Analysis of the climate change in the Dagu river basin in recent 50 years

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Abstract: Due to the influence of global warming and environmental change, the meteorological and hydrological elements of the Dagu River Basin have also undergone a series of response changes, which have led to the change of the spatial and temporal changes of water resources. The natural ecological environment and the economic development of human society have been seriously affected. In this study, hydrological and meteorological factors such as temperature, precipitation, evaporation and runoff were selected as the object of study. Spearman order correlation test, linear regression method and sliding average method were used to analyze the trend of meteorological hydrological elements in Dagu River Basin in Recent 50 Years. The results show that the trend of climate warming in Dagu River Basin is consistent with that of national climate change in recent 50 years. At 0.05 confidence level, the annual mean temperature fluctuates with time, and the annual precipitation is increasing with time. The trend of declining trend is not significant. The annual evaporation decreases with time, and the descending trend is significant. The surface runoff decreases with time.

Introduction

Over the past century, the climate and environment have undergone significant changes; climate warming has become the dominant trend. Due to the impact of global warming, global precipitation has also undergone significant changes. The intensification of the global hydrological cycle has led to increasingly frequent droughts and floods in the region and even in the world. Humans are facing enormous environmental pressures and challenges. The study of the law and mechanism of extreme weather disasters has become one of the important frontiers of science [1,2,and3] . Dagu River Basin is located in Jiaodong coast, on the verge of the Yellow Sea, coastal areas are affected and regulated by the marine environment, which is characterized by oceanic climate and is a humid monsoon zone in the coastal zone of north China warm temperate zone. As the center of economic development in Qingdao City, Dagu River Basin needs enough available water resources to support industrial and agricultural development. However, current groundwater and river water are more polluted. The shortage of water resources severely restricts the future development of the basin[4,5, and6].

Dagu River runoff sources rely on precipitation, due to climate change led to the redistribution of water resources in time and space, the number of water resources has changed, the natural environment and the economic development of human society are seriously affected[7,8]. Therefore,

studying the law of climate change to predict the future trend of climate change is of great significance to the rational allocation of water resources in the basin and the drought relief and disaster mitigation in agricultural development.

Research methods

Sliding averaging method

Based on the principle of smoothing and filtering, the moving average method smooths the original sequence and makes the trend or stage of the hydrological changes more intuitive and obvious [9-10]. It has the advantage of being simple, intuitive, and easy to identify trends. The formula is expressed as

$$y_t=\frac{1}{2k+1}\sum \chi^t+i \quad (1.1)$$

5-point moving average when k = 2 and 7-point moving average when k = 3.

Spearman order correlation test

The Spearman order correlation test mainly verifies whether the hydrological sequence has trend by analyzing the correlation between χ_i and its sequence i [11]. In operation, the hydrological sequence χ_i is represented by its order R_i (that is, the sequence number corresponding to χ_i when the sequence χ_i is arranged in descending order), then the order correlation coefficient is

$$\gamma=1-\frac{6\cdot\sum_{i=1}^{n} d_i^2}{n^3-n} \quad (1.2)$$

Where: n is the length of the sequence;;$d_i=R_i-i$。

If the order R_i is close to the time sequence i, then d_i is small, the order correlation coefficient is larger and the trend is significant.

T test is usually used to test the trend of the hydrological sequence is significant, the statistic T is calculated as:

$$T = r\sqrt{(n-4)/(1-r^2)} \quad (1.3)$$

The statistic T can also be used as the scale of the trend of hydrological sequence, and /T/ larger, to some extent, it can be explained that the trend change of the sequence is more significant.

Results and analysis

The trend of temperature changes

The annual temperature anomaly or the change rate of temperature anomaly can characterize the annual variation of temperature. The change rate of temperature anomaly is the percentage of the annual distance of temperature and the average temperature of years. The larger the value, indicating the greater the temperature change range; the contrary, the smaller the value, the smaller the temperature change. The long-series temperature data of four representative meteorological stations in and around Dagu River Basin are selected. The linear regression analysis and the Spearman rank correlation test are used to analyze the annual average temperature trends. The results are shown in Figure 1 and Table 1.

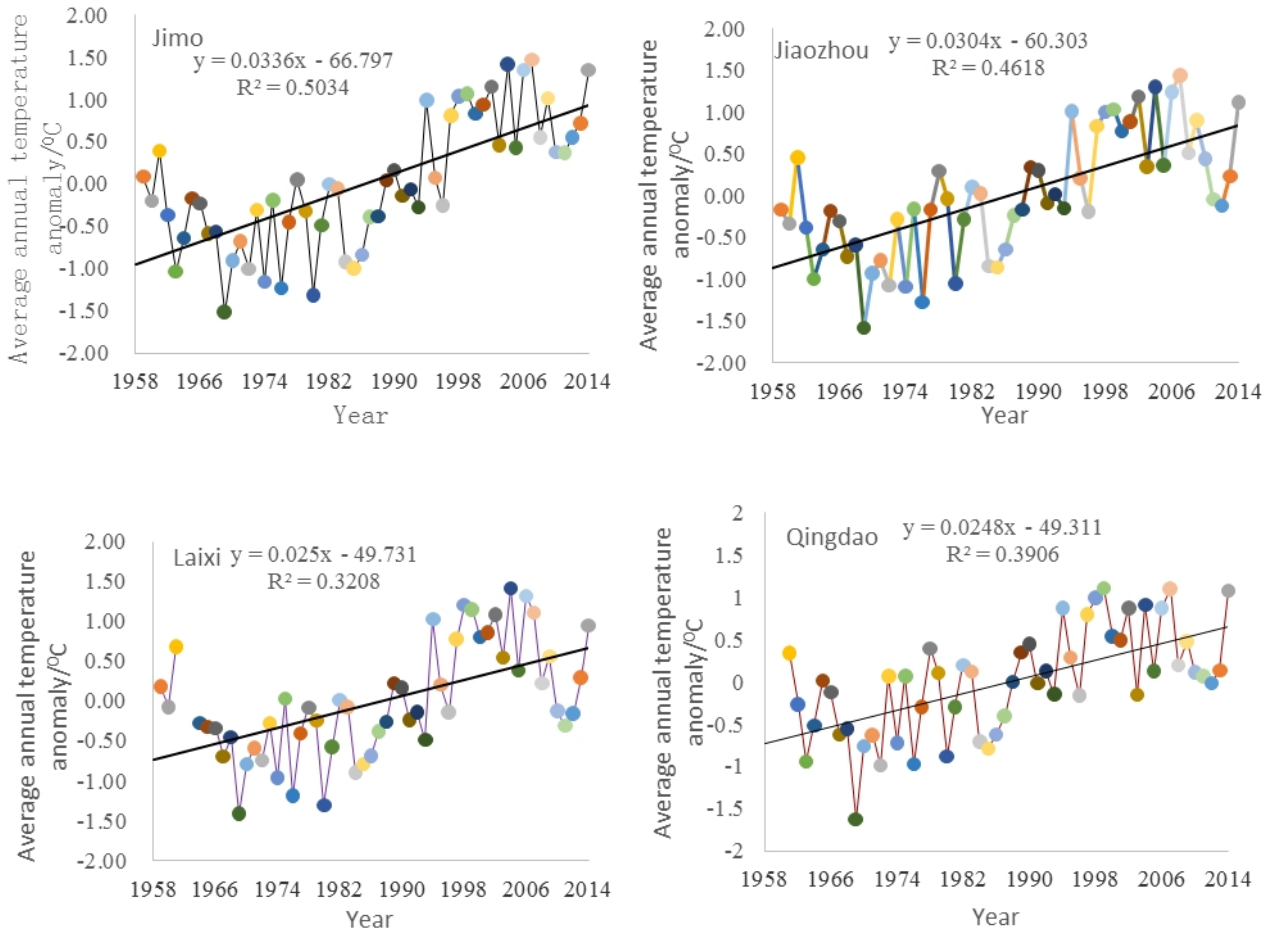

Fig.1 the stations of the average annual temperature linear regression analysis in the study area

Tab.1 Annual mean temperature trend test in Dagu river basin

Representative station	longitude/ E	latitude /N	Spearmancorrelation coefficient（r）	Spearman statistics | T |	Threshold	Trend
Qingdao	120º20'	36°04′	0.61	5.33	2.01	Significant
Jimo	120°11′	36°33′	0.55	5.02	2.01	Significant
Jiaozhou	120°03′	36°26′	0.76	8.9	2.01	Significant
Laixi	120°20′	36°46′	0.79	9.15	2.01	Significant

As can be seen from Figure 1, since the 1950s, the average annual temperature in the basin has fluctuated upward with time. As can be seen from Table 1, the Spearman rank correlation test is used to test the significance of the upward trend of temperature. At the significant level of 0.05, the temperatures of all the representative weather stations show a significant upward trend. This shows that in the past 50 years, the trend of climate warming in the Dagu River Basin basically agrees with the general trend of the national climate change. Due to the increase of atmospheric temperature, the movement of atmospheric molecules intensifies and easily causes weather changes, potentially affecting the occurrence of flood events, resulting in an increasing trend of flood disasters in the Dagu River Basin.

Precipitation trends

Affected by the global warming effect, the variation of regional water cycle leads to the change of precipitation. The IPCC report pointed out that the observed data are sufficient to show that global warming will lead to an increase in precipitation in several regions and an increase in the frequency of extreme weather events [12].The research on precipitation change is mainly divided

into the study on the mean precipitation change and the study on the extreme value change. Based on this, the change trend of precipitation mean is analyzed by means of 5-year slip and Spearman rank correlation test of annual precipitation, as shown in Figure 2 and Table 2.

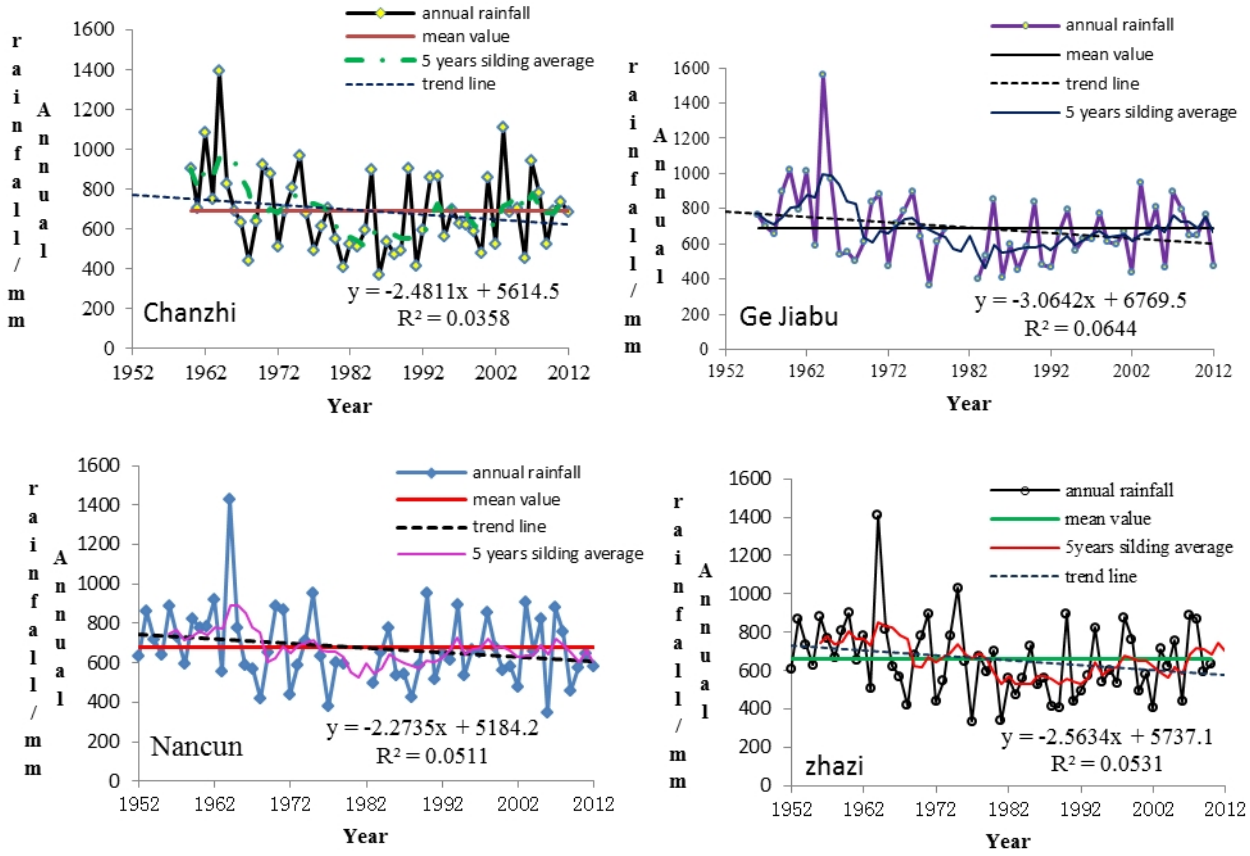

Fig.2The annual precipitation amount five-year moving average trend of representatives station

Tab.2 the annual precipitation trend test of representatives stations in Dagu river basin

Representative station	longitude /E	latitude /N	Spearman correlation coefficient （r）	Spearman statistics ｜T｜	Threshold	Trend
Chanzhi	120º28'	36°56′	-0.10	0.73	2.01	Not obvious
Zhazi	120°05′	36°27′	-0.176	1.23	2.01	Significant
Gejiabu	120°16′	36°44′	-0.24	1.9	2.01	Not obvious
Nancun	120°08′	36°32′	-0.02	0.11	2.01	Not obvious

As can be seen from Figure 2, using the five-year sliding average of annual precipitation on behalf of hydrological stations in the basin, we can see that the annual precipitation fluctuates declining with time, but the trend changes more moderately. According to the Spearman correlation test, it can be seen from Table 2 that under the significant level of 0.05, the precipitation of only the Zhazi Hydrological Station in the basin decreases obviously with time, and the downward trend of other stations is not obvious. Therefore, it is considered that the Dagu River Basin Precipitation decreased with time showed no significant trend.

The trend of evaporation trends

Evaporation is the study of regional hydrological system on the global climate change hydrological response of the key links, the size of the evaporation are closely related to climatic conditions and underlying surface conditions, climate conditions mainly refers to temperature, air

humidity, wind speed and other factors [13].The annual evaporation data of Chanzhi Hydrographic Station and Nancun Hydrological Station were selected. The linear regression and 5-year moving average analysis, Spearman's rank correlation test were used to analyze the trend of annual evapotranspiration, as shown in Figure 3, Table 3.

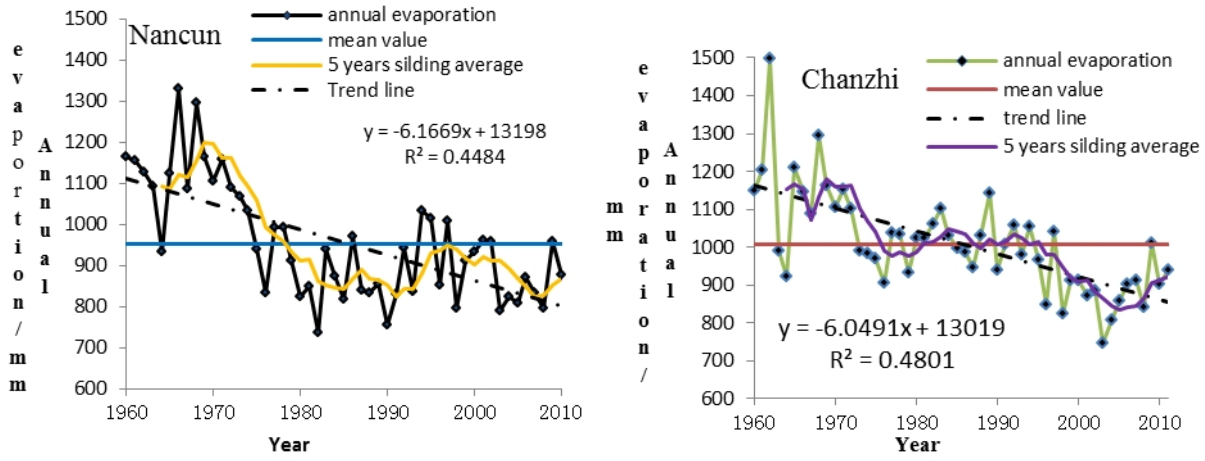

Fig.3The chart of evapotranspiration trend Nancun village and Chanzhi hydrological station

Tab.3 Trends inspection annual evaporation in Dagu river basin

Representative station	longitude /E	latitude /N	Spearman Correlation coefficient (r)	Spearman statistics | T |	Threshold	Trend
Chanzhi	120º20′	36°04′	-0.71	6.94	2.01	Significant
Nancun	119°11′	36°45′	-0.63	5.64	2.01	Significant

As can be seen from Figure3, the average annual evaporation of each station shows a decreasing trend in different degrees under the five-year sliding average condition. As can be seen from Table 3, under the significant level of 0.05, the test of Spearman's rank correlation test shows that the annual evaporation has a significant trend of decline. Generally speaking, the evaporation capacity increases with the increase of air temperature. According to the trend analysis of air temperature, the annual average temperature in Dagu River Basin shows an overall upward trend while the annual evaporation shows a decreasing trend. This phenomenon is consistent with that of domestic and foreign conclusions of the study [14-16]. Therefore, we can not simply assume that the decrease in evaporation is the result of an increase in temperature. The analysis suggests that it may be due to two reasons. On the one hand, it is likely that the concentration of sulfate, nitrate, black coal and mineral aerosol in the atmosphere is likely to increase due to human activities. Their most obvious impact is the reduction of sunshine hours and solar radiation in the Dagu River basin, which in turn reduces water surface evaporation. By analyzing the data of sunshine hours from 1960 to 2014 in Jimu and Jiaozhou in Dagu River Basin, we found that the hours of sunshine in Jimo decreased by 91.5 hours in 55 years and 199.1 hours in Jiaozhou. Through the statistical analysis of the total amount of solar radiation in Qingdao City from 1961 to 2013, it was found that the total solar radiation decreased by 21,763.99 MJ / m^2 in the past 53 years. The decrease of average wind speed at various scales also has some effect on the reduction of water surface evaporation; on the other hand, it may be caused by the error of data acquisition and processing. Before the 1980s, the collected data of surface evaporation mainly come from the observed data of evapotranspiration ϕ20 and ϕ80, but the obtained data are generally larger than the measured data. After entering the

1980s, E601 gradually replaced the above two types of evaporation Dish to observe the data, E601's main advantage is that the measured results and the actual water surface evaporation closer. Evaporation data obtained before the 1980s are all unified to the standard of E601 through the conversion method, but the method of conversion is not accurate, which may bring some errors.

Runoff volume trends

River runoff is a product of the combined effects of climate factors such as temperature and precipitation and human activities. The impact of human activities on runoff is mainly reflected in two aspects. One is to change the characteristics of the underlying surface of the river basin. For example, soil and water conservation changes the land use and land cover of the river basin, thereby changing the characteristics of the underlying surface and further affecting precipitation in the river basin; On the other hand, the construction of large-scale water conservancy projects has changed the natural characteristics of runoff, making the runoff redistribute in time and space [17-18]. Two representative hydrological stations' sequence runoff data were selected and linear regression analysis was used to analyze runoff trends in the basin, as shown in Figure 4.

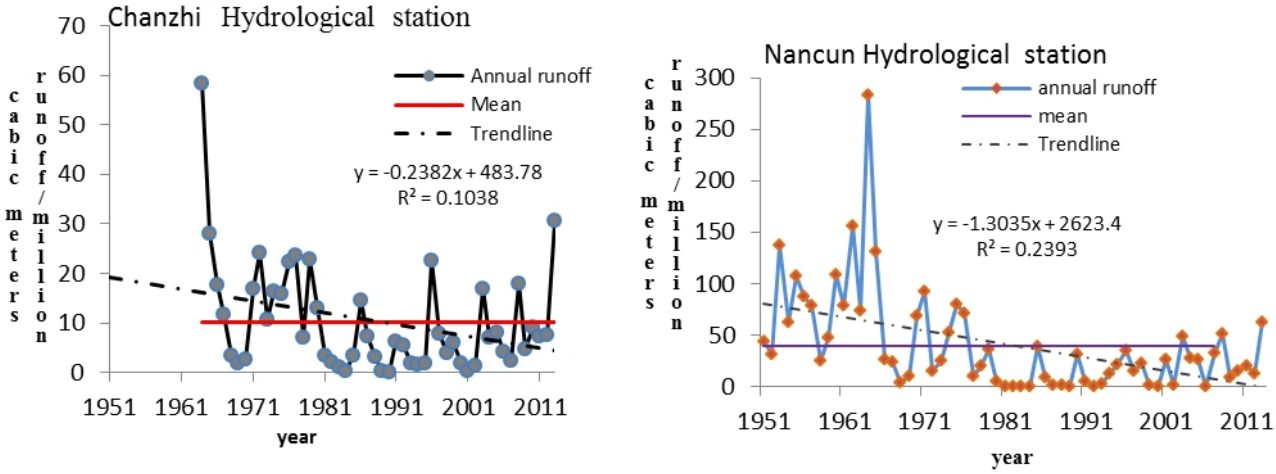

Fig.4 The trend chart of runoff amount in representative's station

As shown in Figure 4, the surface runoff of the Dagu River Basin has generally decreased with time since the 1950s. Especially with the economic development in recent decades, the water demand for industrial and agricultural development has increased. Under the warming trend of the global climate, precipitation decreases and evaporation increases, resulting in a clear trend of annual runoff reduction. According to the change of land use types in Dagu River Basin from 1980 to 2010, the area of water body and the area of urban land use are increasing. In general, the increase of water area increases the evaporation in the basin and reduces the runoff. The urban water intake due to urban development and water diversion irrigation will lead to the decrease of runoff. Therefore, under the combination of climate change and human activities, the runoff of Dagu River Basin shows a decreasing trend during this period.

Discussion

In the recent 50 years, the variation of hydrological and meteorological elements in the Dagu River Basin can be attributed to the following causes:

The main causes of the temperature rise in the Dagu River Basin in recent 50 years are natural and human factors. Natural factors are mainly due to the increase of atmospheric concentrations of greenhouse gases and the variation and adjustment of the atmospheric circulation. The climatic effects of the rising concentrations of greenhouse gases in the atmosphere are global. In the past 100 years, especially in the past 50 years, the climate of the Dagu River Basin may have already

responded to this. The significant warming of the near-surface air temperature may be largely the result of an increase in the greenhouse effect. Owing to the variation and adjustment of the atmospheric circulation, the winter monsoon in eastern China has weakened obviously in the past 50 years, resulting in the high winter temperatures and the annual average temperature increase. With the rapid economic development in Qingdao City, the number of migrant workers increased and the population continued to grow. The large emission of greenhouse gases and aerosols helped to some extent raise the temperature.

The increase of atmospheric sulfate, nitrate, black coal and mineral aerosol content not only directly causes the air quality in the eastern cities or regions of our country to decline, but also may affect the climate of Dagu River in recent decades. The most obvious impact of aerosols on the climate is the obvious decrease of sunshine hours and solar radiation in the Dagu River Basin, further affecting the surface air temperature, precipitation and water surface evaporation.

The variation of precipitation in space and time is great; the reason for the changing trend of precipitation is much more complicated than the cause of the increase in temperature. Since the end of 1970s, the spatial distribution of large scale precipitation in China has continued to show the pattern of "South flood and drought in the north". It is basically determined by the natural variability of climate in the East Asian monsoon and the increase of ENSO events. Warming also leads to the variation of water vapor in the atmosphere of, such as Lin Zhenyao [19] pointed out that the adjustment of the atmospheric circulation in recent years, the northwest high altitude wind field changes, the north wind of the eastern region increased, water vapor from the southeast has been weakened, which may be caused by a decrease trend of precipitation in the eastern. In addition, human activities also have an important impact on the precipitation, mainly comprehensive treatment project in Dagu River Basin, river, embankment, dam and irrigation project changed the underlying surface, affect the distribution of precipitation; human induced greenhouse gas emissions and sulfur compounds, aerosol increased, also increased the area the uncertainty of climate change, thus affecting the regional rainfall hydrological factor.

The impact of human activities is mainly achieved through artificially induced increases in atmospheric concentrations of greenhouse gases and various aerosols and changes in land use and land cover. Table 4 shows the changes of land use in Dagu River Basin in different periods. As can be seen from Table 4, with the rapid economic development, the process of urbanization is accelerating, the scale of cities is expanding, the construction land is increasing, and part of cultivated land is occupied. In addition, in order to increase forest resources, conserve water sources, reforest forests and return farmland to forests measures and other factors prompted a slight decline in arable land. Changes in land use and land cover may also directly affect near-surface air temperature, land surface evaporation and atmospheric precipitation in the Dagu River Basin by changing the exchange of energy and material fluxes in the geo-gas system.

Tab.4 The change of different land use types statistics

Land use type	1990year	2000year	2005year	2010year
arable land（%）	75.63	75.35	76.18	78.27
Woodland（%）	2.60	2.60	2.60	5.92
Meadow （%）	8.22	8.22	5.85	0.15
Water area（%）	3.43	3.14	4.23	3.68
Urban and rural areas, industrial and mining, and residential areas（%）	9.85	10.41	11.10	10.69
Unused land（%）	0.27	0.27	0.04	1.28

In short, natural and human factors, acting alone or in combination, affect the heat budget of the geo-gas system in the basin, affecting the near-surface temperature change and thus affecting the hydrological elements such as precipitation and evaporation in the Dagu River Basin Of the water cycle, highlighting the intensification of acidification, from the development of the arid climate to the hydrological drought and further to the socio-economic droughts and the serious shortage of water resources.

Conclusion

In this paper, we use the data of 50a in Dagu River Basin to analyze the trend of temperature, evaporation and precipitation at different timescales, and test the trend of runoff, and analyze the reason of changing temperature, evaporation, precipitation and runoff. The main conclusions are as follows.

(1) Linear regression analysis, Spearman's rank correlation test show that annual mean temperature in the catchment area fluctuates upward with time, and at 0.05 significant levels, temperature rising trend is significant. In the recent 50 years, the trend of climate warming in Dagu River Basin has been basically consistent with the general trend of climate change in China.

(2) The linear regression analysis, Spearman's rank correlation test and 5-year moving average analysis of annual precipitation on the representative meteorological stations in the basin, the results showed that the annual precipitation in the basin is a trend of falling volatility over time, at 0.05 significant level, draw a downward trend is not significant.

(3) Linear regression and five-year moving average analysis, Spearman order correlation test were used to study annual evaporation of representative meteorological stations. The results showed that the annual evaporation in the basin showed a trend of decreasing with time, at 0.05 significant levels, the test shows a significant downward trend.

(4) By means of linear regression analysis, it is concluded that the surface runoff of Dagu River Basin has been decreasing with time as a whole since the 1950s.

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References:

[1]Milly P C D，Wetherald P T.2002. Increasing risk of great floods in a changing climate [J].Nature, 415:514-517.

[2]Palmer T N, Raianen J.2002.Quantifying the risk of extreme seasonal precipitation events in a changing climate [J]. Nature, 415:512-514.

[3]Easterling D E,Meehl A G,Parmesan C,etal.2000.climate extremes observations,modeling,and impacts[J].Science,689;2068-2074.

[4]Meng Chunxia,Wang Chengjian, Dong Shaojie.Analysis on groundwater quality changes in Qingdao reach of Dagu River [J].Journal of Water Resources and Water Engineering,2008,19(1):73-76.

[5] Yun Kun. Study of water environmental carrying capacity in Qingdao reach of Dagu river [D].Qingdao: Qingdao Technological University, 2010.

[6] Qi Xingfen, Zhuang Zhenye, Han Deliang,etal.Sedimentary Sand and Water Resources in the Backward Position of the Dagu River Plain [J]. MARINE GEOLOGY LETTERS, 2004,20(2)：14-17.
[7]Zhang Liping, Chen Xiaofeng, Zhao zhipeng,etal.Progress in Study of Climate Change Impacts on Hydrology and Water Resources [J]. Progress in Geography, 2008,27(3):61-67.
[8]Yang Lijuan.Evaluation of groundwater resources in Dagu River[D].Qingdao: Ocean University of China,2012.
[9]Xie Ping,Chen Guangcai,Lei Hongfu,etal. Surface Water Resources Evaluation Method under Changing Environment [M].Beijing: Science Press, 2009.
[10]Liu Yufeng,Sun Hu,Yuan Zhihua.Annual and Seasonal Change Characteristics of Temperature in the Fenhe River Basin During the Period 1960-2007[J]. Resources Science,2011, 33（3）:489-496.
[11]Zhang Jianyun,Wang Guoqing,etal. Impact of Climate Change on Hydrology and Water Resources[M].Beijing: Science Press,2007,18-19.
[12]Zhang Qiang.Study on the Evolution of Water Cycle and Watershed Hydrological Process in the Basin of South China [M].Beijing:China Water Conservancy and Hydropower Press, 2013, 15-17.
[13] Zhang Qiang.Study on Climate Change and Hydrological Response of Poyang Lake Basin [M]. Beijing:China Water Conservancy and Hydropower Press,2015,123-125.
[14] Kahya E，Kalaycy S.2004. Trend analysis of streamflow in Turkey. Journal of Hydrology，289：18-144.
[15]Qiu Xinfa,Liu Changming.Changes of pan evaporation in the recent 40 years over the Yellow River Basin[J].Journal of Natural Resources, 2003,18(4):437-442.
[16]Xu Zongxue, Zhang Nan.Long-term trend of precipitation in the Yellow River basin during the past 50 years[J].Geographical Research,2006,25(1):27-34.
[17]Xu Tongxin,Sun Ji.Influence of precipitation and human activities on water fluxes from the Yellow River into the sea in the past 50 years[J].Advances in Water Science,2003,14(6):690-695.
[18]Li Chunhui,Yang Zhifeng.Influence of Main Reservoirs on the Yellow River on Runoff[J]. Yellow River, 2004,26(7):15-17.
[19]Lin Zhenyao,Zheng Du.The tracks of moisture transportation and its vapour geoecological characteristics on the QINGHAI-XIZANGPLATEAU[J]. ARID ZONE RESEARCH, 1992, 9(2):1-7.