CHINESE GEOGRAPHICAL SCIENCE
Volume 13, Number 4, pp. 317–321, 2003
Science Press, Beijing, China

RECENT TRENDS OF TEMPERATURE AND PRECIPITATION DISTURBED BY LARGE-SCALE RECLAMATION IN THE SANGJIANG PLAIN OF CHINA

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ABSTRACT: The regional observed temperature and precipitation changes and their abrupt jumps disturbed by large-scale reclamation in the Sanjiang Plain, Northeast China were studied. Mean annual temperature of the region was tending to go up and has increased by 1.2–2.2℃ over the past 50 years. A warming jump of mean annual temperature of the region occurred in the 1980s, which had an increase amplitude of 0.9℃. Linear tendency rates of annual precipitation were negative in most of the region. The maximum of annual precipitation decrease was 155.8mm over the past 50 years. An abrupt decrease of regional annual precipitation happened in the middle of the 1960s, which had a decrease of 102.1mm. Based on the fact of climatic change of the Sanjiang Plain over the past 50 years, it is held that the region had larger warming amplitude than that of the surrounding areas in the recent years, which resulted from the large-scale reclamation of various kinds of wetlands.

KEY WORDS: temperature; precipitation; warming jump; large-scale reclamation; the Sanjiang Plain

CLC number: P467 Document code: A Article ID: 1002-0063(2003)04-0317-05

1 INTRODUCTION

In the last few years there has been increasing interest in regional climatic changes induced by human activities such as changing ground surface or style of land utilization. A typical example is regional climatic variation induced by Amazon tropical deforestation (SELLERS *et al*., 1993; LEAN and ROWNTREE, 1993; SUD *et al*., 1996; ZHANG and SELLERS, 1996). Chinese scientists have conducted a lot of studies on the characteristics and regularity of climatic variation over China at various spatial and temporal scales. Most of the studies using temperature records have shown that the surface temperature has increased by 0.2℃ to 0.5℃ in China over the last 100 years (ZHANG and LI, 1982; TU, 1984; DING and DAI, 1994). There were two most warming centers north of 35°N in China, which were in Uygur Autonomous Region of Xinjiang and the north of Heilongjiang Province. Some other regions, however, were indicated to have cooling signals in China (LIN and YU, 1990; CHEN, 1991; CHEN *et al*., 1998; GAO *et al*., 1994).

In this study, the Sanjiang Plain was selected as a study case. The plain, lying between 43°49′55" ▮ 48°27′40"N and 129°1′20" ▮ 135°05′10"E, is located in the north of Heilongjiang Province, Northeast China. In the recent 50 years, the characteristics of the underlying surface of the Sanjiang Plain have changed as a result of large-scale reclamation (ZHANG *et al*., 2003; WANG and YANG, 2001). The farmland area increased from 786 600ha in 1949 to 4 572 400ha in 1994. At the same time, the wetland area diminished from 5 345 000ha in 1949, which was 80.17% of the plain part of the region, to 1 040 600ha in 1994. Replacing wetlands, the farmlands become the main landscape in the Sanjiang Plain at present. Besides agricultural land use, urbanization, road construction

Received date: 2003-05-21
Foundation item: Under the auspices of the Knowledge Innovation Program of Chinese Academy of Sciences (No. KZCX2-SW-320-5, KZCX2-SW-118 and KZCX3-SW-NA-03)
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and industrial development also made wetlands diminish.

The main objectives of this study are to examine the facts of regional climatic variations disturbed by large-scale reclamation in the last 50 years and to analyze the trends of climatic variations over the study region. By detecting the existence of climatic jumps with different methods, illustrations were made to describe climatic anomaly quantitatively.

2 DATA AND METHODS

The data used in the study include the mean monthly temperature and monthly precipitation records from 31 meteorological stations within the plain from 1951 to 2000, which were obtained from the meteorological archives of Heilongjiang Province's Meteorological Bureau. The 31 stations, out of 36 stations within the study region, satisfied our acceptance criteria of the record length, percentage of missing data, and quality control. The distribution of the stations used is shown in Fig.1.

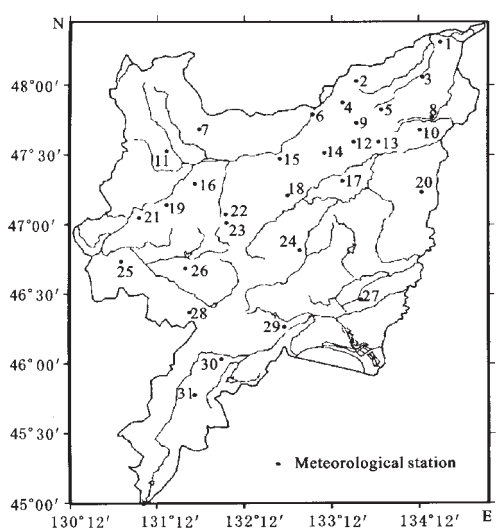

Fig. 1 Meteorological stations selected in the Sanjiang Plain

There was the problem of missing observed values in some stations selected. The missing records were estimated by using correlation and regression methods. The estimated data were less than 10% of all the records used.

The average temperature of March–May was taken as spring temperature and the total precipitation of March–May as spring precipitation. The summer's, autumn's and winter's values of the two climatic factors were deduced by analogy. The regionally seasonal and yearly series of various climatic factors were derived from mean spatial values of all chosen stations.

The trends of climatic changes over the study region were determined by tendency method. The tendency rate of each climatic factor was obtained from its linear equation by using least-squares method. And the climatic jumps were analyzed by cumulative departure method and Mann-Kendall method (FU and WANG, 1992).

3 OBSERVED AIR TEMPERATURE AND PRECIPITATION TRENDS

The tendency rates of mean annual air temperature and annual precipitation of all the stations used are presented in Fig. 2 and Fig. 3, which were derived from linear fitting equations of temperature and precipitation time series.

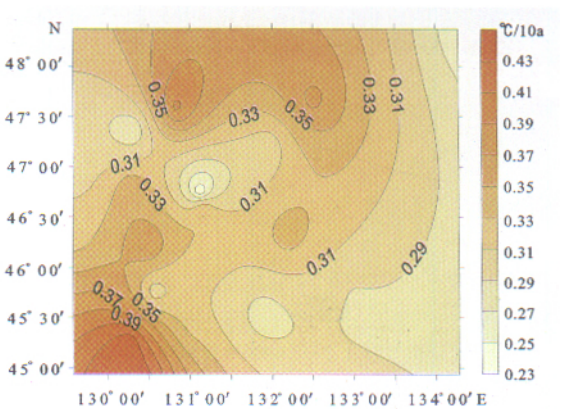

Fig. 2 Distribution of tendency rates of mean annual temperature in the Sanjiang Plain

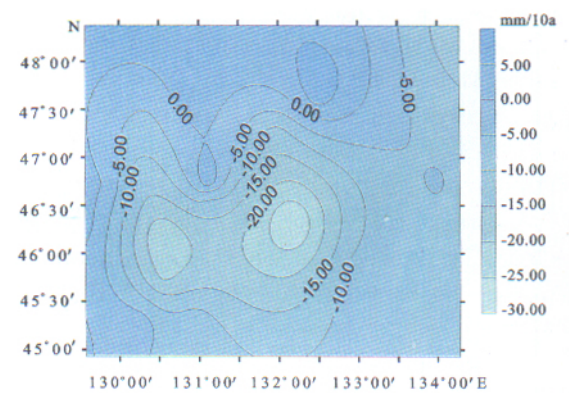

Fig. 3 Distribution of tendency rates of annual precipitation in the Sanjiang Plain

3.1 Observed Air Temperature Trends

All the tendency rates of mean annual temperature presented were positive. This means that temperature of each station shows a warming trend in the future. The maximum tendency rate of temperature occurred in the plain part of the north of the study region. And second one was in the south of the region. They were 0.045℃/a and 0.043℃/a, respectively. The minimum one occurred in the mountainous area of the middle of the study region, and the value was 0.023℃/a. The mean regional tendency rate of temperature was 0.033℃/a, which was higher than 0.03℃/a of the north area of Heilongjiang Province and 0.02℃/a of Northeast China (CHEN *et al*., 1998). Mean annual temperature increased by 1.2℃−2.2℃ in the region over the past 50 years.

The departure of mean annual temperature or annual precipitation was the deviation value relative to normal over 1951 to 2000. Concerning annual mean temperature, there was an undulating decrease trend between 1951 and 1969, and the minimum occurred in 1969. And then there had been an undulating increase pattern since 1970, the peaks occurred in 1975, 1982, 1990, 1995 and 1998 and the maximum was in 1990. It was worth of noting that all the departure values had been positive since 1988, that is, regional warming trend was continuous in the recent 13 years. The maximum and minimum departures of mean annual temperature occurred at the same year in both the Sanjiang Plain and Northeast China. However, the range between the maximum and minimum departures in the plain was 3.8℃, which was 0.7℃ higher than that in Northeast China. This showed that the Sanjiang Plain was one of the most warming regions in Northeast China. Some studies also indicated that the Northeast China was one of the main warming regions in China (DING and DAI, 1994; CHEN *et al*., 1998).

3.2 Observed Precipitation Trends

Annual precipitation of most parts of the region had a decrease trend. The decrease center was located in the plain part of the region. The minimum was −3.1mm/a and others were less than −2.0mm/a in the center. On the other hand, annual precipitation on the east and west fringes of the region had an increase trend, and the maximum was 1.0mm/a. In contrast with other areas in Northeast China, there was a larger precipitation decrease in the region (CHEN *et al*., 1998). The linear trend of annual precipitation shows that there will be a drying tendency in the future.

The change process of annual precipitation could be divided into two phases from 1951 to 2000. During the period of 1951 to 1975, annual precipitation was on the decrease. The minimum occurred in 1975 and its departure was −173.6mm. And annual precipitation increased from 1976 to 2000 and maximum departure was 364.4mm in 1994. The phase of annual precipitation decrease in the region lasted a shorter time than that in Northeast China (CHEN *et al*., 1998) and had larger amplitude.

4 ABRUPT CHANGES OF AIR TEMPERATURE AND PRECIPITATION

The abrupt jumps of the two climatic factors were examined and confirmed by using cumulative departure method and Mann-Kendall method (Table 1 and Table 2). As an example, detected abrupt changes of annual temperature and precipitation are shown in Fig. 4. The detected results with the two methods were almost the same, except for summer's temperature. And more abrupt changes of precipitation were examined by Mann-Kendall method. There were jumps of the two climatic factors in every seasonal and annual time series.

Table 1 Years with abrupt changes of air temperature in the Sanjiang Plain from 1951 to 2000

	Cumulative departure	Mann-Kendall
Spring	1974	1975
Summer	1977	1994
Autumn	1987	1987
Winter	1986	1986
Year	1981	1981

Table 2 Years with abrupt changes of precipitation in the Sanjiang Plain from 1951 to 2000

	Cumulative departure	Mann-Kendall
Spring	1966	1960, 1983
Summer	1966, 1980	1965, 1986
Autumn	1960	1960, 1991
Winter	1960	1960
Year	1965, 1980	1963, 1990

It is worth noting that all jumps of mean seasonal and annual temperatures were warming jumps. The increase amplitude of mean annual temperature was +0.9℃ (the difference between normal of 1966 to 1980 and that of 1982 to 1996) by a warming jump

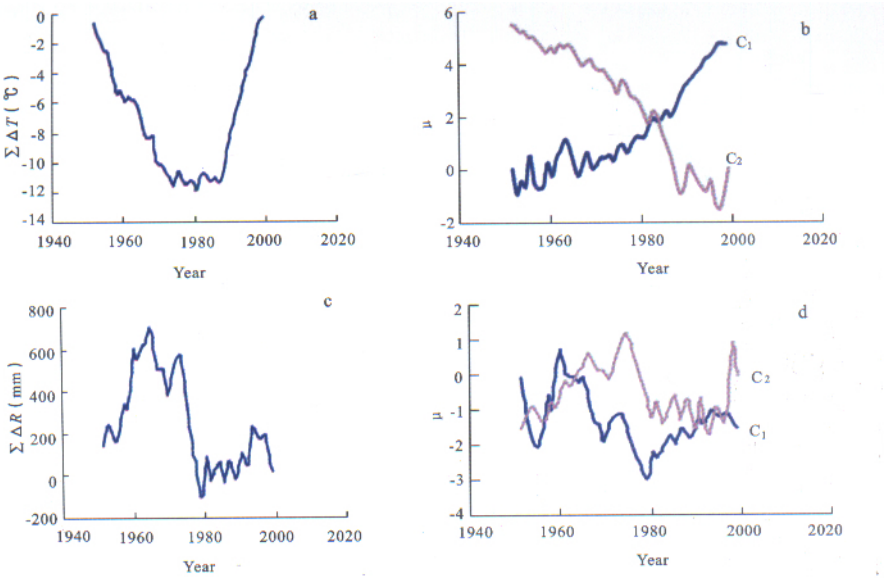

Fig. 4 Test curves of abrupt jumps of mean annual temperature (a, b) and mean annual precipitation (c, d) in the Sanjiang Plain

happened in the 1980s. All the abrupt changes of precipitation in the 1960s were decrease jumps, but those happened in the 1980s and the 1990s were increase jumps. The decrease amplitude of annual precipitation in the 1960s was −102.1mm (the difference between normal of 1951 to 1965 and that of 1966 to 1980) and the increase amplitude of that in the 1980s was +75.3mm.

Some researchers (YAN *et al*., 1990a; 1990b) held that climatic jumps occurred commonly in N. H. summer during the period of the 1960s. In the Sanjiang Plain, precipitation jumps happened in the summer of the 1960s and the amplitude of precipitation decrease was over 20% of regional summer precipitation. However, summer temperature had not any warming jumps during the period, which probably was relative to cold and humid effect of large area of wetlands in the region.

5 BRIEF SUMARY AND DISCUSSION

Except for directly major exterior factors, such as solar constant, content of stratosphere's volcanic ash and adding atmospheric CO_2, major reason that resulted in climatic jumps of the region probably was the change of regional underlying surface, which was caused by large-scale reclamation of wetlands. The characteristics of heat equilibrium of wetland are different from those of farmlands. During growing season of wetland plants, latent heat flux accounts for about 70% of radiation balance of underlying surface, at the same time, sensible heat flux is about 20% of the radiation balance (YAN, 1993), namely, quantity of underlying heat transferred to heat atmosphere is little. However, after wetlands are reclaimed to farmlands, the proportion of sensible heat flux to radiation balance increases because of the change of radiation balance characteristics of underlying surface, so that air temperature goes up and regional water cycle also changes correspondingly. Under the circumstances of the 1960s' N. H. summer warming, there was no summer temperature jump in the region probably because the "cold and humid" underlying surface may homogenize local climate at that time. On the other hand, mean spring and summer temperature had warming jumps in the 1970s, which synchronized with reclamation area increase. Just having gone through large-scale reclamation in the middle 1970s, cultivated land reached 2.048×10^6ha that almost was half of marshy wetland area. The cultivated land of the study region in the early and late 1980s were 3.521×10^6ha and 4.0×10^6ha respectively, and mean autumn, winter and annual temperature all had stronger jumps and jump amplitudes were the largest ones among those in the north of Heilongjiang Province. So, it is held that large-scale reclamation of wetland probably resulted in warming jumps in the Sanjiang Plain.

In the recent 50 years, the general trend of mean annual temperature change was going up and annual mean temperature went up by 1.2℃–2.2℃. And ma-

jor warming center was located in the plain part of the region. Mean annual temperature had a warming jump in the 1980s during the recent 50 years. The amplitude of the jump was +0.9℃.

The regional annual precipitation had a decrease trend and its largest decrease amplitude was 155.8mm during the last 50 years. Annual precipitation had a decrease jump in the middle 1960s and its amplitude was 102.1mm. The dry period that lasted more than ten years provided an available weather conditions for 1969–1973 and 1975–1983's large-scale reclamation.

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