Extreme drought events diagnose along the Yellow River and adjacent area

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Abstract

Drought is a major natural disaster that has long-lasting effects on economic and social activities in northern China and has regional distinctions in duration, severity, and spatial extent. In this study, tree-ring chronologies and historical archives in the Yellow River Basin and its surrounding areas were collected to investigate the dynamic process of the two extreme drought events for the past ~200 years. Here we directly employ the tree index instead of the climate indicator reconstruction to partly overcome the drought information loss during tree-ring based reconstruction. Identified drought history is improved significantly relative to the single indicator reconstruction and drought events are highly consistent with historical recorded ones. Two prominent drought events in the modern Chinese history were analyzed, namely the Ding-Wu Great Famine (1876-1879) and the extreme drought in northern China during the late-1920s. Unexpectedly, the most prestigious Ding-Wu Great Famine is lower than the extreme drought in the late-1920s in terms of drought duration, spatial extent and intensity. Our research further reveals that the drought events recorded in the historical records could be very different from actual events due to the influence of political and other factors. The analysis of spatial dynamics indicates that the potential mechanisms of the two drought events are also different. This is confirmed by research based on reanalysis data that the Ding-Wu Great Famine was caused by a typical strong ENSO event, while the mechanism of the extreme drought in the late-1920s was more complicated.

1 Introduction

Drought, as the world`s costliest natural disaster (Smith and Katz 2013; Wilhite 2000), has plagued civilizations throughout the course of human history. The impacts of extreme drought events, or the so-called mega-droughts, can be multiplied by poor governance and then induce social unrest, famine and massive population fatality, economic collapse, and even dynasty subrogation (Hao et al. 2021). Recent warming is associated with changes in spatial patterns of droughts and extreme precipitation and has increased drought frequency and severity over much of the globe. Especially semi-arid regions have already experienced significant water stress (Allan and Soden 2008), millions of people suffer from crop failure and are confronted with survival pressure (Haywood et al. 2013). It is critical to improve our understanding of drought dynamics and impacts in the context of climate change.

However, drought is difficult to measure or even to define, which hinders accurate drought characterizations. Moreover, due to the lack of instrumental records, it is difficult to diagnose and distinguish whether a disaster is man-made or natural, which in turn makes it difficult to understand the mechanism of disaster occurrence. The demand for monitoring complicated drought conditions has prompted many efforts to develop drought indicators based on different applications, regions affected, and data availability (Heim Jr and Brewer 2012; Mishra and Singh 2010), which take into account a variety of hydroclimatic variables, such as precipitation, soil moisture, streamflow, snow, groundwater, evapotranspiration, and vegetation. Meanwhile, reliable prediction of drought onset, development, and recovery is an important step toward effective early warnings, which can be achieved through either statistical approaches to explore empirical relationships in historical records or dynamical approaches based mostly on state-of-the-art general circulation models (GCMs). To improve the accuracy of future mega-drought projections, it is critical to strengthen our understanding of the mechanisms influencing the occurrence and magnitude of mega-droughts on different time scales. The relatively short duration of instrumental records (typically 150 years or less) limits our understanding of natural climate variability, especially for extreme events such as droughts which are by definition rare and therefore under-sampled in modern observations. These constraints present challenges to attribute droughts to particular causes, including both internal variability and external forcing.

Hydroclimate reconstructions developed from proxy records (e.g., tree-rings, sediment cores, speleothems) are critical for addressing this weakness by extending the instrumental record further back in time. Currently, proxy-based drought reconstructions provide the possibility of climate model simulations, proxy-system models, and proxies themselves are combined to develop estimates of past multivariate climate variability that capture and account for the non-climatic influences of proxy data. Tree-ring data are exactly dated and widespread over the mid-latitudes, which allow them to be statistically compared and calibrated with the instrumental observations in both space and time. Trees are naturally good records of extreme events, especially droughts. Tree-ring-based drought reconstructions have been widely used to better characterize and constrain the magnitude and processes of natural drought variability and contextualize recent trends (Davi et al. 2009). Instead of using the reconstruction index to depict the drought events, using the direct impact of the drought on tree radial growth could be a better way to reflect the severity of the drought. According to dendroecological studies (Gao et al. 2018; Meko et al. 1995), the trees could vary their response strategy to cope with extreme drought although their main limiting factor could be others. This provides another way to investigate the mega-droughts in history.

Yellow River is the mother river of China that gave birth to a splendid Chinese civilization. However, affected by both summer monsoon and westerly, this area has been plagued by various drought disasters in history. Some of those extreme drought events e.g. Ding-Wu Great Famine (1876–1879) and the late-1920s extreme drought events, had caused severe social upheaval. Some studies based on historical documents and other proxy data had tried to unveil the process and mechanism of these mega-droughts (Aceituno et al. 2009; Liang et al. 2003; Peng 2021; Zhang et al. 2011). However, the lack of climatic records and deviations in literature constrain the understanding of the mechanism of these extreme drought events, which has been a limiting factor for establishing an effective drought warning system in these drought-prone areas. Hereby, we apply a simple approach based on tree ring data combined with literature reconstruction in the Yellow River basin to investigate the mega-droughts from a new perspective.

2 Data And Methods

2.1 Study area

The Yellow River Basin mainly refers to the region ranging from 96°E to 120°E and 33°N to 41°N (Fig. 1). The Yellow River originates on the northeastern Qinghai-Tibet Plateau (TP) and spans four geomorphic units, namely the TP, Inner Mongolia Plateau, Loess Plateau and the North China Plain from west to east through northern China over a total length of 5464 km. The altitude also changes from the TP with an average about 4000 m a.s.l., to the Loess Plateau with altitudes varying from 1000 to 1500 m a.s.l., and finally through the alluvial plain with altitudes typically below 110 m a.s.l.. This region is located at the margin of the East Asian summer monsoon and has a subhumid warm temperate climate with the summer and autumn precipitation accounting for approximately 80% of annual precipitation. The climate regimes vary from the arid and semi-arid climate in the upper and middle reaches to the semi-humid and humid climate in the lower reaches of the river (Wang et al. 2007). The spatial distribution of annual total precipitation and annual mean temperature based on meteorological data show clear regional differences (Fig. 1b-d). Based on the monthly meteorological data (China Meteorological Data Service Centre) from 1981 to 2010, annual precipitation increases from 368 mm and 530 mm/year in the upper and middle reaches to 670 mm/year in the lower reaches of the Yellow River. The annual mean temperature in the upper, middle and lower reaches of the Yellow River basin are 3.35°C, 10°C and 11.69°C, respectively. Therefore, the study area has been divided into three subregions, namely Y_{upper}, Y_{mid} and Y_{down}, and the whole study area is abbreviated as Y_{all}.

2.2 Proxy and climate data

29 tree-ring-width series are employed here, that are older than 1850 A.D. and mainly limited by moisture (Table 1, No.1–29). All of these tree-ring series were processed using standard techniques of dendrochronology (Cook and Kairiukstis 1990). In order to compensate for the scarcity of tree-ring data in the Y_{down} area that is heavily affected by intensive human activity, 1 tree-ring based (Table 1, No. 30) and 5 literature-based precipitation or moisture reconstructions have also been included (Table 1, No. 31–35). In this study, climate data were obtained from the Climatic Research Unit (CRU) Time-Series (TS) version 4.05 worldwide dataset available on a 0.5°×0.5° grid (Harris et al. 2021), which were used to reveal the regional representativeness of proxy data.

Table 1
Information of tree ring chronologies and reconstructed precipitation/dry-wet indices

No	Area	Region	Code	Latitude/Longitude	Period	References/ Contributors
1	Y_{upper}	Qumalai	QML	33.80°N/96.13°E	1480–2002	Qin et al., 2003
2		Zhiduo	ZHD	33.72°N/96.28°E	1374–2002	Qin et al., 2003
3		Zhongtie	DQL	35.00°N/100.07°E	1178–2004	Peng et al., 2007
4		Yangyu	YYAH	34.80°N/100.34°E	1399–2002	Peng et al., 2007
5		Hebeidong	HHBMH	34.71°N/100.83°E	1800–2004	Peng et al., 2007
6		Delingha	DLH5	37.45°N/97.79°E	711–2003	Shao et al., 2006
7		Wulan	WL4	36.68°N/98.42°E	900–2001	Shao et al., 2006
8		Jiuquan	DHS	39.55°N/98.10°E	1768–2009	Chen et al., 2011
9		Sidalong	SDL	38.42°N/99.94°E	1785–2005	Zhang et al., 2011
10		Dayekou	DYK	38.52°N/100.25°E	1780–2005	Zhang et al., 2011
11		dongdashan	DDS	39.04°N/100.81°E	1779–2005	Zhang et al., 2011
12		Xidahe	XDH	38.09°N/101.40°E	1770–2005	Zhang et al., 2011
13		Xiyinghe	XYH	37.78°N/102.06°E	1288–2000	Yongxiang Zhang
14		Zhangye	TLC	39.05°N/100.72°E	1737–2010	Chen et al., 2013
15		Shandan	DHG	38.36°N/101.27°E	1768–2006	Chen et al., 2010
16	Y_{mid}	Changling Mts.	CLS	37.45°N/103.68°E	1644–2008	Chen et al., 2012
17		Xinglong Mts.	YDG	35.78°N/104.05°E	1807–2010	Chen et al., 2015

No	Area	Region	Code	Latitude/Longitude	Period	References/ Contributors
18		Dieshan Mts.	DS	34.58°N/103.35°E	1637–2013	Fang et al., 2013
19		Guiqing Mts.	GQM	34.63°N/104.47°E	1618–2005	Fang et al., 2010
20		ShimenMts.	SMS	34.45°N/106.15°E	1666–2008	Chen et al., 2013
21		Kongtong Mts.	KTS	35.55°N/106.51°E	1618–2009	Fang et al., 2012
22		Suyukou	SYK	38.73°N/105.92°E	1700–1999	Yongxiang Zhang
23		Beisi	BSI	39.08°N/106.08°E	1739–1999	Yongxiang Zhang
24	Y_{down}	Huashan	HSW	34.48°N/110.08°E	1359–2005	Shao et al., 1994
25		Huashan	HSE	34.48°N/110.08°E	1458–2005	Shao et al., 1994
26		Huashan	HSS	34.48°N/110.08°E	1512–2005	Shao et al., 1994
27		Lamadong	LMD	40.81°N/111.29°E	1567–2017	Mingqi Li
28		Shiren Mts.	YS	33.73°N/112.25°E	1801–2016	Peng et al., 2020
29		Southern Taihang Mts.	THS	35.21°N/112.8°E	1510–2013	Zhang et al., 2017
30		Luya Mts. *	LY02	38.73°N/111.83°E	1600–2000	Yi et al., 2010
31		North China Plain*		34–40°N/105–125°E	-133–1995	Zheng et al., 2006
32		Hebei Region*			1736–2000	Hao, 2008
33		Jinnan Region*			1736–2000	Hao, 2008
34		Weihe Region*			1736–2000	Hao, 2008
35		Shandong Region*			1736–2000	Hao, 2008

No	Area	Region	Code	Latitude/Longitude	Period	References/ Contributors
* represent this series is reconstructed precipitation.						

2.3 Regional extreme drought diagnosing in proxy data

The standardization has been applied to all series which makes all the data comparable. The principal component analysis (PCA) was applied to identify distinct growth patterns within large datasets. In addition, spatial correlations between climate data and proxy data are used to examine the representativeness of the proxy data for drought events. Drought years are identified with a value < mean-1σ (σ = standard deviation) and extreme drought year as a year with a value < mean-2σ. Periods lasting for two years or more are considered as drought period and extremely drought period, respectively. Moreover, historical documents are used for cross-validation. This article will focus on two extreme drought events: the Ding-Wu Great Famine (1876–1879, DWGF) (Zhao 1981) and the extreme drought in northern China during the late-1920s (1920s-1930s), which is also known as the Minguo extreme drought (MGED) (Dong et al. 2010).

3 Results

3.1 Data representativeness of the moisture change over regions

Based on PCA method, the PC1 series over 1807–1995 explains 23.4%, 38.3%, 43.2%, and 36.4% of Y_{all}, Y_{upper}, Y_{mid} and Y_{down}, respectively. We further performed the spatial correlation between each PC1 series and total summer precipitation (April to June) during 1950 – 1995 (Fig. 2). The results showed that Y_{all} PC1 is significantly positively correlated with summer precipitation in most parts of the study area, indicating that the selected data are spatially representative (Fig. 2a). Moreover, the Y_{down} PC1 has a higher correlation coefficient (Fig. 2d). This is attributable to the fact that the data source in the Y_{down} area is the precipitation reconstructed from historical documents, and most of these data reflect the summer climate conditions. In addition, the Y_{mid} PC1 also has a relatively broad spatial representation, but the correlation coefficient is lower than Y_{down} area (Fig. 2c). However, for the Y_{upper} area (Fig. 2b), the spatial extent that is significantly related to precipitation is limited to tree-ring sampling sites. The above spatial correlation analysis overally shows that proxy PC1 is representative of regional climate.

3.2 Major drought events in the Yellow River Basin

The four PC1 series are shown in Fig. 3a. The mean value of each PC1 series is 0, and the standard deviation (1σ) of the PC1 is 2.86 (Y_{all}), 2.40 (Y_{upper}), 1.86 (Y_{mid}) and 2.09 (Y_{down}), respectively. For the Y_{all} area, 29 drought years and 8 extreme drought years have been identified during the past two centuries (Table 2). The three prominent drought periods lasting more than 2 years are 1861 – 1862, 1918 – 1919, and 1926 – 1932. Furthermore, most of the drought years from the late 1920s to the early 1930s reached an extreme level. As far as the subregion is concerned, the Y_{mid} area has the most drought years, up to 35 years, which may be related to the transitional geographic location of this area. Compared with the Y_{mid} area, the number of drought years in the Y_{down} and Y_{upper} areas is relatively less, which are 30 and 26 years respectively. The extreme droughts mainly happened during 1870 – 1930 in the Y_{down} area, after the 1900s in the Y_{mid} area and evenly distributed throughout the study period in the Y_{upper} area. In addition, the extreme drought in the late 1920s was prominent in all subregions.

Table 2
Listing of the drought years

Region	Drought (< mean-1σ)	Extreme drought (< mean-2σ)
Y_{all}	1810, 1813, 1821, 1824, 1831, 1847, **1861** – **1862**, 1867, 1877, 1881, 1884, 1900, 1916, **1918** – **1919**, **1926** – **1932**, 1934, 1941, 1953, 1960, 1966, 1995	1824, 1861, 1926, **1928** – **1929**, **1931** – **1932**, 1995
Y_{upper}	1818, 1824, 1826, 1831, 1861, 1879, 1881, 1883 – 1885, 1895, **1918** – **1919**, **1925** – **1932**, 1934, 1953, 1966, 1992, 1995	1824, 1861, 1918, **1926** – **1928**, 1931, 1995
Y_{mid}	**1809** – **1810**, **1812** – **1813**, 1821, 1824, 1831, 1840, 1842, 1847, 1853, **1861** – **1862**, 1865, 1867, 1881, 1884, 1892, 1898, 1900, 1902, 1916, 1919, 1926, **1928** – **1932**, 1947, 1953, 1966, 1973, 1982, 1995	1900, 1916, **1928** – **1929**, 1932, 1966, 1995
Y_{down}	1810, 1812–1814, **1846** – **1847**, 1862, 1867, **1876** – **1877**, 1891, 1900, 1902, **1907** – **1908**, 1920, **1926** – **1929**, 1932, 1941, 1945, 1955, 1960, 1965, 1968, 1979, 1981, 1986	1877, 1891, 1900, **1928** – **1929**

3.3 The comparison between DWGF and MGED

These two extreme drought events have different features over our study area as shown in Fig. 3b and 3c. In terms of spatial extent, the MGED or late-1920s extreme drought was well recorded in the three subregions, but the most severe drought occurred in the Y_{upper}. However, DWGF was more like a regional drought event limited to North China compared to the MGED, with the former happened only in the Y_{down} area. In terms of duration, MGED is far greater than DWED. The MGED began earlier at the Y_{upper} than Y_{middle} and Y_{down} which started from 1924 and lasted till 1932, with the Y_{upper} lasting longer than the other two areas. In terms of intensity, DWGF only experienced severe drought in the Y_{down} area in 1877, and it was the most severe one among all identified droughts in our research period. DWGF that occurred in Y_{down} was rapid but more severe, while the MGED was widespread and long-lasting. Therefore, based on the above analysis, it can be found that MGED is more severe than DWGF, which seems to be inconsistent with the situation recorded in historical documents as discussed below.

4 Discussion

4.1 The identification of drought events by tree ring index

In the context of continuous global warming (Allan et al. 2021), the frequency and intensity of some extreme climate events are increasing rapidly (Donat et al. 2016), especially the meterological drought caused by the decrease in precipitation and the increase in temperature in most of the global lands. The change in extreme climate events can have a large impact on ecosystems and human civilizations, and accurate assessment of such potential changes requires detailed information about the past. Tree rings, with their inter-annual resolution and high sensitivity to mean and extreme climate change, are globally recognized to be among the best archives of past climate (Büntgen et al. 2021; Fritts 1976). Tree-ring-based reconstructions provide invaluable paleoclimatic archives for detecting regional and large-scale drought variations and their potential forcing (Cook et al. 2010; Fang et al. 2010). Besides, there are also a few studies using the tree-ring chronologies itself to analyze climate change, especially with better skills in capturing extreme events, avoiding the information loss during regression (Bräuning et al. 2016; Fritts 1976; Gao et al. 2018; Liang et al. 2006; Zhang et al. 2011).

In addition, drought is definitely not a local phenomenon, but occurs on a considerable scale (Zhang 2010). Therefore, the drought and extreme drought years in Table 2 were investigated individually by searching local historical drought records and instrumental data, respectively. The results show that droughts identified in our research are reliable and can well characterize the drought history, especially extreme drought events. For the drought events before 1950, the comparisons show 100% agreement for all the three sub-areas among extreme drought years, and about 86% agreement for the Y_{upper} area and 100% agreement for the Y_{mid} and Y_{down} areas among drought years (Table S1 in the Online Supplementary Information) (Ding 2008; Wen and Zhai 2005; Wen and Wang 2006; Wen and Xia 2007a; Wen and Xia 2007b; Yuan 1994; Zhang 2013; Zhang and Jiang 2004).

For the years after 1950, interannual precipitation variations based on CRU gridded data (Harris et al. 2021) were performed (Fig. S1 in the Online Supplementary Information). The results show that in the Y_{down} area, the drought years 1965, 1968, 1981 and 1986 identified by proxy indicators were also detected by the analysis of instrumental data; for the Y_{mid} region, it is consistent only in 1982; however, there is no overlap in the Y_{upper} region. The inconsistency between the PCA series and the observational precipitation data may have been due to the fact that drought is usually caused by the variation of multi-variables rather than the decrease in precipitation. As for the extreme drought year 1966 in Y_{mid} region, we found that it was lower in 1965 based on instrumental results, which may be related to the lag effect of climate change on tree growth (Fritts 1976). Liu et al. pointed out that the drought lasted consecutive 11 months from May 1965 to March 1966 in the Loess Plateau (Liu et al. 2017). Moreover, in 1995, the summer grain in northern Shannxi and central-southern Ningxia was basically out of production due to drought (Wen and Zhai 2005; Wen and Xia 2007b). All of these concretely demonstrate that climatic information embedded in the tree ring chronologies can provide quantitative measures of drought severity and fill the gaps where historical documents are lacking and insufficient.

4.2 What really happened behind the history records

Drought is one of the most serious climate disaster affecting the stability of agricultural society. However, the historical documents and other materials, which are the main way to reconstruct historical droughts, often deviate from the actual climate disasters because of political factors, information inequity, even the subjective perception bias of the recorder (Zheng et al. 2014). According to historical records, the DWGF, one of the most famous extreme droughts in Chinese history, started in 1876 and ended in 1879, which was documented to affect hundreds of millions of people and cause more than 10 million death (Hao et al. 2010; Xia 1992; Zhao 1981) The MGED is less famous than DWGF but also causing severe disasters. The question here is whether these two drought events really comparable and do they consistent with the fact?

To better understand the dynamic process of these two extreme droughts, the spatial feature of each drought event was demonstrated annually by the standardized values of each sample site (Fig. 4). The DWGF first experienced a large-scale drought in the Y_{down} area in 1876, and then gradually extended from east to west (Fig. 4a) (Zhou et al. 2019). The Y_{down} area had the severest drought in 1877. From 1878 to 1879, the drought eased in the Y_{down} area and continued to develop in the Y_{mid} and Y_{upper} areas. Historical documents have also verified this dynamic evolution process (Zhang and Liang 2010). Combined with Fig. 3c, the MGED appeared sporadically in the early 1920s, and was mainly distributed in the Y_{mid} area, and then expanded to the surrounding areas year by year (Dong et al. 2010), especially the Y_{upper} area. The drought reached its peak in 1928 – 1929, and then gradually eased after 1932.

The visual comparison between Fig. 4a and 4b indicates that the spatial extent and severity of DWGF are far less than MGED which is inconsistent with the record of some historical documents (Zhang and Liang 2010). However, DWGF has been widely discussed and concerned by historians, which is attributed to the drought caused by precipitation change superimposed on the interaction of various social crises in the late Qing Dynasty, making DWGF more outstanding in the historical records. Extreme drought can be multiplied by poor governance and then cause horrible social unrest and even the change of dynasties (Zhai et al. 2020; Zhao 2008). The huge number of deaths in the DWGF, if really happened, might have been caused more by social factors than the decrease in precipitation.

4.3 The potential mechanism of these two extreme droughts

There is considerable evidence that the major El Niño episode that started by the end of 1876 and peaked during the 1877 – 1878 boreal winter contributed significantly to the DWGF (Hao et al. 2010; Kiladis and Diaz 1986). The periodic analysis (Fig. S2b in the Online Supplementary Information) also clearly indicates that the significant cycle in the Y_{down} area in the late 1870s is 2–4 years, which coincided with ENSO. In contrast, the mechanisms affecting MGED are more complex, incorporating other abnormalies of large-scale atmospheric circulation patterns. This severe drought in the Yellow River Basin happened in the relatively warmer period under the background of a century-scale warming, which may be jointly caused by the greenhouse effect, volcanic activity, and solar activity. ENSO and the joint impact of PDO (Pacific Decadal Oscillation) and AMO (Atlantic Multi-decadal Oscillation) may also have been responsible for the decadal dry anomaly during the event (Luo et al. 2019). Fig. S5a shows that the climate variability in the study area may be related to the 30 – 60 year periodicals, which may be partially in association with the PDO. PDO exhibits considerable influence on summer precipitation in eastern China (D'Arrigo and Wilson 2006), by modulating the strength of the summer monsoon and the location of the subtropical high.

5 Conclusions

In this study, 29 tree-ring chronologies, 1 tree-ring based reconstructed precipitation series and 5 historical documents based reconstructed dry/wet indices were employed to analyze the drought events over the past ~ 200 years along the Yellow River and its adjacent area. Principal component analysis was used to extract common signals and the results show that the proxies, mainly tree ring chronologies, can effectively characterize the drought history at a large scale. Identified drought events in our study area have been verified by historical records and meteorological observations. The two prominent drought events, Ding-wu Great Famine (DWGF: 1876 – 1879) and extreme drought during the late-1920s (MGED) had different spatial propagation as well as drought duration, spatial extent and intensity. The DWGF was less severe than the MGED in our study which deviates from their fame recorded in the historical documents. The mechanism analysis indicates that tree ring data can better facilitate the interpretation of the extreme drought mechanism by capturing the real situation of the drought events.

Declarations

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Competing Interests

The authors declare that they have no conflict of interest.

Data availability

Data will be made available on reasonable request.

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Figures

Figure 1

The study area with data sites and climate conditions. Green triangles represent the tree-ring sites adopted in previous studies employed in this study. Purple and red triangles represent the geographic center points of the four subregions and North China Plain respectively, where are literature-based climate reconstruction areas. The climographs b-d of the monthly mean temperature and total precipitation values of the three subregions during the period of 1981–2010. Y_{upper}, Y_{mid} and Y_{down} are marked on the location map.

Figure 2

Spatial correlations between the gridded April to June precipitation (CRU TS 4.05) and the PC1 series of (a) Y_{all}, (b) Y_{upper}, (c) Y_{mid}, and (d) Y_{down} during 1950–1995. The identification of triangles is the same as in Fig 1. The colored areas indicate the areas with significant correlations ($p < 0.1$).

Figure 3

(a) The PC1 series and details of (b) DWGF and (c) MGED. The DWGF and MGED are delineated by green vertical lines annually. The red and blue horizontal dashed lines indicate the mean, mean-1σ and mean-2σ, respectively. The green and red triangles indicate the drought years and extreme drought years, respectively.

Figure 4

The spatial distribution of standardized value of each sample site during DWGF and MGED.The size of circle indicates the standard value. Yellow means less than 0, blue means greater than 0.

Supplementary Files

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