Gao analyzed the data with help from G.P. Ren and W. Xiao. N. Li wrote the manuscript together with G.P. Ren and W. Xiao.

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Figures

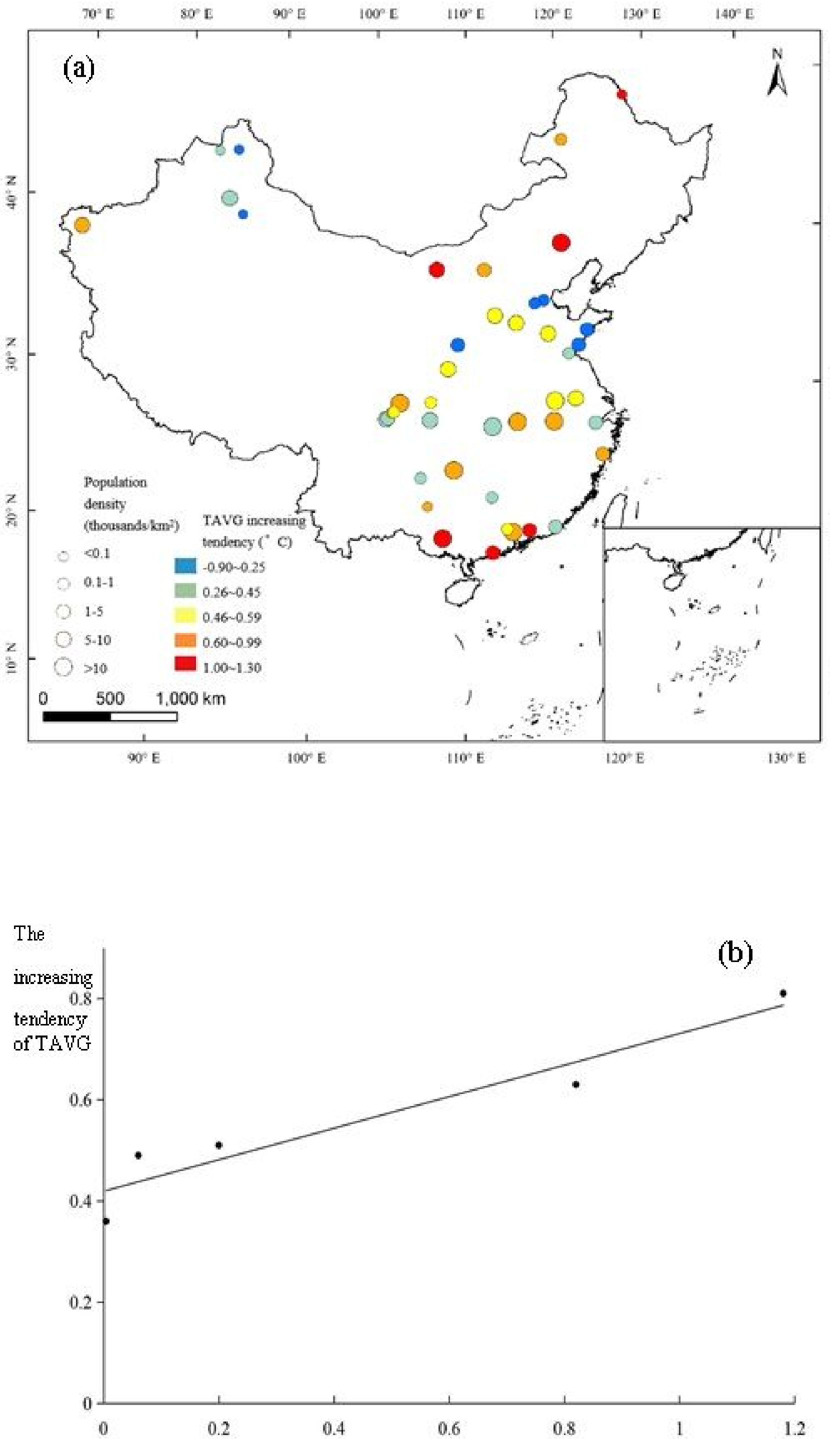

Figure 1

a) The distribution of 44 relocated meteorological stations. The circle size represents population density, and the color represents increasing tendency of average annual temperature (TAVG) between paired urban (old) and rural (new) stations. The 44 paired stations were grouped into five classes based on population density of the urban where temperature station was relocated (i.e. more than 10 thousands, between 5 to10 thousands, between 1 to 5 thousands, between 0.1 to 1 thousand, and less than 0.1

thousand). The increasing tendency of TAVG of each urban class was the averaged difference value between old and new stations during one year after relocation. b) The correlation between population density and increasing tendency of TAVG. The population density of each urban class was the average value of population densities of urban within that class. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

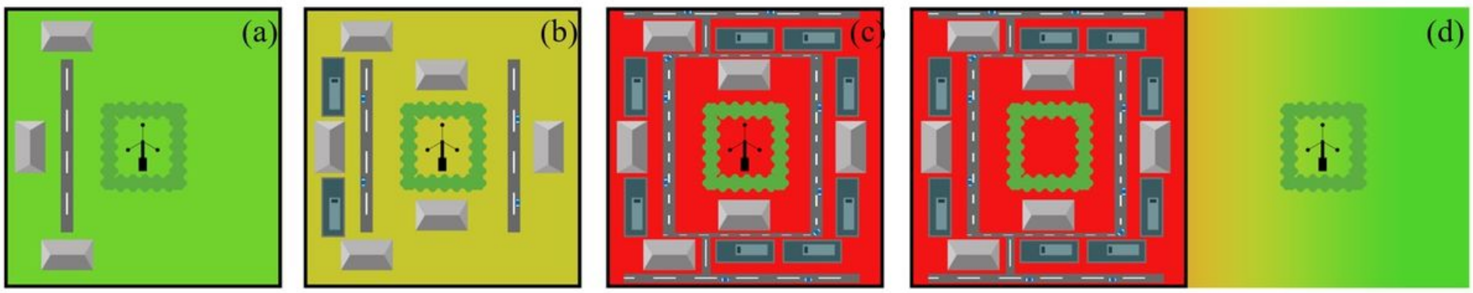

Figure 2

Heat accumulation during the urbanization process and heat release after the meteorological station relocation. a) The earlier stage of urbanization and the record of meteorological station is unbiased. b) The developing stage of urbanization and the temperature record is biased gradually. c) The latter stage of urbanization and the temperature record is biased due to heat island effect . d) The relocation of meteorological station, the accumulated heat is released.