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THE PRELIMINARY STUDY ON POSSIBLE SCENARIOS OF FLOOD AND DROUGHT IN CHINA IN THE CASE OF GLOBAL WARMING

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ABSTRACT: According to Prof. Zhu Kezhen's (Chu K. C.) historical climatic division, the last 500 years in China can be divided into several alternately cold and warm periods. The periods of 1470－1520, 1620－1720, 1840－1890 had cold winters, while those of 1550－1600, 1770－1830 had warm winters. Based on such division, in four kinds of periods, i.e. cold, warm, cold-warm, and warm-cold (transition period), the differences between flood/drought degree in 120 stations in China and average of flood/drought degree in the last 500 years have been calculated. Positive anomaly indicates drought-prone area, while negative anomaly indicates flood-prone area. This historical experience provides a background to analyze the possible scenarios in the case of global warming in the future. The final results suggest that in the case of global warming the hazards of flood probably increase in many parts of China, such as southeast coast area, southwest, northwest, some parts of northeast and inner Mongolia while the hazards of drought probably decrease in the North China Plain, the middle reaches of the Huanghe River and its southern adjacent area. This distribution is basically consistent with that of precipitation in warming periods in this century and that resulted from climatic model in the case of CO_2 doubling.
KEY WORDS: climatic warming, hazards of flood and drought, hazard forecast

The record of observed temperature shows that since the 19th century the global temperature has increased about 0.5℃, and the warming was clear before 1940; in the next 30 years the variation was small; after the middle of the 1970s the warming became fast, and the 6 warmest years during 1900－1992

on record have occurred since 1980, among them the 1990 was the warmest. The globe was covered with heat wave in the 1994 summer, and many areas in the world recorded the highest temperature during the last several decades, even more than one hundred years. The average temperature in July was as high as 28.3℃ in Tokyo of Japan, which was the highest one since 1876; in Vienna of Austria the temperature of the same month arrived at 29.4℃, and it was highest one during the last 158 years; the monthly temperature of July in Shanghai of China was 30.4℃, which broke the highest record of the last 100 years; even in Mohe of China, which is a north-most border town and usually has a long winter but a short summer, the recorded highest temperature in July reached 38℃. The England scientists thought that the global temperature in 1994 was 0.3℃ higher than the average value from 1950 to 1980, and it might be a hottest one since making temperature record.

According to the record of the last 100 years, though without exact reason attributing the rising of temperature to the increasing of CO_2, it is a fact that the global has become warming and the concentration of CO_2 has increased. The concentration of CO_2 and other greenhouse gases in atmosphere will increase, along with further human activities. Many climatic models indicate that the rising of greenhouse gas in atmosphere is inevitable, which probably lead to the global warming. Since much uncertainty exists in the prediction of the degree of warming and change of local climate, the research on these topics become a hotpoint for scientists.

China is an ancient country, the study on historical climate is its superiority. Half century ago Prof. Zhu Kezhen, famous climatologist in China, began studying the climate change over China in the last 500 years and have accumulated a wealth of valuable information. After he died, other scientists continued his work and made a lot of achievements. The book "Yearly Charts of Dryness/Wetness in China for the Last 500 Year Period" was one of the key achievements. By using this information, it is possible to study the characteristics of flood and drought distribution within different historical warm and cold periods, and to reveal the possible scenarios of flood and drought in the case of global warming.

I. DATA AND METHODS

In order to study the distribution of flood and drought within different periods of warm and cold, the first thing is about the division of these periods. In this paper, a classification method put forward by Zhu Kezhen has been used[2]. Based on the Zhu's opinion, there are three warm and two cold peri-

ods in the last 500 years. The cold periods were 1470—1520 A. D., 1620—1720 A. D., 1840—1890 A. D., while warm ones were 1550—1600 A. D., 1770—1830 A. D.. The historical flood and drought data in the book of "Yearly Charts of Dryness/Wetness in China for the Last 500 Year Period" has been used. It provided the flood and drought degrees of 120 stations in China during the last 500 years. The degrees from one to five represent heavy flood, flood, normal, drought and heavy drought respectively. The basic method of this classification is to calculate the departure of flood and drought degree. According to Prof. Zhu Kezhen's historical climatic division for the last 500 years in China, four periods of climatic types, i. e., cold, warm, cold-warm and warm-cold(transition period), has been established. Based on established climatic types mentioned above, we have been calculated the departure between flood and drought degrees in 120 stations in China and the average values of flood/drought degrees in the last 500 years corresponding to four climatic types. The positive departure values represent the trend of drought, while negative values represent the trend of flood. The bigger the departure, the heavier of the flood and drought[3].

In order to use enough information volume and enlarge possibly study area all data have been calculated to make possible scenarios of flood and drought nearly all over the country.

Table 1 Cold and warm periods in the last 500 years

Cold	Warming	Warm	Colding
1470—1520	1521—1549	1550—1600	1601—1619
1620—1720	1721—1769	1770—1830	1831—1839
1840—1890			

It is worthy of noting that the reliability is anomalous in China, due to the anomaly of richness of historical information on flood and drought. In order to report such anomaly accurately, the reliability have been calculated by means of "T-test" as follow:

$$T = \frac{\overline{D}-[\overline{D}]}{\sigma/\sqrt{n}}$$

where: $\overline{D}$—average values of flood and drought degrees for different periods of climatic types.

$[\overline{D}]$—average values of flood and drought degrees in the last 500 years.

σ—square variance.

n—sample size.

II. CALCULATION RESULT

Fig. 1 shows the departure of flood and drought degrees for four climatic types in China during the last 500 years. Positive departure shows drought-prone areas, while negative one indicates flood-prone areas. We can know from this figure that there are some relatively concentrated areas for departure distribution, which clearly represent distribution of either drought or flood-prone areas. It also shows the general trend of distribution of flood and drought in different cold and warm situation, among which the flood and drought distribution are rather complicated in periods of warm and warming, while simple in cold and colding. In warming periods the hazards of drought probably increase in many parts of China, such as Northwest, inner Mongolia,

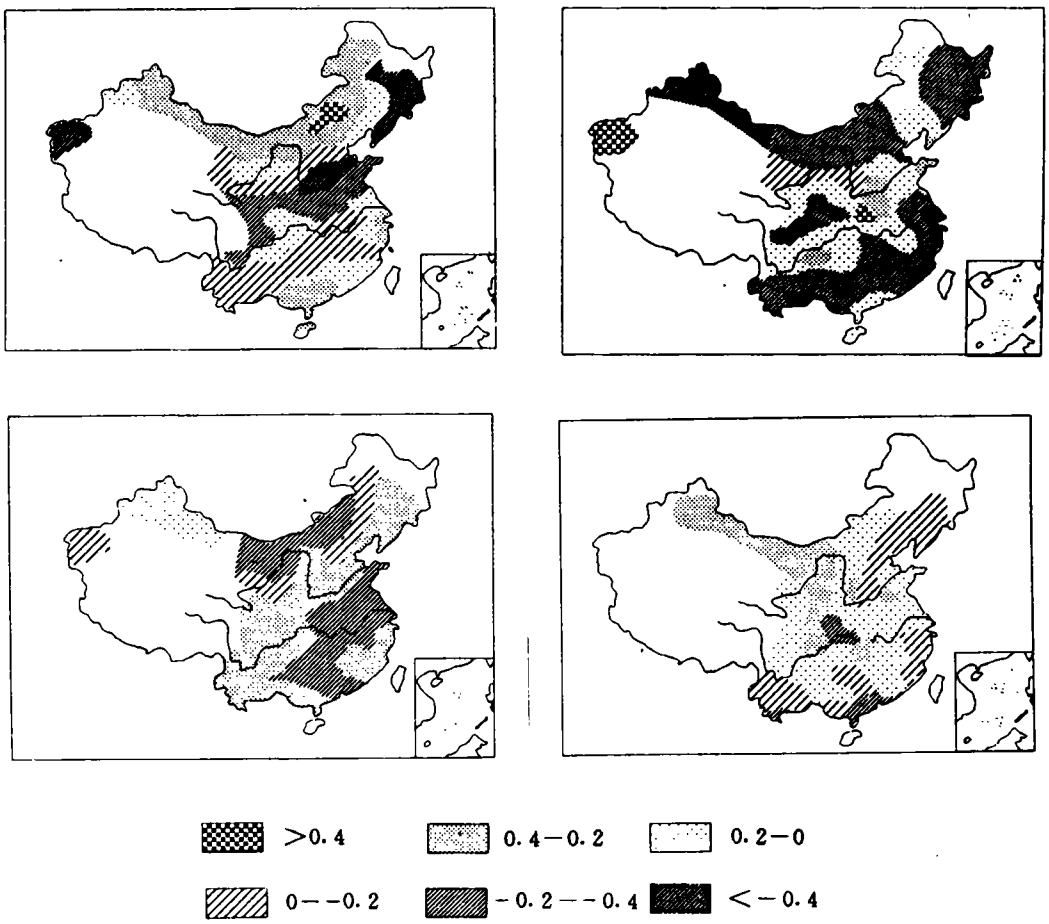

Fig. 1 The departure of flood and drought degrees in the last 500 years (left-up warming, right-up warm, left-down colding, right-down cold)

upper reaches of the Jialing River, lower reaches of the Changjiang River and South China, while flood hazards probably increase in the middle and lower reaches of the Huanghe River, Shandong Peninsula, the middle reaches of the Changjiang River and its southern adjacent hilly land. In warm periods, the distribution of flood and drought is nearly opposite to the trend in warming period, and the flood hazards probably increase in many parts of China, such as Northwest, inner Mongolia, most parts of Northeast, the lower reaches of the Changjiang River and Huaihe River, southeast coast, South China, upper reaches of the Jialing River and Hanshui River, while drought probably increase in such areas as the middle and lower reaches of the Huanghe River, Shandong Peninsula, the middle reaches of the Changjiang River and contiguous areas between Yunnan and Guizhou provinces (Fig. 2). "T test" indicates that, it is reliable enough that those flood-prone areas are in the middle and lower reaches of the Huanghe River, North China Plain, and drought-prone areas are in west parts of Northeast, east parts of Inner Mongolia, southern adjoining area of Taihu lake and Hangzhou Bay, mouth of the Zhujiang River during the warming periods; and drought-prone areas are in the middle and lower reaches of the Huanghe River, and flood-prone areas are in Inner Mongolia, Southeast coastal, southwest area during warm periods.

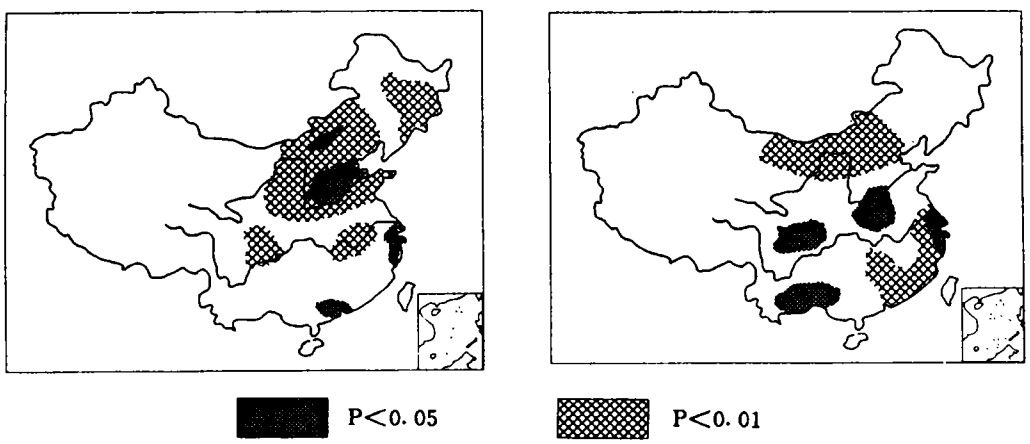

Fig. 2 The "T test" of departure of flood and drought degree in the last 500 years (left warming, right warm)

In order to take further contrast between cold and warm, we use the extreme period of little ice age as cold period and the stable warm period followed as warm period. The difference of flood and drought degrees between these two periods mentioned above has been calculated. The results are given in Fig. 3. The positive value indicates drought-prone areas, while negative value means flood-prone areas in the climatic warm periods. The chart clearly shows

that flood-prone areas with 0. 1 reliability are mainly distributed in southeast coastal area and Southwest, while drought-prone areas in south part of North China Plain and the middle reaches of the Huanghe River. The distributions almost coincide with that of flood and drought in the warm periods of the last 500 years.

To sum up, in warm periods of history there are several flood-prone areas, such as southeast coastal area, southwest part of China, Inner Mongolia, and several drought-prone areas, such as lower reaches of the Huanghe River. It is likely that such distribution could been used as reference for possible scenarios of flood and drought in China in the case of global warming.

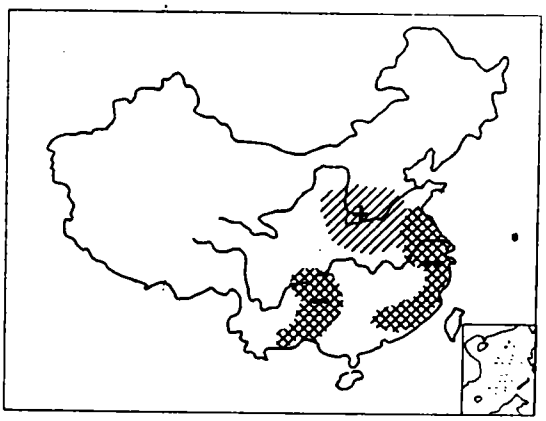

Fig. 3 The difference of flood and drought degree between the extreme little ice age and return warm periods

III. DEMONSTRATING RELIABILITY

1. Compared with Observation Data of This Century

Many researchers indicate that in this century there are approximately two cold periods and two warm periods for annual average temperature in northern hemisphere and China[4-6]. The cold periods are 1901—1920, 1951—1970, and warm periods are 1921—1950, after 1971. In China, except a few stations, most meteorological stations have only recorded for several decades. In order to analyze the precipitation variation in the cold and warm periods in this century, monthly average temperature and precipitation data(1881—1988) of 62 stations in China and its adjacent area, which were supplemented by Prof. Tu Qipu, had been used[7].

Fig. 4 shows the difference of precipitation between two cold and two warm periods in this century. It suggests that in the last 100 years during

warm periods there are several regions where the annual precipitation are on the more side, such as Northwest, south part of Northeast, Southwest, Hangzhou Bay and its southern adjacent area as well as some parts of middle and upper reaches of the Changjiang River and its southern adjacent hilly area, while several regions where the annual precipitation are on the less side such as the Huanghuai Plain, North China Plain and middle reaches of the Huanghe River. The regions where precipitation are on the more and less sides are consistent respectively with flood-prone and drought-prone areas during the warm periods in the last 500 years. In order to expand contrast, the difference of precipitation within periods of extreme cold and extreme warm in the first half of this century (1901—9120 was cold, 1921—1950 was warm) has been calculated. The results obtained are similar to that mentioned above (Fig. 5), It shows that the distribution of flood and drought prone areas in warm periods of the last 500 years are approximately consistent with that of precipitation of more and less area in the warm periods of this century.

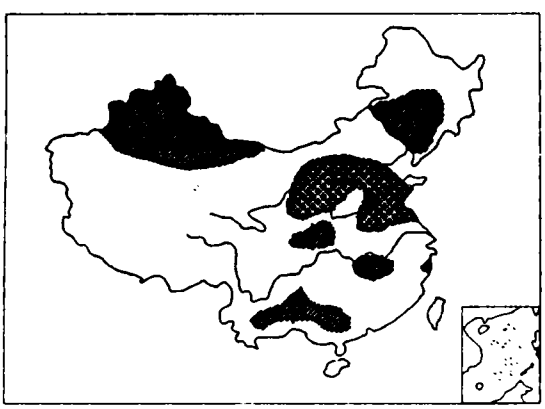

Fig. 4 The difference of precipitation between two cold and two warm periods in this century

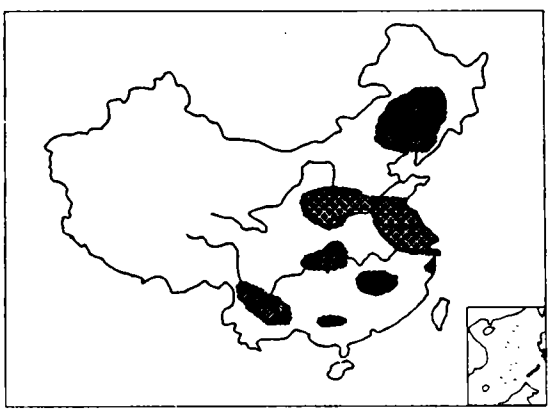

Fig. 5 The difference of precipitation between cold and warm periods in the early half of this century

2. Compared with Climate Simulations

At present, there are more than ten main climatic models all over the world, but much uncertainty remains in the prediction of global climate properties by using these models because our knowledge is still limited. For example, the simulated results on precipitation in China and other east Asia areas show that the changes in summer precipitation range from −5.0% to 10.6% by the year of 2050 when the concentration of CO_2 doubles. The results from

all models show that at least in some areas the precipitation will decrease, but only one of these models shows the great decrease in precipitation. Fig. 6 is the best estimation for summer precipitation in China by 2050[7], which is the synthesized result of these models by Chinese Academy of Meteorological Science. It suggests that by the middle of next century, the precipitation in many areas of China would increase, and the much more increasing areas are those as southeast coastal area, Southwest, Northwest, east part of Inner Mongolia. Such distribution are very similar to that of flood-prone area in the warm periods of the last 500 years. The two decreasing areas of precipitation, i.e. central area and most western area, are approximately consistent with the drought-prone area in the warm periods of the last 500 years, but between them the data in the most western area is so few that its reliability is too low.

Fig. 7 indicates the results of the change of summer precipitation in the case of CO_2 doubling, which is synthesized by Chinese Academy of Meteorological Science, based on the 5 key climatic models (GFOL, GISS, NCAR, OSU, UKMO) in the world[8]. It shows that the summer precipitation may be decrease in southern adjacent area of middle reaches of the Huanghe River and North China Plain when the concentration of CO_2 doubles. Such areas are very similar to drought-prone areas in the last 500 years in the periods of climatic warming. The areas where precipitation may be increase are approximately the same with flood-prone areas in the last 500 years in the periods of climate

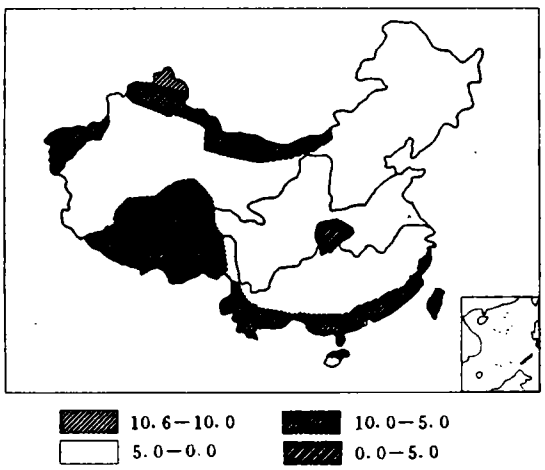

Fig. 6 The best estimation of summer precipitation change 2050 A.D. by GCM model

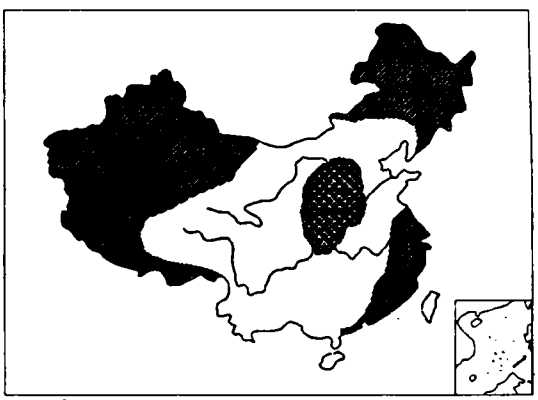

Fig. 7 The best estimation of summer precipitation in China in the case of CO_2 doubling by CFDL, GISS, NCAR, OSU and UKMO models

warming except western parts of China where the historical climatic information are so few that it can not compared with other areas.

In brief, the trend of flood and drought in the warm periods of the last 500 years, which has been obtained by analyzing departure of degree of flood and drought, approximately represents the distribution of observed precipitation in this century and the result of climate simulation in the future when the concentration of CO_2 doubles. So, it is reasonable that the historical trend above are regarded as the possible scenarios of flood and drought in China in the case of global warming.

IV. CONCLUSION

Through analyzing the distributive characteristics of flood and drought during the warm periods of last 500 years, we can conclude that in the case of global warming the flood hazards probably increase in many parts of China, such as southeast coastal area, Southwest, Northwest, some parts of Northeast and Inner Mongolia, while the drought hazards probably decrease in the North China Plain, the middle reaches of the Huanghe River and its southern adjacent area. This distribution is consistent with precipitation distribution in warming periods of this century and is resulted from climatic models in the case of CO_2 doubing, so it is reliable. On the other hand, the complex distribution of historical flood and drought may be regarded as the valuable complement for climate simulation because of the low spatial resolution of the GCM model. For example, compared with reality, the computed result from the composite GCM model shows that the southeast coastal regions of China are rather too dry, while the interior northwestern regions are rather too wet. Certainly, there are many questions needed research further, such as the impacts of the possible evapotranspiration changes on flood and drought hazards due to the climate warming and so on.

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