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ANALYSIS OF LONG TERM CHARACTERISTICS OF INTERANNUAL CHANGE OF TEMPERATURE IN DONGGUAN OVER THE RECENT 50 YEARS

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ABSTRACT: With the series of annual and seasonal temperature during 1957 – 2001 in Dongguan, Guangdong, the statistical characteristic and power spectrum and secular trend and sudden change phenomena are computed in this paper. From the results it is known that (1) the temperatures have obvious characteristics of monsoon climate but do not have normal distribution, showing biased distribution of high or low kurtosis; (2) over the recent half-century, the temperatures tend to rise, specially in the last 10 years, in which mean temperature have quickly ascended by about 1.5°C, and except for the spring, there were sudden change of seasonal temperature rising from the 1980’s to 1990’s, which really reflected the influence of developing and opening and urbanization on Dongguan temperature; (3) except for the spring, the temperature of other seasons show some oscillatory periods in Dongguan and some of them also include long-term variation trends.

Key words: characteristics of temperature change; statistical analysis; Dongguan

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1 INTRODUCTION

With the presence of greenhouse effect and rapid urbanization over the past decades, global climate has been warming up. An agricultural town more than 20 years ago, Dongguan, which sits on the estuary of the Pearl River in the south of China, has grown into a strong industrial base and urbanization with the development has substantially changed the look of its underlying surface and inevitably affects the local climate change. There have been studies on the long-term change of temperature in Shenzhen (Zhang et al.[1]), the climatic change in Guangzhou (Huang et al.[2]), the characteristics of winter temperature over the past 500 years in Guangdong (Li.[3]), the variation of temperature in Foshan over the past 50 years (Chen et al.[4]), urban climate change in Lanzhou over the last 50 years (Zhao et al.[5]), diagnostic analysis of winter temperature in the Guangdong province (Liang et al.[6]) and wavelet analysis of the climate in Guangzhou (Ji.[7]). In this work, the temperature series for Dongguan over the past 45 years is used to probe its variation by ways of statistical quantity computation, spectral analysis, tendency analysis and abrupt change analysis.

2 DATA AND COMPUTATION METHODS

2.1 *Basic dataset*

Monthly temperature dataset for 1957 – 2001 recorded at the Meteorological Bureau of

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Dongguan is used to set up time series of temperature over the course of summer, winter and the whole year, during which the method of difference correction is used to interpolate records that are missing or incorrectly stored.

2.2 *Methods of computation*

2.2.1 COMPUTATION OF STATISTICAL TEMPERATURE QUANTITIES

Following Yao[8], the temperature series can be exploited to obtain its mean, standard deviation, coefficients of variation, skewness and kurtosis.

2.2.2 ANALYSIS OF TENDENCY OF TEMPERATURE SERIES

By the tendency of temperature series, a long-term tendency of variation is shown that is longer than the length of the series, which can be fitted with a polynomial function[9].

2.2.3 ANALYSIS OF ABRUPT CHANGE OF TEMPERATURE SERIES

Following the work by Fu[10] and Wang[11], the Mann-Kendall method is used here to study the abrupt change of the temperature series.

2.2.4 ANALYSIS OF POWER SPECTRUM OF TEMPERATURE SERIES

The analysis of power spectrum can be useful in studying the variation period of element series[10]. The continuous power spectrum of standardized time series $x(t)$ can be obtained using the relevant function method of Blackman-Tukey. To verify the significance of the period, the red-white noise characteristics of the series is based to run a test of χ^2.

3 ANALYSIS OF RESULTS

3.1 *Analysis of statistical temperature quantities*

Mean values, standard deviation, coefficients of variation, skewness and kurtosis of the temperature series for the whole year, spring, summer, autumn and winter are sought and listed in Tab.1. It shows that it is warm through all seasons in Dongguan with the annual mean temperature at 22.2°C, the summer mean at 28.1°C and winter mean at 14.9°C. It is obvious that it is relatively cold only in the three winter months while it is warm in spring and autumn but hot in summer, showing significant characteristics of monsoon climate. The monthly mean temperature shows sinusoidal distribution that peaks in July (28.5°C) and bottoms in January (14.1°C). The standard deviation is small in summer but large in winter, reflecting the effect of continental monsoon in winter is larger than that of the South China Sea in summer. The maximum monthly temperature occurs in August (30.1°C) while the minimum in February (9.8°C), having a difference of 20.3°C. To study the normality of the temperature distribution, the coefficients of variation and skewness are obtained for individual seasons. Tab.1 shows that Dongguan's temperature in January, February, March, July, November and the winter is of negatively biased low-kurtosis distribution while it is of positively biased low-kurtosis distribution in April, May, June, September, October, the spring, summer and autumn. The August temperature shows a positively biased high-kurtosis distribution but the December temperature displays a negatively biased high-kurtosis distribution. Though the skewness coefficients are close to normal distribution for July, December, spring and winter, the kurtosis ones aren't. It is now seen that the Dongguan temperature is not fully normally distributed. If $|\gamma| \geqslant 0.30$ or $|\beta| \leqslant 0.30$ is viewed as the usual case, then January is of negatively biased low-kurtosis distribution, May and summer of positively biased low-kurtosis distribution, June, July and the year of positively biased distribution and April, July, September, October and spring of negatively biased distribution. On the other hand, if $|\gamma| \geqslant 0.6$ or $|\beta| \geqslant 0.6$ is treated as large deviation or kurtosis states, then only August can be seen as positively biased annual distribution while April, May, July, September, spring and summer as low-kurtosis distribution, without significant deviation and kurtosis states simultaneously in any season.

Tab.2 shows the linear tendency equations of standardized variables, correlation coefficients and climate variability for temperature of the whole year and four seasons. The climate variability is calculated following the methods by Lin et al.[11]. It is known from the table that the correlation coefficients are more than 0.67 for the year, summer and autumn and climate variability is also above 0.52 (°C / 10a), which is equivalent of the mean growth rate of temperature across the country over the same period, showing an obvious tendency. In contrast, it is relatively small in the winter and spring, with the correlation coefficient and climate variability below 0.46 and 0.35 (°C / 10a), showing a weak tendency.

Tab.3 shows the tendency regression equations of standardized variables and complex correlation coefficients for temperature of the whole year and four seasons. It is known from the table that the annual temperature has the best-defined tendency with tendency equations that contain the first to third orders, with the correlation coefficient as high as 0.82, followed by autumn and summer. Fig.1 shows the ultra-long-term variation tendency of seasonal temperature. Fig.1a reveals that the annual mean temperature tends to be rising significantly, with a gradual fall in 1957 – 1960, a gradual rise early 1970’s through the end of the 1980’s, with the tendency curve going above the mean in 1986, followed by a rapid increase of about 1.5°C over a dozen year or so. Fig.1b is the spring temperature in which the tendency curve is generally falling between 1957 and 1980 before rising continuously and going above the mean in 1992, contributing a rise of about 1.1°C over a dozen year or so. Fig.1c is the summer temperature in which the tendency curve is generally falling between 1957 and 1980 before rising almost linearly and going above the mean in 1982, contributing a gradual rise over the past few years. The rise is about 0.9°C over a period of more than 40 years. Fig.1d is the autumn temperature in which the tendency curve falls slightly from the 1957 low level before rising in 1971 and going above the higher end of the mean in 1986 and keeps a rapid rise ever since, contributing a rise of about 1.9°C over the past 20 years. Fig.1e is the winter temperature in which the curve is parallel to the mean after 1957 but begins to rise slowly in 1970 and goes above the higher end of the mean in 1987 and starts a rapid rise that is about 1.9°C over the past dozen year or so. Generally kurtosising, temperature in Dongguan shows a rising tendency over the past 50 years, specially in the period after the 1980’s, showing that the reform and opening-door practice and urbanization does have significant effects on it.

Tab.1 Statistics of seasonal temperature in Dongguan (unit: °C)

Time span	mean	Max.	Min.	Standard deviation	Coefficients of skewness	Coefficients of kurtosis
Jan.	14.1	16.6	10.9	1.5	-0.390	-0.454
Apr.	22.4	24.9	20.2	1.2	0.186	-0.781
Jul.	28.5	29.6	27.5	0.5	-0.023	-0.834
Oct.	24.2	26.4	22.3	1.0	0.271	-0.560
Annual	22.2	23.59	21.36	0.5	0.724	-0.207
Spring	22.2	23.63	20.27	0.8	0.039	-0.791
Summer	28.1	29.07	27.3	0.4	0.411	-0.604
Autumn	23.7	25.6	22.03	0.8	0.266	-0.191
Winter	14.9	17.47	12.43	1.1	-0.043	-0.249

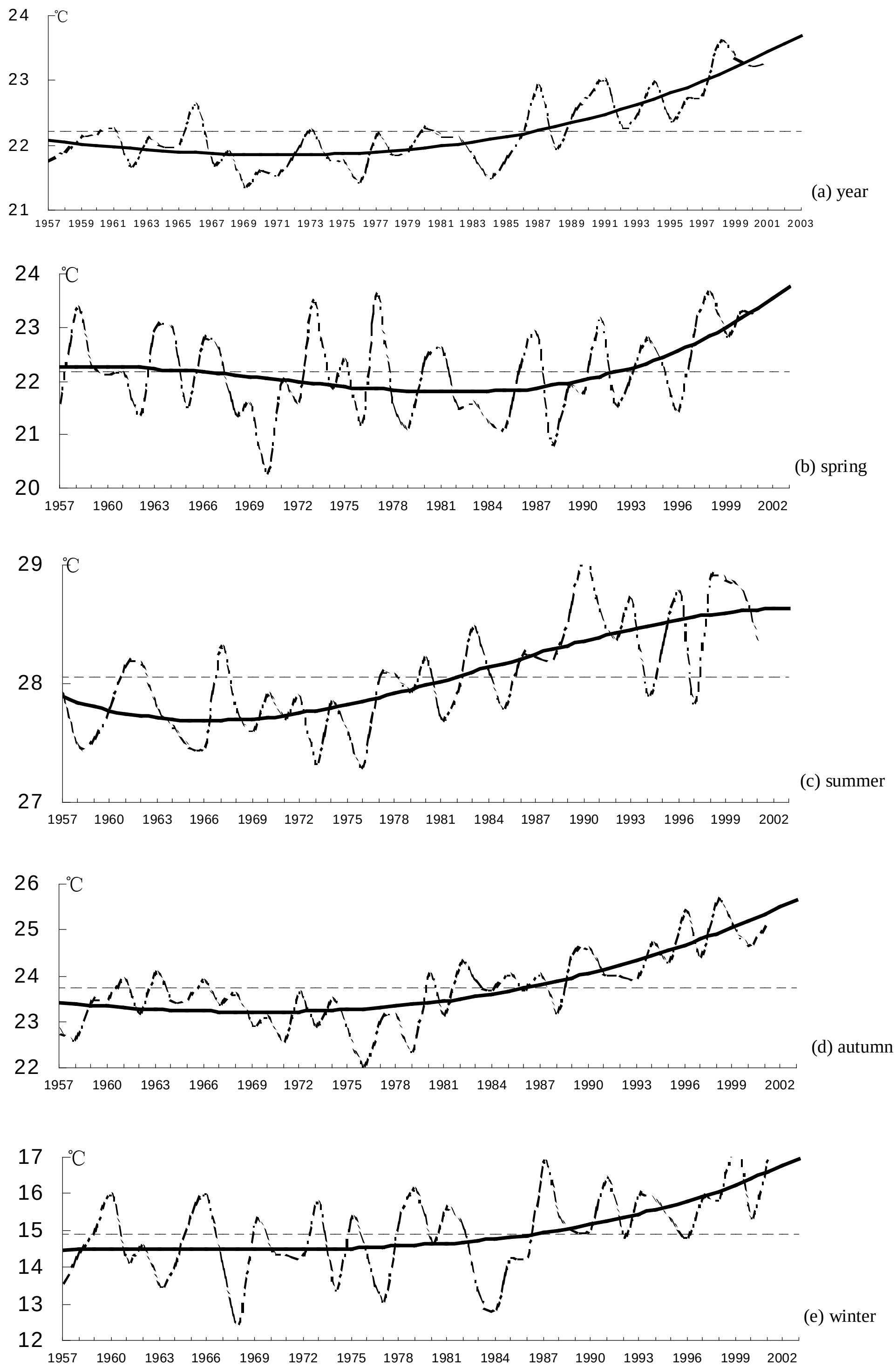

Fig.1 Tendency curves of ultra-long-term variation of temperature in Dongguan. The solid line is the actual tendency and the dashed line is the mean.

Tab.2 The climatic variability of temperature in Dongguan (°C / 10a)

Time span	Spring	Summer	Autumn	Winter	Annual
Equations	y=0.16579t	y=0.68412t	y=0.67542t	y=0.46006t	y=0.67455t
Complex correlation coefficients	0.16549	0.68412	0.67542	0.46006	0.67455
Climate variability	0.13	0.53	0.52	0.35	0.52

Tab.3 Regression equations of long-term temperature tendency in Dongguan

Time span	Equations	Complex correlation coefficients r
Spring	y=-61264.160-0.31 t-2.66 t^2 +2.65 t^3	0.448686
Summer	y=-49503.11-1.54 t+4.39 t^2 –2.21 t^3	0.730895
Autumn	y=-13968.14-0.54 t+0.72 t^2 +0.56 t^3	0.784290
Winter	y=-28218.49+0.17 t-0.84 t^2 +1.21 t^3	0.536259
Annual	y=-20219.28-0.69 t+0.62 t^2 +0.83 t^3	0.826637

3.2 *Analysis of oscillatory periods of temperature*

Tab.3 gives the results computed for seasonal power spectra in Dongguan (figure omitted). As what Tab.4 shows, except spring, Dongguan's temperature shows some periodicity in the summer, autumn, winter, the year and contiguous months, of which significant periods between 2.20 and 3.14 years are found in the annual, winter and autumn (those with * have passed the 95% significance test). It also shows that the winter temperature only has a 44-year period of solar spot and contiguous months' temperature has long periods of 29.33 years and 14.67 years, in addition to an ultra-short period of 0.35 – 0.45 year. It is also clear from the table that temperature in the year, summer, winter and contiguous months is of red noise while that in the summer, winter and contiguous months display strong ultra-long-term variation trends.

Tab.4 Results computed for the power spectra of seasonal temperature variation in Dongguan

Significance periods	1st	2nd	3rd	4th	5th	6th	Red and white noise spectra
Spring							White noise
Summer	3.14	2.59	Strong tendency				Red noise
Autumn	2.32*	2.44	2.20				Red noise
Winter	44.00*	Strong tendency					White noise
Annual	2.44	2.32*					Red noise
Contiguous months	29.33*	14.67*	0.425*	0.43	0.35	Strong tendency	Red noise

3.3 *Analysis of abrupt changes of temperature*

It is known from the analysis of seasonal temperature in Dongguan that there are abrupt changes in the year, summer (Fig.2), autumn and winter, of which the point of change appeared in the early 1990's (1992 – 1993) for the year, autumn and winter while it was in the mid-1980's (1985 – 1986) for the summer. Both are abrupt changes in temperature increase. Temperature changes steadily in spring without any abrupt change. It agrees with the analysis by Chen[4] of temperature in Foshan.

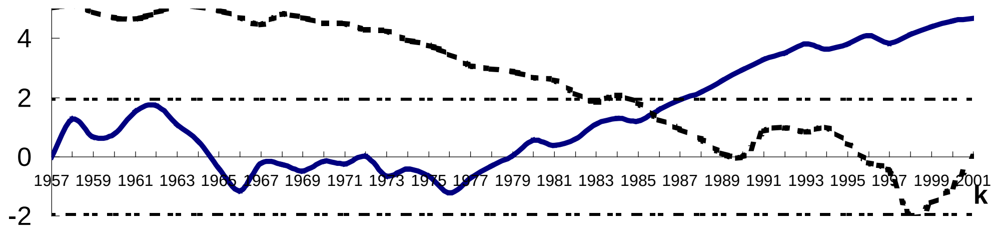

Fig.2 Curves of abrupt temperature changes in the summer of Dongguan.

4 CONCLUDING REMARKS

a. Temperature distributes in approximately sinusoidal patterns over the year and shows significant characteristics of monsoon climate with clearly-cut division of cold and hot seasons. As shown in the computation of the coefficients of skewness and kurtosis, a fully normal distribution of temperature has not been established for Dongguan.

b. Over the past 50 years and more, the Dongguan temperature has been rising on the whole and mean temperature, especially, has been increasing rapidly by about 1.5°C. It shows that the reform and opening-door practice and urbanization does have significant effect on the temperature in Dongguan.

c. Except spring, there are significant periods of 2.20 – 3.14 years in the temperature for the year, winter and autumn. There is a 44-year period of solar spot with the winter temperature and the contiguous temperature has ultra-long-term periods of 29.33 and 14.67 years, together with ultra-short periods of 0.35 – 0.45 year.

d. The points of abrupt change occurred in the mid-1990's for temperature in the year, autumn and winter. They appeared in the mid-1980's for the summer and all during the increase of temperature while temperature varies steadily without any obvious abrupt changes.

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