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Research Article

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Fast Urbanization Causes Overestimation of Global Warming Trends

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Abstract

The contribution of urbanization to the global warming tendency has not been evaluated accurately. We propose that comparing the temperature records of relocated new meteorological stations to those of old meteorological stations is a better method for evaluating the urbanization contribution than the current methods. On the Web of Science and the China National Knowledge Infrastructure, previous studies on temperature records of paired old and relocated new meteorological stations were searched and selected. As a result, we gathered temperature data from 57 paired stations and discovered that the old stations' temperature was 0.66 ℃ higher than the new stations' (-0.90 to 1.63 ℃). The urbanization process may be responsible for more than 60% of the current temperature rise trends. Furthermore, there are strong correlations between periods of global warming and regional rapid urbanization, implying that rapid urbanization causes overestimation of global warming trends. Finally, the IPCC's assessment of global warming should be revised in the next report based on paired urban and rural temperature datasets from globally relocated meteorological stations.

Significances Statement

The goal of this article is to show that, while the global warming trend is well established, the overestimation of global warming trends due to rapid urbanization cannot be overlooked. We believe that comparing the temperature of an old meteorological station (located in an urban area) with a newly relocated new one (located in a rural area) is the most reliable method for capturing the current bias of urbanization on temperature increases. And, using this method, we discovered that urbanization is responsible for more than half of the global warming trend. As a result, global warming trends were overestimated, and our method could be used to revise them.

Introduction

The global warming tendency are widely discussed, and the question of whether the effects of global warming are exaggerated as a result of urbanization continues to be debated. Based on analysis of long time-series meteorological datasets, the average global surface temperature increase rate was 0.12 °C per decade from 1951 to 2012, and the observed global mean temperature from 2006–2015 was 0.87 °C higher than the mean temperature from 1850–1900 [1, 2]. Global warming affects Earth's ecosystems, and its known and potential consequences occur among organisms. Accurate estimation of global warming trends is crucial in climate change studies (e.g., ecological dynamics and species response prediction) and policy-making. According to IPCC (2013) report, urbanization-related meteorological data bias has resulted in global warming rate overestimation, but it does not exceed 10% of the overall rate. Researchers have also concluded that urbanization bias has a negligible impact on global warming trends [3]. Other scholars, on the other hand, believe that the impact of increased surface air temperature due to urbanization (i.e., the urban heat island effect) on global warming trends has been significantly underestimated [4, 5].

Assessing the impact of urbanization on global warming is difficult due to methodological uncertainties. There are three main methods to estimate the effect of urbanization on global

warming: 1) comparing the temperature change tendency at city meteorological stations to that in surrounding rural areas; 2) comparing observations to reanalysis data; and 3) eliminating observation errors at city stations via homogeneous processing based on datasets observed at rural stations in the same region. Uncertainties exist in all three methods. For instance, there is no consistent standard about how to choose paired meteorological stations in rural areas based on those in cities [5]. Moreover, reanalysis data are affected by weather conditions such as clouds and wind [6]. Better methods are therefore needed to assess the impact of urbanization on global warming.

We propose that the optimal method involves the comparison of temperature records of relocated new meteorological stations to those of old meteorological stations during the same period. In general, meteorological stations were initially built in pristine rural areas, but later urbanization promoted station relocation. Therefore, relocated new stations are located nearby geographically and are similar in elevation to old stations, and the main difference between these stations is the degree of urbanization. In this study, we collected paired temperature datasets of old and relocated new stations and evaluated the bias in the global temperature increase tendency attributed to the urban heat effect.

Materials and Methods

We searched the literature on relocated meteorological stations worldwide. On the Web of Science, we adopted the key words "(meteorological station* OR temperature record) AND (relocate* OR relocation OR reposition* OR resituated)" in the topic search process and identified four related papers. On the China National Knowledge Infrastructure and Baidu Scholar websites, we employed the same search form and identified 87 related papers. We obtained papers containing paired temperature records of new and old stations and identified 57 relocated meteorological stations with synchronous one-year observation data across both new and old stations in China. Therefore, we only analyzed the urbanization warming trends in China. We evaluated the difference in minimum temperature (TMIN), maximum temperature (TMAX) and average annual temperature (TAVG) between old and new stations based on the student's t-test. All 57 paired stations recorded TAVG data, and 52 of these stations recorded TMIN and TMAX data. Moreover, we searched for information on official websites regarding the population and urban area of the towns where these 57 stations were located, and accurate information on 44 of the 57 towns was acquired. We calculated the population density of these 44 towns by dividing the population by the area and consequently grouped these 44 towns into five classes based on the population density. The population density values associated with these five classes were more than 10 thousand people, between 5 and 10 thousand people, between 1 and 5 thousand people, between 0.1 and 1 thousand people, and fewer than 0.1 thousand people. Within each class, we calculated the average value of the population density and temperature increase tendency, i.e., TAVG. We then determined the correlation between the temperature increase trend and the population density of the five classes with the Pearson correlation test. All the data in this research are provided in the Supplemental Material.

Results

We found that urbanization contributed more than half to the temperature increase trends based on the obtained land surface temperature records of the paired old and relocated new meteorological stations. The period for the 57 relocated meteorological stations in China extended from 2000 to 2013. The average geographic distance between the old and new stations was 8.31 km (n=51, sd=6.86), and the altitude difference reached 45.5 m (n=46, sd=48.04). Based on the minimum temperature (TMIN), the average annual TMIN value at the old stations (urban) was 0.80 °C higher than that at the new stations (rural areas) (n=52, sd=0.67, t=8.6173, d.f.= 51, p = 1.596e-11). In terms of the average annual temperature (TAVG) and maximum temperature (TMAX), the annual values at the old stations were higher than those at the new stations by 0.66 °C (n=57, sd=0.45, t-test, t=11.122, d.f.=56, p =8.418e-16) and 0.53 °C (n=52, sd=0.45, t-test, t=8.3647, d.f.=51, p = 3.926e-11), respectively. The temperature increase trend was highly obvious based on the comparison of TMIN between the old and new stations, while TMAX exhibited a weaker increase tendency.

We also explored the link between the urbanization process and the temperature increase tendency. The most direct representation of China's urbanization trend is the temporal evolution of population density [7]. Based on accurate urban area and population information on 44 of the 57 towns, we found that there existed a strong correlation between the temperature increase magnitude and population density (r =0.96, p =0.011, adjusted r^2 =0.91; Figure. 1). There occurred a large difference in the synchronous observation data between the new and old stations. The 44 meteorological stations included were scattered across China, including locations in Central, Northeast, Northwest, Southeast, and South. In towns with greater population density values and in southern China, where the urbanization process was more vigorous, the old meteorological stations witnessed more fast temperature rises [5].

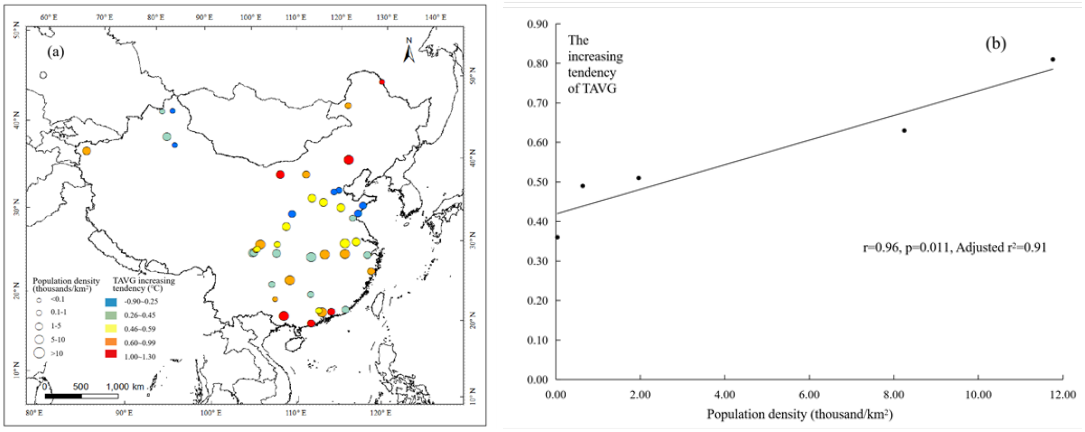

Figure 1: a). The distribution of 44 paired meteorological stations. The circle size represents population density, and the color represents increasing tendency of average annual temperature (TAVG) between paired urban (old) and rural (new) stations. The 44 paired stations were grouped into five classes 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 populations densities of urban within that class.

Discussion

The last accessible datasets in our analysis all came from China, and there were few investigations on relocated meteorological stations in industrialized nations where the urbanization process was completed by the early nineteenth century, resulting in a reduced concern on a global scale. However, an obvious urbanization warming tendency could be observed worldwide. According to the IPCC (2013), the daily average rate of temperature increase in China reached 0.17 °C per decade over the past half century, which is higher than the global rate (0.12 °C per decade). In other studies, urbanization has been verified to contribute 27~55% to the temperature increase tendency (Ren et al. 2010, Jones et al. 2008, Sun et al. 2016). From the 1980s to 2010, the temperature increase did not exceed 1.04 °C in China (Lin and Zhang 2015), and based on our results, urbanization contributed at least 63.5% to the temperature increase tendency, at a rate of 0.22 °C per decade (0.66 °C/30 a). Overestimation of the temperature increase tendency due to urbanization has also been found in western America (Roden 1966), North America (Kukla et al. 1986), South America (Camilloni and Barros 1997), Europe (Jones et al. 2008), Korea (Chao et al. 1988), and South Africa (Hughes and Balling 1996). Therefore, overestimation of the global warming tendency attributed to rapid urbanization could be a global-scale phenomenon. The interference caused by urbanization is hard to exclude even via popular homogenization methods (Ribeiro et al. 2015) and can only be accurately estimated by comparing synchronous observation datasets between old and relocated new stations.

There occur coincidences between the periods of temperature increase and regional fast urbanization. Rapid economic development and urbanization have a significant impact on meteorological stations. Our results indicate that the warming tendency over the past 30 years in China was affected by the unprecedented urbanization process, which caused inconsistencies in the temperature change tendency between China and the rest of the world. China experienced rapid economic growth and consequently a dramatic increase in the population and area of its cities since the 1980s. With rapid urbanization in China, many meteorological stations were moved to new locations due to the increasing encroachment of urban areas. Most meteorological stations were built after 1950, and at the time of construction, these stations were located in rural areas where unbiased observation data could be obtained (Fig. 2a). After the reform and opening policies in the 1980s, meteorological stations increasingly occurred in cities and were continually relocated (Fig. 2b,c; Yang et al. 2012). Before the 1980s, the temperature increase rate in China was lower than the global average level but became higher than the worldwide average value after the 1980s (Ren et al. 2017). The East Asian region, including China, experienced a faster warming tendency over the past half a century (Ren et al. 2017), whereas the European region experienced warming from the end of the 19th century to the beginning of the 20th century (Jones et al. 2008, Jones and Lister 2009). In Europe, the earlier urbanization process has mitigated the heat island effect on the temperature increase tendency in the 20th century because urbanization has remained unchanged during this period. For instance, based on Dienst et al. (2017), the temperature increase tendency would exhibit a rise in the TAVG trend of 0.03°C per decade in Northern Europe if the 20th century was exclusively regarded. In developed areas, heat accumulation and release processes are repeated several times upon station relocation, while in developing countries, heat accumulation continues with the urban process.

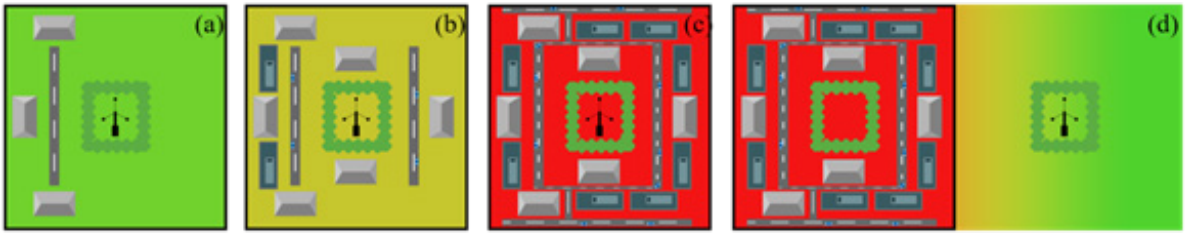

Figure 2: Heat accumulation during the urbanization process and heat release after the meteorological station relocation. **a)** The earlier stage of urbanization and the record of meteorological station is unbiased. **b)** The developing stage of urbanization and the temperature record is biased gradually. **c)** The latter stage of urbanization and the temperature record is biased due to heat island effect. **d)** Relocation of meteorological station, and the accumulated heat is released.

Conclusions

IPCC reports have not emphasized the effect of fast urban urbanization on temperature recordings, and the global warming tendency could be overestimated. The temperature observational bias due to the urban heat island effect greatly contributes to global warming overestimation. In contrast to the IPCC's conclusion that urbanization contributes no more than 10%, our results revealed that urbanization contributes more than 60% to the temperature increase tendency. Although it is unclear whether the global warming trend is as severe as that reported by the IPCC, research analysis of strictly selected city-rural paired datasets has led to the conclusion that urbanization significantly contributes to temperature increase at the regional scale [1, 2, 12]. However, urbanization biases are rarely corrected at the global scale and should be carefully considered to accurately estimate the global warming tendency. The meteorological temperature increase attributed to fast urbanization may be a worldwide phenomenon because developing counties account for more than 70% of the total area of Earth. Urban areas occupy only a small part of the global surface, and assessment of global warming requires a certain understanding of the temperature change trends in remote and rural areas, which account for more than 99% of the land area. What is the bias in the land surface temperature sequence due to urbanization at the global scale? This is a topic that needs to be researched further. Comparing and studying the temperature difference between old and relocated new stations or well-matched rural and urban stations may be the most reliable method to capture the bias in temperature trends attributed to urbanization at present, even though urban heat island biases might also occur in villages [20]. The assessment of global warming by the IPCC should be revised based on paired urban and rural temperature datasets of global relocated meteorological stations in the next report, considering various urbanization processes in different regions.

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Data Availability Statement

Data analyzed in this study were a re-analysis of existing data derived from published papers, and those papers and raw data were upload at DOI: https://doi.org/10.5061/dryad.573n5tb4r. The datasets can be accessed using this temporary link: https://datadryad.org/stash/share/-Se-ncb12V0wYEo1MICqlWqebAgebzVz7lklfFT8iHE. , which would open to public once this manuscript accepted.

References

1. Alexander, L., Allen, S., & Bindoff, N. L. (2013). Working group I contribution to the IPCC fifth assessment report climate change 2013: the physical science basis summary for policymakers (No. Bajados de Internet/2013). OPCC.
2. IPCC. (2018). Special report on global warming of 1.5°C [M]. UK: Cambridge University Press. https://www.ipcc.ch/sr15/.
3. Parker, D. E. (2006). A demonstration that large-scale warming is not urban. Journal of climate, 19(12), 2882-2895.
4. Grimmond, C. S. B. (2006). Progress in measuring and observing the urban atmosphere. Theoretical and Applied Climatology, 84(1), 3-22.
5. Ren, Y. Y., Ren, G. Y., & Zhang, A. Y. (2010). An overview of researches of urbanization effect on land surface air temperature trends. Progress in geography, 29(11), 1301-1310.
6. Kalnay, E., & Cai, M. (2003). Impact of urbanization and land-use change on climate. Nature, 423(6939), 528-531.
7. Qizhi, M., Ying, L., & Kang, W. (2016). Spatio-Temporal Changes of Population Density and Urbanization Pattern in China (2000-2010). China City Planning Review, 25(4).
8. Jones, P. D., Lister, D. H., & Li, Q. (2008). Urbanization effects in large-scale temperature records, with an emphasis on China. Journal of Geophysical Research: Atmospheres, 113(D16).
9. Sun, Y., Zhang, X., Ren, G., Zwiers, F. W., & Hu, T. (2016). Contribution of urbanization to warming in China. Nature Climate Change, 6(7), 706-709.
10. LIN, J., & ZHANG, Q. (2015). Characteristics of China climate states change and its impact on the analysis of climate change. 原气象, 34(6), 1593-1600.
11. Roden, G. I. (1966). A modern statistical analysis and documentation of historical temperature records in California, Oregon and Washington, 1821–1964. Journal of Applied Meteorology and Climatology, 5(1), 3-24.
12. Kukla, G. Gavin, J. and Karl T. R. (1986). Urban warming. Journal of Applied Meteorology, 25(9), 1265-1270.
13. Camilloni, I., & Barros, V. (1997). On the urban heat island effect dependence on temperature trends. Climatic Change, 37(4), 665-681.
14. Cho, H. M., Cho, C. H., & Chung, K. W. (1988). Air temperature changes due to urbanization in Seoul area. J. Korean Meteor. Soc, 24, 27-37.

15. Hughes, W. S., & Balling Jr, R. C. (1996). Urban influences on South African temperature trends. International Journal of Climatology: A Journal of the Royal Meteorological Society, 16(8), 935-940.
16. Ribeiro, S., Caineta, J., & Costa, A. C. (2016). Review and discussion of homogenisation methods for climate data. Physics and Chemistry of the Earth, Parts A/B/C, 94, 167-179.
17. Yang, Y. J., Wu, B. W., Shi, C. E., Zhang, J. H., Li, Y. B., Tang, W. A., ... & Shi, T. (2013). Impacts of urbanization and station-relocation on surface air temperature series in Anhui Province, China. Pure and Applied Geophysics, 170(11), 1969-1983.
18. Ren, G., Ding, Y., & Tang, G. (2017). An overview of mainland China temperature change research. Journal of Meteorological Research, 31(1), 3-16.
19. Jones, P. D., & Lister, D. H. (2009). The urban heat island in Central London and urban-related warming trends in Central London since 1900. Weather, 64(12), 323-327.
20. Dienst, M., Lindén, J., Engström, E., & Esper, J. (2017). Removing the relocation bias from the 155-year Haparanda temperature record in Northern Europe. International Journal of Climatology, 37(11), 4015-4026.