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ARTICLE

Analysis of Surface Air Temperature Change in Macao During the Period 1901–2007

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Abstract

Change related to climate in Macao was studied on the basis of daily temperature observations over the period 1901–2007. The result shows that annual mean surface air temperature in Macao as a whole rose with a warming rate of about 0.066 °C per 10 years in the recent 107 years. The most evident warming occurred in spring and winter. The interdecadal variations of the seasonal mean temperature in summer and winter appeared as a series of waves with a time scale of about 30 years and 60 years, respectively. The annual mean minimum temperature increased about twice as fast as the annual mean maximum temperature, resulting in a broad decline in the annual mean diurnal range. The interdecadal variations of annual mean maximum temperature are obviously different from those of annual mean minimum temperature. It appears that the increase in the annual mean maximum temperature in the recent 20 years may be part of slow climate fluctuations with a periodicity of about 60 years, whereas that in the annual mean minimum temperature appears to be the continuation of a long-term warming trend.

Keywords: surface air temperature change; climate warming; maximum temperature; minimum temperature; Macao
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1 Introduction

Global climate change has become a subject of major concern for the international community. Many studies have been undertaken to examine the various facets of climate change, and some significant results were obtained. Recently, the Intergovernmental Panel on Climate Change (IPCC) concluded in its Fourth Assessment Report that in the recent 100 years (1906–2005), the global mean surface temperature (the mean of all near surface land and sea temperatures) rose by about 0.74 °C; the linear rate of increase in the recent 50 years was 0.3 °C per 10 years, approximately twice that in the past 100 years [*Qin et al.*, 2007]. In China, the trend in surface temperatures in the recent hundred years was found to be similar to that for the global/ Northern Hemisphere [*Ding and Dai*, 1994; *Wang et*

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al., 1998; *Lin et al.*, 1995; *Qian and Zhu*, 2001], but the increase rates range from 0.2 to 0.8 °C per 100 years [*Zhao et al.*, 2005]. The scarcity of data in China in the first 50 years of the 20th century, and the different methods used by the various investigators to interpolate or reconstruct the missing data have been suggested to be some of the causes of these inconsistencies [*Zhao et al.*, 2005].

The causes of global warming are very complex. Solar, volcanic and anthropogenic activities had been proposed as some of the possible reasons for the warming experienced in China. Among the many anthropogenic factors, urbanization and the heat island effect are likely to be the most important [*Ren et al.*, 2005]. It has been pointed out that if the effects of urbanization were excluded, the rise in China's mean surface temperature in the recent 54 years would be far less, about 0.15 °C per 10 years [*Ren et al.*, 2005]. It is very difficult to completely isolate the effect of urbanization from all the other factors influencing temperature rise. The traditional way to assess the contributions of urbanization is to compare temperature trends between urban and rural stations (i.e., "village" stations) using observations during the same period. However, because of the rapid urbanization in eastern China, it may be difficult for some studies already underway to have selected stations truly representative of the "village" conditions [*Ren et al.*, 2005].

Macao has a continuous meteorological record over a hundred years; this is very rare in south China and perhaps even in the whole China. Because of the unique geographical locations of Macao and its observing station, Macao's observations are relatively unaffected by urbanization. This paper analyses the basic characteristics of Macao's near surface temperatures recorded in the recent hundred years.

2 Data and Methodology

From the beginning of the 20th century to the 1920s, temperature observations in Macao were made 5 times a day (at 04:00, 10:00, 13:00, 16:00, 20:00 o'clock). Between the 1920s and the early 1950s, observations were made 3 times a day (at 09:00, 15:00 and 21:00 o'clock). From 1952 until today, observations were made every hour. The daily mean temperatures from 1952 onwards were calculated from the average of these hourly observations. The daily mean temperatures before 1952 were derived by linear regression in the following way. Using data between 1952 and 2000, a linear regression equation was constructed with the daily mean temperature as predictand, and the 3 times (at 09:00, 15:00 and 21:00 o'clock) or 5 times daily observations (at 04:00, 10:00, 13:00, 16:00, 20:00 o'clock) as well as the daily maximum and minimum temperatures as predictors. A linear regression equation was constructed for each month. The regression coefficients were tested with the *F*-test and found suitable to satisfy statistical significance requirements. The daily mean temperatures for the pre-1952 period were then inferred from the corresponding linear regression equations with the pre-1952 3 times or 5 times daily temperature observations as predictors. Using the 2001–2002 observations as a test case, it was found that with the daily maximum and minimum temperatures included as predictors, there was an improvement of some 0.3–0.4 °C in the daily mean temperatures estimated by linear regression when compared with those computed directly from the 3 times daily or 5 times daily observations. In addition, missing or erroneous observations in Macao's records were filled or calibrated through linear regression with the observations from the Hong Kong Observatory.

Since its establishment, the site of Macao's observing station has changed three times. Initially, between 1901 and 1903, this station was situated at Colina de Penha (Penha Hill, 22°11′20″N, 113°31′56″E, a.s.l. 55 m). In 1904, it was moved to Colina de Guia (Guia Hill, 22°11′45″N, 113°32′39″E, a.s.l. 65 m) where it remained till May 1966. The station was then relocated to Mount Fortress (22°12′57″N, 113°32′32″E, a.s.l. 57 m) where it stood till July 1996. Finally, in August 1996, the location