

## China's National Assessment Report on Climate Change (I): Climate change in China and the future trend

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**Abstract:** The climate change in China shows a considerable similarity to the global change, though there still exist some significant differences between them. In the context of the global warming, the annual mean surface air temperature in the country as a whole has significantly increased for the past 50 years and 100 years, with the range of temperature increase slightly greater than that in the globe. The change in precipitation trends for the last 50 and 100 years was not significant, but since 1956 it has assumed a weak increasing trend. The frequency and intensity of main extreme weather and climate events have also undergone a significant change. The researches show that the atmospheric CO<sub>2</sub> concentration in China has continuously increased and the sum of positive radiative forcings produced by greenhouse gases is probably responsible for the country-wide climate warming for the past 100 years, especially for the past 50 years. The projections of climate change for the 21st century using global and regional climate models indicate that, in the future 20–100 years, the surface air temperature will continue to increase and the annual precipitation also has an increasing trend for most parts of the country.

**Key words:** climate change; surface air temperature; precipitation; climate models; China

### Introduction

Intensive scientific research on climate change in China has a history of more than two decades, and plentiful research results have been obtained so far. In 2002, the Ministry of Science and Technology of the People's Republic of China, China Meteorological Administration and Chinese Academy of Sciences decided to initiate the national assessment of climate change. A good scientific team had been formed by that time, and it was possible to conduct such an assessment. On the other hand, it was necessary to draft the national assessment report in order to provide scientific and technological support for forging

the national strategy of climate change, and for involving in the international activity in the field. At the same time, it would also give guidance for scientific research and technological innovation in the field of climate change. Scientists of more than 100 from over 20 institutions were involved in this assessment, and the assessment report was published in the first half of the year 2007.

*China's National Assessment Report on Climate Change* includes three parts: scientific basis of climate change, the impacts and adaptation of climate change, and socio-economic impact of mitigation activities. The report mainly relies on the new research results obtained from the key project of the 10th Five-Year Plan of the Ministry of

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Science and Technology — “Strategy and supporting technology research of the global environment change”. It assesses the features of the observed climate change and the possible causes over the past 100 years in China, as well as the projections of anthropogenic climate change in the 21st century and the possible impacts of the projected climate change on natural and human systems of the country. The report then puts forward the policy measures of adaptation to climate change.

This paper briefly summarizes the main assessment results of the first part of the report, which gives a detailed description of the observed change in climate variables and the possible causes for the change. It also gives the projection of future climate change trends probably induced by human activities in the 21st century in China, which will provide the climatic scenarios for climate change impact research, and the scientific support for the government to establish the strategy of adaptation and mitigation. At the same time, the scientific uncertainties of climate change research are introduced, with the key scientific questions needed to be resolved in the final part of the paper.

## 1 Observed change in climate

*China's Assessment Report on Climate Change* adopted the latest research results on observed change in the country. The researches generally applied a data set of mean temperature, precipitation and other climate elements from 740 stations across Mainland China, and analyzed the changes of these climate elements during the past 50–100 years in the country<sup>[1–3]</sup>. The data set was processed more carefully, and the main inhomogeneities existing in the monthly mean temperature data were checked and corrected in a few of the latest studies. The widely accepted procedures for creating area-averaged climatic time series and for calculating linear trend were used. *China's National Assessment Report on Climate Change* assesses the changes in annual and monthly mean temperature, precipitation, pan-evaporation, sunshine duration, wind speed, and the maximum depth of snow cover.

Annual mean surface air temperature in Mainland China as a whole rose by about 1.1 °C for the last 50 years, with a warming rate of about 0.22 °C per 10 years. The warming rate of China in the later half of the 20th century was more rapid than that of the world and the Northern Hemisphere. The most evident warming occurred in winter and spring as expected. Northeast China, North China and Northwest China experienced more significant warming in

terms of annual mean temperature, while a cooling trend in Southwest China reported in earlier studies is still continuing. Summer mean temperature in the middle and lower reaches of the Yangtze River also decreased in the last 50 years. However, the effect of urbanization on changes in the country-averaged annual and seasonal mean surface air temperature has not been taken into account. The effect is significantly larger than that believed before according to a few case studies conducted so far, and it should be adjusted from the current surface air temperature series<sup>[4]</sup>.

No significant long-term change in the country-averaged annual precipitation was seen for the past 50 years (Fig. 1). However, an obvious tendency of drying in the Yellow River Basin and North China Plain in terms of precipitation was found, and the largest drop in precipitation occurred in Shandong Province<sup>[1–2,5]</sup>. Meanwhile, an insignificant wetting trend in the Yangtze River Basin and most parts of western China was detectable. For the Yangtze River Basin, the increased annual precipitation mainly resulted from the significant rising of summer rainfall, though winter precipitation also tended to increase.

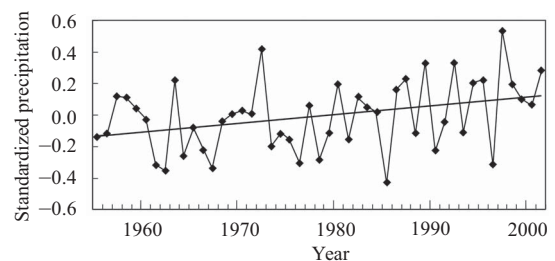


Fig. 1 Change in the country-averaged annual precipitation during 1956–2002

Since 1956, the country-averaged pan-evaporation has had a significant tendency to decrease, with a changing rate of  $-34.5$  mm per 10 years (Fig. 2). The most significant decrease occurred in spring and summer in North China Plain and the lower reaches of the Yangtze River. The largest decrease in pan-evaporation in terms of absolute values was in northwestern China. It is worth noting that average sunshine duration and wind speed also experienced a tremendous drop in most regions of the country during the past 50 years, and they usually bear a similarity with pan-evaporation in spatial pattern of the tendencies, indicating that the decrease of pan-evaporation might be at least partly caused by the declination of solar radiation<sup>[2, 5–6]</sup>. In parts of North China Plain, annual sunshine duration in the recent years is almost 500 hours fewer than that of 50 years ago.

The annual mean surface air temperature of the

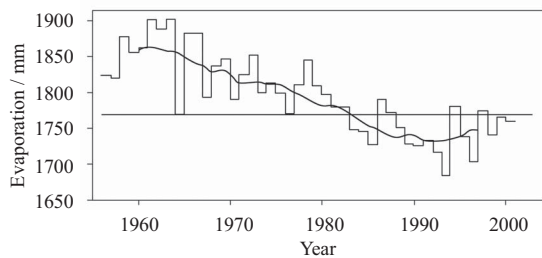


Fig. 2 Change in the country-averaged annual pan-evaporation during 1956–2000

country for the past 97 years (1905–2001) experienced a warming of  $0.79^{\circ}\text{C}$ , with a warming rate of  $0.08^{\circ}\text{C}$  per 10 years which is slightly larger than the global or Northern Hemispheric average as given by IPCC TAR (Fig. 3). Two warm periods, which occurred respectively in the 1930s–1940s and the 1980s–1990s, are evident, with 1946 and 1998 as the warmest ones within the record period<sup>[3]</sup>. It is interesting to note that the temperature anomalies of the 1990s are not higher than those of the 1940s, implying the larger contribution from warming of the cold periods to the long-term positive trend. Seasonal features of temperature changes for the last 97 years are characterized by the more rapid warming of wintertime and springtime, with summer showing an insignificant cooling trend during the 97-year period.

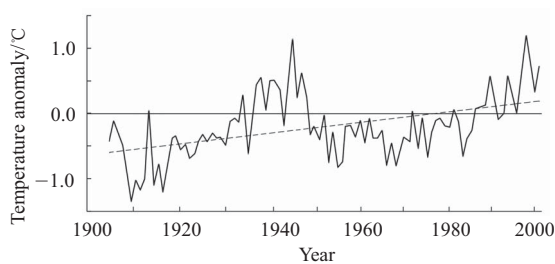


Fig. 3 Annual mean surface air temperature anomalies of China during 1905–2001

It is therefore clear that the observed climate change in China bears a large similarity with that of global average. The country-averaged annual mean surface air temperature increased  $1.1^{\circ}\text{C}$  for the past 50 years and  $0.5\text{--}0.8^{\circ}\text{C}$  for the past 100 years, respectively, slightly larger than the global temperature increase in the same periods<sup>[1–2, 5, 7]</sup>. Northern China and wintertime witnessed the largest increase in surface air temperature. Although no significant trend has been found in the country-averaged annual precipitation, decadal variability and obvious trends on regional scales are detectable, with northwestern China, the middle and

lower reaches of Yangtze River and southeastern China undergoing an obvious increase in precipitation whereas North China and southern part of Northeast China a severe drought. Some analyses show that the frequency and magnitude of extreme weather and climate events also underwent changes in the past 50 years or so<sup>[8]</sup>.

Preliminary temperature series of the past 1000 years for China as a whole have recently been reconstructed mainly based on tree ring data in the west and historical records in the east<sup>[1, 5, 9]</sup>. The reconstructions generally show the warmth of period corresponding to the Medieval Warm Period (MWP) and the marked coldness of the Little Ice Age lasting from about 1400 to 1900. The warmth of the MWP, however, seems not as evident in China as a whole as reported before, though the temperature in the end of the 11th century and in the mid 13th century might be higher than that of any decade of the 20th century.

## 2 Attribution of China's climate change

It is still difficult to answer the question of what cause the observed warming on the surface in regional scale. Some evidence supports the claim that it has mainly been induced by the increased concentration of greenhouse gases in atmosphere, but the influence of other factors like solar activities and the low-frequency oscillations of ocean-atmospheric system could not be ruled out at present.

Record from Mount Waliguan, Qinghai Province of China, shows a continuous rise of atmospheric  $\text{CO}_2$  concentration since the beginning of 1990s, reaching about  $370\text{ mL/m}^3$  (ppm) for 2002<sup>[5]</sup>. This change is consistent with the records from other sites of the world. Studies of attribution of regional climate change, by using climate models and taking consideration of various forcings, show that the warming of the last 50 years may be mainly caused by increased atmospheric concentration of greenhouse gases, while the temperature change of the first half of the 20th century may be dominantly induced by solar activities, volcano's eruptions and sea surface temperature change<sup>[10]</sup>. Significant decline of sunshine duration and solar radiation in eastern China has been attributed to the increased emission of pollutants<sup>[2]</sup>. Aerosols are also thought to cause a transition of climatic pattern to cool/flood of south and warm/drought of north, in spite of the fact that most of the Chinese climatologists attribute the transition to the change in other factors such as sea surface temperature change and increased snow cover on the Tibetan Plateau<sup>[5]</sup>. It is more difficult, however, to attribute the changes of precipitation and extreme events of the past 50 years in China to global

warming, though some studies conducted in the last decade do support this claim<sup>[10]</sup>.

It is worth pointing out that there are still a lot of uncertainties in studies of the anthropogenic impacts<sup>[11,5]</sup>. Efforts are needed to reduce the uncertainties in the future. However, the latest researches conducted are worth serious attention by policy-makers and proper actions should be taken to adapt to and to mitigate the anthropogenic changes in regional climate and environment.

### 3 Projection of future climate

Future climate scenarios probably induced by increased atmospheric concentration of greenhouse gases have been projected based on the climate models developed by the NCC/CMA and IAP/CAS<sup>[12–14]</sup>. Some studies take further steps to look into the impact of climate change on China natural ecosystems and economy, and put forward the policies for adapting to it.

Projections of future climate, by models of the NCC and IAP and 40 abroad models, indicate a significant warming in the 21st century in China, with the largest warming occurring in winter and northern China. Under varied emission scenarios of greenhouse gases, the country-averaged annual mean temperature is projected to increase by 1.3–2.1°C by 2020, 2.3–3.3°C by 2050, and 3.9–6.0°C by 2100, as comparison to the 30-year average of 1961–1990. The increase in temperature will probably be more evident in the northern parts of the country, with Northeast China and Northwest China undergoing the largest warming in wintertime. Most models project a 10%–12% increase in annual precipitation in China by 2100. The wetting will be particularly evident in Northeast China, Northwest China and the Tibetan Plateau, while part of the central China will probably undergo a drying trend<sup>[12–14]</sup>. A few studies also give the preliminary projection of extreme weather and climate events in the 21st century. Projections by climate models also show that anthropogenic climate change will probably lead to a weaker winter monsoon and a stronger summer monsoon in East Asia.

Large uncertainty still exists in the projections of future anthropogenic climate change, in particular in the projections of change in precipitation and extreme events, and further study is needed in the future.

### 4 Conclusions

The annual mean surface air temperature in China as a whole has significantly increased for the past 50 years

and 100 years, with the magnitude of temperature increase slightly greater than that in the globe. The surface air temperature change in China generally bears a considerable similarity to the global change, though there still exist some significant differences between them. The precipitation trends for the last 50 and 100 years were not statistically significant. Since 1956, country-averaged annual precipitation has assumed an insignificant increasing trend. The researches show that the atmospheric CO<sub>2</sub> concentration in China has continuously increased and the sum of positive radiative forcings produced by greenhouse gases is probably at least partly responsible for the country-wide climate warming. The projections of climate change for the 21st century using the global and regional climate models indicate that, in the future 20–100 years, the surface air temperature in China will continue to increase, and the annual precipitation will also has an increasing trend for most parts of the country. Uncertainties still exist in regional climate change detection and projection, and there is an urgent need to further study some key scientific issues in the future.

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