Article ID: 1673-1719 (2006) Suppl. 1-0001-05

Assessment of Climate and Environment Changes in China (I): Climate and environment changes in China and their projections

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Abstract: In the last 100 years, the global climate and environment have greatly changed, which is characterized mainly by global warming. These changes have exerted prominent impacts on the climate and environment changes in China. More than 100 Chinese scientists in areas of climate change, environment, ecology, oceanography, economic and social sciences have assessed the climate and environment changes in China and their impacts on natural ecosystem and socio-economic sectors. On the basis of scientific assessment, response strategies to the adaptation and mitigation of climate change have been suggested. The present paper is extracted from the first part of this scientific assessment report, mainly dealing with the science of the climate and environment changes and the future projections of climate change.

Key words: climate change; environment change; future projections; China

Introduction

In the last 100 years, global climate and environment have greatly changed, which is characterized mainly by global warming. In the global scale, many climate and environment problems have become more and more serious, such as water shortage, ecosystem degradation, soil erosion exacerbation, biodiversity decrease, ozone layer depletion, atmospheric chemistry components change, etc. These changes are caused by both natural and anthropogenic factors. However, the changes in the last 50 years are mainly due to the anthropogenic activities. Since the global changes have exceeded the scope of natural variation of the Earth itself, they exert the severe threat on the sustainable development of society and economy.

Climate changes exert important influences on the climate and environment in China. As a developing country that is vulnerable to the climate change, after "Kyoto Protocol" took effect in 2005, China is faced with the pressures both from reducing greenhouse gases emissions and from developing economy, as well as with the reform of productive ways. It is of great importance to study and resolve the conflicts between developing economy and protecting limited natural resources and controlling increasing population.

The present paper is mainly based on the book *Climate and Environment Changes in China, Volum* I: *Climate and environment changes in China and their projections* [1],

Received: November 1, 2005; revised: April 19, 2006
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which was published by Science Press in Beijing in 2005. This book systematically assesses the scientific facts of changes in climate and environment in China, analyzes the impacts of the climate changes on economy and society, and provides the suggestions to the policymakers on how to mitigate and adapt to the climate changes. In the present paper, climate and environment changes in China are presented in Sections 1 and 2. The projection of future changes in China is discussed in Section 3.

1 Climate change in China

1.1 Climate change in China in the last 2000 years

The climate has fluctuated during the last 2000 years, while overall temperature gradually decreased except for the last 100 years. There were at least four warm periods, 1−209AD, 570−779AD, 930−1319AD (Medieval Warm Period, MWP) and 1920AD to the present; and three cold periods, 210−569AD, 780−929AD and 1320−1919AD (Little Ice Age, LIA). Temperatures in the warm (cold) periods were 0.5−1.0℃ above (1.0℃ below) the normal. Precipitation varied in the last 2000 years independently of temperature changes. During the 2nd−11th centuries, it was dry in western China and wet in eastern China. During the 16th−19th centuries, it was dry in northern China and wet in southern China. Moreover, there was a predominant 80 to100-year period in precipitation change, with the 20 to 30-year interdecadal variability and 2 to 4-year interannual variability overlapped.

Climate change in western China differed from that in eastern China during the last 2000 years. For example, the features of the MWP could be seen more clearly in eastern China than that in western China. Also, it was especially cold in the LIA in eastern China.

1.2 Climate change in China in the last 100 years

Present climate warming is a hot topic in climate change studies. The warming rate was 0.81℃/100a according to instrumental observations of the maximum and minimum temperatures mainly over East China. However, it was 0.58℃/100a based on the instrumental observations of daily mean temperatures blended with proxy data, especially in western China. It can be concluded that the warming in China was about at a range of 0.5−0.8℃/100a, although it varies from author to author due to different data sources and techniques used in their analyses. In the past 100 years there were two warming periods, 1920s−1940s and the period from 1980 to the present.

No trend was found in precipitation change for the last 100 years, but 20 to 30-year variability predominated over eastern China. The pattern of summer rainfall changed in the late 1970s, i.e., from floods in northern China and drought in southern China to drought in northern China and floods in southern China. In western China, especially in Xinjiang region, precipitation significantly increased during the last 20 years.

1.3 Climate change in China in the last 50 years

In the last 50 years, the increase of annual mean temperature was mainly observed over northern China. The increase rate of temperature in northern part of Northeast China, Inner Mongolia and the basins of western China is more than 0.8℃/10a, which indicates an increase of more than 4℃ in the last 50 years in these regions. The most prominent increase in precipitation amount was seen in the basins of western China, with the greatest increase 10%−15%/10a, which indicates that the precipitation amount in these regions has increased by 50%−75% in the last 50 years, while in North China and south of Northeast China, the changes in precipitation amount have shown a decreasing trend.

1.4 Changes in extreme weather events in China

The frequency and intensity of extreme weather have changed in China. Recent studies have shown that the extreme precipitation events have become more frequent and intense. Especially in the 1990s, the contribution from extreme precipitation to total precipitation amount has increased. In the regions south of the Yangtze River, the annual mean precipitation amount and extreme precipitation amount tend to increase, with the intensity of extreme precipitation increased. In northern China, the droughts have become more frequent, especially in recent 20 years. The severe droughts after the 1970s in northern China have caused shortage of water resources and great loss of agricultural production.

The extreme minimum temperature has also increased in China. The diurnal range of temperature has decreased, especially in the winter and spring in northern China. Heat waves in the summer have increased. The number of days with maximum temperature greater than 35℃ has increased since the 1990s, especially in northern China. The number of frost days has reduced in the last 50 years, with the relatively great variability observed in northern, northeastern and northwestern China. The frequency of snow disasters in the Tibetan Plateau has increased, with the peak in the late 1980s. And there is a decreasing trend in the occurrence of dust storms in China, including strong dust storms.

2 Changes in ecosystem and environment in China

2.1 Changes in terrestrial ecosystem and environment

From the LIA to the period of 1960s−1970s, glacier areas in China decreased from 75427 km^2 to 59414 km^2. The number of retreating glaciers contributes to 80.8% of the total number of glaciers and the retreating rate has accelerated in the last 30 years. The increases of glacier melting water and precipitation have enhanced runoff from mountains outlet in inland river systems of Tarim Basin and the western Hexi Corridor in recent years. The thickness of active layer of the permafrost has increased, reflecting a strengthening thawing process. The area of permafrost near Xidatan, which is around the north boundary of permafrost in the Tibetan Plateau, decreased by 12% from 1975 to 2002. The lower boundary of permafrost elevated by 25 m. The permafrost island near Amdo, which is around the southern boundary of the permafrost in the Tibetan Plateau, shrunk by 35.6% from 1975 to 1996. The lower boundary of permafrost in other parts of the Plateau has also elevated up by 50−80 m since the 1960s. The increase in snow cover over the Plateau was also observed in the past 50 years with an annual increase of 2.3%. But in Northeast China and Inner Mongolia, there was decreasing trend in snow cover.

The rainfall and runoff in the upstream of Yellow River have gradually decreased in the past 20 years, with a decline of annual mean runoff from 59.68×10^9−$65.71 \times 10^9 m^3$ (the 1950s−1960s) to $45.53 \times 10^9 m^3$ (the 1990s). During the past 50 years, the demand of water for industry and agriculture in the Yellow River watershed increased, from $12.2 \times 10^9 m^3$ per year to $30.0 \times 10^9 m^3$ per year in late 1990s. Therefore, a combination of climate change and increase of the irrigation water resulted in the frequent flow disruption in the lower reaches of the Yellow River and a gradual decline of water flowing into the sea.

During the last 50 years, in arid and semiarid regions of western China, climate change and overuse of surface water for the agriculture irrigation have caused the severe decrease of river runoff into the inland lakes, resulting in salinization of lake water and shrinkage of lake area. In eastern China, with the development of industry and agriculture and city's growing, the input of pollutants to the lake has increased dramatically. Lakes became eutrophic, water quality was deteriorated, the aquatic ecosystem was stressed, biological diversities were declined and the lake became dominated with large numbers of algal bloom, which posed a serious threat on the development of the social economy of the region. In the middle and lower reaches of the Yangtze River, the heavy deposition and reclamation have caused a decrease of 13000 km^2 in lake areas and a decrease of $50.0 \times 10^9 m^3$ in lake volumes in the last 50 years. This leads to a prominent decline in the adjustment ability of the lakes to the floods and thus causes frequent flood disasters in the regions. In eastern China, 70% of the lakes have become eutrophic, which are the important source of drinking water. In Tai Lake, due to serious pollution, $4.5 \times 10^9 m^3$ (33%) of water resource has lost its application value.

Wetland ecosystem has degraded evidently in China. The eco-environment function of the wetland has intensely declined owing to the large scale of agricultural cultivating in Northeast China. The wetland area shrank from $5340 \times 10^3 hm^2$ in 1949 to $947 \times 10^3 hm^2$ in 2000 in Sanjiang Plain of northeastern China. The wetland of Songnen Plain covered an area of $3.29 \times 10^6 hm^2$ during the 1950s, with salinized wetland $2.00 \times 10^6 hm^2$. However, in 2000, only $0.65 \times 10^6 hm^2$ of the important wetland was left. In recent 20 years, the wetland of the middle and lower reaches of the Huolin River has declined by 44%, with only $34 \times 10^3 hm^2$ left. The desertification of the swamp in the Zoigê Plateau have become an important problem as a result of precipitation decline, draining and overgrazing in the past 30 years, with the total area of 4091 hm^2 and 12023 hm^2 of desertification and potential desertification, respectively.

The area of the forests has decreased in the past 4000 years. The forests covered about 60% of China 4000 years ago. But because of over-reclamation, over-woodcutting and riots caused by the wars, the area of forest has decreased continuously since then. During Han Dynasty (206 BC−220 AD), the forest coverage was under 50%. In Tang Dynasty (618−907 AD) and Song Dynasty (960−1279 AD), forest coverage was below 40%, and it dropped to 15%−17% at the end of Ming Dynasty and the beginning of Qing Dynasty, and 8.6%−15% during Min-Guo Period (1911−1949 AD). From the end of 1970s to the beginning of 1980s, forest coverage dropped to below 8.6%. In recent 50 years, although the effective measures of natural forest protection have been taken, forest coverage has only gone up to 16.55% (standard of forest canopy density is 0.2) by the end of the 20th century, which is only 61% of the world average. The per capita forest area has only 21.3% of the world average.

The area of grassland has decreased in the past fifty years. As an important component of the Eurasia steppe zone, the area of grassland in China has 276 million hm^2. However, because of drought, excessive grazing, unreasonable cultivation and digging, etc., the quality of

grassland is becoming worse. Up to now, about more than 19.30 million hm^2 of grassland (6.7% of the total grassland) has been reclaimed. The area of grassland decreased by 5.49 million hm^2 in the arid areas and by 5548 hm^2 in Hexi Corridor region from 1995 to 2000. Consequently, the boundary of desert has shifted 50 km eastward and the natural grassland in the north of Yinshan and Yanshan Mountains has shifted about 60 km northward since the 1960s. At the same time, the grassland degradation is accelerating. Based on statistics, the area of degenerated grassland accounted for 15% of the total grassland of China in the mid-1970s and over 30% in the mid-1980s. In the mid-1990s, it was more than 50% and dramatically has increased to 90% at the beginning of the 21st Century.

China is a country with many deserts and desertified lands. The desertified lands cover 1.743 million km^2, which is 18.2% of the total land area. Due to the effects of climate warming, drying and human activities, desertification in dryland of China is developing and expanding. In the grassland and desert-oasis regions, the expanding speed of desertification was 1560 km^2/a from the late 1950s to the mid-1970s, 2100 km^2/a from the mid-1970s to the mid-1980s, and about 2400 km^2/a from the mid-1980s to the early 1990s. Across China, the annual expanding speed of desertification was up to 3436 km^2/a in 1994−1999.

China is one of the countries with serious water loss and soil erosion in the world. Area of water loss and soil erosion was 3.56 million km^2 at the end of 1990s, accounting for 37.0% of the total land area, among which there are 1.65 million km^2 of water loss land. The regions with severe water loss and soil erosion are mainly located in Loess Plateau, the upper and middle reaches of the Yangtze River, red soil hilly regions of southern China and Karst regions of Southwest China. Since the 1980s, although areas with water loss and soil erosion across China have tended to decrease, the soil erosion in Karst regions of Southwest China is still accelerating and the area of rock desertification is expanding.

In China, the area of saline-alkaline land is about 36.30 million hm^2 (4.88% of utilizable land). The area of saline-alkaline cultivated land contributes to 6.62% (9.209 million hm^2) of the total area of cultivated land. In six provinces / regions of the western China (Shaanxi, Gansu, Qinghai, Ningxia, Inner Mongolia and Xinjiang), areas of saline-alkaline land occupy a great proportion of 69.03%. The formation and development of saline-alkaline land are affected by natural environment and human activities, mainly by unreasonable irrigation. From 1950s to the mid-1980s, the salinization was expanding as a whole. Until the end of 1980's, it gradually decreased. For example, area of saline-alkaline land in North China Plain increased from 2.60 million hm^2 in the late 1950s to 4.00 million hm^2 in the mid-1980s due to unreasonable irrigation.

The biodiversity in China is very abundant. But in the last 50 years, the loss and reduction of biodiversity was unprecedented by effect of human activities. For wild animals, species loss sharply by the destruction of the forest ecosystem, and some even become extinct. For example, there are only more than 1000 wild giant pandas (*Ailuropoda melanoleuca*) in existence and this has already affected their survival. South China tiger (*Panthera tigris amoyensis*), Amur tiger (*Panthera tigris altaica*), Hoolock(*White-browed*), Gibbon (*Hylobates hoolock*) and Slow loris (*Nycticebus coucang*) are all in the endangered and threatened species list. The degradation of grassland ecosystem makes the wild living environment of the Przewalski's Wild horse (*Equus caballus*) , wild camel, etc. become worse and worse. Because of degradation of freshwater lakes, the species of fish in the middle and lower reaches of Yangtze River has sharply reduced to 30−40 species from more than 100 species. Yangtze River dolphin (*Lipotes vexillifer*), Chinese sturgeon (*Acipenser sinensis gray*) and Chinese alligator (*Alligator sinensis fauvel*) are close to be extinct. Some marine animals are also almost extinct. And for plants, some of bryophyte, pteridophyte, gymnosperm, angiosperm are in endangered situation, and several decades of kinds have already been extinct.

2.2 Changes in ecosystem and environment in offshore and coastal zones of China

The ecosystem and environment in the offshore area and coastal zone of China have also greatly changed. Since the 1970s, the sea ice condition in the Bohai Sea and northern part of the Yellow Sea has tended to be slight. The disasters of red tides have tended to be more frequent since the 1980s. During 1990−1999, marine disasters directly resulted in economic losses of 11.95 $\times 10^9$ RMB Yuan per year on the average.

The sea level has tended to rise. During the past 6000 years, the sea level in China varied based on local conditions, accompanied by oscillatory drop, smooth fluctuation, continuous rising and so on, which is similar to global sea level change. During the last 50 years, the sea level tended to rise with a rate of 1.0−3.0 mm/a.

The sedimentary rate in the deltas of rivers has been increased. The modern Yellow River Delta formed after 1855 AD, with the formation of land 7.5−24.9 km^2/a. The modern Yangtze River Delta has formed since 1500 a BP.

The sedimentary rate of Chongming Shoal is 13.3 km^2/a during recent decades. In the Pearl River Delta, the advance rate of plain is 160−260 m/a during the last 40 years because of influence of human activities.

The sea surface temperature has risen steadily. The variation of growth rate of hermatypic corals in the South China Sea indicates that in 1780−1993, the rising rate of sea surface temperature was 0.26℃/100a on the average. During recent 100 years (1890−1990) the sea surface temperature decreased, but with a temperature rise of 0.2−0.3℃ after 1980.

During the last 50 years, the area of coastal tidal flat in China has decreased by about 50% because of reclamation. There are only 2.182×10^6 hm^2 remained now. The annual average of reclamation is about 20×10^3 hm^2, which is still less than natural increase rate of $27 \times 10^3 - 34 \times 10^3$ hm^2.

The coastal erosion in China is quite common. The proportion of eroded coast is 46% along the Bohai Sea, 49% along the Yellow Sea, 44% along the East China Sea and 21% along the South China Sea.

The ecosystem in the costal areas has degraded.Global warming has further exacerbated degeneration of mangrove and coral reef ecosystems. The coral bleaching and dying to a different extent have been found in the sea areas around Hainan and Guangxi provinces.

3 Projection of anthropogenic climate change in China

Under the scenarios with different emissions of greenhouse gases and aerosols, the climate change of future 100 years in China are projected based on the global and regional climate models developed in China and the data from IPCC Data Distribution Center.

About 40 climate models project that, due to the impacts of human activities, the prominent warming in China will continue, especially over northern China in winter. Compared with the average of 1961−1990, the nationwide annual mean temperature will increase by 1.3−2.1℃ in 2020, by 1.5−2.8℃ in 2030, by 2.3−3.3℃ in 2050 and by 3.9−6.0℃ in 2100. Both daily maximum and minimum temperatures will be rising, but the latter will raise more, resulting in the decrease of daily temperature range.

The annual mean precipitation in China will increase by 2%−3% in 2020, by 5%−7% in 2050, by 7%−9% in 2070, by 11%−17% in 2100, with differences among regions. In Northwest China, Northeast China and South China, precipitation will increase by 10%−25%. However, in the regions along the Bohai Sea Coast and the Yangtze River Delta, it will become dry. The number of rainy days will increase in northern China , and the number of heavy rainy days will increase in southern China resulting from the possible increase in local heavy rainfall events.

Acknowledgements

This work is collective wisdom of more than hundred of professionals and scholars. We would like to thank all the writers and contributors of the scientific reports, as well as all the other members involved. Acknowledgement must give to China Meteorological Administration, Chinese Academy of Sciences, and Ministry of Science and Technology of the People's Republic of China for providing the financial supports to this work.

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