Chapter 2
Climatic and Environmental Changes in China

Yong Luo, Dahe Qin, Renhe Zhang, Shaowu Wang and De'er Zhang

Abstract This chapter addresses climate change of instrumental era in China, including changes in the distribution and regional characteristics of the temperature, precipitation, Asian monsoon, general circulations, extreme weather and climate events, cryosphere (glaciers, frozen ground, and snow cover), sea-level rise, sea surface temperature (SST), and salinity. It also assesses climate variations on

---

The following researchers have also contributed to this chapter

Jiawen Ren

State Key Laboratory of Cryospheric Sciences, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou, China
e-mail: jwren@lzb.ac.cn

Tingjun Zhang

College of Earth and Environmental Sciences, Lanzhou University, Lanzhou, China
e-mail: tjzhang@lzu.edu.cn

Panmao Zhai

Chinese Academy of Meteorological Sciences, China Meteorological Administration, Beijing, China
e-mail: pmzhai@cma.gov.cn

Y. Luo (✉)
Center for Earth System Science, Tsinghua University, Beijing 100084, China
e-mail: yongluo@tsinghua.edu.cn

D. Qin
State Key Laboratory of Cryospheric Sciences, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China
e-mail: qdh@cma.gov.cn

R. Zhang
Chinese Academy of Meteorological Sciences, Beijing 100081, China
e-mail: renhe@cams.cma.gov.cn

S. Wang
Department of Atmospheric and Oceanic Sciences, School of Physics, Peking University, Beijing 100871, China
e-mail: swwang@pku.edu.cn

D. Qin et al. (eds.), *Climate and Environmental Change in China: 1951–2012*,
Springer Environmental Science and Engineering,
DOI 10.1007/978-3-662-48482-1_2

different timescales (130, 20, 10, 2, and 0.5 ka) based on proxy archives such as sediments, ice cores, tree rings, and historical documents. Lastly, the advances in numerical paleoclimate simulation are summarized.

Keywords Climate change · Instrumental observation · Paleoclimate change · Numerical simulation

2.1 Climate Change in China in the Past 100 years

Measurements of climate variables in China began in the 1880s. Since then, these measurements have revealed significant climate warming, particularly since the 1980s.

2.1.1 Temperature Variations in China

It is difficult to establish a long time series of average temperatures in China because of a lack of systematic observations before the mid-twentieth century. Particularly, there have been few meteorological observations in inland of China. Currently, three surface air temperature series, extending more than 100 years, have been reconstructed for China. The temperature series W was calculated by integrating instrumental measurements with proxy data, such as ice cores, tree rings, and historical documents (updated from Wang et al. 1998). The instrumental data come from 50 meteorological stations, with 5 stations in each of 10 regions of China, including Xinjiang, Tibet, and Taiwan. The temperature series T was calculated similar to series W, but applying no proxy data (updated from Tang and Ren 2005). The temperature series C was created with Climatic Research Unit (CRU) datasets, in which data deficiencies over western China are filled in by interpolation from adjacent foreign observations (updated from Wen et al. 2006). High correlation coefficients, ranging from 0.78 to 0.93, among these three temperature series show good consistency. Series W and series T show a warming trend in China during 1906–2005 of 0.53 °C per 100 year (series W) and 0.86 °C per 100 year (series T). Overall, China has warmed by 0.5–0.8 °C during the past 100 years.

Instrumental meteorological observations have been conducted in China with a better coverage since A.D. 1951, at a maximum of 2200 stations. The temperature variations documented by these observations closely correlate with the series W and T data, showing that average surface air temperature has increased 1.38 °C between 1951 and 2009, with a trend of 0.23 °C per 10 year (Fig. 2.1).

D. Zhang
National Climate Center, China Meteorological Administration, Beijing 100081, China
e-mail: derzhang@cma.gov.cn

D. Qin
China Meteorological Administration, Beijing 100081, China

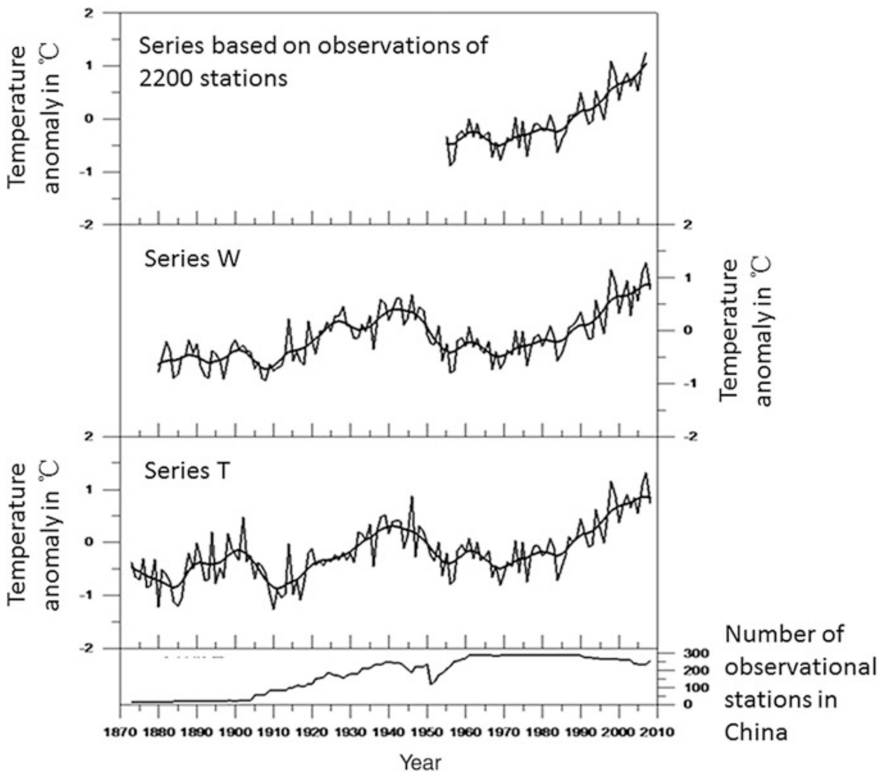

Fig. 2.1 Surface air temperature anomalies across China in 1873–2008 (relative to 1971–2000). The upper series is based on observations of 2200 stations; the middle two are series W and series T; the bottom panel shows the number of observational stations in China applied in series T

2.1.2 Precipitation Variations in China

Four precipitation datasets exist for China. The first dataset, starting from A.D. 1880, is based on seasonal total precipitation anomaly data from 71 stations in eastern China (updated from Wang et al. 2000). The second dataset, beginning from 1901, was constructed using monthly $1^{o}\times1^{o}$ precipitation grid data from the CRU (updated from Wen et al. 2006). The third dataset uses data from 1951 onward and is based on the monthly dataset from 160 stations issued by National Climate Center, China Meteorological Administration. The fourth dataset set up by National Climate Center is similar to the third one except that it is based on observations from 2200 stations. Among these four precipitation datasets, the first has the longest time series, but it excludes western China, while the second has significant uncertainties in the early time series due to data deficiencies over western China. Both the third and fourth datasets cover all of China, but the observations start in 1951. Although these four datasets are calculated based on different source data with different methods, they show consistency in the common period, with correlation coefficients reaching 0.84–0.91. The data show that during the past 50–100 years, precipitation across China varied on a cycle of 20–30 years, with no significant trend compared with surface air temperature. Additionally, the precipitation variations have intensified temporal and spatial variability; for instance, there was excessive precipitation over the lower middle reaches of the Yangtze River but less precipitation over both north China and south China during the 1980s, as a reversal of the pattern in the 1970s.

2.1.3 Variations of Other Climate Parameters

Cloud cover plays an important role in Earth's radiation energy budget and hydrologic cycle. Cloud cover is currently measured with ground-based observations and with satellite observations. Satellite observations have a global coverage, but with shorter time span. In contrast, ground-based observations have been conducted for longer time periods, but they are less accurate than satellite data. Both data from ground and satellite observations show a decreasing cloud cover over China since 1961, especially in north China.

Solar radiation reaching the Earth surface has decreased by 2.5 % per decade during the past five decades, but there is a slight increase since the 1990s.

Upper air temperatures have also been changing over the past 50 years. Data show rising temperatures in the lower troposphere, but with a smaller warming amplitudes than that of surface air temperatures. In contrast, the temperature has a decreasing trend in the upper tropospheric temperatures, with a more pronounced decrease in stratospheric temperatures.

2.1.4 Variations in the East Asian Monsoon

China is located in the region of the East Asian monsoon (EAM), with most of China being influenced by the EAM, especially eastern China. The onset of summer EAM usually occurs in the South China Sea in mid-May. The raining season over the Yangtze valley (Meiyu) begins in mid-June and ends in mid-July, when summer EAM migrates to the north China. The winter EAM usually begins in October in China and slowly diminishes northward, ending in May of the next year. Both the summer and winter EAM have significant interannual and interdecadal variability. The winter EAM was strong from the 1920s to the early 1980s, but has weakened since the 1980s. The summer EAM was strong from the beginning of twentieth century to the end of the 1960s, with the strongest intensity in the 1960s. Since 1980, it has weakened steadily (Fig. 2.2).

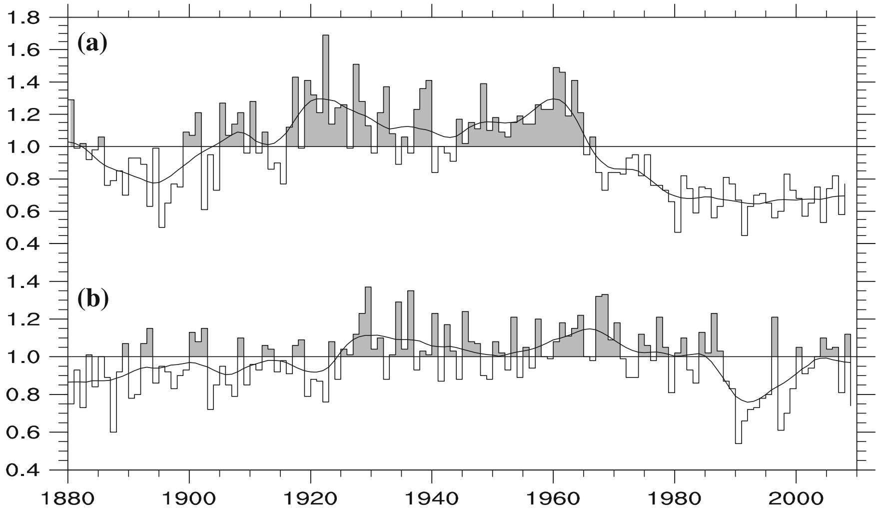

Fig. 2.2 Intensity of summer (**a**) and winter (**b**) EAM during 1880–2009. The East Asian monsoon intensity index is updated from Guo et al. (2003)

2.1.5 Atmospheric Circulation in East Asia

Atmospheric general circulations can affect the climate of China, among which are three prominent high-pressure systems: the Blocking High, the Subtropical High, and the South Asian High. The Blocking High is a high-pressure system at the geopotential height of 500 hPa (middle troposphere) in northeastern East Asia, i.e., the Okhotsk High. Sometimes, another Blocking High exists over the Ural Mountains. In particular, when low-pressure system occurs over Lake Baikal between the two high-pressure systems to its east and west sides in summer, this circulation pattern is typical in Meiyu season. The Subtropical High refers to the high-pressure system over the western Pacific Ocean at the geopotential height of 500 hPa. Its position and intensity play a decisive role in the position of the summertime rain belt in China. The South Asian High refers to the high-pressure system over the southern portion of the Eurasian continent at the geopotential height of 100 hPa (upper troposphere). It can also influence the position of the rain belt in China in summer, due to its close relationship with the Subtropical High over the western Pacific. The intensity of these three high-pressure systems has increased during the second half of twentieth century.

2.2 Variations in Extreme Weather and Climate Events

Climate warming may affect the intensity and frequency of some extreme weather and climate events.

2.2.1 Extreme Maximum and Minimum Temperatures

The annual averaged maximum surface air temperature in China has increased by 0.1 °C per decade. The number of days with a daily maximum temperature above 35 °C experiences significant interdecadal variations. There were more extremely hot days during the period from the 1960s to the early 1970s and in the past 10 years than that from mid-1970s to mid-1980s. This trend shows that the number of extremely hot days has risen gradually since the end of the 1980s (Fig. 2.3). The annual averaged minimum temperature in China is rising at a rate of 0.3 °C per decade (Fig. 2.4). Meanwhile, the averaged frequency of cold wave invasion in China has decreased by 0.3 per decade, and the number of days of frost injury has also decreased.

2.2.2 Extreme Precipitation

Since 1961, the frequency of regional severe precipitation events has slightly increased, with obvious interdecadal variations. The maximum number of severe precipitation events occurred in 1995 (14 events), and the minimum occurred in 1988 (2 events). The severe precipitation events were more frequent from the end of 1980s to 1990s.

The spatial distribution of extreme precipitation events (EPE) is complex. EPE over the Yangtze River and to the south of the Yangtze River tended to be stronger and more frequent, with an opposite trend over northern China. There was no obvious change in the averaged intensity of EPE over the west portion of northwest China, but the frequency of EPE tended to increase.

The number of continuous rain days in western China is increasing and decreasing in eastern China. The number of continuous rain days decreased significantly over northern, northeastern, and southeastern China and increased over the eastern Tibetan Plateau and in some areas along the southeast coast of the country.

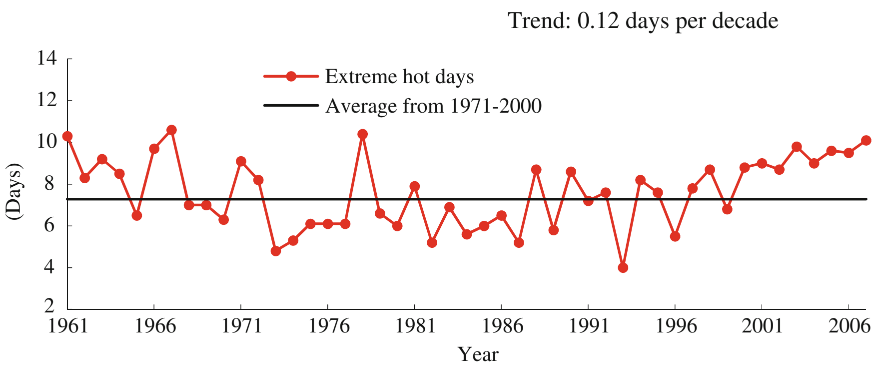

Fig. 2.3 Variation of the annual averaged extreme hot days during 1961–2007 in China, provided by National Climate Center

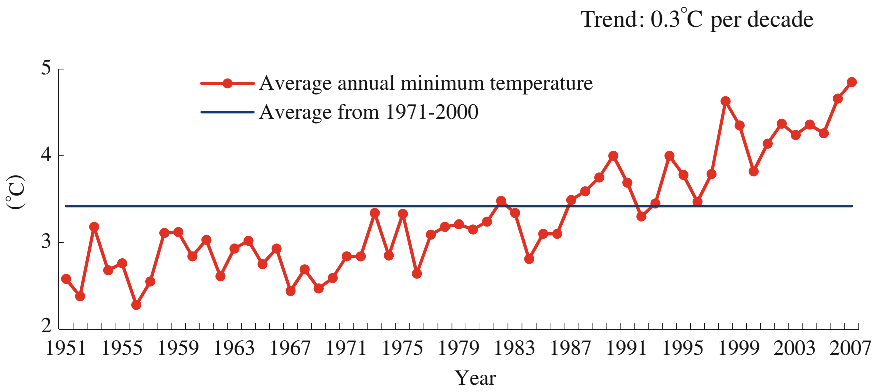

Fig. 2.4 Variation of the annual averaged minimum air temperature during 1961–2007 in China, provided by National Climate Center

2.2.3 Drought

Significant droughts have occurred in the eastern part of northwest China, in north China, and in northeast China over the past 50 years, while severe droughts have decreased in the region to the south of the Yangtze River and in the western part of northwest China (Fig. 2.5). Data show an obvious interdecadal variation in droughts in most parts of south China over the past 50 years. The number of continuous days without precipitation has been increasing in northern China for the past 50 summers. North China experienced an extensive drought for four consecutive years during 1999–2002 after 1997. In the summer of 2006, a severe drought occurred in Chongqing, a southwest city in China, with the return period of one hundred years. And the most severe drought during 50 years occurred in Sichuan Province in that year. Drought hit southwest five provinces, including Yunnan in 2010. Both the amount of precipitation and the number of rainy days decreased significantly in the regions. The surface air temperature increased significantly over northern China, and this increase in temperature enhanced the potential soil evaporation and thus intensified the droughts over the whole northern China.

2.2.4 Tropical Cyclones

From 1951 to 2011, the frequency of typhoons (tropical cyclones with winds ≥8 on the Beaufort scale) that were generated in the northwest Pacific Ocean and South China Sea has decreased with obvious interdecadal variations. And typhoon activities have been less than normal since 1995 (Fig. 2.6).

The frequency of typhoons making landfall in China did not change significantly over the same period, but there was great interannual variability. The maximum number of typhoons striking China was 12 (in 1971), and the minimum was 3 (in

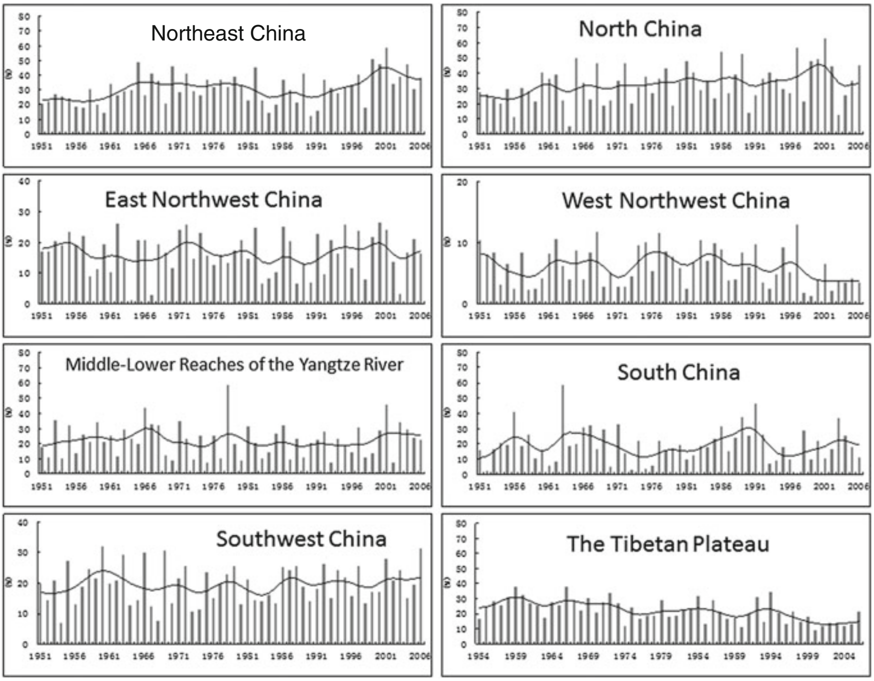

Fig. 2.5 Variations in areal extent (%) of drought over different regions of China during 1951–2006. The smooth curve is generated using an 11-point binomial filter. Because measurements in the Tibetan Plateau began in the early 1950s, the calculation starts from 1954. From Zou et al. (2005)

1951). The ratio of typhoons striking China to the total number of typhoons generated in the northwest Pacific Ocean and South China Sea has increased, especially during the last 10 years, e.g., 50 % in 2010.

2.2.5 *Sandstorms*

In the past 50 years, the number and severity of severe sandstorms in northern China has decreased slightly (Fig. 2.7). But in individual regions, such as north Qinghai Province, western Xinjiang, and Xilinhot of Inner Mongolia, the number of sandstorms has risen. Wind, precipitation, relative humidity, temperature, and vegetation cover are all important factors that affect the frequency of sandstorms. One of the causes of the decrease in sandstorms in northern China over the past 50 years is the reduction in the averaged near-surface wind speed in those areas and in the number of gale days. In most parts of northern China, sandstorms, precipitation, and relative humidity are negatively correlated. Data show that the amount of summer rainfall in the previous year has an important impact on the occurrence of dust storms.

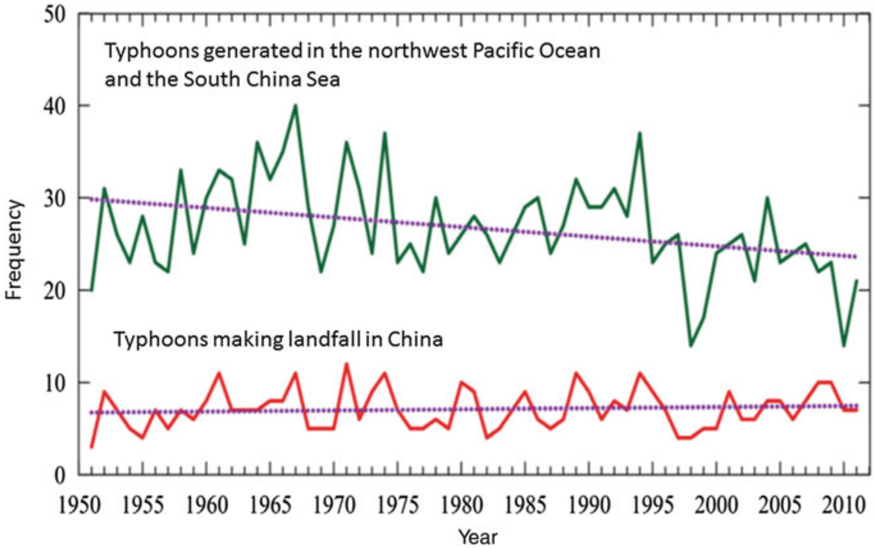

Fig. 2.6 Frequency of typhoons generated in the northwest Pacific Ocean and the South China Sea and making landfall in China during 1951 to 2011 (From China's Climate Change Monitoring Report of 2011, issued by Climate Change Center of China Meteorological Administration 2012)

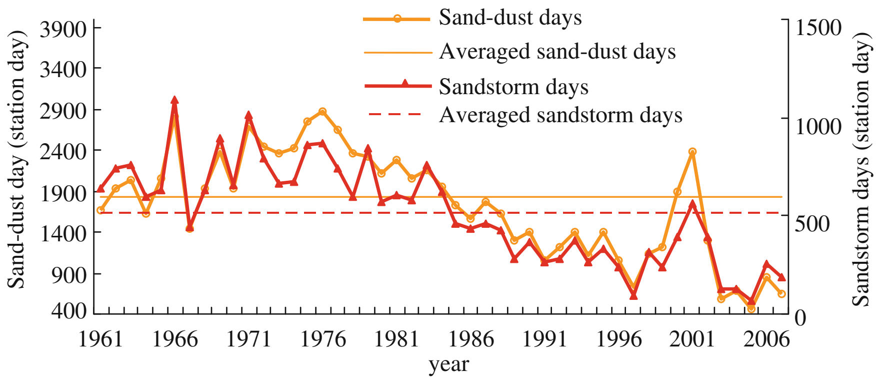

Fig. 2.7 Annual variations in the number of days with sand dust (including blowing sand, sandstorms, and strong sandstorms) and the number of days with sandstorms in springtime in northern China

2.2.6 Other Extreme Weather and Climate Events

2.2.6.1 Hail

China experienced a high incidence of hail events in the 1960s–1980s and significantly fewer events since the 1990s. Across China, hail occurred on average

2.1 days per observational station; it occurred most frequently in 1976 (2.6 days per station) and least frequently in 2000 (1.2 days per station).

2.2.6.2 Wind

Over the past half century, the average number of gale days and the maximum wind speed in China have decreased. Global warming leads to warmer air temperatures in China, which weakens the cold air activities and consequently winds. However, the change in environment of observation stations, e.g., urbanization, during the past several decades, may contribute to the decrease of wind speed on local scale.

2.2.6.3 Fog and Haze

Foggy days have tended to decrease in most areas in China over the past 50 years. Fog events of duration longer than 12 h are mostly concentrated in coastal regions, north China, eastern Gansu and Shanxi, the Sichuan Basin, Yunnan, and Guizhou. However, between 1957 and 2005, haze has increased, and the averaged visibility has decreased by about 10 km in eastern China, at a rate of approximately 0.2 km per year. The magnitude and rate of decline in visibility in western China is half of that in the east, showing that the regional haze problem is getting worse.

2.2.6.4 Thunder and Lightning

In recent decades, the number of days with lightning has decreased across most of China. This decrease is greater in the Tibetan Plateau area and in southern China than in Xinjiang and northern China.

2.2.7 The Relationship Between Global Warming and Extreme Climate Events

In recent decades, the frequency of extreme cold events has been decreasing in China, but the frequency of extreme warm events has been increasing accompanying with global warming. This change of increase in climate fluctuations may be related to global climate change. Climate change can change large-scale global circulation patterns and thereby influence the occurrence frequency of extreme weather and climate events in different regions. Global warming can increase surface evaporation and the saturation vapor pressure, and warmer air contains more water vapor in the atmosphere. It is likely to have more frequent and heavier precipitation at a certain time and place where atmospheric movement induces the convergence of water vapor, leading to more floods. And in other larger areas, due to the increase of surface evaporation, drought becomes more probable (Table 2.1).

Table 2.1 Definitions of extreme weather and climate index and their observed changing trend

Extreme weather and climate index	Definitions	Changing trend
Cold wave	Cool weather in which minimum air temperature dropped by more than 10 °C in 24 h and below 5 °C	The number of cold waves decreased
Frost	Extreme weather that causes plants to damage due to the air minimum temperature dropping below 0 °C	The number of frost days decreased
Heat wave	High temperature (≥35 °C) lasts for over 5 consecutive days	The number of days with daily maximum temperature ≥35 °C slightly increased with significant interdecadal variations
Extreme precipitation	Daily precipitation exceeds 90 % of normal	Extreme precipitation in the Yangtze River valley and to its south increased. The intensity and frequency of extreme precipitation in north China significantly decreased
Continuous rainfall	The wet and cold weather in early spring and late autumn with continuous rainfall and less sunshine over several days or even months	Continuous rainfall days decreased in eastern China and slightly increased in western China
Drought	Little rainfall and dry weather with large surface evaporation which damages crop growing	Drought increased in northern China
Tropical cyclone	Non-frontal vortex in tropical and subtropical oceans, with organized convection and cyclonic circulation, with surface wind speeds ≥10.8 m/s	The number of tropical cyclones generated in the northwest Pacific Ocean and South China Sea decreased, so decreased the number of landfall tropical cyclones on China
Dust storm	An unusual, frequently severe weather condition characterized by strong winds and dust-filled air over an extensive area with the visibility less than 1000 m	The number of sandstorm days decreased
Hail	Weather with precipitation in the form of balls or irregular lumps of ice	Hail days decreased
Gale	Wind speeds greater than 17 m/s	The number of gale days decreased
Fog	Water droplets suspended in the atmosphere in the vicinity of the Earth surface which affect visibility less than 1 km	The number of fog days decreased
Haze	Particles suspended in air, reducing visibility by scattering light less than 10 km	The number of haze days increased
Thunderstorm	Weather with lightning, a transient, high-current electric discharge with path lengths measured in kilometers	The number of thunderstorm days decreased

2.3 Changes in the Cryosphere and the Oceans

Since the 1960s, the glaciers in China have retreated and thinned. The temperature of permafrost has increased and the active layer has thickened. The areas of seasonal permafrost have shrunk, and the thickness has thinned. The extent and amount of snow cover have significantly changed. Sea level is rising along China's coastlines, and sea surface temperature is rising.

2.3.1 Changes in the Cryosphere

Glaciers, permafrost, and snow cover are the main components of China's cryosphere. Sea ice, river ice, and lake ice account for very little proportion. Over half of China's territory is covered by glaciers, permafrost, and/or stable snow cover. The change in cryosphere in China may have a major impact on water resources, the surface water cycle, climate, and engineering projects.

China's cryosphere has been shrinking since the 1960s and 1970s, with 80 % of glaciers in China retreating, at a thinning rate of 0.2–0.7 m/year. For example, according to the long-term observations of Glacier No. 1 at the headwaters of the Urumqi River in the Tianshan Mountains as well as the prediction of a dynamic glacier model, this Glacier No. 1 will disappear in the coming 70–90 years, even disappear within 50 years if the air temperature increases faster than in the past. On the Tibetan Plateau, the ground has been warming and the permafrost active layer has been thickening, with a decrease in the maximum permafrost depth. The mean seasonal permafrost thickness over the Tibetan Plateau has decreased by 10 cm between the 1960s and 1980s and 1980s and 2000s. The maximum permafrost depth has risen by 20–80 m. But the thickening of active layer is quite different across the regions over the Tibetan Plateau. The permafrost temperature has increased by 0.1–0.5 °C along the Qinghai–Tibet Highway from the 1970s to 1990s. This loss of permafrost will lead to a negative influence on ecosystems at future climate scenarios.

Due to the influence of monsoons on China's climate, the change in snow cover across China differs from the Eurasia where snow cover is currently decreasing. There is a trend of decreasing snow cover in the northeast China and increasing snow cover in the northwest China, with significant interannual variations. Snow cover observations are scarce in the plateau regions, and this deficiency together with the error in satellite monitoring shows various snow cover datasets, which bring difficulties about the accurate assessment of the change in snow cover.

Monitoring and research of river ice, lake ice, and sea ice are still relatively weak in China, but the current data show that all of these types of ice are decreasing, in line with global warming.

The latest international research studies on sea-level change and its influencing factors showed that, since 2003, the main reason for global sea-level rise is the melting of cryosphere. An analysis of the total amount of cryospheric melt water in China, from a rough estimate of the areal extent of glaciers, concluded that the potential contribution of the Chinese cryosphere to rising sea level is 0.14 mm/year to ~0.16 mm/year, with a major contribution from glaciers (~0.12 mm/year). In the glacier contribution, glacial melt water supply to river outflows contributed to only 0.07 mm/year to sea-level rise, accounting for about 6.4 % of the global mountain glacier and ice cap contributions to sea-level rise.

2.3.2 Change in the Offshore Environment and Sea Level

The physical and biogeochemical environment alone, the China's offshore has experienced significant changes in recent decades, including the temperature, salinity, circulations, sea level, marine biogeochemical processes, and coastal lines. Sea surface temperature of the offshore of China has been rising, most notably on the continental shelf. The salinity of the Bohai Sea has increased significantly, although salinity changes in other sea areas are not obvious. Offshore winds have weakened, and heat flux and fresh water flux have decreased.

Between 1981 and 2010, the average rate of sea-level rise of offshore China was 2.6 mm/year, higher than the global average by 0.8 mm/year. During that time, average sea-level rise in the Bohai Sea was 2.3 mm/year, 2.6 mm/year in the Yellow Sea, 2.9 mm/year in the East China Sea, and 2.6 mm/year in the South China Sea. Over the next 30 years, the Chinese coastal sea level is expected to rise by 80–130 mm higher than that in 2008 (From People's Republic of China Ministry of Land and Resources, 2010 Sea Level Monitoring Bulletin 2011).

Chinese estuaries are eutrophic, and the Yangtze estuary and adjacent coastal waters have low oxygen levels. In summer, the dissolved oxygen solubility in the hypoxic area of the Yangtze River and adjacent offshore regions is as low as 0.5–1.0 mg/L. Increased CO_2 emissions have also led to acidification of Chinese offshore waters compared to the global median ocean water pH of −0.06. Change in China's coastal waters is, however, also related to human activity, which may exacerbate changes caused by global warming.

2.4 Past Climate Change

Over the past 200–300 million years, global climate has changed in response to continental drift and other environmental factors. Proxy climate records, such as sediment cores, ice cores, tree rings, coral records, and historical documents, have provided information about these past climate changes.

2.4.1 New Findings from the Study of Paleoclimate Proxy Records

The last interglacial–glacial cycle took place 130,000 years ago, and records from Gansu Gulang loess and Shanxi Sanmenxia loess reveal a series of climate change events at the timescale of 1000 years, similar to that in the northern Atlantic Ocean.

Climate events known as the Last Glacial Maximum, and the Younger Dryas events occurred in the past 20,000 years. From the proxy records, such as accumulation of loess, lake sediments, peat deposition, cave deposits, and ice cores, the Younger Dryas event has been identified in China. The $\delta^{18}O$ values from a cave stalagmite in Beijing show that the abrupt climate change in Younger Dryas occurred with almost the same features in northern China as in Greenland region (Fig. 2.8), except for about 80 years later.

The most recent 10,000 years of Earth climate history is called the Holocene megathermal period. The surface air temperature during the early and middle stages of the Holocene was significantly higher than modern times. 7000–6000 years before present was the warmest epoch of the Holocene, with air temperature 1.5 °C higher than present. However, the temperature decreased rapidly 5000 years ago and did not rise again until modern times. Purog Kangri ice cores from the Tibetan Plateau reveal a linear decline of $\delta^{18}O$, indicating a decline in temperature since the Holocene megathermal period. Even during the warm periods, however, there still was occurrence of cold events. Records from a Guliya ice core imply there was a cold event 8200 years ago, with quickly decreasing temperature and a slow subsequent rise; the lowest temperature reached 7.8–10 °C. The warmest phases of the Holocene megathermal period coincided with the flourishing of primitive agriculture in China, when the northern limit of farming and rice production was located north of 2–3° latitudes than the present. At the same time, the inland lakes in northern China, Xinjiang, and Tibet became desalting with high lake level. During the past 2000 years, there have been 100-year fluctuations from cold-warm to dry-wet climate in China. Temperature data have confirmed the occurrence of the Medieval warm period, the Little Ice Age, and climate changes in the twentieth century. The Medieval warm period occurred from A.D. 930 to 1310, with a temperature rise of +0.18 °C (the warmest period was from 1230 to 1250, when temperatures rose 0.9 °C); the Little Ice Age was from A.D. 1320 to 1910, with a temperature decline of −0.39 °C (the coldest period was from 1650 to 1670, when temperature dropped by 1.1 °C). Since A.D. 1920, eastern China has rapidly warmed, the temperature 0.2 °C warmer than the average value over the past 2000 years. There were corresponding cold-warm periods in the area of northwest China and Tibet, but these periods varied from those in eastern China.

In conclusion, paleoclimate data reveal that climate warming in the twentieth century is not as significant as that during the Medieval warm period, but the twentieth century is the warmest period of time in past five hundred years.

Cycles of dry and wet periods over the past 2000 years have varied regionally. Lake sediment records in arid and semiarid areas of China show that the semiarid

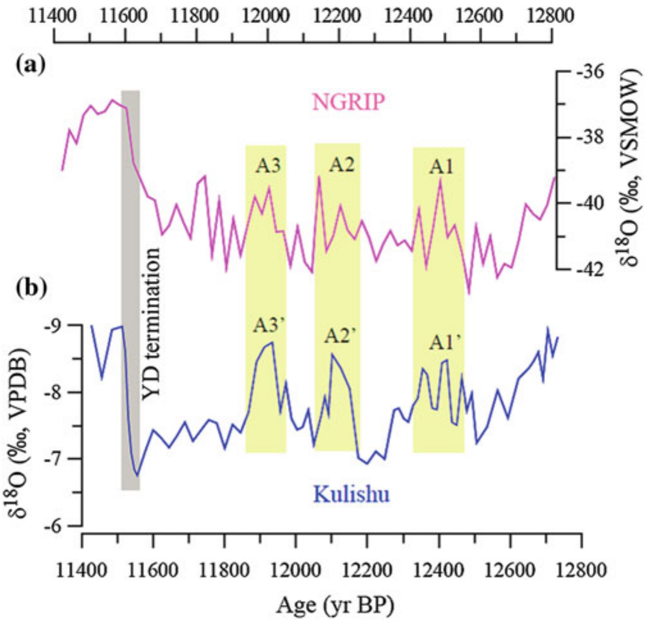

Fig. 2.8 The comparison of oxygen isotope from a stalagmite in Kulishu cave (Beijing, China) with that from an ice core in the North Greenland Ice Core Project (NGRIP). *VPDB* Vienna Peedee belemnite; *VSMOW* Vienna Standard Mean Ocean Water

areas became drier over the past 2000 years, while the arid areas became wet. The centennial-scale changes in climate in semiarid areas were from warm-wet to cold-dry and from cold-wet to warm-dry combination in the arid regions. However, in the eastern humid and semi-humid climate zones, the climate during the Medieval warm period was not persistently droughty; instead, it alternated between drought periods and rainy periods, which lasted several decades. In the most recent 1000 years, a wide range of persistent drought events have occurred in the context of cold climate and their severities were worse than the drought events in the rapidly warming twentieth century.

Over the past 500 years, precipitation was mainly distributed across northern China, occurring more frequently in the warm climates than in cold climates.

2.4.2 Advances in Numerical Simulation of Paleoclimate

2.4.2.1 Simulation of the Last Glacial Maximum and the Holocene warm period

Modeling of Last Glacial Maximum climate using the PMIP2 model (the second phase of Paleoclimate Modeling Intercomparison Project) showed that the weakening of the East Asian summer monsoon is derived from variations of sea surface temperature (SST) and sea ice extent, and changes in the winter monsoon can be attributed to changes in SST, sea ice extent, ice cover on land, and terrain. Increased vegetation is likely to cause a decline in temperature and precipitation in eastern China, and a possible increase of precipitation in western China. Plateau ice cover leads to the cooling of East Asia and weakens the EAM. The distribution pattern of summer precipitation in East Asia in the Holocene is similar to that at the end of the twenty-first century, and this can be used to predict future summer rainfall changes, to some extent.

2.4.2.2 Climate change simulation over the past 1000 years

Modeling has shown that solar activity and volcano eruptions are the main factors causing the Little Ice Age and Medieval warm period. The Little Ice Age (A.D. 1450–1850) and the Medieval warm period (A.D. 1030–1240) occurred during weak and strong periods of global monsoonal precipitation, respectively. NCAR CCSM2 modeling and analysis of summer monsoon precipitation changes show that the root cause of centennial-scale cycles in East Asia precipitation was aperiodic oscillation of solar activity, and interannual and interdecadal variations were likely to be related to feedback within the climate system. The phenomenon of southern floods and northern droughts in recent decades has no climatic precedent.

References

Climate Change Center of China Meteorological Administration. (2012). China's Climate Change Monitoring Report of 2011.

Guo, Q., Cai, J., Shao, X., & Sha, W. (2003). Interdecadal variability of East-Asian summer monsoon and its impact on the climate of China. *Acta Geographica Sinica, 58*, 569–576. (In Chinese with English abstract).

People's Republic of China Ministry of Land and Resources. (2011). 2010 Sea Level Monitoring Bulletin (in Chinese).

Tang, G. L., & Ren, G. Y. (2005). Reanalysis of surface air temperature change of the last 100 years over China. *Climatic and Environmental Research, 10*(4), 791–798. (In Chinese with English abstract).

Wang, S., Gong, D., Ye, J., & Chen, Z. (2000). Seasonal precipitation series of Eastern China since 1880 and the variability. *Acta Geographica Sinica, 55*(3), 281–293. (In Chinese with English abstract).

Wang, S., Ye, J., Gong, D., Zhu, J., & Yao, T. (1998). Construction of mean annual temperature series for the last one hundred years in China. *Quarterly Journal of Applied Meteorology, 9*(4), 392–401. (In Chinese with English abstract).

Wen, X., Wang, S., Zhu, J., & David, V. (2006). An overview of China climate change over the 20th century using UK UEA/CRU high resolution grid data. *Chinese Journal of Atmospheric Sciences, 30*, 894–904. (In Chinese with English abstract).

Zou, X. K., Zhai, P. M., & Zhang, Q. (2005). Variations in droughts over China: 1951–2003. *Geophysical Reseach Letters, 32*(4), L04707. doi:10.1029/2004GL021853.

http://www.springer.com/978-3-662-48480-7

Climate and Environmental Change in China:
1951–2012
Qin, D.; Ding, Y.; Mu, M. (Eds.)
2016, IX, 152 p. 29 illus., 7 illus. in color., Hardcover
ISBN: 978-3-662-48480-7