地理学报(英文版) 2003年第13卷第4期

Extreme climate events over northern China during the last 50 years

作者: HAN Hui GONG Daoyi

Climate extremes for agriculture-pasture transitional zone, northern China, are analyzed on the basis of daily mean temperature and precipitation observations for 31 stations in the period 1956-2001. Analysis season for precipitation is May-September, i.e., the rainy season. For temperature is the hottest three months, i.e., June through August. Heavy rain events, defined as those with daily precipitation equal to or larger than 50 mm, show no significant secular trend. A jump-like change, however, is found occurring in about 1980. For the period 1980-1993, the frequency of heavy rain events is significantly lower than the previous periods. Simultaneously, the occurring time of heavy rains expanded, commencing about one month early and ending one month later. Long dry spells are defined as those with longer than 10 days without rainfall. The frequency of long dry spells displays a significant (at the 99% confidence level) trend at the value of +8.3%/10a. That may be one of the major causes of the frequent droughts emerging over northern China during the last decades. Extremely hot and low temperature events are defined as the uppermost 10% daily temperatures and the lowest 10% daily temperatures, respectively. There is a weak and non-significant upward trend in frequency of extremely high temperatures from the 1950s to the mid-1990s. But the number of hot events increases as much as twice since 1997. That coincides well with the sudden rise in mean summer temperature for the same period. Contrary to that, the frequency of low temperature events have been decreasing steadily since the 1950s, with a significant linear trend of -15%/10a.

Extreme climate events over northern China during the last 50 years HAN Hui1, GONG Daoyi1,2 (1. Key Laboratory of Environmental Change and Natural Disaster, Institute of Resources Science, Beijing Normal University, Beijing 100875, China; 2. Bjerknes Centre for Climate Research, University of Bergen, Norway) 1 Introduction The agriculture-pasture transitional zone over northern China is one of the most sensitive regions to global climate changes. And the environment there as well as the regional eco-activity often suffers from the climate extremes (Ye and Chen, 1992). There are numerous studies analyzing the climate changes over the transitional zone and the vicinities, most of which focused on the mean condition of climate variables, e.g. the monthly-seasonal mean temperature and total precipitation. Based on the analysis of meteorological observations, it was reported that the precipitation in northern China experienced a decreasing trend and notable inter-decadal fluctuations (Huang et al., 1999; Gong and Shi, 2001; Ren et al., 2000). However, to investigate the change of climate extremes might be of interest, particularly in such an arid-semiarid region. For instance, most of the precipitations in northern China come forth in the form of strong convective precipitation. Typically, several heavy rainfalls can contribute a vast amount of the total annual precipitation. Furthermore, strong convective precipitation is well known for the non-uniformity in temporal and spatial distribution. Therefore, the same rainy season precipitation amounts may show different significance for their environmental impacts, if the rainfall´s temporal and spatial distribution is uneven. Thus, the long-term variations of extreme climate events have significant meanings for environmental and ecological system. Some previous studies analyzed the variations of climate extremes in temperature and precipitation (e.g., Zhai et al., 1999a; Zhai and Ren, 1997; Zhai et al., 1999b). Zhai et al. (1999a) found that in association with the decreasing of the annual precipitation amount, some extreme precipitation events also experienced considerable changes in the last 45 years in northern China. For example, the one-day maximum and three-day maximum precipitation have decreased, and the concurrence of heavy rains (including those of daily precipitation in excess of 50 mm and 100 mm). While, the mean intensity of those extreme precipitations is getting larger. However, most of these studies on climate extremes focused on entire China. Few of studies paid attention to the climate extremes in the agriculture-pasture transitional zone. Clearly, the large spatial extent may ignore regional features. Here we aim to study the long-term variations of the precipitation and temperature extremes in the transitional zone over northern China, on the basis of daily precipitation and daily mean temperature observations during the last about 50 years. 2 Data The extent and location of the agriculture-pasture transitional zone varies for different studies made by different authors as their purposes of study vary. But, the critical region has no significant difference among them (Wang et al., 1999). In the present manuscript, the agriculture-pasture transitional zone refers to the area between 105oE and 121oE in northern China, covering a rather broad extent and including agriculture-pasture transitional zone and the vicinities (Figure 1). The daily precipitation and mean temperature data set are derived from the China Meteorological Administration, with the time span of 1951-2001. We chose 31 gauge stations, which have at least 46 years of data available and have no more than 10 missing days. Among these 31 stations, there are 30 rainfall stations and 25 temperature stations. The geographical positions of these stations are plotted in Figure 1. There are some missing records in the early period, thus we employed all data for the time period of 1956 through 2001, 46 years in all. The number of the missing data is small. The interpolation of these missing data may be inappropriate since the daily precipitation is of small spatial-temporal scale. The interpolation might introduce large errors. Therefore, we simply ignored these missing records in our analysis. Daily precipitation data include six types, namely, (1) no precipitation, (2) trace precipitation (daily precipitation readings less than 0.1 mm), (3) precipitation from frost, fog and dew, (4) precipitation from pure snow, (5) precipitation from snow and rain, and (6) precipitation from rainfall. Since the precipitation amount of the third type is considerably low, all the days with this type of precipitation readings are regarded as non-precipitation days in our analysis. Analysis on precipitation extremes focuses on the frequency of heavy rains and the dry spells in rainy season, i.e., May-September. Analysis season for temperature is the warmest three months, i.e. June, July and August. Study contents include the secular changes of extremely high and low temperatures. 3 Precipitation extremes 3.1 Changes in the frequency of heavy rainfall 3.2 The distribution of heavy rainfall events within rainy season 3.3 Maximum daily rainfall 3.4 Long dry spell duration 4 Extreme temperature events 4.1 The definition of extreme temperature events Following an often used method (e.g., Houghton et al., 2001), the highest 10% of mean daily temperatures are defined as the extremely high temperatures, the lowest 10% are the extremely lows. Different from the situation of precipitation, here the analysis months for temperature extremes are confined to June, July and August, i.e., the hottest three months. If we considered the entire May-September, most anomalously low temperatures will take place in May or September. There all analysis for temperature is based on the 1 June to 31 August. Firstly, we sorted all daily temperatures for a given station in the descending order. The first 10% temperatures are the extremely high values, and the last 10% are the extremely low temperatures. Their corresponding dates then are determined and summed to produce the frequency of the extremes each year. After averaging the time series for all stations, we got the regional mean series of the frequency of temperature extremes. For each station there are 423 days of extremely high temperatures and the same number of extremely low temperatures, 9.2 days per year (i.e., 10% of the number of summer days is 9.2, there are 92 days from 1 June to 31 August). 4.2 Extremely high temperatures Figure 6 shows the regional mean frequency of extremely high temperature events. It shows a strong increasing trend of +20.9% per 10 years, this trend is statistically significant above the 99% confidence level. However, it should be pointed out that the trend is mainly caused by an abrupt increase that occurred in the late 1990s. The average frequency of the extremely high daily temperatures in the latest 10 years is 14.1 days per year; it is two times the value of 7 days per year for the period of the mid-1950s to the mid-1960s. When the period of 1997-2001 is excluded, the trend in 1956-1996 is only +4.1% per 10 years, not significant. Therefore, we can infer that the frequency of extremely high daily temperature events displays a slight and not significant increasing trend from the mid-1950s to 1996, whereas the frequency increases sharply since 1997. 4.3 Extremely low temperatures Figure 6 also shows the time series of the regional mean frequency of the extremely low daily temperature events. Generally, the frequency displays a rather steady and consistent decreasing trend. That is clearly different from that in the changes of high temperature extremes. On average the frequency of low temperatures is about 10 days per year during the mid-1950s to the early 1960s. In recent decade the frequency decreases to about 6 days per year. The linear trend estimated from the entire data period is -15.09%/10a, significant above the 99% confidence level. Changes in climatic mean and variability both can lead to variations in the frequency of temperature extremes (Houghton et al., 2001; Katze and Brown, 1992; Robeson, 2002). The variations in summer mean temperature show a rather significant warming trend since the late 1970s; the trend is 0.65oC per 10 years during the period of 1976-2001. For the entire data period of 1956-2001 the linear trend is 0.24oC per 10 years, both significant at the 99% confidence level. This long-term trend is consistent with the trends of the temperature extremes. In addition, the inter-annual fluctuati ons between the low temperature frequency and mean temperature also display good agreement. The frequency of extremely high temperatures increases with the mean temperature; while the frequency of low temperatures decreases as the mean temperature gets higher. It can be inferred that there are close relations between the increasing mean temperature and the frequency of temperature extremes. Some studies (e.g., Zhai and Ren, 1997) indicated that the minimum temperatures in northern China showed an increasing trend from the 1950s to the 1990s. That is consistent with our analysis too. It should be noted that the increase in mean temperature is most prominent since the late 1990s. The warming trend in the previous period is not remarkable (Figure 7). That feature is rather similar to the changes in the high temperature extremes. Thus, the recent abrupt increase in the frequencies of extremely high temperatures might be largely related to the evident warming of mean temperature. 5 Discussion The immediate causes for the anomalous daily precipitation and temperature are the variations of daily synoptic conditions. To thoroughly analyze the relationship between the daily circulation characteristics, patterns and the surface weather conditions is a very difficult task. In fact, many synoptic analyses are based on the individual case study. Considering the variations in climate extremes have close relations with the mean weather situations; furthermore, some indices such as long dry spell itself and its long-term changes are related to the low frequency process of the atmospheric circulation, therefore, here we study the corresponding monthly-seasonal mean circulation condition so as to provide useful information of circulation background for understanding the climate extremes. Figure 8 shows the composites of 500 hPa geopotential height field for four cases. The 500 hPa difference between the 5 highest long dry spell frequency years and 5 lowest frequency years are calculated and plotted. Similarly, the 500 hPa changes between the largest and smallest precipitation years, between the highest and lowest hot temperature frequency years, and between the warmest and lowest mean temperature years are all estimated, for each case 5 highest-value and lowest-value years are considered. For the temperature cases the concerning months are June-August, and for the precipitation cases are from May-September. There is great similarity between Figures 8(a) and 8(b), both displays a center situated between 40-50oN and 90o-100oE with large height anomalies; at the same time, a smaller and weaker center is located over the Korean Peninsula. This kind of circulation pattern suggests that in association with the dry conditions in the transitional zone, there tends to emerge an anomalous anticyclone circulation in the western vicinities, and a cyclonic circulation in the Korean Peninsula and the vicinities, and vice versa. The circulation anomaly can exert direct influence on the precipitation in the transitional zone. It is clear that the anomaly center in the landmass is very strong, implying the importance of the influence from the inland. Unlike the circulation situations related to the precipitation anomalies, the 500 hPa height gets higher over the region of 30-50oN and east of 90oE in association with the extremely high frequency of hot extremes and mean temperatures. The center of the anomalous circulation is about 2-3 degrees latitude north of the transitional zone. This kind of pattern implies that under the control of anomalous anticyclone circulation, surface temperature would increase and the number of extremely high temperatures would get more. And it can be seen from Figures 8(c) and 8(d), the anomaly heights are east-west oriented, which suggests the subtropical high is also located further north than its normal position. Therefore, in addition to the local circulations in northern China, some other factors in the tropics may also be important for the climate and extremes in northern China. Besides the atmospheric circulation, two other important factors have often been emphasized. One is the global warming. Some studies (Hulme, 1996; Jones and Reid, 2001) analyzed the relationship between the global warming and the precipitation or temperature in various arid-semiarid regions, based on observations. But no overall relations were found. A probably important reason is that the mechanism of global warming impacting regional climate is different among regions. The studies of its influence on climate extremes are even more difficult. Recently, the regional simulation results show that during a warmer climate the frequency of heavy rainfall in northern China will increase (Gao et al., 2002), at the same time the maximum and minimum temperatures will get higher. Clearly, as a consequence, the frequency of extremely high temperatures will increase and the frequency of extremely low temperatures will decrease. Simulations forced by the greenhouse gases also show that there are increasing trends in the frequency of heavy rainfall and its contribution to the total precipitation amount in mid-latitude North America (Wilby and Wigley, 2002). The other factor is the land cover change. It was noticed that the surface vegetation deterioration could influence temperature notably (Balling, 1991). Kalnay and Cai (2003) recently indicated that the influence of land cover change and urbanization on temperature is much greater than the estimation by previous studies. Based on the climate model experiments, Zhao and Pittman (2002) reported that the influence of land cover change on extreme temperature and precipitation is as great as the influence of the CO_2-induced global warming. Of course, these studies are preliminary. How the global warming and land cover change influence the climate and the extremes in agriculture-pasture transitional zone need further study. 6 Conclusions Our analyses show that there is no significant increasing linear trend in the frequency of heavy rainfall in the agricu

lture-pasture transitional zone and the vicinities. However, an evident inter-decadal change occurs around 1980. The frequencies of heavy rainfall decrease significantly during the 1980s to the early 1990s. At the same time the heavy precipitation events may appear in more months, the commence date of high frequency heavy rainfalls being about one month early, and the ending date being one month later. The climatological frequency estimated from the entire data period shows that the highest frequency emerges in the mid-July to early August. From the mid-1950s to 1996, the frequency of extremely high temperatures shows a slight increasing trend, but not significant. However, the frequency of extremely high temperatures increases abruptly since 1997. The frequency of low temperatures decreases steadily since the 1950s, with a significant linear trend of -15.09% per 10 years. There are no strict case-to-case relations between the long dry spells and the precipitation anomalies for a given year. Although the precipitation amounts experience no notable trend, the frequency of the long dry spells displays a quite significant increasing trend of +8.34%/10 a. Thus, the changing temporal distribution of rainfall within the rainy season is probably a very important cause for the increasing drought stress in the agriculture-pasture transitional zone.

关键词： agriculture-pasture transitional zone; climate extremes; trends

