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Identifying Weekly Cycles of Air Temperature in Hong Kong: An Alternative Way to Investigate the Influence of Anthropogenic Heat

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Abstract:

Potential effects of anthropogenic heat emissions on urban surface energy balance have been investigated for minimizing its impact on Urban Heat Island (UHI) (Stocker, 2014). While it is difficult to quantify anthropogenic heat, Weekly Cycles (WCs) of thermal climatic parameters provide a proxy to explore the influence of anthropogenic heat emissions on climate. As repeating patterns of thermal parameters on a weekly basis can hardly be found in any natural phenomenon, WCs of climatic parameters can be explained as a strong indication of anthropogenic influence on climate. WCs of meteorological parameters, such as precipitation, air pollutant, solid particles, sunshine duration and air temperature, have been identified. (Gong et al., 2007; Nick, Ian, & Nigel, 2016; Shutters & Balling, 2006).

Air temperature (AT) is a fundamental meteorological parameter for inspecting UHI and has also been explored in previous WCs studies. Temperature variations between weekdays and weekends were observed in Toronto, where WCs was only found within the urban area but not in the rural area (Beaney & Gough, 2002). Their conclusion supports WCs of AT as a local phenomenon. While another study in Germany reported a contradictory conclusion that WCs of AT is a non-local effect, and local heat emission is not responsible for it (Bäumer & Vogel, 2007). This contradiction might be primarily due to different spatial and temporal scales in the analysis.

With limited construction lands surrounded by mountainous terrain, Hong Kong (HK) has been developed in high density. Compact and densely populated urban settings are the primary driving factors of high anthropogenic heat emissions and further exacerbate UHI. Therefore in this study, WCs of AT in HK is investigated for the first time by conducting spatiotemporal analysis. This study aims to address the following research questions: 1) Is there a WCs pattern of AT in HK? 2) How this pattern varies among different geographical locations? 3) How the WCs varies in different temporal scales?

Hourly AT data of 15 Automatic Weather Stations (AWSs) was collected from Hong Kong Observatory (HKO). Five of these AWSs are located in the natural environment with limited human activities, for example on the hills such as Tate's Cairn, and in the islands such as Waglan. Three of them are significantly affected by recreation or transportation, such as Cheung Chau Island and Hong Kong International Airport. The rest of them are surrounded by residential and commercial built-environment and thus are obviously exposed to anthropogenic heat emissions, such as Yau Tsim Mong. Due to the different time ranges of data availability among AWSs and considering the number of very hot days observed at HKO, two periods of WCs analysis have been specified: a long-term (1998-2016) and a short-term (2011-2016) period respectively.

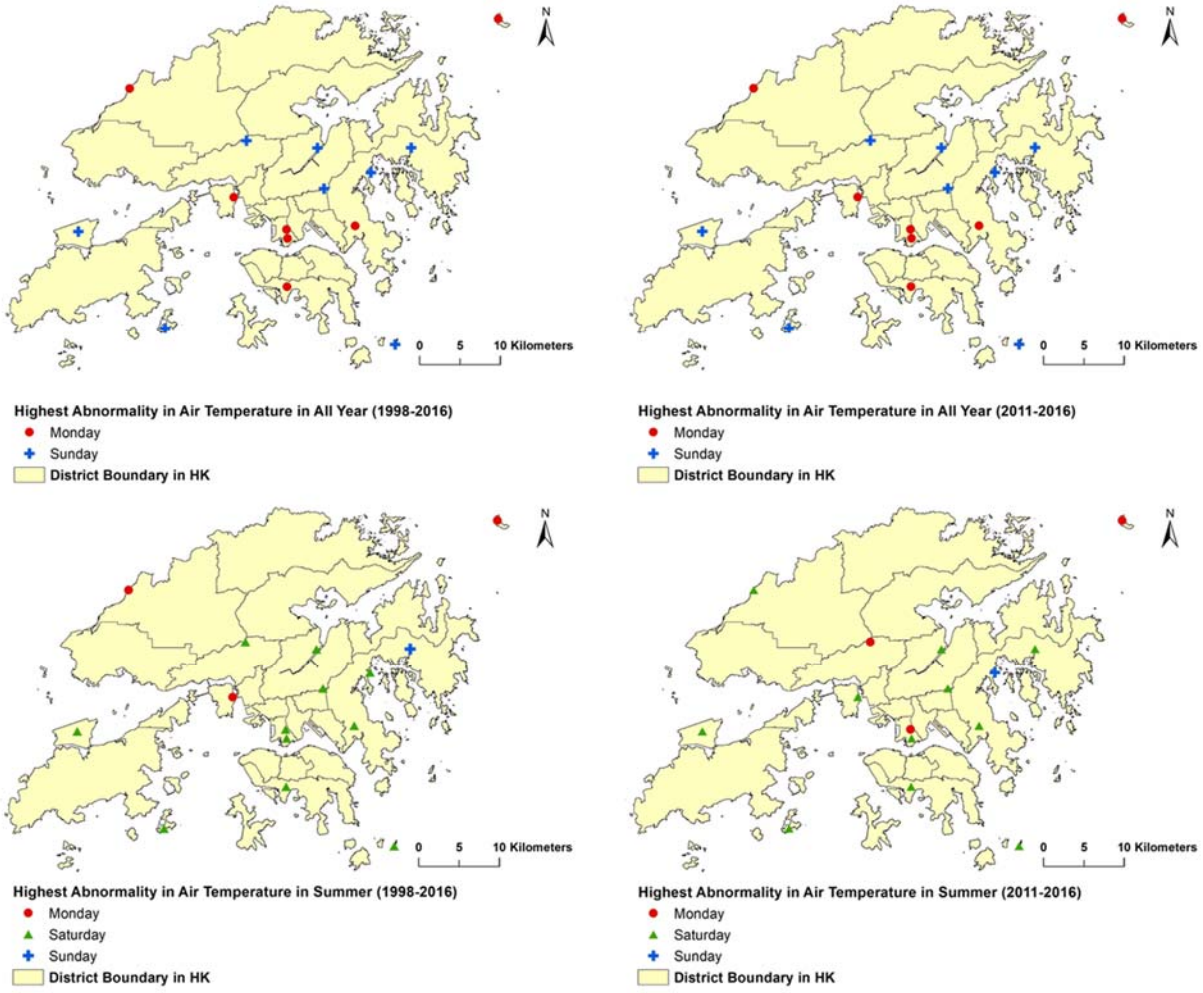
Five analysis procedures were involved: 1) Invalid data due to the failure of thermometers was removed. 2) Possible yearly and seasonal differences were removed by a 31-day moving average algorithm (Bäumer & Vogel, 2007). 3) Moving average was subtracted from daily mean temperature to obtain abnormal value. 4) WCs of AT abnormalities was explored in annual and summertime (June to September) distinctively in two study periods. 5) The statistical significance of the findings was examined.

The results demonstrate that WCs of AT exists in HK. The maximum of annual anomaly appears on Sunday or Monday while the minimum occurs from Wednesday to Friday. The difference between these two abnormalities is generally over 0.15℃. Although seasonal difference and yearly variance have been removed by the moving average calculation, abnormal values during Summer time are higher than that of the annual mean. And the highest abnormality appears on Saturday and Monday during summer time. Spatially, WCs in various geographical locations are weakly different in minimum weekdays or maximum weekends, yet limited distinction can be observed in general patterns. Temporally, WCs in long-term appears as a W-shape while in short-term it is more likely to be a V-shape. These findings are tested by Kendall's test and Monte Carlo test (10,000 times). The results of the former test indicate that the ranking of AT abnormality among 7-day are statistically significant at 99% level, and the results of the latter test imply that it is below 1% of probability to accept the null hypothesis of no significant WCs.

While anthropogenic heat is hardly quantified due to limited data access in energy consumption, WCs provides an effective alternative for observing anthropogenic heat and its impact on climate. Similar weekly patterns of abnormal AT are found spatially and temporally in HK, which means WCs of AT is a common phenomenon in HK at the district-spatial scale as well as both in annual-temporal and summer-temporal scale. Given the frequent abnormal AT on Saturdays and Mondays during summertime in Hong Kong, the government should bring more focus on heat vulnerability and provide priorities for resources reallocation to relieve extreme heat in these two days.

In future analysis, WCs of energy consumption peak hours will be explored. And if data sources in human activities and energy consumptions are available, for example, the cellular signal data, night-time light data, validation should be conducted at an appropriate analysis scale.

Figure:



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