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# Drought Early Warning and Impact Assessment in China

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## **Abstract**

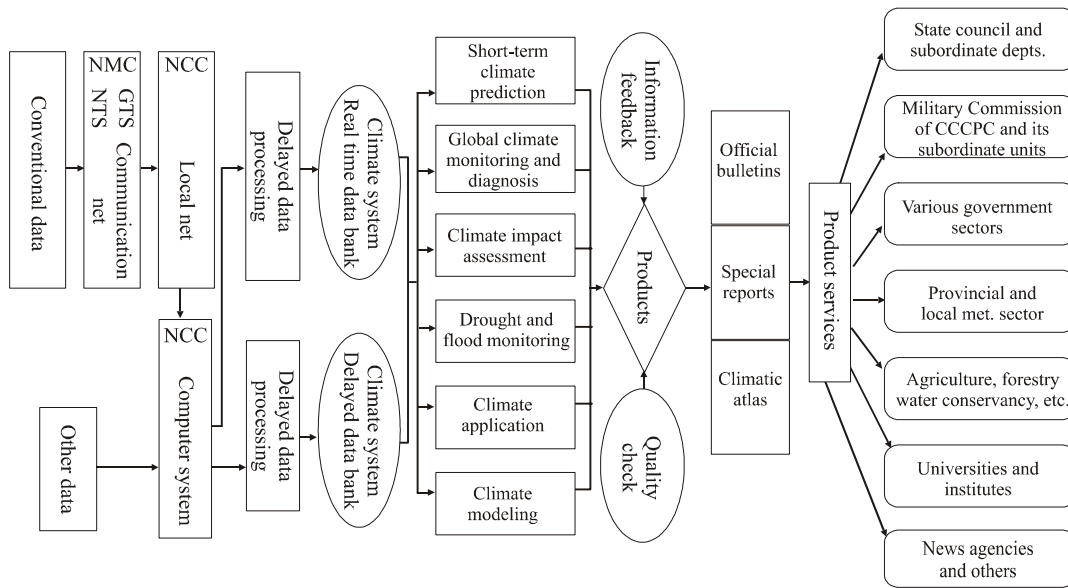
In this chapter, progress on drought early warning and assessment in China is discussed. Soil moisture and drought monitoring have been achieved using satellite remote sensing and station observation data. A drought monitoring system, climate impact assessment system, and short-term climate prediction system were developed in China. This Operational System currently produces 14 products. The problems and limitations of existing systems are also discussed.

## **Introduction and Background**

Drought is China's greatest natural disaster. Among all natural disasters, droughts occur the most frequently, have the longest duration, cover the largest area, and cause the greatest losses in agricultural production. In addition to its direct influence on grain yields, drought also has a potential long-term effect on the environment, desertification, and other disasters. Especially when drought effects are combined with human activities, the environment is at great risk; its survival, and ability to support mankind, becomes more complicated (Li and Lin 1993; Li et al. 2000).

Wilhite (2000) noted that drought is a normal part of climate. Because of its insidious nature, it is difficult to determine its onset, development, and end. This fact emphasizes the importance of developing comprehensive monitoring or early warning systems. Satellite- and station-derived data are also proving to be of significant value in drought monitoring. Drought prediction (monthly, seasonal, or yearly trends) is particularly useful for the drought planning and mitigation.

The China National Climate Center (CNCC) was founded in January 1995. CNCC is assigned major missions of climate (including drought) prediction and studying climate change and its associated impacts. Its focus is placed on short-term (monthly, seasonal, and interannual scale) climate prediction and studies of climate change induced by anthropogenic activities. During 1996-2000, CNCC is establishing the first integrated operational system, based on the implementation of a national study of China's short-term climate prediction system. Figure 1 is the operational flow chart of CNCC.



**Figure 1. The operational flow chart of the CNCC.**

## Overview of Drought Early Warning Systems in China

### Drought Monitoring

Drought is a creeping phenomenon, the extent of which appears gradually, thus offering the possibility for monitoring and early warning of drought. There are two ways to monitor droughts: one is based on a network system of stations, and another is by remote sensing, which offers fast, objective, economic, and large-range characteristics.

Through remote sensing, station networks, and modern communications, including geographical information systems (GIS), a variety of information about climate and water supply conditions can be provided continuously before drought occurs. This information is useful for defining the possible range, period, and risk degree of drought, and it will help in the adoption of drought mitigation measures. During drought, the processes and status of drought can be monitored constantly to provide information to all drought response agencies. Drought losses can be determined quickly and precisely for large areas, and this information will facilitate response and recovery operations. The remote sensing method of drought monitoring will primarily track crop growth, status of soil moisture, evapotranspiration, status of the hydrological system, and precipitation. This technology, combined with station observations, can monitor the formation and development of drought objectively, quickly, and economically for large areas.

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## **Soil Moisture and Drought Monitoring Using Remote Sensing in China**

Monitoring by satellite remote sensing techniques is most appropriate for detecting the status of soil moisture, evapotranspiration, crop growth, land cover type and drought. The Institute of Remote Sensing Application and the Institute of Geography, both part of the Chinese Academy of Sciences, have done considerable work in this area. An improved thermal-inertia model has been developed for monitoring soil moisture in areas without vegetative cover. For vegetated areas, crop water deficit models have been improved. Substantial progress has also been achieved in the dynamic monitoring of soil moisture and drought in China.

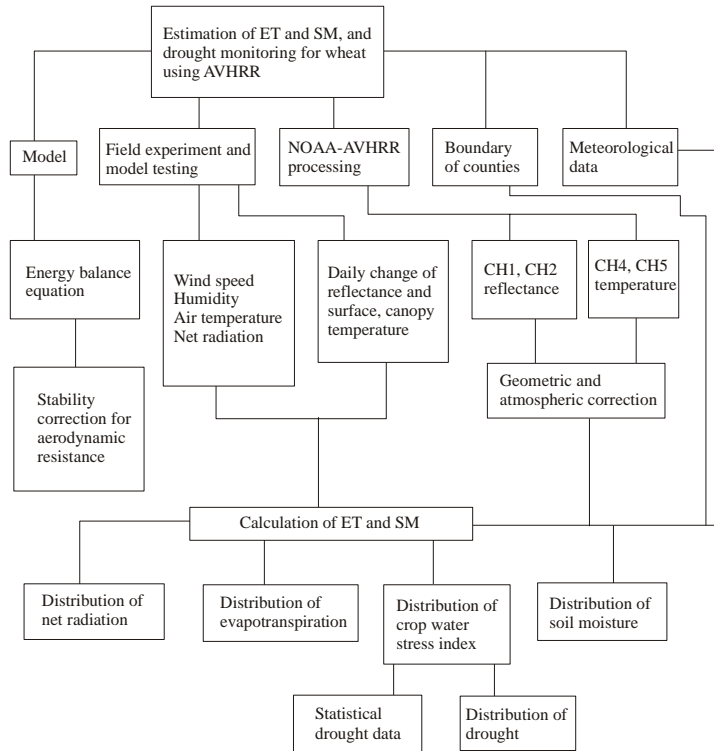
Using a surface observation station network and remote sensing techniques, the development and spread of drought conditions can be monitored in a routine and cost-effective manner. Tian (1993) and Tian et al. (1998) have done considerable work in this area. It provides an excellent strategic monitoring tool for assessing drought stress and the need for response at a regional scale.

A method based on energy balance was developed to estimate evapotranspiration (ET) and soil moisture (SM) to monitor drought in north China using NOAA-AVHRR digital images and meteorological data by Tian (1993). The NOAA-AVHRR data were used to compute reflectance and temperature after atmospheric correction. ET was estimated by combining remotely sensed reflected solar radiation and surface temperature with ground station meteorological data to calculate net radiation and sensible flux. SM was estimated from the relationship between the Crop Water Stress Index (CWSI) and soil water content. Spatial distribution of drought was obtained from the Surface Water Supply Index (SWSI) model. The scheme for estimation of ET, SM, and drought is shown in Figure 2 (from Tian). The other models for monitoring soil moisture and drought using remote sensing are shown in Figures 2-5, and comparisons of the precision of the models are given in Table 1 (from Tian 1993).

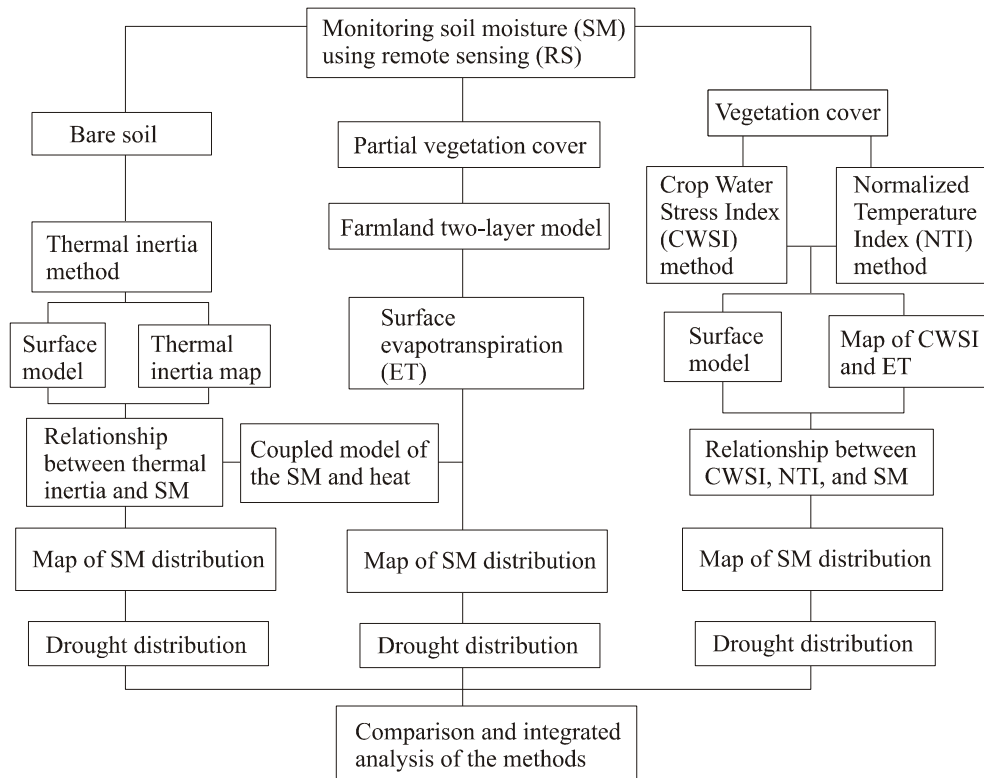
### **The Drought Monitoring System**

Before the drought monitoring and early warning systems are run, at least one objective and practical drought index should be provided. Then certain thresholds, also called the initial point, can be determined so that certain activities are adopted when the drought index exceeds the threshold. In the United States, the Palmer Drought Severity Index (PDSI) is often adopted, while the SWSI is also used.

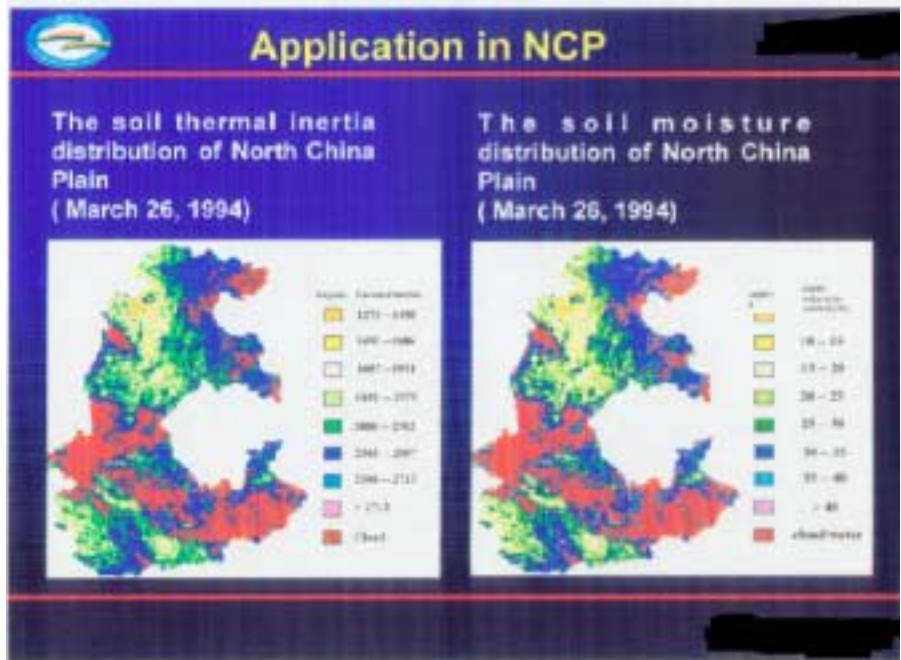
Since no single index is adequate to evaluate meteorological, agricultural, or hydrological droughts, a variety of indexes should be used. The difference between the various regions and economic departments should also be considered.



**Figure 2. Estimating ET and SM and monitoring drought using NOAA-AVHRR data (Tian 1993).**



**Figure 3. Soil moisture and drought monitoring models using remote sensing.**



**Table 1. Comparison of precision of soil moisture estimates using different models.**

Area	County Number	Simple	Precision of Two-Layer Model (%)	Precision of One-Layer Model (%)
Beijing	6	5	87.1	75.2
Tianjin	5	4	89.2	76.1
Hebei	20	14	85.6	73.5
Henan	30	20	87.1	76.1
Shandong	11	8	86.3	72.2
An hui	12	7	82.7	72.6
Jiangsu	10	6	87.2	75.7
Total Precision			86.5	74.3

A drought monitoring and early warning system should be established to provide timely information on the formation, development, persistence, alleviation, and end of drought to those responsible for drought response/recovery. To this end, the following steps should be taken: building a system that can capture, analyze, and transfer drought information in a timely fashion; setting up criteria to confirm drought-affected zones; monitoring the status of and estimating future available water and soil moisture; and establishing a special department to enforce the criteria and issue/cancel drought warnings.

In order to monitor the occurrence and development of droughts efficiently and provide information on the strength and range of drought (and flood), the China Drought-Flood Monitoring System was developed by CNCC. This system can dynamically monitor the occurrence and evolution of droughts (or floods) over the whole country and provide early warning of droughts. It distributes climate information on droughts (or floods) in real time by the network and publishes some written products for decision making and public welfare.

### Methodologies

The methodologies used include qualitative analysis (description, analog analysis, and expert reviews) and quantitative analysis (statistics models, dynamic models, integrated assessment).

The intensity of meteorological drought in China generally can be classified on the basis of departure from normal precipitation. The meteorological drought index (D) is given as:

$$D = [(P - \bar{P}) / \bar{P}] \times 100\%$$

where P is actual month precipitation and  $\bar{P}$  is multiyear mean precipitation for the same month. D can be used to determine the occurrence of drought and its severity. Drought standards are listed in Table 2.

**Table 2. Drought standards by D index.**

<b>Duration of Drought</b>	<b>Moderate Drought (%)</b>	<b>Severe Drought (%)</b>	<b>Extreme Drought (%)</b>
One month	<-80		
Two months	-51—-80	<-80	
Three months	-26—-50	-51—-80	<-80
Four months	-1—-25	-26—-50	-51—-80
Five months		-1—-25	-26—-50
More than six months			-1—-25

Source: Li et al 1996.

### **The Function of the Drought-Flood Monitoring System in China**

The Drought-Flood Monitoring System is responsible for:

- Monitoring the nature of droughts and floods at any station and the evolution of other meteorological elements by using histograms and curve diagrams;
- Consecutively monitoring drought-flood development at the regional and national scale, displaying clearly the characteristics of droughts and floods at various time periods;
- Displaying drought-flood distributions over the country, and determining as soon as possible the geographical positions (longitude and latitude) and station names where droughts or floods are occurring.
- Comparing and ranking the severity, duration, and extent of drought and flood disasters;
- Monitoring precipitation over the country automatically and continuously, giving early warning when or before droughts or floods occur;
- Printing drought and flood monitoring figures and tables.

### **Operational System of Climate (Including Drought) Impact Assessment in China**

Climate impact assessment primarily aims at assessing climate (including drought) impacts on the national economy and society, especially on agriculture. The drought impact assessment system (DIAS) includes a database, statistics analysis software, methodology for impact assessment and appropriate models, graphics software, a disaster search system, and an expert system to assess drought impacts.

Information is the basis of DIAS. In the processes of drought impact assessment, a wide variety of information, such as meteorological, agricultural, satellite remotely sensed, and social and economic, must be collected. An information network must also be developed to analyze and deliver data and information.

## Operational System of Short-term Climate Prediction in China

Short-term climate prediction (long-term forecast) has been carried out for many years in China. The laboratory of climate prediction of CNCC periodically publishes climate trend predictions on various time scales, ranging from one month to one year, over the country. Short-term climate prediction has been focused on significant disasters such as drought and floods. Figure 6 is the Operational System of Short-Term Climate Prediction at CNCC.

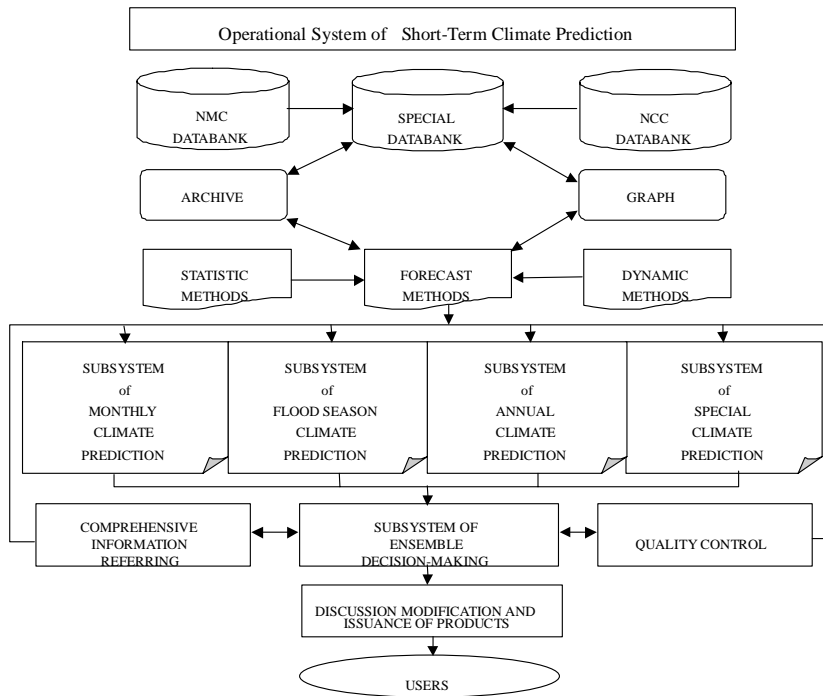


Figure 6. The Operational System of Short-Term Climate Prediction at CNCC.

### Data and Prediction Methods:

#### Data

- General circulation data: geopotential height of pressure levels 1000, 500, 100, 50 hPa
- SST, ice-snow cover, ground temperature, OLR
- Temperature and precipitation over China: 160 stations
- Various physical parameters

#### Methods

- Monthly prediction methods
  - Statistical method

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- Dynamic method
  - Seasonal prediction methods
    - Physical factor analysis methods: SST, ground temperature, snow cover, monsoon, subtropical height over north and east Pacific, etc.
    - Statistical method: time series analysis, multivariate analysis, correlation and analogue analysis
    - Dynamic method (CCM, OSU)

Common methods include correlation and analogue analysis, statistical methods, physical factor analysis, and dynamical numerical forecast, with a special emphasis on analyzing the relationship between the circulation system of the east Asian monsoon, atmospheric active centers, underlying surface thermodynamic anomaly, and Chinese climate. Figure 7 shows the major physical factors influencing China's climate during summer.

## **Primary Data and Information Products**

### **Short-term Climate Prediction Products**

- Monthly Climate Prediction (25th of each month)
- Flood Season Prediction (mid-Apr.)
- Annual Climate Prediction (mid-Nov.)
- Significant Climate Report (periodically)
- Review on Climate Prediction (end of May)

### **Drought and Flood Monitoring Products**

- Monthly Drought and Flood Bulletin
- Annual Drought and Flood Bulletin
- Brief Report on Drought and Flood Monitoring
- Advisory Report on Climate and Service Report on Drought and Flood Disasters

### **Climate Impact Assessment Products**

- Monthly Climate Impact Assessment
- Yearly Climate Impact Assessment
- China Climate Bulletin
- Annals of China's Major Climate Disasters

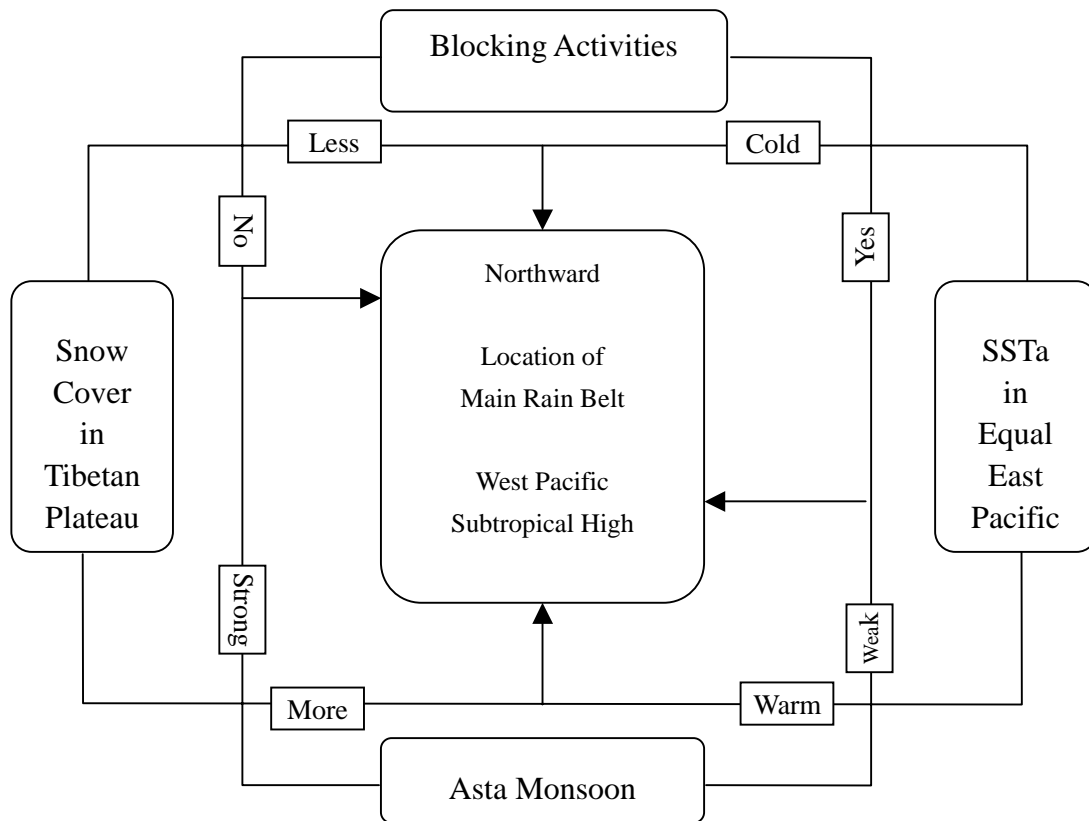


Figure 7. The major physical factors influencing China's climate during summer.

### Status of Delivery Systems and Identification of Primary Users

The CNCC operational system currently prepares 14 products. These products provide the Chinese government and all national economic sectors with real time information and published information for decision making and public welfare. The Drought-Flood Monitoring System and the climate impact assessment system provide climate information on drought and floods, early warning of possible droughts, and advisory service for various users (from government sectors to agriculture, forestry, and water conservancy), enabling them to make good use of climate resources and disaster information.

The ongoing climate operational system can ensure the improved quality of climate service through both equipment and technology. CNCC has provided significant climate information for making decisions, planning national economic strategies, determining policies, conducting important construction projects and participating in relevant international activities.

Figure 8 shows the rainfall anomaly percentage observation (a) and forecast (b) for the summer of 1994. Figure 9 shows the accuracy curve of rainfall prediction for the flood season.

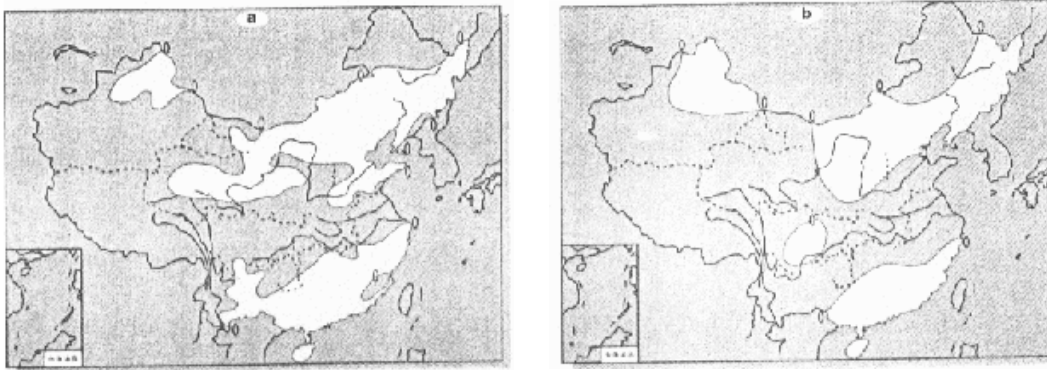


Figure 8. The rainfall anomaly percentage observation (a) and forecast (b) for summer 1994.

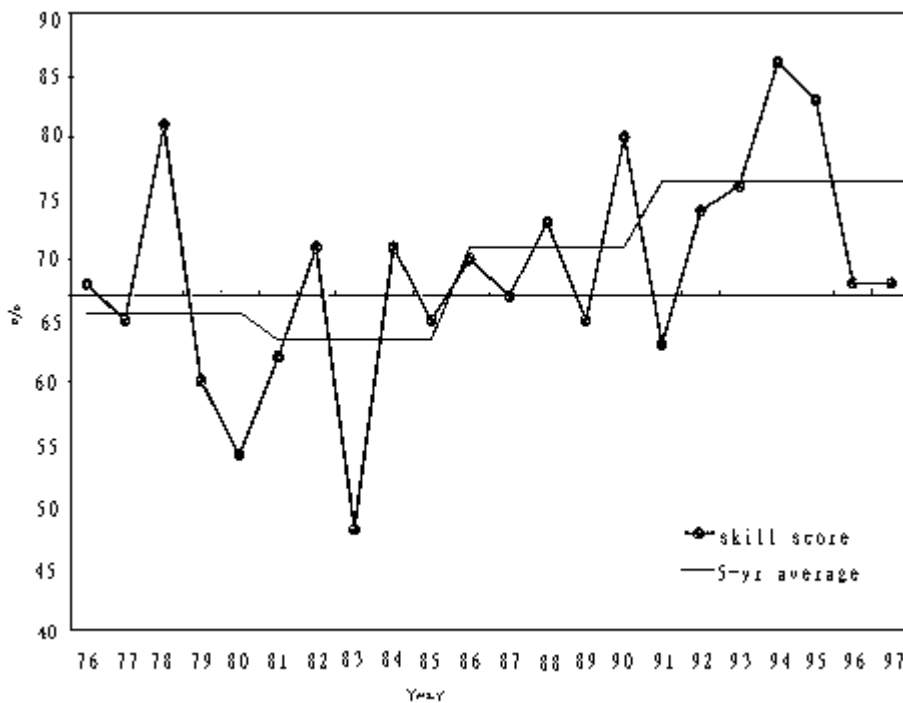


Figure 9. The prediction skill score of summer rainfall.

### Limitations of Current Systems and Future Needs

China's technological equipment in this field is relatively less advanced than that of developed countries. China has a limited number of stations in Qinghai-Xizang Plateau, high mountain areas, immense deserts, and seas. The climatic system cannot be monitored adequately with so few stations.

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Although large quantities of data are available in China, the basic data are kept in many units in various formats. The data quality and the length of record need to be quality controlled. Inadequate data archiving and automatic data processing is one of the limitations.

Numerical climatic models were developed and applied in China later than in some other countries. Dynamic climatology and climate prediction research needs to be reinforced.

A large part of the land in China is located in so-called climatically vulnerable areas, which are susceptible to climate variability and drought. Therefore, understanding the causes and formation mechanisms of short-term climate change and drought leading to strong prediction signals has become an important task in drought early warning and prediction. For example, the large-scale persistent climate anomaly usually demonstrates strong signals. It has been found that tropical low-frequency oscillation and ENSO are strong signals that are considerably beyond the noise background, and these should be applied in monthly, seasonal, and interannual scale predictions.

Monitoring drought and variations in the characteristics of the earth's surface using remote sensing techniques is an important subject. We should improve the inversion model and establish a data bank for information collected by meteorological satellites with high resolution. Other important needs are:

- to study inversion methods and monitoring techniques for assessing land surface physical characteristics (e.g., soil moisture, albedo) using satellite remote sensing techniques,
- to conduct a comparative analysis of remote sensing data and ground-based data
- to study correction methods for atmospheric attenuation, and
- to establish data sets for land cover with high resolution.

### **Conclusion**

Drought is China's greatest natural disaster. Drought monitoring and prediction are particularly useful for drought planning and mitigation. Using satellite remote sensing techniques and surface observation stations, substantial progress has been achieved in the dynamic monitoring of soil moisture and drought in China.

The Drought-Flood Monitoring System and Operational System for Climate Impact Assessment and for Short-term Climate Prediction was developed at CNCC in China. The CNCC Operational System currently prepares 14 products, which provide the Chinese government and all national economic sectors with real time information and also published informational products.

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The problems and limitations of the system include limited number of stations, data quality problems, short length of record, relatively weak qualitative analyses and modeling studies, and a late initiation of a study of remote sensing monitoring.

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