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Investigation on the impact of built environment on summer night temperature in Hong Kong (2006-2015)

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Abstract:
Because of climate change, warming trend and extreme heat events are expected in near future (IPCC, 2014). For high-density cities, their thermal environment will be worsened especially in summer due to urban heat island effect (WMO & WHO, 2015). Hong Kong is a high-density high-rise city located in subtropical climate region. Its local weather records show a significant long-term temperature rising trend influenced by both global warming and local urbanization in past half century (HKO, 2015). It is also observed that numbers of hot nights have increased faster than numbers of very hot days (HKO, 2015). It can potentially cause local people's sleep disorder and other heat-related public health impacts in summer. There is a recent call from World Health Organization (2009) to improve urban planning and building design policies, so heat exposure and potential heat mortality can be reduced. Previous studies have analyzed the impact of built environment on daytime temperature at the city level (Giridharan et al, 2004). However, there are few studies on the intra-urban variation of the effect of built environment. Moreover, local actions and policies only focus on daytime condition. The limited understanding makes the policy makers difficult to find target and efficient solutions to mitigate heat exposure. Thus, given high-density compact urban setting in Hong Kong, there is a need for the spatial understanding of the impact of urban environment on summer night temperature and corresponding heat-related health risk analysis and adaptation management.

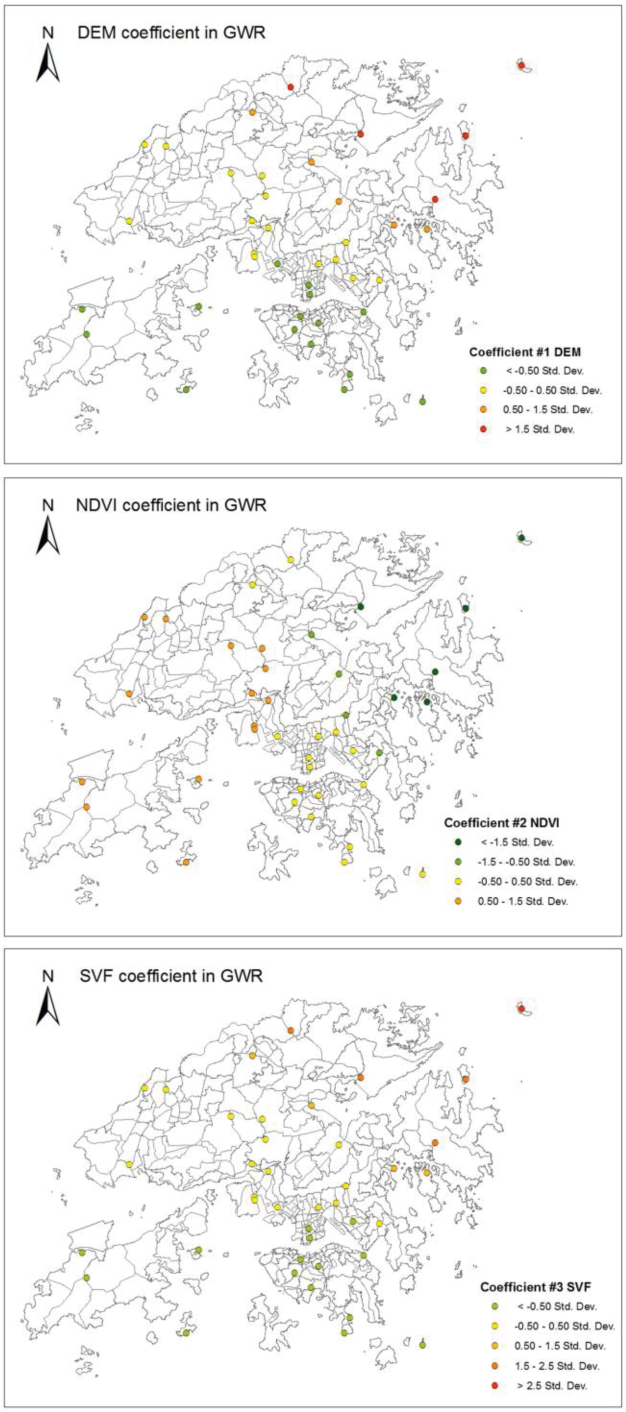
This study aims to: (1) find out the overall impact of built environment on summer night temperature, and (2) analyze intra-urban variations of the impact of built environment in Hong Kong. The spatial understanding on the association between built environment and summer temperature can contribute to more effective adaptation measures and mitigation strategies of heat exposure in Hong Kong.

In this study, firstly, temperature records from 2006 to 2015 were collected from 40 ground stations of the Hong Kong Observatory (HKO). Sky view factor (SVF), normalized difference vegetation index (NDVI) and digital elevation model (DEM) were selected as built environmental factors to represent building morphology, greenery and elevation, respectively. The NDVI was calculated from Sentinal-2 satellite images in 2016 while SVF and DEM were acquired based on the geographic information system (GIS) data from the planning department in 2009. Secondly, ordinary least squares (OLS) regression modelling was applied to investigate the overall relationship between summer night temperature and these selected built environment factors at the city level. A multiple linear regression model can be developed with the selected built environment factors as independent variables. Thirdly, spatial autocorrelation analysis was conducted to examine spatial pattern of the OLS regression residuals to determine whether a geographically weighted regression (GWR) model can be specified. In contrast to OLS regression, GWR can model the spatial variation of the impact of built environment with proper consideration on the sample locations (Fotheringham, 2003). Finally, the GWR was performed to further estimate specific response of summer night temperature to the built environment factors. In this model, adaptive Gaussian kernel and the corrected Akaike information criterion (AICc) were adopted for determining the bandwidth.

The overall impact of the built environment on the temperature can be quantified in the OLS model with an adjusted R^2 of 0.88. The negative coefficients of DEM and NDVI suggest an overall cooling effect on the summer night temperature. According to the standardized coefficients, DEM has the greatest contribution to the decrease of summer night temperature. The relationship between SVF and summer night temperature has large variance across space, especially between high-density urban areas and rural areas, which cannot be described by the global OLS model. Meanwhile, low spatial autocorrelation is identified in the regression residuals, indicating the GWR model can be specified using the three built environment factors. Therefore, it is necessary to apply GWR to exhibit the variations of the impact of the built environment factors across space. The local R^2 ranges from 0.86 to 0.93 in the GWR. The absolute values of coefficients of DEM and SVF in the northern rural areas tend to be higher, indicating the increase in altitude and openness can result in a greater summer night temperature decrease in the north than the south. Meanwhile, greenery in the west and middle of Hong Kong where most areas belong to high-density urban areas such as Kowloon and Hong Kong Island, has greater impact on decreasing the temperature than the rural areas. Therefore, proper planning of green space can potentially reduce summer night temperature in high-density urban areas in Hong Kong.

The results would provide not only climatologists but also planners and governors with a visualized spatial information on the impact of selected built environmental factors. The spatial understanding can be referred by town planners to develop effective climate-responsive design strategies in order to create more resilient cities.

Figure:



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