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Impacts of Climate Change on the Yangtze Source Region and Adjacent Areas

Qinghai-Tibet Plateau, China

WWF China
Edited by John D. Farrington

气象出版社
China Meteorological Press

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Freshwater Marsh, Longbaotan National Nature Reserve, Yangtze Source Region, Jyekundo County, Qinghai Province. Photo by Yifei ZHANG.

Back Cover Photos:

Top Photo: Nieqia River, Yangtze Source Region, Zhidoi County, Qinghai Province. Photo by Gang XIE.

Middle Photo: Glaciers, Yangtze Souce Region, Tangula Range, Tanggula District, Qinghai Province. Photo by Dawa TSERING.

Bottom Photo: Black-necked Crane. Photo by Yifei ZHANG.

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Preface

The Qinghai-Tibet Plateau is the highest plateau on earth and is often referred to as "The Roof of the World." Because of the extremely cold dry climate, soils on the plateau are not well developed, vegetation grows slowly, and the plateau's ecosystems are extremely fragile. The source of the Yangtze River lies at an elevation of 5480 m in the heart of the Qinghai-Tibet Plateau, where the river originates from glacial meltwater and is later nourished by vast areas of alpine wetlands. This region is also the heartland of the Tibetan people's unique nomadic herding culture.

However, since the 1980s, with western China's rapid economic development and population growth, the fragile alpine grassland ecosystems of the Yangtze Source Region have been under increasing pressure brought about by human activities. The overstocking of grasslands with livestock, over-collection of endemic herbs, and unregulated exploitation of mineral resources have resulted in grassland degradation, pika and insect plagues, chronic soil erosion, and other environmental problems.

To add to these problems, global warming now poses another major threat to the Yangtze Source Region. Meteorological records show that temperatures in the Yangtze Source Region rose rapidly in the last two decades of the 20th Century and continue to rise today. As a result of this warming, accelerated meltoff of glaciers is adversely impacting the hydrology of rivers fed by glacial meltwater in the Yangtze Source Region. At the same time, groundwater levels have fallen in many parts of the region due to the degradation of permafrost caused by global warming, which now threatens vast areas of grasslands where grassroots no longer reach the groundwater table. In addition, warming itself may pose a direct threat to various species adapted to a cool alpine climate, while an increase in the number of extreme weather events resulting from climatic change, such as heavy rain and snowstorms, also threatens plateau ecosystems.

Given the multitude of environmental threats resulting from climate change and destructive human activities, both the plateau's ecosystems and indigenous herding culture face uncertain futures, and their survival is by no means assured. Therefore it is imperative that an effective program of wetland conservation be carried out in the Yangtze Source Region to ensure the long-term viability of the region's ecosystems and socioeconomic development. In recent years, the growing ecological problems of the Yangtze Source Region have drawn widespread attention throughout China, and a group of scientists has proposed a "Climate Adaptation and Sustainable Development Strategy" for the region which has received the backing of local officials and China's central government.

Recognizing that an in-depth scientific understanding of the impacts of climate change on the Yangtze Source Region will serve as the basis for developing future conservation and development strategies for the region, in 2004 WWF China initiated a project entitled "Wetland Conservation and Climate Change in the Yangtze Source Region." Under this project, funding was provided to conduct scientific research on the impacts of climate change on weather, wetland ecosystems, glaciers, permafrost, and livestock herding in the Yangtze Source Region. This research included original field work and data analysis as well as a comprehensive review of relevant scientific literature, the results of which are presented in the five chapters that follow.

Authorship of the individual Chapters was as follows:

Chapter 1 on climate: Xueqin ZHANG and Ziying CHU

Chapter 2 on wetlands: Liping ZHU, Junbo WANG, and John D. Farrington

Chapter 3 on glaciers: Yongping SHEN

Chapter 4 on permafrost: Lin ZHAO and Ren LI

Chapter 5 on livestock herding: Jijiao ZHANG and Yujun LI

Originally published in Chinese, this new English edition of the report has been thoroughly revised and updated where possible. New features of this edition of the report include full referencing of all source materials, expanded sections on the ecology of the northeastern Qinghai-Tibet Plateau, particularly with respect to Qinghai Lake and the Zoige Wetlands, as well as a greatly expanded analysis of the findings of the social survey presented in Chapter 5. Other new features of this edition of the report include new report-specific photos and an expanded glossary of technical terms as well as an appendix listing the locations and Romanized and Chinese character spellings of all geographic place names mentioned in the text.

WWF hopes that the publication of this report will draw more attention to the numerous pressing environmental problems facing the Yangtze Source Region today, and it is also hoped that this report will spur further action towards developing and implementing effective climate change adaptation and wetland conservation strategies for the Yangtze Source Region. Only through the development of such climate adaptation and conservation strategies for the Yangtze headwaters will it be possible to achieve truly sustainable socioeconomic development of the entire Yangtze River basin.

Editor, Editorial Review Committee, and Authors.
Lhasa and Beijing, October 2009

List of Acronyms Used

A. D.	*Anno Domini*
B. C.	Before Christ
CASS	Chinese Academy of Social Sciences
DEM	Digital Elevation Model
GIS	Geographic Information Systems
LIA	Little Ice Age
MWP	Medieval Warm Period
TAR	Tibet Autonomous Region
ybp	Years Before Present
YSR	Yangtze Source Region

Contents

Chapter 1 Climate Change on the Qinghai-Tibet Plateau

"We are facing challenges of a changing earth."

— Berrien Moore III, Executive Director of Climate Central (Moore 2002)

1.1 Introduction

According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change: 1) over the previous century (1906—2005), the global mean surface air temperature increased 0.74±0.18℃; 2) over the last 50 years, the planet has warmed at an average rate of 0.13±0.03℃/decade, which is nearly twice the rate of planetary warming for the previous century as a whole; 3) it is very likely that increases in anthropogenic greenhouse gases have caused most of the observed increase in global average temperatures since the mid-20th Century; and 4) unless greenhouse gas emissions are greatly reduced, global surface air temperatures at the end of the 21st Century are projected to be 1.1 to 6.4℃ higher than for the period from 1980—1999 (IPCC AR4 2007).

With an average altitude of over 4000 m above sea level and imposing topographic features, the Qinghai-Tibet Plateau plays an important role in influencing the global climate. Over the past 20 million years, the rapid uplift of the Qinghai-Tibet Plateau has changed the pattern of general atmospheric circulation in East Asia through both dynamic and thermodynamic processes. Furthermore, a plateau monsoon was established, while both the South and East Asian monsoons were intensified, which has increased precipitation in South and East Asia but has left the plateau itself colder and dryer (Zheng, et al. 2002). Due to the unique geography and environment of the plateau, including its extreme climate, extensive wetlands, and fragile high altitude ecosystems, the Qinghai-Tibet Plateau is much more acutely affected by climate change than more resilient low-altitude regions. Thus, some observers are of the opinion that the Qinghai-Tibet Plateau is particularly sensitive to climate change and that the plateau itself may be the trigger of global warming (Feng, et al. 1998).

Impacts of global climate change on the plateau and its high altitude wetlands are diverse and include the meltoff of glaciers; melting of permafrost; changing temperature, precipitation, and evaporation patterns; alteration of grassland ecosystems; disappearance of wetlands, lakes, and rivers; and desertification, all of which can severely impact both ecosystems and human livelihoods on the plateau (Shen 2004; Wang, et al. 2006; Lin, et al. 2000; Wilkes 2008; Li, et al. 2007; Zhang, Wu et al. 2003). While wetlands are some of the most productive ecosystems on earth and have a large capacity for carbon fixation, they also release dissolved and particulate organic carbon to adjacent aquatic environments (Sahagian and Melack 1998). Consequently, wetlands play an important role in the biogeochemical carbon cycle, which itself influences the rate of global climate change. However, in many developing areas like Qinghai Province and the Tibet Autonomous Region (TAR), development needs and increasing populations combined with climate change impacts are accelerating the rate at which natural wetlands vanish. Therefore, better scientific understanding of climate change, local wetland characteristics, and their interdependence is necessary to efficiently and sustainably utilize wetlands on the Qinghai-Tibet Plateau, and to establish priorities for conservation of high altitude wetlands throughout the region.

1.2 Historical Climate Change on the Qinghai-Tibet Plateau over the Past 2000 Years

The study of historical climatic and environmental changes over the past 2000 years is important to understanding climate change at a regional and even a global scale. It is not only the period impacted most severely by human agricultural and industrial activities, but is also the period for which we have scientific as well as natural climate records, such as ice cores, tree rings, lake sediments, and pollen. During this period, two prominent climatic events took place, the Medieval Warm Period (MWP, roughly 800—1300 A. D.) and the Little Ice Age (LIA, roughly 1500—1850 A. D.).

Since the 1980s, the Chinese Academy of Sciences has conducted extensive research involving collection and study of ice cores and tree rings, from which several plateau climate sequences were reconstructed. As indicators of paleoclimates, both ice cores and tree rings are high-resolution climate records (Yao, et al. 1991; Esper, et al. 2002). Ice sheets and ice caps serve as libraries of atmospheric history, with the levels of $\delta^{18}O$ oxygen isotopes found in ice cores being a direct indicator of the temperature at the time the ice was formed. A one part per thousand increase (or decrease) in $\delta^{18}O$ levels in precipitation indicates an increase (or decrease) in temperature of about 1.6℃, while glacier net accumulation values reflect the variations in annual precipitation (Yao, et al. 1996). As for tree-ring records, due to their ease of calibration, continuity, and widespread distribution, they are used extensively for millennial-scale climate reconstruction, since both tree-ring width and density are good indicators of changing climatic conditions.

1.2.1 Historical Temperature Records for the Southern Tibet Autonomous Region

Wu and Lin reconstructed annual mean temperature sequences for the Lhasa area over the past 2000 years using tree-ring records (Wu and Lin 1981). Figure 1.1 indicates that at the beginning of the first millennium A.D. it was relatively cold, while a warm period began in the 6th Century. However, due to the scarcity of tree-ring data from the region for the period from the 7th to 12th Century, the MWP is poorly documented on the plateau, although supplemental historical documents suggest that the period was relatively warm. After this warm period, the Qinghai-Tibet Plateau entered the LIA and the climate grew cold again, especially in the mid-17th Century. During this period, although there were short episodes of warming, most evidence reflects an unusually cold climate on the plateau with nearly all mountain glaciers advancing simultaneously. In the mid-19th Century, the LIA ended and was followed by a modern warming period which began after the industrial revolution.

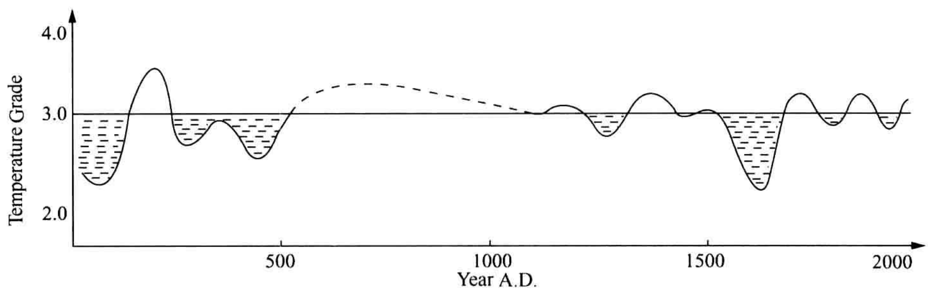

Figure 1.1. Temperature in the Lhasa region over the past 2000 years reconstructed from tree-ring data and historical records.

Note: The solid line is reconstructed from tree-ring data, while the dashed line has been inferred from historical records. A 50 year moving-average has been applied to the original series, with three temperature grades set as follows: 3.0: normal temperature, greater than 3.0: warmer, less than 3.0: colder.

Source: Wu and Lin 1981.

1.2.2 History of Drought and Flooding on the Qinghai-Tibet Plateau

Both the timing and duration of periods of flooding are important environmental indicators of the ecological history of wetlands. Reconstruction of the modern drought and flood history on the Qinghai-Tibet Plateau indicates that there were three rainy periods during the past 125 years (1883—1906, 1916—1934, and 1947—1962), as well as three dry periods (1907—1915, 1935—1946, and 1963—1980) (Figure 1.2) (Lin, et al. 2000). Over this 125-year period, the number of dry days far exceeded the number of rainy days, with the first dry period lasting nine years, the second twelve years, and the third eighteen years, which suggests a trend of increasing aridity on the plateau. Climatic changes on the plateau have also been marked by other natural phenomenon, such as the lowering of groundwater levels, which is indicative of increasing aridity in the region (Lin, et al. 2000).

In addition, many scientists believe that there were other severely arid periods on the plateau in late 15th, late 17th, and early 18th Centuries as well (Lin, et al. 2000; Yao, et al. 1991).

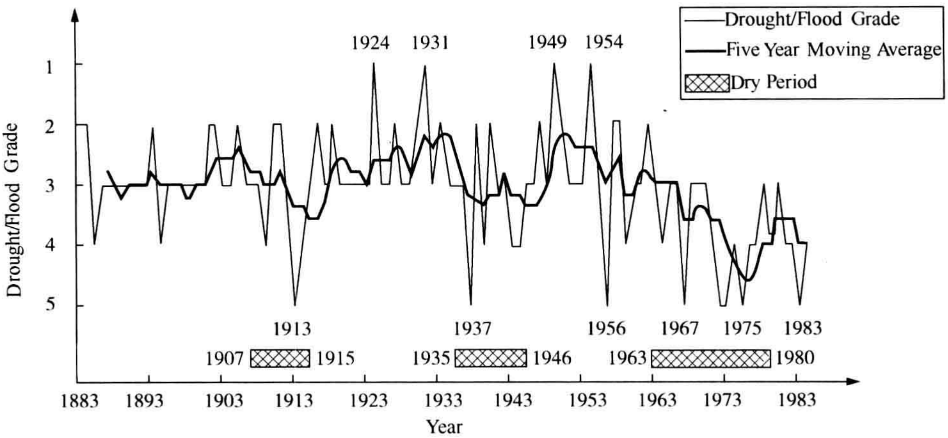

Figure 1. 2. Reconstructed plateau drought/flood variation from 1883 to 1984.

Note: Drought and flood grades were set as follows: 1: severe flood, 2: moderate flood, 3: normal conditions, 4: moderate drought, 5: severe drought.

Source: Lin, et al. 2000.

According to climate reconstructions based on historical documents, the temporal and areal distribution of floods on the plateau from 1803 to 1958 showed considerable variation. Frequent, intense, precipitation-driven flooding occurred from the 1840s to 1880s and further severe flooding occurred from 1924 to 1954, with most flooding on the plateau being restricted to the Yarlung Tsangbo-Lhasa-Nyang River basins (Photos 1. 1 and 1. 2). During this period, flooding occurred most frequently in Shigatse and Lhoka Prefectures as well as in Lhasa Municipality and Nyingchi Prefecture, while little flooding occurred in Chamdo, Ngari, and Nagchu Prefectures (Zhang, et al. 2001).

Photo 1. 1. Aerial view of the Yarlung Tsangbo River, Lhoka Prefecture, TAR. Photo by Dawa Tsering.

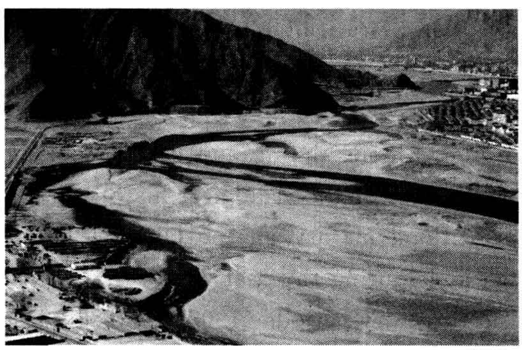

Photo 1. 2. The Lhasa (Kyi Chu) River as it flows past downtown Lhasa, TAR. Photo by John D. Farrington.

1.2.3 Comparison of Guliya Ice-core and Dulan Tree-ring Records

Research shows that ice cores from the Guliya Ice Cap in the northwest TAR and tree-ring records from Dulan County in central Qinghai both provide good records of historical temperatures at their respective collection sites (Figure 1.3, Photo 1.3) (Yao, et al. 1996; Kang 2000; Zhang, Cheng, et al. 2003). Comparison of these two high-resolution records shows that temperatures have increased in a fluctuating manner over the last 2000 years, particularly since the beginning of the 20th Century (Figure 1.3)(Yao, et al. 2001). Both records show three distinct cold periods occurring during the Little Ice Age and indicate that the LIA was not the coldest period of the last 2000 years, with, in all probability, the early centuries of the first millennium A. D. having been even colder. However, these ice-core and tree-ring records also have noticeable differences, such as the Dulan tree-ring series showing strong warming during the Medieval Warm Period, while the $\delta^{18}O$ series of the Guliya ice cores reflect this warm period much more weakly. After the MWP, temperatures indicated by the Dulan tree rings decreased in a fluctuating manner until about 1800, while during the same period a significant warming trend is revealed in the Guliya ice cores. Climate differences between proxy sample sites, proxy calibration errors, and impacts of other environmental factors on the reconstructed series are all possible causes of variations

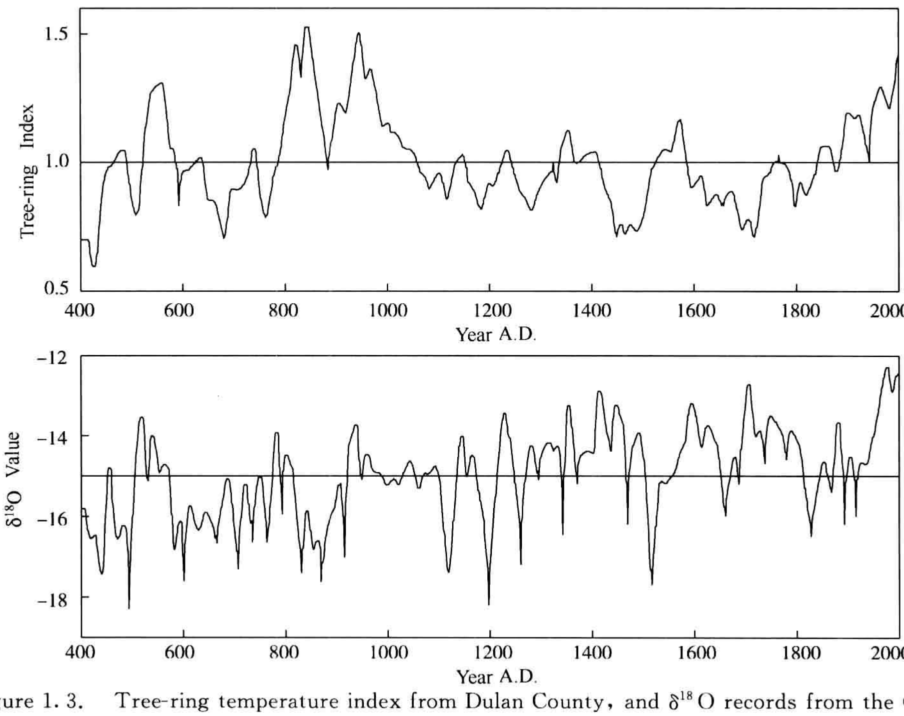

Figure 1.3. Tree-ring temperature index from Dulan County, and $\delta^{18}O$ records from the Guliya ice cores, TAR.

Source: Yao, et al. 2001.

Photo 1. 3. Guliya Ice Cap, Ngari Prefecture, TAR. NASA Landsat image.

between the two series.

Glacier net accumulation records from the Guliya ice cores indicate that 400—1400 A. D. was a dry period and that precipitation at Guliya did not begin to increase substantially until about 1200 A. D. (Figure 1. 4). After a roughly four-century increase in precipitation from 1200 to 1600, net precipitation at Guliya remained at a relatively high and stable level for about 200 years until the late 18th Century when a trend towards increasing aridity began (Yao, et al. 2001; Yao, et al. 1996). However, this decline in precipitation at Guliya was short-lived, with the 20th Century ushering in another wet period at Guliya (Figure 1. 4). Further research indicates that the low glacier accumulation periods recorded at Guliya closely correspond to dry periods in eastern China, while analysis of trans-Pacific precipitation patterns suggests a strong temporal correspondence between Guliya and the Quelccaya Ice Cap records from Peru (Thompson, et al. 1995).

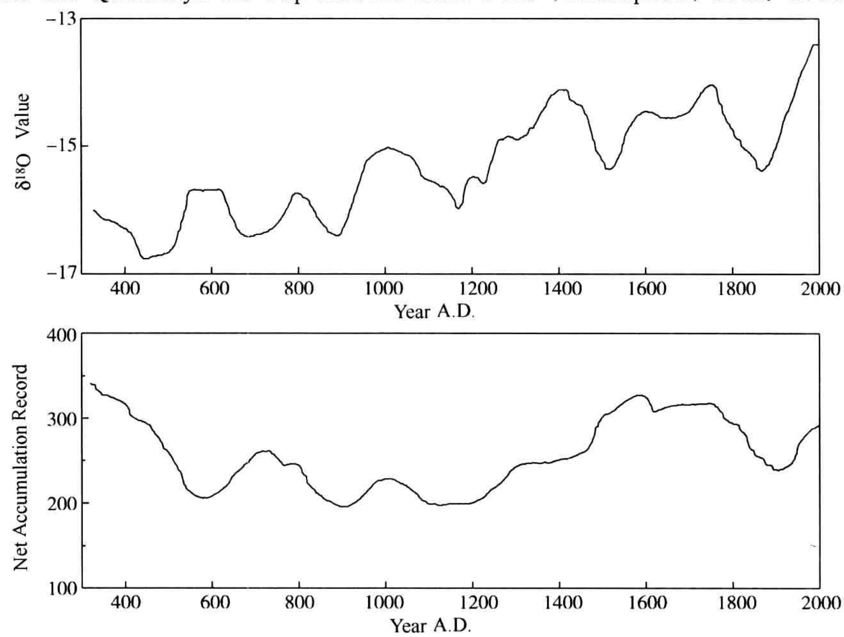

Figure 1. 4. The 11-point moving average of $\delta^{18}O$ and net accumulations records from the Guliya ice cores. Source: Yao, et al. 2001.

The indicators of temperature ($\delta^{18}O$) and precipitation (net accumulation) recorded in the Guliya ice cores show that on a long-term time scale the temperature series is positively correlated to the precipitation series (Figure 1. 3). However, they are not synchronous on a relatively short time scale, which indicates that patterns of cold and warm cycles alternated more frequently than those of precipitation. Although temperatures and precipitation correlate positively at a century scale, changes in precipitation lagged behind changes in temperature by about 50 — 100 years, which is most evident during periods of decreasing temperature (Yao, et al. 2001).

1.3 Modern Meteorological Records of Climate Change on the Qinghai-Tibet Plateau

There were no meteorological observation stations on the Qinghai-Tibet Plateau until the 1950s, and even so, the spatial distribution of meteorological stations on the plateau continues to be sparse, particularly in the west of the plateau (Figure 1. 5). As a result, the length of most instrumental climatic data is relatively short, and the accuracy of regional climatic series cannot be assured.

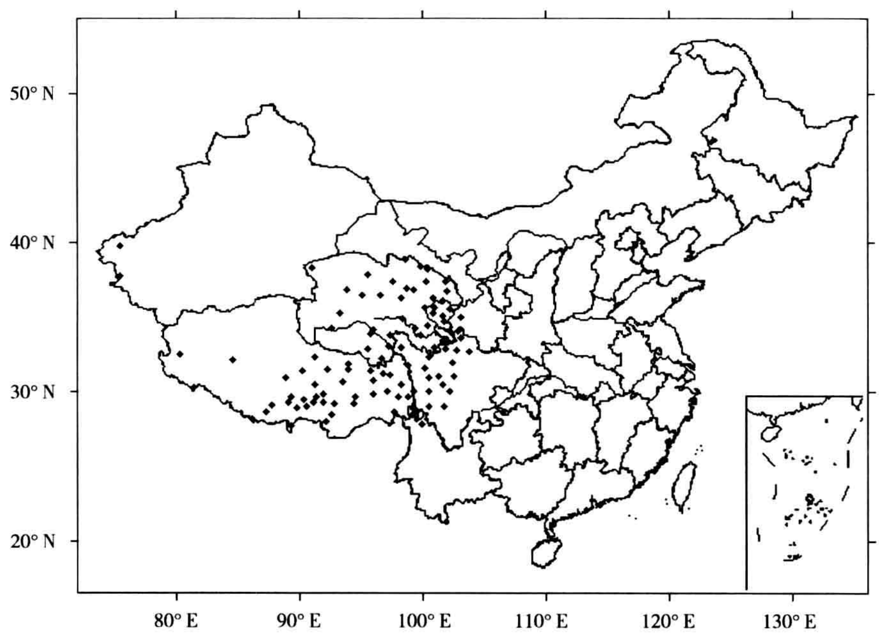

Figure 1. 5 Present distribution of meteorological observation stations on the Qinghai-Tibet Plateau.

1.3.1 Temperature

As with most of the Northern Hemisphere, over the past half century a warming trend has been recorded at nearly all meteorological stations on the Qinghai-Tibet

Plateau, although notably the Ganzi, Kangding, and Maerkang stations in Western Sichuan have documented a significant local cooling trend over the same period (Liu and Chen 2000; Lin, et al. 2000; Lin and Zhao 1996). Figure 1. 6 shows the annual mean surface temperature variation for the plateau from 1951 to 2004, which clearly illustrates the dramatic rise in temperatures since the 1980s. Analysis of available climate data indicates that during this period, the rate of warming on the Qinghai-Tibet Plateau has been about 0. 17℃/decade, and that the seven warmest of the last 54 years have occurred since the 1980s (Ren 2008).

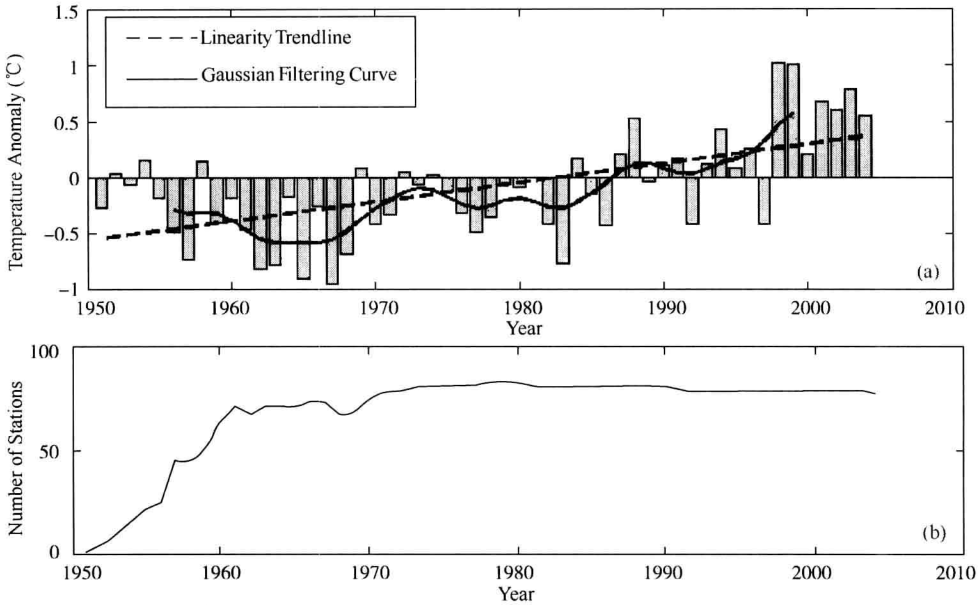

Figure 1. 6. (a) Annual mean surface air temperature variation, and (b) the number of active meteorological observation stations on the Qinghai-Tibet Plateau.

Although the Qinghai-Tibet Plateau is experiencing a period of rapid warming, this warming is highly seasonal in nature. For example, at most plateau meteorological stations, winter temperatures have increased steadily in recent years and have the largest standard deviations, following a pattern similar to that for annual mean temperatures. Spring and autumn temperatures have also risen, although in a range with much smaller standard deviations than for winter temperatures. In contrast, summer temperatures, which have the smallest standard deviations, do not exhibit any obvious warming trends and have even decreased at some stations on the northeastern plateau (Lin, et al. 2000; Lin and Zhao 1996). In general, about three-quarters of the meteorological stations on the Qinghai-Tibet Plateau have shown a more prominent warming trend in winter than in summer (Lin, et al. 2000). At the same time, temperatures on the plateau appear to be rising more quickly in autumn than in spring, which is one of the major differences between the climate trends of the plateau and those of eastern China and may be due to increasing snow cover on the Qinghai-Tibet Plateau in spring (Lin, et al. 2000; Liu and Chen 2000).

1.3.2 Precipitation

Precipitation on the Qinghai-Tibet Plateau decreases from a maximum in the southeast to a minimum on the western and northwestern plateau (Liu and Yin 2001). At most plateau meteorological stations, precipitation is concentrated in summer when over 60 percent of annual precipitation occurs (Liu and Yin 2001). In general, because of the large regional variation in precipitation across the plateau, it is difficult to determine an accurate mean annual precipitation series for the entire plateau. However, after taking into account such factors as the particular station, data collection period, method of measurement, etc., it was possible to derive a mean annual precipitation series for the entire Qinghai-Tibet Plateau using an area-weighted, average-resolution method developed by Jones and Hulme, which indicates that precipitation on the plateau has increased slightly from 1951 to 2004 (Figure 1.7)(Jones and Hulme 1996).

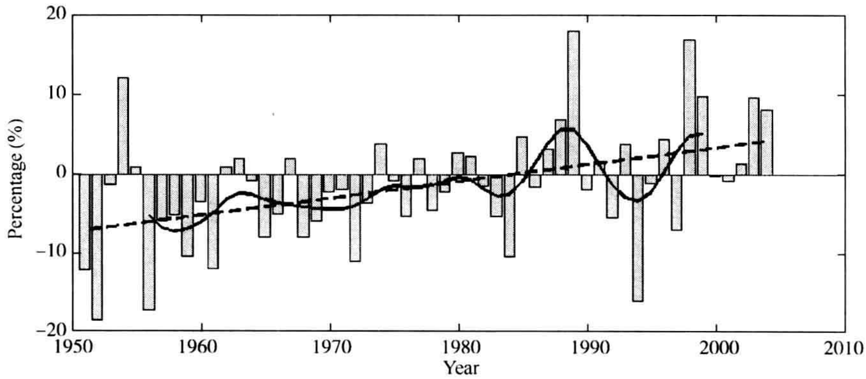

Figure 1.7. Annual precipitation anomaly on the Qinghai-Tibet Plateau, 1951—2004, as a percentage of mean annual precipitation for the period.

However, because the meteorological stations on the plateau are not evenly distributed, many uncertainties remain about any conclusions derived from Figure 1.7. On a station-by-station basis, only 45 percent of the plateau's meteorological stations recorded increases in precipitation, most of which are located in the vicinity of Nagchu in northern Tibet, on the northern slope of the Himalaya, and in the Yarlung Tsangpo-Lhasa-Nyang River Basin (Photo 1.4)(Zhu, et al. 2001; Lin and Zhao 1996).

Photo 1.4. Mt. Everest (Qomolangma, Sagarmatha) and the crest of the Himalaya, TAR and Nepal. Photo by Dawa Tsering.