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# Climate change in the Sanjiang Plain disturbed by large-scale reclamation

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**Abstract:** Up to 1949, wetlands stretched continuously and accounted for 80.17% of the total area of plain part of the Sanjiang Plain. However, wetlands in the plain have gone through 4 periods (1956-1960, 1960-1977, 1980-1986, 1986-the present) of large-scale reclamation from 1956 to the present. Over 50% wetlands had changed into agricultural fields. The underlying surface of the plain has changed tremendously. This study investigated the regional climate change by analyzing regional climatic variation and tendency and examining climate jumps over the last 45 years. Monthly records of 5 climatic factors (air temperature, precipitation, atmospheric pressure, sunshine time and wind speed) for 26 meteorological stations covering the period 1955-1999 were used. The annual mean temperature of the study region was tending to go up and increased by 1.2-2.3 ℃ during the last 45 years. The maximum of annual precipitation decrease in the region was 90 mm over the last 45 years. An abrupt warming of the annual mean temperature occurred in the mid-1980s, which had an increase amplitude of 0.9 ℃. Of increase amplitudes of all the seasonal abrupt warming, the largest one was 1.8 ℃ in the winter since 1987. The plain used to be cold and humid with center of Heilongjiang province even till the late 1960s, for it had an underlying surface of wetlands in the main. However, based on the facts of the climate changes of the plain over the last 45 years, it is held that the plain had a larger warming amplitude than that of area around it in recent years probably resulted from the large-scale reclamation of various kinds of wetlands.
**Key words:** climate change; climate jump; underlying surface; the Sanjiang Plain; large-scale reclamation
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## 1 Introduction

In recent 20 years, Chinese scientists have conducted a lot of studies on characteristics and regularity of climate variation over China on 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 (Ding and Dai, 1990; Tu, 1984; Zhang and Li, 1982). Some regions will have warming trends in the future, however, some other regions are indicated to have cooling signals in China (Chen *et al.*, 1998; Ling, 1984; Liu, 1995; Gao *et al.*, 1994). Developing with WCRP, regional climate change has become the subject of many studies because regional climate directly relates to the development and future of a region. To what extent on earth large-scale reclamation of wetlands in the Sanjiang Plain has affected the regional climate variations is the problem that this study needs to solve.

The Sanjiang Plain is in Heilongjiang province, Northeast China and enclosed by 43°49'55"-48°27'40"N and 129°11'20"-135°05'10"E. In recent 50 years, large-scale reclamation of 4 periods has changed the characteristics of the underlying surface of the Sanjiang Plain. The farmland areas increased from 78,660 $hm^2$ in 1949 to 4,522,400 $hm^2$ in 1994. At the same time, wetland area diminished from 5,345,000 $hm^2$ or 80.17% of the plain part of the region in

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1949 to 1,040,600 $hm^2$ in 1994. Replacing wetlands, the farmlands have become the main landscape in the Sanjiang Plain at present. Except for agricultural land use, urbanization, road construction and industrial development also diminished wetlands.

The main objectives of this study are to examine the facts of regional climate variations during the disturbance period in the last 45 years and to analyze trends in climatic variation over the study region. By detecting the existence of climate jumps with different methods, illustrations were made to describe climate anomaly quantitatively.

## 2 Data and methods

The data used in the study consisted of the monthly mean temperature and pressure, the monthly precipitation and sunshine time records from 21 meteorological stations within the Sanjiang Plain, obtained from the meteorological archives of Heilongjiang Provincial Meteorological Bureau.

The maximum precipitation and temperature both occur in July and August in the study region. The precipitation of June-September accounts for about 71.5% of annual precipitation (June-August precipitation is 58.5% of yearly one) in the region. The local inhabitants are engaged in their agricultural activities mainly from June to September. So they were assumed in the paper that spring months was March-May, summer months were June-September, autumn months were October-November, and winter months were December-February of the next year. Spring temperature, pressure and sunshine time were average values of three months respectively, spring precipitation was total amount of three months' precipitation. The summer, the autumn and the winter values of four climatic factors may be deduced by analogy. The regionally seasonal and yearly series of various climatic factors were derived from spatial mean values of all chosen stations.

The above regional series were subjected to several analyses. The tendency method was used in the study to determine the trends of climate change over the study region. The tendency rate of each climatic factor was obtained from its linear equation by using least-squares method. The departure curve method was then used for analyses of various periods of regional climate change.

A five-term moving average filter was used to smooth the short-term trends of meteorological records. The five-term moving average regional series were subjected to analyses of regional climate jumps. The analysis methods of climate jump were Yamamoto and Mann-Kendall methods (Ling, 1984; Yamamoto *et al.*, 1985; Yan *et al.*, 1990).

## 3 Climate change in the Sanjiang Plain

### 3.1 Temperature change

The tendency rate of air temperature of all the stations used (Figure 1) were derived from linear fitting equations of temperature time series. All the values of tendency rate presented were positive. This meant that temperature of each station used would be 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 the second one was in the mountain part of the south of the region. Their values of tendency rate were 0.05 ℃/a and 0.048 ℃/a, respectively. The ones in the mountain part of the east and west of the region were less than 0.035 ℃/a. The minimum one occurred in the extreme west of the region, and the value was 0.026 ℃/a. The mean regional tendency rate was 0.039 ℃/a, which was far more than 0.03 ℃/a of the northern part of Heilongjiang province and 0.02 ℃/a of Northeast China (Ling, 1984). The temperature increased between 1.2 ℃ and 2.3 ℃ in the region over the past 45 years.

The regional departure curves of seasonal and annual mean temperature were shown in Figure 2a, the departure was deviation value relative to mean temperature in the period


Figure 1 Distribution of linear tendency values of annual mean temperature in the Sanjiang Plain from 1955 to 1999 (unit: 0.01 ℃/a)

1955-2000. Concerning annual mean temperature, there was an undulating decrease trend between 1955 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 should be paid more attention that all the departure values had been positive since 1988, that is, regional warming trend was continuous in recent 12 years. The maximum and minimum departures of annual mean temperature occurred in 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 ℃ more than the one in Northeast China. This showed that the Sanjiang Plain was one of the most warming regions in Northeast China. Some studies indicated that the northeast region was among the main warming regions in China (Ding and Dai, 1994; Ling, 1984). So the Sanjiang Plain was one of the major warming areas.

For mean temperature change of various seasons in the region, the largest change amplitude occurred in winter, the second was in autumn and spring, the third in summer. During the cold period before 1969, winter made the greatest contributions to the negative departure of annual mean temperature. However, during the warming process in the late 1980s, winter and autumn contributed to the positive departure of annual mean temperature.

**3.2 Precipitation change**

The distribution of linear tendency rate of annual precipitation from 1955 to 1999 was shown in Figure 3. Annual precipitation of most parts of the region had a decrease trend. The decrease center was located in plain part of the region. The minimum was -2.5 mm/a and others were less than -2.0 mm/a in the center. On the other hand, annual precipitation on east and west fringes of the region aaahad an iincrease trend, and the maximum was 1.0 mm/a. In

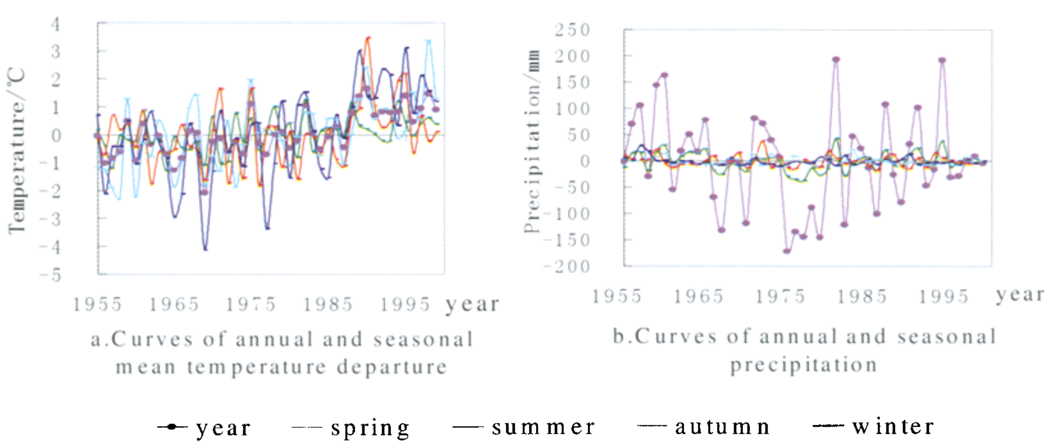


Figure 2 Climate changes of the Sanjiang Plain from 1955 to 1999

contrast with other areas in CNortheast China, there was a notable precipitation decrease trend relatively in the region (Ling, 1984). The linear trend of annual precipitation showed that there would be a drying tendency in the future.

The change process of annual precipitation could be divided into three phases from 1955 to 1999. During the periods of 1955 to 1965 and 1980 to 1999, annual precipitation was on the increase. The peaks occurred in 1960, 1981 and 1994 and their departures were 167.6 mm, 197.7 mm and 196.5 mm respectively. And annual precipitation had a decrease trend from 1966 to 1979 and minimum departure was 167.9 mm occurred in 1975. The phase of annual precipitation decrease in the region last a shorter time than that in Northeast China (Ling, 1984) and had larger amplitude. Figure 2b showed that annual precipitation had quasi-periods of 3 years, 13 years and 21 years. Of precipitation change of various seasons, maximum change occurred in summer, the second one in winter and autumn and minimum one in spring.

## 4 Climate jumps in the Sanjiang Plain

Climatic system, which is a highly non-linear physical system, has some characteristics that cannot be explained by linear physics, such as catastrophe phenomena. In view of catastrophe phenomena of time mean values during decades, Yamamoto *et al.* (1986) and Yan *et al.* (1990a) developed the concept of climate jump and determined the existence of climate jump by statistical methods. The distributions and processes of N. H. summer's climate jumps during the 1960s were examined particularly (Yan, 1992; Yan *et al.*, 1990b). The definitions and various detecting methods of climate jump were explored to direct recognition and measurement of catastrophe phenomena (Li and Zhang, 1991). Climate jumps in Shanghai and

Table 1 Climate jumps measured by Yamamoto method during 1965 to 1989

| | | Temperature | | Precipitation | | Pressure | | Sunshine-time | |
|---|---|---|---|---|---|---|---|---|---|
| | | n=10 | n=14 | n=10 | n=14 | n=10 | n=14 | n=10 | n=14 |
| Spring | stage | 1972-1974 | 1972-1975 | | | | | 1987~1989 | |
| | | 1986-1989 | 1982-1985 | | | | | | |
| | $S/N_m$ | 1.09, 1973 | 1.16,1973 | | | | | 1.18,1989 | |
| | year | 1.92, 1988 | 1.02,1985 | | | | | | |
| | range | +0.6 ℃ | +0.6℃ | | | | | -27.9h | |
| | | +0.9 ℃ | +0.7℃ | | | | | | |
| Summer | stage | 1971-1977 | 1970-1979 | 1965-1968 | 1980-1983 | 1966-1969 | 1972-1974 | 1965-1968 | 1979-1989 |
| | | | | 1981-1986 | | 1983-1986 | 1982-1985 | 1978-1982 | |
| | | | | | | | | 1987-1989 | |
| | | 2.44, 1974 | 1.65,1975 | 1.53,1965 | 1.1,1981 | 1.35,1967 | 1.0,1973 | 1.41,1965 | 1.59,1981 |
| | $S/N_m$, | | | 1.16,1984 | | 1.24,1986 | 1.21,1984 | 1.47,1981 | |
| | year | | | | | | | 1.33,1989 | |
| | | +0.6 ℃ | +0.5℃ | -17.7 mm | +15.8 mm | +0.8 hPPa | +0.7 hPa | +43.2 h | -72.8 h |
| | range | | | +17.3 mm | | +0.4 hPa | +0.4 hPa | -65.6h | |
| | | | | | | | | -47.6h | |
| Autumn | stage | 1983-1989 | 1982-1985 | | | | | 1965-1966 | |
| | $S/N_m$, | 3.32, 1987 | 1.41,1985 | | | | | 1.54,1965 | |
| | year | | | | | | | | |
| | range | +1.4 ℃ | +1.1℃ | | | | | -37.2h | |
| Winter | stage | 1979-1980 | 1977-1985 | 1965-1966 | 1975-1979 | 1976-1977 | | 1978-1982 | 1976-1989 |
| | | 1983-1989 | | 1975-1979 | | | | 1987-1989 | |
| | $S/N_m$, | 1.13,1979 | 1.53,1985 | 1.19,1965 | 1.67,1977 | 1.03,1976 | | 1.42,1980 | 1.21,1981 |
| | year | 2.87,1987 | | 1.68,1977 | | | | 1.59,1989 | |
| | range | +1.0 ℃ | +1.7℃ | -8.0 mm | +4.1 mm | -0.8 hPa | | -14.1 h | -19.5h |
| | | +1.8 ℃ | | +3.8 mm | | | | -18.9 h | |
| Year | stage | 1971-1976 | 1972-1973 | 1965-1966 | | | | 1979-1982 | 1980-1981 |
| | | 1982-1989 | 1979-1985 | | | | | 1988-1989 | |
| | $S/N_m$, | 1.9,1973 | 1.1,1972 | 1.3,1965 | | | | 1.2,1981 | 1.0,1981 |
| | year | 3.8,1987 | 1.6,1985 | | | | | 1.4,1985 | |
| | range | +0.5℃ | +0.5℃ | -69.1 mm | | | | -86.4 h | -111.0 h |
| | | +0.9℃ | +0.9℃ | | | | | -106.8 h | |

Beijing were detected and analyzed initially (Yan, 1993). Various seasonal and annual climate jumps of four climatic factors were examined and confirmed in this paper.

### 4.1 Analyses of results with Yamamoto method

With Yamamoto method, two average time intervals of $n_1 = n_2 = 10$ and $n_1 = n_2 = 14$ were chosen, that is, climate jumps from 1965 to 1989 were examined. The detected climate jumps were given in Table 1. In Table 1, n = 1 and n = 14 represented the two intervals. In Figure 4, arrows indicated the points of determined climate jumps, and mean values (solid line) and standard deviation (dashed line) of time series of climatic factors were superposed on curves of seasonal and annual departures of various factors.


Figure 3 Distribution of linear tendency values of annual precipitation in the Sanjiang Plain from 1955 to 1999 (unit: mm/a)

There are jumps of all the climatic factors occurred in summer and winter. And there were also the jumps on air temperature and sunshine time happened in spring, autumn and year. Stronger temperature jumps occurred in all seasons but spring and year. Certain research results (Yan, 1992; Yan *et al.*, 1990b) revealed that there were climate jumps occurred commonly in N. H. summer during the period of the 1960s. In the Sanjiang Plain, precipitation, sunshine time and pressure jumps happened in the 1960s' summer and their *S/N* values were 1.53, 1.35 and 1.41 respectively. And the amplitude of precipitation decrease was over 17% of mean regional summer precipitation and of pressure change was +0.8 hPa and of sunshine time increase was over 6% of sregional seasonal mean value during the period. At the same time, autumn sunshine time and pppwinter precipitation also had abrupt jumps. However, summer temperature had not any abrupt djumps during the period. Spring, summer and annual temperature, summer and winter pppressure and winter precipitation had abrupt jumps in the

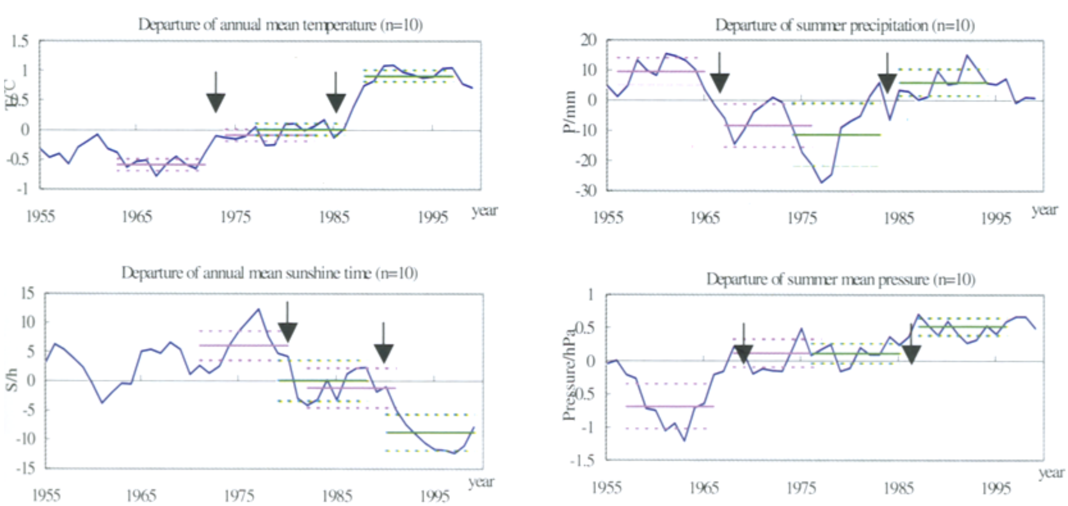


Figure 4 Examples of climate jumps tested by Yamamoto method of 4 climatic factors

1970s. Except for summer wwtemperature, winter precipitation and pressure, other various seasonal and annual climatic afactors all had climate jumps in various years of the 1980s.

It should be paid great attention that the jumps of various seasonal and annual mean temperatures were abrupt warming. For example, after spring temperature went through two abrupt jumps in the early 1970s and late 1980s, regional spring mean temperature went up by +1.5 ℃. And winter temperature went up by +2.8 ℃ after two jumps occurred in the late 1970s and 1980s. Standard deviation values of front and behind time intervals of jump points separated obviously in Figure 5, which showed that climate status in front and behind was discontinuous in fact. During the period 1969-1985, climate jumps determined with the two mean time intervals (n=10 and n=14) were identical.

Table 2 Years of climate jump measured by Mann-Kendall method

| | Temperature | Precipitation | Pressure | Sunshine time |
|---|---|---|---|---|
| Spring | 1980 | | | 1962, 1988 |
| Summer | 1979 | 1956, 1988 | 1994 | 1995 |
| Autumn | 1988 | | | |
| Winter | 1986 | 1958, 1986 | | 1980 |
| Year | 1984 | 1961 | | 1991 |

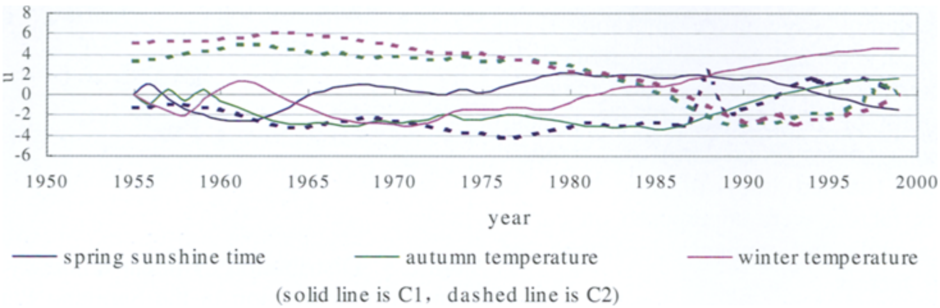


Figure 5 Examples of climate jump by Mann-Kendall method in the Sanjiang Plain

## 4.2 Analyses of results with Mann–Kendall method

The detected climate jumps of regional seasonal time series of four climatic factors with Mann-Kendall method were shown in Table 2. The examined jump years were the years to which $C_l$ and $C_2$ curves' intersection points corresponded. The 1950s' and 1990s' but the 1960s' climate jumps were detected by Mann-Kendall method. However, the 1950s' and 1990s' ones could not be examined by Yamamoto method because of the method's limitation. And climate jumps which happened in the 1980s were examined by both of the two methods. These indicated different methods brought out different results and each method had its limitation (Li and Zhang, 1991). In general, the climate jumps detected by Mann-Kendall method were about 70% of those by Yamamoto method. Some examples of climate jump by Mann-Kendall method were shown in Figure 5. The confidence lines were y = □1.96 when confidence was over 95%. Figure 5 showed that the jumps detected of spring sunshine time and autumn temperature were identical to those by Yamamoto method and just one winter temperature jump in the late 1980s was examined by Mann-Kendall method but not found its two other jumps mentioned above in the late 1970s and early 1980s.

# 5 Summary and discussion

In recent 45 years, the general trend of annual mean temperature change was going up and annual mean temperature went up by 1.2 to 2.3 ℃. And major warming center was located in the plain part of the region. Annual mean temperature had two warming jumps in the 1970s and 1980s and the latter was a stronger jump during the 45 years. The amplitudes of the two jumps were +0.5 ℃ and +0.9 ℃ respectively. Temperature changes of various seasons made their different contributions to the change of annual mean temperature. Annual mean temperature from the late 1970s to early 1980s was going up because both spring and summer mean temperature had a +0.6 ℃ jump in the early 1970s and then +1.0 ℃ jump of winter mean temperature in the late 1970s enhanced local temperature rise. Based on temperature rise at the early stage mentioned above, annual mean temperature rise from the late 1980s to the present was enhanced again, for spring, autumn and winter mean temperature had +0.9 ℃, +1.4 ℃ and +1.8 ℃ stronger jumps in the late 1980s respectively. It was said that various seasons' warming all contributed to regional warming, but by comparison with others, winter warming had a greater contribution.

The regional annual precipitation had a decrease trend and its largest decrease amplitude was 90 mm during the last 45 years. The annual precipitation decrease centers were located at plain and middle mountains part of the region. Annual precipitation had a decrease jump in the mid-1960s and its amplitude was -69.1 mm. Of precipitation changes of various seasons, summer and winter precipitation had two jumps respectively during the last 45 years. The jumps which occurred in the 1960s were decrease ones and their amplitudes were -17.7 mm and -8.0 mm and the jumps in the late 1970s or the early 1980s were increase ones of +17.3 mm and +3.8 mm. There were two rainy periods from the mid-1950s to mid-1960s and from the mid-1980s to the present and there was a dry period from the mid-1960s to early 1980s in the region in summer during the last 45 years. The dry period in the last more than ten years provided available weather conditions for 1969 to 1973 and 1975 to 1983's large-scale reclamation.

For the plain part of the region, allocation relationship of 45 years' linear tendency had not shown a good consistent regularity because seasonal changes of various factors were not synchronous. Summer precipitation, sunshine time and pressure jumps in the mid-1960s had a good allocation relationship. Then, just summer sunshine time increase jump and precipitation decrease jump in the 1980s had a good allocation relationship. This indicated that between summer sunshine time and amount of clouds had a significant relationship. On the other hand, allocation between winter temperature and sunshine time was reversed completely.

Except for major direct exterior influencing factors such as solar constant, content of stratosphere's volcanic ash and increase of atmospheric $CO_2$ emission, the major reason resulting in climate jumps of the region was change of regional underlying, that is, reclamation of large area wetlands. Characteristics of heat equilibrium of wetland are different from those of agricultural field. During growing season of wetland plant, latent heat flux accounts for about 70% of radiation balance of underlying, at the same time, sensible heat flux is about 20% of the radiation balance (Yan, 1993), namely, quantity of underlying heat given up to heat atmosphere is little. However, after wetlands were reclaimed to agricultural fields, the proportion that sensible heat flux accounts for radiation balance increases due to change of radiation balance characteristics of underlying so that air temperature goes up and regional water cycle also changes correspondingly. Under the circumstances of the 1960s' N. H. summer warming commonly, there was no summer temperature jump in the region probably because the "cold and humid" underlying may homogenize local climate at that time. On the other hand, spring, summer and annual mean temperatures all have had warming jumps since the mid-1970s, which synchronized with reclamation area increase. Just having gone through large-scale reclamation in the mid-1970s, cultivated area reached 204.8 □ $10^4$ $hm^2$ that was almost half area of marshy wetland. The cultivated areas of the region in the early and late 1980s were 352.1 □ $10^4$ $hm^2$ and 400 □ $10^4$ $hm^2$ respectively, and spring, autumn, winter and annual mean temperatures all had stronger warming jumps happened and jump amplitudes were the largest ones among the north of Heilongjiang province. So, it was concluded that large-scale reclamation of wetlands probably resulted in warming jumps in the Sanjiang Plain.

## References


Chen Longxun, 1991. A primary analysis of climate change in China in recent 40 years. *Quarterly Journal of Applied Meteorology*, 49(2): 164-173. (in Chinese)

Chen Longxun, Zhu Wenqin, Wang Wen, 1998. Studies on climate change in China in recent 45 years. *Acta Meteorologica Sinica*, 56(3): 257-271. (in Chinese)

Ding Yihui, Dai Xiaosu, 1994. Temperature variation in China during the last 100 years. *Meteorology*, 20(12): 19-26. (in Chinese)

Fu Congbin, Wang Qiang, 1992. The definition and detection of the abrupt climatic change. *Scientia Atmospherica Sinica*, 16(4): 482-493. (in Chinese)

Gao Suhua, Pan Yaru, Guo Jianping, 1994. The temperature change and its influences on agricultural production in China for the last 40 year. *Meteorological Monthly*, 20(5): 36-41. (in Chinese)

Li Yuehong, Zhang Zhengqiu, 1991. A preliminary analysis on abrupt climatic changes in Shanghai and Beijing for the last 100 years. *Meteorological Monthly*, 17(10): 15-19. (in Chinese)

Lin Xuechun, Yu Shuqiu, 1990. Climatic trend in China for the last 40 years. *Meteorological Monthly*, 16(10): 16-21. (in Chinese)

Ling Fuhua, 1984. Catastrophe theory: history, current situation and future. *Advances in Mechanics*, 14(4): 389-404. (in Chinese)

Liu Xingtu, 1995. Wetland and its rational utilization and conservation in the Sanjiang Plain. In: Chen Yiyu (ed.), Study of Wetlands in China. Changchun: Jilin Science and Technology Press, 108-117. (in Chinese)

Tu Qipu, 1984. Trend and periodicity of temperature change in China during the past hundred years. *Journal of Nanjing Institute of Meteorology*, (2): 151-162. (in Chinese)

Yamamoto R, Iwashima T, Sanga N K, 1985. Climatic jump, a hypothesis in climate diagnosis. *J. Met. Soc. Japan*, 63: 1157-1160.

Yamamoto R, Iwashima T, Sanga N K, 1986. An analysis of climatic jump. *J. Met. Soc. Japan*, 64: 273-281.

Yan Minhua, 1993. The impact of forest fire on microclimate of forest swamp in the Daxingan Mountains. *Scientia Geographica Sinica*, 13(4): 389-390. (in Chinese)

Yan Zhongwei, 1992. A primary analysis of the process of the 1960s northern hemispheric summer climatic jump. *Scientia Atmospherica Sinica*, 16(1): 111-119. (in Chinese)

Yan Zhongwei, Ji Jinjun, Ye Duzheng, 1990a. The climatic jump of the Northern Hemisphere in summer during the 1960s: I. precipitation and temperature change. *Science in China* (B), (1): 97-103. (in Chinese)

Yan Zhongwei, Ji Jinjun, Ye Duzheng, 1990b. The climatic jump of the Northern Hemisphere in summer during the 1960s: II. sea level pressure and 500 hPa height change. *Science in China*(B), (8): 879-885. (in Chinese)

Zhang Xiangong, Li Xiaoquan, 1982. Some characteristics of temperature variation in China in the present century. *Acta Meteorologica Sinica*, 40(2): 198-208. (in Chinese)