

**REDUCING THE IMPACT OF
ENVIRONMENTAL EMERGENCIES
THROUGH EARLY WARNING AND
PREPAREDNESS - THE CASE OF EL
NIÑO-SOUTHERN OSCILLATION
(ENSO)**

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**IMPACTS OF THE 1997-98 EL NIÑO EVENT IN
CHINA**

Edited by:

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EXECUTIVE SUMMARY :

China is the largest developing country in the world with a vast territory and nearly 1.3 billion people. Great differences in climate are found from region to region owing to China's extensive territory and complex topography: tropical, subtropical, temperate, plateau and alpine. The major part of China is under the influence of the Asia monsoon. Natural hazards, especially meteorological hazards, such as torrential rains, floods, droughts, typhoons, hail and frost episodes, occur frequently. Drought, flood, typhoon, frost, hail and chill damages are the main climatic hazards that have substantial influence on the country's social and economic stability.

In 1997, people in northern China experienced a very hot and dry summer season. During the 1997-98 winter, extraordinarily heavy snow fell over the Tibetan Plateau and caused great losses of human lives and property. In the summer of 1998, a great flood occurred in the Yangtze River basin, which was ranked as the second greatest flood during the past fifty years. Meanwhile, the greatest flood in the past fifty years occurred in Songhua river basin in northeastern China. Both floods caused total damages of over 350 billion yuan (RMB) (45 billion USD) in property and an estimated 3,000 deaths.

After these natural disasters, the causes were investigated thoroughly by a team led by the Ministry of Water Conservancy with officials from different government agencies and scientists from various research institutions. The El Niño event was considered as the one of major factors to be included in the forecasting process in that year. The preliminary results, however, showed that although El Niño has its most significant impacts on climate in tropical regions, its impacts on climate weaken beyond this region. In China, most forecasters believe that El Niño is a strong signal that could be used for predictions of climate anomaly in China in the future. There are mechanisms that are not fully understood about the relationship between El Niño and China's climate hazards.

Historically, scientific research in China on El Niño advanced in four stages. The first stage occurred before 1950. At this stage, no studies were done on El Niño and the Southern Oscillation (SO) and their impact on China because of the weakness of Chinese science and technology as a whole, the lack of reliable scientific observation instruments, and difficulties to obtain any of the limited number of scientific reports and information about El Niño and the SO from other countries. Research topics such as interannual variability of the Asia monsoon and atmospheric circulation, or the interactions of the atmosphere and the ocean were not addressed at that time.

The second stage occurred from 1950 to 1980. Beginning in the 1950s, anomalous sea surface temperature (SST) variations (which were related with variations of El Niño and the Southern Oscillation - a relationship still not known in China at that time) and their relationship with global and regional atmospheric circulation began to attract attention from China's research community. From 1980 to the early 1990s, owing to the global impacts of one of the strongest El Niño events in the 20th century, the 1982-83 El Niño, El Niño study in China entered its third stage. With the successful forecast on the 1998 Great Flood in the Yangtze River Basin, ENSO studies in China blossomed into in the fourth stage.

The mention of the El Niño phenomenon first appeared in the scientific literature in China about six decades ago, although it was only considered to be a local natural event (near Peru) without any global impact. Only after the 1982-83 El Niño were the relationships between El Niño and anomalous weather events in China and its impact on China agriculture addressed, but only in meteorological research community. In the early 1990s, the media in China started to cover news on the impacts of the longest series of El Niño events (i.e., 1990-1995) on foreign countries, especially in South America and Australia. The public, however, was unaware of the relationship between the El Niño and their own daily lives, because of the lack of communication between the meteorological community (including weather services, research institutions and universities) and the public.

In early 1997, the magic phrase, "El Niño", finally escaped from the "ivory tower" of the scientific community and became one of the hottest words on various TV programs, national and local newspapers around the country. Becoming so concerned about the impact of extreme climate events on national economic development prospects, President Jiang Zeming and other top government leaders consulted with the China Meteorological Administration (CMA) and the National Oceanic Administration (NOA) for information on El Niño and its impacts during the period of the 1998 great flood from June to August, 1998 in the Yangtze River Basin even though El Niño was already in its decaying mode at that time.

Although the Chinese weather service has made seasonal and annual predictions since early 1950s, the predictions have been provided only to the central or local government decision makers when they were making their annual working plans for agriculture, water management and disaster relief. Such information is not available to the general public. This is so, because on the one hand, the accuracy of long-range forecasts is low due to the complexity of climate variations in China. Therefore, the weather service is not confident enough to release its predictions to public. On the other hand, the China weather service for a long time has lacked the trained personnel

to deal with the media and the public to educate them on climate change and weather events, and particularly on societal impacts and on the usefulness of meteorological information to society. With lessons and experiences gained from the 1997-98 El Niño event, both meteorological community and the general public in China are starting to come together to deal with climate and its impacts on society.

Many lessons have been learned from this study and perhaps among the most important ones are the following: 1) there are many scientific uncertainties in the understanding and forecasting of ENSO and its impacts; 2) there is a lack of communication between researchers who try to “eliminate” these uncertainties and users who desperately need the information but either never use it or are skeptical about its reliability because of the uncertainties. With respect to the scientific understanding of ENSO, the uncertainties are due mainly to the lack of proper observation networks which require human capacity building for research. Studies focused on understanding the ENSO phenomenon, especially its teleconnections to China, and more funding for basic research are needed.

The lack of communication among the scientific community, the media and users not only must be dealt with for the benefit of reducing the ENSO’s impacts but also will be useful for building a communication channel to educate the public on a wide range of scientific issues. As a scientific community, good communication is also needed between physical scientists and social scientists. Trained personnel and additional infrastructure and funding are also needed to improve communication with the media and users so that the information provided by scientists is not misinterpreted.

PART I: SETTING :

1.1 THE SOCIOECONOMIC AND POLITICAL SETTING IN CHINA

Since 1949, following the founding of the People’s Republic of China, the political administrative system in China was set up on three levels: provinces, counties, and townships. The entire nation is currently divided into twenty-three provinces, five autonomous regions, and four centrally administered municipalities (Beijing, Shanghai, Tianjin and Chongqing), which have the same political, economical and jurisdictional rights as a province, with two recently established special administrative regions (Hong Kong and Macau). A province or an autonomous region is, in turn, subdivided into autonomous prefectures, counties, autonomous counties, and/or cities. A county or an autonomous county is again divided into townships, national minority townships, and/or towns. Autonomous regions (equivalent to provinces), autonomous prefectures (between autonomous regions and autonomous counties), and autonomous counties are all autonomous ethnic minority governmental units.

The Constitution of the People's Republic of China stipulates that Chinese central state organs comprise six components: the National People's Congress, the President of the People's Republic of China, the State Council, the Central Military Commission, the Supreme People's Court, and the Supreme People's Procuratorate. Among these components, the State Council of the People's Republic of China, namely the Central People's Government, is the highest executive organ of state power, as well as the highest organ of state administration. The State Council is responsible for carrying out the principles and policies of the Chinese Communist Party, and the regulations and laws adopted by the National People’s Congress (NPC), as well as other affairs such as China's internal politics, diplomacy, national defense, finance, economy, culture, and education.

Currently, there is a total of twenty-nine ministries and commissions under the State Council. All the ministries and commissions have their own local offices or bureaus in the provinces, counties and towns. These offices are usually supported and supervised both by local governments and the ministries in the central government. For example, the China Meteorological Administration (CMA) is empowered by the State Council to administer the national meteorological service and is charged with the organization and management of the national meteorological affairs. The local meteorological bureaus exercise dual leadership from the CMA as the principal leader, and from local governments.

The CMA and its local branches are the major players dealing with climate-related issues in China. They provide predictions ranging from several hours to several months, although only the daily forecasts are released to the public. The long-range predictions are provided only to the local and central government authorities for making decisions on national and regional production plans in agriculture and industry. Other government agencies, such as water resources, fisheries, transportation, communications, and agriculture, also consult the CMA regularly for their own management needs.

1.2 THE CLIMATE-RELATED AND OTHER NATURAL HAZARDS AFFECTING CHINA

China is the largest developing country in the world with a vast territory and nearly 1.3 billion people. China's topography is very complex. From the west to the east, the profile descends rapidly from Tibet mountain regions with an elevation averaged at 3000 meters down to sea level. Mountains and hilly terrain take up 65 percent of the

total area. There are five main mountain ranges. Seven mountain peaks are higher than 8,000 meters above sea level. The Bohai Sea, East China Sea, Yellow Sea and South China Sea embrace the east and southeast coasts. China possesses various climates such as tropical, subtropical, temperate, plateau and alpine. The major part of China lies in the northern temperate zone under the influence of the Asia monsoon. From September-October to March-April the next year, the winter monsoon blows from Siberia and the Mongolian Plateau into China. It decreases in force as it goes southward, causing a dry and cold winter in the country and a temperature difference of 40°C between the north and south. The Asian summer monsoon blows into China from the ocean and brings warm and wet currents of air, and thus rain.

Great differences in climate are found from region to region owing to China's extensive territory and complex topography. Natural hazards, especially meteorological hazards, such as torrential rains, floods, droughts, typhoons, and hail and frost episodes, occur frequently. Drought, flood, typhoon, frost, hail and chill damages are the main climatic hazards that have substantial influence on the country's social and economic stability.

DROUGHT Climate-related disasters have resulted in yearly reduction of crop production of 15 to 30 million metric tons. Most of the losses were caused by droughts, particularly in Northwestern China. Moreover, dryness sharpens the problem of demand and supply of water. With decreasing storage of reservoirs and over-extraction of underground water, water shortages have become the shackles for the development of the country's economy.

FLOOD China is a country that has frequent and serious floods each year; floods occur to various degrees somewhere in the country each year. Floods are ranked in second place for total climatic losses. They cause not only grain reduction of millions of metric tons but also an annual loss of thousands of lives and almost 10 billion yuan (RMB) in property. Furthermore, as a result of floods, many geological disasters, such as landslide, and mud-rock flow follow, which cause additional losses of several billion yuan (RMB).

TYPHOON The east coast of China, which is the most developed area in the country with a high density of population, is frequently hit by typhoons generated in the western Pacific Ocean. Typhoons with wind gusts and related storm surges greatly hinder offshore operations and endanger the properties and lives of people in the region.

FROST Severe frost is caused mainly by the intrusion of cold waves or strong cold air masses, which occur in China in all seasons except summer. The frosts in fall are most dangerous to soybean in Northeast China and in the spring season to wheat and cotton in North and Northwest China.

HAIL and CHILL Hailstorms occur in various parts of China and sometimes can cause severe casualties both in human lives and in property damage. Chill damage in warm seasons has a pronounced influence on crops, especially in Northeast China, where the chilliness occurs almost every four years with a severe chill every seven years. On average, it causes over a 30% reduction in crop production.

According to China's National Statistics Bureau, China has more than 1.24 billion people with a natural growth rate of 0.953%, i.e., a net growth in population of 11.8 million in 1998. The population is distributed unevenly with higher levels in the eastern provinces (more than 300 people per square kilometer) and lower levels in the western provinces (about 40 people per square kilometer). More significantly, the rate and levels of social and economic development are quite different, with the fastest development along the east coast and the slowest in the inland provinces. Thus, in the absence of any change in the future, the pressures of population and poverty, the increasing regional differences in possibilities of economic development between east and west, and north and south will constrain the possibilities of an effective disaster reduction capability in China.

Like most countries in the world, damages and losses on property and casualties caused by the disasters in China are getting larger with increasing population and the fast development of the economy. For example, in the 1950s, the average annual losses of crop production caused by natural disasters were about 3.85 million metric tons (about 2.1% of total annual crop production). But, in the 1990s, the average annual losses of crop production were over 23 million metric tons (or about 5% of total annual crop production) (**Table 1**). During the past decade, the natural disasters not only led to direct economic losses of 3%-6% GDP (**Figure 1**)

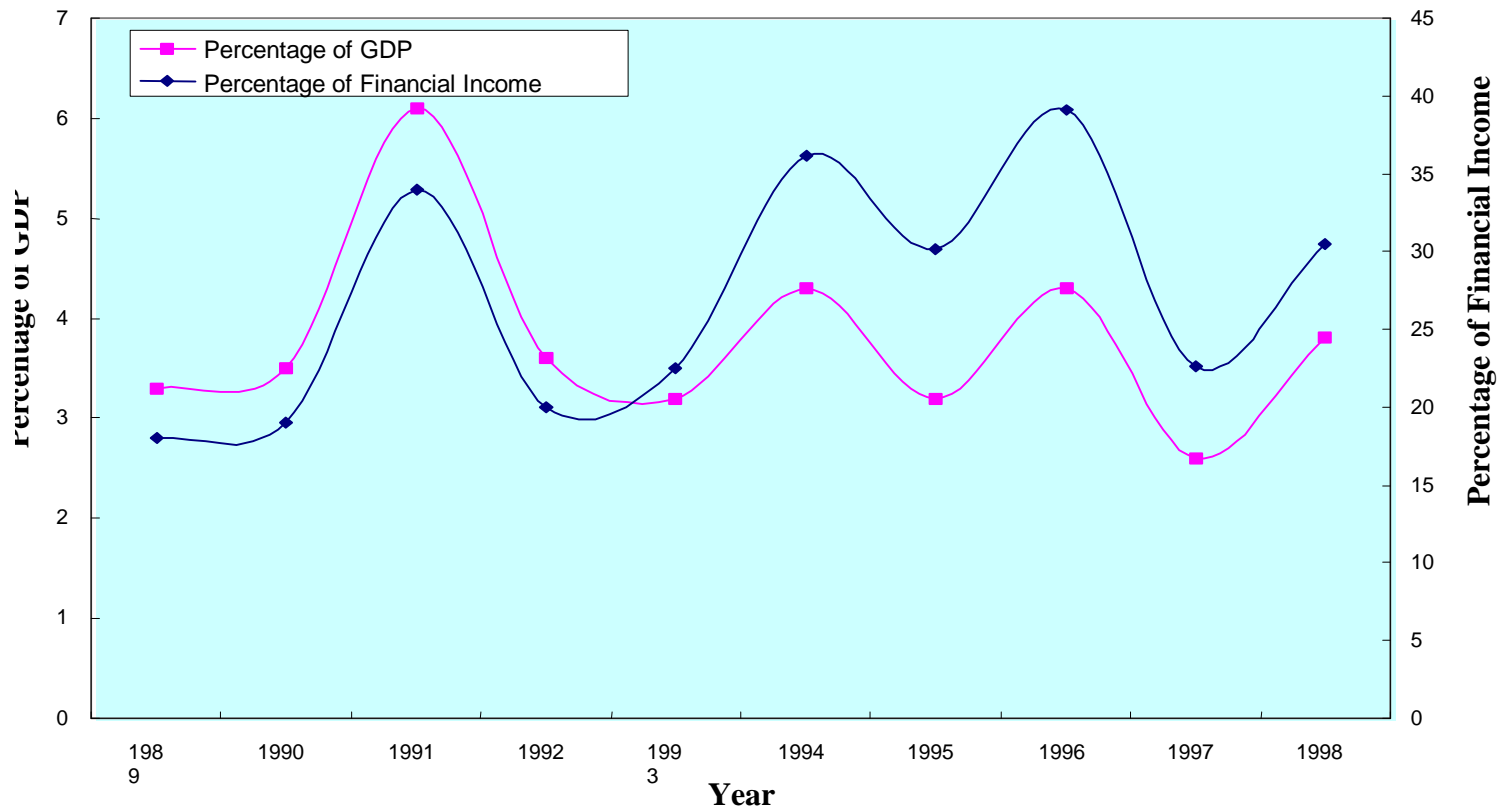


Figure 1. The percentages of economic losses caused by natural disasters in GDP and in the National Financial Income

but also caused the deaths of several thousands of people annually. As a result, the Chinese government always treats disaster reduction as an important approach for realizing the overall objective of sustainable development of the national economy and society, and emphasizes that disaster reduction should help the development of the national economy and society. Unfortunately, being the world largest developing country but relatively weak in economic power, China has not yet built up an enduring capacity against natural disasters.

Table 1: Average Annual Losses of Crop Production Caused by Natural Disasters

Period	Losses (million metric tons)	Total Annual Crop Production (million metric tons)	Percentage of Total Production Losses (%)
1952-1959	3.8	180.5	2.1

1960-1966	6.1	173.9	3.5
1970-1979	6.6	276.1	2.4
1980-1989	15.9	277.0	4.2
1990-1997	23.03	461.4	4.99

In April 1989, responding eagerly to a United Nations request, the Chinese Government established the "China National Committee for International Decade for Natural Disaster Reduction". The committee consists of all twenty-nine ministries under the State Council, the army and non-governmental organizations. Led by high-level officials from the State Council, the CNC/IDNDR, an inter-ministerial coordinating organization, is responsible for drawing up a national disaster reduction framework, making general as well as specific policies for disaster reduction, for coordinating relevant departments and non-governmental organizations to develop disaster reduction, and for directing the disaster reduction works of the local governments.

The Chinese government has made great efforts to increase its ability to reduce the impact of disasters by strengthening the nation's economic power, eliminating poverty, implementing the policy of improving national prosperity through science and education, and encouraging the application of advanced science and technology to the process of disaster reduction.

1.3 THE LEVEL OF SCIENTIFIC RESEARCH IN CHINA RELATING TO EL NIÑO

Scientific research relating to El Niño in China is in its developing stage following the successful forecast of the 1998 Great Flood in the Yangtze River by the National Climate Center in the China Meteorological Administration. The El Niño event was considered as the one of major factors included in the forecasting process in that year. To summarize the current level of scientific research on El Niño in China, it is worth looking at the history of the El Niño research in China. Historically, the development of scientific research on the El Niño in China can be divided into four stages:

The first stage is the period up to 1950. At this stage, no studies on El Niño and the Southern Oscillation or their impact on China were done because of the weakness of Chinese science and technology as a whole, the lack of powerful observation instruments, and difficulties in obtaining scientific reports and information about El Niño and the SO from other countries. Researchers rarely related anomalous climate and natural disaster to El Niño and the SO. Instead, they mainly focused on the relationship between anomalous climate features such as monsoon, atmospheric circulation, and extreme events (droughts and floods). For example, many studies exist on the great flood that occurred in the Yangtze River Basin in July 1931, which was the first great flood in the 20th century (for example, Lu Jiong, 1932; Zhou Kezhen, 1936; Zhen Zizheng, 1937; Tu Changwang, 1937 and Niu Tianren, 1950). Research topics such as the annual variability of the Asia monsoon and atmospheric circulation, and the interactions of air and ocean were not addressed in that period.

The second stage encompasses from 1950 to 1980. Beginning in the 1950s, anomalous SST variations (which were related to El Niño and the Southern Oscillation but still not known in China at that time) and their relationship with atmospheric circulation had attracted the attention of the research community. In 1950, in the *Journal of Meteorology (in Chinese)*, geographer Lu Jiong pointed out that the Kuroshio Current in the Western Pacific Ocean in winter and anomalous SSTs in other regions had a good correlation with variations of atmospheric circulation in East Asia, which in turn, greatly affected the occurrence of droughts and floods during the summer monsoon season. Also in this paper, without mentioning the word "El Niño", Lu Jiong described the El Niño process in China first time. He wrote: "The change of ocean currents led to the change of climate and increase in precipitation. From January to April in 1925, the change of ocean currents along the coast of Peru, the precipitation in mountains increased greatly, and the inhabitants of the lowlands had a difficult time. But northern Peru, where it is usually dry got timely rains, and the luxuriant grass grew everywhere, so flocks and herds were able to consume abundant grasses. Peruvians appreciated it up to now." (Lu, 1950).

Although Lu's paper was published in the only meteorological journal in China at that time, it was not until 1974 that the impact of oceanic circulation on the atmosphere became a research topic in Chinese meteorological community. By investigating the global anomalies in 1972, Chen Lieting from the Chinese Academy of Sciences found that the atmospheric circulation and anomalous weather extremes around the world in 1972 were related to the distinct long term negative SSTs of two huge warm ocean currents ---the Mexican Gulf current and Kuroshio Current (Chen, 1974). Moreover, the relationship between the SST anomaly in the Kuroshio Current and atmospheric circulation in East Asia was confirmed (Chen, 1974).

In 1977, Chen Lieting mentioned the word "El Niño" for the first time in China. By identifying the positive SST departures in the East Pacific as the signal for an El Niño, Chen showed that summer precipitation patterns in China, the westward extension area of cold water in the equator, and the southward extension area of warm water in the west coast of South America in spring were all related. He found that in the years when the equatorial SST in spring is very high or very low, the location and the

intensity of the circulation systems in the tropical Pacific in summer are totally different. Moreover, he found out that from the Indian Ocean to the Pacific Ocean, there are three trans-meridional circulation cycles above the equator. There are two clockwise circulation cycles at both sides, which ascend from warm water areas and descend to cold water areas. The middle one is a counterclockwise cycle. These cycles are the important links between the SSTs in the equatorial western Pacific Ocean, which affect the activity of the subtropical high in western Pacific Ocean, and the precipitation in China in summer monsoon seasons. A possible mechanism about these linkages are shown in **Figure 2**

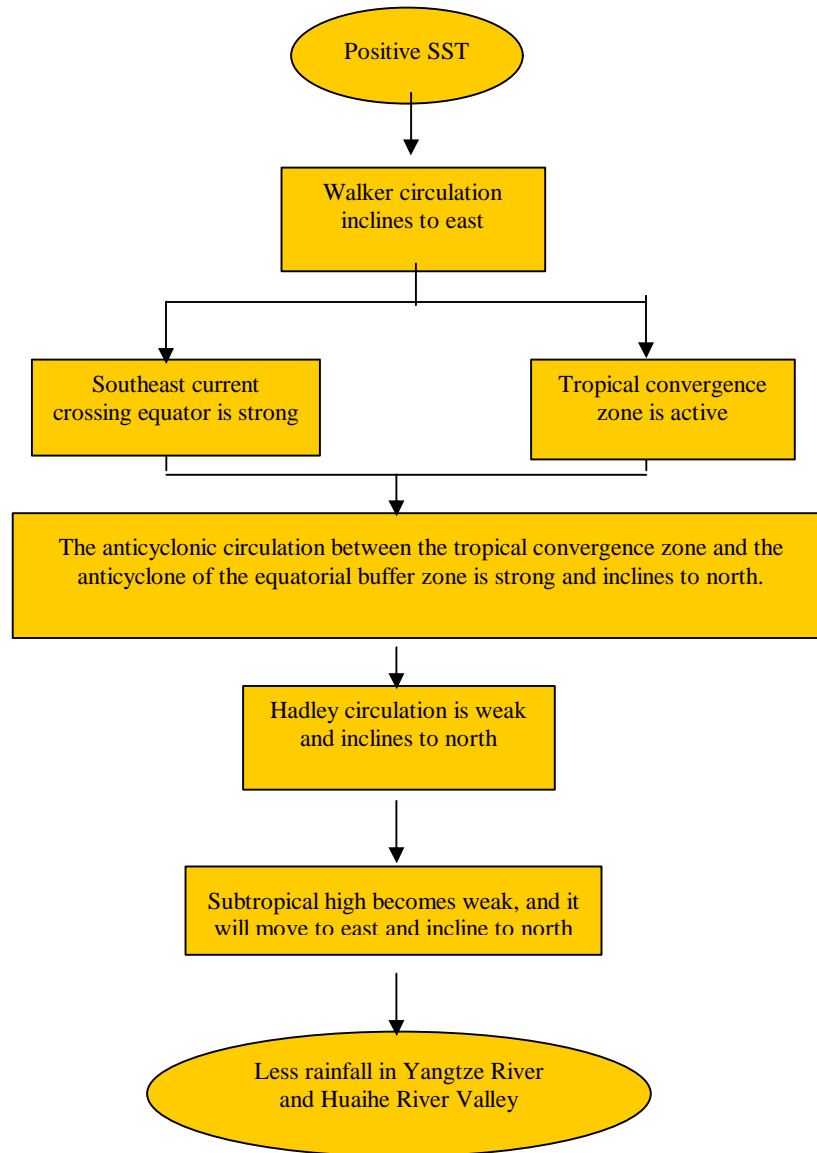


Figure 2: The relationship between the positive SST in equatorial west Pacific and the activity of subtropical high in West Pacific as well as the precipitation of Chinese flood season

and **Figure 3** (Chen, 1977).

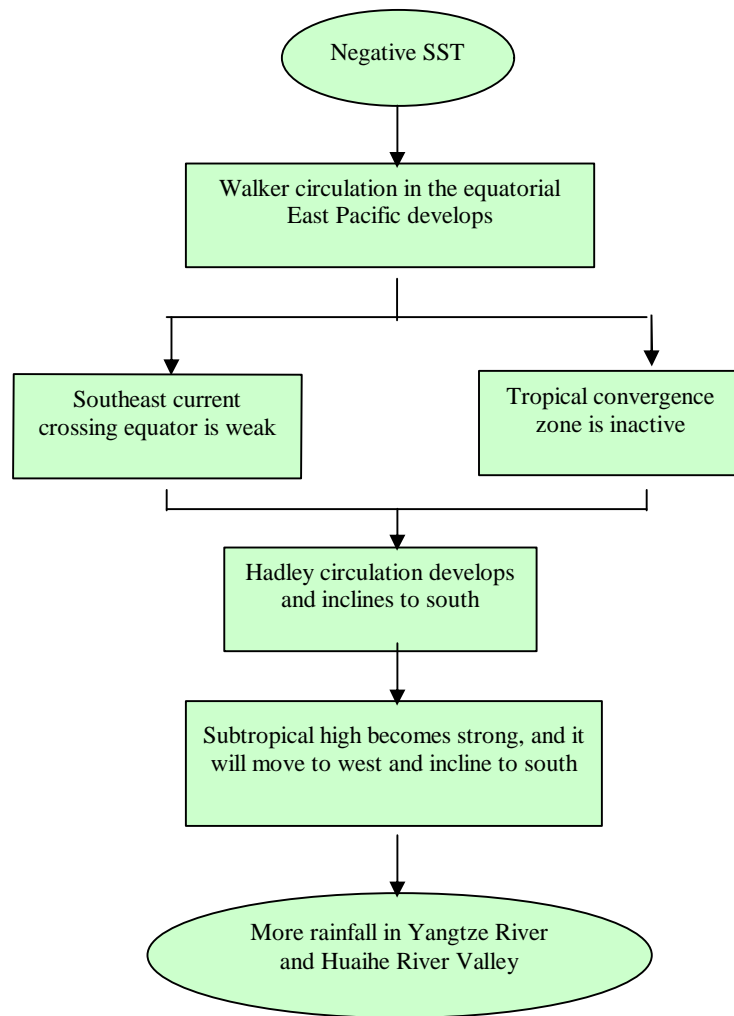


Figure 3: The relationship between the negative SST in equatorial west Pacific and the activity of subtropical high in West Pacific as well as the precipitation of Chinese flood season

In 1980, Professor Wang Shaowu, a famous climatologist from Peking University, pointed out that there is a tight relation between SSTs and atmospheric circulation in the boreal (northern) hemisphere summer. During the boreal winter, the areas with large annual SST variations in the Pacific and the Atlantic are those with distinct warm or cold currents, and in the areas without currents, the variations are not obvious. The SSTs in the areas of the currents have a clear positive relation with pressure at different altitudes and the SSTs are the leading factor which control atmosphere. In areas without currents, the SSTs have an obvious positive relationship to the surface pressure fields. The atmosphere is the leading actor and it influences ocean. In addition, in summer the anomalous SSTs in the Kuroshio Current area obviously influence the atmospheric circulation in East Asia and the western Pacific Ocean, and the relationship between the SSTs of the Kuroshio Current and the atmospheric troughs in East Asia is an obvious positive correlation. On the other hand, the warm current north of the equator has an obvious relationship with the pressure field in the low latitudes of the Northern Hemisphere, and there is also a relationship between the warm current north of the equator and the subtropical high in the Western Pacific Ocean (Wang, 1980). The study of El Niño in China, marked by Professor Wang's work, entered its third stage.

Increased attention has been paid to research on El Niño in China from the early 1980s to the early 1990s, owing to the global impacts of one of the strongest El Niño events in the 20th century, the 1982-83 El Niño. By analyzing historical data and simulating El Niño events using well developed numerical atmosphere-ocean coupled models, relationships between El Niño events and weather systems at different spatial and temporal scales and extreme climate events in China were studied intensively.

Li Chongyin from the Chinese Academy of Sciences studied the relationship between El Niño and the Asian monsoon circulation. He found that, before an El Niño occurs, there is usually a distinct anomaly of the atmospheric circulation system over East Asia and the western Pacific Ocean from October to December in the previous year. Mainly, there are strong cold air movements over the Asia continent. In addition, the Aleutian low and the subtropical high over the western Pacific are both very strong. One to three months before an El Niño event, the atmospheric circulation anomaly in East Asia and the western Pacific Ocean moves from north to south. Although there are still frequent movements of cold air in East Asia, both the location and intensity of the subtropical high are toward to south. As a result, the trade winds in the western Pacific Ocean are weakened which generally leads to the occurrence of an El Niño event.

Chinese scientist Li Maicun further confirmed the above findings by analyzing the relationship between the anomalies of the East Asia monsoon and the anomalies of SSTs in the western and eastern Pacific ocean. He found that the anomalous departure pattern of SSTs, especially the SSTs anomalies in the Kuroshio region and in the eastern equatorial Pacific, has significant influence on the Asian monsoon system. When the SSTs are warm (cold) in the eastern equatorial Pacific and cold (warm) in the western Pacific (Kuroshio Current region), the subtropical highs in the North Pacific and the South Pacific are both strong (weak), and their locations are toward the east (west) and the north (south). At the same time, the Southern Oscillation (SO) index is low (high), and the pressure departure in the lower atmosphere of Australia is positive (negative). So, the air flows which come from the Southern Hemisphere and cross the equator are weaker (stronger) than normal. As a result, the southeast monsoon in southern China is weak (strong). Drought (flood) tends to occur in the Yangtze River Basin, and cold (hot) summer tends to occur in Northeast China (Li, Wu and Huang, 1987).

Other studies were undertaken on the impacts of El Niño on the Asian monsoon. For example, Wang Shaowu linked the low summer temperatures in East Asia to El Niño events (Wang, 1985). Li Chongying studied typhoon occurrences in the western Pacific Ocean and found that, in El Niño years, the average number of typhoons forming in the western Pacific and landing in Guangdong and Guangxi (two provinces located at the southeast of China) were fewer than average. He suggested that this was because in El Niño years, the location of the subtropical high in the western Pacific is toward to the south. The ITCZ (Intertropical Convergence Zone) is weak and located toward to the south too. The sea surface temperatures of the typhoon-forming areas are anomalously low. Such conditions are not favorable for the formation of typhoons (Li, 1986, 1987).

In the first half of the 1990s, several El Niño events appeared in series. Several severe droughts and floods occurred in China during this period. To better understand the relationships between extreme ENSO events and climate disasters in China, the Chinese National Natural Science Foundation and the Ministry of Science and Technology have invested heavily in the study of ENSO and its impacts on China. It is expected that more advanced numerical models, which couple atmosphere, ocean and land processes, will be developed for making more accurate ENSO predictions. The fourth stage of research and interest in the ENSO cycle and its impacts in China is now under way.

1.4 THE HISTORICAL INTEREST IN CHINA IN EL NIÑO BEFORE THE ONSET OF THE FORECAST AND/OR IMPACT OF THE 1997-98 EVENT

Although the 1982-83 El Niño event was also identified as the major contributor to many of the anomalous climate conditions in the world that year, the word “El Niño” was not known by most Chinese government agencies, industries and the general public. Even in the meteorological community, only a small group of scientists tried to relate El Niño to climate in China. The public's interest in El Niño appeared in the beginning of the 1990s with the series of El Niño events which were mentioned frequently in many countries in South America and elsewhere, and then introduced by Chinese newspapers and TV programs in their international news sections. The worldwide destruction caused by El Niño in the early 1990s provided abundant “hot” news material, which easily attracted the attention of the media. Before the 1997-98 El Niño event and as early as 1995 the word “El Niño” started to appear in some major Chinese newspapers such as the People's Daily which is sponsored by the Chinese Communist Party with over several millions subscribers.

On 25 February 1995, the People's Daily first mentioned El Niño from its reporter stationed in the USA. The reporter cited American scientists' views on El Niño and discussed the social and economic impacts of El Niño on countries in the Americas such as Peru and the United States. However, only four articles mentioned El Niño in the People's Daily in the whole of 1995. In 1996, only one announcement, from China's National Oceanic Bureau, mentioning El Niño appeared in the People's Daily as shown in **Table 2**.

Table 2. Dates and Headlines of Articles relating to El Niño that appeared in the People's Daily before the 1997-98 El Niño event

Publication Date	Headline
25 February, 1995	El Niño is coming back again
10 March, 1995	El Niño is still in active mode
2 April, 1995	Current tendency of crop production in the country
9 June, 1995	Summer is arriving Lasha earlier
27 June, 1996	The National Oceanic Bureau warns about oceanic disasters

PART II THE 1997—98 ENSO EVENT :

2.1 TRACE THE FLOW OF INFORMATION ON THE 1997-98 EL NIÑO TO AND THROUGH THE GOVERNMENT

In China, the National Climate Center (NCC) within the China Meteorological Administration (CMA) and the National Oceanic Bureau are the only two government agencies which independently make operational El Niño forecasts based on numerical modeling, statistical and empirical methods. By monitoring both the tropical atmospheric wind field and changes in sea surface temperatures in the equatorial Pacific, Chinese scientists warned as early as the end of 1996 that there was a possible El Niño event in 1997. But the official announcement of this possibility (which was still kept internally) was made in April 1997 after a workshop entitled “Consultative Workshop on the Observation and Prospect of ENSO”. The workshop was hosted every spring by the China Meteorological Administration and attended by experts from the Chinese Academy of Sciences, universities and different government agencies. This announcement appeared in the report “Briefing of ENSO Observation” based on the results of the 1997 workshop. The report was then sent to the State Council and all ministries. In later April, the CMA reported firmly that a new El Niño event would appear.

After the workshop in April, the CMA held another two mid-course-correction consulting meetings focused on the summer climate with El Niño as the major concern in June and July 1997. The results were then reported to the State Council along with discussion about its possible impacts.

The media first reported about this El Niño on May 22, 1997 in the People’s Daily in China with a headline “The New El Niño Is Forming”. However, this news was reported by China’s journalists stationed in Washington, D.C, USA and based on reports from the NOAA’s National Climate Prediction Center. On the same day, the People’s Daily also reported that the Chinese National Oceanic Bureau held a news conference on “Warning on oceanic disasters”. In the news, it cited that experts predicted that the coming El Niño would be a stronger one.

Then, on June 14, the People’s Daily cited the news from the Japan Meteorological Administration (JMA) that the El Niño had possibly formed in May. In the JMA’s report, it warned that “El Niño is starting to form and anomalous climate is possible”. The China Central TV station also covered in its nightly news program on disasters in South America caused by El Niño . In the People’s Daily, there was total of 48 news items on El Niño in 1997 with headlines such as the following: “El Niño is destroying Chile” (June, 23), “Beware of the attack from El Niño” (June, 23), “Chile is suffering severe flooding” (June, 25), “El Niño: 1.3 billion dollar loss in agriculture in Australia” (July, 7), “Severe El Niño in this year”(June, 8), “El Niño is coming back” (July, 13), “Climatologists on the hot summer in Northern China” (July, 26), “El Niño threatening agriculture in South Africa” (July, 20), “On the ENSO phenomenon and anomalous climate ” (August, 8), “Extreme severe El Niño and anomalous climate will stay till next year” (August, 27), “El Niño, the possible dolphin killer” (September, 12), “El Niño is related with forest fire in Indonesia” (September, 29), “South America preparing for the worst El Niño” (September, 29), “El Niño has a great impact on global economy” (October, 11), “Bad El Niño, Good for shrimp industry in Ecuador” (November, 12), “Strong El Niño, Hot Australia” (November, 28), “Water use restriction in the Philippine” (December, 2), “US experts say El Niño is decaying” (December, 12).

It is worthy to point out that before July, 1997, when the El Niño was in its early development stage, the sources of most reports on El Niño from the media in China were either from experts in foreign countries, mainly from South America or from Chinese journalists stationed abroad. Very little information was provided by the relevant internal agencies such as the China Meteorological Administration and the National Oceanic Bureau. Moreover, reports in the media of the impact of El Niño were mostly about impacts on the other countries. There are very few on China.

Before the mention of the 1997-98 El Niño event, the previous mention of El Niño in the media was on June 27, 1996, when the People’s Daily cited a report from the National Oceanic Bureau, which claimed that there was no El Niño in that year. This was the only article to mention the El Niño in 1996, which was in fact a La Niña year.

PART III TELECONNECTION :

3.1 THE EXISTENCE AND THE STRENGTH OF EL NIÑO TELECONNECTIONS

Climate in China is mainly controlled by the Asian monsoon. Because extreme climate events such as drought and flood have tremendous negative impacts on society and economy in China, Chinese scientists have spent great effort to search for possible links between anomalous signals in the global climate system and climate variations in China. The El Niño cycle has become the latest target in both the academic research and the operational forecasting communities. Their preliminary results showed that, although in tropical regions especially in the tropical Pacific, El Niño has the most significant impacts on climate, its impacts on climate weaken beyond the tropical regions and away from the Pacific. In China, most forecasters believe that El Niño is only a strong signal that could be used for constructing predictions of climate anomaly in China. There are still mechanisms that are not yet fully understood about the relationship between El Niño and various climate hazards in China. It is very difficult to identify kinds of specific anomalies that could occur in which part of China during El Niño years (Zhao, 1997).

Chinese forecasters noticed for many years that summer monsoon rainfall in China depended significantly on the intensity and location of the subtropical high over the northwestern Pacific Ocean at 500 hPa; this links sea surface temperature anomalies (SSTA) over both the warm pool in the western Pacific Ocean and the El Niño regions in the central and eastern Pacific. Based on statistical analyses of historical records, certain correlations between El Niño and climate anomalies in China are the following:

- ✍ In El Niño years, with rising SSTs in the eastern equatorial Pacific and decreasing SSTs in the equatorial West Pacific, the East Asia monsoon is weaker, and the subtropical high in the Western Pacific Ocean moves southward. As a result, the main monsoon rain band in China during the summer rainy season shifts toward the south and stays to the south of the Yellow River Basin. An increase in precipitation in the Yangtze-Huaihe River Basin can be expected. In the north of China, especially in the Northern China area and in the Yellow River Basin, there is reduced precipitation (Huang, 1990; Liao and Zhao, 1992; Zhao, 1996; Liu and Ding, 1992; Chen, 1995).
- ✍ In the autumn and winter of El Niño years, it will be drier in most parts of north China and wetter in most parts of south China (**Figure 4**).

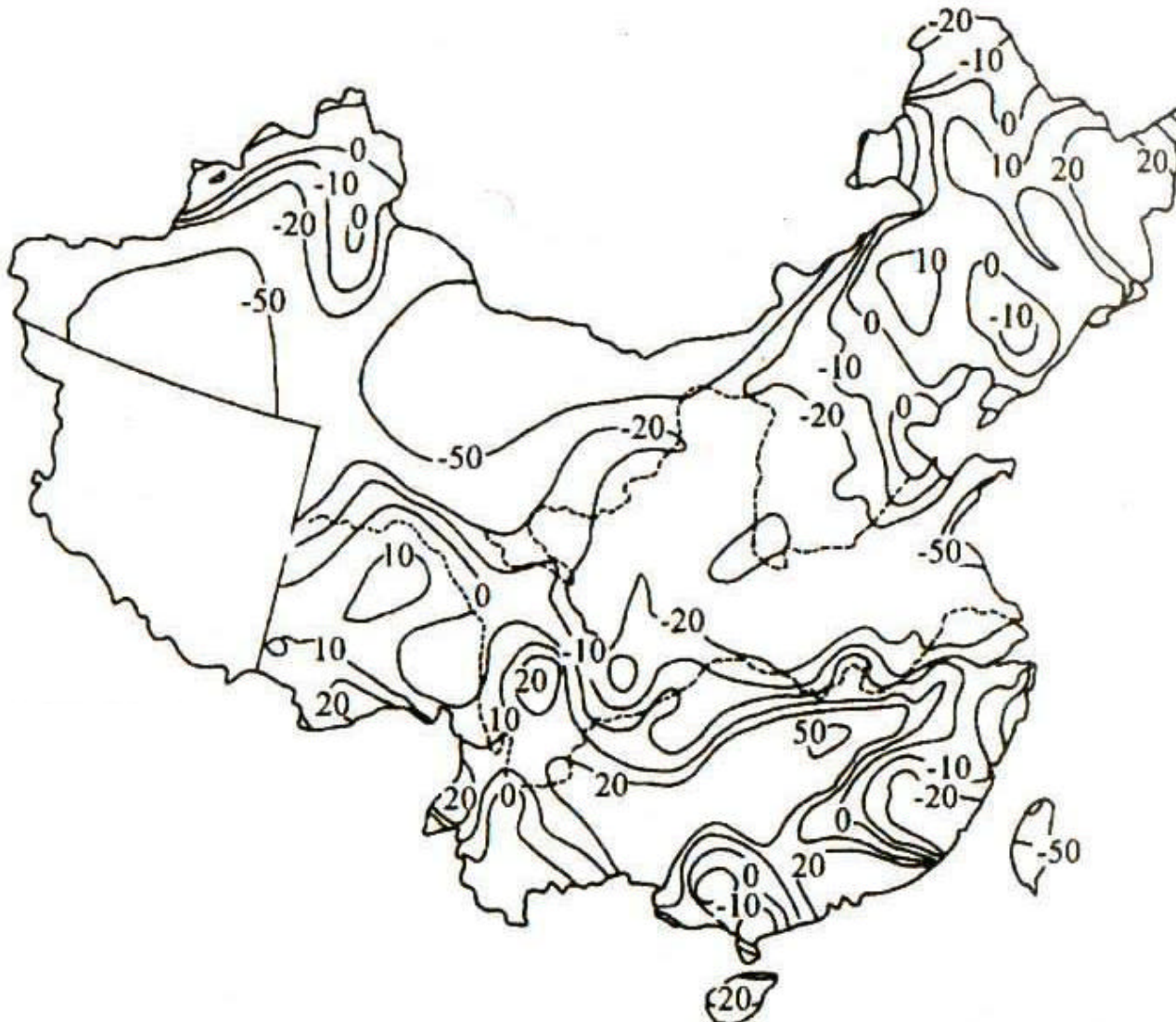


Figure 4: The distribution of abnormal precipitation in autumn of El Niño years.

The Tibetan Plateau receives above average snow. The Meiyu² normally occurring in May will be delayed in the middle and lower reaches of the Yangtze River.

☞ In El Niño years, Chinese winters are warmer and summers are cooler. For example, warm winters appeared in 90 percent of El Niño years since 1951 (**Figure 5**).

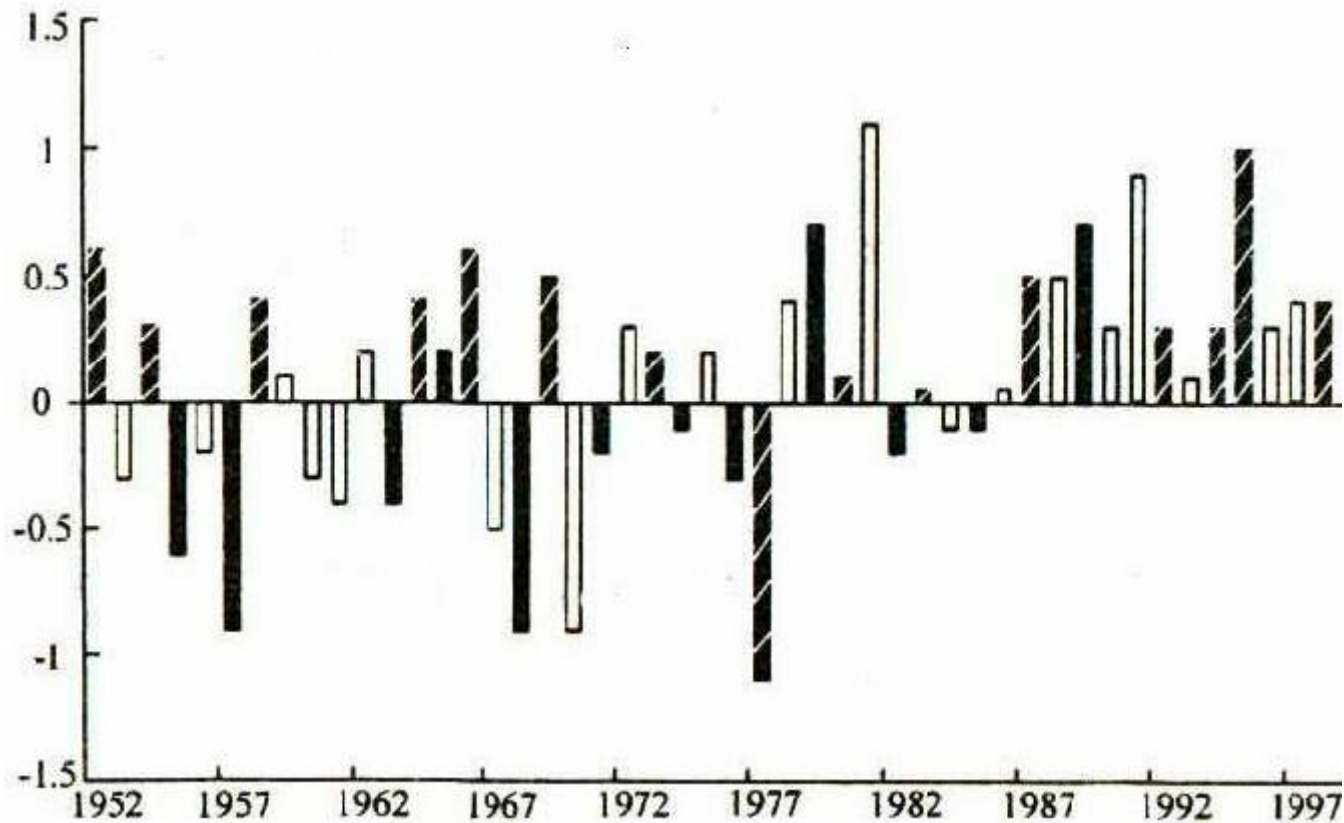


Figure 5: Deviations of the temperature grades in winter (white columns represents normal years, black columns represent La Niña years and lined columns represents El Niño years; the values above the zero line represent high temperature, and the values below are the opposite).

In addition, since 1951, several cold summer years in Northeast were related to El Niño years. This relationship has changed since 1980s when the global climate became warmer. Although the occurrence of El Niño events increased since the mid 1970s, the appearance of cool summers decreased in the Northeastern China. During the El Niños in the 1990s, there were no cool summers in China.

✍ In El Niño years the number of typhoons, which form in the northwestern Pacific Ocean and the South China Sea, is reduced as well as the number of typhoon landings in China. The relationship between typhoons and El Niño events is more direct than the two relations noted above. The correlation coefficient between the number of typhoons in the northwestern Pacific and the number of landings in China and SSTA in the global ocean show that few typhoons occur during the ENSO events (Zhao Zongci, personal communication). An above average number of typhoons occurs in La Niña years. However, currently there are no studies on the strength, landing time and location in China of typhoons related with El Niño events. The damages caused by typhoons in both El Niño and La Niña years have not been studied yet because of the lack of reliable and useable data.

Although some climate anomalies in China do have statistically significant relationships with El Niño, the mechanisms behind those relationships are still not clearly understood. Particularly in the context of global warming, scientific uncertainty surrounding these mechanisms is increasing. For example, during the El Niño events in 1969, 1972 and 1976, temperatures in summer were well below normal in Northeast China, which contributed a great loss in crop production. Summer temperatures were only slightly below normal in the 1982-83 and 1986-87 events and their impacts were weak. During the period of the prolonged El Niño event from 1990 to 1995 and the

strong one of 1997-98, low summer temperatures did not occur. This has happened before; the 1896, 1899-1900, 1925-1926, 1963 and 1965 El Niño events did not lead to low summer temperature in the Northeastern China.

The relationship between El Niño and Chinese summer precipitation is complex and unstable. For example, 1931, 1954 and 1991 are the three strongest Meiyu years in the 20th century. In these years, big floods occurred in the Yangtze River Basin, and caused huge damages to human life and property. These years, however, are not El Niño years. The 1982-83 El Niño event was one of the strongest events in the 20th century besides the 1997-98 El Niño event. But in 1982 and in 1983, there were no major climate disasters in China. At the end of the 1997-98 El Niño event, there was the great flood in the summer of 1998.

In summary, although El Niño can lead to extreme climate events such as floods and droughts somewhere in China, more scientific work is needed to confirm the proposed teleconnections. At the current time, there are too many uncertainties to reach any solid conclusion about El Niño impacts on China's climate.

3.2 CLIMATE ANOMALIES RELATED TO THE 1982-83 EL NIÑO

In 1982 and 1983, there were no significant climate-related hazards in China. No severe floods and droughts occurred and the number of tropical storms was normal. One exception was in the Northeastern China where low temperature and cold problems appeared in summer.

3.3 WHAT WERE THE CLIMATE-RELATED PHYSICAL AND SOCIAL IMPACTS OF THE 1997-98 EL NIÑO IN CHINA? WHAT IS THE RELIABILITY OF THOSE ATTRIBUTIONS?

3.3.1 The physical impacts

During 1997 and 1998, anomalous climate in China included an unremitting heat wave and dryness in North China, dramatic heavy snowstorms on the Tibetan Plateau, and the Great Flood of the Yangtze River. The number of typhoons formed in the Western Pacific Ocean and making landfall in China was less than normal. All of these anomalous climate phenomena were considered to have been related to the 1997-98 El Niño event.

Since March 1997, the SSTs in the equatorial East Pacific had become increasingly high. Based on historical records, this anomalous condition in the Pacific could have led to anomalous climate conditions in China as suggested in **Table 3**, which lists an index for the standard SST departure for March-August in the Niño-3 region from 1951 to 1998. In the 14 strongest years (i.e., when the index summation was greater than 200), the summer atmospheric circulation and the climate of China showed significant anomalies. According to the previous studies, when the ENSO event begins in spring and summer, the tropical atmospheric circulation changes rapidly. The Walker Circulation is weaker and shifts eastward. The position of the subtropical high over the western Pacific shifts southward. As a result, in the middle of China the rainfall was stronger in summer and the temperature was lower. The number of typhoons making landing in China decreased too.

Table 3. The atmospheric circulation in summer and the main anomalous climate of China in the years when SSTs increase anomalously during spring and summer

Year	Standard SST Index in NIÑO-3	Major Climate Anomalies		
		Flood or Drought	Anomalous Temperature	No. of Typhoon Landfall
1983	884	Floods in mid and low reaches of the Yangtze River	Frost damages in Northeast China	5
1997	781	Droughts in South China	Heat waves in South China	4
1987	708	Floods in mid and low reach of the Yangtze River	Low temperature in Northeast China	5
1992	624	Droughts in most parts of China		8

1957	558		Frozen damages in Northeast China	5
1993	541		Cool summer	7
1969	469	Floods in mid and low reaches of the Yangtze River	Frozen damages in Northeast China	5
1972	462	Droughts in South China	Frozen damages in Northeast China (6
1965	417	Huaihe River Flood Droughts in South China		8
1991	283	Yangtze-Huaihe River Basin Flood Drought in North China and to south of the Yangtze River		6
1963	251	Great floods in the North China Severe droughts to the south of the Yangtze River and in the middle reaches of the Yellow River		7
1953	235			7
1994	223	Great floods in the South China	Frozen damages in the South of China	12
1976	211		Frozen damages in Northeast China	6

Table 3 shows that the impacts of ENSO on the circulation at the middle and high latitudes and on the climate of China as a result of teleconnection are very complicated when it comes to attribution. The climate anomalies of China could be caused by many other factors. The rate of development and the intensity of an ENSO extreme event, however, was a very important consideration, when Chinese scientists made their predictions on climate anomalies in China during recent years (Cheng, 1998). For example, by including the ENSO signal in various forecasting models, the National Climate Center was able to claim a successful forecast for the anomalous summer precipitation in 1998.

The 1997-98 El Niño began in May 1997, and reached its peak in November and December (**Figure 6**).

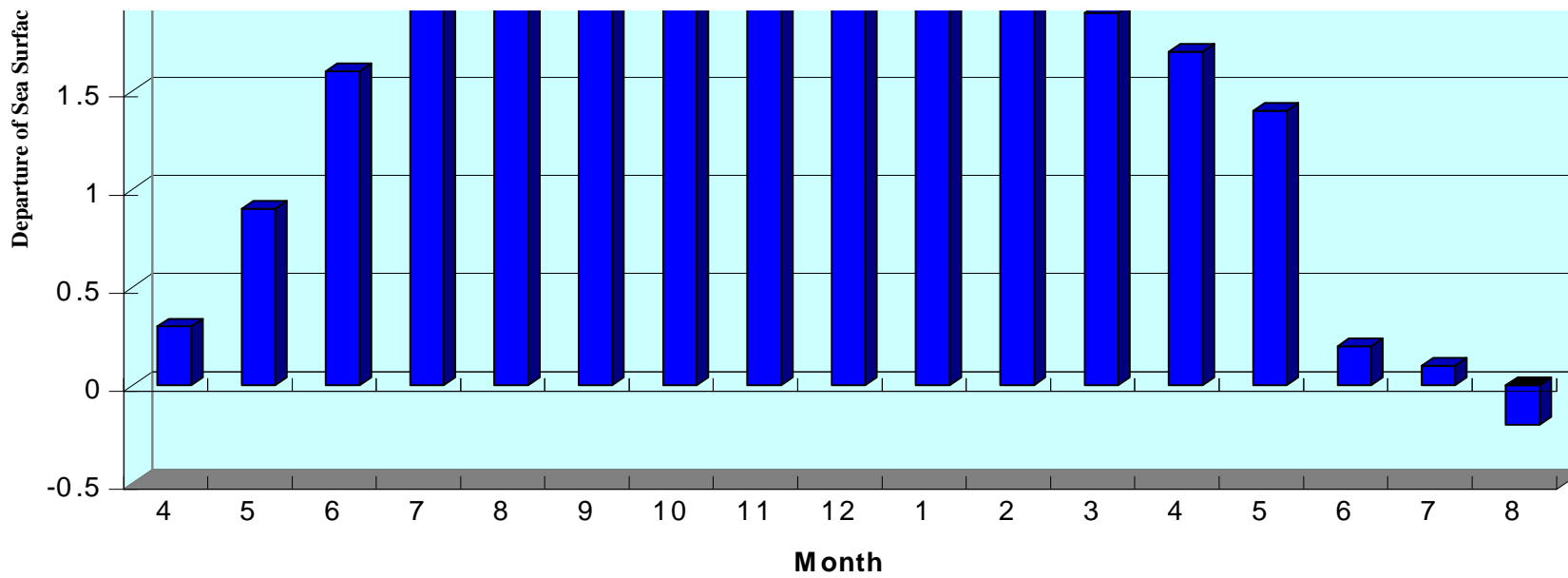


Figure 6: The monthly change of sea temperature departure from average in Nino3 from April 1997 to August 1998

Although the strength of this strong El Niño declined in the first half of 1998 and the SSTs in tropical Pacific Ocean were back to normal in June 1998, this El Niño had a great impact on summer precipitation in China. It was one of the key factors causing the great amount of precipitation in the Yangtze River Basin in the summer of 1998.

Figure 7

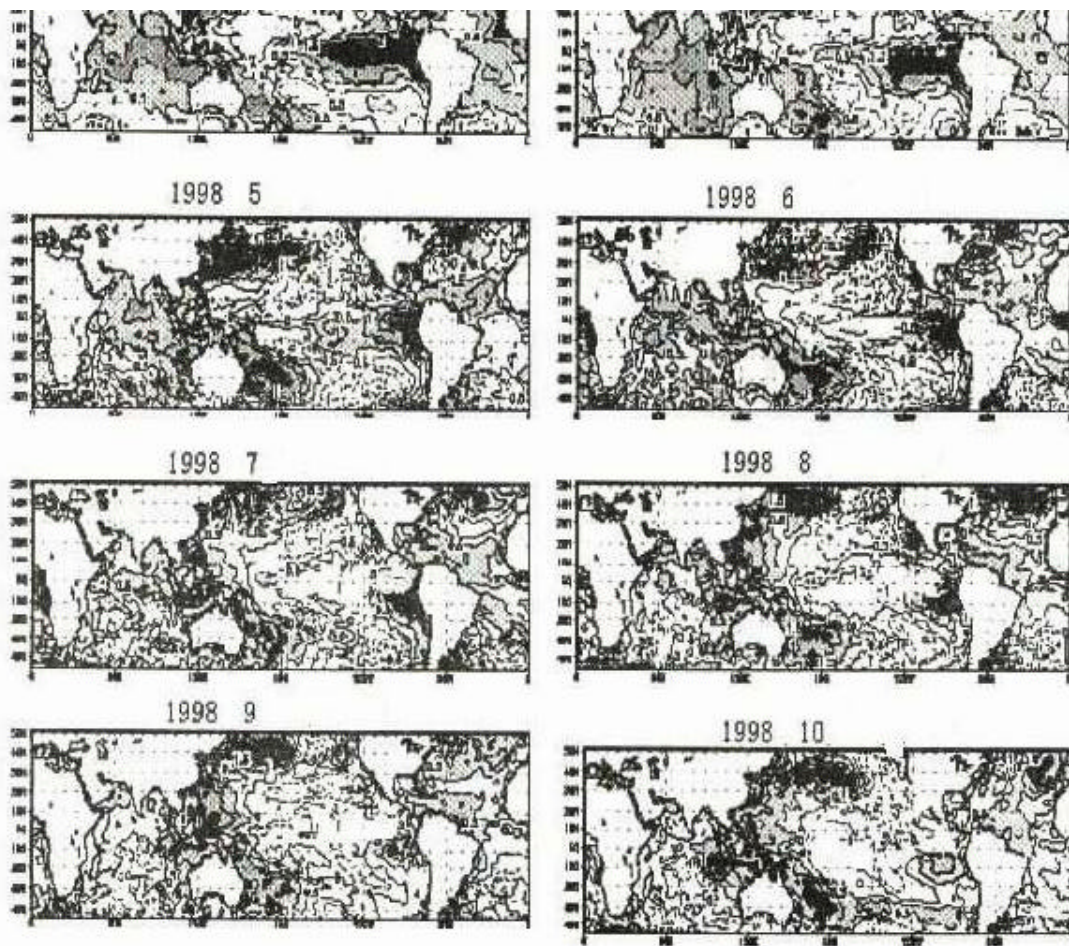


Figure 7: Monthly variations of global SST anomalies from January 1998 to October 1998

shows the monthly variation of the global SST departures from January to October 1998. The SSTs in the equatorial Pacific had a positive departure from January to April, began to descend in May, changed into a negative departure from average after June, and gradually entered the La Niña mode. In the Western Pacific, the most distinct feature was that the SST anomalies were positive in the South China Sea and the inshore sea area of the east of China from January to April. When the SST anomalies in the Indian Ocean turned negative, the sea around the southern China still had distinctly warmer SSTs. The east part of China was encompassed by warm seawater which had appeared since September 1997. The heating from the inshore sea in summer reduced the thermodynamic difference between sea and land and, in turn, the Asian summer monsoon weakened. As a result, the main rainfall band in summer was very stable in the Yangtze River Basin. These circulation anomalies are the main reason for the climate anomalies of China, and they are influenced by 1997-98 ENSO event and other factors.

In addition to ENSO's impacts, there were some other important factors that played an important role in the climate anomalies of China.

1. *Heavy precipitation in the Qinghai-Tibet Plateau in winter and spring*

From December 1997 to February 1998, the amount of snowfall was excessive in most parts of the Qinghai-Tibet Plateau. There were record-setting snowstorms in many places. The anomalous atmospheric circulation continued until April 1998 (**Figure 7**) with strong meridional circulation and a stable blocking high. The ridge of the subtropical high over the Western Pacific was strong but located more southward than normal and, as a result, the location of the main summer rain band in China was southward.

2. The anomalous Asia monsoon

Figure 8

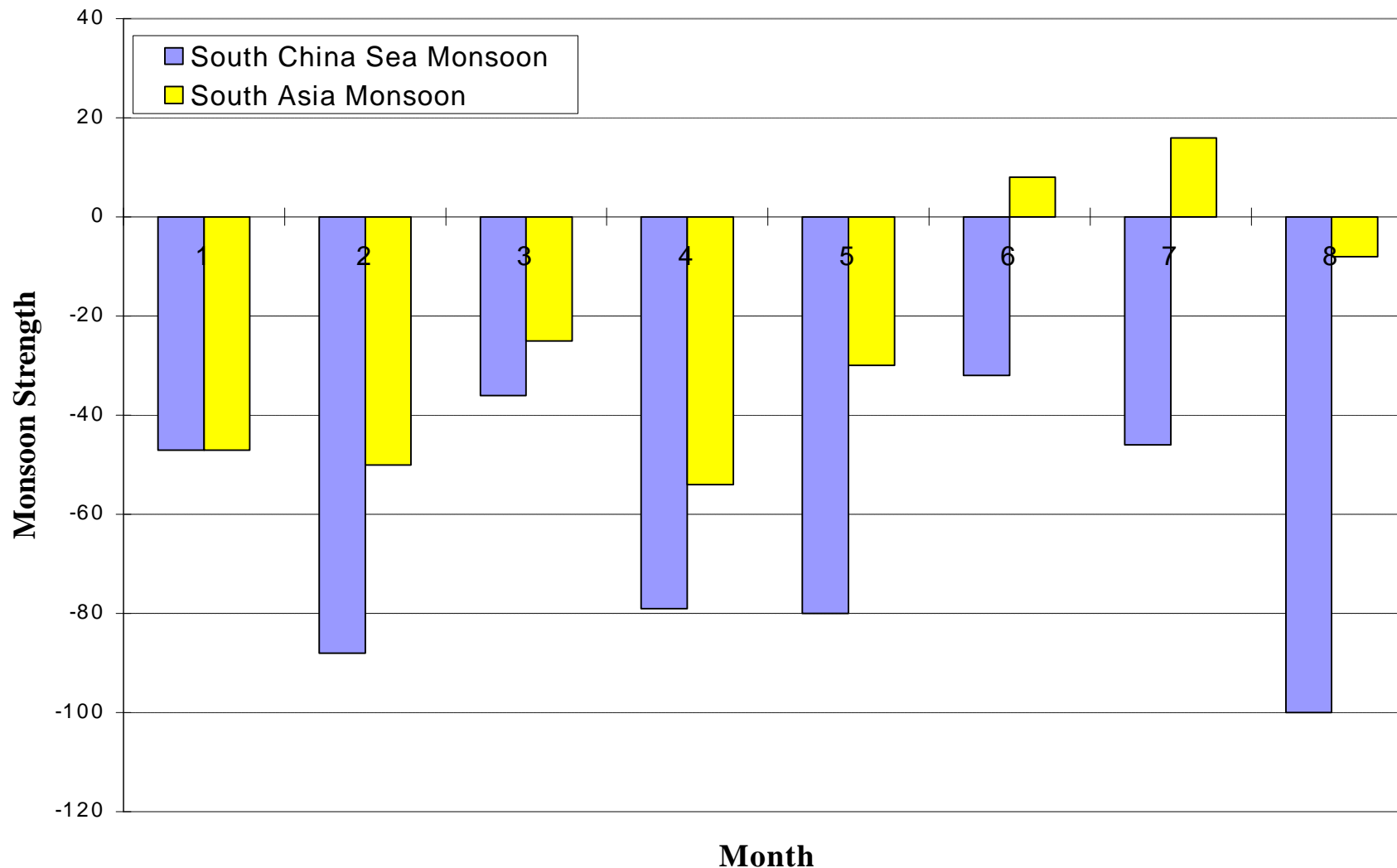


Figure 8: The monthly departure figure for the strength of South China Sea Monsoon and South Asia Monsoon from January 1998 to August 1998

shows the monthly departure of the strength for the South China Sea monsoon and the South Asia monsoon. **Figure 8** shows that the South China Sea monsoon had negative departure (weak) from January to August. The South China Sea monsoon in April, May, July and August is the weakest since 1980. The South Asia monsoon had negative departure too, except in June and July. This indicates that both the South Asia monsoon and the South China Sea monsoon were weak in 1998, which led to the southern shift of the summer location of the subtropical high in the Western Pacific. Hence, the major rain band located in the Yangtze River Basin and the south area of the Yangtze River Basin.

3. The blocking highs in the mid- and high latitudes

The 500hPa blocking highs in the mid- and high latitudes, especially in East Asia, are the main circulation systems influencing the temporal and spatial distribution of precipitation in China. Previous studies indicate that Okhotsk, Baikal and Ural are the three places where the blocking highs often form. When there are the blocking highs in East Asia in summer, the west wind in middle latitude divides into two branches. Meanwhile, the frontal zone shifts to the south and the location of the subtropical high in the Western Pacific Ocean moves to south. Usually, when the blocking highs become established in Okhotsk or Baikal in summer, the Yangtze River Basin receives more than normal precipitation in summer.

Figure 8 is the variation of the mean circulation index in 500 hPa in Asia from January to December 1998. The meridional (West-East) circulation developed from June to August and the latitude (South-North) circulation developed from September to December. The anomalous circulation caused higher than normal temperatures in most areas of China in spring, autumn and winter. Moreover, the development of anomalous circulation in summer led to excessive rainfall in the Yangtze River Basin, the Nengjiang River Basin and the Songhuajiang River Basin.

4. The anomalous movement of the subtropical high over the West Pacific Ocean

Figure 9

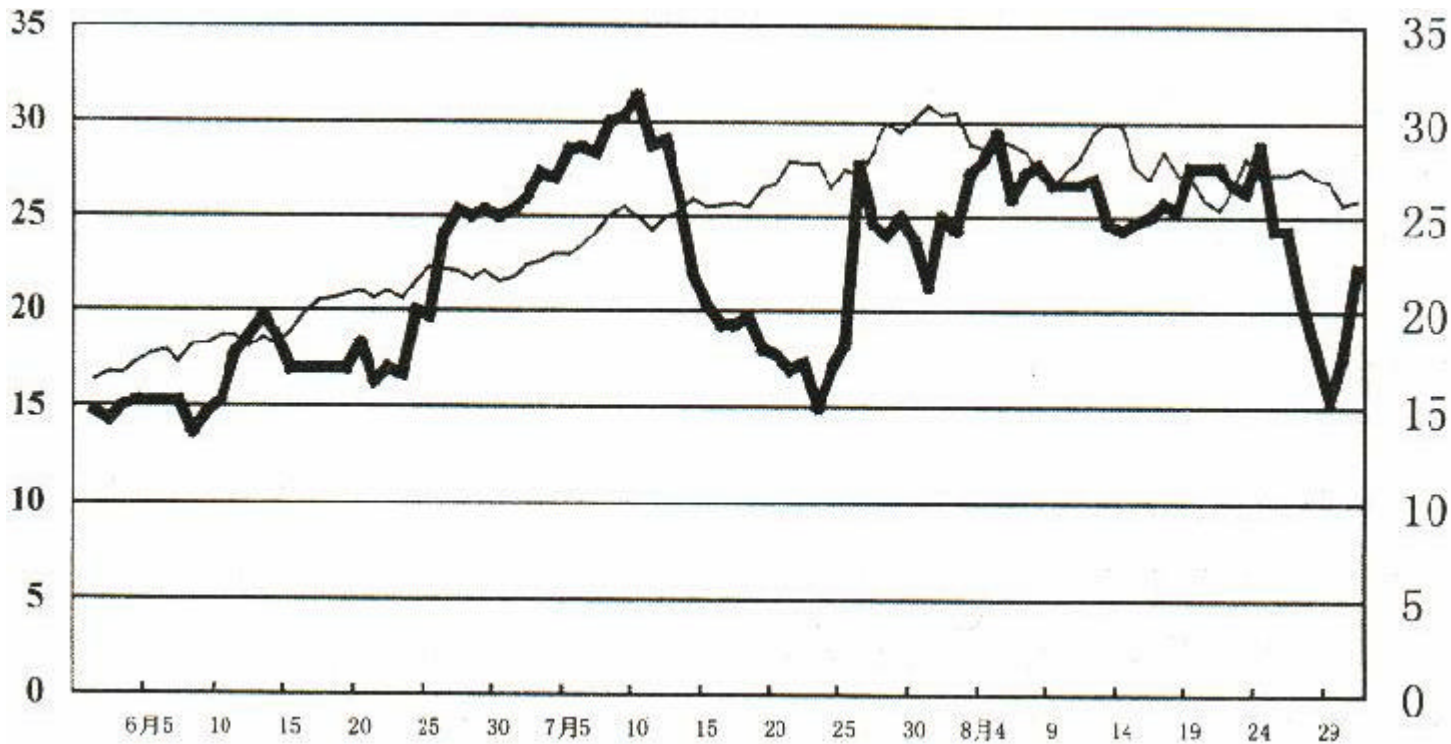


Figure 9: Climate-mean position and the daily variations of positions of the ridge of the subtropical high in the West Pacific. (The thick line represents the subtropical ridge in 110--130⁰E, and the thin line represents the average subtropical ridge from 1976 to 1996).

is the comparison between climate mean and daily movements of positions of the subtropical high in the West Pacific. Clearly, the subtropical high jumped to the south from the mid-June to the end of June. During these twenty days, continuous rainfalls occurred in the Yangtze River Basin, especially in the north and upper streams of the Yangtze River Basin with very strong precipitation. From mid-July to early August, the subtropical high inclined to the south for an anomalously long period. It even receded to 15N at one time, which is rare in history. Then, the second phase of anomalous summer rainfall in the Yangtze River Basin began. **Figure 9** indicates that the location of the subtropical high remained to the south during the whole summer except for the third 10-day period of June to the second 10-day period of July. So the last anomalous shift to the south of the subtropical high is another important reason for the anomalous abundance of summer precipitation in the Yangtze River Basin at that time.

5. The weak equatorial convergence zone

In the summer of 1998, the equatorial convergence zone was unusually weak, and the number of typhoons was well below average. Only 3 typhoons landed in China in 1998, a year with the fewest typhoons in history. The first time a tropical storm landed in China in 1998 was on August 4, the latest time in history. It is the direct result of the weak Asian monsoon and the deflection to the south of the subtropical high in the West Pacific. Under these conditions, the eastward deflection of air current prevailed over a large area of the tropical West Pacific Ocean and as a result, the southwest monsoon was unable to reach the tropical West Pacific. The equatorial convergence zone formed by eastward deflection of air currents and the southwest flow was, thus, very weak or did not exist at all. The anomalies in the equatorial convergence zone which is the main "birthplace" of typhoons allowed very few typhoons to form in the western Pacific Ocean.

Based on the above discussion, there is clear evidence that the El Niño event in the 1997-98 winter and spring led to the anomalous atmospheric circulation over China, which, in turn, caused many climate anomalies around the country. Unfortunately, there are still many uncertainties in the relationship between the ENSO and the occurrence of the atmospheric circulation in China. More scientific research is needed along with an improved ocean observation network and improved atmosphere-ocean coupled numerical models.

3.3.2 Impacts of the 1997-98 ENSO on society and the economy

In 1997 and 1998, many weather and climate anomalies occurred in China. They greatly affected daily life and economic development of society and the economy. The floods around the country caused great loss in both property and human lives. Meanwhile, droughts also occurred and greatly damaged agriculture. The following information relates to some impacts of weather and climate anomalies during the 1997-98 El Niño.

1. Nation-wide damage caused by excessive rainfall and flooding

In the summer of 1998, a major flood occurred in the Yangtze River Basin, which caused great damage to human lives, property and the national economy.

Since the beginning of the winter in 1997, the subtropical high in the Western Pacific Ocean developed anomalously, and its intensity was the strongest since 1949. Intense rainfall events occurred frequently in the south of the Yangtze River Basin. The amount of precipitation was much more than the climatological average. In many places, the amounts of precipitation broke historical records. In this region, some rivers and lakes exceeded the cautionary water level reaching the highest water levels in regional history. Rare winter floods occurred.

From mid-November in 1997 to early March in 1998, there were continuous rains and snows in most parts of the Southern China. The total amount of precipitation ranged from 300 to 600 mm in most places. South of the Huaihe River was 1.5 times more than climatological mean. Recorded precipitation at most weather stations in this region was the largest rainfall for the same period during the past 40 years (**Figure 10, Figure 11, and Figure 12**).

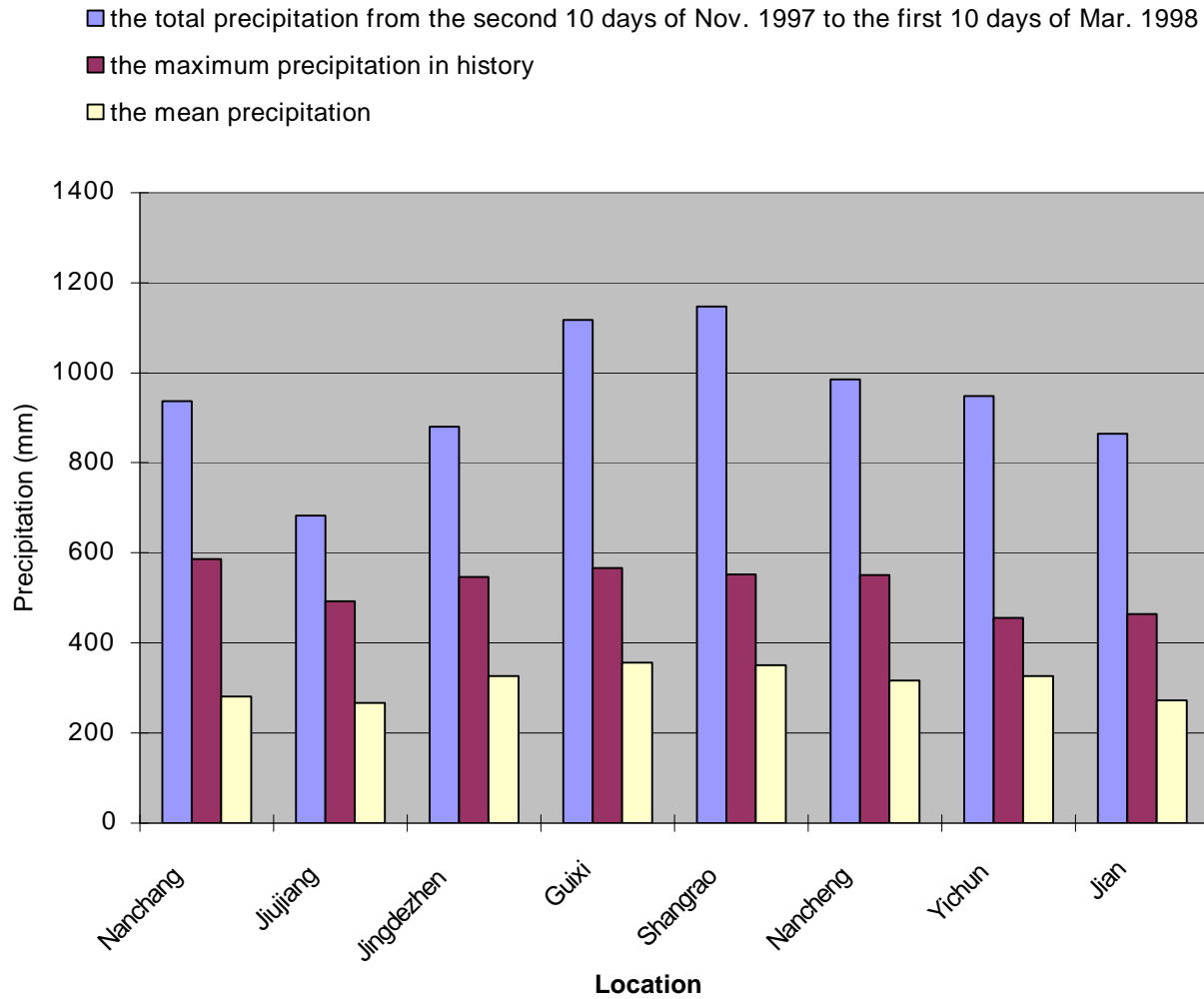


Figure 10: The comparison between the maximum precipitation in history and the total precipitation from the second 10 days of Nov. 1997 to the first 10 days of Mar. 1998 in Jiangxi Province

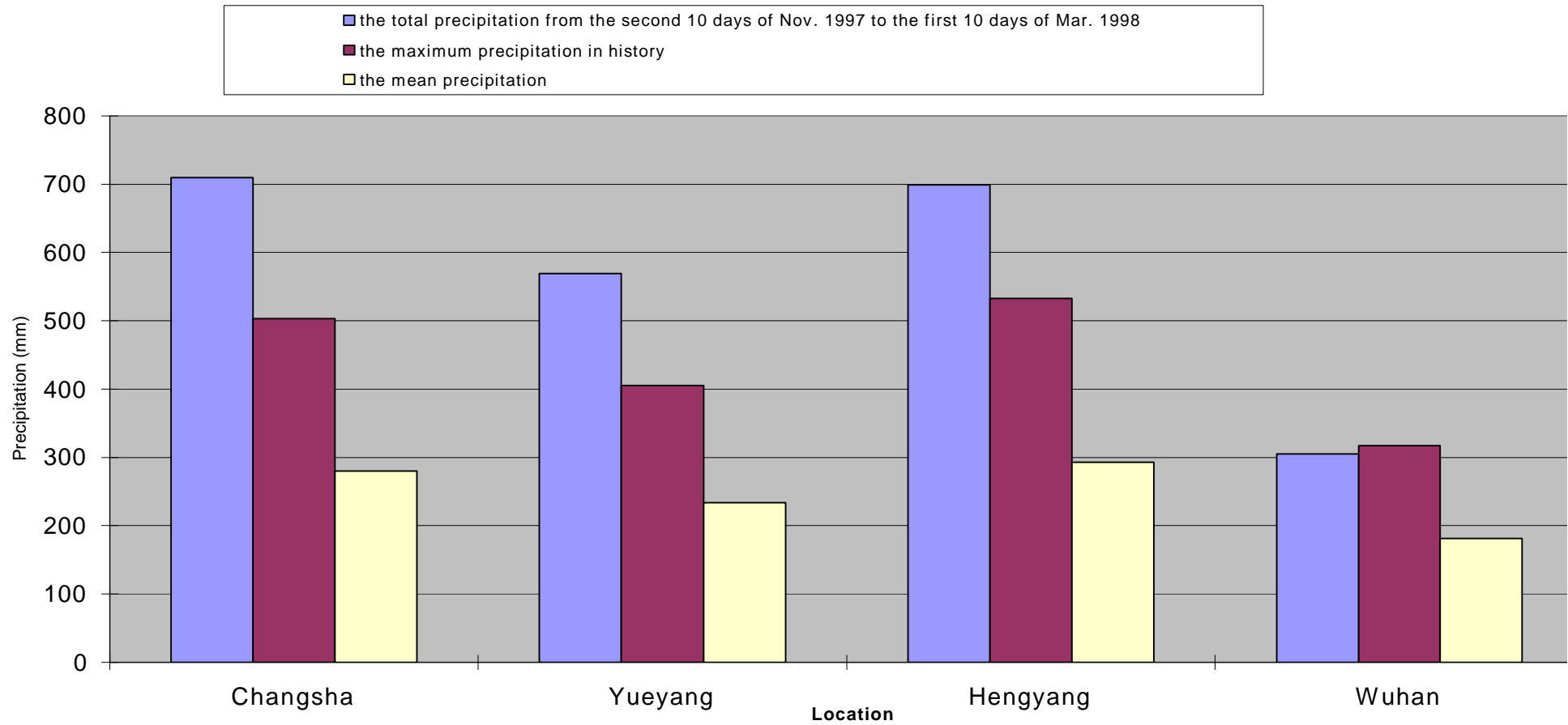


Figure 11: The comparison between the maximum precipitation in history and the total precipitation from the second 10 days of Nov. 1997 to the first 10 days of Mar. 1998 in Hunan and Hubei Provinces

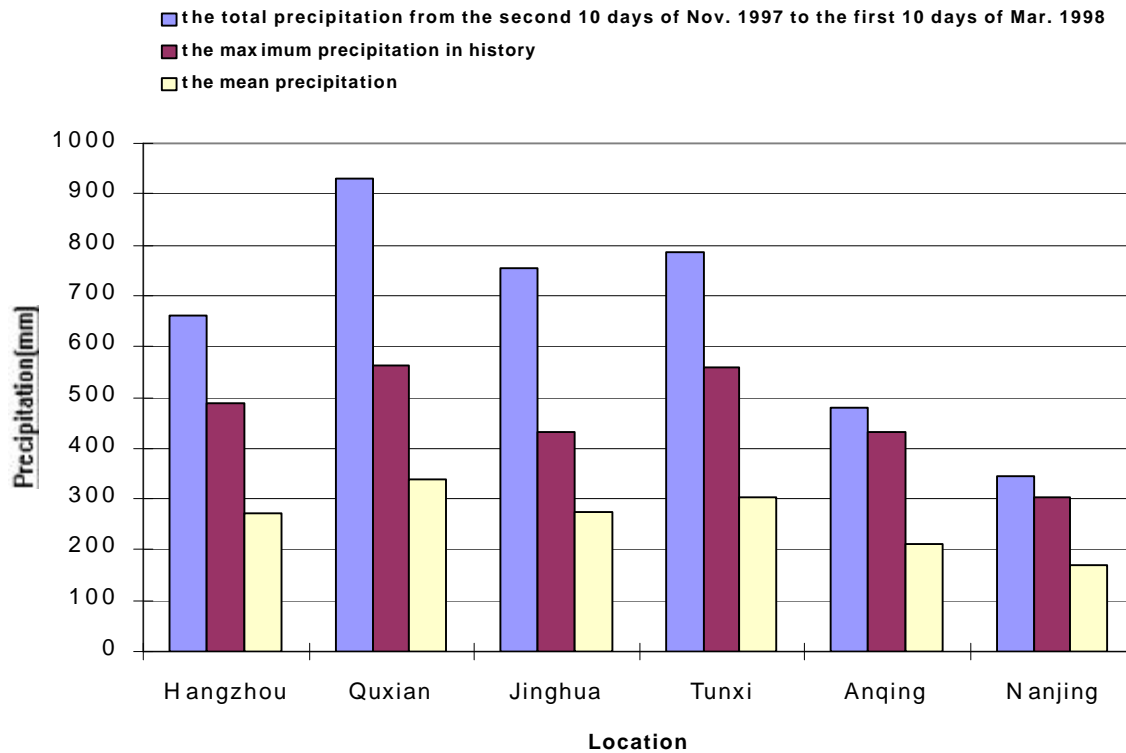


Figure 12. The comparison between the maximum precipitation in history and the total precipitation from the second 10 days of November 1997 to the first 10 days of March 1998 in several cities in the lower reaches of Yangtze River

Continuous rainfall led to the rising water level for some rivers and surpassed critical levels. Wintertime flooding occurred in some rivers. For example, the Xiangjiang and Ganjiang Rivers in Hunan Province, the Mingjiang River in Fujian Province, the Beijiing River each had flooded. On 16 March, 1998, the water level at Hankou (a city in the middle reach of the Yangtze River) reached 21.33 meters, which was the highest value ever recorded at this station. Spring flooding in Jiangxi and Hunan provinces had occurred one month earlier.

In early November 1997, it was warm in Zhejiang Province located on the east coast. Based on the records of eleven weather stations in Zhejiang, there was no rain in the whole province for a 70 days period before mid-November. After that there were endless overcast and rainy days until the end of the year. Continuous rainfall occurred from November 12 with total amount of 1.5 to 3.5 times more than usual in all locations. The rainfall in Quzhou, Longquan, Jinhua, Ningbo, Chenzhou and Zhoushan set their maximum values for the past 40 years. For example, the rainfall in Quzhou for November was 290mm, which had never been seen in the instrument-recorded history of Zhejiang in winter.

In the last twenty days of November 1997, south China was under the influence of the warm moist air from the southwest, resulting a rainy weather in some areas. Rainfall amount increased significantly. Starting on November 24, in northern Jiangxi Province and in the middle of Zhejiang Province, two rainstorm events occurred. The weekly rainfall totally reached 100-200mm which greatly exceeded the maximum on record.

The rainfall for November 1997, in Jiangxi Province exceeded the maximum amount in history. The rainfalls in most areas were three times as much as the climatological averages. On November 25, hail and rainstorms affected Zixi, Nancheng and Ruijin counties. On November 28, the water levels of some segments of the Xingjiang River in Northeastern Jiangxi Province exceeded a critical level. It was rare in the history of Jiangxi Province. Rain continued to fall in the southern part of the Yangtze River Basin in December. The precipitation for the entire winter in many places of Jiangsu Province was far greater than that in a normal year (**Figure 13**).

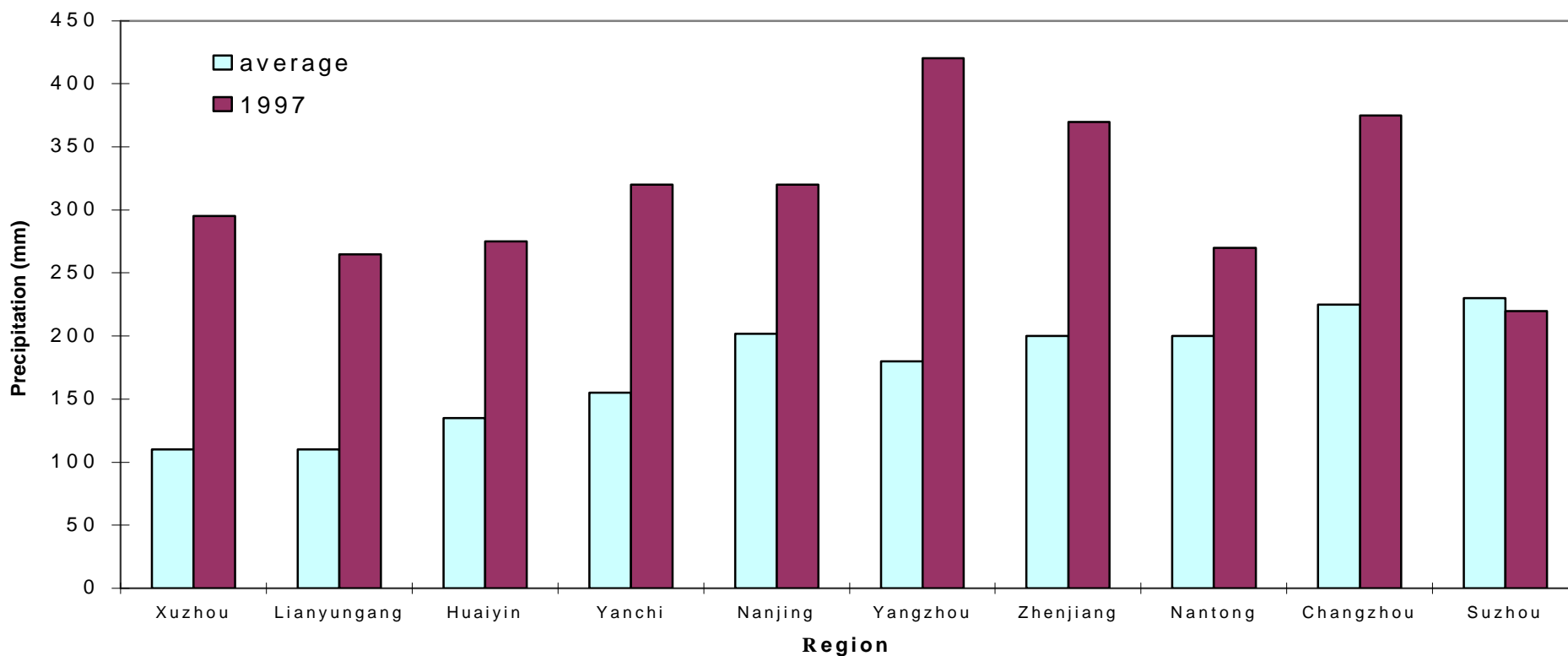


Figure 13: Comparison between the winter precipitation in 1997 and in average year in Jiangsu Province

In mid-January 1998, heavy snow fell in most areas of Northern China with severe rainfall in the Southern China as shown in **Figure 14**.

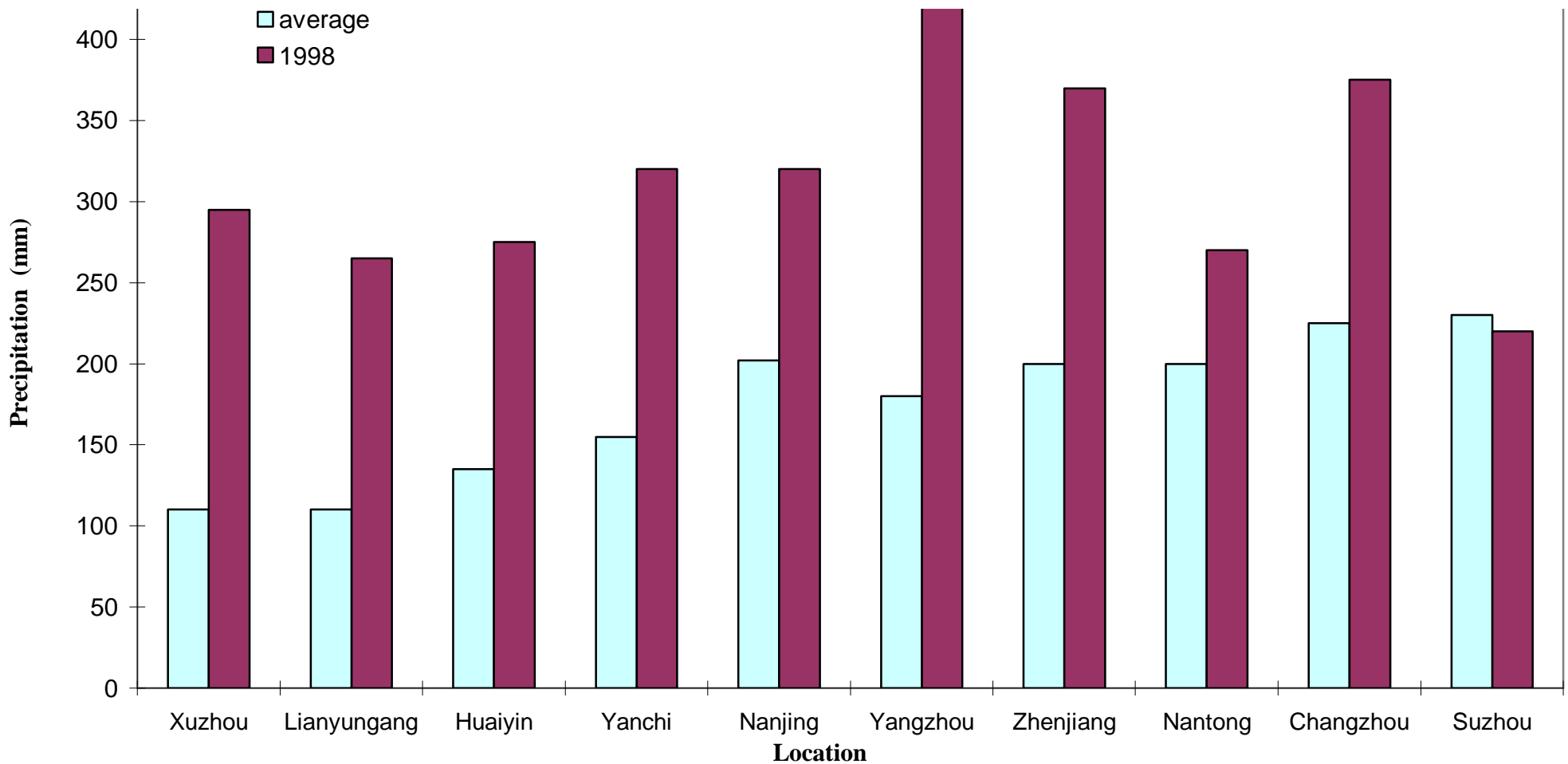


Figure 14: Comparison between spring precipitation in 1998 and in average years in Jiangsu Province

In the spring of 1998, several strong cold waves hit China, and the crops were severely damaged by frost. Meanwhile, in most parts of South China, the rainfall lasted 20 days or so and led to flooding. The anomalous climate badly affected the growth of crops. The respiration of crops became difficult once the fields were covered in water for a long time. Moreover, crop diseases were aggravated. All these calamities adversely affected agricultural production.

In Jiangsu Province, agricultural output was reduced by about 28%. The total production of crops was 3.6 million tons less than the previous year, and the reduction was almost 30%. The percentage of crop reduction in 1997 was not only the largest year in recent history but also the second lowest-production year since 1980. This extremely wet winter also increased soil moisture to a very high level and delayed many flood control projects. The stage was set for summer floods.

During the main rainy season (June-August in China), the main centers of precipitation were in the Yangtze River Basin, west of Northeast China and the east of Inner Mongolia (**Figure 15**).

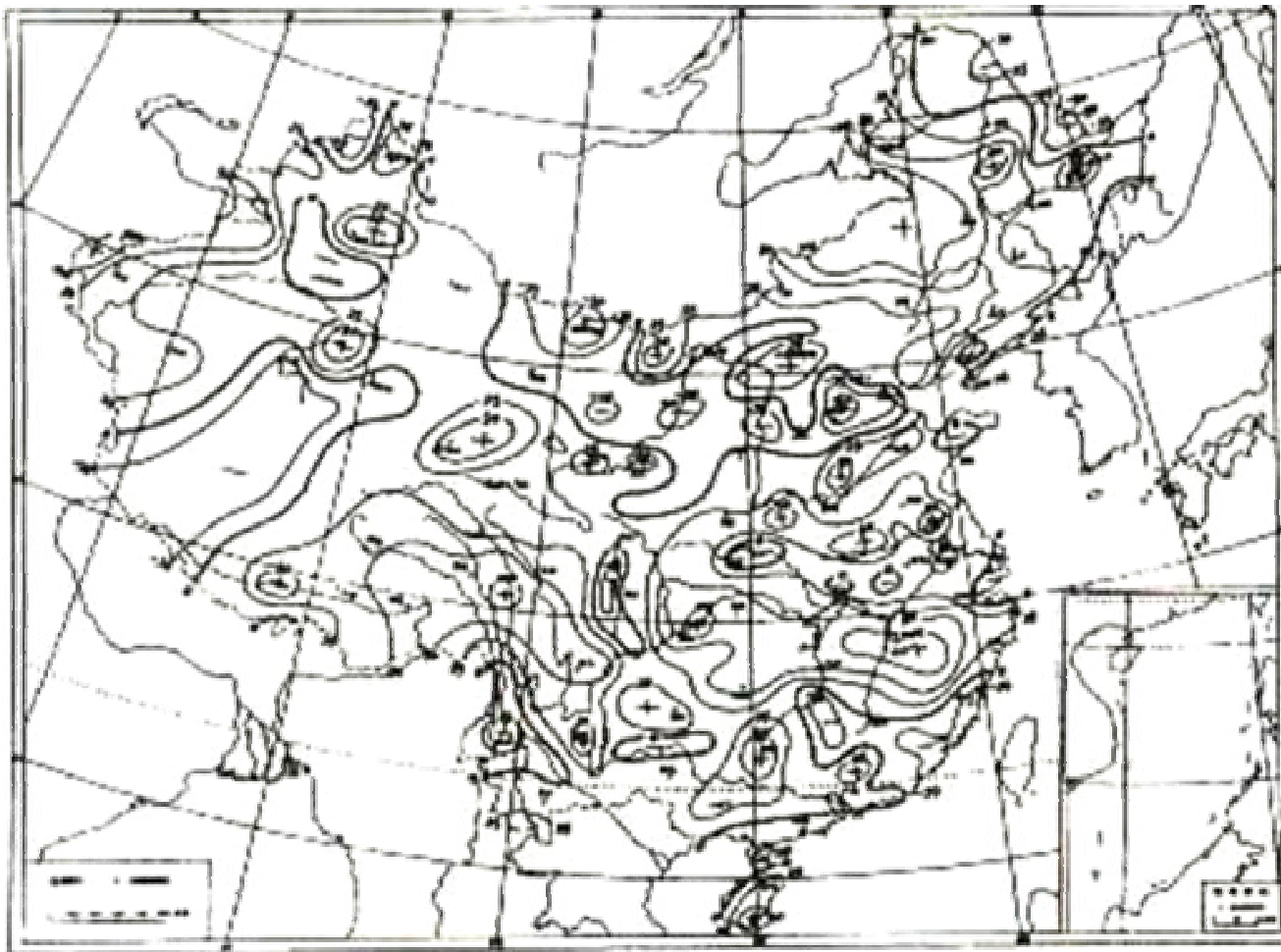


Figure 15: The distribution of precipitation departure (%) from June to August in 1998

Precipitation in most regions was well over the normal amount (Figure 16)

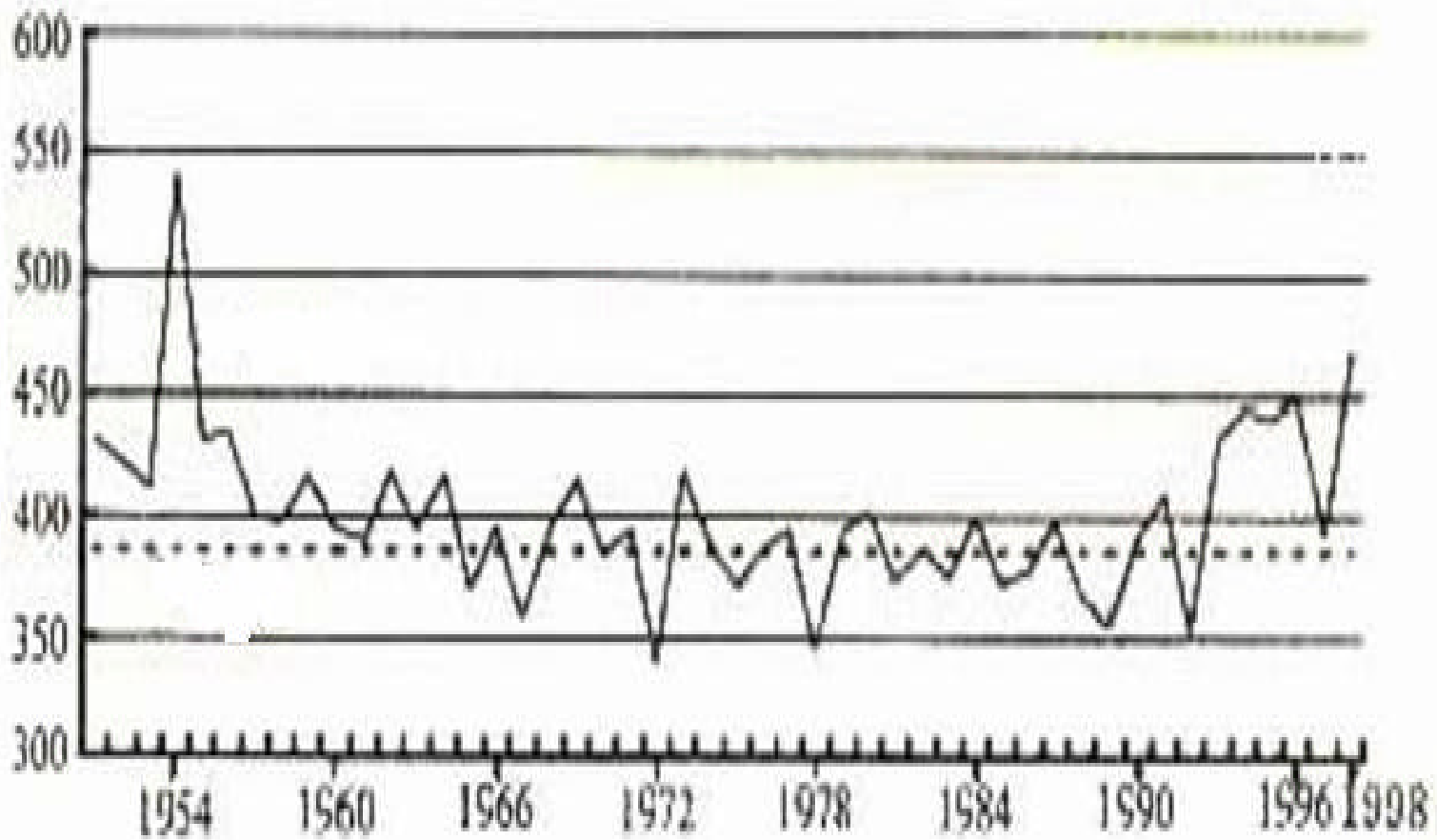


Figure 16: Trend (solid line) of the annual precipitation (mm) from June to August. The average is based on 336 stations in China from 1950 to 1998. The dashed line is the average value for the same period.

with continuous strong rainfall events in some places. For example, there were about 700-900 mm of rainfall north of the Yangtze River Basin, southwest of Hubei Province, in the City of Chongqing and to the east and southwest of Sichuan Province (**Figure 17**).

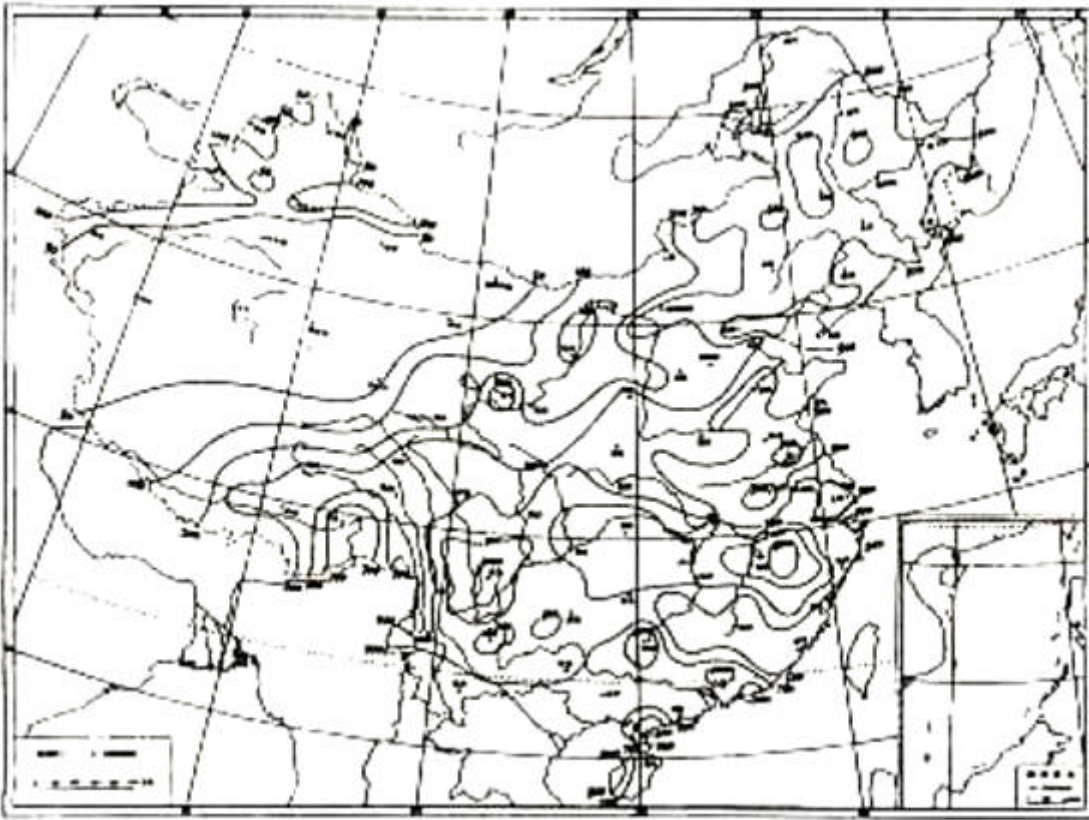


Figure 17: The distribution of precipitation from June to August in 1998. (mm)

Then, the great flood occurred in the whole Yangtze River Basin ranking second since 1950. Meanwhile, a record-setting great flood occurred in the Nenjiang and Songhuajiang Basins in the northeast of China. Moreover, the Xijiang River in the Zhujiang River Basin and the Mingjiang River Basin had unusual floods, too. It is rare in Chinese history that so many rivers and lakes had record-setting floods at the same time and lasted for a long period of time.

At the beginning of the summer of 1998, the subtropical high in the Northwestern Pacific was the strongest one on record. The convection band stayed stalled over the middle and lower reaches of the Yangtze River Basin starting in mid-June. Rainstorms and very heavy rainstorms hit this area continuously. Then, after moving northward for a short period of time, the subtropical high moved back to the Yangtze River Basin in mid-July bringing with it continuous, strong precipitation processes for a second time. The water from Dongtin Lake, Poyang Lake and many small rivers constantly flowed into Yangtze River. The water levels in the middle and lower reaches rose suddenly and at the same time. As a result, the great flood occurred in whole basin.

The whole process of the 1998 Great Flood in the Yangtze River Basin can be divided three periods:

- (1) The first period was from mid-June to the end of June. At the beginning of June, the Meiyu season started in the Dongtin Lake and the Poyang Lake. In mid-June, continuous rainstorms occurred in Jiangxi, Hunan, Zhejiang, Guangxi and Fujian provinces. In these provinces, the total precipitation from June 12 to June 27 ranged from 200 to 500 mm. To north of Jiangxi, north of Hunan, southwest of Zhejiang, south of Anhui, northwest of Fujian and northeast of Guangxi, the precipitation reached 600—900 mm, and some locations exceeded 1000mm. It was rare in the country's history that so much precipitation fell in so short time. The rainfall amount was about 2 times more than the average. Most places achieved a new maximum for their historical records (**Figure 18**, **Figure 19**).

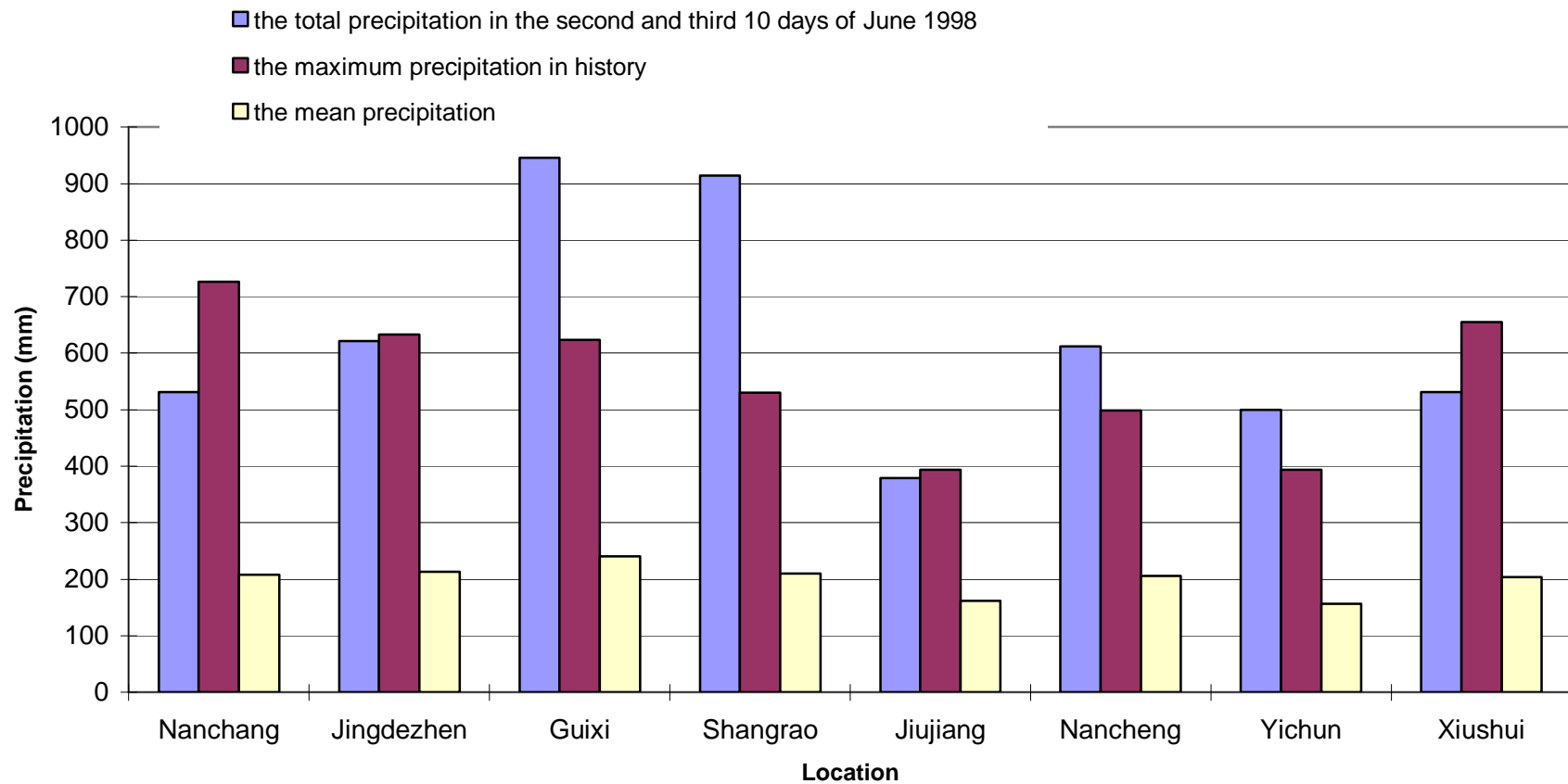


Figure 18: Comparison between the maximum precipitation in history and the precipitation from the second 10 days to the third 10 days of June 1998.

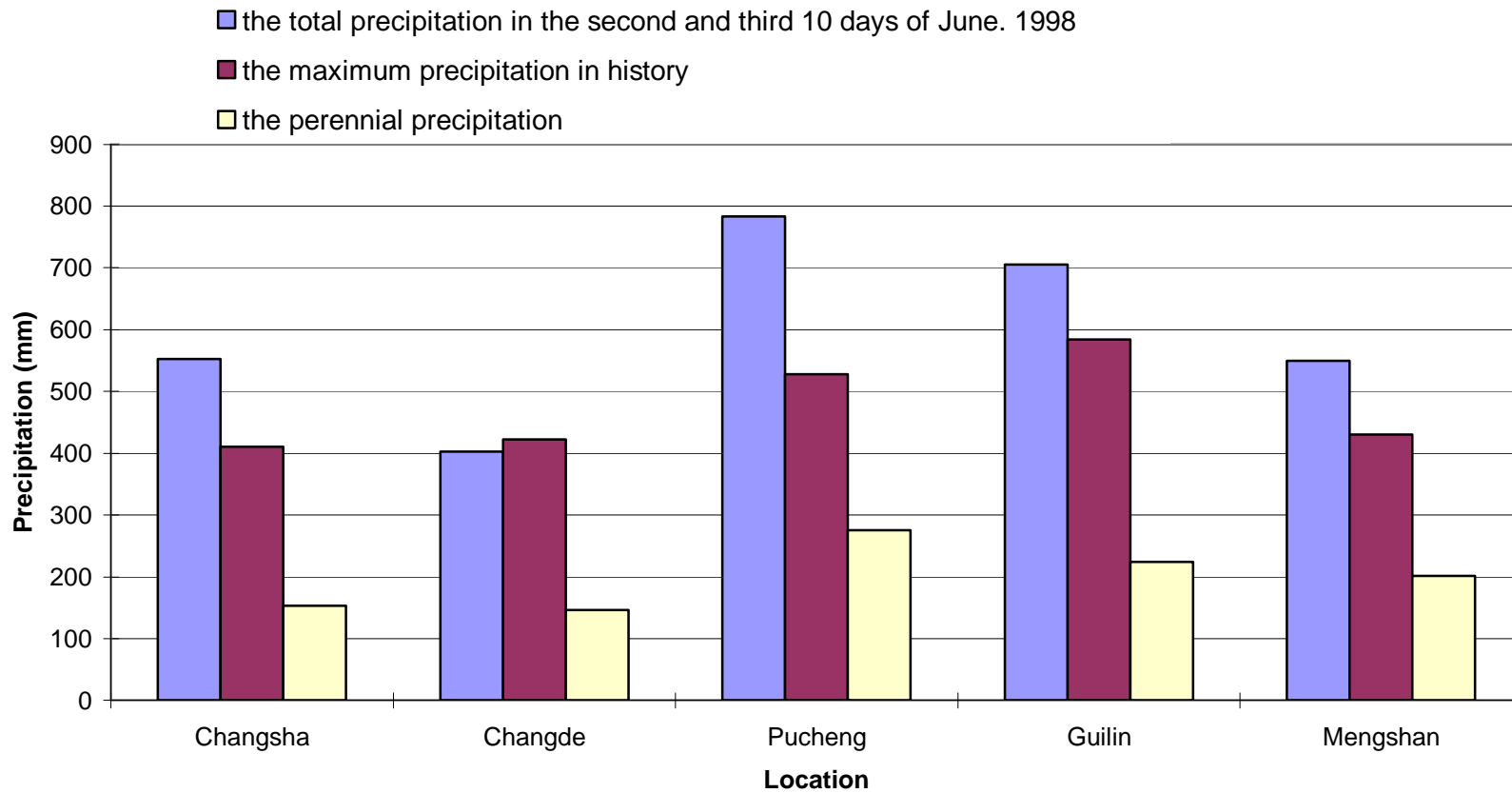


Figure 19: Comparison between the maximum precipitation in history and precipitation from the second 10 days to the third 10 days of June 1998 in several cities.

As early as in February, winter floods occurred in the Xingjiang River and the Fuhe Rivers, which made the water levels of rivers and lakes in the middle and lower reaches of the Yangtze River Basin dangerously high, later reaching their highest levels in history in summer (**Figure 20**).

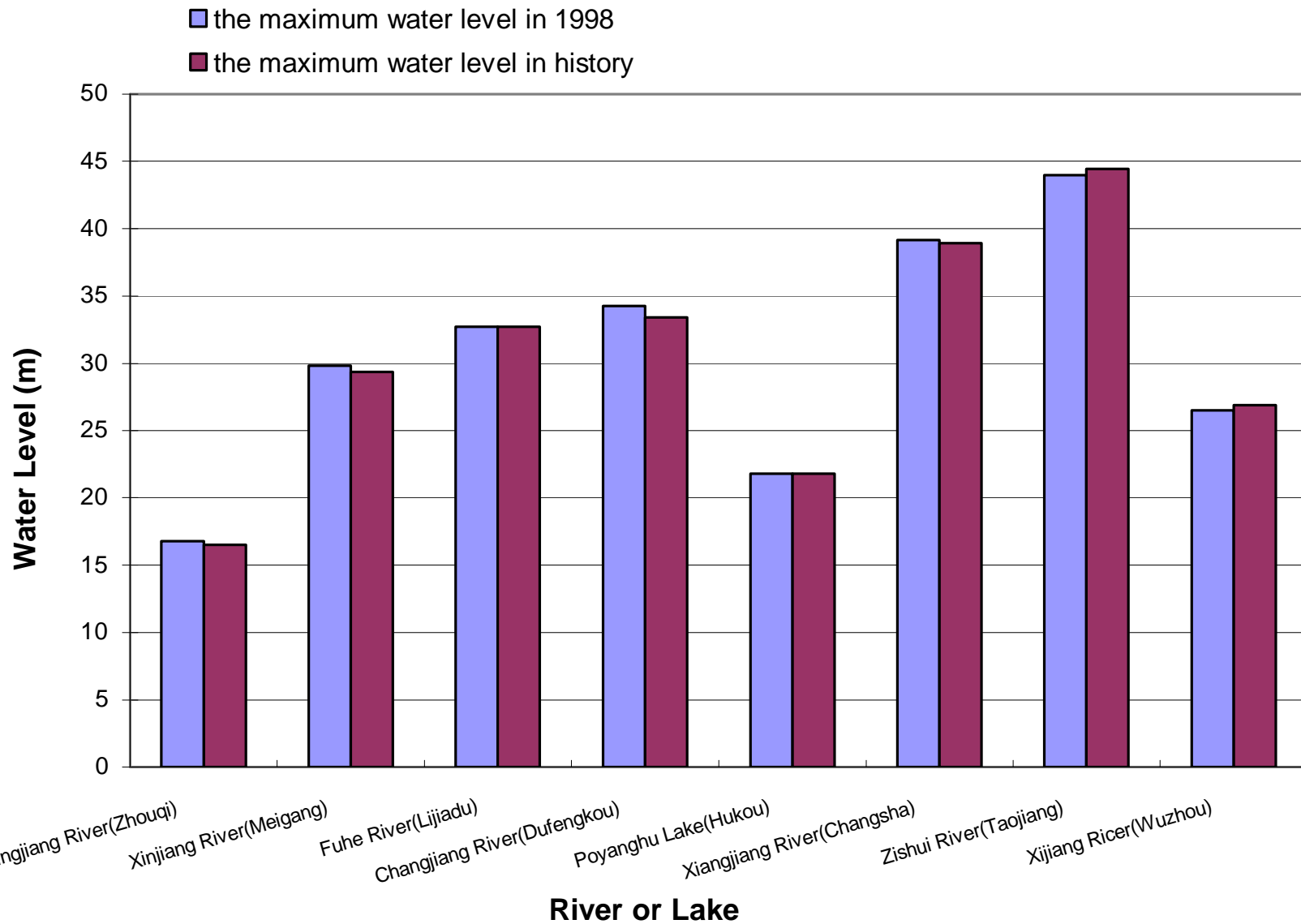


Figure 20: Comparison between the maximum water level in 1998 and in history

After June 28, the subtropical high moved to the west and shifted to the north. The rainfall in the middle and lower reaches of the Yangtze River Basin decreased, and the flooding of the Yangtze declined.

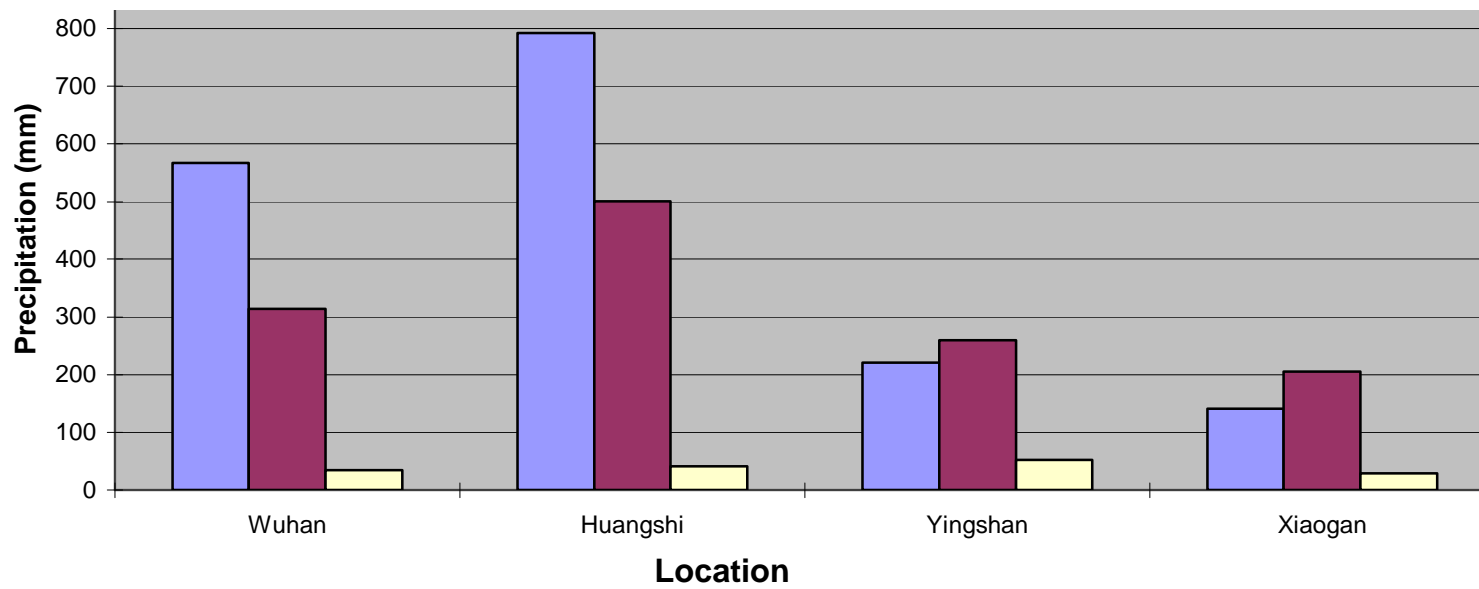


Figure 21: Comparison between the maximum precipitation in history and the total precipitation in the third 10 days of July 1998 in Hubei Province

(2) The second period was in late July. From July 20 to 31, because the strength of the subtropical high had been reduced, it retreated to south and to the east. Large scale rainstorm processes occurred in the middle and lower reaches of the Yangtze River Basin. Compared to the first period, the rainy area was smaller and the rainy period was shorter. The rainfall, however, was heavier and formed downpours. As a result, the water level rose very rapidly.

In this period, precipitation in most areas of the Yangtze River Basin reached 90 to 300mm. Northwest of Hunan, north of Jiangxi, and south of Hubei, precipitation amount reached 300--500mm, and in some locations exceeded 800mm with a maximum of 911mm (**Figure 21, Figure 22, and Figure 23**).

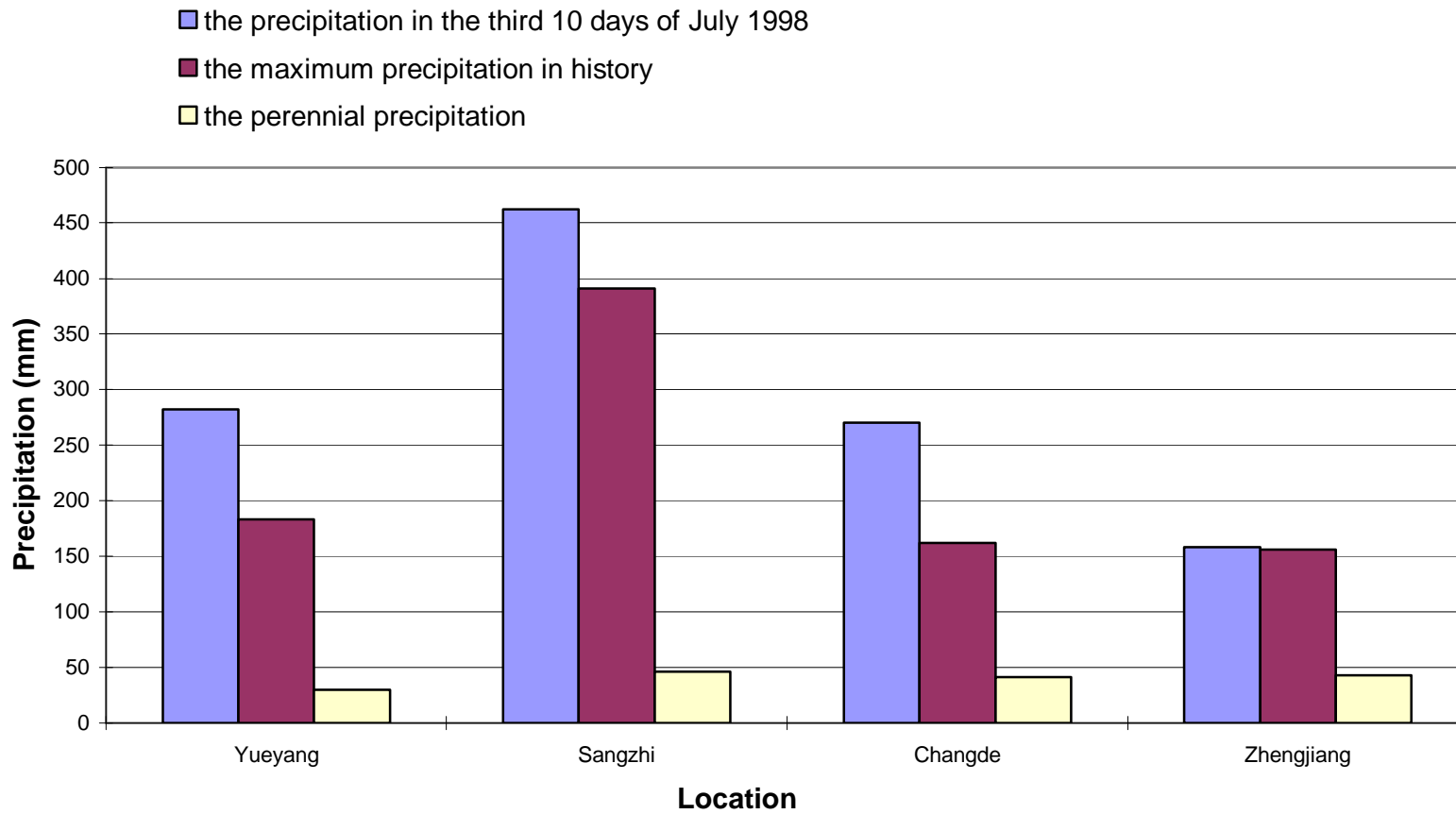


Figure 22: Comparison between the maximum precipitation in history and the total precipitation of the third 10 days of July 1998 in Hunan Province

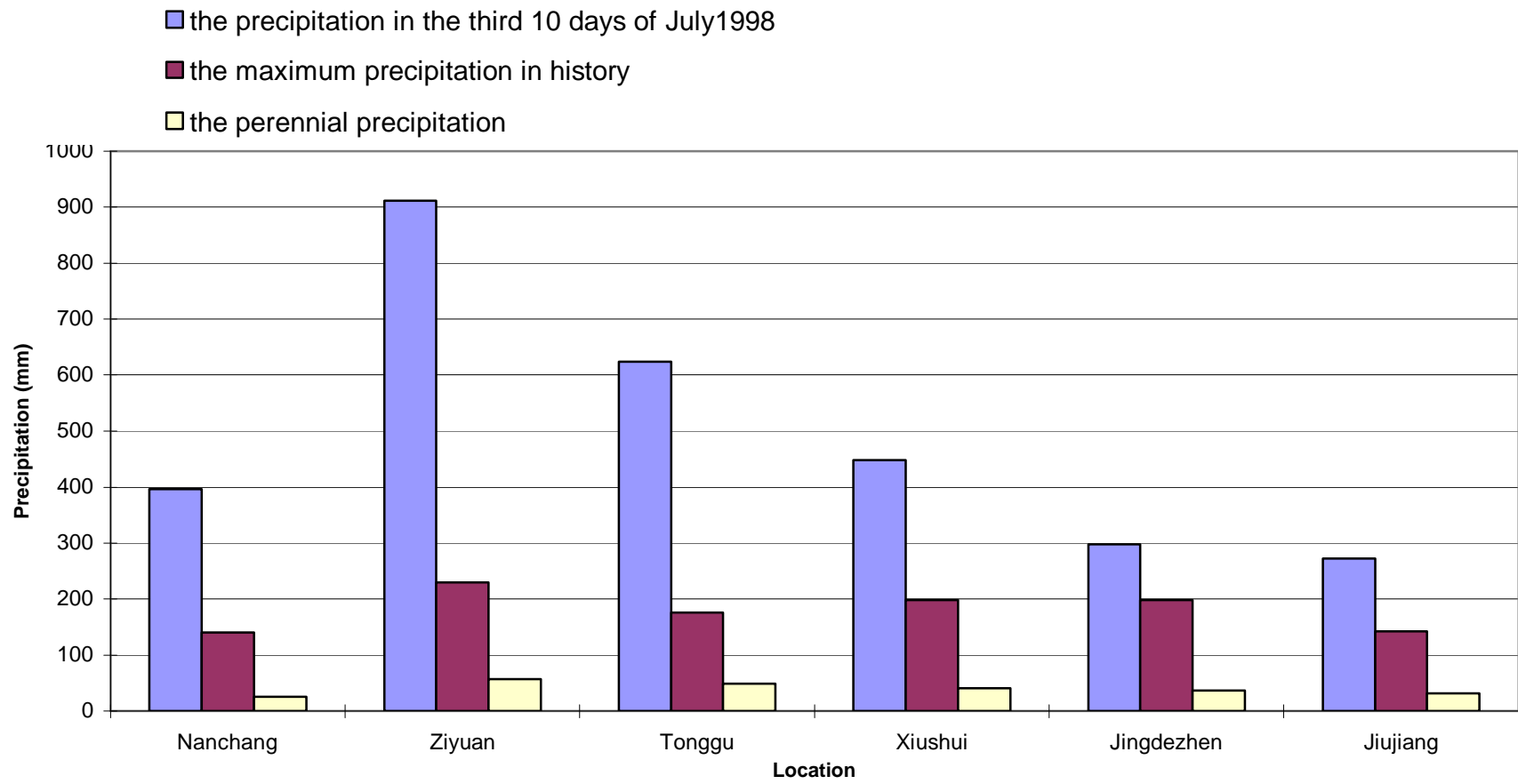


Figure 23: Comparison between the maximum precipitation in history and the total precipitation of the third 10 days of July 1998 in Jiangxi Province

In the previous period, the water level in the Yangtze was already very high, and exceeded the damage level. So, continuous precipitation in this period was really disastrous.

(3) The third period started from the beginning of August. Although the precipitation in the middle and lower reaches of the Yangtze River decreased greatly in August, precipitation increased continuously in the upper reaches of the Yangtze River in Sichuan Province, Chongqing, the Three Gorges area, the Qingjiang River Basin and in the Hanjiang River Basin. The total amount of monthly precipitation ranged from 150 to 250mm, and in some areas exceeded 300mm.

Frequent precipitation in the upper reaches led to the repeated occurrence of flood peaks. There were five peaks in August. On August 7, the dike in the Jiujiang segment was broken and torrential water swarmed into cities, villages and agricultural fields. There was severe damage to property and loss of life.

The Yangtze flood did not subside until late August. The total time of the floods was about three months. It was the one of the most disastrous floods in this century, and had severe impacts on society.

In 1998, the rainy season in the Nenjiang River Basin in Northeastern China came early. As early as late May, rainy days increased significantly. From June to September, the total precipitation in most areas of this basin reached 300-450mm and in some places it reached 500-700mm. From June 5 to June 25, there was rain almost every day. With such frequent rainfall, the water level in the branches of the Nenjiang River rose continuously. Flooding occurred frequently. There was a total of four flood peaks during the season. On August 11, the greatest flood in the recorded history of the Nenjiang River Basin occurred. In the Songhua River Basin located along the border between China and Russia, the water level of Haerbin City (the capital of Heilongjiang Province) reached 120m on August 23, which was almost 0.84m higher than the historical record. The rate of water flow reached 17,000 m³/s.

The damages caused by the 1998 Great Floods were severe in the Yangtze River Basin, Songhua River Basin and other major rivers around China. Based on statistics, twenty-two provinces suffered flood disasters to different degrees. The provinces that suffered the most were Jiangxi, Hunan, Hubei, Heilongjiang, Inner Mongolia and Jining. Nation-wide, crops on about 310 million mu (1 mu=666.6 square meter) of farmlands were destroyed. More than 223 million people suffered from the flood disasters. Officially, there are 3,004 people dead and more than 5 million housed were collapsed. The direct loss was more than 166.67 billion yuan (RMB) (equivalent to \$20 billion US dollar).

Although the 1998 Great Floods were no doubt attributed to the anomalous climate and excessive precipitation, factors related to human activity can not be overlooked. For example, large-scale deforestation since late 1950s in the upper reaches in many river basins caused severe ecosystem deterioration. For quite a long period in history, the forest cover in the Yangtze River Basin was estimated to be as high as 60%~85%. By 1957 it has been reduced to 22% and to 10% in 1986. Now it is only about one percent. This sharp decline on forest cover can be attributed to policy making for economic development. In the 1950s, during the famous "Great Leap Forward Campaign", people encouraged by the government rushed to the plains, the foothills and the forests to find iron ore and fuels to make iron and steel. The forest resources in these areas with dense populations such as the plains, foothill and valleys were thoroughly depleted. Then, to meet this unrealistic and unreachable economic development goal, people began to explore virgin forests in the areas such as the upper reaches of the Yangtze and Yellow Rivers, west Sichuan Province and northwest Yunnan Province. The miserable degraded fate of forests in China began from then on, as the amount of forest cover descended sharply. For example, in the middle part of Sichuan Province, the forest cover for 53 counties, where branch basins of the Yangtze River are located, dropped to 3%, and it was 1% in another 19 counties. In the mid-1960s, to prepare for possible wars with the Soviet Union and the USA, many of the factories in defense and high tech industries were moved to the inland areas. Most of these factories were established in remote mountains in order to avoid detection and a nuclear attack. To supply these millions of workers and their families with enough food and other basic living needs such as housing, millions of trees were cut down. In the late 1980s, in light of the possibility for a more peaceful future for the world, these factories were moved out. What they left behind was a series of unprecedented catastrophes such as forest destruction, damaged ecosystem and polluted land.

Due to deforestation over the past 40 years, a huge amount of nutrient rich soils flowed into rivers and lakes. The reservoirs and the rivers were silted up, and the lakes shrank. People who lived in the upper reaches of the Yangtze River noted that, "In early days, the water in the river was always lucid throughout whole year. But now, any rainstorms can lead to floods, erosion and landslides. The Yangtze River became another Yellow River."

The rapidly increasing population is another factor that made the flooding severe. The middle and lower reaches of the Yangtze River Basin are regions with hundreds of lakes. The abundant lakes are a natural system adjusting for floods in the Yangtze River Basin. With increasing population, many lakes were drained and converted to farmland and residential areas. In the 1950s, the total number of lakes in Hanjiang River Basin was 1046. Now, only 182 exist. Since the 1950s, the water surface areas in Dongtinghu Lake was reduced by 46% and the Poyang Lake by 40%. As shown by the National Statistical Bureau in recent years, the total loss of lakes in the middle and lower reaches of the Yangtze River Basin has been as much as 12,000,000 hectares; the loss is as high as 34%. For example, Hubei Province used to be referred as "The Province with One Thousand Lakes" in the Ming and Qing Dynasties. In the early 1950s, the total number of the lakes, which have a water area greater than 100 mu, was 1332. All these lakes had a capacity to hold floodwater of 11.54 billion m³. By the 1980s, the number of the lakes with water area greater than 100 mu had been reduced to about 800. The effective adjustment and storing volumes dropped to 3.7 billion m³, or about 26.6% of the amount in 1950s.

As a result, the capability of lakes to store floodwater and to reduce the flood peaks became increasingly less. In addition, in the middle and lower areas of the Yangtze River Basin, many factories were constructed along watercourse, and a great amount of industrial garbage such as gangue and scoria were emitted to the watercourses. All of these human factors significantly reduce the capability of flood control.

A third factor is due to the shortsighted view of economic development. Many recent economic development plans focused only on the short term and on local economic benefits. They paid little attention to the possible impact on the environment. Many of the needed disaster-prevention and disaster-reduction measures were impossible to put into practice. In some cities, there are no prevention plans for natural disasters. In general, the country is lacking usable knowledge about sustainable development, environmental protection and reliable disaster-prevention and disaster-reduction plans. Construction of disaster-prevention and disaster-reduction projects has lagged behind the rapid development of the economy. The construction standard for flood-prevention projects was low.

2. Long lasting droughts and heat waves

In 1997, a prolonged drought occurred in southern China in summer and fall. Such an event has been rarely seen in history in terms of its persistent, wide-ranging impact and its degree of dryness. Meanwhile, precipitation was reduced throughout the whole country, especially in most parts of Northwestern and North China, and in some areas in the north of the Yellow River and the Huaihe River Basins.

In the summer of 1997, temperatures in most areas of northern China were anomalously high for a long period of time. The monthly mean temperatures in some northern provinces exceeded the highest in recorded history. Endless heat waves and hot weather hit northern China continuously.

In May 1997, the monthly mean temperatures were 2⁰C - 4⁰C higher than the climate mean in the middle and lower reaches of the Yangtze River Basin and most areas of northwestern China. In the first 10 days of May, the maximum temperatures in the middle and north part of Jiangsu and Anhui provinces reached 35⁰C to 37⁰C. These were the highest temperatures for this period since 1949. The hot weather appeared in the Yangtze River and the Huaihe River Basins half a month earlier than normal.

In early June and in July, heat waves hit Northeastern China. From June 13 to June 15, the maximum temperatures of Tailai in Heilongjiang Province in northern China, were 39⁰C, 39.8⁰C, and 37.7⁰C respectively.

The long lasting excessive hot temperatures were the main weather features of Liaoning Province (in Northeastern China) in July 1997. There were almost 15 days when the daily temperatures exceeded 33⁰C in the whole province. In many places, the maximum temperatures set new records. With little differences between day and night temperature, people felt extremely uncomfortable all day long. With a headline "Hot, Hot, Real Hot" in the *Liaoning Daily*, the hot weather totally affected the people's normal daily life, although many retailers and manufactures did take advantage from it.

"Why is the weather so hot?" became the headlines in many newspapers and on TV programs, as well as having been a hot topic among people that summer. The lasting high temperatures made Shengyang City (the capital of Liaoning Province) suffer under a hot sun adversely affecting people in daytime. The hot weather with mean temperature above 33⁰C did not stop for half a month in July. Usually, this city has the hot weather for 8 to 10 days with a mean temperature of about 28⁰C, and a maximum of 31⁰C.

The high temperature and the "Heat Island Effect" in cities made people unable to stay in their homes at night. Department stores and cinemas equipped with air conditions became places for people to escape to from the heat wave. The sale of water heater, electric fans and air-conditioners increased dramatically. Many shops had to add sales personnel. The assistant manager of the appliance department of Shengyang Commerce City Store noted that, "In that summer, air-conditioners, refrigerators, water-heaters and washing machines, particularly air-conditioners, sold very well. 400 air-conditioners were sold in 20 days in July, and more than 20 refrigerators were sold everyday. Air-conditioners are usually installed by technicians sent by the factories. Because of many sales, it took 5 days to get one installed. So, we had to hire outsiders to install air-conditioners for our customers. We often worked till midnight during that time." The manager of the appliance department of the Shengyang Tiexi General Merchandise Stock Ltd. said, "The hot summer in 1997 was not prepared for. We did not expect that the sale of air-conditioners would go so well mainly because of the continuous hot weather. According to statistics, sales increased about 3 times when compared to the same period in 1996." Not only did the air conditioners become one of hot items to buy, but beverages such as beer, soft drinks, and mineral water also sold very well. For example, the price of famous brand pure water increased by about 60% but was frequently out of stock. With a shortage of well-known brands of beers in the market in Shengyang, many new names appeared and had a good percentage increase in market share.

The causes for the long lasting hot weather in Northeastern China, however, were quite complicated. It is very hard to declare that the 1997-98 El Niño was the only cause. For many El Niño years, according to statistical results, Northeastern China often experienced cold summers, which is the opposite to the situation in 1997. On the other hand, it is also hard to rule out the influence of El Niño. Since there have not been strong El Niño events such as in 1997-98, it is not easy to reach any scientific conclusion on the relationship between hot summers and El Niño.

In August 1998, when the "super flood" was tyrannizing people in the Yangtze River Basin, record-breaking high-temperature weather appeared in Shanghai. From August 8 to 15, the maximum temperature of the seven days exceeded 38°C. On August 11, the temperature reached 39.6°C, and the record of the highest temperature in Shanghai's history was surpassed. According to the August 8-15 reports from in the *XINMIN EVENING NEWS*, daily life of Shanghai people was totally disordered.

Afraid of the scorching sun, few people were in the street. Most people stayed either at home or in the office. General retail sales decreased by 20-30% in this period. The heat wave put the owners of stalls and mobile dollies selling cold drinks and ice creams on street out of business. In contrast, sales in the air-conditioned indoor ice cream shops increased dramatically. Many people enjoyed air-conditioning there for whole days. The prolonged hot weather also made the taxi business change from an off-season to a booming season. To avoid the burning sun, people increased their short-haul rides. Many people called to order pickup and delivery services from their residences, which rarely occurred before. According to the statistics shown by one taxi company (the Qiangshen Co), the average number of calls during that period reached 5170 per day.

3. The rare snow disaster in Qinghai-Tibet Plateau

Beginning in early fall of 1997, heavy snowstorms hit the Tibetan Plateau region frequently. An excessive amount of snow fell on the Laqu, Ali and Rikeze areas of Tibet Autonomous District and the Yushu area in Qinghai Province. Both the duration of and area affected by the super snowstorm were rarely seen in recorded local history. A great number of herdsmen were besieged by the snowstorm, and an estimated 100,000 cattle either froze or starved to death. There were significant losses in both property and human lives during this super snowstorm.

4. The longest flow break in the Yellow River

The break of water flow in Yellow River occurred every year. In 1997, however, the break in the Yellow River Basin was the most severe one in history. The break of water flow not only occurred the earliest but also lasted the longest (a total 226 days from February to December). The break dramatically affected the people's daily life, industry and agriculture.

5. Reduced typhoon landfall and the shortest typhoon season

In 1997, the number of typhoons generating in the Northwestern Pacific Ocean was slightly less than the climatological average (28 cases). The number of typhoons landing in China, however, was significantly small (only four). The first typhoon landed on August 2 and was much later than the climatological average (on June 25). The last typhoon making landfall was on August 29, which was also much earlier than climatological mean. Moreover, all four typhoons landed in August. The typhoon season was the shortest one in history. Although there were far fewer typhoon hits than normal, the damage caused by typhoons was still huge. In August 1997, the No.9711 typhoon landed in eastern China, and swept everything away from the inshore provinces. On August 18, this typhoon landed in the city of Wenlin in Zhejiang Province. The typhoon moved north and landed again at Yingkou City in Liaoning Province on the night of August 20. There were all kinds of heavy weather such as gales, rainstorms and severe thunderstorms along the track of the typhoon. From August 18 to 23, the precipitation reached 50-200mm in the most parts of Zhejiang Province, the eastern part of Anhui Province, most areas of Jiangsu Province, the City of Shanghai, the middle part of Shandong Province, the Shandong peninsula, most areas of Liaoning Province, the middle and western part of Jilin Province, and the south and east part of Heilongjiang Province. In many places, precipitation exceeded 200mm in a short period of time.

The No.9711 typhoon brought huge damage to the provinces and cities along the eastern coast. The losses in agriculture, industry and the facilities of water conservancy and electric power were very high. Many peoples were injured. Based on incomplete statistics, the area of stricken crop reached 5,300,000 hectares, the number of collapsed houses was about 460,000, and the damaged houses were estimated at 1,220,000. The direct losses were more than 35 billion yuan (RMB). In Zhejiang Province, 21,670,000 people in 75 counties suffered from the No.9711 typhoon. In the cities of Taizhou, Ningbo, Wenzhou, Shaoxin and Hangzhou, losses were extremely high due to the dense populations, flourishing economies and concentrated factories in this developed region. In Zhjiang Province as a whole, there were 177,000 collapsed houses, 770,000 damaged houses, and 730,000 hectares of stricken farmland. About 70,000 factories were forced to stop production wholly or in part. Roads, power lines and communication lines were destroyed. The direct losses in the whole province reached 18.6 billion yuan (RMB).

The No. 9711 typhoon also hit hard the inshore and inland areas of Shandong Province. The damaged farmlands covered 2,100,000 hectares, and the number of trees brought down was over 2 million. Furthermore, 54 people died, and 105 people were reported missing. The direct losses in the whole province were over 13.5 billion yuan (RMB).

6. *Other anomalous weather phenomena*

In 1997, the Meiyu was significantly delayed with the main rain band moving north of the Huaihe River Basin. As a result, the Yangtze River Basin suffered extremely hot weather. According to reports from the *Changjiang Daily*, the weather in the city of Wuhan, which is located in the middle of the Yangtze River, had changed dramatically. As early as on May 10, which is usually spring in this region, the temperature had already reached 22°C, which is the sign of summer. That was 11 days early than climatological mean for Wuhan. The hot weather provided favorable conditions for the spread of crop diseases. About 500,000 hectares of farmland were threatened by leaf worms. Wuhan is known as “the Oven City” because of its unbearable heat in summer. In the summer of 1997, however, the number of days with temperatures higher than 36°C was only 13, or 30 days less than normal. Just when people were enjoying a pleasant summer, Wuhan turned hot in the autumn. In the middle of October, the mean temperature was 5°C higher than normal setting a new record.

As reported by the *XINMIN EVENING NEWS*, the winter of 1997-98 was a warm winter. In December 1997, the monthly mean temperature in Shanghai was 8°C (2.1°C higher than normal). In January 1998, the monthly mean temperature was 7.3°C (3.9°C higher). Moreover, during the 1997-98 winter, there was a large number of rainy days with a total precipitation of 102.5mm. This was about three times the average amount. In the first ten days of January 1998, precipitation reached 64mm in Shanghai, which was the third highest rainfall in the same period of time in its recorded history.

PART IV RESPONSES :

4.1 WERE THERE ANY GOVERNMENT REPORTS ISSUED BEFORE ITS IMPACTS APPEARED? WERE ANY REPORTS ISSUED AFTER THE EVENTS? WHAT WERE THE MAJOR RESPONSES TO THE EVENT?

Because there are still so many uncertainties in the mechanism of possible relationships between El Niño events and the Asian monsoon, the government has not been provided with reliable information from the China Meteorological Administration (CMA) on the impact of El Niño on China. Therefore, the government has not issued any official report the public on the impacts of the 1997-98 El Niño, as of June 2000. The National Climate Center (within the CMA), however, did collect information on the impact of extreme climate events on society and published internal reports for research and for government official use only. After an El Niño event or some other climate-related disaster, the CMA usually reviews the whole process and records all related damages on a monthly basis. For the 1997-98 El Niño event, no official reports were specifically pointing to this event. Most reports and reviews from different government agencies were focused on the 1998 Great Flood along the Yangtze River Basin. The major response to the 1997-98 event is the increasing public awareness about both El Niño event and climate change. With the publicity of the El Niño event, the government decided to contribute more funding to basic research and to develop advanced observing instruments and a monitoring network around the country.

4.2 THE EXTENT OF NATIONAL RESEARCH ON EL NIÑO (IN THE PAST 2 DECADES).

Chinese scientists have studied ENSO and its impacts on China for the past three decades. Although the 1982-83 El Niño was the one that made the Chinese meteorological community start to pay attention to ENSO's impact, the series of El Niño events during the 1990s really initiated comprehensive studies of the phenomenon because several droughts and floods occurred in China during that decade. During the past decades, knowledge of ENSO has greatly increased with improved observational systems, comprehensive numerical models and advances in theoretical studies.

Noticing that China's climate is mainly controlled by the Asian monsoon, Chinese scientists pay great attention to research on the interactions between ENSO and Asian monsoon behavior both in winter and summer. Many achievements have been made.

4.2.1 Interactions between ENSO and the East Asian monsoon

The Asian monsoon is an important climate sub-system that not only brings needed rainfall for the inhabitants on the Asian continent but also causes severe hazards such as floods and droughts. In China, for example, floods and droughts are closely related to the anomalous monsoon activity.

It has been noticed by many scientists that the interaction between ENSO and the Asian monsoon is important in order to understand the mechanism of ENSO's occurrence and the monsoon anomalies. Based on data analysis and theoretical studies, it has been found that the precedent signs of El Niño events are from the equatorial western Pacific Ocean. The frequent appearance of stronger East-Asian troughs (cold fronts) in the wintertime plays an important role in exciting an El Niño event (Li, 1988). Further studies have shown that there are clear interactions between anomalous winter monsoons and El Niño events (Li, 1990). Prior to the El Niño event, the stronger winter monsoons (strong and frequent cold fronts) in East Asia cause the trade winds to weaken and cumulus convection to become enhanced over the western Pacific. Then there are the anomalous oceanic Kelvin waves caused by the anomalous westerly (eastward flowing) winds and the strong intra-seasonal oscillation caused by stronger convection, both of which play an important role in the onset of an El Niño event. During winters in El Niño years, the positive SSTA (sea surface temperature anomaly) in the eastern equatorial Pacific enhances the Hadley Cell, the Ferrel circulation and zonal westerlies in middle latitudes, and forces the polar front to move toward the north in East Asia. Meanwhile, the negative SSTA in the equatorial western Pacific causes anomalous southerly winds over the coastal area of the northwestern Pacific Ocean. The winter monsoon is weaker in East Asia, during an El Niño winter.

4.2.2 Impacts of ENSO on the climate in East Asia

ENSO is one of the fundamental factors causing climate anomalies in East Asia and China. The impacts of ENSO on climate in East Asia have been a focus of attention and, as a result, lots of studies have been done since the 1980s. In recent years, some results about impacts of ENSO on the climate in East Asia have been further investigated. Where there is an El Niño event, the SSTs rise anomalously in the equatorial central and east Pacific. It leads to the enhancement of convection in the tropical central Pacific, and strengthens the heat source. Under the impact of teleconnection, the atmospheric circulations in the middle and high latitudes become anomalous, and at the same time, the East Asian monsoon becomes abnormal too.

In general, more precipitation in the Yangtze and Huaihe River Basins but less precipitation in Northern China area and south of the Yangtze River region are expected in summer in the developing stage of an El Niño event. In the developing stage of the El Niño event, there are usually floods in the Yangtze-Huaihe River basin but droughts in Northern China and to the south of the Yangtze River areas. When El Niño is in its decaying stage, less precipitation occurs in Northern China and to the south of the Yangtze River (Huang and Wu, 1989; Huang, Fu and Zang, 1996; Huang and Zhang, 1997).

As an example, the anomalous precipitation distribution in summer is shown in **Figure 24**

Correlation between
Rainfall of 160 stations in China and Nino3 SST (1951-1996)

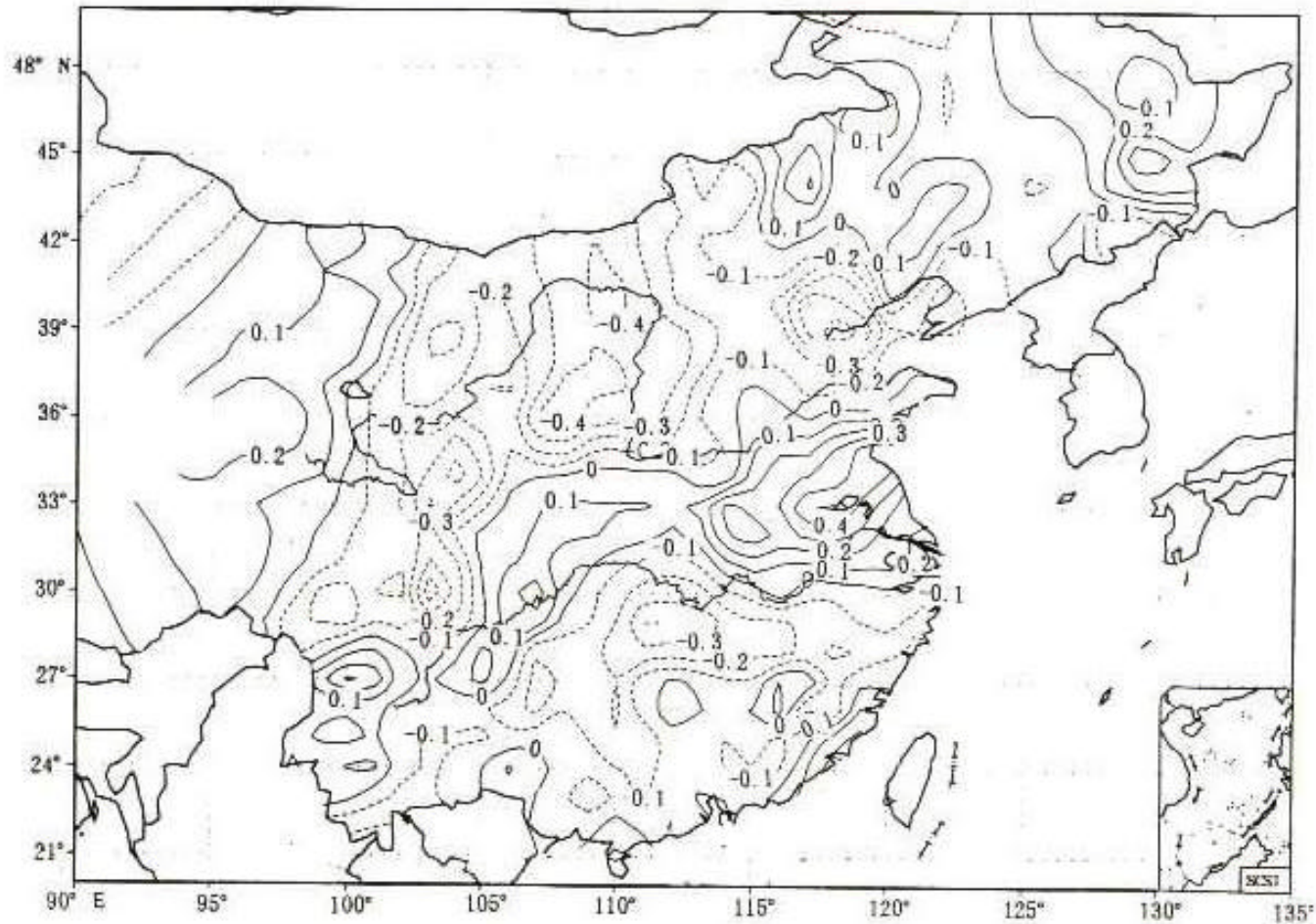


Figure 24: Correlation coefficients between the summer precipitation anomalies in China and the differences between SST in Nino3 in summer and that in the autumn of the previous year during 1951-1996. (Solid lines indicate positive; dashed lines indicate negative)

for the developing stage of an El Niño. It is clear that there is more precipitation in the Yangtze-Huaihe River basin and less in Northern China and to the south of the Yangtze River areas associated with the developing stage of El Niño. In the decaying stage of El Niño events, the distributions of precipitation anomalies in China are reversed, as shown in **Figure 24**.

The interaction between ENSO and the winter monsoon in East Asia has been studied for more than ten years. There is a stronger (weaker) winter monsoon in East Asia prior to the occurrence of the El Niño (La Niña), but the winter monsoon in East Asia is weaker (stronger), during the El Niño (La Niña) wintertime (Zhang, Sumi and Kimoro, 1996). Usually, there are negative SSTAs in the western equatorial Pacific associated with the El Niño event. This leads to an anticyclonic circulation in the lower troposphere in the tropical western Pacific region. The stronger northerly branch of the anticyclonic

circulation is not favorable to the winter monsoon in East Asia. As a result, the winter monsoon is usually weaker during the El Niño winter. During El Niño years, warm SST regions (associated with strong convection most of time) exist not only in the eastern equatorial Pacific, but also in the equatorial Indian Ocean. The annual changes of the SSTs in the equatorial Indian Ocean are linked with the annual change of the SSTAs in the eastern equatorial Pacific. The intensity of convection in the equatorial Indian Ocean is one third of that in the eastern equatorial Pacific, but its thermodynamic contrast in the east-west direction is on the same scale as that in the eastern equatorial Pacific. In winter, the circulation in the middle latitudes is more dependent on the SSTAs in the equatorial Indian Ocean than that in the eastern equatorial Pacific. (Tao and Zhang, 1998).

4.2.3 Interactions between ENSO and the winter monsoon in East Asia

In order to confirm previous findings, the relationship between ENSO and the winter monsoon anomalies in East Asia has been studied extensively in recent years. Studies based on analyses of observations have shown that there are strong (weak) winter monsoons in East Asia and anomalous westerly (easterly) winds over the western equatorial Pacific prior to El Niño (La Niña) events. During El Niño (La Niña) winters, there are weak (strong) winter monsoons in East Asia. In general, corresponding to strong (weak) winter monsoon, there are negative (positive) height anomalies (at 500 hPa) in East Asia, positive (negative) surface pressure anomalies in the Mongolian region, negative (positive) surface temperature anomalies in East Asia, anomalous northerly (southerly) winds in East Asia. The close relationship between ENSO and Asian winter monsoons in East Asia is clearly shown in **Figure 25**.

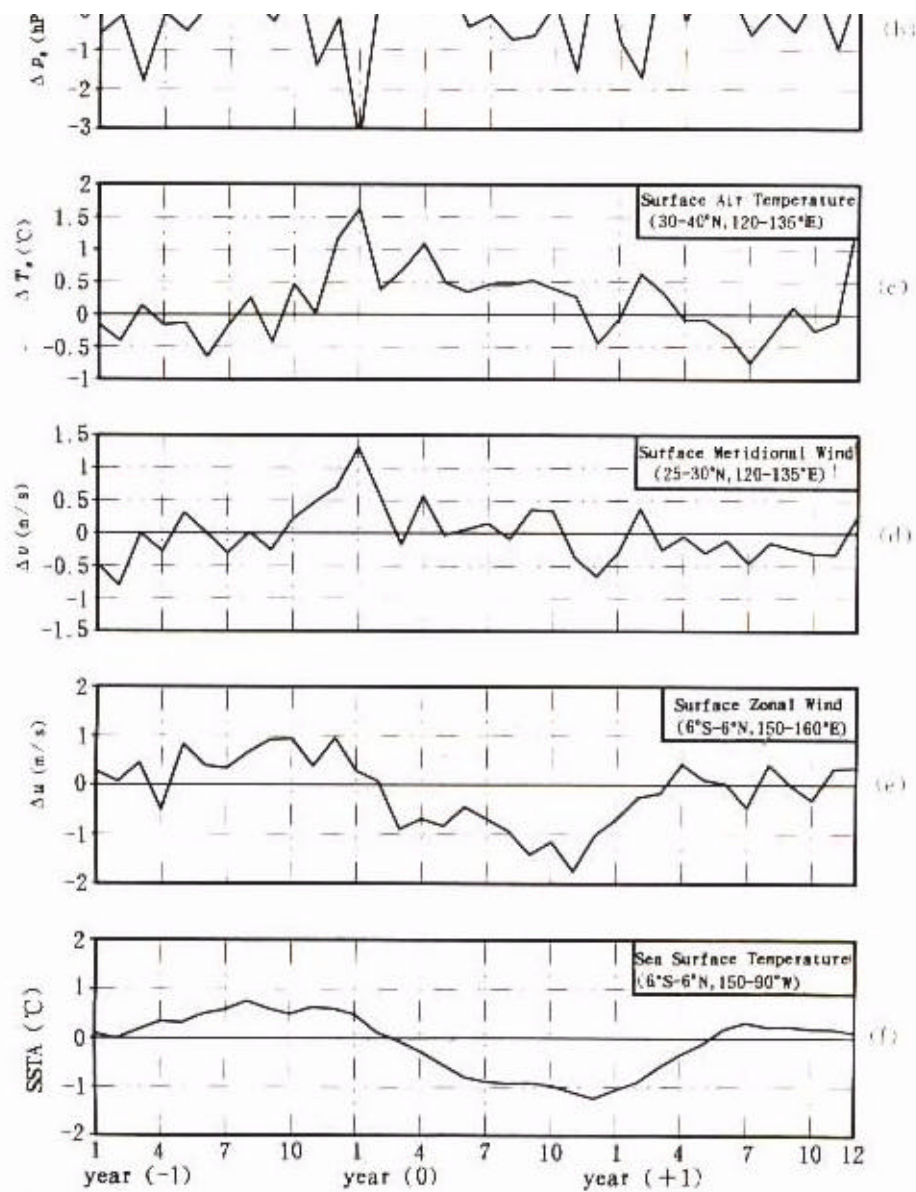


Figure 25: Relationship between surface zonal wind anomaly of winter monsoon in East Asia (e) and El Nino event (f). (a), (b), (c), (d) are temporal variations of some parameters of winter monsoon anomaly in East Asia

In **Figure 25**, variations of anomalies for the geopotential height at 500hpa (in the 30-40°N, 100-130°E region), the sea level pressure (in the 35-50°N, 80-

100°E region), the surface air temperature anomalies (in the 30-40°N, 120-135°E region), the surface meridional wind (in the 25-30°N, 120-135°E region), the surface zonal wind (in the 6°S-6°N, 150-160°E region), and the SSTAs in the Niño 3 region are plotted. The winter monsoon in East Asia is usually strong prior to the onset of an El Niño but weak in the El Niño winter. The relationship between La Niña and the winter monsoon in East Asia is reversed with a weak winter monsoon in East Asia prior to the onset of La Niña but a strong winter monsoon in the La Niña winter. The results shown in **Figure 25** were obtained based on the composite analyses for El Niño and La Niña during the 1954-90 period based at a statistically significant 95% level. A schematic diagram of the interaction between the ENSO cycle and winter monsoon anomalies in East Asia is shown in **Figure 26**.



Figure 26: Schematic diagram of the interactions between ENSO cycle and anomalies of winter monsoon in East Asia

4.2.4 Dynamic processes of the winter monsoon anomalies and ENSO

It has been revealed that a strong winter monsoon in East Asia could stimulate ENSO through two dynamic processes (Li and Hu, 1987; Li, 1990). One is by enhancing anomalous cumulus convection, which, in turn, leads to the anomalously strong intra-seasonal oscillation over the western equatorial Pacific. Another is by enhancing anomalous westerly winds, which, in turn, causes the anomalous oceanic Kelvin wave.

The equatorial westerly wind anomalies over the western Pacific have been picked out in previous studies as one of the important factors to spark an El Niño. The results showed that a strong winter monsoon in East Asia can not only cause continuous westerly wind anomalies over the western equatorial Pacific for a longer time, but also each stronger cold wave and enhancement of winter monsoon in East Asia can cause the weakness of trade winds or a westerly wind burst (Li, 1995b; 1996a).

Some studies also indicated that the westerly wind anomalies over the equatorial middle-western Pacific, which can excite an El Niño, mainly originate from East Asia, but sometimes from the Southern Hemisphere (the Australian region). For example, with regard to the 1982-1983 El Niño, the equatorial westerly wind anomalies resulted from the circulation anomaly in both the Northern and Southern Hemispheres. As to the 1986-87 event, the equatorial westerly wind anomalies resulted mainly from East Asia (Huang et al., 1998; Zhang and Huang, 1998).

Based on an equatorial barotropic oceanic model with wind stress, the dynamic effect of westerly wind anomalies over the equatorial western Pacific to El Niño event was studied using 1982-83 observational data (Huang, Fu and Zhan, 1996). It is clear that the anomalous oceanic Kelvin waves and Rossby waves are excited in the equatorial Pacific, because of the existence of westerly winds over the equatorial middle-western Pacific, then the positive SSTAs in the eastern equatorial Pacific are magnified and El Niño occurs.

Theoretical studies showed that the response of the tropical Pacific Ocean to the equatorial trade winds is lagged, and the eastward propagation from western is faster than westward propagation from eastern. Therefore, the precedent signs of El Niño event may be easy to find in the western equatorial Pacific (Chao and Zhang, 1998).

The intra-seasonal oscillation in the tropical atmosphere is an important component in the climate system. The relationship of the tropical ISO is mainly a monthly to seasonal time scale system, compared with the El Niño cycle, which is on an inter-annual time scale. Li and Zhou (1994) first revealed that El Niño is closely related to the tropical ISO. There is a very strong ISO over the equatorial western Pacific prior to the El Niño, but a weaker ISO during an El Niño event.

More studies (Li and Li, 1995; Li and Li, 1998) showed that the interannual variation of the tropical ISO, which is a fundamental sign of the temporal variation of tropical ISO, is closely related to El Niño. Before the onset of an El Niño, the tropical ISO is very strong, but it decreases abruptly when an El Niño appears. By analyzing observed data, it has also shown that the occurrence of El Niño event is not only related to the intensity variation but also to the zonal propagation of the tropical ISO. There is a systematic eastward propagation of the ISO in the tropical atmosphere (particularly in summertime) prior to the El Niño.

It is, however, well known that the ISO is constantly present in the tropical atmosphere. El Niño, on the other hand, does not occur every year. Therefore, it is not the tropical ISO but the interannual anomalies of the ISO that stimulate the onset of an El Niño. Li and Liao (1998) studied the stimulating mechanism of the tropical ISO on the El Niño based on a tropical air-sea coupled model. They showed that in the absence of an external forcing, air-sea interaction is a self-organized system, which has a periodic oscillation solution and the period depends on the strength of the coupling. When the coupling strength is stronger, the period of coupled waves (self-excited oscillations) is more consistent with the average periodicity of the ENSO. This means that the tropical

air-sea interaction provided the background for the onset of an ENSO. But this periodic regular oscillation is still different from the observed ENSO cycle, which is quasi-periodic with a different pattern of evolution. When adding external atmospheric forcing in the air-sea coupled system, a cycle similar to the observational ENSO episodes can be observed. Thus, the inter-annual anomalies of the tropical ISO, as an external forcing in the atmosphere, plays an important role in stimulating the ENSO cycle.

Research based on the diagnostic analyses of observations and theoretical studies has shown that there are obvious interactions between the East Asian winter monsoon and ENSO; an anomalously strong (weak) winter monsoon plays an important role in the occurrence of an El Niño (La Niña). Li and Mu (1998) confirmed this finding based on their numerical simulations using a tropical Pacific Ocean model (OGCM: Ocean General Circulation Model) and the air-sea coupled model (CGCM: Coupled General Circulation Model). The OGCM used in their simulation is a tropical Pacific (121°E-69°W, 30°S-30°N) model with a free surface and 14 layers vertically and has 2° in longitude and 1° in latitude horizontal resolution. According to the features of the East Asian winter monsoon anomalies, for the sensitivity experiments, anomalous wind stresses were introduced in the northwestern Pacific and western equatorial Pacific regions, i.e., northerly (southerly) wind stress anomalies in the western equatorial Pacific for the strong (weak) winter monsoon case. The difference between the numerical integrations in the sensitivity experiment and in the control run demonstrates clearly the impact of anomalous winter monsoons in the East Asia on the tropical Pacific Ocean. The results clearly show that the simulated SSTAs resulting from a strong East-Asian winter monsoon in the OGCM are very similar to the observed El Niño and the simulated SSTAs resulting from a weak East Asian monsoon are similar to the observed La Niña.

The coupled GCM used in their simulation is the OGCM used above coupled with a two-level global atmospheric general circulation model (IAP-AGCM-2). The IAP-AGCM-2 has proven to have good simulating capabilities. For anomaly experiments with the CGCM, anomalies of surface pressure (central value 14 hPa) and surface air temperature (central value 4°C) in the northern part of the Asian continent (30--66°N, 75--120°E) were added based on the typical characteristics of the winter monsoon in East Asia. The results in three initial states for strong winter monsoons in East Asia (positive pressure anomalies and negative temperature anomalies) are shown in **Figures 27** and **28**.

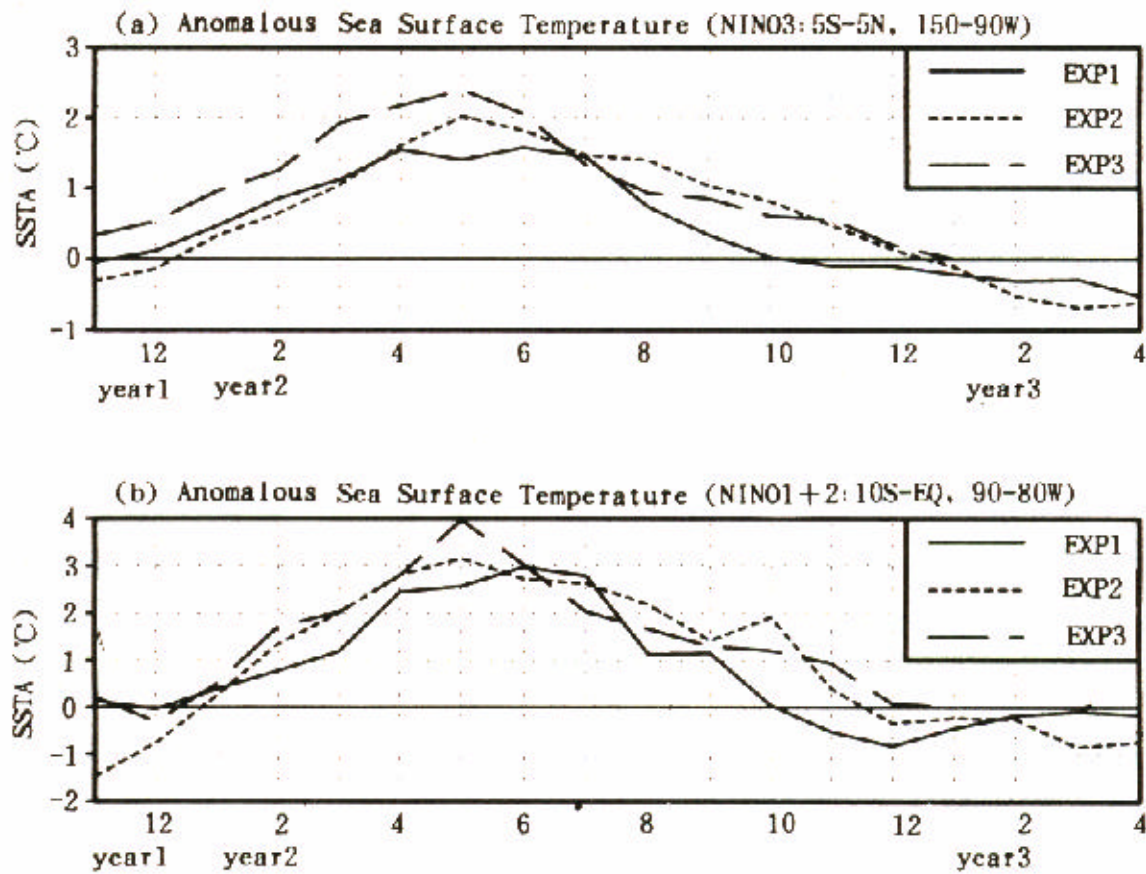


Figure 27: Temporal variation of the simulated SSTA in Nino3(a) and Nino1+2(b) with CGCM excited strong winter monsoon in East Asia for 3 different initiative states

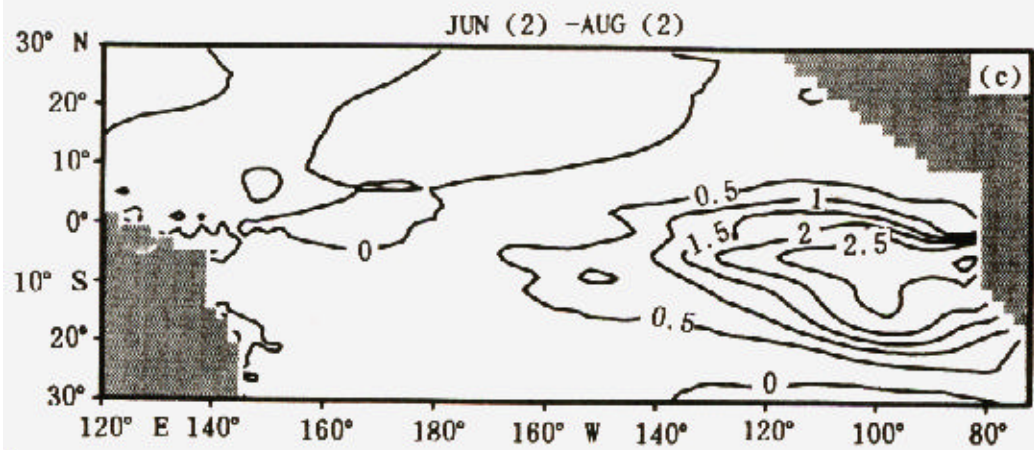
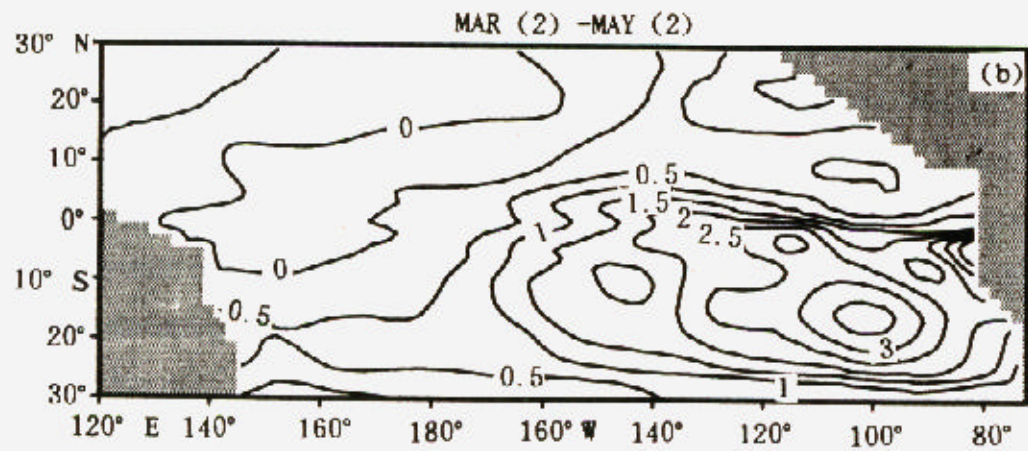
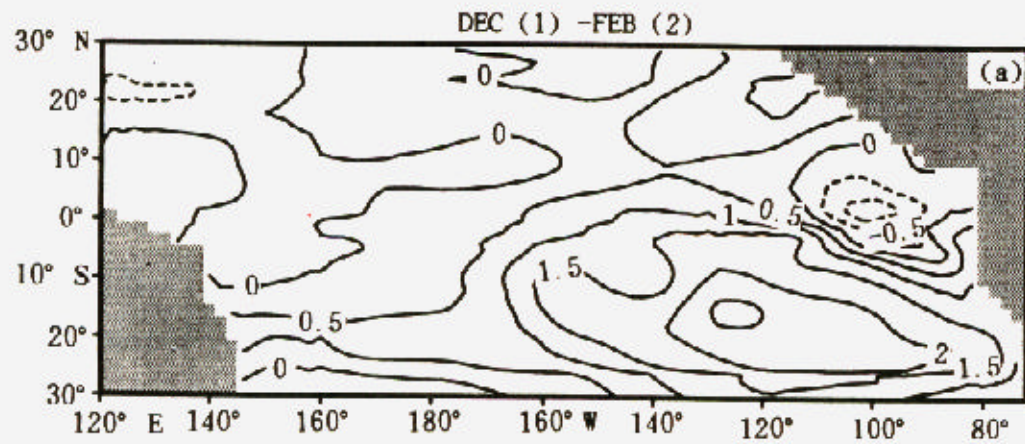


Figure 28: Horizontal distribution of the simulated SSTA ($^{\circ}\text{C}$) in CGCM excited by strong winter monsoon for three initiative states. (a), (b) and (c) are for mean SSTA in December-February, March-May and June-August, respectively.

The temporal variations of the simulated SSTA from the CGCM in the Niño 3 and the Niño 1+2 regions (**Figure 27**) showed that a continuously strong winter monsoon in East Asia could generate positive SSTAs in the central eastern equatorial Pacific for a long prolonged time. The horizontal distribution of the simulated SSTAs using the CGCM showed that the pattern of SSTAs is similar to that when an El Niño is present (**Figure 28**). For a continuously weak winter monsoon in East Asia (negative pressure anomalies and positive temperature anomalies), the SSTA patterns simulated by the CGCM are roughly the opposite to those shown in **Figure 27** and **Figure 28**. These numerical model experiments all show that an anomalous winter monsoon (either strong or weak) in East Asia plays an important role in the initiation of an El Niño or a La Niña.

4.2.5 Development of ENSO prediction models

With great improvements both in theoretical studies and observational technology, Chinese researchers have paid much attention since 1990 to seasonal and inter-annual predictions of ENSO. Several atmosphere-ocean coupled models as well as some statistical models have been used by different Chinese institutes to predict ENSO's extremes. Since 1997, the National Climate Center (NCC), which is part of the China Meteorological Administration, has held a series of ENSO Workshops each spring. In these workshops, predictions about changes in sea surface temperature anomalies (SSTAs) over the tropical Pacific Ocean made by different organizations and individuals were discussed. The NCC then released an official forecast on ENSO, based on the discussions at the workshops.

Several statistical models used for ENSO predictions (Zhang and Pan, 1995; Zhai et al., 1997; Chen et al., 1998) in China are summarized in **Table 4**. These statistical models are the EOF (Empirical Orthogonal Function) iteration models, the SVD model, Analogue prediction and Filter-optimum fold model.

Table 4. Statistic models for seasonal and interannual predictions of ENSO in China

AUTHORS	METHODS	YEAR BEING APPLIED
Zhang and Pan, 1995	EOF iteration	1996
Zhai et al., 1997	SVD	1997
Zhai et al., 1997	Analogue prediction	1997
Zhai et al., 1997	Filter-optimum fold	1997
Chen et al., 1998	SVD	1998
Chen et al., 1998	Analogue prediction	1998
Chen et al., 1998	Filter-optimum fold	1998

Zhang and Pan (1995) calculated 3-, 6-, and 9- month lead time SSTAs forecasts in both the Niño 3 and Niño 4 regions from 1981 to 1996 based on the EOF method. Comparison between the predicted and observed SSTA in Niño 3 for lead times of 3, 6 and 9 months, based on the first six EOF models, showed that the EOF method was able to predict El Niño events reasonably well. Tests on the seasonal and interannual predictions of SSTAs, using three statistical methods (Zhai et al., 1997; Chen et al., 1998) indicated that statistical methods are capable of predicting ENSO with some reliability. For example, all three methods predicated that the 1997-98 El Niño would end in the Niño 3 region around August 1998.

Many researchers have also made predictions of SSTA over the tropical Pacific Ocean using dynamic models (Zhao et al., 1996; Zhao et al., 1997; Li et al., 1997; Qian and Wang, 1997; Qian et al., 1997; Zhao et al., 1997; Li et al., 1998; Zhao et al. 1998; Qian et al., 1998; Ni et al., 1998).

The Institute of Atmosphere Physics (IAP) within Chinese Academy of Sciences developed a coupled atmospheric and oceanic circulation model to predict summer rainfall over China and SSTAs over the tropical Pacific Ocean for several years (Li and Yuan, 1998). The model has two and four layers, respectively, in the atmosphere and the Pacific Ocean. The horizontal resolution is $4^{\circ}\times 5^{\circ}$. The model concentrated on the prediction of summer precipitation in China. It was also used to predict the SSTAs across the tropical Pacific Ocean.

Three types of hybrid dynamic models in China have been developed for ENSO predictions. The first type is the atmospheric general circulation model (AGCM) coupled with a simple oceanic dynamic model. The typical one is the OSU/NCC, which is a model with a two-layer AGCM coupled with a mixed-layer ocean and ice model with the depth of 60m. This model has been applied to predict the SSTAs over the tropical Pacific Ocean since 1990. The tests show that the results between the forecasted by the model and observed SSTA over Niño1+2, Niño3 and Niño4 regions agree with each other at about 60% of the total months (Zhao et al., 1996), although there are some signals indicating the percentage of the agreement decreased since 1996 (Gao and Zhao, 1997).

The OGCM in the Pacific Ocean coupled to a statistical atmosphere has been used to make predictions in 1997 and 1998 (Zhao et al., 1996; 1997 and 1998). The Oxford / NCC model is a simple dynamic ocean model with two and a half layers coupled to a statistical atmosphere. They claimed that their model predicted the starting time of 1997 / 1998 ENSO event successfully.

The LDEO / NCC, LDEO / NCCf and LEDO / PKU models are simple dynamic air-sea coupled models. These are based on the LDEO, which was developed up by Zebiak and Cane (Qian and Wang, 1997; Zhao et al., 1997). The LDEO / NCC has added some new parameters and initial conditions for the LDEO (Li et al., 1997). Based on the LDEO / NCC model, the LDEO / NCCf model has a fine horizontal resolution (Zhao et al., 1997; Li et al., 1998). Adding a Hadley term into LDEO, the LDEO / PKU was set up (Qian and Wang, 1997). Ensemble predictions have been done for these models.

The LDEO / NCC, and LDEO / NCCf and Oxford / NCC models have been combined to predict the SSTAs over the tropical Pacific Ocean for 1997 and 1998. The combined ensemble model forecast the onset, mature and ending time of 1997/1998 ENSO event. The combined ensemble forecasts showed that a negative SSTA might occur in June-July 1998, which really occurred.

With the successful prediction of the 1997-98 El Niño, the Chinese government invested more money for ENSO related research. There are two sub-projects for ENSO predictions within the China Short-term Climate Prediction System project. Models based on both dynamics and statistics are going to be improved. The inter comparisons among the models will be analyzed and used for ENSO predictions at the National Climate Center.

4.3 IS EL NIÑO EXPLICITLY CONSIDERED TO BE A DISASTER IN CHINA?

China is a country influenced to a great extent by natural disasters. **Table 5 and Figures 29, 30 and 31**

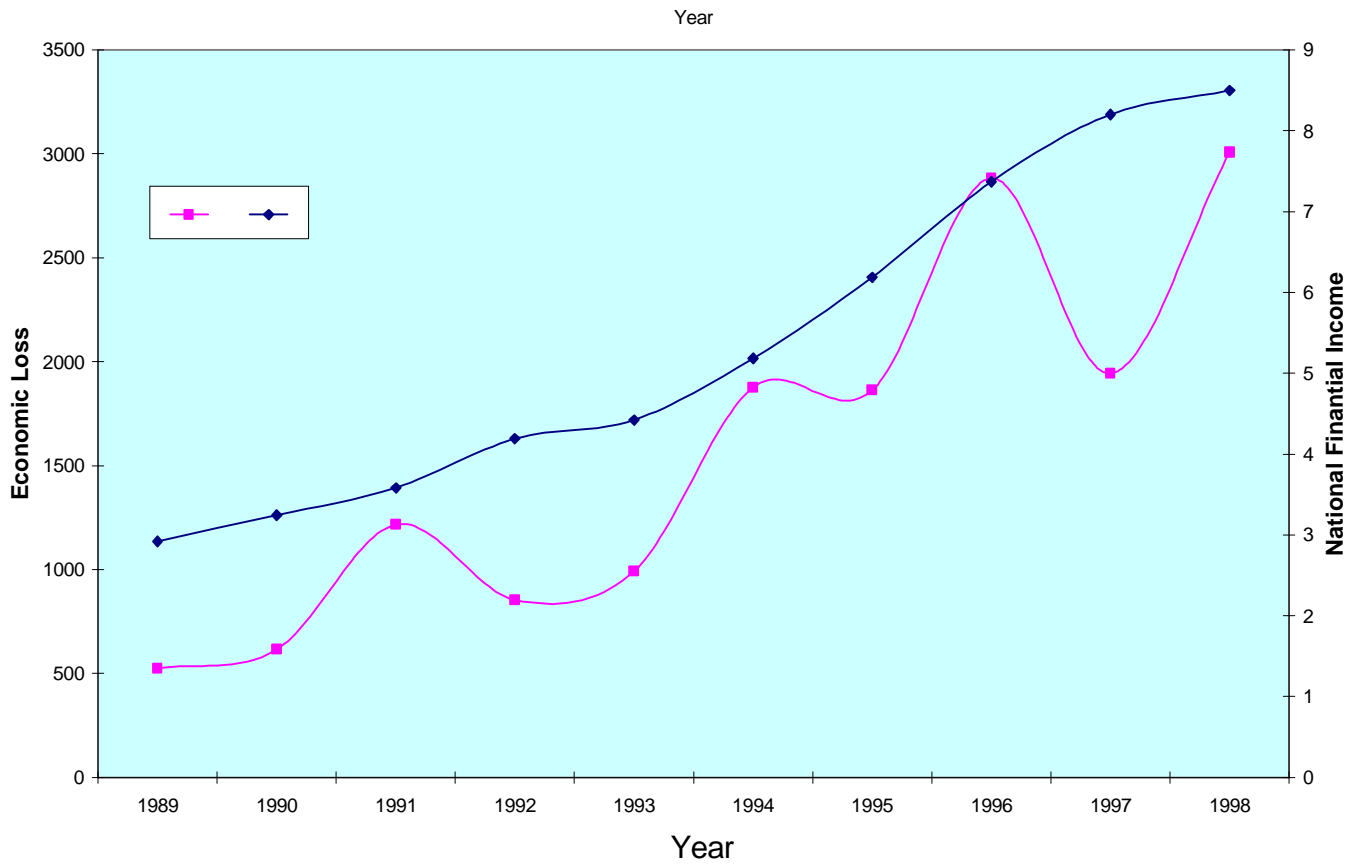


Figure 29: Comparison between the direct economic loss caused by natural disaster and the National Financial Income from 1989 to 1998 in China

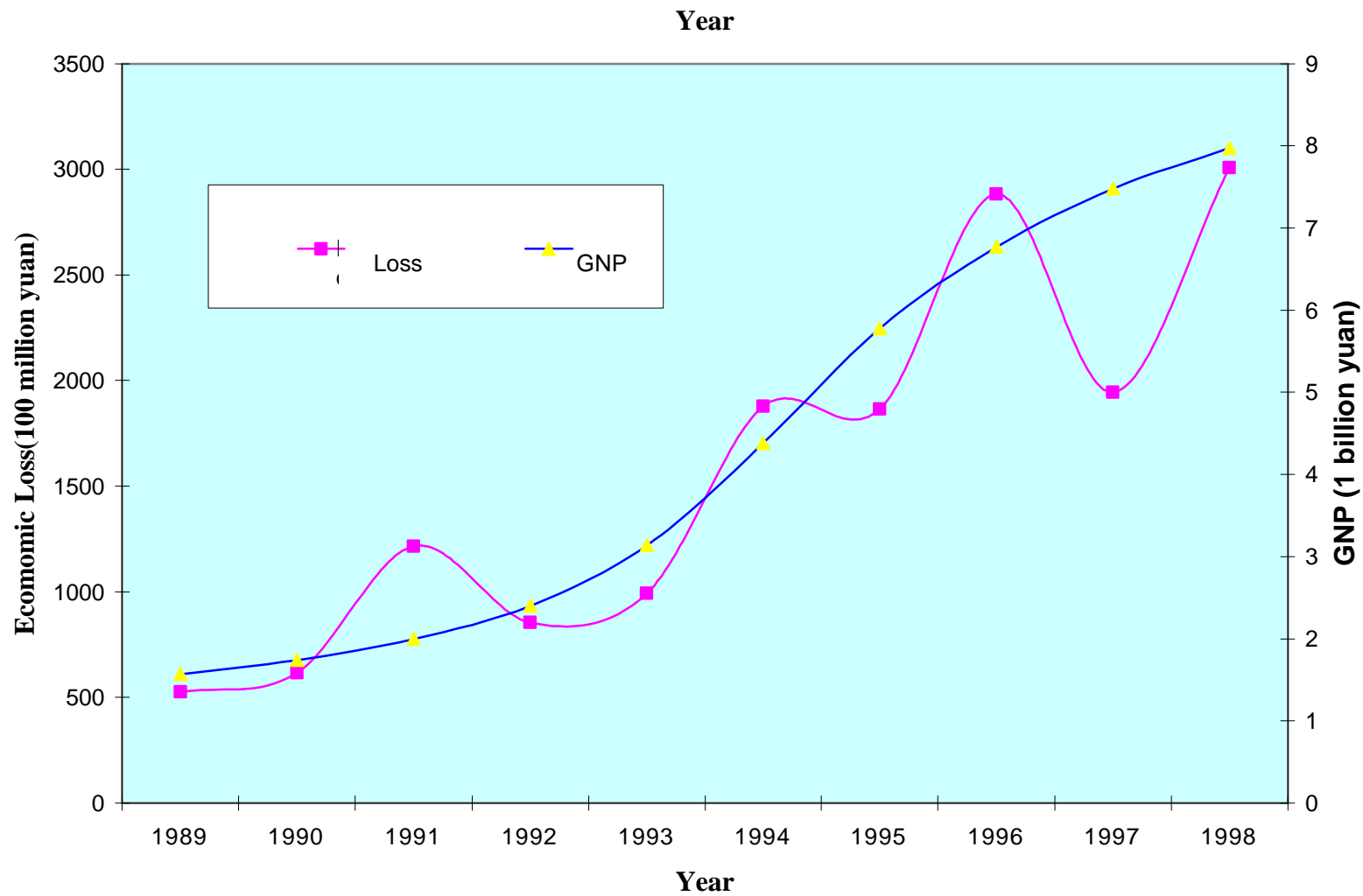


Figure 30: Comparison between the direct economic loss caused by natural disaster and GNP from 1989 to 1998

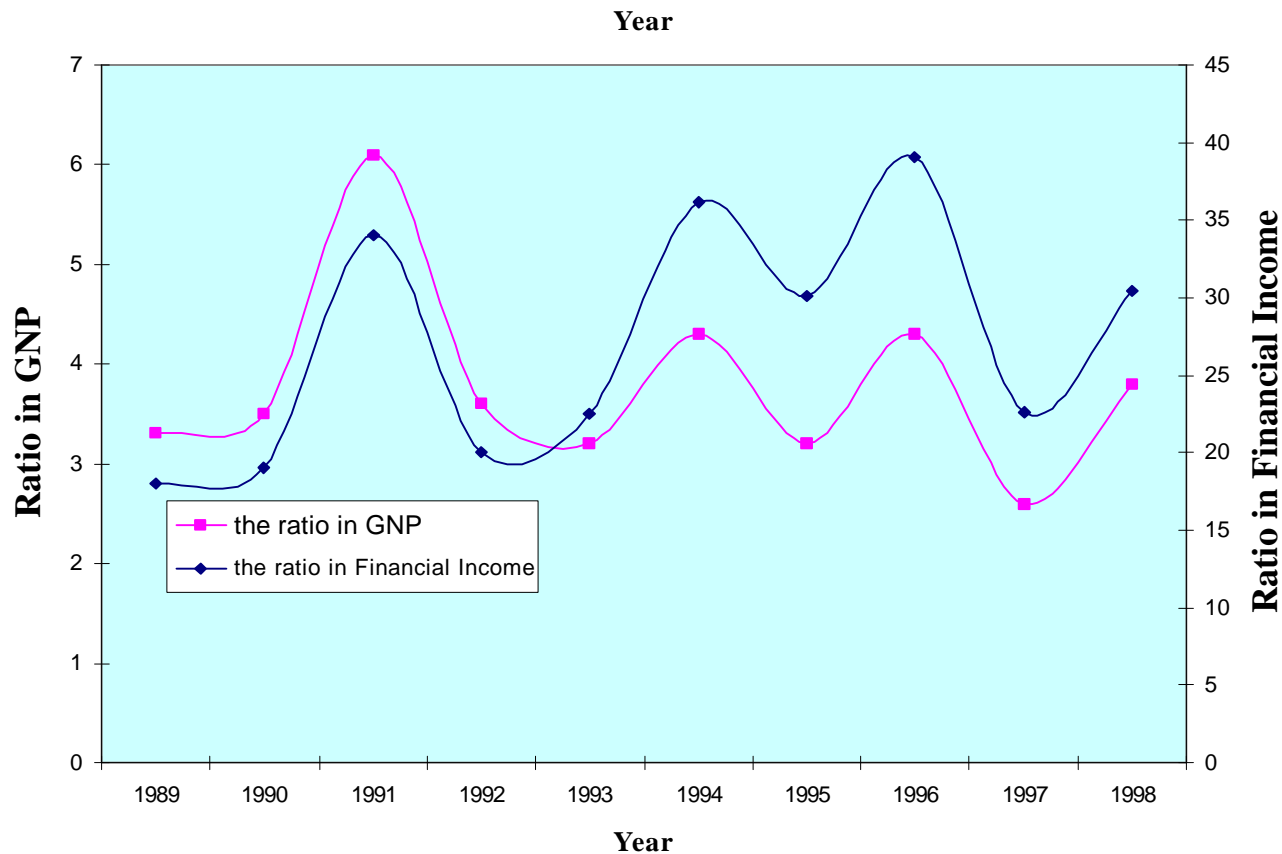


Figure 31: Ratios in GNP and in National Financial Income of the economic loss caused by natural disasters

list the economic losses caused by natural disaster since 1989. The direct economic losses in the past 10 years show a clear ascending trend. This is related to the fast growth of the Chinese economy and the development of high-risk regions to be used for industry or settlement. In the past decade, the direct economic losses caused by natural disasters increased from 52.5 billion yuan (RMB) in 1989 to 300.74 billion yuan (RMB) in 1998 with an annual average of 157.8 billion yuan (RMB). The highest ratio of losses to GNP is 6.1% (1991), and the lowest ratio is 2.6% (1997). This is 10 times higher than the loss ratio in developed countries. The average ratio of losses in National Financial Income is 27.2%. That is to say, one fourth of the wealth created by the Chinese people has been destroyed by natural disasters.

Of the numerous disasters, the disasters related to climate variations and extremes are the majority. **Table 6** lists the most deadly disasters in China since 1950 each with total losses over 5 billion yuan (RMB) or a death roll that exceeded 10,000. Of the 15 deadly events, 11 events were related to rainstorms and floods and 3 events were related to typhoons.

Table 5: The economic losses caused by natural disaster in China
(Unit: 100 million yuan RMB = \$12 million US dollar)

	Economic Loss	GNP		National Fin. Income	
		Annual	Ratio	Annual	Ratio
1989	525	15677	3.3	2920	18.0
1990	616	17400	3.5	3245	19.0
1991	1216	20000	6.1	3582	34.0
1992	854	24000	3.6	4189	20.0
1993	993	31380	3.2	4421	22.5
1994	1876	43800	4.3	5182	36.2
1995	1863	57733	3.2	6188	30.1
1996	2882	67700	4.3	7367	39.1
1997	1944	74779	2.6	8602	22.6
1998	3007.4	79743	3.8	9701	30.5
average	1578		3.8		27.4

Table 6: The deadliest natural disasters in China since 1950

Time	Type of Disaster	Losses (100 million yuan RMB)	Deaths
Summer, 1954	Rainstorm and flood in the Yangtze River Basin	Over 100	30,000
August, 1963.	Rainstorm and flood in Hebei Province	Over 60	20,000
August, 1975	Rainstorm and flood in Henan Province	Over 100	200,000
July 1976	Earthquake in Tangshan City	Over 100	242,000
August, 1981	Rainstorm and flood in Sichuan Province	Over 50	
August 1985	Rainstorm and flood in Liaoning Province	470	
May, 1987	Fire in Daxing'anling forest	50 (1,300,000 ha forest destroyed)	
June-July, 1991	Rainstorm and flood in the Yangtze River and Huaihe River Basins	500	1,163
August, 1992	No. 16 Typhoon	92	
June, 1994	Rainstorm and flood in South China	300	
August. 1994	No. 17 Typhoon	170	1000
June-July, 1995	Rainstorm and flood in Jiangxi, Hunan and Hubei Provinces	Over 300	
July-August, 1995	Rainstorm and flood in Liaoning and Jinin Provinces	460	

June-July, 1996	Rainstorm and flood in Anhui, Jiangxi and Hunan and Hubei Provinces	Over 300	
July-August, 1996	Rainstorm and flood in Hebei and Shanxi Provinces, No.8 Typhoon	546	1,000
June-September, 1997	Drought in North China, Northwest China and the Yangtze River Basin	Over 500	
August, 1997	No. 11 Typhoon	Over 300	
June-September, 1998	The Yangtze River Basin, Songhuajiang River and Nengjian River Basins	Over 3000	3,656

Because of the severe impacts on society and on economic development caused by natural disasters, the Chinese government has paid considerable attention to the management of disasters. As the principal part of disaster management, all levels of government have disaster management measures (reducing disaster, resisting disaster, disaster rescuing and recovering etc.) as the most important activity in stabilizing society and in protecting lives and property.

El Niño is a very complex phenomenon, which has great impacts on the global economy and on human society. The degree of El Niño impacts, however, is different in different places. In some areas, such as Peru, Australia and Indonesia etc., El Niño's impacts are direct and obvious and can cause great damage. In other areas, people really benefit from the El Niño. Of course, there are many areas in the world that are not directly affected by El Niño.

Most Chinese scientists agree that El Niño does affect climate in China. The degree of influence, however, is not as high as that in tropical countries. El Niño is not viewed as a disaster. In some El Niño years, there were no significant climate disasters in China, while in other years when there were all kinds of climate disasters around the country, no El Niño appeared. Although some statistical correlations have been obtained between the El Niño and the anomalous climate in China, the reliability is still questionable because of lack of understanding of the physical mechanism. Moreover, when a new El Niño occurred, there were some disagreements with the previous statistical results.

Many factors play an important role in the climate anomalies in China, such as the Asian monsoon, the degree of snow cover over the Qinghai-Tibetan Plateau, the subtropical high, and blocking highs in the middle and high latitudes, etc. El Niño, as the major quasi-periodic climate phenomenon in the tropical Pacific Ocean, is also an important factor that affects climate variations in China. El Niño is also affected by other factors, which may cause the onset and decay of an El Niño. On the other hand, the onset of El Niño can also modify other physical factors. Because the strength and timing of El Niño events vary, the teleconnected atmospheric circulation systems as well as weather patterns also respond differently. The range of differences is significant.

Because of the complexity of El Niño, Chinese scientists spend great effort in investigation its mechanism. El Niño considerations have also been included in seasonal climate forecasts in recent years.

PART V FORECASTING BY ANALOGY :

5.1 IF A FORECAST HAD BEEN AVAILABLE AS EARLY AS OCTOBER 1996 (KNOWING WHAT WE KNOW NOW ACTUALLY HAPPENED), WHAT COULD HAVE BEEN DONE DIFFERENTLY? ABOUT INFORMATION FLOW? ABOUT RESPONDING TO THE IMPACTS THAT HAD BEEN FORECAST?

If a forecast had been available as early as October 1996, the following actions would most likely have been taken by the Chinese government. First, through the Chinese Center for Natural Disaster Alleviation, the Chinese government could coordinate the actions taken by these concerned government departments, committees and administrations as well as the non-governmental organizations such as the Red Cross. The forecast information would be processed and supplied immediately to all climate-sensitive industries such as transportation, water management, telecommunications and insurance, as well as to agriculture and to retailers when needed. It would be shared by all concerned parties, particularly the general public. The forecast should be accurate and reliable. With all parties involved in the application processes of a climate forecast, the value of the forecast should be optimal. The warnings on impacts of El Niño events would be sent to all business sectors and to the general public. More information would be provided to the media so that general public would have more knowledge on El Niño and its impacts.

According to the book "Research on Important Disaster-reduction Problems in China" (published in 1999), Chinese scientists had pointed out six months in advance that there would be a high possibility of above-normal precipitation in the Yangtze River Basin in the summer of 1998. Unfortunately, no government departments responded to this forecast. For one reason, the forecast on the possible flood was not firm (i.e. reliable) enough. In addition, there was a lack of coordination between different departments and committees and between forecasters and policy makers. For example, the meteorology administration is in charge of the forecast of climate and related natural disasters. The water conservancy administration is in charge of the establishment of irrigation works and the emergency supply of the equipment on flood-prevention and flood-reduction. The agriculture department is in charge of planning the planting of crops. These agencies should exchange information frequently. If the water conservancy departments could have obtained a reliable and accurate forecast of the possibility of the 1998 Great Flood as early as the end of 1996 and had they taken serious preventive actions in all potential flood zones, the actual losses caused by the 1998 Great Floods could have been reduced significantly. If the agriculture agencies could have obtained the information about the 1998 precipitation distribution in late 1996, then they could have arranged to plant different kinds of crops in different locations and to reduce the damages as well.

Like most countries in the world, communication channels between scientists and government agencies are not efficient. Governmental decision-makers are usually not fully confident in scientific prediction related to weather and climate. The scientists' views or comments, which are often contradictory to the government's current policy, are not listened to carefully by government policy makers, although most natural scientists lack a proper understanding on managing society in a way that is both politically and socially correct. In addition, scientists have not been trained to deal with government agencies and the general public. The language they use in their own fields (i.e. scientific jargon) is not understandable by the general public. As a result, much confusion and misunderstanding often occurs when presenting and explaining the scientific messages. Against the same "enemy"- natural disasters- both scientists and forecast users including government agencies and the general public, should work together and cooperate with each other. On the one hand, the users should be aware of the limitations and uncertainties involved in climate forecasting. On the other hand, scientists should teach the forecast users about how to deal with the uncertainties in their decision-making processes.

As an example, if the National Flood/Drought Prevention committee had taken seriously the actual, initial forecast of the possible 1998 Great Flood, it would have had enough time to transport more materials for flood prevention to the high-risk regions, to move people to safe places in advance and to reinforce weak dikes and dams. Unfortunately, it is very hard to treat the neglect of the forecast and the slow reaction of this agency as the primary cause for the huge losses due to the 1998 Great Floods. Ironically, this agency took very serious actions based on the climate forecast in 1998 that there would possibly be a great flood in the Yellow River Basin, the major river in Northern China. Many flood-resistant materials were transported and some large-scale mitigation measures were conducted to mitigate or avoid the losses. The fact was, however, that drought continued in the Yellow River Basin in 1998 but another flood did occur in the Yangtze River Basin. Although there was no official report on the losses due to an erroneous prediction, it is likely to have been in the range of several millions yuan RMB, estimated from the reports in the media. Therefore, improvements in the accuracy and reliability of climate forecast are urgently needed.

5.2 IDENTIFY REALISTIC OBSTACLES THAT MIGHT NOT ALLOW TAKING THOSE THEORETICALLY POSSIBLE ACTIONS

There are at least three obstacles, which are against taking the above noted theoretical actions. The most important obstacle is the lack of reliable and accurate climate forecasts, which could be used by users in their decision-making processes. Because of the complexity of the climate system, the physical mechanisms of many climate phenomena are still not clearly understood. Studies of climate impacts on society are just starting to receive attention, both by the scientific community and the general public in China. However, without sufficient funding to support educational programs in universities and multi-disciplinary projects on the impact of climate vulnerability and change, it is doubtful that useful results can be obtained to serve society's needs. That leads to the second obstacle: the lack of trained personnel who can evaluate the impacts of climate on society, economy and environment and are capable of communicating with users such as governmental policy makers and industrial executives. The third obstacle is the lack of an efficient, high quality and more interactive national network to deal with climate-related emergencies. This network has to consist of different government agencies, experts from different economic sectors and scientists from both natural and social science fields. It is hoped that with the implementation in China of academic programs such as the "Climate Affairs Program", these obstacles could be overcome in the near future.

5.3 CAN EL NIÑO CONSIDERATIONS BE ADDED EXPLICITLY TO NATIONAL DISASTER PLANS?

To answer this question, it may be worth reviewing the development of disaster reduction plans in China for the past decade. For a long time, China did not have national plans or laws which were specifically designed for disaster reduction and mitigation. In order to respond to the 169th resolution of the 42nd convention of the United Nations, the Chinese government established the Committee for the Decade of Disaster Reduction in China (CDRC) in April 1989 and formulated the *Disaster-reduction Plan of China* in October 1994. The purpose of the CDRC is to actually implement the disaster-reduction campaign; to strengthen the consciousness of the Chinese people around the country; to increase the capability to prevent and mitigate disaster; to lessen the losses of life and property caused by natural disaster.

The CDRC is a coordination institution among all government agencies. It is led by the State Council. Commissionaires to the CDRC consist of the heads from twenty-seven government agencies, committees and bureaus as well as the General Staff from the People's Liberation Army. Every year, the CDRC convenes a meeting attended by all commissionaires, scientists and experts in all related fields. During the meeting, the disaster reduction work in the previous year is reviewed and evaluated. Key issues and problems relating to disaster reduction are discussed. The work plan for the next year is then discussed and drafted.

Today, the CDRC consists of the following agencies: the Ministry of Foreign Affairs, the Ministry of Agriculture, the Committee of National Development and Planning, the Ministry of Foreign Trade and Economic Cooperation, the Committee of the National Economy and Commerce, the Ministry of Health, the Ministry of Education, the People's Bank of China, the Ministry of Science and Technology, the Bureau for National Environmental Protection, the Ministry of Public Security, the Bureau of National Broadcast, Film and Television, the Ministry of Civil Affairs, the National Statistical Bureau, the Ministry of the Treasury, the National Forest Bureau, the Ministry of Land Resources, the Chinese Academy of Science, the Ministry of Construction, the Chinese Meteorological Administration, the Ministry of the Railway, the Ministry of Post and Telecommunications, the Red Cross, the Ministry of Information Industry, the National Natural Sciences Foundation, the Ministry of Water Conservancy, and the General Staff of the People's Liberation Army of China.

There are two standing sectors in the CDRC, including the executive office and the expert committee. They are responsible for the daily activities in disaster reduction, scientific research, technological training, information exchange, disaster evaluation and public education around the country. They also provide information to government decision makers and assist in making relevant policies.

The main tasks of the CDRC are to formulate the disaster-reduction plan by listing it in the overall plan for national economic and societal development; and coordinating a disaster-reduction response. By strengthening research in the development of new theories and methods in both fundamental and applied sciences, the CDRC provides useful and reliable information for disaster reduction forecasts. It does so by organizing multidisciplinary conferences to discuss severe natural disasters and by making synthetic forecasts, presenting timely measures of disaster-reduction, formulating the disaster-reduction program, and providing scientifically-based suggestions to the concerned departments of government. The CDRC also promotes communication among specialists from different fields and academic groups; training disaster management staff at all levels. Since its establishment, the CDRC has launched several national campaigns about disaster reduction in order to educate the general public. The CDRC has also fostered bilateral, regional and international cooperation in order to obtain help from the international community and to provide assistance to other countries as well.

With the rapid development of the economy in China, the disaster-prevention and disaster-reduction systems have been significantly developed. Today, China has established the observation and early warning systems for all kinds of natural disasters such as flood, drought, typhoon, severe rainstorms, earthquake and fire. These systems have been established at all administrative levels from the central government to townships, and throughout the country. The network of disaster-observation and disaster early warning systems in China is in the process of being modernized with advanced equipment and technology.

The modernization of the Chinese Meteorological Administration in the disaster observation network is a typical example. The modern meteorological observation system, composed of weather satellites, weather radar, upper air observation and ground observation, is the key element in preventing climate-related disasters. During the past 10 years, the Chinese Communication Emergency Network has been established step by step. This network connects government decision makers at all levels in many ways such as by wire, wireless, satellite, etc.. For example, based on this network, the decisions on flood prevention and drought response from the central government spread quickly all over the seven major river basins in China. This strengthens the observation and early warning system for flood and drought, and also enhances disaster prevention.

Although the CDRC has made significant progress in coordinating disaster reduction efforts in China, there are still obstacles that needed to be overcome in order to meet societal needs. For example, an integrated leadership and management system for disaster reduction is still lacking. All agencies in the central government have their own methods for dealing with specific types of disasters. For example, the Ministry of Water Conservancy pays attention only to flood or drought. There is no communication channel enabling the flood information to reach the Bureau for National Environmental Protection. As a result, there is no quick response to the possible disaster caused by polluted flood water. So, the CDRC should be given more power to overcome these jurisdictional barriers among the government agencies. More research on integrated management is also needed.

There are also practical problems in disaster prevention. First, the current observation systems for the atmosphere, ocean, land and ecosystems have all been built up separately. On the one hand, some systems do overlap. And as a result, resources may be wasted. For example, all observation systems have communication subsystems to transfer data and information. These subsystems are usually not shared by different agencies. On the other hand, this separation creates obstacles to the open exchange and sharing of disaster information.

Secondly, there is a lack of real-time warning systems. Currently, there is only an after-the-fact report system for disasters in the Ministry of Civil Affairs. The build up a real-time disaster warning system is still far away. Thirdly, there remains a great gap in the technology used in disaster monitoring and warning network between China and developed countries. Fourthly, there is an apparent lack of support from society and decision makers for disaster prevention and disaster-reduction work.

Although the natural disasters related to climate anomalies have been explicitly mentioned in the National Disaster Plan, El Niño events have not been specifically written into the plan. First, this is because there are still too many uncertainties about the impact of El Niño events on the climate-related disasters in China. Second, as noted earlier, there are many kinds of natural disasters in China every year. It is very hard for the government to specify the El Niño phenomenon or more generally the ENSO cycle as a major disaster in China. With more scientific research underway, El Niño (or ENSO) impacts on China will be revealed and more reliable and useful information will be obtained. Until then, the El Niño will not be added into the National Disaster Plan.

5.4 IDENTIFY THE STRENGTHS AND WEAKNESSES IN THE WAY YOUR COUNTRY RESPONDS TO EL NIÑO-RELATED CLIMATE ANOMALIES

With the rapid development of the economy in China during the past two decades, China has more economic resources to use in dealing with climate related natural disasters. Improvements in the monitoring of climate vulnerability change and daily observations in addition to the launching of more meteorological satellites and development of more powerful super computers should make climate forecasts in China much more accurate than they are at present. A centralized government structure is more efficient for responding to the climate anomalies at the regional level.

Lack of communication channels between social and natural scientists, among the scientists, governmental policy makers, and general public, bureaucratic and jurisdictional disputes existing in governmental agencies, lack of trained personnel to deal with the impact of climate-related disasters, all weaken the government's ability to respond to El Niño-related climate anomalies and their societal and environmental impacts.

5.5 DID THE 1997-98 EL NIÑO HAVE ANY INFLUENCE ON YOUR COUNTRY'S RESPONSE TO THE FORECAST IN EARLY 1998 OF AN EXPECTED LA NIÑA EVENT?

After the 1998 Great Floods in the Yangtze River Basin and in the Songhua River Basin, the Chinese government started to rethink the value and impacts of climate prediction in the development of society and economy. After the 1998 Great Floods, the government invested an additional 300 million yuan (RMB) to evaluate the impacts of the floods as well as to improve the scientific research facility within the China Meteorological Administration. In addition, several key national super-projects (over 50 million yuan RMB for each project) related to climate variations were approved for the next five years.

When the CMA gave its prediction about a La Niña event in late 1998, the government and general public really listened. Based on historical records, the CMA also predicted that it was highly possible that a big flood would occur in Yellow River Basin in the spring and summer of 1999. The government appointed a special committee to respond to this prediction. The Vice Premier, Wen JiaBao, chaired this committee. He paid several visits to the Yellow River Basin and a great amount of materials for flood prevention was also shipped to this region. Unfortunately, this time the prediction was not right. The Yellow River Basin continued to suffer from a prolonged drought. Meanwhile flooding reoccurred in the Yangtze River Basin. This really taught an important lesson to all Chinese scientists, government decision makers and general public that we (the research community) are still far away from understanding of the impacts of El Niño on China.

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