Long-term trends of extreme precipitation events in the Yellow River Basin: 1961~2000

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Abstract

Water cycle is shifting its gear with the projected global temperature increase, resulting from rising levels of greenhouse gas in the atmosphere. The intensified water cycle is likely to have profound impacts on society and the environment as the frequency or intensity of extreme precipitation events changed. In this paper, long term trends of extreme precipitation events in the Yellow River Basin from 1961 to 2000 have been investigated, considering changes of intensity, frequency, duration and timing. The results have shown that for the YRB as a whole, there were general decreasing tendency of maximum precipitation of n continuous day (N-Pmax), precipitation days (NRI), duration of wet spell (DWmax) but increasing in mean precipitation intensity of rain days (MRI), duration of dry spell (DDmax). The timing of N-Pmax had become 20-40 days earlier during the 40 years from 1961 to 2000. Spatially, the headwater (sub-basin 1) and middle reaches of the YRB (including subbasin 5, 6 and 7) had the most significant changes of extreme precipitation events, which may have great hydrological impacts of the whole basin.

Key words: extreme precipitation events, trend, the Yellow River Basin

Introduction

Water cycle is shifting its gear with the projected global temperature increase, resulting from rising levels of greenhouse gas in the atmosphere (Thomas, et.al, 2005). The intensified water cycle is likely to have profound impacts on society and the environment as the frequency or intensity of extreme precipitation events changed (Karl et al., 1999; IPCC, 2001). With the increasing concern of the impacts of extreme precipitation events, many researches have tried to detect the long term changes of extreme precipitation events. In a review of changes of extreme precipitation, it was reported that trends in 1-day and multiday heavy precipitation events in the some regions have shown a tendency toward more days with heavy precipitation totals over the 20th century (Easterling, et al, 2000).

The Yellow River is known as the cradle of Chinese Civilization (Fig.1). Under the impacts of climate change as well as human activities, hydrological cycle of the Yellow River Basin has changed greatly and rapidly, which has resulted at serious water related problems in the region (Liu & Zheng, 2002) Significant decreasing tendency of annual stream flow in the region have been detected in the past 50 years, however, no significant changes were detected in the annual precipitation (Liu & Zheng, 2004; Fu, et.al, 2004). Water shortage and floods in the region— already a limiting factor for ecosystems, food and fiber production, human settlements, and human health— may be exacerbated by changes of extreme precipitation events.

Climate extremes can be placed into two broad groups: (i) those based on simple climate statistics, which include extremes such as a very low or very high daily temperature, or heavy daily or monthly rainfall amount, that occur every year; and (ii) more complex event-driven extremes, examples of which include drought, floods, or hurricanes, which do not necessarily occur every year at a given location (Easterling, et al, 2000). In this paper, the former concept of extreme events was accepted to detect the tendency of extreme precipitation events in the Yellow River Basin from 1961 to 2000, considering intensity, frequency, duration and timing.

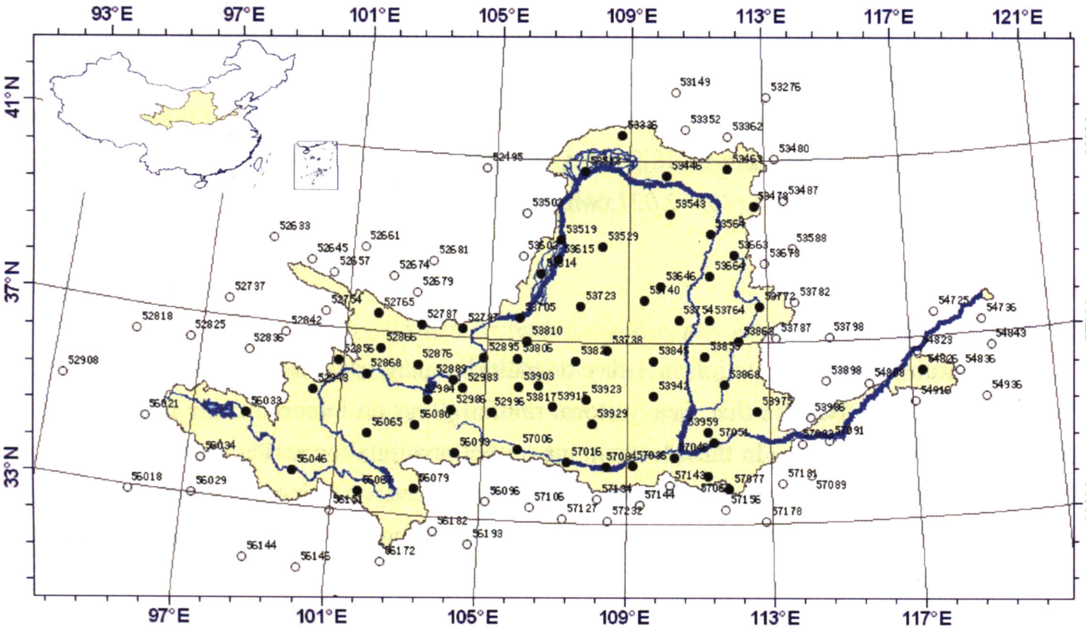


Figure 1. Location of the Yellow River Basin and the distribution of precipitation gauges

Data availability and methodology

Data availability

A dataset of daily precipitation from 1961 to 2000 has been used in this study. It includes almost all first- and second-class national climate stations in China and was developed at the Climate Data Center (CDC) of the China Meteorological Administration. This is the best daily dataset currently available for studying climate change in the country. The data have been subject to quality control procedures of the CDC.

Missing values and temporal inhomogeneity have been checked at the beginning of the subsequent analysis. Stations with too many missing values are dropped and 128 gauges were selected for this study, among which 66 gauges locate in the Yellow River Basin, while the other 62 gauges located near the YRB and were used as reference (Fig.1).

Indices of extreme events

On detecting the changes of extreme precipitation events, we were considering the changes of intensity, frequency, duration and timing of the events. Indices regarding to these aspects were defined as following:

- *N-Pmax*, maximum precipitation amount of n continuous rain days per calendar year, with n equal to 1, 7, 15, 30, 60 and 90;
- *MRI*, average rainfall intensity of the calendar year, considering rain days only;
- *NRI*, number of rain days, i.e. number of days with precipitation amount larger than 0.1mm/day;
- *DWmax*, maximum duration of wet spell, i.e., number of contiguous rain days;
- *DDmax*, maximum duration of dry spell, i.e., number of contiguous days without

precipitation;

- *N-Dmax*, occurrence day of the n-day maximum;

Trend test

The linear regression is adopted herein to detect the linear trends of extreme precipitation events in the Yellow River Basin. For the interpretation of the significance of the results, the trend-to-noise ratio (β/σ) in the form of a t-test of the regression coefficient was used (Kottegoda, 1980), where β is the coefficient of the linear regression function representing the average annual change while σ is the standard error. If $|\beta/\sigma| > t_{\alpha}(40)$, the linear trend hypothesis is accepted. At the significance level of $\alpha=0.05$, $t_{\alpha}(40)=2.021$; while $t_{\alpha}(40)=1.684$ with $\alpha=0.1$.

Results

Trends of intensity

Large amount of precipitation in 1-day or multiday may cause serious flood disaster in the Yellow River Basin. Besides that, heavy storm rainfall plays an important role in soil erosion in the arid or semi-arid region. In this research, maximum precipitation series with n continuous day have been retrieved from the above dataset. It was found there were general agreements among the tendency of 7Pmax, 15Pmax, 30Pmax and 90Pmax. Therefore, only the tendency of 1Pmax and 7Pmax are discussed herein.

From 1961 to 2000, the maximum 1-day precipitation tends to decrease in most part of the Yellow River Basin, except north part of Ning-Meng Region (sub-basin 4) and south part of Weihe Basin (sub-basin 7) (fig.1). However, the decrease trends of the 1-day precipitation are not statistically significant except the headwater (sub-basin 1) and middle reaches (sub-basin 5) of the Yellow River. In these two regions, the decreasing rate can be as large as 0.9mm/a, which indicates that during the 40 years from 1961 to 2000, the maximum 1-day precipitation had decreased about 36mm. The decreasing tendency of maximum 7-day precipitation is much more significant in these two regions, with the decreasing rate of 1.3mm/a. Meanwhile, the spatial distribution of the decreasing tendency had extended to wider area including south part of sub-basin 7

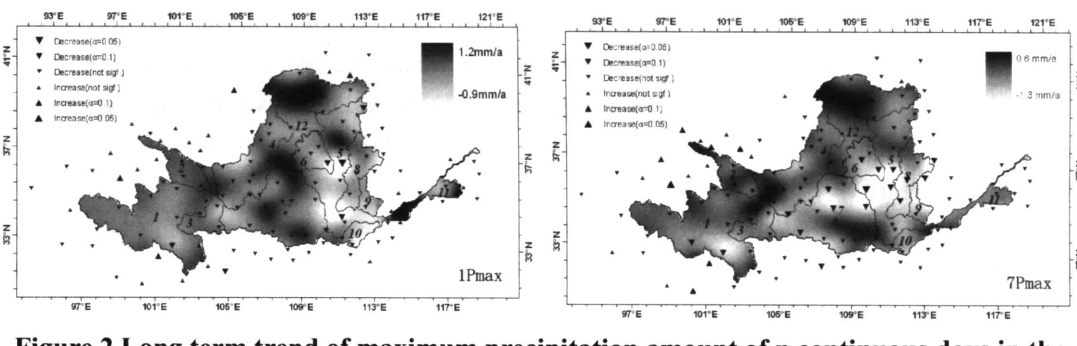


Figure 2 Long term trend of maximum precipitation amount of n continuous days in the Yellow River Basin: 1Pmax/7Pmax (left/right)

The spatial patterns of long term tendency of mean precipitation intensity (MRI) is different to that of the N-Pmax seriss (fig.2). Figure 2 shows that the MRI tends to increase in most region located at the east of 104°E, though the increasing tendency is only significant at south part of sub-basin 5, east part of sub-basin 7, north and south-west part of sub-basin 4. The increasing rate of these region is about 0.09mm/a.

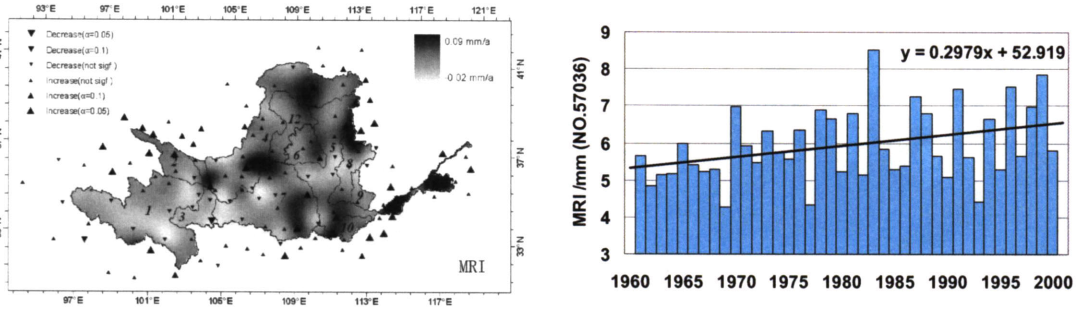


Figure 3 Long term trend of mean precipitation intensity in the Yellow River Basin: 1961-2000

Changes of frequency

Since 1961, number of rain days has decreased significantly almost everywhere in the Yellow River Basin (fig.4). The middle reaches of the Yellow River Basin, including sub-basin 5, 6 and 7, has shown the largest decrease of rain days with the maximum decrease of rain days can be about 48 days during the 40 years (fig.4, taking gauge NO.54826 for example). The place with significant increasing rain days is the north-west part of the headwater (Maduo, gauge NO.56033), of which rain days has an increasing rate of 1.2days/a.

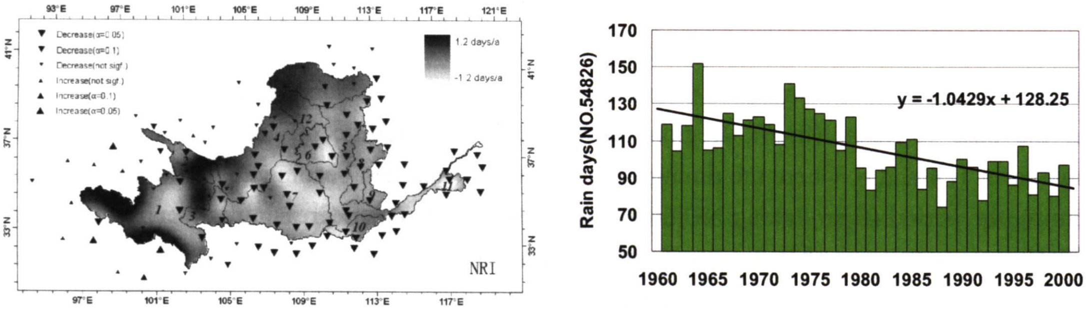


Figure 4 Long term trend of precipitation days in the Yellow River Basin

Trends of duration

The duration of wet/dry spell is practically meaningful for water resources management. In 1997, the long duration of zero flow in the lower reaches of the YRB had caused serious great economic losses and ecological disaster as well. The investigation on the trend of the duration of wet spell shows that there were significant decreasing tendency of the maximum length of wet spell in the YRB since 1961 (fig.5). In areas such as the eastern part of sub-basin 1 and sub-basin 11, the decreasing rate can reach to -0.2-0.4 days/a (for example, gauge NO.56065 in the sub-basin 1, fig.5).

As for the duration of dry spell, meanwhile, there were widely increasing trend in the east of 104°E but significantly decreasing trend has been found in the headwater of the YRB (fig.5). The decreasing rate of DDmax in the headwater can be around -0.5days/a. Sub-basin 4, 5, 6 and 11 are regions with significant increase of DDmax with about 20-30 days increase in the 40 years (fig.5, NO.53810 for example).

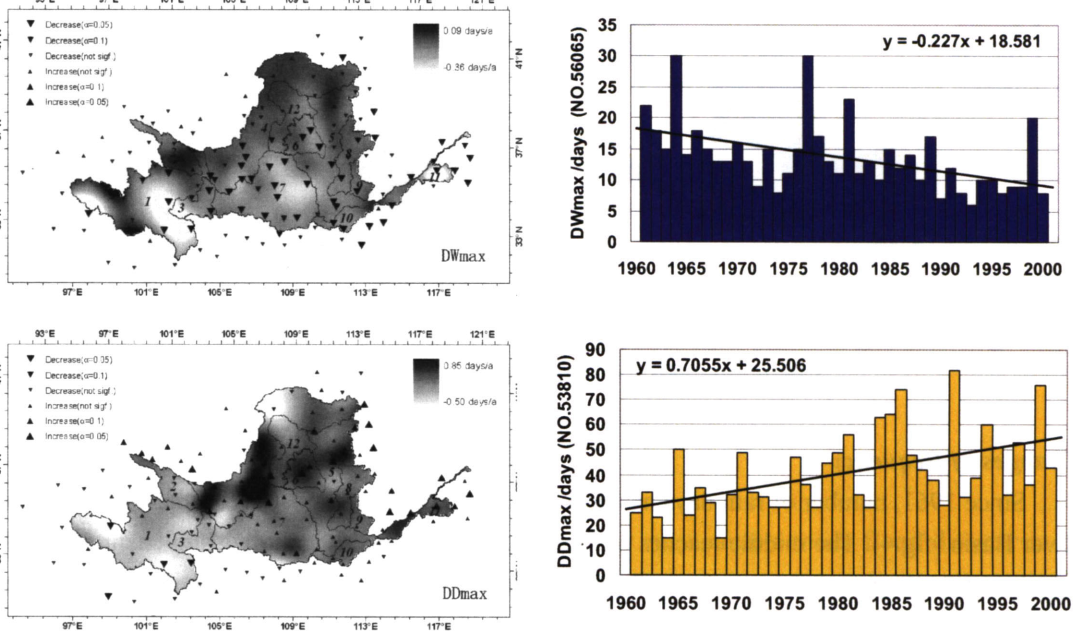
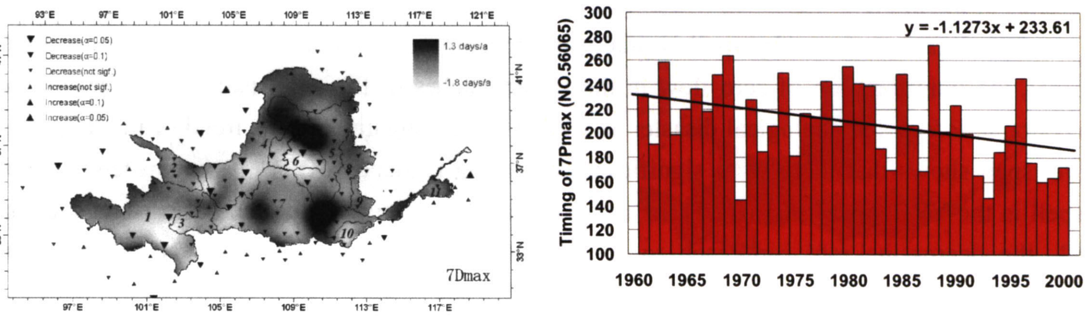


Figure 5 Long term trend of duration wet/dry spell (above/bottom) in the Yellow River Basin

Shifts of timing

The occurrence date of maximum precipitation of n continuous days (i.e. N-Pmax) was taken under consideration in this research. For the 7Dmax series, there is a widespread decreasing in the YRB, which means the timing of the extreme precipitation events tended to be some days earlier in the past 40 years (fig.6). Regions with statistically significant decrease of 7Dmax were sub-basin 1, 4 and 6, where the timing of the extreme event had become about 20-40 days earlier during the period (fig.6, taking NO.56065 as an example). The decreasing tendency of timing of 90Dmax series was much more significant in the YRB with special attention to sub-basin 2, 4, 6, 7 and 11 (fig.6). The occurrence date of maximum precipitation in 90 continuous days became about 20-40 days earlier almost in the YRB as a whole.



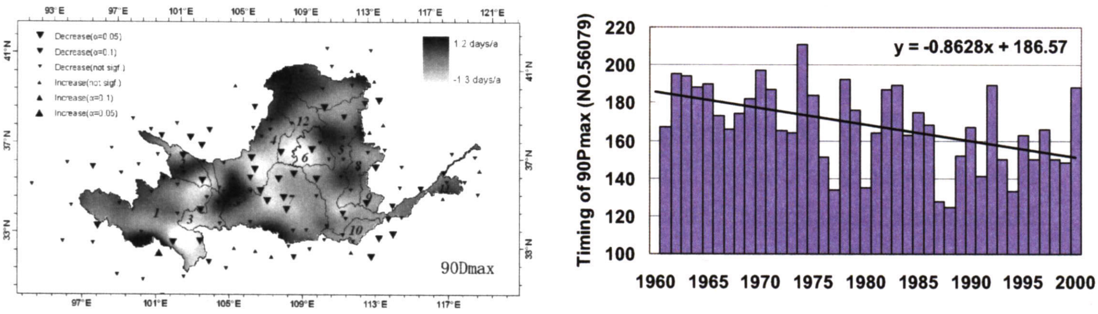


Figure 6 Timing shifts of the extreme precipitation events in the YRB: 7Pmax/90Pmax (above/bottom)

Conclusions

This research have investigated long term trends of extreme precipitation events in the Yellow River Basin from 1961 to 2000, considering changes of intensity, frequency, duration and timing. For the YRB as a whole, there were general decreasing tendency of maximum precipitation of n continuous day (N-Pmax), precipitation days (NRI), duration of wet spell (DWmax) but increasing in mean precipitation intensity of rain days (MRI), duration of dry spell (DDmax). The timing of N-Pmax had become 20-40 days earlier during the 40 years from 1961 to 2000. Spatially, the headwater (sub-basin 1) and middle reaches of the YRB (including subbasin 5, 6 and 7) had the most significant changes of extreme precipitation events, which may have great hydrological impacts of the whole basin.

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