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Erratum to "Temperature and hydrological variations of the urban environment in the Taipei metropolitan area, Taiwan"

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ABSTRACT

In this study, the temperature, precipitation and groundwater level variations and changing patterns with varied time scales are presented for Taipei metropolitan area which consists of the capital city with neighboring counties. Along with the continuous city expansion during the past decades, global warming and heat island effect have generated perceivable negative impacts on environmental and reflect on the climatic and hydrological parameters. In addition to accelerating climate warming, hydrological extremity becomes more evident during the past decades and greatly elevates the risks of drought and floods in the study area. These observations in the Taipei metropolitan area support the common hypothesis that climate variability would increase as climate warms. The air temperature records, in conjunction with hydrological data, provide useful and invaluable information for the ongoing study of subsurface environmental changes resulting from nature and anthropogenic influences in Taipei metropolitan area. The continuing climatic warming and hydrological extremity would create observable impacts on the subsurface environment of Taipei metropolitan area and need to pursue in a fast and efficient pace.

1. Introduction

Taipei is the capital city and serves as political, economic, educational, cultural, transportation, information and technology hub of Taiwan. Surrounded by mountains on all sides, Taipei city and neighboring areas shape as a distinctive basin in the northern Taiwan (25.03° N, 121.31° E; Fig. 1) with an area of 380 km^2 and approximately 5 million inhabitants (WRPC, 1992; EPA, 2006). Its climate is hot and relative low humidity in summer, cool and relative high humidity in winter (Wan, 1973; Wu, 1993; Wang et al., 1994). Three rivers that come from east (Keelung), southeast (Hsintien) and south (Tahan) catchments, respectively, merge into one major stream (Tanshui) in the middle of Taipei Basin and flow northwesterly toward the Taiwan Strait (WRA, 2005).

The topic of climate change has become a major global issue (IPCC, 2007). Along with the continuous city expansion during the past decades, global warming has generated perceivable effects on the Taipei Basin (Wu, 1993; Chen and Wang, 2000; Hsu and Chen, 2002). The impacts of the urban heat island phenomenon and air pollution in this subtropical basin are alarming (Lin et al., 2005a,b,c; EPA, 2006), as many metropolitans show elsewhere (Jones et al., 1989; Chen et al., 2003; Taniguchi et al., 1999). Many research topics that are related to basic geology and earthquakes have been proposed and conducted in the Taipei Basin (Ho, 1974; Teng et al., 2001; Lin, 2005). However, very few studies have yet put focus on the environmental changes resulting from nature and anthropogenic impacts in the Taipei Basin.

This important topic needs to be addressed and investigated as soon as possible (Kaneko, 2005). This work presents the temperature, precipitation and groundwater level records of Taipei metropolitan area for the last century. Our main purpose aims to document the environmental changes through the climatic parameters and illustrate the impacts resulting from anthropogenic influences. These data will also serve as the background information for the integrated research project "Human Impacts on Urban Subsurface Environment" organized by Research Institute for Humanity and Nature (RIHN) of Japan and would be useful to other related studies targeted at the Taipei Basin.

2. Temperature records

As metropolitans elsewhere in the world, Taipei has experienced a steady increasing tendency in the air temperature from both the global warming and urban heat island effects due to fast pace of city expansion (Wu, 1993; Lin et al., 2005a,b,c). Fig. 2 displays the annual time series variations for yearly, January (coldest month, representing winter) and July (hottest month, representing summer) temperatures from 1897 to 2006 (CWB, 1897–2006) of Taipei meteorological station (25 ° 02′ 23″ N, 121 ° 30′24′ E; altitude = 5.3 m above mean sea-level; Fig. 1, red solid star). These temperature records are expressed as

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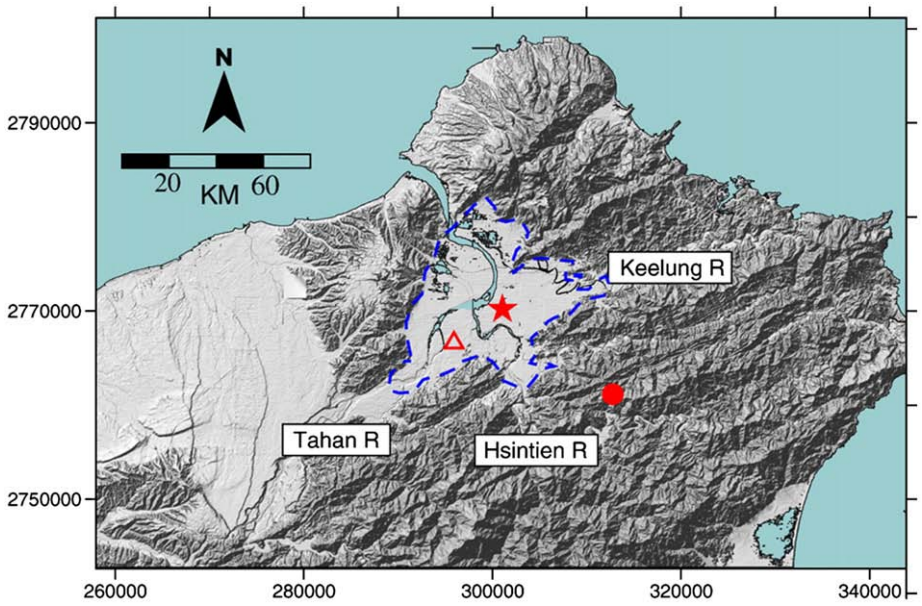

Fig. 1. Location of Taipei metropolitan area (circled by blue dashed line). Red solid star is the Taipei meteorological station; red solid dot is the Wenshan station; red open triangle is the Banchiao groundwater monitoring well. Three major rivers are shown as Keelung (east), Hsintien (southeast) and Tahan (south).

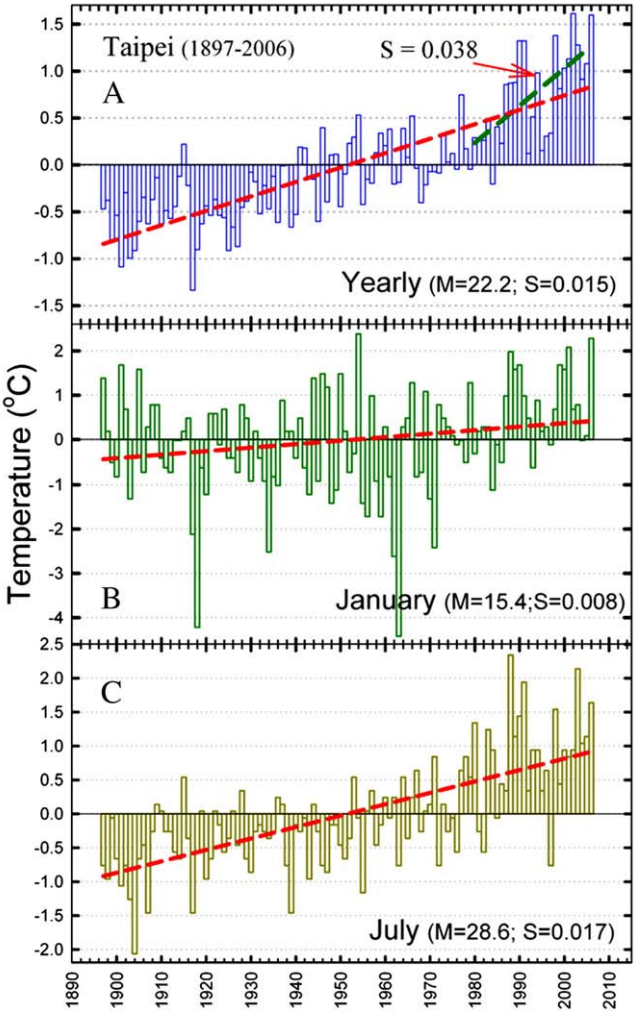

Fig. 2. The long-term annual temperature trends of Taipei meteorological station (A. yearly data; B. January; C. July). Long-term temperature averages are served as reference lines. Linear trends are illustrated as red dashed lines. The long-term temperature means and linear fitting slopes are shown in the respective parentheses.

anomalies relative to their long-term averages (yearly = 22.2 °C; January = 15.4 °C; July = 28.6 °C) which are shown as the zero reference line.

The general feature of the temperature tendency agrees well with the global average trends (IPCC, 2007). It is evident that Taipei has a linear rising rate of 0.15 °C/decade for the annual records (Fig. 2A), that is a factor of 2 higher than the world average and consistent with a previous study (Wu, 1993). However, the rising rate after 1980 shows a faster speed (0.38 °C/decade) than the linear rate for the past century, suggesting the recent acceleration of climate warming in the Taipei Basin. This feature is also observed in other metropolitans (IPCC, 2007). In terms of seasonal variations, the winter (Fig. 2B; slope = 0.008) not only shows a relative slow rate than that of summer (Fig. 2C; slope = 0.017), but also exhibits great fluctuations. Thus, summer temperatures have been warming more profound than the winter ones. This feature (fast rise in summer and slow rise in winter) is contrary to the general tendency observed in the high latitude of northern hemisphere (IPCC, 2001), indicating that the geographic discrepancy exists between the latitudes in terms of warming phenomena. The major reason for this seasonal difference is because the winter of Taiwan is heavily influenced by the cold fronts from Siberia; whereas summer is dominated by the monsoon from the tropics (Chen and Wang, 2000).

Regarding the diurnal variations, Fig. 3 shows the annual time series temperature records for the mean maximum (the highest temperature at day), mean minimum (the lowest temperature at night) and their difference in the Taipei Basin. It is evident that both the mean maximum and minimum temperature records show a rising trends but with different rates. The mean minimum temperature expresses a fast rising rate (0.21 °C/decade; Fig. 3A) than the mean maximum (0.09 °C/decade; Fig. 3B), indicating that night temperatures have been warming relatively fast than that of day temperatures. As a result, the diurnal difference between maximum and minimum temperatures show a decreasing trend (−0.12 °C/decade; Fig. 3C) and the negative anomalies mainly occurred after 1980, which is coincident with the onset of annual temperature rising in Fig. 2A and the fast city expansion in Taipei Basin.

The principle reasons for the decrease in diurnal temperature difference can be attributed to multiple factors, such as wind direction, land uses, high rise buildings expansion, and clouds/cloud albedo changes. Among these factors, the increase in clouds/cloud albedo resulting from anthropogenic aerosols is verified (Liu et al.,