Urban heat islands in Hong Kong: Statistical modeling and trend detection

Weiwen Wang[1,2], Wen Zhou[3], Edward Yan Yung Ng[2, 4, 5], Yong Xu[4]

1. *Institute for Environmental and Climate Research, Jinan University, Guangzhou, China*
2. *School of Architecture, The Chinese University of Hong Kong, Hong Kong SAR, China*
3. *Guy Carpenter Asia-Pacific Climate Impact Centre, School of Energy and Environment, City University of Hong Kong, Hong Kong SAR, China*
4. *Institute of Future Cities, The Chinese University of Hong Kong, Hong Kong SAR, China*
5. *Institute of Environment, Energy and Sustainability, The Chinese University of Hong Kong, Hong Kong SAR, China*

1. Introduction

Urban heat islands (UHIs), usually defined as temperature differences between urban areas and their surrounding rural areas, are one of the most significant anthropogenic modifications to the Earth's climate. This study applies the extreme value theory to model and detect trends in extreme UHI events in Hong Kong, which have rarely been documented.

As illustrated in Fig. 1, large developments occurred in New Territories (northern Hong Kong) and in nearby Shenzhen. On the Kowloon Peninsula, a major change is that the reclaimed areas on the east and west margins of the peninsula in Figure 1a are mostly built up in Figure 1b. Vegetative cover reductions (in red) inside the peninsula are evident as well. Very limited changes are found in Sai Kung (eastern Hong Kong).

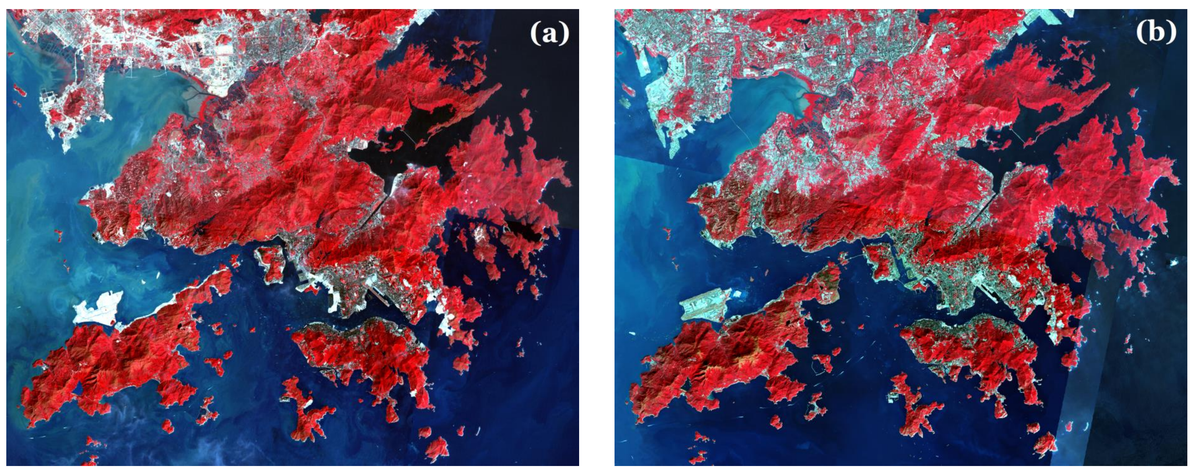

Fig. 1 Landsat images of land cover over Hong Kong and adjacent Shenzhen in (a) 1994, and (b) 2013–2015. Red indicates vegetation, blue indicates water, gray denotes buildings, and white denotes flat artificial covers. Data are downloaded from the United States Geological Survey http://glovis.usgs.gov.

2. UHI in Hong Kong

In this study, we chose HKO as the urban site, and three other weather stations, Ta Kwu Ling (TKL), Tsak Yue Wu (TYW), and Waglan Island (WGL), as rural sites to quantify UHI intensities in Hong Kong.

Because the daily maximum UHI intensities generally occur at night, particularly in the early morning before sunrise (Fig. 2), the daily minimum of hourly temperature is used to characterize temporal trends of temperature at both the urban and rural sites.

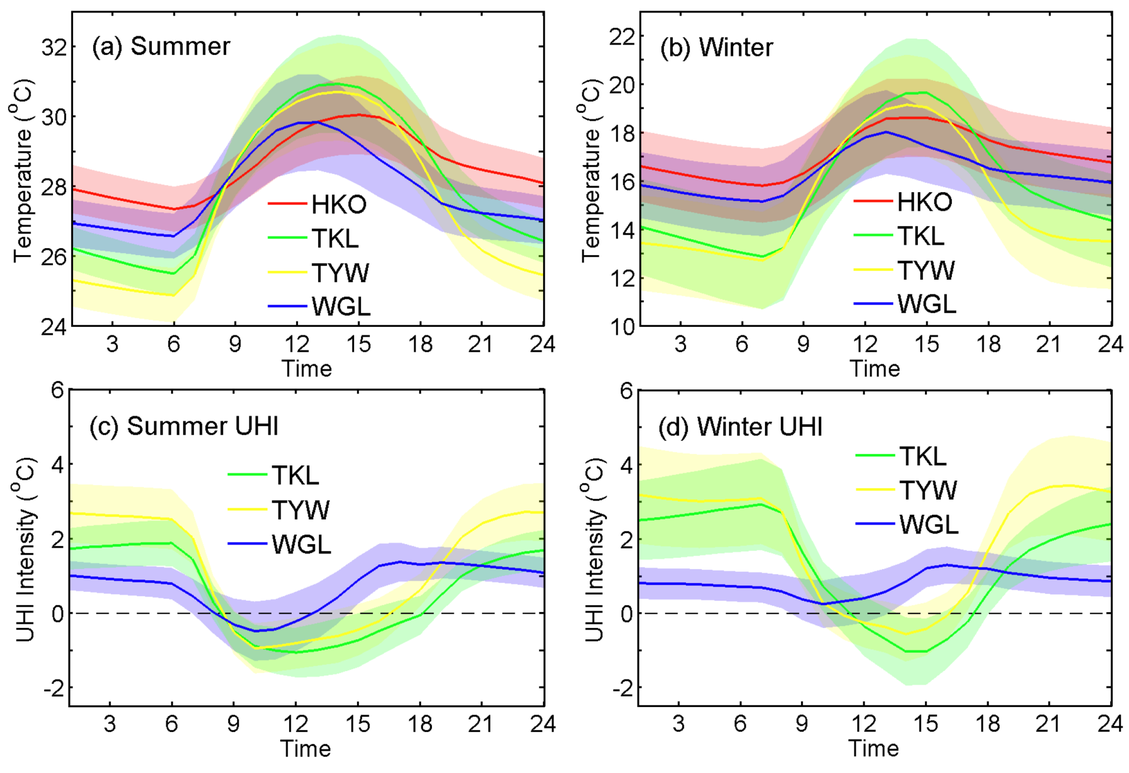

Fig. 2 Diurnal cycle for temperature at four weather stations in (a) summer, and (b) winter, and diurnal cycle of UHI intensities calculated by three pairs of weather stations (taking HKO as the urban site) in (c) summer, and (d) winter. Local standard time is used. The shadings represent one standard deviation

3. Trends in extreme UHI

Extreme UHI events are defined as UHIs with intensity higher than a specific threshold, 4.8°C for summer and 7.8°C for winter. Statistical modeling based on extreme value theory is found to permit realistic modeling of these extreme events. Trends of extreme UHI intensity, frequency, and duration are introduced through changes in parameters of generalized Pareto, Poisson.

In summer, the trend is 0.042 and 0.011 for intensity and frequency per year (Fig. 3). P-values of the log-likelihood test estimated in the peaks-over-threshold model suggest that the trend of intensity is significant at the 0.05 level, while the trend of frequency is not significant. It is found that there is no trend of extreme UHI intensity and frequency in winter (Fig. 4).

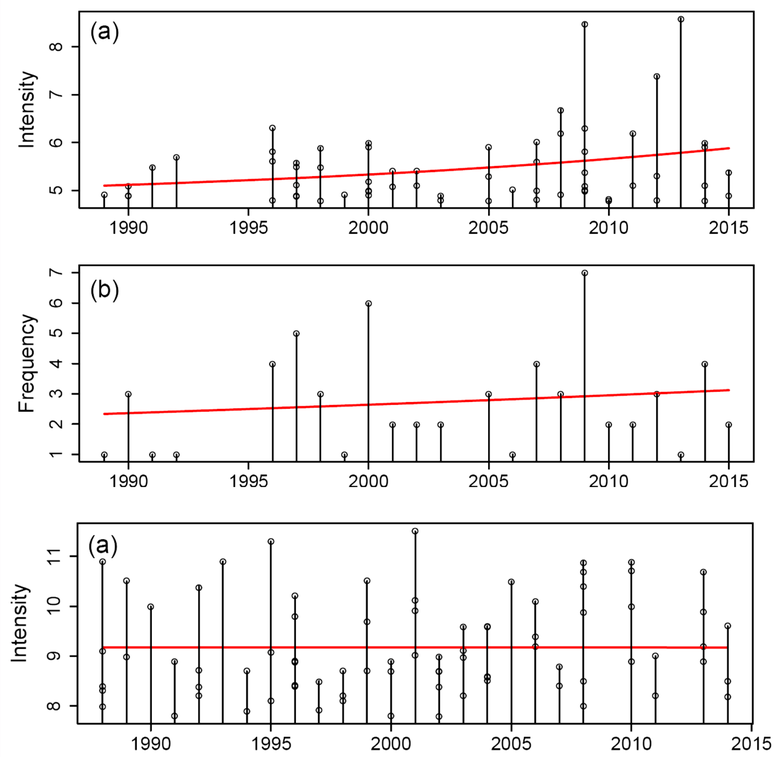

Fig. 3 Trends (red lines) of (a) intensity and (b) frequency of extreme UHI events in summers estimated by the GP and Poisson distributions, respectively. The stems represent observed values

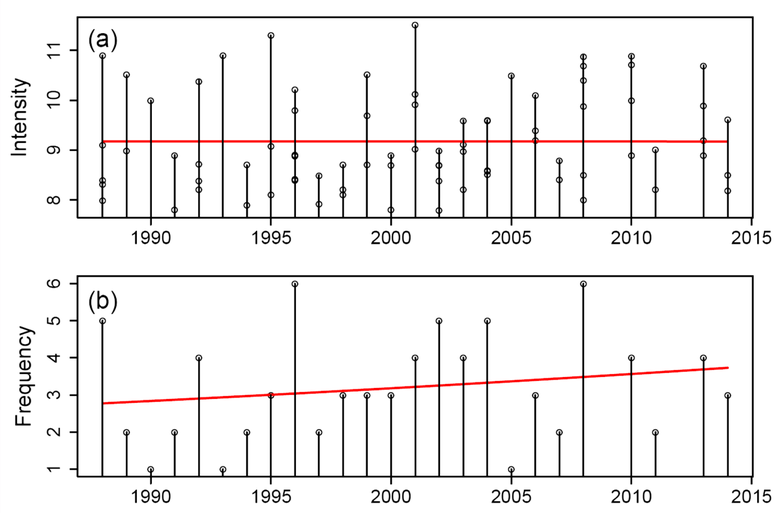

Fig. 4 Trends (red lines) of (a) intensity and (b) frequency of extreme UHI events in winters estimated by the GP, Poisson, and geometric distributions, respectively. The stems represent observed values

4. Conclusion

As a high-density city in the subtropics, Hong Kong is suffering from the ill effects of UHIs due to land use, urbanization, and human activities. The old and the weak living in their tiny rooms in urban areas will have to face an increasing number of hot nights. What we have taken into account is the daily maximum UHI, which usually occurs at nighttime. Meanwhile, extreme UHIs have a high possibility of happening at a time when the background temperature is high, due to the synergistic interactions between UHIs and heat waves (Fig. 5). To mitigate the impacts of UHIs, strategies such as adding greenery and planning a city with good natural ventilation need to be implemented.

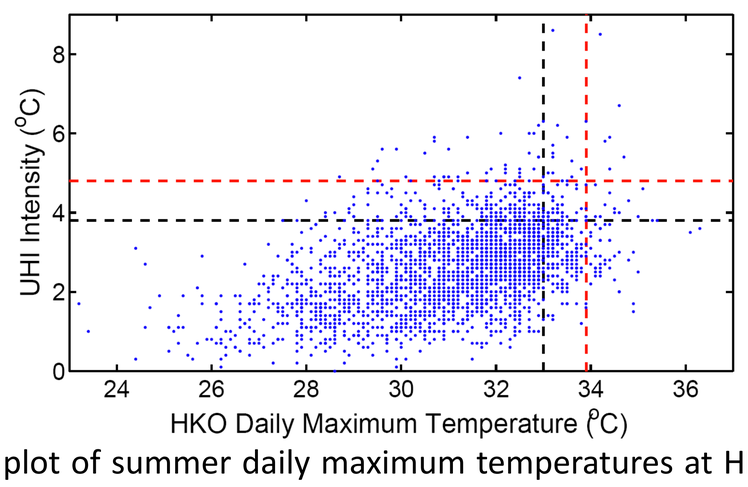

Fig. 5 Scatter plot of summer daily maximum temperatures at HKO versus daily maximum UHI intensities. The vertical (horizontal) black dashed line denotes the 88th percentile of daily maximum temperature, 33.0°C (UHI intensity, 3.8°C). The vertical (horizontal) red dashed line denotes the 97.5th percentile of daily maximum temperature, 33.9°C (UHI intensity, 4.8°C)