# Nocturnal Warming of Urban Heat Island Effect in the Taipei Metropolitan Area

# 台北都會區熱島效應的夜間增溫現象

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## Abstract

This investigation presents the nocturnal warming phenomenon from hourly temperature data of four station pairs in Taipei area during the 1964~2004 period. Analytical results show that the ascending rate of nocturnal warming of Taipei metropolitan area has been significantly rising in recent decades. One of main reason in this nocturnal warming is attributed to a strong negative Urban Heat Island (UHI) during the daytime (9:00am~16:00pm). In addition, the number of hours higher than 30℃ has been increasing at a rate of 2.5 hour/year during 18:00~24:00. The number of hours higher than 35°C in Taipei from 1964 ~ 2004 presents an obviously positive trend with a rate of 0.4 hour/year and indicates a continuous warming tendency toward the future along with the global warming. A strategy to mitigate urban nocturnal warming is urgent and indispensable.

## 1. Introduction

The nocturnal heat island results from diverging rates of cooling between the urban and the rural environments (Oke, 1982) and the thermal performance of an inner city is usually affected by land area, massing and surrounding buildings. UHI in Taipei metropolitan area was found in reaching a peak just two hours after sunset (about 8 p.m.), and its temperature distribution spreads in a nearly uniform pattern (Fig. 2(a)). These two features imply a serious development model for the Taipei metropolitan area. Also, Taiwan has been experiencing a regional scale heat-island effect and diurnal temperature has decreased by about 1.1 degrees since 1950, about twice the corresponding values over major continents. These changes induce significant impacts to air quality, heat stroke etc., and thus raise health risk concerns (Kalkstein and Smoyer, 1993). The effect of UHI in the subtropical Taipei city is showing an alarming signal (Liu, et al., 2002; Lin et al., 2005[a] and 2005[b]).

## 2. Site and Investigation

In this study we chose fifteen CWB and Environmental Protection Administration (EPA) weather stations in Taipei metropolitan area, and selected four urban-rural pairs (Taipei-Wenshan, Taipei-Chuchi, Taipei-Shanchia, and Taipei-Shiji) for detailed comparison. In the text, "Center" represents the average temperature and the geometric center of 15 stations (Fig. 1).

## 3. Results and Discussion

Fig. 2(a) indicates a higher temperature spot in the center-left side and implies where the urban development started. Fig. 2(b) exhibits the 1 standard deviation (SD) contours of temperature variations. The most-uniform temperature distribution area implies the heaviest development section on the entire metropolitan area. Fig. 3 shows the daily average of UHI intensity for four station pairs from 1998~2004: (a) Taipei-Wenshan; (b) Taipei-Chuchi; (c) Taipei-Shanchia and (d) Taipei-Shiji. In Fig. 3(a), peak of UHI intensity occurs at 2 hour after sunset. This feature suggests the earlier reach of temperature climax and is due to a very high urban density in Taipei city center. The fast UHI ascending rate will probably induce higher risk of temperature-related mortality in the future. Fig. 3(b) shows daily average of UHI intensity in Taipei-Chuchi pair from 1998~2004. Fig.3(b)~3(d) pairs exhibit a persistently rising pattern in UHI until 5:00~6:00 am of next day and is quite different from Fig.3(a) that shows abruptly deceasing UHI after pm. 7~8.

In comparison of Type 1 and Type 2, the Taipei-Shiji pair shows a significant difference in UHI pattern that no negative anomaly appears in the record of Taipei-Shiji pair and the temperature in Taipei is always higher than that of Shiji. This observation suggests that although both sites have experienced a similar development pace for the past years, Shijji, however, is located in more mountainous area with easy reaching of northeast monsoon there thus causes better ventilation to cool. Fig. 4 illustrates the anomaly and linear trend of monthly mean maximum UHI for four pairs from 1998~2004. Again, Taipei-Shiji pair shows a negative slope. Fig. 5 shows the trend of night-time at 18:00 to 24:00 from 1964~2004, with a rising rate of 2.5 hour/year. Apparently, the nocturnal warming is

more evident than that of day-time trend at a factor of 2. Fig. 6 shows numbers of hours higher than 35°C in Taipei from 1964 ~ 2004 with an increasing trend through years.

## 4. Conclusion

The warming trend seems inevitable in the Taipei metropolitan area and a strategy to mitigate urban nocturnal warming is urgent and indispensable. This study presents the urban warming phenomenon from hourly temperature data of weather stations in Taipei area during the 1964~2004 period. The temperature contour maps clearly demonstrate the development stages in the Taipei metropolitan area for the past decades. Analytical results also show the warming trends in Taipei metropolitan area has been significantly observed in recent decades. In addition, the number of hours higher than 30℃ has been increasing at a rate of 2.5 hour/year during 18:00~24:00. On the other hand, a reducing trend (1.1 hour/year) has been found for the number of hours less than 10℃ at the same time span. This study is useful for the reference of policy-makers for the development of a sustainable Taipei city and can be applied to other metropolitan areas in Taiwan.

## 5. References


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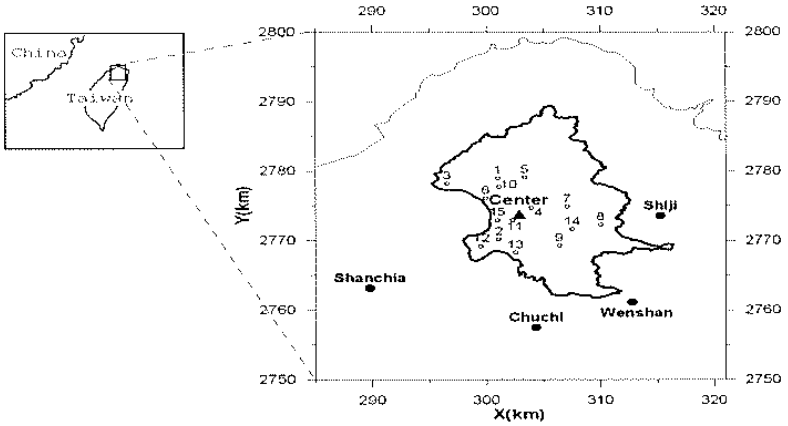



Fig. 1. Location map of 15 Center Weather Bureau (CWB) and Environmental Protection Administration (EPA) stations selected in Taipei, and four urban-rural pairs (Taipei-Wenshabn, Taipei-Chuchi, Taipei-Shanchia, and Taipei-Shiji) of this study. "Center" means the average temperature and the geometric center of 15 stations.

Table 1. The related parameters of four rural stations of Taipei area.

| Station Name | UHI (°C) | H (m) | [a]D (km) | X (km) | Y (km) |
|---|---|---|---|---|---|
| Wenshan | 1.68 | 410 | 16.0 | 312.8 | 2761.2 |
| Chuchi | 2.18 | 90 | 16.3 | 304.3 | 2757.5 |
| Shanchia | 1.60 | 10 | 16.9 | 289.8 | 2763.2 |
| Shiji | 1.72 | 15 | 12.4 | 315.3 | 2773.5 |

D: distance from rural station to "Center"; H: height

[a]Distance: from rural station to "Center" of Taipei station.

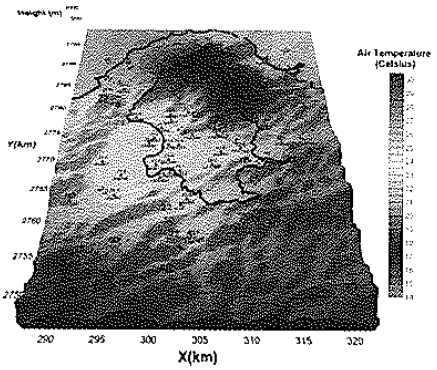



Fig. 2 (a) Temperature distribution in 8:00 p.m. from fifteen stations inside Taipei basin suggests a high temperature area (old downtown) in left side and implies where the urban development was beginning.

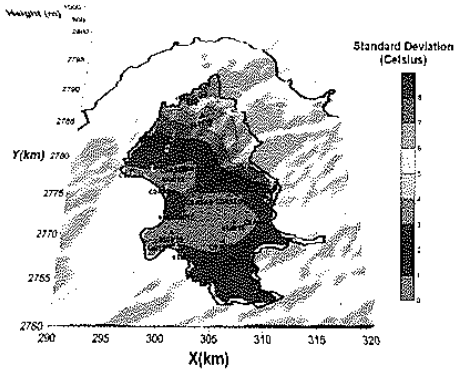
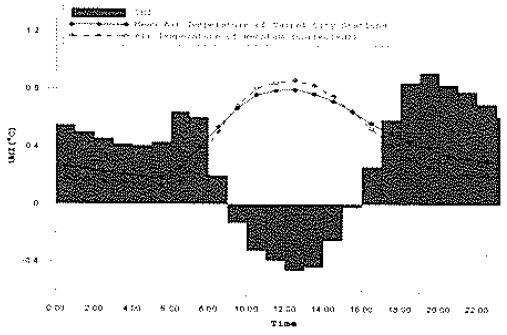
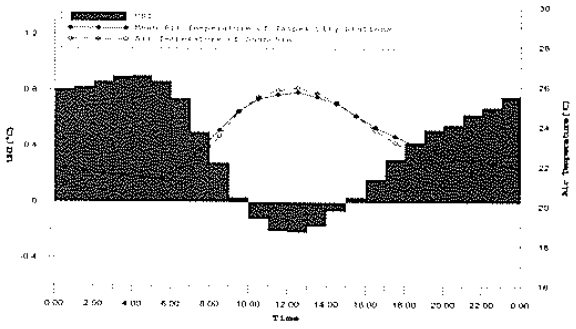



Fig. 2(b) The 1-SD (most-uniform) temperature distribution was marked as the purple color which indicates the densest development section in the entire Taipei basin.

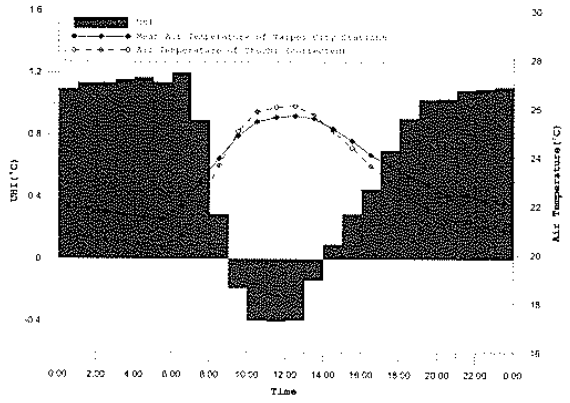
(a ) Type 1 : Taipei-WenShan (UHI=1.68°C)



(b) Type 1 : Taipei-Chuchi (UHI=2.18°C)



(c) Type 1 : Taipei-Shanchia (UHI=1.60°C)



(d) Type 2 : Taipei-Shiji (UHI=1.72°C)

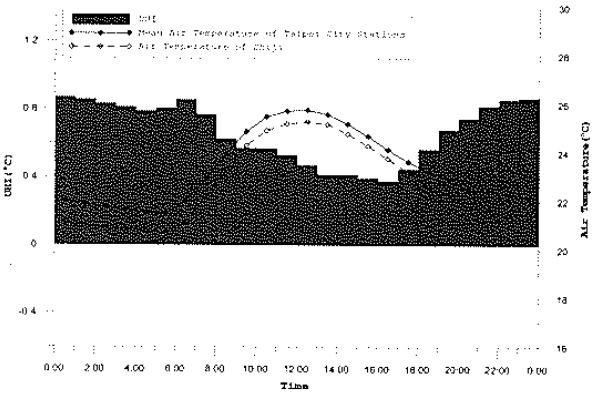
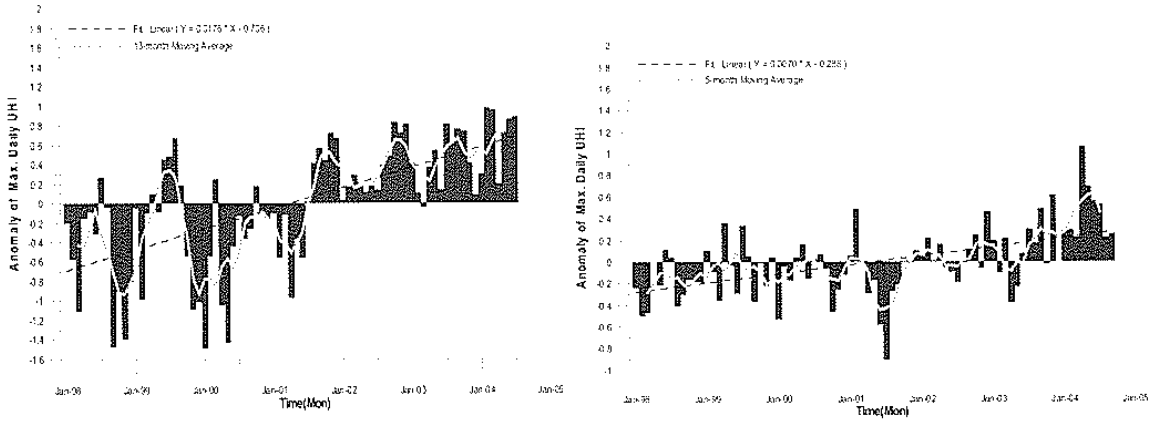


Fig. 3. Daily average of UHI intensity of four station pairs from 1998~2004. Red column shows UHI intensity. The UHI patterns of in type 1 and type 2 are quite different. The former displays negative UHI during the day-time, whereas the latter does not. This discrepancy means no significant temperature difference between city (Taipei) and rural (Shiji). This may be due to a rapid developing pace and better ventilation in Shiji during recent decades. Fig3(a) shows the peak of UHI intensity occurring at 2 hour after sunset and suggests the earlier reach of temperature climax is due to a relatively high urban density in city center. The fast ascending of UHI would induce a higher risk of temperature-related mortality.

(a ) Type 1 : Taipei-WenShan

(b) Type 1 : Taipei-Chuchi




(c) Type 1 : Taipei-Shanchia

(d) Type 2 : Taipei-Shiji

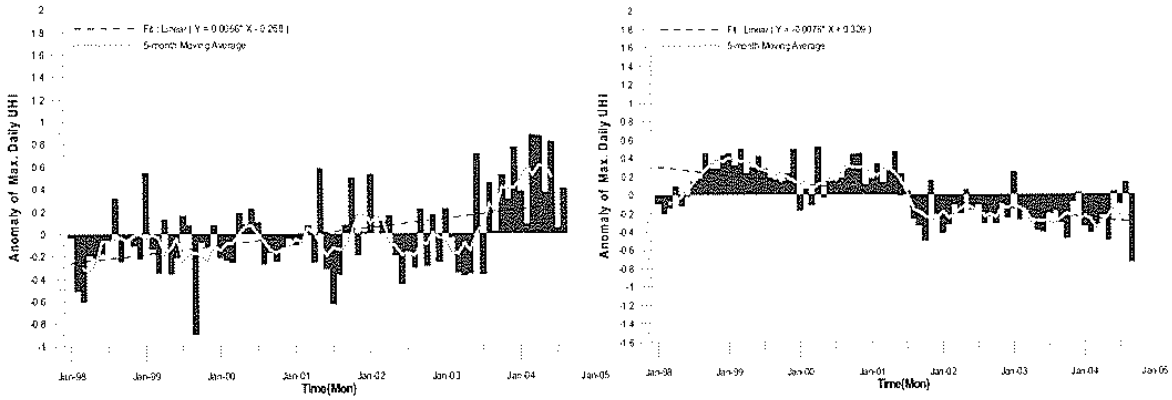



Fig.4. The anomalies and linear trends of monthly mean daily maximum UHI in four pairs of Taipei area in 1998~2004. Type 1 indicates an increasing trend with highest positive anomalies during the latest two years, whereas type 2 shows a decreasing tendency indicating an extensive development in recent years for Shiji area.

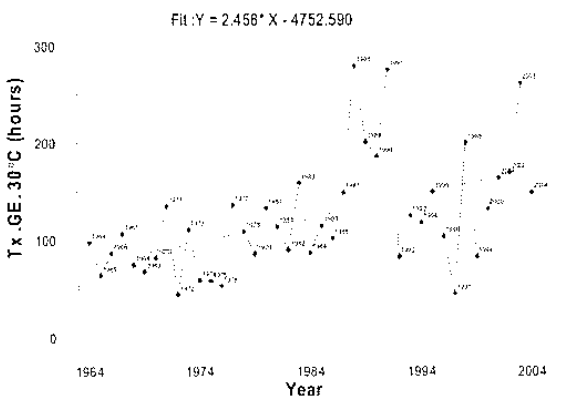



Fig. 5. The fast rising trend of number of temperature hours higher than or equal to 30 °C at 18:00 to 24:00 from 1964~2004 in Taipei.

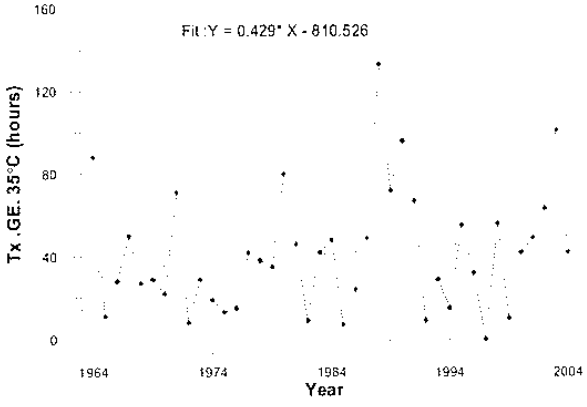



Fig. 6. The rising trend in number of temperature hours higher than or equal to 35 °C from 1964~2004 in Taipei.