

Severe Drought Events as Revealed in the Climate Records of China and Their Temperature Situations over the Last 1000 Years*

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ABSTRACT

The total 15 severe droughts are discovered with the aid of the "Retrieval System of Chinese Historical Climate Records" for the last 1000 years. The droughts are extensive to envelope more than 4 provinces and persistent to cover 3 yr or more, and their severity is equivalent to or in excess of that in the 1930s in China. According to the documentary records and restorations it can be inferred that most droughts are more severe than those in the last 50 years. The 15 droughts may either occur warm or in a cold climate background, with 11 of the 15 cases in the cold phase. This indicates the difference in climate correspondence between China and northern America, showing the severity of the events in China to be in a cold instead of a warm climate situation. That is likely to relate to the monsoon climate in eastern Asia.

Key words: severe drought, last 1000 years, historical climate, temperature situation, warm climate background

1. Introduction

Droughts are one of the greatest concerns of Intergovernmental Panel on Climate Change (IPCC). For the outlook of future climate it is necessary to gain insight into when the climate was dry, what major droughts occurred and why they did in the past (Jonathan and Kevin, 2003). Hence, we have to draw on paleoclimate data of various kinds and fortunately, we have an abundance of Chinese records and descriptions in historical and modern times for the purpose, which serve as one of the important sources.

Located in the East Asian monsoon region, China experiences greater interannual variability of rainfall, resulting in frequent floods and droughts and especially the droughts happen over large areas and persist for years, thus doing heavy damage to agriculture, a problem that is of great concern. With the aid of Chinese meteorological records and descriptions and the Retrieval System of Chinese Historical Climate Records we have sorted out severe drought events in years 960-1911, and restored some of them, revealing the occurrence/development, and inferring the severity of the droughts, which are displayed in the wetness grade sequences of a range of regions and the severe

droughts hitting extensive areas and northwest China are borne out by tree rings.

The relevance of severe droughts with a temperature situation is another noteworthy issue. Although Cook et al.(2004) stated from the study on North American climate that severe dry disasters occur in a warm climate background, a conclusion that has drawn general attention of scientists, and we attempt to investigate the correspondence of such events to a warm or cold climate and the difference between China and other parts of the world.

2. Data and method

The term drought is defined in many ways. Megadrought, for example, although often used at present, has no clear definition (Jonathan and Kevin, 2003). In the research of northern American droughts, the term was utilized in describing those events that equal or exceed the magnitudes, duration, and extent of the 1930s and 1950s droughts. The severe events dealt with in the present article are marked by more than 3-yr persistence and 4-province zone, reaching the severity equivalent to or in excess of that for the driest period in the 1930s in China.

Data used in the present paper come from "A

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Compendium of Chinese Meteorological Records of the Last 3000 Years” (Zhang, 2004a) and the study is conducted also through the Collection-based Retrieval System of Chinese Historical Climate Records* for dryness, rainfall, and snowfall in 960-1911, with little or no rainfall and excessive precipitation denoted in a graphic mode at a county level and from the reproduced diagrams on a yearly basis. We selected 15 severe events with 3-yr or more maintenance and 4 province or more cover, arranged in chronological order as 989-991, 1073-1075, 1209-1211, 1370-1372, 1440-1442, 1483-1485, 1527-1529, 1585-1590, 1616-1618, 1637-1643, 1689-1692, 1721-1723, 1784-1786, 1856-1858, and 1876-1878 (Zhang, 2004b).

Those extensive and persistent droughts can be clearly shown in 960-2000 sequences of wetness grades in the 6 regions of eastern China to the exclusion of southern China. It is noted that such sequences were established in 1992 (Zhang et al., 1997) and now have been extended to 2000, with the breaks in the series interpolated via mean generating functions, thereby constructing annual sequences spanning 1041 yr for each of 6 regions. The regions are separated by means of a cluster analyses of 1961-1990 annual rainfall, leading to Regions I–VI given in Fig.1 with annual wetness grades shown by +2, +1, 0, -1, and -2, where zero denotes a normal condition. Now, set R to be a mean over multi-year rainfall values (1961-1990) and σ to be the standard deviation for the years, and we have the division between $R+1.17\sigma$ / $R+0.33\sigma$ / $R-0.33\sigma$ / $R-1.17\sigma$ for +2 / +1 / 0 / -1 / -2, respectively. The principles for determining wetness grades from historical records are the same as those in separating the dryness/wetness grade for the last 500 years in China (CAMS, 1981). The reader is referred to the demonstration of the problem for the soundness of the scheme (Zhang, 1988). Figure 2 presents the 3-yr running mean for each series of 6 regions for clearly revealing the droughts lasting for more than 3 yr, with the total 15 droughts separated by short vertical bars in the regions and the bar width showing the persistence in unit of year. But it is worth noting that

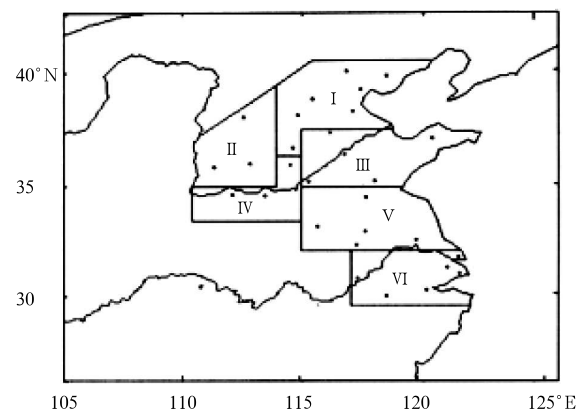


Fig.1. Regional division for the series I-VI.

the 6 regions are exclusive of southern China.

3. Severe drought events in the past millenary

The case studies for the 15 typical events emerged in 4 dynasties of Chinese history (960-1911) include: 1) the reconstruction of the genesis and development of the events from historical records; 2) inference of yearly rainfall anomaly in percentage or the decrease in rainfall based on the length of rain-free stage and observational facts, e.g., wells, rivers, and lakes drying-up; 3) description of accompanying disastrous phenomena, such as famine, locust destruction, and pestilence; and 4) analysis of the climate background and forcing factors. In this paper, 1) and 2) are just mentioned only. The results suggest that many of the events are much more severe than those after 1951. And the modes of 5 typical events thereof are presented briefly as follows.

The drought in 1637-1643, called the Event of Ming Dynasty Emperor Chongzhen on his throne, is noted for its persistence and hit area that exceed those of the heaviest drought ever known in the past 100 years. That drought hit progressively 23 provinces in the north and south, with more than 5 yr rain-free zones dominantly in Hebei, Henan, Shanxi, Shandong, and Jiangsu, especially in 1640 (Table 1). In the early stage the rainfall pattern is the “drought in the north

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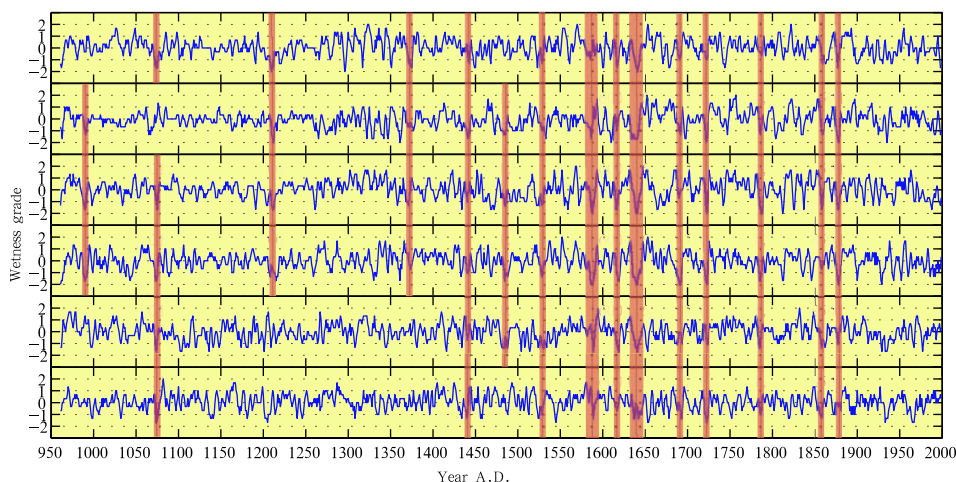


Fig.2. The 3-yr running mean curves of the annual wetness grades during 960-2000 and severe droughts (vertical bars) over regions I-VI of East China.

Table 1. The number of drought-hit counties recorded in the documents in 1637-1643

Year	HB	SX	HN	SD	SaX	GS	JS	ZJ	AH	HuB	HuN	JX
1637	6	3	2	10	1	5	7	1	1	—	—	
1638	4	10	16	24	11	1	21	3	4	—	—	
1639	16	7	26	28	4	3	14	3	7	2	2	—
1640	57	26	54	55	29	20	37	16	20	9	—	6
1641	39	9	14	24	5	—	38	17	22	9	—	4
1642	14	3	3	1	—	—	6	9	5	4	5	—
1643	8	—	4	4	—	—	8	12	2	2	24	15

HB = Hebei, SX = Shanxi, HN = Henan, SD = Shandong, SaX = Shaanxi, GS = Gansu, JS = Jiangsu, ZJ = Zhejiang, AH=Anhui, HuB = Hubei, HuN = Hunan, JX = Jiangxi, FJ = Fujian, and SC = Sichuan. Beijing and Tianjin are included in HB, Shanghai in JS.

and flood in the south”, followed by the drought-hit area extending eastward and southward but after 1640 the pattern was reversed, during which the zones were infested with pestilence and locust destruction.

The 1585-1590 drought is characterized by extensive stricken area, variable severity, and 6-yr persistence. It shows a typical process of migration on the hit regions that in the earlier stage of the period drought was in the north, beginning to expand into the mid-lower basins of the Changjiang River and even to the south, reaching its extreme dryness in 1589. Table 2 presents the statistical figures of the hit counties, indicating that the hit counties making up the highest percentage are in provinces of Hebei, Henan, and Shanxi at the earlier stage of the disaster while in the later stage the counties forming the highest percentage are in provinces of Jiangsu, Anhui, and Hu’nan,

the province of Henan being drought-stricken for the longest time. The severity of the 1585-1590 dryness is defined by the written statements given in a table (omitted) of which the 1589 statements indicate the highest severity that has never been seen in the past 50 years, such as Huaihe River: dryness from spring to June, dried-up; Lake Taihu in Suzhou: dried up over a distance of a few li (half a km); Lake Dianshan and all rivers in Wujiang: dried up; Lake Longhu in Susong: dry spring-summer, lake bottom cracking up; Jian’an of Fujian: wells dried up and no spring water, and so on.

The 989-990 drought is a typical case of Middle China. The inferred annual rainfall in 989 A.D. is 191 mm at Kaifeng and the percentage rainfall anomaly $\Delta R = -72\%$, the figures that are lower than those posterior to 1951, and corresponding figures are 357 mm

Table 2. The number of drought-hit counties recorded in the documents in 1585-1590. Otherwise as in Table 1

Year	HB	SX	HN	SD	SaX	GS	JS	ZJ	AH	HuB	HuN	JX	FJ	SC
1585	25	8	19	7	2	1	2	1	4	—	2	2	—	—
1586	30	29	13	12	9	9	1	1	—	1	—	—	1	—
1587	15	15	23	19	4	8	5	5	8	3	1	2	—	—
1588	4	3	11	9	1	—	24	22	20	17	14	16	3	6
1589	5	1	13	4	—	—	39	17	23	18	27	26	4	2
1590	14	5	8	6	—	—	12	10	6	3	12	13	5	—

and -43% in 990. Yearly rainfall of the central zone decreased by, on average, about 60% in 989-990, totaling less than 300 mm, a figure that is lower than the lowest rainfall subsequent to 1951.

The 1876-1878 drought is a typical case, a 3-yr extensive dryness occurred in northern China initially, then extended westward to Gansu, Sichuan, and southward to the Jiang-Huai (Changjiang-Huaihe River) basin (Table 3). The 1877 drought had a greater size and a longer duration hit by severe dryness in summer and autumn, with sufficiently too long rainless interval to be seen in history. Dry climate is characterized by the statistics of rainy days, rainless days, and a spell of rainless days on a yearly, seasonal and monthly basis. In the literature used there are many records of rainless periods on a local basis. How-

ever, the statement “no rainfall” thereof refers sometimes to “not enough rainfall”, thereby differing from the definition of “rainless day” in modern meteorology. Yet the well-defined day for “no rain at all” and “the day with rainfall beginning” can be adopted to estimate the number of rainless days and the longest spell. For instance, we have estimated the long spell of rainless days in Huaying of Shaanxi at more than 290 days in 1877, which is in concord with the statement made at Pinglu of Shanxi in the same year of “more than 200 days with no rainfall from spring to winter”, a dry interval that has hardly occurred in the last 50 years. During the 1876-1878 droughts local records have the statements (omitted) of drying up of rivers, lakes, wells, and springs as data showing the dryness.

The 1784-1787 drought typical of the mid-lower

Table 3. The number of drought-hit counties recorded in the documents in 1876-1878. Otherwise as in Table 1

Year	HB	SX	SaX	GS	HN	SD	JS	AH	HuB	HuN	SC
1876	35	16	5	1	20	56	14	6	3	1	6
1877	43	57	42	15	43	33	13	2	12	4	19
1878	14	33	7	7	9	10	0	0	2	0	10

basins of the Yangtze (Changjiang) River led to “the Taihu Lake is dried up for more than one hundred li and an antique canoe is discovered ” and the severe event lasted for 4 yr, accompanied by pestilence and locust disaster, with a larger number of rain-free days than that after 1951. The 1785 summer rainfall over the Jiang-Huai and Taihu Lake watersheds was lower compared with the minimum of the records made in modern times. For instance, Suzhou had 28 rainy days in June-August of the year and the calculated rainfall is 174 mm (Zhang, 2000), which is the second minimum of the synchronous precipitation in the 18th century, lower than the record subsequent to 1951 whose percentage anomaly reached -57.4%, meaning a nearly

60% reduction. During the persistence locusts multiplied, migrating in vast quantities, and pestilence spread at rapidity, creating an unbelievably terrible picture in the Huang-Huai (Huanghe-Huaihe) River and Jiang-Huai basin.

Precipitation varies greatly between the eastern and western parts of the country. Comparison with the series of precipitation from tree rings as proxy data over the last 1000 years for Delingha of Qinghai Province (Shao et al., 2004) indicates that some extensive droughts spanning the east and west portions can be substantiated in the Delingha sequence. The severe events mentioned before, e.g., those in 1483-1485, 1527-1529, 1585-1590, 1689-1692, and 1876-1878,

although happening in the eastern part, have their effects felt in the Delingha sequence, with less than 72 mm annual rainfall reflected therein that is lower than those after 1957.

4. Severe droughts in relation to a warm or cold climate situation

Therefore noteworthy is the problem as to the temperature background corresponding to severe droughts. In the study on North American drought events, it is indicated that the four driest epochs occurred in 936, 1034, 1150, and 1253 which are broadly consistent with the Medieval Warm Period (MWP), a warm phase (Cook et al., 2004). Obviously, the correspondence bears a relation to adopted time scales. The 15 drought events quoted here for discussion persisted for 3-7 yr, some corresponding to a warm and the others to a cold climate phase in the Northern Hemisphere. The about 2000-long series of winter half year temperature for East China (Ge et al., 2002) are suitable for the linkage of severe multiyear droughts (including the 15 cases) to the climate background (Fig.3).

The sequence of winter half-year temperatures from historical records is built on the anomalies from the mean over 1951-1980, with 30-yr resolution in 1110-1500 and 10-yr resolution in the other intervals. Table 4 presents the plus or minus sign of the anomalies over 30-yr intervals in which the droughts fall, indicating that only three of the 15 cases are relative

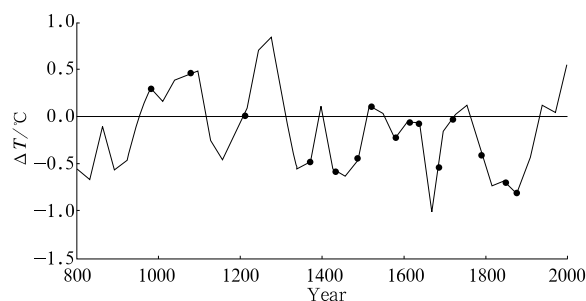


Fig.3. Comparison between the 15 severe drought events (dots) and winter-half-year temperature with 30-yr resolution in East China (after Ge et al., 2002).

to the plus sign of anomaly, one to zero and the rest to the minus sign, meaning that the 30-yr intervals in which they fall have lower winter half-year mean compared with the condition in 1951-1980, equivalent to a cold regime. On the whole, during the past phase (more than 1000 yr) in the cold climate background of Little Ice Age more than one severe drought occurred, possibly related to the monsoon climate in East Asia.

Also, this table gives the graded wet values annually for the 15 severe droughts in those regions. For comparative purposes it presents the wetness grades in regions I-VI in 1934-1936 and 1997-1999, which are the heavily dry phases but short of 3-yr persistence in the century. However, our discussion is limited to data available of the 6 regions to the exclusion of southern and western China.

5. Conclusions

From the foregoing analysis we come to the conclusions as follows.

(1) The total 15 severe droughts are discovered with the aid of the "Retrieval System of Chinese Historical Climate Records" (960-1911) and the droughts are extensive enough to envelope more than 4 provinces and so persistent as to cover 3 yr or more, with some lasting beyond 5 yr even more. According to the historical descriptions and restorations it can be inferred that most droughts are more severe than those recorded in the last 50 years.

(2) The cases of persistent and large-scale droughts found in the 960-1911 tend to happen initially in North China, spreading towards NW China or into the mid-lower basins of the Yangtze River.

(3) The study of 15 droughts may either occur in a warm or cold climate background, with 11 of the 15 cases in the cold phase, whose winter half-year mean is lower than the average over 1951-1980 values. This indicates the difference in climate correspondence between China and North America, showing the severity of the events in China to be in a cold instead of a warm climate situation. That is likely to relate to the monsoon climate in East Asia.

No.	Year	Region						ΔT (+, 0, -)
		I	II	III	IV	V	VI	
1	989	-1	0	-2	-2	1	0	+
	990	-2	-2	-1	-2	2	1	
	991	2	-1	-2	-1	1	-1	
2	1073	-1	1	1	-2	-2	-1	+
	1074	-2	-2	-2	-2	-2	-2	
	1075	-2	1	-2	-1	-1	-2	
3	1209	-2	-1	0	-1	-1	-2	0
	1210	-2	-1	-2	1	-2	2	
	1211	-2	-2	-2	-2	1	1	
4	1370	-2	-1	-2	1	-1	-2	-
	1371	-1	0	0	0	0	0	
	1372	-1	-1	-2	-1	1	1	
5	1440	0	-1	-1	-1	-2	-1	-
	1441	-1	-2	-1	-1	-1	-2	
	1442	-2	-2	2	-1	2	-1	
6	1483	0	-1	0	-2	-1	0	-
	1484	-2	-2	-2	-2	-1	1	
	1485	0	-1	-2	-1	0	-1	
7	1527	-1	0	-1	-1	0	2	+
	1528	-1	-2	-2	-2	-1	-2	
	1529	-2	-1	-1	-1	-2	-1	
8	1585	-1	-1	-1	-2	0	0	-
	1586	-2	-2	-2	-2	2	2	
	1587	1	-2	-2	-2	-2	2	
	1588	1	2	-2	-2	-1	-1	
	1589	0	1	0	-1	-2	-2	
	1590	-1	0	-1	-1	0	-1	
9	1616	-1	-1	-2	-1	-1	-1	-
	1617	-2	-1	-1	-2	-2	0	
	1618	-1	1	0	-1	-1	-1	
10	1638	-1	-2	-2	-2	-1	-1	-
	1639	-2	-1	-2	-2	-1	-1	
	1640	-2	-2	-2	-2	-2	2	
	1641	-2	-2	-2	-2	-2	-2	
	1642	-1	0	0	0	0	-1	
	1643	-1	0	0	-1	0	-1	
11	1689	-2	-1	-1	-2	-1	0	-
	1690	0	-1	0	-2	1	1	
	1691	-1	-1	0	-2	0	-1	
12	1692	-1	-2	0	-2	-1	-1	
	1721	-1	-2	-2	-2	0	-2	
	1722	-2	-2	-2	-2	-1	-1	
	1723	0	-1	-2	-2	-2	-2	
	1784	0	-1	-1	-2	-2	0	
	1785	-1	-2	-2	-2	-2	-2	
14	1786	0	-1	-2	-1	1	1	
	1856	1	-1	-2	-1	-2	-2	
	1857	-2	-1	-2	-1	-1	-1	
15	1858	-1	-1	-1	0	-1	-1	
	1876	-2	-2	-2	-2	-2	-1	
	1877	-2	-2	-2	-2	-1	-1	
	1878	1	-2	-1	-2	2	1	
	1934	0	-2	0	1	-2	-2	
	1935	-2	-2	-1	1	-2	-1	
	1936	-1	-2	-1	-2	-1	-1	

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